
24 GHz Patch Antenna Array Design for RADAR

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Radio Detection And Ranging (RADAR) is a technology that is widely used in many diverse areas; from monitoring space down to ocean surveillance, with many more applications in between. It uses radio waves to detect objects and can give their 3D position and speed. Antennas are used to transmit and receive these radio waves, and a very attractive type of antenna is the patch antenna. In this study, different patch antenna arrays were designed and tested with a 24 GHz radar system.

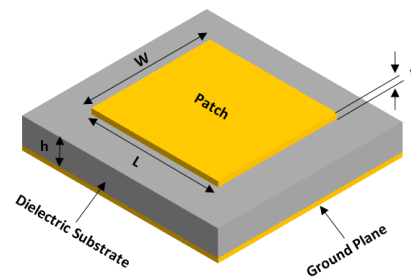


Figure 1: A patch antenna with dimensions $L \times W$ and thickness t . The height of the dielectric material is h .

Introduction

The earliest significant achievements in radar technology were made during World War II along with many other technological advancements. This is also where the term "radar" was coined by two U.S. Navy officers Samuel M. Tucker and F. R. Furth in 1940. Radar technology has since then grown fast and is today not exclusive to the military but also used in commercial applications such as weather monitoring, traffic speed control, and air traffic control. The simplest form of a radar system is made of a radio transmitter which sends out electromagnetic pulses that bounce off an object and a receiver which collects the reflected waves. This information can then give the 3D position and speed of the object, and that is what makes radar a very attractive technology to use. To send and receive these pulses, antennas are used.

The Patch Antenna

The patch antenna is a very attractive and widely used form of antenna that is cheap to manufacture and easy to implement. The basic look of it is shown in Figure 1, where it consists of a thin metal element,

a "patch", that is mounted on top of a dielectric substrate (a material that doesn't lead electricity when an electric field is applied, but where the electric charges are slightly shifted from their positions) and a thin layer of metal on the other side.

It is very common to put multiple patches together, in what is called an *antenna array*. These arrays can be formed in many different geometric shapes and will in general increase the antenna gain, compared to the single patch antenna.

Manufactured Patch Antenna Arrays

Three different design configurations of patch antenna arrays were designed and manufactured to be used with a 24 GHz radar system. These were put together on a single layout for easy implementation during testing. Figure 2 shows the different designs.

The transmit antennas are named Tx and the receive antennas Rx. Design 2 and 3 uses the same Tx antennas, while as Design 1 uses a different setup of Tx antennas. The spacing between the antenna arrays is related to the wavelength $\lambda = 12.5$ mm. A common design guide rule is not to use an element

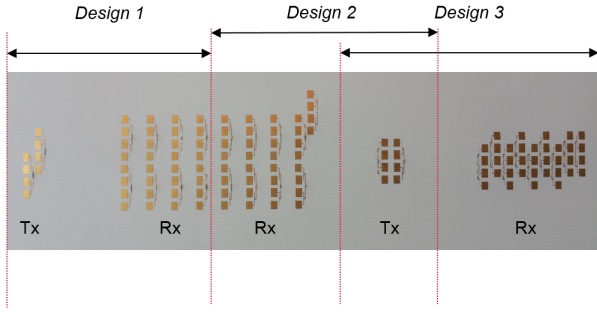


Figure 2: The three manufactured patch antenna arrays put together on a single layout.

spacing longer than $\lambda/2$, since this can cause false targets to appear for the radar. To investigate this, Design 1 uses a spacing that is longer than this.

Prior to manufacturing, the antennas were designed and simulated in the software program *Computer Simulation Technology* (CST) to ensure they would show good performance.

Measurement Results

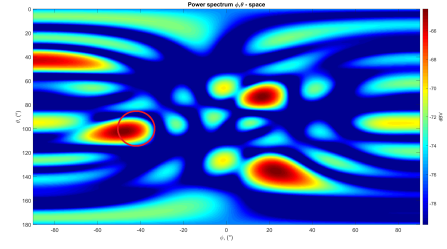
A test scenario containing a radar reflector located $R = 5.5$ m from the radar with an horizontal angle of $\phi = -43^\circ$ and an elevation angle of $\theta = 100^\circ$ relative to the radar, was conducted.

Three different, so called *Direction-of-Arrival* (DOA), algorithms were implemented in order to calculate the angles: *Delay-And-Sum*, *Capon/MVDR* and *MUSIC*. The most used one is the Delay-And-Sum algorithm, while the two others are more complex.

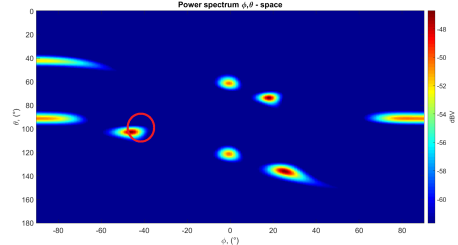
Figure 3 shows the results obtained with Design 1 for the Delay-and-Sum and MUSIC algorithms. Figure 4 show the results obtained with Design 3 for the Delay-and-Sum and Capon/MVDR algorithms. The position of the reflector is marked with a red circle.

Conclusions

From Figures 3-4 it can be seen that the algorithms seem to work very well; the results are accurate with the correct (ϕ, θ) angles identified in the spectrum and the methods seem to be working as intended. The Delay-and-Sum algorithm suffers from low resolution, which can be seen in Figures 3a & 4a as the peaks are "smeared out", while as for the more complex Capon/MVDR and MUSIC algorithms, the resolution is much higher. The main difference between the designs is that Design 1 suffers from false

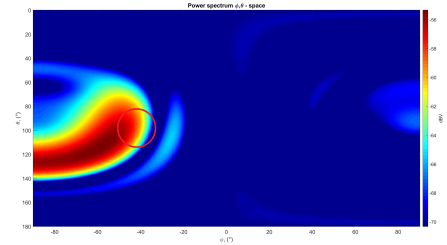


(a) *Delay-and-Sum* algorithm.

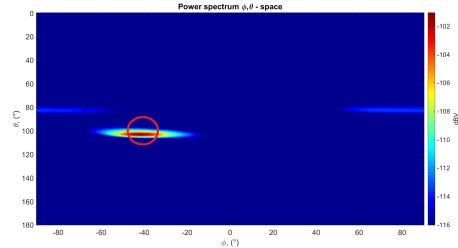


(b) *MUSIC* algorithm.

Figure 3: The results with Design 1 for the Delay-and-Sum and MUSIC algorithms.



(a) *Delay-and-Sum* algorithm.



(b) *Capon/MVDR* algorithm.

Figure 4: The results with Design 3 for the Delay-and-Sum and Capon/MVDR algorithms.

targets, as can be seen in Figure 3, while Design 3 suffers from a lower resolution. The false targets appear in Design 1 due to the antenna arrays being spaced more than $\lambda/2$.

To conclude, three different design configurations of patch antenna arrays were designed and tested with a 24 GHz radar. DOA algorithms were implemented to calculate the angular information and their performances were analyzed. The measurements were successful and the implemented algorithms worked.