Directional Measurements in an Indoor Corridor under Line-of-Sight Conditions at 140 GHz

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***Abstract*—Achieving adequate coverage with high-gain antennas is crucial for fully utilizing the mmWave and sub-THz bands. This study reports indoor measurements at 140 GHz in Line-of-Sight (LOS) conditions within a corridor using a narrowband channel sounder. A 10° (24 dBi) receive horn antenna on a rotating platform and a 50° (10 dBi) transmit antenna were used. Path gain was modeled with a power-law, yielding an RMS error of 1.75 dB. Scattering degraded azimuth gain by up to 2.82 dB in the corridor with 90% probability.**

Keywords—indoor, 140 GHz, sub-THz, corridor, directional antenna.

I. Introduction

The sub-Terahertz (sub-THz) band (100-300 GHz) offers promising potential for Tb/s data rates due to its vast spectrum, making it ideal for 6G indoor systems. However, challenges like high path loss, dynamic blockages, and limited coverage—typically within hundreds of meters—require highly directive antennas to mitigate these effects, especially in the first meter of propagation. Yet, multipath propagation reduces their effective antenna gain. As indoor environments demand shorter transmission ranges with both line-of-sight (LOS) and non-line-of-sight (NLOS) paths, understanding sub-THz channel characteristics is critical for developing accurate models and supporting their adoption [1].

It is crucial to quantify the gain achieved by highly directive antennas, as this gain is essential for offsetting the increased frequency-related losses at sub-THz frequencies. Recent studies in indoor corridor environments at 140 GHz have primarily focused on path loss and delay spread [1][2]. However, there is a lack of research on the effectiveness of directional antennas in these settings, leaving a gap in understanding their performance at sub-THz frequencies. To the best of the authors' knowledge, the available reference measurements for sub-THz communications that statistically quantify the actual gain of directional antennas in indoor environments, based on a substantial amount of collected data, remain limited.

II. Measurement Description

A. Measurement Equipment

To accurately characterize the effective gain of a directional antenna at 140 GHz in indoor environments, Pontificia Universidad Católica de Valparaíso (PUCV) developed a continuous wave (CW) sounder. This system includes a directional antenna with a 10° half-power beamwidth (HPBW) and a 24 dBi gain, mounted on a rotating platform. The receiver data is collected using a portable spectrum analyzer (6–170 GHz) with a noise figure of 55 dB on the receiver side. On the transmitter (Tx) side, a signal generator produces a CW signal with an output power of 20 dBm, through a horn antenna with a half-power beamwidth (HPBW) of 50° and a gain of 10 dBi.

B. Measurement environment

Measurements were conducted in one of the buildings at Universidad Técnica Federico Santa María (UTFSM). The building features a 60-meter-long corridor, 2.74 meters wide, flanked by offices, classrooms, and laboratories. The interior walls are composed of a mixture of sheetrock and concrete.

The **Corridor-to-corridor** (LOS) measurements were taken in a straight-line corridor environment under line-of-sight (LOS) conditions. We fixed the transmitter equipment (Tx) at the beginning of the corridor and move the receiver equipment (Rx) for 47 m. Both equipment were always placed in the middle of the corridor at a 1.66 m height. We conducted measurement campaigns with a distance between Tx and Rx of 1 m for all links.

III. Results

A. Path Gain measurements in Corridor

For our path gain results, we estimate the effective path gain (PG) by considering the transmitted power(P_{Tx}), the received power across all directions (P_{all}), and the gains of both transmitter (G_{Tx}) and receiver (G_{elev}) antennas, using (1). We assume that the azimuthal average of the received power (P_{all}) corresponds to the spatial average of the power received by an omnidirectional antenna.

$$PG = 10\log_{10}(P_{all}) - P_{Tx} - G_{Tx} - G_{elev}\ [dB] \qquad (1)$$

The validation of (1) assumes that the elevation gain of both the transmitter (Tx) and receiver (Rx) antennas remains unaffected by scattering. This assumption has been confirmed through our measurement results and is supported by [3]. To ensure the accuracy of the power measurements, the system was calibrated both in the laboratory and in an anechoic chamber.

The measured path gain values in Corrido-Corridor (CC) depend on the distance x in LOS, and were well represented by the power law [4], as indicated by (2):

$$PG_{CC} = P_1 + 10n\log_{10} d + X_\sigma \qquad (2)$$

where d denotes the distance in meters between the antennas, P_1 is a fixed intercept at 1 m based on the Friis free-space formula in dB, n is the path loss exponent (negative path loss in dB), and X_σ is the zero-mean random deviation from the linear fit, i.e., the root-mean-square modeling error (RMSE) in dB.

We present our measured data and the fitted model in Fig. 1. For comparison, we also included the models according to [1] and [2] (blue and green dashed models), with RMSE values of 5.76 and 3.59 dB, respectively. Table 1 shows the parameter values of our model, the comparison models, and their respective RMSE values.

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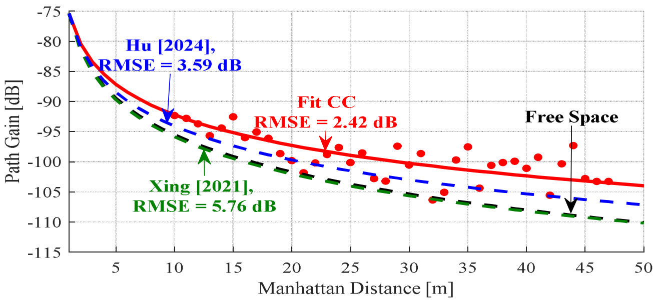

Fig.1. Path Gain data for coverage in corridors (red dots), adjusted Corridor-Corridor model (red), model with parameters defined by [1] (green), model with parameters defined by [2] (blue), and the Friis equation (dashed in black).

TABLE I
Summary of fitting parameters of the fit model for Corridor-Corridor, the comparison models, and the RMSE values.

Model	Intercept P_1	Exponent n	RMSE [dB]
CC LOS	-75.38	$n = -1.68$	2.42
[1]	-75.38	$n = 2.05$	5.76
[2]	-75.38	$n = 1.80$	3.59

The slope with distance is slower than the power of 2 ($n = -1.68$ dB) expected in free space, consistent with the orientation of the corridor waveguide (as per [2][4]). This observation aligns with findings at 28 GHz based on measurements conducted in the same corridor [4]. In contrast, studies in LOS environments at 140 GHz over short distances (1-12 m) showed slope values equal to 2 [1][5].

The RMSE difference between our corridor-corridor (CC) model and the other models is 3.34 and 1.17 dB, indicating that our model achieves a lower RMSE, effectively representing and estimating the path gain. It is important to note that Xing's study [1] used 9 data points, and Hu's study [2] used 23 points, both significantly fewer than the dataset we collected. A massive amount of data is crucial for a robust characterization of the wireless channel.

B. *Azimuth Gains analysis*

To mitigate the high propagation losses in sub-terahertz bands, high-gain antennas are essential. The effective antenna pattern is the result of convolving its nominal pattern, measured in an anechoic chamber, with the channel angular response. This process diminishes the effective gain while broadening the antenna's effective coverage. The azimuthal gain is defined as the ratio of the maximum power to the average power over all azimuth angles [4] as shown in (3):

$$Azimuth\ Gain = \frac{max_{\varphi} P(\varphi)}{(1/2\pi)\int_0^{2\pi} d\varphi\, P(\varphi)}. \quad (3)$$

The distributions of the measured azimuth gains are shown in Fig. 2. The shaded regions represent the 90% confidence intervals, while the vertical black line marks the 14.6 dB azimuth gain measured in an anechoic chamber. For reference, gains from a fully scattering environment (Rayleigh amplitude distribution) are also provided, where the 10° wide antenna beam gains solely from angular selection diversity. The degradation of the 10th percentile azimuth gain relative to the ideal (14.5 dBi in an anechoic chamber) is about 2.82 dB when both the transmitter and receiver are in LOS corridor conditions.

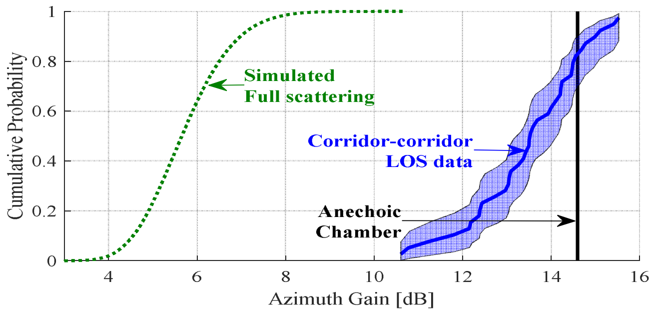

Fig.2. Distribution of observed effective azimuth gain for corridor-corridor data.

IV. Conclusions

This study provides a comprehensive analysis of 140 GHz signal propagation in indoor corridor environments under line-of-sight (LOS) conditions, using high-gain directional antennas. Our measurements, conducted with a narrowband channel sounder, show that path gain in LOS corridors is well-represented by a power-law model with a low RMSE of 1.75 dB. Obtainable azimuth gain, measured in the corridor, was found to be degraded by no more than 2.82 dB in 90% of locations, with 90% confidence. These findings are critical for optimizing antenna placement and beamforming strategies in future high-frequency indoor wireless communication systems, contributing valuable empirical data for 6G studies and results. The measurable path loss with our measurement system extends up to 160 dB with directional antenna gains. For future work, we intend to perform measurements in indoor environments of perpendicular corridors to analyze diffraction loss and in corridors to workshops to analyze path gain in non-line-of-sight conditions.

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