Numerical Estimation of Electric Field Distribution in Wireless Office LANs Using the FDTD Method

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Abstract

The purpose of this study is to develop accurate and reliable estimation method of Electromagnetic field distributions in practical environments including humans absorption effects. In this paper, large-scale numerical simulations are carried out to examine the electromagnetic fields excited by the wireless LAN terminal inside an office. We used a typical office model and employed the FDTD technique and a supercomputer to estimate the field distributions inside the whole area of the room. Furthermore, a simplified histogram estimation method for electric field strength was employed to deal with the complicated EMF distributions inside the office.

1. Background

An increasing number of devices that can communicate using wireless networks have been developed in recent years. It has become common for large data files to be transmitted using wireless networks and the devices' transmission frequencies continue to increase. Good signal coverage throughout the entire area is a requirement of a wireless local area network (WLAN) environment in order for portable devices to experience no signal interruptions. Signal reflection, refraction and absorption are important factors that must be considered in a good indoor WLAN radio propagation service area estimation in order for signal coverage to remain above a minimum value. When designing indoor WLANs, it is also necessary to consider the optimum number of access points (APs) that are needed as well as the best positions in which they should be placed for optimum data throughput. This is very important because too many APs increases the overall cost of a WLAN design unnecessarily. Likewise, non-optimal placement of the APs will result in unreliable coverage in certain parts of the environment [1]. When using higher frequencies, the effect on radio wave signal strength of absorption by different objects and humans has a greater impact than when lower frequencies are used. All of these factors point to the need for a precise estimation method for electric field (E-field) strength distribution before implementing a design. Currently used estimation methods (such as ray-tracing) are limited with respect to their precision and this paper proposes an estimation technique that is based on the more precise Finite-Difference Time-Domain (FDTD) electromagnetic field analysis method [2][3][4].

2. FDTD Analysis for Estimation of EMF in Office

With the FDTD method, the Electromagnetic Field Strength at every point within the bounded area can be calculated. These calculations take into account signal absorption and reflection due to every object that is defined within the space. The data that is of interest in this study is in the plane 0.9 m - 1.1 m from the floor and using histograms, the E-field distribution in these planes were visualized. A significant amount of memory is required for performing these calculations and they were done using the Hokkaido University Information Initiative Centre's supercomputer.

The dimensions of the model room and the positions of objects inside the room are exactly the same as a room in this Department which has dimensions of: 11.34 m x 3.64 m x 15.09 m [5]. Identical measurements are used because it would then be possible to take experimental measurements in the room for comparison with simulated results. If there is a good correlation between the two datasets, it will be possible to proceed with plans to examine ways of improving the data throughput in various sections of the room and subsequently to extend these techniques to wireless LANs in general, regardless of the layout of the rooms.

Figure 1 shows a model of the room. Metallic (reflective) objects within the room include bookshelves, desks, partitions, lockers and a refrigerator. The Access Point (AP) is at a height of 2.65 m from the floor and its initial position is in the centre of the room but in subsequent simulations, the position and amount of APs used were varied.

Figure 1 shows the scenario when there is one AP and no persons present. Also, in subsequent models, homogenous human phantom models are added in order to examine the absorption effects of the human body on the E-field distribution. FDTD and room parameters are listed in Table 1.

3. Results

In Figure 2, the histogram shows data for the case when a single AP is in the centre of the room. This histogram shows the variation of the absolute E-field values in the planes 0.9m, 1.0m and 1.1m from the floor. According to the graph, the maximum E-field strength in all 3 planes is approximately 114dBuV/m for a signal input power of 20mW. However, the distribution throughout the room differs and higher signal intensities exist in higher planes closer to the AP. This is expected under the stated conditions. Figure 3 is a top-view visual representation of the E-field distribution in the room.

4. Conclusion

It can be concluded that the FDTD method gives a reliable estimation of the E-field strength in environments with objects made from different materials. Other techniques, such as ray-tracing methods, may also be used but the FDTD method has the advantage of taking into account signal absorption and reflection due to physical and electrical properties of every material in the environment. Hence it is more accurate. Further study has also been done where the number of APs, human phantom models present, and other parameters are varied.

References

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Table1. COMPUTATION PARAMETERS

Cell size (cubic)	D = 10 mm
Total Problem Space	1134×1509×364 (cells)
Absorbing B. C.	PML (8 layers)
Signal Frequency	2.45 GHz (CW)
Room model	Walls/Roof: Concrete (ε= 4.5;σ= 6.06 x 10^{-4}) Floor/Desks/Shelves/Partitions/Refrigerator: Metal Chairs: Plastic (ε= 2.2;σ= 1.0 x 10^{-13}) Cushion (ε= 1.0;σ= 1.0 x 10^{-7}) Glass (ε= 5;σ= 3.0 x 10^{-3})
Access Point	Dipole antenna; 2.65m from floor Input Power: 20mW

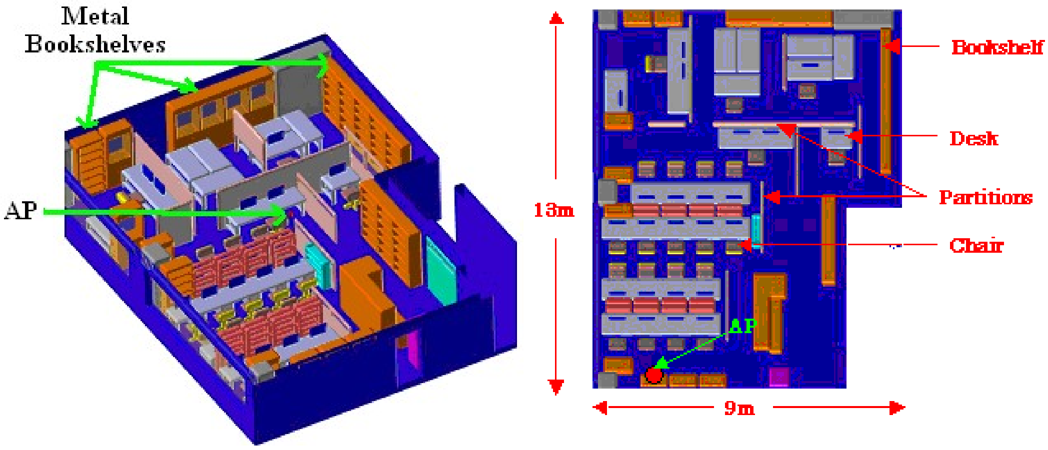

Figure1. Model of the room under investigation

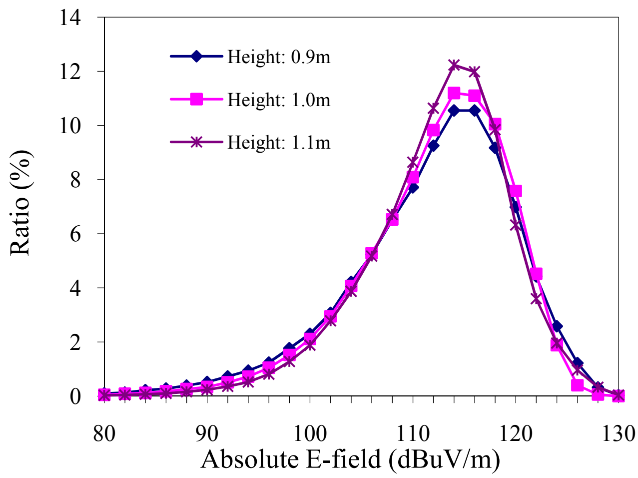

Figure2. Histogram showing Absolute Electric Field Intensity (dBuV/m)
in the planes 0.9m, 1.0m and 1.1m from the floor

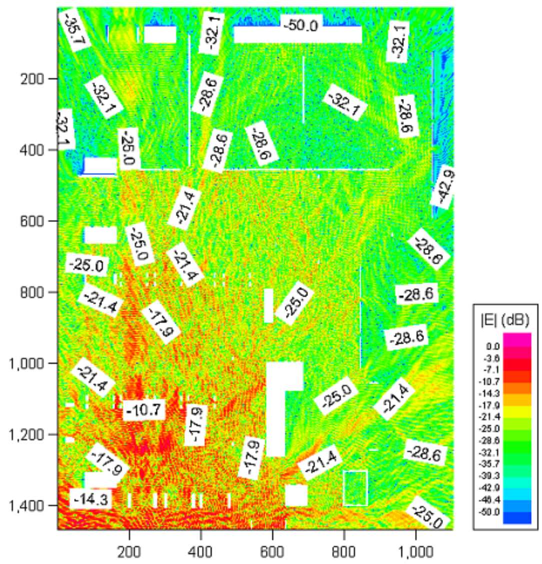

Figure3. Visualization of data in the plane 1.0m from the floor.