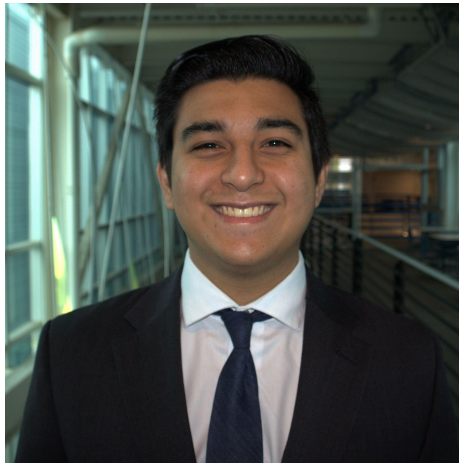
Digital Beamsteering Phased Array

Team 311
Sponsor: L3Harris
February 11th, 2022

Team Introductions

Katheryn Potemken
Financial Advisor / Webmaster

Tiernen Pan
Team Lead / Software Engineer



Christian Balos
Software Engineer

William Snyder
Hardware Engineer

Andrew Cayson
Hardware Lead

Sponsor, Advisors, and Assisting Instructor

Assisting Instructor:
Dr. Arigong

Advisor:
Dr. Uwe Meyer-Baese

Customer:
Dr. Hooker

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Outline

- Previous Project Development
  - Choosing the design
  - Block diagram
  - components
- Current Progress Update
  - Team Assignments
  - VHDL coding implementations
  - PCB design
- Future Work
  - Microcontroller?
  - Future VHDL code

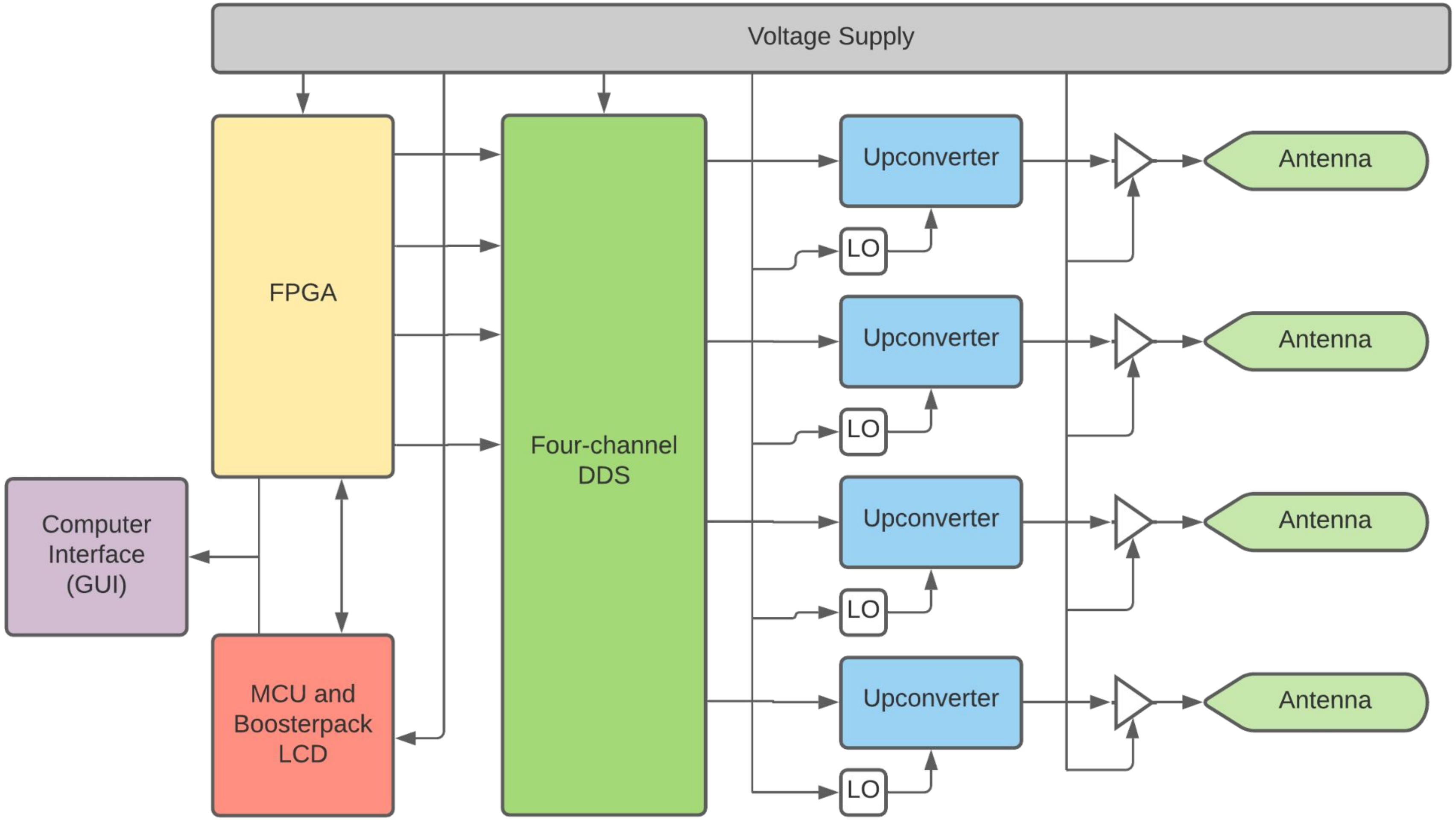
Modulating Roles

- **Tiernen Pan:**
  - VHDL software lead
- **Christian Balos:**
  - VHDL software integrator
- **Billy Snyder:**
  - PCB Designer
- **Katheryn Potemken:**
  - Webmaster and Antenna Lead
- **Andrew Cayson:**
  - Hardware Lead and Microcontroller Design

Digital Vs. Analog Beamforming

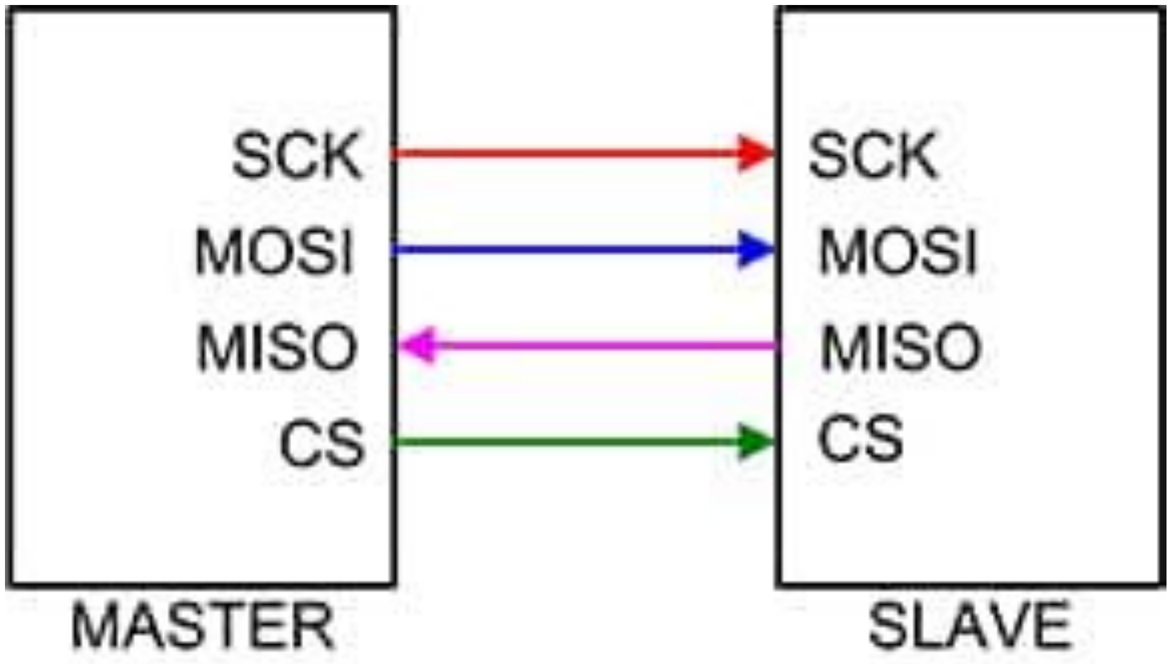
- Analog Beamforming
  - Requires phase shifter, splitter and upconverter
  - Produces one RF chain source which is then split and sent to multiple phase shifters and antennas
- Digital beamforming
  - Requires only DDS and upconverter
  - Amplitude scaling, phase shifting of each antenna elements and summation are done digitally.
  - Produces multiple RF sources that go to the respective antenna

Block Diagram



Serial Peripheral Interface

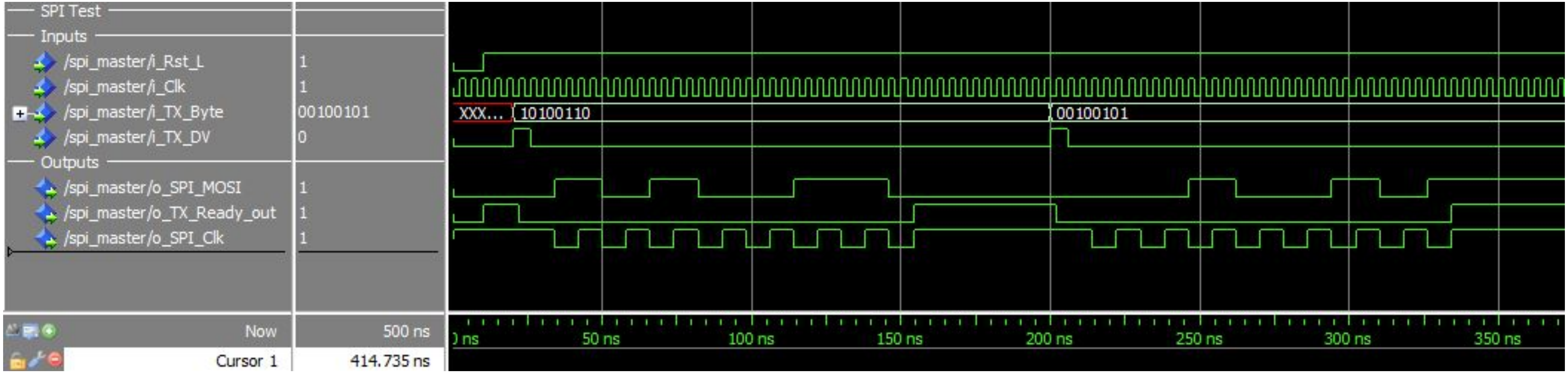
An SPI allows the FPGA to communicate with the DDS without using a GUI.



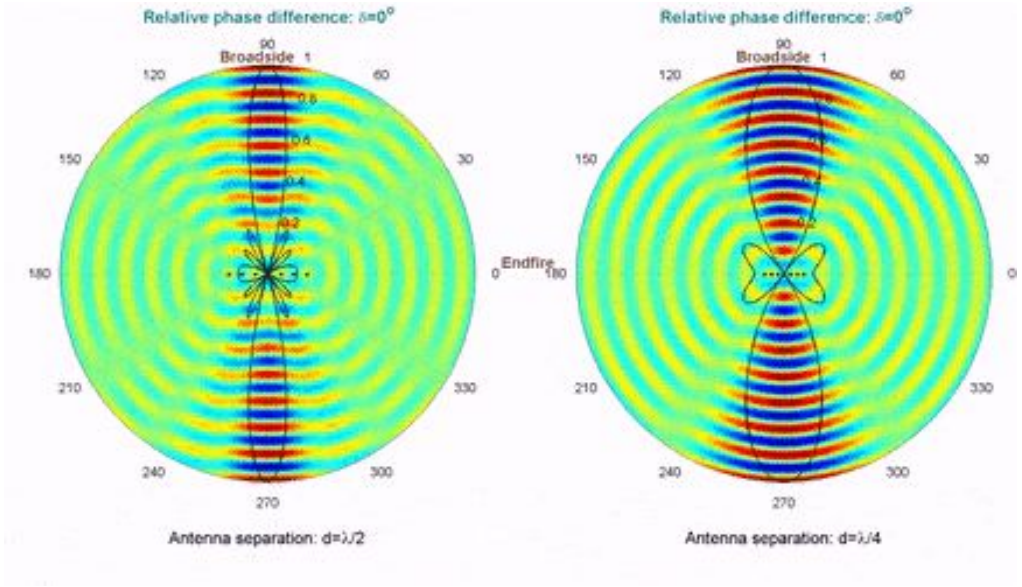
Simulation inputs

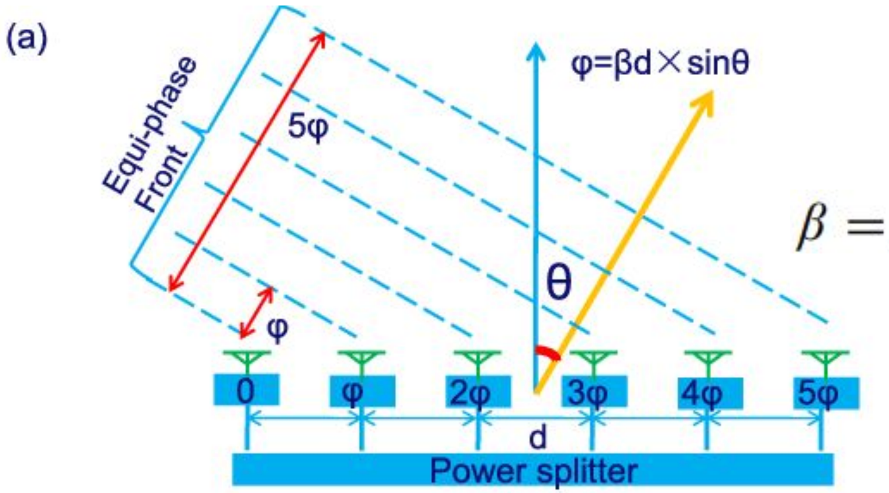
```
###Input Data
radix -binary
force i_Clk 0 0ns, 1 2ns -r 4ns
force i_Rst_L 0 0ns, 1 10ns
force i_TX_Byte 10100110 20ns, 00100101 200ns
force i_TX_DV 0 0ns, 1 20ns, 0 26ns, 1 200ns, 0 206ns
```

SPI VHDL Inputs and Outputs



Next Step: Implementing Equation





$$\beta = 2\pi/\lambda$$

$$d = \frac{\lambda}{2}$$

$$\phi = \frac{2\pi}{\lambda} d \times \sin(\theta)$$

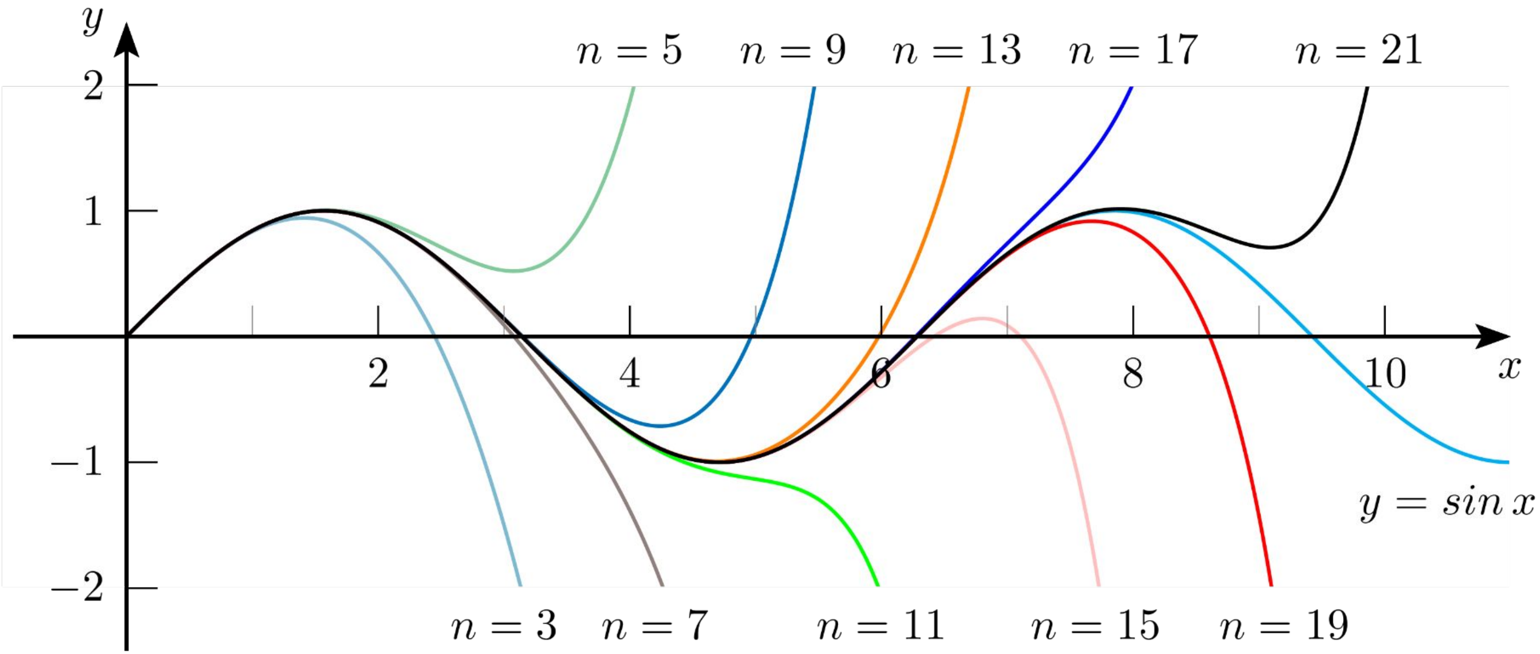
$$\phi = \frac{2\pi}{\lambda}\frac{\lambda}{2} \times \sin(\theta) \rightarrow \phi = \pi \times \sin(\theta)$$

Presenter: Tiernen Pan

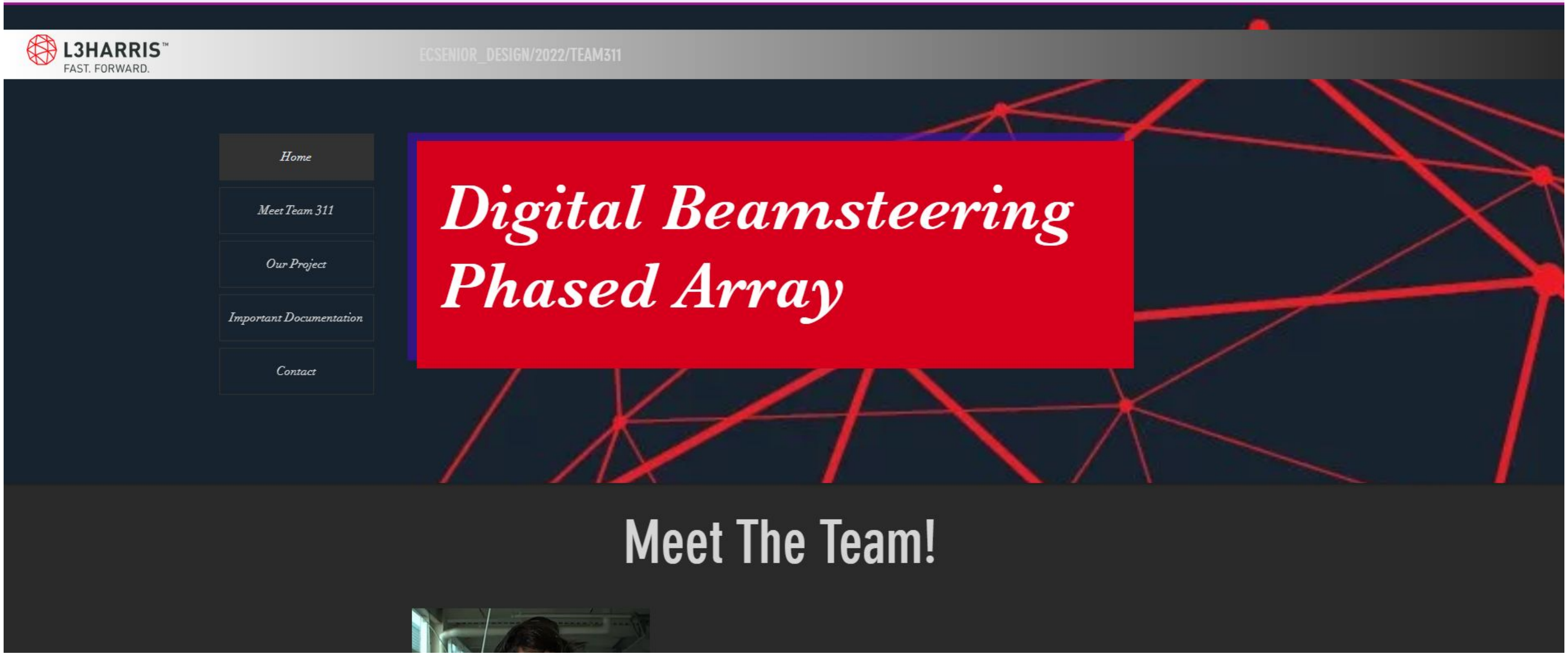
Taylor Series to Implement the Sine Function

$$\sin(x) = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots$$

$$= \sum_{n=0}^{\infty} \frac{(-1)^n}{(2n+1)!} x^{2n+1}$$



Website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Meet The Team!

Antenna Testing

- Test Antennas in 2.4 GHz range
  - Voltage Standing Wave Ratio (VSWR)
    - 2 < VSWR <4
  - Forward gain across antenna bandwidth
    - 3 [dBi] < Gain < 5.5 [dBi]

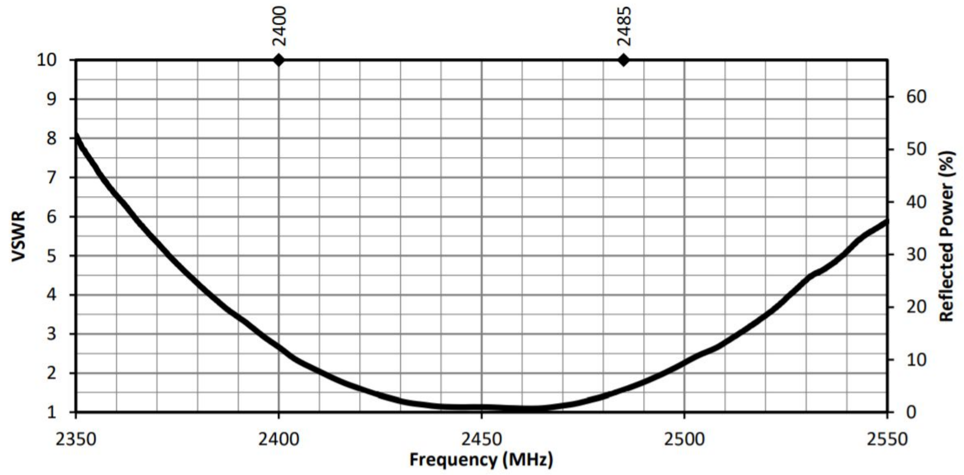


Figure 2. 2.4-CPA VSWR

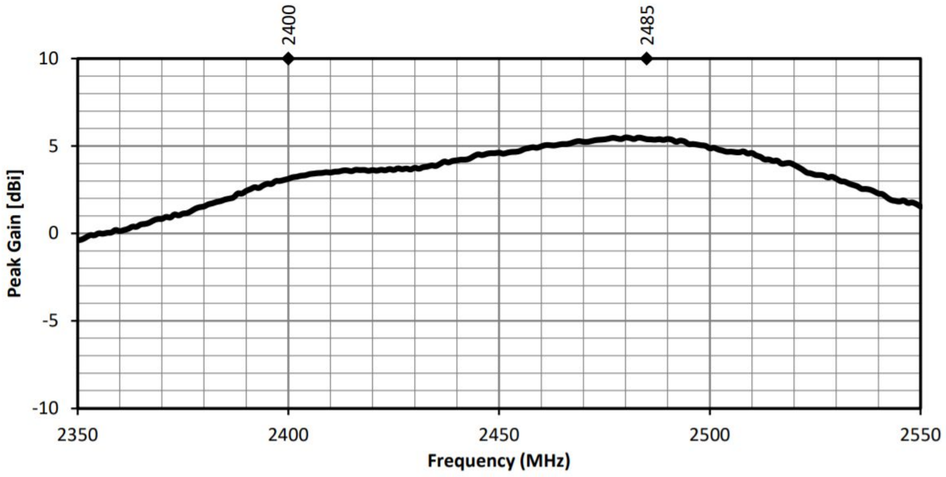


Figure 4. 2.4-CPA Peak Gain

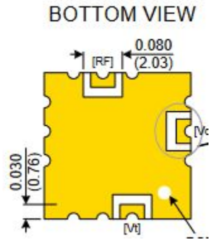
Antenna Assembly

- Antennas are mounted to PCB using a re-peelable adhesive backing
  - Antennas will have their own PCB for Antenna array
- Need large ground plane (40 mm x 40 mm)
  - Ensures better VSWR performance
  - Produces narrower antenna signal beam
    - Maximizes forward gain / radiation efficiency
- Antennas must be properly spread out
  - distance of $d = \lambda / 2 = 62.5$ mm

PCB Design - Main Components

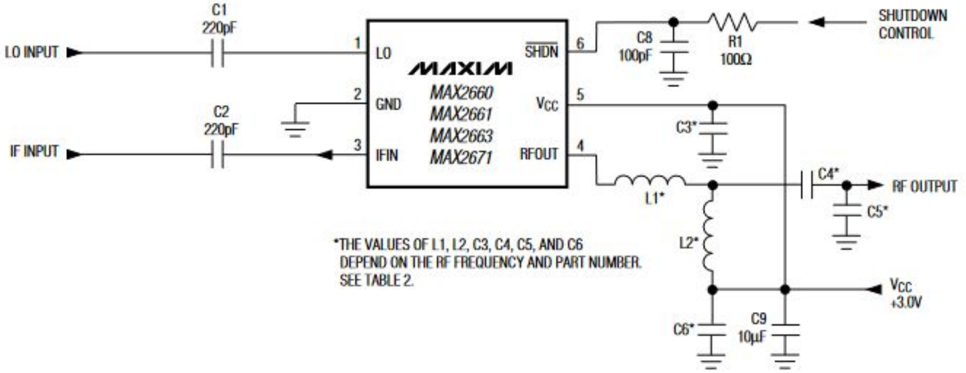
Local Oscillator

- Crystek CVCO33-1950-2400
- Generates 2.2GHz Signal



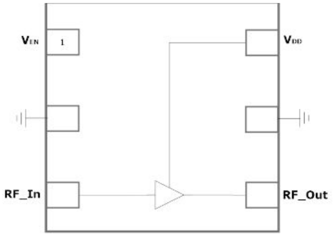
Upconverter Mixer

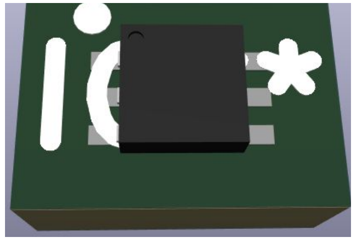
- Maxim MAX2660
- Mixes 2.2GHz signal from the oscillator with 200MHz signal from the DDS



Low Noise Amplifier

- Guerilla RF GRF2201
- Provides 20dB Amplification





PCB Design - Challenges

Challenges

- Learning KiCad EDA software
- Ensuring proper voltage and current biasing
- Maintaining signal integrity
- Soldering must be precise
- Must design footprints for oscillator and upconverter
- Must use 4-layer PCB
  - reduces EMI radiation
  - 8 mm thermal vias required for amplifiers

Microcontroller? Is it worth it?

- Microcontroller is not necessary, so we want to make sure we have system properly working

Pros

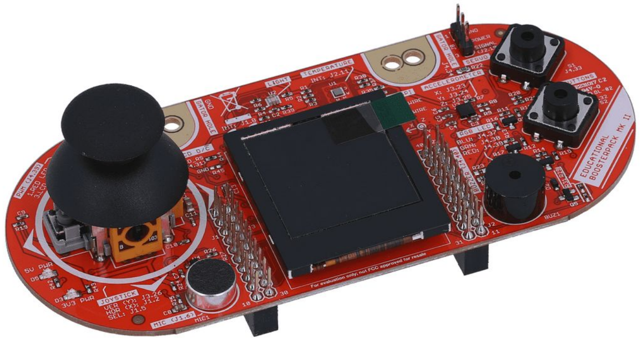
- Increase ease of use
- Could take place of GUI
- Multiple options for control (Boosterpack)
- LCD can come in handy for debugging and testing
- LCD Easy to configure

Cons

- Use extra pins on the FPGA
- More time added to project
- Can be accomplished with FPGA Hex display and buttons

Presenter: Tiernen Pan

If we use Microcontroller



- SPI for communication
  - Microcontroller Master, FPGA Slave
- Booster Pack
  - Joystick
    - Move joystick up or down to scroll through possible beam angles
  - LCD Display
    - Will display the desired angle of the beam
- Resolution
  - DDS takes 14 bit input for phase shift
  - Beam should steer from 0 - 180 degrees, but the DDS sees 0 - 360, so
  - 0.02197 degrees = 1 bit
  - Microcontroller will convert desired angle in degrees to a 14 bit equivalent

Presentation Recap

- Previous Project Development
  - Digital Vs Analog
- Current Progress Update
  - Configuring SPI with FPGA to DDS
  - Website
  - PCB Design
- Future Work
  - Implement equations in FPGA
  - Wire components together, Soldering
  - Testing and Calibration

References

- Datasheets:
  - https://www.mouser.com/datasheet/2/94/CVCO33BE_1950_2400-2303170.pdf
  - https://www.mouser.com/datasheet/2/256/MAX2660-MAX2673-1515397.pdf
  - https://www.mouser.com/datasheet/2/777/GRRF_S_A0010122589_1-2575831.pdf
  - https://www.mouser.com/datasheet/2/238/LNNC_S_A0009494921_1-2551007.pdf

Questions?