Indoor Micro Cell Area Prediction System using Ray-tracing Method for Mobile Communication System

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1. INTRODUCTION

There is an increasing demand for wireless indoor communications systems such as the digital wireless PBX system. The coverage area prediction system is effective for designing base station positions. It is difficult to predict the coverage area accurately because components such as wall partitions, etc., are not only positioned randomly but also made from complex materials. The ray-tracing method is suitable, because propagation loss is calculated easily by searching, from transmitter to receiver, only the geometrical ray trace which includes reflection, transmission and diffraction in the components (1).

In this paper, the Indoor Micro cell Area Prediction system (IMAP), using the ray-tracing method, is proposed, and its system configuration and major performance are described.

2. RAY-TRACING

An example of the ray-tracing method is shown in Fig.1. Rays are launched in all directions from a transmitter, and arrive at the receiving point after geometrical reflections, transmissions and diffractions. The field strength at the receiving point can be calculated by summing the electric field of all the arrived rays.

To trace rays, two methods, imaging and launching, are generally known. The former method strictly traces the ray path between the transmitter and the receiver by producing the transmitter's equivalent image with respect to the components. Field strength can be calculated exactly, but calculation time increases with the power of the number of components. So this method may be unrealistic when there are a lot of reflections, transmissions and diffractions.

The latter method, launching, is shown in Fig.2. A ray is launched at every angle $\Delta\theta$ from a transmitter, and its path is traced, through reflection, transmission and diffraction. This method can calculate faster than the imaging method, especially in the case where there are a lot of components. Of these launched rays, the ones which eventually arrive at the receiver are determined. In some cases, however, no rays arrive at the receiver, because of the discrete values of the launching angle. To solve this problem a reception area ΔS, instead of a reception point, is introduced. If a ray arrives within the reception area ΔS, it is considered to have arrived at the reception point. Accordingly, the prediction accuracy for this method depends on $\Delta\theta$ and ΔS.

The IMAP employed a launching method with 3-dimensional paths, taking into account ceiling and floor reflection.

(a) RAY RECEIVING MODEL

When $\Delta\theta$ is large or ΔS is small, it can be the case that no rays arrive within the area ΔS, although there must be rays arriving at the receiving point. This reduces the accuracy of the predicted field strength. On the other hand, when $\Delta\theta$ is small or ΔS is large, too many rays can arrive within the area ΔS, although these arriving rays must be a single ray, reflecting, transmitting or diffracting with the same component. This results in a larger predicted field strength than the true value.

The IMAP allows smaller $\Delta\theta$ and larger ΔS in order not to miss the rays that should arrive at the reception point, and employs a new method to avoid repeated adding of the ray. The new method is that when rays arriving at the area ΔS have exactly the same reflection, transmission, and diffraction points, the rays are reduced to a single ray. Thus, the IMAP can obtain high accuracy without always setting the optimum values of $\Delta\theta$ and ΔS.

(b) RAY LAUNCHING MODEL

It is natural to test all the rays launched spherically, which dramatically increases the number of rays that must be considered, and hence increases the calculating time. The IMAP uses a new method for shortening the time, as shown in Fig.3. 2-dimensional rays are launched and traced first. Rays that arrive at the reception area ΔS are determined, then the image transmission points are calculated by considering the first-order reflection by the floor or the ceiling. It is found that a sufficient accuracy is obtained by considering only first-order reflection.

Figure 4 shows another technique to reduce calculation time. If all components that compose the indoor layout must be searched to find reflection (transmission, diffraction) points, a vast amount of time is required. In the IMAP, all components are categorized into geographically spaced blocks. Instead of searching all the components serially, the components within the block in the direction of the ray are searched first, to find the points.

3. PROPAGATION MODEL

Figures 5(a),(b),(c) show reflection, transmission and diffraction models. Reflection coefficient R is calculated assuming that the thickness and area of the components are infinite [2]. Transmission coefficient T is calculated assuming that the area of the components, having thickness Δw, is infinite [2]. Diffraction coefficient D is calculated using GTD (Geometrical Theory of Diffraction) [3]. At the receiving point the total field strength E is given by

$$E = \sum_i E_i = \sum_i \left(\frac{K \cdot P_T \cdot G_T \cdot G_R}{r^2} \prod_j R_j \cdot \prod_k T_k \cdot \prod_l D_l \right)$$

Where E_i is field strength of the ith ray, P_T is transmitter power, G_T and G_R are transmitter and receiver antenna gain, r is path length, and K is a constant given by wavelength, etc. [4].

4. PERFORMANCE OF IMAP

Figure 6 shows functions of IMAP. CAD software is used for constructing the indoor layout. The algorithms mentioned in the section 2 are realized at the ray-tracing calculation step.

The values predicted by the IMAP are compared with the values measured in the NTT laboratory. Figure 7(a) shows the layout of this building. Transmitted power was 10mW at 2.2GHz. Both transmitted and received antenna were dipole and had a height of 2m. Figure 7(b) shows the results of prediction using IMAP. Figure 7(c) shows the predicted and the measured values for the mean propagation loss versus distance along the measured course. They are close to each other. The calculation for this prediction took 10 minutes using a SUN workstation (SS20).

5. CONCLUSION

We propose algorithms to decrease calculation time while maintaining precision of prediction for the ray-launching method. We also show the Indoor Micro cell Area Prediction system (IMAP) developed based on these algorithms.

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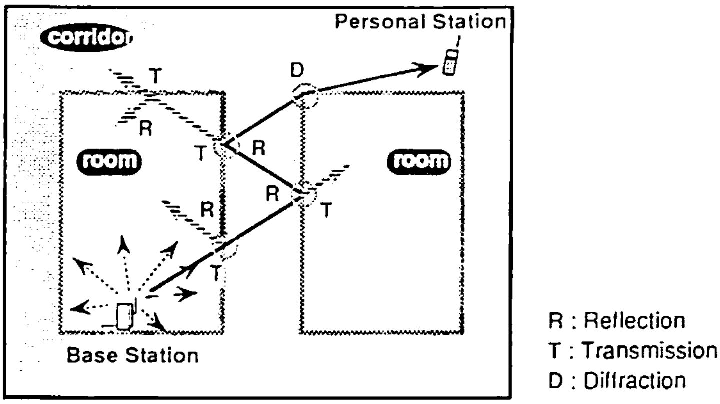


Fig.1 Ray-tracing for prediction of propagation characteristics

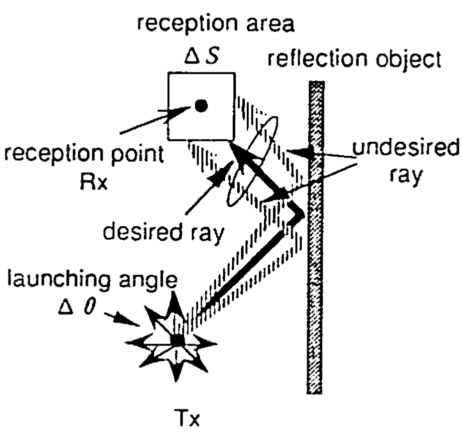


Fig.2 Launching method

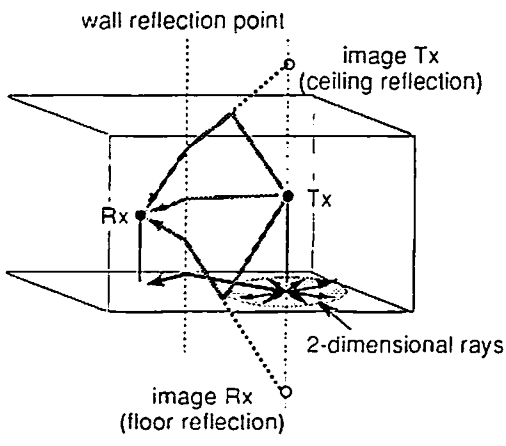


Fig.3 Launching method in IMAP

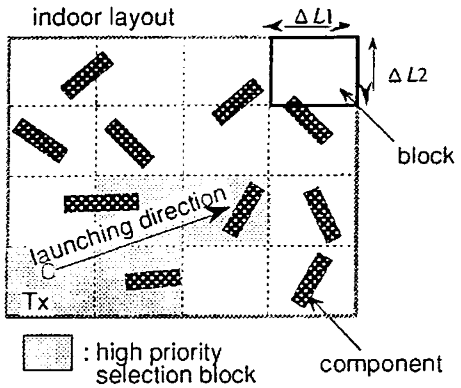
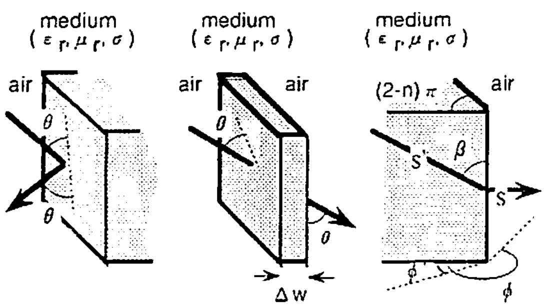


Fig.4 Search of reflection components



(a) Reflection (b) Transmission (c) Diffraction

Fig.5 Propagation model

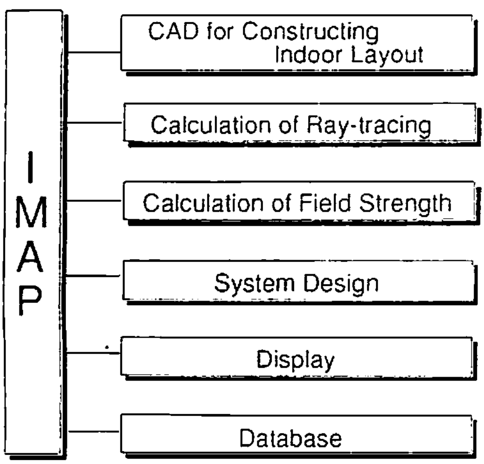
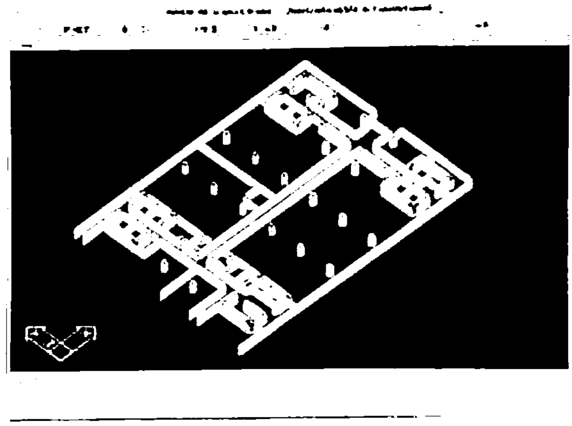
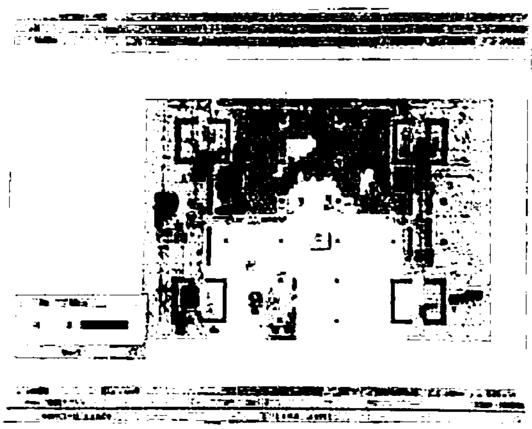


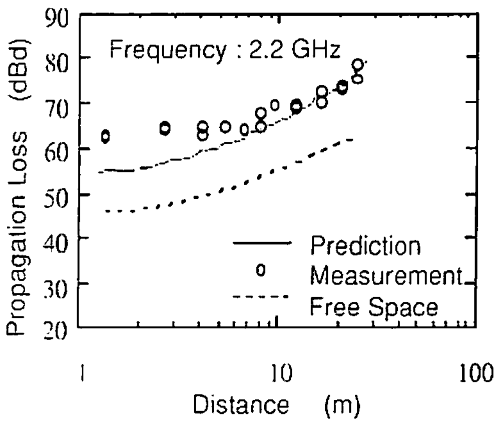
Fig.6 Function of IMAP



(a) Indoor layout



(b) Received level predicted by IMAP



(c) Propagation Loss

Fig.7 Prediction versus measurement