mmWave Indoor Blockage Solution: High/Low Gain Switching

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***Abstract*—Indoor blockage in a mmWave (millimeter wave) wireless communication link introduces significant signal attenuation. Solving the blockage problem is a key to enable the under licensed 60 GHz band spectrum. This work used various V-band horn antennas to collect signal measurements in an indoor lab environment. As an object blocks the Tx-Rx LOS (Line of Sight) path, the signal fades deeply. Results showed that switching to a wider beam with lower gain, albeit not efficacious as LOS, it still have the potential to restore or maintain a communicating link. Beam switching to a wider beam allows fast beam search and shortens the deep fading which is crucial for mmWave communication systems that are very sensitive to the spatial signature of the environment.**

I. Introduction

Enabling the 60 GHz band Gbps data rates can achieve the anticipated yearly 130 exabit share of mobile data per subscriber in the coming few years [1]. One of the obstacles that need to be addressed in this pursuit is the reliability of point to point links using high gain narrow beam antennas or antenna arrays [2], [3]. Human blockage, for example, can result in more than 20 dB shadowing attenuation that can last for more than 100 milliseconds [4]. These observations motivated this work to address this issue by analyzing indoor blockage in the mmWave regime links and by providing an efficient solution through beam switching. Our contribution is in using a Network analyzer based measurement setup for analyzing beam switching performance at one or both sides of the transmission link observing the effectiveness of wider beams to recover a blocked link. Beam switching to a wider beam allows fast recovery of the signal before reapplying 2^{nd} level of pencil beam steering to achieve the high possible data rates at mmWave links that are almost interference free and utilize a relatively wide bandwidth. The rest of the paper is organized as below: Section II cites the related work. Section III shows the experiment setup we used to collect measurements. Section IV depicts and analyzes our results. Section V concludes this work.

II. Related Work

mmWave blockage analysis and avoidance have been extensively investigated recently. In fact it is one of the key problems that need to be solved to enable the Gbps promise of mmWave communication. The work in [5] explained that blockage avoidance in an outdoor setting can be done by tracking LOS and multipath reflections, and by switching to other base stations in a dense pico cell network. Indoor work can take advantage of the reflective indoor environment to provide mulitpath sources for NLOS beam search. The authors of [6] proposed adaptive beamwidth for blockage avoidance where they emulated a variety of beamwidths using absorbers without specifying the exact gain which can drastically change by the absorbers. In our work we used horn antennas with known gain and beamwidth characteristics. The work in [7] utilized a phased array with controllable steering to combat blockage at 60 GHz frequecies in an indoor lab environment. Our work used a Network Analyzer for collecting measurements using horn antennas with a focus on beam switching rather than beam steering as fast beam steering algorithms at both Tx and Rx are being investigated in the research community. The work in [4] is an outdoor experiment that analyzed the effect and the time duration of the blockage caused by pedestrian crowds. Our work focuses on the indoor environment as we

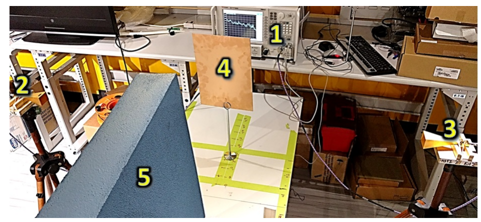


Fig. 1. Measurement setup: 1. Network analyzer 2. Horn Antenna 3. Horn Antenna 4. 23×31 cm^2 Copper Sheet 5. Absorber

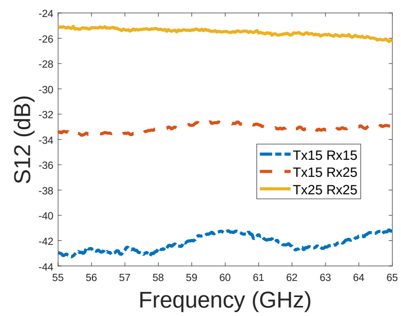
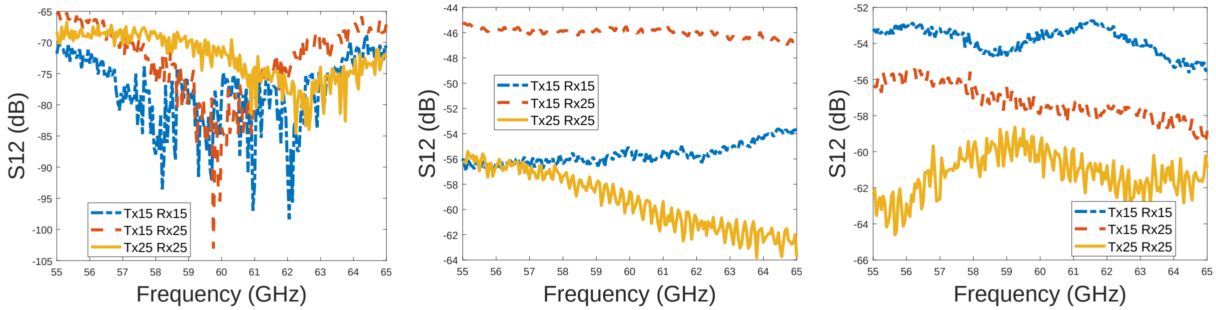


Fig. 2. LOS. The legend [15, 25] correspond to [15, 25] dBi gains



(a) No reflector (b) reflector at 5 cm (c) reflector at 10 cm

Fig. 3. S12 measurements. 15 and 25 legend text correspond to antenna gains of 15 dBi, 25 dBi respectively

believe it will be the environment of initial deployment for 5G mmWave based nodes and devices.

III. Measurement Setup

In this work we aimed at taking measurements in the 55-65 GHz band, which includes the 60 GHz band, using a Network Analyzer with 5 dBm port power. We set various horn antennas of 25, and 15 dBi at both ports. The antennas were fixed on 2 tripods that are 5ft apart. The measurement took place in the DWSL (Drexel Wireless Systems Laboratory) to represent our indoor environment. We measured LOS S12 parameters before we blocked the LOS. Then, we measured different scenarios to evaluate the possibility of restoring connection when a blockage occurs by placing an absorber in the LOS path. We placed a copper sheet at different positions from the absorber edge to assure that any illumination of the sheet by the antenna beams can be reflected towards the receiver. Fig. 1 shows our setup.

IV. Results

LOS measurements clearly show that narrow beam high gain antennas result in better performance given that an LOS connection has already been established as shown in Fig. 2. Pencil beamforming in mmWave spectrum is vulnerable to the spatial misalignment and can cause significant attenuation. To validate this theory we blocked the LOS completely and plot the results in Fig. 3a where all beam combination showed significant attenuation. Then we studied the result of beam switching with the presence of a copper sheet that allows signals to be reflected to the Rx. Fig. 3b shows the results of our antenna repertoire while placing the copper sheet at 5 cm from the edge of the absorber that blocks the LOS path. This sheet allows the beams of both the 15 dBi and 25 dBi gain antennas to detour and restore the connection. However, this detour introduced a roughly 10 dB of loss compared to the LOS case. Moreover, Fig. 3c depicts a similar set of measurements while placing the copper sheet at 10 cm distance from the absorber edge. In this case the 25 dBi gain narrow beam antenna relatively failed to detect the detour of the 15 dBi antenna gain reflections. In this scenario using 15 dBi gain wider beams antennas at both Tx and Rx outperformed the narrow beams. It is obvious that by switching to a wider beam by using the 15 dBi antenna instead of the 25 dBi antenna we were able to overcome the blockage introduced. These results make it evident that there should be a trade off between gain and beamwidth of the communicating antennas in order to maintain a reliable connection and to switch to higher gain whenever the LOS to the receiver is restored.

V. Conclusion

We ran different measurements for 60 GHz band antennas of various gains. Although LOS propagation benefits from the narrow beamwidth and high gain of the antennas, this was not the case when an object of the size of a human body blocks the LOS. The blockage caused a significant signal strength deterioration. However, switching at least one side of the link to have a wider beam and lower gain antenna resulted in stronger signal. This is a very optimistic result that can be a key for solving indoor blockage problem and allows either side of the connection to switch beams in the case of LOS blockage before a beam steering algorithm can restore an LOS or a narrow beam high gain connection.

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