Beamforming Application Using RFSoC 4x2

Project Members

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Introduction

In this project, we implemented a digital beamforming system using the Zynq UltraScale+ RFSoC 4x2 platform and the PYNQ framework. Beamforming is a signal processing technique that enhances the reception or transmission of signals in specific directions by leveraging antenna arrays.

By utilizing the powerful capabilities of the RFSoC, including integrated data converters and programmable logic, we developed a beamforming application. The PYNQ framework facilitated the integration of high-level Python programming with the underlying hardware, enabling efficient development and testing.

This project aimed to demonstrate the feasibility and performance of digital beamforming for applications such as wireless communication and radar systems in a laboratory setting.

Project Setup

The project setup was designed to implement and test digital beamforming using the Zynq UltraScale+ RFSoC 4x2 board. On the transmitter side, two DAC ports were connected to two dipole antennas configured as a phased array.

This configuration allowed us to manipulate the phase of the transmitted signals, enabling directional transmission through beamforming techniques. The transmitted signals were centered at 433 MHz, a frequency commonly used in communication and sensing applications.

On the receiver side, a single dipole antenna was used to capture the transmitted signals. This receiving antenna was connected to one of the ADC ports of the RFSoC board through a 433 MHz bandpass filter.

nThe filter ensured that only signals within the desired frequency band were processed, reducing noise and enhancing system performance. This setup demonstrated the capability of phased arrays for directional signal transmission and also provided a controlled environment to evaluate the RFSoC’s integrated data converters and its suitability for real-time signal processing applications.

Illustration of The Setup

RFSOC

RFSOC

Transmitter Side

Receiver Side

Antenna

Phased Array

Bandpass Filter

Contributions of Members

1.Berke Kaan Cetinkaya (3398171)

- Setting up the Transmitter Side

- Designing and Building the Bandpass Filter

- Running Simulations

2.Ilkay Kerim Özküney ()

- Setting up the Receiver Side

- Running Simulations

The Transmitter Side

As mentioned in the introduction part, the transmitter side is consisting of the RFSoC 4x2 board and two antennas connected to the DAC A and DAC B ports of the board. The antennas are forming a phase array to control the direction of the radiation pattern.

PhasedArray

A phased array antenna is a configuration of multiple antennas arranged in a specific geometry to enable beamforming, which directs the signal in a desired direction without physically moving the antennas. This is achieved by adjusting the relative phase of the signals fed to each antenna element. When the signals combine constructively in certain directions and destructively in others, the array forms a directional radiation pattern. The beam's direction can be steered electronically by changing the phase differences between the antennas, allowing for rapid and precise adjustments. Phased arrays are widely used in applications like radar, wireless communication, and satellite systems due to their flexibility, efficiency, and ability to suppress interference by controlling sidelobe levels.

MATLAB Simulation

I wanted to build and simulate our setup in MATLAB to test it.

I set up a phased array in MATLAB as below:

array = linearArray; -> Setting up a linear phased array

array.NumElements=2; -> 2 Antennas

freq=433e6; -> Frequency is 433 MHz

c= 300000000; -> Speed of light

lambda = c/freq; -> Calculating the Wavelength

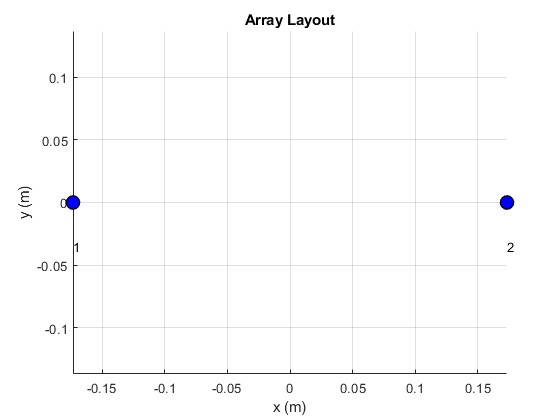
array.ElementSpacing=lambda/2; -> Distance between elements are half wavelength

array.PhaseShift=[0, 0]; -> Phase shift

pattern(array,freq); -> Drawing the 3D Radiation pattern

patternAzimuth(array,freq) -> Drawing the Azimuth pattern

Antennas are placed in a linear form, one half wavelength away from each other as below



0.39m

The three dimensional radiation pattern, and the Azimuth pattern of the phased array can be seen below, as I set the phase shift of the second antenna from 0 to 90 to 180 incrementally.

A diagram of a colorful sphere

Description automatically generated with medium confidence3D Radiation Pattern at 0 degree phase shift

Figure Radiation pattern at 0 degree phase shift

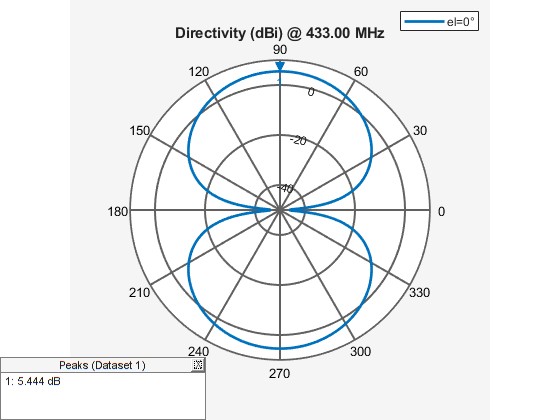


Figure Azimuth pattern at 0 degree phase shift

3D Radiation Pattern at 90 degree phase shift

A diagram of a red and yellow sphere

Description automatically generated with medium confidence

Figure Radiation pattern at 90 degree phase shift

A screen shot of a graph

Description automatically generated

Figure Azimuth pattern at 90 degree phase shift

3D Radiation Pattern at 180 degree phase shift

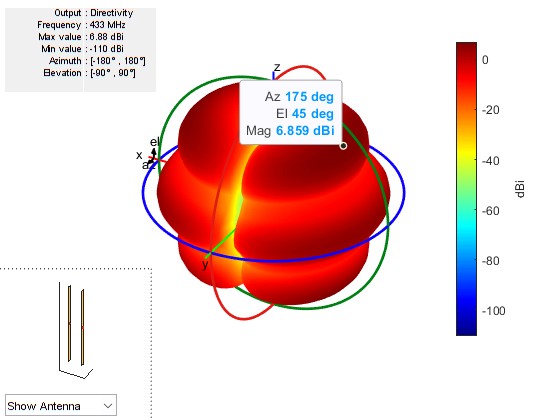


Figure Radiation pattern at 180 degree phase shift

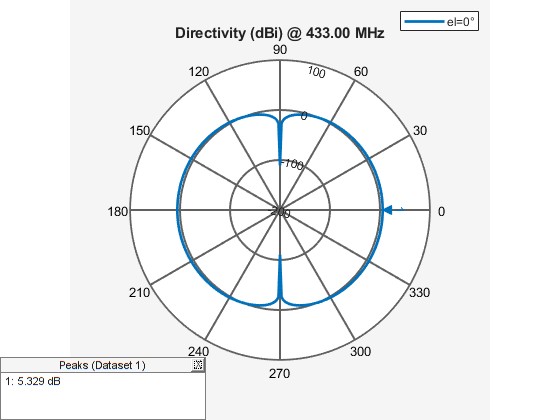


Figure Azimuth pattern at 180 degree phase shift

After looking at the images, one can see that at 180 degree phase shift, we have the maximum directivity at 6.859 db at 45 degrees of elevation. After understanding how our system will work, we went further with the tests and received following results:

TO DO

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"Phased Array Antennas." *Microwaves101*, <https://www.microwaves101.com/encyclopedias/phased-array-antennas>

linearArray MATLAB documentation

<https://de.mathworks.com/help/antenna/ref/lineararray.html>