mmWave Antenna Gain Switching to Mitigate Indoor Blockage

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***Abstract*—Indoor blockage in a millimeter wave (mmWave) wireless communication link introduces significant signal attenuation. Solving the indoor blockage problem is critical to effectively using the unlicensed 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 line of sight (LOS) path, the signal fades deeply. Experimental results showed that switching to a wider beam with lower gain has the potential to partially restore or maintain a communicating link. Effective beam switching and coordinated beam steering can shorten deep fades which is crucial for mmWave communication systems that are very sensitive to the spatial characteristics of the environment. The experimental results in this paper thus motivate the design of future indoor mmWave antennas capable of beam switching and facilitate fast beam search.**

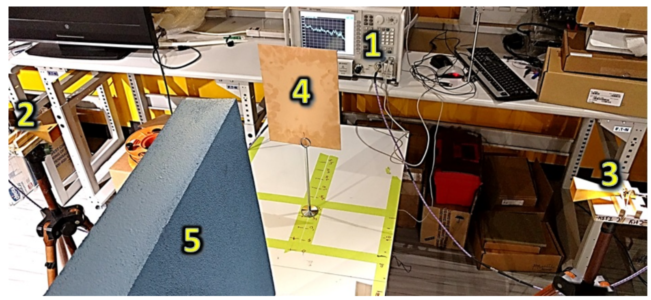


Fig. 1. Measurement setup: 1. Network analyzer 2. Horn Antenna 3. Horn Antenna 4. $23 \times 31\ cm^2$ Copper Sheet 5. Absorber

I. Introduction

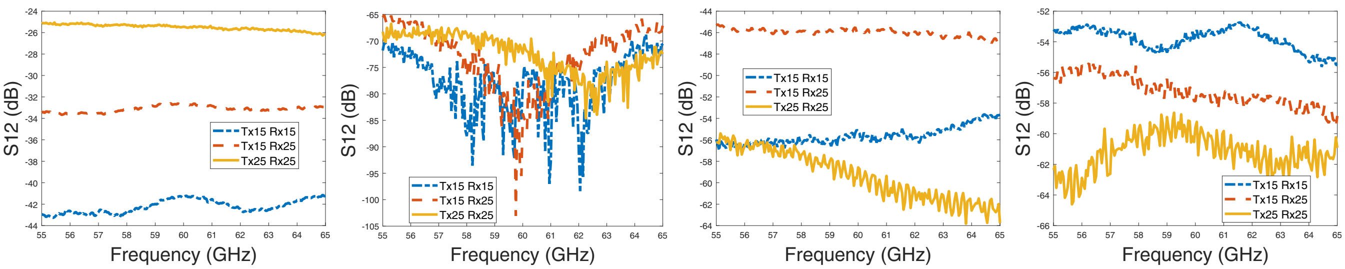
Achieving future gigabit per second data rates to mobile data subscribers will require effective and efficient use of unlicensed 60 GHz mmWave spectrum [1]. One of the obstacles that need to be addressed in this pursuit is the reliability of point to point links using high gain narrow beam antennas or 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 our work in this paper to address this issue by analyzing indoor blockage in mmWave regime communication links and proposing an efficient solution through beam switching. Our contribution is in the use of a network analyzer based measurement setup to analyze beam switching performance at one or both sides of the transmission link and observing the effectiveness of wider beams to recover a blocked link. Beam switching to a wider beam allows for fast recovery of the signal before reapplying a second 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 provides an overview of related work. Section III shows the experiment setup we used to collect measurements. Section IV depicts and analyzes our results, and conclusions are drawn in Section V.

II. Related Work

mmWave blockage analysis and avoidance have been extensively investigated recently. 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 picocell network. Indoor systems can take advantage of the reflective indoor environment to provide mulitpath sources for non line of sight (NLOS) beam search. The authors of [6] proposed adaptive beamwidth for blockage avoidance where they emulated a variety of beamwidths using absorbers, but 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 signal effects and time duration of the blockage caused by pedestrian crowds. Our work focuses on the indoor environment as we 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 dBi and 15 dBi at both ports. The antennas were fixed on 2 tripods that were 5 ft apart. The measurement took place in



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

Fig. 2. S12 measurements. LOS is blocked with an asborber in b,c,and d. 15 and 25 legend text correspond to antenna gains of 15 dBi, 25 dBi respectively

the Drexel Wireless Systems Laboratory (DWSL) 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 ensure 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 a LOS connection has already been established as shown in Fig. 2a. Pencil beamforming in mmWave spectrum is vulnerable to spatial misalignment and can cause significant attenuation. To observe this phenomena, we blocked the LOS completely and plotted the results in Fig. 2b where all beam combinations showed significant attenuation. Next, we studied the result of beam switching with the presence of a copper sheet that allows signals to be reflected to the Rx. Fig. 2c shows the results of our antenna testing 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 take another path to restore the connection. However, this multipath introduced a roughly 10 dB signal loss compared to the LOS case. Moreover, Fig. 2d depicts a similar set of measurements while placing the copper sheet at a distance of 10 cm from the absorber edge. In this case, the 25 dBi gain narrow beam antenna failed to detect the multipath that was observed in the measurements with the 15 dBi antenna. In this scenario, using 15 dBi gain antennas with wider beams at both Tx and Rx outperformed the narrow beams. Thus, 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 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 the indoor blockage problem and allows either side of the connection to switch beams and employ adaptive beamsteering in the case of LOS blockage. The experimental results in this paper thus motivate the design of future indoor mmWave antennas capable of beam switching and fast beam search.

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