

16-Element Phased Array for Coarse AoA Estimation

Problem

Signal intelligence is key for the United States to maintain spectrum dominance. Signal intelligence involves direction finding. A primary technique for radio-based direction finding is angle of arrival estimation. A 16-element antenna array coupled with a custom 16-port software defined phase shifting network serve as a demonstrative platform for coarse angle of arrival estimation.

Key Ideas

- Custom 16 port phasing network (See Figure 2)
- Completely software defined
- Brute force angle of arrival estimation with precomputed phase states

Technical Approach/Methodology

By changing the phase of the excitation of each element in a rectangular array (see Figure 1) you can effectively steer the main lobe of the radiation pattern in a specific direction, and it works

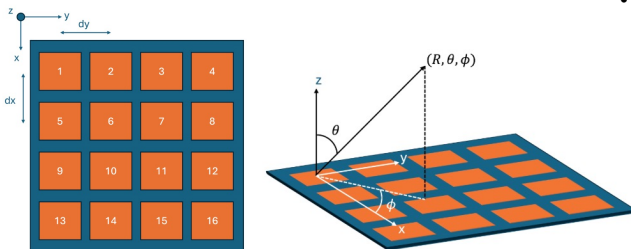


Figure 1: Chosen Coordinate System for Antenna Array

Specifically, a progressive phase shift (β_x, β_y) is applied to steer the main lobe to (θ_0, ϕ_0)

$$\beta_x = -kd_x \sin \theta_0 \cos \phi_0, \quad \beta_y = -kd_y \sin \theta_0 \sin \phi_0$$

Process

- Precompute 256 discrete phase states for angles: $\theta_0 \in [0, 45], \phi_0 \in [0, 360]$

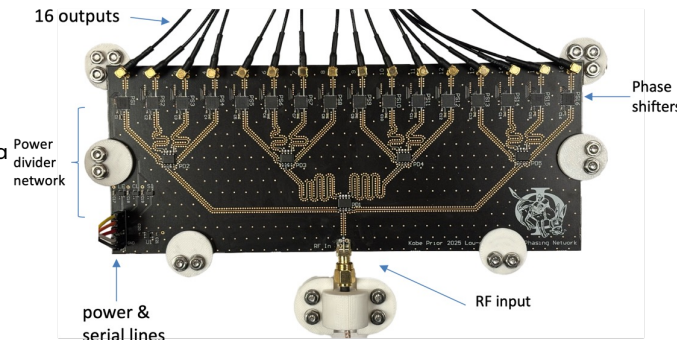


Figure 2: Custom 16-port software-defined phasing network

- Use a microcontroller to deliver phases to each addressable phase shifter via serial peripheral interface (SPI)
- Use a full-duplex software defined radio (SDR) to provide a continuous wave source to a local transmitter
- The output of the 16:1 power combiner network is sampled by the receive channel of the SDR

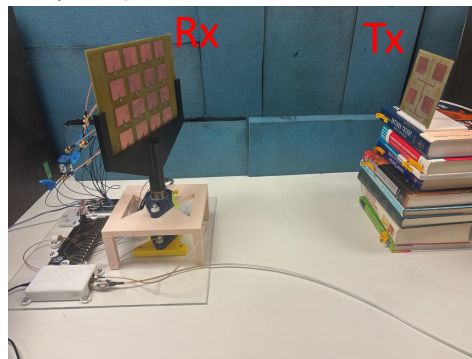


Figure 3: Experimental Setup

- Sampling is done for each phase state
- The angle with the highest received power is the most likely angle of incidence.

Results

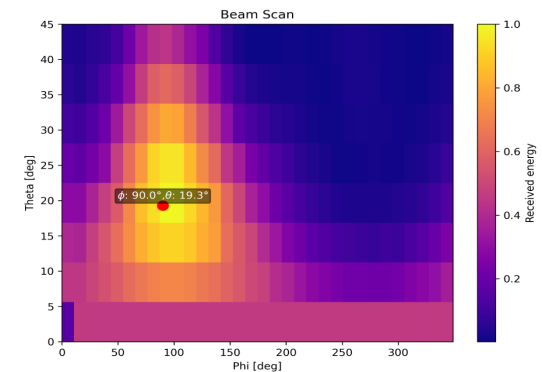


Figure 4: AoA Estimation for Figure 2

After about 25 ms an angle of arrival estimate is generated. The hot spot on the heat map corresponds to the highest relative energy received (see Figure 4). For the experimental setup shown in Figure 3 $\theta = 90^\circ, \phi = 19.3^\circ$ which is consistent with reality within 1°

- By knowing where a signal is coming from the probability of intercept is increased drastically

Next Steps

- By adding amplitude control more sophisticated beam forming is possible
- Transition to field programmable gate array for real-time digital beamforming
- Classify emitters by discriminating modulation schemes
- Multiple phased arrays for precise geolocation using time difference of arrival

Team

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