Robotically Controlled Pattern Measurements of 60 GHz Phased Array Antenna

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***Abstract*— The characterization of antenna radiation patterns in the millimeter wave band are particularly challenging. This is due to the fact that a misalignment of just a few millimeters between the probe and the antenna can generate substantial measurement errors. This paper describes a strategy to reduce measurement errors by introducing a highly precise measurement system using a 6-axis small robotic arm to characterize the performance of a phased array antenna operating at 60 GHz. The position accuracy of the robotic arm itself is approximately 20 μm and a maximum far field distance of approximately 380 mm can be achieved. The robot is programmed to perform a spherical trajectory around the array with stops every 0.5° along the path to gather the measured gain. It operates continuously by communicating with a computer, which triggers the network analyzer at preprogrammed locations. The system is tested initially using a horn antenna as the antenna under test (AUT), and the results are presented.**

I. Introduction

Interest in millimeter-wave antenna arrays has emerged due to continuous increasing demand for high data rate transmission. With the increase of cellular data traffic, wireless communication systems are expected to operate with higher bandwidth [1]. Because of the 7 GHz unlicensed spectrum, the 60 GHz band is of much interest for this type of application.

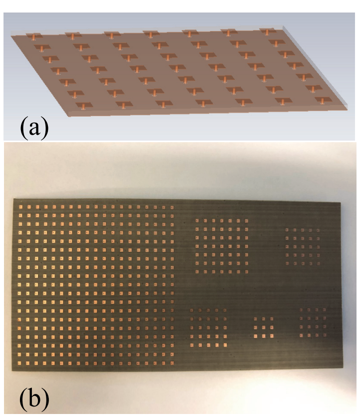

Figure 1. (a) Schematic of the CST Simulated 7 x 7 Array (b) Fabricated PCB antenna arrays.

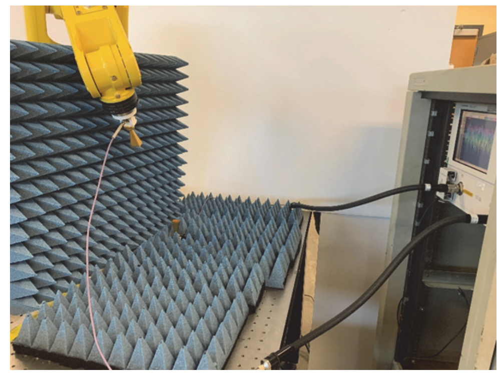

Figure 2. Millimeter-wave robotic pattern measurement setup.

Advancements have been made in the area of phased array antennas to develop new ways to meet such requirements. An example of such antennas have been designed at the ElectroScience Laboratory. These antenna arrays are fabricated on a printed circuit board (PCB) or silicon substrate. In the case of PCB-based phased arrays, via feeding is used for ease of testing and integration with current fabrication techniques [2]. For the antenna under test, the unit cell elements are square patches of 3 mm x 3 mm in size. The substrate material used is for these arrays is RO3003. Figure 1 (a) shows the 7 x 7 array simulated using CST Microwave Studio and Figure 1 (b) shows the fabricated arrays.

The characterization of these arrays is challenging for several reasons. One of the most common hurdles is that with wavelengths of just a few millimeters, the misalignment of the setup can cause major amplitude and phase errors [3]. The frequency of operation of these antennas also causes a significant path loss [2]. The radiation pattern of lower frequency antennas in the ElectroScience Laboratory is typically measured at the anechoic chamber. However, the instrumentation is designed for operation below 40 GHz. Therefore, a more accurate and small system using a robotic arm is proposed for characterizing millimeter-wave antennas. Previously, similar systems have been developed by [4-6] in which robotic arms of different sizes are used for characterizing antennas that operate above 40 GHz. For these systems, the accuracy ranges from hundredths of microns to several millimeters, and the repeatability ranges from approximately 50 µm to 100 µm. The FANUC robotic arm used in this system has both a repeatability and accuracy of approximately 20 µm.

II. Measurement System

The measurement setup is shown in Figure 2. The robot used is a Fanuc LR Mate 200iD. It has 6 degrees of freedom (DOF), an accuracy of 20 µm and a repeatability of around 20 µm. While the maximum reach of the robotic arm is 717 mm, this value is further limited when performing a half circle trajectory, shortening the maximum reach to only 300 mm. For this reason, to achieve far-field distances for some antennas is challenging when using this setup. Robot programming is performed by writing a file with the coordinates and the commands and then loading it to the robot's controller. This program is initially tested using a simulation software from the manufacturer. The trajectory followed for the initial measurements is half a circle with 360 stops around the antenna under test (AUT).

The reference antenna used is a V-band linear horn antenna with a gain of 18-20.9 dBi. This antenna, as shown in the schematic of Figure 3, is attached to the robot using a 3-D printed fixture and connected to a 67 GHz network analyzer using low-loss flexible RF cables. A computer that is constantly receiving the coordinates from the robot triggers measurements in the network analyzer at each of the robot stops.

High performance pyramidal absorbers are used to avoid reflections due to the limitation that the system cannot be placed inside the anechoic chamber. Maximum reflection at normal incidence is expected to be -45 dB. These absorbers are placed on the optical table in front of the robot as shown in Figure 2. Eventually, the robot will also be covered with flexible foam sheet absorbers.

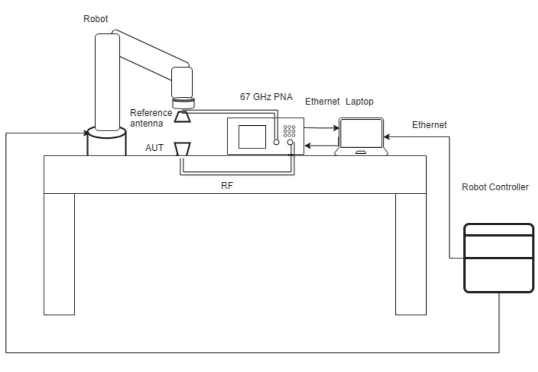

Figure 3. Conceptual diagram of the testing system.

III. Measurement Results

Preliminary measurements are done using two identical standard gain horn antennas. Expected radiation pattern is shown of each horn is shown in Figure 4 (a). The first test is performed in the time domain with the antennas facing each other without moving. The purpose of this test is to strategically place the absorbers around the area to avoid reflections as much as possible. A reduction in S_{11} from approximately -20 dB to -28 dB. Next, a series of tests are carried out by moving the robot to ensure the system is reading the positions correctly and that the VNA is triggered when it is expected to. Finally, *S*-parameters of the horn antennas are captured with a step of 0.5°. The measured radiation pattern is shown in Figure 4 (b). By comparing these results, it can be observed that the measured gain agrees with the expected gain provided by the manufacturer. The only major difference is that as the angle gets closer to 90º and 270º, the measured gain is somewhat higher at some points. This is most likely to reflections from the table and inadequate absorbers on the table.

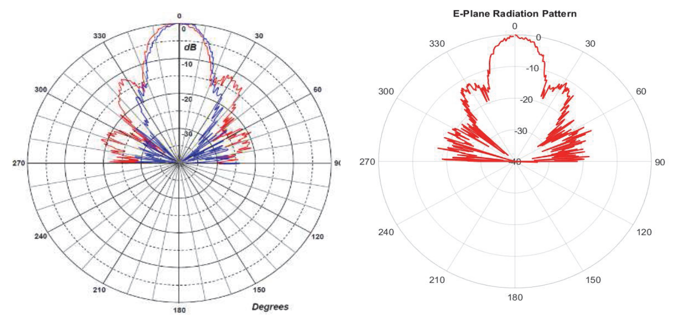

Figure 4. (a) Radiation pattern provided by manufacturer (b) Measured radiation pattern.

IV. Conclusion

A robotically controlled radiation pattern measurement system for 60 GHz antenna arrays is presented. Preliminary radiation pattern results using two identical V-band horn antennas are shown and discussed. Results from the 60 GHz PCB antenna array will be presented at the conference.

V. References

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