FPGA Enhanced Digital Beamsteering Phased Array

Team 311
Sponsor: L3Harris
November 12th, 2021

Team Introductions

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Sponsor:
L3Harris

Outline

- Motivation
- Project Scope
- Targets
- Concept Generation
- Concept Selection
- Preliminary Design

Motivation

- With new emerging technologies there is more need for higher data transmissions.
  - Beam steering deliver higher signal quality to your receiver
    - Faster information transfer and fewer errors
  - Does not need an increase transmitting power
  - Attenuation of side lobes

Project Scope

Project description

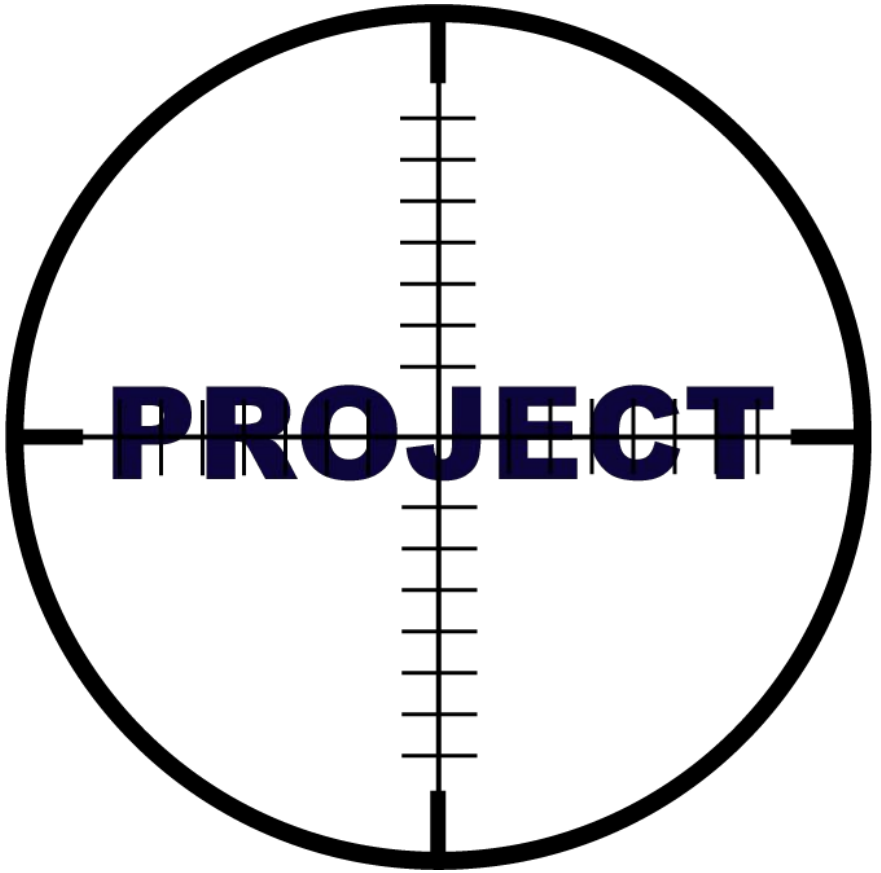
FPGA controlled transmitting antenna array.

Key Goal

Control a digital signal to control the radiation direction of the array using beam steering.

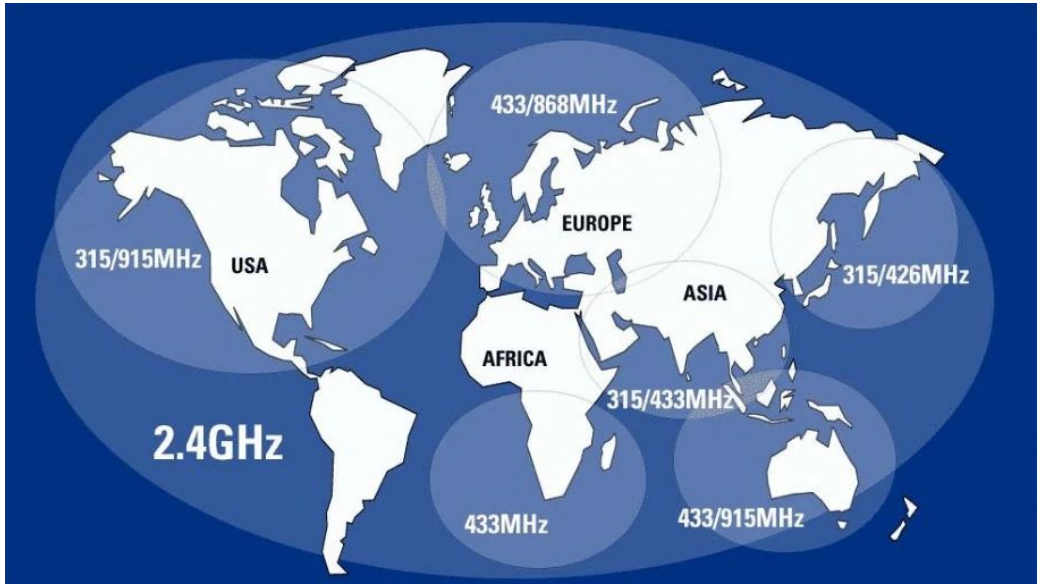
Market

Radar, sonar, wireless communication



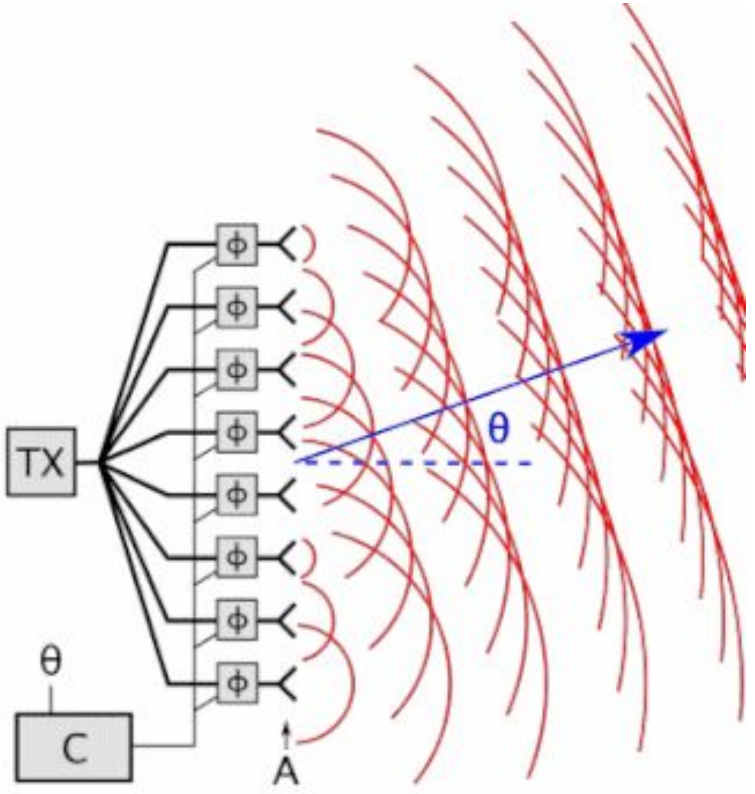
Customer Needs

- FPGA Controlled 0-360 degree range
- Steer the direction of radiation (Beam-Steering)
- Transmitter will operate in the ISM band with <30 dBm output power into the antenna
- Array will be linear and consist of four antennas



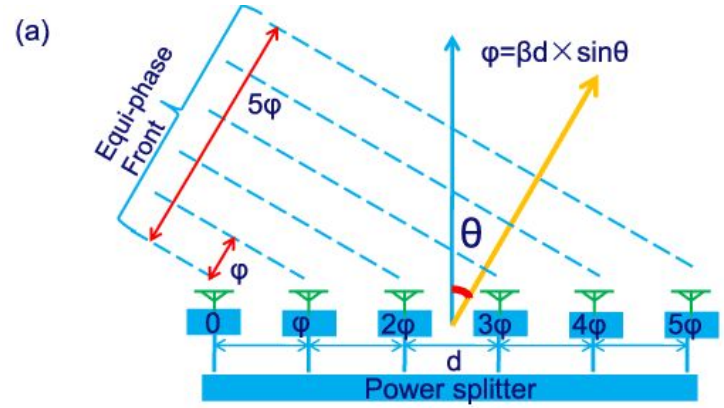
Requirements

- Algorithm to control and maintain the optimum radiation beam position
- Operating Frequency within ISM Band
- 4 Channel DDS/Antenna Array
- Measure Phase Difference and dB Gain

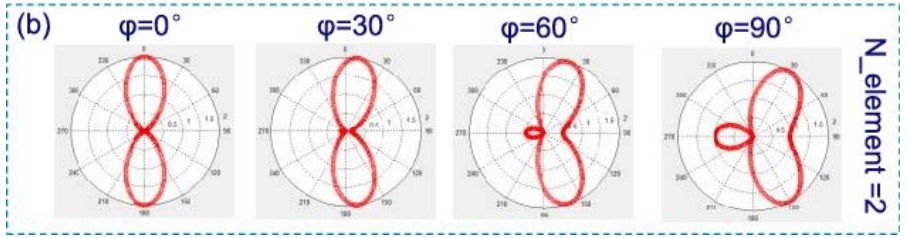


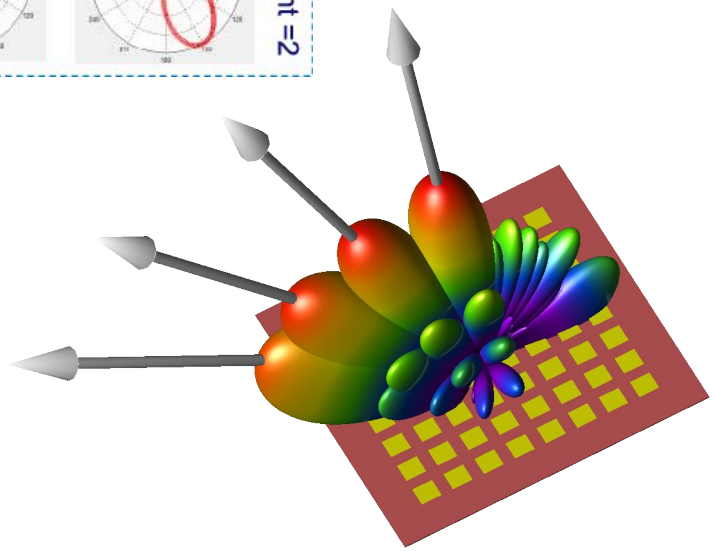
Functions

- Relate the phase difference to the desired angle of the beam
- Generate four digital sine waves with each one having ‘n’ magnitude
- Convert digital signals to analog signals
- Amplify the signals to the proper frequency using an amplifier
- Generate the radiation pattern
  - Done by Feeding the amplified signals into the antennas in the correct order



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





Targets

- Anticipated Parts List with inputs and outputs
- Key components of the entire system are the GUI, FPGA, Up-Converter and DDS

Module	Computer Interface GUI
Inputs	120V AC power
Outputs	USB interface with FPGA

Module	FPGA
Inputs	USB interface, 12V dc
Outputs	1.8V, 3.3V dc

Module	Up-Converter
Inputs	4 analog sine wave patterns at 200.3MHz a piece
Outputs	4 analog sine wave patterns at 2.4GHz

Module	DDS X4
Inputs	1.8V, 3.3V dc
Outputs	4 analog sine wave patterns with phase offset, 200.3 MHz (Highest the DDS can output)

Concept Generation

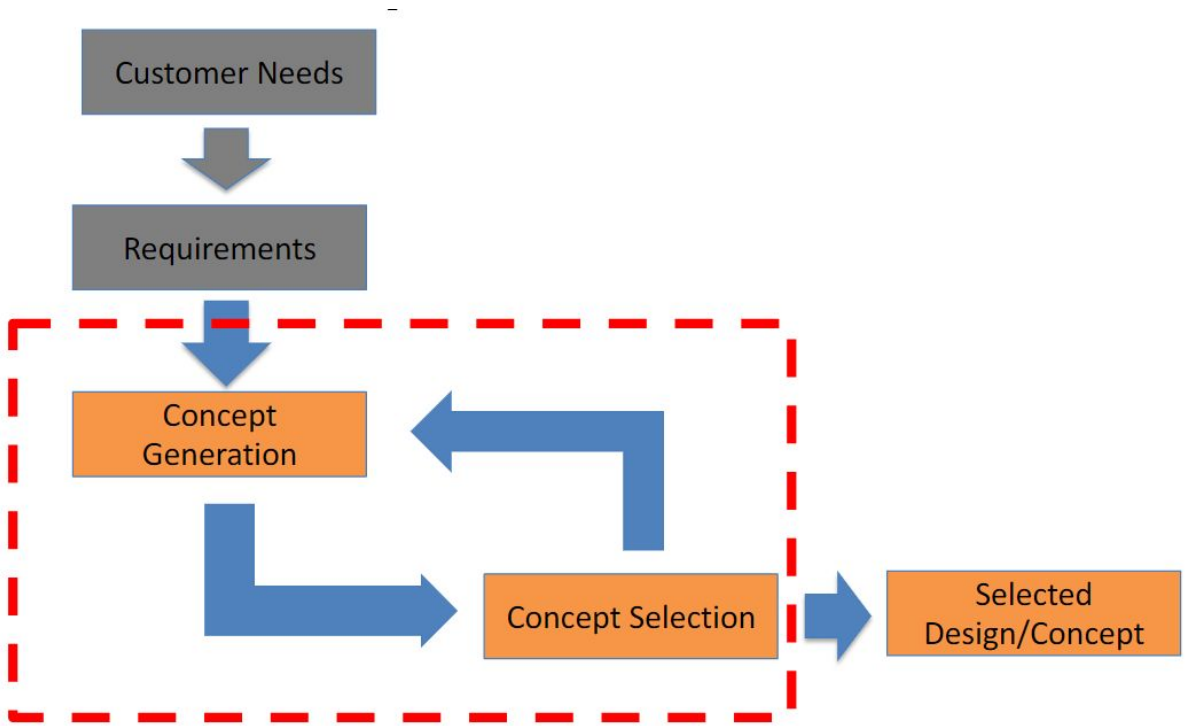
High Fidelity Concepts:

- Pre-built 4-Channel DDS (no PCB required)
- FPGA and MCU based
- Operation Frequency Band is 2.4 - 2.5 GHz
- 120V 60Hz Power Supply
- 7-segment Display and LCD Display

Concept Selection

Finalized Selected Concepts:

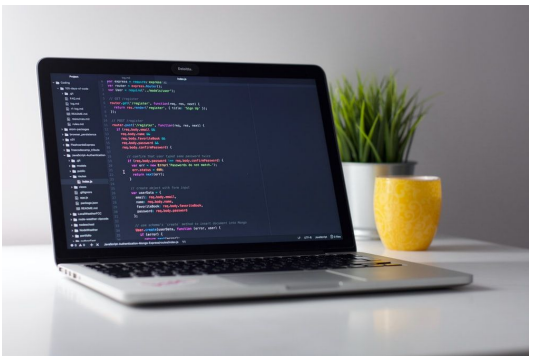
- Digital Antenna Array
- FPGA and MCU
- Handheld size
- USB Power Supply

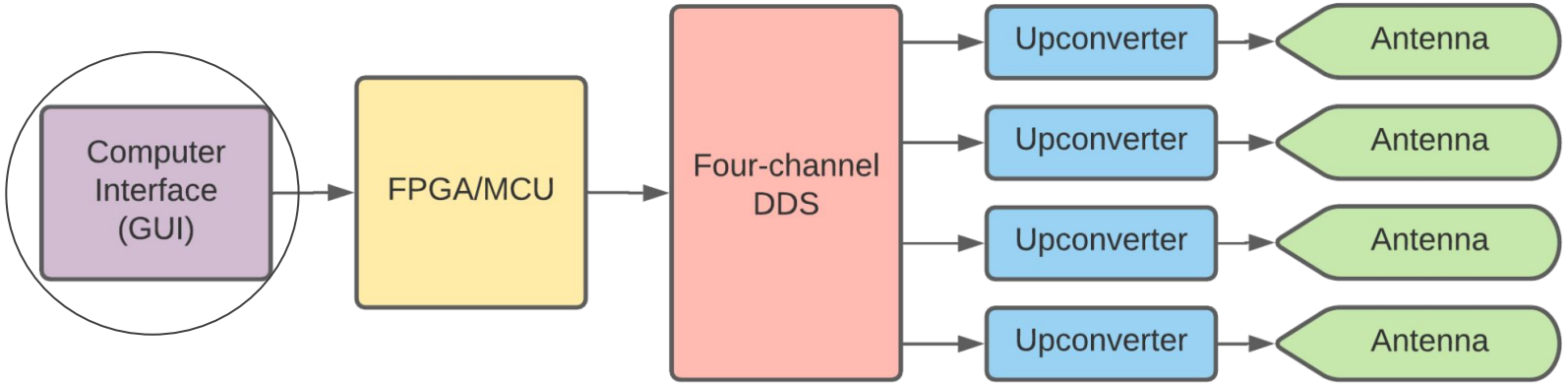


Computer Interface (GUI)

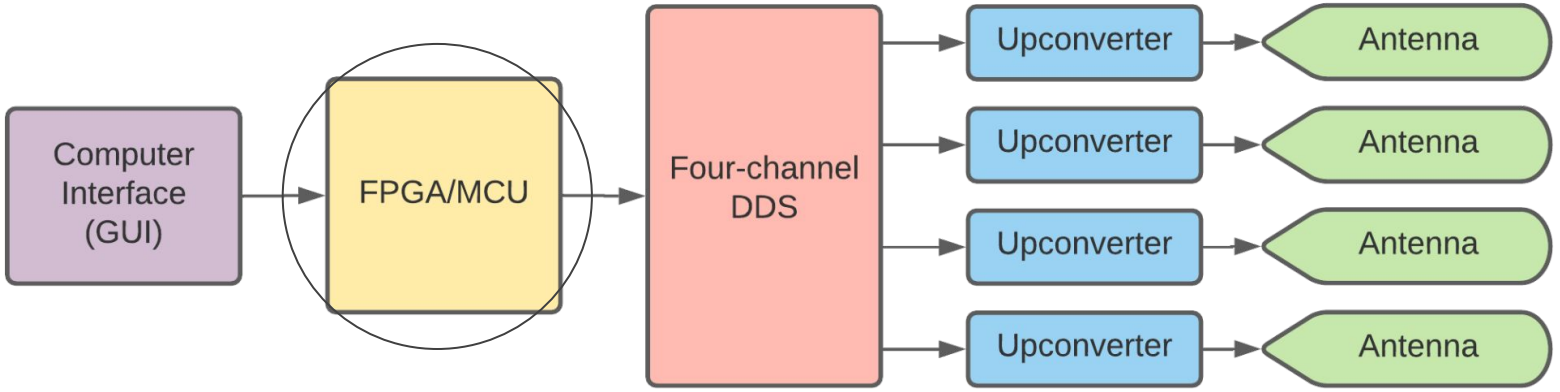
We will be using a laptop:

- Quartus for FPGA
  - VHDL
- Code Composer Studio (CCS) for MCU
  - C

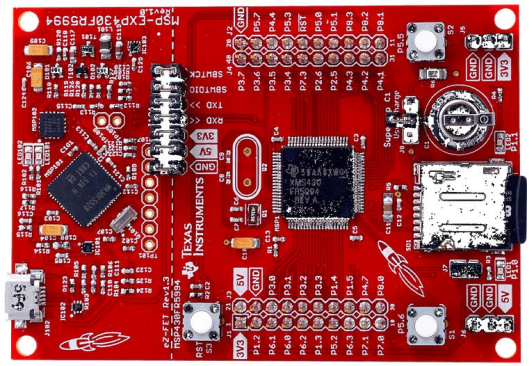




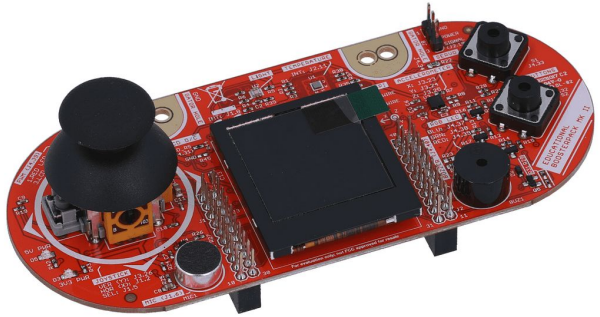
FPGA & MCU



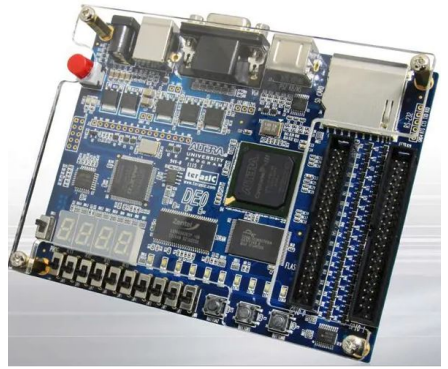
MSP430FR5994 LaunchPad



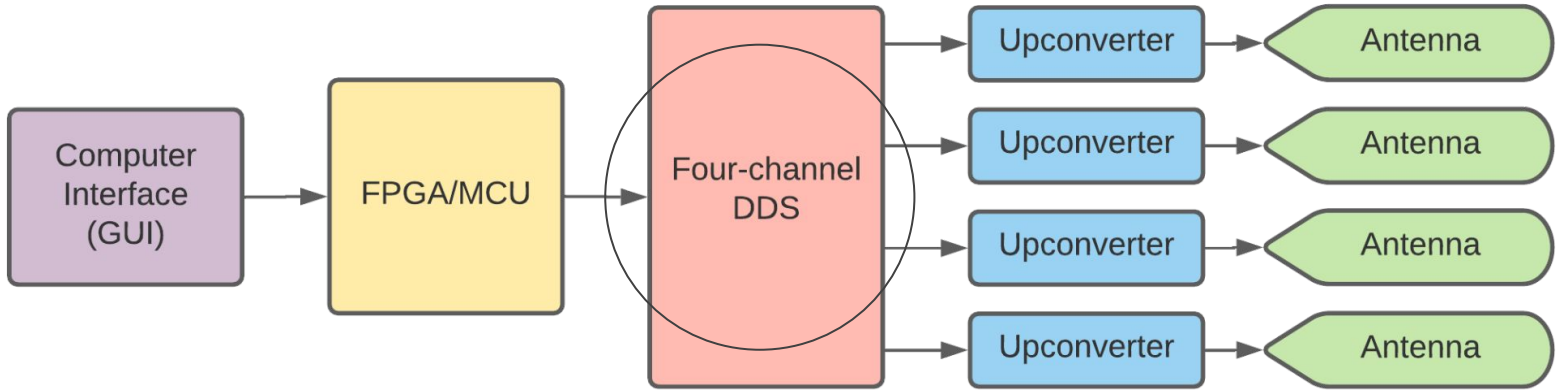
BOOSTXL-EDUMKII Educational BoosterPack MKII



DE1 SoC Cyclone V FPGA



Four-Channel DDS



Waveform generators, Phase shifters, DACs

AD9959/PCBZ

FUNCTIONAL BLOCK DIAGRAM

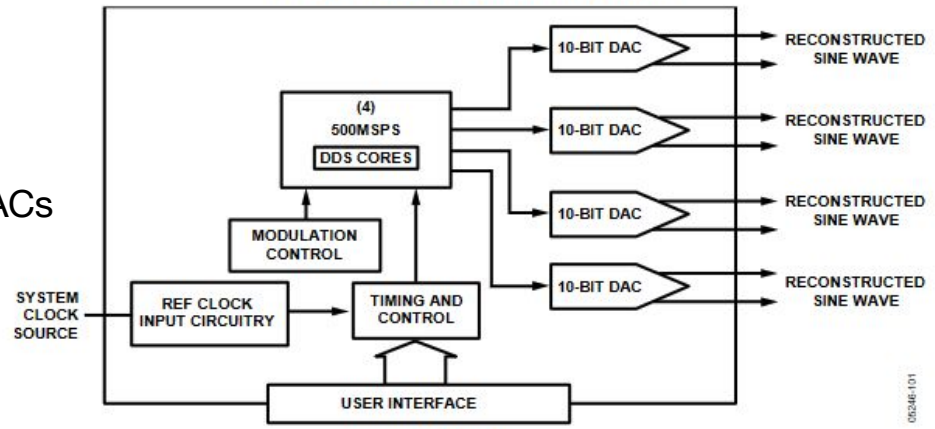
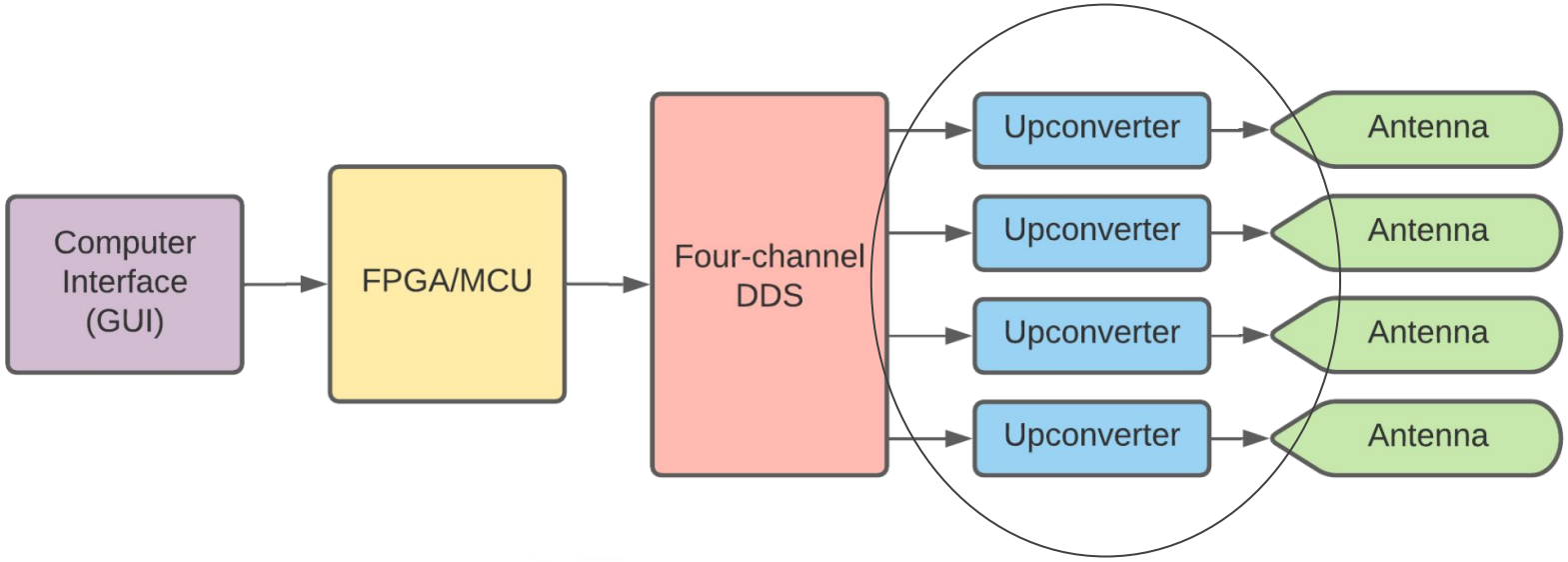


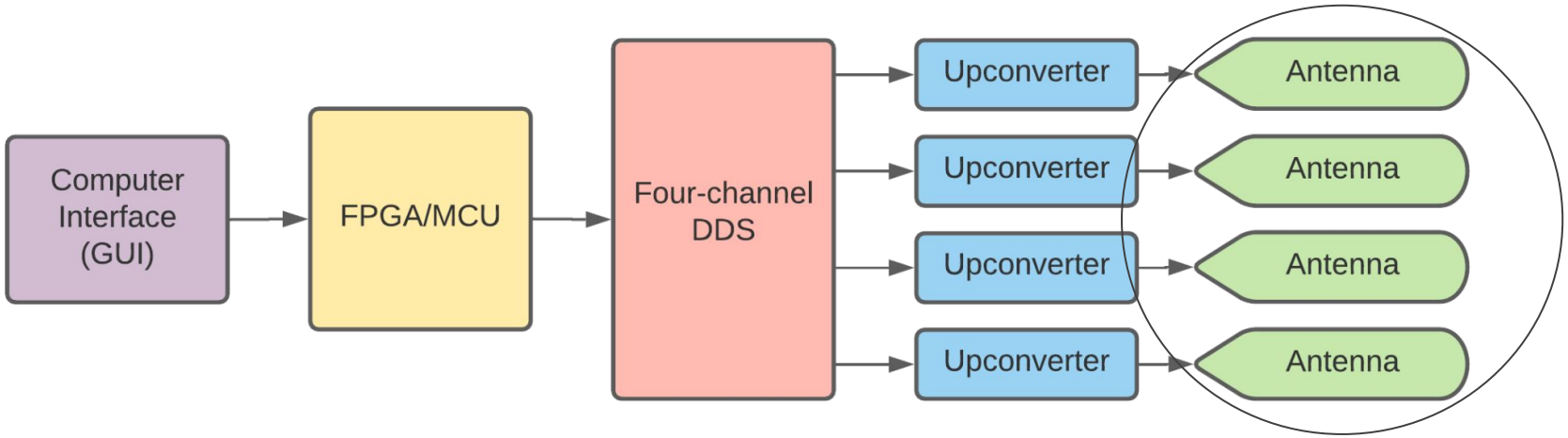
Figure 1.

Up Converter

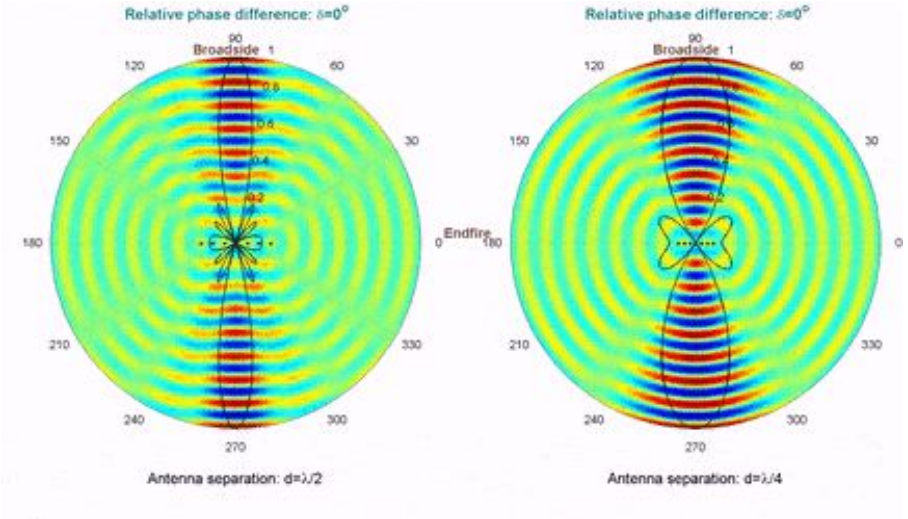


$$f_{RF} = f_{IF} + f_{LO}$$

Antenna

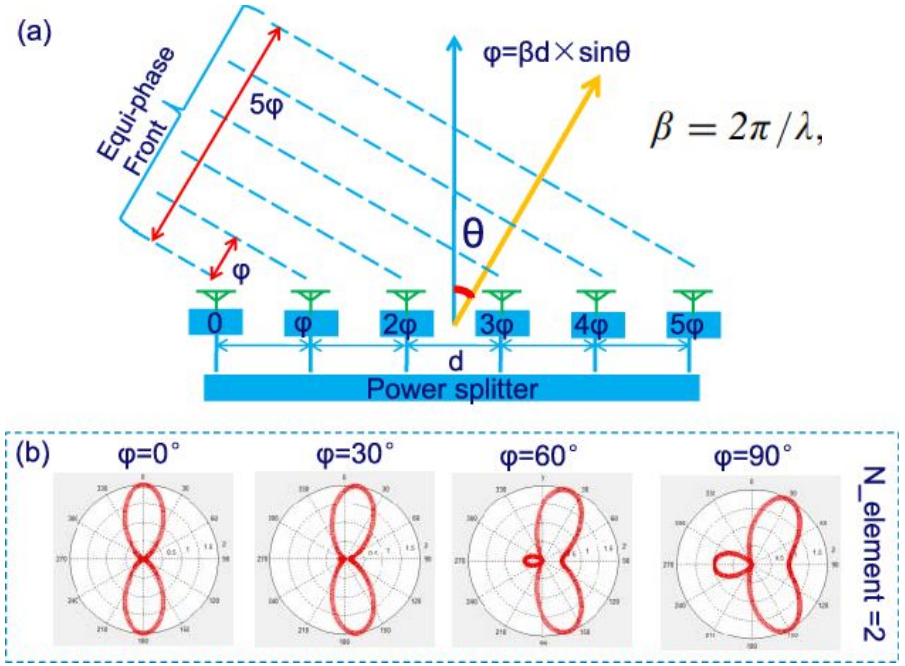


2.4GHz antenna



Preliminary Design

-PVC Junction box
    -Mounting Brackets
    -Made for electrical components
-Booster Pack for control



Presentation Recap

- Motivation
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References

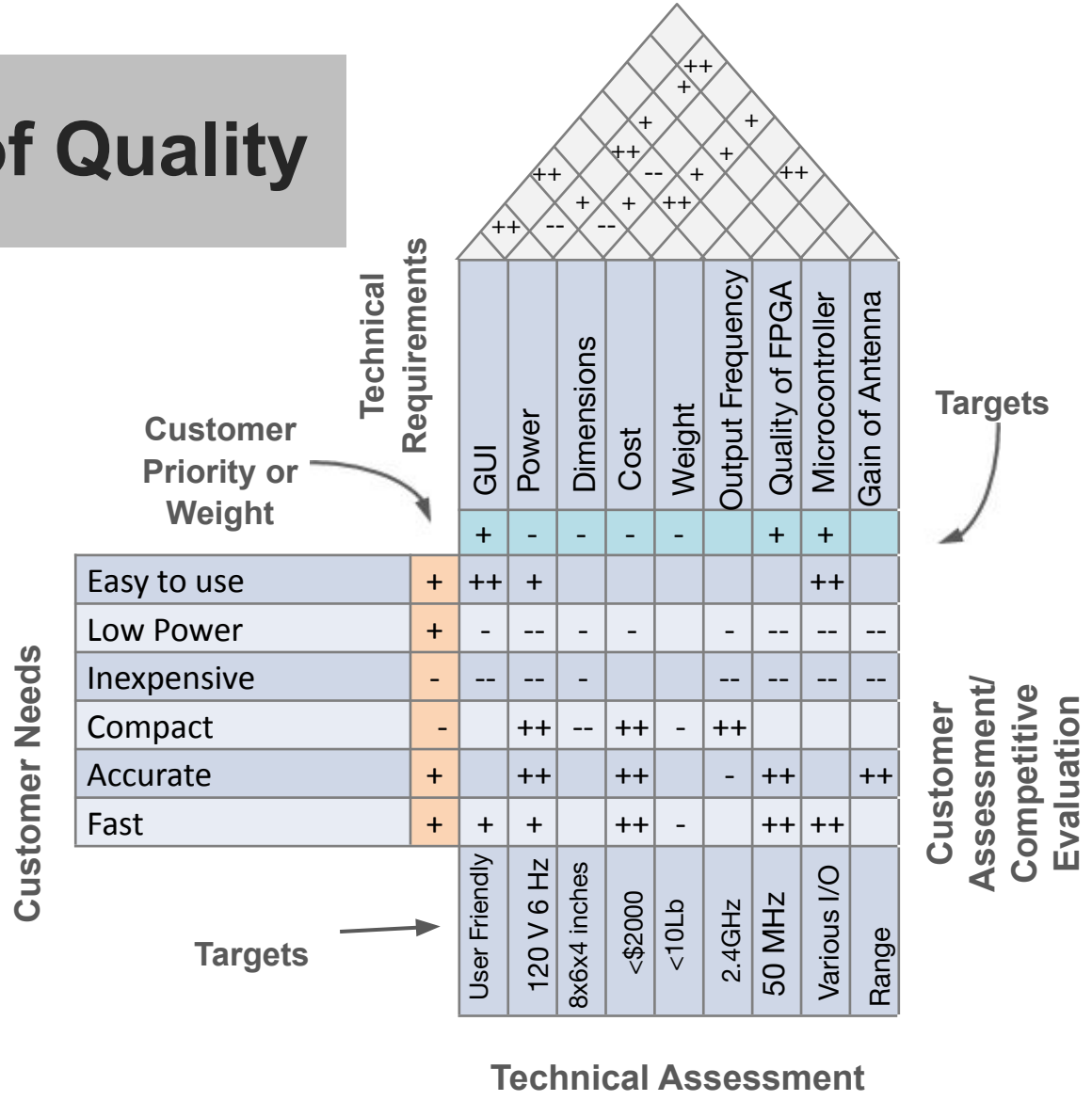
- C. Fulton, M. Yeary, D. Thompson, J. Lake, A. Mitchell, "Digital Phased Arrays: Challenges and Opportunities," Proceedings of the IEEE, vol. 104, pp. 487-503, March 2016.
- https://www.youtube.com/watch?v=A1n5Hhwtz78
- https://www.youtube.com/watch?v=P-8-v_M7TWM
- https://www.youtube.com/watch?v=HKpQP8H4JRc
- https://www.youtube.com/watch?v=n8_iSL4xKj8

Questions?

Presenter:

CHARTS

House of Quality



Correlations:

- ++ Strong Positive
- + Positive
- -- Strong Negative
- - Negative

Relationships:

- •• Strongest= 10
- • Strong= 7
- ⊙ Fair= 4
- ○ Weak= 1

Analytical Hierarchy Process (AHP)

	Ease of Use	Compactness	Weight	Accuracy	Speed	Mean $\sqrt[n]{\prod a_i}$	Weights
Ease of Use	1	3	5	1/7	1/5	0.844	0.103
Compactness	1/3	1	3	1/7	1/7	0.46	0.056
Weight	1/5	1/3	1	1/9	1/7	0.254	0.031
Accuracy	7	7	9	1	3	4.21	0.515
Speed	5	7	7	1/3	1	2.412	0.295

Pugh Chart

		Digital Antenna Array	Digitized Antenna Array	Analog Antenna Array
Ease of Use	0.103	-	0	-1
Compactness	0.056	-	0	-1
Weight	0.031	-	-1	-1
Speed	0.295	-	0	0
Accuracy	0.515	-	-1	-1
Score		0	-0.546	-0.705