A New Method of Generating FM and Television Stereo Composite Baseband Yields Improved Broadcast Performance.

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ABSTRACT

A Digital Signal Processing technique now allows for the conversion of the L - R component of the stereophonic baseband from double sideband AM to a single sideband (SSB) AM subcarrier. When lower sideband operation of the L - R subcarrier is employed, a reduction in the distortions to the L - R audio under the effects of multipath occurs. Additionally, much lower crosstalk into the revenue bearing SCA channels is realized, while maintaining a stereophonic transmission that is 100% compatible with existing receivers. Implementing an SSB demodulator in the stereo receiver yields a 4 dB improvement in stereo signal to noise along with reducing the effects of multipath generated crosstalk from the SCA band into the stereo subchannel.

BUILDING A CASE FOR SSB

A characteristic of Frequency Modulation (FM) detectors employed in FM broadcast and television receivers is that they exhibit a response to noise that falls within the IF bandwidth of the receiver that increases at 6 dB per octave over the demodulated baseband frequency spectrum (figure 1).

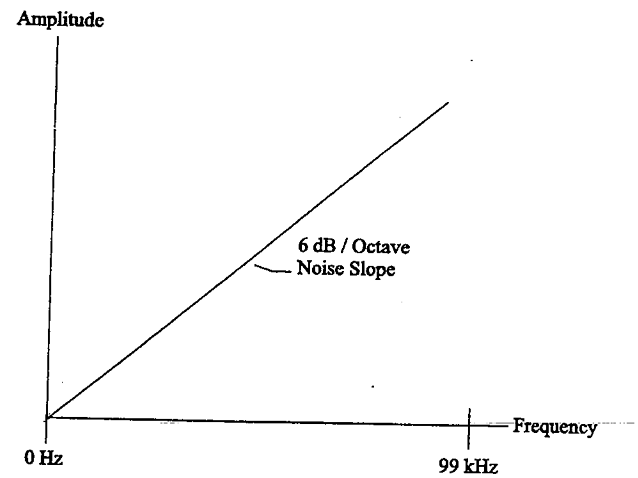

Figure 1. FM Detector Noise Response

In the 1930's when FM was developed, this rising noise was anticipated and compensated for by employing pre-emphasis at the transmitter and de-emphasis at the receiver.[1] The receiver de-emphasis rolled off the frequency response of the detected audio at a rate that complemented the rising noise and flattened the detector's response to the noise. Pre-emphasis was then required at the transmitter to make the overall frequency response of the system flat for the transmission of high fidelity audio.

In the late 1950's as the transmission of stereo audio was being developed, a method of multiplexing the FM carrier was derived that transmitted the monophonic sum (L+R) of the two channels of audio as baseband intelligence to provide for compatibility with existing monophonic FM receivers. It was determined that the Left and Right channels could be mathematically derived at the stereo receiver if the difference in the two audio channels (L-R) was also transmitted at the same time. This difference signal was linearly modulated on a supersonic subcarrier of 38 kHz employing double sideband suppressed carrier (DSBSC) amplitude modulation.

In addition to the two intelligence bearing signals described above, a 19 kHz pilot tone of tightly controlled frequency and phase is also broadcast as baseband audio at between 8 and 10 percent modulation. This tone allows the stereo receiver to synchronize a 38 kHz oscillator for the proper demodulation of the DSBSC L-R signal (figure 2, following page).

When we superimpose the FM detector's noise response over the composite FM baseband signal, we can see the linearly modulated L-R signal will suffer significant degradation from the effects of the FM noise (figure 3, following page). From this view we can also see that the upper sideband of the L-R suffers the most degradation from the effects of FM detector noise. It has been generally accepted that this method of broadcasting FM stereo suffers from a 23 dB penalty in signal to noise ratio when compared to monophonic FM.[2]

Another innate characteristic of FM stereo is that the amount of degradation suffered under the effects of multipath is proportional to the modulation index of the baseband component. As frequency in the baseband increases, modulation index decreases, for a given FM deviation. Thus, the upper sideband of the L-R has a much lowere modulation index when compared to the lower sideband.

A PROPOSAL

A new system is proposed employing SSB modulation of the L-R sub-channel. Modulation of the L-R information is in the lower sideband (LSB) only. The resulting sideband amplitude is twice the value when compared to the lower sideband in the DSBSC system to derive the correct mathematical sum for demodulation and re-matrixing of the left and right channels (figure 4, following page).

The transmitted baseband signal shown in figure 4, yields these main features:

Compatible with the product detectors used in current FM stereo demodulator chips, yielding compatibility with existing stereo and, of course, no degradation to monophonic receivers.

Lower stereophonic cross talk into the SCA portion of the baseband due to the addition of a 15 kHz guard band for better SCA performance.

Narrows the L-R occupied bandwidth and increases the modulation index in the LSB by a factor of two, providing for less L-R distortion due to the effects of FM signal multipath.

Narrows the overall FM transmission bandwidth reducing the degradation in stereophonic performance caused by the finite bandwidth performance of transmitter cavities, antennas, and RF mutiplexing systems.

A 38 kHz carrier broadcast in phase quadrature with the 38 kHz suppressed carrier, injected at 2% FM modulation to signal SSB L-R receivers to switch into the lower sideband mode for reduced noise and distortion

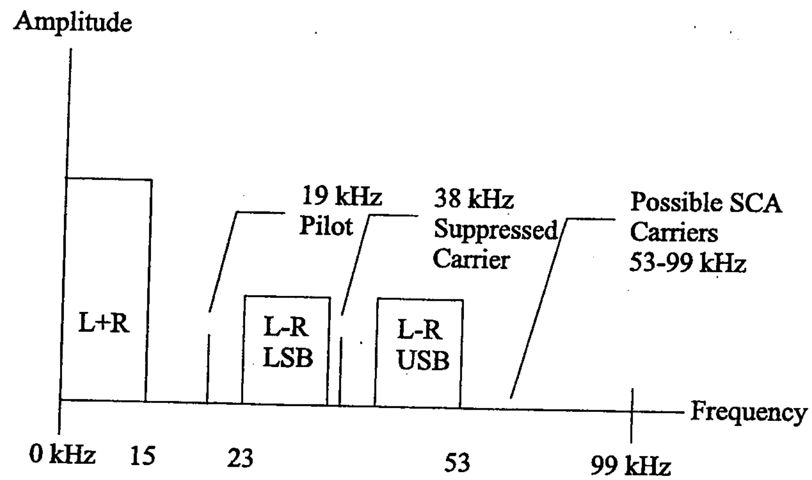

Figure 2. FM Stereophonic Baseband

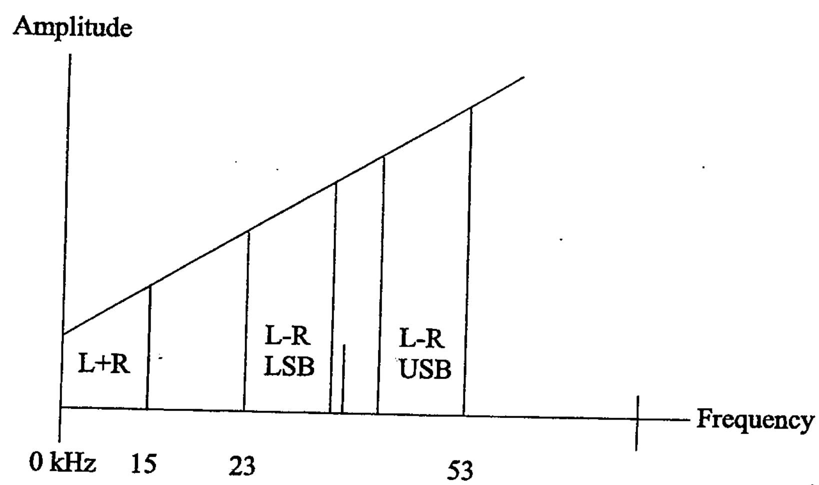

Figure 3. FM Stereophonic Noise Contribution

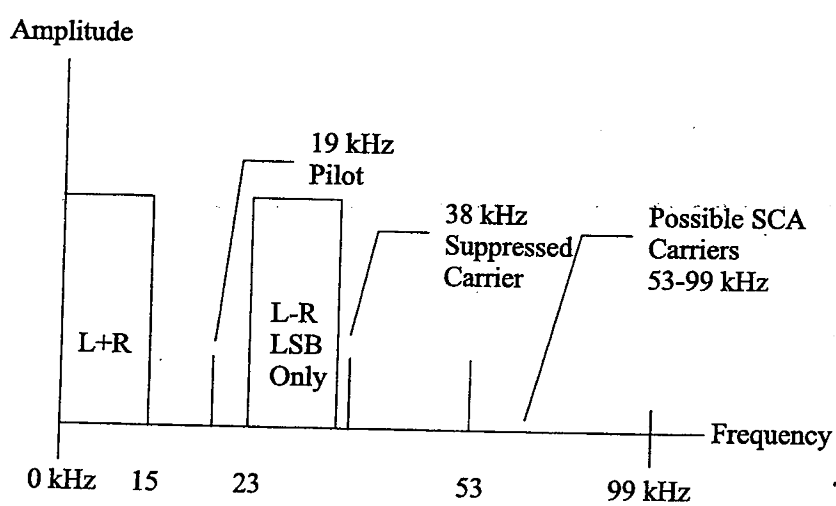

Figure 4. FM Stereophonic SSB L-R Baseband

reception. This quadrature carrier amplitude integrates to zero volts in the demodulation process of existing stereophonic receivers.

The benefits listed above can be realized with or without SSB L-R receivers.

AN IMPLEMENTATION

Of the three common methods used to generate linear SSB amplitude modulation, The Weaver Method,[3] when realized with the perfect multipliers and linear phase filters available through Digital Signal Processing, provides an efficient implementation algorithm that yields excellent stereo performance.

The circuit required by the transmitter to generate the SSB L-R is shown in figure 5 (following page). The Weaver circuit uses dual carrier quadrature oscillators for conversion and frequency shifting, for proper placement of the L-R lower sideband. Linear phase Finite Impulse Response (FIR) filters along with the finite time delay in the L+R channel provide for near perfect stereo separation in the generator.

MAXIMIZING THE BENEFITS

Again, all previously stated benefits can be realized with no changes to the existing receiver base and is 100% compatible with receivers now is use. Additional benefits could be realized if stereo decoder IC manufacturers would adopt SSB L-R into their designs. The single sideband L-R receiver circuit also implemented as a DSP algorithm is shown in figure 6 (following page). When combined with the above encoding at the transmitter allows for the following benefits:

The receiver is compatible with existing DSBSC L-R transmissions. Switching to the SSB mode upon detection of the 2% injected 38 kHz quadrature pilot signal.

Increases the L-R signal to noise ratio by 4 dB, increasing the useful stereophonic coverage range of the SSB L-R generating broadcast station. A 4 dB improvement here is equivalent to more than doubling the broadcast station power.

Reduces significantly the SCA to L-R cross talk caused by the effects of multipath, improving stereo performance.

The employment of lower sideband DSB L-R increases the effects of de-emphasis in removing high frequency noise and hiss from the re-matrixed left and right channels.

The receiver derives a better signal for controlling monophonic blending at the fringe coverage areas by measuring the noise power in the now unused upper sideband of the 38 kHz subcarrier, combined with a relative amplitude and phase measurements between the 19 kHz and the 38 kHz quadrature pilot subcarriers.

The receiver achieves its SSB L-R performance again, using a DSP implemented Weaver demodulator (figure 6). Linear-phase, digital FIR low-pass filters employed in the Weaver circuit, along with a finite time delay and FIR low pass filter in the L+R channel allow for near perfect stereo separation.

STEREO TELEVISION

Stereo for television has a big advantage over FM stereo. The designers of this system clearly saw the noise problems and counteracted them

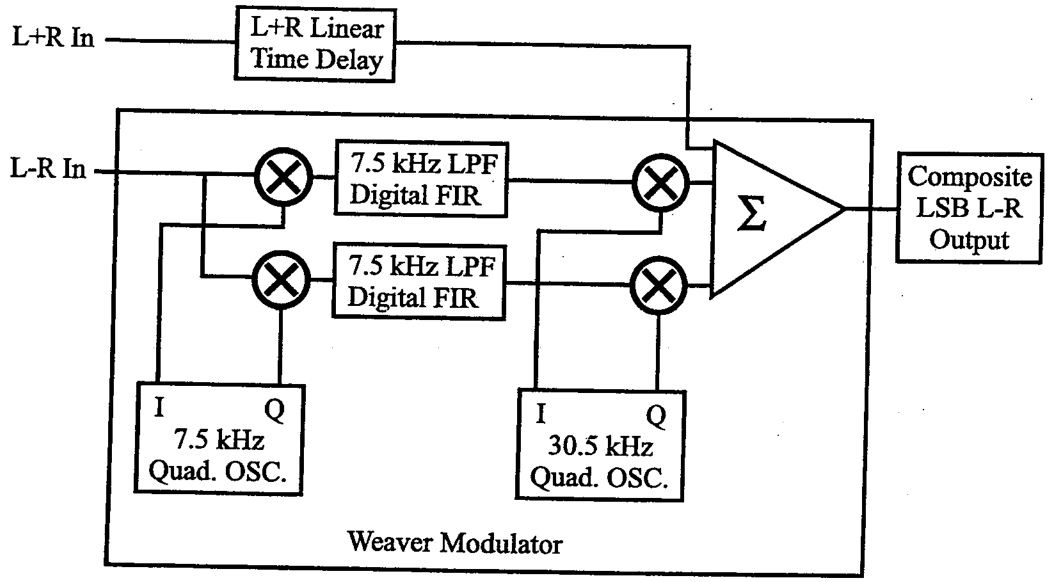

Figure 5. LSB L-R Stereo Baseband Generator

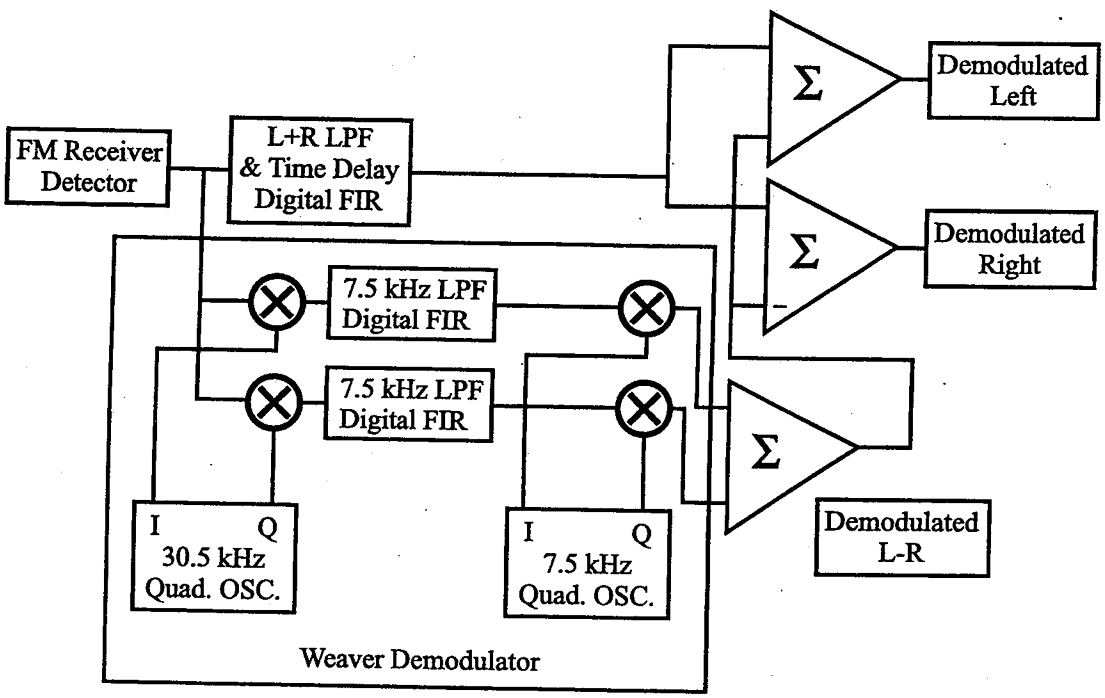

Figure 6. LSB L-R Stereo Baseband Demodulator

by adding signal gain compression to the L-R channel at the transmitter and then adding gain expansion at the receiver. It is felt, however, that the SSB L-R system adds the possibility of further improvement of TV stereo through the reduction in cross talk from the L-R to Second Audio Program (SAP) and Professional (PRO) channels, and from the SAP and PRO into the L-R. All of the distortion reduction benefits under the effects of multipath would also be realized in a television implementation.

CONCLUSION

SSB modulation of the L-R appears to be a possible incremental engineering improvement that could increase the performance and value of broadcast facilities. Of course improvement in listener satisfaction is the ultimate goal.

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[2] Norman Parker and Donald W. Ruby, "Some Notes on the Calculations of the Signal to Noise Ratio for an FM System Employing a Double Sideband AM Multiplex." *IEEE Transactions on Broadcast Television Receivers,* (International Convention Issue), vol. BTR-8, Apr. 1962, pp. 42-46.

[3] D.K. Weaver, Jr., "A Third Method of Generation and Detection of Single Sideband Signals", *Proceedings of the Institute of Radio Engineers,* vol. 44, no. 12, Dec. 1956, pp. 1703-1705.