Diffraction Measurements at 60 GHz and 300 GHz for Modeling of Future THz Communication Systems

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Abstract — Indoor wireless communication channels will be operated in the 60 GHz band soon and will work at 300 GHz and beyond in the foreseeable future. Although diffraction occurs at a multitude of objects in indoor environments and needs to be considered for reliable propagation simulations, very few work exists on this topic in the mm and sub-mm wave bands. Here, we present measurements of the diffraction at wedges (cuboids) at 300 GHz with different materials and real antennas. The measurements are used to validate theoretic descriptions of diffraction phenomena.

I. INTRODUCTION AND BACKGROUND

THE development of future THz communication systems will require the exact knowledge of the radio channel properties [1]. While the feasibility of signal transmission in the lower THz frequency range has been demonstrated successfully [2-4], few work has been done on actually measuring channel transfer functions [5]. However, the reliable prediction of coverage and system performance based on ray tracing simulations [1] requires the accurate knowledge of reflection properties of materials present in the considered scenario [6] as well as the proper modeling of scattering and diffraction effects. A very recent study including angular resolved and 1D translatory diffraction measurements in comparison to calculations based on the uniform geometrical theory of diffraction (UTD) and the knife edge diffraction (KED) showed the importance of diffraction for propagation modeling in the THz frequency range [7]. These measurements are now extended to 2D studies including considerations of occurring measurement uncertainties [8, 9].

II. RESULTS

Results in [7] include angularly resolved diffraction loss measurements with a translation of the object in one direction, only. Now, we demonstrate 2D translatory diffraction measurements where the object is moved between transmitter (Tx) and receiver (Rx) in two directions orthogonal to the propagation direction as depicted in Fig. 1 at 300 GHz both in horizontal and vertical polarization. Additionally, the diffraction behavior is simulated with UTD. Fig. 2 shows an example of such a measurement and its successful modeling. A non-ideal antenna alignment in x-direction results in a slightly asymmetry of the interference pattern regarding the x-direction (Fig. 2 a)) and has been taken into account for the simulations shown in Fig. 2 b), also.

Fig. 1. Setup for a) translation stage and b) angular dependent measurements.

Fig. 2. Diffraction loss at 300 GHz (in dB) a) measured and b) simulated with the UTD at a metallic cuboid (8x8x8 cm³) in horizontal polarization for different displacements orthogonal (x direction) and parallel (y direction) to the transmission link.
Fig. 3. Angular diffraction measurements in comparison to simulations based on the UTD for horizontal (HH) and vertical (VV) polarization. Positive angles correspond to the lit region, negative angles to the shadow region.

Fig. 4. Comparison of measurement and simulation for four different angles in horizontal polarization as a function of frequency.

Fig. 3 shows angularly resolved measurements in comparison to simulations based on the UTD. Especially in the shadow region, the simulations are in very good and in the case of vertical polarization in almost perfect agreement with the measurements. Fig. 4 shows the frequency dependence at four different angles in horizontal polarization. Over a wide frequency range between 280 GHz and 320 GHz, the frequency dependence is almost negligible. All measurements have been performed using a vector network analyzer (Rohde & Schwarz ZVA50) with frequency extensions in the WR 3 band between 220 GHz and 325 GHz. Standard gain horn antennas radiate the generated test signals. In the case of angularly resolved measurements, additional polyethylene lenses have been used to collimate the beam. A first estimate of the measurement uncertainty that includes contributions from the vector network analyzer and the applied method of system error correction [8] as well as from the positioning setup and the available antenna diagrams yields measurement uncertainties in the order of 1 dB (95% confidence interval) if misalignment errors can be excluded that yield measurement uncertainties in the order of a few dB [9].

III. CONCLUSION

Two dimensional translatory and angularly resolved diffraction measurements have been performed showing good agreement with calculations based on the KED. Apparently, this approach is well suited to describe diffraction in the THz frequency range in realistic environments. Here we have shown examples of a successfully modeling of the diffraction at a metal cuboid at 300 GHz by UTD. Moreover, the frequency dependence of diffraction effects and first results of an uncertainty analysis have been discussed.

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