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FDTD Analysis of Incident Plane Wave Indoor Propagation

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1. Introduction

The digital terrestrial broadcasting services for mobile receivers had already been started in Japan [1]-[3]. The service is effective as communication means at outbreaks of natural disaster. Experimental studies of the reception characteristic in various environments and countermeasures for the deterioration of reception are carried out until now [4].

In this report, we consider the incidence plane wave of digital terrestrial broadcasting due to clarifying its indoor propagation characteristics. A large-scale numerical analysis by using the finite-difference time-domain technique [5] is effective for this purpose. First, two kinds of model, an empty room and a room with a set of furniture are explained in detail. Next, we carry out a computer simulation about indoor propagation of the incident plane wave toward the rooms. Finally, the propagation characteristics for the two models will be discussed.

2. Analysis Method and Results

Figure 1 shows a numerical model of a room with a set of furniture. The dimensions of room are length of 9.83 m, width of 6.85 m and height of 3.02 m. It is surrounded by the concrete walls of 260 mm thick which include metal plates of 300 mm wide and 10 mm thick. There is a large window of 5.59 m wide and 1.80 m high in front of the room. The incident plane wave goes on the room through the window. Table 1 lists the parameters of media, relative permittivity and conductivity, in the room used in the FDTD calculations.

The FDTD technique is a versatile and efficient tool for the solution of Maxwell's equations in complex structures. It can also treat problem spaces that contain lossy media. In the FDTD analysis, the problem space is quantized by Yee cells (cubical cells). On the outer boundary, the FDTD algorithm employs the absorbing boundary condition to simulate the extension of the field sampling space to infinity by suppressing reflection off the outer boundary. The cell size must be small enough to obtain accurate analytical results. Generally, it is less than one tenth of the wavelength of the frequency for the analysis. Therefore, in the case of analyzing large-scale models such as the room, the computational memory size required becomes extremely large. Then we employed a supercomputer to analyze the EMF in the room. The FDTD analysis is used in order to obtain spatial electric field distributions throughout the inner space of the room. A frequency band of 513.25 MHz to 561.25 MHz is used in the digital terrestrial broadcasting service. To achieve a precise computation, spatial resolution is set to 1 cm^3 in this paper. To analyze the indoor propagation characteristics, the excitation for the plane wave is performed using a Gaussian pulse with the horizontal polarization. In this work, the time step size is chosen as 1.67×10^{-11} sec for the computational stability.

In this report, the propagation characteristics of the two indoor models, an empty room and a room with a set of furniture, are examined. Figure 2 shows the amplitudes of the electric field for the indoor models where the observation point is the centre of the room and its height is 1.1 m above from the floor. It is evident from the figure that the amplitudes converge to zero after about

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8,000 time steps independent upon the models. The first peak of the amplitude is observed at the same time and its values are almost same for the two models. But the additional peak appears for the room with a set of furniture. It is the reflection caused by the metal screen in the room.

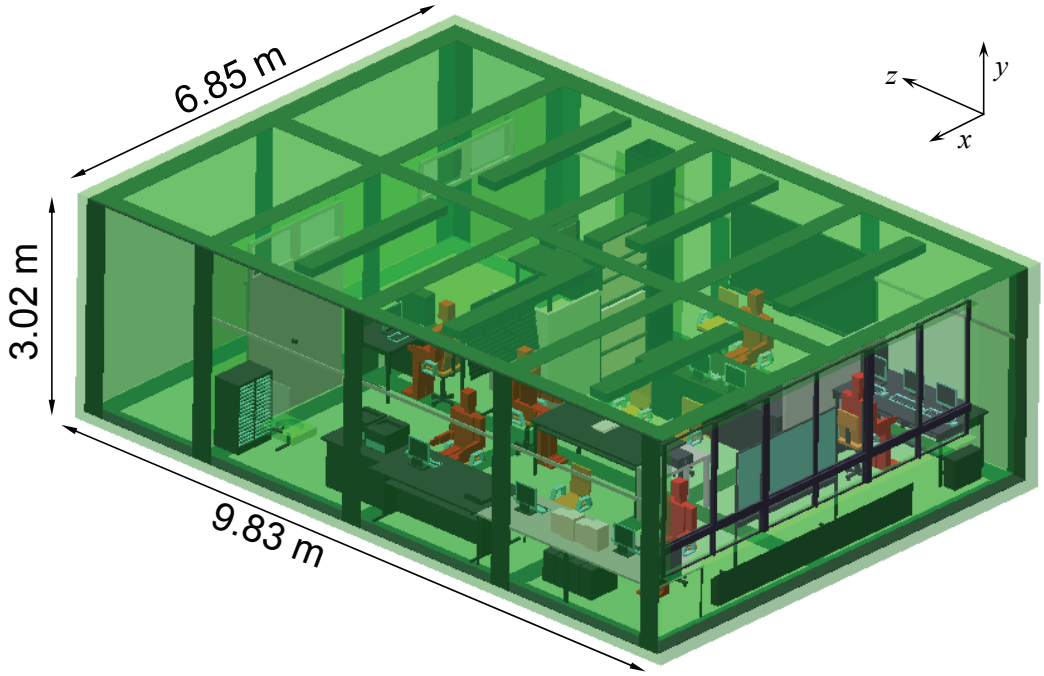

Figure 1: A numerical model of a room with a set of furniture.

Table 1: Parameters of media considered in the calculation.

Items	Relative permittivity	Conductivity
Free space	1	0
Metal	-	∞
Concrete	5.5	0.023
Wooden material	2.5	0.001
Window glass	5.0	0.003
Plastics material	3.2	0.008
Rubber material	2.4	0.005
Phantom	50.0	2.2253
Seat polyfoam	2.0	0.001
Paper	2.9	0.008

Figure 3 shows the magnitudes of the electric field versus frequency in the steady-state condition. They are derived from the time domain data of 16,384 time steps shown in Fig. 2 by the Fourier transform. The solid and dashed lines denote the results for the room with a set of furniture and the empty room, respectively. Additionally, the blue and red lines denote the results for the horizontal and vertical field components, E_x and E_y. The figure illustrates that the vertical field component is slightly appeared for the empty room although it is obviously increased in the room with a set of furniture.

Figure 4 depicts the magnitudes of the electric field versus frequency for three different observation points shown in figure (d) and whose height is 1.1 m above from the floor. The computed results show that the vertical filed components, E_y, are evidently increased for the all three cases shown in the figure. Especially at the observation point adjacent to the window the vertical filed component is relatively larger than those at the other points because reflected field components propagate a long distance.

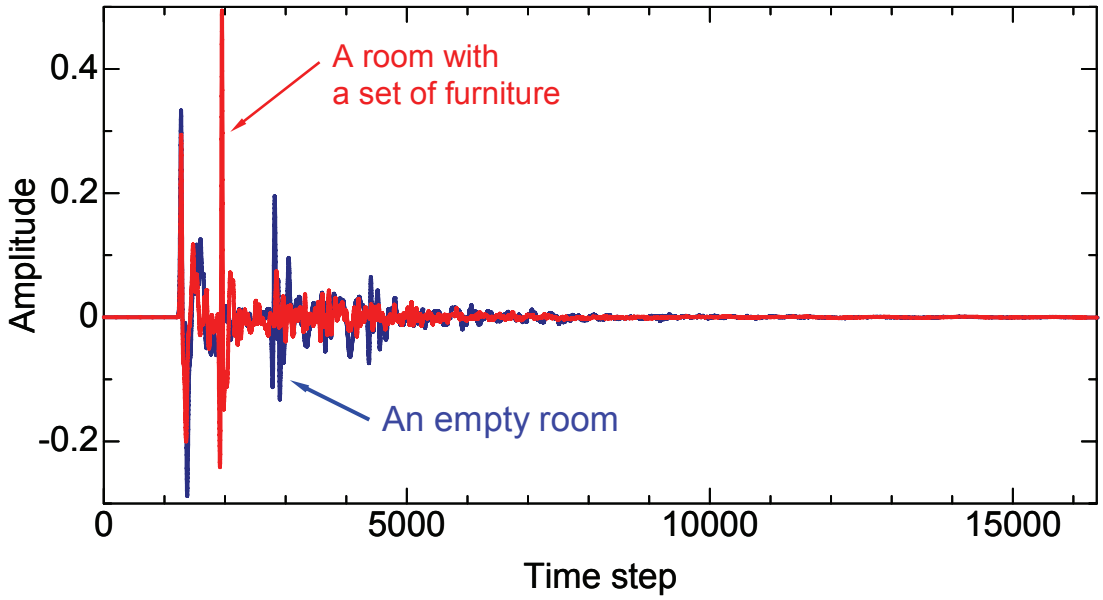

Figure 2: The waveforms at the observation point for the Gaussian pulse input. They are observed at the centre of the room and 1.1 m above from the floor. The red and blue lines denote the waveforms for the room with a set of furniture and the empty room, respectively.

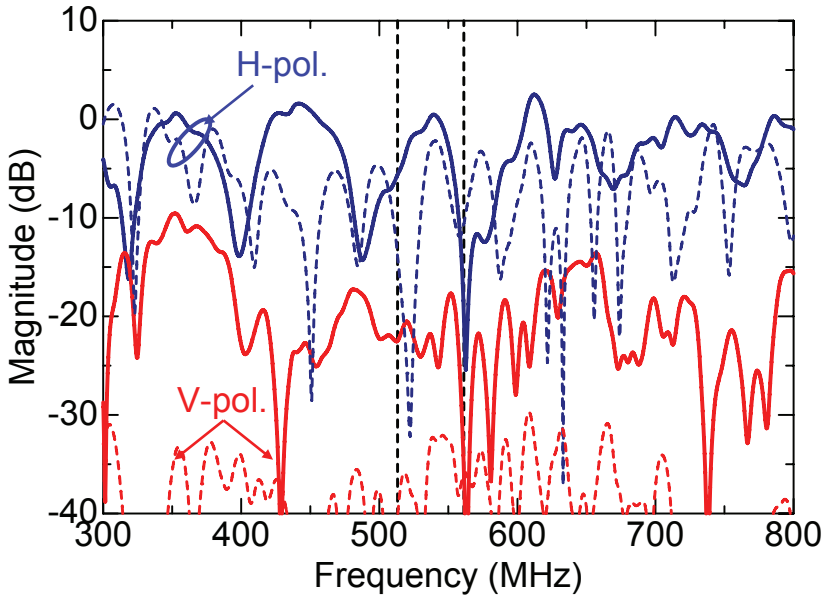

Figure 3: Magnitudes of the electric field in the frequency domain for the two kinds of room. The solid and dashed lines denote the electric field distributions in the room with a set of furniture and the empty room, respectively. Additionally, the blue and red lines correspond to the magnitudes of the horizontal and vertical fields for the horizontal incident field, E_x.

3. Conclusions

The paper discusses the indoor propagation of the plane wave incident from outside and the electromagnetic field distribution by using the FDTD technique. The two kinds of indoor model, the empty room and the room with a set of furniture, are built and are used in the numerical analysis. As a result, we conclude that the vertical field components are slightly observed for the horizontal incident field in the empty room although they are evidently detected in the room with a set of furniture.

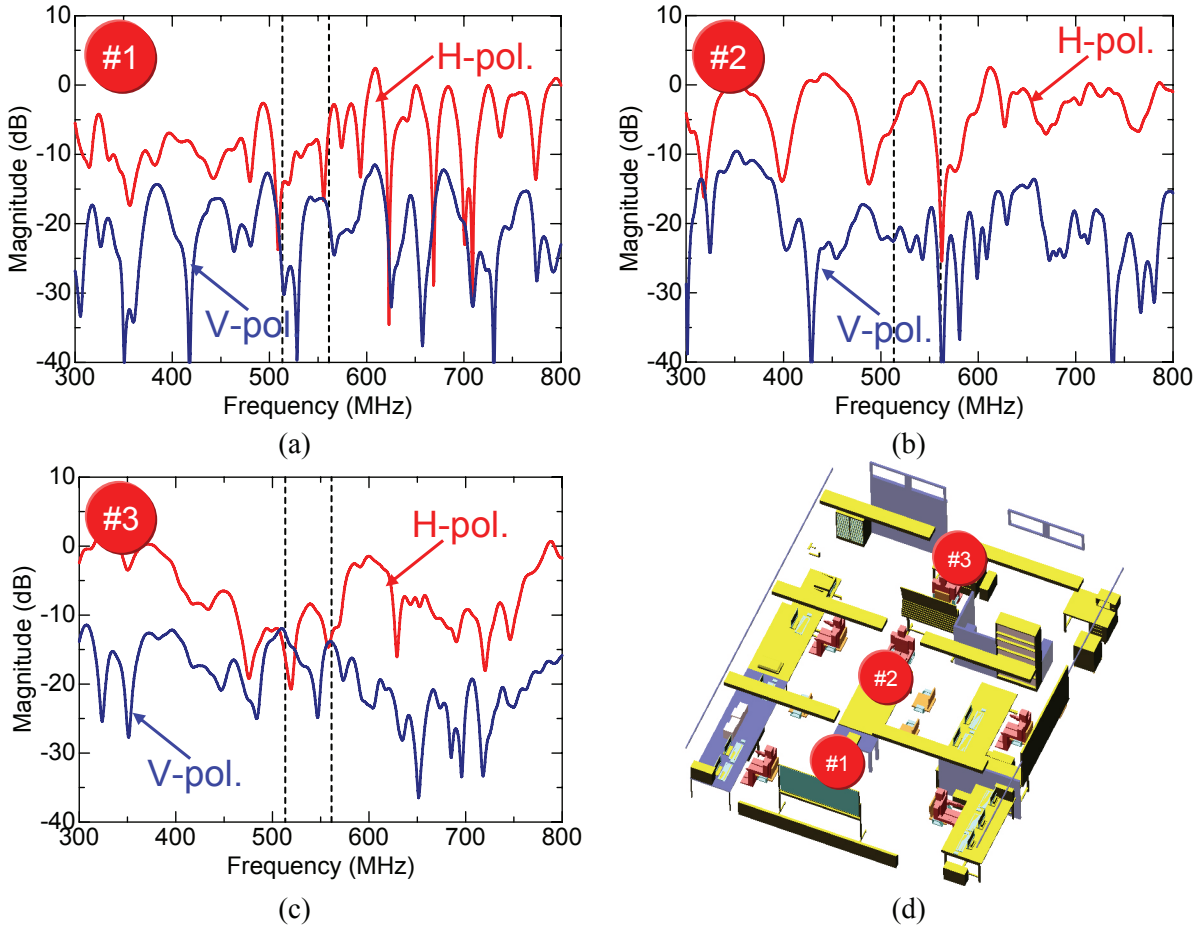

Figure 4: Magnitudes of the electric field versus frequency for the three different observation points shown in (d) and at the height of 1.1 m above from the floor.

Acknowledgments

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