# Design and Implementation of a Millimeter Wave Imaging Apparatus

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***Abstract*— A pair of planar antennas were used to conduct an imaging experiment at 23.5 GHz. The experiment involved three iterations that explored the idea of using arrays of antennas to increase gain and mechanical scanning of the object to form two-dimensional images. A discernable image was obtained at 23.5 GHz, which encourages repeating the experiment at higher frequencies. Images and results obtained are reported below.**

***Index Terms*— millimeter wave imaging, antenna array, mechanical scanning.**

## I. INTRODUCTION

MILLIMETER wave imaging has been an emerging topic of interest both within and outside of academia, more so as we advance the limits of the frequency of silicon-based mmWave ICs. Certain special properties of mmWave make them particularly desirable for practical applications.

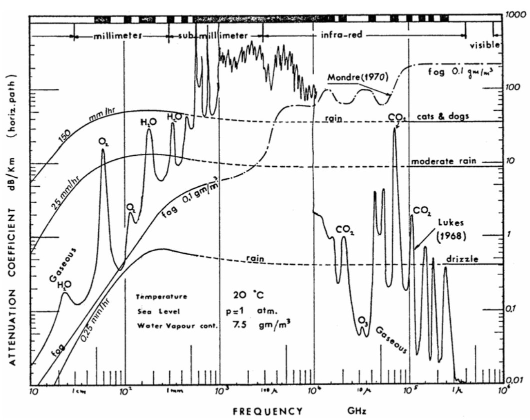


Fig 1. Atmospheric Attenuation across the Electromagnetic spectrum.

Millimeter wave images are more effective in comparison to infrared images in poor weather conditions as can be seen from Fig 1. A possible use case would be Airplanes employing mmWave imaging for takeoff and landing in bad weather conditions. Another important property of mmWaves is that they aren't as harmful to the human body as some other types of radiations that are used for imaging. Potential applications that use this property include scanning for weapons, and medical diagnostics.

With these applications in mind, the objective of the research was to explore the engineering aspects of creating a mmWave image.

## II. PROJECT WORK AND RESULTS

The theory behind the experiment is that different materials have different transmission coefficients. Typically metals have lower transmission coefficients and higher reflection coefficients.

The experiment involved placing an object between two antennas, one served as the transmitter and another served as the receiver. The transmitter was fed a mmWave using a function generator and the receiver was connected to a spectrum analyzer to measure the power transmitted through the object that was placed directly in between the two antennas. The power reading is positively correlated with the transmission coefficient of the point in between the two antennas.

The first iteration of the experiment was performed with the test object as a thick cylindrical copper cup 6 cm in diameter placed inside an anechoic chamber that was placed midway between the antennas translated perpendicular to them to obtain various power readings.

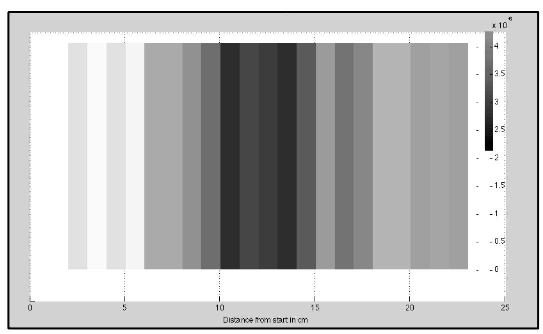


Figure2. Matlab representation of the 1-D image of test object using single antennas.

The power readings were normalized and a Matlab representation can be seen in Figure 2 above. The dark lines in the above image extend beyond what they should as the antenna beam width wasn't narrow enough. To tackle this problem we used 2 in-phase antenna arrays for both the transmitter and the receiver. The radiation pattern below shows that we have maximum antenna gain at the desired 90-degree angle.

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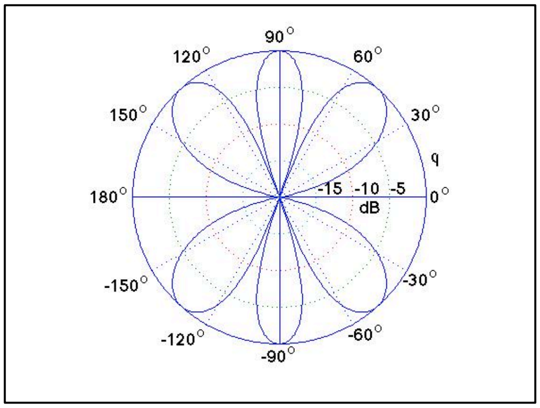


Figure 3. Radiation pattern for 2 in-phase antennas.

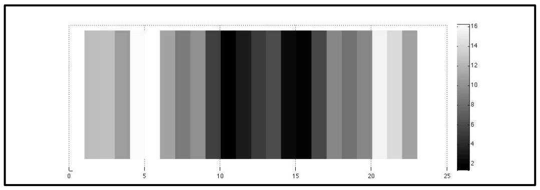

Figure 4. Matlab representation of the 1-D image of test object using in-phase array of antennas.

The results of the second iteration using the in-phase array of antennas can be seen in figure 4.

Next, it was desired that a 2 dimensional image be formed. This required precise motions along 2 Axis to capture the required data points. This was achieved by employing a mechanical X-Z scanner, with a plastic extension to hold the object in place. For this iteration we changed the test object to an envelope with a coin taped at the center. Another change from the previous setup was that the anechoic chamber was no longer used.

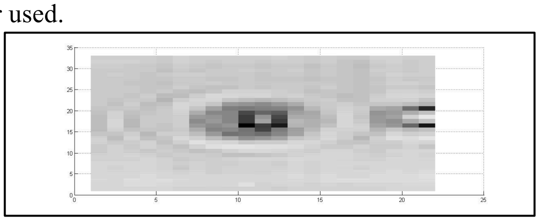

Figure 5. Matlab representation of the 2-D image of test object using single antennas and an X-Z Scanner.

A 33x22 image was thus constructed in this third iteration as can be seen in Fig 5. The coin in the center of the envelope can be clearly observed. The dark lines that appear on the right of the image are due to the plastic extension that was employed to hold the object.

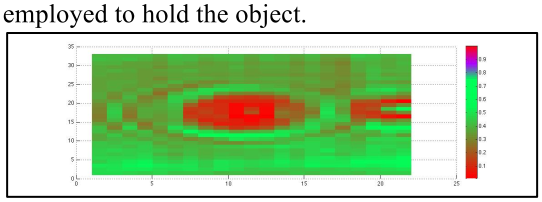

Figure 6. Alternate Matlab representation of the 2-D image of test object using single antennas and an X-Z Mechanical Scanner.

An interesting observation is the formation of standing waves between the two sides of the envelope that are observed as concentric circles. This can be better observed in Fig 6.

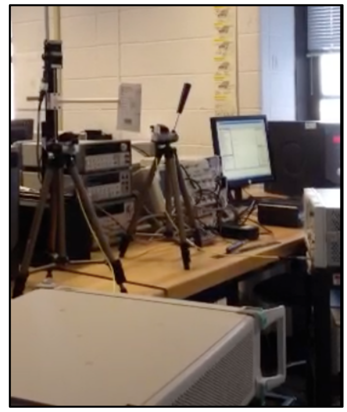

Figure 7. Image of the experimental setup for the 2-D Image using an X-Z mechanical scanner.

The experimental setup can be observed in Fig 7. It was conducted using planar antennas at 23.5 GHz, an Agilent E4448A spectrum analyzer, an Anritsu MG3697C Signal generator. S-parameter measurements were performed using Anritsu 37397E Vector Network Analyzer. Velmex X Slide was used to make the X-Z mechanical scanner.

## III. CONCLUSION

The experiment was successfully able to produce a discernable image at 23.5 GHz. The experiment is currently constrained by the beam width diameter and the number of pixels in the image. Strategies to address this would be to have a lens to focus the waves and to have an array of antennas, both of which are something we would like to pursue at 23.5 GHz and hopefully at higher frequencies.

## IV. ACKNOWLEDGEMENTS AND CAREER PLANS

I am extremely grateful to my Professor Harish Krishnaswamy for giving me the opportunity to work under him and for his guidance.

I would also like to thank IEEE and MTT-S for their generous funding and encouragement that enabled me to take up this research.

This summer I will be working at Sanford C. Bernstein, as a research associate. I hope to use this business experience along with the academic experience made possible through the MTT-S scholarship to purse an engineering based entrepreneurial venture.

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