A Propagation Modeling for Microcellular Communications in Urban Environments with Vehicles and Trees

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Introduction

Buildings, vehicles, and trees affect the radio wave propagation in a microcell for mobile radio communications. There have been a lot of papers discussing the propagation loss, cell coverage, and delay spread in simple environment using ray tracing technique and multiple-image concept [1][2]. Although these methods were useful, in their formulations the streets were empty — no cars, no trucks, and no trees. In this paper, we combine 2D ray tracing and simple 3D geometric considerations to generate an efficient and comprehensive three dimensional propagation model for a general propagation environment as shown in Fig. 1. By this approach, we can handle any distribution of buildings, vehicles, and trees in an urban environment. To the authors' knowledge, few papers considered the effects of vehicles. One of them examined the effect of vehicles in the tunnel [3] and another reported the measurement of signal attenuation caused by a large vehicle [4].

Propagation Modeling

A typical urban environment consists of streets, buildings, vehicles and groups of trees on safeisland. The streets are lined with tall buildings. The vehicles and groups of trees on safeisland are modeled by perfect electric conductor boxes and dielectric slabs, respectively. Figure 1 shows a plane view of the street scene. Consider the projection Txp of a transmitting antenna Tx on ground. We shoot 360 or 3600 2D ray tubes from Txp and trace each ray tube which may bounce from the projections of the buildings, vehicles, and trees or transmit through the projections of trees and vehicles as shown in Fig. 4. A ray tube hits the projection of a vehicle or a group of trees is split into a reflected and a transmitted ray tube. Based on this idea, a binary reflection/transmission tree for a ray tube shot from Txp is constructed. For each ray tube, we check whether the projection Rxp of the receiver Rx falls within the ray tube. If it does, an exact 2D ray from Txp to Rxp can be determined using the 2D image sources. If Rxp doesn't fall within the ray tube, keep on tracing until all the branches are traversed.

Once an exact 2D ray from Txp to Rxp is established, the third dimension is taken into consideration to determine if an exact 3D ray from Tx to Rx exists. Let there be m reflections and n transmissions for an exact 2D ray. If all the heights of the m reflection points are lower than those of the m obstacles, an exact 3D ray exists. Otherwise the ray can not reach the receiver. Then we check whether the ray transmit through the n trees or vehicles or fly over the top of them to the receiver. If the height of the transmission point is higher than that of the obstacle, the ray flies over the top of the obstacle. If not, the ray penetrates the obstacle when it is a group of trees, or is blocked and thus ignored when the obstacle is a vehicle.

Then we compute the received power at the receiver. If the 3D ray is with reflections from m obstacles and transmission through n obstacles, the field at the receiver is given by

$$\bar{E}^r = \bar{E}^i \cdot \prod_{i=1}^{m} \overline{\overline{R_i}} \cdot \prod_{j=1}^{n} \overline{\overline{T_j}} \cdot e^{-j(kj-k)d_j} \cdot \frac{e^{-jks}}{s} \tag{1}$$

where $\bar{E}^i$ is the electric field at 1m from the transmitter; $\overline{\overline{R_i}}$ is the dyadic reflection coefficient at the i'th reflection point; $\overline{\overline{T_j}}$ is the dyadic transmission coefficient at the j'th transmission point; k_j is the wave number in the j'th group of trees; d_j is the ray path length in the j'th group of trees; s is the ray path length from the transmitter to the receiver; k is the wave number in free space. Repeat tracing the ray tubes until all ray tubes have been traced and their contributions have been included, then we can get the propagation loss.

Results

Simulations were arranged to determine the propagation loss in a straight street with various distributions of vehicles and trees. The street width was 20m. The relative dielectric constant and absolute conductivity of the buildings and ground were 4.0 and 0.00075 S/m[5], respectively. We computed the propagation loss for radio wave of 1 GHz. A Truck on the road was modeled by a PEC box with a length of 5.6896m, a width of 2.4384m, and a height of 4.6736m. The groups of trees on safeisland were modeled by a 80m×1m×4m dielectric slab of which relative dielectric constant and absolute conductivity were 1.2 and 0.0001 S/m[5], respectively. For the cases given in this paper, the x-axis was set to be along the street. The transmitter placed at x=0 was established at a height h_t=6m, while the receiver moved at a fixed height h_r=1.5m.

To get the effect of trucks, we randomly placed ten trucks in the 50m long street region. For each case, we could find the severe fast fading and blockage due to reflection and shadowing by vehicles, respectively. The mean propagation losses of 8 cases are shown in Fig. 3. We can find that the received power is lower than the no-truck case, and the difference increases with the distance. Figure 4 shows the propagation loss due to groups of trees on safeisland. From the results, we found the attenuation due to groups of trees on safeisland were more than 10 dB. The attenuation was even more obvious in the farther region.

Conclusion

The hybrid method combined with 2D ray tracing and simple 3D geometry considerations has been generated an efficient and comprehensive propagation modeling for a general propagation environment with buildings, vehicles, and trees. We have investigated the effects of vehicles and groups of trees on safeisland. Attenuation due to shadowing from vehicle and transmission from groups of trees are significant. More simulation results will be presented in the conference.

References

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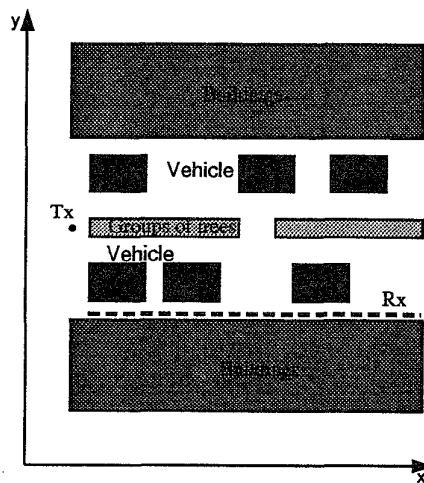
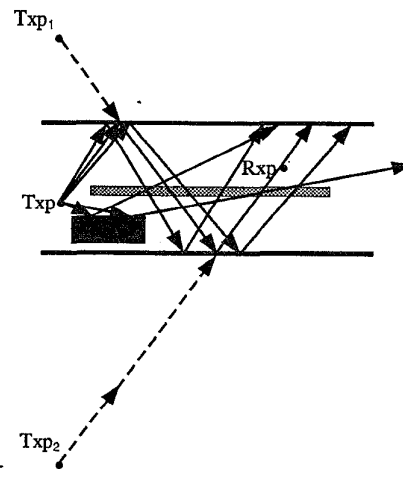Fig. 1 Plane view of a typical street scene.

Fig. 2 Geometry of 2D ray tracing. Txp and Rxp are the projections of transmitting antenna and receiving antenna on ground respectively. Txp1 and Txp2 are the 2D images of the first and second bounces.
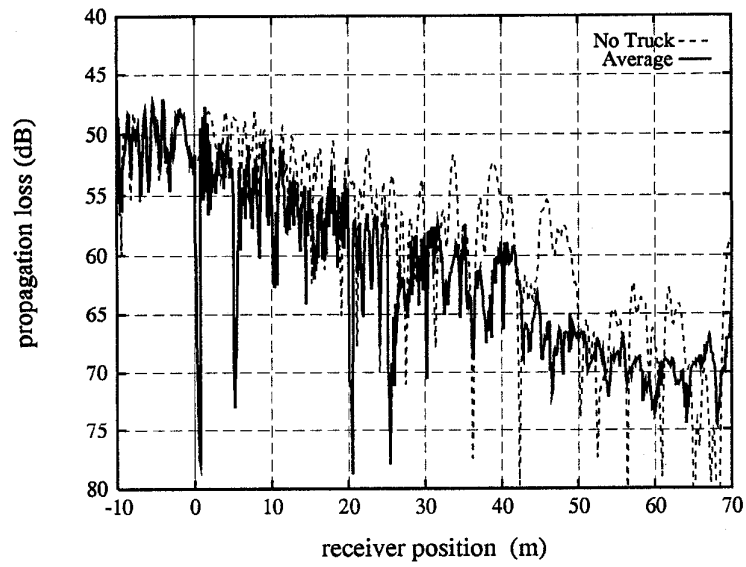
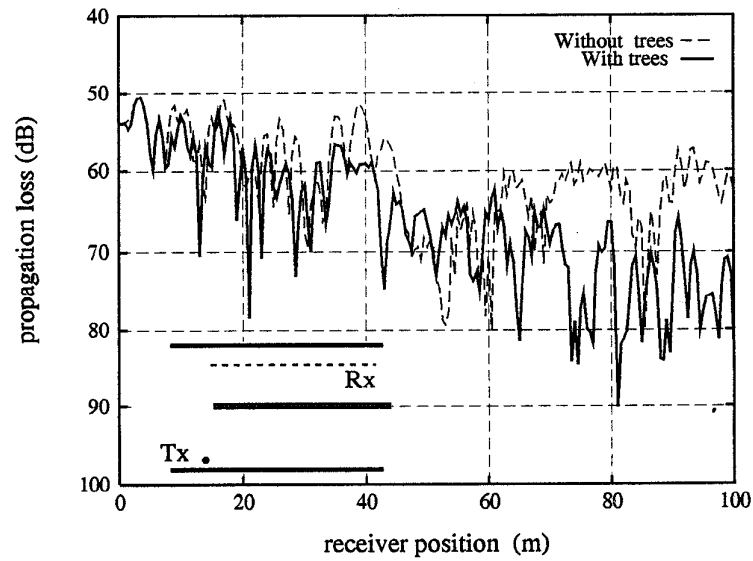Fig. 3 Mean propagation loss variation according to random distribution of ten trucks.

Fig. 4 Propagation loss variation according to trees.