

Characterizing EVM and SINR in mmWave Communication Link with Common Indoor Materials

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Abstract—This paper investigates the 28 GHz communication link propagation characteristics in an indoor environment, focusing on line-of-sight (LoS) effects caused by materials like human body, glass, wood, and drywall. Unlike traditional setups, our measurements use a real-life scenario with commercial beamforming transceivers at a 4m distance. Results, including key metrics like EVM, spectrum, and SNR, demonstrate the impact of these materials at 28 GHz. Using a modulated signal for real-world simulation, our findings provide insights into signal distortion and modulation scheme sensitivity in uncontrolled indoor settings, aiding the design of mmWave wireless communication systems.

I. INTRODUCTION

Millimeter-wave (mmWave) communication is a key technology for 5G and 5G-Advanced wireless networks, leveraging its broad spectrum for achieving remarkable data rates [1], [2]. Particularly, the 28 GHz band stands out as a critical technology for diverse applications, including augmented reality (AR), virtual reality (VR), high-definition (HD) video streaming, and Internet of Things (IoT) devices [3]. Nevertheless, mmWave signals encounter challenges in indoor settings, contending with impediments like walls and human bodies [4].

While research on mmWave propagation beyond the 5G era remains limited [5], recent studies, such as those spanning the 19, 28, and 38 GHz frequency bands in an indoor corridor, underscore the importance of understanding path loss results fitted to functions like CI, FI, CIF, and ABG. Our paper contributes a distinctive Over-The-Air (OTA) study at 28 GHz in indoor environments. Unlike conventional OTA measurements using continuous wave (CW) signals, our approach employs modulated 16-QAM baseband signals to evaluate the impact of diverse materials on key performance indicators (KPIs) like Error Vector Magnitude (EVM) and Signal-to-Noise Ratio (SNR). Through comprehensive empirical studies, our objective is to offer practical insights and solutions that enhance the reliability and efficiency of mmWave wireless links, paving the way for their seamless integration into Beyond 5G and 6G applications.

II. INDOOR RADIO PROPAGATION MEASUREMENTS

This section introduces the 28 GHz wireless channel, outlining its capabilities and essential details for understanding experiments on the OTA communication links. Link performance was assessed with various indoor components, including the human body.

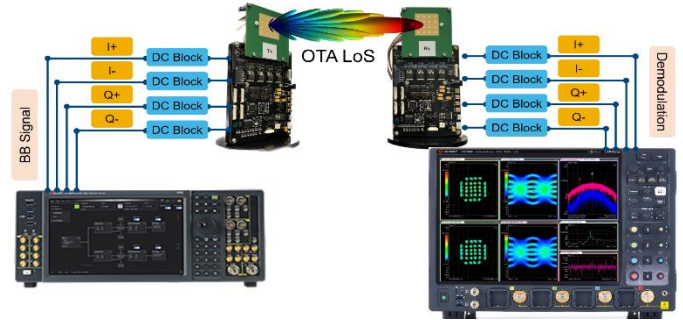


Figure 1. The experimental setup consisting of 200 MHz OTA RF link at 28 GHz for evaluating the propagation losses. The TX and Rx consists of 16 dual polarization antennas and placed at a 4 m distance.

A. Measurement Setup

The mmWave beamforming RFICs used in our experiments are Siivers IMS modules based on the TRB02801 transceiver IC, supporting the 24.25–29.5 GHz frequency range with a throughput of 5 Gbits/s [6]. The RFIC integrates LO synthesizer, up/down converter, and beamformer blocks, supporting 2×2 MIMO layers with a 4×4 antenna array for 2D beam steering. Our setup involves two beamformer transceivers operating at 28 GHz, Tx and Rx, transmitting a 16-QAM modulated signal with a 200 MHz bandwidth for high-resolution measurements. The Tx array generates the signal using a Keysight M8195A AWG, and the Rx array, connected to a Keysight VXG M9484C vector generator, demodulates and analyzes the received signal with Keysight UXG running VSA 89600 software.

In our experiment the Tx is placed 4m from the Rx to create a LoS scenario, assessing signal degradation caused by materials in indoor environments (Figure 2). The choice of 28 GHz frequency allows accurate LoS measurements, and the 200 MHz bandwidth enables wideband signal evaluation.

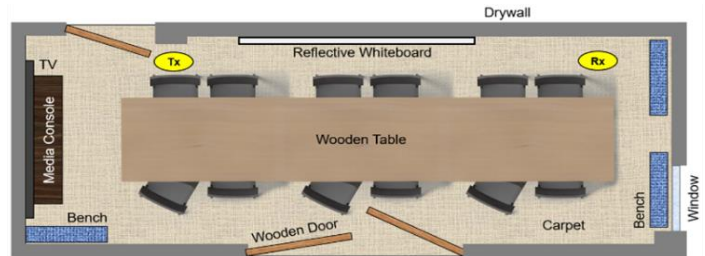


Figure 2. The indoor measurement setup at 28 GHz, showing an arbitrary indoor environment, which can include different components depicted on the picture. Tx and Rx are 4m spaced.

Modulated signals, rather than CW signals, provide a realistic representation of wireless communication scenarios, assessing the impact of varying channel conditions on link performance through EVM and SNR analysis. Optimal measurements require adjusting parameters in the mmWave RFIC using custom Python scripts. Tx parameters include power amplifier gain, attenuator, filter settings, and polarization adjustments, while Rx adjustments focus on low-noise amplifier gain, RF and baseband gain, and filter settings for optimal performance. Equalizers on the receiving side ensure desired outcomes.

B. Utilizing Common Indoor Materials

The analysis investigates the propagation loss impact of various indoor materials at 28 GHz, including ceiling tiles, clear glass, drywall, plywood, metal sheet, human body, and a leather office chair. The setup maintains a 200 cm distance from the Tx and Rx to the materials to minimize diffraction and edge scattering. This distance aligns with far-field criteria, ensuring consistent radiation patterns. Geometric calculations confirm main lobe projections within material dimensions to prevent diffracted signals or strong multipath components reaching the Rx. Broadband pyramidal absorbers (24"×12"×4") near the Tx minimize reflections. A calibration process establishes an OTA baseline, achieving a robust 2.6% EVM and clear demodulation. Optimized parameters from calibration assess common materials' impact on link performance in LoS conditions (Table I).

TABLE I. TABLE OF MATERIALS AND THEIR THICKNESSES.

Index	Material	Thickness (in.)	Index	Material	Thickness (in.)
A	Human body	30	I	Leather bag	0.5
B	Bubble wrap	0.05	J	Acoustic Panels	0.75
C	3-layer bubble wrap	0.15	K	Plastic 1-layer	0.1
D	Styrofoam Sheet	0.5	L	Plastic 3-layers	0.3
E	Styrofoam Sheet	2	M	Rubber matt	0.5
F	Cardboard	0.25	N	Glass	0.25
G	Standard MDF	0.75	O	ESD Mat 3-layers	0.6
H	Metal Sheet	0.05			

C. Results and Discussion

The analysis primarily focused on two KPIs: EVM and SNR. EVM represents signal accuracy relative to the ideal signal, while SNR measures signal quality amid noise and interference. Monitoring these metrics allowed assessing the impact of materials (wood, human body, drywall, and glass) on modulated signal performance, revealing varying levels of signal distortion and phase noise. Figures 3(a) and 3(b) display the IQ signals with material index-A (human body) and index-N (Glass), while Figure 3(c) shows the received baseband spectrum at 28 GHz with a 200 MHz signal, and Figure 3(d) represents the measured CCDF probability.

Figure 4 illustrates the EVM and SNR performance of various materials listed in Table I. Materials with high electrical conductivity, like metal sheet (H), exhibit significant signal distortion (EVM > 20%) and a sharp SNR reduction below 10dB, emphasizing the impact of surface conductivity b-

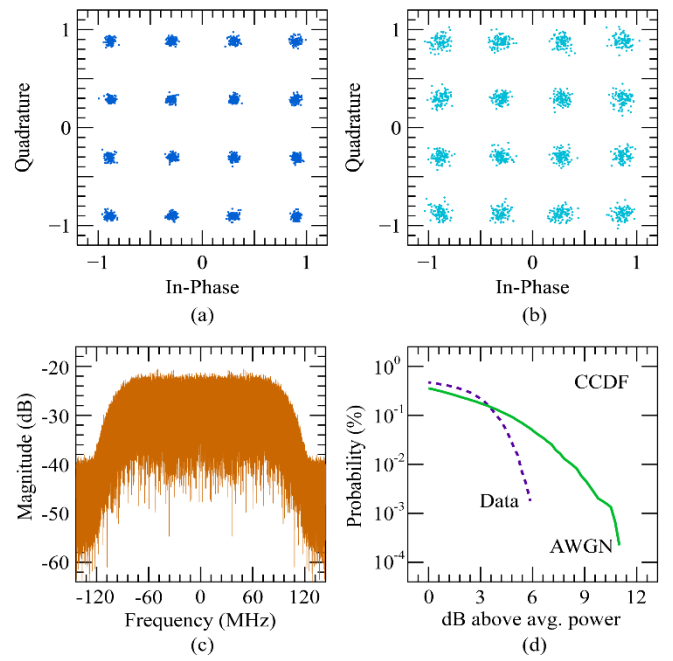


Figure 3. Measured (a) IQ response of index-A, (b) IQ response of index-N, (c) 200 MHz spectrum at receiver, and (d) CCDF.

elow 10dB, emphasizing the impact of surface conductivity on wave interactions. This underscores the need for advanced signal processing in mmWave communication systems. The results offer crucial insights into signal quality in LoS scenarios at 28GHz, highlighting the importance of sophisticated beamforming techniques to mitigate multipath interference from highly reflective materials. Conversely, materials like leather (I) and glass (N) demonstrate superior EVM and higher SNR, positioning them as favorable choices for maintaining signal integrity.

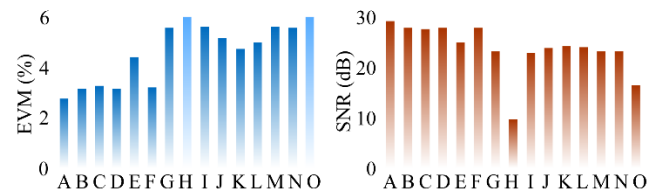


Figure 4. RF link characterization using various materials.

REFERENCES

- [1] E. Torkildson, U. Madhow and M. Rodwell, "Indoor Millimeter Wave MIMO: Feasibility and Performance," IEEE Trans. Wireless Comm., vol.10, no. 12, pp. 4150-4160, Dec. 2011.
- [2] C. Meisch, "FCC adopts rules to facilitate next generation wireless technologies," Technical Report. [Online]. Available: <https://www.fcc.gov/document/>
- [3] Y. Xing et al., "Indoor wireless channel properties at millimeter wave and sub-terahertz frequencies," in GLOBECOM, Dec. 2019, pp. 1-6.
- [4] N. Hosseini et al., "Attenuation of Several Common Building Materials: Millimeter-Wave Frequency Bands 28, 73, and 91 GHz," IEEE Ant. Propag. Mag., vol. 63, no. 6, pp. 40-50, Dec. 2021.
- [5] A.M. Al-samman, T.A. Rahman, M.H. Azmi, "Indoor Corridor Wideband Radio Propagation Measurements and Channel Models for 5G Millimeter Wave Wireless Communications at 19 GHz, 28 GHz, and 38 GHz Bands," Wireless Commun. Mobile Comput., 2018, pp. 1-3.
- [6] Sivers IMA. EVK02001 28GHz Eval Kit.(2023). <https://www.siversima.com/product/evk-02001-00/>