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Numerical and Experimental Study on Planar Waveguide Sheet with Switching Diversity

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Abstract: A planner waveguide sheet is used to improve the management efficiency of smart-shelf system. Radio frequency identification (RFID) is the protocol used in this system to read the tag which includes information of the goods on the smart-shelf system. The planar waveguide is used as antenna of the RFID reader. In this report, a method of switching diversity is proposed to improve the radiation performance of the RFID reader and the electric field distribution analysis and experiment results are shown.
Keyword: Smart-shelf system, Radio frequency identification, Planar waveguide, Near field

1. Introduction

RFID is one of the most promising technologies for wireless identification systems and sensor network systems. Two-dimensional waveguide sheet is capable of increasing area of the read and write of the RFID system in the smart-shelf system, which can be utilized not only in the management and administration of the books and documents, but also widely in inventory and security management in retail store [1]. The two-dimensional transmission sheet was also used in sensor networking [2-4], localization [5], and power transmission[6-7]. It was shown the straight and meandering microstrip lines mounted on the bookshelf was used as the leaky wave transmission line to enhance the electromagnetic coupling between the RFID reader and tags[8], where the characteristic impedance of the microstrip line is 50 ohms and the microstrip line is terminated by 50 ohm load. A planar waveguide sheet [2][6][9] was also used as the leaky wave transmission line in the smart-shelf system. However, because the standing wave exists in the two-dimensional waveguide sheet due to the impedance mismatch at edges of the sheet, the near field distribution of the waveguide sheet is non-uniform and the response performance of the tags is significantly degraded when the tags are in the area of the minimum of the standing wave. In order to improve the transmitting efficiency, different shapes of the mesh on the two-dimensional transmission sheet were studied [6][9][10-11] to increase the leakage field of the transmission sheet. Some experimental and simulated results of the electric field distribution near the two-dimensional transmission sheet were presented in [7][12-13]. However, there are still some problems to be solved. For example, the receiving power of the tag depends on the position of tag on the waveguide sheet, and it becomes very small in some places of the sheet.

In order to solve this problem and to improve the response performance of the tags in the smart-shelf system using the planar waveguide sheet, the planar waveguide sheet terminated by switched open/short termination and switching diversity reception is proposed. The numerical simulations of the proposed methods are performed using the method of moments, and the increase of the near field level due to the selection switching diversity reception and resistance termination are demonstrated by measurement result.

2. Planar Waveguide Sheet

The geometry of the planar waveguide sheet consists of a conducting mesh layer, dielectric substrate layer and a conducting ground plane, as shown in Fig. 1. The planar waveguide sheet is analyzed using the method of moments numerically. In this numerical simulation, the size of this sheet is W= 110 mm, L= 400 mm, h= 2 mm. The shape of the mesh is square and each one is 7 mm × 7 mm, and width of the mesh line is 1 mm. The dielectric constant of the substrate is ε_r= 1.3 which is very low and treated as ε_r= 1 in this simulation. Both the mesh and the ground plane are assumed to be perfect electric conductor. The ground plane is treated as an infinitely conducting plane. The waveguide sheet is fed by a voltage source between the mesh and the ground plane. The working frequency is 950 MHz.

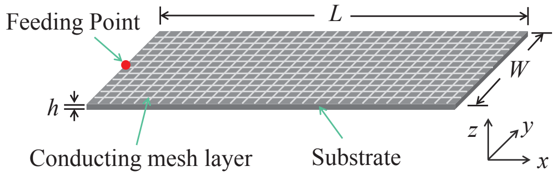

図 1: The simulation geometry of the planar waveguide.

Because the RFID tag antennas is assumed to a linear wire antenna located vertically above the sheet, it is mainly coupled with the waveguide sheet by z-component

2013 年 5 月 28 日
東北大学　電気・情報系 103 会議室

of the electric field. Therefore, only the z-component of the electric field is shown in this paper. The $|E_z|$ distribution at xz plane of $y = 55$ is shown in Fig. 2, where the input power is 1 watt. Because the waveguide sheet is terminated by the open circuit, a standing wave distribution of electric field is observed.

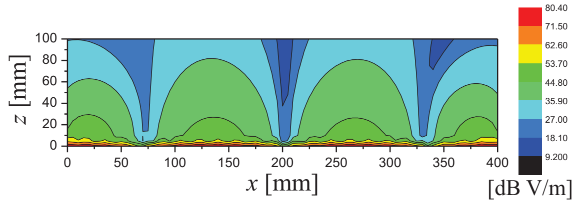

図 2: $|E_z|$ distribution at xz plane of y= 55 mm when waveguide sheet is terminated by open circuit.

3. Switching Diversity

The electric field distribution was calculated when the waveguide sheet was terminated by open circuit and short circuit. The geometry of those two terminations is shown in Fig. 3. The switching diversity was applied to the electric field under these two conditions and the larger electric field at each observation point was selected. The electric field distribution using the switching diversity is shown in Fig. 4.

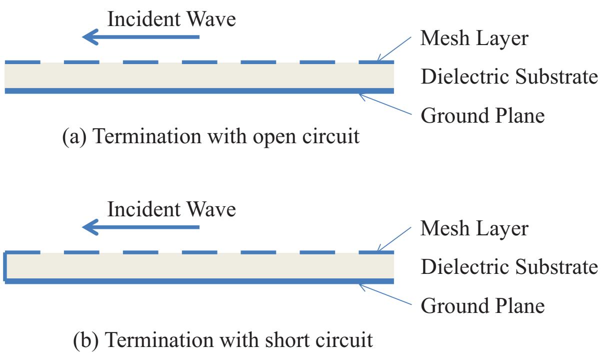

図 3: The waveguide sheet was terminated by (a) open circuit and (b) short circuit.

The cumulative distribution function (CDF) of the electric field in the observation plane at y= 55 mm is shown in Fig. 5 for the cases of open termination, short termination and switching diversity reception. The electric field of switching diversity is larger than that of open termination by 6 dB at 1% CDF and by 8dB at 0.1% CDF, demonstrating that the switched open/short termination combined with diversity reception can increase

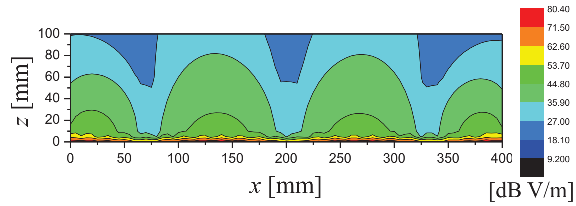

図 4: $|E_z|$ distribution of switching diversity at xz plane of y= 55mm.

the receiving level by tags. In the case of L= 400 mm, the electric field of open termination is much larger than that of short termination as shown in Fig.5, but the relation changes when the length of waveguide L changes because the input power is fixed while the input impedance strongly depends on the waveguide length L. However, the effect of the switching diversity using open/short termination can be similarly demonstrated for arbitrary waveguide length L.

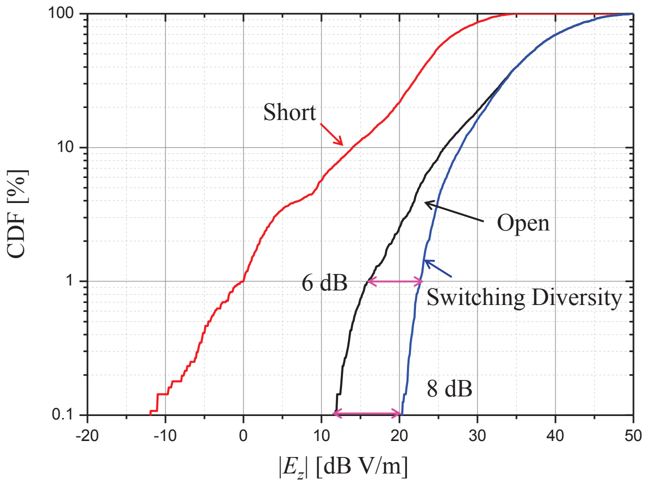

図 5: The CDF of $|E_z|$ of switching diversity compared with that of open and short terminations.

4. Measurement

The measurement system is composed of a signal generator (Agilent E4438C), a spectrum analyzer (Rohde/Schwarz FSU26), and a xyz 3-axis scanner, as shown in Fig. 6. Because the near field distribution on the waveguide sheet is measured, in order to reduce the influence of an probe, a dipole antenna type optical electric field sensor (NEC/Tokin OEFS) shown in Fig. 7 was used to measure the near field. The geometry of the dipole antenna type OEFS and the planar waveguide are shown in Fig. 8. The length of the dipole antenna is l_a= 60 mm. The distance between the receiving antenna and planar waveguide is d_{sa}.

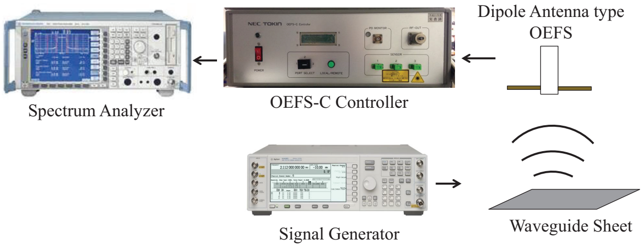

図 6: The experiment system for near field measurement.

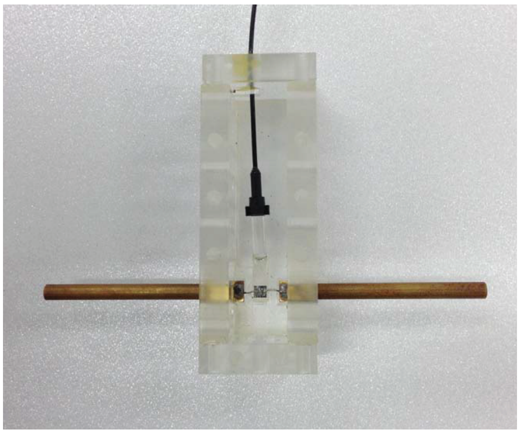

図 7: The dipole antenna type optical electric field sensor.

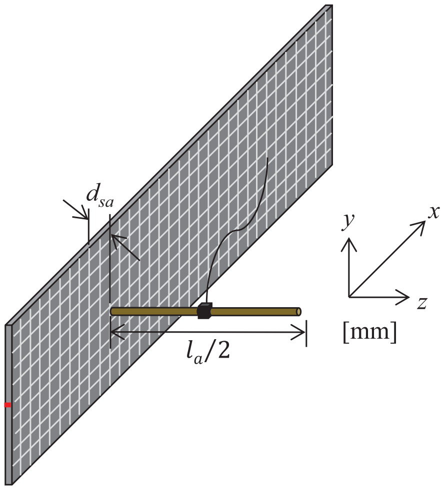

図 8: The geometry of the receiving dipole antenna type OEFS and the planar waveguide sheet.

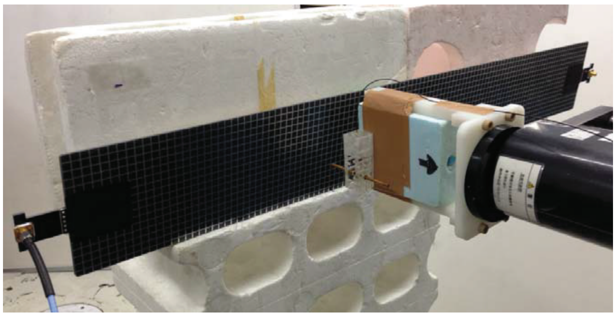

図 9: The dipole antenna type OEFS moved above the planar waveguide to measure the electric field on the sheet.

The size of the sheet is W= 110 mm, L=800 mm, and h=2 mm. The experiment environment is shown in Fig. 9. The dipole antenna type OEFS was moved by xyz 3-axis scanner scan above the planar waveguide to measure the electric field on the sheet. The planar waveguide with open and short termination are shown in Fig. 10 (a) and (b).

Fig. 11 shows the received power by the dipole antenna type OEFS when d_{sa} was 30 mm. The top one shows the termination was open, the middle one shows the termination was short, and the last one shows the result of switching diversity reception. Compared with the results of the open and short termination, the result of the switching diversity was greatly improved because the received power became much uniformed.

Fig. 12 shows the CDF of the received power with open/short termination and switching diversity reception. The proposed method can increase the received power by 4.5 dB at 1% CDF and 3 dB at 50% CDF, demonstrating that the switched open/short termination combined with diversity reception can increase the receiving level greatly.

The load termination was also used in the experiment which is shown in Fig. 10 (c). The measurement result is shown in Fig. 13. The received power above the sheet is more uniform then the one with open or short termination. The CDF is shown in Fig. 14. The received power with load termination is smaller than switching diversity but it can also provide uniform distribution without switching the termination.

5. Conclusions

The planar waveguide sheet applied to the system of RFID has been analyzed numerically using the method of moments and the received power received by dipole antenna type OEFS has been measured. It has been found by simulation and measurement that the switched open/short termination combined with switching diversity reception and load termination can increase the receiving level of RFID system. It was demonstrated that

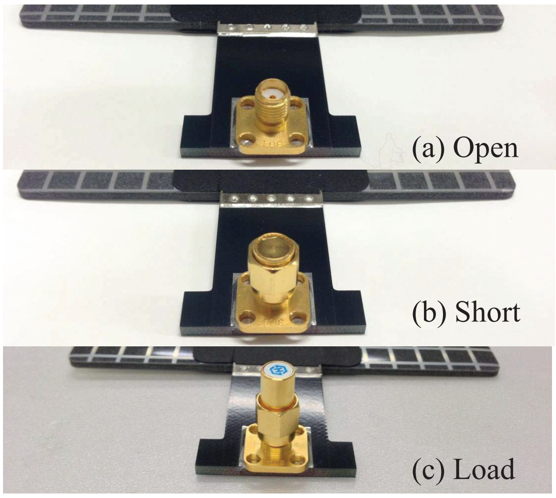

図 10: The planar waveguide sheet with (a)open, (b)short, and (c)load termination

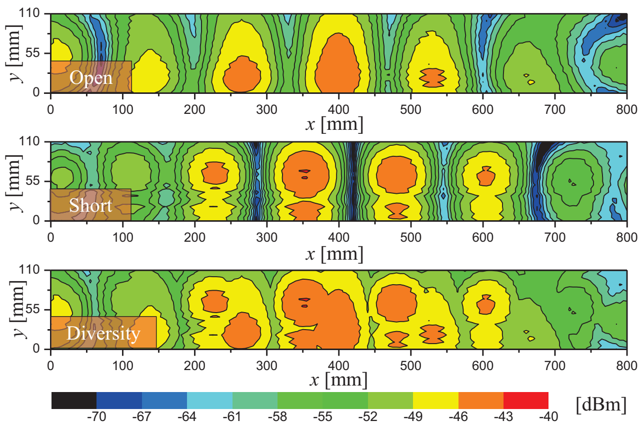

図 11: The received power distribution above the waveguide sheet at d_{sa}= 30.

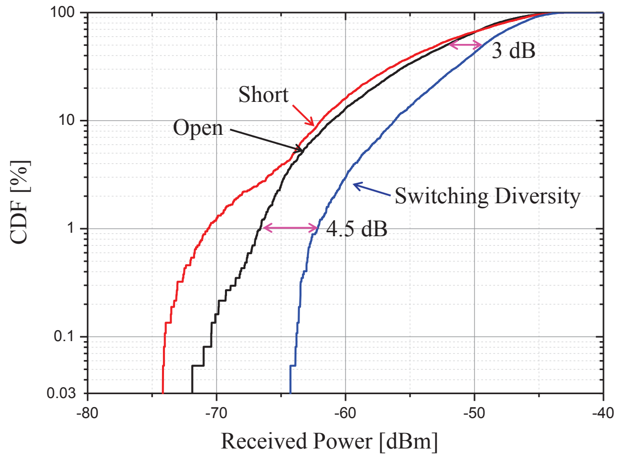

図 12: The CDF of received power of switching diversity compared with that of open and short terminations.

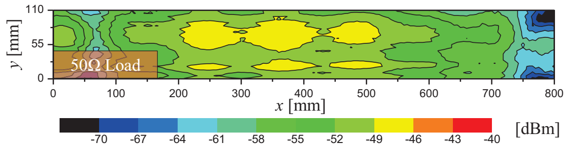

図 13: The received power distribution above the waveguide sheet with load termination at d_{sa}= 30.

the proposed system can contribute to further improvement of the RFID system.

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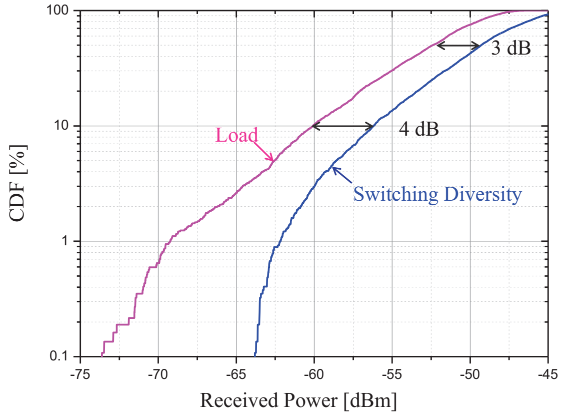

図 14: The CDF of received power of load termination compared with that of switching diversity.

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