For the past month, I've been attending an MIT IAP course entitled "Build a Small Radar System Capable of Sensing Range, Doppler, and Synthetic Aperture Radar Imaging" (http://student.mit.edu/searchiap/iap-a570.html). The course was taught by staff from MIT Lincoln Laboratory, Dr. Gregory L. Charvat, Mr. Jonathan H. Williams & Dr. Alan J. Fenn, Dr. Stephen M. Kogon, Dr. Jeffrey S. Herd.

Introduction

I was invited to attend by a group of Northeastern students (Spiros Mantzavinos [BSECE 2011], Kate Williams [MSEE Candidate], and Galia Ghazi [Ph.DEE Candidate]) who were taking the course as background information for their research project. The course was mostly project-based, in which we assembled a kit of parts into a functional FMCW radar for around $300. As we were building the radar, we took it into the field (locations around Northeastern's campus) and acquired Doppler, range, and SAR (Synthetic Aperture Radar) images testing out various functionalities of the system and learning its basic principles of operation. The incredible part about this design is the cost - using simple components such as coffee can antennas and a wood mounting platform, this radar system costs around $300 dollars and the components are commonly available.

The Technical Stuff

The radar design was provided to us by our instructors, but it was our job to assemble and debug it. This type of radar is called an FMCW (Frequency Modulated Continuous-Wave) radar.

> FMCW is a radar system where a known stable frequency continuous wave radio energy is modulated by a triangular modulation signal so that it varies gradually and then mixes with the signal reflected from a target object with this transmit signal to produce a beat signal.
>
> --http://en.wikipedia.org/wiki/FMCW

The radar operates at a base frequency of 2.4 GHz (ISM or S-band). The radio waves are generated by a voltage-controlled oscillator allowing us to perform the frequency modulation needed for FMCW operation. The signal is transmitted and received by a pair of "cantenna" waveguides, and both the transmitted and received signals are mixed to create a beat signal. This beat signal is then passed through an amplifier and a low-pass filter, and then carried by a standard 3.5mm audio cable to a laptop sound card, which acts as an ADC. The data is recorded and then processed using MATLAB to generate Doppler, range, and SAR images.

The "Cantennas"

The antennas are actual coffee cans (selected specifically for their dimensions - radius<(lambda/3.4) - to allow propagation of the waves). They were the only part of the kit that came pre-assembled; the placement and size of the monopole in the can is critical for setting up the correct propagation mode, so technicians at MITLL customized each pair and ensured their correct functionality with a network analyzer.

The RF Components

The radio signal is generated by a voltage controlled oscillator with a 240MHz bandwidth around 2.4GHz. We used a triangle wave with a 40ms period to sweep the frequency spectrum in a smooth, linear fashion. The signal was then passed through a 3dB attenuator and a 12dB amplifier. The signal was then split to the transmitting antenna and the feedback path. The line from the receive antenna goes to the mixer, which multiplies the the received signal with feedback transmitted signal. The output of this multiplication is brought to the breadboard.

The Analog Circuity

The RF input first passes through an amplifier with the gain set to around 12dB, and then a 4th order low-pass filter tuned to 15kHz. The outp

ut of the low-pass filter is then sent to the laptop sound card via audio cable. The circuit also contains a waveform generator configured to output a 5V triangle wave with a 40ms period. The generator also outputs a square wave sync pulse that aligns with the start of each triangle period.

The Processing

We used MATLAB scripts to post-process the data collected from each run.

The Results

What you've all been waiting for - the images!