FDTD Analysis of Millimeter Wave Data Communication between Data-servers in Server-rack

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It is pointed out that cable connections between data-servers for data communication occupies large space inside a server-rack, and causes reduction of cooling performance which leads to a considerable amount of electric power consumption. To solve this problem, it is considered to replace the wired communication by a millimeter wave wireless communication. For the millimeter wave communication, it is required that the millimeter wave has to be isolated inside the rack to keep information security, at the same time, the rack wall has to have sufficient amount of aperture to keep cooling performance by airflow. Accordingly the rack back door has to have mesh structure to satisfy these conditions. To find out the appropriate shielding mesh structure, this paper presents a design study of the shielding mesh using the finite difference time domain (FDTD) method simulations.

***Index Terms*—Millimeter wave propagation, Data communication, Datacenter, Data-server, Server-rack, finite difference time domain (FDTD) method, electromagnetic shielding**

I. Introduction

It is pointed out that one of biggest problems in daily operation of the datacenter is a huge amount of electric power consumption. In particular, the power consumption by air-conditioning units occupies about half amount of the all power consumption, and the main part of the air-conditioning is cooling of data-server machines. One of the biggest obstacles for cooling of the server machines is LAN cables of wire communication between server machines, which occupies considerable space inside a server-rack and reduces the cooling performance by airflow. In addition, it is also pointed out that the cable connection leads to difficulty in maintenance works for servers inside the rack.

To solve these problems caused by the cable connection, it is proposed to replace the cable connection by wireless communication using a millimeter wave [1]. The use of the millimeter wave band avoids interference with the conventional microwave band, in addition, higher speed data communication is expected compared with the microwave band. However, we need to carefully consider the millimeter wave data communication inside the rack since the propagation of millimeter wave will be affected seriously by the fine structure of the rack. From this point of view, this paper presents simulations and a design of the rack structure using the FDTD method [2].

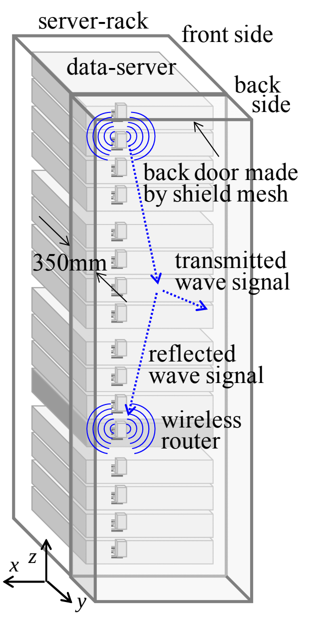

Fig. 1. Millimeter wave communication inside server-rack

II. Millimeter Wave Communication inside Server Rack

Overview of the millimeter wave data communication between servers inside the rack is indicated in Fig.1. It is assumed that 60 GHz millimeter wave communication is carried out via stick-like antennas which are connected at the USB or LAN interfaces on back panels of the servers. The millimeter wave propagates from a transmitter server to a receiver server in 350mm gap space between the back panel and the rack back door. Then it is necessary to suppress the transmitted (leaked) millimeter wave signal across the rack back door since information security has to be kept, in addition, the reflected millimeter wave signal from the back door has to have sufficient quality to be used for data communication. On the other hand, it is also necessary to keep a sufficient amount of airflow through the rack back door for cooling of the servers. Accordingly, the rack back door has to have mesh structure to keep both of the sufficient amount of airflow and sufficient shielding performance for the millimeter wave at the same time. This means that we need to design the shielding mesh structure of the rack back door very carefully, and appropriately decide the valance of millimeter wave shielding and the amount of airflow. This paper presents considerations on characteristics of transmission and reflection of the millimeter wave at the shielding mesh of the rack back door using the FDTD method simulation.

Numerical Study of Transmission and Reflection Characteristics of Millimeter Wave at Shield Mesh

First of all, we consider transmitting characteristic of the shield mesh by using a simplified numerical model indicated in Fig.2. It is assumed that the millimeter wave signal emitted from the z-direction dipole source is reflected and transmitted at the x-z plane shield mesh with circular holes in the 30 x 50 x 50 mm region. It is known that aperture size of the mesh has to be more than 60% for keeping sufficient amount of airflow. Under this condition, we try to find appropriate mesh parameters to achieve less than 7% transmission ratio as a target performance of isolation of the millimeter wave inside the rack. Examples of calculations of the transmission ratio are indicated in Fig.3. The transmission ratios for various aperture diameters of the circular hole with a constant thickness of 1mm and various thicknesses with the constant diameter of 2.4mm are shown in Fig.3(a) and (b) respectively. We here choose 2.4mm diameter and 3mm thickness as one of the most preferable parameters which satisfy the above conditions.

Another task in this work is an evaluation of the quality of reflected signal from the shield mesh door of the rack. It is readily found that the size of inside rack space, 350mm, is too wide compared with the millimeter wave length of 5mm. To reduce computation cost, we employ the scattered field formulation [2] of the FDTD method. That is, a scattered component of electromagnetic fields is used as unknowns of the FDTD scheme, then the numerical model is limited to the vicinity of the shield mesh (see Fig.4). By comparing the intensity of the scattered field from the shield mesh with that from flat metal plate (without mesh), a gain and phase shift of the reflected wave signal are evaluated for the incident angle range 0 to 50 degree (see Fig.5). Although both of the gain and phase shift are fluctuating by several percents owing to an interference caused by the mesh structure, we can roughly understand that the gain is almost same as the flat plate but about 45 degree phase shift occurs in the reflected wave signal by the mesh structure.

III. SUMMARY

This paper has presented FDTD numerical analysis and evaluations of transmission and reflection characteristics of the millimeter wave around shield mesh back door of the rack. It is found that the reflection characteristic still include a considerable amount of numerical error. Any other schemes such as use of Bloch's boundary condition [3],[4] for the periodical mesh structure should be considered in future works.

IV. ACKNOWLEDGMENT

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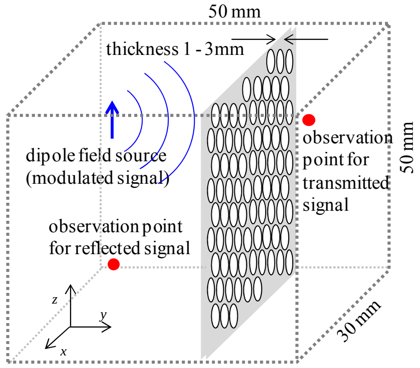

Fig. 2. Simlified numerical model for dipole source of millimeter wave at shielding mesh

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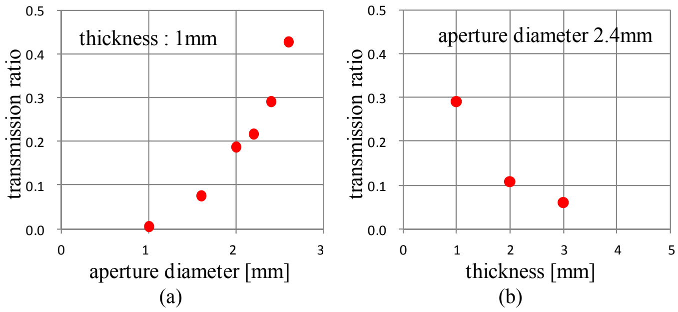

Fig. 3. Examples of numrical calculation for transmission ratio

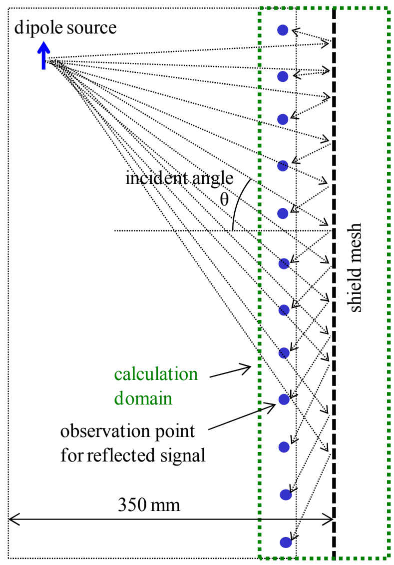

Fig. 4. Numerical model for scattered field fomulation of FDTD method

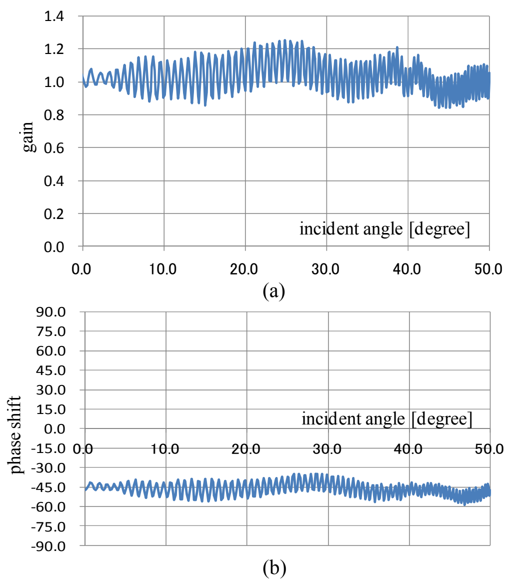

Fig. 5. Incident angle dependencies of reflected signal (a) gain, (b) phese shift