Millimeter-Wave High Multipath Channel Measurements

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Abstract

We provide the frequency response of a high multipath propagation channel using a narrow beamwidth synthetic aperture measurement technique from 26.5 – 40 GHz.

1 Introduction

A high multipath channel provides a unique challenge for the development of millimeter-wave (mmWave) fifth-generation (5G) communication systems. The effects of a mmWave propagation channel on a signal requires further understanding. Quantifications of the propagation channel of more intricate channel environments such as high multipath are progressing by such groups, such as the 5G mmWave Channel Model Alliance [1,2].

At the National Institute of Standard and Technology (NIST), we undertook a channel measurement study in a high multipath scenario by measuring a small utility plant [3] on the Boulder, Colorado campus. We were interested in observing the channel behavior across a wide frequency range of 26.5 – 40 GHz between a stationary transmitter (Tx) and a synthetic aperture receiver (Rx).

2 High Multipath mmWAve Measurements

A key feature of our measurement campaign is the Synthetic Aperture Measurement with UnceRtainity and Angle of Incidence (SAMURAI) system. We provide a complete description of this system in [4]. The basis of the SAMURAI measurement technique is a vector network analyzer with complete quantified uncertainty. SAMURAI uses the synthetic aperture technique to create a virtual phased-array with a single antenna on a robotic arm. The robotic arm scans the Rx antenna across the channel at specific spatial positions. As seen in Figure 1, we can steer the Rx beam to specific angles by coherently adding up the received signals [5], allowing us to look at specific scatters in the propagation channel with post-processing.

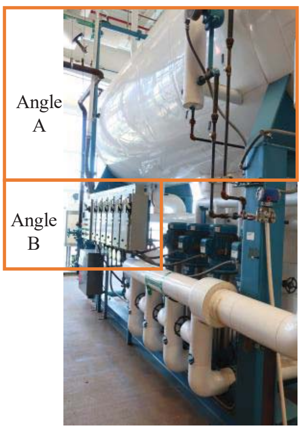

Figure 1: Scatters for Angle A and B are circled in orange.

We conducted the measurements at the NIST utility plant. The plant is a medium-sized steam plant with the floor plan in Figure 2. This plant is on the NIST Boulder campus and contained large machineries such as boilers and multiple overhead pipes. The boiler floor dimensions are approximately 20 m x 80 m, with a ceiling height of approximately 7.6 m. During the measurement campaign, we pointed the Tx antenna upwards to capture scattering from the boilers as well as a bank of control boxes, as seen in Figure 2.

A single SAMURAI measurement occurs over 24 hours. We discussed with the plant's management reduction of personnel movement near our measurements. We monitored the plant for movement, temperature, and humidity during this time. In the future, we plan on investigating the effects of this movement on our measurements.

The SAMURAI input measurement parameters are frequency range of 26.5 – 40 GHz with $\lambda/2$ Rx antenna spacing at 40 GHz. The SAMURAI's synthetic aperture was a 35 x 35 antenna positions. The synthetic aperture Rx has a 3-degree beamwidth at 40 GHz. In post-processing, we removed the complex pyramidal horn antenna response,

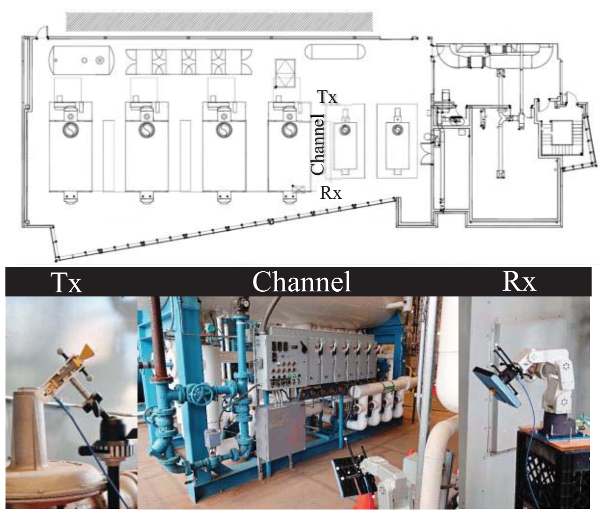

Figure 2: Small utility plant (a) floor plan and (b) measurement set-up.

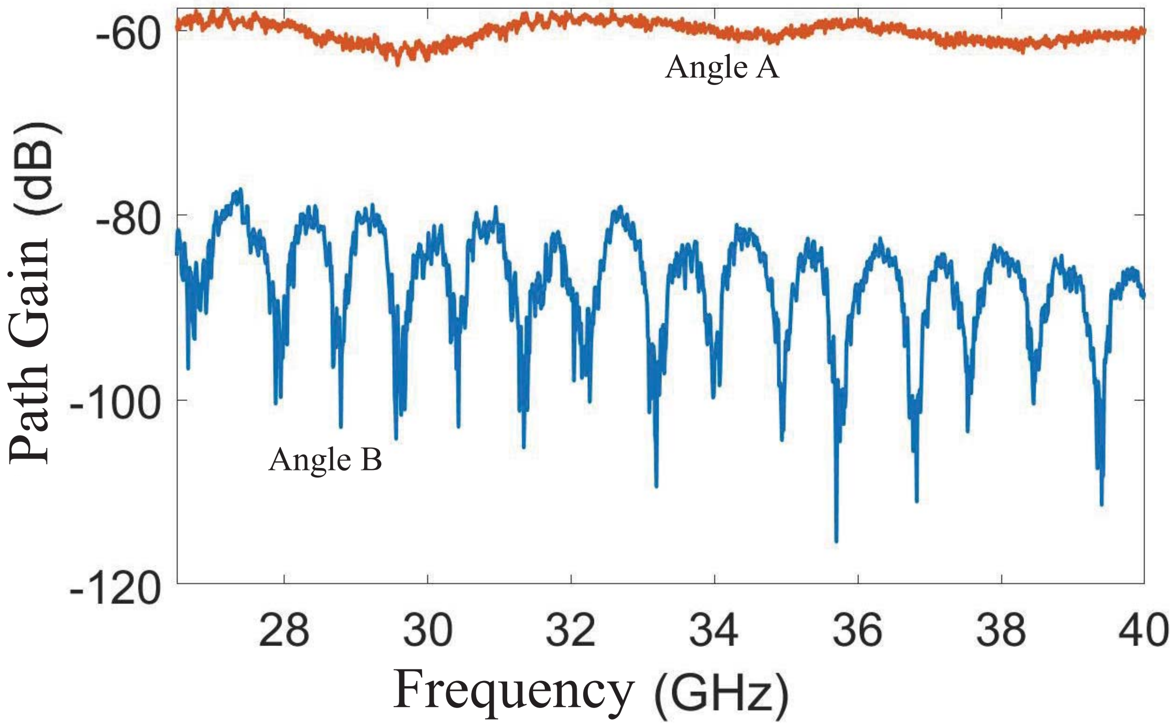

Figure **3**: The high multipath propagation channel path gain frequency response provided for the metal tank (Angle A) and bank of control boxes (Angle B).

computed from an analytical model [6]. The measurement uncertainties include the mechanical standard calibration kit. We attempted to include uncertainties due to VNA drift. However, the long measurement time combined with the fluctuating environment led to unrealistic results in our initial attempt. We plan to add this uncertainty contribution as well as uncertainties due to the de-embedding of the antenna complex measurement response, positional uncertainties, and reflections from the robotic arm.

3 SAMURAI Measurements versus Angle

We provided the path gain frequency response from the metal tank, shown as Angle A in Figure 3, respectively. These frequency responses have a distinct angle dependence. From a visual inspection, the metal tank response appears to have a single dominant channel path. Scattering from the metal tank is very similar to scattering from a large metal cylinder. This cylinder is electromagnetically large with respect to the measurement wavelengths. It interesting to see that it maintains a constant mean value of -60.2 dB and a standard deviation of ± 1.1 dB [7] over this frequency range. It is important to note that this dominant path result may be a ramification of the 3-degree beamwidth of the synthetic aperture. This narrow beamwidth spatially filters and reduces any incoming off-angle paths. A larger beamwidth receiver system may have different results.

Angle B is the path gain frequency response from the control boxes in Figure 3. Unlike the response from the metal tank, this measurement appears to have multiple dominant paths. These paths are constructing and deconstructing with one another. The constant mean value is -87.5 dB with a standard deviation ± 5.8 dB over the entire frequency range. The multiple interfering paths have increased the standard deviation, as expected.

4 Conclusion

We provided the path gain measurements versus angle and frequency range for a high multipath channel. For the Angle A and Angle B measurements, it appears that only a few paths dominant and not multiple dominant paths for a narrow beamwidth synthetic aperture receiver.

5 References

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