"Radar-a-thon" Concept Paper Submission

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This document outlines the concept and path to solution of the University of New Haven's small undergraduate RF research group invested in exploring innovations in both small-form radar hardware as well as signal processing techniques. This submission serves to highlight the technologies and processes we intend to develop in order to compete at the IEEE-AESS 2020 "Radar-A-Thon" competition in the "Maximum Value Radars" category.

1. Development of an Active Phased Array

Active phased arrays are commonly used for large object tracking in applications such as the military and weather research. Phased arrays, in general, rely on a cluster of spaced elements that use signal delay to propagate a "steered" beam. The elements are phased such that constructive and deconstructive interference effectively created a shaped beam allowing for higher signal gain and directionality of a stationary antenna cluster.

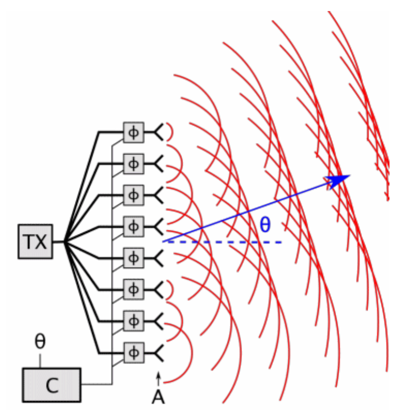

Figure 1: A schematic showing a phased array steering the signal

We plan to purchase 8-12 XM112 – Pulsed Coherent Radar's that operate at 60 GHz and form an array with these units. These small boards retail for $60 each and have no dependence on specific processing software. This allows our team to develop the steered beam method and use all the information pulled from the hardware.

One of the benefits of using an active phased array, where the transmitters and receivers are integrated into TR modules, is that the transmitter and receiver share the same phase shift. This results in a minimization of post-processing needed compensating for two different phase shifts of the signal. Traditionally, the use of integrated TR modules for radar applications resulted in very high hardware costs. However, we believe that by purchasing inexpensive COTS and relying on software development, we can bring this technology down to a more tangible consumer level.

2. Array Cluster Layout and Potential MIMO Integration

The layout we plan to use will mimic that of common ultrasonic phased arrays: a rectangular grid with minimal spacing between units. It is effective to space the TR modules such that the received signals of each element are de-correlated and have minimal interference. It is recommended that the minimum spacing between two units is at least a half wavelength, but good practice is 3-5 wavelengths. At 60 GHz this translates to roughly a 5mm gap. Since each module is 24 mm x 16 mm with a centered TR component, the minimum gap possible would be 16 mm or roughly 3 wavelengths.

MIMO (multi-input, multi-output) radar is another method that uses an array cluster like what we are developing. Instead of using a phase delay to steer a beam, each units sends a slightly different frequency and receivers with corresponding match-filters can extract this information to achieve a higher spatial resolution than typical phased array systems.

Typical MIMO systems utilize separate transmitters and receivers and involve process-heavy filter designs to extract the proper signals. Our design, in theory, will allow for less-dissimilar frequency units, and minimal match-filter processing. Since we are using integrated TR units, spaced such that there is minimal inter-correlation, the receiver will most likely only receive it's transmitted signal and minor noise from the other TR modules. Therefore, instead of frequency match-filters, we could instead use a sort of gain filter, which is less processor intensive and easier to manipulate.

One potential modification we may need to make is acquiring a few TR modules at different frequencies. We believe we can modify the XM112's to slightly alter the 60 GHz frequency enough to be able to utilize MIMO, however in the chance that we cannot, we will instead purchase a combination of XM112's and a different TR module in a similar price range that operates at a different frequency. The overall hope is to be able to have a system that can handle phased array and MIMO, differing only by software functionality.

3. Use of Guard Channel

It is impossible to completely de-correlate the signals between the TR modules in any array, phased or MIMO. We plan to use a guard channel, which consists of a signal element not integrated into the array as a reference signal of amplitude. The guard channel serves as a logic check to see if the received signal is larger than the transmitted signal (which could only be caused by the side modules interfering). A simple gate filter will be applied such that any amplitude signal higher than the guard unit will be assumed a product of echoing and negated.

4. Justification For Use of COTS Components

Our focus is to rely on our prior experience in RF signal manipulation and processing to convert standard off-the-shelf packages into a powerful, high resolution radar unit. As described above, we plan to couple multiple transmitter-receiver units into a cluster. We will purchase relatively inexpensive units to make up an array of 8-12 transmitter/receiver pairs. The ingenuity and modifications will come by way of using the array to create shaped beams and design a signal processing system that minimizes computational power. Since our team has little to no experience in radar hardware development, it was determined to be more efficient to purchase integrated components that contain the bulk of the hardware needed so that we can spend more time developing more advanced processing techniques.

5. Predicted BOM

Part Name	Manufacturer	Use	Cost
XM112 TR Unit	Acconeer	Trans/Rec Units	$55 ea. for 10
		Total	$550.00

6. Things to Consider

The XM112 units are not explicitly labeled as FCC Part 15 compliant and therefore we will have to ensure that we follow those guidelines. Higher cost TR modules have more capabilities and expandability, but result in smaller arrays. An array of 3 $200 TR units, FCC compliant, with variable frequency may be as or more effective than an array of 10 XM112's. Further analysis is needed to justify one over the other.

We assume that the desired test object will be "in front" of the system. Therefore, we do not see a benefit in having an electro-mechanical aspect that rotates or moves the radar system, although we may find we need one due to the narrow band of MIMO.

Propagation distance at 60 GHz is a real concern. We will evaluate performance as the array is constructed and keep and eye out for TR modules in lower frequency bands to increase range.