TeraHertz vs Microwaves Ray-Launching Model in a 0.45 THz Indoor Wireless Scenario

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***Abstract*—Ray tracing is the gold standard for microwave channel modelling. The lack of a comprehensive material library and ray tracing implementations capturing both surface scattering and atmospheric absorption represent a barrier for the use of ray tracing at millimeter-waves (mmw) and TeraHertz (THz). We report here a ray-launching algorithm implementation that includes a library of microwaves-to-THz material properties, surface scattering and atmospheric absorption that enables us to benchmark a 0.3 THz experimentally-validated THz ray-launching model against a microwaves one in the context of a meeting room 0.45 THz wireless system.**

I. INTRODUCTION

WIRELESS communications systems are evolving from microwaves to millimeter-waves (mmw) and TeraHertz (THz) to meet the needs of our data-hungry society [1]. In these high frequency ranges, two physical phenomena ignored in radiofrequency and microwave propagation planning tools become significant, specially at THz: surface scattering and atmospheric absorption. To adopt ray tracing as a planning tool for mmw and THz, such phenomena need to be included [2]. Equally important is the input of the electromagnetic properties of materials at these high frequencies. Unfortunately, existing mmw and THz databases of materials are not as comprehensive and reliable as those found for microwaves and optics.

In this framework, we have been implementing a ray-launching algorithm that includes surface scattering through a Rayleigh-Rice theory (following the path set by others [3]) and atmospheric absorption using ITU recommendation [4] that has been validated against channel soundings measurements at 0.3 THz [5],[6]. We have been also carrying an extensive campaign of time-domain measurement covering the frequency range up to 1 THz to construct an extensive database of common materials found in indoor scenarios [7] that we have cross-correlated against existing scattered data [6]. This combined approach enables us to assess here the impact that ignoring surface scattering and atmospheric absorption, as well as using microwaves material properties rather than the actual mmw and THz material properties have on the propagation planning at 0.45 THz.

II. METHODOLOGY

A THz time-domain spectroscopy technique is used to extract the electromagnetic properties of common materials found in indoor scenarios like a meeting room. Transmission or reflection measurements are carried out depending on the absorption of the sample under test. For the former modality, the commercial software TeraLyzer is used to process the waveforms (i.e., temporal signals) for the retrieval, whereas a substrative Kramers-Kronig based retrieval algorithm is used for the latter modality [8]. The samples are split into six categories: woods, tiles, stones, plastics, fabrics, and leathers.

Simulations are based on a three-dimensional (3D) ray-launching algorithm based on geometrical optics and the uniform theory of diffraction [6]. The simulation box is gridded to map accurately enough the objects' geometries in the scenario. The voxel has 0.1 m × 0.1 m × 0.1 m dimensions. A set of rays departures from the emitter position with a predefined angular distribution modelling an open-ended waveguide radiation pattern. All rays are tracked through the scenario until they exist the simulation box or the number of rebounds reaches 4. The Rayleigh-Rice surface scattering model is used here because it performs better than the Beckmann-Kirchhoff model for scenarios with slightly rough surfaces such as the modern meeting room under investigation and when large scattering and incidence angles needs to be considered [3]. In a nutshell, this approach results in a rough surface reflection coefficient that is the conventional Fresnel reflection coefficient for a smooth surface multiplied by the so-called Rayleigh roughness parameter. The atmospheric absorption due to gas molecular vibrations that is relevant at THz even in indoor scenarios is implemented using ITU recommendation [4].

III. RESULTS

The dielectric properties of different materials at 0.45 THz are plotted in Fig. 1. Tile, stone, and leather materials cluster with a small deviation, whereas wood and specially fabric materials show a large distribution in terms of loss tangent. Hence, for an accurate propagation analysis, the precise knowledge of the fabrics in the scenario is more important than knowing the exact materials for the other material categories.

The scenario under study is a meeting room on the premise of the Fraunhofer HHI in Berlin, Germany (Fig. 2). The meeting room is approximately 4.7 m wide by 7.8 m long by 2.9 m height. The meeting room includes walls, glass fronts and furniture such as office chairs, a large wooden table, a TV screen and a whiteboard. The transmitter is assumed to be placed in the corner of the room at a height of 1.86 m and the receiver on several positions on the table at a height about 0.93 m to be consistent with the channel sounding campaign and the ray-launching model validation carried out in earlier works at 0.3 THz [5],[6].

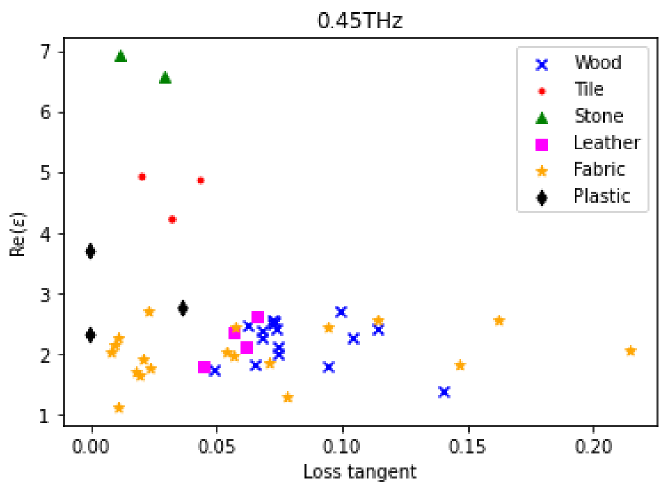

Fig. 1. Relative permittivity against loss tangent at 0.45 THz for a collection of materials grouped into six categories: woods, tiles, stones, leathers, fabrics, and plastics.

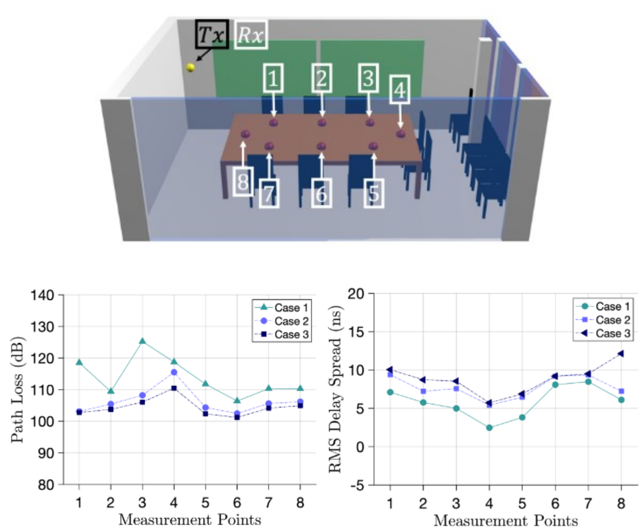

Fig. 2. (Top) Conference room modelled in the THz 3D ray-launching algorithm. (Bottom): path loss (left) and RMS delay spread (right) for the 8 positions on the table shown in the top schematic: full THz ray-launching model [Case 1], THz ray-launching model considering microwave material properties [Case 2] and microwaves ray-launching model [Case 3].

Fig. 2 benchmarks the full THz ray-launching model (Case 1) against a partial THz (i.e., without diffuse scattering) (Case 2) and microwave ray-launching models (i.e., no diffuse scattering or atmospheric attenuation and microwave material properties) (Case 3) in terms of path loss $(dB) = P_{tx}(dBm) - P_{rx}(dBm)$ and root mean square (RMS) delay spread. The path loss highlights the significant importance of modelling surface scattering (compare Case 1 vs. Case 2) and, to less extend, using accurate material properties (compare Case 2 and Case 3). The lower RMS delay spread shown by the full THz ray-launching model displays is arguably due to the reduction of multipath components. This is corroborated by inspecting the power delay profile for points 1 and 3, see Fig. 3. The multipath still has some significance for the closest point to the emitter (point 1), but for the furthest point (point 3), multipath represents a minor contribution to the total received signal; hence, the large difference in path loss observed in point 3 in Fig. 2.

IV. SUMMARY

A THz ray-launching model previously validated with channel sounding measurements at 0.3 THz has been compared against a partial THz ray-launching model and a microwave ray-launching model at 0.45 THz. The benchmark study highlights the paramount importance of modelling surface scattering and inputting the precise material properties at the frequency of operation (0.45 THz in this contribution).

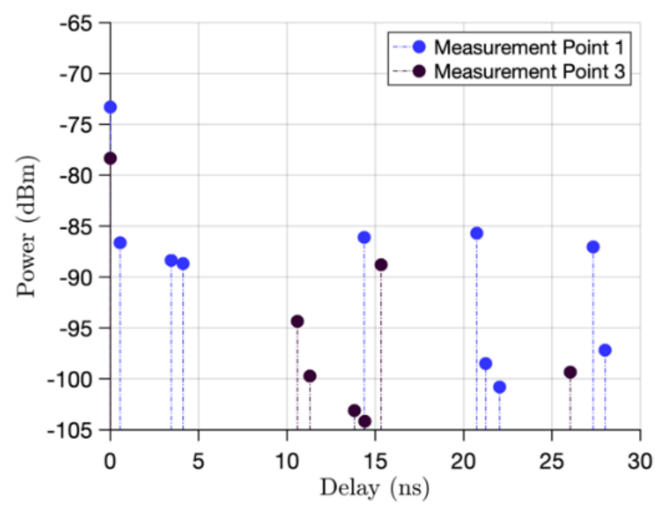

Fig. 3. Power delay profile measurement points 1 and 3 for the full THz ray-launching model [Case 1].

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