HUGHES

MICROWAVE PRODUCTS DIVISION

HUGHES MILLIMETER-WAVE PRODUCTS

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1. The millimeter-wave products identified in your order and sold by Hughes Aircraft Company, Microwave Products Division, are warranted to the original Buyer to meet the published specifications, drawing and/or such modifications thereof as Buyer and Seller have agreed to in writing and to be free from defects in workmanship and materials. Seller's entire warranty obligation is limited to making adjustments by repairing, replacing or refunding the purchase price of any product which fails to meet this warranty and which is returned to Seller, as provided below, within one (1) year from date of first shipment by Seller. Replacement, repairs, or adjustments under this warranty shall not reinstate the warranty set forth herein. Under all circumstances, except as provided for in Paragraph 7, the warranty will expire not later than one (1) year after such first shipment.
2. Adjustment will not be allowed for products which have been subjected to abuse, improper application or installation, alteration, accidental or negligent damage in use, storage, transportation or handling. Alteration or removal of serial number or identification markings voids the warranty.
3. Seller shall have the right of final determination as to the existence and cause of a defect, and whether to make adjustment by repair, replacement or refund. When adjustment is not allowed, a reasonable charge will be made to Buyer to cover Seller's cost of inspection and handling.
4. In the event Seller determines that any product claimed to be defective is not subject to adjustment set forth herein, Buyer will be notified that product is not subject to adjustment. Unless the Buyer furnishes disposition instructions for the product within thirty (30) days after such notification, Seller may return the product "as is" to Buyer, transportation collect.
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6. **There are No Warranties That Extend Beyond the Description on the Face of The Contract.** Seller shall not be liable for consequential damages. No change in this warranty shall be binding upon Seller unless it shall be in writing signed by a duly authorized representative of the Seller.
7. **Exclusion of Certain Semiconductors.** (a) Field replaceable diodes or wafer assemblies are not warrantied. (b) A product that contains a Schottky diode is warrantied for one (1) year. If the diode fails during the warranty period, upon the initial return of the product to Hughes, Hughes will replace the failed diode free of charge. If the product fails again, during the one (1) year warranty period, Hughes will repair the product in accordance with the provisions of the REPAIR WARRANTY described herein. (c) Separately sold semiconductors are not warrantied.

Statement re:
Specifications subject to change ~~at any time~~ without notice.

REPAIR WARRANTY

1. Hughes Microwave Products Division will provide repair service for all products sold from the Hughes Millimeter-Wave Products Catalog. All products no longer under Hughes NEW PRODUCT WARRANTY which are repaired, modified, tuned, or calibrated at the Buyers' expense, will be covered by this REPAIR WARRANTY. The REPAIR WARRANTY applies only to products returned for repair at Sellers' facility. The warranty does not apply to any products returned to the Seller with obvious physical damage, or which have been modified by the Buyer in any relevant way. Under all circumstances, the REPAIR WARRANTY will expire not later than ninety days after shipment.
2. To return products for repair under this warranty, or to inquire on the status of returned units, write to Hughes Aircraft Company, Microwave Products Division, Customer Service, 3100 Fujita Street, Torrance, California 90505, or telephone our monitored 24 hour Customer Service line at (213) 517-6110.

EXTENDED WARRANTY

An extended warranty is available for certain instrumentation products such as Sweep Generators, Synthesizers, Network Analyzers, Noise Gain Analyzers and Power Meters. This extended warranty can be written to extend the period of the initial warranty, to provide on-site repair of these certain products, or both. This may be initiated either before the placement of the original purchase order or at any time during the initial warranty period. Contact your local representative or Hughes for information on this service.

SERVICE CONTRACTS

A service contract is available for certain instrumentation products that may be written to provide repair and calibration services for Hughes manufactured products. These contracts would provide parts and labor for all necessary repairs and periodic calibrations of the product as deemed necessary by Hughes. These service contracts can be written to provide either factory or on-site service. Calibrations should be done at the Hughes factory. Contact your local representative or Hughes for information on this service.

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A certificate of compliance to manufacturers specifications is available upon request on all applicable Hughes Microwave Products Division manufactured products. Hughes MPD manufactured products are tested with equipment meeting MIL-STD-45662 with traceability to the National Institute of Standards and Technology. In addition, Hughes MPD can calibrate and certify applicable manufactured products in accordance with MIL-STD-45662. Contact Hughes MPD for information on this service.

In this catalog...

Making waves in millimeter-wave technology.

It's what we've been doing since we were one of the first to pioneer this specialized field several decades ago... by developing and offering the most complete line of mm-wave products commercially available—test equipment, devices, components, subsystems, and instrumentation systems... in production and available now.

MILLIMETER-WAVE PRODUCTS

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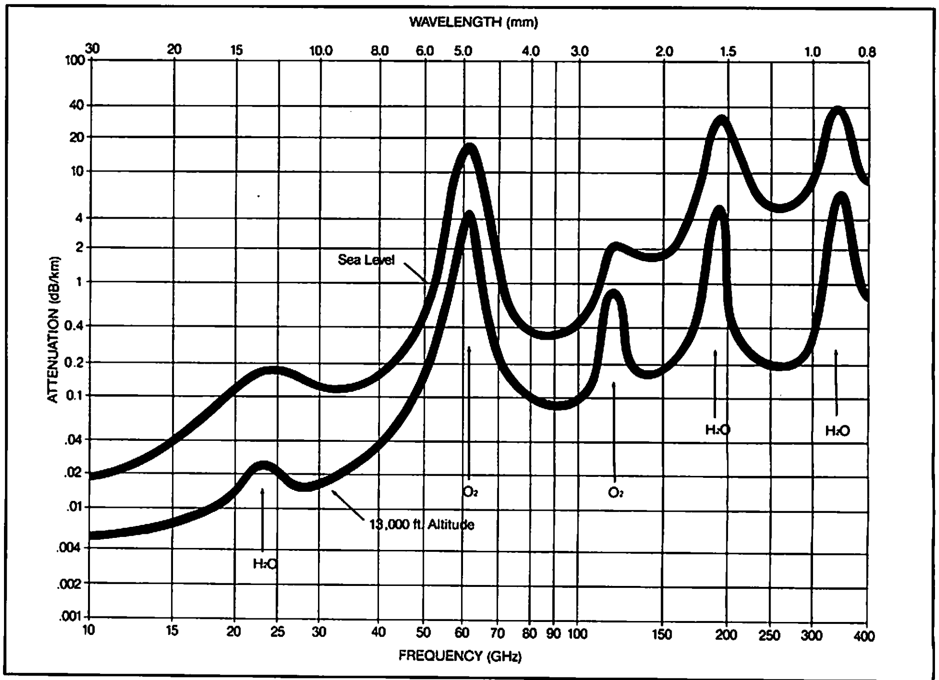
WHY MILLIMETER WAVES

INTRODUCTION

Millimeter-waves offer a new and attractive way of solving systems problems. Millimeter-waves have many advantages over microwaves such as broad bandwidths, higher spatial resolution, low probability of interference/interception and small antenna and equipment size. Their ability to penetrate clouds, smoke, dust and fog make them a logical choice over IR and optical wave lengths for adverse weather applications. In addition, selective molecular absorption in the millimeter spectrum, as illustrated, offers unique solutions to many special problems.

Areas where millimeter-waves are currently being used include communications, radar, radiometry, missiles, radio astronomy, plasma diagnostics, spectrometry, nuclear resonance measurements, spectroscopy, and the precise measurement of distances. These uses span military, industrial, medical and scientific requirements. In this section of the catalog we shall discuss some of the more important applications and the current state-of-the-art.



AVERAGE ATMOSPHERIC ABSORPTION OF MILLIMETER WAVES (HORIZONTAL PROPAGATION).

Millimeter-wave measurements will be covered, listing the specific test instruments available for sale. Component technology will also be covered, listing specific components available for sale. There is also a discussion of millimeter-wave instrumentation systems and subsystems that are available for making system measurements.

MILLIMETER WAVES AND HUGHES

Early investigation of the millimeter wavelength portion of the electromagnetic spectrum was stimulated by scientific (molecular spectroscopy) and military (radar) developments. The feasibility of generating signals with wavelengths near 1 cm was first demonstrated by Cleeton and Williams in studies of ammonia molecular resonances in the early 1930's.

The observation by L.A. Hyland of the Naval Research Laboratory (NRL) in 1930 that over-flying aircraft would reflect radio signals stimulated the investigation of radar techniques at NRL, Fort Monmouth and elsewhere in the United States. During this period, independent and excellent work was done in England with high priority since there was the threat of war in Europe with impending raids by bomber aircraft. This early connection between aircraft and radar has been preserved to this day. Radar for detecting aircraft from remote ground locations or from ships; airborne radar for detecting other aircraft, ships and ground features; and countermeasures against these uses, have been the major applications for which microwave technology has been developed. In terms of radar equipment this has meant a push toward higher microwave frequencies where high directivity can be achieved with small antennas more suitable for portability and for mounting on ships and aircraft.

It was determined during the early stages of World War II, however, that most requirements for aircraft related radar could be met by frequencies of 10 GHz or less. At the M.I.T. Radiation Laboratory an attempt to build a radar in the 1cm wavelength range was a disappointment. Unfortunately, the frequency chosen was near a water vapor molecule absorption resonance which severely curtailed the radar range. As a result, there was no driving force to develop radar technology for frequencies above 30 GHz.

During World War II, J.H. Van Vleck made a theoretical prediction that atmospheric oxygen (O_2) would absorb near 60 GHz. This work was given a security classification because of its military significance. Work was initiated at NRL to explore and develop millimeter-wave technology for secure communications predicated on Van Vleck's theory.

After World War II millimeter-wave work continued at NRL for military applications and at Bell Telephone Laboratories (BTL) for telecommuncation applications. Then, in the late 1950's, Hughes Aircraft Company became involved when it was recognized that the coupled-cavity traveling-wave tube (TWT), which had been successfully developed at Hughes, could be extended in frequency to 100 GHz and higher, and would be capable of generating hundreds of watts of average power.

Another significant phase in the development of millimeter waves was in the 1960's. During this period, intensive work was done at BTL on solid-state components for the development of underground waveguide repeater systems. These systems were planned for telephone trunk-line service capable of very wide band operation. This work was concentrated in the 40 to 100 GHz portion of the spectrum.

The early millimeter-wave TWT work at Hughes has been continued and supplemented by semiconductor device and component development that began in the mid 1960's. Then, in 1970, Hughes began manufacturing a solid-state millimeter-wave sweep generator—the first millimeter-wave catalog product to be introduced by Hughes. Since that first introduction, a full line of devices, components and instruments covering 18 to 160 GHz have been added with development work continuing at the higher frequencies.

MILLIMETER-WAVE APPLICATIONS

There are many applications for millimeter-wave technology. A few of the more prevalent ones will be discussed below.

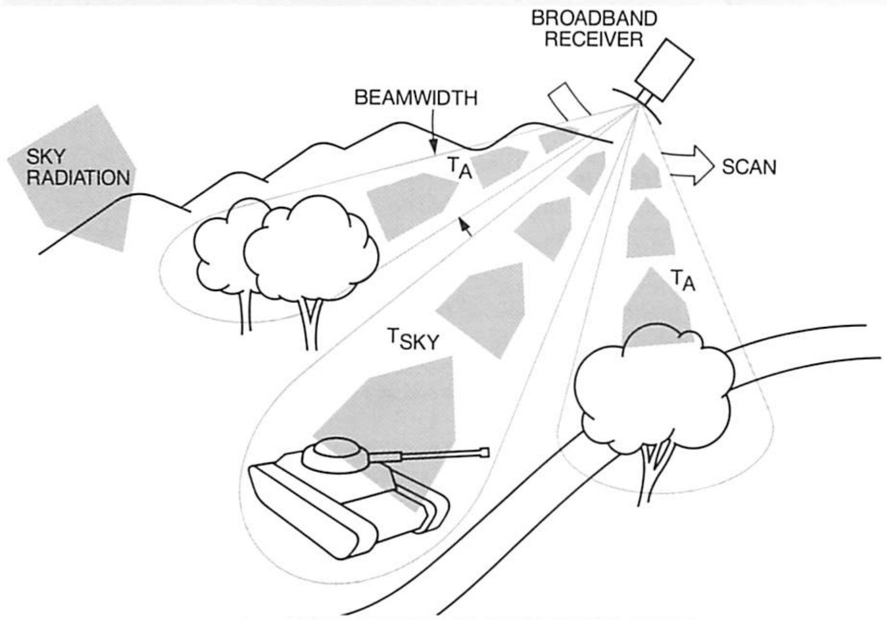


FIG. 1. RADIOMETERS SENSE TEMPERATURE CONTRAST.

Radiometers

Microwave radiometers have been in use for many years for laboratory instrumentation, meteorological research, and radio astronomy. Recent developments in broadband, low-noise, solid-state millimeter-wave components have stimulated interest in applying radiometers as military sensors for ground target detection. The small-size, light-weight, high-reliability, and low-cost potentials of millimeter-wave radiometers have precipitated this interest.

A millimeter-wave radiometric sensor is a low-noise, high-gain receiver that senses thermal radiation at its antenna as it scans targets and background. Consider the signal available for detection by an airborne sensor looking down. The signal results from the radiometric temperature contrast that exists between a reflecting metal target and the terrain background. A perfect reflector reflects the temperature of the "cold" sky. At millimeter-wave frequencies, a metal target has an emissivity near zero while that of the background is nearly one. Ground background temperature is normally at or near standard ambient, 290°K. Thus, as shown in Figure 1, the available signal, $\triangle T$, can be approximated by:

$$\triangle T \approx 290°K - T_{sky}$$

Due to atmospheric absorption of radiation, the sky temperature is a sensitive function of weather and frequency. Sky temperature is also dependent on the viewing angle of the scanning antenna, since the absorption path through the atmosphere is much longer at angles near horizontal than at zenith.

Largest temperature differentials (colder sky) occur at the lower frequencies. However, since antenna aperture is almost always a fixed parameter in a sensor system, one must consider the beam-fill factor (BFF), in addition to $\triangle T$, in order to optimize available signal. Under most conditions of target acquisition, the area projected by the antenna beam on the ground greatly exceeds that presented by the target. The measured contrast, therefore, is diluted by intercepted background radiation. Since higher operating freqencies allow smaller antenna beam-widths, this dilution is reduced; thus providing a significant advantage for high-frequency radiometers.

Video and millimeter-wave radiometric images of a freeway scene south of Carlsbad, California taken by a team from the Jet Propulsion Laboratory, Pasadena, California, from a helicopter with a scanning 3-mm radiometric system are shown in Figure 2. During this rainy day, the sensor was flown over a layer of broken clouds, as seen in the pictures from the video. The moderate-resolution (0.5°) radiometric images of the ground show that the sensor can be used to produce images through clouds, smoke, and dust when visual and IR sensors are not useable. The 15-level color scale is from 250°K (dark blue) to 300°K (red).[1]

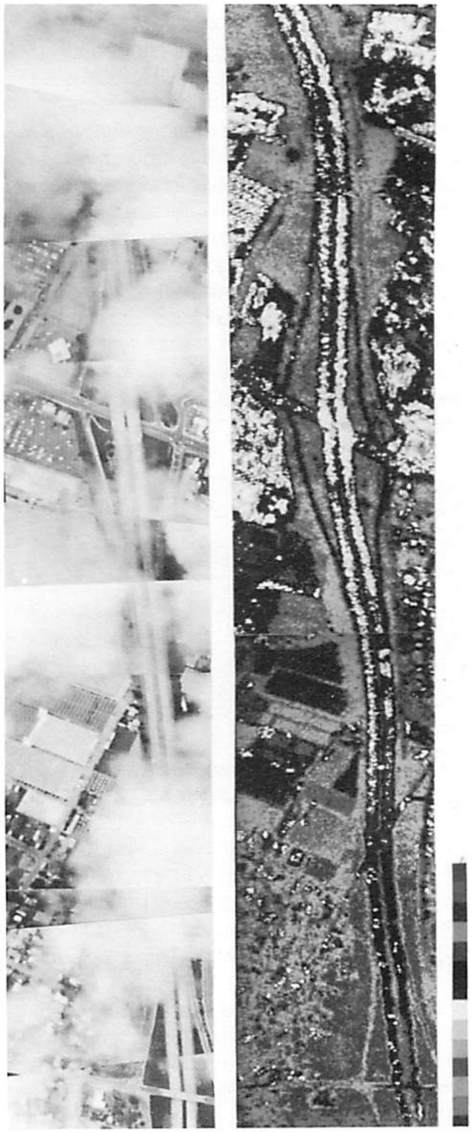


FIG. 2. VIDEO AND MILLIMETER-WAVE IMAGES OF A FREEWAY SCENE SOUTH OF CARLSBAD, CA, ON SEPT. 26, 1985.[1]

[1] William J. Wilson, R.J. Howard, Anthony C. Ibbott, Gary S. Parks, and William B. Ricketts: "Millimeter-wave Imaging Sensor" I.E.E.E. Transactions on Microwave Theory and Techniques, Volume MTT-34, No. 10, October 1986 © 1986 IEEE

Radiometers which are used for meteorological or navigational purposes need long term accuracy. Accuracy is achieved by a repetitive calibration against a known temperature which compensates for changes in system gain with time and temperature. Pictured in Figure 3 is a two-channel radiometer used for the simultaneous but independent measurement of water vapor and liquid water in the atmosphere. The system measures the natural emission of water vapor at 20.6 GHz and of water droplets in clouds at 31.65 GHz. An overall system noise temperature of 618°K with a system sensitivity $\triangle T_{rms} \approx 0.123$°K at 31.65 GHz was achieved.

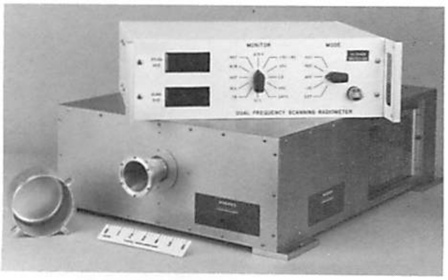


FIG. 3. TWO-CHANNEL RADIOMETER OPERATING AT 20.6 GHz AND 31.65 GHz.

Similar radiometers have been used for navigational purposes using radiometric area correlation data. Received emissions are compared with expected emissions stored in a computer "map."

The ability to maintain solid-state receiver performance over long periods of time and under adverse environments has been demonstrated by space-qualified radiometers. Typical of such radiometers are the units shown in Figure 4, which were manufactured by Hughes for space experiments.

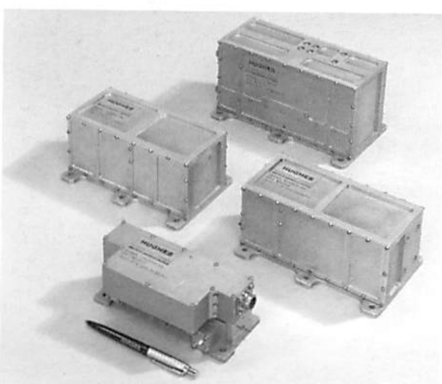


FIG. 4. SPACEBORNE RADIOMETERS USED IN REENTRY VEHICLE EXPERIMENTS. THEY WERE QUALIFIED TO PERFORM WHILE UNDERGOING VIBRATION FORCES OF 30g AT 2000 CYCLES PER SECOND.

Radar

Since there is a fine line of distinction between a radar and a radiometer, particularly with the advent of active radiometry (where the ground is illuminated with millimeter-wave energy and the radiometric receiver measures the reflected power), the simple definition adopted here is that a radar sensor is capable of measuring range. A simple, and straightforward, approach to range measurement is achieved by means of conventional pulse modulation wherein the round-trip travel time of a transmitted pulse is measured in the receiver. Pulsed radar sensors have been developed using millimeter-wave solid-state components at frequencies beyond 100 GHz. Current capabilities include transmitters using a 94 GHz IMPATT pulsed source capable of 40 watts peak power output by combining the power from two IMPATT diodes.

Pulse Doppler or coherent radars require a pulse-to-pulse phase coherent transmitter waveform that is also coherent with the receiver local oscillator in order to extract phase information from the returning echoes. The term coherency means simply that there is phase consistency between pulses and the receiver reference. Phase stability permits the use of coherent integration which can approach 100 percent efficiency. Pulse-doppler was a forerunner of many modern radar techniques that use coded pulse trains to achieve remarkable improvements in radar performance. Spread-spectrum coding, pulse compression, and synthetic-aperture radar are current techniques that use signal processing to extract detailed target information.

"Signal processing" implies operations performed in the RF or IF portions of the radar receiver, whereas data processing operations are performed after video detection. Requirements for waveform coherency exist with all signal processing systems but the resulting advantages usually outweigh the added complexity. As an example, pulse compression gives the range resolution and accuracy associated with an extremely short pulse even though the actual transmitted RF pulse is long. Consequently, efficient use of the average power available from a transmitter is achieved, obviating the need for high peak power signals. For millimeter-wave systems employing small solid-state transmitters, peak power is limited to relatively low levels. A technique that avoids the need for high peak power is not only attractive but perhaps essential.

FM-CW radar sensors have been successfully built at millimeter-wave frequencies. The FM-CW waveform is attractive for use in altimetry, fuzes, and similar applications where a single target is involved and efficient use of average power and/or very short range measurements are needed. To prevent direct transmitter leakage into the receiver a dual antenna system is preferred for CW radars. While space availability could prevent the use of dual antennas at microwave frequencies, the smaller aperture (for constant beamwidth) permitted by millimeter-wave radars makes dual antenna systems feasible. Furthermore, propagating signals decay more rapidly due to atmospheric absorption at millimeter wavelengths resulting in lower sidelobe levels. When compared with microwaves, these features result in improved local isolation, less mutual interference between multiple sensors, and protection against signal-intercept receivers.

Millimeter-wave technology has now reached the point where small low cost millimeter-wave front ends for rugged environmental performance are practical. Measurements of the system's performance must be made before the final integrated version is built. The first step leading to this integration is the design of a prototype or breadboard front-end which combines design flexibility and high performance. Examples of this capability are provided by coherent and free-running millimeter-wave radar front ends, which are offered on pages 141 through 145. Monostatic or bi-static operation, single or dual plane monopulse reception, frequency agile stable master oscillators and pulse compression can be implemented with these subsystems.

RADAR CROSS SECTION AND BACK SCATTER MEASUREMENTS

Millimeter-wave frequencies are also used in RCS measurement systems where the RCS of scale models is being evaluated. The Hughes short pulse radar system is described in more detail on pages 152 and 153. A short-pulsed radar system for scattering cross-section measurements differs significantly from traditional radar designs. The differences are even more pronounced for compact ranges due to the short distances involved.

The transmitter needs to be agile and coherent, requiring the use of a synthesizer. This CW source then must be modulated and amplified into a short-pulse waveform with the appropriate pulse width, rise and fall times, pulse flatness, pulse repetition frequency and on/off ratio. Pulse width is usually dictated by the overall requirements of the target size in order to minimize clutter. When using stepped frequency imaging, the pulse must fully envelop the target, thereby establishing a minimum pulse width equal to the transit time of the maximum target dimension.

Rise and fall times will have different requirements depending upon the type of measurements being made. If making

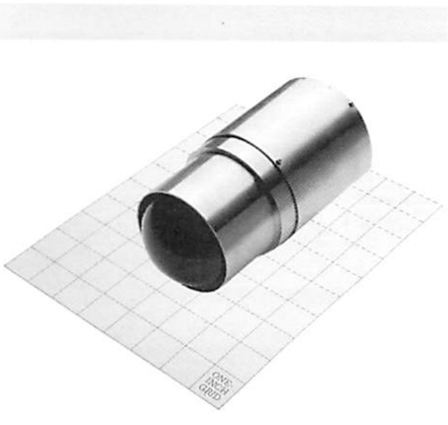


FIG. 7. 60 GHz RADAR WITH GUNN OSCILLATOR TRANSMITTER DESIGNED FOR VEHICULAR DETECTION.

single-frequency range strobes, the rise and fall times need to be short enough to provide the necessary target range profile resolution. When used in the stepped frequency mode, rise and fall times are relatively unimportant, provided the pulse width requirement is met. However, for a compact range, rise and fall times are important for both modes of measurement because of range clutter. Clutter must be minimized about the target region over the dynamic range of the radar which can only be accomplished by limiting the total transmission radiation time.

Figure 7 shows a 60 GHz radar with a Gunn oscillator transmitter designed for vehicular detection out to 300 meters. A companion micro-processor-based signal processor provides automatic range acquisition as well as selectable transmitter pulse widths and adjustable receiver range gates. Depending on the specific application, similar units have been designed at frequencies ranging from 50 to 94 GHz. Low cost is achieved with dielectric lens antennas and the minimum use of millimeter-wave semiconductors. In certain applications a single semiconductor can act as transmitter source, local oscillator, and mixer.

Communications

Satellite communications systems utilizing millimeter-waves because of the low probability of intercept and broad bandwidth capabilities have become a reality and are one of the largest markets for millimeter-wave technology in the eighties. Figure 8 depicts the latest in mobile, tactical, satellite communications systems utilizing 44 GHz uplinks and 20 GHz downlinks.

Hughes-manufactured millimeter-wave semiconductors, low-noise receiver subsystems, and solid-state power combiners (see page 46 in this catalog), are helping to make these satellite communications systems possible.

Hughes GaAs FET low noise amplifiers are described on pages 82 and 83. They have noise figures ranging from under 3 dB at 20 GHz to under 4 dB at 35 GHz. Shown in Figure 8 is a custom Hughes low noise receiver subsystem. IMPATT diode combiners which offer up to 25 Watts over the 43.5 to 45.5 GHz band are also shown in Figure 8 for use in uplink transmitters.

Silicon IMPATT diodes with MTBFs of greater than 10^7 hours as determined by accelerated constant stress testing analysis have been used in satellites for years. Amplifiers using them are suitable for both downlink and cross-link applications. Silicon IMPATT amplifiers have been operating continuously at Hughes for over 11 years without a failure on life test.

Low cost millimeter-wave communications links which operate in the lightly used Government frequency band of 36 to 38.6 GHz have been built for distances from 50 feet up to 20 miles. The beams are virtually undetectible outside their narrow path, making these systems ideal for secure point-to-point communications, data transmission, teleconferencing, and security monitoring.

Electronic Warfare

Designing electronic countermeasures to millimeter-wave weapons and communications systems present formidable challenges. Millimeter-wave solid state and vacuum technology advances have permitted radar and communications systems designers to implement fieldable equipment using these frequencies. As a result millimeter-wave EW technology must also progress.

Since a radar suffers a two way path loss and ECM system suffers only a one way path loss, the broadband receiver sensitivities needed to detect threats at their maximum range are well within the current state-of-the-art for superheterodyne receivers. This is true even when performance is required in hostile environments, such as wing tips, external aircraft pods, arctic and tropical mast tops and trucks, are considered. Highly sensitive broadband receivers of all shapes and sizes are now practical due to advances in integration and packaging techniques.

The low probability of intercepting high directivity millimeter-wave signals make jamming of these systems a truly formidable task. The investment now being made in the development of these systems is excellent testimony to their effectiveness.

HUGHES MILITARIZED COMPONENTS AND SUBSYSTEMS FIND APPLICATION IN MM-WAVE SATELLITE COMMUNICATIONS SYSTEMS.

A key factor in the improved performance and producibility of millimeter-wave systems and components is the availability of quality instrumentation. Much excellent equipment, designed for microwave measurements, can be adapted for use at millimeter-wave frequencies, but a substantial investment is now being made by instrumentation manufacturers to design complex and automated equipment specifically for making millimeter-wave measurements. As a leader in this field, Hughes has designed millimeter-wave synthesizers; automatic network analyzers; frequency, phase, noise figure and power measurement equipment; and a complete line of solid state sweep frequency generators.

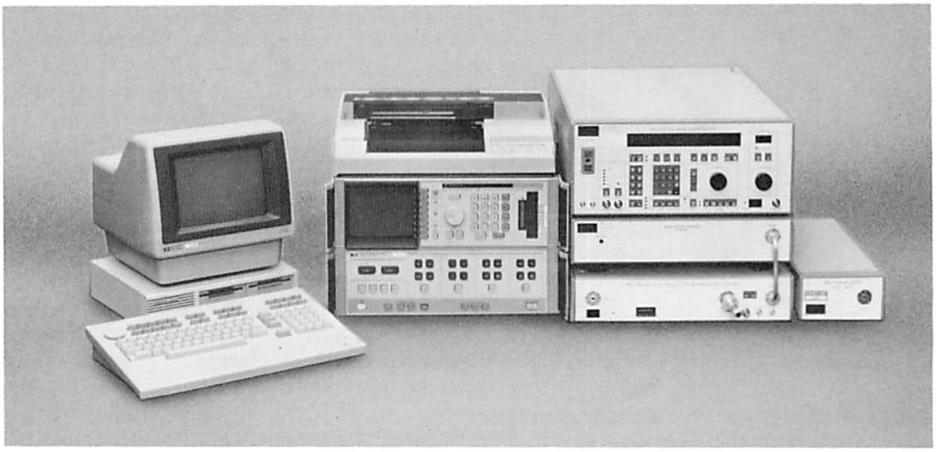


FIG. 1. MILLIMETER-WAVE AUTOMATIC VECTOR NETWORK ANALYZER.

SIGNAL GENERATION

Hughes offers a complete line of fundamentally generated and multiplied solid-state millimeter-wave signal sources for all instrumentation applications. This line includes both synthesized and free-running oscillators utilizing GaAs FET, Gunn and IMPATT devices. In offering this wide variety of instrumentation sources, Hughes provides the user the best unit for his application and/or pocketbook.

If excellent signal quality and stability is required, the Hughes 4785xH series of millimeter-wave synthesizers described on pages 10 and 11 is available. These instruments feature full-band coverage in K-, Ka-, Q-, U-, V- and W-bands. If a more economical approach is required, partial bandwidth units are offered in W-band. This high performance instrument offers low phase noise signals in both the CW and stepped frequency mode. In addition, a free-running sweep is available for applications where the synthesized mode is not required. Stabilities of $1x10^{-9}$ parts/day are achieved with phase noise typically 72 dB below the carrier in a 1 Hz bandwidth, 1 kHz from the carrier in Ka-band. Other features include resolutions of 100 Hz; amplitude, frequency and pulse modulation and full GPIB programmability. A modular construction allows the expansion of frequency coverage from 18 to 110 GHz by the addition of a millimeter-wave module. This fully programmable GPIB compatible instrument is ideally suited as the signal source in vector network analyzers, receiver testing and other measurements where stability and low phase noise are important.

For applications such as scalar network analyzers and other measurements where phase noise and high stability is not as important a consideration, a free-running sweep source may be the best choice. The Hughes series 4772xH plug-in sweep generators are full featured sweepers compatible with the Hewlett Packard 8350B mainframes. This series of sweepers covers full waveguide bandwidths from 18 to 110 GHz. Above 110 GHz, partial bandwidths (up to 25 GHz) are offered to 160 GHz. Hughes sweep sources are all solid state sources. The K-, Ka- and Q-band units are fundamental YIG tuned GaAs FET oscillators and in U- and V-bands they are doubled GaAs FET oscillators. In W-through D-bands, IMPATT sources are used to provide fundamental frequency coverage. The combination of these IMPATT oscillators provide the full band coverage in W-band and the 25 GHz bandwidth in F- and D-bands. Two methods of combining of sources are offered. First, for applications such as scalar network analysis where a broadband single sweep is required, full band coverage through 110 GHz is obtained by means of PIN switches. For broadband requirements above 110 GHz, an electromechanical switch is used to combine the sources. Single source options and high power reduced bandwidth units are also available. (See discussion on IMPATT sources, page 41.) These sweep generators utilizing the sweep mainframe are described on pages 12 and 13. If improved frequency stability is required, all sources may be automatic frequency controlled by using a mixer and an EIP 578 source locking counter. In some applications, such as frequency agile local oscillators, where high power and low AM noise is a requirement, in addition to the GaAs FET oscillators in K- through V-bands, Gunn oscillators may be incorporated, either singly or combined, with the sweep mainframe.

The simplest and least expensive sweep generator consists of a voltage sawtooth generator and a Hughes adjustable sweep source as described on pages 14 and 15 in the catalog. Controls are provided to adjust the minimum and maximum sweep frequencies or to run the source CW at any fixed frequency within its bandwidth. Leveling and square wave amplitude modulation can be added to this system by using the separate Hughes model 4771xH modulator/leveling loop described on pages 16 and 17.

NETWORK ANALYSIS

Vector Measurements

Microwave designers have had the convenience of using network analyzers for many years. Frequency response information about the device under test is displayed directly in rectangular or polar form in real time and can be viewed while optimizing the circuit in question.

The use of a downconverter technique enables the millimeter-wave designer to make swept frequency response measurements at higher frequencies. The Hughes Synthesizer previously described and the S-Parameter Test Sets and Reflection/Transmission Test Sets described on pages 18 through 21 can be used directly with microwave vector network analyzers.

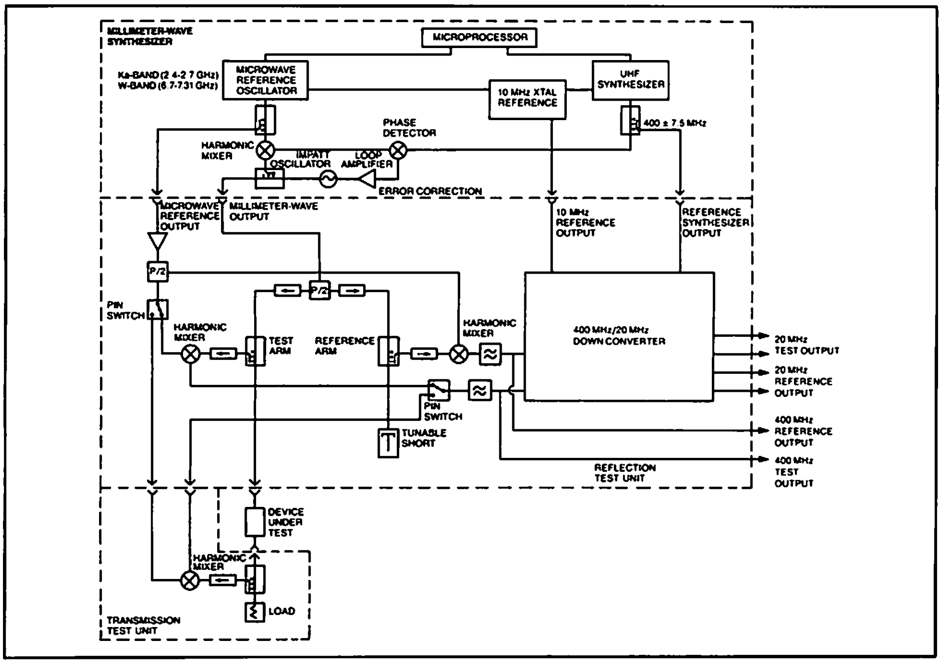


FIG. 2. SYNTHESIZER DRIVEN REFLECTION/TRANSMISSION TEST SET.

This eliminates the need for special signal processing and display instrumentation to extend measurements to higher frequencies. For the user this translates to significant cost savings and a tremendous increase in measurement capability. Figure 1 shows the hardware required to make a downconverter analyzer. A Hewlett Packard microwave vector network analyzer coupled with a Hughes S-Parameter or Reflection/Transmission Test Set, and the Hughes Synthesizer are the key components. All features of the microwave analyzer are now available to the millimeter-wave designer.

Two versions of the test set used with the Hughes Synthesizer are available. The S-Parameter Test Set provides full internal switching of all signals necessary to allow the automatic measurement of the four S-parameters without reversing the device under test. This feature is extremely useful when many devices are being tested and it minimizes measurement inconsistencies associated with connecting and re-connecting waveguide flanges. The Reflection/Transmission Test Set provides the flexibility of a remote transmission test unit which is cable connected to the reflection test unit. Both systems are described on pages 18 and 19, and they are a particularly cost-effective approach to complex measurements. They are based on the structure of the Hughes synthesizer. The synthesizer (see block diagram, Figure 2) downconverts the fundamental millimeter-wave oscillator to approximately 400 MHz at which frequency phase comparison takes place. As seen in the block diagram, the reference signals from the synthesizer are used in the reflection/transmission test set or S-parameter test set to downconvert to a constant 20 MHz for use in the HP 8510, or, if desired, the near constant 400 MHz first downconversion which can be used as an input to the HP8411/8410 system. This approach provides an extremely stable phase coherent system of measurement.

To demonstrate the usefulness of the system for characterizing active components, an IMPATT diode injection-locked-oscillator (ILO) amplifier was analyzed for all four S-parameters. The amplifier was operated from 93.5 to 94.5 GHz. The S_{21} magnitude and phase results are shown in Figures 3 and 4 respectively. The correct drive levels for injection-locking the amplifier were achieved by placing a second, similar amplifier and attenuator between it and the signal source input to the bridge. In this way, the synthesizer is employed to injection-lock the second amplifier, which is in turn used to injection-lock the amplifier under test. To check theoretical expectations with actual performance, the drive level to the amplifier under test was reduced until it would no longer lock outside the 1 GHz operating bandwidth. Theoretically, the amplifier should contribute 180 deg. of phase shift when its IMPATT diode is on and it is operating in its locking bandwidth. When run outside of the locking bandwidth, the diode has no effect on the measurement system, since its output is different from the reference (or injection-locked) frequency. Therefore, the phase change for the locked frequency bandwidth minus the phase change for an equivalent-bandwidth unlocked amplifier should equal 180 deg. As Figure 4 shows, theoretical and actual measurements agree to within a few degrees.

All the vector measurements systems described above provide ease of expansion to all waveguide bands. A common synthesizer mainframe and S-parameter control unit facilitates this expansion.

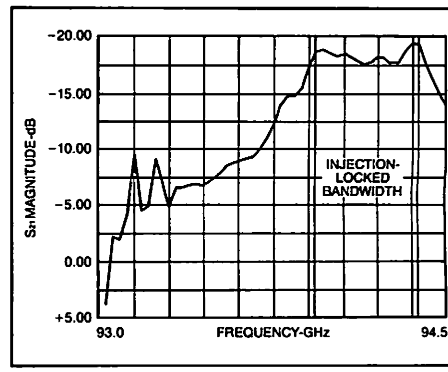


FIG. 3. S_{21} MAGNITUDE OF CW INJECTION-LOCKED OSCILLATOR.

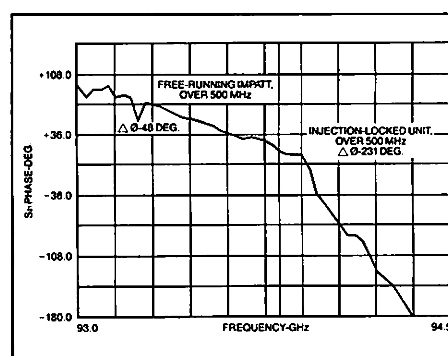


FIG. 4. S_{21} PHASE OF CW INJECTION-LOCKED OSCILLATOR.

Automation is accomplished by adding a computer. Specially designed software is provided that controls the synthesizer, test set, and network analyzer to provide fast, accurate, error corrected measurements. Completed, automated turnkey systems are described on pages 20 and 21.

Scalar Measurements

In many cases, vector measurements are not necessary and scalar measurements will supply all the information that one needs. In these instances a scalar network analyzer or reflectometer will suffice. Figure 5 shows the block diagram of a scalar network analyzer. Basically, a well isolated source is used to measure the amplitude component of the return loss and insertion loss of the device under test. Initially a system calibration is performed and recorded. A reference short is utilized at the test plane for the return loss calibration and coupler 1 is connected to coupler 2 for the insertion loss calibration. The device under test is then inserted and the voltages of detectors 1 (return loss) and 2 (insertion loss) are compared to the calibration data.

Provided that the detectors are operating in their square law region, the output voltages will be proportional to the incident, transmitted, or reflected power so that both the return loss and insertion loss can be measured. All components in the system cover complete waveguide bandwidths and the detectors are compatible with scalar network analyzer/displays such as the Wiltron model 560A, Wavetek/Pacific Measurements model 1038/N10, or either the Hewlett Packard model 8756A or 8757A.

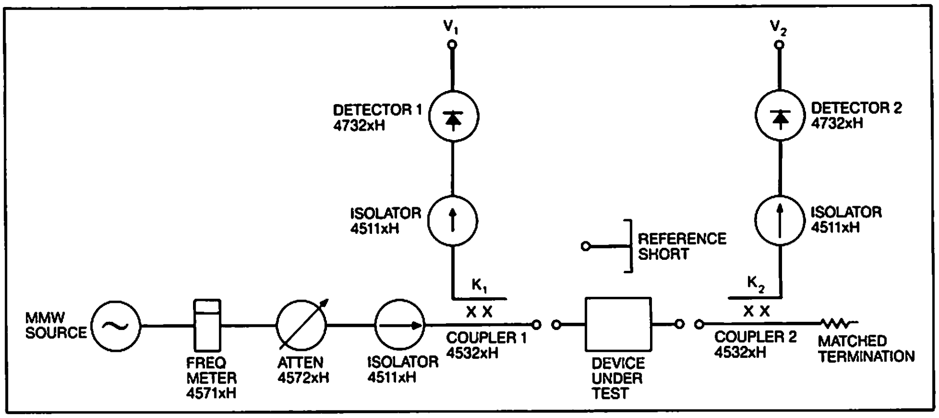


FIG. 5. SCALAR NETWORK ANALYZER BLOCK DIAGRAM.

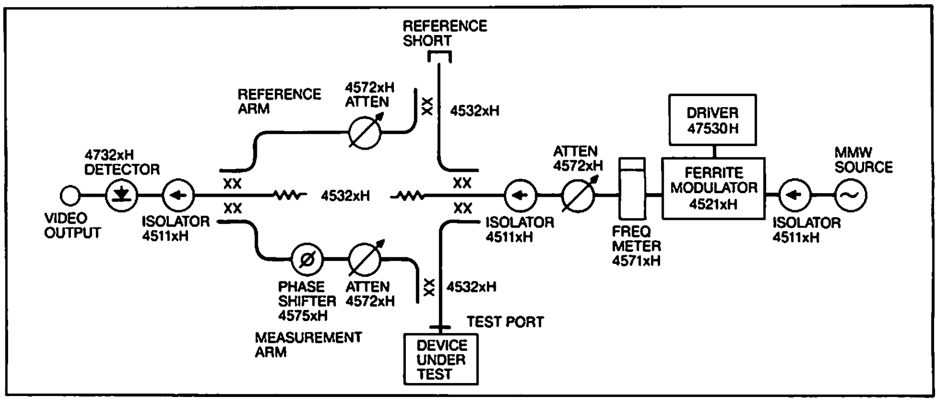


FIG. 6. COMPLEX REFLECTION COEFFICIENT BRIDGE.

Complex Impedance Bridge

If scalar measurements are insufficient for a particular requirement and the user does not wish to make the investment required for a down-converter network analyzer, then the complex impedance bridge is likely to be the most cost-effective set up. It is basically a manual system that is quite easy to configure with waveguide components described in this catalog. The bridge is illustrated in Figure 6. A millimeter-wave source is amplitude modulated by the ferrite modulator, typically at a 1 kHz rate. The power is then split between the reference arm and the test arm. During calibration, the device under test is replaced by a known reference short. The attenuators and the phase shifter in the bridge arms are adjusted for a detector null as measured on an oscilloscope, AC volt meter, or lock-in analyzer. The device to be measured is then connected to the test port. By adjusting the attenuator and phase shifter in the test arm, the detector output may again be nulled. Noting the difference in the calibration and measurement settings of the attenuator and phase shifter, the complex impedance of the device under test may be calculated. For the best accuracy, a frequency stabilized source or a phase locked source, such as the Hughes synthesizer described on page 10, is useful.

Although Figure 6 shows the bridge configured to measure the reflection characteristics of single port devices, it may be easily arranged to measure transmission characteristics as well. The two couplers are simply replaced with straight sections permitting the insertion of an unknown two-port device as shown in Figure 7. The concept may be extended to multi-ports by using terminations on the other ports. Using the two-bridge configuration, it is therefore possible to measure complete scattering coefficients of multi-port components.

SIGNAL ANALYSIS

Equipment is also readily available for the measurement of signal parameters such as frequency, power, spectrum, and noise figure. In many cases the same instruments used at microwave frequencies can be adapted for use at millimeter-waves with the help of a millimeter-wave component.

Power Measurements

One example of this is the Hewlett Packard model 432 power meter which, with the aid of the Hughes temperature compensated thermistor mount, described on pages 28 and 29, enable the user to measure power in ranges from 10 microwatts to 10 milliwatts in the frequency range between 26.5 to 170 GHz. This power range is easily extended with the use of the Hughes direct reading precision rotary vane attenuator described on pages 34 and 35.

A new advancement in power measuring instruments is the Hughes Millimeter-Wave Power Meter and Diode Power Sensors described on pages 26 and 27. This measurement system takes advantage of the ultra sensitive zero bias silicon detector diodes. Each sensor has a pair of anti-parallel detectors which drive an extremely

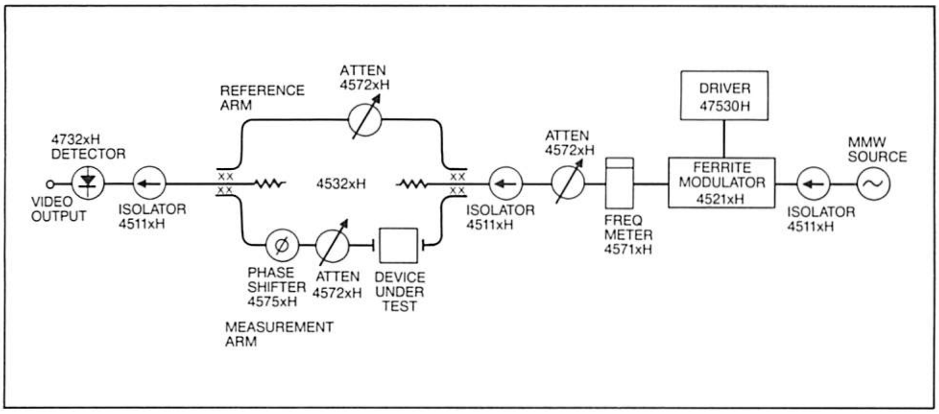


FIG. 7. COMPLEX TRANSMISSION COEFFICIENT BRIDGE.

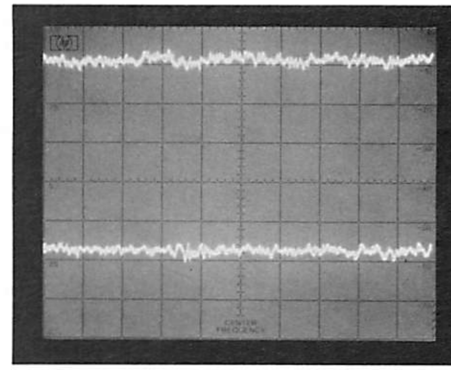


FIG. 8. ENR FOR 51 TO 55GHz IMPATT NOISE SOURCE. VERTICAL SCALE IS 5 dB PER DIVISION.

sensitive nano-voltmeter. The result of this combination of detector and nano-voltmeter with micro-processor correction for non-linearity yields 60 dB dynamic range from +10 dBm to −50 dBm. These instruments may be configured with dual channel sensors and IEEE 488 bus. This new power measurement system is offered in waveguide in K-, Ka-, Q-, U-, V-, and W-bands (18 to 110 GHz), and in the 18 to 40 GHz WRD 180 doubled ridged waveguide band.

Another power measurement instrument is the Hughes Millimeter-Wave Dry Calorimeter. This device compares RF energy with DC energy. It has historically been the preferred approach to power measurement by calibration labs. These instruments are described further on pages 30 and 31, and are offered in Q-, V-, and W-bands.

Frequency and Phase Measurements

Frequency can be measured with the direct reading precision frequency meters described on pages 32 and 33. Similarly, phase change can be measured in a phase bridge with the use of the precision direct reading phase shifters described on pages 36 and 37.

Spectrum Analysis

For spectrum analysis two approaches are now available. One is based on harmonic downconversion using a local oscillator signal from the spectrum analyzer and the other uses a direct downconversion technique with either a free-running or phase-locked millimeter-wave local oscillator. The harmonic mixers described on pages 98 and 99 feature broadband operation with wide IF bandwidths and are available for use with spectrum analyzers with or without built-in diplexers. When properly connected, the analyzer and mixer allow the display and analysis of millimeter-wave signals. Positive and negative polarity options of the mixers are provided so that the frequency range can be extended on most available analyzers.

The direct downconversion method uses broadband planar balanced mixers and has several key advantages over harmonic mixing. Dynamic range is the highest available. Spurious signals are easily identified and a calibration curve is supplied with each system for power measurement. These mixer/local oscillators are further described on pages 98 and 98 and are offered in the bands covering 18 to 110 GHz.

Noise Figure Measurements

Accurate and dependable noise figure measurements are possible at millimeter-wave frequencies by using available microwave noise figure meters and millimeter-wave noise sources. Both solid state and tube noise sources are available for this purpose. Hughes has developed solid state noise sources using IMPATT diodes. Solid state noise sources offer advantages over conventional gas tubes including: low voltage operation, compact size, and high excess noise ratio (ENR). A very flat power spectrum full waveguide bandwidth is readily available from IMPATT noise sources as shown in Figure 8 for V-band. Solid state noise sources are available to 100 GHz for a wide variety of instrumentation applications. Gas tube noise sources are available through 220 GHz.

Figure 9 shows an automated noise figure meter operating at millimeter-wave frequencies. The ferrite modulator/driver is used to gate the output of the noise source. The gating signal is derived from the noise figure meter and is the external input signal to the modulator driver. The gated noise output is applied to the input of the device under test (low noise amplifier, etc.). The output of the device under test is downconverted to the noise figure meter IF frequency (typically 30 MHz) by use of a planar crossbar balanced mixer and a frequency agile local oscillator such as a Hughes plug-in sweep generator with a GaAs FET or Gunn source. In addition, the sweep generator output is available. This output can be used as the RF input to a balanced mixer for direct conversion loss and noise figure measurements of these devices. The Noise Figure Meter performs the measurements and acts as the controller for the local oscillator, and any peripheral equipment such as a plotter. Systems are available that provide full waveguide bandwidth noise figure and gain measurement in K-, Ka-, Q-, U-, and V-bands and up to 8 GHz bandwidth in W-band. The systems are compatible with either the HP8970 or Eaton 2075 Noise Figure Meters. These systems are described on pages 22 and 23 of this catalog.

1

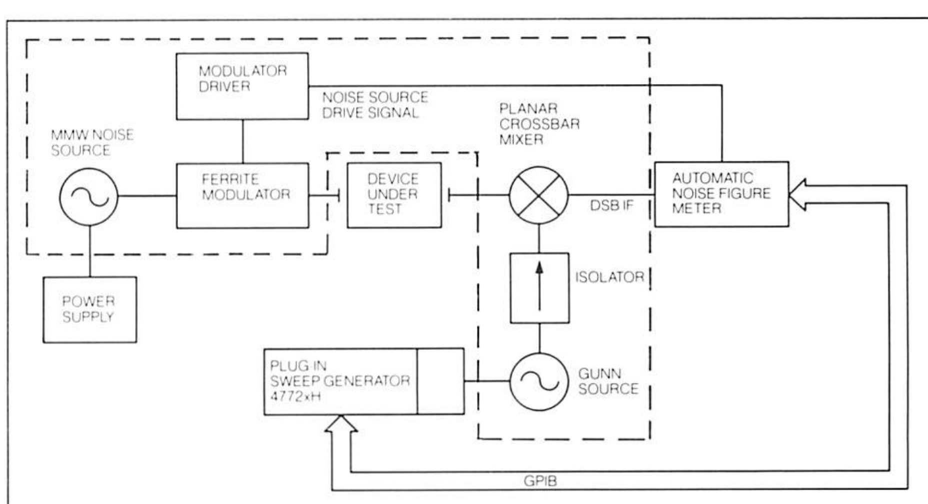
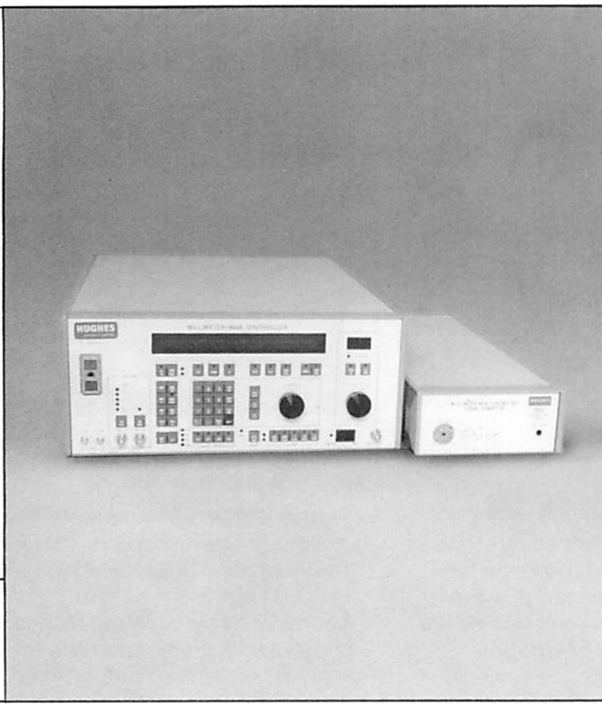


FIG. 9. AUTOMATED MMW NOISE FIGURE TEST SET.

Millimeter-Wave Synthesizer



Hughes 4785xH series of solid state, microprocessor based Millimeter-Wave Synthesizers provide high stability and very low phase noise signals in seven waveguide bands from 18 up to 140 GHz. This is accomplished by phase locking a solid state oscillator to an internal crystal reference or a customer-provided external reference. The synthesizer offers three modes of operation: a CW synthesized mode, a synthesized frequency stepping mode, and a free running swept frequency mode. It is ideal where a wide band low phase noise source is required such as the signal source for complex impedance measurements and broadband receiver testing. Power outputs vary from as high as + 5dBm in W-band to + 13dBm in K-band depending on the option selected, but higher power levels over narrower bandwidths are available for special applications.

The synthesizer consists of a main frame and a millimeter-wave module. The main frame is common to all bands. The main frame contains the microprocessor, power supplies, the GPIB interface, the low frequency reference synthe-

GPIB

FEATURES:

SPECIFICATIONS

	Frequency Band (GHz)								
	K (18-26)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	W (75-100)			D (140)
Power Output, (dBm min) (without leveling or pulse modulation option)②	+13	+10	+5	+2	−1	25 GHz Bandwidth +3 10 GHz Bandwidth +5			0
With Leveling Option–Output Power Reduced (dB max)②	2.5	2.5	3.0	3.0	3.0	3.0			–
With Pulse Modulation Option–Output Power Reduced (dB max)②	0.5	1.0	1.0	1.0	2.0	25 GHz Bandwidth −3.0 10 GHz Bandwidth −2.0			–
Bandwidth (GHz min) Broadband Option	Full waveguide	Full waveguide	Full waveguide	Full waveguide	Full waveguide	25 GHz			–
Partial Bandwidth Option (GHz min)	–	–	–	–	–	7	10	–	10
For Center Frequencies between	–	–	–	–	–	78.5-85	85-95		140
Unleveled/Leveled Output Flatness (± dB typical)	2.0/1.5	2.0/1.5	2.0/1.5	3.0/1.5	3.0/1.5	6.0/1.5			2.0
RF Output Attenuator (dB min)①⑦	10	10	10	10	10	10			–
Attenuator Accuracy (± dB max)	1	1	1	1	1	1			–
Waveguide and Flange	See Page 157								

SYNTHESIZED MODES

Frequency Specifications
- Resolution (Hz) 100
- Switching Time (ms. typ) .... .25
- Aging Rate (Internal Reference)③ .... <1x10⁻⁹/Day
- Stability (Internal Reference) (+15 to +35°C)③ .... ±5 x 10⁻¹⁰
- External Frequency Reference Input (MHz) (5 to 10 dBm into 50Ω) 10
- Reference Frequency Output (MHz) (0 dBm min into 50Ω) 10
- Spurious Responses (non-harmonic, typ) .... <−40 dBc
- Spurious Responses (harmonic, typ) .... <−25 dBc

Modulation Specifications

Amplitude⑦
- Depth (%, typ) 0-50
- Rate (kHz) 0-5
- Distortion (THD% max) 10
- External Input (VPK into 1kΩ, nom) 1

Frequency
- Modulation Index (max)⑧ 1
- Rate (MHz min-max) 0.01-5
- External Input for Peak Deviation (VPK into 50Ω, nom) 1

Pulse⑤⑥
- Width (ms min/max) 0.001/5
- Repetition Rate (kHz min/max) 0.1/100
- On-Off Ratio (dB min) 20

SWEEP AND FREQUENCY STEPPING (SYNTHESIZED) MODES

- Sweep Modes .... Synthesized or Free Running
- Control Functions .... CW, Start-Stop, ΔF, marker sweep and marker→CF
- Sweep and Trigger Modes .... Internal sweep 10 ms to 100 sec. per sweep (free running mode) Manual Sweep/Single Sweep External Trigger/Line Sync.
- Markers .... 3 Independent Markers selected from Keyboard or Increment Knob

Marker Accuracy
- —Synthesized Mode .... Same as time base
- —Free Running Mode .... ±10 MHz or ±1% of span (whichever is greater)

- RF Blanking (dB typ)④⑦ 20
- Internal Square Wave Rate (kHz)⑥ .... 0.1 to 100
- Pulse Modulation Depth (dB typ)④⑥ 20
- Step Size (Synthesized Mode)(Hz) 100
- Dwell Time (Synthesized Sweep Mode) (seconds per frequency) .... 0.001 to 10
- Save n/Recall n .... Allows up to 9 front panel settings to be stored and recalled
- Local/Remote .... Selects local or remote programming of all front panel controls except the POWER ON switch via the GPIB (IEEE-488)

① Specification with leveled output Attenuation range greater with unleveled output
② See How to Order
③ After 72-hour warmup
④ Specification with attenuator set at zero
⑤ Selectable from front panel or from external input
⑥ Not applicable on option without pulse modulation
⑦ Not applicable on units without leveling
⑧ Modulation index = Deviation (Δf) ÷ Modulation rate (fm)

sizers, and crystal reference oscillator. The millimeter-wave module consists of an electrically tuned solid state oscillator and all the necessary millimeter-wave components and electronics to phase lock the millimeter-wave source to the crystal reference. The K-, Ka- and Q-band oscillators are full waveguide bandwidth fundamental GaAs FET oscillators, and in U- and V-band they are doubled GaAs FET oscillators. In W- and D-bands, the oscillators are IMPATT sources. W-band offers either broadband units where multiple IMPATTs are combined or as a single IMPATT partial band unit. In the broadband units, the oscillators are combined through PIN switches and offer 25 GHz bandwidth. A leveling loop is available on all units except D-band. The millimeter-wave module is cable connected to the main frame.

The instrument provides synthesized millimeter-wave signals in precise increments of 100 Hz. Frequency acquisition time is typically 25 milliseconds or less and a variable dwell time of 1 millisecond to 10 seconds is provided. A 10 MHz reference frequency output is provided, which allows locking other instrument time bases to the synthesizer. In addition, provision for locking the synthesizer to an external 10 MHz reference is available.

CW signals can be AM modulated at a 0 to 5 kHz rate with a depth of modulation up to 50% or be FM modulated at a rate between 0.01 and 5 MHz with a maximum modulation index of 1. Pulse modulation and leveling are optional on all units thru W-band. The unit has a built-in programmable attenuation capability of 0 to 10 dB, on all units with leveling.

The sweep modes provide all the features expected of a microprocessor based synthesized sweep generator and are listed in the specifications. Full programmability of all instrument functions is provided. Data entry is made from the front panel keyboard or via the GPIB (IEEE 488). Up to nine front panel settings may be stored and recalled. This feature allows the operator to rapidly change any or all instrument parameters, which reduces set-up time.

- **Fundamental Oscillators**
- **Lowest Phase Noise Signals to 140 GHz**
- **Full Waveguide Bandwidths through V-Band**
- **GaAs FET Oscillators in K- through V-Bands**

HOW TO ORDER

Main Frame 47850H-53xx

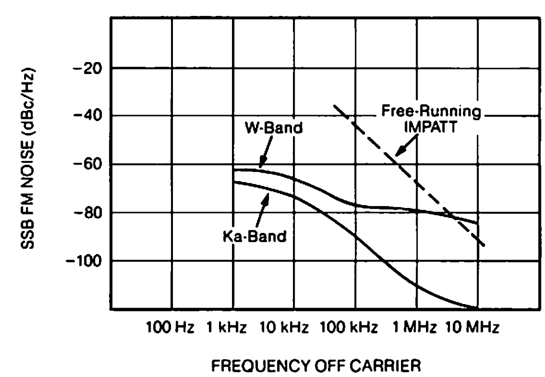
Cable Location and Rack Mount Option	**0:** Front Panel **1:** Rear Panel **2:** Front Panel/Rack Mount **3:** Rear Panel/Rack	
AC Input Voltage (50/60 Hz)	**1:** 110 VAC **2:** 220 VAC	**3:** 100 VAC **4:** 235 VAC

Millimeter-Wave Module 4785xH-xxxx

Frequency Band	**0**: K **1**: Ka **2**: Q **3**: U	**4**: V **6**: W **8**: D
Flange	**1**: Round (Available Ka- through D -bands only) **2**: Square (Available in K- and Ka-bands only)	
Pulse Modulation Option	**0**: With Pulse Modulation (Not available in D-band) **1**: Without Pulse Modulation	
Bandwidth Option	**2**: Partial Waveguide Band (Specify Center Frequency. Available in W- and D-bands only) **4**: 25 GHz (75 to 100 GHz in W-Band only) **5**: Full Waveguide Band (K- through V-bands only)	
Leveling Option	**0**: With Leveling (Not available in D-band) **1**: Without Leveling	

Example: To order a 75 to 100 GHz Synthesizer for use on 110 VAC rear panel cable location, and pulse modulation and leveling capabilities, specify a Model 47850H-5311, and a millimeter-wave module model 47856H-1040.

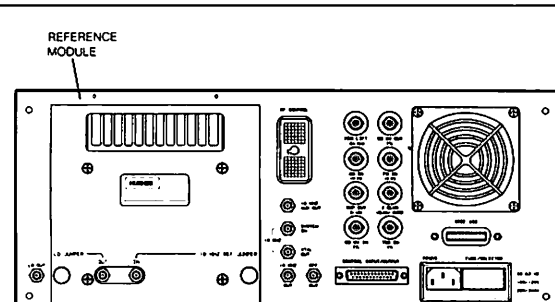
TYPICAL PERFORMANCE CURVE



SSB FM Noise of Ka- and W-band Synthesized Signal Generator (Excluding Spurious Response)

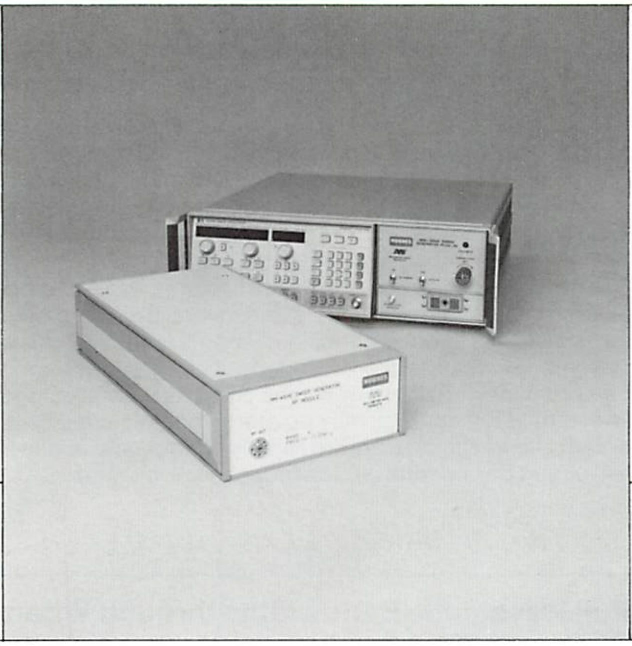
OUTLINE AND MOUNTING DRAWING

Main Frame (rear panel)



DIMENSIONS ARE IN INCHES (CM): 17 (43.18) WIDE x 7.5 (19.05) HIGH x 23 (58.42) DEEP
APPROXIMATE WEIGHT: 55 LBS. WITHOUT MM-WAVE MODULE.

NOTE: K- through V-band full band and W-band partial band millimeter-wave modules dimensions and weight (inches (cm)/lbs (kg) approx) 3.4 (8.6) x 8.0 (20.3) x 16.5 (91.9)/15 (7)
Full band and 25 GHz bandwidth W-band millimeter-wave modules dimensions and weight (inches (cm)/lbs (kg) approx) 3.4 (8.6) x 16 (40.1) x 22 (55.9)/28 (12.5)



Hughes GaAs FET and multiple IMPATT Plug-In Millimeter-Wave Sweep Generators consist of a sweep source, a sweep plug-in and the Hewlett-Packard 8350B main frame. The sources feature oscillators with electronic tuning in eight waveguide bands from 18 to 160 GHz. The system makes all features of the main frame available including a high resolution digital display of operating frequency.

In K- through Q-Bands, the sweep sources are full waveguide bandwidth GaAs FET oscillators, and in U- and V-Bands doubled GaAs FET oscillators. These oscillators provide excellent AM and FM performance which makes them suitable as local oscillators as well as for most instrumentation applications. These sources deliver up to +14 dBm output power in K-Band and up to 0 dBm in V-Band.

In W, F and D-Bands, the sweep sources are multiple IMPATT

GPIB

FEATURES:

HOW TO ORDER

Model Number 4772xH-xxxx

Frequency Band
- **0**: K
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **6**: W
- **7**: F
- **8**: D

Flange Type
- **1**: Round (available in Ka- through D-bands only)
- **2**: Square (available in K- and Ka-bands only)

Main Frame
- **3**: With 8350B Main Frame
- **5**: Without Main Frame. For use with HP8350B. Requires HP11869A (not supplied)

Bandwidth
- **4**: Any 25 GHz Bandwidth (F- and D-bands up to 160 GHz only—specify center frequency)
- **5**: Full Waveguide Bandwidth using electronically tuned GaAs FET oscillator (K- through V-bands only)
- **6**: Full Waveguide Bandwidth using PIN switched IMPATT oscillators (W-band only)
- 7: GUNN VCO (W-band only)

Leveling Option
- **0**: With Leveling (Modulator only in F- and D-bands)
- **2**: Without Leveling

Example: To order a sweep generator including the HP8350B main frame capable of supplying + 1dBm of leveled output power in W-band, specify a 47726H-1360.

oscillators which are combined to produce sweeps timed in milliseconds over wide bandwidths. The combining is accomplished through either matched hybrid Tee or PIN diode switching with switching time between bands accomplished in 8 milliseconds in the auto sweep mode, and 20 milliseconds in the manual sweep mode. These sources deliver output powers of +3 dBm in W-Band and 0 dBm in F and D-Bands.

All sources include integral isolators that provide excellent source match. A leveling loop is available that provides excellent output flatness. The instantaneous wideband performance makes these oscillators ideally suited for most instrumentation applications where a flat, fast broadband sweep is required.

The fully solid-state design of the sweep source provides a compact package and assures excellent temperature stability and reliability.

The main frame allows control of all sweep functions through front panel data entry or full programmability via the IEEE 488 Bus. The sweep plug-in provides the interface between the main frame and the sweep source.

Single head oscillators and high power oscillators operating at frequencies up to 160 GHz are also available. See pages 14 and 15

• Extends HP8350B with Full Band Coverage to 160 GHz

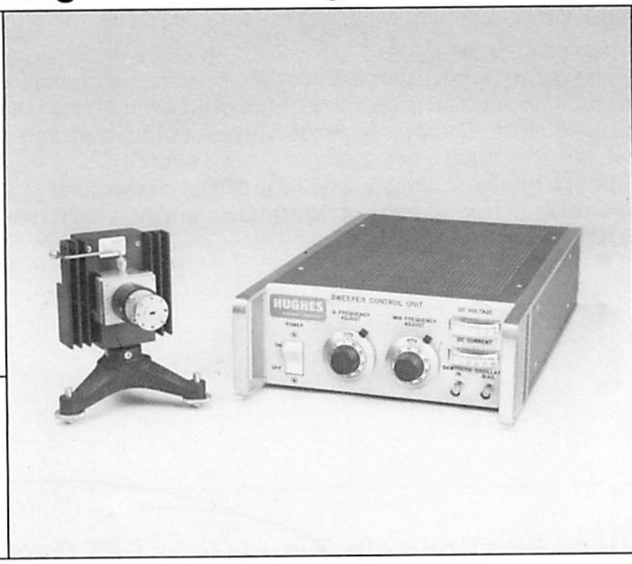
• Uses Electronically Tuned GaAs FET Oscillator in K- Through V-Bands + GUNN VCO's in W-BAND.

SPECIFICATIONS

	Frequency Band (GHz)								
	K (18-26.5)	Ka (26.4-40)	Q (33-50)	U (40-60)	V (50-75)	W (75-110)	W (90-98)	F (90-140)	D (110-160)
Sweep Bandwidth (GHz min)	Full Band	Full Band	Full Band	Full Band	Full Band	Full Band	8	25	25
Power Output, Unleveled (dBm min) (Without leveling option)	+14	+10	+6	+3	0	+3	+5	0	0
With Leveling Option Output Power Reduced (dB max)	2.5	2.5	3.0	3.0	3.0	2.0	4.0	NA	NA
Unleveled Output Flatness (± dB typical)	2.0	2.0	2.0	3.0	3.0	6.0	2.0	3.0	3.0
Leveled Output Flatness (± dB max)	1.5	1.5	1.5	1.5	1.75	1.75	1.75	–	–
Temperature Stability (MHz/°C typ) (15 to 30°C)	1	1	1	1	2	2	-5	4	4
Modulation Depth (dB typ)①	25	25	25	25	25	25	25	25	25
Max Ext Mod Rates (kHz)							–	50	50
Ext Mod Input Voltage (+V)	5	5	5	5	5	5	–	5	5
RF Blanking①	RF is turned off during retrace until next sweep								
FREQ. ACCURACY:									
CW MHz max	30	40	50	60	150	220	±75	280	320
Sweep (100 msec) MHz max	60	80	100	150	300	450	±125	600	650
Waveguide and Flange	See page 157								

① With Leveling Option Only
Main Frame Dimensions (inches (cm)): 5.25 (13.3) x 16.75 (42.5) x 16.6 (42.2)
Sweep Source Dimensions (inches (cm)): 3.4 (8.6) x 8.0 (20.3) x 16.5 (91.9)

Single Head and Adjustable Sweep Sources



The Hughes 4712xH and 4772xH series of single head and adjustable sweep sources offer economical approach for the generation of narrow band low and high power millimeter-wave swept signals. The Model 4712xH consist of an Impatt oscillator and a Hughes Model 47510H Sweep Control Unit (ordered separately). The Hughes Model 4772xH uses the same type of Impatt oscillator, but is controlled by a Hewlett Packard Model 8350B sweeper main frame. Both configurations are available with and without leveling and with standard or high power options.

The Model 4772xH is available with single or multiple MMW plug-ins to cover the frequency range of 26.5 to 160 GHz and is controlled by the 8350B main frame. The main frame

GPIB

FEATURES:

HOW TO ORDER (Adjustable Sweep Source)

(Center frequency for sources must be specified at time of order)

IMPATT Sweep Source 4712xH-xx00
Control Unit 47510H-500x

Frequency Band	**1**: Ka **2**: Q **3**: U **4**: V **5**: E **6**: W **7**: F **8**: D
Flange	**1**: Round **2**: Square (available in Ka-band only) **3**: Pin Contact (available in F- and D-bands only)
Bandwidth/Power Option	**0**: Standard single source **1**: Full waveguide bandwidth set (Ka- through W-bands only) **2**: 75-100 GHz set (W-band) **3**: 90-110 GHz set (W-band) **4**: High Power Unit (available in Ka- through W-bands only)
AC Input Voltage	**1**: 110 VAC 60 Hz **2**: 220 VAC 50 Hz

Examples: To order a 35 GHz Ka-band IMPATT Sweep Source with square flange, specify 47121H-2000, center frequency = 35 GHz.
To order a Sweep Control Unit with 110 VAC 60 Hz AC input voltage, specify 47510H-5001.

HOW TO ORDER (Sweeper Plug-in)

(Center frequency for sources must be specified at time of order)

Model Number 4772xH-xxxx

Frequency Band	**1**: Ka **2**: Q **3**: U **4**: V **5**: E **6**: W **7**: F **8**: D
Flange Type	**1**: Round **2**: Square (available in Ka-band only) **3**: Pin Contact (available in F- and D-bands only)
Main Frame	**3**: With 8350B Main Frame **5**: Without Main Frame. For use with HP8350B requires HP11869A (not supplied) **6**: Without Main Frame. For use with HP8620C
Power Option	**0**: Standard Unit **2**: High Power Option
Single Head Option	**1**: With Leveling Loop (modulator only in F- and D-bands) **2**: Without Leveling Loop **3**: Without Plug-in (Plug-in must be modified)

Example: To order a sweep generator using the HP8350B main frame capable of supplying 1 milliwatt of leveled power output between 90 and 100 GHz in W-band, specify a 47726H-1301, center frequency 95 GHz.

Single Heads
Strung out on
Bench

provides total computer control of all front panel settings and has a high resolution digital display of operating frequency, marker frequency, and sweep time. It is also available with a leveling loop consisting of a ferrite modulator, directional coupler, and a flat broad band detector in any of the frequency bands listed below. In F and D bands only the ferrite modulator is provided with the leveling loop option. Wider frequency coverage is achieved by replacing the sweeper plug-in and MMW components. Separate single head oscillators can be ordered to operate with previously supplied plug-in electronics and main frames. This may require minor modifications to the plug-in which can be factory implemented.

The Model 4712xH includes an Impatt source and optional leveling loop. Power and sweep control functions are provided by the Hughes Model 47510H Control Unit. In addition to the Model 4771xH leveling loop (page 16), other Hughes components can be added to facilitate complete millimeter-wave swept measurements.

Two types of single head oscillator are offered for both configurations with up to 6 GHz of bandwidth in Ka Band, 7 GHz in Q Band, 8 GHz in U Band, and 10 GHz in V, E, W, F and D Bands. Higher power units normally provide less band width (see specifications below). Special configurations are available to meet specific ATE/STE requirements. Contact Hughes or your representative.

Standard and High Power Units Available
Frequency Coverage 26.5 to 160 GHz
Bandwidths up to 10 GHz
Single/Multiple Heads for New or Upgrade Applications

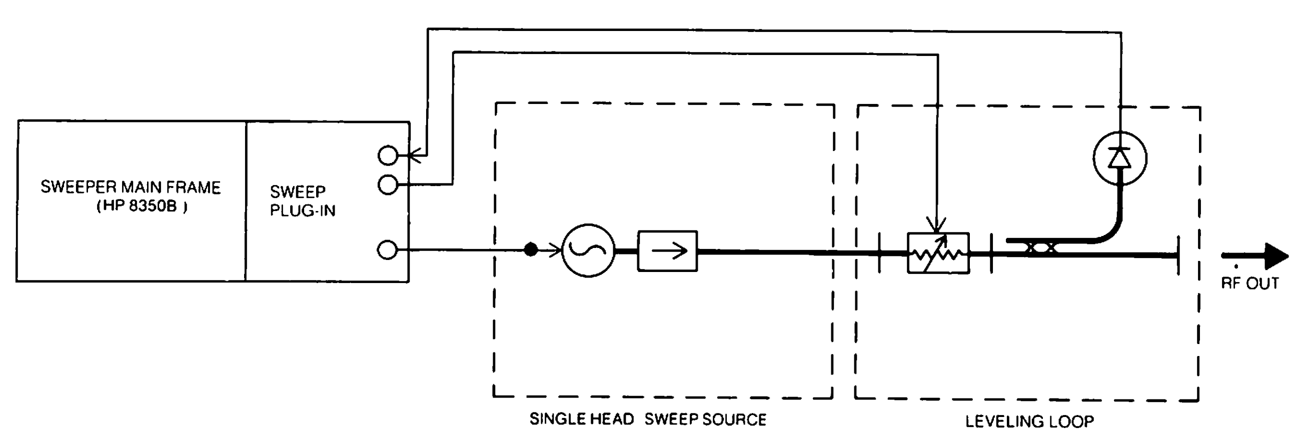
SPECIFICATIONS

	FREQUENCY BAND (GHz)							
	Ka 26.5-40	Q 33-50	U 40-60	V 50-75	E 60-90	W 75-110	F 90-140	D 110-160
STANDARD UNITS								
Sweep Bandwidth (GHz min)	5 / 6	6 / 7	8	8 / 10	8 / 10	8 / 10	10	10
For Center Frequencies Between (GHz)	29-33 / 33-37	36-40 / 40-46.5	46-56	54-60 / 60-70	64-75 / 75-85	79-85 / 85-105	95-135	115-155
Power Output (mW min) With Mod/Lev Loop	2	2	2	2	2	1	0.5	0.5
Without Mod/Lev Loop	5	5	5	5	5	5	1	1
HIGH POWER UNITS								
Sweep Bandwidth (GHz min)	3	4	4	4	5	5	NA	NA
Power Output (mW min, without level loop)	40	30	25	20	20	20	NA	NA
GENERAL								
Temperature Stability (MHz/°C typ)	5	8	8	10	12	14	18	20
Leveled Output Flatness (± dB)	1.5	1.5	1.5	1.5	1.5	1.5	3	3
Modulation Depth (dB typ)①	20	20	20	20	20	20	20	20
Max Ext Mod Rates (kHz)①	30	30	30	30	30	30	30	30
Ext Mod Input Voltage (+ V)①	5	5	5	5	5	5	5	5
RF Blanking (dB typ)①	20	20	20	20	20	20	20	20
CW Frequency Calibration Accuracy ± MHz typ	40	50	60	75	90	110	140	160
Waveguide and Flange	See Page 157							

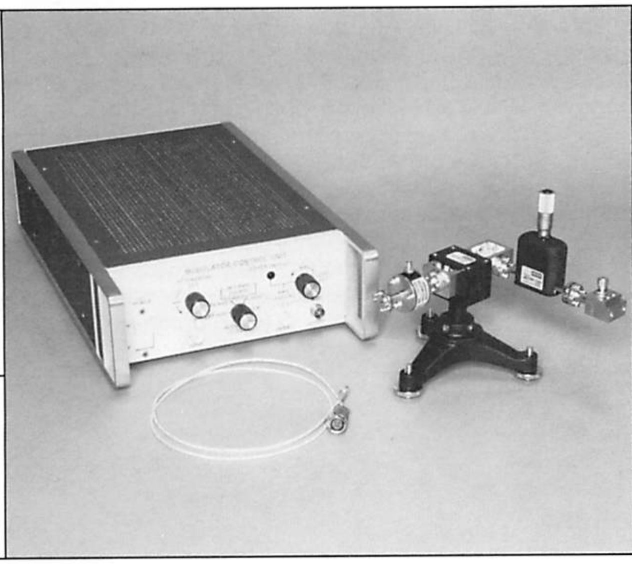
Main Frame Dimensions (inches (cm))...5.25 (13.3) x 16.75 (42.5) x 16.6 (42.2)
① Does not apply for single head option without leveling loop.

BLOCK DIAGRAM

Plug-in Sweep Generator Functions



Modulator/Leveling Loops



Hughes 4771xH series of Modulator/Leveling Loops consist of a ferrite modulator, a directional coupler, a flat detector, a level set attenuator and a Modulator/Leveler Control Unit.

The modulators are Faraday rotation-type devices which utilize a varying magnetic field to change their attenuation characteristics. The modulators and couplers are described on Pages 108 and 114 of this catalog. The flat detectors are described on Page 100.

Power leveling of IMPATT or BWO sweep oscillators is accomplished by varying the attenuation of the modulator. The DC amplifier in the control unit amplifies the difference between the output of the detector and a preset reference volt-

FEATURES:

HOW TO ORDER

Model Number 4771xH-x21x

Frequency Band	**1**: Ka **2**: Q **3**: U **4**: V **5**: E **6**: W **7**: F **8**: D	
Flange Type	**1**: Round (Ka- through D-bands only) **2**: Square (available in Ka-band only) **3**: Pin Contact (available in F- and D-bands only)	
AC Input Voltage	**1**: 110 VAC, 60 Hz **2**: 220 VAC, 50 Hz	

Example: To order a W-band leveling loop which is to be operated off a 220 Volt, 50 Hz line, order a 47716H-1212.

age. The amplifier output controls the modulator and keeps the level of the power output from the coupler constant. The level set attenuator between the coupler and detector allows setting the inputs to the detector so that it operates in its optimum range with RF inputs between -10 dBm and +30dBm.

The control unit also provides variable (950-1050 Hz and 26.4-29.2 KHz) square wave modulation rates. This square wave modulation is achieved when the modulators are switched between their lowest and highest insertion loss states. This can be done by the internal square wave or an external square wave with minimum input of +5 volts. It is possible to let the external modulation voltage vary the attenuation of the modulator when it is not leveling, or to switch the modulator between its high and low insertion loss states at rates up to 50 KHz.

The modulator and driver can also be used to gate the output of a millimeter-wave noise tube to extend automated noise-figure test sets to millimeter-wave frequencies. This gated noise source is applied to the input of the device-under-test (DUT), whose output is down-converted to an Intermediate Frequency which is compatible with the microwave noise-figure meter. Contact Hughes or your local representative for details on this application.

Full Waveguide Bandwidth Leveling to 170 GHz
Modulation Rates to 50 KHz
Compatible with HP8970 and Eaton 2075 Noise Figure Meters

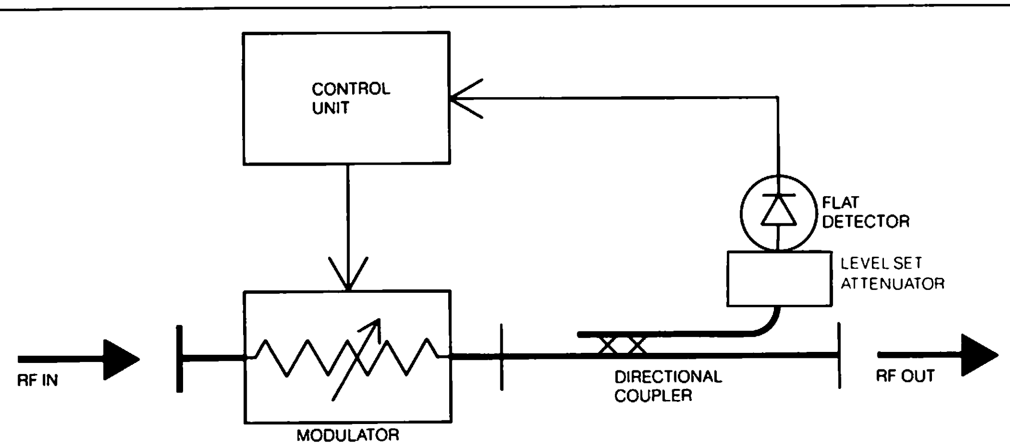
SPECIFICATIONS

	Frequency Band (GHz)							
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)
Flatness (± dB max)	1.5	1.5	1.5	1.5	1.5	1.5	2.5	2.5
Insertion and Coupling Loss ① (dB max)	2.5	3.0	3.0	3.0	3.5	4.0	5.5	6.0
Dynamic Range/Modulation Depth (dB min)⑤	20	20	20	20	20	20	20	20
Minimum Power Input (dBm)	–10	–10	–10	–10	–10	–10	–10	–10
Maximum Power Input (dBm)	+30	+30	+30	+30	+30	+30	+30	+30
Rise Time (10-90%, μsec max)	3	3	3	3	3	3	3	3
Waveguide Size ②	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
Waveguide Flange ②	UG-381/U ③ UG-599/U ④	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod) pin contact	UG-387/U (mod) pin contact
Control Unit Dimensions (inches (cm))	3.6 (9.15) x 9.4 (23.9) x 15.6 (36.6)							

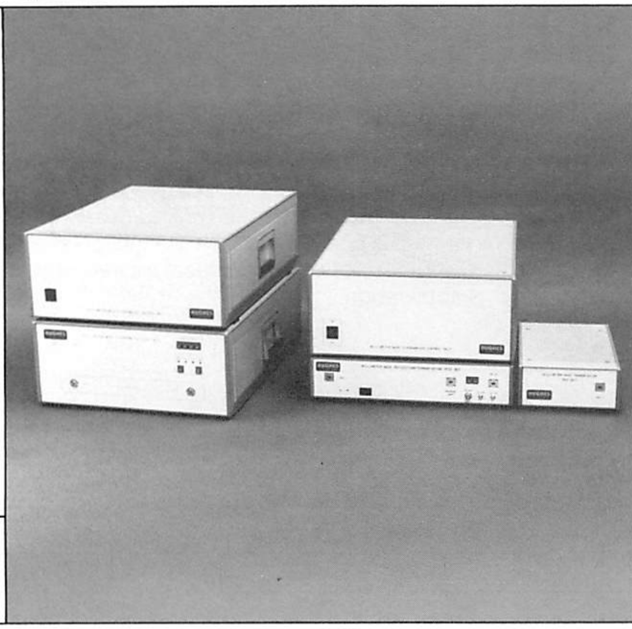
① With the modulator biased to its lowest insertion loss state ② Refer to Page 157 for specifications and MIL specification cross reference
③ Round flange ④ Square flange ⑤ With 0 dBm minimum inputs

BLOCK DIAGRAM

Leveling Loop Functions



Synthesizer Driven Vector Test Sets



The Hughes 4787xH series of Millimeter-Wave Reflection-Transmission and S-Parameter Test Sets are designed to make vector measurements in six waveguide bands from 18 to 110 GHz when used with the Hughes series 4785xH Millimeter-Wave Synthesizer, the Hewlett Packard 8510 Network Analyzer and an HP Series 200 or 300 computer.

Both test sets contain the millimeter-wave and microwave components that comprise the reference and test arms that downconvert the millimeter-wave signal to a constant 20 MHz IF signal for analysis by the HP 8510.

Both the Reflection Transmission and S-Parameter Test Sets consist of a control unit and test units. The control units contain power supplies and other circuitry not related to the waveguide band. Either control unit may be used separately with other test units of the same type.

The Reflection Transmission test unit consists of a reflection test unit and a remote transmission unit. The transmission unit is connected to the reflection test unit by means of flexible coaxial cables which allows S11 and S21 mea-

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FEATURES:

SPECIFICATIONS: (Applies to both S-Parameter and Reflection-Transmission Test Sets)

BANDWIDTH	
K- through W-Bands	Full Waveguide Bandwidth
IF OUTPUT	
For HP8410/8411 (MHz)	383 to 417
For HP8510 (MHz)	20
DYNAMIC RANGE (dB Typical)①	60
TEST PORT RETURN LOSS (dB Typical)②	35 to 40
DIRECTIVITY (dB Typical)②	35 to 45
RF AND LO INPUTS	From Hughes series 4785xH Synthesizer
AC INPUT VOLTAGE	100, 110, 220, 235 VAC (50 to 60 HZ)
DIMENSIONS	
S-Parameter Test Unit (Inches (cm))	7.5 x 17 x 23 (19.1 x 43.2 x 58.4)
Reflection Unit (Inches (cm))	4 x 8 x 17 (10.2 x 20.3 x 43.2)
Transmission Unit (Inches (cm))	4 x 8 x 13 (10.2 x 20.3 x 33)
Control Unit (For S-Parameter Test Set) (Inches (cm))	7.5 x 17 x 23 (19.1 x 43.2 x 58.4)
Control Unit (For Reflection/Transmission Test Set) (Inches (cm))	4 x 17 x 23 (10.2 x 43.2 x 58.4)

① With an averaging factor of 1000.
② Corrected data.

HOW TO ORDER*

CONTROL UNIT (For Reflection/Transmission Test Set)	47870H-5101
CONTROL UNIT (For S-Parameter Test Set)	47870H-5102
TEST UNIT	4787xH-xx1x

Frequency Band:	**0**: K **1**: Ka **2**: Q **3**: U **4**: V **6**: W
Flange Type:	**1**: Round (Ka- through W-Bands only) **2**: Square (K- and Ka-Bands only)
Test Set Type:	**1**: Reflection/Transmission **2**: Full S-Parameter
Calibration Kit Option	**1**: With Calibratiion Kit **2**: Without Calibration Kit

*See page 10 for Synthesizer ordering information.

Example: To order a W-Band S-Parameter Test Set, including Calibration Kit, specify a model 47870H-5102 and a model 47876H-1211.

surements to be made with no interconnecting waveguide to de-imbed. The S-Parameter test unit contains the components comprising the reference and test arms. Included in this test set is an electro-mechanical waveguide switch that allows all S-parameters to be measured without reversing the test device. The S-Parameter Test Set is fully programmable via the IEEE 488 Bus for automated S-parameter measurements.

These test sets take advantage of a unique harmonic downconversion technique. Using local oscillator signals from the microwave reference module of the Hughes series 4785xH Millimeter-Wave Synthesizer, this system downconverts first to an IF frequency of 400 MHz ± 17 MHz. A second conversion uses the 10 MHz crystal reference frequency and the 400 MHz ± 17 MHz reference signal from the synthesizer to produce a constant 20 MHz IF that is compatible with the HP 8510 (see Figure 2 on page 7 of introduction). Both the S-parameter and reflection transmission test sets thus offer phase coherence with the millimeter-wave signal source. The 400 MHz ± 17 MHz signal is selectable to make the test sets compatible with the HP 8410/8411 network analyzer.

Standard features of the units are full-waveguide bandwidth, high dynamic range (60 dB typical), 35 to 45 dB directivity, and test port return loss of typically 35 to 40 dB.

A software package is provided, compatible with the HP series 200 or 300 computers, that controls the synthesizer, test set and HP 8510. The software also allows full error correction as provided in the HP 8510.

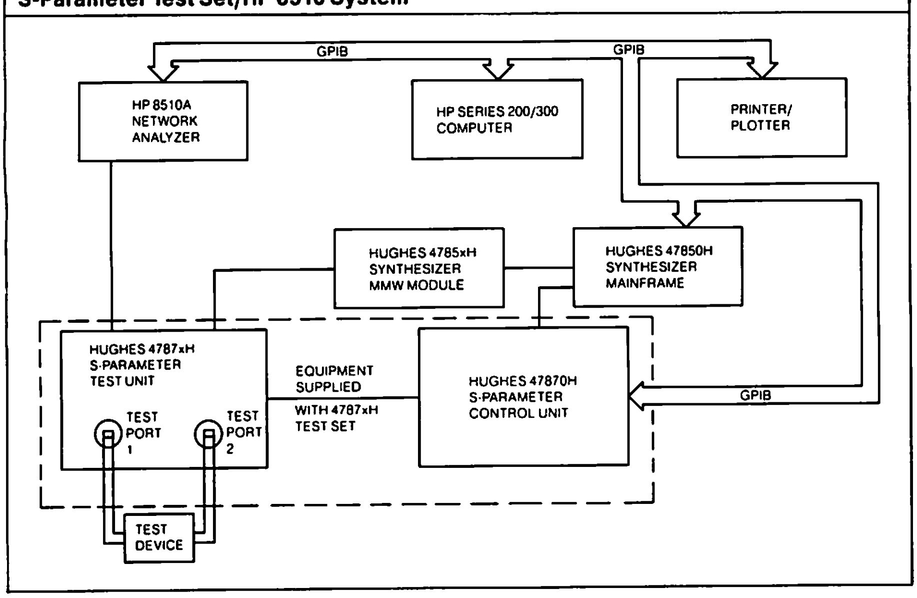
A calibration kit is available that includes all millimeter-wave components required to calibrate the test sets and additional waveguide sections useful in connecting test devices to the test set.

Turnkey systems, including all peripheral equipment, are also available. These products are described on pages 20 and 21.

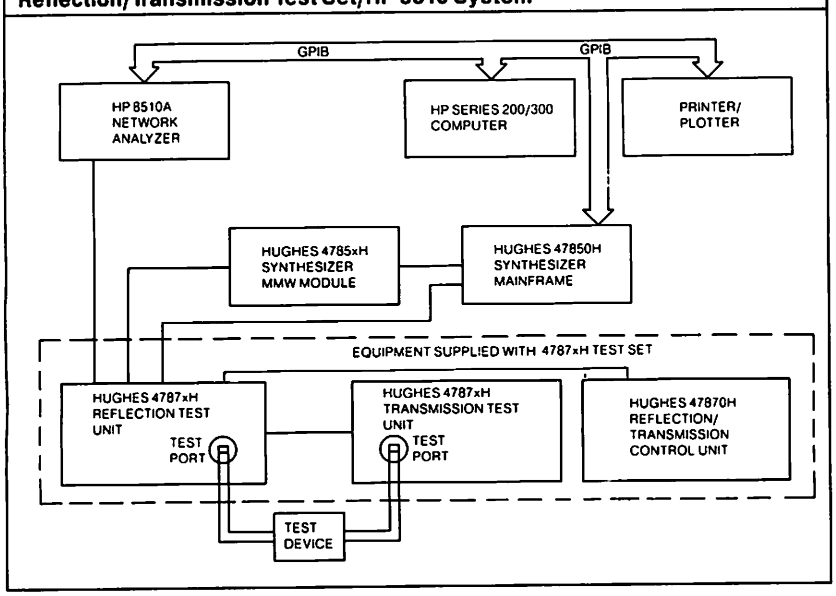
Automated Vector Measurements to 110 GHz 60 dB Dynamic Range

BLOCK DIAGRAMS

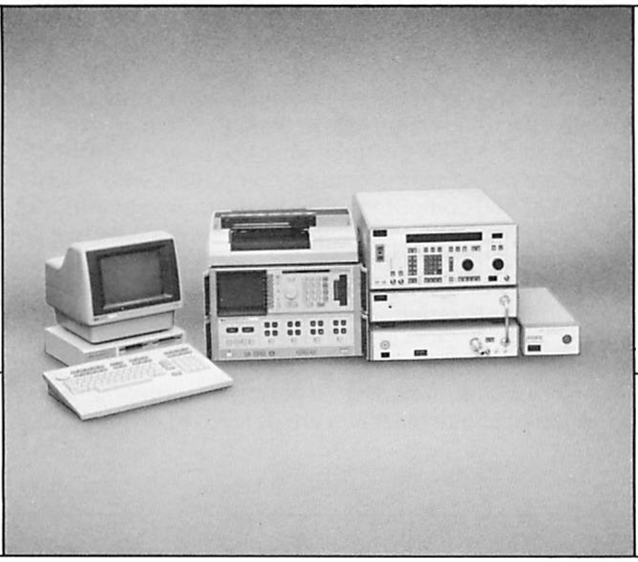
S-Parameter Test Set/HP 8510 System



Reflection/Transmission Test Set/HP 8510 System



Automatic Vector Network Analyzers



Hughes 4781xH series of Automatic Vector Network Analyzers provide both manual and automated S-parameter measurements in six waveguide bands from 18 to 100 GHz. The system consists of the Hughes 4787xH Synthesizer Driven S-Parameter Test Set or Reflection/Transmission Test Set, Hughes 4785xH Millimeter-Wave Synthesizer as the signal source, and a Microwave Network Analyzer, based on the Hewlett-Packard 8510 system. The HP8510 and a computer with printer and plotter are also provided. In addition, all software necessary to make automated measurements is supplied.

The test set downconverts the millimeter-wave signals to

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FEATURES:

SPECIFICATIONS:

BANDWIDTH	
Broadband Options	
K- through W-Bands	Full Waveguide Bandwidth
W-Bands (GHz min)	25
Partial Band Option (W-Bands only)	See bandwidth specifications for millimeter-wave synthesizer, single head option, on page 11
FREQUENCY RESOLUTION (KHz)	0.1
DYNAMIC RANGE (dB min)①	60
TEST PORT RETURN LOSS (dB typical)②	35 to 40
DIRECTIVITY (dB min typical)②	35 to 45

① With an averaging factor of 1000
② Corrected data

HOW TO ORDER

Model Number . . . 4781xH-xxxx

Frequency Band:	**0**: K **1**: Ka **2**: Q **3**: U **4**: V **6**: W
Flange Type:	**1**: Round (Available in Ka-through W-Bands only) **2**: Square (Available in K- and Ka-Bands only)
Synthesizer Bandwidth:	**1**: Full Waveguide Bandwidth (K- through V-Bands only) **2**: 25 GHz Bandwidth (W-Band 75-100 GHz) **3**: Partial Band Option (W-Band only. Specify center frequency)
Network Analyzer Configuration:	**1**: Complete System with HP 8510 **3**: Extension System for previously purchased system①
Test Set Type:	**1**: With Synthesizer Driven S-Parameter Test Sets **2**: With Synthesizer Driven Reflection/ Transmission Test Set

① Includes only test set unit and synthesizer millimeter-wave module.

EXAMPLE: To order a complete automatic vector measurement system operating over the full waveguide bandwidth in Q-Band (33-50 GHz) with the Hewlett-Packard 8510 Network Analyzer, specify 47812H-1111 or a 47812H-1112.

a VHF frequency for analysis by the network analyzer. This unit operates over full waveguide bandwidths from K- through V-Bands. The millimeter-wave synthesizer provides either full band coverage in K- through V-Bands, 25 GHz bandwidth in W-Band, or a partial band option in W-Band.

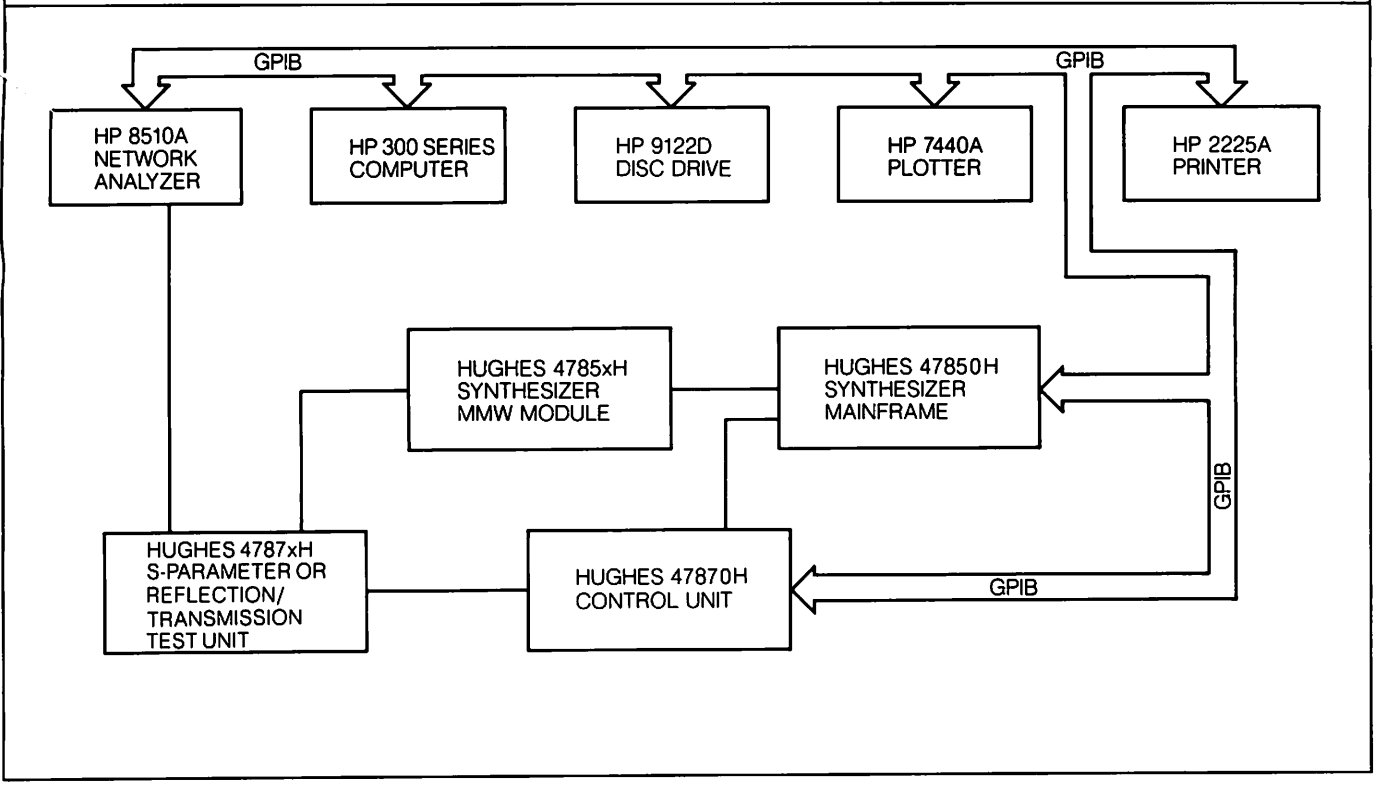
The software package that is provided with the system prompts the operator during both the calibration and measurement cycles with all instructions necessary to operate the system. A hard copy of the test data is available. The operator may request either a listing of the data or a plot in either a Magnitude, Polar, or Smith chart format.

Since the synthesizer is based on a common mainframe for all waveguide bands, and the Synthesizer Driven Test Sets have a common control unit for all bands, extension of a system for additional waveguide bands requires only adding a vector test unit, and a synthesizer millimeter-wave module. See pages 18 and 19 for a full description of the test sets, and pages 10 and 11 for a full description of the synthesizer.

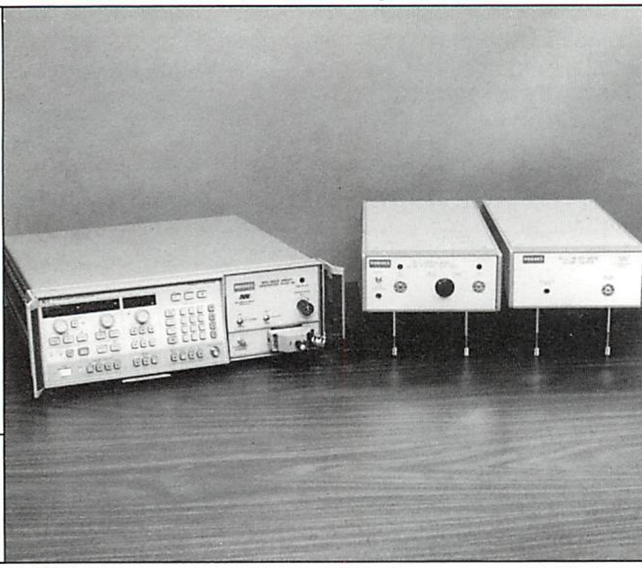
Fully Automated Turnkey System Vector Network Analysis to 100 GHz

BLOCK DIAGRAM

Automatic Vector Network Analyzer



Millimeter-Wave Noise/Gain Test Sets



Hughes 4782xH series of Noise/Gain Test Sets provide automated noise figure and gain/loss measurements in the millimeter-wave frequency bands from 18 to 110 GHz. These systems are designed to interface directly with either the Hewlett-Packard 8970A/B, or the Eaton 2075 Noise Figure Meters. The test sets consist of a broad-band downconverter which utilizes the Hughes 4772xH Sweep Generator as the local oscillator, a broadband noise source, and all other components necessary to interconnect the test device and make measurements.

The downconverter provides a fixed frequency IF in the range of 10 MHz to 500 MHz to the Noise Figure Meter by the use of the broadband local oscillator. The local oscillator is a GaAs FET oscillator in all bands through 75 GHz, and a Gunn oscillator in

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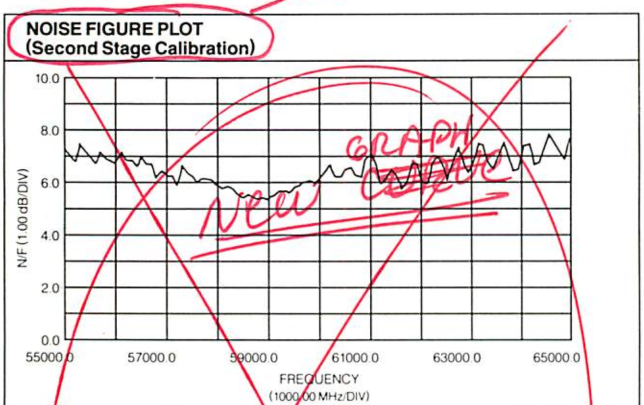
FEATURES:

TYPICAL TEST DATA



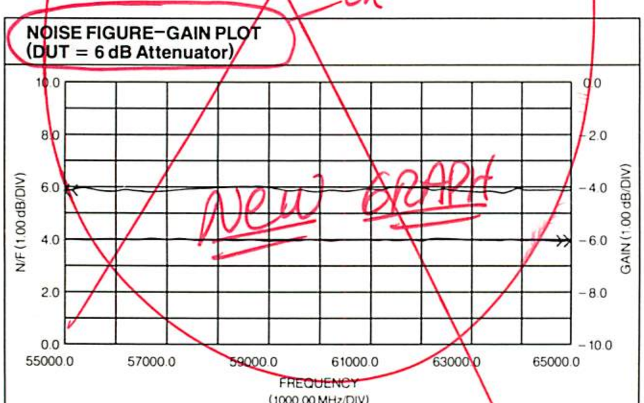


FIGURE 1

HOW TO ORDER

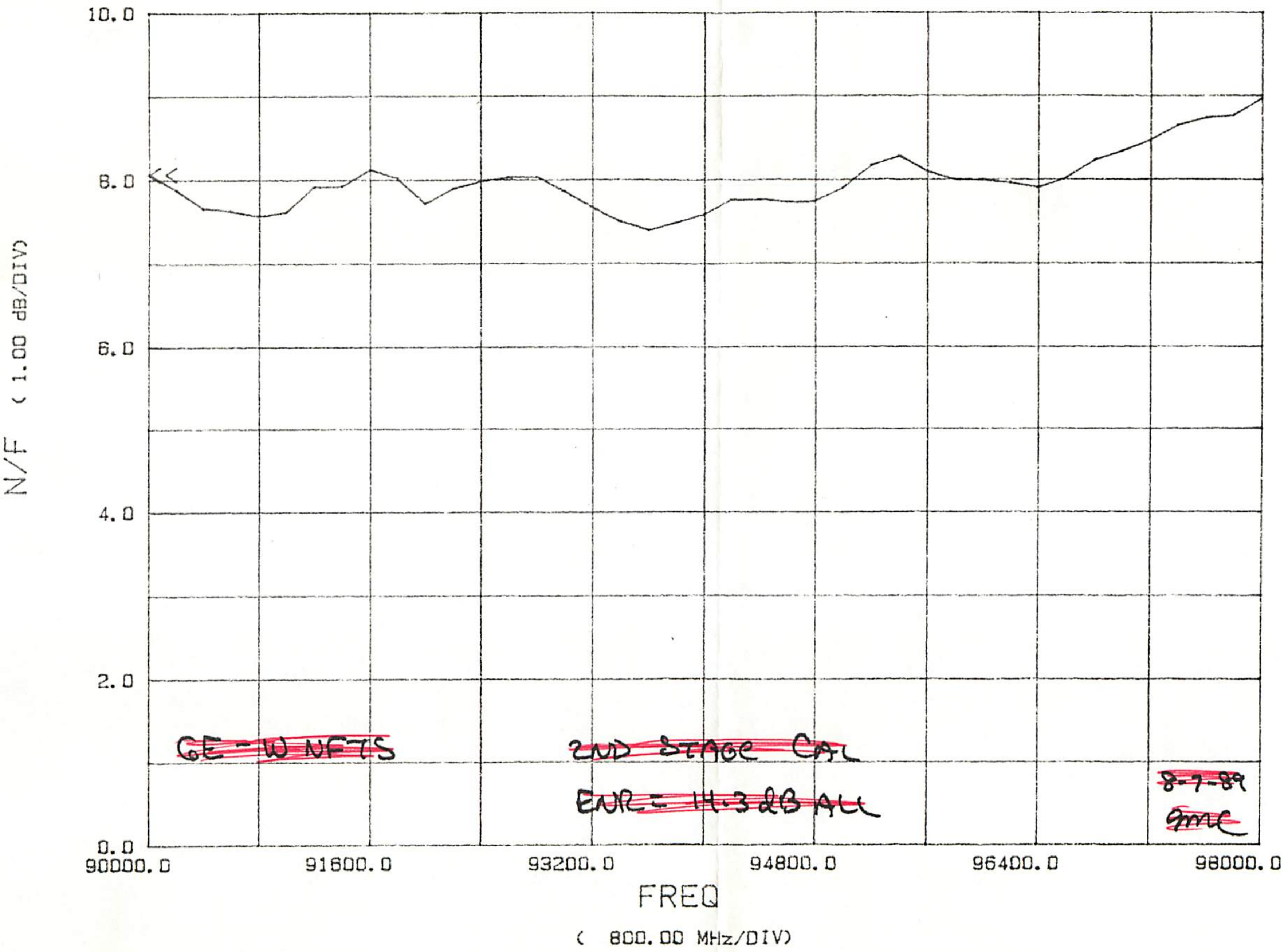
Model Number 4782xH-xxxx

Frequency Band	**0**: K, **1**: Ka, **2**: Q, **3**: U, **4**: V, **6**: W
Flange Type	**1**: Round (Available in Ka- through W-Bands only) **2**: Square (Available in K- and Ka-Bands only)
Bandwidth	**2**: Full Band (Available in K-through V-Bands only) **3**: 4 GHz Bandwidth (Available in W-Band Only, Specify Center Frequency) **4**: 8 GHz Bandwidth (Available in W-Band Only, Specify Center Frequency)
Configuration	**0**: Noise/Gain System Including: HP 8350B Main-Frame **1**: Complete Integrated System Including: HP 8350B Main-Frame and HP 8970 Noise Figure Meter **2**: Complete Integrated System Including: HP 8350B Main-Frame, and Eaton 2075 Noise Figure Meter **3**: Noise/Gain Test Set Only **4**: Noise/Gain Test Set with HP 8970 Noise Figure Meter (without 8350B) **5**: Noise/Gain Test Set with Eaton 2075 Noise Figure Meter (without 8350B)
Noise Source Option	**0**: Solid-State Noise Source **1**: Gas-Discharge Noise Tube

EXAMPLE: To order a complete noise/gain system operating over the full waveguide in Q-band with the HP 8350B main-frame and Eaton 2075 noise figure meter, specify a model 47822H-1220.

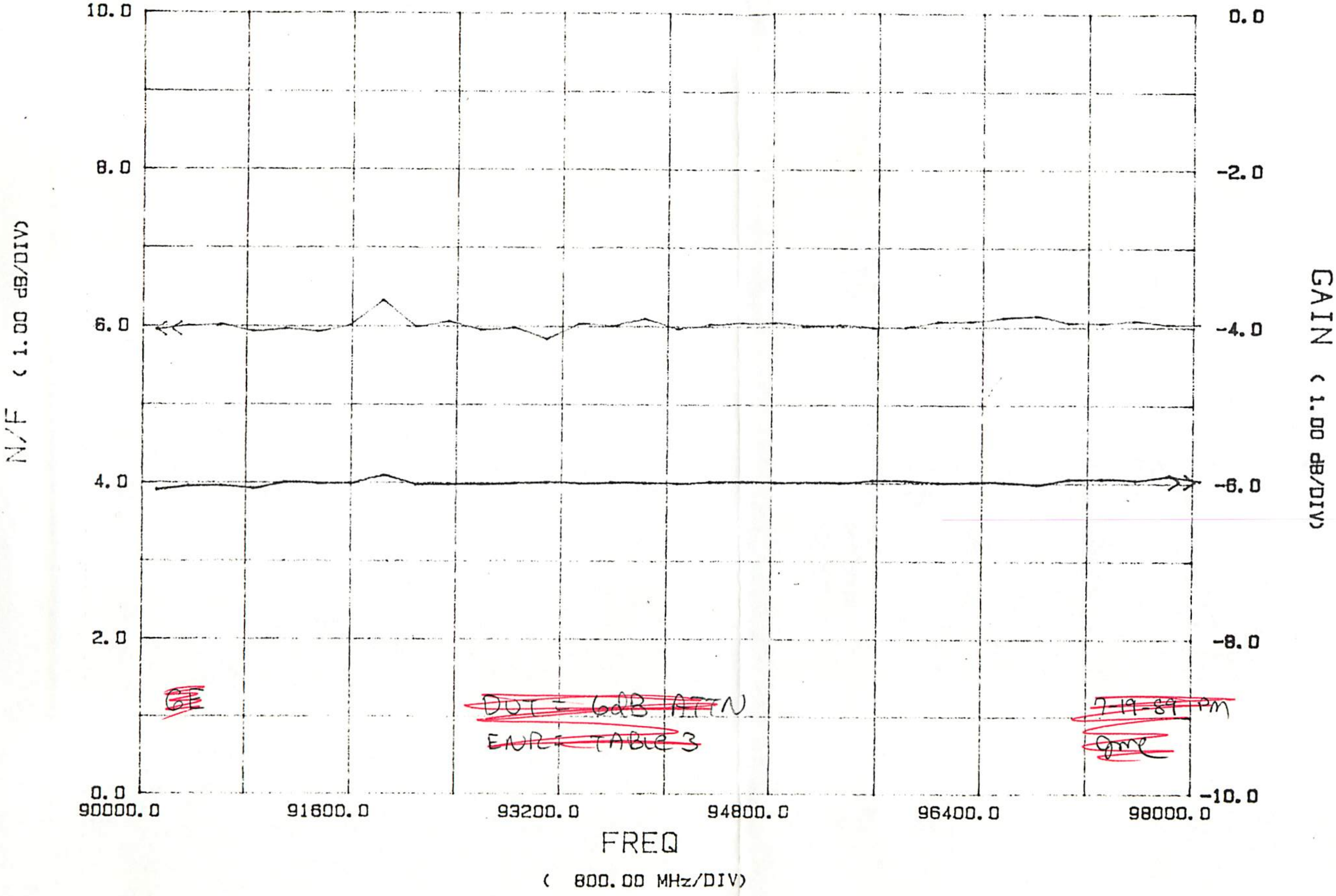
#1

~~EATON 2075~~ NOISE FIGURE PLOT



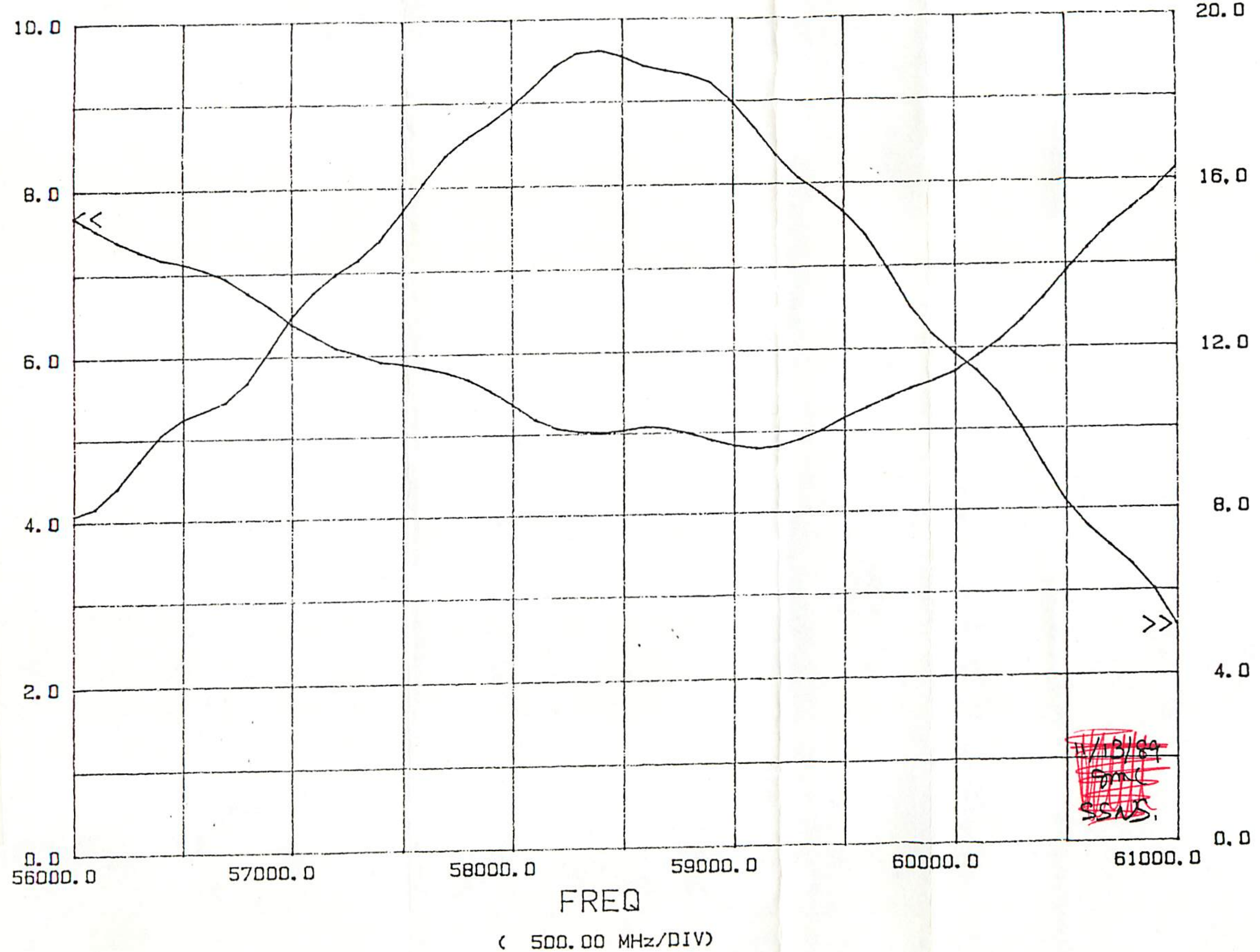
#2

EATON 2075 NOISE FIGURE - GAIN PLOT



~~EATON 2075~~ NOISE FIGURE - GAIN PLOT

#3



~~the 75 to 110 GHz bands~~. These oscillators, which have excellent AM, FM, and spurious noise performance in conjunction with a high performance balanced mixer, insure the performance level of the system. A 10 to 500 MHz IF amplifier is included. This amplifier, with its nominal 30 dB of gain, is used to reduce measurement uncertainty and speed measurement time.

These systems offer full waveguide bandwidths in K- through V-bands, and up to 8 GHz bandwidth in W-band. The wide bandwidth offered by the system adds to the measurement possibilities in that all HP 8970 A/B or Eaton 2075 operating features are available.

The Noise Figure Meter performs the measurements, and acts as the controller for the local oscillator and any peripheral equipment such as an oscilloscope or plotter, and as the modulation source for the noise source. The noise source is turned on and off using a ferrite modulator controlled from the Noise Figure Meter. The on/off ratio of the modulator is 25 dB, and the ENR of the noise source is nominally 15 dB.

In addition to making noise figure and gain/loss measurements of 2-port devices, the system provides the sweeper output directly. This output can be used as the RF input to a balanced mixer for direct conversion loss and noise figure measurements of these devices. An internal switch is provided to switch the sweeper output to a front panel waveguide port.

Solid State Noise Sources are available as a replacement for the Gas Discharge Noise Source. See page 24 for details.

- **Automatic Noise Figure and Gain Measurements to 110 GHz**
- **Compatible with HP8970 and Eaton 2075 Noise Figure Meters**
- **Solid State Noise Source Available**
- **Sweep Generator Mode**

SPECIFICATIONS

	FREQUENCY BAND (GHz)						
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	W (75-110)	
Bandwidth (GHz min)	Full Band	Full Band	Full Band	Full Band	Full Band	4	8
Unleveled Sweep Output (dBm typ)	+ 12	+ 9	+ 4	+ 1	+ 1	+ 5	+ 5
Dynamic Range Noise Figure (dB min)	0 to 20	0 to 20	0 to 20	0 to 20	0 to 20	0 to 20	
Gain (dB min)	− 20 to + 30	− 20 to + 30	− 20 to + 30	− 20 to + 30	− 20 to + 30	− 20 to + 30	
Accuracy Noise Figure (± dB max)	0.4	0.4	0.4	0.4	0.4	0.4	
Gain (± dB max)	0.3	0.3	0.3	0.3	0.3	0.3	
ENR[1] At Noise Head Test Port (dB min)	10	10	10	10	10	10	
Modulator On/Off Ratio (dB typ)	25	25	25	25	25	25	
Waveguide and Flange	See Page 157						

[1] Calibration is available. Please consult factory.

DIMENSIONS: Sweep mainframe (inches(cm)): 5.25(13.3) x 16.75(42.5) x 16.6(42.2)
MMW Modules (inches(cm)): 3.4(8.6) x 8.0(20.3) x 16.5(41.9)
Noise Source Power Supply (inches(cm)): 6.5(16.5) x 11.0(27.9) x 5.5(14.0)

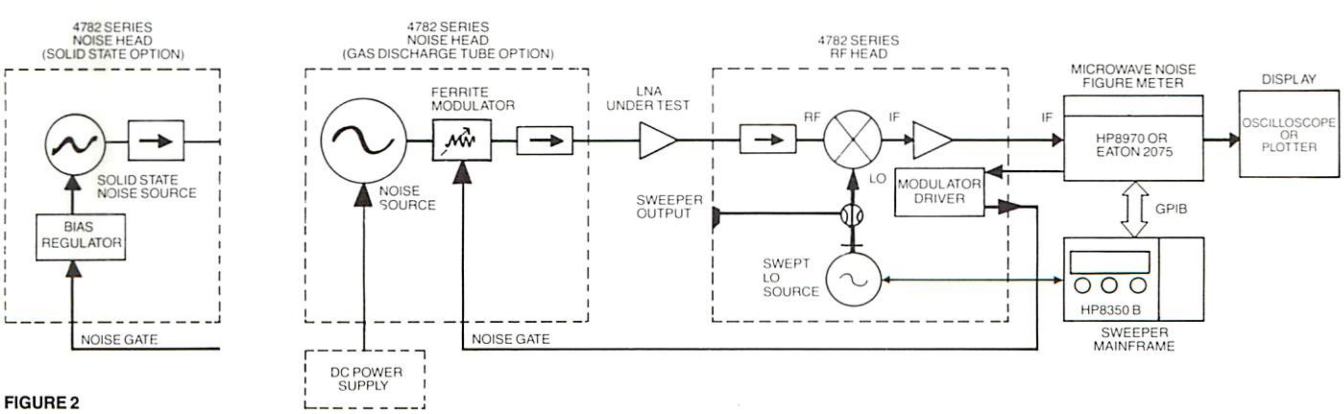
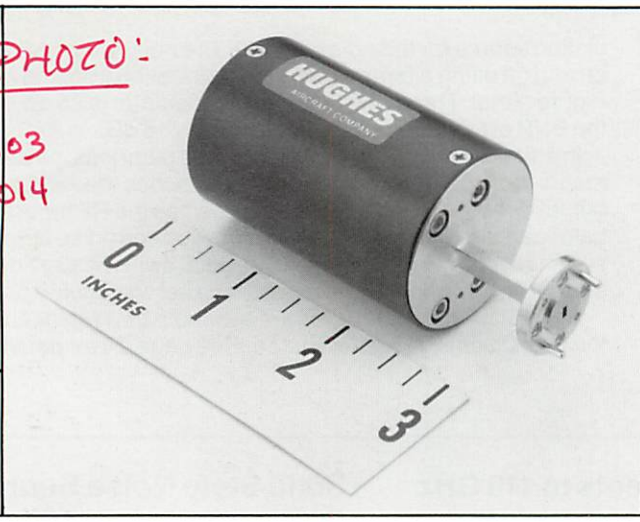


FIGURE 2

Noise Sources

high-voltage

NEW PHOTO:
Color = 1089603
B+W = 1189014



The Hughes 4711xH series of Solid-State Millimeter-Wave Noise Sources provide a unique capability not previously available for noise figure testing at millimeter-waves. These small lightweight sources employ silicon diodes operating in a specially designed cavity/waveguide assembly. Low DC power requirements eliminate the need for ~~special~~ power supplies. In Ka- through U-bands, gated primary power is provided directly from the noise drive output available on most commercial noise figure meters, such as the Hughes 4782xH series of Noise/Gain Test Sets (typically +28 V pulsed). Excess Noise Ratio (ENR)

At V-band and above, the noise drive signal gates the regulated output of a separate DC power supply input which is furnished with and applied to the DC power connector on the Solid State Noise Source.

FEATURES:

SPECIFICATIONS

	FREQUENCY BAND (GHz)①				
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	W (75-100)
Output Waveguide	WR-28	WR-22	WR-19	WR-15	WR-10
Bandwidth	Full Band				10 GHz
ENR (dB nom)②	5 and 15				~~12~~ 15
Flatness (± dB max)					
ENR = 15 dB	1.0	1.5	1.5	2.5	2.0
~~ENR = 12 dB~~					~~2.0~~
ENR = 5 dB	0.75	1.0	1.0	1.5	1.5
VSWR (typ)	1.2:1	1.25:1	1.25:1	1.3:1	1.4:1
Stability/°C (dB typ)	0.01	0.01	0.01	0.01	0.01
Stability/Day (dB typ)	0.05	0.05	0.05	0.05	0.05
Input Power (V)	28 ± 1	28 ± 1	28 ± 1	28 ± 1	28 ± 1
Input Connector	All Bands: BNC (Female)				
Size	See Outline Drawing				
Weight (Ounces)	All Bands: 6				

① Narrower frequency ranges available
② Other ENR values available

HOW TO ORDER

Model Number 4711xH-x0xx

Frequency Band
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **6**: W (Specify center frequency)

Flange Type
- **1**: Round
- **2**: Square (Ka-band only)

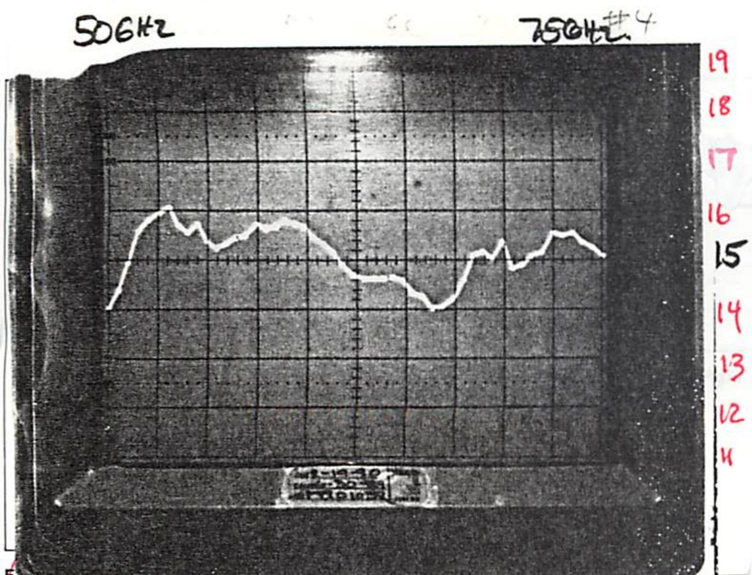
ENR
- **05**: 5 dB
- ~~**12**: 12 dB~~
- **15**: 15 dB

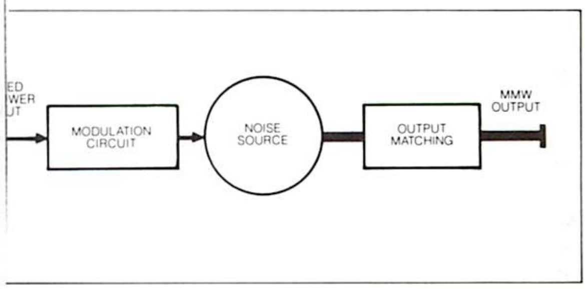
Example: To order a V-band noise source with a round flange and an ENR of 15 dB, specify a 47114H-1015.

values of greater than 30 dB are obtainable.

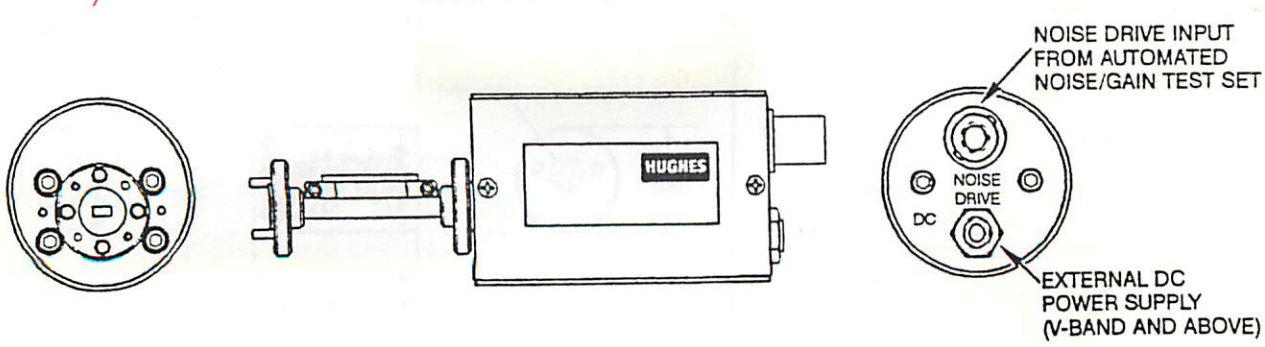
The Millimeter-Wave Solid-State Noise Sources offer low VSWR and flat output response over standard waveguide bands from 26.5 to 100 GHz. Full waveguide bandwidth is available in Ka- through V-bands and 10 GHz bandwidth in W-band. Figure 1 shows a typical response for a V-band source with an ENR of 15 dB. Units include integral current regulator and offer high operational stability as a function of time and temperature. Other ENRs are available; please consult your local representative or the factory.

- **26.5 to 100 GHz**
- **ENR 5 to 15 dB**
- **Solid State**
- **No Special Power Supply Required**
- **Internal Regulator Output Matching**
- **Lower Power Consumption**
- **Rugged Construction**

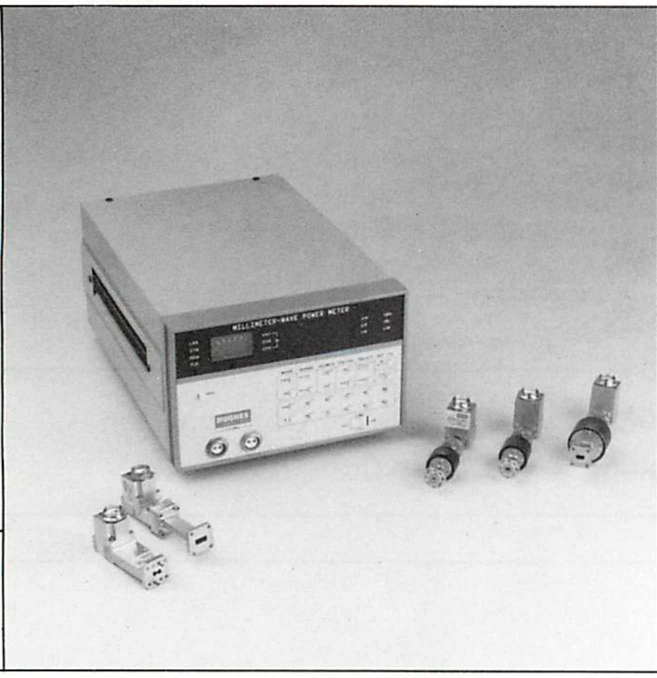




Solid State Millimeter-Wave Noise Source



Power Meters



The Hughes 47770H Power Meter and 4777xH series of Schottky-barrier diode power sensors allow automatic power measurements to be made from 18 GHz to 110 GHz. Millimeter-wave sensors are available in two models in six waveguide bands. One model incorporates a full-band ferrite isolator, allowing accurate measurement of power in the −50 dBm to +10 dBm range in Ka- through V-band, and −45 dBm to +10 dBm range in W-band. The other model incorporates an integral attenuator at the detector input, allowing power measurements from −40 dBm to +10 dBm in K-band, −40 dBm to +20 dBm in Ka- through V-band, and −35 dBm to +20 dBm in W-band. In addition, a sensor using the WRD-180 double-ridge waveguide band of 18-40 GHz, and allows measurements from −40 to +10 dBm.

Sensor calibration data is supplied with each sensor and can be easily entered into the meter's memory from the front panel or via the IEEE-488 bus. When meters and sensors are ordered together, sensor calibration data will be entered into the power meter memory at the factory. A certificate of cali-

FEATURES:

SPECIFICATIONS[6]

	FREQUENCY BAND (GHz)[4]						
	K (18-26.5)	K & Ka (18-40)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	W (75-110)
CW Power Range (dBm min/max) with isolator	N/A	N/A	−50/+10	−50/+10	−50/+10	−50/+10	−45/+10
with Integral Attenuator	−40/+10	−40/+10	−40/+20	−40/+20	−40/+20	−40/+20	−35/+20
Bandwidth (GHz)	Full Band	Full Band	Full Band	Full Band	Full Band	Full Band	Full Band
VSWR (max) with Isolator	N/A	N/A	1.45:1	1.45:1	1.45:1	1.45:1	1.45:1
with Integral Attenuator	1.3:1	1.4:1	1.4:1	1.4:1	1.4:1	1.4:1	1.4:1
Overload Capability[5] (dBm max or Peak) with Isolator	N/A	N/A	+20	+20	+20	+20	+20
with Integral Attenuator	+25	+25	+25	+25	+25	+25	+25
Basic Accuracy (±dB max) @ 0 dBm	0.5	0.5	0.5	0.5	0.5	0.5	0.5
at Calibration Frequency (GHz)	22	33	33	40	50	60	94
Frequency Cal-Factor Uncertainty (±dB max)	0.25	0.25	0.25	0.5	0.5	0.5	0.5
Number of Calibration Points[7]	10	20	15	18	20	20	20
Level Calibration Uncertainty (±dB max per dB relative to 0 dBm) ±0.5 dB	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Waveguide Size[1]	WR-42	WRD-180	WR-28	WR-22	WR-19	WR-15	WR-10
Waveguide Flange[1]	UG-595/U[2]	M39000/3-084 (Mod)	UG-599/U[2] UG-381/U[3]	UG-383/U	UG-383/U *(Mod)*	UG-385/U	UG-387/U *(Mod)*

Zero Drift (nW/hr. on W range max) 1
Measurement Speed (lowest range/other ranges, seconds worse case) 2.5/0.5
Output Data Speed (readings/sec, max.) 20
Recorder Output (V full scale, proportional to indicated power or dB) 10
Recorder Output sensitivity (8 Volts = 0 dBm) (v/10 dB) 1
AC Input Voltage (V) 100, 120, 220, 240
AC Input Frequency (Hz min/max) 50/400
Power Consumption (VA max) 24
Meter Weight (lbs/Kg typ) 10/4.54
Meter Size (inches (cm)) typ .... 8.3 (21.1) x 5.85 (14.9) x 13.75 (34.9)

[1] Refer to page 157 for specifications and MIL Specification cross reference. [2] Square Flange. [3] Round Flange. [4] Standards traceable to NBS exist only in WR-42, WR-28, WR-22, WR-15 & WR-10. [5] Safe operation. [6] Specifications apply over 0° to 50°C. [7] Additional calibration points are available: consult factory. [8] In two bands (0.01-26.5 and 26.5 to 40 GHz)

bration is supplied with each sensor.

Additional coverage of the microwave range of DC to 18 GHz is possible using compatible sensors from other manufacturers. This feature allows direct measurements of mixer conversion loss from millimeter-wave RF inputs to microwave band IF outputs.

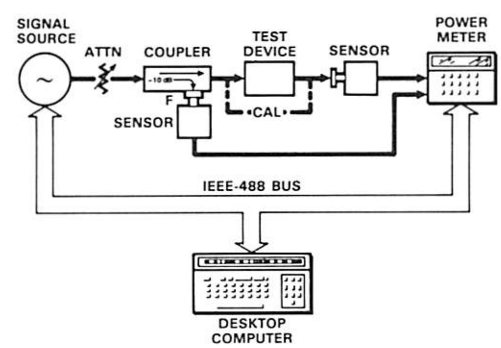
The power meter is microprocessor controlled and has a stored program memory and a separate non-volatile memory. Data for up to 8 interchangeable sensors with calibration factors spaced across each sensor's band is stored in the non-volatile memory, allowing accurate interpolations of sensor measurements to be digitally displayed. Readings are shown with either a 3½ digit power display, or 4 digit dB display with a resolution of 0.01 dB to any chosen input reference. An automatic, panel-operated, zero correction function stores all zero offsets as a function of range, and then automatically corrects displayed readings. A range hold key can prevent the meter from automatically changing range when making repetitive measurements of similar value. A rear panel TTL output may be used to automatically turn off the RF power source when the front panel zero key is depressed.

Model 47770H-0020 offers the IEEE 488 Bus interface with all meter functions being Bus programmable except for the ON-OFF power switch. This model also provides a second power sensor input channel which allows power measurements to be displayed in three different modes; one for each sensor and one for the difference between the two sensors. This allows measurements of gain, loss, and reflection coefficients to be made and shown directly on meter display in dB, as illustrated below.

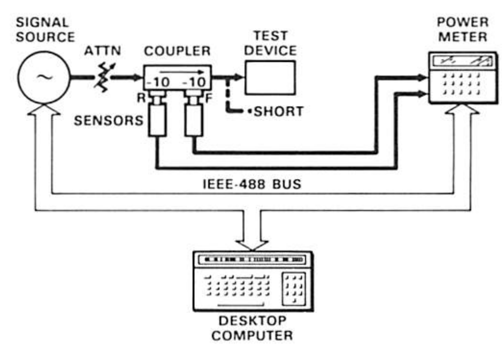
The power meter has enterable high and low dB limits with out-of-limit readings being indicated on the front panel and by a TTL output from the rear panel. They also have a DC recorder output and a rear-panel connector in parallel with the front panel input connector. A rack mounting kit is available. Standard 5′ sensor cables are supplied with each power meter.

• − 45 to + 10 dBm Dynamic Range to 110 GHz • Range Selects, and Zeros Automatically • IEEE 488 Bus Interface with Two-Channel Model • DC-110 GHz • Calibration Certification Supplied with Each Sensor

GAIN OR LOSS MEASUREMENT USING DUAL SENSORS



RETURN LOSS MEASUREMENT USING DUAL SENSORS

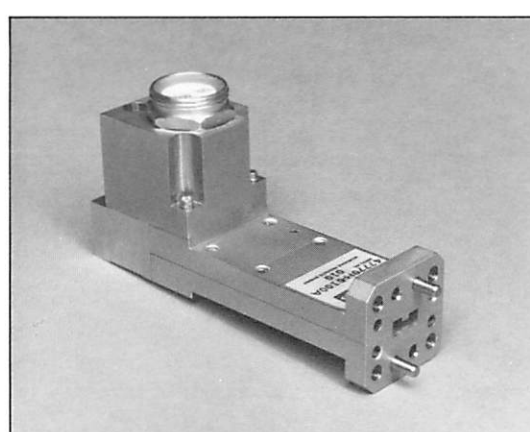


HOW TO ORDER

Power Meter Model Number 47770H-0020
Sensor Model Number 4777xH-xx00
Rack Mounting Kit Model Number 47770H-0001
Additional Sensor Cables: length 5′ 47770H-0105
length 10′ 47770H-0110
length 50′ 47770H-0150

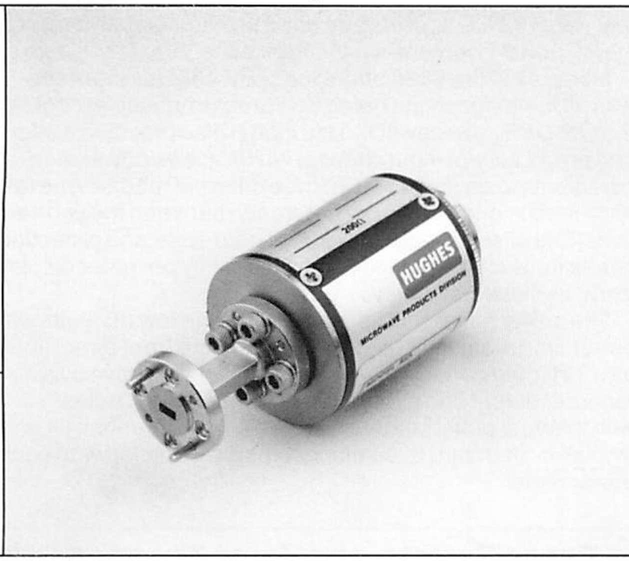
Frequency Band	**0**: K, WRD-180 **1**: Ka **2**: Q	**3**: U **4**: V **6**: W
Flange Type	**1**: Round (Available in Ka- through W-bands only) **2**: Square (Available in K- and Ka-bands only) **6**: WRD-180 (18–40 GHz)	
Sensor Configuration: cables are NOT supplied with sensors	**1**: With Integral Input Isolator (Ka- through W-bands) (Not available in WRD-180 **2**: With Integral Input Attenuator (K- through W-bands)	

Example: To order a power meter capable of testing from 50 GHz to 110 GHz with IEEE 488 Bus compatibility with sensors configured with isolators, specify a Model 47770H-0020 meter, a Model 47774H-1100 sensor and a Model 47776-H1100 sensor.



WRD-180 BAND SENSOR COVERS 18-40 GHz

Temperature Compensated Thermistor Mounts



Hughes 4577xH series of Thermistor Mounts are designed for use with the Hewlett-Packard Model 432 series power meters. These Temperature Compensated Thermistor Mounts are used in the power ranges from 10μW (− 20 dBm) to 10 mW (+ 10 dBm) in the frequency range of 26.5 to 166 GHz in eight waveguide bands. The temperature compensated feature of these mounts provides relatively drift-free operation in a changing ambient environment.

Calibration is provided every 5 GHz (additional calibration points available upon request) over any waveguide band through WR-10 waveguide (75 to 110 GHz). At each calibration

FEATURES:

HOW TO ORDER

Model Number. 4577xH-xx00

Frequency Band	**1**: Ka **2**: Q **3**: U **4**: V **5**: E **6**: W **7**: F **8**: D
Flange Type	**1**: Round **2**: Square (Ka-band only)
Bandwidth	**1**: Full Band (available in Ka- through W-bands) **4**: 20 GHz Bandwidth (available in W-band only: specify center frequency) **5**: 10 GHz Bandwidth (available in F- and D-bands only: specify center frequency)

Example: To order a W-band Thermistor Mount at 94 GHz, specify 45776H-1400, center frequency 94 GHz for a 20 GHz bandwidth unit, or a 457776H-1100 for a 75-110 GHz full band unit.

frequency, a correction factor (in +dB) is shown on the label of the thermistor mount. This calibration correction factor takes into account all losses within the thermistor mount. The correction factor is added to the power meter reading to yield the value of true power. This is illustrated in the example below. The example supposes that a 1 mW (0 dBm) deflection is indicated on the power meter. The true power, based on the correction factor, would be the figures shown. A certificate of calibration is supplied with each unit. The thermistor is supplied and calibrated with an input waveguide section and standard flange, for ease of connection and use.

- **Full Waveguide Bandwidth Power Measurements to 110 GHz.**
- **HP-432 Compatible**
- **Temperature Compensated Stability**
- **Calibration Certification Supplied**

SPECIFICATIONS

		Frequency Band (GHz) ⑥							
		Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-166)
Bandwidth (GHz)		Full	Full	Full	Full	Full	Full or 20	10	10
Power Range	CW: Low (dBm)	−20	−20	−20	−20	−20	−20	−20	−20
	CW: High (dBm)④	+10	+10	+10	+10	+10	+10	+10	+10
	PULSE: PEAK (dBm)④⑤	+27	+27	+27	+27	+22	+22	+22	+22
Operating Resistance (ohms)		200	200	200	200	200	200	200	200
VSWR (max)		2:1	2:1	2:1	2:1	2.3:1	2.3:1	2.5:1	2.5:1
Number of Calibration Points (min)		6	5	5	6	7	9/5⑦	3	3
Basic Accuracy, worse-case (±dB)		0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.8
Waveguide Size ①		WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
Waveguide Flange ①		UG-599/U ③ UG-381/U ②	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)

Dimensions (inches (cm)) . . . . 1.8 (4.6) x 1.3 (3.3) Dia. Weight (lb/gr) 0.25/115

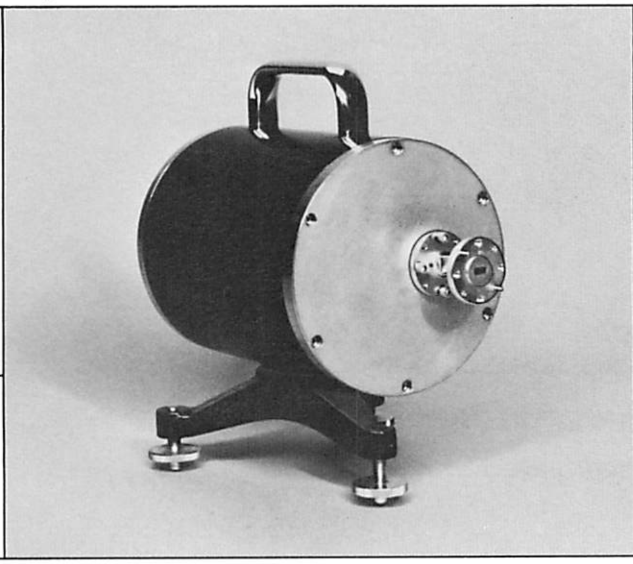
① Refer to page 157 for specifications and MIL specification cross reference ② Round Flange ③ Square flange.
④ Safe operation ⑤ 100 nanosecond pulses. 1% duty cycle. ⑥ Standards traceable to NBS exist only in WR-28, WR-22, WR-15 & WR-10 ⑦ Full-Band/Partial-Band.

CORRECTION FACTOR EXAMPLE ⑧

Frequency (GHz)	50	55	60	65	70	75
Correction Factor (+dB)	0.65	1.15	0.70	0.80	1.25	1.00
Meter Reading (dBm/mW)	0/1	0/1	0/1	0/1	0/1	0/1
True Power (dBm/mW)	0.65/1.16	1.15/1.30	0.70/1.175	0.80/1.202	1.25/1.333	1.0/1.259

⑧ HP-432 power meter's calibration factor control set at 100% and mount resistance switch set at 200

Dry Calorimeters



Hughes 4578xH series of millimeter-wave dry calorimeters is offered in three waveguide bands: Q-Band (33-50 GHz), V-Band (50-75 GHz), and W-Band (75-110 GHz). They offer rapid and accurate measurement of absolute millimeter-wave power in the range of 1 mW (0 dBm) to 100 mW (+20 dBm). Dry calorimeters are used as standards for calibration of thermistors, bolometer bridges and other power measuring instrumentation.

The calorimeter consists of a cylindrical double-wall aluminum case in which two symmetrical, electroformed waveguides are assembled. Each waveguide is terminated

FEATURES:

SPECIFICATIONS ①

	Frequency Band (GHz)		
	Q (33-50)	V (50-75)	W (75-110)
Accuracy (± % typ)	2.5	2.5	2.5
Input Return Loss (dB min)	20	20	20
Temperature Coefficient (± μV/°C max)	1	1	1
Power Measurement Range (mW)	1 to 100	1 to 100	1 to 100
Response Time (sec typ)	60	60	60
Dimensions (in/cm nom) (Length x Diameter)	5.45/13.9 x 4.35/11.0		
Weight (lbs /kg nom)	9/4.1	9/4.1	9/4.1
Waveguide Size②	WR-22	WR-15	WR-10
Waveguide Flange②	UG-383/U	UG-385/U	UG-387/U (mod)

① Suggested indicator: Fluke model 845A, 8505A or Keithley 153A microvolt meter or equivalent.
② Refer to page 157 for specifications and MIL specification cross reference.

HOW TO ORDER

Model Number. 4578xH-x000

Frequency Band	**2**: Q **4**: V **6**: W	
Flange	**1**: Round **8**: Maury Precision Flange	

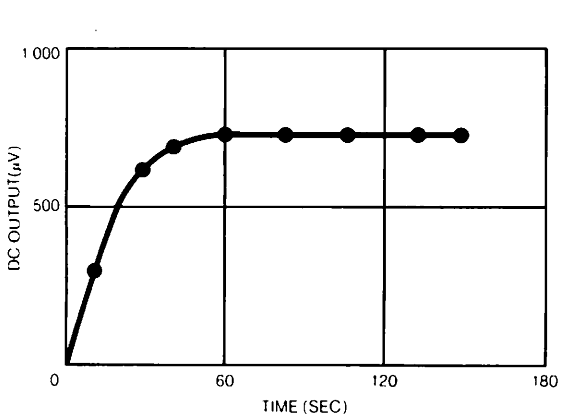
EXAMPLE: To order a Q-band Dry Calorimeter with a standard flange, specify 45782H-1000 in a low-reflection RF load made of Beryllia (BeO) and nickel-chrome evaporated film. The film is shaped so as to minimize reflection of RF power and equalize the thermal distribution on the load by both RF and DC power.

A thermopile consisting of interleaved bismuth antimony junction-pairs is thermally connected to the two absorbers. RF power into the waveguide input of the calorimeter heats one absorber, and the resulting temperature difference between the absorbers generates a DC voltage output from the thermopile. The time for measurement is typically one minute. In addition to the rear panel connections for the thermopile, DC connection to the evaporated film on the RF load is provided for DC calibration. A DC calibration curve, as illustrated, is supplied with each unit. A one-inch waveguide twist is installed on each unit. Additionally, the Maury precision waveguide flange is available to assure precision alignment of waveguide junctions with significantly reduced return-loss.

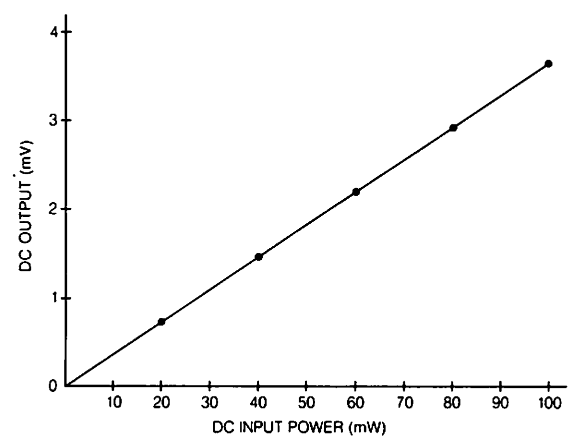
Accurate Power Determination
Rapid Power Measurement
Easy to Use

TYPICAL DATA

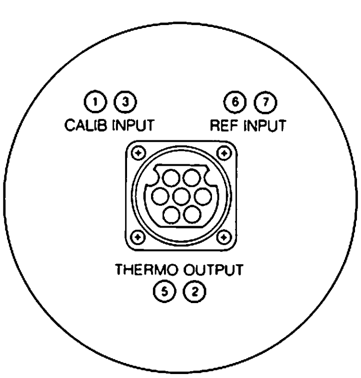
Response Time (typical)



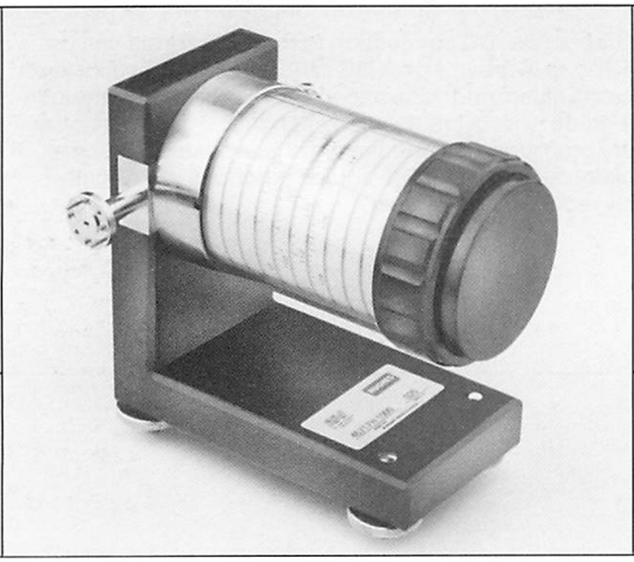
Typical DC Sensitivity (Q-Band)



Rear Panel Connections



Direct Reading Frequency Meters



Hughes 4571xH series Millimeter-Wave Direct Reading Frequency Meters consist of a TE_{111} mode cavity resonator tuned by a noncontacting choke plunger. The calibration is scaled around a drum dial which indicates frequency directly in GHz. It is supplied with an appropriate stand which is adjustable in height for easy connection to waveguide flanges. Eight waveguide bandwidth models are offered in the frequency ranges between 26.5 and 166 GHz.

These frequency meters are recommended for use whenever quick and accurate determination of frequency is desired in laboratory and production testing.

FEATURES:

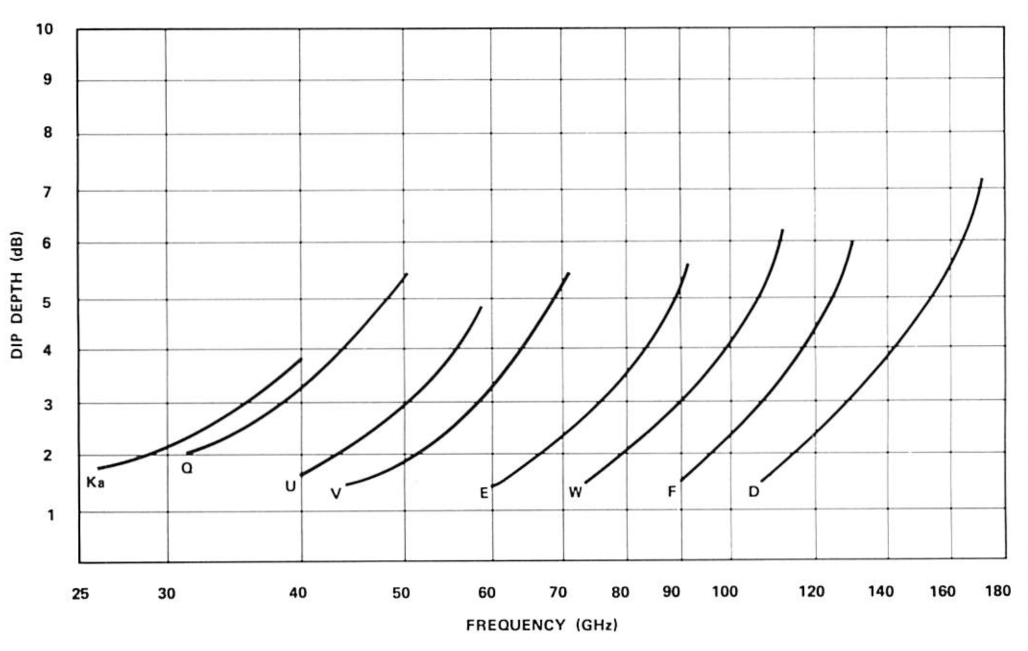
HOW TO ORDER

Model Number 4571xH-x000

Frequency Band	**1:** Ka **2:** Q **3:** U **4:** V **5:** E **6:** W **7:** F **8:** D
Flange Type	**1:** Round **2:** Square (available in Ka-band only) **3:** Pin Contact (available in F and D-bands only)

Example: To order a W-Band Frequency Meter, specify a 45716H-1000.

PERFORMANCE CURVES—TYPICAL DATA

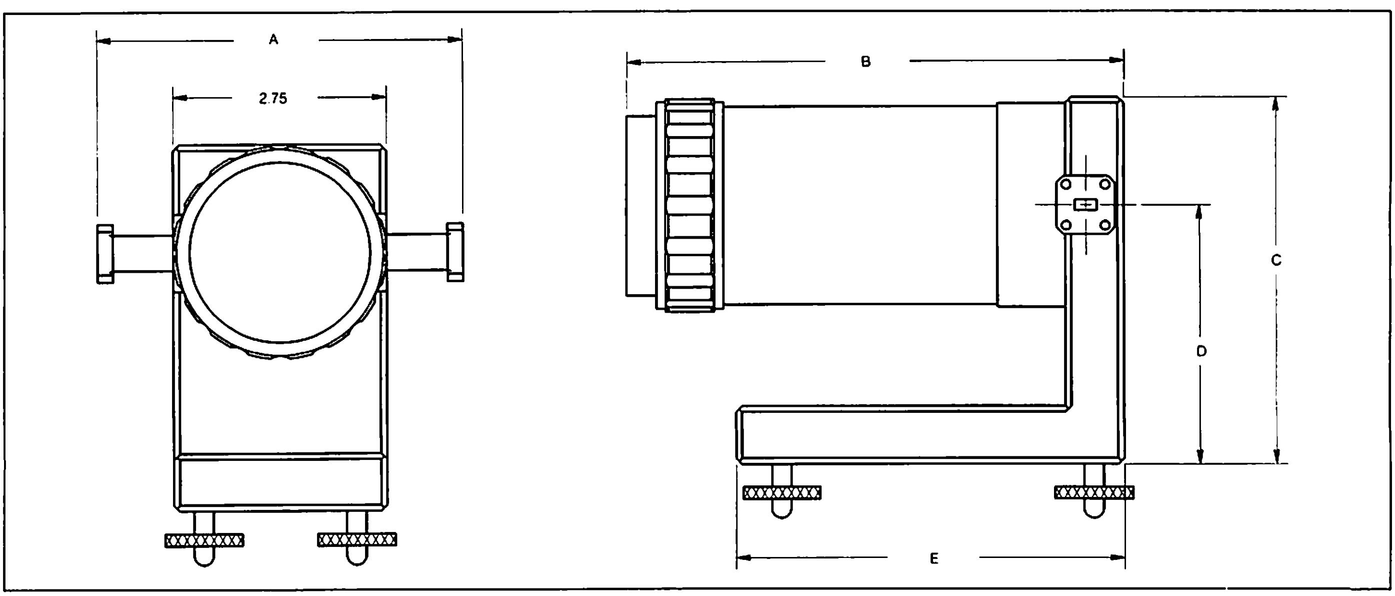


0.12% Direct Reading Accuracy

ELECTRICAL SPECIFICATIONS

	Frequency Band (GHz)							
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F ④ (90-136)	D ④ (110-166)
Accuracy* (% max)	0.12	0.12	0.15	0.20	0.20	0.25	0.50	0.50
Scale Increment (MHz)	20	20	20	50	50	100	200	200
VSWR (max)	1.3:1	1.3:1	1.3:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1
Insertion Loss (dB max)	1.0	1.0	1.0	1.2	1.5	1.5	2.0	2.0

OUTLINE DRAWING

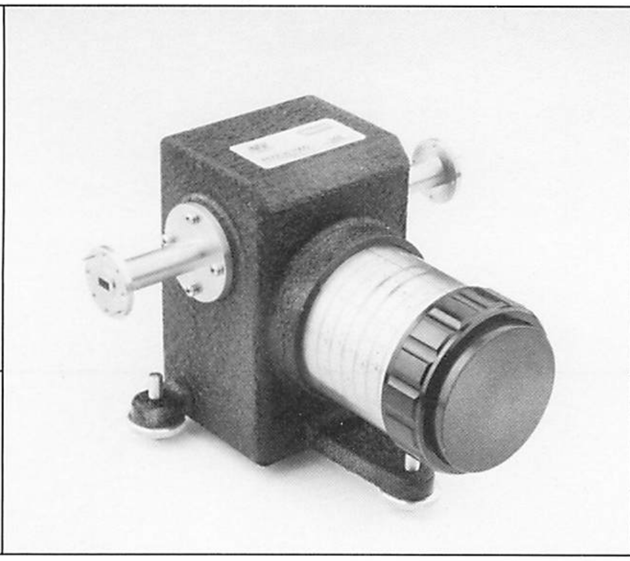


MECHANICAL SPECIFICATIONS

		Frequency Band (GHz)								
		Ka (Square)	Ka (Round)	Q	U	V	E	W	F	D
Dimensions (inches (cm))	A	4.73 (12.01)	4.73 (12.01)	4.73 (12.01)	4.73 (12.01)	4.73 (12.01)	4.73 (12.01)	4.73 (12.01)	4.73 (12.01)	4.73 (12.01)
	B	6.50 (16.51)	6.50 (16.51)	6.50 (16.51)	6.50 (16.51)	6.50 (16.51)	6.50 (16.51)	6.50 (16.51)	6.50 (16.51)	6.50 (16.51)
	C	4.75 (12.06)	4.75 (12.06)	4.75 (12.06)	4.75 (12.06)	4.75 (12.06)	4.75 (12.06)	4.75 (12.06)	4.75 (12.06)	4.75 (12.06)
	D	3.35 (8.51)	3.35 (8.51)	3.35 (8.51)	3.35 (8.51)	3.35 (8.51)	3.35 (8.51)	3.35 (8.51)	3.35 (8.51)	3.35 (8.51)
	E	5.00 (12.70)	5.00 (12.70)	5.00 (12.70)	5.00 (12.70)	5.00 (12.70)	5.00 (12.70)	5.00 (12.70)	5.00 (12.70)	5.00 (12.70)
Waveguide Size ①		WR-28	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
Waveguide Flange ①		UG-599/U③	UG-381/U②	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod) pin contact	UG-387/U (mod) pin contact

*At 25°C ambient temperature.
①Refer to page 157 for specifications and MIL specification cross reference ②Round flange ③Square flange ④No NBS standards exist in these bands.

Direct Reading Attenuators



Hughes 4572xH series of Millimeter-Wave Direct Reading Attenuators are of the rotary-vane type. The value of attenuation is determined by the angle of rotation of a resistive film with respect to the waveguide and thus is independent of frequency. An expanded helical drum scale with an anti-backlash drive permits highly accurate attenuation readings over a full 60 dB range.

The Attenuators are provided in eight full waveguide bands between 26.5 GHz and 170 GHz. The small variation of phase shift, low VSWR, low insertion loss, and high direct reading accuracy make difficult millimeter-wave measurements practical.

FEATURES:

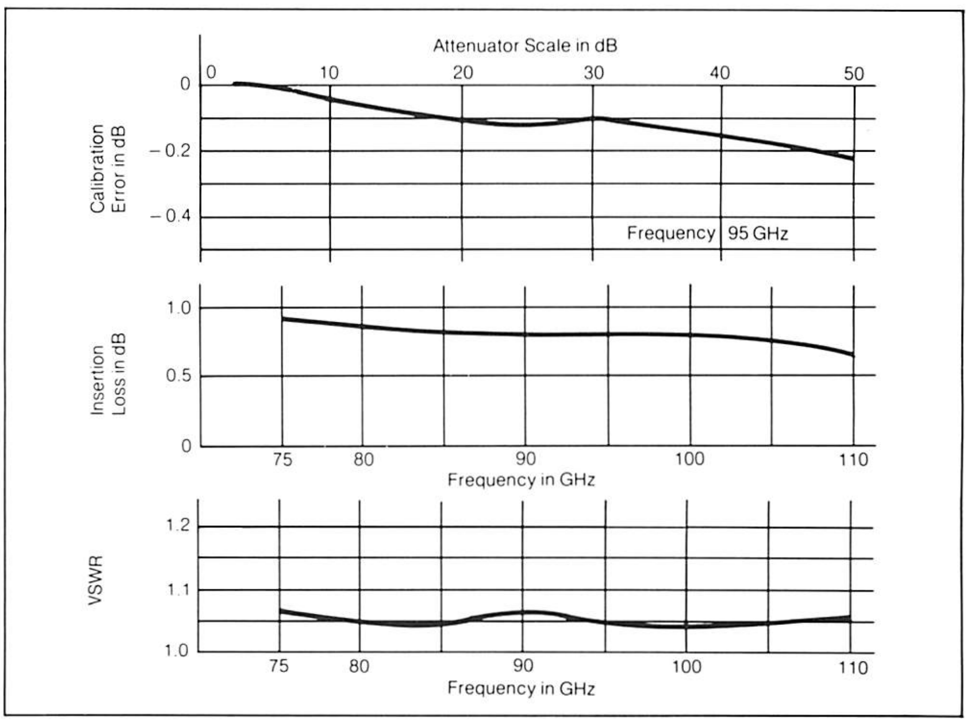
HOW TO ORDER

Model Number 4572xH-x000

Frequency Band	**1:** Ka	
	2: Q	
	3: U	
	4: V	
	5: E	
	6: W	
	7: F	
	8: D	
Flange Type	**1:** Round	
	2: Square (available in Ka-band only)	
	3: Pin Contact (available in F and D-bands only)	

Example: To order a W-Band Attenuator, specify 45726H-1000.

PERFORMANCE CURVES—TYPICAL DATA

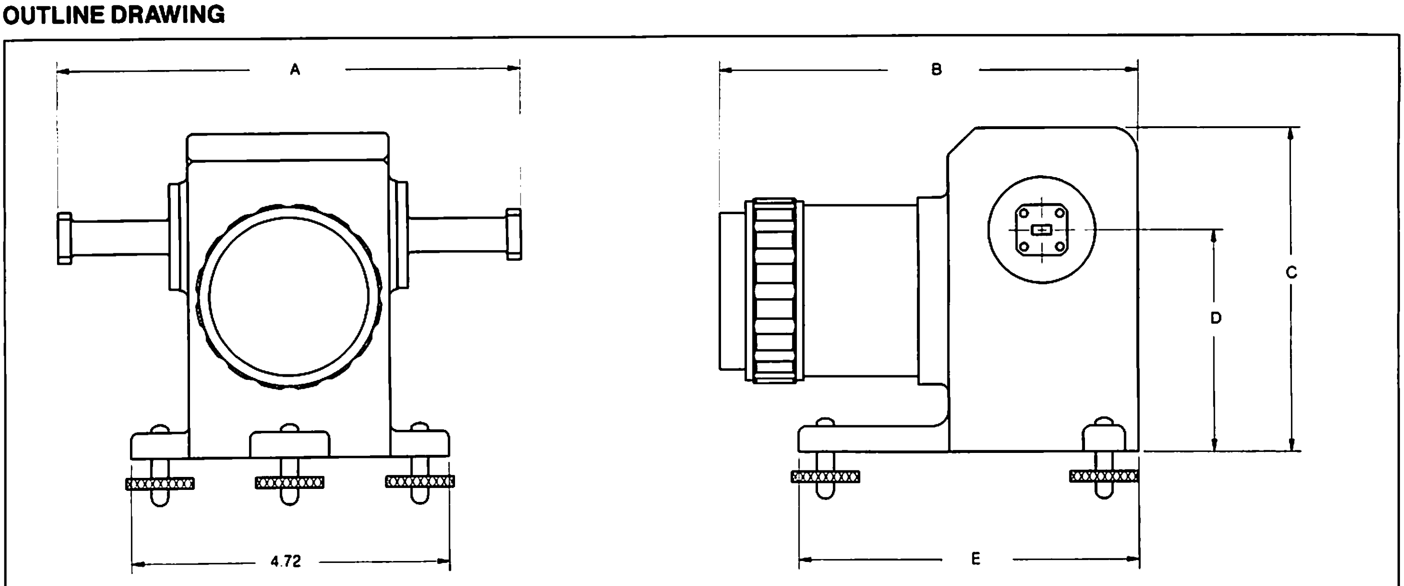


2% Direct Reading Accuracy

ELECTRICAL SPECIFICATIONS

	Frequency Band (GHz)							
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F④ (90-140)	D④ (110-170)
Attenuation Range (dB)	0-60	0-60	0-60	0-60	0-60	0-60	0-60	0-60
Accuracy* (dB/%)	0.1/2.0	0.1/2.0	0.1/2.0	0.1/2.0	0.1/2.5	0.1/2.5	0.2/3.0	0.3/3.0
VSWR (max)	1.15:1	1.15:1	1.15:1	1.15:1	1.20:1	1.20:1	1.25:1	1.25:1
Insertion Loss (dB max)	0.5	0.6	0.7	0.8	1.0	1.0	1.5	2.0
Rated Power (W max)	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3

OUTLINE DRAWING

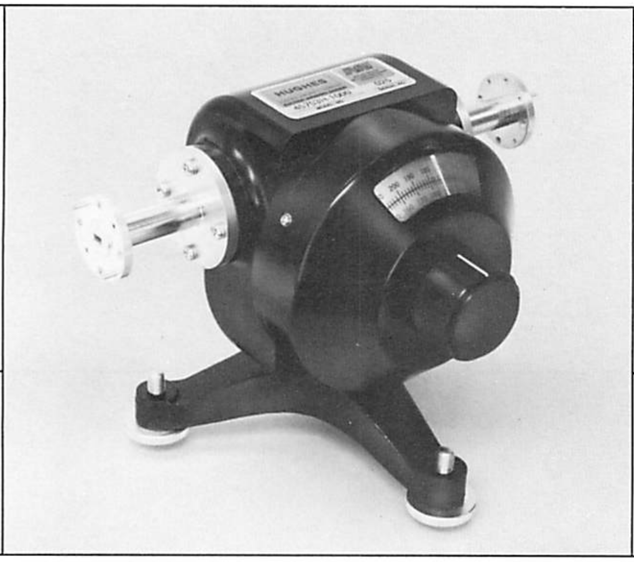


MECHANICAL SPECIFICATIONS

		Frequency Band (GHz)								
		Ka (Square)	Ka (Round)	Q	U	V	E	W	F	D
Dimensions (inches (cm))	A	6.89 (17.50)	6.89 (17.50)	5.90 (14.97)	4.92 (12.50)	3.94 (10.01)	3.94 (10.01)	3.94 (10.01)	3.94 (10.01)	3.94 (10.01)
	B	6.40 (16.27)	6.40 (16.27)	6.40 (16.27)	5.40 (13.72)	5.40 (13.72)	5.40 (13.72)	5.40 (13.72)	5.40 (13.72)	5.40 (13.72)
	C	4.80 (12.19)	4.80 (12.19)	4.80 (12.19)	4.25 (10.80)	4.25 (10.80)	4.25 (10.80)	4.25 (10.80)	4.25 (10.80)	4.25 (10.80)
	D	3.31 (8.41)	3.31 (8.41)	3.31 (8.41)	3.23 (8.20)	3.23 (8.20)	3.23 (8.20)	3.23 (8.20)	3.23 (8.20)	3.23 (8.20)
	E	5.04 (12.80)	5.04 (12.80)	5.04 (12.80)	3.94 (10.01)	3.94 (10.01)	3.94 (10.01)	3.94 (10.01)	3.94 (10.01)	3.94 (10.01)
Waveguide Size①		WR-28	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
Waveguide Flange ①		UG-599/U③	UG-381/U②	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod) pin contact	UG-387/U (mod) pin contact

*Whichever is greater. ①Refer to page 157 for specifications and MIL specification cross reference ②Round flange ③Square flange ④No NBS standards exist in these bands.

Direct Reading Phase Shifters



Hughes 4575xH series Millimeter-Wave Direct Reading Phase Shifters are of the rotary vane type. These Phase Shifters are provided in eight full waveguide bandwidths between 26.5 GHz and 170 GHz.

The Phase Shifters consist of rectangular to circular waveguide transitions with mode suppressors, and rotary phase shift vane. Phase shift is controlled by the relative position of the mica card in the circular waveguide section. Phase shift angle may be read on either of two scales

FEATURES:

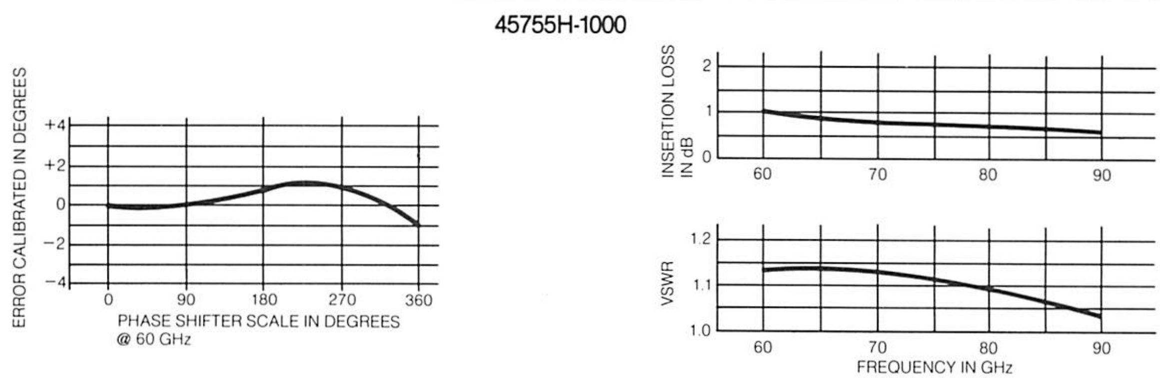
HOW TO ORDER

Model Number .... .4575xH-x000

Frequency Band	**1:** Ka **2:** Q **3:** U **4:** V **5:** E **6:** W **7:** F **8:** D
FlangeType	**1:** Round **2:** Square (available in Ka- band only) **3:** Pin Contact (available in F and D-bands only)

Example: To order a Ka-Band Phase Shifter with square UG-599/U flange, specify a 45751H-2000.

PERFORMANCE CURVES—TYPICAL DATA



graduated from 360 to 0 degrees counterclockwise, and 0 to 360 degrees clockwise.

These Broadband Direct Reading Phase Shifters provide precise variations in electrical lengths of transmission lines with low insertion loss and VSWR. They are useful in controlling phase relations of millimeter-wave phase bridges, antenna arrays, and for phase shift measurement through transmission media.

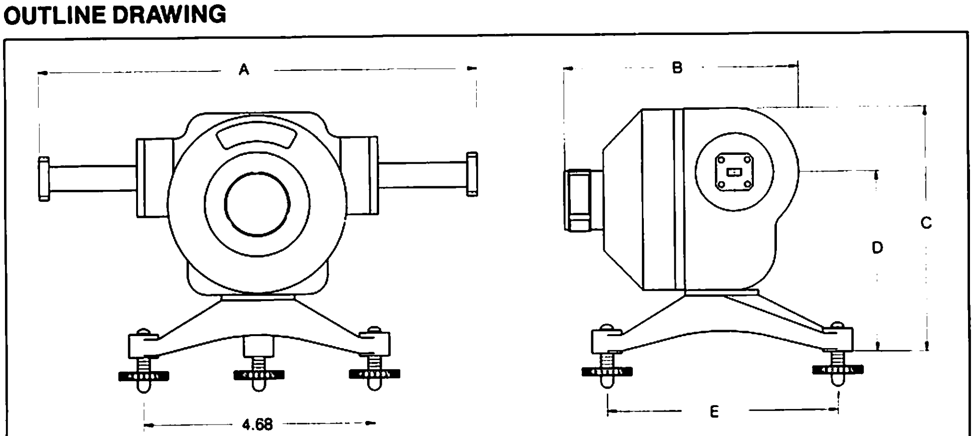
For information on programmable versions, see page 38 of this catalog; or consult your representative or the factory.

Full Waveguide Band Coverage to 170 GHz

ELECTRICAL SPECIFICATIONS

	Frequency Band (GHz)							
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F④ (90-140)	D④ (110-170)
Phase Shift Range (±degrees)	360	360	360	360	360	360	360	360
Accuracy (degrees)	4	4	4	4	4	4	5	6
Insertion Loss (dB max)	1.5	1.5	1.5	1.5	2.0	2.5	2.5	3.0
VSWR (max)	1.20:1	1.20:1	1.20:1	1.20:1	1.25:1	1.30:1	1.40:1	1.50:1
Maximum Power (W Average)	1	1	1	0.5	0.5	0.5	0.5	0.5

OUTLINE DRAWING



MECHANICAL SPECIFICATIONS

		Frequency Band								
		Ka (Square)	Ka (Round)	Q	U	V	E	W	F	D
Dimensions (inches (cm))	A	8.90 (22.61)	8.90 (22.61)	7.80 (19.81)	7.1 (18.03)	5.12 (13.00)	4.41 (11.20)	4.41 (11.20)	4.8 (12.19)	4.8 (12.19)
	B	4.75 (12.07)	4.75 (12.07)	4.75 (12.07)	4.75 (12.07)	4.75 (12.07)	4.75 (12.07)	4.75 (12.07)	4.75 (12.07)	4.75 (12.07)
	C	4.97 (12.62)	4.97 (12.62)	4.97 (12.62)	4.97 (12.62)	4.97 (12.62)	4.97 (12.62)	4.97 (12.62)	4.97 (12.62)	4 97 (12.62)
	D	3.67 (9.32)	3.67 (9.32)	3.67 (9.32)	3.67 (9.32)	3.67 (9.32)	3.67 (9.32)	3.67 (9.32)	3.67 (9.32)	3.67 (9.32)
	E	4.68 (11.89)	4.68 (11.89)	4.68 (11.89)	4.68 (11.89)	4.68 (11.89)	4.68 (11.89)	4.68 (11.89)	4.68 (11.89)	4.68 (11.89)
Waveguide Size①		WR-28	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
Waveguide Flange①		UG-599/U③	UG-381/U②	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod) pin contact	UG-387/U (mod) pin contact

①Refer to page 157 for specifications and MIL specification cross reference ②Round flange ③Square flange ④No NBS standards exist in these bands.

Programmable Attenuators/Precision Instrument Controllers

The Hughes precision programmable attenuators and instrument controllers offer a unique annd versatile approach for millimeter-wave signal control applications. Attenuators and integrated subsystems are available for laboratory, ATE, STE, and OEM applications. Attenuation control options include manual front panel and GPIB (with the precision instrument controller) and RS-232C. Diagnostics are included as part of the user interfaces.

Hughes' Model 4572xH series of precision motor-driven rotory-vane type attenuators provides resolution to 0.01 dB over the ranges of 0 to 60 and 0.05 dB for 0 to 100 dB in any of the standard waveguide bands from 26.5 to 170 GHz. (See Direct Reading Attenuators— pages 34 & 35). Attenuation values are selected in less than 5 seconds by a quiet dc motor

GPIB

FEATURES:

ELECTRICAL SPECIFICATIONS

ATTENUATOR

	Frequency Band (GHz)							
	Ka 26.5-40	Q 33-50	U 40-60	V 50-75	E 60-90	W 75-110	F 90-140	D 110-170
Accuracy dB/% (To 50 dB)①	0.1/2.0	0.1/2.0	0.1/2.0	0.1/2.0	0.1/2.5	0.1/2.5	0.2/3.0	0.3/3.0
VSWR (Max)	1.15:1	1.15:1	1.15:1	1.15:1	1.12:1	1.2:1	1.25:1	1.25:1
Insertion Loss (dB Max)①	0.5	0.6	0.7	0.8	1.0	1.0	1.5	2.0
Rated Power (W Max)	0.5	0.5	0.5	0.3	0.3	0.3	0.3	
Attenuation Range (dB)	0 to 60 or 0 to 100							
Resolution (dB Typical)	0.01 for 60dB/0.1 for 100dB							
Repeatibility	0.1dB at 60dB/0.2dB at 100dB							
Setability (dB Typical)	0.01 for 60dB/0.1 for 100dB							
Selection Speed	< 5 Seconds							

① x2 for 100dB Range

PRECISION DRIVER

Interface RS-232C
Power . . . . + 12Vdc at 1.5A Max

PRECISION INSTRUMENT CONTROLLER

Interface IEEE-488
Power . . . . 115/230 Vac
Enclosure . . . . 7.5" Rack Mount

capable of 125,000 incremental steps. Programmable attenuators can be provided with or without an expanded helical drum scale. Single or ganged units provide low VSWR and insertion loss. Units include internal limit and "homing" reference devices to ensure reliability and long term accuracy. Typical performance Data is shown in Figure 1.

The Hughes' Model 424xxH series of precision instrument controllers offers programmable control of the Model 4572xH attenuators and model 4575xH phase shifters. The Model 42400H precision instrument controller is a complete laboratory instrument, complete with front-panel controls and IEEE-488 interface. The Model 42410H is a precision driver, including RS-232C interface. Both configurations are compatible for ATE/STE applications. Typical configurations are shown in Figure 2. The Model 42410H driver requires a user-provided + 12 volt power supply. The Model 42400H operates from 115 VAC or 220 VAC and is bench or rack mountable. Special variations of the precision instrument controller allow the user to customize controls and interfaces for integration into ATE/STE systems.

Precision instrument controllers include front-panel controls, an integral keyboard, a 40 column/4 line "super twist" LCD display, GPIB interface, and diagnostic features. Controllers have options for 1 to 3 channels to drive attenuators and/or phase shifters. Hughes offers a number of special configurations to meet the most exacting millimeter-wave measurement requirements.

- **26.5 to 170 GHz**
- **Better Than 2% Accuracy**
- **0.01 dB Resolution**
- **0 to 60 and 0 to 100 dB Range**
- **IEEE-488 or RS-232C**
- **ATE/STE / Attenuation Standard**

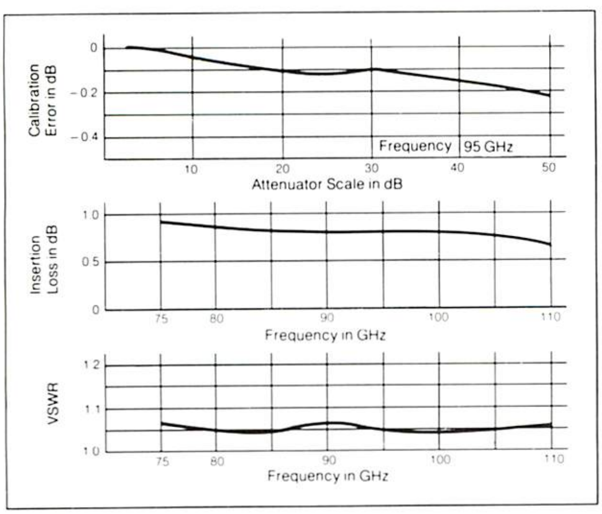


FIG. 1 TYPICAL ATTENUATOR PERFORMANCE DATA

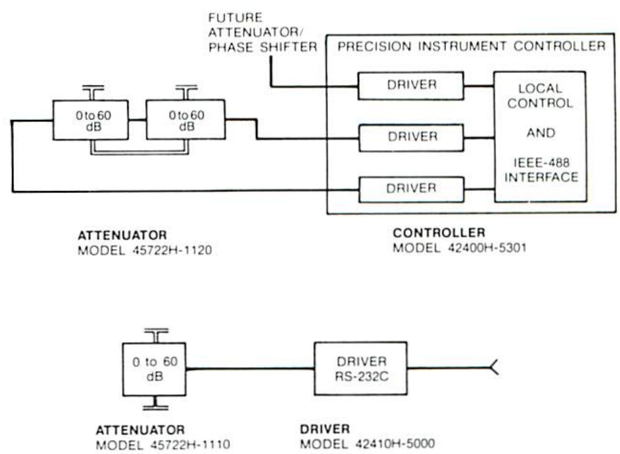


FIG. 2 TYPICAL PROGRAMMABLE ATTENUATOR CONFIGURATIONS

HOW TO ORDER

Programmable Attenuators . . . 4572xH-xxx0

Frequency Band
- **0**: K
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **5**: E
- **6**: W
- **7**: F
- **8**: D

Configuration
- **1**: Single 0 to 60 dB
- **2**: Dual 0 to 100 dB

Control
- **1**: Programmable
- **2**: Prog W/O Scale

Flange
- **1**: Round
- **2**: Square
- **3**: Pin Contact

Precision Instrument Controller 42400H-5x0x

Number of Channels
- **1**: 1
- **2**: 2
- **3**: 3

Primary Power
- **1**: 115 VAC
- **2**: 220 VAC

RS-232C Precision Driver

42410H-5000

EXAMPLE: To order a 0 to 100 dB (dual) attenuator with three channel driver in Q-Band, round waveguide flanges, controller with IEEE-488 interface for operation at 115 vac—specify model numbers: Attenuator 45722H-1120
Controller 42400H-5301

ADD Programable Phase-Shifters.

POWER GENERATING COMPONENTS

Solid state power sources have made widespread use of millimeter waves feasible. There are two types of two-terminal semiconductor devices that are presently being used to generate fundamental-frequency, millimeter-wave power: Gunn and IMPATT diodes. Three-terminal devices such as GaAs field-effect transistors (FET's) are being used as small-signal low-noise RF amplifiers at frequencies up to 60 GHz and are being developed as power sources throughout the same frequency range. They presently have CW output power capabilities of up to 100 mW at 40 GHz and further developments now in progress are expected to increase this number significantly.

Gunn and IMPATT semiconductor diodes are used to generate fundamental-frequency, millimeter-wave energy by virtue of a "negative resistance" that is exhibited when appropriate dc electrical bias is applied. The principle of operation of these two devices is described on pages 72 and 73.

In order for Gunn and IMPATT diodes to generate millimeter-wave power they must be incorporated into resonant structures. It is desirable to make the device area as large as possible to minimize heating, thereby ensuring long life operation. This results in a low value of RF impedance since capacitive reactance is inversely proportional to device area.

This means that, in general, the RF impedance of a diode is much lower than the characteristic impedance of the transmission line or cavity circuit in which it must be used. There are two undesirable by-products of low device impedance—parasitic impedance of the package elements has a strong influence on overall circuit performance, and circuit impedance must be reduced to match the device impedance by using transformers. Both contribute to making broadband circuit design difficult.

CW DIODE OSCILLATORS

Temperature rise due to dc power dissipation is a limitation that must be considered in any power device. In a semiconductor device there are chemical-rate processes associated with the semiconductor material and applied metallizations that are accelerated at elevated temperatures and ultimately cause failure. For this reason it is appropriate to compare power generation capability on the basis of a fixed temperature rise. Table I contains a power and efficiency comparison of Gunn diodes, and double-drift silicon IMPATT's mounted on diamond heat sinks at a temperature rise not exceeding 225°C.

	Frequency (GHz)					
	35	44	60	94	140	220
CW IMPATT Diodes (silicon) Power Output (mW)	1500	1700	1400	500	120	50
Efficiency (%)	12	13	13.5	6	5	2
CW Gunn Diodes Power Output (mW)	400	300	140	75	2	
Efficiency (%)	6	5	2	2	0.2	
Pulsed IMPATT Diodes Peak Power Output (Watts)	28			30	5	1
Efficiency (%)	6			5	5	2

TABLE I. BEST LABORATORY RESULTS FOR CW POWER OUTPUTS AND EFFICIENCIES OF HUGHES GUNN AND IMPATT DIODES OPERATING AT TEMPERATURE RISES OF LESS THAN 225°C PLUS PULSE POWER OUTPUTS AND EFFICIENCIES OF IMPATTS WITH PULSE WIDTH OF 100 NANOSECONDS OR LESS.

The comparison is based on best data obtained from Hughes' silicon IMPATT and GaAs Gunn diodes. It should be noted that Gunn diodes normally exhibit a saturation in output power as dc input power is increased. For the size of diodes normally used, the power maximum usually occurs at a temperature rise of less than 225°C. Thus, a power/efficiency comparison of Gunn and IMPATT diodes at equal temperatures would be more favorable for Gunn diodes than is indicated by Table I.

At frequencies above 100 GHz, Hughes has developed Gunn driven multipliers to be used as local oscillators. The output frequency of these multipliers ranges from 100 to 150 GHz. The output power ranges from 5 to 20 mW depending on frequency. Both doublers and triplers are available. The high power Gunn oscillators that drive these multipliers can be injection locked by a phase lock oscillator at the fundamental and therefore provide phase locked sources at the high millimeter-wave frequencies. Figure 1 shows a 65 GHz Gunn injection locking two higher power 65 GHz Gunn oscillators. One channel then drives a times two multiplier to obtain 130 GHz. The other channel provides 65 GHz with an output power of 80 mW which is adjustable with the level set attenuator provided.

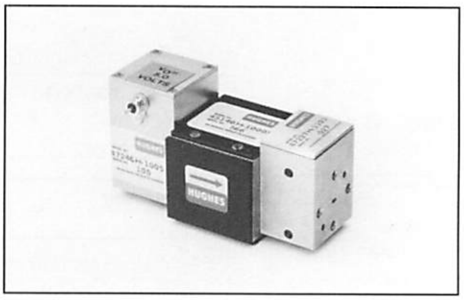


FIG. 1. 15 mW 130 GHz GUNN SOURCE WITH 80 mW HARMONICALLY RELATED 65 GHz SIGNAL.

PULSED DIODE OSCILLATORS

Gunn and IMPATT diodes can be designed to produce much higher peak power in short pulses than is available on a continuous basis. As shown in Table I, peak power levels greater than an order-of-magnitude higher than CW levels can be achieved if the pulse width is a small fraction of the

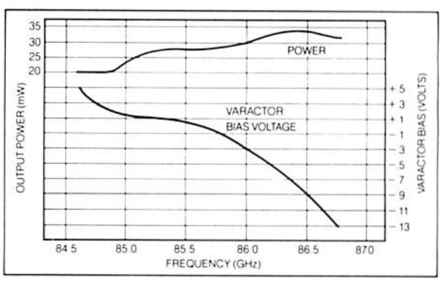


FIG. 2. TYPICAL TUNING CURVE OF VARACTOR TUNED GUNN OSCILLATOR.

semiconductor thermal time constant (i.e., 100 ns or less). The design of a pulsed diode is somewhat different than a CW diode to accommodate the higher peak current densities and resulting space-charge widening.

Frequency chirp occurs as a natural consequence of heating during the pulse and can be controlled by shaping the bias current pulse.

TUNABLE DIODE OSCILLATORS

Modern micro/millimeter-wave systems are heavily dependent on electronically tunable solid state oscillator technology. Tuning is presently accomplished by several methods. The YIG resonator is useful technique, but is limited to 50 GHz due to the large magnetic fields required. Varactor controlled Gunn and IMPATT oscillators can provide high power over narrow tuning ranges and power levels adequate for local oscillators over much wider tuning ranges.

An example of a varactor tuned Gunn oscillator delivering over 20 mW over 2 GHz tuning range is shown in Figure 2. Tuning bandwidths of up to 5 GHz with 10 mW minimum output power are now achievable.

IMPATT oscillators can be tuned by changing the dc bias. Monotonic tuning of an IMPATT oscillator can be achieved by sweeping the diode bias current. This effect formed the basis of the first Hughes millimeter-wave catalog product—the IMPATT sweeper. Several versions of these sweepers are described on pages 10 through 14. In general, as bias current is increased, power output as well as frequency increases. This type of behavior is shown in Figure 3.

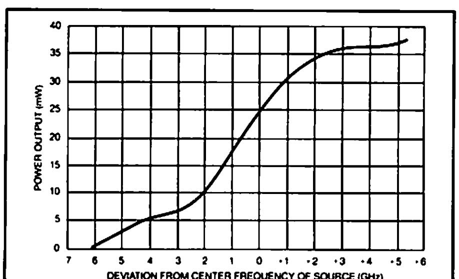


FIG. 3. POWER OF AN IMPATT SWEEPER INCREASES WITH FREQUENCY.

AMPLIFIERS

Although FET's are becoming practical as low power amplifiers in the lower millimeter-wave frequencies, the use of negative resistance IMPATT and Gunn diodes is still the only practical means of getting significant mW power output. Indeed 25 Watts CW is offered over a 2 GHz bandwidth at 44 GHz in a combiner, using Hughes silicon IMPATT diodes, described on pages 54 and 55. High gain amplifiers producing several watts or more of CW output power can require many diodes, each one acting as a reflection amplifier in either a stable amplifier mode or an injection locked oscillator mode. The circuit hardware required to operate a given diode in any of these modes is essentially the same. The mode of operation is determined by the circuit impedance presented to the diode, and normally there are only minor tuning differences between amplifiers operating in the two different modes.

To understand the minor differences in the tuning of amplifiers for the stable and injection locked mode, extensive experiments have been performed. A single diode amplifier was tuned to operate at 60 GHz in the stable amplifier mode. Output power of over 1 watt with between three and four dB saturated gain was obtained over a 2.5 GHz bandwidth. The same amplifier, when tuned for the injection locked mode, provided the same output power over the 2.5 GHz band, but with higher gain (8 to 10 dB).

The maximum achievable bandwidth of single stage amplifiers is determined by the circulator rather than the diode or cavity. Hughes has developed wideband circulators which improve amplifier performance greatly (page 110).

The negative resistance of Gunn and IMPATT diodes exist over very wide frequency ranges, typically an octave or more. As long as the circuit impedance presented to the diode at any frequency is greater than the negative resistance of the diode at that frequency, the diode operates as a stable amplifier. As the load impedance decreases and becomes equal to the negative resistance, gain goes to infinity and the diode begins to oscillate. The frequency of oscillation depends upon the diode and circuit reactances. A further reduction in the load impedance will cause the oscillations to grow until the non-linear nature of the diode causes the diode negative resistance to decrease in magnitude to match the circuit impedance. The power output of the oscillator is determined by the circuit impedance and the impedance-amplitude characteristic of the diode. High power is associated with low circuit impedance.

Stable Amplifier Mode

The advantages of the stable amplifier mode are listed below:

- The output power vanishes when the input signal goes to zero. No additional circuit elements or control functions are required.
- There is no lock-up or phase settling time. The instantaneous bandwidth of the amplifier is the full bandwidth of the amplifier.
- The amplifier is nearly linear and can reproduce amplitude modulation as well as frequency or phase modulation. The amplitude modulation capability can be used to control power level directly. Multiple signals can be amplified with moderate intermodulation distortion.
- There is low AM to PM conversion across the entire operating bandwidth in the small signal region of operation.
- Broad bandwidths are more easily achieved.

Injection Locked Operation

The advantages of injection locked oscillator (ILO) operation are listed below:

- Power and efficiency obtainable from a diode are inherently greater. Circuit impedance can be optimized for output power.
- Higher gain can be achieved. To obtain high gain in a stable amplifier, the load impedance must be closely matched to the diode impedance. To maintain this match consistently over a wide bandwidth, the gain usually must be reduced. In the ILO mode, higher gain can be obtained without these requirements.
- Weight, size, cost and efficiency of multiple diode amplifiers are better because of the power per diode and increased gain per stage of the ILO amplifier.
- There is more experience with power combiners based on ILO modules. Because tuning and alignment of ILO modules are easier than that of stable amplifiers, most reported power combiners have used ILOs.
- Meeting reliability requirements is easier because fewer high temperature, high power density components are required.

The ILO approach offers great promise if the limitations of injection locking can be overcome. Limitations and some methods of overcoming them are discussed below:

1. Output power must go to zero when no input signal is present. One approach is to turn off the ILO by reducing its bias current below threshold when no signal is present. The turn on time is almost instantaneous.
2. The ILO is unable to reproduce multiple-carrier modulation or anything other than an angle-modulated, single-carrier signal. Actually, stable amplifier IMPATT power stages themselves have very high intermodulation distortion when driven to full output power levels. Therefore, even stable IMPATT amplifiers may not be well-suited for multiple-carrier modulation where efficiency and high output power of the amplifier are at a premium.
3. AM to PM conversion occurs when the actual input signal is near the minimum required to maintain lock. It can be reduced to stable amplifier levels by providing extra locking margin. Measurements at Hughes on 44 GHz ILOs and power combiners have shown that the extra locking margin is readily obtainable.

Low power driver stages can be as difficult as high power output stages when input dynamic range, gain flatness, broad bandwidth, and temperature requirements are taken into account. In some cases it is necessary to reduce the gain of these driver stages in order to meet these other specifications. For example, in order to meet an input power dynamic range requirement of 5 dB and an output power flatness response of ±0.5 dB over a 2.5 GHz bandwidth at 60 GHz with a 4 watt amplifier, the driver stage had to be tuned so that only 7 dB gain was realized although a full 10 dB gain was possible over the band with both Gunn and IMPATT diodes.

If low noise figure is required, Gunn diodes can be used in the first stage of complex power amplifiers. A noise figure of approximately 20 dB can be obtained vs 30 dB expected with an IMPATT first stage. Similar performance in terms of gain and bandwidth can be obtained, but the added complexity of dealing with two different power supplies usually precludes the use of Gunn diodes unless the improvement in noise figure is needed. FET amplifiers are both low noise and compatible in operating voltage with IMPATTs. Recent advances in low noise millimeter-wave FETs have gradually made FET amplifiers viable input drivers at lower millimeter-wave frequencies.

Single and multistage CW injection locked amplifiers are described on pages 56 thru 59. Catalog unit output levels of 1 Watt at frequencies of 30, 44, and 60 GHz are available with 2 GHz bandwidth. The same bandwidth is available at 94 GHz with 500 milliwatts output. 17 dB gain single stage pulsed amplifiers and 33 dB gain dual stage pulsed amplifiers covering bandwidths of 50 to 250 MHz are listed on pages 48 and 49 of the catalog. The many trade-offs between gain, bandwidth, power output, dynamic range, number of stages, etc., usually require custom tuning to the user's specific requirements. In addition, special configurations—such as the one shown in Figure 4, where 44.5 GHz, 1 Watt, 2 GHz bandwidth, 10 dB gain single stage injection locked IMPATT amplifiers are ready for use in a spatial combining array—can be designed for the user. Size and weight can be substantially reduced when the application calls for it by using aluminum, eliminating excess metal, and using integration techniques to eliminate bulky flange connections.

POWER COMBINING

The variety of techniques that can be considered for combining various numbers of diodes fall into three general categories: chip level, circuit level and module level power combining schemes.

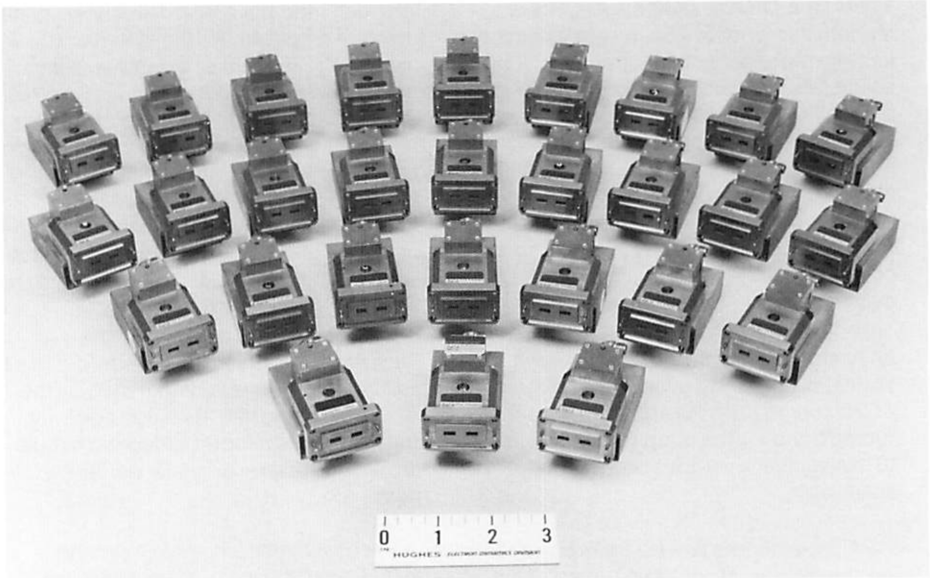


FIG. 4. 1 WATT OUTPUT 43.5 TO 45.5 GHz 10 dB GAIN AMPLIFIERS READY FOR USE IN A SPATIAL COMBINING ARRAY.

Chip Level Combining

In chip level combining, multiple diode chips are connected in a series, parallel or combination arrangement and mounted in a single package. The physical separation between diodes is small compared to the operating wavelength. The composite structure may be regarded as a single lumped device. Conceptually, by connecting the diode chips in series electrically but in parallel thermally, the chip level combiner will provide a much increased source impedance and a decreased thermal impedance as compared to a single device of the same total area. Therefore, increased power is possible over that obtained from a single diode.

In principle, chip level combining is quite simple; however, from the limited experimental work performed at Hughes, it is clear that some problems remain. Chip level combiners are prone to various types of instabilities due to the fact that IMPATT diodes have negative resistance over a very wide bandwidth and strong nonlinearities.

Considerable development work remains to be done before chip level combiners can be considered a viable candidate for manufacturable low cost amplifiers. A severe problem is the lack of high electrical isolation between diodes.

Circuit Level Combining

In circuit level power combiners, spacings between discrete devices are comparable to a wavelength at the operating frequency. Isolation between diodes can be obtained and tends to suppress the large number of possible modes of interaction between various combinations of diodes. Circuit level combiners have been demonstrated to be a viable power combining technique for various types of solid state devices over the full microwave and millimeter-wave frequency range. Three circuit level combining schemes are used: (1) the cylindrical cavity combiner, (2) the resonant rectangular waveguide combiner and (3) the conical line combiner. Resonant combiners employ a relatively high Q resonant structure to achieve power combining and diode-to-diode isolation. Because of the resonance characteristics, resonant combiners are classified as narrow bandwidth devices. On the other hand, the conical line combiner, which in principle is nonresonant, is theoretically capable of broadband operation.

Overall, resonant combiners have demonstrated impressive power output levels and combining efficiencies. The rectangular waveguide resonant combiner was first proposed and developed by Kurokawa. It was later modified by Harp into a cylindrical configuration to accommodate a large number of diodes in a small volume. Considerable development has been subsequently carried out at Hughes to achieve state-of-the-art performance in an X-band cylindrical resonator combiner.

An eight-diode cylindrical resonant power combiner operated in TM_{010} mode at Ka-band was developed several years ago at Hughes. A CW output power of 10 W at 28.4 GHz with 200 MHz bandwidth was obtained with individual diode power output of about 1.3 Watts when measured in a single oscillator circuit.

The cylindrical cavity combiner has proven to be an effective means of obtaining efficient power combining of IMPATT diodes in a very compact unit. However, this approach is only suitable for relatively narrow bandwidth applications.

Hughes has a considerable amount of experience with the resonant rectangular waveguide power combiners. A number of R&D programs funded by DoD for the study of power combining at 60, 94, 140 and 217 GHz with the resonant rectangular waveguide approach have been completed. The most significant results have been the realization of a W-band coherent pulsed two-diode combiner and a four-diode combiner capable of 36 Watts and 60 Watts, respectively. Both combiners have over 300 MHz locking bandwidth. Two- and four-diode power combiners of this type are offered at 94 GHz guaranteeing 30 Watts and 40 Watts of output power. See pages 46 and 47.

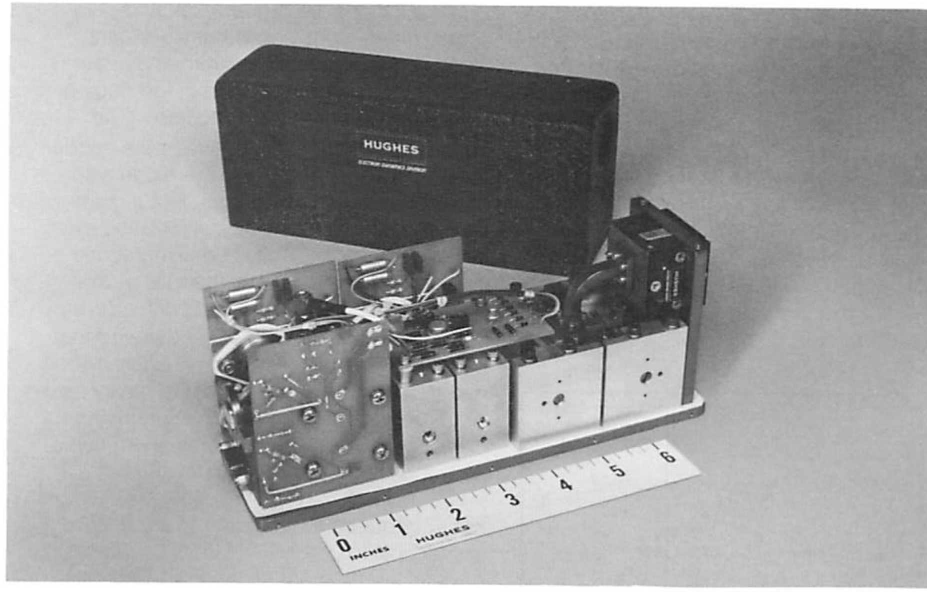


FIG. 5. A Q-BAND TRANSMITTER UTILIZING A 4-MODULE COMBINER. THE UNIT PRODUCES OVER 5 WATTS ACROSS 2 GHz BANDWIDTH AT 44.5 GHz.

While the conical line power combiner does offer the theoretical advantage of wide bandwidth, the total amount of development effort which has been devoted to this power combiner approach to date has been quite limited. It is an approach which requires a great deal more work, especially at millimeter-wave frequencies, to be proven a practical power combining technique.

Module Level Power Combining

The output power level obtained from a single module can be multiplied by means of module level power combining techniques. The single module may be a reflection amplifier or a two-port amplifier and can be either a stable amplifier or an amplifier operating in the ILO mode. The module may have only one active device or may itself be a circuit level power combiner.

A straightforward manner of combining two IMPATT diode modules is with 3 dB hybrids. Each module is a two-port amplifier consisting of an IMPATT reflection amplifier of either ILO or stable type and a circulator. Input power is equally divided by a 3 dB hybrid, and output power is combined by a second hybrid. The hybrid couplers and the circulators provide isolation between the IMPATT diodes. The hybrids can have bandwidths in excess of that of the individual modules. Each module can be tested and optimized as a single building block, and because of the high isolation between diodes, the two modules should not interact. Either 90° hybrids, such as the short slot type, or 180° Magic Tee couplers can be used. To combine four modules, three Magic Tees are required. The center Tee can be converted to a 90° hybrid by the addition of a quarter wave spacer in one arm. This type of combiner has been fabricated at both Q- and V-band. At Q-band, a four-module combiner, shown in Figure 5 as the output stage of a transmitter, has produced output power over 5 Watts across a 2 GHz band at 44.5 GHz, as shown in Figure 6. The unit has operated over the temperature range from −20°C to +60°C and is packaged to withstand severe military environment. (See pages 48 and 49). At V-band, similar amplifiers have been developed. Figure 7 shows the 4-diode hybrid power combiner. The combiner is capable of 4 Watts over more than 2 GHz bandwidth.

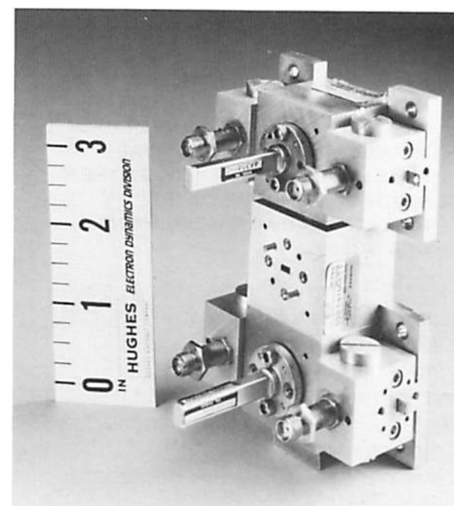


FIG. 7. A FOUR-MODULE V-BAND HYBRID POWER COMBINER DELIVERS 4 WATTS OVER A 2 GHz BANDWIDTH.

2

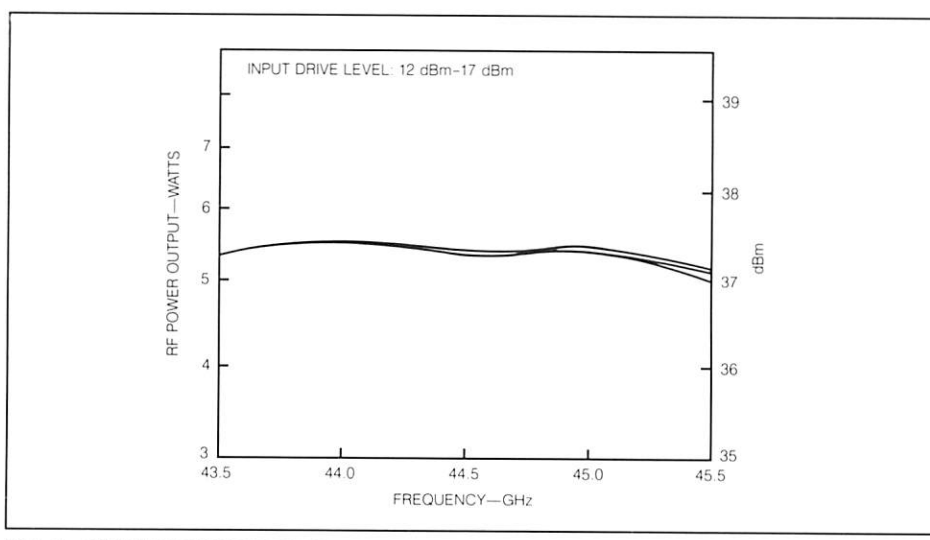


FIG. 6. OUTPUT POWER VERSUS INPUT POWER FOR THREE STAGE Q-BAND AMPLIFIER EMPLOYING A 4-DIODE Q-BAND HYBRID POWER COMBINER IN THE OUTPUT.

Power Combining by N-Way Reactive Networks

This power combining technique, illustrated in Figure 8 is in principle very simple and is widely used at lower microwave and RF frequencies. While the hybrid combining schemes of the previous section apply to either reflection amplifiers or two-port modules, the N-way divider/combiner method requires the use of two-port modules. This type of combiner is ideal for large numbers of modules combined for high power broadband applications.

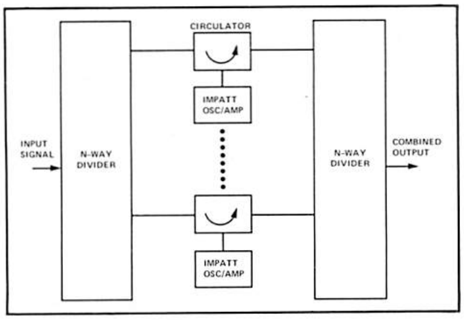


FIG. 8. TECHNIQUE EMPLOYING A PAIR OF N-WAY POWER DIVIDERS/COMBINERS AND N CIRCULATORS TO POWER COMBINE N MATCHED REFLECTION AMPLIFIER MODULES. THE METHOD ALSO APPLIES MORE GENERALLY WHERE THE N SINGLE-STAGE MODULES ARE REPLACED BY N AMPLIFIER CHAINS OF STAGES.

A 36-way combiner of this design has been developed at Q-band, as shown in Figure 9. More than 40 watts output is provided with greater than 90% combining efficiency. Injection locking bandwidth is greater than 2 GHz. The input operates over the temperature range −55°C to +71°C. The combiner exhibits graceful degradation as predicted by the formula:

$$P_{out} = \frac{(N-M)^2}{N} P_{avail}$$

where P_{out} = Power output at the combiner terminal
P_{avail} = Available power output when all diodes are operating
N = Total number of diodes
M = Number of diodes failed or turned off.

The significance of the graceful degradation is that, from a systems point of view, better reliability and lower life cycle cost can now be achieved.

OSCILLATOR NOISE

The RF noise power generated in a negative-resistance semiconductor device is dependent on many factors. Detailed noise analysis, including diode doping-profile parameters, bias conditions, RF signal level, and parametric interactions show that significant improvements in noise performance can be expected with alterations in the doping profile and in operating conditions. The impedance relationship between the oscillator, or amplifier circuit, and the diode also strongly affects noise output. Not a great deal of flexibility for noise optimization exist because of the difficulty in making subtle doping-profile and circuit changes at millimeter frequencies. Therefore, with a given type of diode it is commonly observed that samples from different wafers, when placed in a simple waveguide or coaxial cavity resonator, will produce about the same noise-to-carrier ratio when tuned for minimum noise at a specified power output level.

For IF frequencies less than 1 GHz it is impractical to use IMPATT local oscillators because of high AM noise. If a 1 GHz or higher IF frequency is used an RF filter can be used on the IMPATT LO output to reduce the AM noise sidebands.

IMPATT oscillators generally exhibit higher AM noise than Gunn oscillators. They are not typically used as receiver local oscillators when the receiver's IF signal is below 1 GHz due to the difficulty of eliminating the noise, which contributes directly to the noise figure of the receiver. For receivers with IF frequencies higher than 1 GHz, IMPATT sources are used as local oscillators provided the AM noise is sufficiently low. This is most easily accomplished with an RF bandpass filter (following the IMPATT) to provide rejection at the receiver passband.

Gunn oscillators have low AM noise and are consequently very well suited as receiver local oscillators. Best AM noise data for both IMPATT's and Gunn's (at 94 GHz) is given on pages 67 and 69 (respectively).

The phase noise of IMPATT and Gunn oscillators is primarily determined by the Q of the resonant circuit. Free-running oscillators have generally relatively low Q's and consequently high phase noise. Since the bias tuning factor is also high (1 MHz/mA and 1 MHz/mV are typical for a 94 GHz IMPATT and Gunn respectively), power supply noise is in practice a big contributor to overall phase noise. Fortunately, phase-locking techniques yield very low phase noise for both types of oscillators, close to the theoretical limit. It should be noted, however, that just as with microwave oscillators, phase locking does not affect AM noise, one way or another.

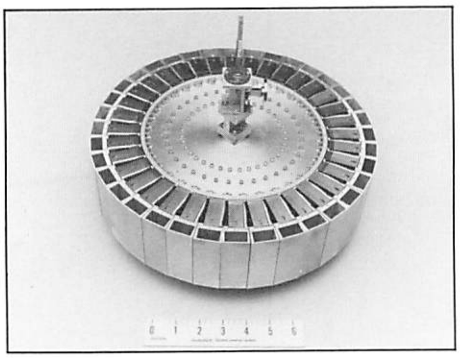


FIG. 9. Q-BAND 36-WAY COMBINER

PHASE LOCKING

For many applications the frequency stability and/or phase noise of a free running Gunn or IMPATT oscillator are inadequate. These characteristics can be improved by phase locking the oscillators to a lower frequency reference oscillator. The millimeter-wave oscillator takes on the stability characteristics of the reference oscillator when phase locked. Figure 10 shows the block

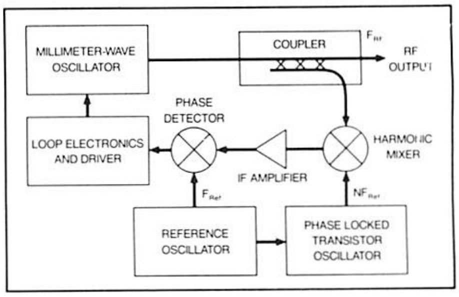


FIG. 10 BLOCK DIAGRAM OF PHASE LOCKED OSCILLATOR.

diagram for our single frequency units which are described further on catalog pages 64 and 65. The output RF frequency is:

$$F_{RF} = (NM \pm 1) F_{Ref}$$

(M is the harmonic number used on the harmonic mixer).

The phase noise of the phase locked millimeter-wave oscillator can be discussed by observing the plot of phase noise vs. frequency from carrier of a 94 GHz phase locked Gunn oscillator in Figure 11. The phase noise is divided into four regions. In the first region, the phase noise is equal to the normalized phase noise of the reference oscillator (Phase noise of reference oscillator plus 20 Log NM). This region extends to the loop bandwidth of the transistor oscillator's phase lock circuit. The loop bandwidth is set at a point where the normalized phase noise of the free running transistor oscillator (actual noise degraded by 20 Log M) equals the normalized phase noise of the reference

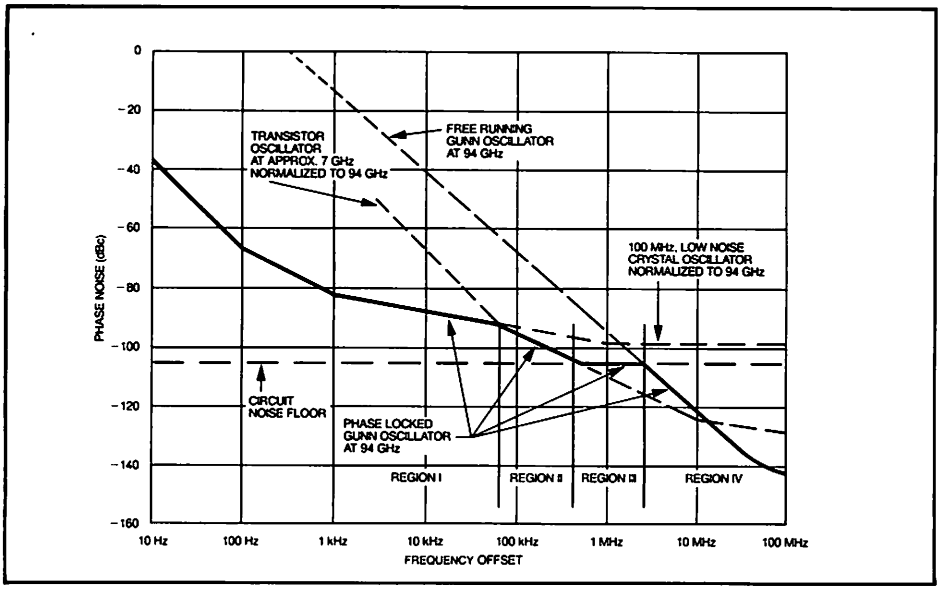


FIG. 11 PHASE NOISE VS FREQUENCY FROM CARRIER FOR 94 GHz PHASE LOCKED GUNN OSCILLATOR.

oscillator (approximately 50 KHz). Beyond the loop bandwidth the phase noise of the free running transistor oscillator determines the phase noise of the phase locked millimeter-wave oscillator. This second region ends where the normalized phase noise of the free running transistor oscillator becomes lower than the noise floor of the millimeter-wave phase lock circuit (approximately 500 KHz). This noise floor dominates the phase noise for region III which ends at the point determined by the loop bandwidth of the millimeter-wave phase lock circuit. This loop bandwidth is set at a point where the phase noise of the free running millimeter-wave oscillator equals the millimeter-wave phase lock circuit's noise floor. This usually occurs at about 1 MHz for a varactor tuned Gunn oscillator, 2-5 MHz for a bias tuned Gunn oscillator, and from 10-30 MHz for an IMPATT oscillator. Beyond this point is region IV where the phase noise of the phase locked millimeter-wave oscillator becomes the same as the phase noise of the free running millimeter-wave oscillator.

Generally the reference oscillator is a low noise crystal oscillator in the 100-110 MHz region. The frequency of the phase locked transistor oscillator is usually between 6 and 7.5 GHz. It is possible to have the reference oscillator phase locked to a 5 or 10 MHz standard for systems where coherency with the system's standard is necessary.

Frequency Agile Phase Locked Oscillators (Synthesizers)

There are five basic schemes used for synthesizers, four of which are very similar to the basic single frequency phase locked oscillator discussed above. The first and simplest method involves replacing the 100 MHz crystal oscillator with an internal or external synthesizer in the 100 MHz region. When the 100 MHz synthesizer is stepped by ΔF, the output changes by $(NM + 1)\,\Delta F$. The phase noise of the millimeter wave oscillator for frequency offsets of less than about 50 KHz will be determined by the input synthesizer with a degradation of 20 log NM. Any spurious signals from the 100 MHz synthesizer within 50 KHz from the carrier will also be multiplied up by 20 log NM. This kind of unit is capable of wide tuning bandwidths and fairly small step sizes.

Methods 2, 3, and 4 have the Reference Oscillator and Local Oscillator referenced to a standard crystal oscillator. The second method uses a fixed frequency phase locked transistor oscillator for the LO and a synthesizer for the reference oscillator. They are both referenced to a frequency standard, usually a 10 MHz crystal oscillator. This method is capable of extremely small step sizes as the reference synthesizer is not multiplied up (a step of ΔF at the reference synthesizer results in a step of ΔF at the RF frequency). The bandwidth of operation of such a synthesizer is typically limited to 100 MHz. Since the phase noise of the reference synthesizer is not multiplied by 20 log NM, its level is not as critical as in the first method.

The third method involves a fixed frequency reference oscillator and a synthesized local oscillator. This method is ideally suited for use with an external microwave synthesizer since most of the commercially available microwave synthesizers have a 100 MHz crystal output that can be used as the reference oscillator. This method allows extremely wide tuning bandwidths and has the potential of fairly small steps (a step of ΔF at the LO results in a step of $M\,\Delta F$ at the RF output).

The fourth method is essentially the same as is used in the Hughes model 4785xH synthesizer. It is the most expensive of the four but offers the greatest capability. In this method both the reference oscillator and the LO are independent frequency synthesizers referenced to the same 10 MHz crystal standard. This method can be used to cover broad bandwidths with extremely small steps. Specifications for an 800 MHz bandwidth. 35 GHz synthesizer of this type are given in Figure12.

Frequency Range (GHz)	34.444 to 35.252
Resolution (KHz)	100
Output Power (dBm)	20.8 to 21.7
Power Output Stability (dBc/°C)	0.01
Frequency Stability	1×10^{-8} per day
Temperature Range (°C)	0 to 50°
Frequency Switching Time (msec)	
Small Steps (typ)	1.5
Full Range (max)	15
SSB Phase Noise (dBc/Hz max)	
Offset from Carrier	
100 Hz	− 50
1 KHz	− 68
10 KHz	− 76
100 KHz	− 89
1 MHz	−100
10 MHz	−105
Spurious Signals (dBc max)	− 53

FIG. 12 SYNTHESIZER PERFORMANCE SPECIFICATIONS.

Any of the four methods discussed have switching speeds which are usually limited to a few milliseconds at best. For applications where microsecond switching is required, a direct synthesis approach typically is required. Figure 13 is a block diagram of such a synthesizer. It uses a direct synthesizer in the 1-4 GHz range, a Hughes model 4747xH upconverter, and a fixed frequency phase locked millimeter-wave oscillator. To increase power output a Hughes model 4719xH CW injection locked amplifier can be used at the output. Any of these frequency agile phase locked sources are available on a special order basis.

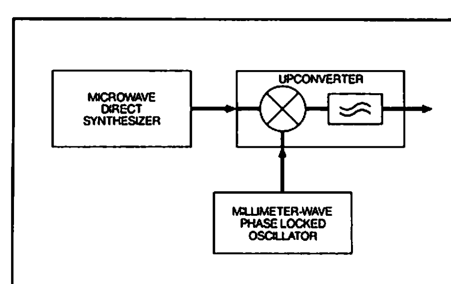
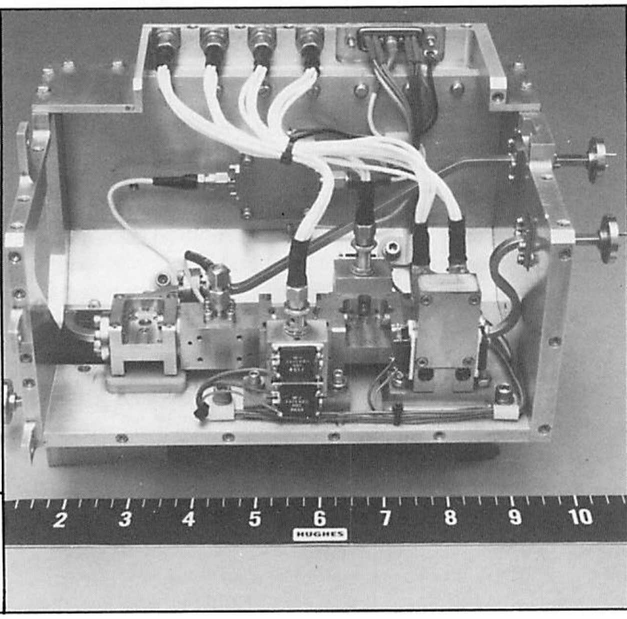


FIG. 13. FAST SWITCHING SYNTHESIZER.

Multi-Stage Pulsed Power Amplifiers



Hughes High Power Multi-Stage Pulsed Amplifiers are available in the key millimeter-wave radar frequencies at 35 GHz, 94 GHz, and 140 GHz. Injection locking bandwidths of up to 500 MHz are standard at all three frequencies.

Using Hughes Pulsed IMPATT Diodes, the Ka- and W-band units have pulsed power outputs available from 5 watts to 40 watts. The D-band unit provides 1 watt of pulsed power. All units can be driven from as little as 3 dBm of power.

The 1-watt, 5-watt,10-watt and 15-watt versions all have single diode modules on the output. The 1-watt, 5-watt and 10-watt amplifiers are two stage amplifiers and the 15-watt unit is a three stage version. The 25- and 40-watt amplifiers use a hybrid combiner to achieve the high power output and the power is developed over three stages of amplification. The 25-watt utilizes a two diode combiner while the 40-watt has a 4-diode combiner. Pulse widths

FEATURES:

SPECIFICATIONS

FREQUENCY (GHz)	Ka (34-36)	W (92-96)	D (135-145)
Pulsed Power Output (W min)	5, 10, 15, 25, 40	5, 10, 15, 25, 40	1
Bandwidth (MHz min/max) ①	100/500	100/500	100/500
Pulse Width (ns min/max)	50/100	50/100	50/100
PRF (KHz min/max)	1/100	1/100	1/100
Trigger Input to Output Delay	300	300	300
Trigger Width Input (ns typ)	100-1000	100-1000	100-1000
Trigger Input (VTTL)	5.0	5.0	5.0
Injection Drive Level (dBm min)	+3 dBm	+3 dBm	+3 dBm
DC Voltage Requirements Modulator (V typ)	28 80	28 80	28 80

① Bandwidth is dependent on gain per stage

HOW TO ORDER (Specify center frequency, pulse width, bandwidth, and PRF at time of order)

Model Number 4718xH-14xx

Frequency Band	**1**: Ka **6**: W **8**: D	
Power Output	**01**: 1 Watt (D-band only) **05**: 5 Watts (Ka- and W-bands only) **10**: 10 Watts (Ka- and W-bands only) **15**: 15 Watts (Ka- and W-bands only) **25**: 25 Watts (Ka- and W-bands only) **40**: 40 Watts (Ka- and W-bands only)	

can be specified between 50 and 100 nanoseconds with pulse repetition frequencies between 10 and 100 KHz.

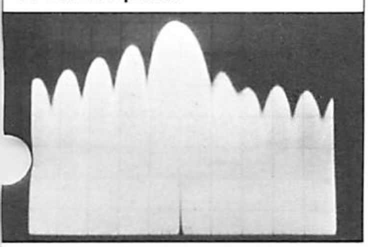
Many of the standard features can be modified or adapted to meet specific requirements. For example, by using the gain/bandwidth product, a 1 GHz bandwidth has been achieved in W-band and 800 MHz in Ka-band. Special output powers and input drive levels are also available.

These amplifiers are ideal for target identification applications for satisfying target acquisition requirements found in today's missile systems. The amplifiers can be custom packaged for field and military applications. Consult your local Hughes representative for specific details.

Up to 40 watts pulsed at 35 GHz and 94 GHz.

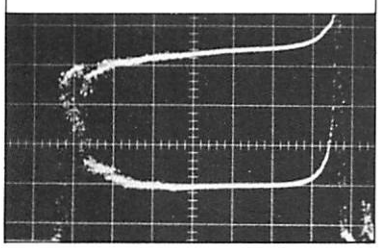
PERFORMANCE DATA

Spectrum of Amplified Signal for Dual Stage 5-Watt 94 GHz Amplifier



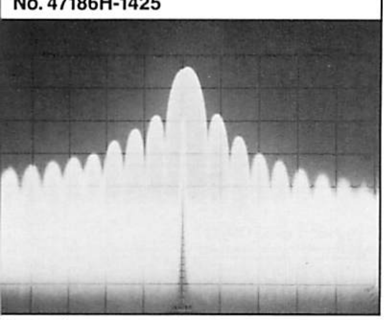
HORIZONTAL: 10 MHz / DIV.
BANDWIDTH: 300 KHz
VERTICAL: 10 dB / DIV.
PRF: 100 KHz
PULSEWIDTH: 100 ns

Frequency Meter Dip of 94 GHz Amplified Pulse



HORIZONTAL: 10 ns / DIV.
FREQUENCY METER SETTINGS
UPPER TRACE . . .94.1 GHz
LOWER TRACE . .94.0 GHz

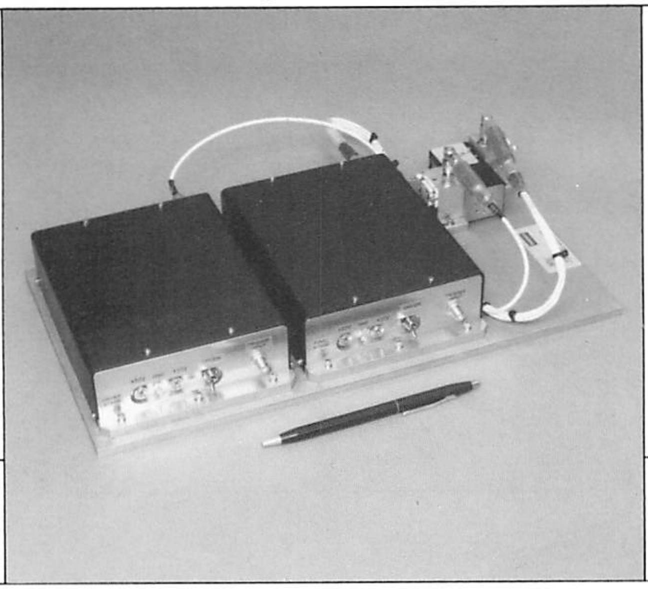
RF Output Spectrum of Model No. 47186H-1425



Center frequency is 94 GHz; horizontal scale is 20 MHz/div; vertical scale is 10 dB/div. PRF is 50 KHz and pulse width is 100 nanoseconds.

2

Short Pulsed Injection-Locked Amplifiers



Hughes 4718xH series of Short Pulsed Injection-Locked IMPATT Amplifiers is available in single stage or dual stage configurations. 5, 12, 20 or 30-Watt output power versions are available for both the single stage and dual stage configurations at 34-36 GHz ar 92-96 GHz.

The single stage configuration consists of a temperature stabilized waveguide cavity IMPATT oscillator with integral circulator and input and output isolators, thermal impedance shim, pulse modulator and matched pulse cable assembly. These amplifiers can be specified for pulse widths between 50 and 100 nanoseconds with a PRF between 10 and 100 KHz. Injection locking bandwidths of 400 MHz in W-band and 150 MHz in Ka-band are available. Amplifiers will require a drive level as listed below in specification section. Without drive, the amplifier will oscillate

PULSE POWER OUTPUT AVAILABLE ①

① For other power outputs available see specifications

SPECIFICATIONS: ②

	SINGLE STAGE	DUAL STAGE
PULSED POWER OUTPUTS AVAILABLE (W min)	5, 12, 20, 30	5, 12, 20, 30
PULSE WIDTH (ns min/max) ③	50/100	50/100
PRF (KHz min/max) ③	10/100	10/100
TRIGGER INPUT TO RF OUTPUT DELAY (ns typ)	300	300
TRIGGER WIDTH INPUT (ns)	100-1000	100-1000
TRIGGER INPUT (V TTL)	5.0	5.0
INJECTION LOCKING BANDWIDTH (MHz max)		
Ka-band (34–36 GHz)	150	150
W-band (92–96 GHz)	400	400
INJECTION DRIVE LEVEL FOR		
5.0 W PEAK (dBm min/max)	20/30	2/12
12.0 W PEAK (dBm min/max)	23/33	2/12
20 W PEAK (dBm min/max)	26/36	4/14
30 W PEAK (dBm min/max)		6/16
DC POWER REQUIREMENTS		
MODULATOR (V/mA max)	80/220 30/250	80/440 30/500
TEMPERATURE CONTROLLER (V/A max)	28/1.5	28/3.0

② Consult factory for requirements not covered by these specifications.
③ Center frequency, pulse width, and PRF must be specified at time of order.

HOW TO ORDER (Specify center frequency, pulse width, and PRF at time of order)

Model Number 4718xH–xxxx

FREQUENCY BAND
- **1**: Ka
- **6**: W

FLANGE TYPE
- **1**: Round
- **2**: Square (Available in Ka-band only)

NUMBER OF STAGES
- **1**: Single Stage
- **2**: Dual Stage

POWER OUTPUT
- **51**: 5 Watts Peak
- **22**: 12 Watts Peak
- **30**: 20 Watts peak
- **40**: 30 Watts peak

EXAMPLE: To order a 94 GHz, 5-Watt dual stage pulsed injection-locked amplifier with a 70 ns pulse width and 100 KHz PRF, specify a 47186H-1251, 94 GHz center frequency, 70 ns pulse width, and a 100 KHz PRF.

and have a chirp frequency output. RF lock-up occurs within 1 nanosecond of drive signal application.

The dual stage amplifier consists of two temperature stabilized waveguide cavity IMPATT oscillators with integral circulators and isolators, thermal impedance shims, two pulse modulators and matching low impedance pulse cable assemblies. These amplifiers are designed to operate from the output of an upconverter at drive levels of +2 dBm to +6dBm minimum to full output power specified. Pulse width and PRF are as stated for single stage operation. Injection locking bandwidths of 400 MHz in W-band and 150 MHz in Ka-band are available.

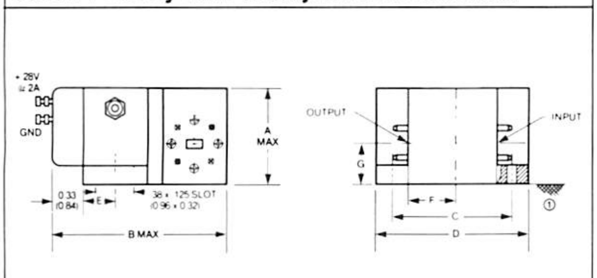
In general, the phase noise characteristics of the output signal are the same as the driver's, but the finite rise and fall time of the modulator bias pulse and the temperature change of the diode during the pulse introduce phase noise. Phase noise on the leading and trailing edge of the pulse can be eliminated by use of a PIN switch. The phase noise during the pulse can be minimized by special tuning for specific applications. See picture showing the frequency meter dip for a 94 GHz pulse source.

Hughes also offers fully coherent front ends including monopulse receivers and antennas, up-converters and phase-locked drivers. Please see our measurement systems and subsystems section of this catalog or consult the factory for information.

30 Watts

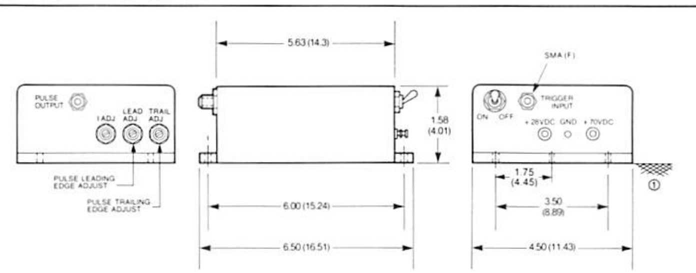
OUTLINE AND MOUNTING DRAWINGS

IMPATT cavity with multijunction circulator



① Heat sink this surface
Note: Dimensions are in inches (cm)

Bias Pulse Modulator



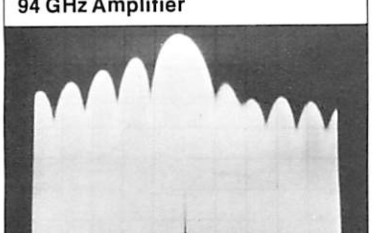
① Heat sink this surface
Note: Dimensions are in inches (cm)

DIMENSIONS, WAVEGUIDE SIZES AND FLANGES		FREQUENCY BAND (GHz) Ka (34–36)	W (92–96)
DIMENSIONS (inches (cm))	A	1.64 (4.17)	1.30 (3.30)
	B	2.75 (6.99)	2.30 (5.84)
	C	1.56 (3.96)	1.25 (3.18)
	D	1.88 (4.78)	1.56 (3.96)
	E	0.50 (1.27)	0.38 (0.95)
	F	0.75 (1.91)	0.55 (1.40)
	G	0.88 (2.24)	0.66 (1.68)
WAVEGUIDE SIZE ①		WR-28	WR-10
WAVEGUIDE FLANGE ①		UG-381/U ③	UG-387/U
		UG-599/U ②	mod

① Refer to page 157 for specifications and MIL specifications cross reference ② Square flange ③ Round flange

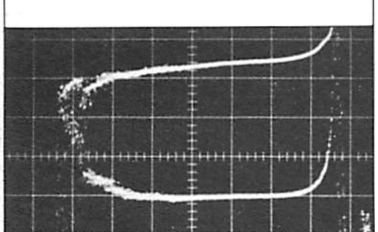
PERFORMANCE DATA

Spectrum of Amplified Signal for Dual Stage 5-Watt 94 GHz Amplifier



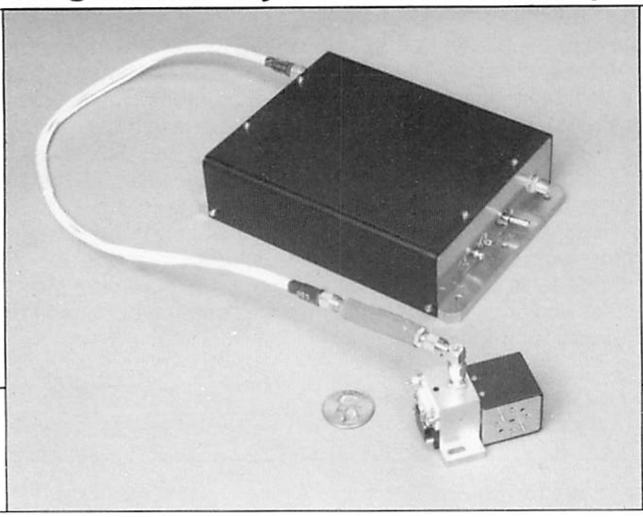
HORIZONTAL: 10 MHz / DIV.
BANDWIDTH: 300 KHz
VERTICAL: 10 dB / DIV.
PRF: 100 KHz
PULSEWIDTH: 100 ns

Frequency Meter Dip of 94 GHz Amplified Pulse



HORIZONTAL: 10 ns / DIV.
FREQUENCY METER SETTINGS
UPPER TRACE . . .94.1 GHz
LOWER TRACE . .94.0 GHz

Long Pulsed Injection-Locked Amplifiers



Hughes 4718xH series of Long Pulsed Injection-Locked Amplifiers consists of a temperature stabilized waveguide cavity IMPATT oscillator with integral circulator and input and output isolators, thermal impedance shim, regulator and a cable assembly. They are available in five different waveguide bands with the power output and locking bandwidth dependent on the frequency.

The highest power outputs are available in frequency windows of five waveguide bands with 1 Watt available in the 34-36 GHz region of Ka-band, 1 Watt available in the 42-46 GHz region of Q-band, 500 mW available in the 54-62 GHz region of V-band, 300 mW available in the 92-96 GHz region of W-band, and 50 mW available in the 135-145 GHz

POWER OUTPUT AVAILABLE ①

① See "HOW TO ORDER" for other frequencies.

SPECIFICATIONS ②

	Narrow Band	Broad Band
POWER OUTPUTS AVAILABLE	See "HOW TO ORDER"	
PULSE WIDTH (μ SEC, MIN/MAX)	0.5/1000	0.5/1000
DUTY CYCLE (% MAX)	50	50
INJECTION LOCKING BANDWIDTHS (MHz min)		
Ka-band	150	400
Q-band	150	400
V-band	200	500
W-band	300	750
D-band	300	750
MINIMUM INJECTION DRIVE LEVEL (dBm)		
Ka-band	+3	+10
Q-band	+3	+10
V-band	+3	+8
W-band	+3	+5
D-band	+3	+5
MAXIMUM INJECTION DRIVE LEVEL (dBm)		
Ka-band	+10	+17
Q-band	+10	+17
V-band	+10	+15
W-band	+10	+12
D-band	+10	+10

FREQUENCY STABILITY AS FREE RUNNING OSCILLATOR (% typical)	±0.0025③
AMPLITUDE STABILITY (dB typical)	±0.025③
TRIGGER WIDTH INPUT (ns)	100–1000
TRIGGER INPUT (V TTL)	5.0
DC POWER REQUIREMENTS	
MODULATOR (V/mA max)	50/800
MODULATOR (V/mA max)	8/100
TEMPERATURE CONTROLLER (V/A max)	28/2.0
MODULATOR TRIGGER (V TTL)	5.0
OPERATING BASEPLATE TEMPERATURE RANGE (°C min/max)	0/50

② Power output, locking bandwidth, and injection drive level are all mutally interdependent. Consult factory for requirements not covered by these specifications.
③ Temperature controller and thermal impedance shims will maintain cavity temperature within ± 2.5°C when base plate is varied between 0°C and 50°C.

HOW TO ORDER (Specify center frequency, pulse width, and duty cycle at time of order)

Model Number 4718xH–xxxx

Frequency Band
- **1**: Ka
- **2**: Q
- **4**: V
- **6**: W (75–100 GHz only)
- **8**: D (135-145 GHz only)

Flange Type
- **1**: Round
- **2**: Square (Available in Ka-band only)

Bandwidth Option
- **3**: Narrow band
- **4**: Broad band

Power Output
- **02**: 20 mW (Available in 135-145 GHz only)
- **05**: 50 mW (Available 75–100 GHz and 135-145 GHz only)
- **10**: 100 mW (Available 50–96 GHz only)
- **20**: 200 mW (Available 26.5–75 GHz only)
- **30**: 300 mW (Available 26.5–50 GHz and in W-band 92–96 GHz only)
- **50**: 500 mW (Available 54–62 GHz only)
- **11**: 1.0 Watt (Available in Ka-band 34–36 GHz and in Q-band 42–46 GHz only)

EXAMPLE: To order a W-band long pulse injection-locked amplifier, 300 mW power output, locking bandwidth 300 MHz, center frequency of 94 GHz, pulse width 100μsec., duty cycle 10%, specify 47186H–1330, center frequency = 94 GHz, pulse width = 100μsec., duty cycle = 10%.

region of D-band. At frequencies other than the above, power outputs are available from 300 mW at 26.5 GHz to 50 mW at 100 GHz.

The temperature controller and shim enable the amplifier to maintain its locking bandwidth over a baseplate operating temperature range of 0°C to 50°C.

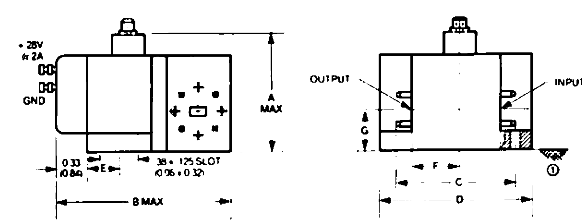
In general, the FM noise of the amplifiers is equal to that of the injected signal. The AM noise characteristic is approximately the same as a free running IMPATT oscillator.

Specifications for specific applications involving wider locking bandwidths and higher power outputs can be met with extra engineering effort.

FREQUENCY BAND (GHz)				
Ka (34–36)	Q (42–46)	V (54–62)	W (92–96)	D (135-145)
1.0 Watt	**1.0 Watt**	**500 mW**	**300 mW**	**50 mW**

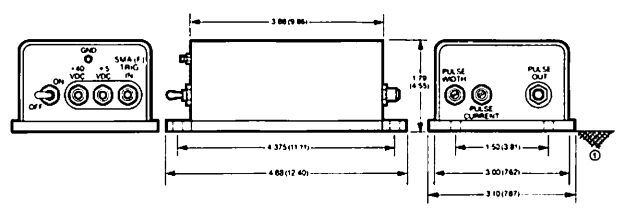
OUTLINE AND MOUNTING DRAWINGS

IMPATT oscillator with integral circulator and isolators



① Heat sink this surface
Note: Dimensions are in inches (cm)

Bias Pulse Modulator (Long Pulse)



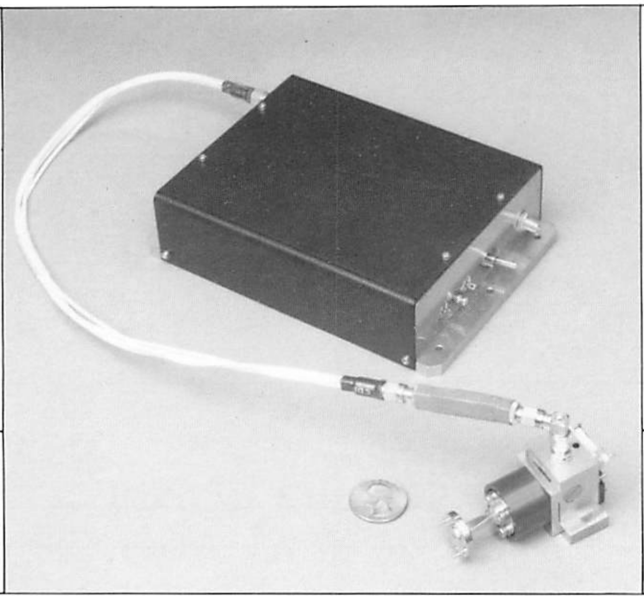
① Heat sink this surface
Note: Dimensions are in inches (cm)

DIMENSIONS WAVEGUIDE SIZES AND FLANGES		FREQUENCY BAND (GHz)				
		Ka (26.5-40)	Q (33-50)	V (50-75)	W (75-110)	D (135-145)
DIMENSIONS inches (cm)	A	2.04 (5.18)	2.04 (5.18)	1.70 (4.32)	1.70 (4.32)	1.70 (4.32)
	B	2.75 (6.99)	2.75 (6.99)	2.30 (5.84)	2.30 (5.84)	2.30 (5.84)
	C	1.56 (3.96)	1.56 (3.96)	1.25 (3.18)	1.25 (3.18)	1.25 (3.18)
	D	1.88 (4.78)	1.88 (4.78)	1.56 (3.96)	1.56 (3.96)	1.56 (3.96)
	E	0.50 (1.27)	0.50 (1.27)	0.38 (0.95)	0.38 (0.95)	0.38 (0.95)
	F	0.75 (1.91)	0.75 (1.91)	0.55 (1.40)	0.55 (1.40)	0.55 (1.40)
	G	0.88 (2.24)	0.88 (2.24)	0.66 (1.68)	0.66 (1.68)	0.66 (1.68)
WAVEGUIDE SIZE①		WR-28	WR-22	WR-15	WR-10	WR- 6
WAVEGUIDE FLANGE①		UG-381/U② / UG-599/U③	UG-383/U	UG-385	UG-387/U mod	UG-387/U mod

① Refer to page 157 for specifications and MIL specification cross reference ② Round flange ③ Square flange

2

Pulsed IMPATT Power Sources



Hughes 4715xH series of Short and Long pulsed IMPATT Power Sources consist of a temperature stabilized waveguide cavity IMPATT oscillator with integral isolator, matched pulse modulator, and a low impedance interconnecting coaxial cable.

The short pulse sources are available in frequency windows in Ka-, W-, and D-bands with power outputs available up to 20 Watts in the 34-36 GHz window in Ka-band and the 92-96 GHz window in W-band, or 1 Watt in the 137-143 GHz window in D-band. These sources are available as low chirp units (less than 100 MHz of frequency variation during pulse) or as high chirp units with the frequency change during the pulse being between 100 MHz and 500 MHz. Pulse widths between 50 and 100 ns can be specified with PRFs

PULSED POWER OUTPUT AVAILABLE①

① See "HOW TO ORDER" for other frequencies.

Short Pulse

Long Pulse

SPECIFICATIONS②

SHORT PULSE TYPE

- POWER OUTPUTS AVAILABLE .... See "HOW TO ORDER"
- PULSE WIDTH③ (ns min/max) 50/100
- PRF③ (KHz min/max) 10/100
- CHIRP BANDWIDTH④
  - LOW CHIRP UNIT (MHz max) 100
  - HIGH CHIRP UNIT (MHz min/max) 100/500
- TRIGGER INPUT TO RF OUTPUT DELAY (ns typ) 300
- TRIGGER WIDTH INPUT (ns) 100-1000
- TRIGGER INPUT (V TTL) 5.0
- DC POWER REQUIREMENTS
  - MODULATOR (V/mA max) 80/220
    30/250
  - TEMPERATURE CONTROLLER (V/A max) 28/1.5
- OPERATING BASEPLATE TEMPERATURE RANGE
  (°C min/max) 0/50

LONG PULSE TYPE

- POWER OUTPUTS AVAILABLE .... See "HOW TO ORDER"
- PULSE WIDTH (μ sec, min/max) 0.5/1000
- DUTY CYCLE (% max) 50
- CHIRP BANDWIDTH (MHz max) 500④
- TRIGGER WIDTH INPUT (ns) 100-1000
- TRIGGER INPUT (V TTL) 5.0
- DC POWER REQUIREMENTS
  - MODULATOR (V/mA max) 50/800
  - MODULATOR (V/mA max) 8/100
  - TEMPERATURE CONTROLLER (V/A max) 28/2.0
- OPERATING BASEPLATE TEMPERATURE RANGE
  (°C min/max) 0/50

② Consult factory for requirements not covered by these specifications.
③ Operating frequency (0.5% accuracy), pulse width, and PRF to be specified at time of order.
④ 90% of specified power level is contained within chirp bandwidth. Linear and other special chirp bandwidths are available on request.

HOW TO ORDER (Specify operating frequency, pulse width, and PRF at time of order)

Model Number 4715xH–xxxx

FREQUENCY BAND
- **1**:Ka (26.5-40 GHz)
- **2**:Q (33–50 GHz, Long Pulse units only)
- **3**:U (40–60 GHz, Long Pulse units only)
- **4**:V (50–75 GHz, Long Pulse units only)
- **5**:E (60–90 GHz, Long Pulse units only)
- **6**:W (75–110 GHz)
- **7**:F (90–140 GHz, Long Pulse units only)
- **8**:D (110–170 GHz)

FLANGE
- **1**: Round
- **2**: Square (Available in Ka–band only)
- **3**: Pin Contact (Available in F– and D–bands only)

TYPE
- **1**: Short Pulse Low Chirp
- **2**: Short Pulse High Chirp
- **3**: Long Pulse

EXAMPLE: To order a 500 mW 10 μsec. pulse width source at 60 GHz with 100 KHz PRF. Specify a 47154H-1350, operating frequency = 60 GHz, Pulse width = 10 μsec. and PRF = 100 KHz.

POWER OUTPUTS

Long Pulse
- **01**: 10 mW (Available 110-150 GHz only)
- **02**: 20 mW (Available 137-143 GHz D-band only)
- **05**: 50 mW (Available 96-110 GHz only)
- **10**: 100 mW (Available 75-96 GHz only)
- **20**: 200 mW (Available 50-75 GHz only)
- **30**: 300 mW (Available 26.5-50 GHz and 92-96 GHz W-band only)
- **50**: 500 mW (Available 54-62 GHz V-band only)
- **11**: 1 Watt (Available 34-36 Ka-band & 42-46 GHz Q-band only)

Short Pulse
- **11**: 1 Watt peak (Available in D-band, 137-143 GHz only)
- **51**: 5 Watt peak (Available in Ka-band, 34-36 GHz, or in W-band, 92-96 GHz only)
- **22**:12 Watt peak (Available in Ka-band, 34-36 GHz, or in W-band, 92-96 GHz only)
- **25**: 15 Watt peak (Available in Ka-band, 34-36 GHz, or in W-band, 92-96 GHz only)
- **30**: 20 Watt peak (Available in Ka-band, 34-36 GHz, or in W-band, 92-96 GHz only)

of 10 to 100 KHz. A pulse trigger must be supplied at the trigger input SMA connector.

The long pulse units are available in eight different waveguide bands with the power output dependent on the frequency. Highest power outputs are available in frequency windows of five waveguide bands with 1 Watt available in the 34-36 GHz region of Ka-band, 1 Watt available in the 42-46 GHz region of Q-band, 500 mW available in the 54-62 GHz region of V-band, 300 mW available in the 92-96 GHz region of W-band, and 20 mW available in the 137-143 GHz region of D-band. At frequencies other than the above, power outputs are available from 300 mW at 26.5 GHz to 10 mW at 150 GHz in any of eight waveguide bands. Pulse widths between 0.5μsec and 1 ms can be specified with duty cycles of up to 50 percent. Provision can be made for CW operation when specified by the user.

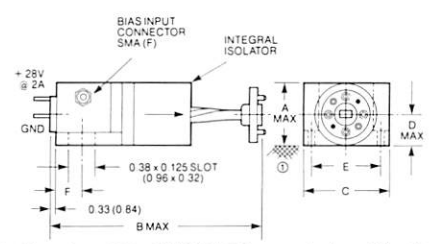
The oscillator cavity is supplied with a thermal impedance shim which allows the temperature controller to keep the cavity temperature stable. Mounting of the cavity and modulator can thus be made to a base plate whose temperature can vary between 0°C to 50°C without performance degradation.

In general, most frequency shift occurs at the leading edge of the pulse. Advantage can be taken of the natural chirp of the oscillator due to temperature for clutter rejection. Linear and other special chirp bandwidths are available on request.

FREQUENCY BAND (GHz)				
Ka 34-36	Q 42-46	V 54-62	W 92-96	D 137-143
20 W	**—**	**—**	**20 W**	**1.0 W**
1.0 W	**1.0 W**	**0.5 W**	**0.3 W**	**0.02 W**

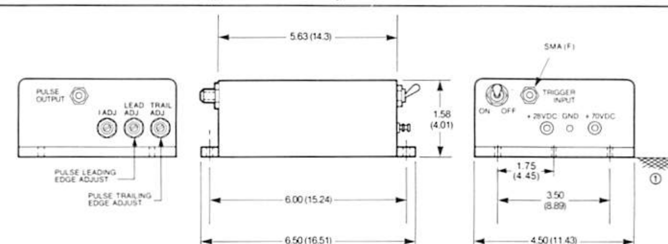
OUTLINE AND MOUNTING DRAWINGS

Short Pulse Oscillator ②



① Heat sink this surface ② See CW IMPATT Sources for Long Pulse Oscilaltor O&M
Note: Dimensions are in inches (cm)

Bias Pulse Modulator (Short Pulse)

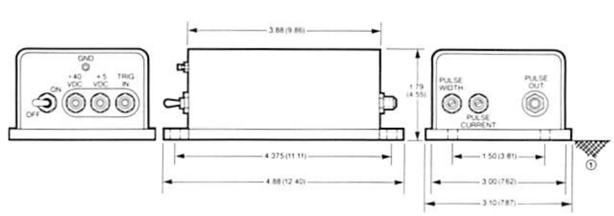


① Heat sink this surface
Note: Dimensions are in inches (cm) Weight is 1.4 lbs. (650 grams) typ.

DIMENSIONS, WAVEGUIDE SIZES AND FLANGES		FREQUENCY BAND (GHz)		
		Ka (34-36)	W (92-96)	D (137-143)
DIMENSIONS (inches (cm))	A	1.64 (4.17)	1.30 (3.30)	1.30 (3.30)
	B	3.85 (9.78)	2.04 (5.18)	2.04 (5.18)
	C	1.88 (4.78)	1.56 (3.96)	1.56 (3.96)
	D	0.88 (2.24)	0.66 (1.68)	0.66 (1.68)
	E	1.56 (3.96)	1.25 (3.18)	1.25 (3.18)
	F	0.50 (1.27)	0.38 (0.97)	0.38 (0.97)
WAVEGUIDE SIZE ①		WR-28	WR-10	WR-6
WAVEGUIDE FLANGE ①		UG-381/U ② UG-599/U ③	UG-387/U mod	UG-387/U mod pin contact
WEIGHT (lbs (grams) typ)		1.1 (495)	0.5 (220)	0.5 (220)

① Refer to page 157 for specifications and MIL specification cross reference.
② Round flange ③ Square flange

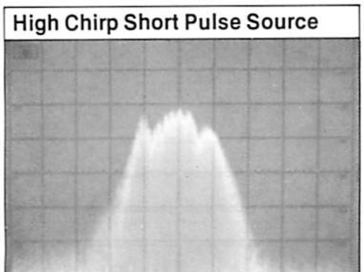
Bias Pulse Modulator (Long Pulse)



① Heat sink this surface
Note: Dimensions are in inches (cm)
Weight is 1 lb. (470 grams) typ.

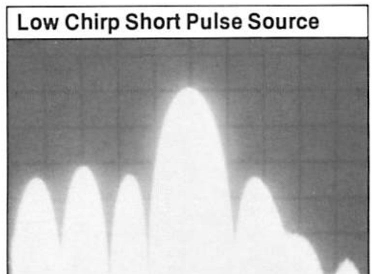
PERFORMANCE DATA

High Chirp Short Pulse Source



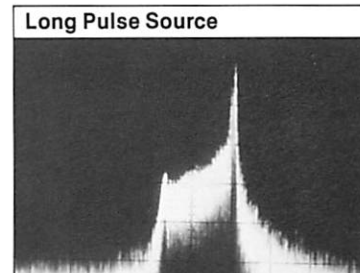
Spectral Characteristic of a 3–Watt 94 GHz source with 100 nanosecond pulse width 50 KHz PRF.
Horizontal Scale: 100 MHz / Div.
Vertical Scale: 5dB / Div.

Low Chirp Short Pulse Source



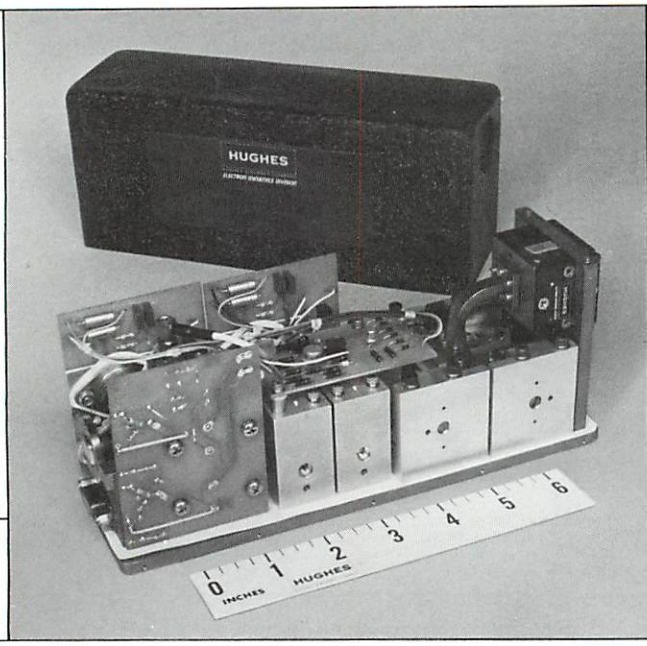
Spectral Characteristic of a 5-Watt 94 GHz source with 50 n sec. pulse at 50 KHz PRF.
Horizontal scale: 20 MHz / Div.
Vertical scale: 5 dB / Div.

Long Pulse Source



Spectral Characteristic of a 200 mW 94 GHz source with 10 μ sec. pulse width and 33% duty cycle.
Horizontal scale: 100 MHz / Div.
Vertical scale: 10 dB / Div.

Multi-Stage High Power IMPATT Solid State CW Amplifiers



Hughes multi-stage high power solid state CW amplifiers are available at 30, 44, and 60 GHz. They operate in the injection locked or the stable amplifier modes. Bandwidths are available up to 2 GHz in V-band, 2 GHz in Q-band, and 1.5 GHz in Ka-band.

By using highly reliable IMPATT Diodes fabricated at Hughes and employing combining circuits designed at Hughes, power levels of up to 25 watts in Ka- and Q-bands and up to 10 watts in V-band are available. Input levels of only 13 dBm are required to lock the injection locked units and drive the stable amplifier units.

Separate voltage regulators for each diode are integrated into each amplifier. The amplifiers are designed to operate over baseplate temperatures of 0° to 50°C. Integral fans or liquid cooled versions can be implemented for use in systems requiring more severe operating environments. Each amplifier is mounted in a rugged package for outdoor operation.

FEATURES:

SPECIFICATIONS

Frequency Band (GHz)	Ka (29-31)	Q (43.5-45.5)	V (58-62)
Bandwidth (GHz min)	1.5	2	2
CW Output Power (Watts min)	5, 10, 15 20, 25	5, 10, 15 20, 25	5, 10
RF Input Requirement (dBm)	+13	+13	+13
Output Power Flatness (dB max)	±0.5	±0.5	±0.5
Input VSWR (max)	1.3:1	1.3:1	1.3:1
Load VSWR (max)	1.5:1	1.5:1	1.5:1
DC Input (V typ)	48	48	40
Temperature Range (°C Baseplate)	0-50	0-50	0-50
Waveguide Size	WR-28	WR-22	WR-15
Flange	UG-381/U UG-559/U	UG-383/U	UG-385/U

① Square Flange ② Round Flange

HOW TO ORDER

Model Number 4719xH-xxxx

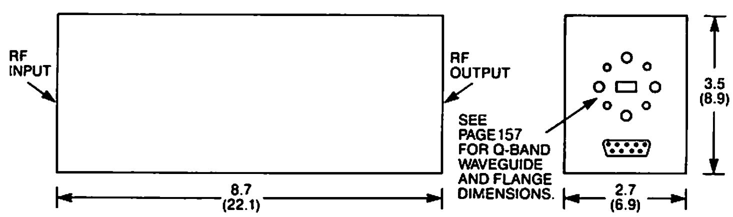
Frequency Band	**1**: Ka **2**: Q **4**: V
Flange Type	**1**: Round **2**: Square (available in Ka-band only)
Type	**5**: Injection Locked 7 ~~**6**~~: Stable Mode
Power Output	**05**: 5 Watts **10**: 10 Watts **15**: 15 Watts (Ka- & Q-bands only) **20**: 20 Watts (Ka- & Q-bands only) **25**: 25 Watts (Ka- & Q-bands only)

These multi-stage amplifiers are ideal for EHF communications systems where low prime power, high reliability, and an ability to perform in a tough ground terminal environment are important. The V-band units are ideal for consideration for use in space systems. Special space qualification programs are available from Hughes. BITE circuitry, power detection circuits, and integral IF upconverters are all available as modifications to these amplifiers. Other frequency bandwidths and gain levels are also applicable. Consult your Hughes representative for these special details.

Up to 25 watts CW at 44 GHz and 10 watts CW at 60 GHz.

OUTLINE AND MOUNTING DRAWING

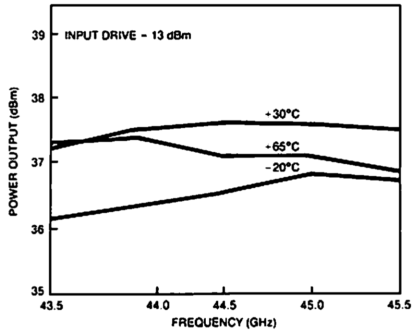
Model #47192H-1505



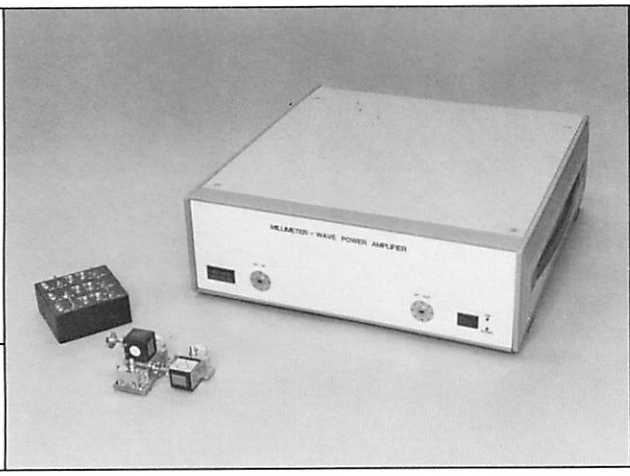
Dimensions in inches (cm.)

TYPICAL TEST DATA

Power output vs. Temperature and Frequency of Model No. 47192H-1505



High Power Instrumentation and OEM Broadband CW Injection-Locked Amplifiers



Hughes series of High Power Broadband Injection-Locked Amplifiers are available either as instrumentation amplifiers complete with power supply and cooling for laboratory use, or for OEM (Original Equipment Manufacturer) use as temperature stabilized waveguide cavities with integral multijunction circulators providing input and output isolation, thermal impedance shims, regulators, and cable assemblies. Instrumentation amplifiers covering 2 GHz bandwidths are available in Q-, V-, and W-bands, and OEM types are available in Ka-, Q-, V-, and W-bands at popular window frequency ranges.

POWER OUTPUT AVAILABLE

SPECIFICATIONS

	Frequency Range (GHz)			
	Ka 34-36	Q 42-46	V 58-62	W 93-95
INSTRUMENTATION UNIT				
Power Output (Watts min)	—	1	1	0.3
Injection Locking 1dB Bandwidth (GHz min)	—	2	2	2
Minimum Injection Drive Level (dBm) ①	—	+9	+9	+5
Flatness (dB typ)	—	±1	±1	±1
Frequency Stability as Free Running Oscillator (% typ)	—	±0.0025	±0.0025	±0.0025
Amplitude Stability (dB typ)	—	±0.025	±0.025	±0.025
AC Power Input	100, 110, 220, or 235 VAC 50/60 Hz			
Operating Temperature (°C Amb)	0 to +35			
TWO STAGE OEM UNIT				
Power Output (Watts min)	1	1	1	0.3
Injection Locking 1dB Bandwidth (GHz min)	1	2	2	2
Minimum Injection Drive Level (mW min) ①	50	50	50	15
Maximum Injection Drive Level (mW max)	200	200	200	50
Flatness (dB type)	±1	±1	±1	±1
Frequency Stability as Free Running Oscillator ② (% typ)	±0.0025	±0.0025	±0.0025	±0.0025
Amplitude Stability (dB typ)	±0.025	±0.025	±0.025	±0.025
DC Power Input				
For Regulators (V/A max)	60/1.0	60/1.0	60/1.0	60/1.0
For Temperature Controllers (V/A max)	28/4.0	28/4.0	28/4.0	28/4.0
Operating Baseplate Temperature (°C min/max)	0/50	0/50	0/50	0/50
SINGLE STAGE OEM UNIT				
Power Output (Watts min)	1	1	1	0.3
Injection Locking 1dB Bandwidth (GHz min)	1	2	2	2
Minimum Injection Drive Level (mW min) ①	250	250	250	75
Flatness (dB type)	±1	±1	±1	±1
Frequency Stability as Free Running Oscillator ② (% typ)	±0.0025	±0.0025	±0.0025	±0.0025
Amplitude Stability (dB typ)	±0.025	±0.025	±0.025	±0.025
DC Power Input				
For Regulators (V/A max)	60/0.5	60/0.5	60/0.5	60/0.5
For Temperature Controllers (V/A max)	28/2	28/2	28/2	28/2
Operating Baseplate Temperature (°C min/max)	0/50	0/50	0/50	0/50

① Gain can be increased at the expense of bandwidth. See Performance Curve.
② Temperature Controller and Thermal Impedence shims will maintain cavity temperature within ±2.5°C when baseplate is varied between 0°C and 50°C.

HOW TO ORDER (Specify center frequency at time of order)

Model Number 4719xH-xxxx

Frequency Band **1**: Ka
2: Q
4: V
6: W

Flange Type **1**: Round
2: Square (Available in Ka-band only)

Type **2**: Single Stage High Power Broadband Unit
3: Two Stage High Power Broadband Unit
4: Instrumentation Unit (Available in Q-, V-, and W-bands only)

Power Output **30**: 300 mW (Available in W-band only)
11: 1 Watt (Available in Ka-, Q-, and V-bands only)

EXAMPLE: To order a 1-watt, 21 dB gain 43 to 45 GHz instrumentation amplifier, specify a 47192H-1411, center frequency equals 44 GHz.

The instrumentation amplifiers are multistage 2 GHz bandwidth units providing 1 Watt output at 44 and 60 GHz with an injection locking signal of +9 dBm and 300 milli watts output at 94 GHz with an injection locking signal of +5 dBm. The OEM types are available as single stage or two stage units delivering 1 Watt output at 35, 44, and 60 GHz and 300 mW at 94 GHz. Drive levels required vary from 15 mW for a two stage unit at W-band, to 250 mW for a single stage unit at Ka-, Q-, and V-bands.

The temperature controller and shim enable the OEM types to maintain locking bandwidth over a baseplate operating temperature range of 0°C to 50°C.

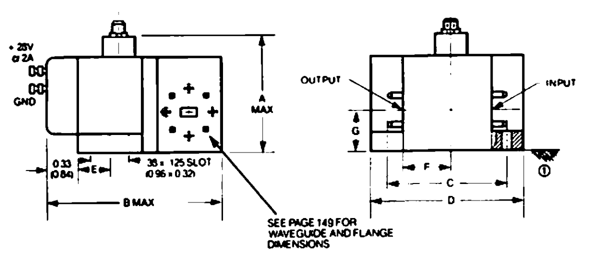
In general, the FM noise of the amplifiers is equal to that of the injected signal. The AM noise characteristic is approximately the same as a free running IMPATT oscillator.

Other frequency OEM type amplifiers are described on pages 58 and 59. Power output, locking bandwidth, and locking gain are all highly interdependent. Consult factory for available performance on specific requirements. Stabilized reflection type amplifiers are also available on special order for applications where injection-locked amplifiers cannot be used.

FREQUENCY BAND (GHz)			
Ka (34-36)	Q (42-46)	V (58-62)	W (93-95)
1 Watt	**1 Watt**	**1 Watt**	**300 mW**

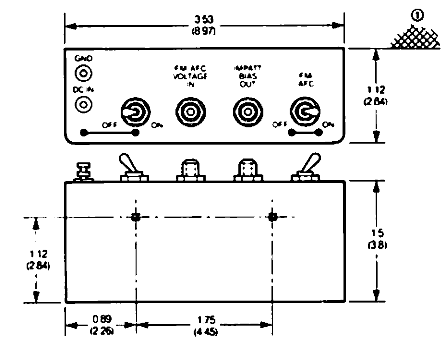
OUTLINE AND MOUNTING DRAWINGS

IMPATT cavity with multijunction circulator



① Heat sink this surface
Note: Dimensions are in inches (cm)

Regulator

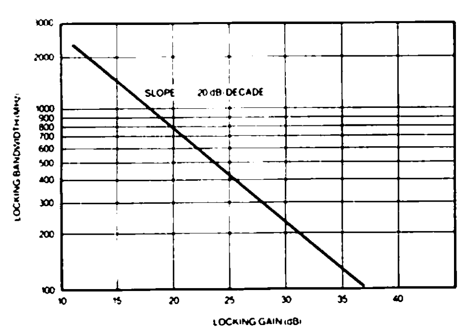


① Heat sink this surface
Note: Dimensions are in inches (cm)

DIMENSIONS WAVEGUIDE SIZES AND FLANGES		FREQUENCY BAND (GHz) Ka (26.5-40)	Q (33-50)	V (50-75)	W (75-110)
DIMENSIONS (inches (cm))	A	2.04 (5.18)	2.04 (5.18)	1.70 (4.32)	1.70 (4.32)
	B	2.26 (5.74)	2.26 (5.74)	1.70 (4.32)	1.70 (4.32)
	C	1.56 (3.96)	1.56 (3.96)	1.25 (3.18)	1.25 (3.18)
	D	1.88 (4.78)	1.88 (4.78)	1.56 (3.96)	1.56 (3.96)
	E	0.50 (1.27)	0.50 (1.27)	0.38 (0.95)	0.38 (0.95)
	F	0.75 (1.91)	0.75 (1.91)	0.55 (1.40)	0.55 (1.40)
	G	0.88 (2.24)	0.88 (2.24)	0.66 (1.68)	0.66 (1.68)
WAVEGUIDE SIZE ①		WR-28	WR-22	WR-15	WR-10
WAVEGUIDE FLANGE ①		UG-381/U ③ UG-599/U ②	UG-383/U	UG-385/U	UG-387/U mod
Instrumentation Amplifier Size (inches (cm))		16 x 15 x 4.9 (41 x 38 x 12.5)			

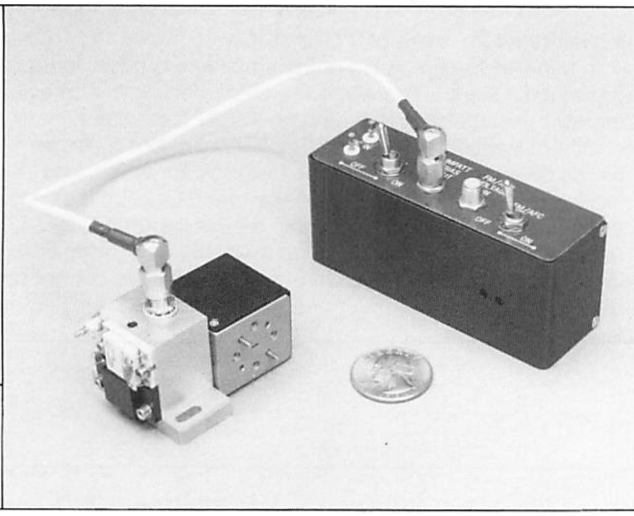
① Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

PERFORMANCE CURVE



Typical Locking Characteristics for W-Band Amplifier.

CW Injection-Locked Amplifiers



The Hughes series of CW Injection-Locked Amplifiers described below consists of a temperature stabilized waveguide cavity IMPATT oscillator with an integral Hughes multijunction circulator (including input and output isolation) thermal impedance shim, regulator, and a cable assembly. They are available at any frequency between 30 and 100 GHz in four different waveguide bands.

In general, they are for use at those frequencies at which the Hughes High Power Broadband CW Injection-Locked Amplifiers described on pages 56 and 57 are not available, or when a 2 GHz bandwidth is not necessary.

The temperature controller and shim enable the amplifier to maintain its locking bandwidth over a baseplate operating

POWER OUTPUT AVAILABLE

SPECIFICATIONS ①

STANDARD UNIT

POWER OUTPUTS AVAILABLE .... See "HOW TO ORDER"

INJECTION LOCKING BANDWIDTHS (MHz min)

Ka band	200
Q-band	200
V-band	200
W-band	300

MINIMUM INJECTION DRIVE LEVEL (dBm min) .... +2

MAXIMUM INJECTION DRIVE LEVEL (dB below output min) .. 12

FREQUENCY STABILITY AS FREE RUNNING OSCILLATOR (% typical) .... ±0.025 ②

AMPLITUDE STABILITY (dB typical) .... ±0.025 ②

DC POWER REQUIREMENTS

FOR REGULATOR (V/mA typical) 60/500

FOR TEMPERATURE CONTROLLER (V/A max) 28/1.5

OPERATING BASEPLATE TEMPERATURE (°C min/max) 0/50

① Power output, locking bandwidth, and injection drive level are all mutually interdependent. Consult factory for requirements not covered by these specifications.

② Temperature controller and thermal impedance shims will maintain cavity temperature within ± 2.5°C when base plate is varied between 0°C and 50°C.

HOW TO ORDER (Specify center frequency at time of order.)

Model Number 4719xH-x6xx

Frequency Band	**1**: Ka **2**: Q **4**: V **6**: W (75-100 GHz only)
Flange Type	**1**: Round **2**: Square (Available in Ka-band only)
Power Output	**10**: 100 mW (Available 50-100GHz only) **30**: 300 mW (Available 75-100 GHz only) **40**: 400 mW (Available 50-75 GHz only) **60**: 600 mW (Available 30-50 GHz only)

EXAMPLE: To order a 250 mW 38 GHz CW injection-locked amplifier in Ka-band with a square flange, specify a 47191H-2625, center frequency-38 GHz.

temperature range of 0°C to 50°C. The FM noise of the amplifiers is equal to that of the injected signal. The AM noise characteristic is approximately the same as a free running IMPATT oscillator.

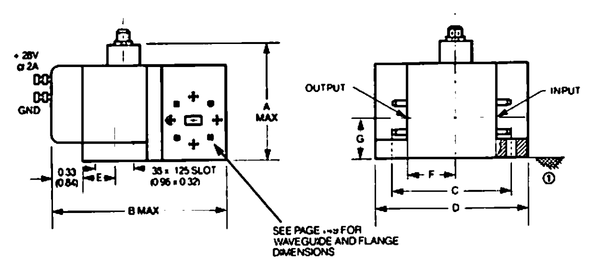
Specifications for specific applications involving wider locking bandwidths and higher power outputs can be met with extra engineering effort. Power output, locking bandwidth, and locking gain are all highly interdependent. Consult factory for available performance on specific requirements. Stabilized reflection type amplifiers are also available on special order for applications where injection-locked amplifiers cannot be used.

FREQUENCY RANGE (GHz)①		
30-50	50-75	75-100
600 mW	**400 mW**	**300 mW**

① See pages 54 – 57 for higher power broadband units at 34-36, 42-46, 58-62 and 93-95 GHz.

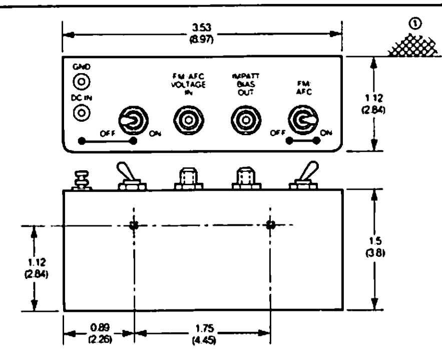
OUTLINE AND MOUNTING DRAWINGS

IMPATT cavity with multijunction circulator



① Heat sink this surface
Note: Dimensions are in inches (cm)

Regulator

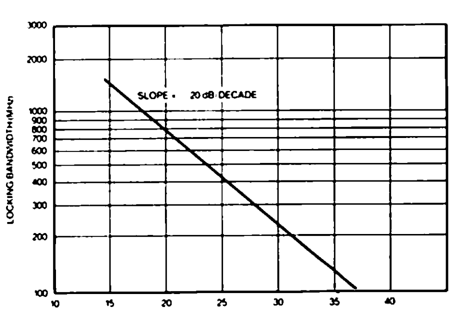


① Heat sink this surface
Note: Dimensions are in inches (cm)

DIMENSIONS WAVEGUIDE SIZES AND FLANGES		FREQUENCY BAND (GHZ)			
		Ka (26.5-40)	Q (33-50)	V (50-75)	W (75-110)
DIMENSIONS (inches (cm))	A	2.04 (5.18)	2.04 (5.18)	1.70 (4.32)	1.70 (4.32)
	B	2.26 (5.74)	2.26 (5.74)	2.00 (5.08)	2.00 (5.08)
	C	1.56 (3.96)	1.56 (3.96)	1.25 (3.18)	1.25 (3.18)
	D	1.88 (4.78)	1.88 (4.78)	1.56 (3.96)	1.56 (3.96)
	E	0.50 (1.27)	0.50 (1.27)	0.38 (0.95)	0.38 (0.95)
	F	0.75 (1.91)	0.75 (1.91)	0.55 (1.40)	0.55 (1.40)
	G	0.88 (2.24)	0.88 (2.24)	0.66 (1.68)	0.66 (1.68)
WAVEGUIDE SIZE①		WR-28	WR-22	WR-15	WR-10
WAVEGUIDE FLANGE①		UG-381/U③ UG-599/U②	UG383/U	UG-385	UG-387/U mod

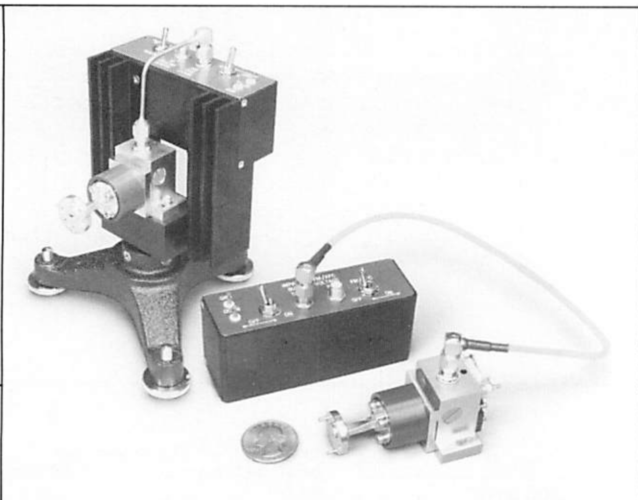
Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

PERFORMANCE CURVE



Typical Locking Characteristics for W-Band Amplifier.

CW IMPATT Sources



Hughes 4717xH series of CW IMPATT sources consist of a silicon IMPATT oscillator with an integral isolator and a regulator with connecting cable. They are supplied either with a temperature controller and thermal impedance shim for mounting to a baseplate or mounted directly on a heat sink and stand without the temperature controller and shim for laboratory testing. They are available in eight different waveguide bands with the power output dependent on the frequency band and the range within the band. Highest power outputs are available in five frequency ranges of five waveguide bands with 1 watt available in the 34-36 GHz region of Ka-band, 1 watt available in the 42-46 GHz region of

CW POWER OUTPUT AVAILABLE ①

① **See "HOW TO ORDER" for other frequencies.**

SPECIFICATIONS: ②

POWER OUTPUTS AVAILABLE . . . . See "HOW TO ORDER"
ELECTRICAL TUNING BANDWIDTH AT 3 dB PTS. (MHz min) . . . 100
RESIDUAL FM (MHz typ/max) 2.5/5
FREQUENCY STABILITY (%/°C typ) 0.001③
AMPLITUDE STABILITY (dB/°C typ) 0.01③
DC POWER REQUIREMENTS (V/mA typ) 60/500
TUNING VOLTAGE (V) 0-10
MODULATION RATE (KHz max) 20
DC TEMPERATURE CONTROLLER POWER (V/A max) 28/1.5④
OPERATING BASEPLATE TEMPERATURE (°C min/max) 0/50⑤

② Consult factory for requirements not covered by these specifications.
③ Units supplied with temperature controller and thermal impedance shims will maintain cavity temperature within a ±2.5°C spread when base plate is varied between 0°C and 50°C.
④ Temperature controllers are optional. Units without controllers are supplied with heat sink and stand for laboratory testing.
⑤ Applies to units supplied with a temperature controller and shim only. Specifications apply at 25°C baseplate for the units without temperature controllers.

HOW TO ORDER (Specify center frequency at time of order.)

CW IMPATT Source Model Number. 4717xH-xxxx

Frequency Band
- **1**:Ka
- **2**:Q
- **3**:U
- **4**:V
- **5**:E
- **6**:W
- **7**:F
- **8**:D

Flange Type
- **1**: Round
- **2**: Square (Available in Ka-band only)
- **3**: Pin Contact (Available in F- and D-bands only)

Temperature Controller Option
- **1**: Without controller and with heat sink and stand
- **2**: With controller and without heat sink and stand

Power Output
- **01:** 10mW (Available 96-150 GHz only)
- **02:** 20mW (Available 137-143 GHz only)
- **30:** 300mW (Available 26.5-75 GHz and in W-band 92-96 GHz only)
- **50:** 500mW (Available 26.5 to 50 GHz and in V-band 54-62 GHz only)
- **80:** 800mW (Available in V-band 54 to 62 GHz only)
- **11:** 1 watt (Available in Ka-band 34-36 GHz and in Q-band 42-46 GHz only)

EXAMPLE: To order a V-band CW IMPATT source, 500 mW power output, center frequency of 60 GHz, with temperature controller, specify 47174H-1250, center frequency = 60 GHz.

Q-band, 800 mW available in the 54-62 GHz region of V- band, 300 mW available in the 92-96 GHz region of W-band and 20 mW available in the 137-143 GHz region of D-band. At frequencies, other than the above, power outputs are available from 500 mW at 26.5 GHz to 10 mW at 150 GHz in any of eight waveguide bands.

The frequency of oscillation can be electrically tuned over 100 MHz by an external 0 to 10-volt signal applied to an input connector on the regulator. This tuning feature allows frequency stabilization or modulation. When purchased with the temperature controller option, the unit will meet all specifications over a baseplate temperature range of 0°C to 50°C.

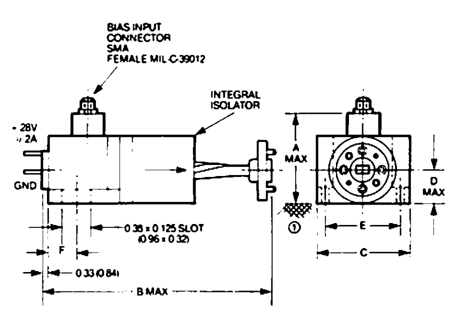
The Hughes silicon double-drift IMPATT diodes used in these sources have undergone many years of life testing and reliability studies. The predicted mean time to failure of a diode operating at a junction temperature of 250°C is approximately 100,000 hours. High power Gunn sources and phase-locked oscillators are also available and are described in the Gunn Diode Products portion of this catalog.

For applications where low phase noise is required, phase-locked IMPATT sources are available and are described on pages 64 and 65.

FREQUENCY BAND (GHz)				
Ka (34-36)	Q (42-46)	V (54-62)	W (92-96)	D (137-143)
1W	**1W**	**800 mW**	**300 mW**	**20 mW**

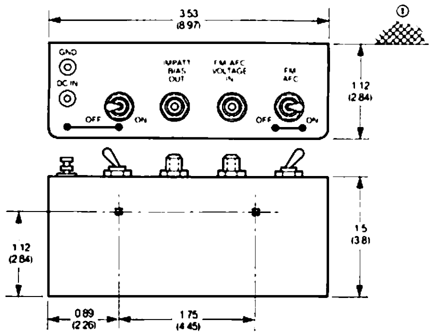
OUTLINE AND MOUNTING DRAWINGS

Oscillator



① Heat sink this surface
Note: Dimensions are in inches (cm)

Regulator



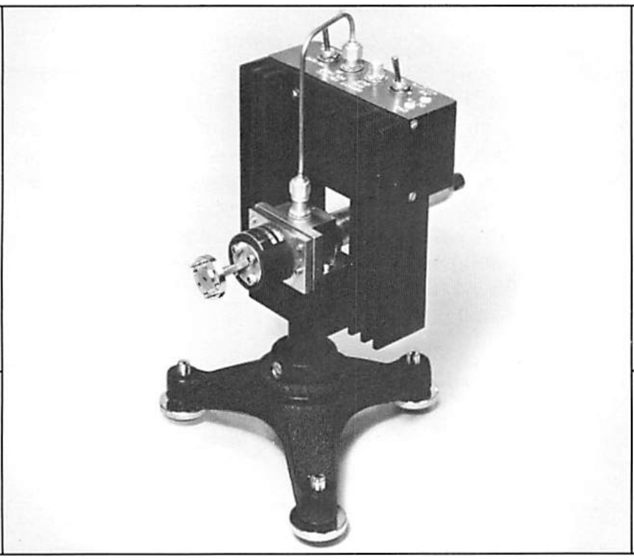
① Heat sink this surface
Note: Dimensions are in inches (cm)

DIMENSIONS, WAVEGUIDE SIZES AND FLANGES		FREQUENCY BAND (GHz)							
		Ka (26.5–40)	Q (33–50)	U (40–60)	V (50–75)	E (60–90)	W (75–110)	F (90–140)	D (110–140)
DIMENSIONS (inches (cm))	A	2.04 (5.18)	2.04 (5.18)	2.04 (5.18)	1.70 (4.32)	1.70 (4.32)	1.70 (4.32)	1.70 (4.32)	1.70 (4.32)
	B	3.85 (9.78)	3.85 (9.78)	3.85 (9.78)	2.04 (5.18)	2.04 (5.18)	2.04 (5.18)	2.04 (5.18)	2.04 (5.18)
	C	1.88 (4.78)	1.88 (4.78)	1.88 (4.78)	1.56 (3.96)	1.56 (3.96)	1.56 (3.96)	1.56 (3.96)	1.56 (3.96)
	D	0.88 (2.24)	0.88 (2.24)	0.88 (2.24)	0.66 (1.68)	0.66 (1.68)	0.66 (1.68)	0.66 (1.68)	0.66 (1.68)
	E	1.56 (3.96)	1.56 (3.96)	1.56 (3.96)	1.25 (3.18)	1.25 (3.18)	1.25 (3.18)	1.25 (3.18)	1.25 (3.18)
	F	0.50 (1.27)	0.50 (1.27)	0.50 (1.27)	0.38 (0.97)	0.38 (0.97)	0.38 (0.97)	0.38 (0.97)	0.38 (0.97)
WAVEGUIDE SIZE ①		WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
WAVEGUIDE FLANGE ①		UG-381/U ③	UG-383/U	UG-383/U mod	UG-385/U	UG-387/U	UG-387/U mod	UG-387/U mod	UG-387/U mod
		UG-599/U ②						pin contact	pin contact

① Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

2

Micrometer Tuned IMPATT Sources



Hughes Model 4713xH series of Millimeter-Wave Micrometer Tuned IMPATT Sources consist of a silicon IMPATT oscillator, integral isolator, tuning micrometer, regulator and heat sink stand. They are available in six waveguide bands between 26.5 GHz and 110 GHz. The sources feature 3 dB tuning bandwidths up to 5 GHz with power outputs up to 100 mW through 100 GHz. A combination of voltage tuning and micrometer adjustment allows any desired frequency setting.

The regulator is adjusted so that an input to the FM/AFC voltage input jack provides a minimum of 50 MHz of tuning at

FEATURES:

HOW TO ORDER

(Center frequency must be specified at time of order)

Model Number 4713xH-x1xx

Frequency Band	**1**: Ka **2**: Q **3**: U **4**: V **5**: E **6**: W	
Flange Type	**1**: Round **2**: Square (Ka-band only)	
Power mW	**02**: 20 **05**: 50 **10**: 100 **15**: 150 **20**: 200 **30**: 300	

Example: To order a W-band 94 GHz, 100 mW Micrometer Tuned Source, specify a 47136H-1110 the center frequency in Ka-, Q- and U-bands and 100 MHz of tuning at the center frequency in V-, E-, and W-bands. This voltage is nominally 0 to 10 volts. Modulation rates as high as 20 KHz are possible. Higher modulation rates are available on special order. Consult Hughes or your local representative with your special application.

This source is specifically designed to provide high power millimeter-wave sources for many instrumentation applications.

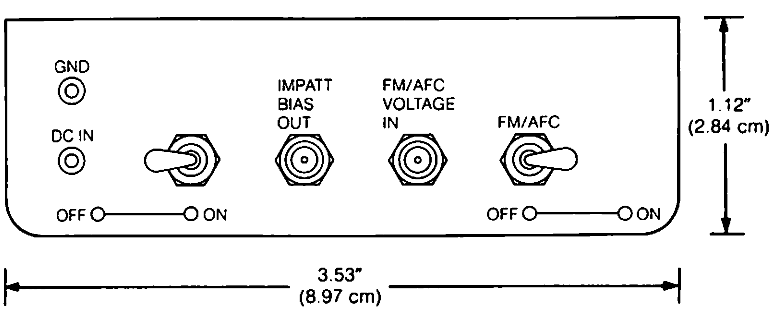
100 mW through 100 GHz

SPECIFICATIONS

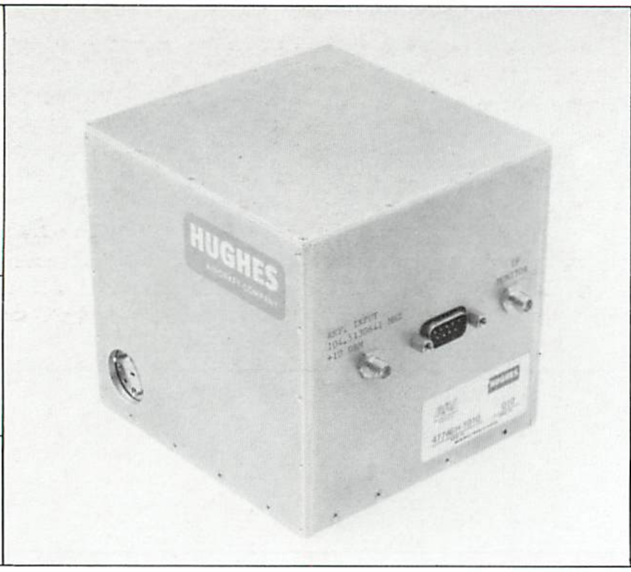
	Frequency Band (GHz)													
	Ka (26.5-40)		Q (33-50)		U (40-60)		V (50-75)		E (60-90)		W (75-100)		W (95-110)	
Center Frequency (GHz)	28-38.5		34.5-48.5		41.5-58.5		52-73		62-88		77.5-97.5		97.5-107.5	
Min Power Output over 1 GHz Bandwidth (mW)	300	150	300	150	200	100	150	100	100	50	100	50	50	20
3 dB Tuning Bandwidth (GHz)*	3④	3④	2	3	2	3	3	4	3	4	4	5	4	5
Tuning Repeatability (± %)	0.1		0.15		0.15		0.2		0.2		0.2		0.2	
Residual FM (MHz typ/max)	2.5/5		2.5/5		2.5/5		2.5/5		2.5/5		2.5/5		2.5/5	
Frequency Stability (%/C°typ)	−0.005		−0.005		−0.005		−0.005		−0.005		−0.005		−0.005	
Spurious Outputs (dBc max)	−30		−30		−30		−30		−30		−30		−30	
DC Power Required (V/mA max)	60/500		60/500		50/500		45/500		40/500		40/500		40/500	
Waveguide Size ①	WR-28		WR-22		WR-19		WR-15		WR-12		WR-10		WR-10	
Waveguide Flange ①	UG-381/U ② UG-599/U ③		UG-383/U		UG-383/U (mod)		UG-385/U		UG-387/U		UG387/U (mod)		UG-387/U (mod)	

*Combination of electrical and mechanical tuning.
① Refer to page 157 for specifications and MIL specification cross reference ② Round flange ③ Square flange ④ 3 GHz bandwidth above 31 GHz only. Below 31 GHz, bandwidth is 2 GHz.

REGULATOR TOP VIEW



Millimeter-Wave Phase-Locked Oscillators



Hughes 477xxH series of MMW phase-locked oscillators consist of a Hughes Gunn Source and all the necessary circuitry for locking them to an extremely stable low frequency reference signal. They are available with the choice of a self-contained reference crystal oscillator or an input jack for an external reference signal. The frequency of the reference signal is determined by the specified millimeter-wave output frequency. Two options are available if the internal reference is to be used:

Gunn Oscillators

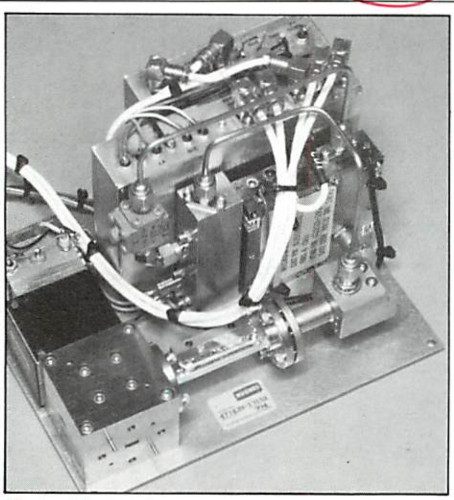
*Gunn-Driven Frequency Multiplie

Gunn Driven IMPATT Injection Locked Oscillator

SPECIFICATIONS

	Option 3 (Low Phase Noise)	Option 4 (Very High Stability)
FREQUENCY STABILITY (with internal reference)		
Stability over 0° to 50°C	$\pm 1 \times 10^{-8}$	$\pm 2 \times 10^{-9}$
Aging	$\pm 3 \times 10^{-6}$/yr.	$\pm 3 \times 10^{-7}$/yr.
	$\pm 1 \times 10^{-8}$/day	$\pm 1 \times 10^{-9}$/day
FREQUENCY AGILITY (with external reference, MHz, nom)	± 10	
POWER OUTPUT	See "How to Order"	
POWER STABILITY (30° to 50°C) (db/°C max)	−0.05	
LOAD VSWR (max)	2:1	
SPURIOUS RESPONSES (NON-HARMONIC) (dBc max)	−40	
EXTERNAL REFERENCE SIGNAL		
Frequency (MHz) (Determined by MMW output frequency)	90-112 ①	
Input Power Level (dBm min)	+10	
Input Impedance (ohms nom)	50	
PHASE-LOCK ACQUISITION TIME (sec. typical)	1	
LOCK ALARM (Common collector to ground: 25 mA max)	Locked = Open	
	Unlocked = Ground	
DC POWER REQUIREMENTS (V/A typ.)		
Gunn Bias ②	+15/2.0 (MAX)	
Impatt ILO Bias ③	+35 to +60/0.5	
Electronics ②	+15/~~1.5~~ 1.0 (MAX)	
Electronics/Heater	−15/1.5 (MAX)	
DC INPUT CONNECTIONS	9-Pin D (Male) Connector	
EXTERNAL REFERENCE SIGNAL INPUT	SMA–Female	
WAVEGUIDE & FLANGE	See page 157	
BASEPLATE OPERATING TEMPERATURE (°C) ④	0 to 50	

① Many MMW output frequencies (most integer multiples of 100 MHz) are available using 5, 10 or 100.0 MHz reference signal. Consult factory.
② A single, common power supply can be used: 15V @ ~~8.5~~ A max. ← 3.0
③ 4773x models only. Value depends on band.
④ Specifications apply at 30°C only.



Contact factory for:
Alternative Open-Plate Configuration

HOW TO ORDER (Specify center frequency at time of order) ①

MMW Phase Locked Oscillators 477xxH-xxxx

Oscillator Type	**3:** Gunn-Driven Impatt ILO **4:** Gunn Oscillator **5:** Gunn-Driven Frequency Multiplier
Frequency Band	**0:** K, **1:** Ka, **2:** Q, **3:** U, **4:** V, **5:** E, **6:** W, **7:** F, **8:** D
Flange	**1:** Round (Ka- through D-bands only) **2:** Square (K- and Ka-bands only)

Power Output	**00:** 5 mW, **01:** 10 mW, **02:** 20 mW, **03:** 30 mW, **04:** 40 mW, **05:** 50 mW, **07:** 70 mW, **10:** 100 mW, **20:** 200 mW, **30:** 300 mW, **50:** 500 mW
Reference Signal	**0:** External ⑤ **3:** Low Phase Noise Interna **4:** Very High Stability Inter

⑤ 100.0 MHz is the preferred reference frequency if applicable to the MMW output frequency (consult factory).

EXAMPLE: To order a W-band Gunn Phase Locked Oscillator at 94 GHz with a round flange, internal very high stability reference signal and a power output of 10 mW, specify a 47746H-1401, center frequency 94 GHz.

very high stability, and low phase noise. A choice of at least two power output levels is offered in each frequency band between 18 and 100 GHz.

The Gunn sources offer exceptionally low AM and FM noise. They are ideal for stable local oscillators or reference signals. Hughes also has the capability of providing frequency agile Gunn phase-locked sources. Please contact the factory for information.

For higher power, a phase-locked Gunn oscillator is combined with a CW injection-locked IMPATT amplifier.

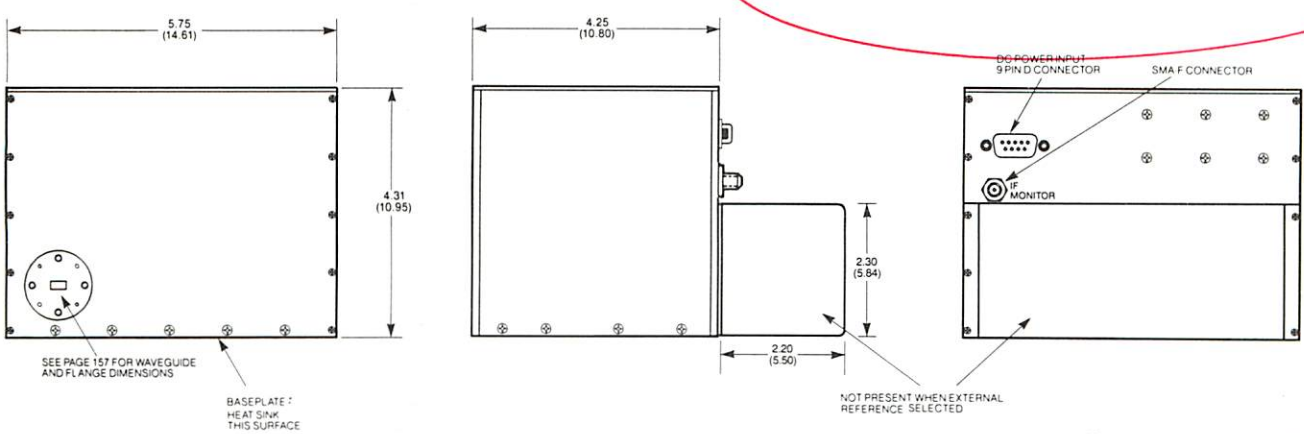
Above 100 GHz, a phase-locked Gunn drives a passive multiplier to even higher frequencies. Other output powers, stabilities, and phase noise characteristics may be furnished on special request.

FREQUENCY BAND (GHz)							
K	Ka/Q	Q/U	U/V	V/E	V/E/W	E/W	F/D*
(18-26.5)	(26.5-40)	(40-50)	(50-60)	(60-70)	(70-85)	(85-100)	(138-142)
200mW	**200mW**	**100mW**	**70mW**	**40mW**	**30mW**	**10mW**	**5mW**

FREQUENCY BAND (GHz)							
	Ka	Q	V		W		
	(34-36)	(42-46)	(54-62)		(92-96)		
	500mW	**500mW**	**300mW**		**200mW**		

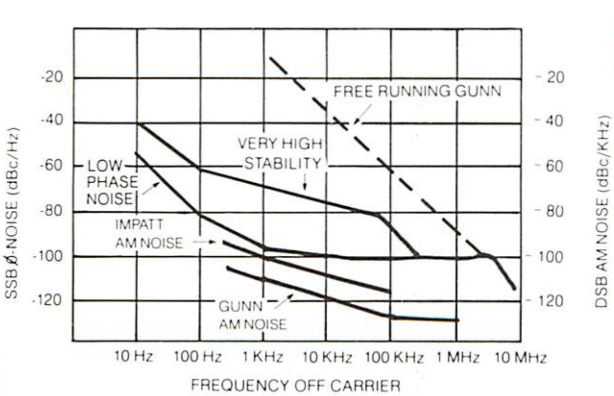
OUTLINE AND MOUNTING DRAWING

PHASE-LOCKED GUNN OSCILLATOR WITH INTERNAL REFERENCE (and EXTERNAL REFERENCE in K and Ka-BAND) AND PHASE-LOCKED GUNN OSCILLATOR/IMPATT ILO.



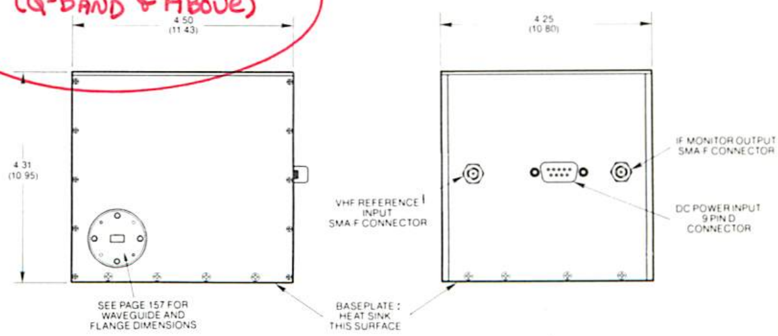
Dimensions are in inches (cm)

TYPICAL PERFORMANCE

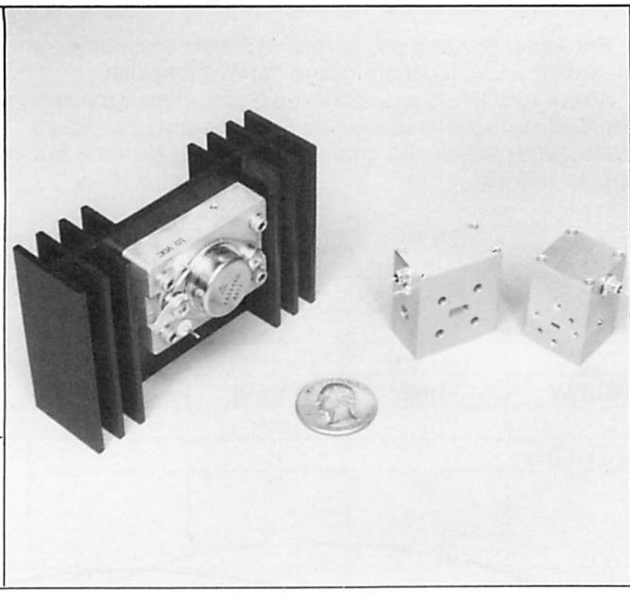


Typical AM & FM noise performance of a W-band PLO

PHASE-LOCKED GUNN OSCILLATOR (External Reference Only)
(Q-BAND & ABOVE)



Mechanically Tuned Gunn Oscillators



Hughes series 4724xH *mechanically tuned Gunn oscillators* provide a low cost and highly reliable source for the generation of microwave and millimeter-wave signals. The reliable GaAs semiconductor material is used to fabricate the Gunn device that is used in these Gunn oscillators.

Their low AM and FM noise characteristics make them ideally suited for local oscillators in many system applications. The Gunn oscillators can be supplied with an integral isolator which will reduce the frequency pulling caused by changes in load VSWR. See page 110 for dimensions of the single junction isolator which is used as the integral isolator. The mechanically tuned Gunn oscillators in Q- and U-bands are also available with the square UG-599/U output flange pattern. This allows the use of through-hole mounting and

POWER OUTPUT AVAILABLE
TUNING BANDWIDTH AVAILABLE

SPECIFICATIONS

		FREQUENCY RANGE (GHz)							
		K 18-26.5	Ka/Q 26.5-40	Q/U 40-50	U/V 50-60	V/E 60-70	E/W 70-85	E/W 85-96	W 96-100
POWER OUTPUT AVAILABLE (mW min)①	Standard	250	250	150	100	70	50	40	30
	Broadband	200	200	100	70	50	40	30	20
TUNING BANDWIDTH (MHz min)	Standard	± 200	± 200	± 200	± 200	± 200	± 100	± 100	± 100
	Broadband	± 500	± 500	± 500	± 500	± 500	± 500	± 500	± 500
FREQUENCY PUSHING (MHz/volt typ)		150	150	150	150	150	300	300	300
FREQUENCY STABILITY (MHz/°C typ)②		− 1.5	− 2.0	− 2.0	− 2.0	− 3.0	− 3.0	− 4.0	− 5.0
BIAS VOLTAGE (V typ)		+ 7.0	+ 6.0	+ 5.0	+ 4.5	+ 3.5	+ 5.5	+ 5.0	+ 5.0
BIAS CURRENT (A typ)③		.9	.70	.75	.75	.70	.65	.65	.65
THRESHOLD CURRENT (A typ)		1.1	.85	.90	.80	.85	.80	.80	.80
POWER STABILITY (dB/°C typ)		− 0.04	− 0.04	− 0.04	− 0.04	− 0.04	− 0.04	− 0.04	− 0.04
WEIGHT (Ozs.)		4.0	4.0	4.0	4.0	3.0	3.0	3.0	3.0

NOTE: ① The table lists the maximum power available for two different mechanical tuning bandwidths over a frequency range. Lower output powers available for these mechanical tuning bandwidths and are listed in the How To Order section below. The output powers available are the minimum power over the mechanical tuning bandwidth and are measured at 30°C. When a temperature controller is used, the output power is reduced by 1.5 dB.
② The frequency stability shown is for oscillators without temperature controllers. An optional temperature controller is available and it maintains the temperature of the Gunn at 55°C. The temperature controller requires + 15 volts at 1 Amp.
③ Bias current for maximum output powers; lower currents are available at lower output power levels.

HOW TO ORDER (Specify center frequency at time of order)

Gunn Oscillator with Regulator 4724xH-xxxx

Frequency Band
- **0**: K
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **5**: E
- **6**: W

Output Flange Type
- **1**: Round (Q- through W-band)
- **2**: Square (K- through U-band)
- **8**: Round (Q- through W-band) integral isolator
- **9**: Square (K- through U-band) integral isolator

Tuning Bandwidth and Configuration
- **4**: Standard unit
- **5**: Standard unit with temperature controller
- **6**: Broadband unit
- **7**: Broadband unit with temperature controller

Power Output
- **00**: 5 mW
- **01**: 10 mW
- **02**: 20 mW
- **03**: 30 mW
- **04**: 40 mW
- **05**: 50 mW
- **07**: 70 mW
- **10**: 100 mW
- **15**: 150 mW
- **20**: 200 mW
- **25**: 250 mW

EXAMPLE: To order a 10 mW, 200 MHz mechanically tuned 94 GHz oscillator, specify a 47246H-1401 center frequency 94 GHz. To reduce the frequency change with temperature, a temperature controller could be specified with the Gunn. This model number would be 47246H-1501.

the use of a smaller isolator on the output of the Gunn oscillator.

The specifications below show the various power levels and mechanical tuning bandwidths available. The power output shown is the maximum power available in that frequency range. Lower power outputs can be ordered and the levels available are shown in the *How To Order* section.

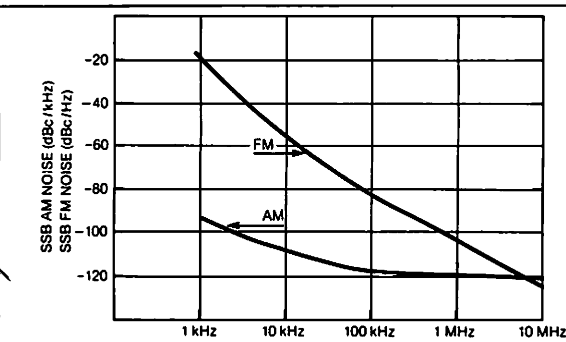
DC power is applied to the Gunn oscillators through a low pass EMI filter. The oscillators have an internal bias suppression network to eliminate bias circuit oscillations. An optional temperature controller is available on these oscillators which improves the frequency stability with changes in ambient temperature. The temperature controller is set to maintain 55°C and therefore reduces the output power by about 1.5 dB when compared to the power output at 30°C. See notes in the specifications section for more information on power output and the temperature controller.

A Gunn bias regulator is supplied with each oscillator. An outline of the regulator is shown below.

The standard and broadband models satisfy many applications for mechanically tuned Gunn oscillators. For your different requirements Hughes' engineering staff will work with you to custom design a circuit to satisfy your needs. Hughes has the resources and facilities to build these custom oscillators in production quantities. For any questions and further information, consult the factory or your local Hughes representative.

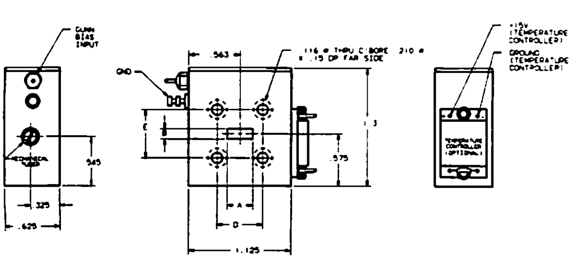
FREQUENCY RANGE (GHz)							
18-26.5	26.5-40	40-50	50-60	60-70	70-85	85-96	96-100
250 mW	**250 mW**	**150 mW**	**100 mW**	**70 mW**	**50 mW**	**40 mW**	**30 mW**
1 GHz	**1 GHz**	**1 GHz**	**1 GHz**	**1 GHz**	**1 GHz**	**1 GHz**	**1 GHz**

TYPICAL PERFORMANCE CURVES

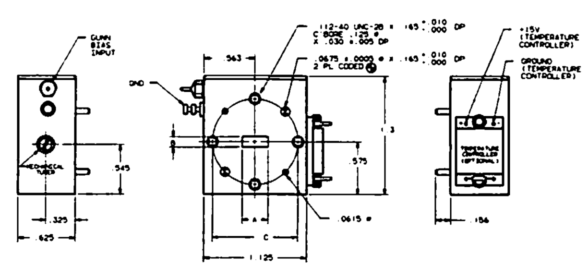


Measured AM and FM Noise Performance of a W-band Gunn Oscillator

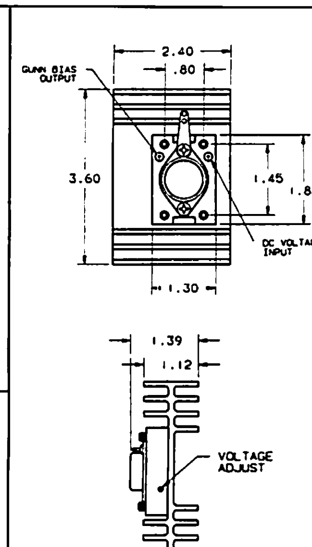
OUTLINE AND MOUNTING DRAWINGS



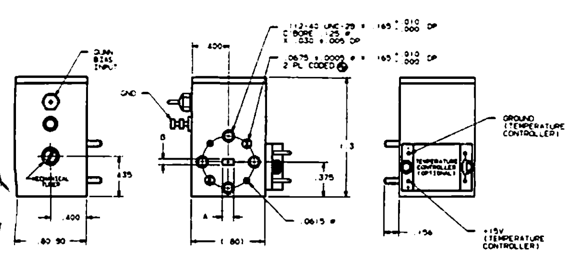
Oscillators Operating in K- through U-bands



Oscillators Operating in Q- and U-bands



Gunn Bias Regulator

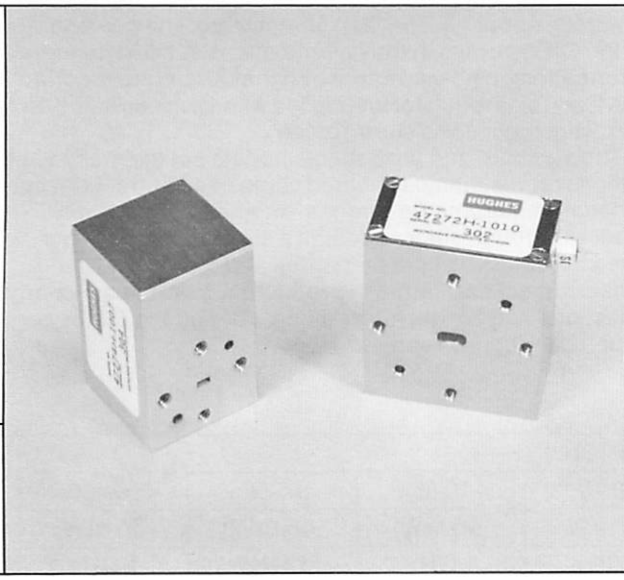


Oscillators Operating in V- through W-bands

MMW OUTPUT WAVEGUIDE			MMW OUTPUT MATING FLANGE			
BAND DESIGNATION	FREQ GHz	DIMENSIONS (INCHES) A X B	TYPE	DIMENSIONS (INCHES) C	D	E
K WR-42	18-26 5	420 X 170	UG-595/U	N/A	640	670
KA WR-28	26 5-40	280 X 140	UG-599/U UG-381/U	N/A 9375	.500 N/A	530 N/A
Q WR-22	33-50	224 X 112	UG-599/U UG-383/U	N/A 9375	.500 N/A	530 N/A
U WR-19	40-60	188 X 094	UG-599/U UG-383/U	N/A 9375	.500 N/A	530 N/A
V WR-15	50-75	148 X 074	UG-385/U	5625	N/A	N/A
E WR-12	60-90	122 X 061	UG-387/U	5625	N/A	N/A
W WR-10	75-110	100 X 0050	UG-387/U	5625	N/A	N/A

Oscillator Output Waveguide and Flange Information

Varactor Tuned Gunn Oscillators



Hughes series 4727xH varactor tuned Gunn oscillators provide a low cost and highly reliable source for the generation of microwave and millimeter-wave signals. The reliable GaAs Semiconductor material is used to fabricate the Gunn device that is used in these Gunn oscillators.

Their low AM and FM noise characteristics make them ideally suited for local oscillators in many system applications. The Gunn oscillators can be supplied with an integral isolator, which will reduce the frequency pulling caused by changes in load VSWR. See page 110 for dimensions of the single junction isolator, which is used as the integral isolator. The varactor tuned Gunn oscillators in Q- and U-bands are also available with the square UG-599/U output flange pattern. This allows the use of through-hole mounting and the use of a smaller isolator on the output of the Gunn oscillator.

POWER OUTPUT AVAILABLE
TUNING BANDWIDTH AVAILABLE

SPECIFICATIONS

		FREQUENCY RANGE (GHz)							
		K 18-26.5	Ka/Q 26.5-40	Q/U 40-50	U/V 50-60	V/E 60-70	E/W 70-85	E/W 85-96	W 96-100
VARACTOR TUNED OSCILLATORS									
Power Output Available① (mW min)	Standard	200	200	150	100	70	50	40	30
	Broadband	150	150	100	70	50	40	30	20
Tuning Bandwidth–Standard (MHz min.)		± 100	± 100	± 100	± 100	± 100	± 100	± 100	± 100
Broadband (MHz min.)		± 500	± 500	± 500	± 500	± 500	± 500	± 500	± 500
Varactor Tuning Voltage (V Typ)		0 to − 20	0 to − 20	0 to − 20	0 to − 20	0 to − 20	0 to − 20	0 to − 20	0 to − 20
Varactor Tuning Sensitivity (MHz/V typ)		120 to 80	120 to 80	120 to 80	120 to 80	220 to 180	220 to 180	220 to 180	220 to 180
Modulation Rate (MHz)		0–80	0–80	0–80	0–80	0–80	0–80	0–80	0–80
Frequency Stability (MHz/°C typ)②		− 2.0	− 2.0	− 2.5	− 3.0	− 3.0	− 4.0	− 4.5	− 5.0
Bias Voltage (V typ)④		+ 7.0	+ 6.0	+ 5.0	+ 4.5	+ 3.5	+ 5.5	+ 5.0	+ 5.0
Bias Current (A typ)③		.90	.70	.75	.75	.70	.65	.65	.60
Threshold Current (A typ)		1.1	.85	.90	.90	.85	.80	.80	.75
Power Stability (dB/°C typ)		− 0.04	− 0.04	− 0.04	− 0.04	− 0.04	− 0.04	− 0.04	− 0.04
Weight (Ozs.)		4.0	4.0	4.0	4.0	3.0	3.0	3.0	3.0

NOTE: ① The table lists the maximum power available for two different mechanical tuning bandwidths over a frequency range. Lower output powers available for these mechanical tuning bandwidths and are listed in the How To Order section below. The output powers available are the minimum power over the mechanical tuning bandwidth and are measured at 30°C. When a temperature controller is used, the output power is reduced by 1.5 dB.

② The frequency stability shown is for oscillators without temperature controllers. An optional temperature controller is available and it maintains the temperature of the Gunn at 55°C. The temperature controller requires + 15 volts at 1 Amp. ③ Bias current for maximum output powers; lower currents are available at lower output power levels.

④ Indicates Gunn oscillator voltage input to regulator will be approximately 3 volts higher.

HOW TO ORDER (Specify center frequency at time of order)

Gunn Oscillator With Regulator 4727xH-xxxx

Frequency Band
- **0**: K
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **5**: E
- **6**: W

Output Flange Type
- **1**: Round (Q- through W-band)
- **2**: Square (K- through U-band)
- **8**: Round (Q- through W-band) integral isolator
- **9**: Square (K- through U-band) integral isolator

Tuning Bandwidth and Configuration
- **4**: Standard unit
- **5**: Standard unit with temperature controller
- **6**: Broadband unit
- **7**: Broadband unit with temperature controller

Power Output
- **00**: 5 mW
- **01**: 10 mW
- **02**: 20 mW
- **03**: 30 mW
- **04**: 40 mW
- **05**: 50 mW
- **07**: 70 mW
- **10**: 100 mW
- **15**: 150 mW
- **20**: 200 mW

EXAMPLE: To order a 5 mW, 1 GHz varactor tuned 94 GHz Gunn oscillator, specify a 47276H-1600, center frequency 94 GHz. To reduce the frequency change with temperature, a temperature controller could be specified with the Gunn. This model number would be 47276H-1700.

The specifications below show the various power levels and voltage tuning bandwidths available. The power output shown is the maximum power available in that frequency range. Lower power outputs can be ordered and the levels available are shown in the *How To Order* section.

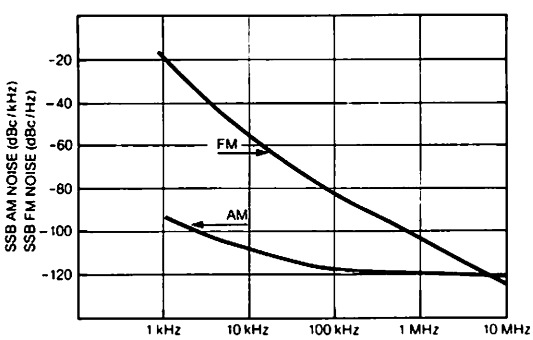
DC power is applied to the Gunn oscillators through a voltage regulator and a low pass EMI filter. The oscillators have an integral bias suppression network to eliminate bias circuit oscillations. An optional temperature controller is available on these oscillators which improves the frequency stability with changes in ambient temperature. The temperature controller is set to maintain 55°C and therefore reduces the output power by about 1.5 dB when compared to the power output at 30°C. See notes in the specification section for more information on power output and the temperature controller.

A Gunn bias regulator is supplied with each oscillator. An outline of the regulator is shown below.

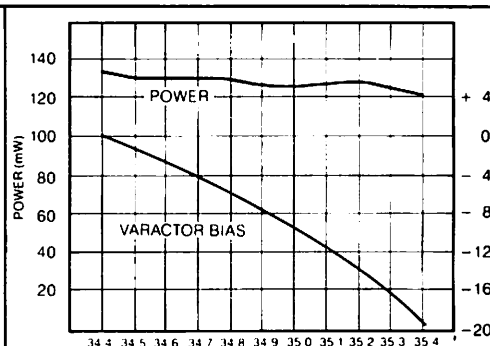
The standard and broadband models satisfy many applications for varactor tuned Gunn oscillators. For your different requirements, Hughes' engineering staff will work with you to custom design a circuit to satisfy your needs. Hughes has the resources and facilities to build your custom oscillators in production quantities. For any questions and further information, consult the factory or your local Hughes representative.

FREQUENCY (GHz)							
18-26	26-40	40-50	50-60	60-70	70-85	85-96	96-100
200 mW	**200 mW**	**150 mW**	**100 mW**	**70 mW**	**50 mW**	**40 mW**	**30 mW**
1 GHz	**1 GHz**	**1 GHz**	**1 GHz**	**1 GHz**	**1 GHz**	**1 GHz**	**1 GHz**

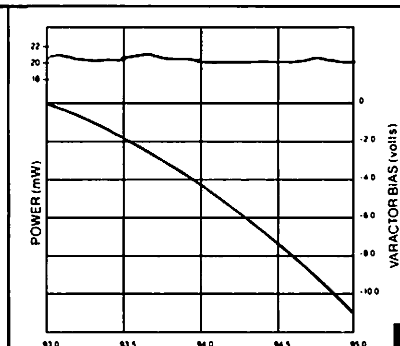
TYPICAL PERFORMANCE CURVES



Measured AM and FM Noise Performance of a W-band Gunn Oscillator

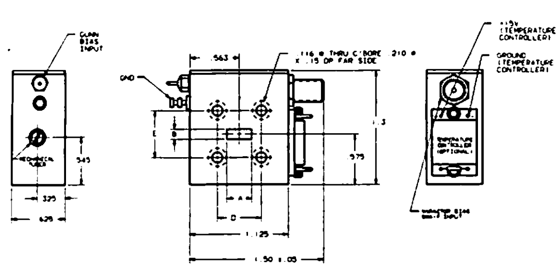


Power Output and Tuning Voltage For Ka-band Varactor Tuned Oscillator

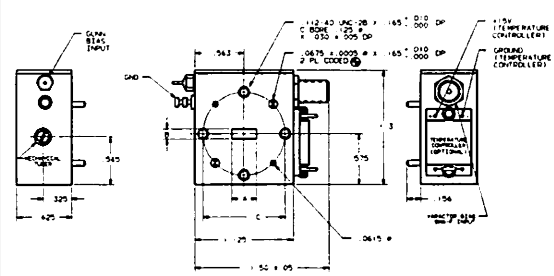


Power Output and Tuning Voltage for W-band Varactor Tuned Oscillator

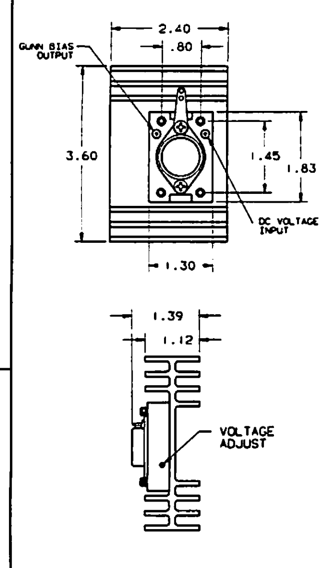
OUTLINE AND MOUNTING DRAWINGS



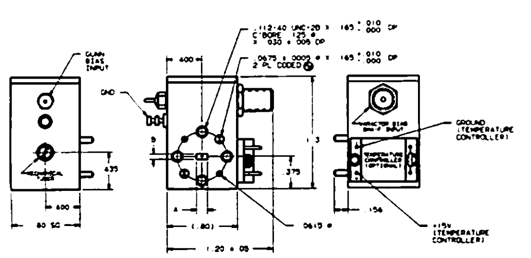
Oscillators Operating in K- through U-bands



Oscillators Operating in Q- and U-bands



Gunn Bias Regulator



Oscillators Operating in V- through W-bands

MMW OUTPUT WAVEGUIDE			MMW OUTPUT MATING FLANGE			
BAND DESIGNATION	FREQ GHz	DIMENSIONS (INCHES) A X B	TYPE	DIMENSIONS (INCHES) C	D	E
K WR-42	18-26.5	.420 X .170	UG-595/U	N/A	.640	.670
KA WR-28	26.5-40	.280 X .140	UG-599/U UG-381/U	N/A .9375	.500 N/A	.530 N/A
Q WR-22	33-50	.224 X .112	UG-599/U UG-383/U	N/A .9375	.500 N/A	.530 N/A
U WR-19	40-60	.188 X .094	UG-599/U UG-383/U	N/A .9375	.500 N/A	.530 N/A
V WR-15	50-75	.148 X .074	UG-385/U	.5625	N/A	N/A
E WR-12	60-90	.122 X .061	UG-387/U	.5625	N/A	N/A
W WR-10	75-110	.100 X .0050	UG-387/U	.5625	N/A	N/A

Oscillator Output Waveguide and Flange Information

Gunn Driven Frequency Multiplier Sources

Hughes series 4723xH Gunn oscillator frequency multiplier sources are available from 100 to 150 GHz in three waveguide bands. These sources consist of a GaAs Gunn oscillator driving a passive multiplier assembled as one integrated unit. They provide output power levels of 10 mW from 100 to 130 GHz and 5 mW from 130 to 150 GHz. The sources are designed for single frequency operation, however, they do have mechanical tuning of 100 MHz.

The low AM and FM noise characteristics of these sources make them ideally suited for local oscillators in systems

POWER OUTPUT AVAILABLE:

HOW TO ORDER (Specify Center Frequency at Time of Order)

Model Number 4723xH- 13xx

Frequency Band	**6**:W **7**:F **8**:D
Flange Type	**1**:Round
Power Output	**00**: 5mW **01**: 10mW

Example: To order a 5 mW source at 140 GHz with a round flange with WR-6 waveguide, specify 47238H-1300 applications. They may be ordered with an input for injection locking the Gunn oscillator with an external source. This injection locking signal could be from a low power phase-locked Gunn oscillator, thus providing the ultimate in stability and spectral purity at frequencies up to 150 GHz.

DC power is applied to the Gunn oscillator through a low pass EMI filter. The oscillator includes an internal bias suppression network to eliminate bias circuit oscillators. The multiplier diode is self-biasing and thus does not require external bias.

These models are designed to satisfy both OEM and instrumentation applications for low noise oscillators above 100 GHz. For special requirements, our engineering staff will work with you to custom design a circuit to satisfy your particular applications. For any questions regarding these sources, contact Hughes or your local representative.

FREQUENCY BAND (GHz)	
W/F/D 100-130	F/D 130-150
10 mW	**5 mW**

SPECIFICATIONS

	FREQUENCY BAND (GHz)	
	W/F/D (100-130)	F/D (130-150)
Power Output Available (mW min)	10	5
Mechanical Tuning Bandwidth (MHz min)	±50	±50
Bias Voltage (V typ)	+6.0	+6.0
Bias Current (A typ)	1.4	1.4
Threshold Current (A typ)	1.7	1.7
Waveguide and Flange	See Page 157	

POWER GENERATING DIODES

Gunn and IMPATT semiconductor diodes are used to generate fundamental-frequency, millimeter-wave energy by virtue of a "negative resistance" that is exhibited when appropriate electrical bias is applied. There are a number of subclasses of these two devices and there are a number of different modes in which they can operate. The literature on the electronic properties of these two devices is enormous and the art of making practical diodes is still advancing. The principle of operation of these two devices will be described below for illustrative purposes; however, no attempt will be made to go beyond a very simple phenomenological description of electronic behavior.

Gunn Diodes

Gunn diodes are bulk-effect semiconductor devices that do not consist of any p-n junction or any interfaces except the two ohmic contacts on either side of the device. It is a transit time device, i.e. the frequency of operation is approximately equal to the reciprocal of the carrier time across the length of the active region. The oscillation or amplification in a Gunn diode is generated by a differential negative resistance when the device is biased above a threshold field. The mechanism responsible for the differential resistance is a field-induced transfer of conduction-band electrons from a low-energy, high mobility valley to a high energy, low mobility satellite valley. Such a transfer results in current-voltage characteristics shown in Figure 1. There are many possible oscillation modes and hybrids of these modes that can occur in Gunn devices exhibiting transferred-electron effects. At low millimeter-wave frequencies (below 60 GHz) the most common is the fundamental transit time Gunn mode. At higher frequencies, hybrid modes may exist.

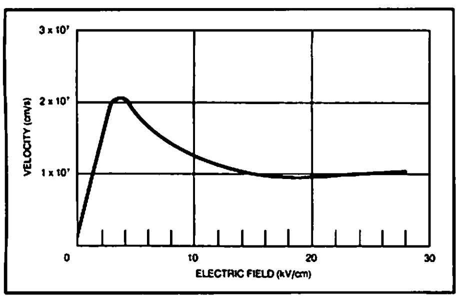


FIG. 1. ELECTRON VELOCITY DECREASES WITH INCREASING ELECTRIC FIELD OVER A RANGE OF FIELD VALUES IN GALLIUM-ARSENIDE CRYSTALS.

IMPATT Diodes

A multi layer negative resistance diode structure was proposed by W. T. Read in the early 1950's. In a very thorough paper, Read analyzed the performance of this device but it took approximately twenty years for semiconductor technology to mature to the point that a device closely duplicating the Read model could be fabricated. The results achieved in modern devices indicate that Read's original predictions about the usefulness of the device for efficient power generation were remarkably correct. A family of avalanche devices for generating microwave power, commonly called IMPATT (Impact Avalanche Transit Time) diodes, have evolved from the specific structure that Read proposed.

The most practical structure for millimeter-wave applications and the one being used in all the silicon IMPATT diode products described in this catalog, is the double-drift structure. The layers in double-drift diodes are: a heavily doped p region (p^+), a moderately doped p region (p), a moderately doped n region (n), and a heavily doped n region (n^+). The p^+ and n^+ regions allow ohmic (non-rectifying) electrical contacts to be made to the external circuit.

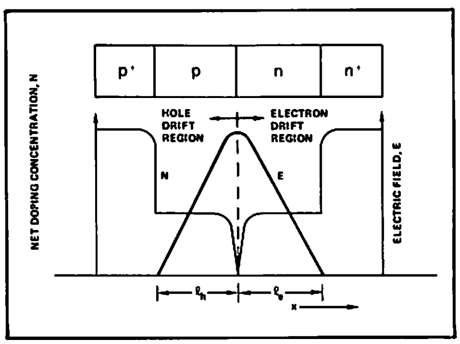


FIG. 2. DOUBLE-DRIFT IMPATT SHOWING FIELD PROFILE.

The doping density profile of the p^+pnn^+ IMPATT diodes, along with the electric field profile at avalanche breakdown, are shown in Figure 2. When the IMPATT diode is reverse biased, the electric field has a strong peak at the pn junction. Impact ionization of atoms in the silicon lattice by accelerated free carriers (electrons and positive holes) begins to occur in the region of the peak electric field as the reverse bias is increased.

Assuming that the diode is dc biased into a state of avalanche breakdown, the response of the diode to a sinusoidal voltage can be described with the aid of the waveforms shown in Figure 3. When the ac voltage swings above the dc voltage, impact ionization increases causing the current generated in the high-field region to increase exponentially, i.e., dI/dt is proportional to I. Due to this exponential increase in current, the peak in the generated ac current occurs near the end of the positive voltage swing as illustrated. The electrons and holes that constitute this avalanche current move in opposite directions under the influence of the applied dc voltage. The electrons and the holes drift across the drift regions (See Figure 2) at the saturated drift velocities. If the diode is designed so that the drift regions are the proper length (given by $L=v_sT$) where the frequency of the ac voltage is given by $f = \frac{1}{2T}$*, then the current induced in the external circuit by the drifting electrons and holes will appear as shown in the lower waveform. As indicated, this current waveform has a fundamental Fourier component that is 180° out of phase with the voltage waveform. This constitutes an ac negative resistance.

*Strictly speaking, the saturated drift velocities of electron and holes are almost, but not quite, equal. The electron and hole drift lengths, l_e and l_h, are designed to take this into account.

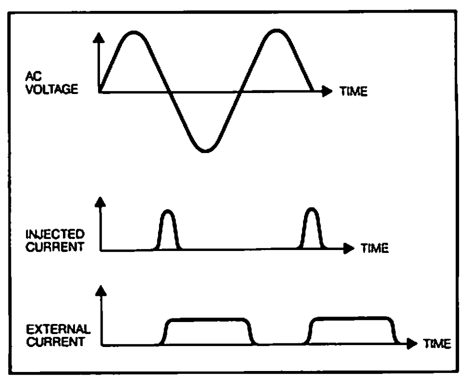


FIG. 3. OSCILLATION WAVEFORMS.

Diode Packaging

The usefulness of a Gunn or IMPATT diode depends not only on the fundamental electronic processes that generate or operate on millimeter-wave energy, but, to a large degree, on the techniques for packaging and/or circuit mounting of the basic semiconductor chip. Reliability is largely determined by packaging and mounting since bond integrity, exclusion of contaminants, and heat removal are known to be the most important factors in achieving long operating life.

With presently available mounting/packaging techniques, the mount/package will not usually be a limitation to performance at microwave frequencies except for broadband circuit designs. At millimeter wavelengths (30 GHz upward) the mounting parasitics usually are a limitation even in narrow-band circuits. It is often useful to be able to tailor the mount/package design to achieve the desired performance. To be able to adequately limit and control the parasitics however, it is necessary to work within extremely small volumes.

It is often stated that an optimum package design has minimum parasitics. This is not altogether true. It is desirable to minimize resistive loss associated with the chip and its mounting connections. It is also desirable to minimize capacitance that shunts the chip in order to reduce circulating RF currents that are dissipated in the resistive parasitics. However, the inductance of the connecting lead often has an optimum nonminimum value. A package, or mount, should be designed to have a shunt capacitance value that is a small fraction of the operating diode capacitance and to have a means for varying the inductance of the connecting lead(s). Such a package is shown in Figure 4.

A mounting scheme is required that provides adequate heat removal and also has the necessary mechanical strength to withstand thermal expansion and contraction. The copper heat sink bases are plated on Gunn diodes in wafer form. The individual diodes with integral heat sinks are then punched from the wafer. IMPATT diode chips can be thermo-compression (TC) bonded to diamond heat sinks which have been imbedded in a copper base as shown in Figure 5. High purity diamond has a thermal conductivity value several times larger than that of copper so this packaging technique is used for all high power CW IMPATT diodes. The IMPATT is TC bonded directly to the copper for short pulse (100 nanoseconds) and low power CW diodes.

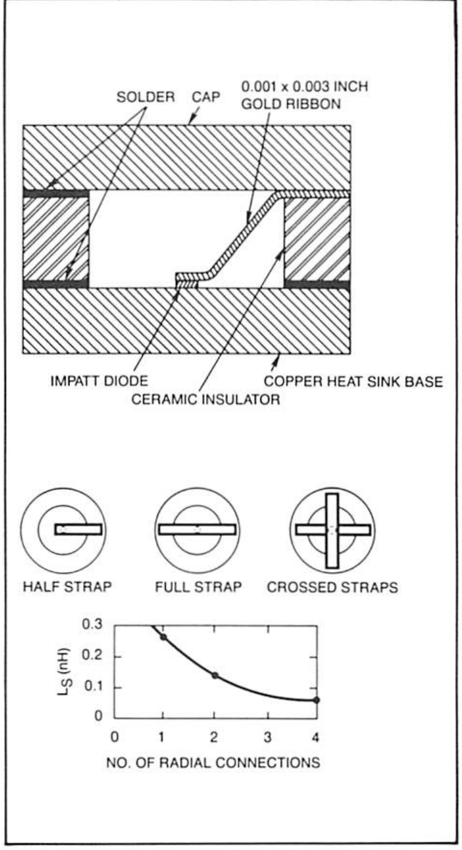


FIG. 4. DIODE PACKAGE DESIGN ALLOWS THE INDUCTANCE IN SERIES WITH THE DIODE CHIP TO BE TAILORED.

Ceramic insulating rings are used at the lower millimeter-wave frequencies but for many applications at frequencies above 50 GHz the insulating rings are ultrasonically cut from a single crystal quartz plate. This enables a lower parasitic shunt capacitance to be achieved. The quartz insulating ring on a 140 GHz IMPATT diode has an outside diameter of only 0.018 inches (0.46 mm).

Reliability

Silicon IMPATT diodes have been subjected to accelerated life testing programs at Hughes since 1972. During this time, considerable data have been accumulated which enable operating life projections to be made. Dedicated life test facilities have been developed at Hughes for these IMPATT reliability studies. A concerted effort in failure analysis has led to the identification and elimination of several failure modes.

To obtain adequate information on IMPATT reliability in a reasonable amount of time, it is necessary to resort to accelerated life testing. Accelerated life test techniques can be organized into two general categories: step-stress testing and constant-stress testing. In a step-stress test, devices are operated for a fixed period of time at each of a series of increasing stress levels until all have failed. The specific stress parameter chosen for IMPATT diodes is temperature.

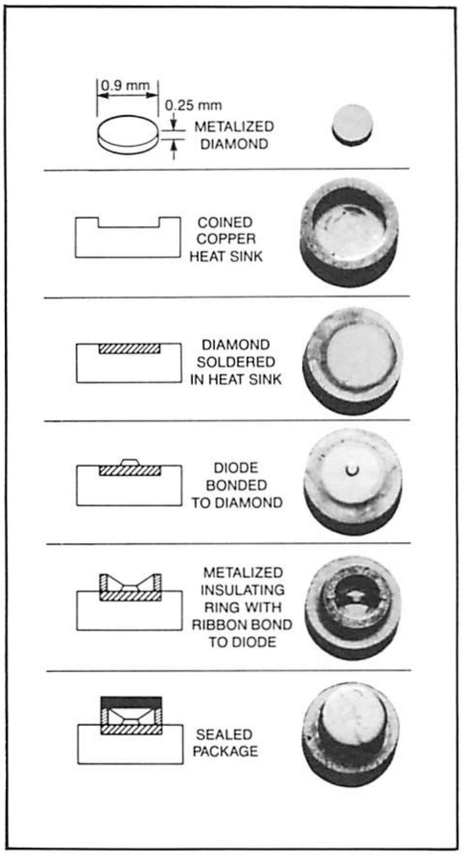


FIG. 5. DIAMOND IS USED FOR EFFICIENT HEAT REMOVAL.

The purpose of step-stress testing is to accelerate failure mechanisms. Step-stress testing is also useful for determining operational limits and for establishing device screening procedures for eliminating early failures.

In a constant-stress test, each group of diodes remains at the same level of stress for the entire duration of the test. The stress levels are sufficient to accelerate device failures so that an adequate amount of failure rate data for statistical analysis can be generated in a reasonable time.

A regression analysis is used to extrapolate constant-stress test data to obtain failure rates at operating temperatures. The results of such testing are easier to interpret than step-stress results, as the effects of prior stress levels do not have to be considered.

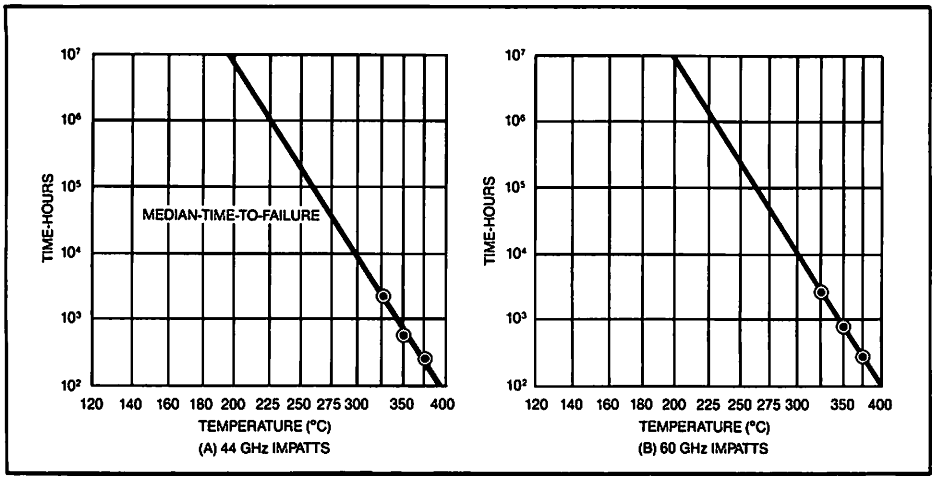


FIG. 6. ESTIMATED MTTF VS JUNCTION TEMPERATURE OF SILICON DOUBLE-DRIFT IMPATT DIODES.

Hughes silicon IMPATT diodes are currently being flown in various spacecraft with excellent reliability. Similar diodes have been RF constant stress tested for 10 years. The reliability projections obtained previously based on dc accelerated testing have now been verified under actual RF conditions. Data obtained from constant stress on silicon 44 GHz and 60 GHz double-drift IMPATT diodes on diamond heat sinks is presented in Figure 6 A & B.

DIODES FOR SIGNAL DETECTION, TRANSLATION AND CONTROL

Several types of passive semiconductor diodes have proven to be useful for millimeter-wave signal detection, translation and control. These devices exhibit nonlinear resistive (rectifying) properties as well as a nonlinear dependence of capacitive reactance on bias. As an example, in the extreme case of a diode switch, the device ideally changes from zero RF impedance (short circuit) to infinite RF impedance (open circuit) as the dc bias state is switched.

PIN Diodes

PIN diodes are junction devices that have a relatively long and lightly doped (intrinsic) region interposed between a P-doped region and an N-doped region. The PIN diode has two features. Consider the PIN diode in reverse bias. The I region is swept free of charge carriers due to the low background doping level, thus it is a parallel plate capacitor with a plate separation that corresponds to the length of the I region. If this length is large, then the capacitance is very low and a very high RF impedance is presented by the device. In addition, with a long I region, a high value of avalanche breakdown voltage can be achieved. This is true because a large voltage can be absorbed by the diode before the average electric field in the I region reaches a level at which impact ionization begins to occur. This high voltage capability is important for handling large amounts of RF power, thus PIN diodes are useful as high-power limiters, switches and phase shifters. In the forward-bias condition, injected charge fills up the I region forming a nearly neutral electron-hole plasma. As in the case of the simple P-N junction device, this plasma exhibits a very low RF impedance. Thus the PIN diode can be switched from a very high impedance state to a very low impedance state. This effect can be used to accomplish RF switching and, in combination with appropriate transmission line networks, phase shifting.

Schottky-barrier diodes

The Schottky-barrier device is the best device for detectors and mixers. By choosing the proper metal to form the barrier, the barrier potential can be reduced to a low value. This is an additional advantage for achieving high sensitivity in unbiased detectors and for mixers that are operated at low local oscillator power levels. One disadvantage of the Schottky device is that it tends to exhibit leakage current under reverse bias. This can be attributed, in part, to the fact that the barrier is at the surface of the semiconductor material. Therefore, the barrier is more susceptible to contaminants and fabrication irregularities than is a junction device, with the junction buried below the surface.

Although junction and Schottky-barrier diodes are used for a wide variety of RF applications, these applications often have unrelated, or in some cases, conflicting requirements. However, there is a diode figure-of-merit, called the cut-off frequency, which is broadly applicable to most requirements. The equivalent circuit of a junction or Schottky diode chip can be represented as shown in Figure 7. Both the junction resistance and capacitance are shown as variable in this Figure, depending on the dc bias and the RF drive level. The parasitic series resistance of the chip, R_s, also may vary with bias, but this is usually a second order effect. For an RF voltage applied at the terminals of the chip, maximizing the RF voltage appearing across the junction (across the parallel combination of C_j and R_j) is desirable. To do this, the cut-off frequency, f_{co}, given by $f_{co} = (1/2\pi)\, R_s C_j$ should be large compared to the operating frequency. (Approximately 10:1 for optimum performance).

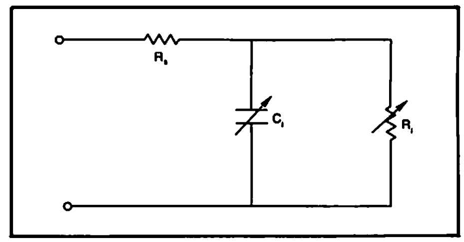


FIG. 7 CIRCUIT REPRESENTATION OF A SEMICONDUCTOR DIODE CHIP.

In many cases where the device is operated over a range of forward and/or reverse bias conditions, the values of C_j and R_s take on different values. Therefore, a hybrid figure-of-merit may be more appropriate. There are, of course, other figures-of-merit that can be applied for specific applications, but f_{co} is important in all cases and is widely used by manufacturers in specifying device performance.

Diode Packaging

Several types of Schottky barrier and PIN diodes have been used successfully for millimeter wave applications. There are two types of Schottky barrier configurations: the whisker-contacted honeycomb structure and the surface oriented beam lead device. Generally the characteristics of the Schottky barrier junction of these diodes are the same, but substantial differences exist in terms of performance, parasitics, reliability, and production techniques. PIN diodes are made in these same configurations but are also made in an etched pill configuration packaged similarly to IMPATT diodes described in the preceding pages.

The honeycomb diode, as shown in Figure 8, has photolithographically defined junction diameters etched in an SiO_2 layer on an n-type epitaxial layer grown on an n^+ substrate. The SiO_2 layer also serves as a protective layer for the diode junction. Gold or other appropriate metals are deposited into the arrays of 2 to 5 micron diameter circular holes which have been etched through the SiO_2 layer to form the Schottky barrier junction. The contact to the anode of these small diodes is accomplished by a thin, conically pointed metal whisker bent in a C-spring shape held against the Schottky barrier by compression. The ohmic metalization on the bottom of the chip serves as a common cathode to all the diodes on the chip. Honeycomb diodes have exhibited the best performance for millimeter-wave mixer and detector applications because of their high cut off frequency, although new Hughes beam lead diodes show promise of matching or surpassing their performance.

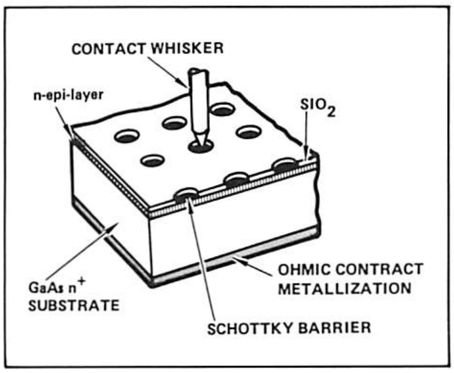


FIG. 8. HONEYCOMB SCHOTTKY BARRIER DIODE.

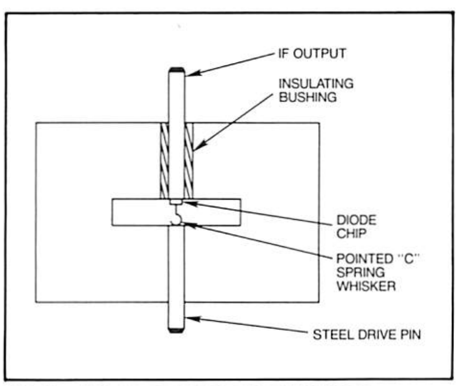


FIG. 9. WAFER PACKAGE FOR WHISKER-CONTACTED MILLIMETER-WAVE DIODES.

A wafer type mount taking the form of a reduced height waveguide section as depicted in Figure 9 is commonly used for millimeter wave mixer and detector diodes. Usually two posts are inserted from opposite sides. One has the pointed whisker attached, the other has the diode chip bonded to it. Instead of a simple insulating bushing, often a filter structure is used on one side providing the IF output connection. Coaxial and strip line filter structures have been used successfully. The whisker is positioned over a diode junction by a specially designed probe while being observed on a scanning electron microscope.
A scanning electron micrograph of a pointed whisker contacting a semiconductor chip with five micron diameter honeycomb Schottky diodes is shown in Figure 10.

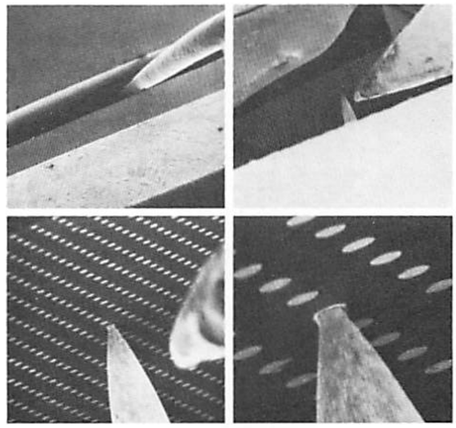


FIG. 10. MICROPOSITIONER IN A SCANNING ELECTRON MICROSCOPE (SEM) IS USED TO MAKE WHISKER CONTACTS.

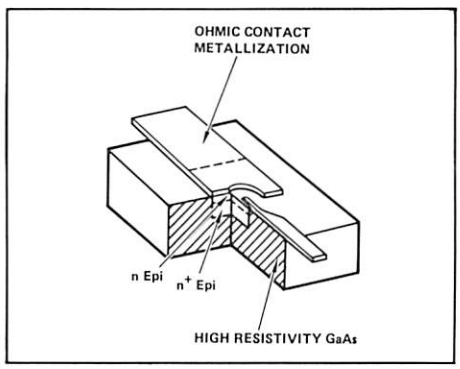


FIG. 11. DRAWING OF PLANAR BEAM LEAD DIODE.

A drawing of a surface oriented beam lead diode that is mechanically reliable and has low parasitics is shown in Figure 11. To fabricate the diode a two layer n^+ epitaxial structure is grown on a semi-insulating substrate. To reduce contact resistance, Se^+ ion implantation on selected areas is used prior to the ohmic contact metalization. The Schottky barrier junction is formed by deposition of either titanium or platinum on the conducting areas. The junction geometry and dimensions are defined by photolithographic processes. The contacting beam leads to the diode are formed by depositing metal striplines over the diode terminals.

Although the honeycomb Schottky barrier diode structure has been the best performer at millimeter-wave frequencies, its suitability for high volume low cost systems is questionable. The advantage of surface oriented beam lead diodes shown in Figure 12 is that it has the combined attributes of high cut off frequency and mechanical ruggedness. This is because the junction area can be made less than three square microns by photolithographic techniques, and the beam anchor area rests on semi-insulating material, resulting in negligibly small parasitic capacitance.

FIG. 12. HUGHES BEAM LEAD DIODES.

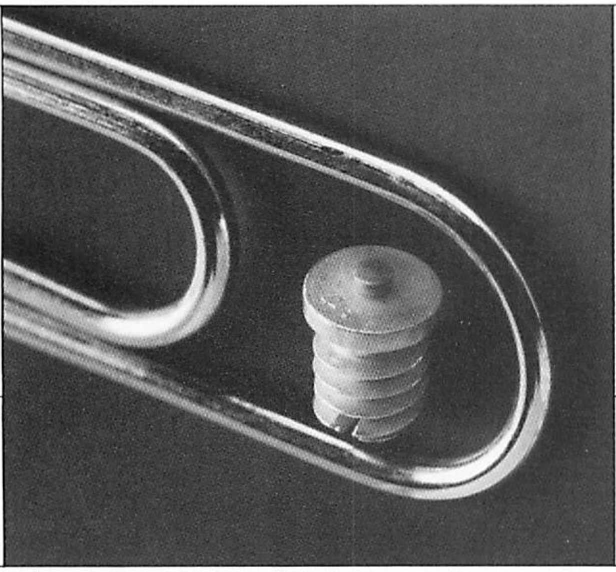
Reliability

Extensive accelerated life tests have been conducted for millimeter-wave silicon honeycomb Schottky barrier mixer/detector diodes. Results from these tests are summarized in Table I.

Table I Millimeter Silicon Honeycomb Schottky Diode Life Test Summary

Type	Number of Devices	Test Condition	Duration	Diode Condition	Number of Failures
Packaged	20	Constant Temp., 90°C	8630 Hrs	5 mA Forward	1
Packaged	10	Constant Temp., 120°C	1520 Hrs	5 mA Forward	0
Packaged	12	Thermal Cycle, −8 to +55°C	4736 Cycles	None	0
Chip	10	Constant Temp., 200°C	60 Hrs	5 mA Forward	0
Chip	10	Constant Temp., 250°C	30 Hrs	5 mA Forward	0
Chip	13	Constant Temp., 300°C	6 Hrs	5 mA Forward	0

Gunn Diodes



Diode mounted on heatsink shown with standard size paper clip

Hughes 4720xH series of GaAs Gunn Diodes are available for operation at any specified frequency between 26.5 and 95 GHz. Power output levels range from 20 mW at 95 GHz to 350 mW at 40 GHz. Their low noise characteristics make them ideally suited for receiver applications such as paramp pumps and local oscillators.

The diodes are packaged in a 0.035-inch diameter ceramic package which is mounted to a copper heat sink with threaded base.

Every diode is tested at the specified frequency for output power, threshold voltage and current and operating voltage and current in a critically coupled cavity.

POWER OUTPUT AVAILABLE*

Frequency (GHz)	26-40	40-60	60-75	75-95
Power Output	**350 mW**	**150 mW**	**80 mW**	**50 mW**

*Higher power outputs are available at lower end of frequency ranges (consult factory).

GUNN DIODE SPECIFICATIONS

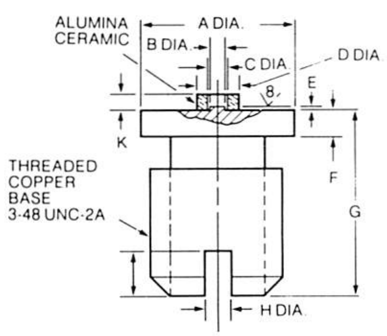
	FREQUENCY BAND (of test circuit in GHz)					
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-95)
Power Output Available (mW min)	250, 350	from Table	100, 150	from Table	from Table	20, 50
Bias Voltage (V typ)	6.5	6.0	5.0	4.0	5.5	5.0
Bias Current (A typ)	1.10	1.0	1.0	1.0	1.0	1.0
Threshold Current (A typ)	1.3	1.3	1.3	1.3	1.3	1.3
Package Capacitance (pF typ)	0.18	0.18	0.18	0.18	0.18	0.18
Package Inductance (nH typ)	0.10	0.10	0.10	0.10	0.10	0.10

NOTE: Each diode is supplied with the following data: frequency, output power, threshold current and voltage, and operating current and voltage. Diodes are designed to operate over a temperature range of −30°C to +75°C. Storage temperature range is −54°C to +125°C.

NOTE: All specifications apply at 25°C ambient temperature.

OUTLINE AND MOUNTING DRAWINGS

Gunn Diode



DIM.	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.114	0.116	2,90	2,95
B	0.011	0.013	0,28	0,33
C	0.014	0.018	0,36	0,46
D	0.030	0.034	0,76	0,86
E	0.003	0.005	0,08	0,13
F	0.019	0.021	0,48	0,53
G	0.140	0.144	3,56	3,66
H	0.015	0.025	0,38	0,64
J	0.030	0.040	0,76	1,02
K	0.020	0.024	0,25	0,36

HOW TO ORDER GUNN DIODES

Gunn Diode Model Number 4720xH-04xx

Test Circuit Frequency Band
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **5**: E
- **6**: W

Power Output (Gunn Diodes)
- **02:** 20mW
- **05:** 50mW
- **08:** 80mW
- **10:** 100mW
- **15:** 150mW
- **25:** 250mW
- **35:** 350mW

IMPATT Diodes and Test Fixtures

Diode shown mounted on heatsink

Hughes 4710xH series IMPATT diodes are silicon double drift diodes mounted in hermetically sealed packages and supplied mounted to a copper heat sink. Standard products are offered with power outputs tested in specific frequency windows.

Similar diodes have undergone many years of accelerated life testing. This testing coupled with failure analysis has enabled Hughes to achieve very high mean-time-to-failure (MTTF) rates.

A microwave cavity test fixture is offered for both CW and pulsed IMPATT diodes. Purchase enables the user to verify Hughes' test data.

POWER OUTPUT AVAILABLE

Frequency (GHz)	33-37	42-46	54-62	92-96	135-145
CW Output	**1.4 W**	**1.0 W**	**1.0 W**	**500 mW**	**40 mW**
Pulse Output	**20 W**	**—**	**—**	**20 W**	**1 W**

CW IMPATT DIODE SPECIFICATIONS

Test Circuit Waveguide Band (GHz)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	W (75-110)	D (110-170)
Test Frequency Range (GHz)	33-37	42-46	54-58②	58-62	92-96	135-145
Power Outputs Available (W min)①	.25, .60, 1.4	.25, .60, 1.0	.20, .50, 1.0	.20, .50, 1.0	.20, .30, .50	.02, .04
Operating Voltage Range (V)	35-50	30-42	24-34	24-34	16-22	9-12
Total Capacitance at V = 0 (pF)	1.0-3.0	1.0-3.0	0.8-3.0	0.8-3.0	0.7-2.5	0.7-1.0

① Diodes are tested in test fixture to have minimum power and output at an unspecified frequency in the test frequency range with the estimated junction temperature not exceeding 250°C with test cavity at 50°C.

② Diodes tested in 54-58 GHz range may be tested in a V-band test circuit.

PULSED IMPATT DIODE SPECIFICATIONS

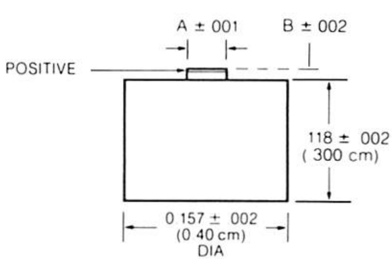
Test Circuit Waveguide Band (GHz)	Ka (26.5-40)	W (75-110)	D (110-170)
Test Frequency Range (GHz)	34-36	92-96	135-145
Peak Power Outputs Available (W min)①	5.0, 12, 20	5.0, 12, 20	1.0
Total Capacitance at V = 0 (pF typ)	3.5-5.0	2.5-6.5	1.0-4.0

① Diodes are tested in test fixture to have minimum power output at an unspecified frequency in the test frequency range.

3

OUTLINE AND MOUNTING DRAWINGS

IMPATT Diode



DIMENSIONS (inches (cm))		Ka & Q-Band IMPATTS	V- & W-Band IMPATTS	D-Band IMPATTS
	A	0.035(0.089)	0.035 (0.089)	0.018(0.046)
	B	0.013(0.033)	0.013 (0.033)	0.010(0.025)

HOW TO ORDER IMPATT DIODES AND TEST FIXTURES

CW IMPATT Diode Model Number 4710xH-04xx
Pulsed IMPATT Diode Model Number 4710xH-45xx
CW IMPATT Diode Test Fixture 4713xH-x600
Power Supply for CW Test Fixture
110 V., 60 Hz 47510H-5001
220 V., 50Hz 47510H-5002
Pulsed IMPATT Diode Test Fixture 4713xH-x500

Test Circuit Frequency Band
- **1**: Ka
- **2**: Q (Available only for CW IMPATT Diodes)
- **3**: U (Available only for CW IMPATT Diodes)
- **4**: V (Available only for CW IMPATT Diodes)
- **6**: W
- **8**: D (Avail. only on IMPATT Diodes)

Flange Type
- **1**: Round
- **2**: Square (Available Ka-Band only)

Power Output (IMPATT Diodes)
- **02**: 20 mW (Available in D-band only)
- **04**: 40 mW (Available in D-band only)
- **20**: 200 mW (Available in U-, V- and W-bands only)
- **25**: 250 mW (Available in Ka- and Q-bands only)
- **30**: 300 mW (Available in W-bands only)
- **50**: 500 mW (Available in U-, V- and W-bands only)
- **60**: 600 mW (Available in Ka- and Q-bands only)
- **11**: 1 Watt Peak (Available in D-band only), 1 Watt CW (Not available in D- or W-bands) or 1.4 Watts CW (Available in Ka-band only)
- **51**: 5 Watts Peak (Available in Ka- and W-bands only)
- **12**: 12 Watts Peak (Available in Ka- and W-bands only)
- **22**: 20 Watts Peak (Available in Ka- and W-bands only)

Beam Lead Mixer Diodes

The Hughes 47401H-0000 and 47406H-0000 beam lead mixer diodes are available for use in EHF mixer applications requiring the ultimate in performance. Conversion losses of 5 dB in Ka-Band and 6.5 dB in W-Band have been achieved in components utilizing these diodes. Pull strengths are in excess of 10 grams, assuring a high yield of diodes both in design and production stages.

Two types are offered. One for Ka- through V-Band and the other for W- through D-Band requirements. Consult Hughes for special requirements such as matched pairs or quads and other special selections.

FEATURES:

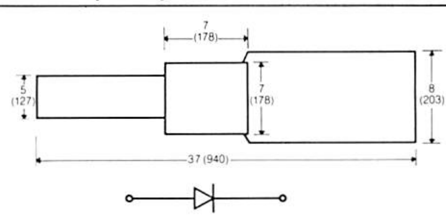
BEAM LEAD MIXER DIODE SPECIFICATIONS

	Model #47401H-0000	Model #47406H-0000
Operating Frequency Range (GHz)	26.5-75	75-160
Capacitance (@ 0V. bias fF typ) ①	55	45
Series Resistance (Ω typ)	3.5	3.5
Cut-Off Frequency (GHz min/typ) ②	700/800	800/950
Breakdown Voltage V_b @ 5 mA (V)	5	5
Pull Strength (grams min)	10	10

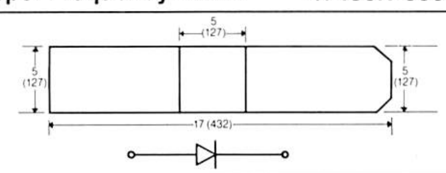
① $C_o = C_j$ (@ 0V bias) + C_p
② F_c = Calculated using total capacitance

OUTLINE AND MOUNTING DRAWING
Beam Lead Mixer Diodes

Lower Frequency Bands — **47401H-0000**



Upper Frequency Bands — **47406H-0000**



NOTE: All dimensions are in 0.001" (microns).

Beam Lead Varactor Diodes

The Hughes model 47401H-0101 beam-lead varactor is a GaAs Schottky-barrier device which features a rugged beam-lead structure that provides lead pull-strengths of 10 g or better. The structure consists of a 7 x 8 mil (0.18 x 0.20 mm) GaAs chip mounted in an integral beam-lead configuration that has a total length of 37 mil (0.94 mm).

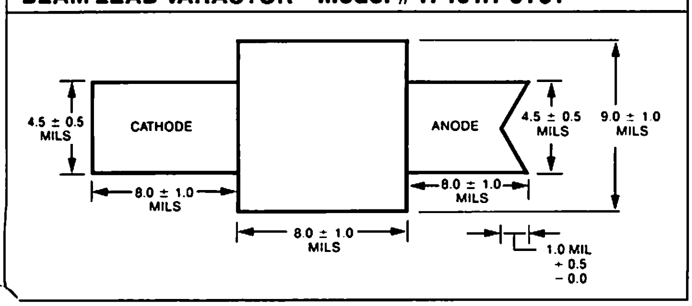
Varactor Schottky-barrier diodes work by exhibiting a change in device capacitance relative to an applied tuning voltage. The Hughes diode can be tuned over a 4-to-1 capacitance range when reverse voltages of 2 to 20 V are applied.

With the beam-lead varactor, it is possible to build a planar microstrip VCO that is considerably smaller than existing waveguide cavity VCOs. A typical circuit using the varactors with a Gunn source on a 5 mil (0.13 mm) thick RT/duroid substrate is shown in Figure 1. Measurements indicate that the circuit is capable of 100 mW output power across a 600 MHz tuning bandwidth centered at 32 GHz.

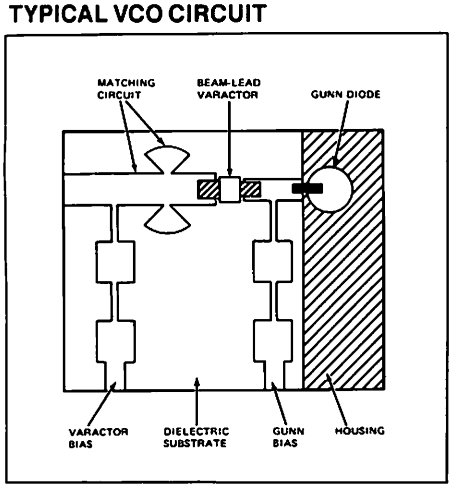
10 Gram Lead Pull Strengths

OUTLINE AND MOUNTING DRAWING

BEAM LEAD VARACTOR Model #47401H-0101



TYPICAL VCO CIRCUIT



SPECIFICATIONS:

	Model #47401H-0101
Breakdown Voltage V_{bd} (@ 10 µA, Volts, min/max)	16/22
Capacitance $C_{.4}$ (pF, min/max)	0.60/0.80
Tuning Ratio (Capacitance @-2V/-20V, min)	4 to 1
Q Factor (@ 50 MHz, min)	2000

HOW TO ORDER Beam Lead Mixer Diodes
Beam Lead Mixer Diode (26.5-75 GHz) 47401H-0000
Beam Lead Mixer Diode (75-160 GHz) 47406H-0000
Beam Lead Varactor Diode 47401H-0101

3

A wide variety of components for signal detection, translation and control have been developed by Hughes. Many are fully described in the following pages of this section.

LOW NOISE AMPLIFIERS

Applications for FET low-noise amplifiers (LNAs) operating in the 18 to 40 GHz frequency range are rapidly emerging with the development of high-performance microwave and millimeter-wave electronic-support-measures (ESM), electronic-countermeasures (ECM), satellite-communication, radar, and radiometer systems. In particular, when used as an RF preamplifier or IF amplifier, an LNA improves receiver sensitivity by reducing the system noise figure. Also, when used as an RF preamplifier, an LNA allows the use of broad IF bandwidths without any reduction in receiver sensitivity.

Recently, several GaAs FET and HEMT amplifiers operating in the 18.0 to 40.0 GHz frequency range have demonstrated low noise figures, high gains, and wide bandwidths. In addition, amplifiers employing GaAs technology have been reported operating at frequencies up to 60 GHz. A line of GaAs MESFET LNAs operating in the 18 to 40 GHz frequency range are described on pages 82 and 83 in this catalog. Communications amplifiers with 3 dB maximum noise figures at 20 GHz are described along with 35 GHz 4 dB noise figure radar amplifiers and 5 dB noise figure 18 to 26 GHz broadband EW LNAs.

Low noise amplifier technology lends itself to integrated receiver front ends. Figure 1 shows a unit developed for military communications terminals with a gain of 40 $\pm$ 1 dB, and a noise figure of 2.75 $\pm$ 0.1 dB over the RF frequency band from 19.9 to 21.5 GHz. It consists of a three-stage FET low noise preamplifier (LNA), a low loss waveguide isolator, a waveguide-to-microstrip transition, an IF amplifier, a ferrite microstrip isolator, an RF bandpass/image-rejection filter, a diode mixer and an IF lowpass filter. A second microstrip isolator also is used at the LO port. These MIC components are integrated into a compact package, 5.0x1.5x1.0 inches in size and 235 grams in weight.

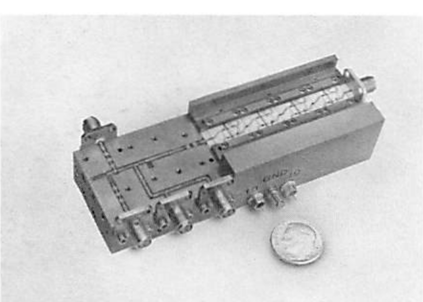


FIG. 1. INTEGRATED LOW NOISE RECEIVER FRONT END.

Frequency Band	Frequency (GHz)	Best Conversion Loss* (dB)	Typical Conversion Loss (dB)
Ka	35	3.8	4.3
Q	44	4.1	4.7
V	60	4.4	5.0
E	75	4.7	5.2
W	94	5.0	5.5
D**	140	5.7	6.0

*IF = 500 MHz
**GaAs only

FIG. 2. BEST MEASURED BALANCED MIXER CONVERSION LOSS USING SILICON SCHOTTKY BARRIER DIODES.

MIXERS AND DETECTORS

At millimeter wavelengths, where a device for detection or frequency translation need not dissipate much power, the whisker contracted honeycomb or planar beam lead Schottky diode as described on pages 72 through 75 is used. Schottky diodes are normally operated with either zero or a small forward voltage bias, so that the nonlinear resistance characteristic used for rectification (detection) and mixing is described by the current-voltage relationship:

$$I = I_0\left[\exp\left(\frac{eV}{nkT}\right) - 1\right]$$

with n approximately equal to one, k being Boltzman's constant and T being the absolute temperature of the crystal. Both silicon and GaAs Schottky honeycomb diodes are used in a wide variety of mixers, harmonic mixers, single sideband upconverters, mixer preamplifiers, and detectors listed in the following pages of this catalog.

Balanced Mixers

Measured conversion loss data for balanced mixers using Hughes silicon honeycomb Schottky diodes is shown in Figure 2. Hughes GaAs honeycomb diodes can provide approximately 0.5 dB lower conversion loss but at the expense of requiring higher local oscillator power. The relatively small superiority of GaAs over silicon is explained by the high cut off frequencies of both diode types.

Recent mixer results have established that comparable performance can be achieved with beam lead diodes and honeycomb diodes up to 170 GHz. Since beam lead diodes are better suited for low cost mixer manufacturing techniques, a substantial effort has been undertaken by Hughes in this technology. Two different types of mixers are offered in this catalog: the hybrid mixer, and the beam-lead cross-bar mixer.

Hybrid Planar Mixer

This type of balanced mixer is used for

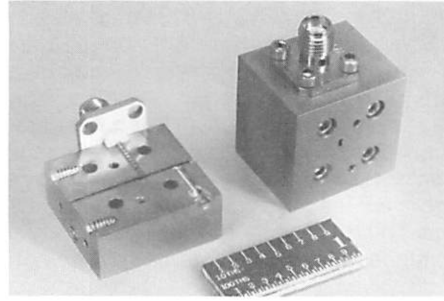


FIG. 3. PLANAR HYBRID BALANCED MIXER INCORPORATING BEAM LEAD DIODES.

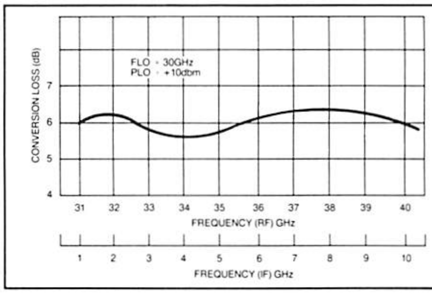


FIG. 4. CONVERSION LOSS OF BROADBAND HYBRID MIXER.

fixed-LO frequency and ultra-large RF and IF bandwidths. (See pages 86 and 87.) The hybrid mixers(shown in Figure 3) derive their name from the fact that the planar substrate containing the diodes incorporates two or three types of transmission lines, depending on the configuration of the mixer. Fin-line, suspended microstripline, and shielded microstripline are used optionally, depending on size constraints along with RF, IF and LO bandwidth requirements. The housing is simple split-block design without critical fabrication tolerances that are required for the standard whisker contacted balanced mixer. The mixer consists of two mixer diodes, a circuit board, a split block housing, and a connector in its entirety. The substrate is fabricated using standard photolithographic techniques.

The inherent wide instantaneous RF and IF bandwidth of this mixer makes it particularly useful for EW applications and for millimeter-wave laboratory instrumentation, where development work requires a broad range of frequencies.

The performance of an in-line LO injection mixer is shown in Figure 4. The conversion loss is between 5 and 7 dB for an IF bandwidth of 1 to 10 GHz. When the mixer is designed for narrowband operation, the conversion loss is 4.5 dB. Figure 5 shows the response of a probe coupled LO injection mixer for an IF of 2 GHz to 16 GHz. Catalog versions of these mixers are available either without IF amplifiers or with standard bandwidth low noise IF amplifiers up to 18 GHz. They are described on pages 86 and 87.

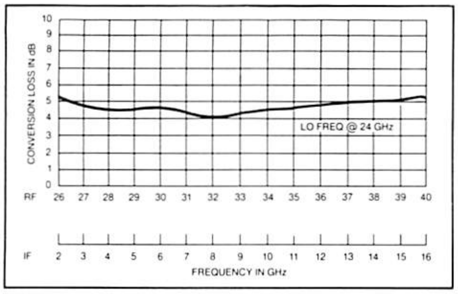


FIG. 5. PERFORMANCE OF Ka-BAND HYBRID MIXER.

Integrated Planar Cross-bar Mixer

The theory of operation of the dielectric loaded cross-bar mixer can be explained with reference to the schematic diagrams shown in Figures 6 and 7. The LO signal is injected through a waveguide to a suspended stripline transition and applied to the beam lead diodes with the polarity shown in Figure 7. The RF signal is applied directly from the waveguide to the diode pair. The IF signal is extracted via a microstripline etched on the same substrate.

The parts list for the dielectric cross-bar mixer is small: three metal blocks, substrate, RF short, LO short (optional) and diode pair. The IF preamplifier can be integrated into the same microstrip substrate following the low-pass filter. Diode location is not critical, since the LO signal is applied with the correct phase because it is fed through the center conductor of the stripline. The RF diplexer has been eliminated in this design. The RF waveguide dimensions are not critical; the most restrictive tolerances are imposed by the dimensional requirements of the output waveguide flange.

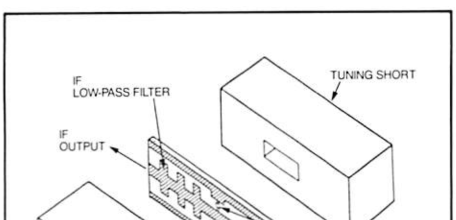


FIG. 6. SCHEMATIC DIAGRAM OF PLANAR CROSS-BAR MIXER.

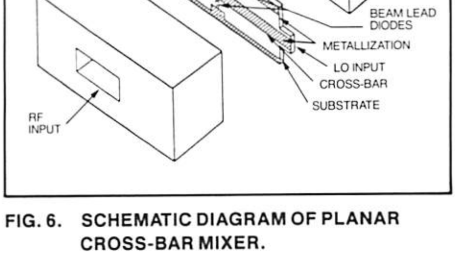


FIG. 7. DIODE POLARITY FOR BALANCED CROSS-BAR MIXER.

Electrically, the mixer is well matched at the RF and IF ports by virtue of the series connection of the diodes, as seen from the RF port, and the parallel connection as seen from the IF. It is also inherently broadband, as can be seen from the performance data shown in Figure 8. RF and LO tunability are achieved via tuning shorts. The mixer is normally self-biased, although it can be externally biased. This type of balanced mixer preamplifier is described in pages 84 and 85.

Balanced Upconverters

Single sideband upconverters manufactured with beam lead diodes are shown on pages 90 and 91. Upconversion provides a simple means of generating millimeter wave signals with complex wave forms, i.e., pulse to pulse frequency hopping, linear chirp, etc., by direct frequency translation of a low frequency signal. The availability of medium power diode amplifiers diminishes the importance of achieving high power upconversion directly. Besides having advantages of producibility, the beam lead planar upconverters offer the added advantage of being able to utilize broadband IFs.

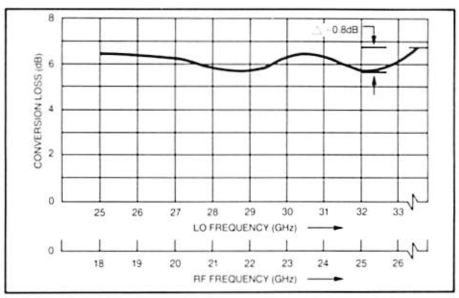


FIG. 8. PERFORMANCE OF PLANAR CROSS-BAR MIXER.

PIN DIODE PRODUCTS

PIN diodes are used in the control of millimeter wave power, e.g. attenuation, on/off switching, amplitude and phase modulation and phase shifting. The diode is either used to switch between two impedance states, so as to provide two different conditions of transmission and reflection, or as a continually variable impedance to achieve simple attenuation or amplitude modulation. The PIN diode is most commonly used for these applications because it can exhibit a very low impedance under forward bias and a nearly open circuit under reverse bias, which is an advantage for most control applications. There are a number of factors which must be considered in the choice of a particular device for a control function. In most cases, insertion loss is important. The diode cut-off frequency is a useful measure of this performance. Power handling is also important and some trade-off is generally required between power rating and the switching response time of the diode. Bi-phase and quadra-phase modulators using honeycomb PIN diodes have been built with multi-gigabit data rate capabilities. The power handling capability of these diodes, however, is limited to a hundred milliwatts. Beam lead and pill diodes TC bonded on copper heat sinks have been incorporated into switches with power handling capabilities of one watt CW and five watts peak. These switches are described on pages 102 through 105.

Etched pill PIN diodes have been TC bonded to diamond heat sinks and used in multi-diode receiver protectors capable of handling 200 watts peak power and 50 watts average power with less than 100 nanosecond recovery time and less than 2 dB insertion loss over 3-5% bandwidths in U-Band. A block diagram and picture of the unit is shown in Figures 9 and 10. The receiver protector was not pre-triggered externally and would activate automatically whenever the incident RF power exceeded a preset value. An incident power level monitor and a limiter control circuit were incorporated to achieve passive operation.

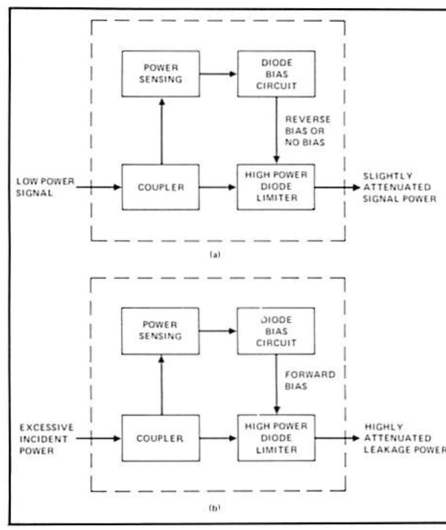


FIG. 9. FUNCTIONAL BLOCK DIAGRAM FOR THE RECEIVER PROTECTOR. (A) LOW POWER RECEPTION. (B) HIGH POWER PROTECTION.

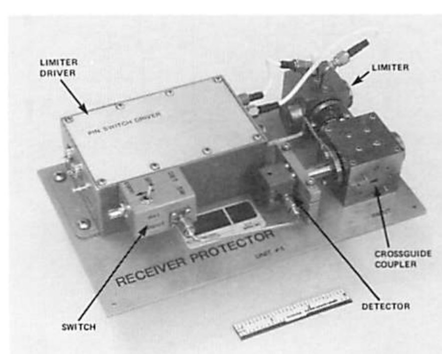
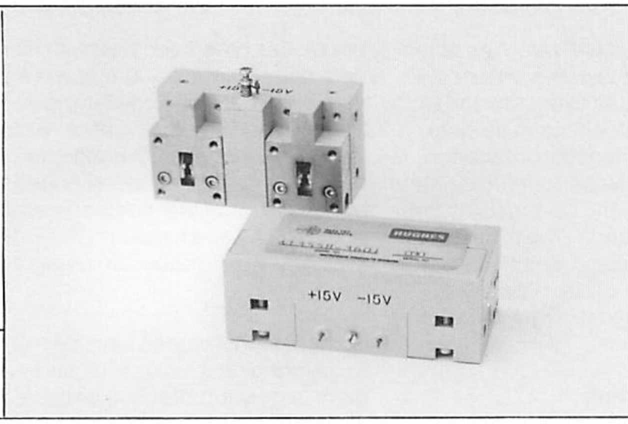


FIG. 10. A RECEIVER PROTECTOR WITH VARIOUS FUNCTIONAL COMPONENTS IDENTIFIED.

GaAs MESFET Low Noise Amplifiers



The Hughes series of mm-wave low noise amplifiers cover the frequency range of 18 to 40 GHz. These amplifiers are the lowest noise figure amplifiers available at these frequencies. The ultra low noise figure is made possible by the use of reliabl one-quarter micron gate length GaAs MESFETs fabricated by Hughes. High gain, low input and output VSWRs and high 1 dB compression point power levels are additional features of these amplifiers.

All amplifiers have waveguide input and output flanges. WR-42 waveguide is used for the 18 to 26.5 GHz range, and

FEATURES:

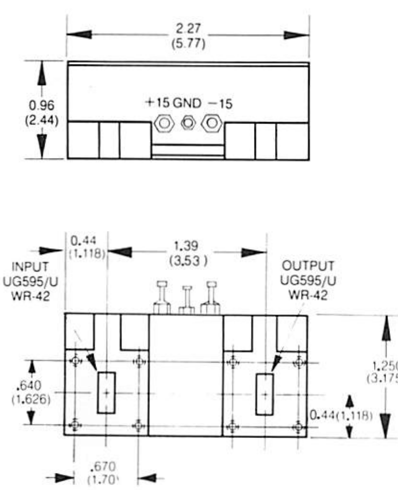
SPECIFICATIONS

Model No.	Frequency Range (GHz min)	Noise Figure (dB max)	Gain (dB min)	Gain Flatness (dB max)	1 dB Compression Point Power (dBm min)	VSWR In/Out (max)	Current @ + 15 Volts (mA max)	Outline Dwg.
A1335H-2001	18-22	3.5	25	± 2	+ 6	1.5:1	50	A
A1330H-2001①	18-22.5	3.0	25	± 1	+ 6	1.5:1	50	A
A1335H-2401①	21.5-26.5	3.5	25	± 1	+ 6	1.5:1	50	A
A1350H-3001	26.5-33	5.0	20	± 2	+ 7	1.5:1	50	B
A1360H-3601	33-40	6.0	16	± 2	+ 7	1.5:1	50	B
A1340H-2901①	27.5-31	4.0	22	± 1	+ 7	1.5:1	50	B
A1343H-3501	34.5-35.5	4.3	20	± .5	+ 7	1.5:1	50	B
A1452H-2221	18-26.5	5.2	25	± 2	+ 10	2.0:1	100	C

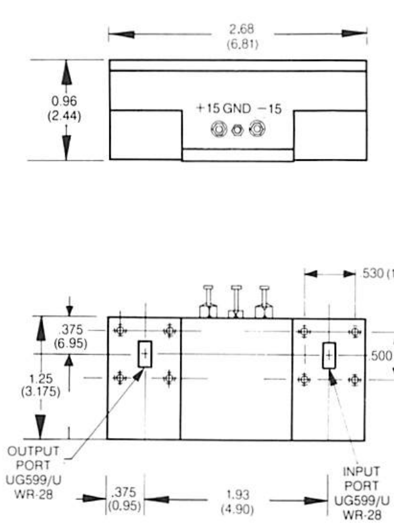
①Specify center frequency when ordering this unit. Bandwidth is 2 GHz anywhere within frequency range.

OUTLINE DRAWING

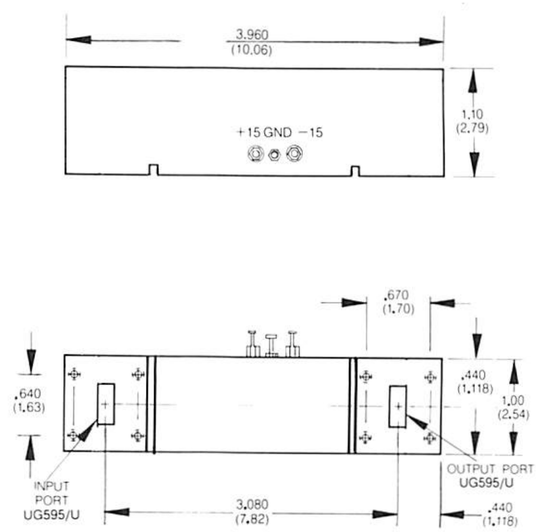
DRAWING A



DRAWING B



DRAWING C



DIMENSIONS ARE IN INCHES (CM)

WR-28 for the 26.5 to 40 GHz range. Specifications given are for room temperature (25°C), but the new LNAs operate over the full − 54°C to + 71°C temperature range. All amplifiers are hermetically sealed and have internal voltage regulation and reverse/over voltage protection. They require both positive and negative bias supplies of 15 volts. The negative supply draws a current level of typically 2 mA.

Application for these state-of-the-art amplifiers include communication receivers, radar receivers, and instrumentation where low system noise figure is important. Performance of low noise receivers can be dramatically improved by the addition of LNAs in front of the mixer assembly. In this configuration, the system noise figure is determined primarily by the GaAs MESFET LNA. In addition to the amplifiers shown on this page, special amplifiers and circuits, including unpackaged circuits, are available.

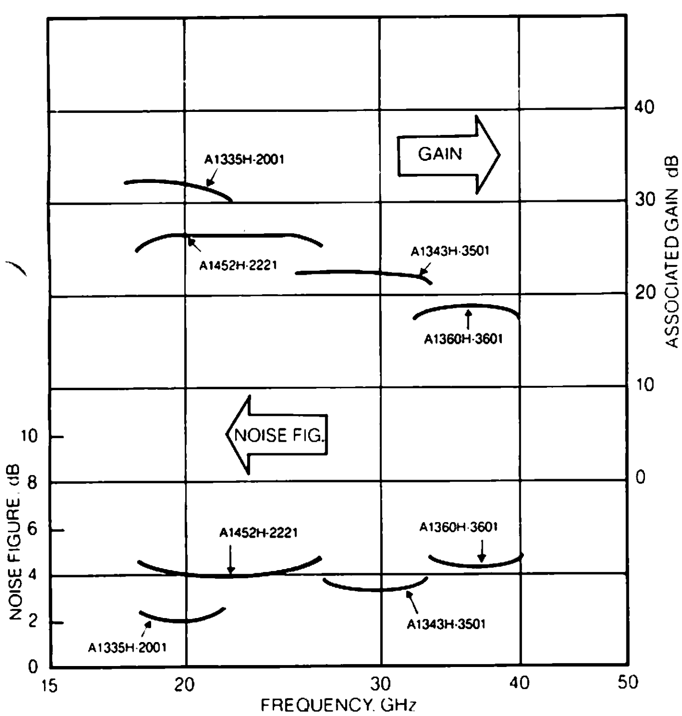
Contact Hughes Microwave Products Division, or your local Hughes representative for further details.

3.0 dB Max Noise Figure to 22.5 GHz

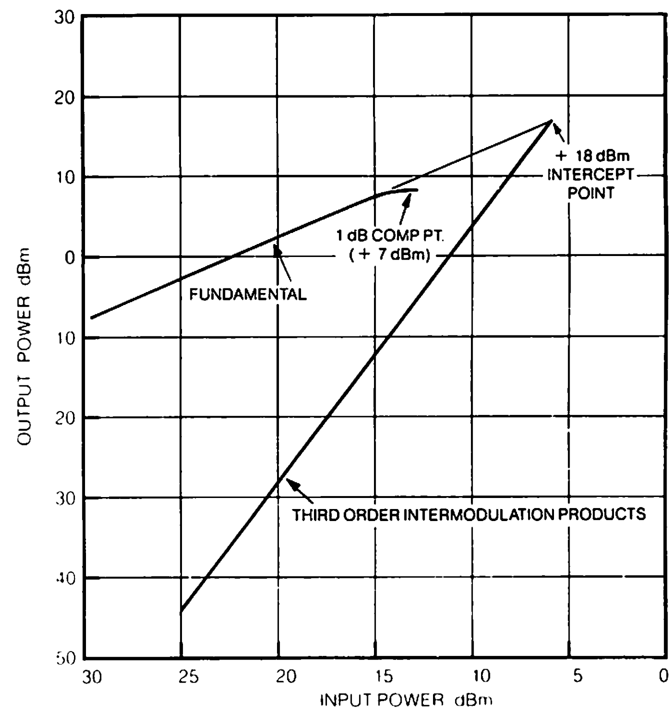
4.3 dB Max Noise Figure @ 35 GHz

TYPICAL PERFORMANCE CURVES

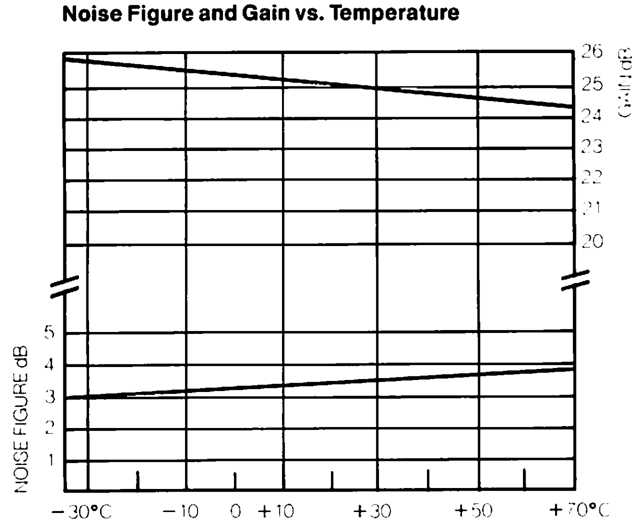
Noise Figure and Gain vs. Frequency



Gain Compression Characteristics

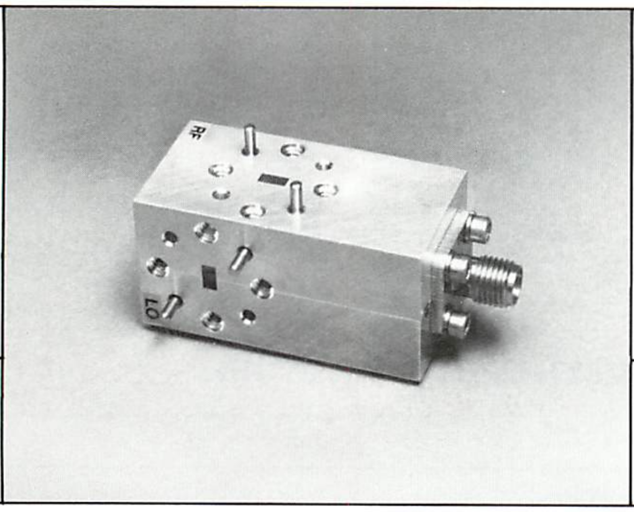


Noise Figure and Gain vs. Temperature



4

Broadband LO Balanced Mixers and IF Preamplifiers



Hughes series of broadband LO balanced mixers offer low flat conversion loss with LO frequency agility and IF frequencies as high as 6 GHz. They are combined with broadband connector coupled low noise amplifiers to provide state-of-the-art RF noise figures in seven waveguide bands from 18 to 150 GHz.

The use of Hughes GaAs beam lead diodes enables these mixers to offer significant advantages over the waveguide types. Besides their ability to provide state-of-the-art conversion losses over broadband IFs, these mixers are particularly adaptable to high volume production since only six

FEATURES:

SPECIFICATIONS

	RF Band (GHz)							
	18-26.5	26.5-40	40-50	50-60	60-90	90-110	130-140	130-150
Noise Figure (dB DSB max)								
10-510 MHz F	5.0	5.5	5.5	5.5	6.0	6.5	7.0	7.0
10-1010 MHz IF	5.0	5.5	5.5	5.5	6.0	6.5	7.0	7.0
1-2 GHz IF	6.0	6.5	6.5	6.5	7.0	7.5	8.0	8.0
2-4 GHz IF	6.5	7.0	7.0	7.0	7.5	8.0	8.5	8.5
2-6 GHz IF	7.5	8.0	8.0	8.0	8.5	9.0	9.5	9.5
Conversion Loss (without IF preamplifiers) (dB max)								
For IFs of 5 MHz to 6 GHz	5.5	5.5	6.0	6.0	6.5	7.0	7.5	7.5

RF Frequency . . . . Full Waveguide
RF Bandwidth . . . . Full Waveguide④
RF Input VSWR (max) 2:1
LO Frequency . . . . Full Waveguide
LO Bandwidth
K- through Q-Bands . . . . Full Waveguide
U- through F-Bands (GHz min) 10
Local Oscillator Drive Power (dBm typ) 13③
LO to RF Isolation (dB min) 20①
RF to IF Gain (dB min) (with preamp) 20
IF Frequency (GHz max) 6②
IF Output Impedance (Ohms nom) 50
IF Amp DC power . . . . 15 VDC @ 250 mA max
1 dB Input Compression Point (dBm typ) 9
Operating Temperature (specs apply at 25°C) . . . . 0 to +50°C 60
Waveguide and Flange . . . . see page 157

① An isolator is recommended at local oscillator output for optimum performance.
② For fullband RF LO tracking, maximum IF frequency is 2 GHz.
③ Lower drive level available, consult factory.
④ K- thru Q-bands only; all others 10 GHz minimum.

HOW TO ORDER (Specify Center Frequency and LO Frequency at time of order)

Model Number 4741xH-xx0x

Frequency Band
0: K
1: Ka
2: Q
3: U
4: V
5: E
6: W
7:F (available from 130 to 140 GHz only)
8:D (available from 130 to 150 GHz only)

Flange Type
1: Round (Ka- thru W-bands only)
2: Square (available in K- and Ka-bands only)

IF Preamplifier
0: without preamp①
2: 10-510 MHz
3: 10-1000 MHz
4: 1000-2000 MHz
5: 2000-4000 MHz
6: 2000-6000 MHz

0: Without LO
1: With LO (available through 110 GHz only. Specify LO frequency at time of order).

① Specify IF frequency and bandwidth at time of order.

EXAMPLE: To order a Ka-band Balanced Mixer-IF Preamplifier at 35 GHz with a square flange and an IF bandwidth of 10-510 MHz, with an LO, specify a 47411H-2201, center frequency 35 GHz, LO frequency 34.75 GHz.

parts, including the diodes, are used in their construction. They are very rugged by design and can operate over extremes in temperature.

The standard mechanical configurations can be modified to allow for special mounting configurations which might require a different physical relationship between LO, RF, and IF ports than shown. Also, in many cases specials can be supplied for other frequencies, bandwidths, and waveguide bands than those shown.

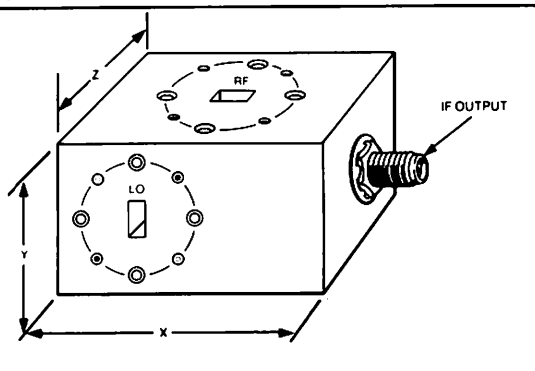
These mixers are available with integral matched Hughes Gunn diode local oscillators for best guaranteed performance. Other planar configurations such as the broadband IF balanced mixers described on pages 86 and 87 are also available. Consult the factory concerning your specific application.

Frequency Agile Local Oscillator

IF Bandwidths to 6 GHz

OUTLINE DRAWING

Dimensions

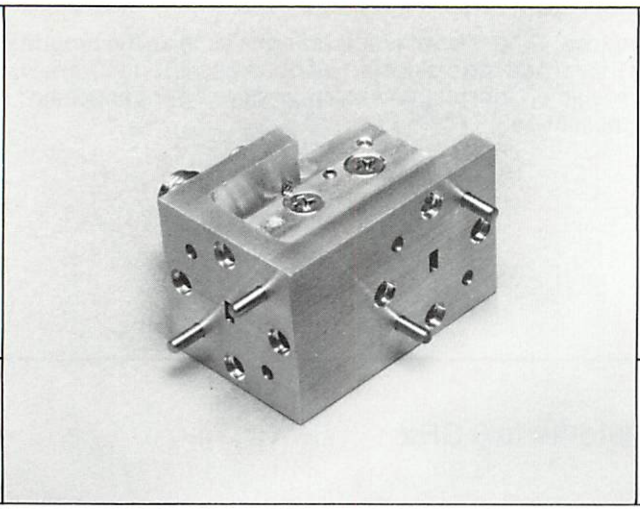


Freq. Band (GHz)	Dimensions (inches(cm))		
	x max① (includes 0.37 connector)	y	z
K (Sq) (18-26.5)	2.200 (5.59)	1.310 (3.33)	1.150 (2.92)
Ka (Sq) (26.5-40)	2.000 (5.59)	1.150 (2.92)	1.150 (2.92)
Ka (Rd) (26.5-40)	2.000 (5.59)	1.150 (2.92)	1.150 (2.92)
Q (33-50)	1.800 (4.57)	1.150 (2.92)	1.150 (2.92)
U (40-60)	1.700 (4.39)	1.150 (2.92)	1.150 (2.92)
V (50-75)	1.500 (3.81)	.780 (1.98)	.780 (1.98)
E (60-90)	1.400 (3.56)	.780 (1.98)	.780 (1.98)
W (75-110)	1.320 (3.35)	.780 (1.98)	.780 (1.98)
F (130-140)	.850 (2.16)	.750 (1.91)	.900 (2.29)
D (130-150)	.850 (2.16)	.750 (1.91)	.900 (2.29)

① Dimension is for unit without preamplifier. Preamplifiers are separately attached.

4

Broadband IF Balanced Mixers and IF Preamplifiers



Hughes series of broadband IF balanced mixers allow extremely broad RF bandwidths to be downconverted to IF bandwidths with a fixed frequency local oscillator. Full millimeter-wave waveguide bandwidths through W-band (75-110 GHz) can be downconverted to 5 MHz to 18 GHz by using a mid-band local oscillator and making use of both sidebands. This broad bandwidth capability makes these mixers ideal for both electronic warfare and instrumentation applications. They are also offered with connector coupled IF preamplifiers covering standard IF bandwidths up to 18 GHz. The Hughes GaAs beam lead Schottky barrier diodes

FEATURES:

SPECIFICATIONS

	RF Band (GHz)				
	18-26.5	26.5-50	50-60	60-95	95-110
Noise Figure (with IF preamplifier) (dB DSB max)					
10-510 MHz IF	5.5	5.5	6.0	6.5	7.5
10-1000 MHz IF	5.5	5.5	6.0	6.5	7.5
1-2 GHz IF	6.5	6.5	7.0	7.5	8.5
2-4 GHz IF	7.0	7.0	7.5	8.0	9.0
2-6 GHz IF	8.0	8.0	8.5	9.0	10.0
4-8 GHz IF	8.5	8.5	9.0	9.5	10.5
8-18 GHz IF	9.5	10.0	10.5	11.0	11.5
Conversion Loss (without IF preamplifiers) (dB max)					
5 MHz-6 GHz	5.5	5.5	5.5	6.0	7.0
4-8 GHz IF	5.5	5.5	6.0	6.5	7.5
8-18 GHz IF ②④	6.0	6.5	7.0	7.5	8.0

RF Frequency .... Full Waveguide
RF Bandwidth .... Full Waveguide
RF Input VSWR (max) 2:1
LO Frequency .... Full Waveguide
LO Bandwidth (max) .... 5% of LO Center Frequency ⑤
Local Oscillator Drive Power (dBm typ) ①③ 13
LO to RF Isolation (dB min) 20
RF to IF Gain (dB min) (with preamp) 20
IF Output Impedance (Ohms nom) 50
DC Input Voltage (V typ) 15
DC Input Current (mA typ) 200
Operating Temperatures (specs apply at 25°C) .... 0 to +60°C ~~−55 to +70°C~~
Waveguide and Flange .... see page 157

① An isolator is recommended at local oscillator output for optimum performance. ② Higher IF's available—contact factory. ③ Lower drive level available—contact factory. ④ In K-band, the LO and min RF frequency MUST BE AT LEAST 5 GHz ABOVE the max IF frequency. ⑤ 1 to 6 GHz depending on LO band.

HOW TO ORDER (Specify Center Frequency and Local Oscillator Frequency at time of order)

Model Number 4741xH-xx1x

Frequency Band	0: K, 1: Ka, 2: Q, 3: U, 4: V, 5: E, 6: W
Flange Type	1: Round (Ka thru W-bands only); 2: Square (available in K- and Ka-bands only)
IF Preamplifier	0: without preamp ②; 2: 10-510 MHz; 3: 10-1000 MHz; 4: 1-2 GHz; 5: 2-4 GHz; 6: 2-6 GHz; 7: 4-8 GHz; 8: 8-18 GHz
Local Oscillator	0: LO Port in RF band; 1: With LO source in RF band included ①; 2: LO Port in upper waveguide band ③; 3: With LO source in upper waveguide band included ①③; 4: LO Port in lower waveguide band ④; 5: With LO source in lower waveguide band included ①④

① Specify LO frequency at time of order.
② Specify IF bandwidth at time of order.
③ Not available on W-band mixers.
④ Not available on K-band mixers.

EXAMPLE: To order a full waveguide bandwidth Q-band mixer using a LO above the band, specify a 47412H-1012 with LO frequency equal to 50.5 GHz.

used in these hybrid balanced mixer structures along with the low noise preamplifiers allow single sideband noise figures below 10 dB to be achieved over 10 GHz wide millimeter-wave bandwidths.

Like the planar crossbar types, these mixers are particularly adaptable to high volume production since only six parts, including the diodes, are used in their construction. They are also extremely rugged and can operate over extremes in temperature.

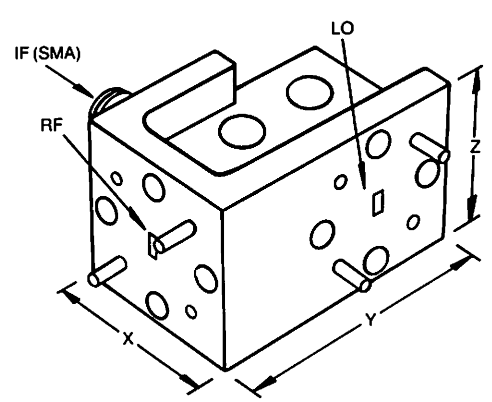
These hybrid balanced mixers offer the option of having LO ports available in waveguide bands both above and below the RF band as well as within the RF band. Hughes Gunn diode oscillators may be ordered as matched integral local oscillators for best guaranteed performance. Consult the factory for special cases such as incorporating phase-locked local oscillators, special mechanical configurations, or other frequencies, bandwidths, and waveguide bands than those shown. Also, see Hughes planar crossbar mixers described on pages 84 and 85, and Hughes waveguide balanced mixer-IF preamplifiers described on pages 88 and 89.

Full Waveguide RF Bandwidth

IF Bandwidth—5 MHz to 18 GHz

OUTLINE DRAWING

Maximum Dimensions for Balanced Mixer

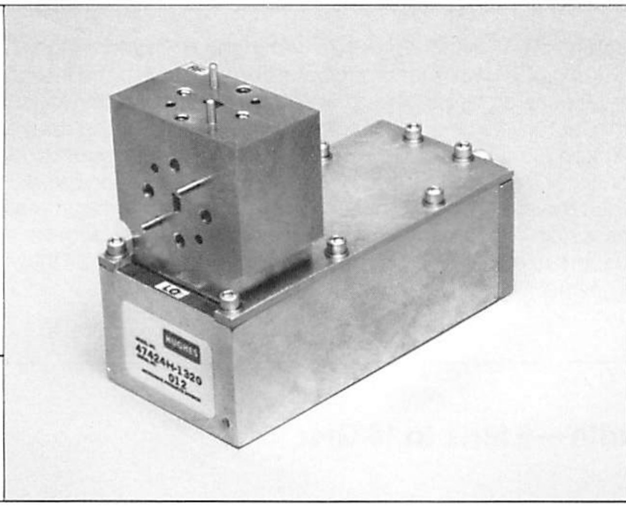


Freq. Band (GHz)		Dimensions (inches (cm))		
RF Band	LO Band	X max	Y max	Z max①
K (Sq)	K (Sq)	1.190 (3.02)	1.890 (4.80)	.880 (2.24)
K (Sq)	Ka (Sq)	1.090 (2.77)	1.780 (4.52)	.880 (2.24)
Ka (Sq)	K (Sq)	1.030 (2.62)	1.690 (4.30)	.880 (2.24)
Ka (Sq)	K (Sq)	1.030 (2.62)	1.940 (4.93)	.880 (2.24)
Ka (Sq)	Ka (Sq)	1.000 (2.54)	1.550 (3.94)	.750 (1.91)
Ka (Sq)	Ka (Sq)	1.000 (2.54)	1.610 (4.09)	.750 (1.91)
Ka (Rd)	Ka (Rd)	1.130 (2.87)	1.740 (4.42)	1.130 (2.87)
Ka (Rd)	Ka (Rd)	1.130 (2.87)	1.800 (4.58)	1.130 (2.87)
Ka (Rd)	Q	1.130 (2.87)	1.740 (4.42)	1.130 (2.87)
Q	Ka (Rd)	1.130 (2.87)	1.740 (4.42)	1.130 (2.87)
Q	Q	1.130 (2.87)	1.640 (4.17)	1.130 (2.87)
Q	U	1.130 (2.87)	1.640 (4.17)	1.130 (2.87)
U	Q	1.130 (2.87)	1.640 (4.17)	1.130 (2.87)
U	U	1.130 (2.87)	1.565 (3.98)	1.130 (2.87)
U	V	1.130 (2.87)	1.375 (3.49)	1.130 (2.87)
V	U	.800 (2.03)	1.465 (3.72)	1.130 (2.87)
V	V	.800 (2.03)	1.200 (3.05)	.750 (1.91)
V	E	.800 (2.03)	1.200 (3.05)	.750 (1.91)
E	V	.750 (1.91)	1.200 (3.05)	.750 (1.91)
E	E	.750 (1.91)	1.200 (3.05)	.750 (1.91)
E	W	.750 (1.91)	1.200 (3.05)	.750 (1.91)
W	E	.750 (1.91)	1.150 (2.92)	.750 (1.91)
W	W	.750 (1.91)	1.150 (2.92)	.750 (1.91)

①Dimension is for unit without preamplifier. Preamplifiers are separately attached. Add 0.38 inch to X for SMA connector.

4

Waveguide Balanced Mixers and IF Preamplifiers



Hughes Waveguide Balanced Mixer-IF Preamplifiers are available at frequencies from 26.5 to 110 GHz. Featured in this broad variety of mixer-IF preamplifiers is their low noise figure, high LO noise suppression, and low LO-to-RF leakage. The noise figures have been tabulated for some standard IF bandwidths up to 1 GHz. For higher bandwidths, see our planar balanced mixer preamplifiers on pages 84 through 87.

These rugged units utilize Hughes silicon or GaAs Schottky barrier diodes which can be replaced by the customer in a microwave laboratory. These diodes have been successfully

NOISE FIGURE (DSB)

GaAs

Silicon

SPECIFICATIONS

NOISE FIGURE	
10-110 MHz IF	From Table
10-510 MHz IF	From Table +0.5 dB
10-1000 MHz IF	From Table +1.0 dB
INSTANTANEOUS RF BANDWIDTH (% min)	4
RF INPUT VSWR (max)	2:1
LOCAL OSCILLATOR DRIVE POWER, SILICON (dBm typ)	+5
LOCAL OSCILLATOR DRIVE POWER, GaAs (dBm typ)	+10
RF-TO-LO ISOLATION (dB min)	20
LO NOISE SUPPRESSION (dB typ)	35
RF-TO-IF GAIN (dB min)	20
IF OUTPUT IMPEDANCE (ohms nom)	50
DC INPUT VOLTAGE (V typ)	+15
DC CURRENT REQUIRED (mA typ)	30-50
OPERATING AMBIENT TEMPERATURE (°C, specifications apply at 25 °C)	20-50①
WAVEGUIDE AND FLANGE	See page 157

① When ordered with Local Oscillator, heatsinking must be provided to keep the case temperature of the oscillator within specified limits.

HOW TO ORDER (Specify Center Frequency and LO frequency at time of order)

BALANCED MIXER . . . 4742xH-xxxx

REPLACEMENT
DIODE WAFER SET . . . 4739xH-00x0

Frequency Band
- **1**: Ka
- **4**: V
- **6**: W

Flange Type
- **1**:Round
- **2**:Square (available in Ka-band only)

IF Bandwidth
- **0**:without preamp
- **1**:10-110 MHz
- **2**:10-510 MHz
- **3**:10-1000 MHz

- **0**: Without LO
- **1**: With LO (available through 100 GHz only. Specify LO frequency at time of order.)

Diode Type
- **1**:Silicon
- **2**:GaAs (available in V and W-bands only)

EXAMPLE: To order a Ka-band Balanced Mixer-IF Preamplifier at 35 GHz with a square flange and an IF bandwidth of 10-510 MHz, with an LO, specify a 47421H-2211, center frequency 35 GHz, LO frequency 34.75 GHz.

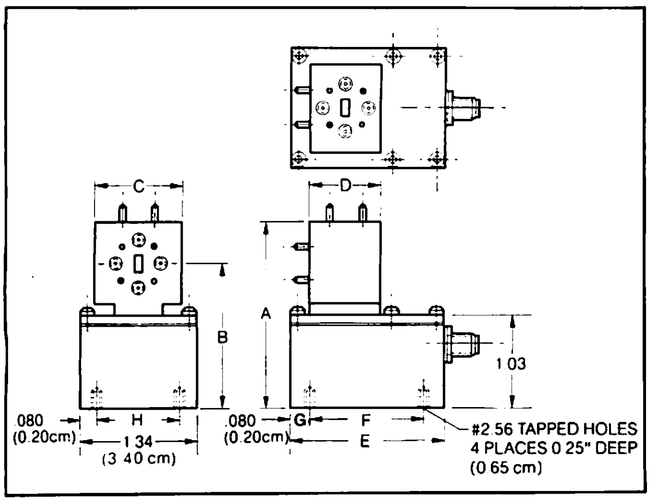
used in many military and space qualified receiver and radiometer applications. Since 1970 they have accumulated over one and a half million operating hours without a relevant failure.

The units with silicon diodes require low local oscillator power of about +5 dBm. Units with GaAs diodes require about +10 dBm. For certain applications where this much power is not available, provisions may be made for externally biasing the diodes. Special diagnostic outputs can also be made available on request. Very low noise discrete component preamplifiers are used. These balanced mixers are also offered without the integral IF preamplifier.

Hughes low noise Gunn local oscillators may be purchased with these mixers. They are tested as an integrated mixer-LO subassembly.

FREQUENCY (GHz)			
(26.5-40)	(50-60)	(60-95)	(95-110)
—	**4.5 dB**	**4.5 dB**	**5.0 dB**
4.5 dB	**5.0 dB**	**5.5 dB**	**6.0 dB**

OUTLINE AND MOUNTING DRAWINGS



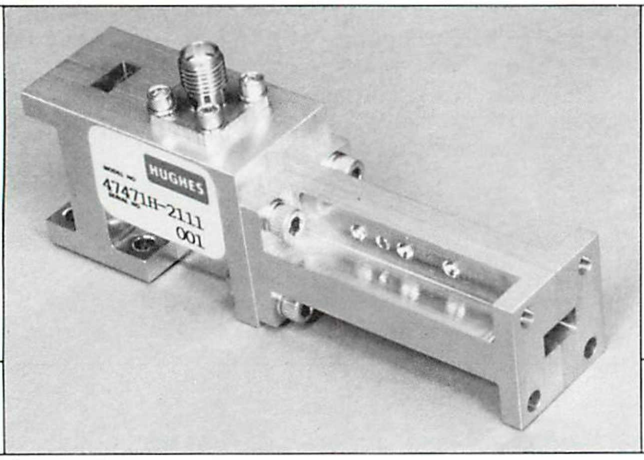
DIMENSIONS, WAVEGUIDE SIZES AND FLANGES		FREQUENCY BAND (GHz)		
		Ka (26.5-40)	V (50-75)	W (75-110)
DIMENSIONS (inches (cm))	A	2.81 (7.14)	2.19 (5.56)	2.13 (5.41)
	B	2.02 (5.13)	1.59 (4.04)	1.53 (3.89)
	C	2.03 (5.16)	1.24 (3.15)	0.99 (2.51)
	D	1.14 (2.90)	0.81 (2.06)	0.81 (2.06)
WAVEGUIDE SIZE①		WR-28	WR-15	WR-10
WAVEGUIDE FLANGE①		UG-381/U② UG-599/U③	UG-385/U	UG-387/U Mod

① Refer to page 157 for specifications and MIL specification cross reference. ② Round flange ③ Square flange

IF BANDWIDTH (MHz)	DIMENSIONS (inches (cm))			
	E	F	G	H
10-110	2.34 (5.94)	1.67 (4.24)	0.25 (.64)	1.18 (3.0)
10-510	2.34 2(5.94)	1.67 (4.24)	0.25 (.64)	1.18 (3.0)
10-1000	2.34 (5.94)	1.67 (4.24)	0.25 (.64)	1.18 (3.0)
WITHOUT IF PREAMPLIFIER	1.63 (4.14)	0.95 (2.41)	0.25 (.64)	1.18 (3.0)

4

Up-Converters



Hughes Single Sideband Up-Converters are available with RF outputs from 18 through 150 GHz in 9 waveguide bands. The units are available with IF frequencies from 1 through 10 GHz depending on the RF band. Any in band local oscillator can be used and must be specified at time of order (see exceptions below).

Two signals (IF and LO) are applied to the Up-Converter. The RF Output is the sum or difference of the IF and LO frequency ($F_{IF} \pm f_{LO} = f_{RF}$). Power outputs of +4dBm SSB are guaranteed when the Up-Converters are driven by 50mW IF and a 50mW LO signal. A conversion flatness of ±1 to

POWER OUTPUT

SPECIFICATIONS

	SSB (with filter)	DSB (without filter)
RF Output power① (dBm min)	+4.0	+8.0
RF Output frequency (min)④	2 GHz from LO freq	No Restrictions
RF Output Bandwidth (max)	15% of RF center freq②③	No Restrictions
Conversion flatness over RF Bandwidth (dB max):		
BW: 2 GHz or less	±1.0	±1.0
BW: 2 to 4 GHz	±1.5	±1.5
BW: Larger than 4 GHz	±2.0	±2.0
1 dB Output Compression Point (dBm typ @ +17 dBm LO)	+10.0	+10.0
Third Order Output Intercept Point (dBm typ)	+20.0	+20.0
IF Bandwidth (GHz max)	15% of RF center freq③	18.0
IF VSWR (typ)	2:1	2:1
IF Input Power (dBm typ)	+17.0	+17.0
LO Power (dBm typ)	+17.0	+17.0
LO Power (dBm min)	+13.0	+13.0
Combined LO & IF Power (dBm max)	+20.0	+20.0
LO VSWR (typ)	2:1	2:1
LO to RF Isolation (dB min)	30.0	20.0
Image Rejection (dB min)	40.0	None
LO Frequency (min)	2 GHz from min RF freq	No Restrictions
LO Bandwidth (max)	5% OF LO CENTER FREQUENCY⑤	
Operating Temperature (specs apply at 25°C)	~~−55°C to 70°C~~ 0 to +60°C	

① Minimum output power is guaranteed at customer specified RF frequency with +17 dBm applied to both LO and IF ports.
② Minimum filter bandwidth is 2% of RF center frequency.
③ 1 to 10 GHz depending on the RF band.
④ In K-band the LO and minimum RF frequency MUST BE AT LEAST 5 GHz ABOVE the maximum IF frequency.
⑤ 1 to 6 GHz depending on LO band.

HOW TO ORDER (Specify IF, RF, and LO frequencies and bandwidths at time of order)

Model Number 4747xH-xx3x

Frequency Band
- **0**: K
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **5**: E
- **6**: W
- **7**: F (available from 130 to 140 GHz only)
- **8**: D (available from 130 to 150 GHz only)

Flange Type
- **1**: Round (Ka- thru D-bands only)
- **2**: Square (K- and Ka-bands only)

RF Output
- **1**: SSB (with filter)
- **2**: DSB (without filter)

Local Oscillator
- **0**: LO port in RF band
- **1**: With LO source in RF band included①
- **2**: LO port in upper WG band②
- **3**: With LO source in upper WG band included①②
- **4**: LO port in lower WG band③
- **5**: With LO source in lower WG band included①③

① Available thru 110 GHz only
② Not available on F- & D-bands
③ Not available on K-, F- and D-bands

EXAMPLE: To order an up-converter to convert a 3 GHz ±100 MHz signal to a 94 GHz signal, specify a Hughes model #47476H-1131. IF frequency = 3 GHz ±100 MHz, LO frequency = 91 GHz. RF frequency = 94 GHz. (with SSB filter).

±2 dB is typical depending on bandwidth. Small signal conversion loss will be between 7 and 10 dB depending on RF and IF power levels (see performance characteristics).

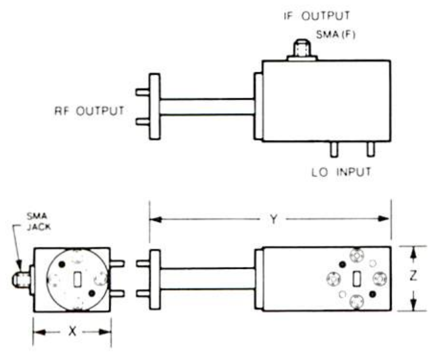
The Up-Converter consists of a planar balanced mixer and can be provided with a bandpass filter as illustrated in the block diagram. When using the filter, LO/RF isolation and rejection of the unwanted sideband is greater than 30dB. A planar crossbar balanced mixer is used for F and D bands.

In addition to the Up-Converters shown, other configurations are available. Contact Hughes or your local representative with your specific requirements.

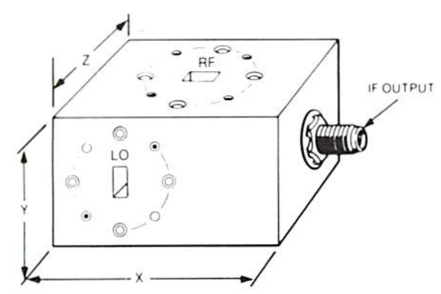
+ 4dBm minimum SSB (18-150 GHz)

OUTLINE AND MOUNTING DRAWING

K thru W Band



F & D Bands (Shown without filter)

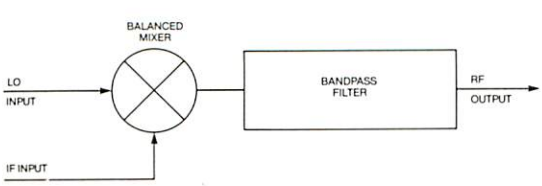


Freq. Band (GHz)		Dimensions (inches (cm))		
RF Band	LO Band	X max	Z max	Y max
K (Sq)	K (Sq)	1.190(3.02)	.880 (2.24)	4.390 (11.15)
K (Sq)	Ka (Sq)	1.090 (2.77)	.880 (2.24)	4.280 (10.87)
Ka (Sq)	K (Sq)	1.030 (2.62)	.880 (2.24)	3.190 (8.10)
Ka (Sq)	K (Sq)	1.030 (2.62)	.880 (2.24)	3.440 (8.74)
Ka (Sq)	Ka (Sq)	1.000 (2.54)	.750 (1.91)	3.050 (7.75)
Ka (Sq)	Ka (Sq)	1.000 (2.54)	.750 (1.91)	3.110 (7.90)
Ka (Rd)	Ka (Rd)	1.130 (2.87)	1.130 (2.87)	3.240 (8.23)
Ka (Rd)	Ka (Rd)	1.130 (2.87)	1.130 (2.87)	3.300 (8.38)
Ka (Rd)	Q	1.130 (2.87)	1.130 (2.87)	3.240 (8.23)
Q	Ka (Rd)	1.130 (2.87)	1.130 (2.87)	3.240 (8.23)
Q	Q	1.130 (2.87)	1.130 (2.87)	3.140 (7.98)
Q	U	1.130 (2.87)	1.130 (2.87)	3.140 (7.98)
U	Q	1.130 (2.87)	1.130 (2.87)	3.140 (7.98)
U	U	1.130 (2.87)	1.130 (2.87)	3.065 (7.79)
U	V	1.130 (2.87)	1.130 (2.87)	2.875 (7.30)
V	U	.800 (2.03)	1.130 (2.87)	2.465 (6.26)
V	V	.800 (2.03)	.750 (1.91)	2.200 (5.59)
V	E	.800 (2.03)	.750 (1.91)	2.200 (5.59)
E	V	.750 (1.91)	.750 (1.91)	2.200 (5.59)
E	E	.750 (1.91)	.750 (1.91)	2.200 (5.59)
E	W	.750 (1.91)	.750 (1.91)	2.200 (5.59)
W	E	.750 (1.91)	.750 (1.91)	2.150 (5.46)
W	W	.750 (1.91)	.750 (1.91)	2.150 (5.46)
F	F	.850 (2.16)	.900 (2.29)	1.750 (4.45)
D	D	.850 (2.16)	.900 (2.29)	1.750 (4.45)

Refer to Page 157 for W/G and Flange Sizes

BLOCK DIAGRAM

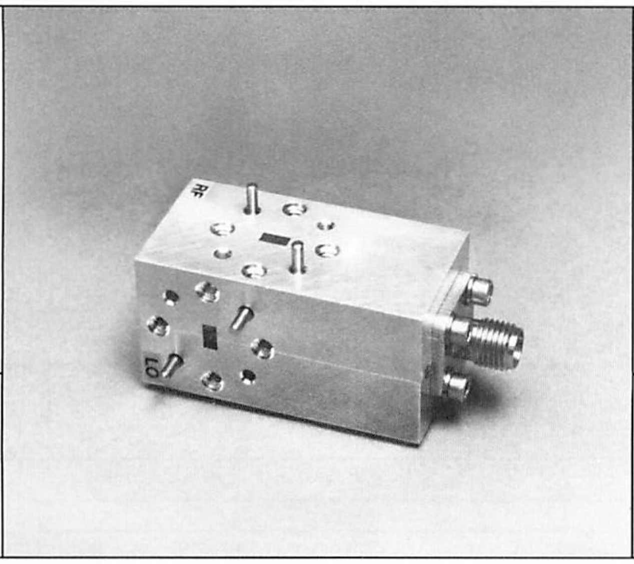
Single Sideband Up-Converter



PERFORMANCE CHARACTERISTICS

Typical Input-Output Characteristics

Balanced Phase Detectors



Hughes 4749xH series of Balanced Phase Detectors enable phase comparision of two RF signals. These detectors are particularly adaptable to high volume production as only six parts, including the diodes, are used in their construction. They are very rugged by design and can operate over extremes in temperature.

Careful matching of the diodes provides isolation between RF ports, low DC offset, noise cancellation and suppression of adverse effect of amplitude modulation. The detected output will be proportional to phase differences up to 180°

FEATURES:

HOW TO ORDER

(Specify center frequency at time of order)

Model Number 4749xH-x100

Frequency Band	**0**: K **1**: Ka **2**: Q **3**: U **4**: V **5**: E **6**: W	**7:**F **8:**D (Available from 130 to 150 GHz only)
Flange Type	**1**: Round **2**: Square (available in K- and Ka-band only)	

Example: To order a Ka-Band Balanced Phase Detector with Square Flange, specify 47491H-2100, center frequency 32 GHz.

for two equal amplitude signals at the same frequency.

This balanced phase detector is the key element of a phase bridge and can also be used in a receiver for phase modulated systems.

Linear Transfer Characteristics

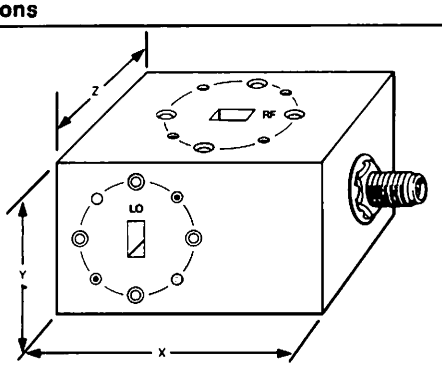
SPECIFICATIONS

	Waveguide Bank (GHz) ①								
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (130-150)
Bandwidth (typ)②	4	4	4	4	4	4	4	4	4
Sensitivity (mV/°typ)③	5	5	5	5	4	3	3	3	3
RF Isolation (dB typ)	20	20	20	20	20	20	20	20	20
AM Supression (dB typ)	20	20	20	20	20	20	20	20	20

① Frequency of operation must be specified at time of order.
② At 5 dBm input into each port with 1 MegOhm output load.
③ Minimum signal levels Ka thru U −15dBm and V thru D −5dBm

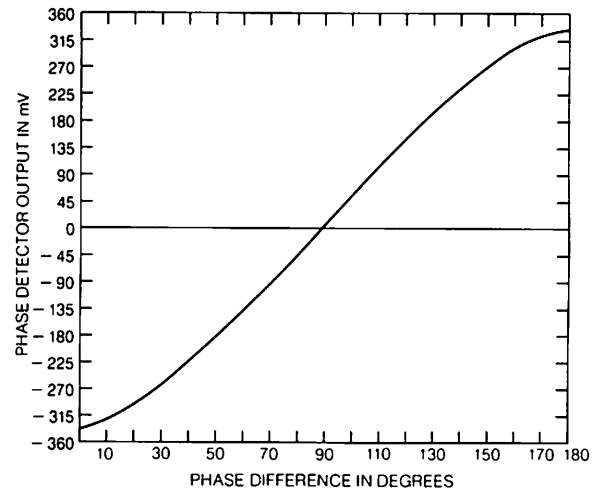
OUTLINE DRAWING

Dimensions

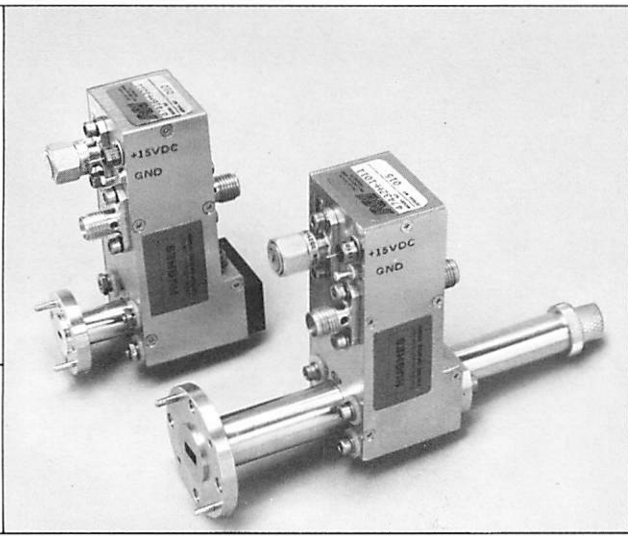


Freq. Band (GHz)	Dimensions (inches(cm))		
	x max (includes 0.37 connector)	y	z
K (Sq) (18-26.5)	2.200 (5.59)	1.310 (3.33)	1.150 (2.92)
Ka (Sq) (26.5-40)	2.000 (5.59)	1.150 (2.92)	1.150 (2.92)
Ka (Rd) (26.5-40)	2.000 (5.59)	1.150 (2.92)	1.150 (2.92)
Q (33-50)	1.800 (4.57)	1.150 (2.92)	1.150 (2.92)
U (40-60)	1.700 (4.39)	1.150 (2.92)	1.150 (2.92)
V (50-75)	1.500 (3.81)	.780 (1.98)	.780 (1.98)
E (60-90)	1.400 (3.56)	.780 (1.98)	.780 (1.98)
W (75-110)	1.320 (3.35)	.780 (1.98)	.780 (1.98)
F (90-140)	.850 (2.16)	.750 (1.91)	.900 (2.29)
D (130-150)	.850 (2.16)	.750 (1.91)	.900 (2.29)

TYPICAL TRANSFER CHARACTERISTICS W-BAND



Harmonic Mixers



Hughes Harmonic Mixers offer a simple and direct way of downconverting millimeter-waves with a low frequency local oscillator. Downconversion is accomplished by mixing the millimeter-wave signal with the appropriate harmonic of the LO generated in the mixer itself. This eliminates the need for multiplier chains. The Harmonic Mixers are available either as tunable partial waveguide bandwidth types or as flat full waveguide bandwidth units.

The highly reliable Schottky barrier diode is capable of handling up to 100 mW of combined RF and LO power without damage. Lowest conversion loss typically occurs

CONVERSION LOSS ①

SPECIFICATIONS

CONVERSION LOSS TUNABLE UNIT (dB typ) .... From Table
CONVERSION LOSS (BROADBAND UNIT)
 (dB typ) .... From Table +5 dB
L.O. FREQUENCY (GHz) 2-4, 4-8, 8-15①
MAXIMUM COMBINED RF AND LO POWER
 WITHOUT DAMAGE (mW) 100
IF BANDWIDTH (MHz)
 WITH PREAMPLIFIER 10-500①
 NON-PREAMPLIFIER
  2-4 GHz LO 10-500
  4-8 GHz LO 10-1000
  8-15 GHz LO 10-2000
BIAS FOR 25 dB GAIN PREAMPLIFIER (volts/ma max) 15/50
OPERATING TEMPERATURE (°C ambient)
 (Specifications apply at 25 °C) 20-50
WAVEGUIDE AND FLANGE .... See page 157

① Other LO and IF frequencies available on request. Highest IF frequency available with an internal IF preamplifier is 2.0 GHz.

HOW TO ORDER

BROADBAND 4744xH-x0xx
TUNABLE 1 .... 4743xH-x0xx

Frequency Band
- **0**: K
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **5**: E
- **6**: W
- **7**: F
- **8**: D
- **9**: G (not available for tunable models)

Flange
- **1**: Round (Ka- thru G-bands only)
- **2**: Square (K- and Ka-bands Only)
- **3**: Pin Contact (F-, D-, and G-bands only)

LO Frequency
- **0**: 2-4 GHz
- **1**: 4-8 GHz
- **2**: 8-15 GHz

IF PREAMPLIFIER
- **0**: Without
- **1**: With

① Instantaneous bandwidth of 4743xH tunable mixer is typically 100 MHz.

EXAMPLE: To order a tunable W-band Harmonic Mixer, with an integral IF preamplifier with 4-8 GHz LO, specify a 47436H-1011.

with LO powers of 40 to 50 mW.

An integral IF preamplifier is offered as an option with typical gain of 25 dB over a bandwidth of 10-500 MHz.

Harmonic mixers are particularly suited for phase-lock loop applications where millimeter-wave sources need to be referenced to a crystal-controlled oscillator. They can be used with a low frequency local oscillator and a microwave spectrum analyzer as a millimeter-wave spectrum analyzer.

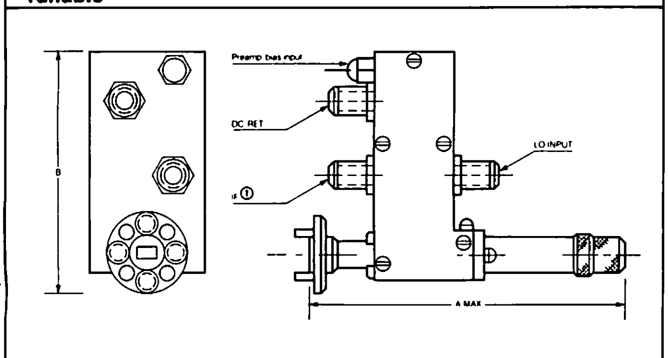
Further, a millimeter-wave counter can be implemented by using a local oscillator/harmonic mixer combination with a microwave frequency counter.

FREQUENCY BANDS (GHz)									
K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
15 dB	**16 dB**	**18 dB**	**19 dB**	**21 dB**	**24 dB**	**29 dB**	**35 dB**	**41 dB**	**45 dB**

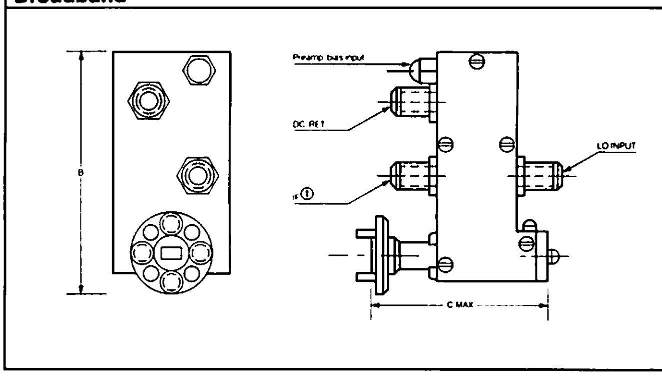
① Conversion loss numbers are typical for the midband frequency with 40 to 50 mW of LO power and harmonic mixing numbers of 8 or less at frequencies up to 100 GHz on units without preamplifier.

OUTLINE AND MOUNTING DRAWINGS

Tunable



Broadband

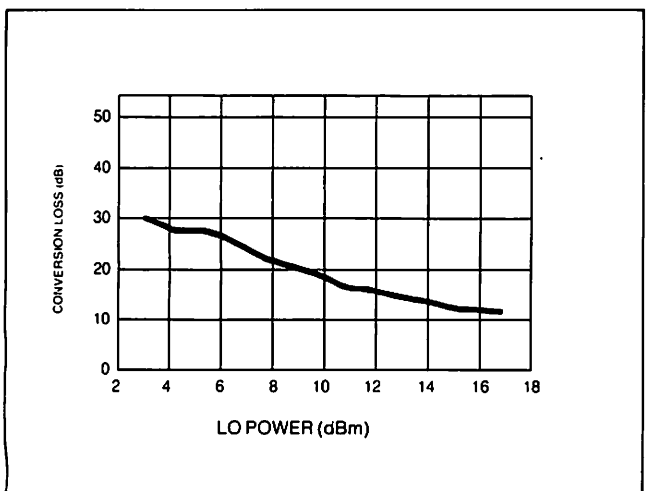


①IF output port is on opposite side (same side as LO Input) when unit is ordered without preamp.

DIMENSIONS (inches (cm))	FREQUENCY BAND (GHz)									
	K	Ka②	Q②	U②	V②	E	W	F	D	G
	(18-26)	(26.5-40)	(33-50)	(40-60)	(50-75)	(60-90)	(75-110)	(90-140)	(110-170	(140-220)
A	3.38 (8.59)	3.97 (10.08)	4.00 (10.16)	3.72 (9.45)	3.07 (7.80)	2.93 (7.44)	2.88 (7.32)	2.87 (7.29)	2.87 (7.29)	2.87 (7.29)
B	2.62 (6.65)	2.62 (6.65)	2.62 (6.65)	2.62 (6.65)	2.43 (6.17)	2.43 (6.17)	2.43 (6.17)	2.43 (6.17)	2.43 (6.17)	2.43 (6.17)
C	1.87 (4.75)	2.46 (6.25)	2.49 (6.32)	2.21 (5.61)	1.96 (4.98)	1.82 (4.62)	1.77 (4.50)	1.76 (4.47)	1.76 (4.47)	1.76 (4.47)

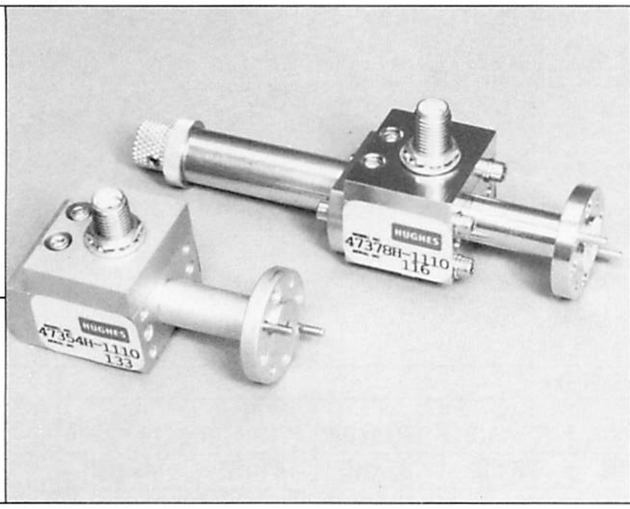
② Shorter units may be supplied. Consult factory if required.

TYPICAL PERFORMANCE CURVE



Typical Conversion Loss vs. LO Power for a Tunable U-band Unit at 52 GHz with the LO at 12.938 GHz, the IF at 250 MHz, and a harmonic mixing number of 4.

Single Ended Mixers



Hughes Single-Ended Mixers are available in either Narrowband Fixed Tuned, Broadband Fixed Tuned or Tunable configurations. The Tunable Mixers can be tuned over the full waveguide bandwidths from 18.0 to 170 GHz. The Narrowband Mixers are tuned for optimum performance at a specified frequency. The Broadband Mixers are tuned for operation over a full waveguide bandwidth. Both the Broadband and Narrowband Mixers are offered in waveguide bandwidths from 18 to 220 GHz.

CONVERSION LOSS

GaAs

Silicon

SPECIFICATIONS

	Narrowband Mixer	Tunable Mixer	Broadband Mixer
CONVERSION LOSS (dB typ)	From Table	From Table +1 dB	From Table +4 dB
INSTANTANEOUS BANDWIDTH (%)	10	10	full waveguide bandwidth
TUNING BANDWIDTH (GHz min)	—	full waveguide bandwidth	—
MAXIMUM CW RF POWER WITHOUT DAMAGE (LO & Signal) (mW)	100	100	100
AMBIENT OPERATING TEMPERATURE (°C) (Specifications apply at 25°C)	20-50	20-50	20-50
WAVEGUIDE AND FLANGE	See page 157	See page 157	See page 157

HOW TO ORDER

NARROWBAND MIXER (Specify Center Frequency. . . .4736xH-xxx0
TUNABLE MIXER 4737xH-xxx0
BROADBAND MIXER 4735xH-xxx0
MIXER REPLACEMENT DIODE (for any of above) 4739xH-0xx0

Frequency Band
0: K
1: Ka
2: Q
3: U
4: V
5: E
6: W
7: F
8: D
9: G (not available for tunable mixers)

Flange Type
1: Round (Ka- through G-bands only)
2: Square (available in K- and Ka-band only)
3: Pin Contact (F-, D-, and G-bands only)

Polarity ① **1**: Positive (grounded anode)
2: Negative (grounded cathode)

Diode Type
1: Silicon (available in K- through D-bands only)
2: GaAs (available in V- through G-bands only)

① Positive and negative polarities refer to mixer output voltage with respect to case.

EXAMPLE: To order a U-band Silicon Tunable Mixer with a round flange and negative polarity, specify a 47373H-1210.

Any of these mixers are available with either positive or negative polarity Shottky barrier diodes. Silicon diodes are offered in K- through D-bands. Lower conversion loss GaAs diodes are offered in V-through G-bands. Both silicon and GaAs diodes can be self biased by RF or biased by a low DC current. RF self bias power levels for silicon are 2 to 5 mW while the RF self bias level for GaAs diodes is 7 to 12 mW. The mixers are designed for operation at intermediate frequencies from 0.1 to 5 GHz. They are tested by tuning out the mismatch at the IF port. Allow a 1 to 2 dB degradation when using IF bandwidths greater than 2 GHz.

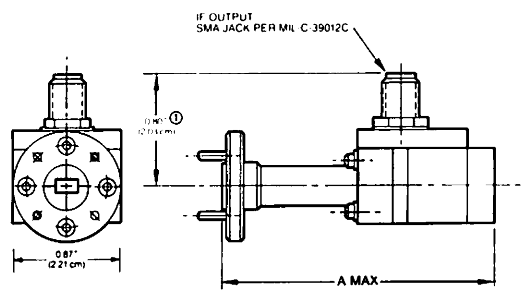
The diodes are packaged in a reduced height waveguide wafer, which is a field replaceable catalog item. These rugged wafer diodes meet the shock, vibration and temperature requirements for military and space applications. Over a million and a half hours of successful operation have been logged by these mixer diodes since 1970.

FREQUENCY BANDS (GHz)									
K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
—	**—**	**—**	**—**	**5.0 dB**	**5.5 dB**	**6 dB**	**10 dB**	**12 dB**	①
5.5 dB	**5.5 dB**	**6.0 dB**	**6.0 dB**	**6.5 dB**	**7 dB**	**8.5 dB**	**10 dB**	**12 dB**	**—**

① Consult factory

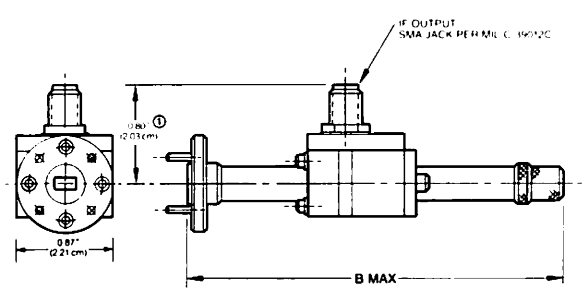
OUTLINE AND MOUNTING DRAWINGS

Narrow and Broadband Fixed Tuned Mixers



① K-band unit is 1.04" (2.64 cm)

Tunable Mixer

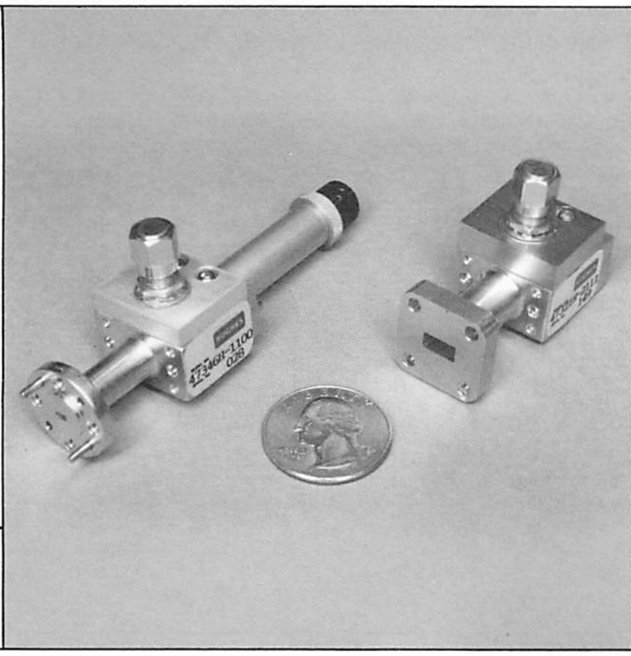


① K-band unit is 1.04" (2.64 cm)

DIMENSIONS (inches (cm))	FREQUENCY BANDS (GHz)									
	K (18-26.5)	Ka② (26.5-40)	Q② (33-50)	U② (40-60)	V② (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
A	1.87 (4.75)	1.76 (4.47)	1.76 (4.47)	1.76 (4.47)	1.76 (4.47)	1.81 (4.60)	1.76 (4.47)	1.76 (4.47)	1.76 (4.47)	1.76 (4.47)
B	3.38 (8.59)	3.01 (7.65)	3.01 (7.65)	3.01 (7.65)	2.61 (6.63)	2.66 (6.76)	2.61 (6.63)	2.61 (6.63)	2.61 (6.63)	–

② Shorter units may be supplied. Consult factory if required.

Spectrum Analyzer Mixers and Downconverters



Hughes 4734xH and 4743xH series of Spectrum Analyzer Mixers and 4746xH series of Fundamental Downconverters are designed to provide the display and analysis of millimeter-wave signals. The mixers operate in nine waveguide bands from 18 to 170 GHz and the downconverters in seven waveguide bands from 18 to 110 GHz.

The Spectrum Analyzer Mixers are designed to operate with many microwave spectrum analyzers that provide local oscillator outputs and IF inputs. Two configurations of spectrum analyzers are currently available. One has a diplexer built into the analyzer that separates the LO and IF signals. In this case, the mixer is connected to the "EXT MIXER" output on the spectrum analyzer. Harmonics of the LO are generated in the mixer and combined with the millimeter-wave signal to provide the IF signal. The other type of analyzer has separate LO and IF ports. In this case, the diplexer is provided in the mixer or provided as an external unit with the spectrum analyzer. In both cases, the IF spectrum is displayed on the

FEATURES:

SPECIFICATIONS

	Frequency Band (GHz)								
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)
MIXERS									
Min. Detectable Signal (dBm Typ) ① HP8566, Tektronix 492/494 and Anritsu 710 ②	−108	−108	−106	−106	−95	−90	−85	−75	−65
Other Analyzers ③	−71	−71	−71	−70	−69	−67	−65	—	—
DOWNCONVERTERS									
Conversion Loss (dB Max)	6.0	6.5	7.0	7.0	7.5	8.0	8.0	—	—
LO Frequency (GHz)	17.9	26.4	32.9	49.9	62.5	75.0	92.5	—	—
IF Output (GHz)	0.1-8.6	0.1-13.6	0.1-17.1	0-10.1 ④	0-12.5 ④	0-15 ④	0-17.5 ④	—	—
Stability Phase-Locked LO ⑤	±1 x 10^{-8} over 0 to 50°C							—	—
Free Running LO (MHz/°C Typ)	−1.0	−1.0	−1.5	−3.0	−5.0	−8.0	−10.0	—	—
FM Noise Phase-Locked LO ⑤	See Low Phase Noise Curve on Page 65							—	—
Free Running LO	See Curve on Page 67							—	—
Output Amplitude Calibration Accuracy (±dB Max)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	—	—
AC input voltage	100, 110, 220, 235 VAC (50/60 Hz)							—	—
DIMENSIONS Mixers	See Pages 95 and 97								
Downconverters (Inches (cm)) approx.	5.5 (13.97) x 17 (43.18) x 17 (43.18)							—	—
WAVEGUIDE SIZE	WR-42	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
WAVEGUIDE FLANGE ⑧	UG-595/U ⑥	UG-599/U ⑥	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)
		UG-381/U ⑦						Pin Contact	Pin Contact

① Minimum detectable signal in 1 KHz bandwidth. ② Specified with an LO power of + 14 dBm minimum. An amplifier may be required to provide + 14 dBm LO power. ③ See how to order section for spectrum analyzers supported. ④ Analysis at either side of the LO frequency is limited by the low frequency response of the spectrum analyzer. ⑤ For units with internal crystal. For units utilizing the 10 MHz reference signal from spectrum analyzer, refer to stability and noise specifications of analyzer. ⑥ Square flange. ⑦ Round flange. ⑧ Refer to page 157 for specifications and Military specification cross reference.

analyzer screen as the signal response. A tuner on the mixer is provided to achieve maximum sensitivity at the particular frequency of operation. These units operate over full waveguide bandwidths.

The fundamental downconverters provide the ultimate in sensitivity and stability for the analysis of millimeter-wave signals. In addition, this method eliminates the multiple responses and the need for signal identification associated with harmonic mixers. The downconverters contain either a phase-locked or free running Gunn local oscillator, a broadband balanced mixer and the power supplies required to operate the unit. Two configurations of the phase-locked version are offered. For spectrum analyzers that have a 10 MHz reference output, this signal is used as the reference for the local oscillator. For analyzers that do not provide this 10 MHz reference, a high stability, low noise crystal oscillator is provided in the downconverter as the reference.

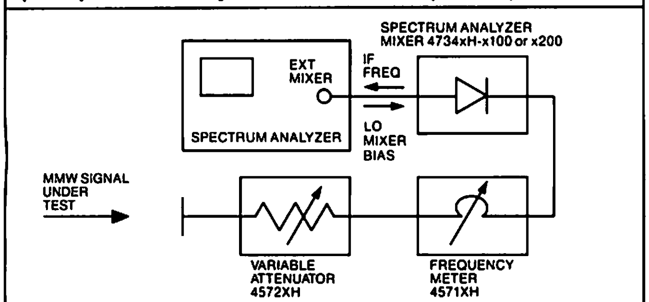
The downconverters have conversion losses ranging from 6 dB in K-Band to 8 dB in W-Band. This equates to sensitivities approaching the noise floor of the spectrum analyzer. In addition, the conversion loss over the bandwidth of the downconverter is extremely flat. A calibration curve is supplied that allows accurate absolute power measurements on the analyzer. The IF output frequencies have been limited to no greater than 18 GHz to maintain a low conversion loss and to accommodate most microwave spectrum analyzers. In K-, Ka- and Q-Bands, the local oscillator is set below the RF band and the full waveguide bandwidth is converted to the IF frequency. In U- through W-Bands, the LO is set at mid-band and both upper and lower sidebands are used for the analysis. A small window at mid-band (dependent on the analyzer's low frequency response) exists where analysis is limited.

For applications requiring analysis above 110 GHz or if special analysis at the LO frequency of the fundamental downconverter is required, special models are available. Consult Hughes or your local representative for information.

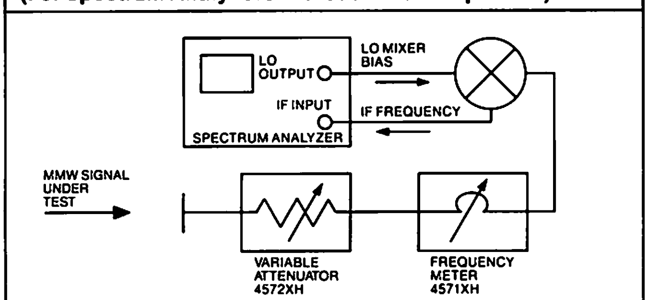
Extends Spectrum Analyzers to 110 GHz
Provides Calibrated Measurements

BLOCK DIAGRAMS

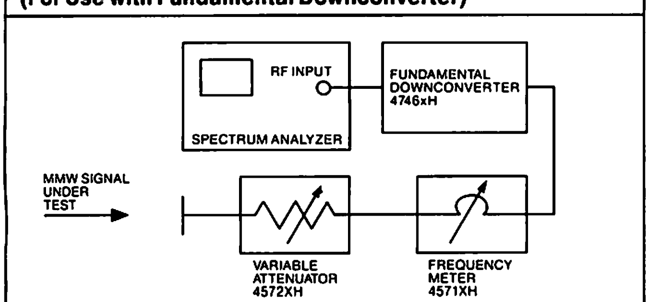
Spectrum Analysis Measurement Setup
(For Spectrum Analyzers with Built-in Diplexers)



Spectrum Analysis Measurement Setup
(For Spectrum Analyzers without Built-In Diplexers)



Spectrum Analysis Measurement Setup
(For Use with Fundamental Downconverter)



HOW TO ORDER

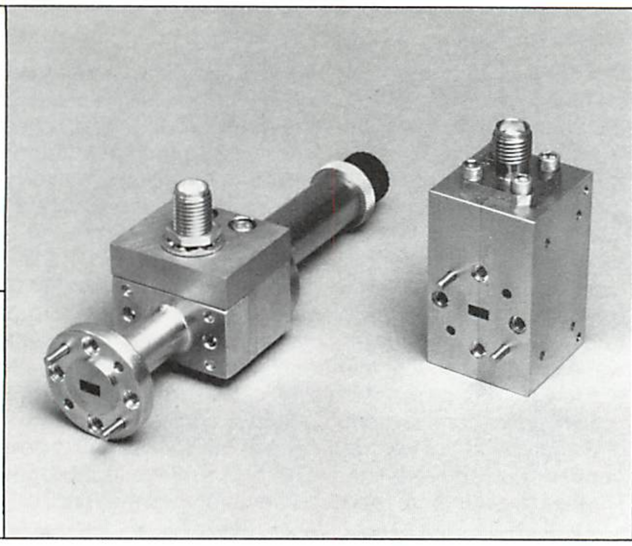
Fundamental Downconverter 4746xH-x0x0
Spectrum Analyzer Mixer 4743xH-x00x
Spectrum Analyzer Mixer 4734xH-xx00
Replacement Diode (For 4734xH Models Only) . . . 4734xH-0x00

Frequency Band	0	K
	1	Ka
	2	Q
	3	U
	4	V
	5	E
	6	W
	7	F (Available in 4743xH only)
	8	D (Available in 4743xH only)
Flange Type	1	Round (Available Ka- through W-Bands only)
	2	Square (Available in K- and Ka-Bands only)
	3	Pin Contact (Available in F- and D-Bands only)
Type (4734xH)	1	Positive polarity for use with Spectrum Analyzers with built-in or provided diplexers (Tektronix 7L18 and 492)①②
	2	Negative polarity for use with Spectrum Analyzers with built-in diplexers (HP8555A, 8565A and 8569A)
Local Oscillator Option (4746xH)	1	Free Running Gunn Oscillator
	2	Phase-Locked Gunn Oscillator utilizing 10 MHz reference from spectrum analyzer
	3	Phase-Locked Gunn Oscillator with internal high stability low noise crystal
Type (4743xH)	3	For use with HP8566A/B Spectrum Analyzer (without built-in diplexer)
	4	For use with HP8569B Spectrum Analyzer (without built-in diplexer)
	6	For use with Anritsu Model 710 Spectrum Analyzer

① Positive and negative polarities refer to output voltage with respect to case./
② Tektronix 492 requires external diplexer supplied by Tektronix.
Example: To order a U-Band Spectrum Analyzer Mixer for use with an HP8565A, specify 47343H-1200.

4

Tunable, Flat and Low VSWR Broadband Detectors



Hughes detectors are offered in three types: tunable, flat broadband, and low VSWR broadband. All types are available with either positive or negative output voltage. The tunable and flat broadband types use silicon whisker contact diodes, an the low VSWR broadband type uses silicon beam lead diode

The tunable detectors exhibit minimum sensitivities of up to 1500 mV/mW across full waveguide bandwidths. They are available in all waveguide bandwidths between 18 and 170 GHz and use field replaceable diode wafers.

DETECTOR SENSITIVITY① (mv/mW min)

Tunable
Flat Broadband
Low VSWR Broadband

SPECIFICATIONS

TUNABLE DETECTORS
- SENSITIVITY .... From Table
- MAXIMUM INPUT POWER (mW max) 100

FLAT BROADBAND DETECTORS
- SENSITIVITY .... From Table
- BANDWIDTH .... Full Waveguide
- FLATNESS (dB max) .... ±1.5*
- MAXIMUM INPUT POWER (mW max) 100

LOW VSWR BROADBAND DETECTORS
- SENSITIVITY .... From Table
- BANDWIDTH .... Full Waveguide
- VSWR (max) 3:1
- FLATNESS (dB max/typ) .... ±2.0/1.5
- MAXIMUM INPUT POWER (mW max) 100

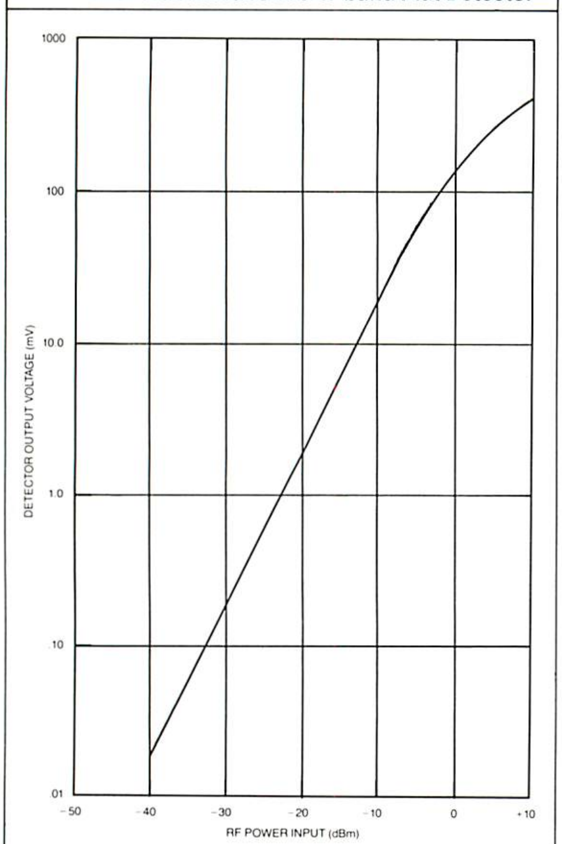
ISOLATION AMPLIFIER
- FREQUENCY (KHz max) 100
- OUTPUT IMPEDANCE (Ohms typ) 100

GENERAL
- WAVEGUIDE AND FLANGE .... See Page 157
- TEMPERATURE (°C ambient) .... 20 to 50

*Specification applies through W-band. Above W-band flatness is unspecified and units are tuned at Hughes selected frequency.

TYPICAL PERFORMANCE CURVE

Transfer characteristics of a W-band Flat Detector



HOW TO ORDER

- Low VSWR Broadband Detectors 4730xH-xx00
- Tunable Detectors 4731xH-xx11
- Flat Broadband Detectors 4732xH-xx11
- Replacement Diode Wafers ① 4738xH-0x10
- Sharpless Replacement Diode ② 4733xH-0x10
- Isolation Amplifier 47500H-5000

Frequency Band
- 0: K
- 1: Ka
- 2: Q
- 3: U
- 4: V
- 5: E (Unavail. on low VSWR units)
- 6: W
- 7: F (Unavail. on low VSWR units)
- 8: D (Unavail. on low VSWR units)

Flange Type
- 1: Round (Ka- through G-bands only)
- 2: Square (K- and Ka-bands only)
- 3: Pin Contact (F-, D-, and G-bands only)

Polarity ③
- 1: Positive (grounded anode)
- 2: Negative (grounded cathode)

① For either the Tunable or the Flat Broadband detectors
② Wafers for obsoleted model 4731xH-xxx0 and 4732xH-xx00
③ Positive and negative polarities refer to detector output voltage with respect to case.

EXAMPLE: To order a V-band Tunable Detector with positive polarity, specify a 47314H-1111.

The flat broadband detectors have a sensitivity flatness of ±1.5 dB over the full waveguide bandwidths without tuning and are available in waveguide bands between 18 and 220 GHz.

The low VSWR broadband detectors have a maximum VSWR of 3:1 with reduced sensitivity and flatness specifications from the flat broadband type.

Shown below is typical performance of millimeter-wave detectors showing the output voltage as a function of input RF power. The detector video output is connected to a high input impedance oscilloscope (1000 Hz bandwidth).

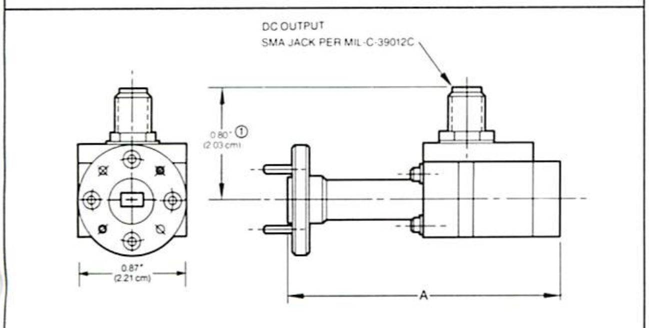
Isolation amplifiers are available which offer some protection from degradation due to voltage transients. The amplifiers are supplied with a polarity switch and a self-contained battery. The amplifier features a drift of less than 5 millivolts per 24-hour period. It transforms the output impedance down to 100 Ohms.

FREQUENCY BAND (GHz)									
K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G② (140-220)
1500	**1500**	**1500**	**1000**	**1000**	**750**	**750**	**200**	**200**	**—**
1000	**1000**	**1000**	**800**	**800**	**500**	**500**	**100**	**100**	**75**
500	**500**	**450**	**400**	**300**	**—**	**250**	**—**	**—**	**—**

① NOTE: Sensitivities are taken at power levels in the square law region into a megohm load.
② NOTE: Specifications are typical values at Hughes selected frequencies.

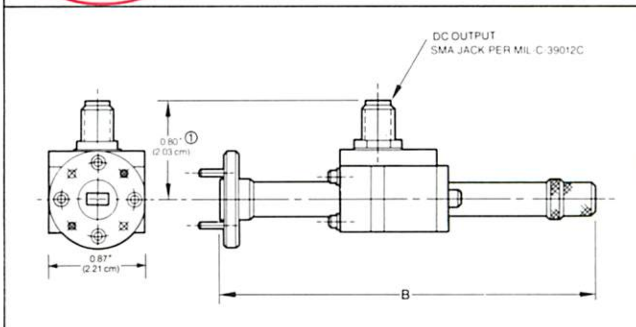
OUTLINE AND MOUNTING DRAWINGS

Flat Broadband Detector



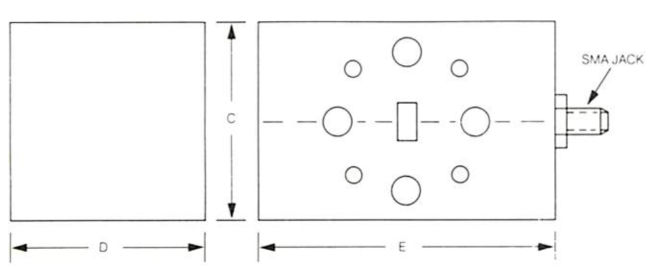
① K-band unit is 1.04" (2.64 cm.)

Tunable Detector



① K-band unit is 1.04" (2.64 cm.)

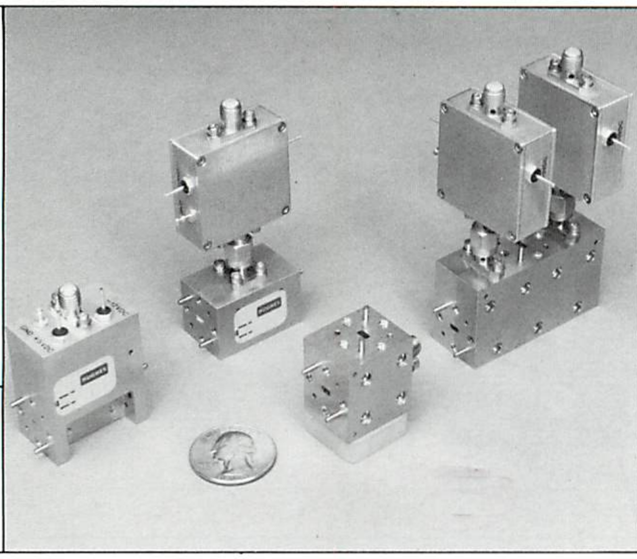
Low VSWR Broadband Detector



DIMENSIONS (inches (cm))		FREQUENCY BAND (GHz)										
		K (18-26.5)	Ka (26.5-40)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
	A	1.87 (4.75)	2.46 (6.25) ③	2.46 (6.25)	2.49 (6.32) ③	2.21 (5.61) ③	1.96 (4.98) ③	1.82 (4.62)	1.77 (4.50)	1.76 (4.47)	1.76 (4.47)	1.76 (4.47)
	B	3.38 (8.59)	3.97 (10.08) ③	3.97 (10.08)	4.00 (10.16) ③	3.72 (9.45) ③	3.07 (7.80) ③	2.93 (7.44)	2.88 (7.32)	2.87 (7.29)	2.87 (7.29)	—
	C	0.875 (2.2)	0.8 (2.0)	0.75 (1.9)	1.2 (3.1)	1.2 (3.1)	0.75 (1.9)	—	0.75 (1.9)	—	—	—
	D	0.875 (2.2)	1.2 (3.1)	0.75 (1.9)	0.8 (2.0)	0.8 (2.0)	0.75 (1.9)	—	0.75 (1.9)	—	—	—
	E	1.5 (3.8)	1.45 (3.7)	1.25 (3.2)	1.25 (3.2)	1.25 (3.2)	1.25 (3.2)	—	1.25 (3.2)	—	—	—
WAVEGUIDE ④ SIZE		WR-42	WR-28	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6	WR-5
WAVEGUIDE ④ FLANGE		UG-595/U	UG-381/U	UG-599/U	UG-383/U	UG-383/U mod	UG-385/U	UG-387/U	UG-387/U mod	UG-387/U mod pin contact	UG-387/U mod pin contact	UG-387/U mod pin contact

③ Shorter units may be supplied; consult factory if required.
④ Refer to page 157 for specifications and MIL specification cross reference.

Broadband SPST and SPDT PIN Switches



Hughes Broadband PIN Switches are available in Single-Pole-Single-Throw (SPST) or Single-Pole-Double-Throw (SPDT) configurations for 18 GHz to 110 GHz in seven separate waveguide bands. They make use of advanced circuit techniques so that full waveguide bandwidth performance can be achieved in K- through W-bands.

Isolation is greater than 22 dB through V-band and greater than 19 dB in E- and W-bands. Insertion loss varies from less than 1 dB to less than 2 dB depending on the configuration and frequency band. The SPDT versions are available with either a single bias input or a dual bias input.

INSERTION LOSS (max)

SPST

SPDT

SPECIFICATIONS

	FREQUENCY BAND (GHz)						
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)
SWITCHES							
BANDWIDTH (GHz min SPST)	Full W/G	Full W/G	Full W/G	Full W/G	Full W/G	Full W/G	Full W/G
INSERTION LOSS (dB max SPST/SPDT)	1.0/1.5	1.0/1.5	1.0/1.5	1.0/1.8	1.3/2.0	2.0/3.0	2.0/3.0
ISOLATION (dB min)①	22	22	22	22	22	19	19
POWER HANDLING (W max CW/peak)	1/10	1/10	1/10	1/10	1/10	1/10	1/10
SWITCHING SPEED (10%-90%) (ns typ)②	250	250	250	250	250	250	250
DC BIAS INPUT③							
REVERSE VOLTAGE (V max/min)	−30/−5	−30/−5	−30/−5	−30/−5	−30/−5	−30/−5	−30/−5
FORWARD CURRENT (mA max/typ oper)	20/2.5	20/2.5	20/2.5	20/2.5	20/2.5	20/1.0	20/1.0
TEMPERATURE RANGE (°C Amb. min/max)	0/50	0/50	0/50	0/50	0/50	0/50	0/50

DRIVER

PROPAGATION DELAY (ns typ) 20
DC VOLTAGE INPUT (V +/−5%) . . . . +5/−12
DC CURRENT INPUT (mA typ) . . . . ±20
TEMPERATURE RANGE (°C Amb. min/max) 0/50

① Isolation of 40 dB minimum is available with narrower bandwidths. Consult factory.
② Switching speed specifications apply to any switch/driver combination. Switching speed is driver dependent.
③ Forward current on SPST switch corresponds to isolation state and negative voltage to transmit state.

HOW TO ORDER

Model Number . . . . 4797xH−xxxx

Frequency Band 0:K, 1:Ka, 2:Q, 3:U, 4:V, 5:E, 6:W

Flange Type
- 1: Round (Available on Ka− through W−bands only)
- 2: Square (Available in K− and Ka−bands only)

Switching Speed
- 1: 250 nanoseconds

Configuration
- 0: SPST
- 1: SPDT Single Bias
- 2: SPDT Dual Bias
- 3: SPST with integral driver (Ka- through W-bands only)
- 4: SPST Single Bias with integral driver (Ka- through W-bands only)

Switch/Driver Options:
- 0: Single switch without driver.
- 1: One SPST switch with external or integral driver. TTL high to driver corresponds to transmit state.
- 2: One single SPST switch with external or integral driver. TTL low to driver corresponds to transmit state.
- 3: Two SPDT switches with two cable connected drivers. TTL high to driver corresponds to transmit state.
- 4: Two SPDT switches with two cable connected drivers. TTL low to driver corresponds to transmit state.
- 7: SPDT dual bias with two individual drivers.
- 8: SPDT single bias with external or integral driver.

EXAMPLE: To order two 94 GHz W-band single-pole-single-throw switches to be driven by the same TTL input with the TTL high corresponding to the transmit state, specify a 47976H-1103, center frequency=94 GHz.

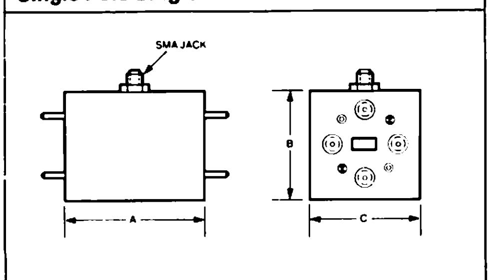
The switches can be purchased with or without a driver. The driver is available as either an external or built in to the body of the PIN switch. Cable connected drivers are provided when two switches are ordered together. The customer can specify which TTL input is required for which PIN switch state. The switching speed is driver dependent and is guaranteed to be less than 250 ns, when purchased with the driver. If ordered without a driver, units are provided with a current-limiting resistor and the switching speed for all bands is 250 ns. High speed PIN switches with switching speeds of less than 5 ns but with narrower bandwidths are available and are described on pages 104 and 105.

Higher isolation can be obtained on special request by increasing the number of diodes used in the switch with some increase in insertion loss. The switches are particularly useful with Hughes pulse power sources for variable pulse width applications or as receiver protectors in pulsed radar applications.

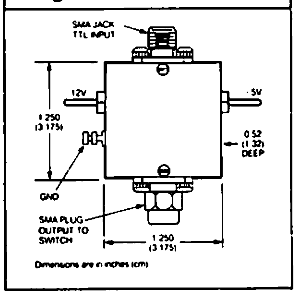
	FREQUENCY BAND (GHz)						
	K (18–26)	Ka (26.5–40)	Q (33–50)	U (40–60)	V (50–75)	E (60–90)	W (75–110)
	1.0 dB	**1.0 dB**	**1.0 dB**	**1.0 dB**	**1.3 dB**	**1.7 dB**	**1.7 dB**
	1.5 dB	**1.5 dB**	**1.5 dB**	**1.8 dB**	**2.0 dB**	**2.5 dB**	**2.5 dB**

OUTLINE AND MOUNTING DRAWINGS

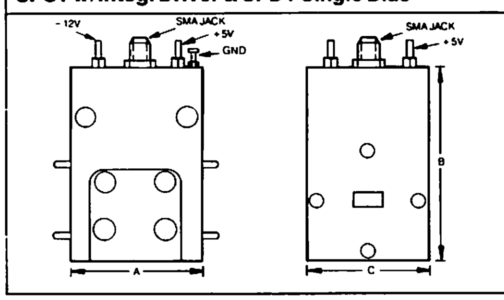
Single Pole Single Throw



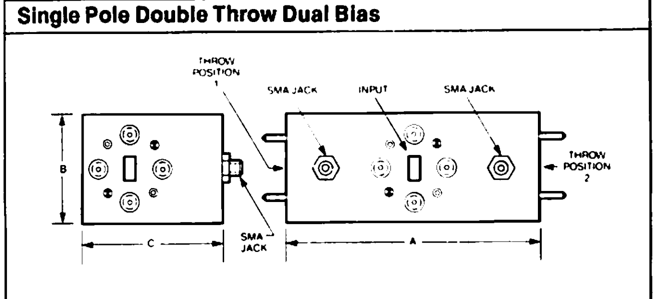
Single Channel Driver



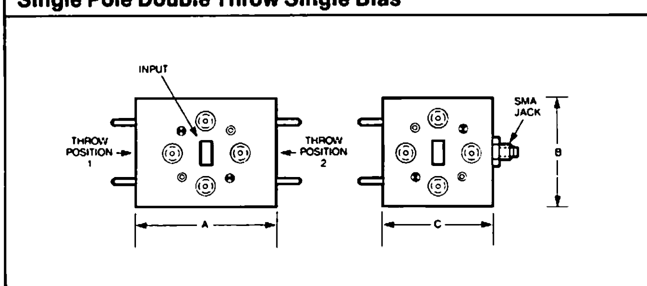
SPST w/Integ. Driver & SPDT Single Bias



Single Pole Double Throw Dual Bias



Single Pole Double Throw Single Bias

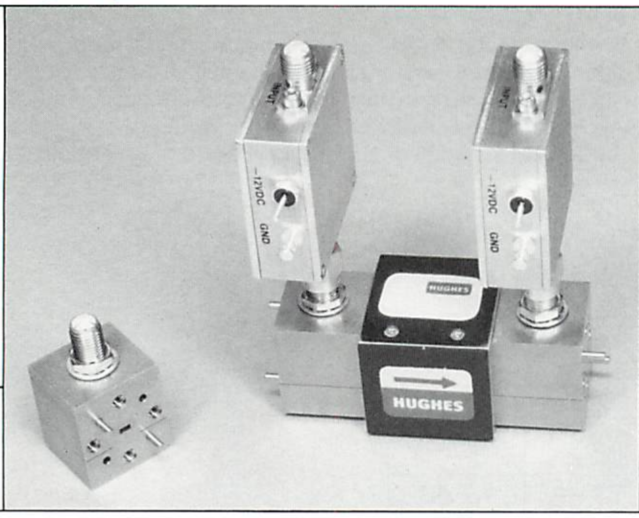


DIMENSIONS, WAVEGUIDE SIZES AND FLANGES			FREQUENCY BAND (GHz)							
			K (18-26.5)	Ka (26.5-40)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)
DIMENSIONS (inches (cm))	SPST	A	1.50 (3.81)	1.50 (3.81)	1.50 (3.81)	1.25 (3.18)	1.00 (2.54)	0.75 (1.91)	0.75 (1.91)	0.75 (1.91)
		B	0.88 (2.24)	0.75 (1.91)	1.16 (2.95)	1.16 (2.95)	1.16 (2.95)	0.75 (1.91)	0.75 (1.91)	0.75 (1.91)
		C	0.88 (2.24)	0.75 (1.91)	1.16 (2.95)	1.16 (2.95)	1.16 (2.95)	0.75 (1.91)	0.75 (1.91)	0.75 (1.91)
	SPDT Single Bias	A	1.50 (3.81)	1.00 (2.54)	1.2 (3.05)	1.2 (3.05)	1.2 (3.05)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)
		B	0.88 (2.24)	0.75 (1.91)	1.2 (3.05)	1.2 (3.05)	1.2 (3.05)	0.75 (1.91)	0.75 (1.91)	0.75 (1.91)
		C	1.00 (2.54)	0.90 (2.29)	1.4 (3.56)	1.4 (3.56)	1.4 (3.56)	0.90 (2.29)	0.90 (2.29)	0.90 (2.29)
	SPDT Dual Bias	A	2.00 (5.08)	2.00 (5.08)	2.32 (5.89)	2.32 (5.89)	2.32 (5.89)	2.00 (5.08)	2.00 (5.08)	2.00 (5.08)
		B	0.88 (2.24)	0.75 (1.91)	1.13 (2.87)	1.13 (2.87)	1.13 (2.87)	0.75 (1.91)	0.75 (1.91)	0.75 (1.91)
		C	1.19 (3.02)	1.13 (2.87)	1.5 (3.81)	1.5 (3.81)	1.5 (3.81)	1.13 (2.87)	1.13 (2.87)	1.13 (2.87)
	SPST with Integral Driver	A	—	1.20 (3.05)	—	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)
		B	—	1.80 (4.57)	—	1.80 (4.57)	1.80 (4.57)	1.50 (3.81)	1.50 (3.81)	1.50 (3.81)
		C	—	1.13 (2.87)	—	1.13 (2.87)	1.13 (2.87)	.75 (1.91)	.75 (1.91)	.75 (1.91)
	SPDT Single Bias with Integral Driver	A	—	1.2 (3.05)	—	1.2 (3.05)	1.2 (3.05)	1.25 (3.18)	1.25 (3.18)	1.25 (3.18)
		B	—	2.0 (5.08)	—	2.0 (5.08)	2.0 (5.08)	1.6 (4.07)	1.6 (4.07)	1.6 (4.07)
		C	—	1.13 (2.87)	—	1.13 (2.87)	1.13 (2.87)	.75 (1.91)	.75 (1.91)	.75 (1.91)
WAVEGUIDE SIZE[1]			WR-42	WR-28	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10
WAVEGUIDE FLANGE[1]			UG-595/U[3]	UG-599/U[2]	UG-381/U[2]	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)

[1] Refer to page 157 for specifications and MIL specification cross reference [2] Round flange [3] Square flange

4

High Speed PIN Switches



Hughes High Speed PIN Switches are single-pole-single-throw (SPST) millimeter-wave switches which achieve isolation by reflecting a portion of the input power. They are available in six waveguide bands from 26.5 GHz to 110 GHz.

An isolation greater than 17.5 dB is obtained with an insertion loss of no more than 2.5 dB over a 1 GHz bandwidth in Ka-band and a 3 GHz bandwidth in W-band. The units are capable of switching in less than 1 ns. The switching speed is driver dependent.

The switches can be purchased with or without a driver. The switching speed when supplied with driver is guaranteed

SWITCHING SPEED

SPECIFICATIONS

	Ka-band Switch	Q-band Switch	U-band Switch	V-band Switch	E-band Switch	W-band Switch	With ① Driver
FREQUENCY BAND (GHz)	26.5-40	33-50	40-60	50-75	60-90	75-110	—
BANDWIDTH (GHz min)	1.0	1.2	1.6	2.0	2.4	3.0	—
INSERTION LOSS (single/dual dB max)	2.5/5.5	2.5/5.5	2.5/6.0	2.5/6.0	2.5/6.5	2.5/6.5	—
ON/OFF RATIO (single/dual dB min)	15/30	15/30	15/30	15/30	15/30	15/30	—
POWER HANDLING (W typ CW/peak)	1/5	1/5	1/5	1/5	1/5	1/5	—
SWITCHING TIME (10% to 90% ns max) ②	1.0	1.0	1.0	1.0	1.0	1.0	5.0
DC VOLTAGE INPUT (V max) ③ Isolation State	+1, −15	+1, −15	+1, −15	+1, −15	+1, −15	+1, −15	+5, −12
CURRENT (mA max/typ) Insertion Loss State	10/5	10/5	10/5	10/5	10/5	10/5	± 20 typ
MODULATION FREQUENCY (MHz max)	250	250	250	250	250	250	50
TEMPERATURE RANGE (°C Amb. min/max)	0/50	0/50	0/50	0/50	0/50	0/50	0/50

① Specifications refer to any switch/driver combination.
② Switching time is driver dependent.
③ Positive voltage corresponds to isolation state and negative voltage to transmit state.

OK ?

HOW TO ORDER (Specify Center Frequency at time of order)

Model Number .... 4797xH−xx0x

Frequency Band: **1**:Ka, **2**:Q, **3**:U, **4**:V, **5**:E, **6**:W

Flange Type: **1**: Round; **2**: Square (Ka−band only)

Dual Switch/Driver Options
- **0**: Single switch
- **3**: Dual switch without driver.
- **4**: Dual switch with independent drivers. TTL high to driver, corresponds to transmit state.
- **5**: Dual switch with independent drivers. TTL low to driver, corresponds to transmit state.

Single Switch/Driver Options
- **0**: Single switch without driver.
- **1**: Single switch with driver. TTL high to driver corresponds to transmit state.
- **2**: Single switch with driver. TTL low to driver corresponds to transmit state.
- **7**: Dual Switch

minimum insertion loss

EXAMPLE: To order a V−band PIN Switch without driver to work at 60 GHz, specify a 47974H−1000, center frequency = 60 GHz.

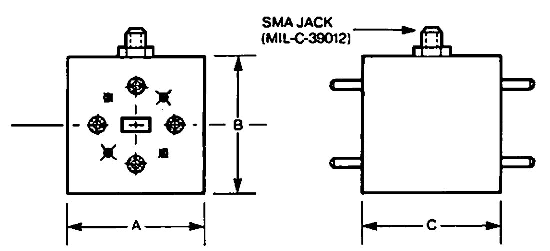
to be less than 5 ns. The customer can specify which TTL input is required for which PIN switch state.

Higher isolation may be obtained by using multiple PIN switches in series. A dual PIN switch with separating integral isolator is offered as a standard unit having a 30 dB ON/OFF ratio with insertion loss varying between 5.5 and 6.5 dB, depending on band. The switches are particularly useful with Hughes pulse power sources for variable pulse width applications or as receiver protectors in pulsed radar applications. They can also be used as double-throw switches in conjunction with Hughes circulators. Broadband units with slower switching speeds covering full waveguide bandwidths in Ka- through V-bands and 10 GHz bandwidths in E- and W-bands are described on pages 102 and 103.

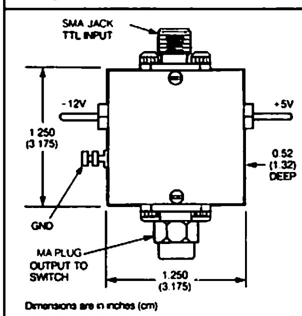
1 NANOSECOND MAXIMUM

OUTLINE DRAWING

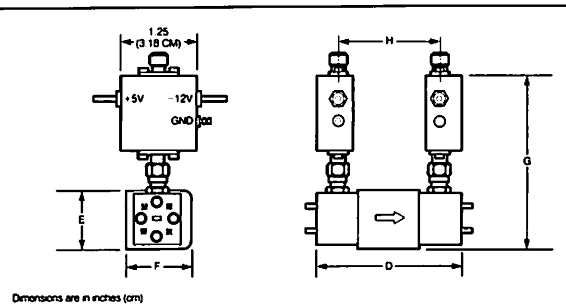
High Speed PIN Switches



Single Channel Driver



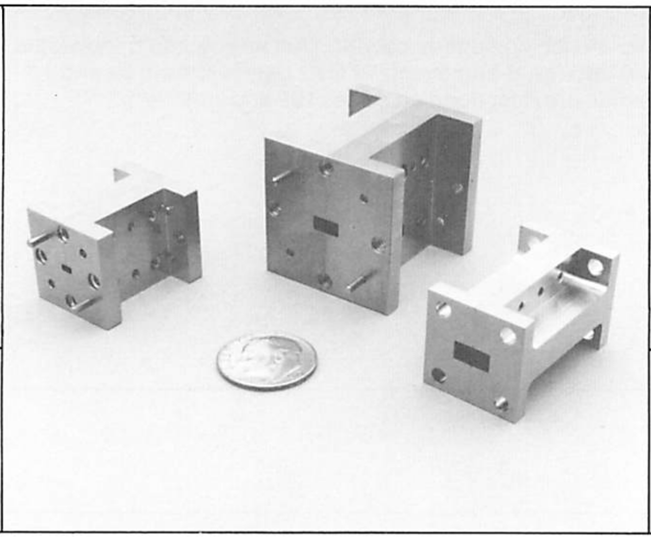
Dual Switch with Independent Drivers



		FREQUENCY BAND (GHz)					
		Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)
DIMENSIONS (inches (cm))	A	1.13 (2.87)	1.13 (2.87)	1.13 (2.87)	0.75 (1.91)	0.75 (1.91)	0.75 (1.91)
	B	1.14 (2.90)	1.14 (2.90)	1.14 (2.90)	0.84 (2.13)	0.84 (2.13)	0.84 (2.13)
	C	1.10 (2.79)	0.70 (1.78)	0.70 (1.78)	0.70 (1.78)	0.70 (1.78)	0.70 (1.78)
	D	3.38 (8.59)	2.54 (6.45)	2.54 (6.45)	2.36 (5.99)	2.36 (5.99)	2.36 (5.99)
	E	1.27 (3.23)	1.27 (3.23)	1.27 (3.23)	0.98 (2.49)	0.98 (2.49)	0.98 (2.49)
	F	1.43 (3.63)	1.43 (3.63)	1.43 (3.63)	1.08 (2.74)	1.08 (2.74)	1.08 (2.74)
	G	3.20 (8.13)	3.20 (8.13)	3.20 (8.13)	2.90 (7.37)	2.90 (7.37)	2.90 (7.37)
	H	2.30 (5.84)	1.87 (4.75)	1.87 (4.75)	1.68 (4.27)	1.68 (4.27)	1.68 (4.27)
WAVEGUIDE SIZE①		WR-28	WR-22	WR-19	WR-15	WR-12	WR-10
WAVEGUIDE FLANGE①		UG-381/U ③ UG-599/U ②	UG-383/U	UG-383/U mod	UG-385/U	UG-387/U	UG-387/U mod

① Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

Waveguide Bandpass Filters



Hughes 4583xH series of 3, 5 and 7 section Chebychev waveguide bandpass filters is offered in nine waveguide bands between 18 and 170GHz. Bandwidths of up to 15% are offered through W-Band (75-110 GHz), and 10% through D-Band (110-170 GHz). Standard bandwidths starting at 2% are offered, but other bandwidths are available when specified by the customer.

The filters feature low insertion loss and high out-of-band rejection (see typical performance curves). They are extremely

FEATURES:

SPECIFICATIONS

	Frequency Range (GHz)		
	18-50	50-110	110-170
2% Bandwidth Filters (0.99 to 1.01 x RF Center Frequency), (ripple bandwidth),			
Insertion Loss (dB max) ①	1.5	1.7	2.5
High Side Rejection at 1.04 x RF Center Frequency ② (dB min)	35	35	35
Low Side Rejection at 0.96 x RF Center Frequency ② (dB min)	40	40	40
In-Band SWR (max)	1.5:1	1.5:1	1.5:1
Design Ripple (dB)	0.1	0.1	0.1
5% Bandwidth Filters (0.975 to 1.025 x RF Center Frequency), (ripple bandwidth),			
Insertion Loss (dB max) ①	1.0	1.25	2.0
High Side Rejection at 1.10 x RF Center Frequency ② (dB min)	30	30	30
Low Side Rejection at 0.90 x RF Center Frequency ② (dB min)	40	40	40
In-Band VSWR (max)	1.5:1	1.5:1	1.5:1
Design Ripple (dB)	0.1	0.1	0.1
10% Bandwidth Filters (0.95 to 1.05 x RF Center Frequency), (ripple bandwidth),			
Insertion Loss (dB max) ①	0.8	1.0	1.8
High Side Rejection at 1.10 x RF Center Frequency ② (dB min)	30	30	30
Low Side Rejection at 0.90 x RF Center Frequency ② (dB min)	40	40	40
In-Band VSWR (max)	1.5:1	1.5:1	1.5:1
Design Ripple (dB)	0.1	0.1	0.1
15% Bandwidth Filters (0.925 to 1.075 x RF Center Frequency), (ripple bandwidth),			
Insertion Loss (dB max) ①	1.2	1.2	—
High Side Rejection at 1.15 x RF Center Frequency ② (dB min)	25	25	—
Low Side Rejection at 0.86 x RF Center Frequency ② (dB min)	40	40	—
In-Band VSWR (max)	1.5:1	1.5:1	—
Design Ripple (dB)	0.1	0.1	—

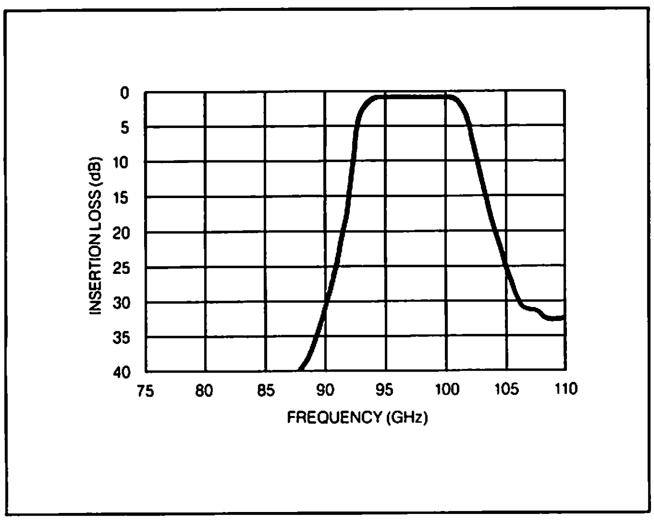
① Insertion loss values are maximum and depend on center frequency and waveguide band.
② Rejection values are minimum and are predicated for worst case with frequency center at mid-waveguide band.

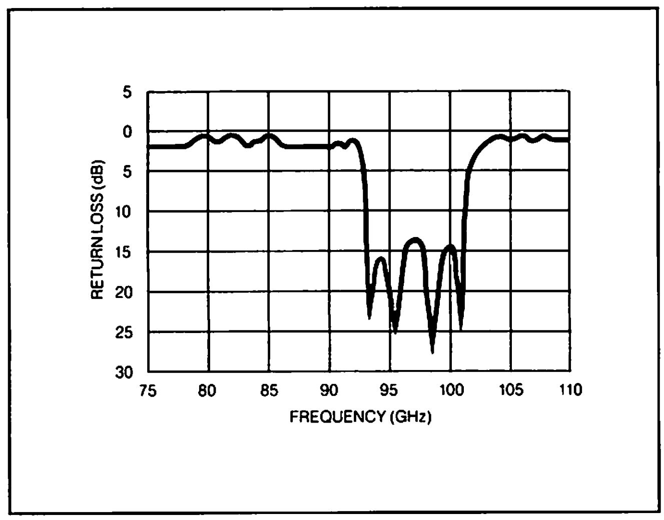
rugged since construction is completely planar up to the waveguide transitions. They will operate over extended temperature ranges with −30°C to +50°C being specified.

Consult the factory for other filter configurations, bandwidths, and inband diplexer applications. Custom designs are available on request.

CAD/CAM Direct-Coupled Filters from 18-170 GHz
Insertion Loss as low as 0.8dB Maximum

TYPICAL PERFORMANCE CURVES





HOW TO ORDER (Specify Center Frequency at time of order)

Model No. 4583xH-x1xx

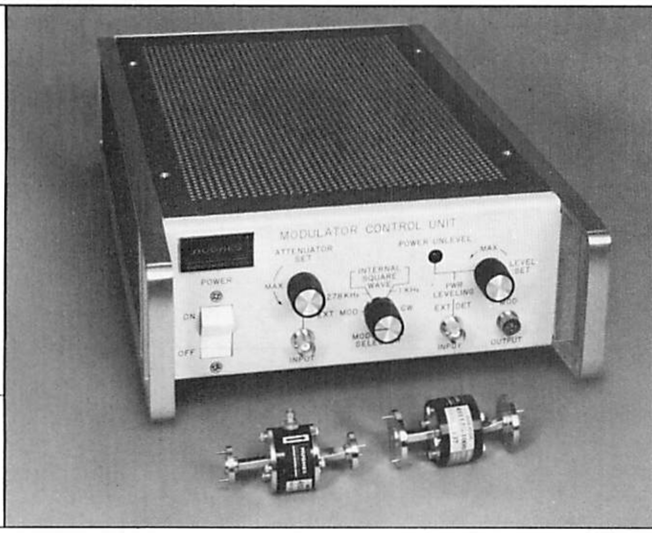
Frequency Band
- **0**: K-band
- **1**: Ka-band
- **2**: Q-band
- **3**: U-band
- **4**: V-band
- **5**: E-band
- **6**: W-band
- **7**: F-band
- **8**: D-band

Flange:
- **1**: Round (Available in Ka- through D-bands only)
- **2**: Square (Available in K- and Ka-bands only)
- **3**: Pin Contact (Available in F- and D-bands only).

Bandwidth:
- **02**: 2%
- **05**: 5%
- **10**: 10%
- **15**: 15% (Available in K- through W-bands only)

5

Full Band Isolators and Modulators



Hughes 4511xH series of Millimeter-Wave Full Band Isolators and Hughes 4521xH series of Full Band Modulators are Faraday rotation type ferrite devices. They consist of a section of waveguide containing low loss ferrite material and impedance matching elements. An external magnetic bias field is supplied to the ferrite core by means of a permanent magnet for the isolator and a bifilar-wound solenoid for the modulator. The biasing current for the modulator passes through one arm of the solenoid driving the ferrite into a condition of minimum insertion loss. Current passing through the other arm biases the ferrite for maximum insertion loss.

FEATURES: **27 dB Isolation**

ELECTRICAL SPECIFICATIONS

	FREQUENCY BAND (GHz)									
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D① (110-170)	G① (140-220)
ISOLATORS										
Insertion Loss (dB max)	1.5	1.5	1.5	1.7	1.8	2.0	2.5	3.0	3.5	4.5
Isolation (dB min)	25	27	27	27	27	27	27	20	20	20
Input/Output VSWR (max)	1.4:1	1.4:1	1.4:1	1.4:1	1.4:1	1.4:1	1.4:1	1.4:1	1.4:1	1.4:1
Power Rating (W max)	2.0	2.0	1.5	1.5	1.0	1.0	1.0	.75	.75	.75
STANDARD MODULATORS										
Forward Insertion Loss (db max)	1.7	1.7	1.7	1.8	1.8	2.0	2.5	3.0	3.5	4.5
On-Off Ratio (dB min)	20	23	25	25	25	25	25	18	18	18
Rise Time (10-90%, μsec max)	250	3	3	3	3	3	3	3	3	3
Input/Output VSWR (max)	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1
Bias Current (mA max)	500	500	500	500	500	500	500	500	500	500
Coil Resistance (Ω typ)	25	2	2	2	2	2	2	2	2	2
Coil Inductance (mH typ)	7.9	0.056	0.048	0.041	0.034	0.027	0.021	0.013	0.015	0.015
Power Rating (W max)	2.0	2.0	1.5	1.5	1.0	1.0	1.0	.75	.75	.75
LOW CURRENT MODULATORS										
Forward Insertion Loss (dB max)		1.7	1.7	1.8	1.8	2.0	2.5			
On-Off Ratio (dB min)		20	20	20	20	20	20			
Rise Time (10-90% μ/sec max)		100	100	100	100	100	100			
Input/Output VSWR (max)		1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1			
Bias Current (mA max)		50	50	50	100	100	100			
Coil Resistance (typ)		10	10	10	5	5	5			
Coil Inductance (mH typ)		7.0	7.0	7.0	0.8	0.8	0.8			
Power Rating (W max)		2.0	1.5	1.5	1.0	1.0	1.0			

①Specifications are typical values measured at Hughes selected frequency. Consult factory.

HOW TO ORDER

Modulator Driver 47530H-511x
Full Band Isolator 4511xH-x000
Full Band Modulator 4521xH-xx00

Frequency Band
- **0:** K (1kHZ units only)
- **1:** Ka
- **2:** Q
- **3:** U
- **4:** V
- **5:** E
- **6:** W
- **7:** F
- **8:** D
- **9:** G

AC Input Voltage
- **1:** 110 VAC, 60 Hz
- **2:** 220 VAC, 50 Hz

Modulation Rate
- **0:** Up to 1 kHz (available in K-band only)
- **1:** Up to 50 kHz (available in Ka- through G-bands only)
- **2:** Low current for Noise Source (available in Ka- through W-bands only)

Flange Type
- **1:** Round (Ka- through G-bands only)
- **2:** Square (available in K and Ka-bands only)
- **3:** Pin Contact (available in F, D, and G-bands only)

Example: To order an E-Band modulator and driver capable of being used as a variable attenuator and of being modulated at a rate of 27.8 kHz, specify a 45215H-1100 modulator and a 47530H-5111 driver.

Both the isolators and modulators are available in full waveguide bandwidths between 18-220 GHz. The isolators provide greater than 25 dB isolation and can typically have 33 dB over most of the band. The modulators when switched between their high and low insertion loss states provide an on-to-off ratio greater than 20 dB. When biased in their low insertion loss state the modulators also provide an isolation of greater than 20 dB in the reverse direction. Three types of modulators are offered, a 50 kHz unit in Ka- through G-bands with switching speeds of 3 µs, a 1 kHz unit in K-band with switching speeds of 250 µs, and a low current type with switching speeds of 100 µs.

The full waveguide bandwidth of these millimeter-wave isolators and modulators makes them particularly useful in swept frequency applications. The modulators are very useful as unidirectional switches and can be used as electrically variable attenuators in conjunction with the Hughes Modulator Driver. The modulator driver contains all the electronic circuitry and power supplies required to bias the modulator coils. It has a built-in 1 kHz square wave generator that is tunable from 950 to 1050 Hz, and a 27.8 kHz one tunable from 26.4 to 29.2 kHz. A CW operation mode biases the modulator to its lowest loss state for use as an isolator. External modulation up to a 50 kHz rate may be applied to switch the modulator between its high and low insertion loss states, or optionally to vary the attenuation with the external voltage applied.

Full Waveguide Bandwidths

50 kHz Modulation Rates

MECHANICAL SPECIFICATIONS

		Frequency Band (GHz)									
		K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
Modulator Dimensions (inches (cm))	A	4.23 (10.7)	3.85 (9.8)	3.27 (8.3)	3.14 (8.0)	2.68 (6.8)	2.58 (6.6)	2.48 (6.3)	2.48 (6.3)	2.48 (6.3)	2.48 (6.3)
	B	1.76 (4.5)	1.75 (4.5)	1.75 (4.5)	1.75 (4.5)	1.25 (3.2)	1.25 (3.2)	1.25 (3.2)	1.25 (3.2)	1.25 (3.2)	1.25 (3.2)
Isolator Dimensions (inches (cm))	A	4.34 (11.0)	3.28 (8.3)	2.69 (6.8)	2.62 (6.7)	2.56 (6.5)	2.51 (6.4)	2.46 (6.3)	2.34 (5.9)	2.31 (5.9)	2.29 (5.8)
	B	1.32 (3.4)	1.32 (3.4)	1.32 (3.4)	1.32 (3.4)	0.99 (2.5)	0.99 (2.5)	0.99 (2.5)	0.98 (2.5)	0.98 (2.5)	0.98 (2.5)
Waveguide Size (1)		WR-42	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6	WR-5
Waveguide Flange (1)		UG-595/U	UG-599/U (2)	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)
			UG-381/U (3)						pin contact	pin contact	pin contact

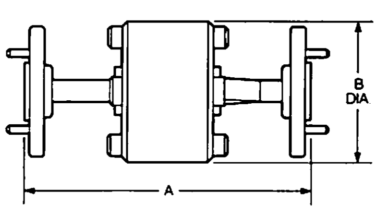
(1) Refer to page 157 for specifications and MIL specifications cross reference (2) Square flange (3) Round flange

MODULATOR DRIVER SPECIFICATIONS FOR MODEL 47530H-511x

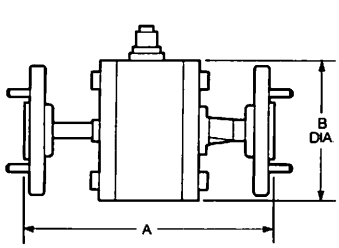
Square-Wave Modulation Frequency (tunable) .... 1 kHz±5% and 27.8 kHz ±5%
Switching Voltage for External Modulation .... 0 to +5V
Input Voltage for Variable Attenuation .... 0 to +10V
AC Input Voltages .... 110 V, 60 Hz
.... 220 V, 50 Hz
Size .... 3.6" (9.15 cm) x 9.4" (23.9 cm) x 15.6" (39.6 cm)

OUTLINE DRAWINGS

Isolator

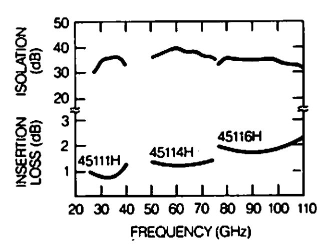


Modulator

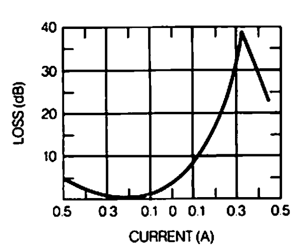


TYPICAL DATA

Typical Isolator Performance Curve

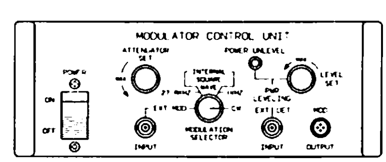


Typical Modulator Attenuation vs. Current

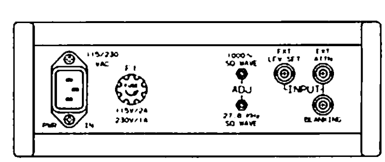


PANEL VIEW OF MODULATOR DRIVER

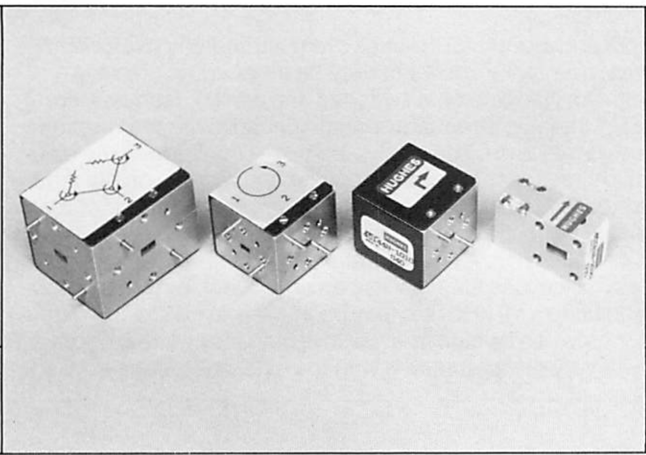
Front Panel



Rear Panel



Single and Multi-Junction Circulators and Isolators



Hughes 4516xH series of three-port junction circulators and 4514xH series of low loss isolators (terminated circulators) cover 18 to 140 GHz in eight waveguide bands. Single junction units are available in both a partial band and full band configuration. Single junction full band units are available only in K- to Ka-band and multi-junction units are available only from Ka- through W-bands 26.5 to 110 GHz.

FEATURES: **Tee Configuration**

ELECTRICAL SPECIFICATIONS FOR SINGLE JUNCTION UNITS (Partial Band/Full Band)①

	Frequency Band (GHz)							
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	D② (110-170)
Isolation (dB min)	20/20	20/18	20	20	20	20	20	18
Insertion Loss (dB max)	0.3/0.4	0.5/0.6	0.5	0.6	0.7	0.8	0.8	1.5
VSWR (max)	1.2:1/1.25:1	1.2:1/1.3:1	1.2:1	1.3:1	1.3:1	1.3:1	1.3:1	1.5:1
Bandwidth (GHz min)	2.0/8.5	2.0/13.5	2.0③	2.0	3.0	3.0	3.0③	2.0
Power Rating (W max)	10.0/10.0	10.0/10.0	8.0	7.0	6.0	5.0	5.0	3.0

①Full waveguide bandwidth units available in K- and Ka-bands only ②At 140 GHz only ③Bandwidth is 4 GHz on units centered at 39 GHz through 47 GHz and 92 GHz through 96 GHz.

ELECTRICAL SPECIFICATIONS FOR THREE-JUNCTION CIRCULATORS

	Frequency Band (GHz)						
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	D② (110-170)
Isolation (Ports 2 to 1 and 3 to 2, dB min)	35	35	35	35	35	35	30
Insertion Loss (Ports 1 to 2 and 2 to 3, dB max)	0.8	0.8	1.0	1.1	1.3	1.3	2.5
VSWR (max)	1.2:1	1.2:1	1.2:1	1.3:1	1.3:1	1.3:1	1.5:1
Bandwidth (GHz)	2	2③	2	3	3	3③	2
Power Rating (W max)	10	8	7	6	5	5	3

②At 140 GHz only. ③Bandwidth is 4 GHz on units centered at 39 GHz through 47 GHz and 92 GHz through 96 GHz.

ELECTRICAL SPECIFICATIONS FOR THREE-JUNCTION ISOLATORS

	Frequency Band (GHz)					
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)
Isolation (dB min)	50	50	50	50	50	50
Insertion Loss (dB max)	1.2	1.2	1.2	1.5	1.7	1.7
VSWR (max)	1.2:1	1.2:1	1.2:1	1.3:1	1.3:1	1.3:1
Bandwidth (GHz)	2	2③	2	3	3	3 ③
Power Rating (W max)	10	8	7	6	5	5

③Bandwidth is 4 GHz on units centered at 39 GHz through 47 GHz and 92 GHz through 96 GHz.

HOW TO ORDER

(Specify center frequency of partial band units at time of order)

Circulator 4516xH-xxx0
Junction Isolator 4514xH-xxx0

Frequency Band
- **0**: K
- **1**: Ka
- **2**: Q (Available for partial band units only)
- **3**: U (Available for partial band units only)
- **4**: V (Available for partial band units only)
- **5**: E (Available for partial band units only)
- **6**: W (Available for partial band units only)
- **8**: D (Not available for three junction isolators)

Number of Junctions
- **0**: Single Junction (Straight)
- **1**: Single Junction (Right angle, isolators only)
- **2**: Single Junction Miniature (Ka-band square flange only)
- **3**: Three-Junction (Partial band units only)

Bandwidth
- **0**: Partial Band
- **1**: Full Band

Flange Type
- **1**: Round (Ka- through D-bands, partial band units only)
- **2**: Square (Ka-band on single junction miniature isolators, K- and Ka-bands only on other products)

Example: To order a U-band single junction isolator with a round flange, specify a 45143H-1000 with center frequency of 50 GHz.

The In-Line Tee configuration allows simplified circuit lay-out and maximum usage of space allocations. The high isolation, low insertion loss, and low VSWR associated with these circulators make them ideal for use in negative resistance amplifiers, injection locked oscillators, phase modulators, and transmitter/receiver diplexers. The low insertion loss and small size of the junction isolators make them better suited than the broadband Faraday rotation isolators (Hughes series 4511xH) for many system applications.

All single junction partial band isolators are available to mate with standard round flange configurations in Ka-, Q-, U-, V-, E-, W-, and D-bands. This allows use of a smaller body size and the direct attachment to the Hughes 472xxH series of Gunn oscillators.

18 dB Isolation | **0.6 dB Insertion Loss** | **Full Band Waveguide Bandwidths 18-40 GHz**

MECHANICAL SPECIFICATIONS

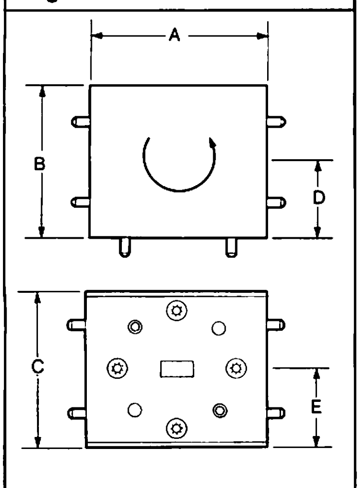
Dimensions (inches (cm))		K (18-26.5)	Ka (Square) (26.5-40)	Ka (Round) (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	D (110-170)
		Frequency Band (GHz)								
Single Junction (partial band units only)	A	1.20 (3.05)	1.10 (2.79)①	1.19 (3.02)	1.19 (3.02)	1.19 (3.02)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)
	B	1.25 (3.18)	1.15 (2.92)①	1.43 (3.63)	1.43 (3.63)	1.43 (3.63)	1.05 (2.67)	1.05 (2.67)	1.05 (2.67)	1.05 (2.67)
	C	.95 (2.41)	.815 (2.07)①	1.25 (3.18)	1.25 (3.18)	1.25 (3.18)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)
	D	.76 (1.93)	.725 (1.84)①	0.80 (2.03)	0.80 (2.03)	0.80 (2.03)	0.50 (1.27)	0.50 (1.27)	0.50 (1.27)	0.50 (1.27)
	E	.475 (1.21)	.405 (1.03)①	0.63 (1.59)	0.63 (1.59)	0.63 (1.59)	0.50 (1.27)	0.50 (1.27)	0.50 (1.27)	0.50 (1.27)
Miniature Square Flange Single Junction Isolators	A	NA	0.60 (1.52)	NA	NA	NA	NA	NA	NA	NA
	B	NA	1.00 (2.54)	NA	NA	NA	NA	NA	NA	NA
	C	NA	0.75 (1.91)	NA	NA	NA	NA	NA	NA	NA
	D	NA	.375 (0.95)	NA	NA	NA	NA	NA	NA	NA
	E	NA	.375 (0.95)	NA	NA	NA	NA	NA	NA	NA
Three Junction (circulators only, add 0.5 inch load to B dimension for isolators. Isolators not available in D-band)	A	NA	1.50 (3.81)	1.50 (3.81)	1.50 (3.81)	1.50 (3.81)	1.10 (2.79)	1.10 (2.79)	1.10 (2.79)	1.00 (2.54)
	B	NA	1.25 (3.18)	1.25 (3.18)	1.25 (3.18)	1.25 (3.18)	1.14 (2.90)	1.14 (2.90)	1.14 (2.90)	1.045 (2.65)
	C	NA	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)	0.98 (2.49)	0.98 (2.49)	0.98 (2.49)	1.00 (2.54)
	D	NA	.643 (1.63)	.643 (1.63)	.643 (1.63)	.643 (1.63)	0.58 (1.47)	0.58 (1.47)	0.58 (1.47)	0.53 (1.35)
	E	NA	.603 (1.53)	.603 (1.53)	.603 (1.53)	.603 (1.53)	0.49 (1.24)	0.49 (1.24)	0.49 (1.24)	0.50 (1.27)
Full Band	A	1.00 (2.54)	0.90 (2.29)	NA	NA	NA	NA	NA	NA	NA
	B	1.15 (2.92)	0.90 (2.29)	NA	NA	NA	NA	NA	NA	NA
	C	1.05 (2.67)⑤	1.00 (2.54)⑤	NA	NA	NA	NA	NA	NA	NA
	D	0.88 (2.24)	0.90 (2.29)	NA	NA	NA	NA	NA	NA	NA
	E	0.44 (1.12)	0.45 (1.14)	NA	NA	NA	NA	NA	NA	NA
	F	0.44 (1.12)	0.38 (0.97)	NA	NA	NA	NA	NA	NA	NA
Waveguide Size②		WR-42	WR-28	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-6
Waveguide Flange②		UG-595/U	UG-599/U③	UG-381/U④	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)

①Dimension applies to circulators only: See miniature square flange single junction isolators ②Refer to page 157 for specifications and MIL specification cross reference
③Square flange ④Round flange ⑤Dimension not applicable for model numbers 45160H-2100 and 45161H-2100

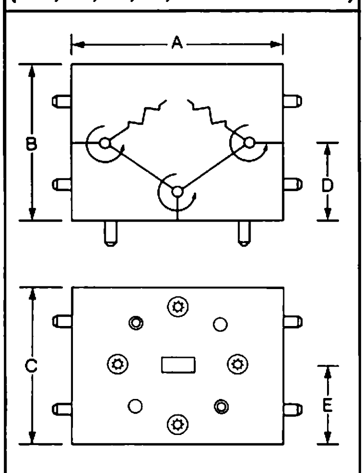
5

OUTLINE DRAWINGS

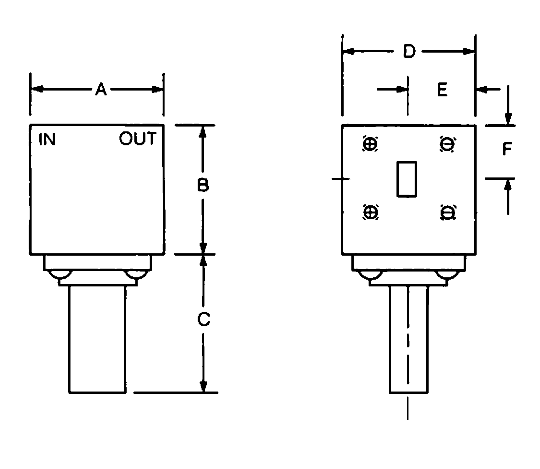
Single Junction Circulators



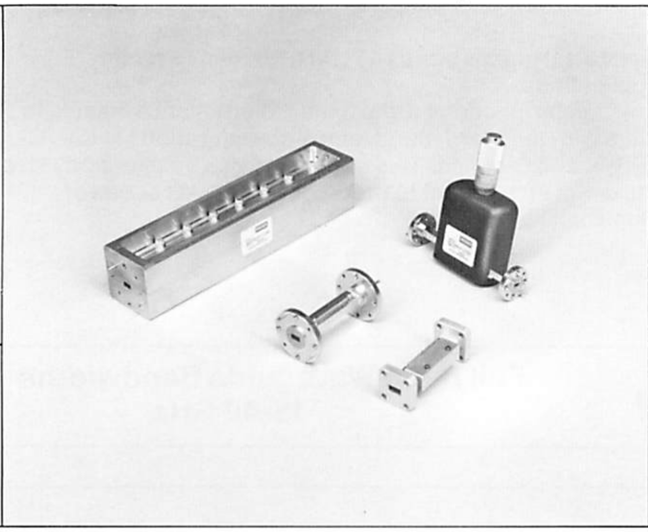
Three-Junction Circulators (Ka-, Q-, U-, V-, E- and W-bands)



Full Band Junction Isolators (K-, Ka-bands only)



Precision and General Purpose Fixed Attenuators, Level Set Attenuators



Hughes Precision Fixed Attenuators are made with a rugged split block design. This attenuator can be used as a lab standard against which other instruments or devices are calibrated.

The General Purpose and Level-Set Attenuators consist of a section of waveguide with a precisely cut resistive vane. In the level-set attenuator, the micrometer drive sets the level of attenuation by movement of the vane. The level-set attenuators have an adjustment range of 25 dB. The General Purpose and Precision Attenuators are available in values of 3, 6, 10, 20, 30 and 40 dB in Ka-

FEATURES:

Fixed Attenuators 0-40 dB

ELECTRICAL SPECIFICATIONS

	Frequency Band (GHz)							
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)
PRECISION FIXED ATTENUATORS								
Attenuation (dB)	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40		
Accuracy ± dB (max)	0.7	0.7	0.7	0.7	0.7	0.7		
Flatness ± dB (max)	0.5	0.5	0.5	0.5	0.5	0.5		
VSWR (max)	1.05:1	1.05:1	1.06:1	1.08:1	1.08:1	1.08:1		
Power Rating (W max)	1.0	1.0	1.0	1.0	0.5	0.5		
GENERAL PURPOSE ATTENUATORS								
Attenuation (dB)	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10	3, 6, 10
VSWR (max)	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.20:1	1.20:1
Power Rating (W max)	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3
LEVEL-SET ATTENUATORS								
Attenuation (dB)	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0-25
Insertion Loss (dB max)	0.5	0.5	0.7	0.7	1.0	1.0	1.2	1.2
VSWR (max)	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.20:1	1.20:1
Power Rating (W max)	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3
PHASE SHIFTERS								
Insertion Loss (dB max)	0.5	0.5	0.7	0.7	1.0	1.0	1.2	1.2
Phase Shift Range (degrees)	0-180	0-180	0-180	0-180	0-180	0-180	0-180	0-180
VSWR (max)	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.20:1	1.20:1
Power Rating (W max)	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3

HOW TO ORDER

Level-Set Attenuator 4573xH-x200
Variable Phase Shifter 4576xH-x200
Fixed Attenuator 4574xH-xxxx

Frequency Band
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **5**: E
- **6**: W
- **7**: F
- **8**: D

Flange Type
- **1**: Round
- **2**: Square (Ka-band units only)
- **3**: Pin Contact (Not available on Precision Attenuators) (Available on F- & D-bands only)

Fixed Attenuation Value
- **03**: 3 dB
- **06**: 6 dB
- **10**: 10 dB
- **20**: 20 dB (Not available F- & D-bands)
- **30**: 30 dB (Not available F- & D-bands)
- **40**: 40 dB (Not available F- & D-bands)

Attenuator Type
- **0**: General Purpose
- **1**: Precision (Available Ka- through W-bands only)

Example: To order a U-band level set attenuator, specify 45733H-1200 through W-Band only. Values of 3, 6, and 10 dB are available only on the General Purpose Attenuators in F- and D-Band. Both the General Purpose Fixed and Level-Set Attenuators are available in eight waveguide bands from 26.5 through 170 GHz.

The Hughes series of 4576xH Variable Phase Shifters consists of a waveguide section with a movable dielectric vane driven by a micrometer. The Micrometer Driven Phase Shifters have 0-180° phase shift range and are offered in eight waveguide bands from 26.5 through 170 GHz.

Level Set Attenuators 0-25 dB

Phase Shifters 0-180°

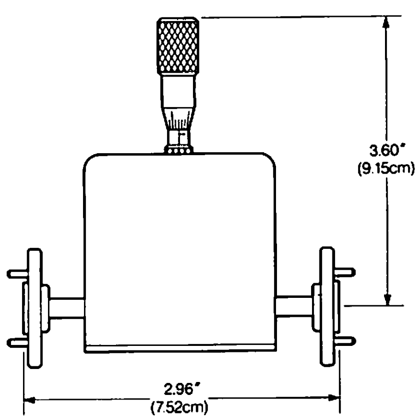
MECHANICAL SPECIFICATIONS

Dimensions (inches (cm))		Frequency Band (GHz) Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)
Fixed Attenuator Length		2.0 (5.08)	2.0 (5.08)	2.0 (5.08)	1.6 (4.06)	1.6 (4.06)	1.6 (4.06)	1.6 (4.06)	1.6 (4.06)
Precision Fixed Attenuator	A	7.260 (18.440)	6.080 (15.44)	5.320 (13.152)	3.980 (10.109)	3.310 (8.04)	3.120 (7.925)		
	B	1.330 (3.385)	1.330 (3.385)	1.330 (3.385)	1.200 (3.048)	1.200 (3.048)	1.200 (3.048)		
	C	1.300 (3.302)	1.300 (3.302)	1.300 (3.302)	.860 (2.184)	.860 (2.184)	.860 (2.184)		
Waveguide Size ①		WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
Waveguide Flanges ①		UG-599/U②	UG-383/U	UG-383/U (mod)	UG-85/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)
		UG-381/U③						pin contact	pin contact

① Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

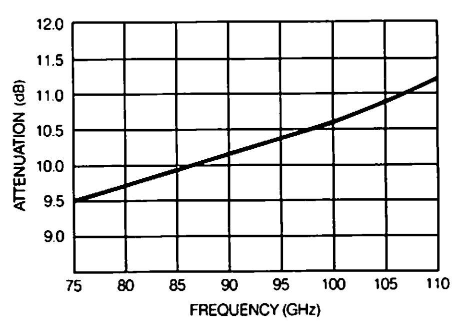
OUTLINE DRAWINGS

Level-Set Attenuator and Phase Shifter

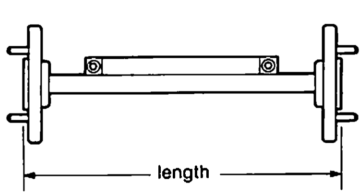


TYPICAL PERFORMANCE CURVE

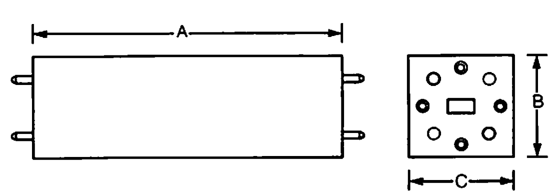
Level-Set Attenuator



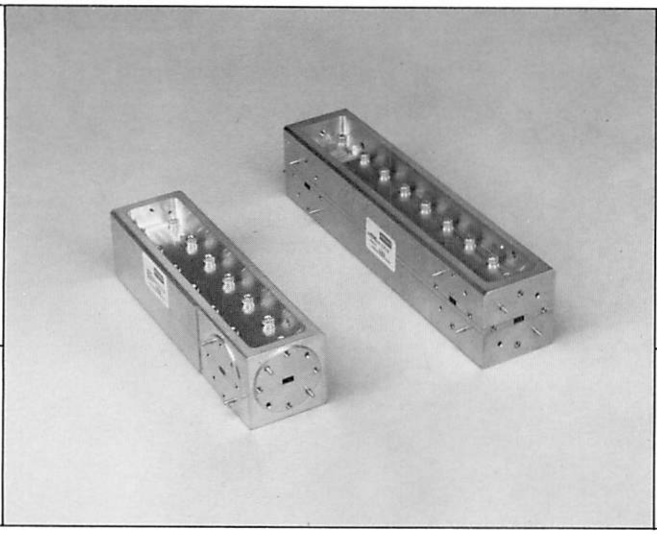
General Purpose Fixed Attenuator



Precision Fixed Attenuator



High Directivity Directional Couplers



Hughes High Directivity Directional Couplers are available as three port couplers and four port dual couplers.

The couplers are made with a rugged split block design. The three port couplers, and four port dual couplers, are available with coupling values of 3, 6, 10, 20, 30 and 40 dB. The four port dual couplers are available with or without an internal load.

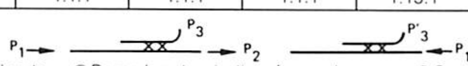
The three port type has a directivity of up to 37 dB and the four port dual coupler with internal load has a directivity of up to 35 dB. The four port dual coupler without load can provide up to 35 dB directivity, but this is dependent on the external ter-

FEATURES: **37 dB Directivity**

ELECTRICAL SPECIFICATIONS

	FREQUENCY BAND (GHz)								
	K (18-26)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)
3 PORT COUPLERS									
Coupling Value① (dB)	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40
Mean Coupling Accuracy ± (dB max)	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.1	1.3
Coupling Flatness② (± dB)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Insertion Loss③ (dB max)	0.8	0.8	0.8	0.8	1.1	1.5	1.5	2.2	2.5
Directivity④⑤ (dB min)	37	37	37	37	34	32	32	28	28
Main Line VSWR (max)	1.05:1	1.05:1	1.05:1	1.06:1	1.08:1	1.10:1	1.10:1	1.15:1	1.15:1
Secondary Line VSWR (max)	1.1:1	1.1:1	1.1:1	1.1:1	1.1:1	1.15:1	1.15:1	1.2:1	1.2:1
4 PORT DUAL COUPLERS W/LOAD									
Coupling Value① (dB)	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40
Mean Coupling Accuracy ± (dB max)	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.1	1.3
Coupling Flatness② (± dB)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Insertion Loss③ (dB max)	1.0	1.0	1.0	1.0	1.3	1.7	1.7	2.2	2.5
Directivity④⑤ (dB min)	35	35	35	35	33	31	31	27	27
Main Line VSWR (max)	⑦	1.1:1	1.1:1	1.1:1	1.1:1	1.15:1	1.15:1	1.2:1	1.2:1
Secondary Line VSWR (max)	⑦	1.1:1	1.1:1	1.1:1	1.1:1	1.15:1	1.15:1	1.2:1	1.2:1
4 PORT DUAL COUPLERS W/O LOAD									
Coupling Value① (dB)	⑦	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40	3, 6, 10, 20, 30, 40
Mean Coupling Accuracy ± (dB max)	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.1	1.3
Coupling Flatness② (± dB)	⑦	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Insertion Loss③ (dB max)	⑦	0.8	0.8	0.8	1.1	1.5	1.5	2.2	2.5
Directivity④⑥ (dB min)	⑦	35	35	35	33	31	31	27	27
Main Line VSWR (max)	⑦	1.05:1	1.05:1	1.06:1	1.08:1	1.10:1	1.10:1	1.15:1	1.15:1
Secondary Line VSWR⑥ (max)	⑦	1.1:1	1.1:1	1.1:1	1.1:1	1.15:1	1.15:1	1.2:1	1.2:1

① Coupling value = $-10 \log_{10}(P_3/P_1)$ ② Over full waveguide bandwidth
③ Insertion loss = $-10 \log_{10}[(P_2+P_3)/(P_1)]$ ④ Directivity = $10 \log_{10}(P_3/P_3')$



⑤ On 4 Port Couplers, directivity is dependent on impedance match at coupled ports. ⑥ Depends on termination of secondary arm ⑦ Consult Factory

HOW TO ORDER

3 Port Split Block Style (High Directivity) 4532xH-x3xx
4 Port Dual Split Block Style (High Directivity) .4534xH-xxxx

Frequency Band	**0**: K	**3**: U	**6**: W
	1: Ka	**4**: V	**7**: F
	2: Q	**5**: E	**8**: D

Coupling Value	**03**: 3 dB	**20**: 20 dB
	06: 6 dB	**30**: 30 dB
	10: 10 dB	**40**: 40 dB

Flange Type
1: Round (available in Ka- through D-bands only)
2: Square (available in K- and Ka-bands only)

4 Port Style
3: With Internal Load
4: Without Internal Load

Example: To order Q-Band 4 port dual split block, 30 dB, without internal load coupler, specify a 45342H-1430 mination of the secondary arm. The High Directivity Directional Couplers are available in nine waveguide bands from 18 to 170 GHz.

Hughes Directional Couplers are convenient devices for extracting or introducing RF power flowing in a transmission line without disturbing the other characteristics of the circuit. A function for which high directivity couplers offer an ideal solution is the measuring of RF power and comparing incident and reflected signals.

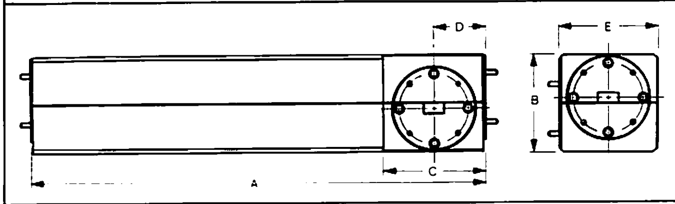
A waveguide stand that mates with Hughes split block couplers is available. (See page 156.)

Insertion Loss as low as 0.8 dB MAX

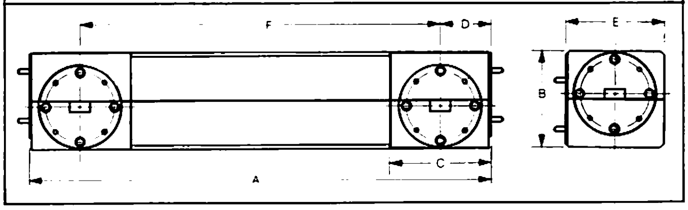
VSWR as low as 1.1:1 MAX

OUTLINE AND MOUNTING DRAWINGS

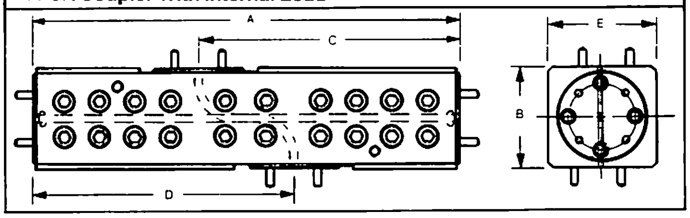
3 Port Coupler



4 Port Coupler



4 Port Coupler With Internal Load

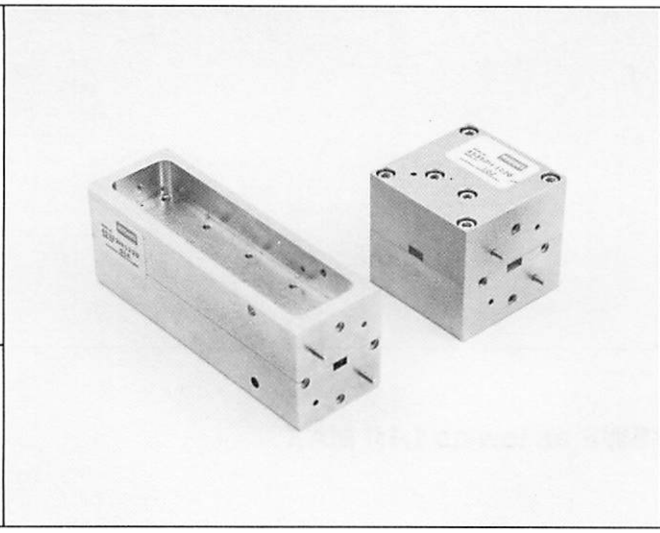


MECHANICAL SPECIFICATIONS

Dimensions (inches (cm))		FREQUENCY BAND (GHz) K (18-26)	Ka (Round) (26.5-40)	Ka (Square) (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)
3-Port	A	8.25 (21.0)	6.21 (15.77)	6.21 (15.77)	5.48 (13.92)	4.90 (12.45)	3.83 (9.73)	3.38 (8.59)	3.28 (8.33)	3.28 (8.33)	2.60 (6.60)
	B	1.30 (3.30)	1.30 (3.30)	.93 (2.36)	1.30 (3.30)	1.30 (3.30)	.86 (2.18)	.86 (2.18)	.86 (2.18)	.83 (2.11)	.85 (2.16)
	C	1.30 (3.30)	1.38 (3.50)	1.12 (2.84)	1.65 (4.19)	1.65 (4.19)	1.22 (3.10)	1.22 (3.10)	1.22 (3.10)	1.22 (3.10)	1.00 (2.54)
	D	.69 (1.75)	.69 (1.75)	.69 (1.75)	.83 (2.10)	.83 (2.10)	.61 (1.55)	.61 (1.55)	.61 (1.55)	.61 (1.55)	.51 (1.30)
	E	1.33 (3.38)	1.33 (3.38)	1.33 (3.38)	1.33 (3.38)	1.33 (3.38)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)	.85 (2.16)
4-Port	A	[4]	6.21 (15.77)	6.21 (15.77)	5.48 (13.92)	4.90 (12.45)	3.83 (9.73)	3.38 (8.59)	3.28 (8.33)	3.28 (8.33)	3.28 (8.33)
	B	[4]	.93 (2.36)	1.30 (3.30)	1.30 (3.30)	1.30 (3.30)	.86 (2.18)	.86 (2.18)	.86 (2.18)	.83 (2.11)	.83 (2.11)
	C	[4]	1.12 (2.84)	1.38 (3.50)	1.65 (4.19)	1.65 (4.19)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)
	D	[4]	.69 (1.75)	.69 (1.75)	.83 (2.10)	.83 (2.10)	.61 (1.55)	.61 (1.55)	.61 (1.55)	.61 (1.55)	.61 (1.55)
	E	[4]	1.33 (3.38)	1.33 (3.38)	1.33 (3.38)	1.33 (3.38)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)	1.20 (3.05)
	F	[4]	4.78 (12.14)	4.78 (12.14)	3.94 (10.01)	3.34 (8.49)	2.62 (6.65)	2.28 (5.79)	2.21 (5.60)	2.21 (5.60)	2.21 (5.60)
4-Port With Internal Load	A	—	—	—	8.00 (20.32)	—	—	—	4.40 (11.18)	—	3.60 (9.14)
	B	—	—	—	1.20 (3.05)	—	—	—	.85 (2.16)	—	.85 (2.16)
	C	—	—	—	4.40 (11.18)	—	—	—	2.55 (6.48)	—	2.20 (5.59)
	D	—	—	—	4.40 (11.18)	—	—	—	2.55 (6.48)	—	2.20 (5.59)
	E	—	—	—	1.43 (3.63)	—	—	—	.94 (2.39)	—	.90 (2.29)
Waveguide Size[1]		WR-42	WR-28	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
Waveguide Flange[1]		UG-595/U	UG-381/U[3]	UG-599/U[2]	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)

[1] Refer to page 157 for specification cross reference [2] Square flange [3] Round flange [4] Consult factory

General Purpose and Crossguide Couplers



The Hughes General Purpose Coupler is a three port coupler made with rugged split block design. It is available with coupling values of 3, 6, 10, 20, 30 and 40dB. The directivity of these couplers is 20dB. They are available in nine waveguide bands from 18 to 170 GHz.

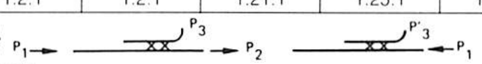
The compact Hughes Crossguide Coupler is available with 20 dB nominal coupling. For coupling values above 20 dB, consult factory. The directivity of this coupler is 20 dB at W-band or below and 15 dB at F-band and above. In Ka- through D-band, two designs of Crossguide Couplers

FEATURES: **± 0.7 dB Coupling Flatness**

ELECTRICAL SPECIFICATIONS

	Frequency Band (GHz)								
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)
General Purpose Split Block Coupling Value ① (dB)	3, 6, 10, 20 30, 40	3, 6, 10, 20 30, 40	3, 6, 10, 20 30, 40	3, 6, 10, 20 30, 40	3, 6, 10, 20 30, 40	3, 6, 10, 20 30, 40	3, 6, 10, 20 30, 40	3, 6, 10, 20 30, 40	3, 6, 10, 20 30, 40
Coupling Flatness ② (± dB)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Insertion Loss ③ (dB max)	0.7	0.7	0.7	0.7	0.8	1.4	1.4	2.0	2.0
Directivity ④ (dB min)	20	20	20	20	20	20	20	20	20
Main Line VSWR (max)	1.2:1	1.2:1	1.2:1	1.2:1	1.2:1	1.2:1	1.2:1	1.2:1	1.25:1
Secondary Line VSWR (max)	1.2:1	1.2:1	1.2:1	1.2:1	1.2:1	1.25:1	1.25:1	1.25:1	1.3:1
Crossguide									
Bandwidth (GHz)									
Low Band	18-26.5	26.5-35	33-44	40-54	50-67	60-81	75-99	90-125	110-152
High Band		30-40	38-50	46-60	57-75	69-90	85-110	105-140	128-170
Coupling Value ① (dB)	20	20	20	20	20	20	20	20	20
Coupling Flatness (± dB)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Insertion Loss ③ (dB max)	0.5	0.5	0.5	0.6	0.6	1.0	1.0	1.5	1.7
Directivity ④ (dB min) ⑤	20	20	20	20	20	20	20	15	15
Main Line VSWR	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.2:1	1.2:1	1.2:1	1.25:1
Secondary Line VSWR	1.2:1	1.2:1	1.2:1	1.2:1	1.21:1	1.25:1	1.25:1	1.25:1	1.3:1

① Coupling value = $-10 \log_{10}(P_3/P_1)$ ② Over full waveguide bandwidth
③ Insertion loss = $-10 \log_{10}[(P_2 + P_3)/P_1]$ ④ Directivity = $10 \log_{10}(P_3/P_3')$



⑤ On 4 Port Couplers, directivity is dependent on impedance match at coupled ports.

HOW TO ORDER

4 Port Crossguide 4535xH-xx20
3 Port Crossguide (fourth port terminated) 4535xH-xx20
3 Port Split Block Style General Purpose 4532xH-x2xx

Frequency Band
- **0**: K
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **5**: E
- **6**: W
- **7**: F
- **8**: D

Flange Type
- **1**: Round (Ka- through D-band only)
- **2**: Square (Available in K- and Ka-bands only)

Coupling Value
- **03**: 3 dB
- **06**: 6 dB
- **10**: 10 dB
- **20**: 20 dB
- **30**: 30 dB
- **40**: 40 dB

Crossguide Coupler Type
- **2**: 3 Port (4th port terminated) Low Frequency Band
- **3**: 3 Port (4th port terminated) High Frequency Band
- **4**: 4 Port Low Frequency Band
- **5**: 4 Port High Frequency Band

Example: To order a W-band 94 GHz 3 Port Terminated Crossguide Coupler, specify a 45356H-1320.

are available per band. One design covers the lower 70% of the band, the other the upper 70%. The Crossguide Couplers are available in nine waveguide bands from 18 to 170 GHz.

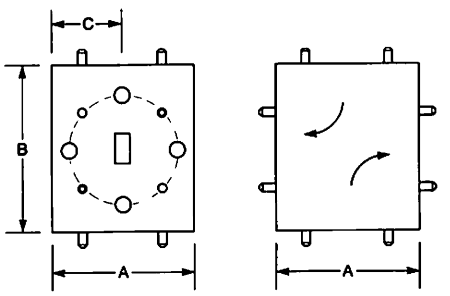
Hughes Directional Couplers are convenient devices for extracting or introducing RF power flowing in a transmission line without disturbing the other characteristics of the circuit. Some of the functions for which couplers offer ideal solutions are measuring and sampling RF power and comparing incident and reflected signals.

Insertion Loss As Low As 0.7 dB MAX

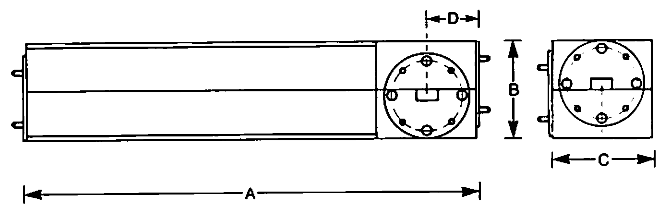
VSWR As Low As 1.2:1 MAX

OUTLINE DRAWINGS

Crossguide Coupler



General Purpose Split Block Coupler

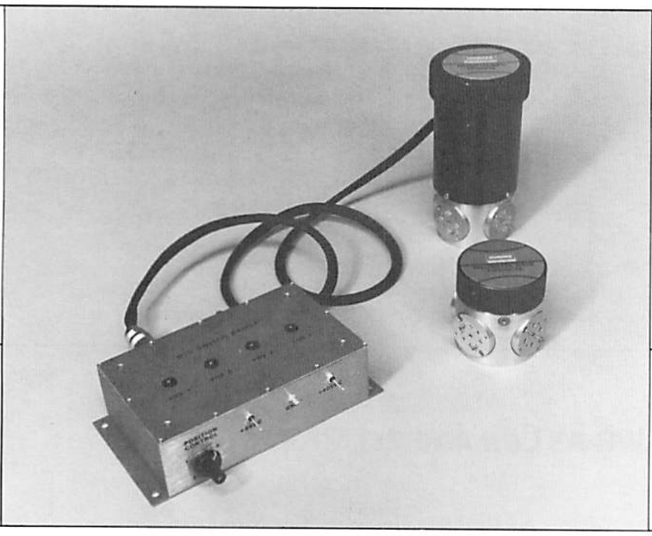


MECHANICAL SPECIFICATIONS[1]

		Frequency Band (GHz)									
		K (18-26.5)	Ka (Round) (26.5-40)	Ka (Square) (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)
Dimensions (inches (cm)) General Purpose Split Block Style	A	4.5 (11.43)	3.70 (9.40)	3.29 (8.36)	3.70 (9.40)	3.70 (9.40)	3.20 (8.13)	3.20 (8.13)	3.20 (8.13)	3.20 (8.13)	3.20 (8.13)
	B	1.3 (3.30)	1.30 (3.30)	0.93 (2.36)	1.30 (3.30)	1.30 (3.30)	0.86 (2.18)	0.86 (2.18)	0.86 (2.18)	0.83 (2.10)	0.83 (2.10)
	C	1.4 (3.56)	1.23 (3.12)	1.12 (2.84)	1.23 (3.12)	1.23 (3.12)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	0.92 (2.34)	0.92 (2.34)
	D	.775 (1.97)	.689 (1.75)	0.51 (1.30)	.689 (1.75)	0.80 (2.03)	0.61 (1.55)	0.61 (1.55)	0.61 (1.55)	0.61 (1.55)	0.61 (1.55)
Crossguide Style	A	1.46 (3.70)	1.46 (3.70)	1.46 (3.70)	1.46 (3.70)	1.46 (3.70)	1.03 (2.61)	1.03 (2.61)	1.03 (2.61)	1.03 (2.61)	1.03 (2.61)
	B	1.50 (3.81)	1.50 (3.81)	1.50 (3.81)	1.50 (3.81)	1.50 (3.81)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)
	C	0.80 (2.02)	0.80 (2.02)	0.80 (2.02)	0.78 (1.98)	0.77 (1.96)	0.55 (1.39)	0.54 (1.37)	0.53 (1.36)	0.53 (1.36)	0.53 (1.36)
Waveguide Size[2]		WR-42	WR-28	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
Waveguide Flange[2]		UG-595/U	UG-381/U[4]	UG-599/U[3]	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)

① Aluminum Housing K Thru U-Bands
Brass Housing V Thru D-Bands
② Refer to page 157 for specifications and MIL specification cross reference.
③ Square flange
④ Round flange

Manual and Stepper Motor Driven Waveguide Switches



Hughes 4552xH series of Manual Waveguide Switches have a three-channel rotor accurately indexed to eight 45° switch positions with continuous clockwise or counterclockwise rotation. The switch has four ports and four functional switch positions so that each port can be coupled to any other port or be isolated.

The Hughes 4551xH series of Stepper Motor Driven Waveguide Switches are the manual switches described above with a stepper motor drive. The motor steps in increments of 15° for each applied electrical pulse of 30 to 45 milliseconds. Three pulses are required to switch between index positions.

FEATURES: **3 Channel 4 Port**

ELECTRICAL SPECIFICATIONS

	Frequency Band (GHz)									
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
Isolation (dB min)	60	60	60	60	60	50	50	50	50	50
Insertion Loss (dB max)	0.4	0.4	0.4	0.5	0.6	0.8	1.0	1.5	1.5	2.0
Repeatability (dB typ)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.1	0.1
VSWR (max)	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1
Stepper Motor Pulse Power Requirement (without driver)* (Volts/Amps Peak (typ) Occasional Switching	38/5.5	38/5.5	38/5.5	38/5.5	38/5.5	38/5.5	38/5.5	38/5.5	38/5.5	38/5.5
Continuous Switching	30/3.5	30/3.5	30/3.5	30/3.5	30/3.5	30/3.5	30/3.5	30/3.5	30/3.5	30/3.5
Power Requirements with TTL Drivers (V/A max)	40/5.5 5/0.2	40/5.5 5/0.2	40/5.5 5/0.2	40/5.5 5/0.2	40/5.5 5/0.2	40/5.5 5/0.2	40/5.5 5/0.2	40/5.5 5/0.2	40/5.5 5/0.2	40/5.5 5/0.2

*Also operates at 28 volts 3 amps or 20 volts 2.5 amps at slower speeds.

HOW TO ORDER

Stepper Motor Driven Waveguide Switch 4551xH-x00x
Manual Waveguide Switch 4552xH-x000

Frequency Band
- **0**: K
- **1**: Ka
- **2**: Q
- **3**: U
- **4**: V
- **5**: E
- **6**: W
- **7**: F
- **8**: D
- **9**: G

Flange Type
- **1**: Round (Ka- through G-bands only)
- **2**: Square (available in K- and Ka-band only)

Encoder Option: **2**: With encoder and TTL driver

Example: To order a G-band Stepper Motor Waveguide Switch with encoder and TTL driver specify a 45519H-1002.

Both the Manual and Stepper Motor Driven Switches are available between 18 and 220 GHz. They have inter-channel isolation of greater than 60 dB to 75 GHz and greater than 50 dB to 220 GHz. The Stepper Motor Driven Waveguide Switch has switching speeds as low as 122 milliseconds between positions for occasional switching and as low as 405 milliseconds on a more continuous basis.

The Stepper Motor Driven Waveguide Switch is available with a built-in encoder and TTL compatible driver. The encoder consists of an optical alignment system comprised of LEDs and phototransistors mounted in the switch assembly. A cable connects the encoder to the driver. TTL logic supplied to the driver controls the switch position. In addition, the switch may be operated by a switch on the driver unit.

The Hughes family of four-port rotary switches are extremely useful in the laboratory as well as in system applications. Laboratory setups requiring more than one source, detector, or thermistor combinations for substitution or comparison purposes prove to be ideal candidates.

Positive Index and Switching Action

60 dB Isolation

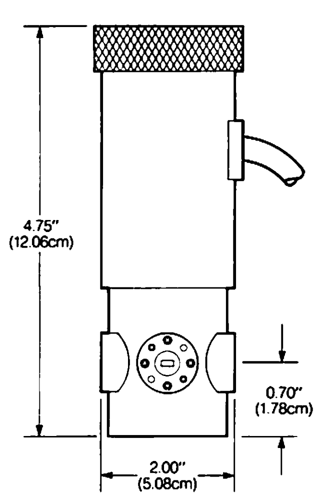
MECHANICAL SPECIFICATIONS

	Frequency Band (GHz)									
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
Waveguide Size ①	WR-42	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6	WR-5
Waveguide Flange ①	UG-595/U ②	UG-599/U ②	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)
		UG-381/U ③								

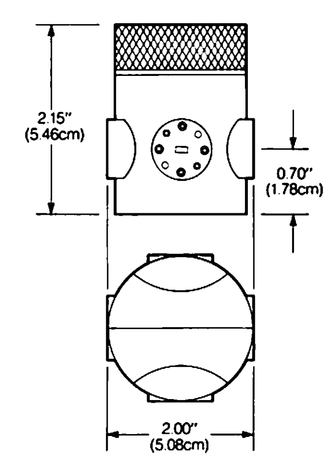
① Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

OUTLINE DRAWINGS (Ka- through G-band)

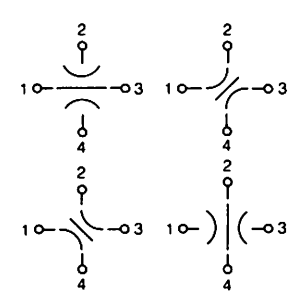
Stepper Motor Driven Waveguide Switch



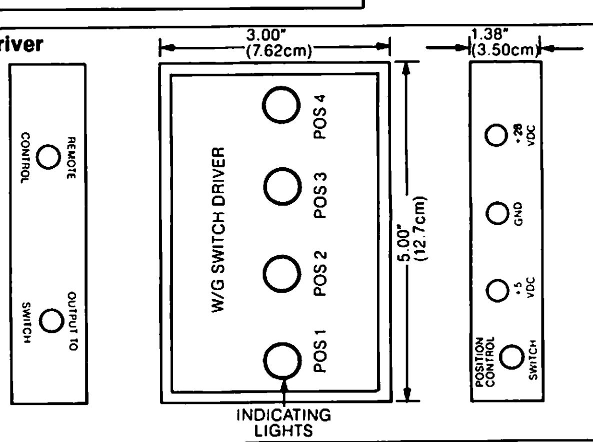
Manual Waveguide Switch



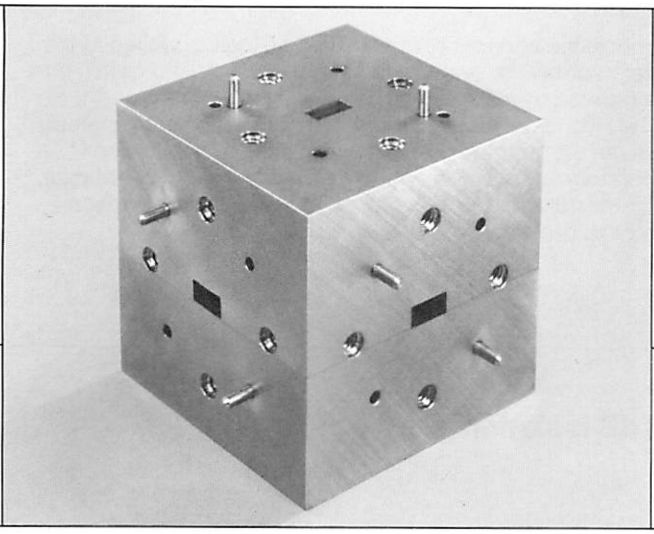
Switch Positions



TTL Driver



Matched Hybrid Tees



Hughes 4539xH series of Matched Hybrid Tees are available in two types—one covering 60% bandwidths in specified bands and another covering 90% of the waveguide bandwidth. These Matched Hybrid Tees are four port transmission line components made in a split block construction. The series arm (E-plane) and the shunt arm (H-plane) are positioned in such a way as to give equal power division in both directions of the colinear transmission line. Power transmitted into the series arm (E-plane) will split so that the power in each direction

FEATURES: **30 dB Isolation**

ELECTRICAL SPECIFICATIONS

		Frequency Band (GHz)								
		K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)
Frequency Coverage	90% bandwidth type (GHz)	18-25	26.5-38	33-48	40-58	50-72	60-87	75-106	—	—
	60% bandwidth type bandwidth (GHz)	5	8	10	12	15	18	21	30	36
Center Frequency Range	60% bandwidth type only (GHz)	20.5-24	30.5-36	38-45	46-54	57.5-67.5	69-81	85.5-99.5	105-125	128-152
Insertion Loss		.5	.5	.7	.8	1.0	1.0	1.0	1.2	1.2
VSWR	(H-Plane max)	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1
	(E-Plane max)	1.6:1	1.6:1	1.6:1	1.6:1	1.6:1	1.6:1	1.6:1	1.6:1	1.6:1
Isolation	(Sum-Difference Port dB min)	30	30	30	30	30	30	30	30	30
	(Colinear Arms dB min)	20	20	20	20	20	20	20	20	20
Balance (± dB max)		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

HOW TO ORDER

(Specify center frequency for 60% bandwidth type)

Model Number 4539xH-xx00

Frequency Band	**0:** K **1:** Ka **2:** Q **3:** U **4:** V **5:** E **6:** W **7:** F (Available in 60% band widths only) **8:** D (Available in 60% band widths only)
Flange Type	**1:** Round (Ka- through D-bands only) **2:** Square (available in K and Ka-bands only)
Bandwidth	**2:** 90% waveguide bandwidth (Available in K-thru W-bands only) **3:** 60% waveguide bandwidth

Example: To order a W-band 90% bandwidth matched Hybrid Tee, specify a 45396H-1200.

of the colinear transmission line will be 180° out of phase. Power transmitted into the shunt arm (H-plane) will be in phase in both directions of the colinear transmission line.

Sixty percent bandwidth Matched Hybrid Tees are available in nine waveguide bands between 18 and 170 GHz. Ninety percent bandwidth Matched Hybrid Tees are available in seven bands between 18 and 110 GHz. They have a 1.5:1 maximum VSWR in the H-plane and a 1.6:1 maximum VSWR in the E-plane.

These matched Hybrid Tees are extremely useful where balanced power division and high isolation are required over a broad bandwidth. Typical applications include use in millimeter-wave bridge circuits for impedance and phase measurement, power dividers/combiners, balanced mixers, and phase/frequency discriminators. An alternate mechanical configuration with folded colinear arms is available on request for special applications.

± 0.5 dB Balance **1.5:1 VSWR**

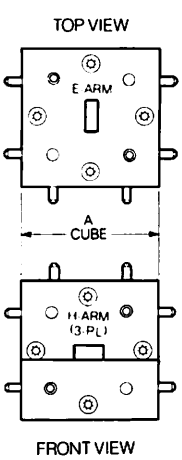
MECHANICAL SPECIFICATIONS

		Frequency Band (GHz)								
		K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)
Dimensions (inches (cm))	A	1.5 (3.8)	1.5 (3.8)	1.5 (3.8)	1.5 (3.8)	1.2 (3.0)	1.2 (3.0)	1.2 (3.0)	1.2 (3.0)	1.2 (3.0)
Waveguide Size ①		WR-42	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
Waveguide Flange ①		UG-595/U ②	UG-599/U ②	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)
			UG-381/U ③							

① Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

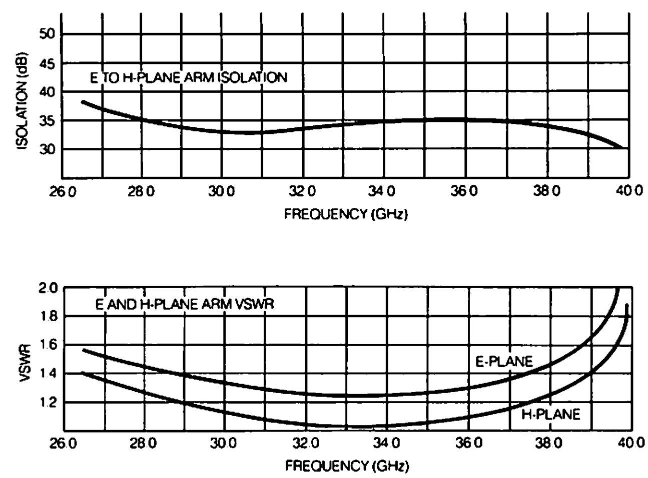
OUTLINE DRAWINGS

Matched Hybrid Tee

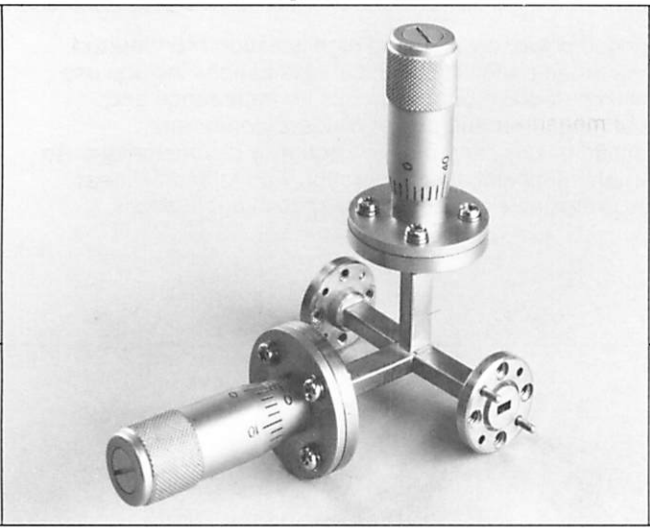


TYPICAL DATA

Broadband Matched Hybrid Tee



E-H Tuners and Hybrid Tees



Hughes 4558xH series of E-H Hybrid Tees are four-port transmission line components where the junction of the series arm (E-plane) and the shunt arm (H-plane) are positioned in such a way to give power division and combination in both directions of the transmission line. These Tees are available in nine waveguide sizes between 26.5 and 220 GHz. They are useful for many laboratory measurements. For those applications requiring high isolation between shunt and series arms, impedance matching, and balanced power splitting,

FEATURES: 26.5 to 220 GHz Coverage

HOW TO ORDER

E-H Hybrid Tees 4558xH-x000
E-H Tuners 4568xH-x100

Frequency Band	**1:** Ka **2:** Q **3:** U **4:** V **5:** E **6:** W **7:** F **8:** D **9:** G (available for Hybrid Tees only)
Flange Type	**1:** Round **2:** Square (available in Ka-band only) **3:** Pin Contact (available in F, D, and G-bands only)

Example: To order an F-band E-H Tuner with round flange, specify a 45687H-1100

Hughes Matched Hybrid Tees series 4539xH should be purchased.

Hughes 4568xH series of E-H Tuners are an extension of the Tee in that micrometer tuned noncontacting adjustable shorts are placed in both the series and shunt arms. These E-H Tuners allow simultaneous adjustment of both the phase and amplitude of the reflection coefficient and are very useful for all impedance matching applications.

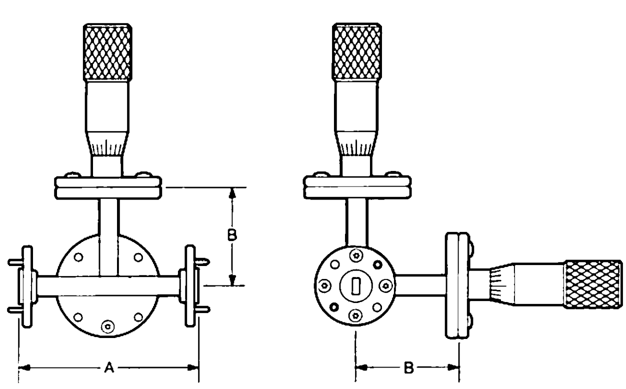
MECHANICAL SPECIFICATIONS

		Frequency Band (GHz)								
		Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
E-H Hybrid Tees Dimensions (inches (cm))	A	2.8 (7.1)	2.8 (7.1)	2.8 (7.1)	2.2 (5.6)	2.2 (5.6)	2.2 (5.6)	2.0 (5.1)	2.0 (5.1)	2.0 (5.1)
	B	1.5 (3.8)	1.5 (3.8)	1.5 (3.8)	1.1 (2.8)	1.1 (2.8)	1.1 (2.8)	1.0 (2.5)	1.0 (2.5)	1.0 (2.5)
E-H Tuners Dimensions (inches (cm))	A	2.8 (7.1)	2.8 (7.1)	2.8 (7.1)	2.2 (5.6)	2.2 (5.6)	2.2 (5.6)	2.0 (5.1)	2.0 (5.1)	—
	B	1.5 (3.8)	1.5 (3.8)	1.5 (3.8)	1.1 (2.8)	1.1 (2.8)	1.1 (2.8)	1.0 (2.5)	1.0 (2.5)	—
Waveguide Size①		WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6	WR-5
Waveguide Flange①		UG-599/U②	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)
		UG-381/U③						pin contact	pin contact	pin contact

① Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

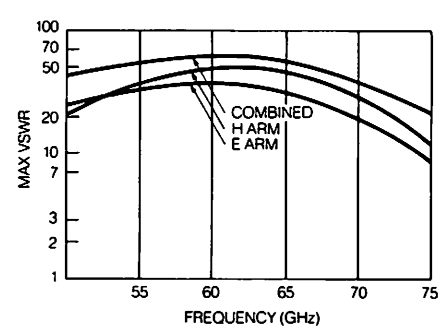
OUTLINE DRAWINGS

E-H Tuner



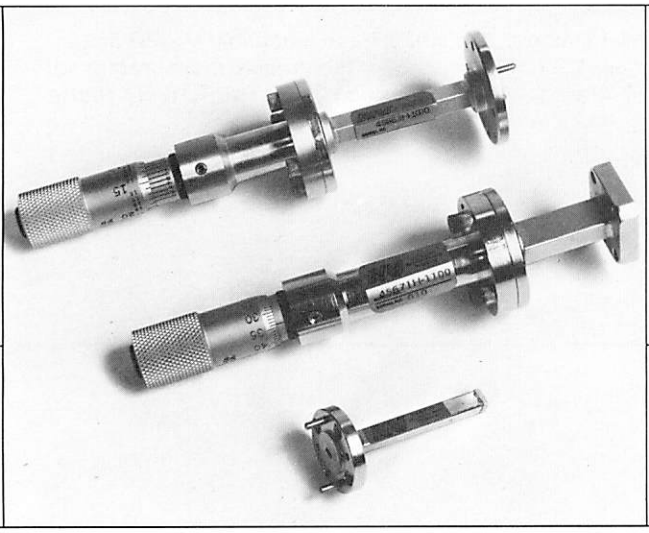
TYPICAL DATA

Hybrid Tee



5

Terminations, Tunable Loads, and Tunable Shorts



Hughes 4566xH series Tunable Loads and Hughes series 4561xH Terminations consist of tapered absorbers within a waveguide section. The Tunable Loads utilize a metric micrometer tuning mechanism which allows the microwave absorber to be positioned within the guide while maintaining a constant magnitude of reflection coefficient. Travel of the load within the waveguide section is greater than one-half wavelength at the lowest frequency. Hughes series 4567xH Tunable Shorts consist of movable noncontacting choke plungers within a straight section of waveguide.

FEATURES: **Terminations to 220 GHz**

ELECTRICAL SPECIFICATIONS

	Frequency Band (GHz)								
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
VSWR									
Terminations (max)	1.03:1	1.03:1	1.04:1	1.05:1	1.05:1	1.06:1	1.08:1	1.1:1	1.12:1
Tunable Loads (nom)	1.05:1	1.05:1	1.05:1	1.05:1	1.05:1	1.06:1	1.08:1	1.1:1	—
Tunable Shorts (min)	20:1	20:1	20:1	20:1	20:1	20:1	18:1	15:1	—
Average Power (W max)	1.0	0.7	0.3	0.3	0.3	0.2	0.1	0.1	0.1

HOW TO ORDER

Terminations 4561xH-x000
Tunable Loads 4566xH-x200
Tunable Shorts 4567xH-x200

Frequency Band
1: Ka
2: Q
3: U
4: V
5: E
6: W
7: F
8: D
9: G (Terminations only)

Flange Type
1: Round
2: Square (available in Ka-band only)
3: Pin Contact (available in F, D, and G-bands only)

Example: To order a W-band Tunable Short with round flange, specify a 45676H-1200.

The terminations are available in nine waveguide bands between 26.5 and 220 GHz. The Tunable Loads and Shorts are available in eight waveguide bands between 26.5 and 170 GHz. The terminations are designed to have a maximum VSWR ranging from 1.03:1 in Ka- and Q-bands to 1.12:1 in G-band. The Tunable Shorts offer VSWR in excess of 20:1 through 110 GHz and 15:1 through 170 GHz. Micrometer resolution on both the Tunable Loads and Tunable Shorts is 0.01 millimeter.

The Tunable Loads which have a nominal VSWR of 1.06:1 to 110 GHz are used for the precise measurement of small reflections in transmission lines. The Tunable shorts are adjustable short circuit reference planes.

Tunable Loads and Shorts to 170 GHz

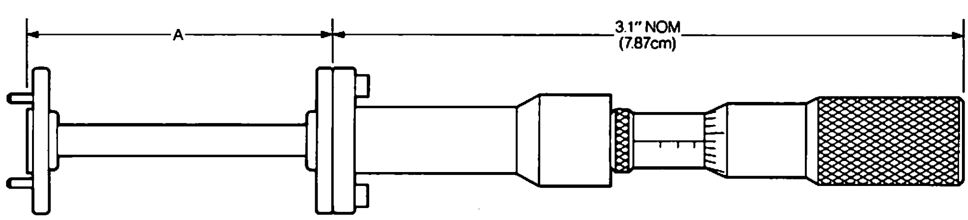
MECHANICAL SPECIFICATIONS

	Frequency Band (GHz)								
	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
Dimensions (inches (cm)) Terminations A	2.7 (7.0)	2.7 (7.0)	2.7 (7.0)	1.5 (3.8)	1.5 (3.8)	1.5 (3.8)	1.0 (2.5)	1.0 (2.5)	1.0 (2.5)
Tunable Loads & Shorts A	1.2 (3.1)	1.2 (3.1)	1.1 (2.8)	1.1 (2.8)	1.0 (2.5)	1.0 (2.5)	1.0 (2.5)	1.0 (2.5)	—
Waveguide Size①	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6	WR-5
Waveguide Flange①	UG-599/U②	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)
	UG-381/U③						pin contact	pin contact	pin contact

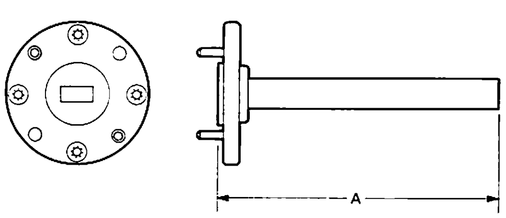
① Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

OUTLINE DRAWINGS

Tunable Load And Short



Termination



E- and H-Plane Bends, Twists, and Tees

Hughes 4542xH series of E- and H-Plane Bends, 4541xH series Waveguide Twists, 4557xH series of E-Plane Tees, and 4559xH series of H-Plane Tees are precisely formed waveguide sections which maintain internal waveguide dimensions while changing the external orientation. The bends, tees, and twists are all offered in ten waveguide bands between 18 and 220 GHz. The bends are supplied with angles of 30,° 45,° 60,° and 90.° The twists are supplied with angles of 45° left or right hand and 90.°

FEATURES: **18 to 220 GHz Coverage**

HOW TO ORDER

H-Plane Tees 4559xH-x000
E-Plane Tees 4557xH-x000
Twists 4541xH-xxxx
E- and H-Plane Bends 4542xH-xxxx

Frequency Band
- **0:** K
- **1:** Ka
- **2:** Q
- **3:** U
- **4:** V
- **5:** E
- **6:** W
- **7:** F
- **8:** D
- **9:** G

Flange Type
- **1:** Round (Ka- through G-bands only)
- **2:** Square (available in K-and Ka-bands only)
- **3:** Pin Contact (F- through G-bands only)

Twist Polarity and Bend Plane

Twists
- **0:** 90°
- **1:** 45,° Left hand
- **2:** 45,° Right hand

Bends
- **1:** E-plane
- **2:** H-plane

Twist and Bend Angle
- **30:** 30°
- **45:** 45° *
- **60:** 60°
- **90:** 90° *

* Twist available in 45° and 90° only

Example: To order a V-band 45° right hand Twist with round flange, specify a 45414H-1245.

30°, 45°, 60°, and 90° Bends

45° LH and RH and 90° Twists

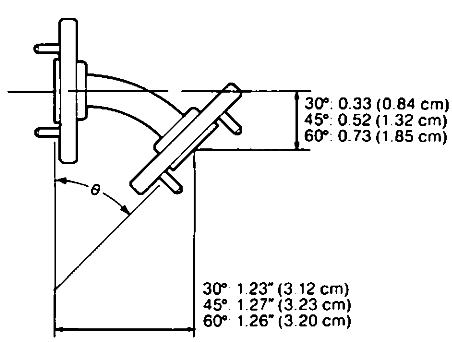
MECHANICAL SPECIFICATIONS

		Frequency Band (GHz)									
		K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
Waveguide Twist Length (inches (cm))	90°	2.56 (6.50)	1.75 (4.45)	1.25 (3.18)	1.25 (3.18)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)
	45°	2.56 (6.50)	1.25 (3.18)	1.25 (3.18)	1.25 (3.18)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)	1.00 (2.54)
Tee Dimensions (inches (cm))	A	2.8(7.1)	2.8 (7.1)	2.8 (7.1)	2.8 (7.1)	2.2 (5.6)	2.2 (5.6)	2.2 (5.6)	2.0 (5.1)	2.0 (5.1)	2.0 (5.1)
	B	1.5(3.8)	1.5 (3.8)	1.5 (3.8)	1.5 (3.8)	1.1 (2.8)	1.1 (2.8)	1.1 (2.8)	1.0 (2.5)	1.0 (2.5)	1.0 (2.5)
Waveguide Size ①		WR-42	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6	WR-5
Waveguide Flange ①		UG-595/U②	UG-599/U②	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)
			UG-381/U③						pin contact	pin contact	pin contact

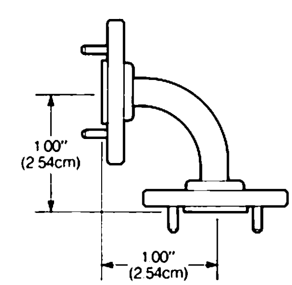
① Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

OUTLINE DRAWINGS

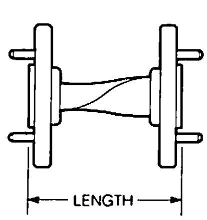
30°, 45°, and 60° E-Plane and H-Plane



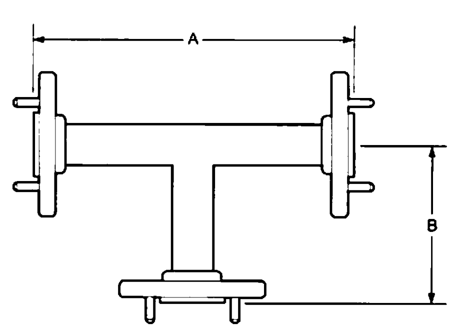
90° E-Plane and H-Plane



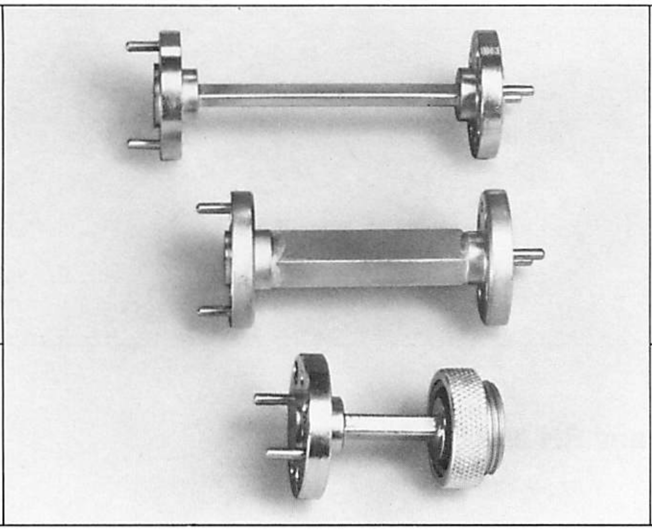
Waveguide Twist



Waveguide Tee



Straight Waveguide Sections, Tapered Transitions, Flange Adapters



Hughes 4543xH series of Straight Waveguide Sections are sections of waveguide offered in customer specified lengths up to ten inches. Hughes 4547xH series of Flange Adapters are short sections of waveguide with different flange types suitable for that waveguide size on either end. Hughes 4545xH series Tapered Transitions are short sections of tapered waveguide terminated with standard waveguide band waveguide dimensions at each end. They are made using electroforming techniques for precise dimensions resulting in a high degree of mode

FEATURES: Frequency Coverag

HOW TO ORDER

Tapered Transitions . . . . 4545xH-x x x0

Large Size Waveguide	**0:** K **1:** Ka **2:** Q **3:** U **4:** V **5:** E **6:** W **7:** F **8:** D	
Large Size Flange	**1:** Round (Ka- through D-bands only) **2:** Square (available in K and Ka-bands only) **3:** Pin Contact (available in F and D-bands only)	
Small Size Waveguide	**1:** Ka **2:** Q **3:** U **4:** V **5:** E **6:** W **7:** F **8:** D **9:** G	
Small Size Flange	**1:** Round **2:** Square (available in Ka-band only) **3:** Pin Contact (available in F, D and G-bands only)	

Example: To order a Tapered Transition from W to G-band with a round flange at W-band (WR-10) and a pin contact flange at G-band (WR-5), specify a 45456H-1930.

Flange Adapters. 4547xH-x x00

Waveguide Band	**0:** K **1:** Ka **7:** F **8:** D **9:** G
Input Flange	**1:** Round **2:** Square (available in K and Ka-bands only) **3:** Pin Contact (available in F, D and G-bands only)
Output Flange	**1:** Round **2:** Square (available in K and Ka-bands only) **3:** Pin Contact (available in F, D and G-bands only)

Example: To order a D-band Flange Adapter with a round input flange and pin contact output flange, specify a 45478H-1300.

Straight Sections 4543xH-x0xx

Waveguide Band	**0:** K **1:** Ka **2:** Q **3:** U **4:** V	**5:** E **6:** W **7:** F **8:** D **9:** G
Flanges Input and Output (2 Places)	**1:** Round (Ka- through G-bands only) **2:** Square (available in K and Ka-bands only) **3:** Pin Contact (available in F, D, and G-bands only)	
Length in Inches	**01:** 1 **02:** 2 **03:** 3 **04:** 4 **05:** 5	**06:** 6 **07:** 7 **08:** 8 **09:** 9 **10:** 10

Example: To order an E-band Straight Section with round flanges 5 inches long specify a 45435H-1005.

purity in the transfer process along with minimum VSWR and insertion loss. The units are available in ten waveguide bands between 18 and 220 GHz.

WAVEGUIDE FLANGE
QUICK-DISCONNECTS ~~w/o FLANGES~~ NOW AVAILABLE.
Contact Factory

from 18 to 220 GHz

TAPERED TRANSITION LENGTHS (inches (cm))

	Frequency Band (GHz)									
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
K-Band (18-26.5 GHz) (WR-42)		2.2 (5.6)	2.2 (5.6)	2.5 (6.4)	2.7 (6.9)	3.3 (8.4)	3.3 (8.4)	3.4 (8.6)	3.5 (8.9)	3.6 (9.2)
Ka-Band (26.5-40 GHz) (WR-28)			2.0 (5.1)	2.0 (5.1)	2.0 (5.1)	2.4 (6.1)	1.8 (4.6)	2.2 (5.6)	2.3 (5.8)	2.4 (6.1)
Q-Band (33-50 GHz) (WR-22)				1.8 (4.6)	1.8 (4.6)	1.8 (4.6)	1.8 (4.6)	1.8 (4.6)	1.8 (4.6)	1.8 (4.6)
U-Band (40-60 GHz) (WR-19)					1.2 (3.1)	1.5 (3.8)	1.5 (3.8)	1.5 (3.8)	1.5 (3.8)	1.5 (3.8)
V-Band (50-75 GHz) (WR-15)						1.4 (3.6)	1.4 (3.6)	1.4 (3.6)	1.4 (3.6)	1.4 (3.6)
E-Band (60-90 GHz) (WR-12)							1.3 (3.3)	1.3 (3.3)	1.3 (3.3)	1.3 (3.3)
W-Band (75-110 GHz) (WR-10)								1.2 (3.1)	1.2 (3.1)	1.2 (3.1)
F-Band (90-140 GHz) (WR-8)									1.1 (2.7)	1.1 (2.7)
D-Band (110-170 GHz) (WR-6)										1.0 (2.6)

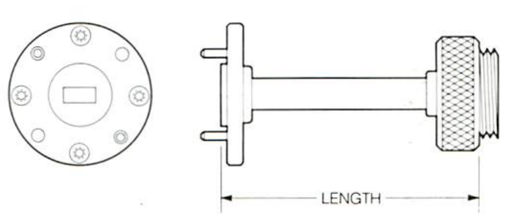
FLANGE ADAPTERS

	K	Ka	Q	U	V	E	W	F	D	G
Length (inches (cm))	1.0 (2.54)	1.0 (2.54)						1.0 (2.54)	1.0 (2.54)	1.0 (2.54)
Waveguide Size①	WR-42	WR-28						WR-8	WR-6	WR-5
Waveguide Flanges①	UG-595/U to /67-004	UG-599/U② to UG-381/U③						UG-387/U (mod) to pin contact	UG-387/U (mod) to pin contact	UG-387/U (mod) to pin contact

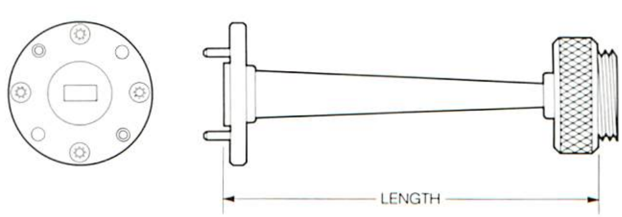
① Refer to page 157 for specifications and MIL specification cross reference ② Square flange ③ Round flange

OUTLINE DRAWINGS

Flange Adapter



Tapered Transition



ANTENNAS AND ANTENNA PRODUCTS

Hughes offers a wide range of antennas complemented with related products such as polarizers, orthomode transducers, transitions, adaptors, monopulse comparators and others. In addition, Hughes offers custom designs of many types, including fully integrated antennas, mounts and RF subsystems. Figure 1 shows, for example, an integrated direction finding system covering 18 to 100 GHz, which includes a remote-control rotating splash plate integrated with a cluster of conical horns and the receiver itself.

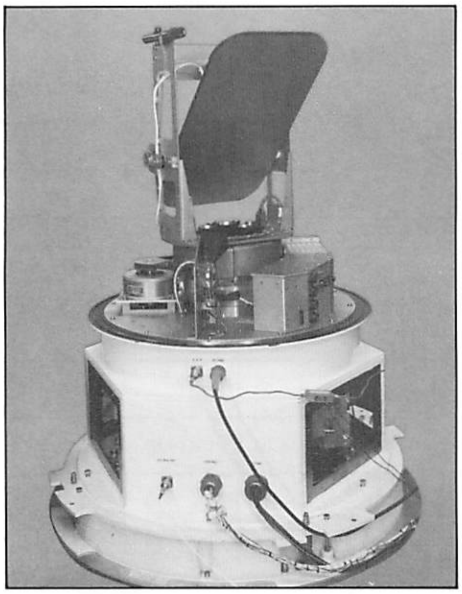


FIG. 1. INTEGRATED DIRECTION-FINDING RECEIVER SYSTEM WITH ROTATING REMOTE-CONTROL SPLASH PLATE AND CLUSTER OF CONICAL HORNS COVERING THE 18 TO 100 GHz FREQUENCY RANGE.

ANTENNAS

There are three standard types offered in the catalog:

1) *Parabolic Reflectors* (pages 132 and 133). These include prime-focus feed and Cassegrain types. They are used for applications requiring narrow beamwidth, high gain or both. Cassegrain antennas are also offered with single-plane or dual-plane monopulse capability. Custom designed parabolic reflector antennas with offset feeds, which eliminate the aperture blocking and mismatch at the feed, have been made and tested. Since for all practical purposes the offset feed is out of the path of the reflected energy, there is no pattern distortion due to aperture blockage, nor any significant energy intercepted by the feed. The sidelobes of the offset feed antenna were all measured to be greater than 26 dB down when used with a 20 inch parabolic reflector. This configuration is shown in Figure 2.

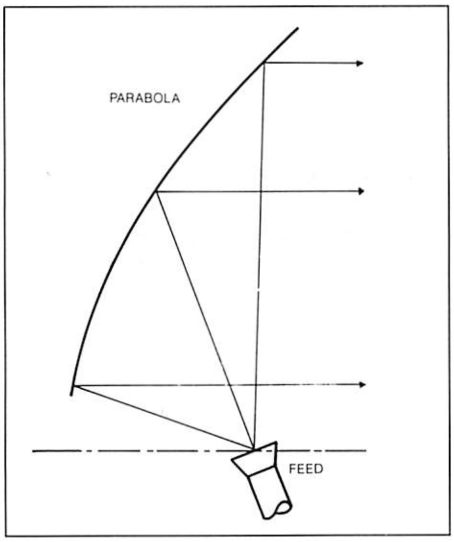


FIG. 2. PARABOLIC REFLECTOR WITH OFFSET FEED

2) *Horn-Lens Antennas*
A full range of low-weight horn-lens antennas specially designed for low sidelobes is offered on pages 134 and 135 of this catalog.

3) *Pyramidal and Conical Standard Gain Horns* (pages 136 and 137)
These antennas are designed and manufactured to precise aperture and flare tolerances to permit their use as (calibration) gain standards, but they can also be used for general applications.

In addition to the three types mentioned above, special custom designs are also available. Our extensive capabilities can be illustrated with a few examples:

1) *Lens Antennas*
Lens antennas provide design flexibility and can be produced at a relatively low cost compared to reflectors up through 6 inches diameter. Plano-convex and spherical lenses can provide a wide range of gain with aperture diameters ranging from under 1 inch to over 6 inches (see Figure 3). Because of low loss of dielectric lens material, lenses may be used up through 250 GHz with little sacrifice in performance. Figure 4 shows a typical radiation pattern for a 2″ spherical lens at 60 GHz. Lenses can also be designed to tailor the azimuthal and elevation patterns independently. With proper design, radiation patterns with over 70° coverage in one plane and under 5° beamwidth in the orthogonal plane are possible.

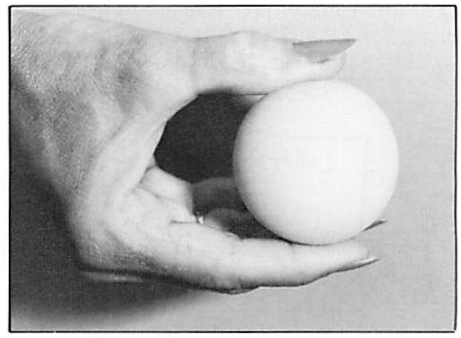


FIG. 3. SPHERICAL LENS ANTENNA.

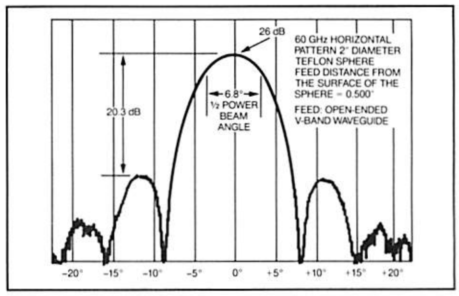


FIG. 4. 2-INCH TEFLON SPHERICAL LENS RADIATION PATTERN AT 60 GHz.

2) *Horns*
Our capabilities include circular, corrugated and scalar horns in addition to the conical and rectangular ones shown on pages 136 and 137. Figure 5 shows a special circular horn with a 3 dB beamwidth of 55 degrees and a gain flatness of ±1.0 dB over the full 75 to 110 GHz band.

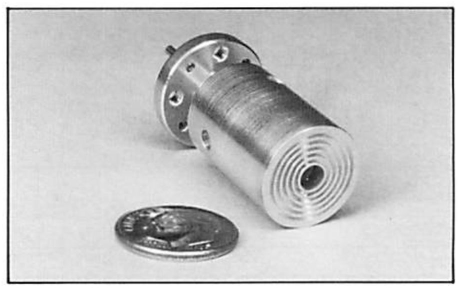


FIG. 5. CIRCULAR HORN WITH 55 DEGREES 3-dB BEAM WIDTH OVER 75-110 GHz RANGE.

3) *Omnidirectional*
Hemispherical coverage can be obtained with special reflectors such as the one used in the portable noise source described in the Measurement Systems and Subsystems Section on page 140. A radiation pattern for this antenna is shown in Figure 6.

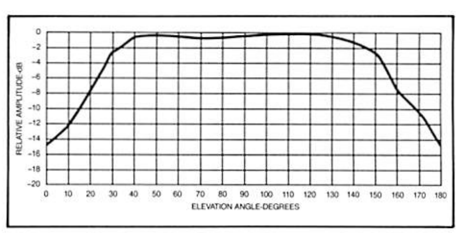


FIG.6. RADIATION PATTERN OF HEMISPHERICAL ANTENNA.

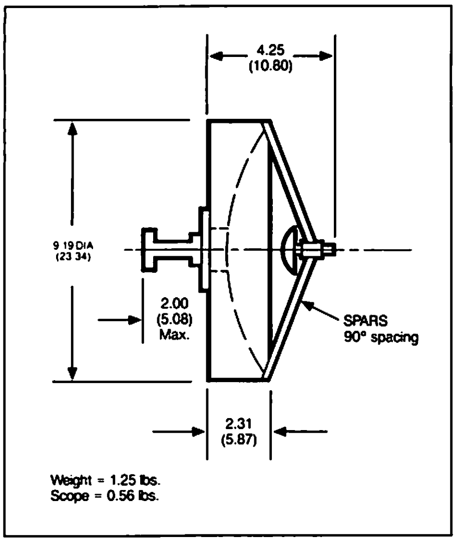


FIG. 7. OUTLINE DRAWING OF LOW COST 9-INCH COPPER-CLAD PRESSED FOAM ANTENNA.

4) Copper Clad Pressed Foam
A low cost copper clad pressed foam antenna shown in Figure 7 reduces the cost of cassegrain antennas by a factor of 2:1. A nine inch diameter model has been tooled for manufacture and other diameters can be tooled where the quantity will justify the cost.

ANTENNA PRODUCTS

All antennas in this catalog except the pyramidal standard gain horns and prime feed dishes have a circular waveguide input, designed for interfacing with the polarizers and orthomode transducers described on pages 138 and 139. Rectangular to circular waveguide transitions are offered from the circular waveguides to the standard rectangular waveguide sizes. (Page 138)

1) *Polarizers* (Page 138)
These components are two-port reciprocal devices which accept a linear polarized input and generate a circularly polarized output. Both input and output are in circular waveguide. Fixed polarizers generate either a left or a right-hand circular polarization. Switchable polarizers allow for user selection of output circular sense (left or right). Both types are reciprocal, i.e. they convert a circularly polarized wave (of the right sense) into a linear polarized one.

2) *Orthomode Transducers* (page 138)
These components are three-port devices, two in circular waveguide and one in rectangular waveguide. They are used to separate (on receive) or combine (on transmit) two linear polarizations into a circular waveguide. In the standard receive application, the antenna circular waveguide output is directly connected to the orthomode transducer input. The vertical and horizontal components received by the antenna are separated in the transducer and exit through the other two ports. A circular to rectangular waveguide transition is normally connected to the through port to mate with standard rectangular waveguide equipment.

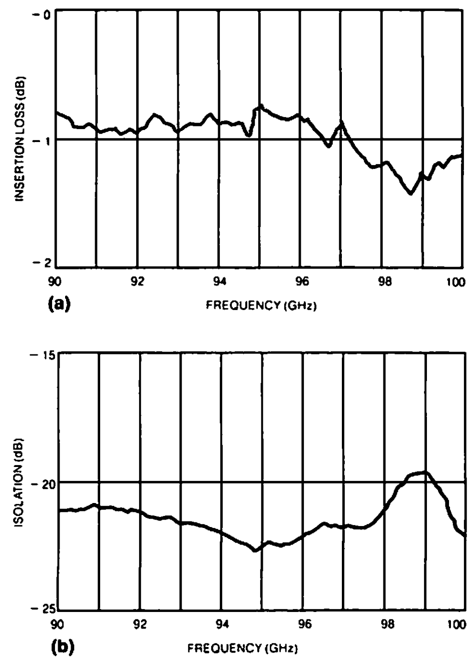


FIG. 8. INSERTION LOSS (a) AND ISOLATION (b) OF A 90 TO 100 GHz ORTHOMODE TRANSDUCER WHEN USED IN A POLARIZATION DIVERSITY RECEIVER.

Test data shown in Figure 8 shows the performance of a W-band orthomode transducer when used in a receiver capable of receiving both orthogonal polarizations (either linear or circular).

In addition to these products, special designs are available. Monopulse comparators are described on page 132. Vertical to horizontal switchable polarizers can be configured by a series connection of one fixed and one switchable polarizer.

CIRCULAR WAVEGUIDE SIZES

All standard antennas and antenna products in this catalog which have circular waveguide inputs or outputs are designed for operation in the fundamental TE_{11} mode. The circular waveguide sizes have been chosen to minimize the possibility of exciting unwanted higher-order modes. Since the spurious-free frequency range is smaller in circular than in rectangular waveguide, each standard waveguide band has been divided into sub-bands chosen for single TE_{11} mode propagation. The mode hierarchy is shown in Figure 9; it is readily seen that the cut-off frequency of the first TE

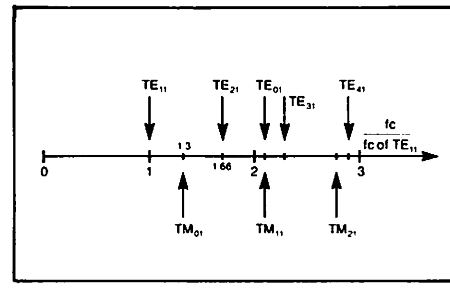


FIG. 9. RELATIVE CUTOFF FREQUENCIES OF MODES IN CIRCULAR WAVEGUIDE.

higher-order mode (the TE_{21}) is 1.66 times the cut-off frequency of the fundamental TE_{11}, (the TM_{01} mode is not normally excited from a rectangular TE_{10} transition, but can not be totally ignored. Most Hughes waveguide transitions and circular waveguide components have built-in mode supressors).

ANTENNA DESIGN AIDS

To aid the system designer in selecting the right antenna, Hughes offers a millimeter-wave system calculator (supplied free upon written request) that covers antenna performance from 1 to 300 GHz with aperture diameters ranging from 2 inches to 20 feet. This handy calculator will help you determine: free space attenuation vs range, near and far field limits, gain reduction vs surface tolerance, beamwidth, gain, and ERP.

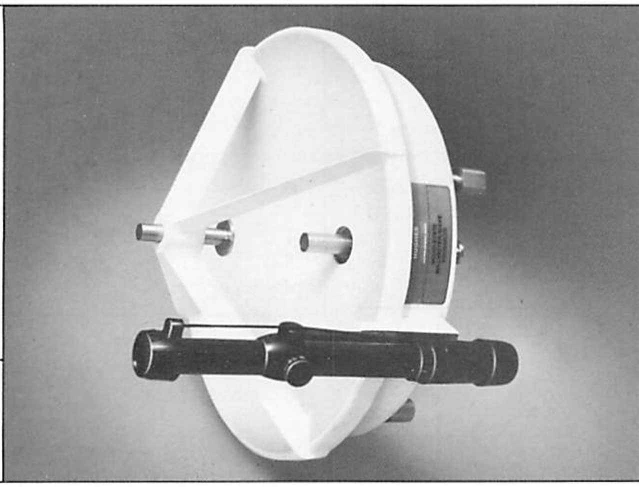
TABLE 1. CIRCULAR WAVEGUIDE SIZES

Rectangular Waveguide Band		Frequency Range① (GHz)	Circular Waveguide Diameter (inches (cm))	
K	LARGE	17.5-20.5	0.455	(1.16)
	MED	20-24.5	0.396	(1.01)
	SMALL	24-26.5	0.328	(0.83)
Ka	LARGE	26.5-33	0.315	(0.80)
	MED	33-38.5	0.250	(0.64)
	SMALL	38.5-40	0.219	(0.56)
Q	LARGE	33-38.5	0.250	(0.64)
	MED	38.5-43	0.219	(0.56)
	SMALL	43-50	0.188	(0.48)
U	LARGE	40-43	0.210	(0.53)
	MED	43-50	0.188	(0.48)
	SMALL	50-60	0.165	(0.42)
V	LARGE	50-58	0.165	(0.42)
	MED	58-68	0.141	(0.36)
	SMALL	68-75	0.125	(0.32)
E	LARGE	60-66	0.136	(0.35)
	MED	66-88	0.125	(0.32)
	SMALL	88-90	0.094	(0.24)
W	LARGE	75-88	0.112	(0.28)
	SMALL	88-110	0.094	(0.24)
F	LARGE	90-115	0.089	(0.23)
	SMALL	115-140	0.075	(0.19)
D	LARGE	110-140	0.073	(0.19)
	SMALL	140-160	0.059	(0.16)

① Select the large diameter within the band when complete waveguide band coverage is necessary.

6

Parabolic Dish Antenna with Monopulse Capability



The Hughes 4581xH series of Parabolic Dish Antennas incorporate a prime focus feed for the four inch diameter model and a Cassegrain feed for the 6, 10, 12, 18, 24, and 36-inch diameter models. A Cassegrain feed is used for the larger diameter models in order to reduce the attenuation in the feed and to achieve better sidelobe performance. The 4, 6, 10, and 12-inch models are available between 18 and 170 GHz. The 18, 24 and 36-inch models are available to 110 GHz.

The 4 inch Prime Focus model uses a standard rectangular feed and features low sidelobe performance and low VSWR (1.2:1 is typical).

VSWR
(without Comparator) 1.2:1 typ.

SPECIFICATIONS

	WITH MONOPULSE COMPARATOR	WITHOUT MONOPULSE
BEAMWIDTH	See Figure 1	See Figure 1
GAIN	See Figure 2	See Figure 2
SIDELOBES (dB down typ)	18	18
VSWR (typ)	1.5:1	1.2:1
MONOPULSE NULL DEPTH		
@ CENTER FREQUENCY (dB min)	30	
OVER 8% BANDWIDTH (dB min)	15	
CHANNEL SEPARATION		
Δ AZIMUTH TO Δ ELEVATION (dB min)	25	
SUM TO Δ ELEVATION (dB min)	25	
SUM TO Δ AZIMUTH (dB min)	25	
COMPARATOR INSERTION LOSS		
ALL FOUR CHANNELS (dB max)	3.5	

HOW TO ORDER (Specify center frequency and circular waveguide diameter (see page131) at time of order.)

Model Number 4581xH-xxxx

Waveguide Band
0: K **3**: U **6**: W
1: Ka **4**: V **7**: F
2: Q **5**: E **8**: D

Flange (Circular Waveguide on Cassegrain types)
1: Round (Ka- through D-bands only)
2: Square (Available in K- and Ka-bands only)
3: Pin Contact (Available in F- and D-bands only)
4: Square, Mating with Orthomode Transducer (Available in non-monopulse K- and Ka-bands only)

Reflector Material and Feed Type
0: Aluminum Prime Focus (Available in 4" only)
1: Epoxy-glass-laminate (E-G-L) Cassegrain
3: E-G-L Cassegrain with monopulse feed and comparator③
4: Graphite Cassegrain
5: Graphite Cassegrain with monopulse feed and comparator③

Dish Diameter
04: 4" (10.2 cm)② **18**: 18" (45.7 cm)①
06: 6" (15.2 cm) **24**: 24" (61.0 cm)①
10: 10" (25.4 cm) **36**: 36" (91.4 cm)①
12: 12" 930.5 cm)

① Available in K- through W-bands only. ② Available on prime focus only. ③ Available in Ka-, V-, and W-bands only.

Monopulse-to-Standard Flange Adapters 4547xH-x020
(Specify Center Frequency at time of order)

Waveguide Band
1: Ka **4**: V **6**: W

Flange Type
1: Round
2: Square (Available in Ka-band only)

Figure 1: Beamwidth

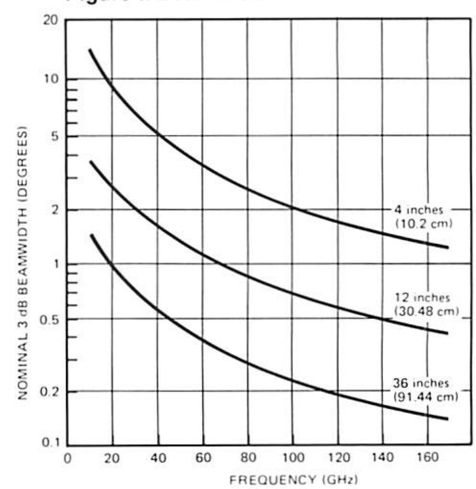
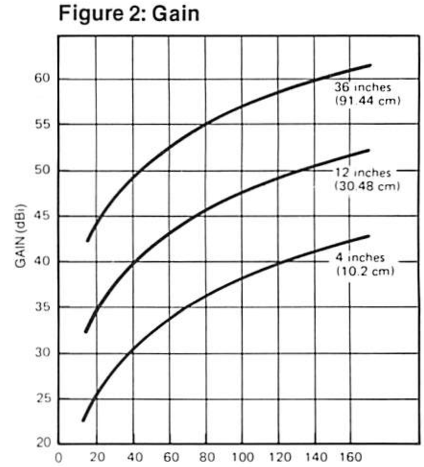


Figure 2: Gain



The reflectors are constructed of graphite or solid epoxy-glass-laminate with bonded aluminum flame spray surface metalization. They feature low sidelobe performance. (The Cassegrain feed models have sidelobes typically down 18 dB as shown in the radiation patterns given.) VSWRs of 1.2:1 are typical. All Cassegrain feed types are supplied with a boresighted telescopic sight. Cassegrain models use circular waveguide feeds, but a monopulse feed and comparator is also available on the Ka-, V-, and W-band models. The short compact comparator has been designed for the broadest possible bandwidths by carefully keeping all path lengths short and equidistant. Null depths of 15 dB are guaranteed over 8% bandwidths and 30 dB is guaranteed at center frequency. A single plane monopulse feed and comparator are available on special request.

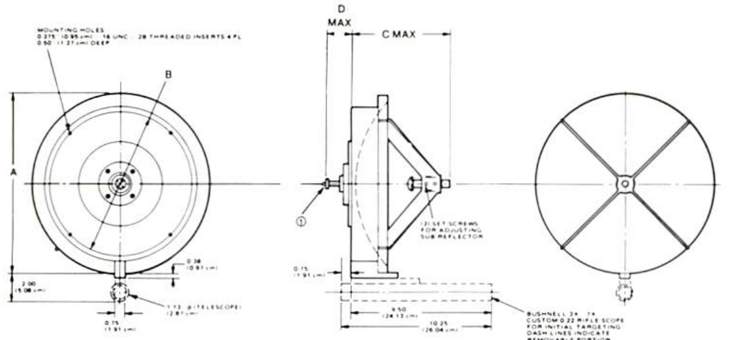
Hughes circular to rectangular waveguide adaptors are available along with switchable and non-switchable polarizers and orthomode transducers described on pages 138 and 139. Radiation patterns are supplied with each antenna at the customer specified frequency. Thirteen-inch and 15-inch reflectors are also available on special request. Please consult factory.

MONOPULSE NULL DEPTH
30 dB min.

SIDE LOBES
18 dB down typ.

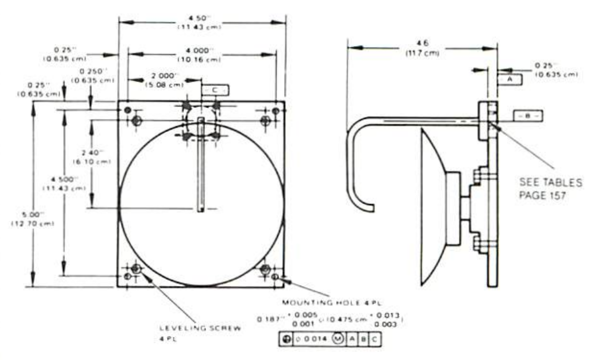
OUTLINE AND MOUNTING DRAWINGS

Cassegrain Types



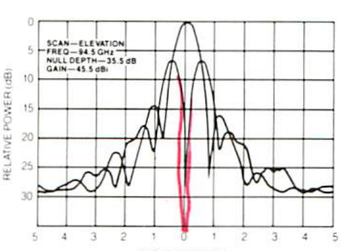
① See page 131 for circular waveguide dimensions.
See page 157 for flange dimensions. Monopulse units mate with Hughes 4547xH-x020 adaptors.

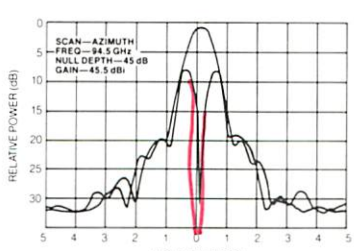
Prime Focus Type

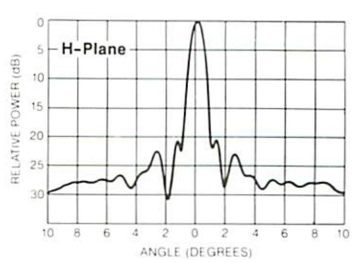


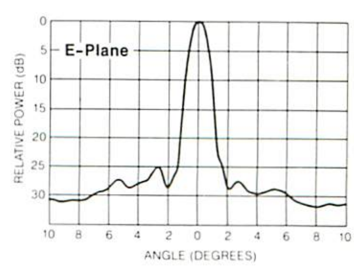
MECHANICAL SPECIFICATIONS		ANTENNA SIZE (inches)					
DIMENSIONS (inches (cm))		6	10	12	18	24	36
	A	6 (15.2)	10.0 (25.4)	12.0 (30.5)	18.0 (45.7)	24.75 (62.9)	37.0 (94.0)
	B	4 (10.2)	7.0 (17.8)	10.0 (25.4)	10.0 (25.4)	16.5 (41.9)	24.0 (61.0)
	C	4.3 (10.9)	6.5 (16.9)	7.0 (17.8)	9.0 (22.9)	11.0 (27.9)	15.0 (38.1)
Without monopulse (variable, max)	D	2.5 ~~1.0 (2.54)~~					
With KA-band monopulse (variable, max)	D	8.6 (21.84) + 3.5 (8.9) for Adapter					
With V-band monopulse (variable, max)	D	7.6 (19.30) + 3.0 (7.6) for Adapter					
With W-band monopulse (variable, max)	D	5.6 (14.22) + 2.3 (5.8) for Adapter					
Weight (lbs (kg) approx)	E-G-L	1.1 (0.5)	4.16 (1.89)	4.92 (2.24)	7.91 (3.60)	12.66 (5.75)	19.24 (8.75)
	Graphite	0.6 (0.26)	2.12 (0.96)	2.64 (1.20)	4.61 (2.10)	6.28 (2.85)	9.71 (4.41)

TYPICAL PERFORMANCE CURVES

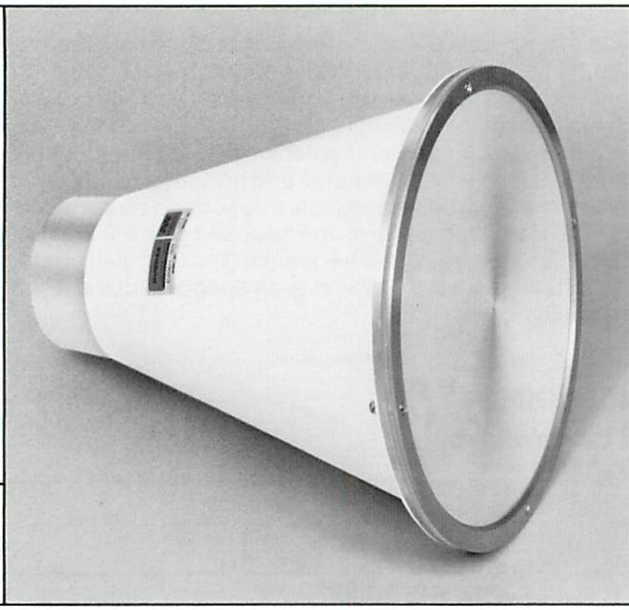








Horn Lens Antennas



Hughes 4580xH series of low side lobe Horn Lens Antennas feature the use of corrugated conical horn radiators and plano-convex lenses connected in a graphite/epoxy housing. The corrugated horn is linearly polarized and produces equal E and H plane amplitude patterns. The polarization may be changed with the addition of the appropriate Hughes 4586xH or 4587xH polarizer. The antennas are designed with a focal length to diameter ratio (F/D) of 1.0 for size and performance considerations.

These Horn Lens Antennas cover ten percent bandwidths and feature extremely good side lobe performance with side lobes being typically 26 dB below the main beam. The input VSWR is typically 1.15:1. They are available in 1, 1.5, 3, 4, 6, 9 and 12-inch models in K- through D-bands.

FEATURE:

ELECTRICAL SPECIFICATIONS

BEAMWIDTH .... See Figure 1
GAIN .... See Figure 1
SIDELOBES (dB down typ.) 26
VSWR (typ.) 1.15:1

HOW TO ORDER (Specify center frequency at time of order)
Model Number 4580xH-xxxx

Waveguide Band
0: K **3**: U **6**: W
1: Ka **4**: V **7**: F
2: Q **5**: E **8**: D

Flange (Circular Waveguide)
1: Round (Ka- through D-bands only)
2: Square (Available in K- and Ka-bands only)
3: Pin Contact (Available in F- and D-bands only)
4: Square, mating with orthomode transducer (K- and Ka-bands only)

Circular Waveguide Diameter
1: Large Diameter (see Table below)
2: Medium Diameter (see Table below, K- through E-Bands only)
3: Small Diameter (see Table below)

Dimensions
01: 1″ (2.5 cm) (made of aluminum only)①
15: 1½″ (3.8 cm) (made of aluminum only)①
03: 3″ (7.6 cm) (made of aluminum only)
04: 4″ (10.2 cm) (made of aluminum only)
06: 6″ (15.2 cm)
09: 9″ (22.9 cm)
12: 12″ (30.5 cm)

① W- through D-bands only

Example: To order an E-band 9″ Horn Lens Antenna, specify a 45805H-1009

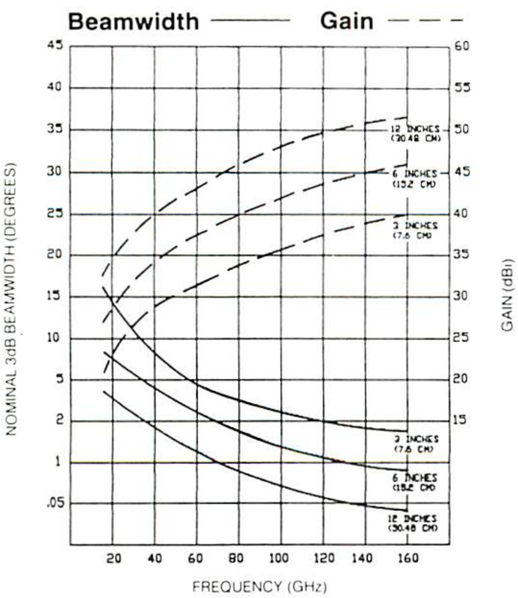


Figure 1. Beamwidth & Gain vs. Frequency

CIRCULAR WAVEGUIDE SIZES

Rectangular Waveguide Band		Frequency Range① (GHz)	Circular Waveguide Diameter (inches)	(cm)
K	LARGE	17.5-20.5	0.455	(1.16)
	MED	20-24.5	0.396	(1.01)
	SMALL	24-26.5	0.328	(0.83)
Ka	LARGE	26.5-33	0.315	(0.80)
	MED	33-38.5	0.250	(0.64)
	SMALL	38.5-40	0.219	(0.56)
Q	LARGE	33-38.5	0.250	(0.64)
	MED	38.5-43	0.219	(0.56)
	SMALL	43-50	0.188	(0.48)
U	LARGE	40-43	0.210	(0.53)
	MED	43-50	0.188	(0.48)
	SMALL	50-60	0.165	(0.42)
V	LARGE	50-58	0.165	(0.42)
	MED	58-68	0.141	(0.36)
	SMALL	68-75	0.125	(0.32)
E	LARGE	60-66	0.136	(0.35)
	MED	66-88	0.125	(0.32)
	SMALL	88-90	0.094	(0.24)
W	LARGE	75-88	0.112	(0.28)
	SMALL	88-110	0.094	(0.24)
F	LARGE	90-115	0.089	(0.23)
	SMALL	115-140	0.075	(0.19)
D	LARGE	110-140	0.073	(0.19)
	SMALL	140-160	0.059	(0.16)

① Select the large diameter within the band when complete waveguide band coverage is necessary

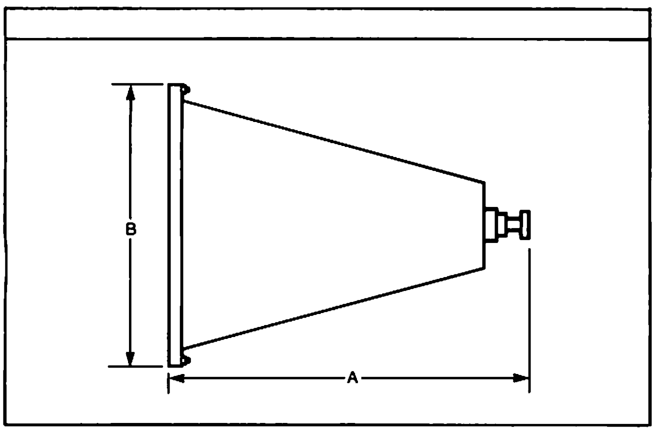
All Horn Lens models use circular waveguide feeds, however a monopulse feed is available in Ka, V and W-bands. The short compact comparator is designed for the broadest possible bandwidths by carefully keeping the path lengths short and equidistant. Null depths of 15 dB are guaranteed over 8% bandwidths with 30 dB or greater guaranteed at center frequency. A single plane monopulse feed and comparator is available in the same bands stated above.

The Horn Lens Antennas are provided with mounting holes close to the lens surface, around the circumference of the housing. It can be easily adapted to sealed pressurized applications. A mounting flange designed to meet customer requirements can be obtained on request. For weight critical applications zoned lens types are available which reduce weight by as much as 30%. Each antenna is tuned for the specified center frequency. Radiation patterns are supplied with each unit ordered.

A monopulse comparator is available on certain Horn Lens Antennas. See description of the comparator on pages 132 and 133. Please contact factory with your requirements.

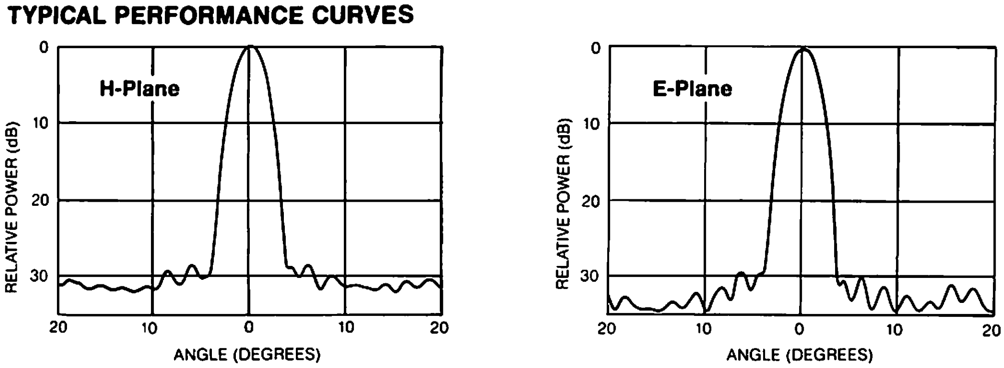
Side Lobes 26 dB Down

MECHANICAL SPECIFICATIONS

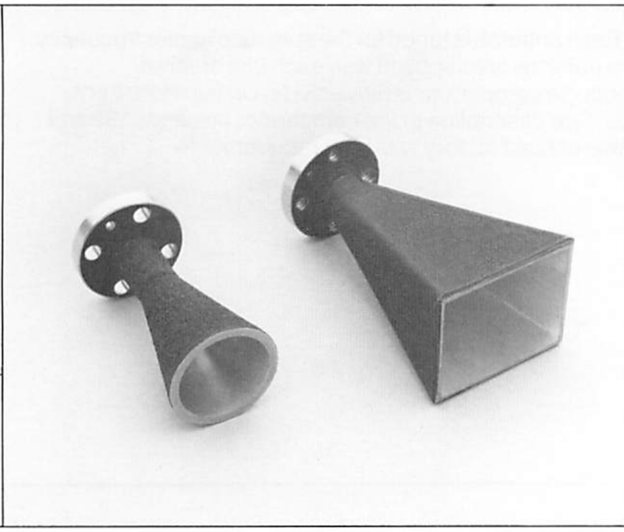


		ANTENNA SIZE						
		1"	1.5"	3"	4"	6"	9"	12"
DIMENSIONS	A	2.5 (6.4)	3.0 (7.6)	7.0 (17.8)	8.6 (21.8)	10.5 (26.7)	14.0 (35.6)	17.5 (44.5)
(inches (cm) typ)	B	2.0 (5.1)	2.5 (6.4)	5.0 (12.7)	6.0 (15.3)	8.5 (21.6)	12.0 (30.5)	15.5 (39.4)
WEIGHT (lbs (kg) typ)		1.25	1.5	2.0 (0.91)	2.5	3.0 (1.36)	6.0 (2.72)	9.5 (4.31)
WAVEGUIDE AND FLANGE		SEE PAGES 131 AND 157						

TYPICAL PERFORMANCE CURVES



Standard Gain Conical and Pyramidal Horns



Hughes 4582xH series of standard gain conical and pyramidal horns are electroformed to precisely control the aperture and flare angle. The pyramidal horns are available in nine waveguide bands from 18.5 to 220 GHz. The conical horns are available in ten waveguide bands between 18 GHz and 220 GHz. The pyramidal horns have an approximate gain of 24 dB at mid band, while the approximate mid band gain of the conical horns is 21 dB.

Standard gain horns are used to determine the gain of an antenna under test by a conventional substitution method. This is the accepted method since the gain horn has an IEEE standard assigned value in dB referenced to an isotropic

FEATURES:

SPECIFICATIONS:

	Frequency Band (GHz)									
	K (18-26.5)	Ka (26.5-40)	Q (33-50)	U (40-60)	V (50-75)	E (60-90)	W (75-110)	F (90-140)	D (110-170)	G (140-220)
PYRAMIDAL HORNS Gain at Mid Band Frequency (dB approx)	24	24	24	24	24	24	24	24	24	24
VSWR (max)	1.10:1	1.10:1	1.10:1	1.10:1	1.15:1	1.15:1	1.15:1	1.20:1	1.25:1	1.25:1
CONICAL HORNS Gain at Mid Band Frequency (dB approx)	21	21	21	21	21	21	21	21	21	21
VSWR (max)	1.10:1	1.10:1	1.10:1	1.10:1	1.15:1	1.15:1	1.15:1	1.20:1	1.25:1	1.25:1

MECHANICAL SPECIFICATIONS

PYRAMIDAL HORNS	K	Ka	Q	U	V	E	W	F	D	G
Length (in. (cm) nom)	7.480	4.9 (12.5)	4.0 (10.2)	3.4 (8.7)	2.8 (7.0)	2.3 (5.9)	2.0 (5.0)	1.6 (4.2)	1.4 (3.5)	1.2 (3.0)
Height (in. (cm) nom)	3.093	2.2 (5.5)	1.8 (4.4)	1.5 (3.8)	1.2 (3.0)	1.0 (2.5)	0.8 (2.1)	0.7 (1.8)	0.6 (1.5)	0.5 (1.2)
Width (in. (cm) nom)	4.068	2.8 (7.1)	2.3 (5.8)	1.9 (4.9)	1.5 (3.9)	1.3 (3.3)	1.1 (2.7)	0.9 (2.2)	0.7 (1.9)	0.6 (1.5)
Waveguide Size①	WR-42	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6	WR-5
Waveguide Flange①	UG-595/U②	UG-599/U②	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)
		UG-381/U③						pin contact	pin contact	pin contact
CONICAL HORNS										
Diameter (in. (cm))	2.31 (5.87)	1.45 (3.68)	1.13 (2.87)	0.92 (2.34)	0.78 (1.98)	0.68 (1.73)	0.54 (1.37)	0.44 (1.12)	0.36 (0.91)	0.28 (0.71)
Length (in. (cm))	4.09 (10.39)	2.75 (6.98)	2.27 (5.77)	1.95 (4.95)	1.90 (4.83)	1.64 (4.17)	1.43 (3.63)	1.30 (3.30)	1.17 (2.97)	1.10 (2.79)
Waveguide Flange④	UG-595/U②	UG-599/U② UG-381③	UG-383/U	UG-383/U (mod)	UG-385/U	UG-387/U	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)	UG-387/U (mod)
								pin contact	pin contact	pin contact

① Refer to page 157 for specifications and MIL specification cross reference ② Square ③ Round ④ Mates with circular waveguides and flanges of Hughes adapters, polarizers, and transducers. See page 131 for circular waveguide dimensions.

HOW TO ORDER

Model Number 4582xH-x0xx

Frequency Band **0**: K
1: Ka
2: Q
3: U
4: V
5: E
6: W
7: F
8: D
9: G

Circular Waveguide Diameter
0: Not used (Pyramidal Horns only)
1: Large Diameter (see Table page 131)
2: Medium Diameter (see Table page 131, Available in K- through E-Bands only)
3: Small Diameter (see Table page 131)

Type **2**: Standard Gain Pyramidal Horn (Rectangular Waveguide)
3: Standard Gain Conical Horn (Circular Waveguide)

Flange Type **1**: Round (Available in Ka- through G-bands only)
2: Square (Available in K- and Ka-bands only)
3: Pin Contact (Available in F-, D-, and G-bands only)
4: Square, mating with orthomode transducer (Available on Conical Horns in K- and Ka-bands only)

Example: To order a V-band Standard Gain Pyramidal Horn, specify a 45824H-1020.

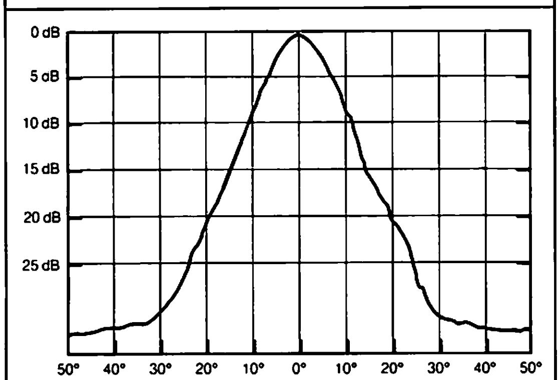
radiator. They are also used as reference sources in dual channel antenna test receivers and can be used as pickup horns for radiation monitoring.

The conical horns are used when a small inexpensive antenna capable of polarization diversity is needed. With the appropriate combination of Hughes' switchable polarizers, horizontal and vertical linear polarizations plus left hand and right hand circular polarizations can all be achieved on the same antenna without movement of it.

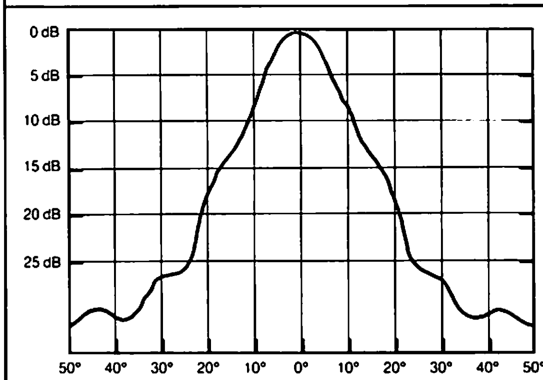
18–220 GHz Coverage

TYPICAL PERFORMANCE CURVES

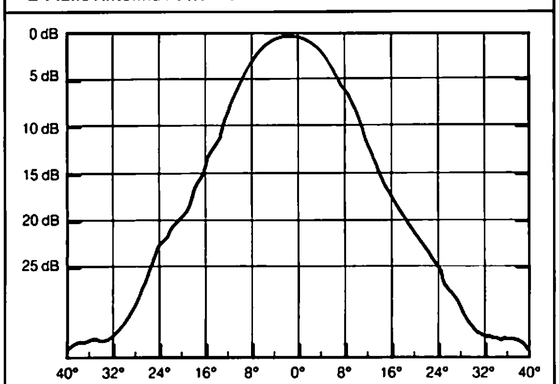
E-Plane Antenna Pattern of Ka-band Conical Horn at 35 GHz



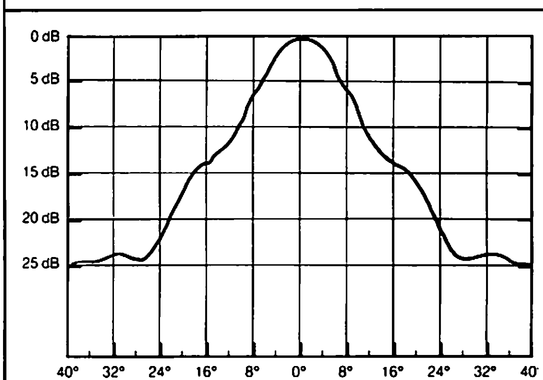
H-Plane Antenna Pattern of Ka-band Conical Horn at 35GHz



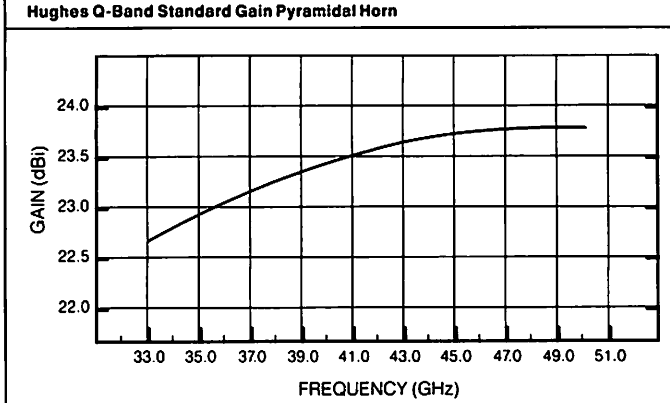
E-Plane Antenna Pattern of W-band Concial Horn at 92 GHz



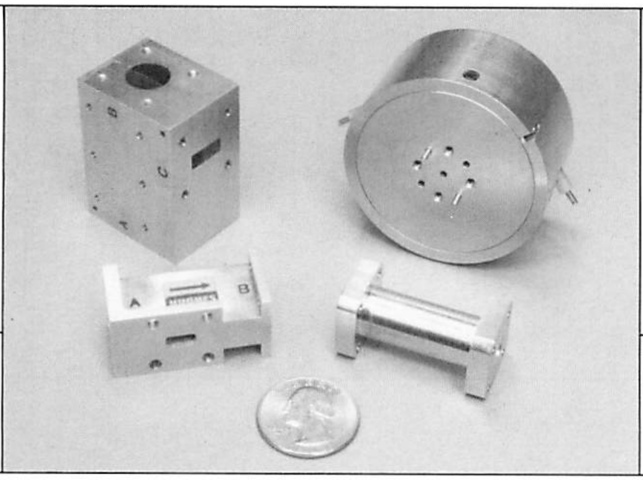
H-Plane Antenna Pattern of W-band Conical Horn at 92 GHz



Hughes Q-Band Standard Gain Pyramidal Horn



Antenna Products: Adapters, Polarizers, and Orthomode Transducers



The Hughes 4547xH series of circular-to-rectangular waveguide adaptors are available to transition from standard rectangular waveguide to circular waveguide, and conversely, from circular waveguide to standard rectangular waveguide.

The Hughes 4586xH series of linear-to-circular polarizers are circular waveguide sections with dielectric cards inserted in the circular waveguide at a 45 degree angle to the E-plane of the electromagnetic wave. It takes a linearly polarized signal in circular waveguide and converts it to either a left-hand circular or a right-hand circular polarized signal depending on the orientation of the part. Conversely,

AXIAL RATIO
Polarizer: 1 dB Max.

SPECIFICATIONS	FREQUENCY BAND (GHz)								
	K (18–26)	Ka (26.5–40)	Q (33–50)	U (40–60)	V (50–75)	E (60–90)	W (75–110)	F (90–140)	D (110–170)
POLARIZERS ①									
AXIAL RATIO (10% BW dB max)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
VSWR (typ)	1.3:1	1.3:1	1.3:1	1.3:1	1.3:1	1.4:1	1.4:1	1.5:1	1.5:1
LENGTH (in/cm typ)									
SWITCHABLE ②	2.50/6.35	2.50/6.35	2.25/5.72	2.25/5.72	1.70/4.32	1.70/4.32	1.70/4.32	1.70/4.32	1.70/4.32
FIXED	1.50/3.81	1.38/3.51	1.23/3.12	1.03/2.62	1.00/2.54	1.00/2.54	1.00/2.54	1.00/2.54	1.00/2.54
DIAMETER (in/cm typ)									
SWITCHABLE ②	1.875/4.76	1.875/4.76	1.875/4.76	1.875/4.76	1.50/3.81	1.50/3.81	1.50/3.81	1.50/3.81	1.50/3.81
FIXED	1.125/3.18	1.125/3.18	1.125/3.18	1.125/3.18	0.750/1.91	0.750/1.91	0.750/1.91	0.750/1.91	0.750/1.91
ORTHOMODE TRANSDUCER ①③									
ISOLATION (5% BW dB min)	25	25	25	25	25	25	25	18	18
VSWR (typ)	1.3:1	1.3:1	1.3:1	1.3:1	1.3:1	1.4:1	1.4:1	1.5:1	1.5:1
CIRCULAR TO RECTANGULAR ① WAVEGUIDE ADAPTERS									
VSWR (max)	1.15:1	1.15:1	1.15:1	1.15:1	1.15:1	1.2:1	1.25:1	1.3:1	1.4:1
LENGTH (in/cm typ)	2.0/3.81	1.50/3.81	1:30/3.30	1.10/2.79	1.00/2.54	1.00/2.54	1.00/2.54	1.00/2.54	1.00/2.54
MONOPULSE TO STANDARD FLANGE ADAPTERS									
VSWR (max)	—	1.15:1	—	—	—	—	1.25:1	—	—

① Circular waveguide mates with Hughes antennas, polarizers, orthomode transducers and adapters. For other sizes consult factory. See page 131 for circular waveguide dimensions.
② Applies to manually switched units only. ③ Test Data for W-band unit is given on page 131.

HOW TO ORDER

Circular-to-Rectangular Waveguide Adapter 4547xH-xx1x
(Specify Center Frequency at time of order)

Waveguide Band
0:K
1:Ka
2:Q
3:U
4:V
5:E
6:W
7:F
8:D

Circular Guide Flange
1: Round (Available in Ka- through D-bands only)
2: Square (Available in K- and Ka-bands only)
3: Pin Contact (Available in F- and D-bands only)

Rectangular Guide Flange
1: Round (Available in Ka- through D-bands only)
2: Square (Available in K- and Ka-bands only)
3: Pin Contact (Available in F- and D-bands only)

Circular Waveguide Diameter
1: Large Diameter (see Table page 131)
2: Medium Diameter (see Table page 131) (Not available in W- thru D-band)
3: Small Diameter (see Table page 131)

Linear-to-Circular Polarizers 4586xH-x00x
(Specify Center Frequency at time of order)

Waveguide Band
0:K
1:Ka
2:Q
3:U
4:V
5:E
6:W
7:F
8:D

Flange Type (Circular Waveguide)
1: Round (Available in Ka- through D-bands only)
2: Square (Available in K- and Ka-bands only)
3: Pin Contact (Available in F- and D-bands only)
4: Square for mating with orthomode transducer (Available in K- and Ka-bands only)

Circular Waveguide Diameter
1: Large (see Table page 131)
2: Medium (see Table page 131) (Not available in W- thru D-band)
3: Small (see Table page 131)

it will also convert a circularly polarized signal to a linearly polarized one.

The Hughes 4587xH series of manually switchable polarizers enables the dielectric polarizing card to be rotated to either of three positions 45 degrees apart. The switchable polarizers enable the user to convert linearly polarized signals to either left-hand or right-hand circular polarized ones, and conversely, to convert left-hand or right-hand circular polarized signals to linear polarization. The mid-position allows linear polarized signals to go through the switch without a change in polarization. The electronically switchable polarizer series rotates the dielectric card between two positions 90 degrees apart (no mid-position). Electronic control is accomplished by opening or grounding a single control lead.

The Hughes 4588xH series of orthomode transducers couples two orthogonal, linearly polarized signals to its circular waveguide output port with greater than 24 dB isolation. Conversely, signals applied to the circular waveguide port are resolved into their vertical and horizontal components at the linear ports.

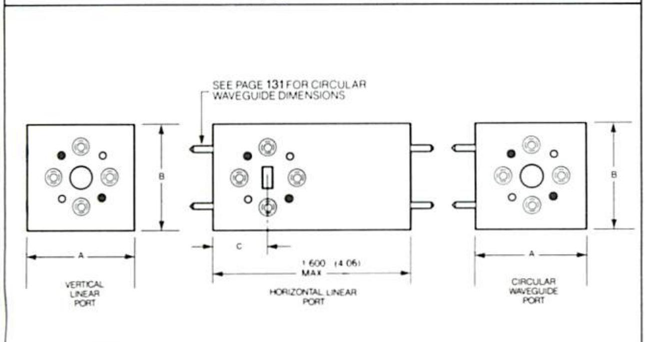
Also available are high power orthomode transducers that offer low insertion loss. Please consult factory for details.

ISOLATION

Orthomode Transducer: 25 dB Min.

OUTLINE AND MOUNTING DRAWINGS

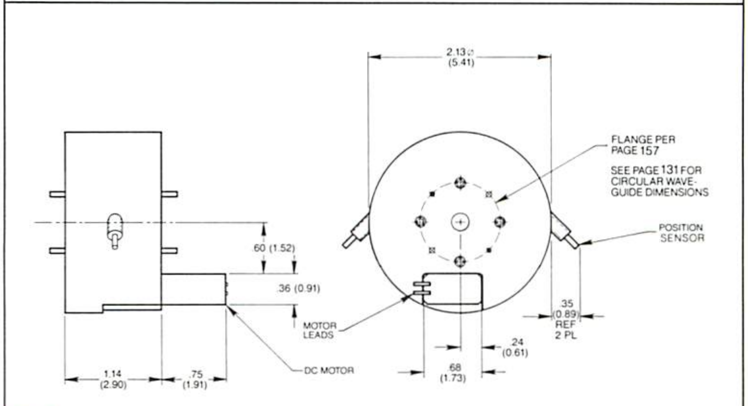
Orthomode Transducer (Typical Configuration)①



①	FREQUENCY BAND (GHz)		
	K- thru Ka-bands (18–40)	Q- thru U-bands (26.5–60)	V- thru D-bands (60–160)
A	1.00 (2.54)	1.30 (3.30)	0.75 (1.91)
B	1.10 (2.79)	1.15 (2.92)	0.75 (1.91)
C	0.584 (1.483)	0.584 (1.483)	0.80 (2.03)

① Consult factory for other mechanical specifications.

Electrically Switched Polarizer



Dimensions are in inches (cm)

HOW TO ORDER (Cont'd)

Orthomode Transducer 4588xH-xx00x
(Specify Center Frequency at time of order)

Waveguide Band
- 0: K
- 1: Ka
- 2: Q
- 3: U
- 4: V
- 5: E
- 6: W
- 7: F
- 8: D

Flange Type (Rectangular Waveguide)
- 1: Round (Available in Ka- through W-bands only)
- 2: Square (Available in K- and Ka-bands only)

Flange Type (Circular Waveguide)
- 1: Round (Available in Ka- through D-bands only)
- 4: Square (Available in K- and Ka-bands only)

Circular Waveguide Diameter
- 1: Large (see Table page 131)
- 2: Medium (see Table page 131) (Not available in W- thru D-band)
- 3: Small (Not available in W-band. See Table page 131)

Switchable Polarizer 4587xH-xx0x
(Specify Center Frequency at time of order)

Waveguide Band
- 0: K
- 1: Ka
- 2: Q
- 3: U
- 4: V
- 5: E
- 6: W
- 7: F
- 8: D

Flange Type
- 1: Round (Available in Ka- through D-bands only)
- 2: Square (Available in K- and Ka-bands only)
- 4: Square for mating with orthomode transducer (Available in K- and Ka-bands only)

Control Option
- 0: Manually switched
- 1: Electrically switched

Circular Waveguide Diameter
- 1: Large Diameter (see Table page 131)
- 2: Medium Diameter (see Table page 131) (Not available in W- thru D-band)
- 3: Small Diameter (see Table page 131)

6

MEASUREMENT SYSTEMS AND SUBSYSTEMS

As more systems applications arise at millimeter-wave frequencies, the need for precise measurements of millimeter-wave transmitted, received, and reflected signals has become critical. In this section we describe measurement systems designed for precise, accurate and repeatable measurements of millimeter-wave signals. Measurements are needed to evaluate antenna performance, to determine path loss under varying atmospheric conditions or through various mediums, to analyze radar cross section signatures, to measure radar backscatter and to analyze existing signals. Furthermore, by using millimeter-wave frequencies in radar cross section measurements, scale models of targets can be used to measure microwave cross-sections at a substantial cost reduction. Hughes is helping to fill this need with products presented in this catalog.

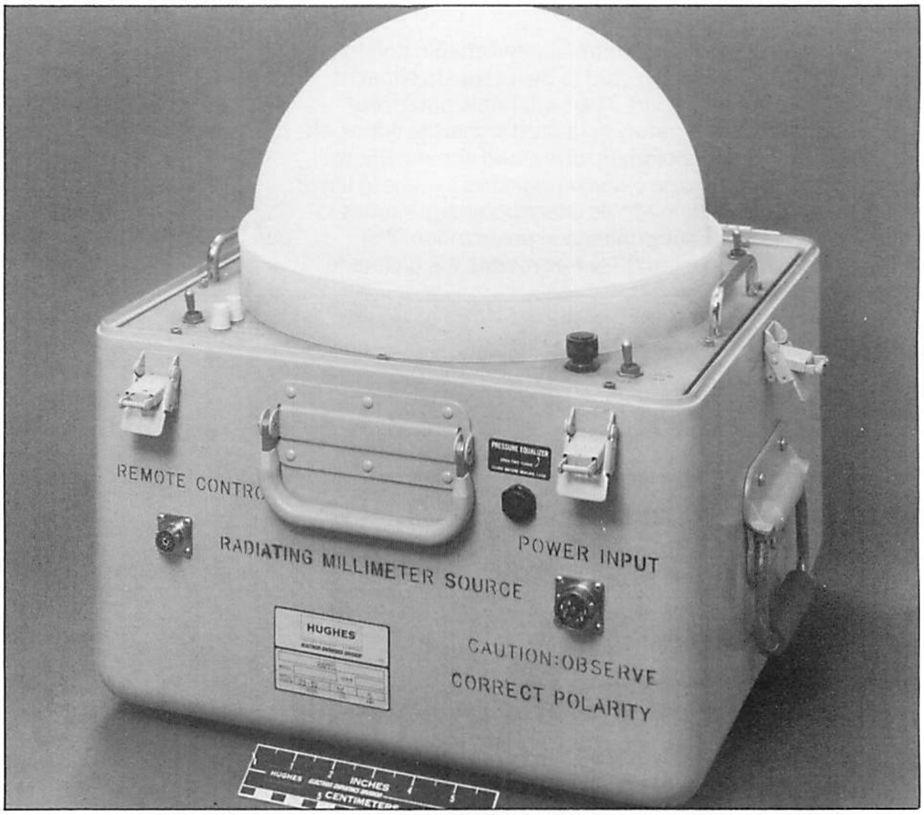


FIG. 1. Ka- AND W-BAND INSTRUMENTATION NOISE SOURCE.

NOISE JAMMING MEASUREMENTS

It is frequently useful to test the performance of radiometers or radar receivers in the presence of noise jamming. Such testing can be simulated in the laboratory using low power noise sources or thermal loads. Field testing, however, often requires free space noise radiation for evaluation under realistic conditions. When the geometry permits, highly directional antennas are used to increase the radiated power density; however, omnidirectional coverage is desirable in most cases. An example of a Ka- and W-band instrumentation noise source is shown in Figure 1. The method used to produce high Excess Noise Ratio and wide RF bandwidth is direct frequency modulation of an IMPATT oscillator having a bias tuning bandwidth of over 10 percent at W-band and 16 percent at Ka-band. Output power levels are 3 dBm at W-band and 10 dBm at Ka-band over the respective bandwidths.

The wideband noise source was designed to radiate in a hemispherical pattern. A front-feed reflection antenna design was selected because of its simplicity and wide bandwidth. The circularly polarized feedhorns illuminate a hyperbolic reflector producing the hemispherical radiation pattern.

This system uses the omnidirectional antennas radiating wide band noise in both Ka-band and W-band with excess noise ratio (ENR) exceeding 80 dB. The system is portable and operates in adverse environmental conditions.

SIGNAL CHARACTERIZATION AND MEASUREMENT

Collection systems already in existence at microwave frequencies can incorporate a frequency extension module (or modules) allowing wide instantaneous downconversion at millimeter-wave frequencies to the already existing microwave equipment. Frequency accuracy can be preserved by providing the host system's crystal frequency to the extension module for phase-locking. Instantaneous bandwidths up to 16 GHz (2 GHz to 18 GHz IF) can be accommodated. More typically, IFs ranging from 6 to 18 GHz are optimum because of low noise amplifier availability.

An example is shown in Figure 2 of an 18 to 100 GHz direction finding receiver system with state-of-the-art sensitivity. All of the receiving functions can be remotely controlled by computer.

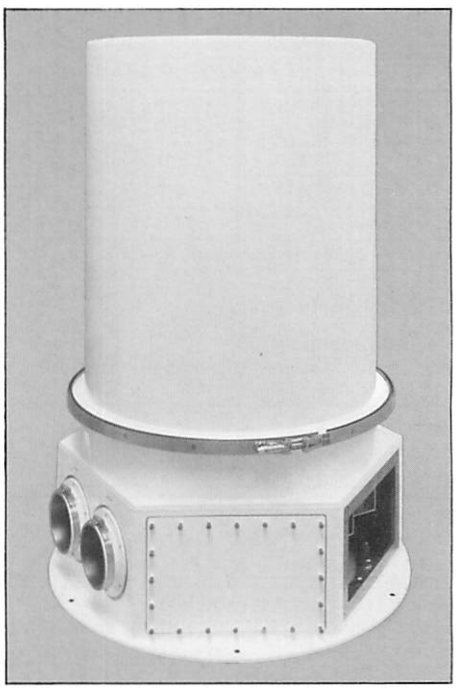
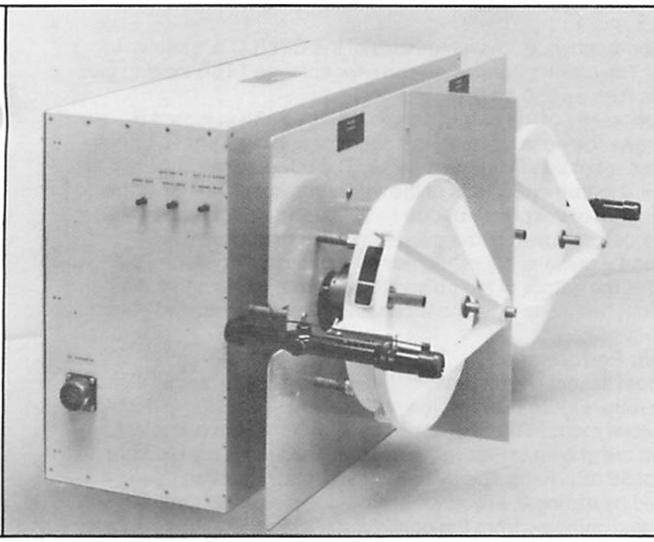


FIG. 2. 18 TO 100 GHz REMOTELY CONTROLLED DIRECTION FINDING RECEIVER SYSTEM.

Coherent Instrumentation Front Ends



FEATURES:

CW or 10—70 nsec. variable pulse width operation.

The development of solid state transmitters has enabled low cost, compact, lightweight, millimeter-wave instrumentation radar front ends to be made. Concurrently, semiconductor devices have been developed so that system functions such as mixing, detecting, switching and modulating can be simply and economically accomplished.

The development and mechanization of millimeter-wave front ends for a specific application requires various measurements to determine the type of unit to be built. Hughes manufactures a coherent subsystem which incorporates all functions needed to provide a real-world millimeter-wave data base: the Model 4226xH-2000 Subsystem for either 35 or 95 GHz.

Two basic types of data are required at millimeter wavelengths: radar cross-section (RCS) and background reflectivity data. Radar cross-section data (during varying atmospheric and environmental conditions) is required to estimate system performance using the conventional radar range equations.

Extrapolation of data measured at lower frequencies is inaccurate because the amplitude returns from complex targets vary with target properties and wavelength. Similarly, the return characteristics of backgrounds, both man-made and natural, varies with intrinsic properties and wavelength. Consequently, the millimeter-wave designer needs the data derived from a measurement program. The Model 4226xH-2000 subsystem has the flexibility needed to provide him this data with ease and convenience in a timely manner, making it possible to characterize targets and backgrounds for optimum system design.

SPECIFICATIONS	35GHz	95GHz
MODEL NUMBER	42261H-2000	42266H-2000
UPCONVERTER INPUTS		
CW MODE		
IF Input Power (dBm, min.)	17	17
Frequency (GHz, nom.)	3	3
Bandwidth (MHz, max.)	200	200
FM Waveform	ramp, sawtooth or sinusoidal	same
PULSED MODE		
Pulsewidth (selected by S Band PIN switch incorporated into the system; ns)	20—200	20—200
PRF (same as mm-wave system; KHz, max.)	60	60
Peak Power (dBm, min.)	17	17
Rise Time (ns, max.)	5	5
Fall Time (ns, max.)	5	5
Frequency (GHz, nom.)	3	3
Bandwidth (MHz, max.)	200	200
TRIGGER AND GATE INPUTS		
IF PIN Switch	TTL gate	same
Pulse Modulators	TTL trigger	same
RF PIN Switch Driver	TTL gate	same
TRANSMITTER		
CW MODE		
SSB FM Noise (dBc/Hz, max.)		
5 KHz from carrier	−93	−85
10 KHz from carrier	−96	−88
100 KHz from carrier	−100	−92
1MHz from carrier	−103	−95
Output Power (dBm, min.)	20	20

SPECIFICATIONS	35GHz	95GHz
MODEL NUMBER	42261H-2000	42266H-2000
TRANSMITTER (cont.)		
CW MODE		
Output Frequency (GHz, nom.)	35	95
Bandwidth (MHz, min.)	200	200
PULSED MODE		
Spectral Peak-to-Valley Ratio (dBc/Hz, min.)	−80	−73
Peak Output Power (watts, min.)	2.0	1.0
Frequency (GHz, nom.)	35	95
PIN Switch ON/OFF Ratio (dB, min.)	30	30
Pulsewidth (ns) (5n sec. steps)	10—70	10—70
Rise Time (ns, max.)	3	3
Fall Time (ns, max.)	3	3
PRF (KHz, max.)	60	60
RECEIVER		
SSB NF (dB, max.) (Includes comparator and IF noise contribution)	9	10
RF/IF Gain (dB, min.)	20	20
IF Bandwidth (GHz ± 200 MHz)	3	3
ANTENNAS		
Gain (dB, nom.)	38	47
Null Depth (Receive Antenna Only 30 dB Goal) (dB, min.)	25	25
Polarization	linear	same
PACKAGING		
Transmitter and Receiver	mounted behind antennas	same
Antenna(s)	mount included (common mount)	same
Ambient Temp. (°C)	0-50	0-50
Dimensions (inches (cm) approx.)		18 (45.7) x 30 (76.2) x 20 (50.8)

(Continued on following page.)

System Description and Theory of Operation

A simplified block diagram of the system is shown in Figure 1. The master oscillator for the system is a crystal oscillator at 100 MHz, which is used as reference oscillator for a phase-locked Gunn oscillator (PLO) at 32 or 92 GHz. The Gunn PLO signal is amplified without phase noise degradation by a CW IMPATT injection-locked oscillator (ILO) with an output power of 20 dBm. The Gunn PLO and CW IMPATT ILO together constitute the millimeter-wave stable master oscillator (STAMO) which drives both the transmitter and receiver.

The transmitter consists of a single sideband (SSB) upconverter with an IF input frequency of 3 GHz (±100 MHz) (which is coherent with the master crystal oscillator), followed by two injection-locked amplifiers, one CW and one pulsed, which can be connected inline between the upconverter output and the transmit antenna by means of two waveguide switches.

The receiver consists of an antenna with a single-plane monopulse comparator and two balanced mixer/IF preamplifiers, one connected to the sum and one to the difference channel. Both mixers have an IF bandwidth of 3 GHz using the STAMO as local oscillator. A bandpass filter is used to filter out excess AM noise from the CW ILO. Phase shift adjustment is independently provided to the two channels by two manually adjustable phase shifters.

The transmitter and receiver assemblies are vertically mounted behind the antenna plate holding the transmit and receive antennas. The transmit antenna can be adjustable independently in both azimuth and elevation to ensure beam parallelism between the two antennas.

Functional Characteristics

The system can be used as a multifunction instrumentation radar front-end capable of either CW or pulsed coherent operation. In both CW and pulsed modes, the receiver LO signal provided by the STAMO is at a constant frequency. Since the STAMO also pumps the upconverter, the receiver IF output frequency is therefore the same as the SSB upconverter input frequency. The system can be operated in several configurations.

a. CW Mode. In the CW mode, the system can perform as either a single frequency or a multifrequency CW coherent front-end. The transmitter output frequency is controlled by the upconverter IF input. It is also possible to configure the system as an FM-CW front-end by supplying a swept IF input (saw tooth, ramp, sinusoid or other) to the upconverter. The frequency deviation is limited by the output CW IMPATT ILO to 200 MHz for a power output of 100 mW.

b. Pulsed Mode. In the pulsed mode, the system performs as a single-frequency coherent pulsed radar front-end or as a coherent system with frequency diversity in the form of pulse-to-pulse frequency agility, coherent chirp or combinations of both.

STAMO Performance Characteristics

The most important characteristic of the STAMO for optimum system sensitivity to Doppler signals is the phase noise, as determined by the Gunn PLO. The minimum achievable phase noise is established by the phase noise of the reference crystal oscillator. Figure 2 (bottom line) shows the measured phase noise of the crystal oscillator in the frequency range of 2 KHz to 600 KHz from the carrier. The STAMO minimum theoretical noise is higher than the crystal noise by a factor equal to 20 Log_{10} N, where N is the ratio of the STAMO's output frequency (92 GHz) to the crystal frequency (100 MHz). This value is shown as the dotted line in Figure 2. The actual measured noise of a STAMO is shown by the solid line at the top of Figure 2, in the range of 2 KHz to 10 MHz from carrier.

Transmitter Performance Characteristics

The performance characteristics of the transmitter are determined by the SSB upconverter and the output ILO's. The SSB upconverter transfer characteristics are shown in Figure 3. An upper sideband output power of +3 dBm was obtained with 18 dBm LO input power and 17 dBm IF input power. This output power is sufficient to lock the CW and pulsed output ILO's.

The gain-bandwidth characteristics of the CW ILO are shown in Figure 4. The locking bandwidth corresponding to 18 dB locking gain can be as high as 650 MHz.

The coherency of the output pulsed ILO is shown in Figure 5, which shows the output of a phase detector used in a phase bridge measurement of additive phase noise. The three traces shown correspond to three positions of the reference phase shifter in the reference arm of the phase bridge (+90°, 0° and −90°, respectively). The peak output power of the pulsed ILO is 5 Watts, with a PRF of 60 KHz and a pulse-width of 100 nanoseconds. PIN switches are included at the output of the pulsed ILO in order to provide variable pulse-width (from 5 to 90 nanoseconds) at a cost of reduced output power.

System Performance

The most salient characteristic of the system is the overall signal-to-noise ratio. Figure 6 shows the spectrum of the system's IF output in the pulsed mode. The PRF lines at the center of the (sin x/x) spectrum are shown in Figure 7. The total peak-to-valley ratio is in excess of 50 dBc/KHz. The system's coherency has also been measured by mixing the receiver's IF output in a phase detector with a CW signal sampled from the upconverter's IF input. The resultant pulsed output signals are shown in Figure 8 for three different values of relative phase shift between transmitter and receiver. (+90°, 0° and −90°, respectively). The total peak-to-peak noise of the system, integrated over a 100 MHz bandwidth, is less than 10°.

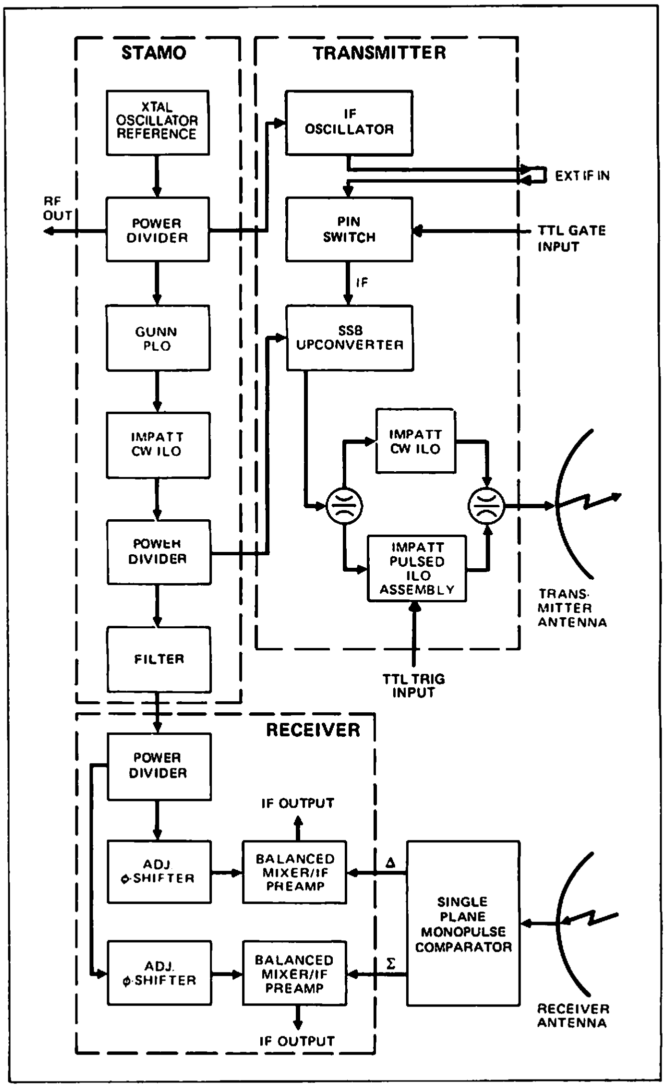


Figure 1. FUNCTIONAL BLOCK DIAGRAM OF 95 GHz COHERENT RADAR FRONT-END

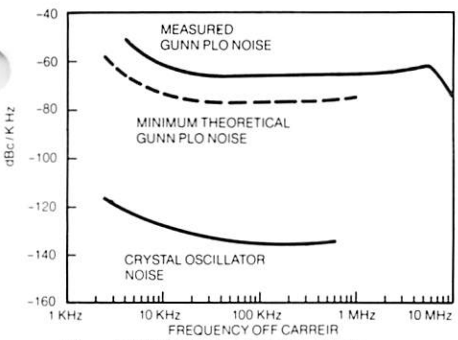


Figure 2. PHASE NOISE OF 92 GHz STAMO.

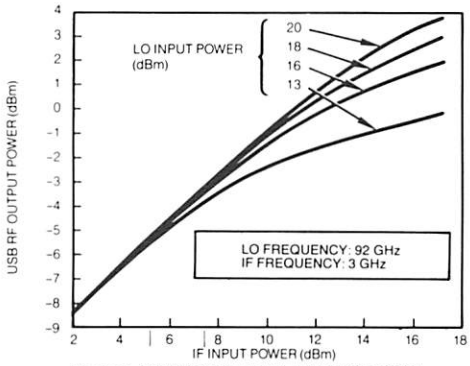


Figure 3. TRANSFER CHARACTERISTICS OF SSB CONVERTER.

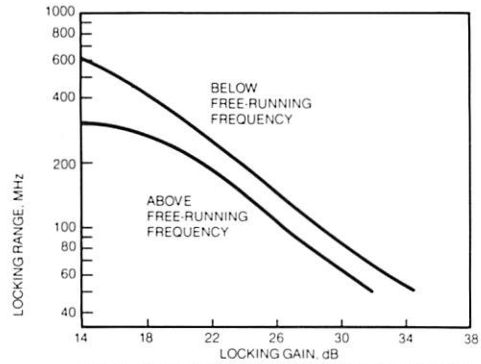
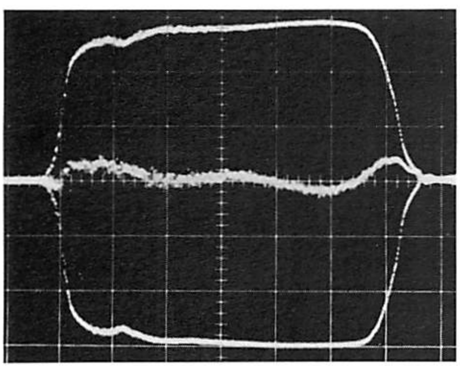
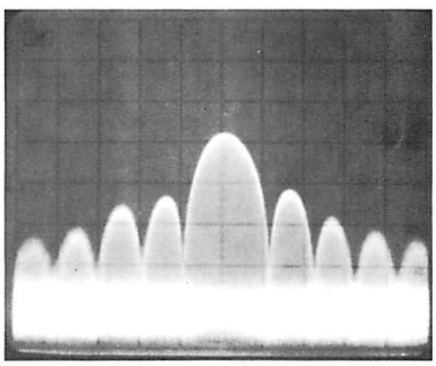


Figure 4. LOCKING GAIN-BANDWIDTH CHARACTERISTICS OF TRANSMITTER CW IMPATT ILO.



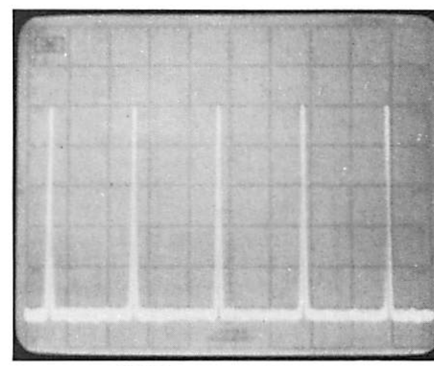
HORIZONTAL: 10 NSEC/DIV

Figure 5. PHASE DETECTOR OUTPUT WITH ILO LOCKED AT CENTER FREQUENCY (95 GHz). TOP, MIDDLE AND BOTTOM CORRESPOND TO +90°, 0°, AND −90° PHASE SHIFT IN THE PHASE BRIDGE'S REFERENCE ARM, RESPECTIVELY.



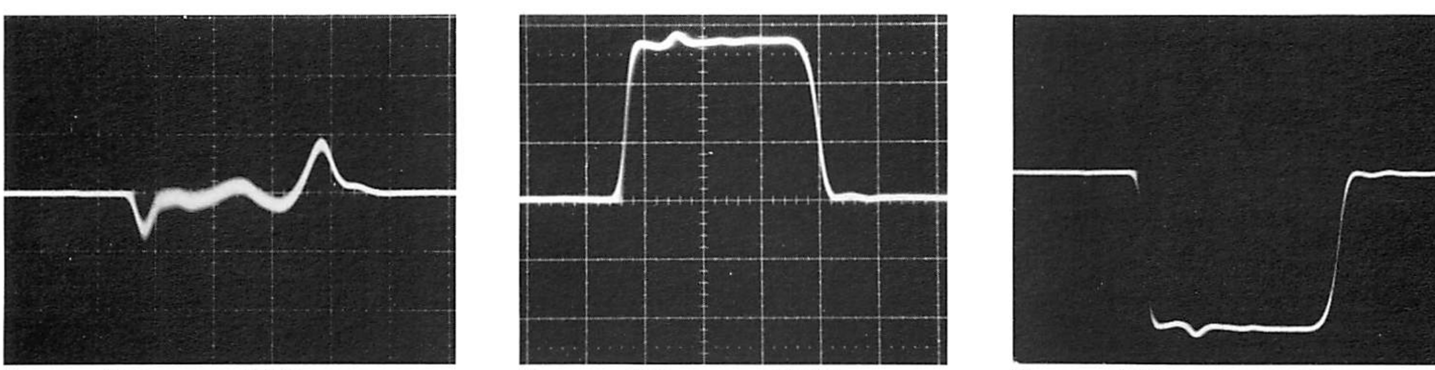
HORIZ:	20 MHz/DIV
BW:	300 KHz
VERT:	10 dB/DIV
TOP:	−15 dBm
PRF:	100 KHz
PULSEWIDTH:	60 ns

Figure 6. SPECTRUM OF PULSED IF OUTPUT SIGNAL.



HORIZ:	50 KHz/DIV
BW:	1 KHz
VERT:	10 dB/DIV
TOP:	−34 dBm
VIDEO BW:	10 Hz

Figure 7. LINE SPECTRUM OF PULSED IF OUTPUT SIGNAL.



(a)

VERT:	24°/DIV
HORIZ:	20 NS/DIV
PRF:	100 KHz
PHASE-SHIFTER:	0°

(b)

HORIZ:	20 NS/DIV
PHASE-SHIFTER:	+90°

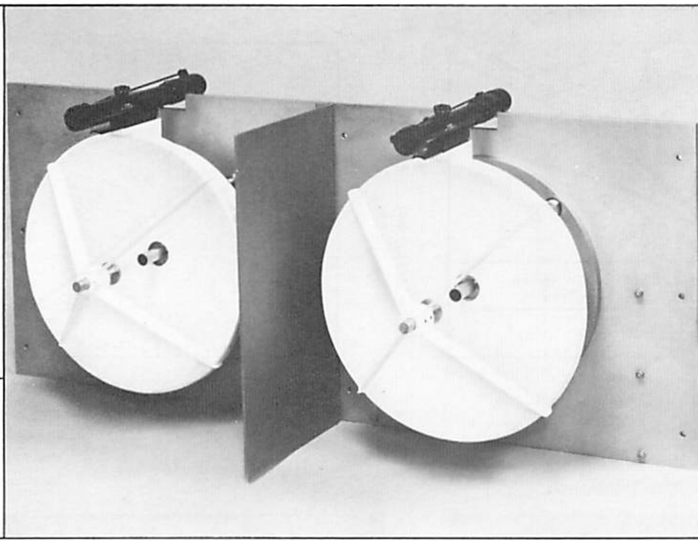
(c)

HORIZ:	20 NS/DIV
PHASE-SHIFTER:	−90°

Figure 8, (a), (b), (c). TOTAL INTEGRATED PHASE NOISE OF THE SYSTEM (OVER 100 MHz BANDWIDTH).

7

Free-Running Instrumentation Millimeter-Wave Radar Front Ends



Hughes now offers a series of either long or short pulse free-running radar front ends incorporating state-of-the-ar solid state components. The development of solid state transmitters using IMPATT diodes and other millimeter-v components using mm-wave semiconductor devices has enabled low cost, light weight and compact instrumentatio radar front ends to be made. These systems can be ordere at operating frequencies from 26 GHz to 150 GHz.

The main application of Hughes instrumentation radar front ends is to obtain radar cross-section data of both targets and backgrounds in order to estimate real-world system performance. Amplitude returns from complex tar-

PULSED POWER OUTPUT AVAILABLE

Short Pulse
Long Pulse

SPECIFICATIONS②

SHORT PULSE MODULE

POWER OUTPUTS AVAILABLE .... See "HOW TO ORDER"
PULSE WIDTH③(ns min/max) 50/100
PRF③(KHz min/max) 10/100
CHIRP BANDWIDTH④ (MHz max) 100
TRIGGER INPUT TO RF OUTPUT DELAY (ns typ) 300
DC POWER REQUIREMENTS
MODULATOR (V/mA max) 70/150
TEMPERATURE CONTROLLER (V/A max) 28/6.0
MODULATOR TRIGGER PULSE (V TTL) 5.0
OPERATING BASEPLATE TEMPERATURE RANGE
(°C min/max) 0/50

LONG PULSE MODULE

POWER OUTPUTS AVAILABLE .... See "HOW TO ORDER
PULSE WIDTH (μ sec, min/max) 0.5/1000
DUTY CYCLE (% max) 50
CHIRP BANDWIDTH (MHz max) 500
DC POWER REQUIREMENTS
MODULATOR (V/mA max) 45/350
MODULATOR (V/mA max) 5/10C
TEMPERATURE CONTROLLER (V/A max) 28/2.C
MODULATOR TRIGGER (V TTL) 5.C
OPERATING BASEPLATE TEMPERATURE RANGE
(°C min/max) .... 0/5(

ANTENNA ASSEMBLY MODULE

Standard antenna type .... 12" Cassegrain
Polarization .... linear
Receive/Transmit isolation
(dB, min) 60

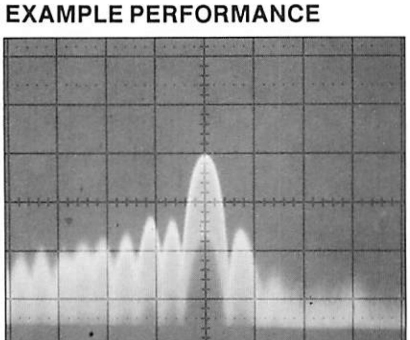
OVERALL DIMENSIONS .... 36.5" (92.7) x 15" (38.1) x 20" (50.8)

RECEIVER MODULE

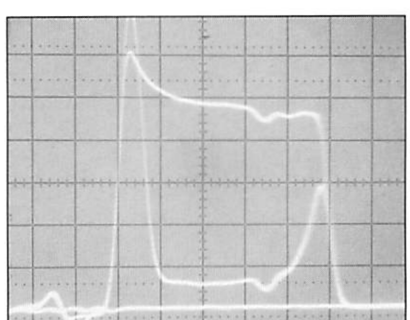
RF Center Frequency (GHz) .... See "HOW TO ORDER
RF Bandwidth (GHz) ....
IF Band (MHz) .... 10—101
RF/IF Gain (dB, min) .... 2(
Noise Figure (DSB, dB max)
26.5-50 GHz ....
50-96 GHz ....
96-150 GHz 8.5
RF input VSWR (max) 2:
DC Power Requirements
IF Amplifier (V/mA, max) .... 15/7(
Gunn Oscillator (V/A, max) .... 10/2.4 (to 96 GHz only
Temperature Controller
(V/A, max) 28/1.5

② Consult factory for requirements not covered by these specifications.
③ Operating frequency (0.5% accuracy), pulse width, and PRF to be specified at time of order.
④ 90% of specified power level is contained within chirp bandwidth. Linear and other special chirp bandwidths are available on request.

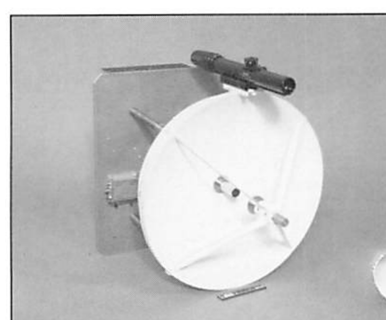
EXAMPLE PERFORMANCE



Transmitter Spectrum @ 94 GHz: PW = 50 nsec, PRF = 100 KHz, Pout = 10W PK. HORIZ = 50 MHz/DIV, VERT = 10 dB/DIV.



Detected Transmitter Output Pulse Lower Trace: Freq. Meter at 94.0 GHz. HORIZ = 10 nsec/DIV.



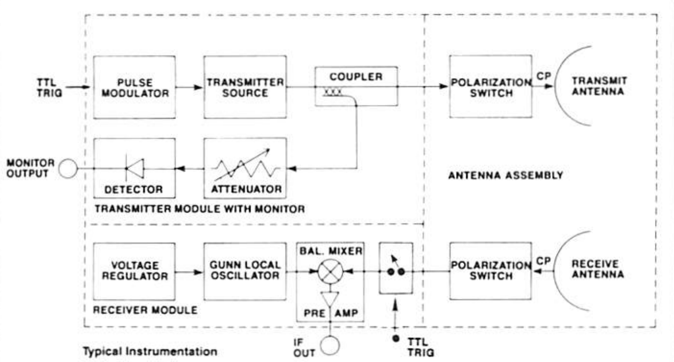
W-band Single-Antenna Non-Coheren Radar Transceiver.

gets vary with intrinsic properties and are a strong function of wavelength. Therefore, extrapolation from measurements at lower frequencies can be ambiguous and misleading. Consequently, the millimeter-wave designer needs the data supplied from a measurement program. The measurement equipment must have parameters consistent with the ultimate application of interest. Hughes can deliver instrumentation radar subsystems having the flexibility needed to meet your needs.

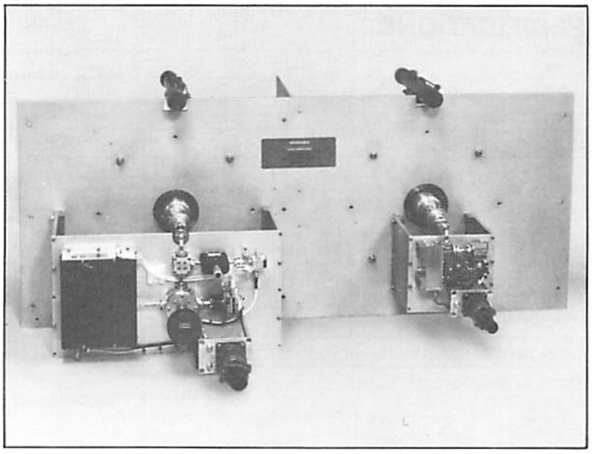
The basic configurations are modularized for convenience. These are: long or short pulsed transmitter modules, with or without power monitors, superhet receiver modules with either free-running or phase-locked Gunn LOs, and a 12-inch antenna module. These configurations include temperature stabilized oscillators designed to operate over an ambient temperature range of 0 to 50 degrees centigrade. The dual antenna configuration allows maximum flexibility to the instrumentation radar user because polarization switches can be used with each antenna. The two-antenna configuration eliminates the need for receiver protection due to the inherent high isolation. A compact, single-antenna version is available with receiver PIN switch protection and STC capability. Consult the factory for your unique sub-system configuration.

FREQUENCY BAND (GHz)				
Ka (34-36)	Q (43-45)	V (58-62)	W (92-96)	D (137-143)
10.0W	**—**	**—**	**10.0W**	**1.0W**
1.0W	**1.0W**	**0.5W**	**0.3W**	**0.02W**

BLOCK DIAGRAM



Typical Instrumentation Radar Front-End



Transmitter Front End **Receiver Front End**

HOW TO ORDER (Specify operating frequency, pulse width, and PRF or duty cycle at time of order.)

Model Number .... 421 xx H-2x xx

TYPE OF SYSTEM
- **2:** Short Pulse
- **3:** Long Pulse

FREQUENCY BAND
- **1:**Ka (26.5-40 GHz)
- **2:**Q (33-50 GHz, Long Pulse units only)
- **3:**U (40-60 GHz, Long Pulse units only)
- **4:**V (50-75 GHz, Long Pulse units only)
- **5:**E (60-90 GHz, Long Pulse units only)
- **6:**W (75-110 GHz)
- **7:**F (90-140 GHz, Long Pulse units only)
- **8:**D (110-170 GHz, Long Pulse units only)

EXAMPLE: To order Long Pulse 70 GHz System with 2 μsec. pulse width and duty cycle of 20%, specify 42134H-2320

POWER OUTPUTS

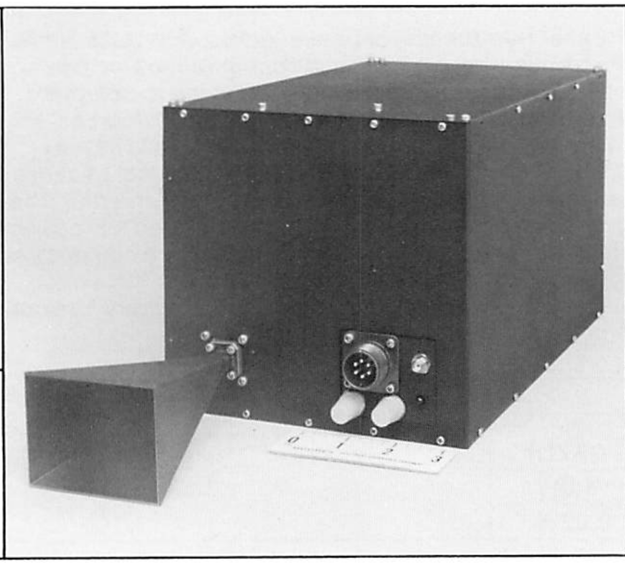
Long Pulse Only
- **01:** 10 mW (Available 110-150 GHz only)
- **02:** 20 mW (Available 137-143 GHz D-band only)
- **05:** 50 mW (Available 96-110 GHz only)
- **10:** 100 mW (Available 75-96 GHz only)
- **30:** 300 mW (Available 26.5-96 GHz only)
- **50:** 500 mW (Available 58-62 GHz V-band only)
- **11:** 1 Watt (Available 34-36 Ka-band & 43-45 GHz Q-band only)

Short Pulse only
- **11:** 1 Watt peak (Available in D-band, 137-143 GHz only)
- **51:** 5 Watt peak (Available in Ka-band, 34-36 GHz, or in W-band, 92-96 GHz only)
- **12:** 10 Watt peak (Available in Ka-band, 34-36 GHz or in W-band, 92-96 GHz only)

- **0:** Without polarization switches or power monitor
- **1:** With polarization switches only
- **2:** With power monitor only
- **3:** With polarization switches and power monitor

7

Broadband Downconverters



The Hughes Model 4231xH series of broadband downconverters extends broadband receiver capabilities above microwave frequencies. Fourteen specific models are specified operating from 30 GHz to 170 GHz, downconverting to an IF bandwidth of from 8 GHz to 18 GHz. This output can then be connected to many existing receivers or spectrum analyzers for numerous applications.

Standard options for the downconverter include: a free running oscillator, a phase locked local oscillator, a free running Built-In-Test (BIT) oscillator, a horn lens antenna, and a power supply. In addition, the downconverter can be modified for receiver remote control, polarization diversity, other IF band-

FEATURES:

SPECIFICATIONS

	Frequency Band (GHz)							
	Ka (30-40)	Q (40-50)	U (50-60)	V (60-70)	E (70-90)	W (90-110)	F (110-140)	D (140-170)
Frequency Range (GHz)								
only range in band	(30-40)	(40-50)	(50-60)	(60-70)	—	—	—	—
lowest range in band	—	—	—	—	(70-80)	(90-100)	(110-120)	(140-150)
second range in band	—	—	—	—	(80-90)	(100-110)	(120-130)	(150-160)
third range in band	—	—	—	—	—	—	(130-140)	(160-170)
Noise Figure (dB SSB typ)	12	12	13	13	14	16	17	18
IF Band (GHz)	(8-18)	(8-18)	(8-18)	(8-18)	(8-18)	(8-18)	(8-18)	(8-18)
LO Location (relative to RF band)	above	above	below	below	below	below	below	below
Horn Lens Aperture Size (inches/cm approx)	12/30	6/15	6/15	6/15	3/8	3/8	3/8	3/8
Waveguide Size (without antenna option)①	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10	WR-8	WR-6
Waveguide Flange (without antenna option)①	UG-599/U	UG-383/U	UG-383/U mod	UG-385/U	UG-387/U	UG-387/U mod	UG-387/U mod	UG-387/U mod

① Refer to page 157 for specifications and MIL specification cross reference

Output, dB compression point (dBm min) 15
RF to IF gain (dB min) 20
Input Filter Bandwidth (GHz) .... 8 to 18
BIT Oscillator Frequency .... middle of RF Frequency Range
BIT Oscillator Input Level (dBm typ, referred to input port) .... −40
Temperature Range (°C) .... 0 to 50
External Crystal Reference Frequency (MHz, for optional phase lock) .... 5, 10, or 100
External Crystal Reference Power (dBm, for optional phase lock) 0
Internal Crystal Reference Frequency (MHz for optional phase lock) .... 5, 10, or 100
Lock Indicator (for optional phase lock) .... LED
DC Power Requirements. ② (V/A max for units without power supply).

	Units with Free Running LO's	Phase Locked LO Units
Temperature Controller	+28/1.25 (at cold start)	+28/3.5 (at cold star
BIT Oscillator (option units only below 100 GHz)	+10/2.2	+10/2.2
BIT Oscillator (option units only above 100 GHz)	+28/0.5	+28/0.5
Local Oscillator (below 100 GHz)	+10/2.2	+15/2.0 −15/0.2
Local Oscillator (above 100 GHz)	+28/0.5	+28/0.5 ±15/0.2
IF Amplifier	+15/0.45	+15/0.45

AC Power Input (Power Supply option only)
Volts .... 110 or 22(
Frequency (Hz) 50-60
IF Output Connector .... SMA Female
DC Power Connector .... MS 3102A-145-6S
External Crystal Reference Connector .... SMA Female

② Add current requirements for common voltages depending on option purchased widths, and reduced oscillator radiation on a custom basis.

The basic frequency extension receiver is shown in the block diagram (Figure 1). The optional horn lens antenna is broadband and provides high gain along with reduced side lobes (as shown in typical performance curves). The input is connected to the RF bandpass filter which defines the bandwidth at 10 GHz, rejects the image frequency, and attenuates the mixer local oscillator frequency. The optional Built-In-Test (BIT) mid band oscillator is used to check receiver operation. The BIT option uses a crossguide coupler to inject a − 40 dBm test signal. The optional local oscillator can be either a temperature controlled free running Gunn or a temperature controlled IMPATT source. Gunn oscillators are used up to 100 GHz and IMPATT oscillators, with bandpass filters to reduce AM noise, are used above 100 GHz. Phase locked oscillators, however, achieve much higher stability and frequency conversion accuracy. The balanced mixer is a low noise broadband planar type using beam lead GaAs diodes. The IF output of the mixer is from 8 GHz to 18 GHz. The IF is amplified 40 ± 2 dB by an integral low noise amplifier. A power supply option is available for either 110VAC or 220VAC. Talk to us about your special package requirements.

10 GHz Instantaneous Bandwidths from 30 GHz to 170 GHz

Customized packaging

HOW TO ORDER:

Model Number 4231xH-1xxx

Frequency Band: (Input Waveguide Reference)
- **1**: KA — **5**: E
- **2**: Q — **6**: W
- **3**: U — **7**: F
- **4**: V — **8**: D

Frequency Range:
- **0**: Only range in band
- **1**: Lowest range in band
- **2**: 2nd range in band
- **3**: 3rd range in band

Test, Antenna, and Power Supply Options:
- **0**: Down converter only
- **1**: BIT option
- **2**: Horn lens antenna
- **3**: Power supply
- **4**: BIT and horn lens antenna options
- **5**: BIT and power supply options
- **6**: Horn lens antenna and power supply options
- **7**: BIT, horn lens antenna and power supply options

Local Oscillator Options:
- **0**: Free running oscillator (temperature controlled)
- **1**: PLO external reference (5 MHz)
- **2**: PLO external reference (10 MHz)
- **3**: PLO external reference (100 MHz)
- **4**: PLO internal reference

Example: To specify a 90 to 100 GHz phase locked downconverter with BIT option including a horn lens antenna and power supply order a 42316H-1174.

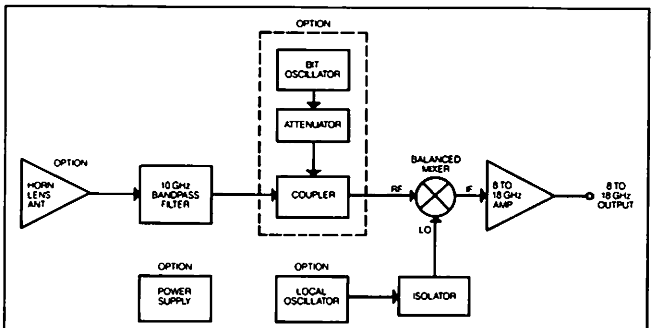
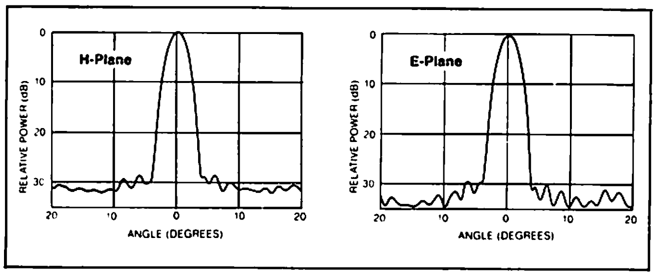
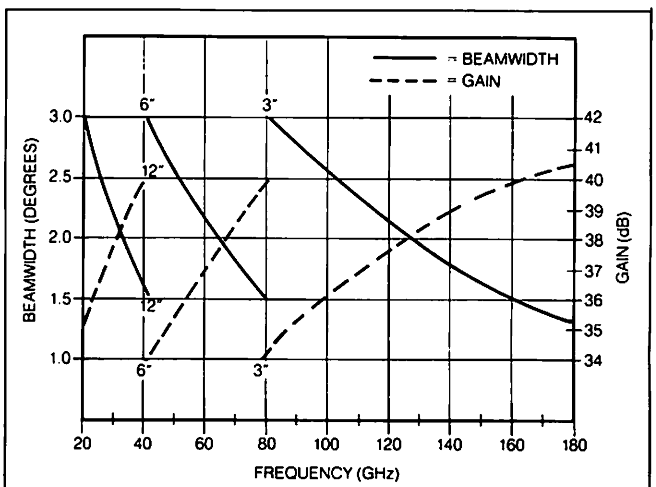


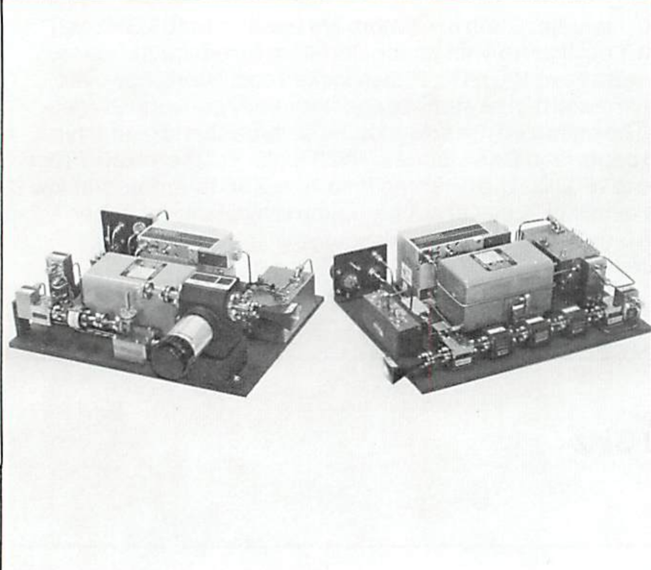
FIGURE 1. BROADBAND DOWNCONVERTER BLOCK DIAGRAM

TYPICAL PERFORMANCE CURVES FOR HORN LENS ANTENNAS





Transmission Amplitude and Phase Measurement Systems



Hughes millimeter-wave ultra stable (one part in a billion long term) 4245xH-111x transmitters and 4231xH-141x receivers, when used in pairs with lower frequency spectrum or vector network analyzers, allow precision amplitude and phase measurements of signal transmissions and reflections with the broadest possible dynamic range. Screen room leakage and anechoic chamber back-scatter can be measured at signal levels of less than −100 dBm. 1 dB gain compression does not occur until input signal levels reach +1 dBm. The transmitter and accompanying receiver make up an ideal system for making repeated periodic analyses of changes in attenuation due to atmospheric conditions and for the measurement of path loss and phase change through various mediums.

FEATURES:

SPECIFICATIONS:

Transmitter Power Output (mW Min)	100
RF Frequency	Customer Specified
IF Frequency (MHz Approx)	200
Crystal Reference Frequency (MHz)	95 to 105
Frequency Stability (Parts per 10^9/day)	±1
Antenna Gain (Standard Gain Horn, dB nominal)	24
Receiver Noise Figure (DSB, dB Max)①	7.5
Receiver RF to IF Gain (dB Typ)①	5 20
Receiver 1 dB Compression point (Referred to Input (dBm Typ))	1.0 −10
Waveguide Size	See Page 157
Ka-band Flange	UG599/U
Flange for Other Bands	See Page 157
Operating Power Inputs	
With Power Supply (VAC, 50-60 Hz)	100, 110, 220, or 235
Without Power Supply (VDC/A Max)	
Transmitter ②	+10/0.5 +35 to +60/0.5
	+15/1.5 3.0
	−15/1.7 1.5
Receiver	+10/2.0②
	+15/1.5 4.0
	−15/1.6 1.5

① Specifications apply with the variable attenuator setting at 0 dB.

② On units between 50 and 75 GHz this requirement is +15/2.0.

② Value depends on band: contact factory.

HOW TO ORDER

Receiver Model Number 4231xH-141x

Frequency Range:
- 1: Ka-Band
- 2: Q-Band
- 4: V-Band
- 6: W-Band

Configuration:
- 0: Without Power Supply or Horn Antenna
- 1: With Power Supply and Horn Antenna
- 2: With Power Supply and Without Horn Antenna
- 3: With Horn Antenna and Without Power Supply

Transmitter Model Number 4245xH-111x

Frequency Range:
- 1: Ka-Band
- 2: Q-Band
- 4: V-Band
- 6: W-Band

Configuration:
- 0: Without Power Supply, Horn Antenna, or Power Monitoring
- 1: With Power Supply, but Without Horn Antenna and Power Monitoring
- 2: With Power Supply and Horn Antenna, but Without Power Monitoring
- 3: With Power Monitoring Option, but Without Power Supply or Horn Antenna
- 4: With Power Monitoring and Antenna, but Without Power Supply
- 5: With Power Monitoring and Power Supply, but Without Antenna
- 6: With Power Supply, Horn Antenna, and Power Monitoring
- 7: With Horn Antenna, but Without Power Supply or Power Monitoring

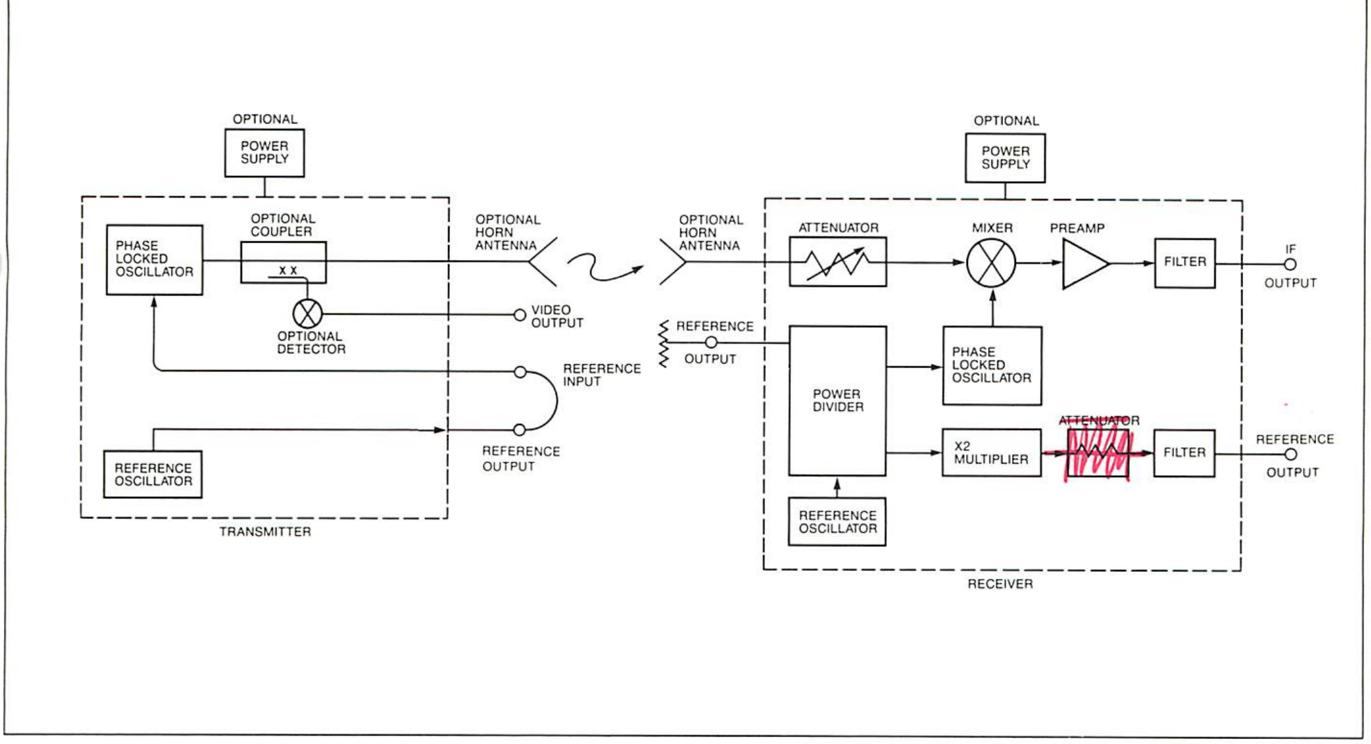
Example: To order a system complete with power supplies and antennas, but selecting a transmitter without the power monitoring option to operate at 94 GHz, order a 42316H-1411 receiver and a 42456H-1112 transmitter, RF frequency 94 GHz.

The transmitters and receivers can be used in either a stand alone mode for the measurement of amplitude or in a cable connected mode, where the 100 MHz reference output from the receiver is used to phase-lock the transmitter, for the measurement of phase and amplitude. They are available with or without power supplies and horn antennas. All receivers have a built-in 0 to 50 dB variable attenuator, and the transmitters have an optional built-in power monitoring capability.

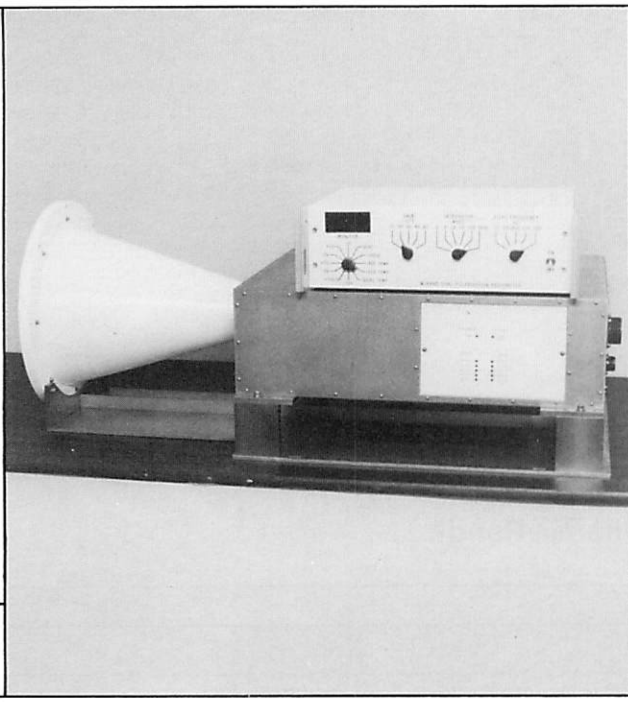
26.5 to 100 GHz Coverage

Ultra High Dynamic Range

BLOCK DIAGRAM



Dicke-Switch Radiometers



Hughes series 4280xH Dicke Switch Radiometers are available in two versions with different options. A listing of the various models that may be ordered is found in the "how to order" section below. In one version, the calibration is performed by automatic switching between the radiometer antenna, a calibration hot load, and a second reference load of lower temperature. In the other version, calibration is performed by automatic switching between the radiometer antenna and single reference hot load. Both versions can be equipped with five choices of standard antenna, or a customized antenna, or without an antenna, and can be ordered with a dual polarization option or with two separate frequency channels. Every effort has been made to provide the best possible sensitivities by using low noise GaAs FET amplifiers up to 26.5 GHz and balanced planar GaAs beam lead diode mixers up to 100 GHz. For the ultimate in long term stability and accuracy along with maximum flexibility in automatic control, the Hughes series 4280xH Radiometer with two reference loads is strongly suggested. This radiometer can be controlled by two separate manually selectable computer interface ports. The radiometer is contained in two separate chassis connected by two ten foot cables. The control chassis contain all the power supplies, monitor read-

FEATURES:

SPECIFICATIONS

	FREQUENCY RANGE (GHz)			
RADIOMETERS	18-26.5	26.5-50	50-75	75-100
Sensitivity① (°K max)	0.15	0.15	0.15	0.15
SYSTEM NOISE TEMPERATURE② (°K max)				
Single Channel or Single Polarization	417	712	888	1095
Dual Channel or Dual Polarization	450	760	973	1582

INTEGRATION TIME③ (msec max)
- One Reference Load Type .... Adjustable to 2, 5, 10, 50, 100 or 1000
- Two Reference Load Types .... Customer Specified

DICKE SWITCHING FREQUENCY (Hz)
- One Reference Load Type .... Adjustable to 25, 125, 250, 500 or 1250
- Two Reference Load Types .... Customer Specified

GAIN (°K/Volt)
- One Reference Load Type .... Adjustable to 10, 20, 30, 40 or 50
- Two Reference Load Types .... Customer Specified

OPERATING TEMPERATURE RANGE (°C) .... +10 to +40

TEMPERATURE MEASUREMENT RANGE (°K) .... 40 to 500

ANTENNAS	Scalar Feed Horn	12" Cassegrain	12" Horn Lens	6" Horn Lens	Offset Fed Paraboloid
Gain (dB typ)	21	SEE CURVES			
Sidelobes (dB down typ)	25	18	26	26	26
Beam Width (degree typ)	12	SEE CURVES			

① Sensitivity (ΔT) is calculated assuming a scene temperature (T_{ANT}) = 500°K (worse case), a bandwidth (BW) of 1 GHz and an integration time (τ) = 1 second from the formula $\Delta T = \frac{C(T_S + T_{ANT})}{\sqrt{BW \cdot \tau}}$ where T_S is system noise temperature and C = 2 for single channel, single polarization, single reference load type and = $\sqrt{6}$ for other types. Due to temperature control limitations, the best sensitivity guaranteed will be 0.15°K RMS.

② System Noise Temperature at antenna port assumes ambient temperature of 25°C.

③ Integration time should be ≥ 20 divided by the Dicke switching frequency.

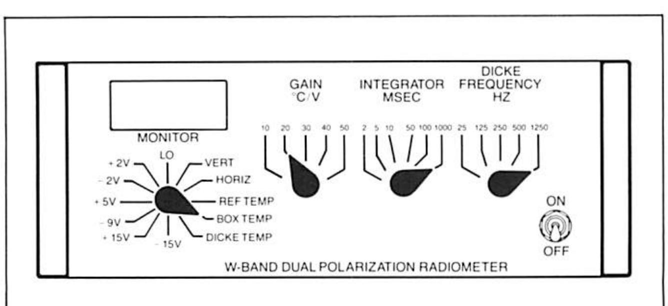


FIG. 1. FRONT PANEL OF ONE REFERENCE LOAD RADIOMETER CONTROL UNIT.

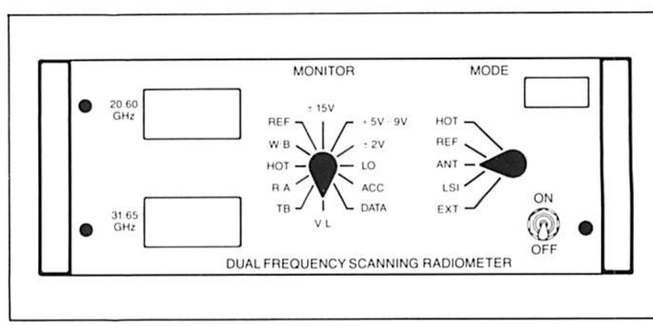


FIG. 2. FRONT PANEL OF TWO REFERENCE LOAD RADIOMETER CONTROL UNIT.

out digital voltmeters, switches for monitor and mode changes, and the connectors for the computer control lines. The rest of the radiometer is housed in an aluminum chassis whose temperature is held stable by a fan, controlled heater, and two adjustable side vents. Temperature stabilization of sensitive components is critical and is accomplished by mounting the switchable circulators, low noise amplifiers, mixers, IF amplifiers and local oscillator on temperature controlled aluminum plates.

The two reference load Dicke Switch Radiometer has two outputs, one of which is proportional to the measured temperature as observed by the antenna, and the other which is proportional to the difference between the two reference loads. A three junction switchable circulator samples, in sequence, the noise signals from the antenna, a temperature-controlled termination at 45°C (reference load), and a second temperature-controlled termination at 145°C (hot load). After frequency conversion, IF amplification, detection, video amplification, synchronous demodulation, and integration, two DC outputs are sent to the computer for accurate determination of the temperature observed by the antenna.

Controls on the control chassis allow the monitoring of the waveguide, box, room, and antenna temperatures as well as the scene temperature observed by the antenna. All supply voltages as well as the voltage outputs representing the hot, reference, and difference temperature between hot and reference loads and antenna output and reference loads can also be monitored. Calculations from the user supplied software can be sent back to the control chassis and displayed on a digital read out.

If a manually controlled radiometer is desired, the Hughes radiometer with one reference load (hot load) gives more flexibility than the two reference load unit. They are very similar, but on the manually controlled unit, the operator can select the Dicke switching frequency, the integration time and the gain of the radiometer with switches on the front panel of the control chassis. The same degree of temperature control of the box and critical components is employed on both types of radiometers. Two way "Dicke" switching is used presenting voltages representing the hot reference load and the noise power observed by the antenna. These voltages can be monitored along with all the supply voltages and the temperatures of the box and of the Dicke switch on the front panel of the control chassis.

0.15°K RMS Sensitivity From 18 to 100 GHz.

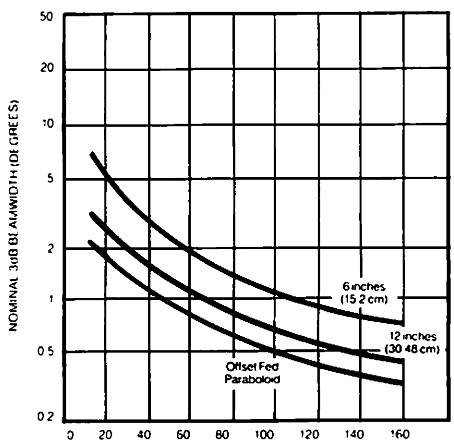


FIG. 3. BEAMWIDTH vs. FREQUENCY

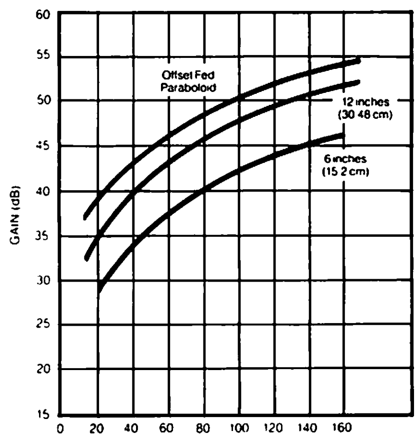


FIG. 4. GAIN vs. FREQUENCY

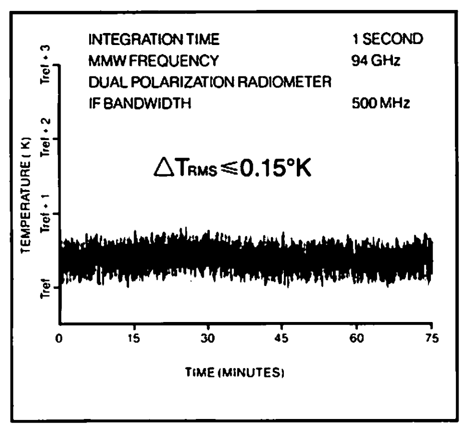


FIG. 5. STRIP CHART RECORDING.

HOW TO ORDER (Specify center frequency at time of order)

Model Number 4280xH-xxxx

Type
- **1**: Single Channel One Reference Load
- **2**: Single Channel Two Reference Loads
- **3**: Type 1 with Dual Polarization
- **4**: Type 2 with Dual Polarization
- **5**: Dual Channel One Reference Load
- **6**: Dual Channel Two Reference Loads

Frequency Range of First Channel
- **0**: 18-26.5 GHz (LNA Front End)
- **1**: 26.5-100 GHz (Balanced Crossbar Mixer Front End)

Frequency Range of Second Channel
- **0**: Single Channel Unit With No Second Channel
- **1**: 18-26.5 GHz (LNA Front End)
- **2**: 26.5-100 GHz (Balanced Crossbar Mixer Front End)

Antenna
- **0**: Supplied Without Antenna
- **1**: Scalar Feed Horns
- **2**: 12" Cassegrain (Single Channel Units Only)
- **3**: 12" Horn Lens (Single Channel Units Only)
- **4**: 6" Horn Lens
- **5**: Offset Fed Parabaloid

IF Bandwidth
- **0**: 10-510 MHz
- **1**: 10-1010 MHz

EXAMPLE: To order a manually controlled 30 GHz dual polarization radiometer with a 1 GHz IF bandwidth without antenna, specify a 42803H-1010.

MMS-300 Instrumentation Radar System

The Hughes MMS-300 Instrumentation Radar System defines the state-of-the-art for antenna pattern measurements and radar cross-section measurements in indoor or outdoor environments. This versatile system can generate simple one-dimensional line plots or the most sophisticated, high-resolution ISAR images available anywhere.

The MMS-300 features a modular design that allows for expansion of frequency coverage from as low as 100 MHz to 100 GHz in a variety of Transmitter and Receiver bandwidths. The system features continuous coverage from 100 MHz all the way through 40 GHz and spot frequency coverage at bands of interest up through 100 GHz. The radar control software allows the operator to reconfigure the radar to accommodate any hardware configuration. The system easily interfaces to any antenna system and standard positioner equipment.

The system is both frequency agile and band agile, so it can switch from band to band on a pulse to pulse basis. It can accommodate a variety of polarization and output power options, depending upon the particular types of measurements and range environments involved. Polarization options range from electromechanical switches to pulse-to-pulse agile switches. Receivers can be configured with either single or dual-channel capability. Power options range from solid state power to medium power traveling-wave tubes (TWT's), all the way through kilowatt level TWT's.

Both monostatic and bistatic configurations are readily accommodated. For bistatic applications, the Receiver and Transmitter can be easily separated. For maximum flexibility, the RF modules can even be removed from the Transmitters and Receivers and located at the antenna site.

The Hughes MMS-300 measurement radar is designed with reliability in mind. Extensive built-in test capabilities exercise the radar each time the system is powered up or on demand. A log of critical parameters is stored on disk file each time and significant deviations are reported to the operator. Diagnostic routines trace potential problems right down to the lowest replaceable module level. The entire radar is constructed in a building block fashion with easy access to each element. Repairs are fast and simple, guaranteeing minimum downtime.

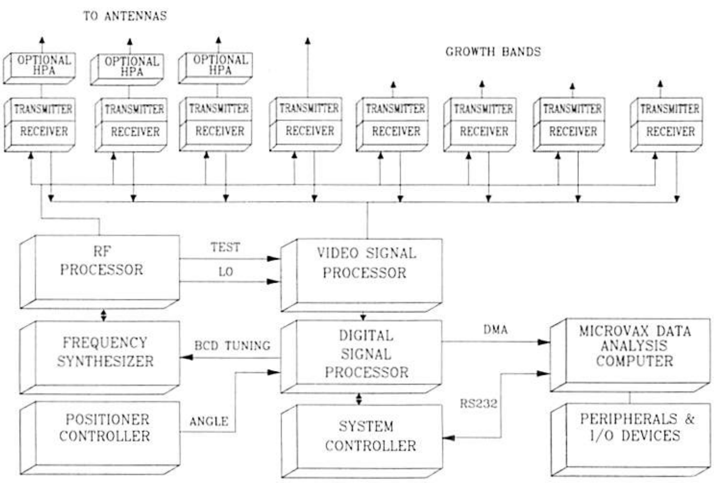


FIG. 2 MMS-300 SYSTEM BLOCK DIAGRAM

MMS-300 RADAR SYSTEM HARDWARE PACKAGING

The MMS-300 Radar can be packaged in a variety of rack-mounted configurations. The system shown in Figure 1 is an example of an MMS-300 radar system covering 100 MHz to 18 GHz continuously with solid state output power levels. In this three-rack configuration, the low-band Transmitter and Receiver (covering the 1 to 18 GHz range) are on the right-hand bay. In the middle bay is the Transmitter and Receiver covering the 2 to 18 GHz range. Below are the common modules: the Video Signal Processor and theDigital Signal Processor. On the left-hand rack are the Frequency Synthesizer, the RF Processor, and the GPIB bus extender which allows the radar to be remoted over long distances.

As an example, the particular system shown above weighs approximately 750 pounds and is configured in racks that are 48 inches high. The power consumption for this system is about 500 watts.

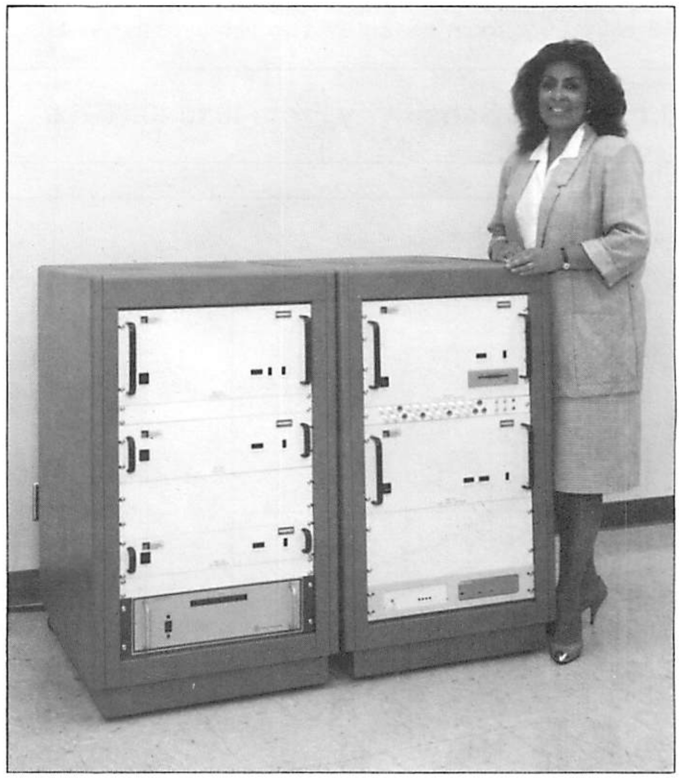


FIG. 1 MMS-300 RADAR SYSTEM HARDWARE

MMS-300 RADAR SYSTEM HARDWARE

The modular nature of the MMS-300 system is clearly visible in the system block diagram shown in Figure 2. In the lower part of the diagram are the common modules, which include the Positioner Controller, Frequency Synthesizer, RF Processor, Video Signal Processor, Digital Signal Processor, System Controller and MicroVax Data Analysis Computer.

In the upper part are the individual Transmitters and Receivers that are used to cover the desired frequency range. The MMS-300 allows up to eight such Transmitter/Receiver pairs to be configured in a system. The Transmitters can be configured either with solid state or low power TWTA's internal to the boxes or external high power amplifiers which are located external to the box. These Transmitter/Receiver pairs are modular in that *they can be added at any time* as the measurement requirements grow *without the need to add additional hardware or to change the system software.* The common equipment can be configured with a variety of options depending on the particular types of measurements desired.

For one-dimensional measurements (that is, all measurements except ISAR imaging) only the AT-compatible System Controller is required. The MicroVax computer is totally optional, since it is required for only two-dimensional imaging software.

MODULARITY

The structural modularity of the System 300 can best be appreciated by describing the baseline system configuration. As shown in Figure 2, the configuration requiring the minimum hardware implementation consists of the following:

1. One Transmitter and one Receiver anywhere in the 0.1 GHz to 100 GHz range.
2. Three common modules: RF Processor, Video Signal Processor, and Digital Signal Processor (RFP, VSP and DSP, respectively).
3. System Controller (an AT-compatible PC) and control software.
4. Frequency Synthesizer (Comstron or Hewlett-Packard).

At any future time, without altering the baseline configuration, the following options can be added:

1. Up to seven additional Transmitter/Receiver pairs, anywhere in the 0.1 to 100 GHz frequency range.
2. A variety of high power amplifiers, including 20 watt TWT's which are designed internal to the Transmitters, or 1 kW power amplifiers that are external to the Transmitters.
3. Transceiver selectors, used in systems with more than one Transmitter/Receiver pair allow automatic selection of the various Transmitter/Receiver chassis in the system without reducing data throughput rates.
4. MicroVax data analysis computer for high resolution ISAR imaging.
5. GPIB and DMA extenders for remote operation.

SYSTEM CONTROLLER

The System Controller is an AT-compatible computer that runs the applications software package designed to manage the radar programming and handle the data collection. It uses a color-overlay, menu-driven approach that is very user friendly and allows the user to interact either through cursor keys or with a mouse.

The system control software comes with a standard data analysis software package that allows near real time display and analysis of data for all of the 1-dimensional types of measurements. It also offers an options for an analog processor that provides the capability to drive strip chart or pen plotters with an analog input.

Because the System Controller programs the radar system through the GPIB, it can be remotely located from the radar by extended distances with GPIB bus extenders.

The AT-compatible computer has the following configuration:

- 80286 Main Processor
- 80287 Math Coprocessor
- EGA card and monitor
- 640 kB main memory
- 3 MB expansion memory
- 3½-inch 720 kB microfloppy disk drive
- 5¼-inch 1.2 MB high density disk drive
- Logitech mouse
- IEEE-488 bus interface
- 1 parallel port
- 2 or 4 RS-232 serial ports
- Epson FX-286e printer
- 80 Mbyte internal hard disk

MMS-300 SYSTEM SPECIFICATIONS

Transmitter Specifications

Pulsewidth	Programmable from 5 nsec to greater than 1 msec in steps of 0.5 nsec.
Transmit Pulse Rise/Fall Time (10 to 90%)	Typically 1 nsec for Transmitter frequencies over 1.0 GHz. From 0.1 to 0.3 GHz, the rise and fall time is less than 20 nsec, from 0.3 to 0.5 GHz it is less than 10 nsec, and from 0.5 to 1.0 it is less than 5 nsec.
On/Off Ratio	100 dB minimum. The Transmitter amplitude typically decays 100 dB within 50 nsec after the falling edge.

Transmitter Power:

Model	Frequency	Baseline Power	Opt A1 Power	Opt A2 Power
TXB	0.1-2.0 GHz	26 dBm		
TXC	2.0-4.0 GHz	26 dBm	43 dBm	60 dBm
TXD	4.0-8.0 GHz	26 dBm	43 dBm	60 dBm
TXE	2.0-8.0 GHz	26 dBm	40 dBm	
TXF	8.0-12.0 GHz	22 dBm	43 dBm	60 dBm
TXG	12.0-18.0 GHz	22 dBm	43 dBm	60 dBm
TXH	8.0-18.0 GHz	22 dBm	43 dBm	60 dBm
TXI	2.0-18.0 GHz	22/26 dBm		
TXJ	18.0-26.0 GHz	27 dBm	40 dBm	
TXK	26.0-40.0 GHz	27 dBm	40 dBm	
TXL	95 GHz	30 dBm		

Receiver Specifications

Noise Figure	From 6 dB at the 0.1 to 2.0 GHz Receiver bandwidth to 13 dB at the 95 GHz bandwidth.
Channel Isolation	70 dB for electro-mechanical switches and 50 dB for agile or dual channel Receivers.
Receiver On/Off Ratio	100 dB minimum.
Range Gate Delays	Programmable from 10 nsec prior to the Transmitter pulse to greater than 1 msec downrange in steps of 0.5 nsec.
Range Gate Width	Programmable in 0.5 nsec steps from 5 nsec to at least 1 msec.
Video Bandwidths	Programmable to 10, 20, 50, 100 and 250 MHz.
ADC Resolution	12 bits for each I and Q signal.
I/Q Circularity	I and Q channels are balanced to within 1 dB in amplitude and 1 degree in phase without software compensation. With software compensation, the balance is typically within 0.2 dB and 0.25 degrees.
Saturation Recovery Time	For Receivers above 2 GHz, the recovery time is typically under 20 nsec. For the 0.1 to 2 GHz band Receiver, the recovery time is under 60 nsec.

Other Key Specifications

Frequency Stability	1×10^{-9}/day
Frequency Step Size	With Comstron FS2000-18 frequency synthesizer: 4 Hz resolution standard, 0.4 Hz optional. With HP8671B frequency synthesizer: resolution of 1 kHz to 3 kHz, depending upon frequency.
Tuning Rate	2 μsec or 1 μsec *plus* the PRI, whichever is greater.
PRI	PRIs may be programmed from 1 μsec out to 10 msec in steps of 40 nsec, which corresponds to a PRF range of 1 MHz to 100 Hz.
Coherent Integration	Programmable from 1 pulse to 65,534 pulses in binary increments with a S/N improvement of at least 45 dB at the maximum integration gain.
Instantaneous Dynamic Range	Single pulse dynamic range of 60 dB in a 100 MHz bandwidth is standard. An integrated dynamic range of at least 90 dB (bandwidth dependent) can be achieved when using the coherent integration feature.
Operating Power	120 VAC or 240 VAC single phase, 50-60 Hz operation.

MMS-300 SOFTWARE OVERVIEW

The Hughes MMS-300 software system is unmatched in power, speed and accuracy. The Radar Control and Data Collection software is multilevel, menu-based windowing system which allows full programmable control of the radar and all measurements. Repetitive measurement setups can be easily saved and executed repeatedly, simply and quickly. To ensure measurement integrity, a quick-look feature allows the operator to observe the measurements as they are performed. The radar control software performs extensive diagnostics on the entire system. Additionally, each major chassis of the system can be operated and diagnosed as a stand-alone instrument.

The full capabilities of the MMS-300 can be appreciated when used in conjunction with the ISAR imaging software package. This software is the result of over 12 years of development efforts and customer feedback. The Hughes Aircraft RCS Evaluation Software (HARES) processes and presents the data in numerical, line plot, polar plot, and two-dimensional image formats. Extensive compensation and calibration routines, such as background subtraction and weighting, are available to the operator.

Data interpretation and analysis are easily carried out with the many image manipulation and editing features such as: Automatic or manual scaling, off-axis image cuts, pixel dumping, zooming and panning, pixel editing, variable threshold and dynamic range, variable color map, multiple image processing, target overlay, medianization, data averaging, and sector reports.

Data output can be saved to disk for later recall, display and editing. With multiple terminals, a number of people can be reviewing and analyzing data simultaneously as shown in Figure 3.

A comprehensive target drawing capability allows the analyst to create a library of different target drawings that can be easily called from a disk file to overlay displayed images. This provides for quick correlation of target features and scattering characteristics.

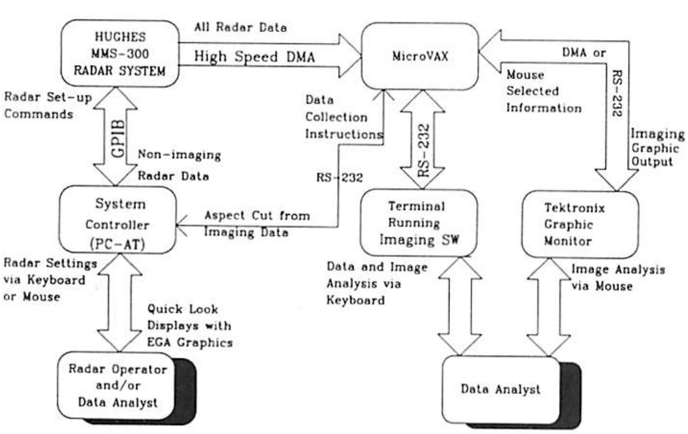


FIG. 3. DATA PROCESSING APPROACH

SYSTEM CONTROLLER SOFTWARE

The System Controller Software controls the radar measurement and performs non-imaging data analysis as well as near real-time "quick-looks" at imaging data. The System Controller Software is a menu-driven application package with on-line help. The main menu of the System Control Software provides the branching point to the four major functions of the System Controller: Measurements, Data Analysis, Utilities and Diagnostics. Figure 4 shows an example of a Measurement Setup Screen.

Data processed on the System Controller is displayed on an EGA terminal in full color. Plots may be dumped to a character printer, color copier, HPGL-compatible color plotter or any of dozens of display and hardcopy devices.

The following graphic data displays are supported by the System Controller: RCS versus Frequency; RCS versus Range; RCS versus Aspect (Cartesian and Polar); Waterfall plots; I versus Q plots; Raw I and Q plots; RCS versus Time.

Additionally, all plot types on the System Controller can be displayed with Mean, Median, and Standard Deviation statistical analyses.

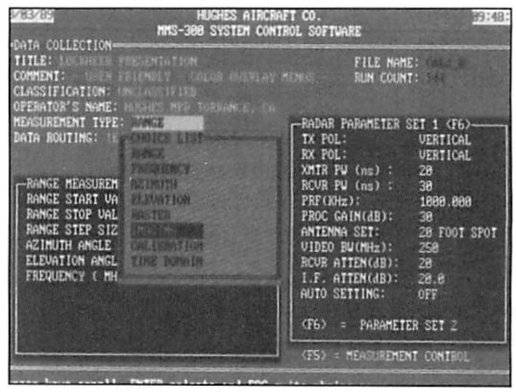


FIGURE 4. MEASUREMENT SETUP SCREEN

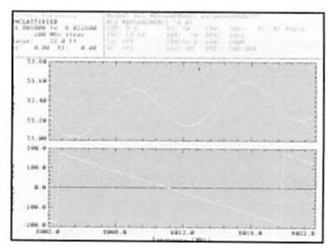


FIGURE 5.

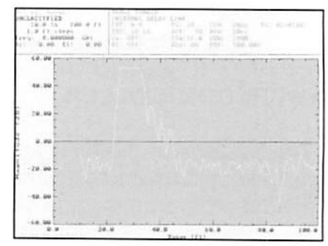


FIGURE 7.

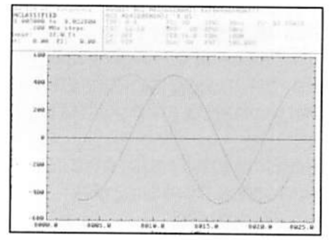


FIGURE 6.

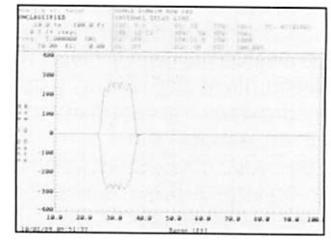


FIGURE 8.

FIGURE 5 SHOWS AN EXAMPLE OF A RCS MAGNITUDE AND PHASE PLOT AS A FUNCTION OF FREQUENCY. THE USER HAS THE OPTION OF DISPLAYING MAGNITUDE ONLY OR PHASE ONLY. PHASE CAN BE DISPLAYED IN THE WRAPPED MODE AS SHOWN ABOVE OR IN THE UNWRAPPED MODE TO AVOID THE DISCONTINUITIES AT THE AXIS EXTREMITIES. NOTICE THAT THIS PARTICULAR PLOT IS UNCALIBRATED, AS INDICATED BY THE MAGNITUDE SCALE IN DB AND THE IDENTIFICATION (CA:OFF) IN THE PLOT HEADER. FIGURE 6 SHOWS RAW I AND Q AS A FUNCTION OF FREQUENCY.

FIGURE 7 SHOWS AN RCS VERSUS RANGE PLOT WITH DATA COLLECTED BY MOVING THE RANGE GATE. THIS PLOT REPRESENTS UNCALIBRATED DATA. PHASE IS ALSO AVAILABLE AT THE USER'S REQUEST. FIGURE 8 SHOWS RAW I & Q DATA AS A FUNCTION OF RANGE.

HARES HIGH RESOLUTION ISAR IMAGING SOFTWARE

The full capabilities of the MMS-300 system are evident with the high-resolution ISAR resident software package. HARES (Hughes Aircraft RCS Evaluation Software) is a VAX-resident software package used for high resolution 1D and 2D RCS analysis. It is an option for the MMS-300 system and is only required if 2D images are desired.

When using HARES, the System Controller still provides all radar control, but data is streamed directly to the VAX from the Digital Signal Processor through a DMA path. If the VAX and the Digital Signal Processor are separated by more than 50 feet, a fiber optic DMA extender is available to facilitate communications out to 1 kilometer without any reduction in data transfer rates.

As data is collected on the VAX, a quick-look display is provided by a utility program that sends data from the VAX to the System Controller screen while the measurement is in progress. Data collected on the VAX may be stored on a variety of media including removable hard disks and tapes. Data may be outputted to printer, plotter or color copier devices. The graphics terminal is a Tektronix 4235 workstation.

HARES supports all of the 1D line plots that the System Controller provides. In addition, HARES also provides high resolution synthetic range profiles through transformation of stepped frequency data. 2D images are displayed in the form of color-mapped pixel plots.

The 2-D ISAR images generated by HARES are displayed on the Tektronix graphics workstation. Two image windows are defined on the screen. The left window displays the image in its full size, while the right window is reserved for user-specified analysis of the image. A region at the bottom of the screen is reserved for cross-sectional cuts of the images.

The analysis features of HARES include the following: Vertical Image Cuts; Horizontal Image Cuts; Pixel Dumping; Image Zooming; Image Panning; Pixel Editing; Reconstruction; Threshold Reassignment; Color Map Reassignment; Storage/Recall of Processed Images; Multiple Image Display; Statistical Processing; Line Drawing Editor; Target Line Drawing Overlay. Figures 9, 10 and 11 show examples of these HARES analysis features.

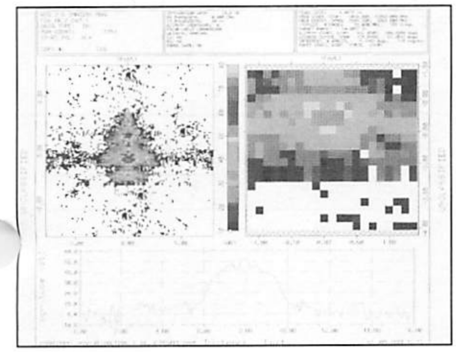


FIGURE 9.

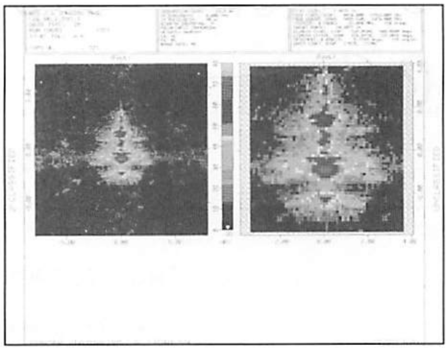


FIGURE 10.

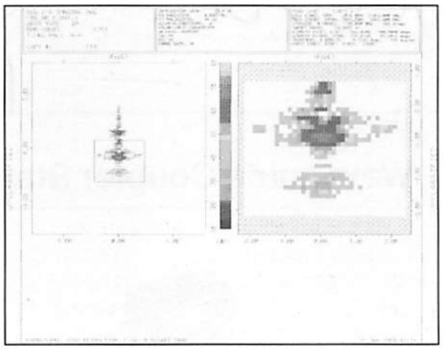


FIGURE 11.

COMPACT ANTENNA TEST RANGE

In 1988, the Microwave Products Division completed construction of a 60-foot indoor compact range RCS measurement facility for system test and demonstration. Shown in Figure 12, this facility is outfitted with a complete MMS-300 series system equipped to make RCS measurements and ISAR imaging measurements.

For additional information about any aspect of the Hughes MMS-300 Instrumentation Radar System or for a demonstration of its capabilities in our just completed indoor compact range, call the Hughes RCS hotline (213) 517-7600.

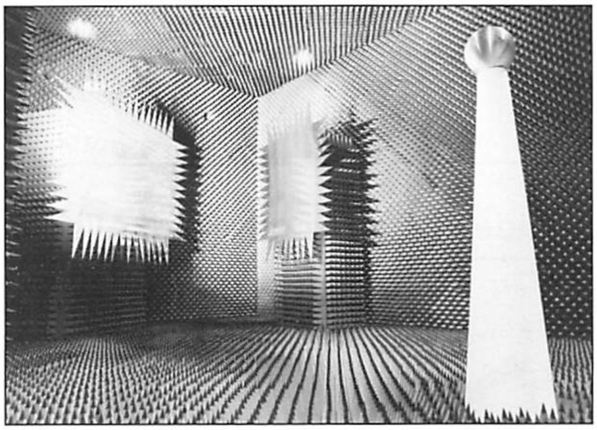
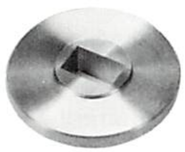


FIG. 12. COMPACT ANTENNA TEST RANGE

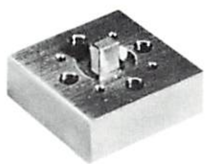
7

Waveguide Flanges, Sections, and Drill Fixtures



UG TYPE WAVEGUIDE FLANGE (ROUND ONLY)

SILVER WAVEGUIDE SECTIONS



DRILL FIXTURE FOR WAVEGUIDE FLANGE ALIGNMENT PIN HOLES

HOW TO ORDER

Waveguide Flanges 4546xH-1000
Drill Fixtures 4546xH-1100
Straight Coin Silver Waveguide 4543xH-00xx

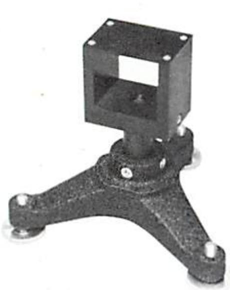
Waveguide Band ①
- **1**: Ka (26.5-40 GHz)
- **2**: Q (33-50 GHz)
- **3**: U (40-60 GHz)
- **4**: V (50-75 GHz)
- **5**: E (60-90 GHz)
- **6**: W (75-110 GHz)
- **7**: F (90-140 GHz)
- **8**: D (110-170 GHz)
- **9**: G (140-220 GHz)

Length in Inches (60 inches max)
- **01**: 1 inch
- **02**: 2 inches
  continues in 1-inch increments up thru
- **60**: 60 inches

① See page 157 for waveguide and flange dimensions

INCLUDE 4546 QUICK-DISCONNECT FLANGES
— HERE —

Waveguide Coupler Stand



SUPPORTS TEST SET UPS
USING HUGHES SPLIT BLOCK COUPLERS

HOW TO ORDER

Waveguide Coupler Stand 4550xH-0100

- **1**: Fits Ka-Band square flange coupler
- **2**: Fits K-Band square and Ka- to U-Band round flange couplers
- **7**: Fits V- to D-Band couplers

Waveguide Flange Screws and Alignment Pins

SOCKET HEAD
CAPTIVE SCREWS FOR
UG TYPE FLANGES

.0615" DIA
ALIGNMENT PINS

HOW TO ORDER

Waveguide Flange Screws
(bag of 50) 45550H-0000
Waveguide Flange Alignment Pins
(bag of 50) 45460H-0000

HUGHES

MICROWAVE PRODUCTS DIVISION
Industrial Electronics Group

MILLIMETER-WAVE QUICK DISCONNECTS FOR ROUND WAVEGUIDE FLANGES

Hughes Model 45460H-1X0X Quick Disconnect

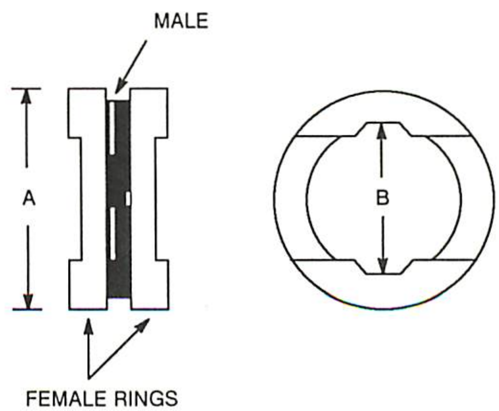
Description

The Hughes Model 45460H-1X0X series of millimeter-wave waveguide flange quick disconnects are designed to be used with all round flanges. Model 45460H-1103 is used with Ka (UG-381/U), Q (UG-383/U Model) flanges covering the frequency range of 26.5 to 60 GHz. Model 45460H-1409 is used with V (UG-385/U) through G (UG-387/U Mod) flanges covering the frequency range of 50 to 220 GHz.

Quick disconnects are particularly useful in applications where there is a need to repeatedly connect and disconnect waveguide flanges. They are designed to provide uniform compression across the face of the connection without deforming the flange face as can happen with waveguide screws. The quick disconnects are used by unscrewing the outer rings from the center threaded or male insert and working each ring over a mating flange with the waveguide screws removed. The male section is then re-threaded into one of the rings on one flange. After mating the flanges under test the two sets of rings are then brought back together, mated and tightened by hand. The Hughes Quick Disconnects allow fast reliable testing at millimeter-wave frequencies.

HUGHES
MICROWAVE PRODUCTS DIVISION
Industrial Electronics Group

OUTLINE DRAWING



Band	A	B
Ka thru U	1.50''	1.0''
V thru G	1.12''	0.625''

Model 45460H-1X0X Quick Disconnect
How to Order:

Model Number 45460H-1103
For Ka, Q and U Bands

Model Number 45460H-1409
For V through G Bands

PO Box 2940, Torrance, CA 90509-2940
(213) 517-6400/FAX (213) 517-7665

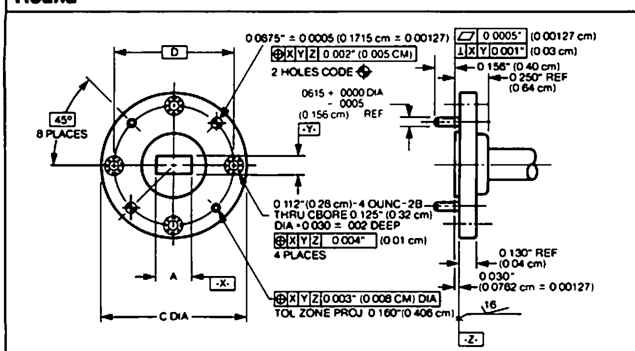
Waveguide Specifications and MIL Specification Cross Reference

			Waveguide Specifications				Flange Specifications		
Band Desig-nation	Frequency (GHz)	MIL-W-85/ X-XXX (Silver)①	Inside Dimensions (inches (cm)) a x b	Inside Dimensions tol ±	Outside Dimensions (inches (cm)) a x b	Outside Dimensions tol ±	MIL-F-3922/ XX-XXX (Brass)①	UG-XXX/U Equivalent (REF)	Remarks
K	18-26.5	1-106 (WR-42)	0.420 x 0.170 (1.07 x 0.43)	0.0020 (0.0051)	0.500 x 0.250 (1.27 x 0.635)	0.0030 (0.0076)	54-001 67-004	UG-595/U —	Square② Round
Ka	26.5-40	3-006 (WR-28)	0.280 x 0.140 (0.711 x 0.356)	0.0015 (0.0038)	0.360 x 0.220 (0.914 x 0.559)	0.0020 (0.0051)	54-003 68-002 67B-005	UG-599/U — UG-381/U	Square Square③ Round
Q	33-50	3-010 (WR-22)	0.224 x 0.112 (0.57 x 0.28)	0.0010 (0.0025)	0.304 x 0.192 (0.772 x 0.488)	0.0020 (0.0051)	67B-006	UG-383/U	Round
U	40-60	3-014 (WR-19)	0.188 x 0.094 (0.48 x 0.24)	0.0010 (0.0025)	0.268 x 0.174 (0.681 x 0.442)	0.0020 (0.0051)	67B-007	UG-383/U Mod	Round
V	50-75	3-017 (WR-15)	0.148 x 0.074 (0.38 x 0.19)	0.0010 (0.0025)	0.228 x 0.154 (0.579 x 0.391)	0.0020 (0.0051)	67B-008	UG-385/U	Round
E	60-90	3-020 (WR-12)	0.122 x .061 (0.31 x 0.15)	0.0010 (0.0025)	0.202 x 0.141 (0.513 x 0.356)	0.0020 (0.0051)	67B-009	UG-387/U	Round
W	75-110	3-023 (WR-10)	0.100 x 0.050 (0.254 x 0.127)	0.0010 (0.0025)	0.180 x 0.130 (0.458 x 0.330)	0.0020 (0.0051)	67B-010	UG-387/U Mod	Round
F	90-140	3-026 (WR-8)	0.08 x 0.040 (0.232 x 0.102)	0.0005 (0.0013)	0.160 x 0.120 (0.406 x 0.305)	0.0015 (0.0038)	— 74-001	UG-387/U Mod	Round Pin Contact
D	110-170	3-029 (WR-6)	0.065 x 0.0325 (0.17 x 0.083)	0.0005 (0.0013)	0.145 x 0.1125 (0.368 x 0.2858)	0.0015 (0.0038)	— 74-002	UG-387/U Mod	Round Pin Contact
G	140-220	3-032 (WR-5)	0.051 x 0.0255 (0.130 x 0.0648)	0.0005 (0.0013)	0.131 x 0.1055 (0.333 x 0.2680)	0.0015 (0.0038)	— 74-003	UG-387/U Mod	Round Pin Contact

① All waveguide and flange assemblies are gold plated per MIL Spec MIL-G-45204 ② Also available with #4-40 threaded holes instead of through holes ③ Threaded holes

OUTLINE AND MOUNTING DRAWINGS

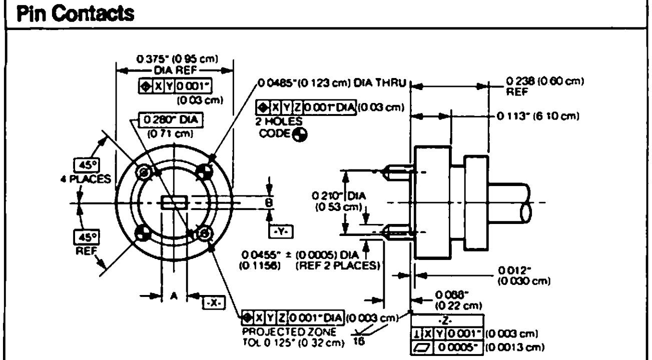
Round



DIMENSIONS (inches (cm))

BAND	A	B	C dia	D dia
K	0.420 (1.07)	0.170 (0.43)	1.125 (2.86)	0.9375 (2.38)
Ka	0.280 (0.71)	0.140 (0.36)	1.125 (2.86)	0.9375 (2.38)
Q	0.224 (0.57)	0.112 (0.28)	1.125 (2.86)	0.9375 (2.38)
U	0.188 (0.48)	0.094 (0.24)	1.125 (2.86)	0.9375-(2.38)
V	0.148 (0.38)	0.074 (0.19)	0.750 (1.91)	0.5625 (1.43)
E	0.122 (0.31)	0.061 (0.15)	0.750 (1.91)	0.5625 (1.43)
W	0.100 (0.25)	0.050 (0.13)	0.750 (1.91)	0.5625 (1.43)
F	0.080 (0.23)	0.040 (0.10)	0.750 (1.90)	0.5625 (1.43)
D	0.065 (0.17)	0.0325 (0.083)	0.750 (1.90)	0.5625 (1.43)
G	0.051 (0.13)	0.0255 (0.064)	0.750 (1.90)	0.5625 (1.43)

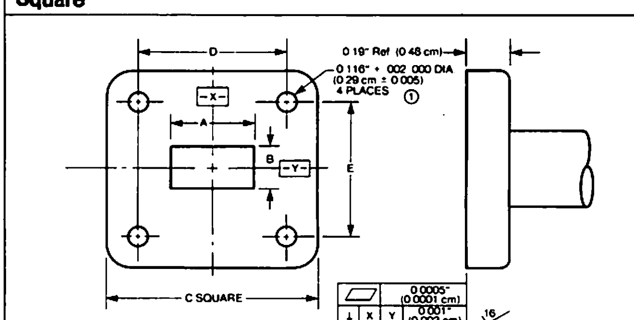
Pin Contacts



DIMENSIONS (inches (cm))

BAND	A	B
F	0.080 (0.20)	0.040 (0.10)
D	0.063 (0.16)	0.0325 (0.083)
G	0.051 (0.13)	0.0255 (0.065)

Square



① Also available with #4-40 threaded holes.

DIMENSIONS (inches (cm))

BAND	A	B	C	D	E
K	0.420 (1.07)	0.170 (0.43)	0.875 (2.22)	0.640 (1.63)	0.670 (1.70)
Ka	0.280 (0.71)	0.140 (0.36)	0.750 (1.91)	0.500 (1.27)	0.530 (1.35)

Product Functional Index

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