A Full 3-D Ray Tracing tool for electromagnetic wave propagation

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Abstract A full 3D ray tracing approach for the prediction of electromagnetic wave propagation is presented. Unlike other method such as 2D or 2.5D models, this approach is based on full 3D computational geometry. Wireless cells are modeled by buildings and ground plane represented by solid bodies which comprise polygons. Possible ray paths are represented by 3D ray tubes, generated by transmitting antennas, reflections, and diffractions. Method for finding ray tubes and obtaining path losses are presented.

Introduction

With personal wireless communication systems widespread, cell planning becomes increasingly difficult due to a highly density of building walls and interference from competing service providers. Traditionally, wireless cell planning depends on statistical models and site measurement. But those models become useless when new buildings are constructed or demolished. Site-specific channel prediction is made possible with the invent of ray-tracing techniques. Ray tracing methods adopt either a shoot and bounce method or ray tube concepts for searching possible ray paths. The shoot and bounce method is easy to implement and accurate but time consuming. The ray tube method is more efficient in that it searches all possible ray paths with a small number of calculations. It finds boundaries of ray bundles. According to the building models, 2D or 3D ray tracing methods are possible. Because of easiness, 2D or 2.5D methods have been developed widely. Recently, 3D methods have been developed, but most of them are based on 2D building models with the inclusion of over the roof paths [1][2].

This paper presents a ray tracing method with full 3D building models and 3D ray tubes. In our 3D model, ray tubes are generated by three mechanisms. They are transmitting

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antennas, reflecting faces like walls and diffracting edges. Unlike 2D model, reflecting walls also include reflections from roofs and ground plane. Edge diffractions are generated from roof top edges as well as wall edges. The three ray tubes are called by TX ray tube, reflection ray tube and edge ray tube. Each ray tube has boundary faces, which wrap ray bundles. When a transmitting antenna generates TX ray tubes, faces such as walls or roofs of buildings are found, which subsequently generate reflection ray tubes and edges of the visible faces generates edge diffraction ray tubes. When the ray tubes are made, sources at image points or edges are also generated. Field calculations at an observation point are performed by finding ray tubes which include the point and adding up contributions by fields of ray tubes found.

3D Cell model

In 3D ray tracing approach, a building is represented by a solid body which is composed of plane faces. The faces are for walls and roofs. A face is composed of edges and vertices. The ground surfaces are also represented by faces. Faces can be represented by a normal vector and vertex points. By equations of plane, it is determined whether a ray is inside a wall ray tube or not.

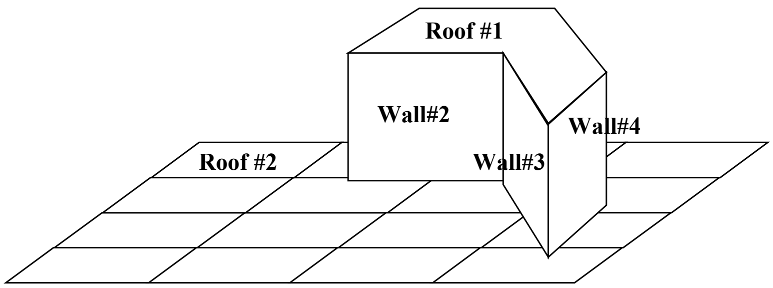

Fig. 1. 3D cell model. A building is identified by the faces it has. Reflections from the ground are also taken into account by the roof tiles covering the ground.

Ray tubes

When electromagnetic fields emanate from transmitting antenna, a TX ray tube is generated. The TX ray tube encircles antenna and has an angle of 2π radian, but can be divided into small angular sectors to accelerate ray tube searching. A ray in the tube propagates away from the source point until it encounters planar faces such as walls, roofs and ground surface. When blocked by such obstacles, new rays are generated according to the scattering mechanisms. A reflection ray tube is produced when a ray meets walls or roofs. An edge ray tube is produced when a ray meets edges of the wall. All kinds of ray tubes have their own source points. A source for a reflection ray tube is the image of the original source of the incident ray. A source for an edge ray tube is located at some point on the edge. Where the source exists is determined by the locations of those of the previous ray tube and the following one. In 3D model, each ray tube is of pyramidal shape, angular sector capped with or without cones.

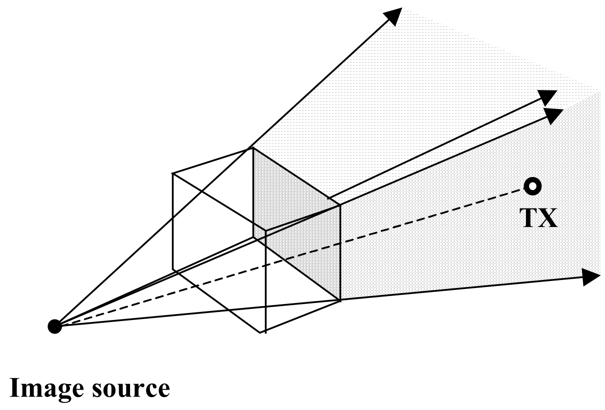

Fig. 2. A wall ray tube is in the shaded region When an incident ray illuminates a face, a wall ray tube is generated with its source located at the image position of TX location.

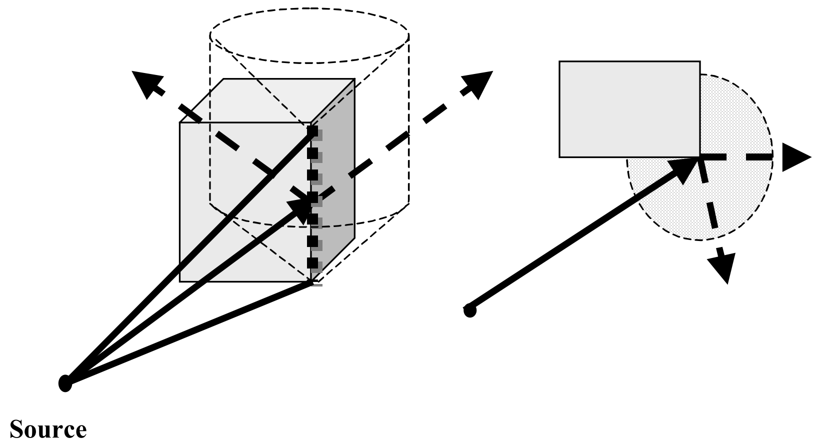

Fig. 3. An edge ray tube is in the cylindrical sector drawn with dotted line. When an incident ray illuminates a face, edges belonging to it generate edge ray tubes.

Source locations for the ray tubes are determined by the original source location and the next visible faces from the edge and by the law of diffraction. The branches of the tree can increase exponentially if power level checking is not performed. We do this in searching visible faces by checking the magnitude of the electric field on the center of the face. If the magnitude is under the threshold level, path search process is terminated.

Electric field calculation

When a TX ray tube is generated, visible faces included in the ray tube are found. The faces generate wall ray tube and edge ray tube. In doing so, the TX tube has tree-like children ray tubes. The tree-like structure includes all the possible ray paths. This means that all the ray path traversed can be found by ascending the ray tree from the children. In practice, we can calculate electric field at a specific point by adding up the fields contributed by the ray tubes which include the observation point. The electric field contributed by each tube is easily calculated by GO(geometrical optics) or GTD(Geometrical Theory of Diffraction).

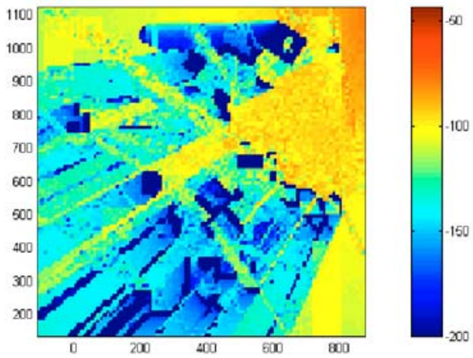

Fig. 4. Electric field strength map of 3D cell. In the figure, the number of buildings is 20. TX antenna is located at (1000, 1100).

Conclusion

Using 3D cell model, wave propagations over the roofs are automatically taken into account in generating ray tubes, thus we can get more accurate result. The 3D ray tubes presented allow the calculation on the site to be performed independently of other tubes, because each ray tube has its own source obtained in tube generation. The accuracy could be sacrificed for acceleration by raising the threshold level. The tube model accompanied with source could easily be programmed in object-oriented languages.

References

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