Validation of Robotics for Antenna Measurements

Jeff R. Guerrieri, David Novotny, Josh Gordon, Mike Francis, Alexandra Curtin
National Institute of Standards and Technology, 325 Broadway, Boulder, CO 80305 USA, jguerrieri@nist.gov

Abstract **— This paper presents recent measurements using the newly developed Configurable Robotic Millimeter-Wave Antenna (CROMMA) facility by the Antenna Metrology Lab at the National Institute of Standards and Technology (NIST). NIST set out to develop an antenna measurement facility that would be reconfigurable to different near-field antenna measurement geometries and perform antenna measurements from 100 to 500 GHz. The positioning capability of the robot has been evaluated and spherical near-field measurements performed at 183 GHz. Spherical far-field and extrapolation measurements have been performed at 112, 118 and 125 GHz. Spherical near-field measurements have been performed at 118 GHz on a CubeSat feed horn and compared to simulated results. Finally, the concept of multiple robot antenna measurement facility is discussed.**

Index Terms **— robotic arm, millimeter wave, spherical near-field, extrapolation technique.**

I. Introduction

The explosion of mobile communications demands more data and is pushing the industry into the millimeter wave (mmwave) spectrum. This also increases the demand for accurate mmwave antenna measurements. To address this demand, the National Institute of Standards and Technology (NIST) developed a new robotic arm scanning system to perform near-field antenna measurements at mmwave frequencies above 100 GHz. The goal of this work was to develop a configurable platform that can perform different measurement geometries with minimal setup and have dynamic probe position correction to 0.02λ at frequencies above 100 GHz [1].

II. CROMMA Facility Components

The **C**onfigurable **RO**botic **M**illi**M**eter-wave **A**ntenna (CROMMA) facility shown in Fig. 1 uses two robotic positioners and one rotary positioner. [2,3]. The robotic arm uses a serial kinematic model that consists of six rotation joints connected in series by ridged linkages. This allows for six degrees of freedom (6DoF), x, y, z, roll, pitch and yaw, positioning of the probe. The robotic arm has a 2 m reach which spans a spherical volume of ~ 1 m radius. CROMMA is capable of extrapolation, planar, spherical, cylindrical, and mixed-geometry scanning. The position and orientation information provided by a laser tracker are used along with spatial metrology software to assess the quality of the alignment and provide information for the implementation of dynamic position and orientation correction, and post processing correction algorithms [4].

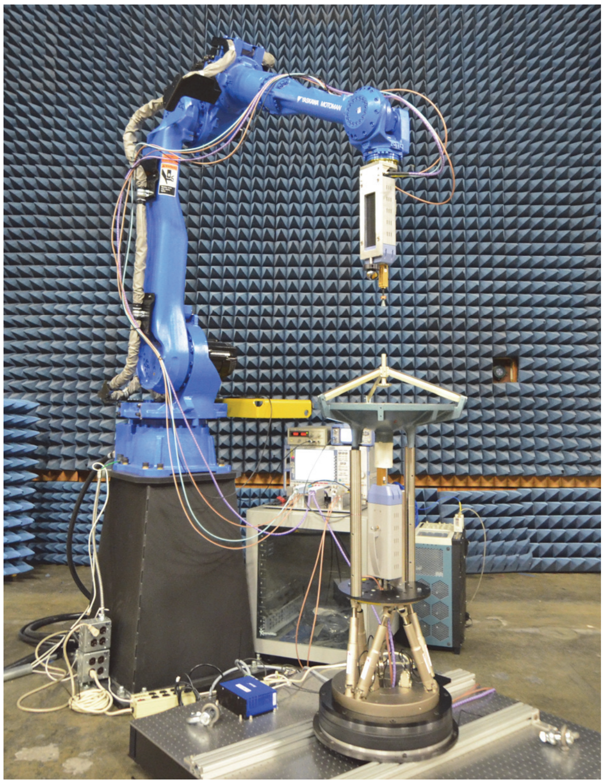

Fig. 1. CROMMA facility positioners. Serial 6DoF robotic arm, parallel 6DoF hexapod, precision rotary stage, probe and test antenna.

III. Measurements and Results

Antenna measurements have been made in various geometries in mmwave bands at NIST to exercise the ability of CROMMA and verify its capability.

Spherical near-field measurements were performed on a WR-5 standard gain horn at 183 GHz at a radius of 10 cm and compared to a theoretical model and far-field measurements with favorable results [2]. Fig. 2 and Fig. 3 are the comparison of the E- and H-plane far fields, respectively, for: (1) measured at 100 cm, (2) transforming the 100 cm data to the 'true' far field, (3) theoretical, and (4) transforming the 10 cm near-field data to far field.

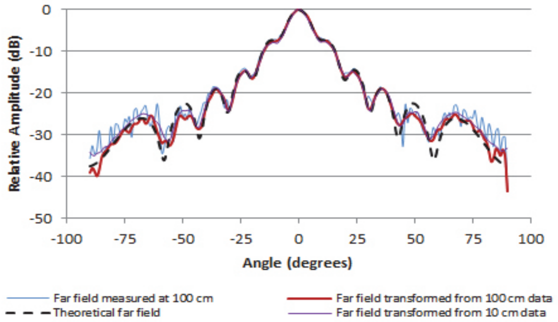

Fig. 2. E-plane far field comparison.

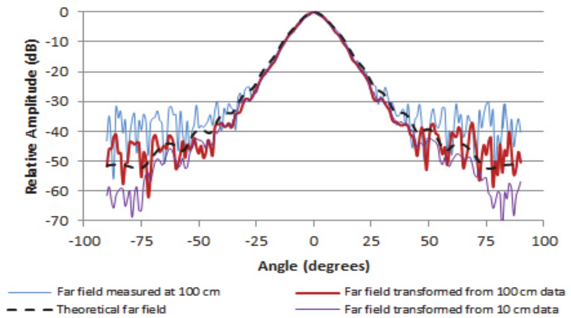

Fig. 3. H-plane far field comparison.

Spherical far-field measurements were performed at three frequencies, 112, 118, and 125 GHz, for a μ=±1 probe at 100 mm, which corresponds to $4D^2/\lambda$. Sample co- and cross-polarization results are shown in Fig. 4. In this case, χ = 0° corresponds to the co-polarization and χ = -90° corresponds to the cross polarization. The co-polarization peaks agree within ±0.5 dB. The cross polarization data are generally below the -40 dB level, which is the detectable limit for the measurement system [5].

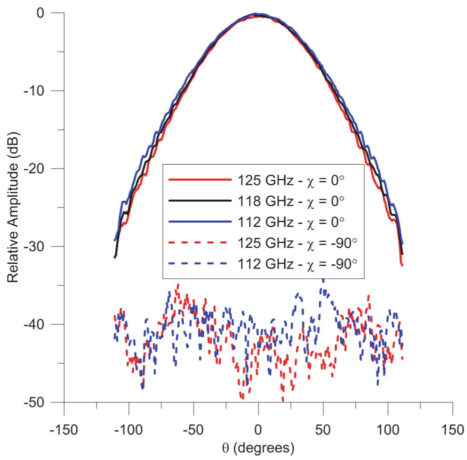

Fig. 4. E-plane pattern at a separation distance of 100 mm for three frequencies. The solid lines correspond to the co-pol patterns and the dashed lines to the cross-pol pattern.

The three-antenna extrapolation method is used to determine the gain of the μ=±1 probe along with two standard gain horns at 118 GHz without having a priori knowledge of any of the antenna gains [5]. This pair gain is derived from the leading term of a power series fit to the data in $1/r^n$ [6]. Here r is the separation distance between the two antennas. Sample extrapolation results are shown in Fig. 5. The smoothed data in Fig. 5 come from averaging data over a wavelength to account for multiple reflections between the two antennas. A pair gain of 24.69 dB was determined from these measurements. The data span a range of $2D^2/\lambda$ to $24D^2/\lambda$ (where D is the diameter of the largest antenna).

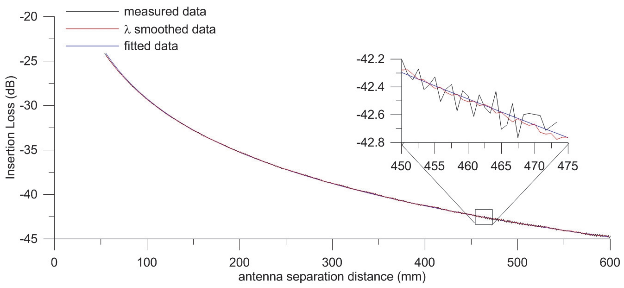

Fig. 5. Plot of extrapolation data at 118 GHz for the μ=±1 probe versus a 15 dBi standard gain horn.

Spherical near-field measurements were performed on a CubeSat feed horn with a 17 degree offset at 118 GHz. The transformed far field for the measurements and simulated far field are shown in Fig. 6.

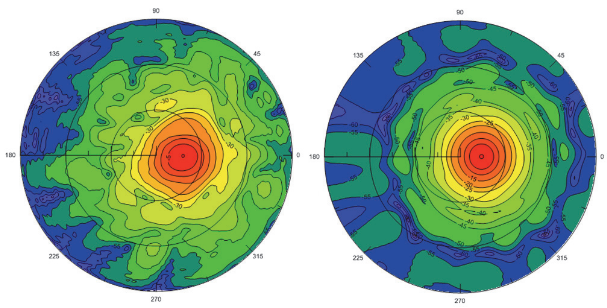

Fig. 6. Far field pattern of CubeSat feed horn at 118 GHz from near-field measurements, (left), and simulated (right).

IV. Future Multiple Robot System

A multiple robot facility using the CROMMA technology is being developed at NIST. Fig. 7 is a conceptual drawing that shows one stationary robot and one attached to a cart on a rail system that will all be integrated to operate as one system. The rail system will offer 7 m of travel to expand the extrapolation technique past the articulated reach of a single robotic arm. It will still support the three traditional near-field measurement geometries (planar, spherical and cylindrical). More importantly the multiple robot system provides the ability to actively track multiple beams and perform dynamic beamforming characterizing of electronically steerable array antenna systems.

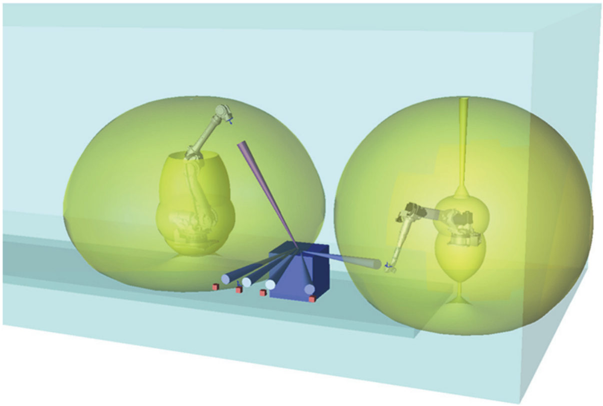

Fig. 7. NIST proposed multiple robot antenna measurement system.

V. Conclusion

NIST has demonstrated the viability of using commercial available robotics, guided by laser trackers and other metrology equipment to perform quality antenna testing.

This paper shows measurement results that demonstrate the successful integration of an industrial robot and positioners with a laser tracker that monitors and corrects the relative position and orientation of the probe. Using position correction feedback and spatial analyzer software the system can provide adequate positioning for antenna measurements in different measurement geometries for frequencies above 100 GHz. Finally, the paper introduces the concept of a multiple robot antenna measurement facility that would support performance testing of communication antenna systems in real world environments.

References

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