Beamforming: Shaping the Wireless World

Grooving Shredders

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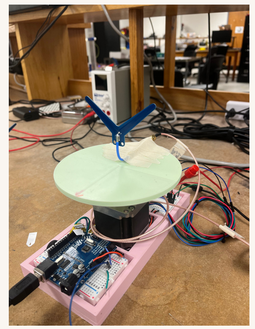


Software-Guided Antenna That Neutralizes Hostile Jamming Attacks

Our Journey

We learned:

- High frequency PCB design -> controlled impedance
- Antenna design
- What and how to simulate before jumping into design
- How to design and execute tests that provide usable feedback
- Teamwork and task delegation, coordination between different subgroups
- Radio transmission and reception
- Digital signal processing techniques
- FPGA design (specifically Verilog within Vivado)
- Shared memory management
- Sorting through sparse documentation for unfamiliar/newer software and hardware, such as GNU Radio, Vivado, and the RFSoC
- Understanding what is in vs. out of scope and not "biting off more than we can chew"
- Understanding how to leverage support and resources

Challenges:

- Implementing the FPGA configuration in Vivado
- Flashing new code to the 4x2 RFSoC board
- Troubleshooting bugs within PYNQ and Vivado
- Communication between Arduino UNO and the 4x2 RFSoC Board
- Learning how to perform antenna simulations in HFSS

The most unexpected issue we encountered was our Arduino test system would only work when the laptop was plugged in to charge. We realized this was due to the test system being floating and not Earth grounded while trying to talk to our earth grounded Xilinx board. We solved this by introducing a wire to connect the grounds of the two systems.

Most Proud Of:

- Functioning custom patch antennas with a known gain value.
- Functioning filter and amplification PCBs with 50ohm controlled impedance and custom component library.
- Hundreds of hours spent building a custom FPGA configuration for the RFSoC 4x2.

Our Project

Tech:

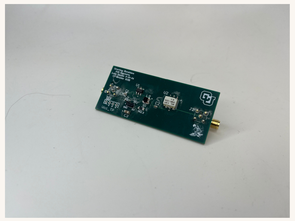
- Patch antennas for 1.24GHz using FR4 PCBs
- GALI-6+ low noise amplifier
- SYBP-1275+ LC bandpass filter
- RFSoC 4x2 by Xilinx
- Arduino UNO with stepper driver/motor

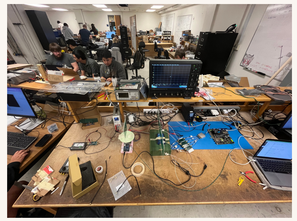
Nifty Features:

- Automated test system
- Custom patch antennas
- Ultrafast digital beam steering

Favorite Parts:

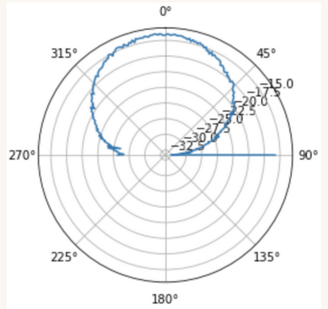
- Custom patch antennas
- LNA/filter boards
- Automated test system
- Custom FPGA IP blocks
- Custom drivers made in Pynq



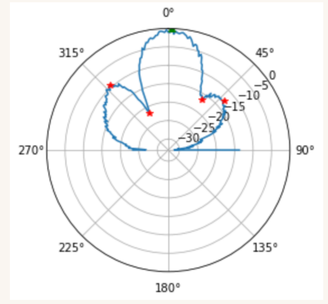


Beamforming Diagrams

Patch Antenna Radiation Pattern



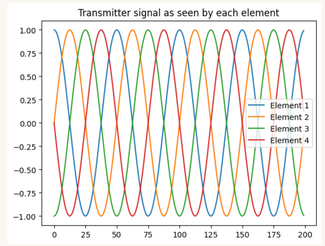
Phased Array Radiation Pattern



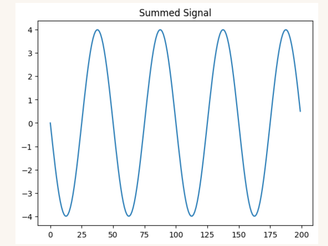
Lobes

These diagrams generated by our system show received signal power and help illustrate why beamforming is so valuable.

Before Beamforming



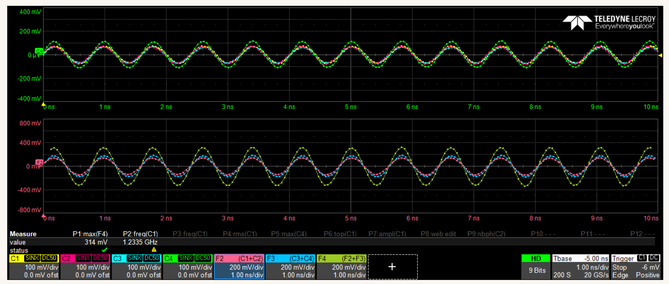
After Beamforming



Beamforming Time-Domain

These graphs simulate the process of beamforming: reception of the signals, followed by phase shifting, and then summing the signals together.

Phase is Everything



Power and Phase

This scope waveform taken with the transmitter located at the array's broadside shows the 4 channels phase aligned in the top window. Notice the summation of these 4 channels (green signal in the bottom window) has the highest amplitude of any signal on the screen. Beamforming benefits!