Over-the-Air (OTA) mmWave Antenna Testing

Introduction

Antenna test is often a crucial step in the RF design process. Portable devices in the 5G band above 24 GHz might use embedded antennas with beam-steering accomplished through MIMO or meta-material technology [1], [2]. This is especially true in the case of Fixed Wireless Access (FWA) terminals which must operate effectively in the face of high attenuation through building infrastructure. The radiation pattern of a 24 GHz radar for commercial human detection or a 79 GHz automotive radar must be characterized to ensure proper target detection in defined zones. A radome material might be evaluated by placing a sheet between two reference antennas to measure attenuation over frequency. A capable and affordable OTA test system is needed for these projects.

What is an ideal System?

An ideal OTA system should be easy to use, affordable, and have a minimal footprint. The traditional anechoic chamber used for VHF, UHF, and frequencies to 18 GHz is large and expensive.

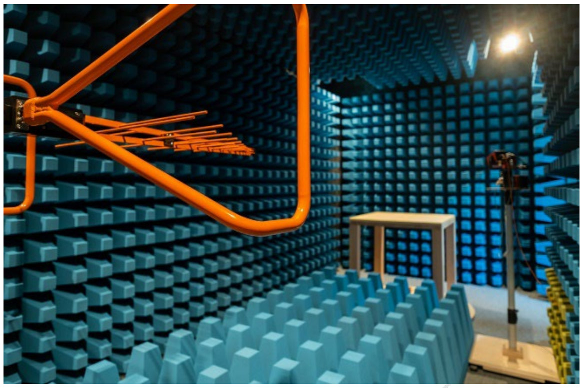

Figure 1 - Anechoic Chamber

The room must be large to accommodate the far-field requirements of these relatively low frequencies [3]. Additionally, it must be shielded from external signals. Metal walls and sealed doors are required. Absorbers must cover the walls to dampen reflections from the metal walls. The cost of a chamber like this is very high indeed, as high as a million dollars. The footprint is large, hundreds of square feet.

Fortunately, for frequencies above 18 GHz, it isn't necessary to shield the measurement with metal walls and the chamber can be much smaller for a far-field measurement of only 235 cm. Milliwave Silicon Solutions created the Millibox system with these

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characteristics and teamed with Copper Mountain Technologies (CMT) to provide a turn-key solution for OTA measurement.

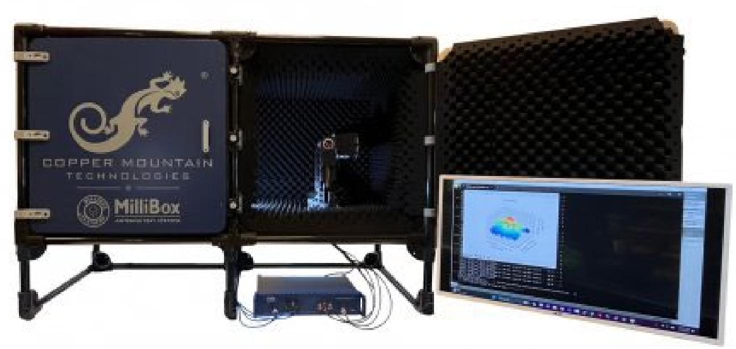

Figure 2 – CMT/Millibox OTA System

The system is composed of two to four cubes in one of two sizes, 24" or 30" on a side. The panels are wood, framed with PVC structural members, and covered with 50 dB anechoic absorbers internally. A reference antenna is held in a rigid frame on the left side, while the Antenna Under Test (AUT) is held in a USB-controlled gimbal on the right side. Python software, provided with the system controls gimbal motion and the provided 9 GHz CMT VNA. Eravant mmWave frequency extenders embedded within the reference antenna frame and AUT gimbal (Figure 3) allow fully automated measurement of antenna characteristics over frequencies from 50 to 220 GHz in bands determined by waveguide size. The reference antenna may also be rotated 90° to allow measurement of the other polarization.

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Figure 3 - Gimbal with Embedded Extender

The system makes far-field measurements, 72 to 235 centimeters, suitable for mmWave antenna characterization. Near-field to far-field conversion is not performed and should not be necessary.

How Does it Work?

The gimbal shown in Figure 3 rotates 360° vertically and horizontally with 0.088° resolution under program control. The User Interface (UI) plots the data in several formats including 1D-Line, H-V Lines, 2D Surface, 2D Heatmap, 2D Multiline Slice, and 3D Radiation Pattern as in Figure 4.

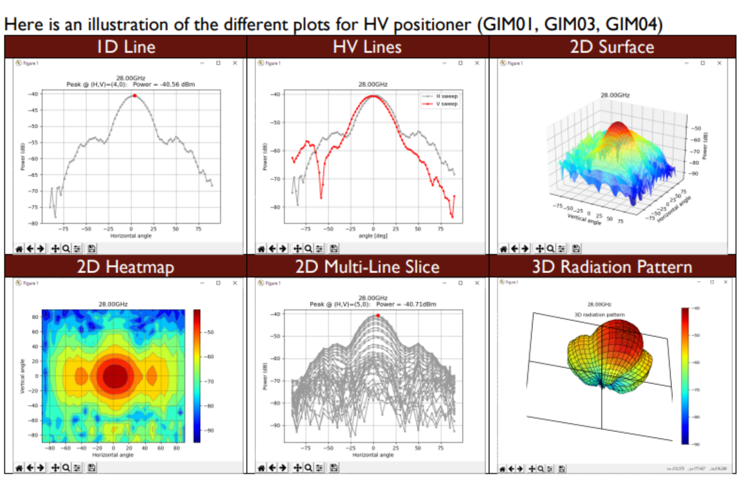

Figure 4 - Output Plots

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The plots may be generated while data is being accumulated or from stored results. An STL file of the 3D radiation pattern may also be created such that a 3D representation of the antenna can be printed.

Figure 5 - 3D Printed Radiation Pattern

The gimbal starts at a programmed vertical start angle and steps horizontally through programmed start and stop angles, making VNA measurements from one antenna to the other at each point, then stepping to the next vertical angle. All data is saved to a CSV file, and the chosen frequency generates the plot in its selected format.

The UI is written in Python and may be customized for particular use cases. Additionally, DLL drivers are provided to allow integration of antenna testing into an existing test framework.

With 50 dB isolation provided by the internal RF absorbers, it’s possible to have two systems side-by-side without detectable interference.

Conclusion

Many industries can benefit from a compact OTA system in applications such as 28 GHz antennas for Fixed Wireless Access, 77 GHz Automotive radar and radome material testing, 60 and 24 GHz human detection radar and others. Universities are experimenting with meta-material antennas for compact designs requiring OTA characterization. Putting all the pieces together to form a test system can be daunting, but Copper Mountain Technologies has made it easy with turn-key systems to meet most needs. Please use the technical articles, videos and webinars on the CMT website that can help make you an expert on VNA technology.

References

1. Shiban K., Using Metamaterials in mmWave 5G Antennas, Microwave Journal, June 13, 2024.
2. Metamaterials' Potential in mmWave 5G Telecommunications and Beyond, Nature, Scientific Reports, Microwave Journal, December 14, 2022.
3. Walker B, Near and Far Field Measurement. Copper Mountain Technologies, September 26, 2022