Diffraction Calculations and Measurements in Millimeter Frequency Band

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Abstract. *The paper deals with a study of diffraction on dielectric wedge (building corner) in millimeter frequency band, both theoretically and experimentally, to provide knowledge support for ray tracing/launching calculations of MWS interference issues in urban areas. The main motivation was to find balance between reasonably reliable results and necessary demands on calculation complexity and input data accuracy. Verification of Uniform Theory of Diffraction (UTD) was made both for perfectly conducting and dielectric wedge-shaped obstacle. Comparisons of theoretical results and experimental measurement at millimeter waves in anechoic chamber are presented.*

Keywords

Electromagnetic diffraction, UTD, radiowave propagation, millimeter waves, LMDS, MWS, FWA.

1. Introduction

Line-of-sight (LOS) between a hub and a terminal station is usually required in deployment of point-to-multipoint systems operating in millimeter frequency bands [1]. Since these systems, known as LMDS (Local Multipoint Distribution Systems), MWS (Multimedia Wireless Systems), FWA (Fixed Wireless Access), etc. [2], deliver broadband connections for the "last mile" in urban areas, building blockage is the main limiting factor for the service [3]. Because of the high attenuation in millimeter frequency bands connections using reflections or even diffractions are not considered reliable for the standard service. On the other hand, when interference within the systems is examined, both the reflections and diffractions due to buildings have to be considered.

Simple ray tracing or ray launching technique can be used to determine the LOS in built-up areas [4]. Inclusion of reflections and diffractions into the interference calculations is much more complicated task. The main problem is to provide the algorithm with reasonably accurate input data. It includes not only the geometry of the scenario (antenna positions, shape and positions of buildings) but also electrical parameters of the building materials. Due to large variety of used building materials and unknown water content inside it is quite impossible to provide universal reliable data for the input [5].

Goal of the project, which results are presented here, was to study diffraction on dielectric wedge (building corner) in millimeter frequency band both theoretically and experimentally to provide knowledge support for ray tracing/launching calculations of MWS interference issues in urban areas. The main motivation was to find balance between a reasonably reliable results and necessary demands on the calculation complexity and input data accuracy.

2. Theory

Theoretical results were obtained by UTD, considering normal incidence of the incident field on the wedge. UTD is a method based on geometrical optics and is therefore suitable to be used in ray-tracing and ray-launching models. Uniform theory of diffraction [6] is an improvement of Geometrical Theory of Diffraction (GTD) [7], which has the disadvantage of giving incorrect results close to reflection and shadow boundaries, Fig. 1. UTD and its modifications [8] eliminate this inaccuracy and enable to compute diffracted field on a dielectric as well as perfectly conducting wedge. Capability of computing both field magnitude and phase makes this approach suitable for use in urban area where multipath occurs.

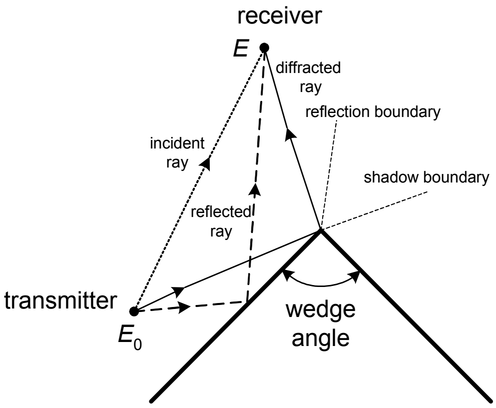

Fig. 1. Components of the received field.

The resulting field according to UTD is the sum of incident, reflected and diffracted components. The diffracted field region is all around the wedge, the reflection and incident field regions are up to reflection and shadow boundaries, Fig. 1. The field strength was computed all around the wedge, thus taking into consideration not only diffracted field, but incident and reflected components as well and also the radiation patterns of transmitting and receiving antennas. Example of the UTD computation of the field strength around a conducting wedge-shaped obstacle is given in Fig. 2.

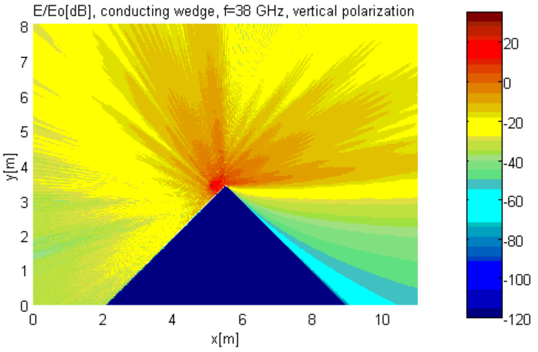

Fig. 2. Field strength around a conducting wedge.

3. Experiment

Measurements were performed in anechoic chamber at the Dept. of Electromagnetic Field, Czech Technical University in Prague. Used frequencies were 18 GHz and 38 GHz. Geometry of the wedge and polarization of incident field are shown in Fig. 3. The perfectly conducting wedge with wedge angle of 90 degrees was made of metal reflection foil and an aluminum plate. The dielectric wedge was formed by two breeze-blocks standing next to each other, Fig. 4. An open waveguide was used as a transmitting antenna, the receiving antenna was of a horn type. The distances *s'* and *s* are 0.425 m and 4.86 m, respectively.

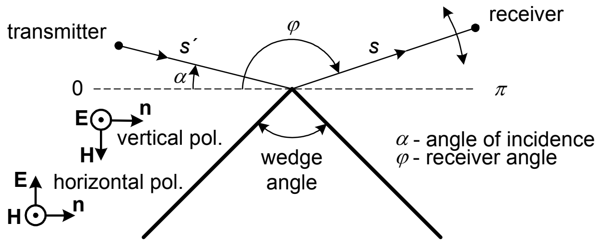

Fig. 3. Geometry of the wedge.

4. Comparisons

Fig. 5 shows comparison of measured and theoretical values for conducting wedge (reflection foil) at 38 GHz, incident angle 0 degrees and vertical polarization. The same comparison but for a dielectric wedge is given in Fig. 6. Relative permittivity of the dielectric wedge was unknown and was estimated by comparing theoretical computation for various ε_r with measured data, Fig. 7. We can see that the measurement result fits the theoretical one for $\varepsilon_r = 2$.

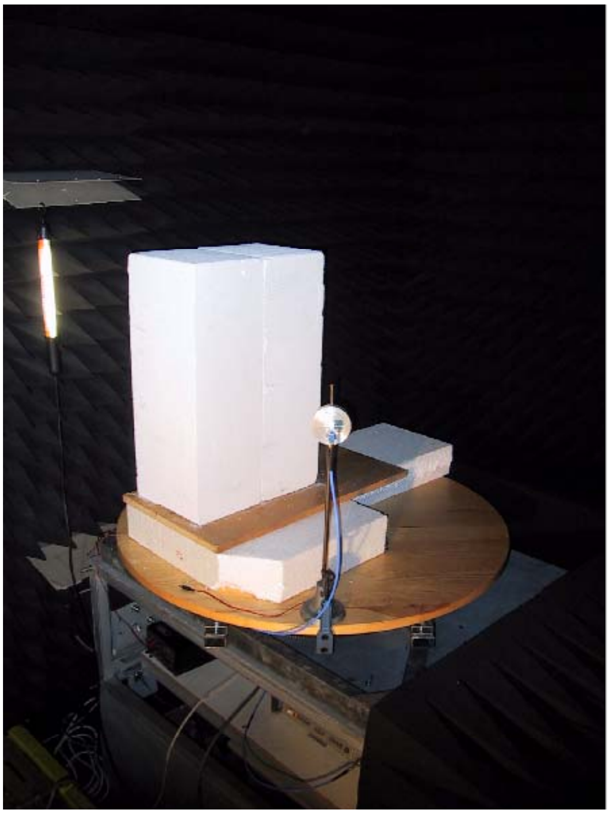

Fig. 4. Dielectric wedge measurement.

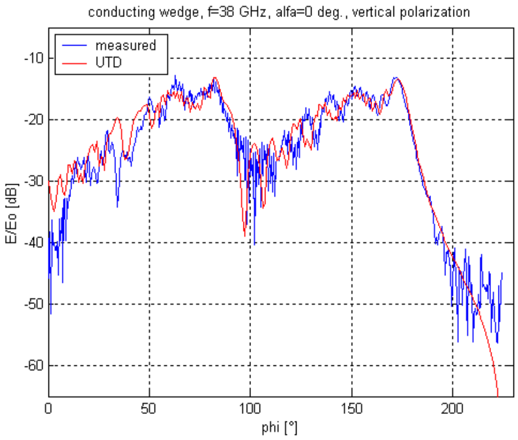

Fig. 5. Conducting wedge - UTD.

Angular dependencies of E/E_0 in Figs. 5 and 6 are the sum of incident, reflected and diffracted fields up to 90 °, the sum of incident and diffracted fields up to 180 °, and for $\varphi > 180$ ° only diffracted component is present. The dependencies are thus of oscillatory character up to 180 ° because of phase summation of the components involved. In the case of dielectric wedge the oscillatory nature is emphasized up to 90 ° which is caused by the fact that the incident and reflected fields are of almost the same magnitude due to radiation patterns of antennas and lower reflection coefficient of the dielectric wedge. Lower reflection component then causes lower total field in this region. For $\varphi > 180$ ° the dependencies are formed by diffraction component alone and thus have smooth characteristics. Oscillation of measured dependencies for $\varphi > 200\,°$ are caused by phase summation of rays diffracted by corner of the wedge and by unwanted rays diffracted by the other edge of the obstacle because of its finite size.

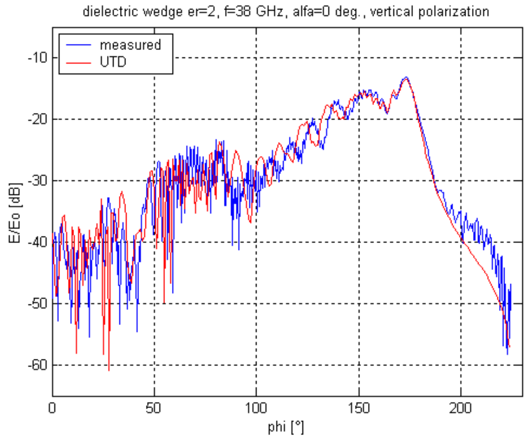

Fig. 6. Dielectric wedge - UTD.

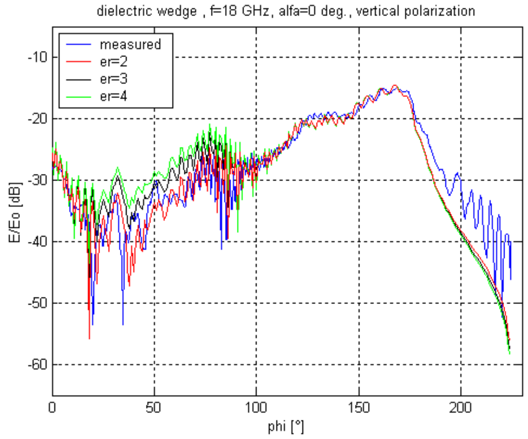

Fig. 7. Comparison of measured and theoretical (UTD) results for various ε_r.

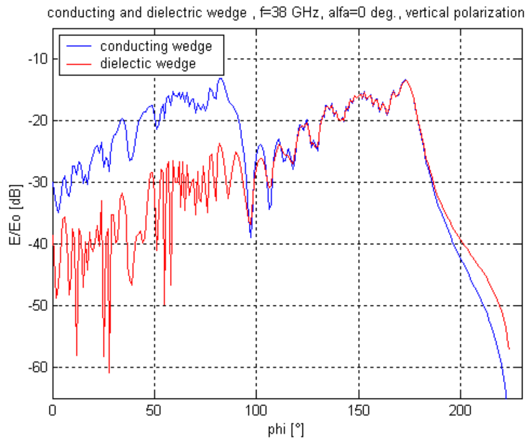

Fig. 8. Conducting and dielectric wedge - UTD.

Fig. 8 gives comparison of theoretical results for conducting and dielectric wedge at 38 GHz, vertical polarization. The plots show that the field is equal both for conducting and dielectric wedges for $\varphi > 90\,°$ with some difference when approaching back face of the wedge (for φ close to 225 °). This theoretical assumption is confirmed by measurement at 18 GHz and 38 GHz, resp. (Figs. 9 and 10).

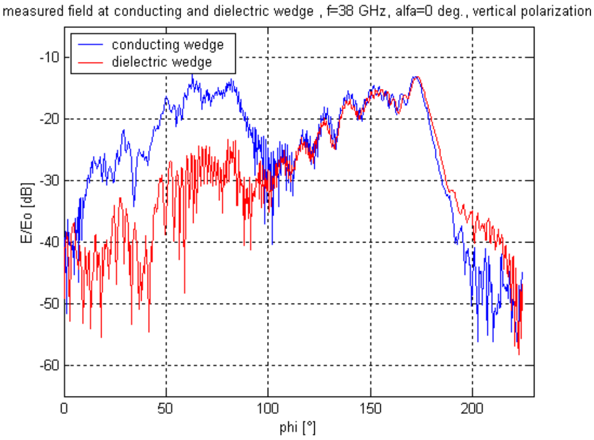

Fig. 9. Conducting and dielectric wedge – measurement.

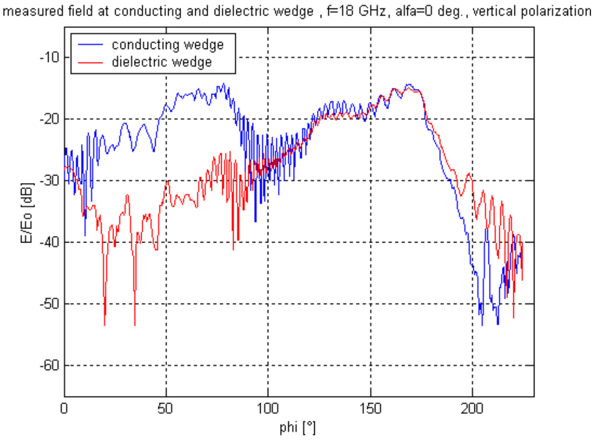

Fig. 10. Conducting and dielectric wedge – measurement.

5. Conclusions

Comparisons of measured and theoretically computed field strength levels around a wedge-shaped obstacle using UTD were presented. Theoretical and experimental results show good agreement. Some disagreements are caused by the arrangement of measurement. A method for estimation of unknown relative permittivity of a dielectric wedge using the comparisons was presented. Theoretical and measurement results predict equal field for conducting and dielectric wedges as well as for dielectric wedges with various ε_r outside the reflection region for vertical polarization. The results can be utilized for MWS interference calculations by ray tracing/launching techniques.

Acknowledgements

This work has been partially supported by the Czech Ministry of Education, Youth and Sports project OC 280.003 “Propagation of Electromagnetic Waves in Millimeter Waveband for Advanced Communication Systems” and the research program No. 210000014 “Research in the Area of Information Technologies and Communications" of the CTU Prague.

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