Very Low Cost L/S-Band Radar System

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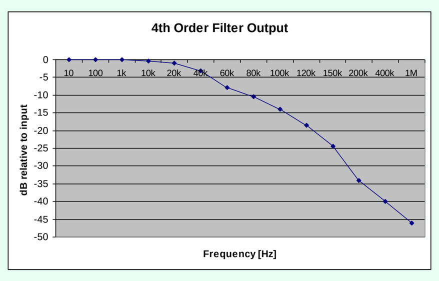
1. Motivation

Need existed for L/S-Band radar system for use in synthetic aperture radar research for the MSU Electromagnetics Research Group.

Cost <$50, including coffee can antennas and DIP/SMT components.

Need complete system in 10 weeks through Summer Research Internship.

2. Methodology



Fit design to strict cost requirements

Manage cost at all times using commodity components—parts were sourced from obsolete test equipment and even a cordless phone and clock radio. Build own PCBs and design microwave microstrip PCBs.

Easy upgradeability essential to system—will want to expand beyond simple low-power FMCW operation in future.

Pursue spectrum in needed band with availability for future higher power testing, balanced with available components.

Must have low noise figure for use at low power, yet accommodate increased power without excessive sacrifice of dynamic range.

3. Research

Consider characteristics of and parameters for each module:

Level Translator: Converts output of National Instruments DAQ card or PC sound card to 0..20V as necessary for VCO frequency tuning, with sufficient bandwidth for triangular waveform driving FMCW operation. Uses very common LM324 op amp.

VCO: POS-2000 covers 1.4-2.0GHz. Includes on-board power supply for best isolation and stability. VCO response to linear tuning voltage is non-linear frequency change, which causes increased ranging error—partially mitigated by feedback algorithm.

VCO Amplifier: To provide a stable load to the VCO and to provide for increased power, an ERA-4 amplifier with on-board power supply providing approximately +15dBm output is included in the system. This stage feeds the transmit antenna as well as providing the homodyne receiver reference.

LNA: The ERA-4 possesses a good noise figure and IP3 to be used for the receive Low Noise Amplifier (LNA) with on-board power supply. Immunity to overload is critical in CW systems using integrated antennas.

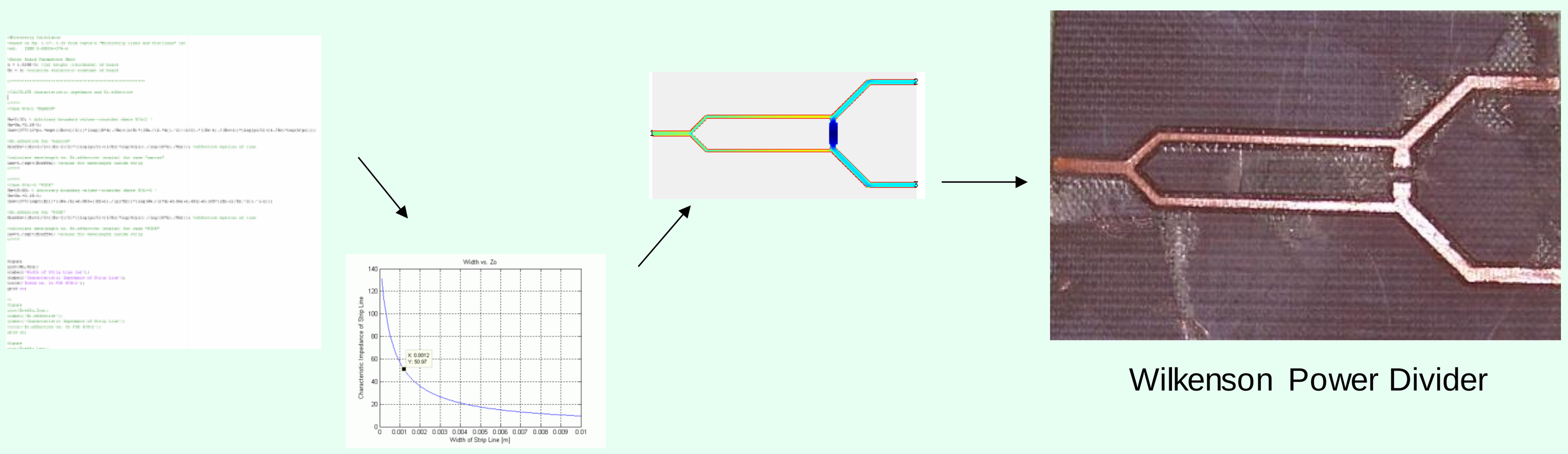
Mixer: The surface mount MCA1-42 mixer provided excellent IP3 to maintain system performance under signal overload conditions.

Low-Pass Filter and Video Amp: A single MAX414 was selected for its very low noise and high gain capability. A 4^{th} order Sallen-Key Butterworth anti-aliasing filter is used to achieve good pass-band flatness with readily available components. The weak FMCW beat signals are amplified to the 0..5V range for acquisition by National Instruments DAQ PC card. The system may also use a PC sound card in place of the DAQ card.

Antenna System: Must be small enough to mount on rail module housing, while maintaining adequate TX/RX isolation. In FMCW mode, the transmitter and receiver constantly operate and receiver overload is a concern. Open-ended circular waveguide (coffee can) selected.

4. Design

Matlab was used to calculate necessary component values and range of compromise, and Sonnet was used to design circuit board parameters and layout. Limits of in-house circuit board milling machine were an issue—normal arcs with small trace width could not be accomplished. Designs had to be altered to use only straight lines.



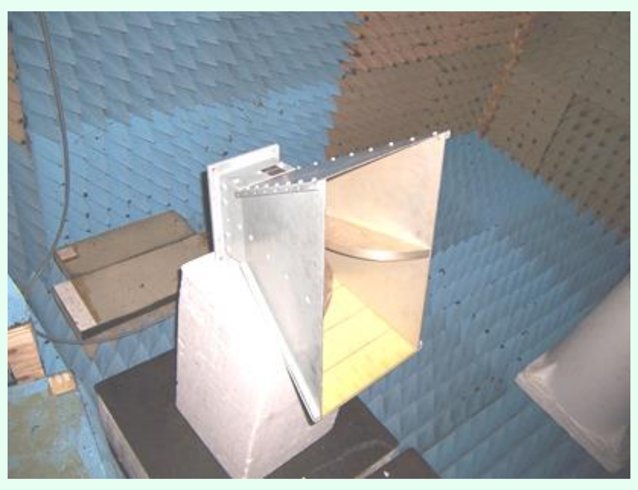
Wilkenson Power Divider

Since new design included potential for a power amplifier, and maintaining proper mixer drive *on-rail* is essential to proper system performance, a variable attenuator salvaged from obsolete test equipment was added to the rear panel of the power divider rail housing.

5. Build & System Tests

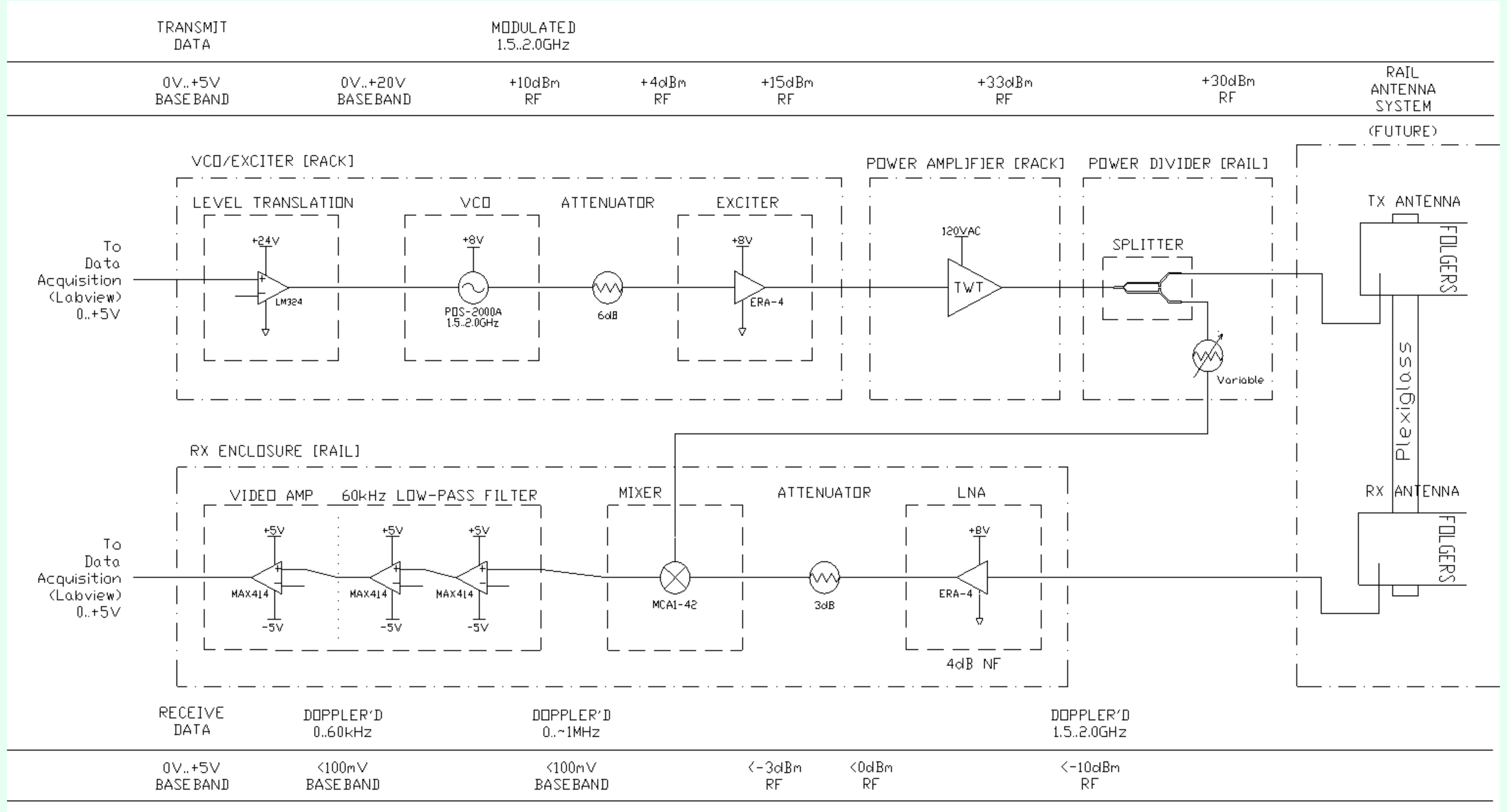
Initial build exhibited good sensitivity and stability.

In light of these results, it was decided that the system should be disassembled and rebuilt during the fall 2006 semester to add capacity for additional modes beyond CW/FMCW and expanded frequency coverage.



500MHz..6GHz Anechoic Range Antenna for reference testing

Coffee can 1.5—2.0GHz as open-ended circular waveguide antenna—female SMA attached to ¼ wavelength probe for TE mode excitation



Coffee Can Radar Block Diagram

6. Ongoing and Future Work

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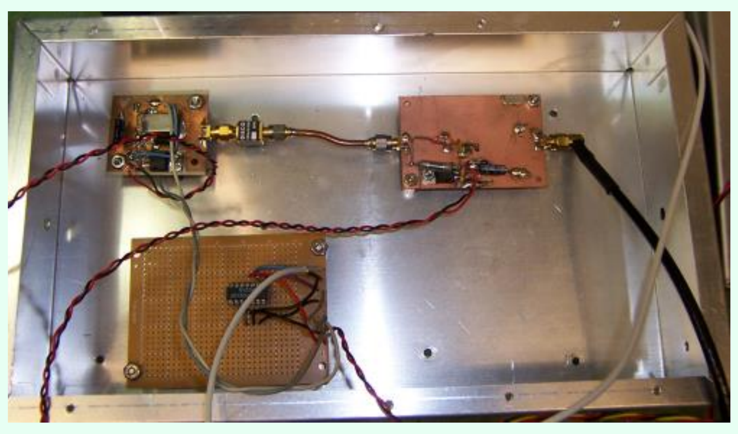
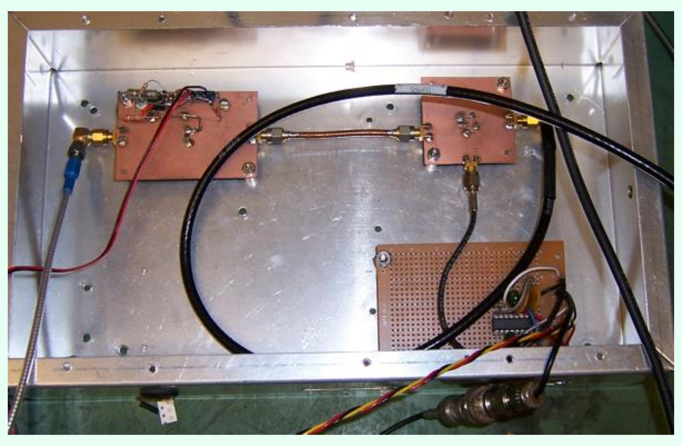


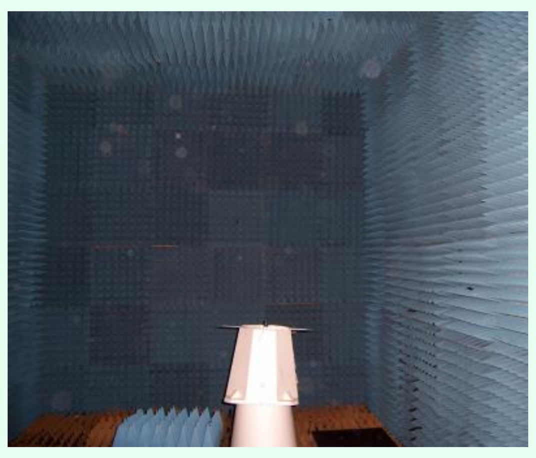
Transmit/VCO modules (original design)



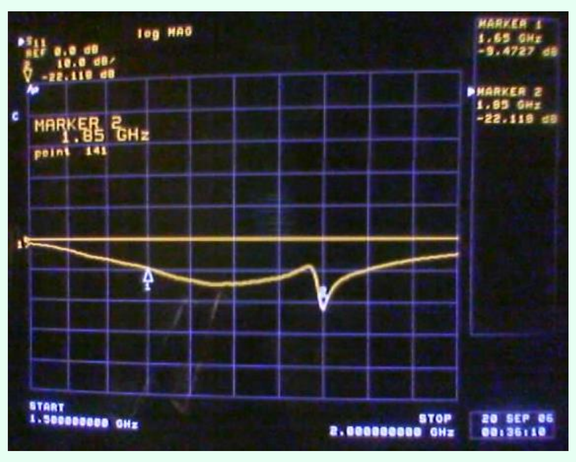
Receive/Video Amp. Modules (original design)

Rebuild system with only receive modules and power divider with variable attenuator on radar rail.

Move all transmit modules and master power supply to rack-mountable housing.



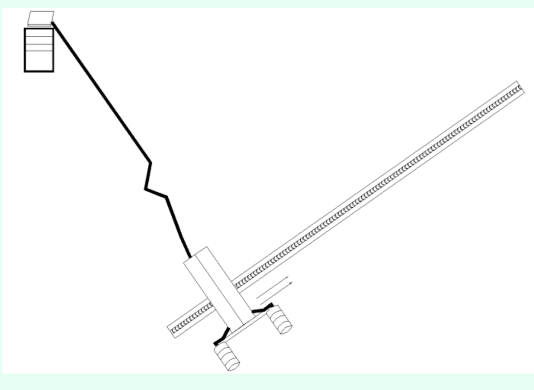
Anechoic chamber rotary antenna-under-test location



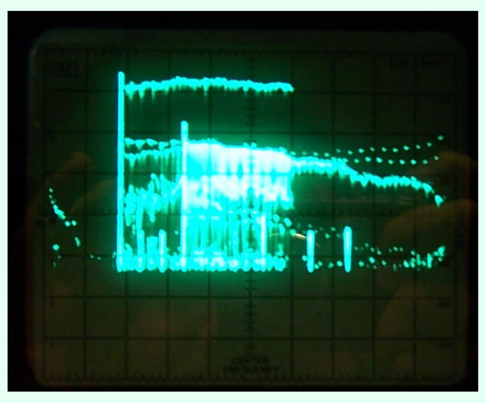
S11 plot of open-ended circular waveguide antenna prototype

Smith chart of open-ended circular waveguide antenna

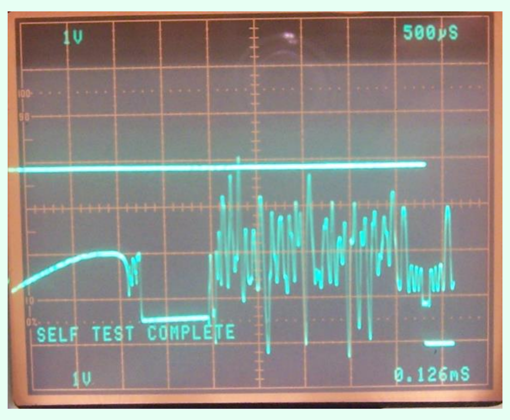
Create new Labview-based control software to control anechoic chamber rotary table simultaneously with HP8510 network analyzer control to provide increased automation and precision of antenna testing.



Synthetic Aperture Radar rail layout



400MHz bandwidth FMCW Spectrum



Video amp output to scope

Create Matlab and Labview-based rail control and imaging algorithm—this is the ultimate goal of a system of this type, to provide useful cross-range and down-range information to the operator, whether from an aerial or mobile ground-based standpoint.

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