ASTIGMATIC BEAM TRACING FOR MULTIPATH PREDICTION IN URBAN ENVIRONMENT

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Abstract: Mobile communications in urban environment are influenced by multipath effects. Astigmatic Beam Tracing (ABT), a deterministic method based on ray tracing, can be applied to urban propagation modelling. ABT can handle multiple reflections and diffractions. Recent improvements allow ABT to treat higher order diffraction by selecting specific sequences of diffracting wedges. A numerical code has been applied to a model of urban scenario. Preliminary results of a validation activity, showing a fair agreement with published measurements and results of other methods, are presented.

INTRODUCTION
Electromagnetic propagation in urban, indoor and terrain scenarios suffers from the effects of multipath. Empirical and semi empirical models are able to determine some parameters of the propagation channel, but often, they are constrained by a lot of specific conditions. On the other hand, deterministic methods based on Geometrical Optics (GO) and Uniform Theory of Diffraction (UTD) offer a systematic and versatile way to treat complex and heterogeneous environments provided that detailed geometrical and morphological information are available. The development of an algorithm able to determine all possible GO/UTD contributions (without restrictions on geometrical and morphological information) using a personal computer and with a reasonable computational time, is again a challenge. In particular, for multiple edge diffraction in urban and terrain scenarios two-dimensional propagation models are used owing to the difficulty of three-dimensional investigation. Astigmatic Beam Tracing is a new method developed to take into account the GO/UTD contributions of any order to a three-dimensional environment described by means of polygonal flat facets (Di Giampaolo et al.[1]). ABT differs from other algorithms in the ability to handle multiple wedge diffraction (Di Giampaolo et al.[2]). A computational code based on ABT has been developed. Suitable data structures together with Computational Geometry algorithms have been used in order to reduce the computational time (Di Giampaolo et al. [3]). Code validation by comparisons with both measurements and published results is in progress (Di Giampaolo et al. [4]). In this paper we shall show through examples that higher order diffraction contributions have to be accounted for field estimation in a nontrivial urban environment. An improvement to ABT will be discussed showing the ability of ABT to deal with the higher order diffraction problem with low computational costs.

ABT MULTIPATH PREDICTION
The ABT code is structured into two parts, one off-line and the other on-line. Filling a data base with the characteristics of sources and obstacles, and performing the visibility computations by means of a forward beam tracing constitute the main steps of the off-line part. Thus, a partition of the environment is performed resulting in a hierarchical arrangement of beams. ABT adopts a beam-tree for data storage. Backward ray path determination from an observation point to a source, and field propagation using GO/UTD along ray paths constitute the main steps of the on-line part. This part calculates the electromagnetic field at any point of the computational domain using beam-tree data. It is under the user’s control and can be repeated any time for different sets of observation points, whereas the off-line part is executed only once for given scene and sources. For non trivial scenarios the off-line part is the most expensive in terms of computational time and memory. Depending on the number of beams traced in an environment, time and memory increase with the complexity of the scene and with the number of interactions (Di Giampaolo et al.[3]). In particular, the computational charge increases with the power of the interaction order as each wedge behaves as a secondary source of diffracted beams. This feature could limit the application of ABT to small environments when multiple diffraction is accounted for. However, only a subset of the wedges gives relevant contributions to the diffracted field in portions of a large environment, e.g. a street not in visibility with the source. To save computational resources, therefore, ABT has been improved allowing the user to select this subset exploiting the global visibility performance of ABT (Di Giampaolo et al.[3]). Indeed, ABT provides the differential contribution due to any increase in the reflection and diffraction order for any facet of the model.
Let us consider the urban scenario in Fig.1 (Teh et al.[5]). The scene consists of 64 buildings with 432 facets, 910 edges and ground. Calculations were performed at 900 MHz with $\varepsilon_r = 7.0$ and $\sigma = 0.2(S/m)$ considering dielectrically homogeneous buildings and ground. The source was a half wavelength dipole located at 8.5 m from the ground as shown in Fig.1. The total number of beams, the allocated memory, and the time required for beam tracing are shown in Table I for four different tests. In Test I, ten reflections and single diffraction have been considered. The electromagnetic field was calculated on the sampling line labeled (a) in Fig.1. The diagrams in Fig.2 are for a comparison of ABT results with the results shown in the work of Teh et al.[5]. A fair agreement can be appreciated. We observe that diffraction gives less contribution to the path loss than reflections along the sampling line, so that only first-order diffraction has been considered. At points of the sampling line (b) (Test II), instead, higher-order diffraction cannot be neglected as only few multiple reflections reach this line. On the other hand, the wedges in the nearness of line (b) mainly contribute to the diffracted field. To speed up the tracing, therefore, we account for diffraction only at the wedges on the left-hand side of line (a). Second order diffraction was sufficient in order to achieve continuous ray coverage along line (b). Fig.3 shows the double diffracted ray paths. Even if double diffraction can be sufficient for coverage prediction in a micro/picocell environment, it is often required higher-order diffraction in order to determine interference between co-channel cells or to model over rooftops propagation in mobile to mobile communication or to find propagation loss over irregular terrain. Seventh order diffraction from two sets of selected wedges has been treated in Test III and Test IV. Ray paths are shown in Fig. 4. From the data in Table I we observe that even if the number of diffracted beams in Test III is larger than in Test I, the computational time is strongly smaller. The reason is that, for each diffraction order, only few beams light the wedges and must be considered for next order diffraction, while the other beams propagate undisturbed. This feature allows ABT to treat long sequences of diffracting edges.

CONCLUSIONS

Astigmatic Beam Tracing has been applied to multipath prediction in urban environment. Few hundreds of seconds are sufficient to propagate reflected beams up to tenth order and diffracted beams up to second order in a non trivial urban scene. Recent improvements allow ABT to treat higher order diffraction in few seconds by selecting specific sequences of diffracting wedges. A validation of the method is in progress, while preliminary results show a fair agreement with published measurements and results of other methods.

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REFERENCES

Table I

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<th>Number of edges</th>
<th>Number of beams</th>
<th>Memory [MB]</th>
<th>Time [s]</th>
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<td>/</td>
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Fig.1 Urban scene for tests.

Fig.2 Test I. Path loss along line (a) of Fig.1.

Fig.3 Test II. Double diffracted ray paths.

Fig.4 Test IV. 7\th order diffraction over rooftops.