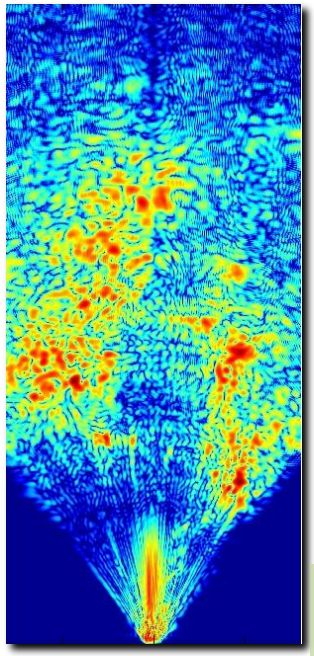
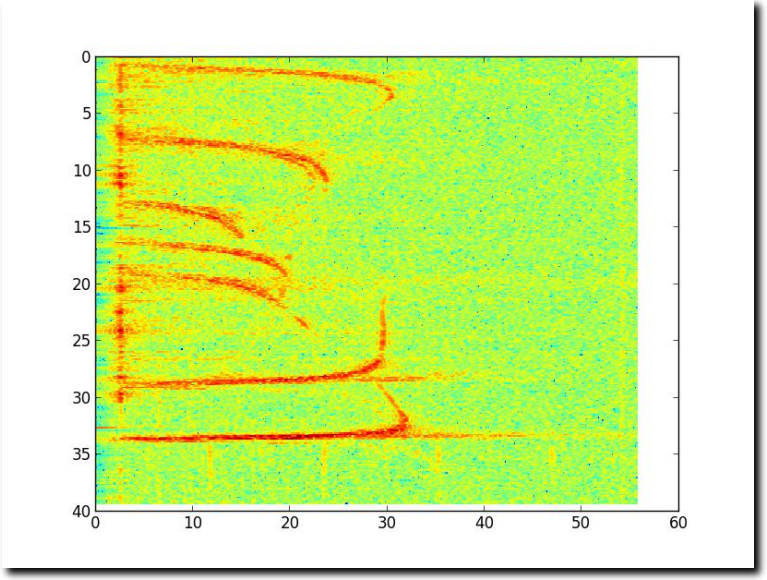
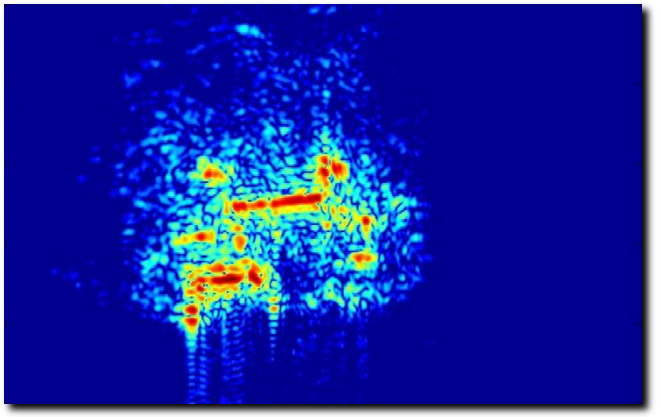






Recent Developments in Small Radar Technology

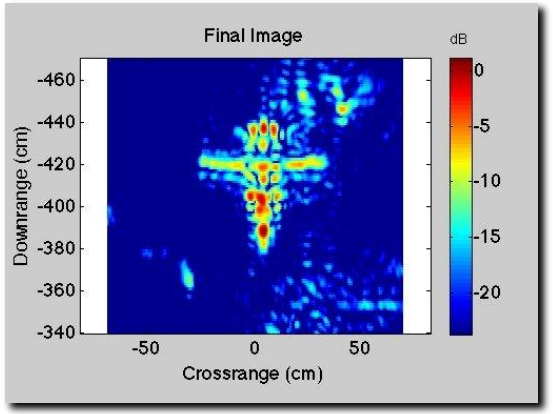
San Bernardino Microwave Society

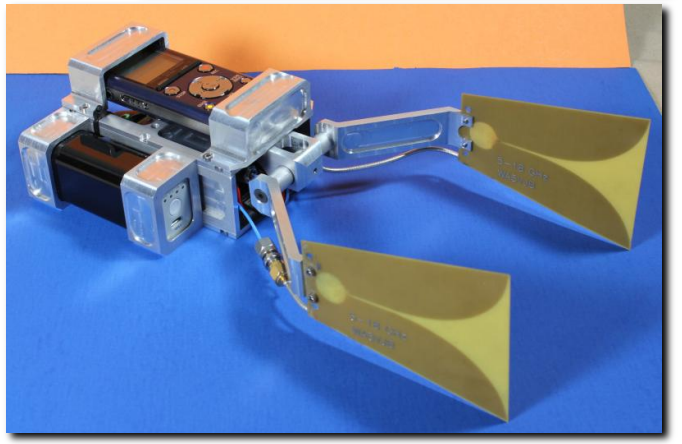
January 3, 2012

Tony Long KC6QHP

Outline

- Brief Introduction to RADAR concepts
- Greg Charvat
- The Coffee Can RADAR
  - Doppler
  - Ranging
  - Synthetic Aperture RADAR (SAR)
- Coffee Can RADAR Catches On
  - MIT Open Courseware Class
  - UC Davis
- Applications
- My 5.8 GHz RADAR





RADAR Basics

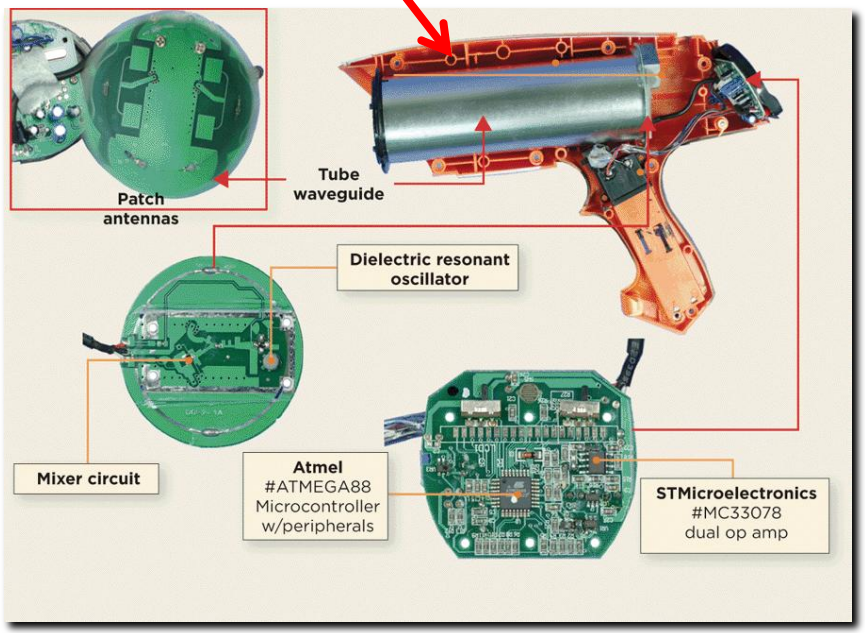
- Speed RADAR
  - Measure speed using Doppler shift of transmitted signal
  - Very simple hardware (e.g. Gunnplexer)
  - Audio frequency range Doppler frequencies when using microwaves and typical car speeds
  - I/Q detection required to determine direction

Not a toy

$$f_D = \frac{2 \times V_{target} \times cos\theta \times f_{tx}}{C}$$

$f_D = Doppler\ Frequency$
$V_{target} = Speed\ of\ the\ target\ in\ m/s$
$\theta = Angle\ to\ target$
$f_{tx} = Transmitter\ frequency\ in\ Hz$
$C = Speed\ of\ Light\ in\ m/s$

Toy



RADAR Basics

- Ranging Radar
  - Measure distance to target
  - Compute delay of transmitted signal
  - Transmission and detection of pulse
  - Comparison of returned frequency with current frequency in FMCW

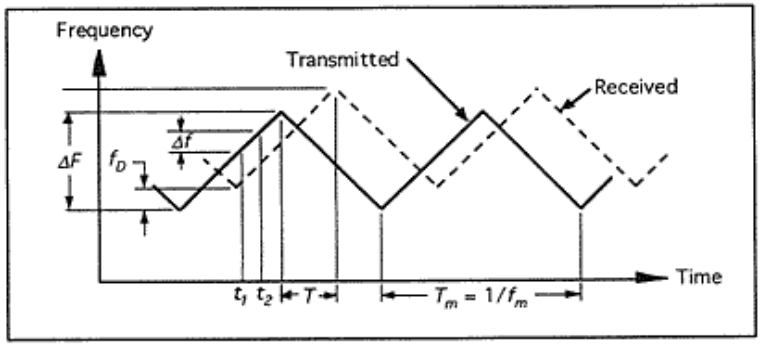


Figure 5-5. FMCW Waveform Parameters

$$R = \frac{C \times |f_{rx} - f_{tx}|}{4 \times (f_{high} - f_{low}) \times f_{mod}}$$

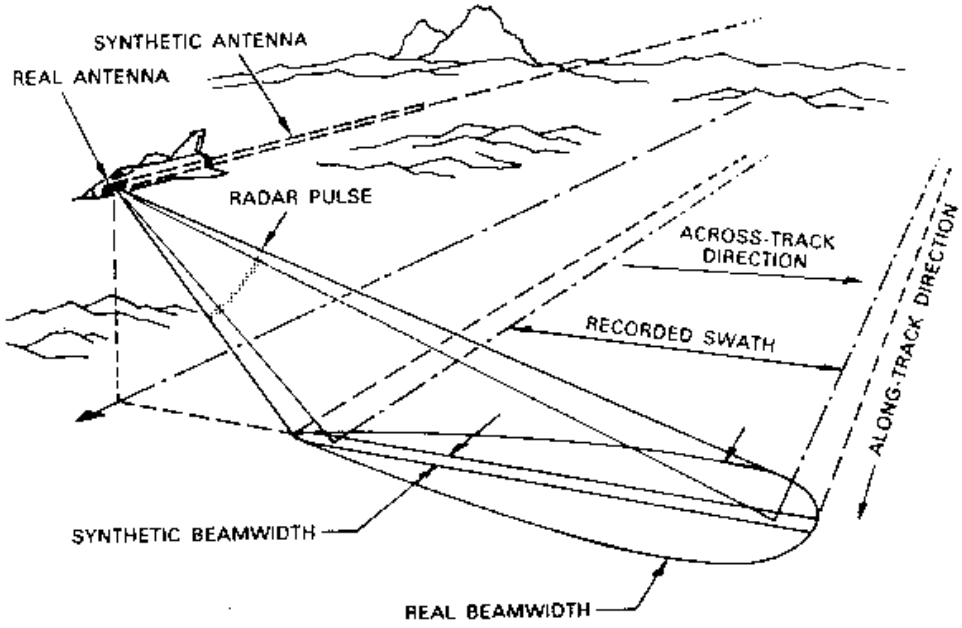
$R = Range\ to\ target\ in\ meters$
$C = Speed\ of\ light\ in\ m/s$
$f_{rx} = Frequency\ of\ received\ signal\ in\ Hz\ at\ time\ t$
$f_{tx} = Frequency\ of\ transmitted\ signal\ in\ Hz\ at\ time\ t$
$f_{high} = Highest\ transmitted\ frequency\ in\ Hz$
$f_{low} = Lowest\ transmitted\ frequency\ in\ Hz$
$f_{mod} = modulation\ frequency\ in\ Hz$

Not to be confused with the Radar Range

RADAR Basics

- Synthetic Aperture Radar
  - Military and Scientific uses for mapping from a moving air/space platform
  - Allows a small RADAR to act like a big one – by 'synthesizing' a much larger aperture with motion
  - Resolution down to the sub-millimeter level has been achieved using THz SAR imaging
  - For the small RADARs discussed here, the SAR is of the chirped type.

Surface of Mars by SAR

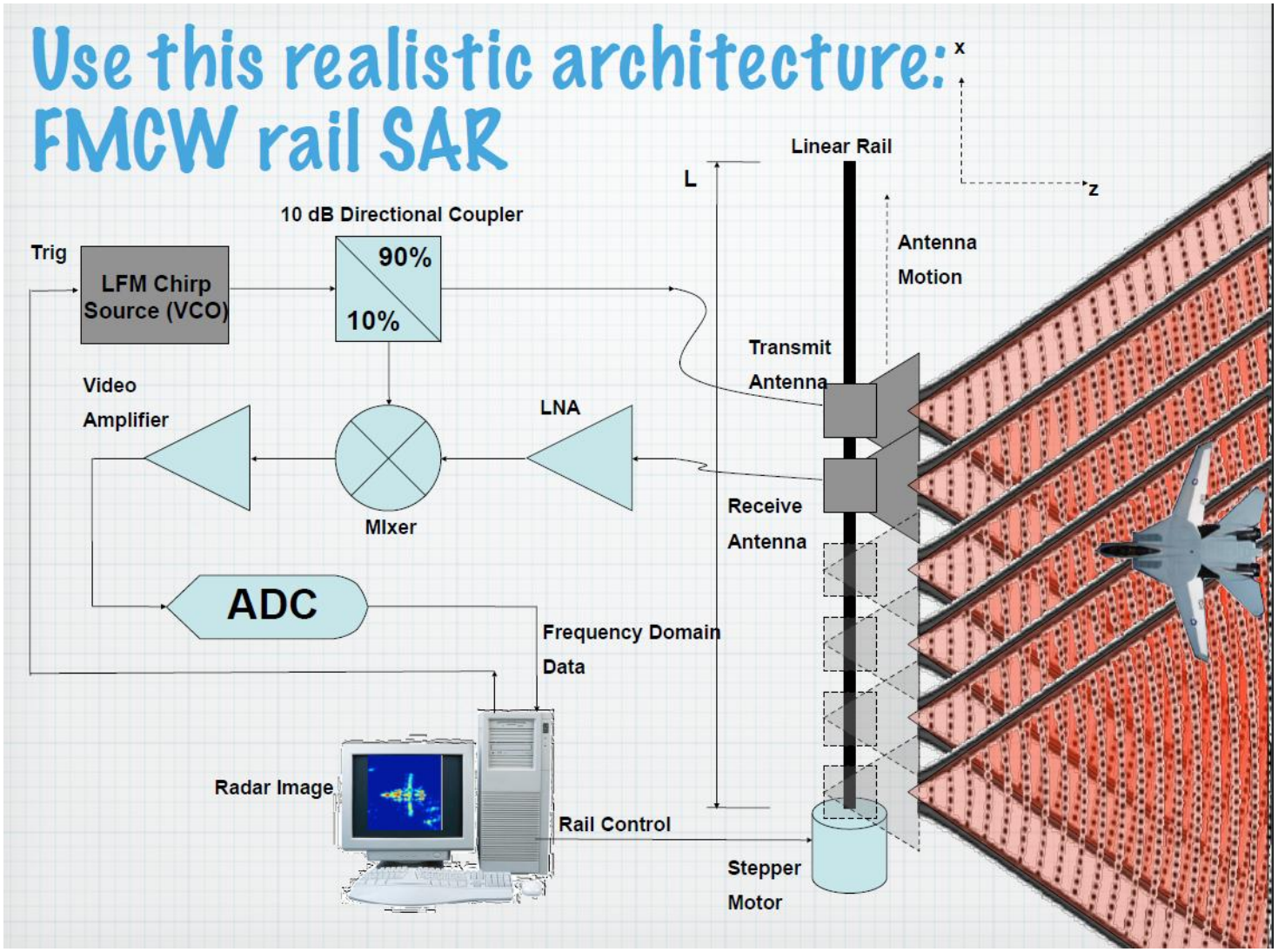


Ku-Band SAR image of the Pentagon

Greg Charvat

- Ham, rig builder, tube enthusiast, radar enthusiast, MIT lecturer, entrepreneur
- For his pHd dissertation, wrote about an X-band SAR radar he built from parts gathered at Dayton Hamvention, etc.
- Wrote algorithms for processing radar data in Matlab
- Developed an easy to build SAR capable radar system using Mini-Circuits connectorized parts and coffee can antennas
- Taught courses at MIT, Lincoln Labs on the subject of small radars

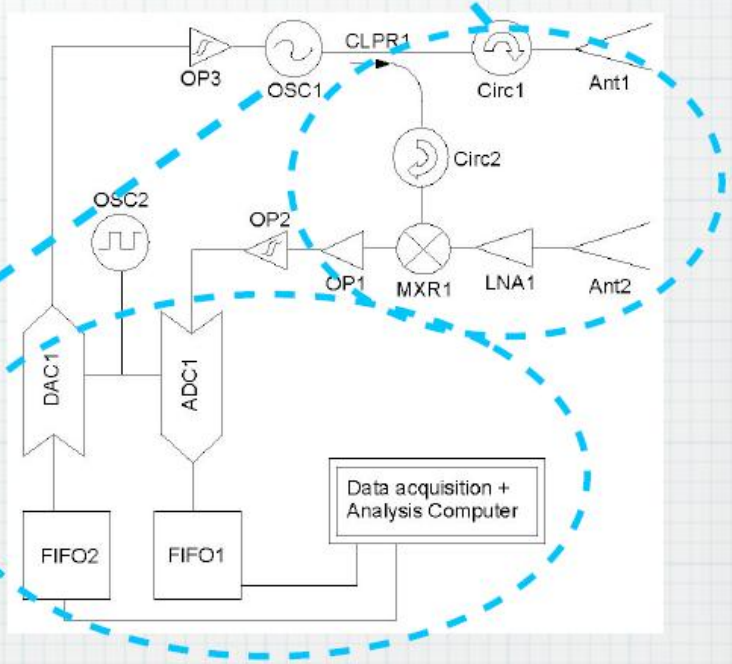
Greg's Rail SAR



Greg's Rail SAR

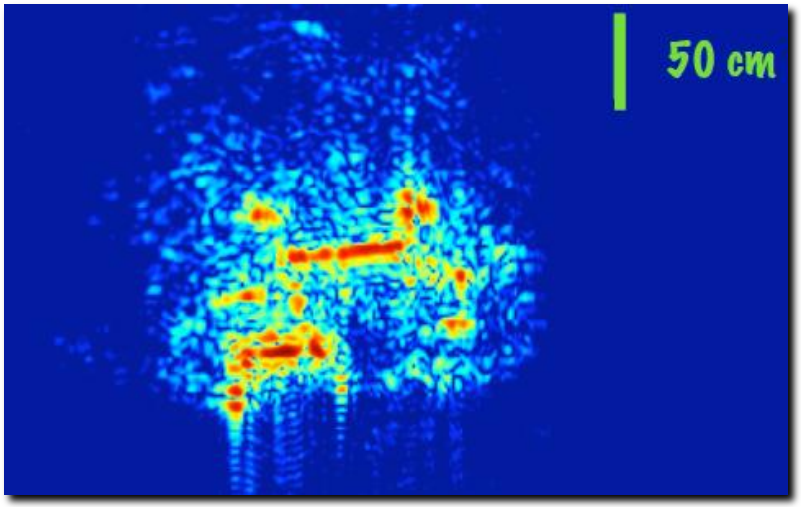
Radar sensor built from hamfest parts

* LFM stretch mode
* Pulse compression
* 7.5-12.5 GHz chirp in 10 ms
* +15 dBm TX Power
* 15 dBi horns, +- 25 deg E and H plane

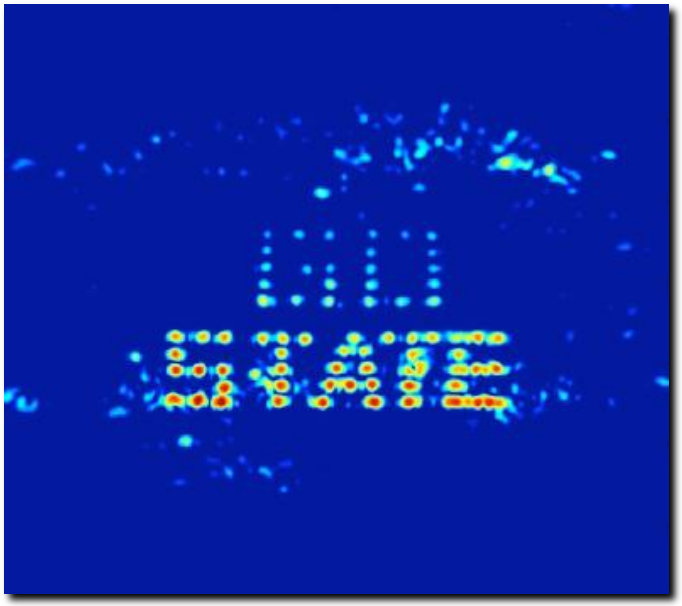


Greg's Rail SAR

Rail made from garage door opener screw drive

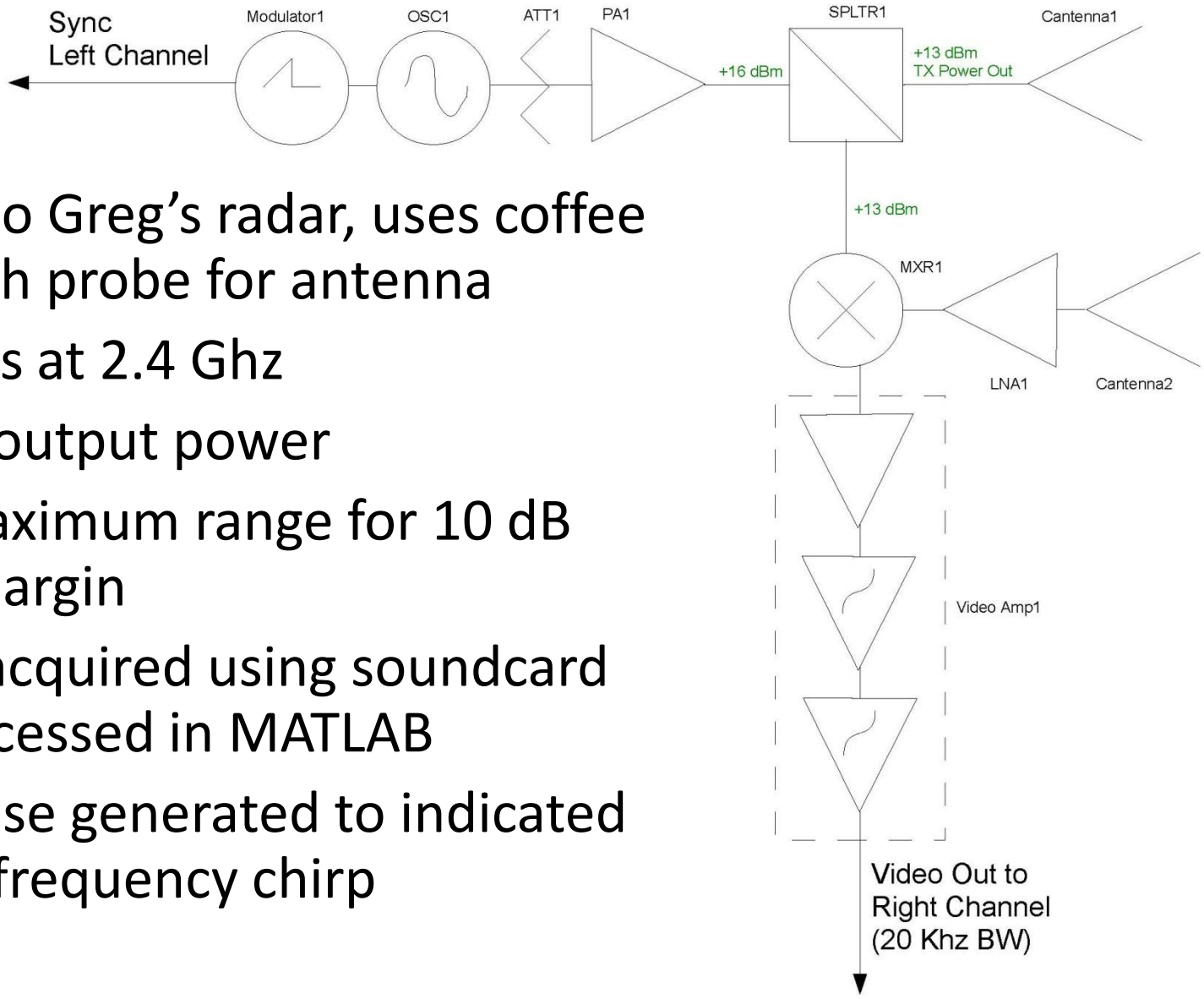


Bicycle SAR image



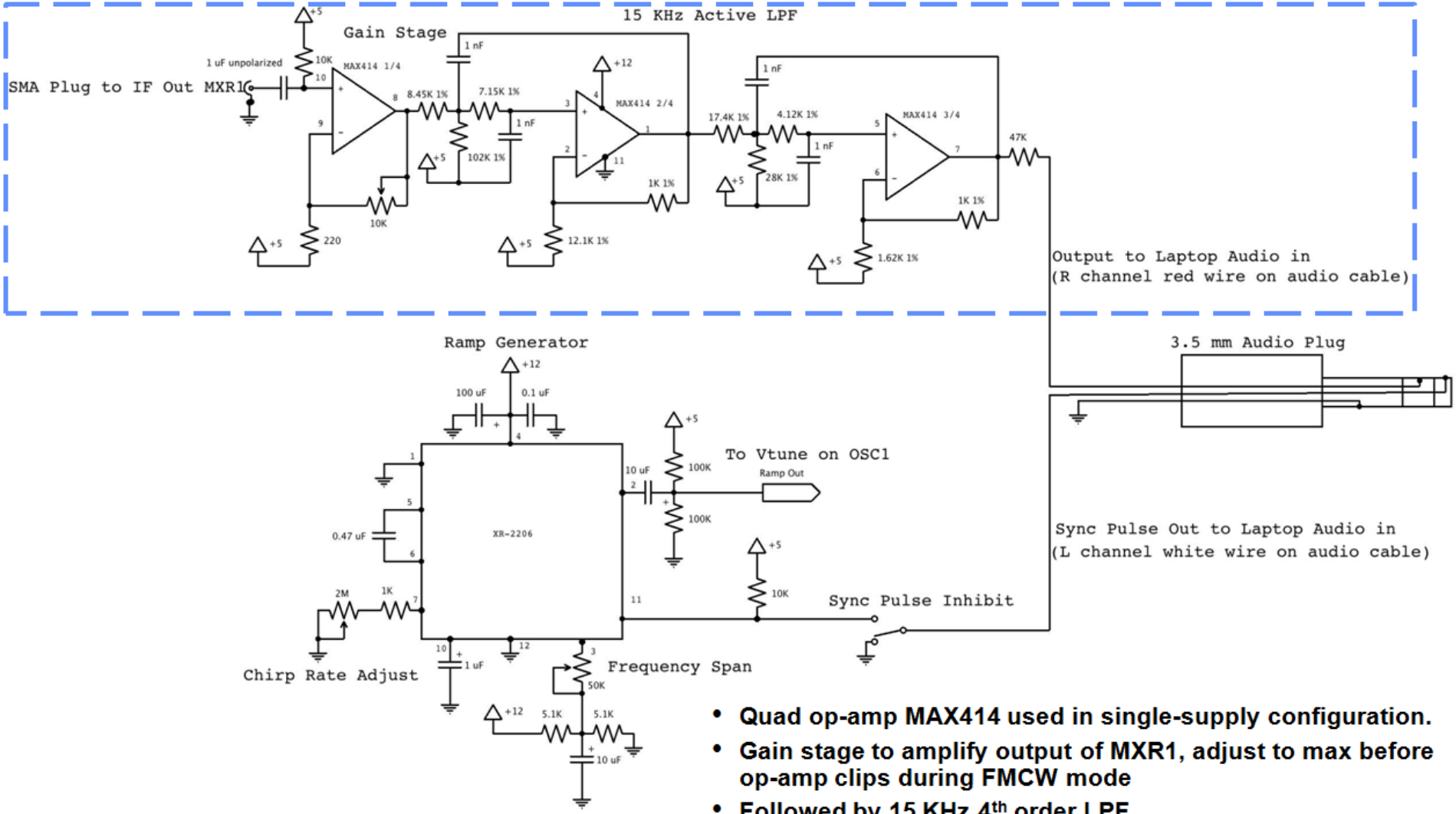
Pushpins in Styrofoam

Coffee Can Radar



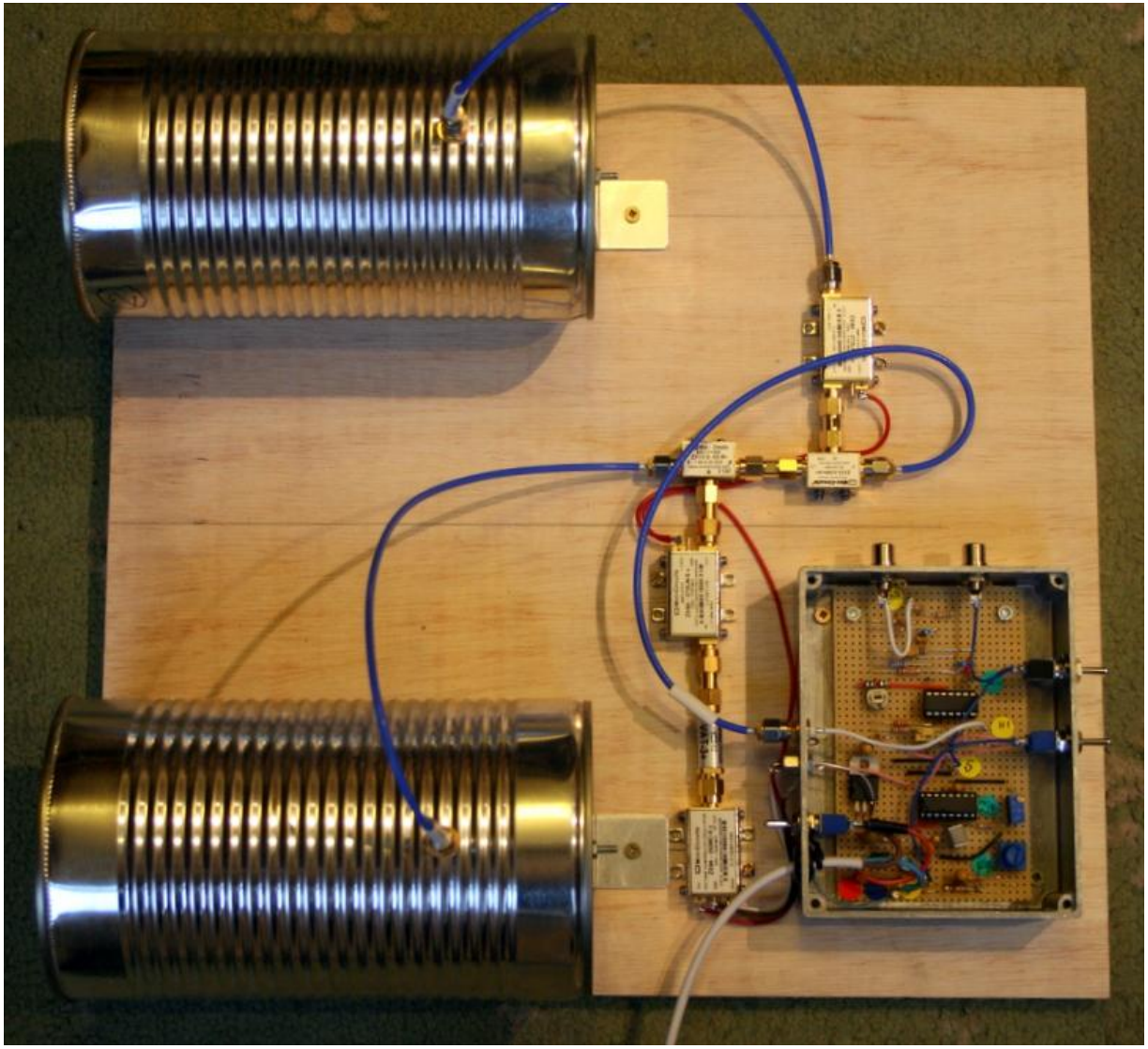
- Similar to Greg's radar, uses coffee cans with probe for antenna
- Operates at 2.4 Ghz
- 10 mW output power
- 1 km maximum range for 10 dB signal margin
- Data is acquired using soundcard and processed in MATLAB
- Sync pulse generated to indicated start of frequency chirp

Coffee Can Radar Schematic



- **Quad op-amp MAX414 used in single-supply configuration.**
- **Gain stage to amplify output of MXR1, adjust to max before op-amp clips during FMCW mode**
- **Followed by 15 KHz 4th order LPF**
  - **Prevents aliasing of PC's input audio port**

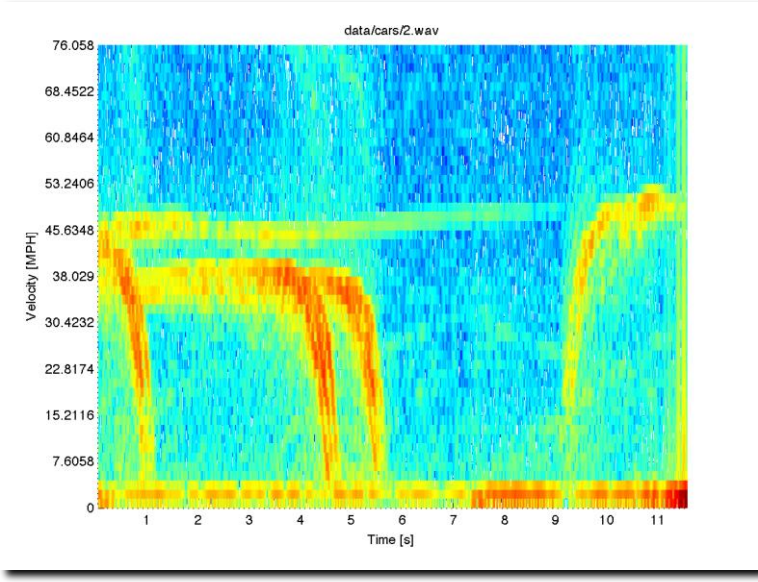
Coffee Can RADAR Construction



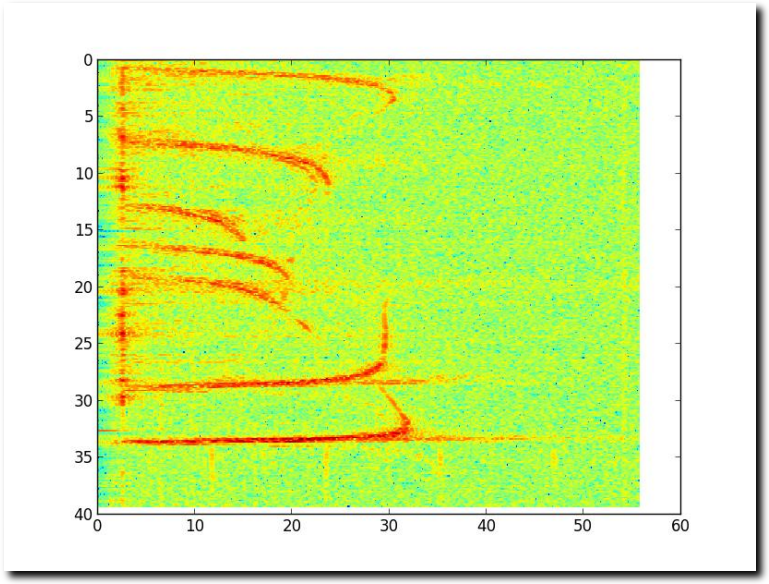
- RF components are all connectorized Mini-Circuits Parts
- Everything else is discrete components on a breadboard
- Total cost is ~$300

Coffee Can RADAR Doppler Measurements

- VCO is kept at a constant frequency
- Reflected signal is a Doppler shifted version of the transmitted signal
- Processing done in MATLAB allows visualization



Results from MIT students

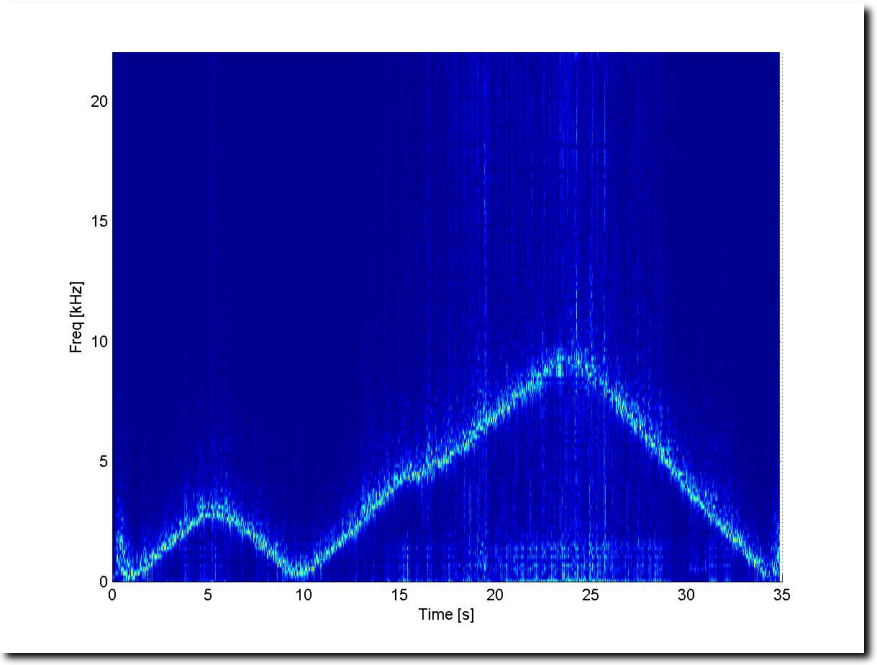


Results from my 5.8 GHz RADAR

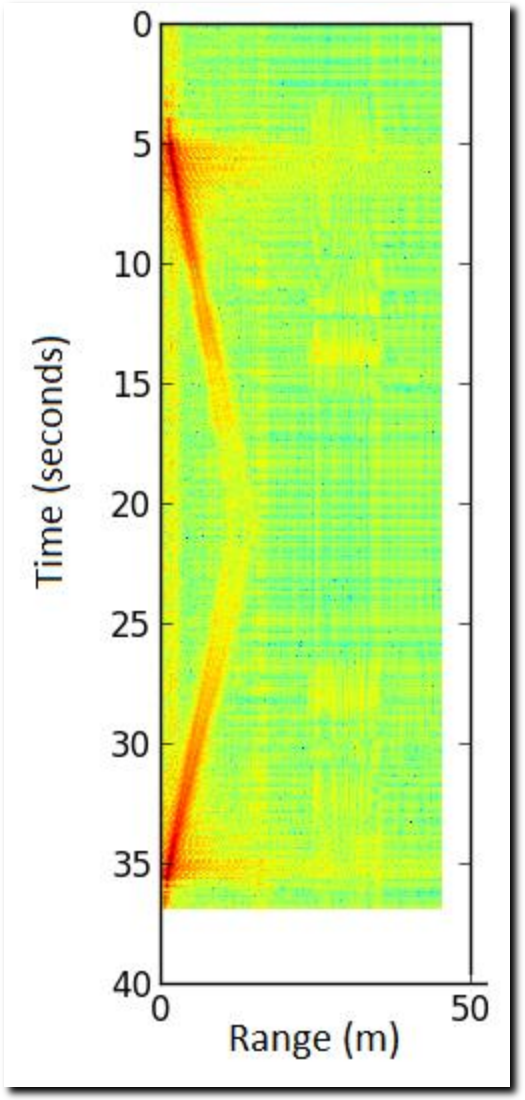
Rapid dropoff in speed is due to that $\cos(\theta)$ term in the Doppler radar equation. As the car passes, the Doppler shift reduces dramatically.

Coffee Can Ranging Measurements

- Range Measurements made using chirped VCO
- Results processed in MATLAB



MIT Students results

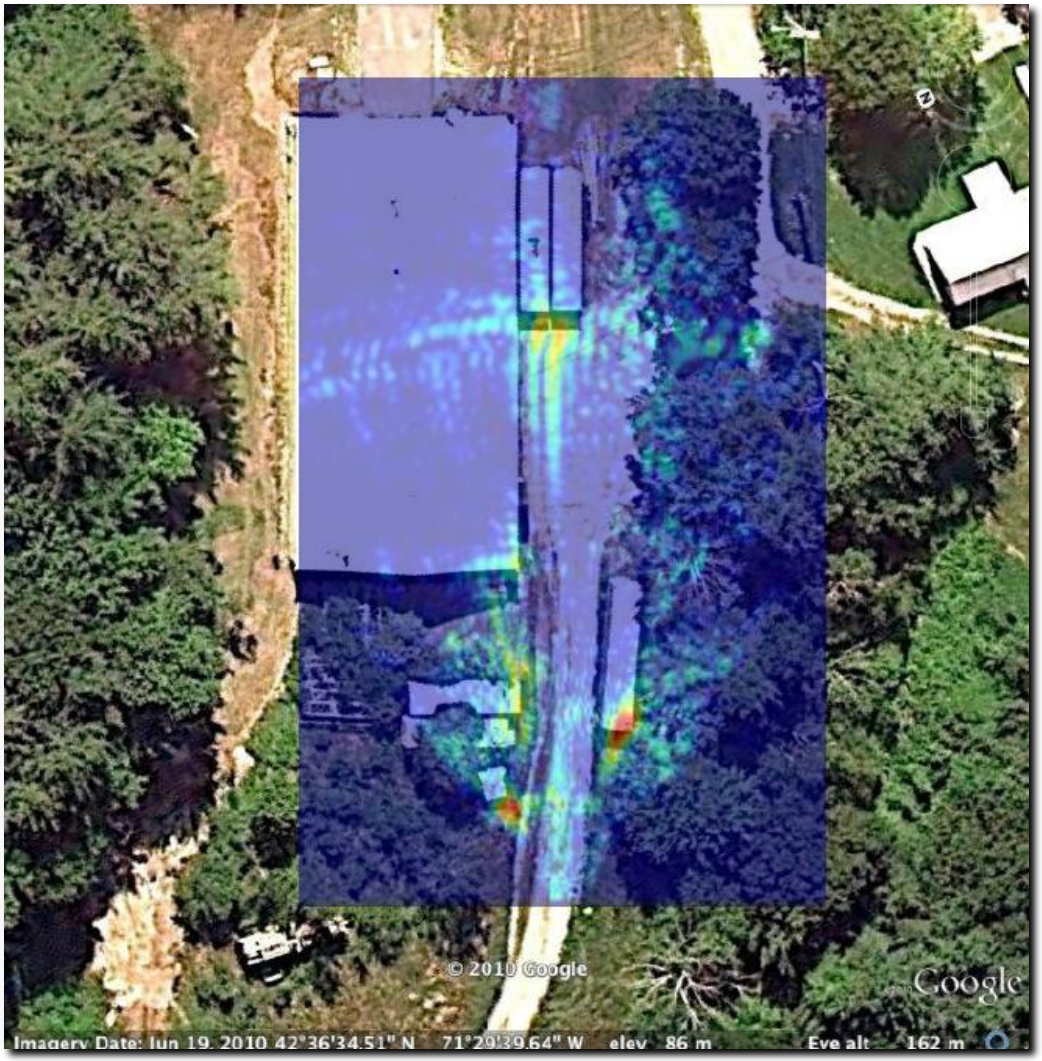


Range measurement from my 5.8 Ghz RADAR

Coffee Can SAR Measurements

- RADAR is moved along a rail every two inches
- Sequence of data is recorded at each point
- MATLAB script processes the results

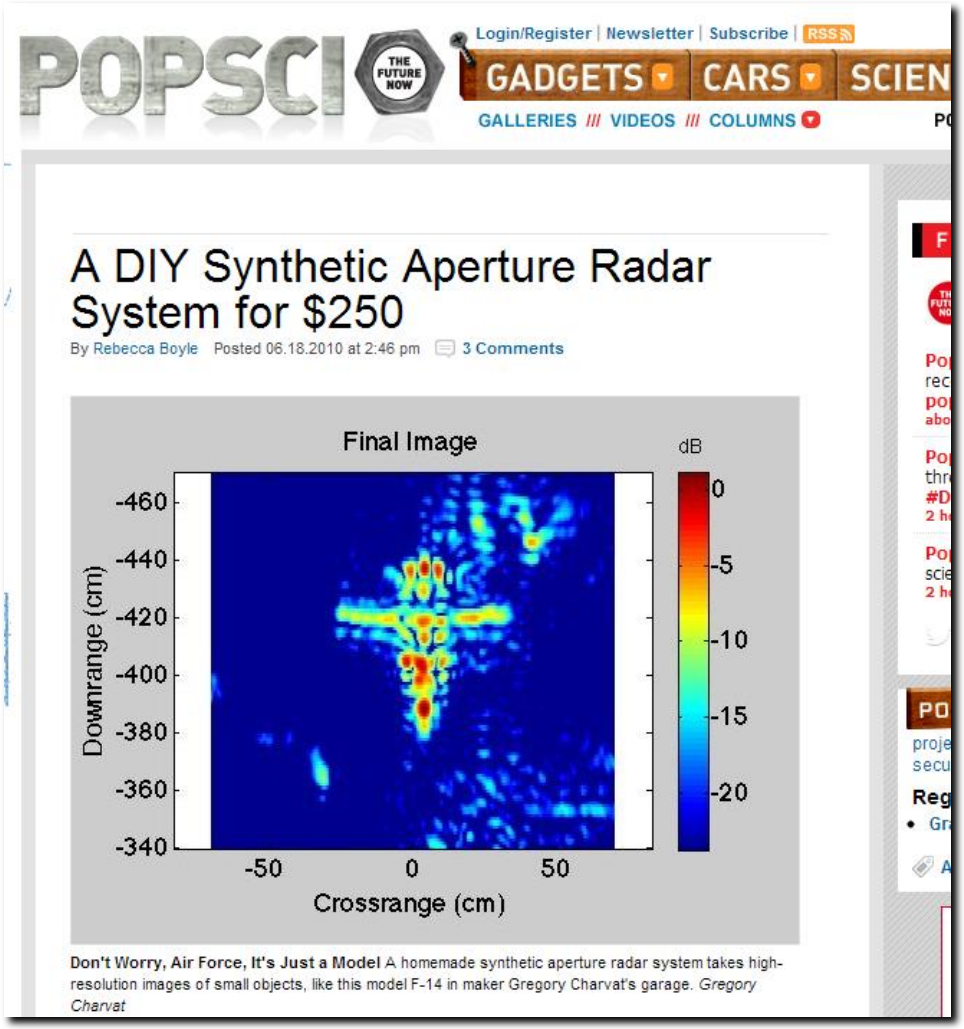
MIT students capturing SAR imagery



SAR image overlayed on photograph

The Coffee Can RADAR Becomes Popular

- Articles in
  - Popular Science
  - IEEE Spectrum
  - MAKE Magazine
  - MIT News
  - Hackaday
- Classes being offered at
  - University of Vermont
  - University of California Davis
  - Michigan State University
  - MITRE
  - MIT
  - MIT Lincoln Labs
- Courseware available at MIT's Open Courseware site: http://goo.gl/xXatA



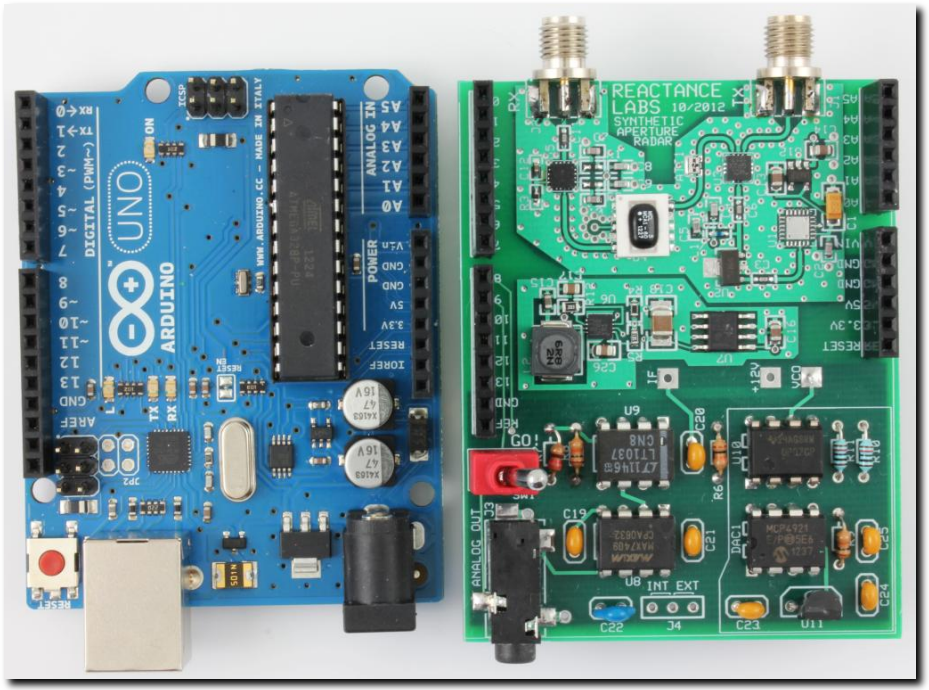
UC Davis Presentation At Microwave Update

- Dr. Leo Liu at UC Davis teaches a senior design class featuring the Coffee Can Radar
- Students build the radar in the first part of the class and are required to develop measurement and testing plans to demonstrate system capabilities.
- Students are split into groups for designing segments of the radar themselves on a printed circuit board.
- Students have also put together RF visualization demos (and won an IEEE contest with it)

Applications

- Doppler
  - Motion sensing
  - Vehicle speed
  - Collision avoidance
- Ranging
  - Parking assist
  - Measuring long distances
- SAR
  - Mapping
  - Driving assistance (night vision)
  - Seeing through smoke, fog, etc.
  - Disaster recovery (surveying damage, etc.)
  - Hobby UAV interest
- Education!

The RADARduino

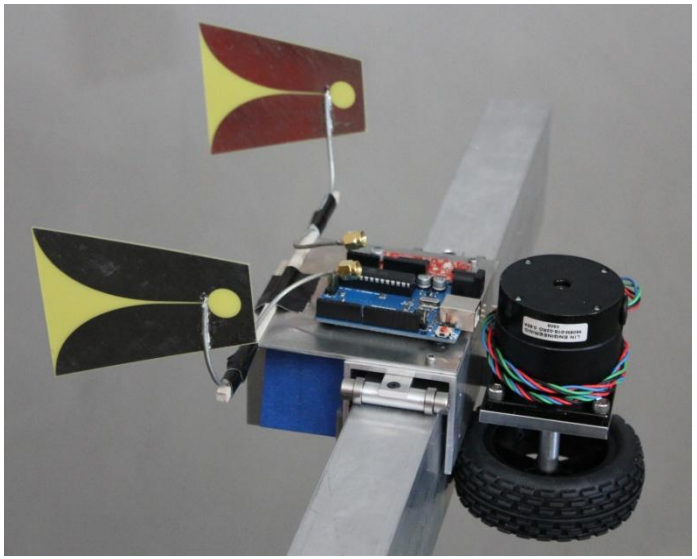


Arduino microcontroller next to the first RADARduino prototype

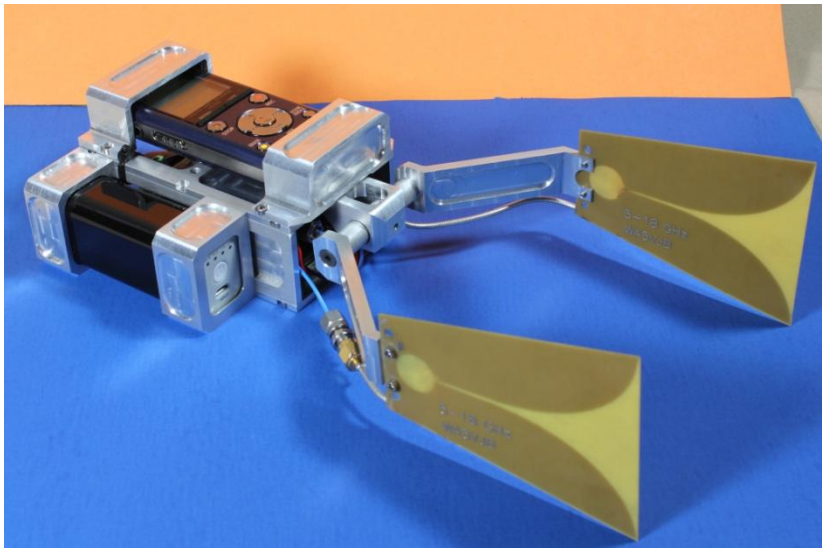
- Kit version of the Coffee Can Radar
- Uses off the shelf components
- 5.8 GHz ISM band
- Uses the popular Arduino microcontroller board for controlling the VCO via a DAC
- Can be used to generate arbitrary chirp for experimentation
- Smaller antennas than 2.4 Ghz(using WA5VJB's Vivaldi antennas)

The RADARduino

My motorized rail SAR setup



Detail of the carriage



Airborne demo packaging

Resources

- Tin Can Radar Forum: http://glcharvat.com/tincan/?page_id=6
- MIT Open Courseware website: goo.gl/xXatA
- UC Davis RADAR course: http://www.ece.ucdavis.edu/~lxgliu/sd_radar/2012fall/2012.05.EEC193.Flyer.pdf
- Books:
  - Intro to Airborne Radar by George W Stimson
  - Spotlight Synthetic Aperture Radar: Signal Processing Algorithms
  - Introduction to Radar systems by Merrill Skolnik
  - Radar Handbook by Merrill Skolnik