Performance of Novel Two-Dimensional Communication Sheet with Slits for Smart-Shelf System

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Abstract—**Recently, RFID smart-shelf system has received a great attention. This system is capable of tracking and identifying books via communication between a two-dimensional communication sheet and RFID tags. One of the challenging problems to be solved for the system is to eliminate so-called low sensitivity area where the RFID is difficult to be detected. In this paper, numerical simulation demonstrates that the low sensitivity area of the sheet in both its length and width direction can be eliminated using a diversity reception technique and the communication sheet with slits.**

Keywords- two-dimensional communication; RFID; antenna; smart-shelf system

I. INTRODUCTION

Radio Frequency Identification (RFID) is one of the most promising technologies for a wireless identification system and sensor network system such as a smart-shelf system which is helpful for tracking and identifying books. The smart-shelf system uses a two-dimensional communication sheet [1] in order to detect RFID tags on the sheet by the near field coupling. One of the challenging problems of the smart-shelf system is to eliminate a low sensitivity area. The electric field distribution of the sheet is like a standing wave and non-uniform due to an impedance mismatching at the edges of the sheet. Therefore, it is difficult to detect the RFID tags when they are on the low sensitivity area because the receiving power of the tags is significantly weak in the area.

In our previous research, a diversity reception technique has been proposed in order to switch the electric field distribution of the sheet and eliminate the low sensitivity area [2]. The diversity reception technique is capable of switching the electric field distribution of the sheet in its length direction but not in its width direction. As a result, it is difficult to eliminate the low sensitivity area of the sheet along with its width direction even when the diversity reception technique is used. Therefore, an another remedy is required in order to eliminate the low sensitivity area of the sheet when its width is over half-wavelength [3].

In this paper, a two-dimensional communication sheet with slits is proposed in order to eliminate the low sensitivity area of the sheet in its width direction. The diversity reception technique is also used in order to eliminate the low sensitivity area of the sheet in its length direction. Numerical simulation demonstrates that the electric field distribution of the proposed sheet is uniform and diversity gain of the system improves..

II. TWO-DIMENSIONAL COMMUNICATION SHEET

Fig. 1 shows the geometry of a two-dimensional communication sheet. The sheet provided by Teijin Limited consists of three layers : conducting mesh layer (top layer), dielectric layer (middle layer) and conducting ground plane (bottom layer). The size of the sheet is 800 mm×300 mm×2 mm. The size of square mesh is 7 mm×7 mm and the width of the microstrip line of the mesh layer is 1 mm. The working frequency is 920 MHz and width of the sheet (=300 mm) is over half-wavelength (=163 mm) of the working frequency. As a result, the sheet has low sensitivity area in its width direction.

In order to eliminate the low sensitivity area of the sheet in its width direction, two slits are loaded with the mesh layer of the sheet as shown in Fig. 1. The length of the slits is 81 mm and their width is 7 mm. The spacing between the center of the sheet and the slits is 115 mm. The sheet is fed by voltage source between the mesh layer and the ground plane. The low sensitivity area of the sheets in its width direction is expected to be eliminated by loading the slits because current distribution of the sheets is affected by the slits.

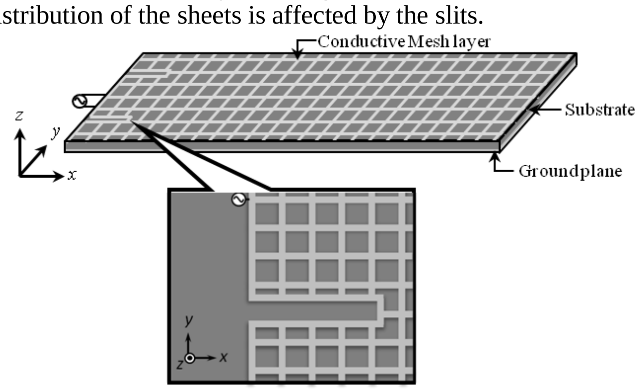

Figure 1. Geometry of proposed two-dimensional communication sheet

III. SIMULATION RESULT

Numerical simulation is performed using the method of moments (MoM) and the input power is 1 watt. In our numerical simulation model, the dielectric layer of the sheet is approximated as a free-space because its relative permittivity is ε_r=1.3 and quite low. The mesh layer and the ground plane are both modeled as a perfect electric conductor (PEC). The sheet is open or short circuited as shown in Fig. 3 in order to eliminate the low sensitivity area using the diversity reception technique in its length direction. In this paper, only the *z*-component of the electric field is shown because the RFID tags are perpendicular to the sheet and receive the *z*-component of the electric field. The $|E_z|$ distribution on the open circuited sheet at z=30 mm is shown in Fig. 2. The low sensitivity areas are found in both length and width direction of the sheet without the slits. On the other hand, the low sensitivity areas are only found in the length direction of the sheet with the slits. The low sensitivity areas in the width direction of the sheet are eliminated because the current distribution of the width direction of the sheet is affected by the slits. Fig. 4 shows the received $|E_z|$ distribution of the sheet with or without the slits when the diversity reception technique is used. As shown in Fig. 4 (a), the low sensitivity areas in the width direction of the sheet without slits cannot be eliminated even when the diversity reception technique is used. On the other hand, it is observed that the $|E_z|$ distribution in the width direction of the sheet with slits is uniform. Therefore, it can be concluded that the low sensitivity areas in the width direction of the sheet can be eliminated when the slits are loaded with the sheet. As a result, the low sensitivity areas in the length and width direction of the sheet can be completely eliminated except for the edge of the sheet when the slits are loaded with the sheet and the diversity reception technique is used.

The cumulative distribution function (CDF) of the received electric field on the sheet using the diversity reception technique is shown in Fig. 5. In order to fairly evaluate how much the received power improves when the slits are loaded with the sheet, the received electric field on the edge of the sheet and in the vicinity of the feeding points are excluded in the CDF. Fig. 5 shows that the received electric field becomes uniform when the slits are loaded with the sheet. Furthermore, it is shown that the electric field on the sheet with slits is 9dB larger than that without slits at 1% CDF. It can be concluded that slits are helpful in order to eliminate the low sensitivity areas and improve the diversity gain of the system.

Finally, the effect of the slits on the electric field on the sheet is discussed from a physical point of view. Fig. 6 shows the current distribution on the mesh layer of the sheet without slits while Fig. 7 shows that of the sheet with slits. It is observed that the y-component of the current is suppressed when the slits are loaded with the sheet. Therefore, it can be said that the electrical size of the sheet is reduced in its width direction when the slits are loaded with the sheet. As a result, the $|E_z|$ distribution on the y-direction of the sheet becomes uniform because no standing wave appears in the width direction of the sheet .

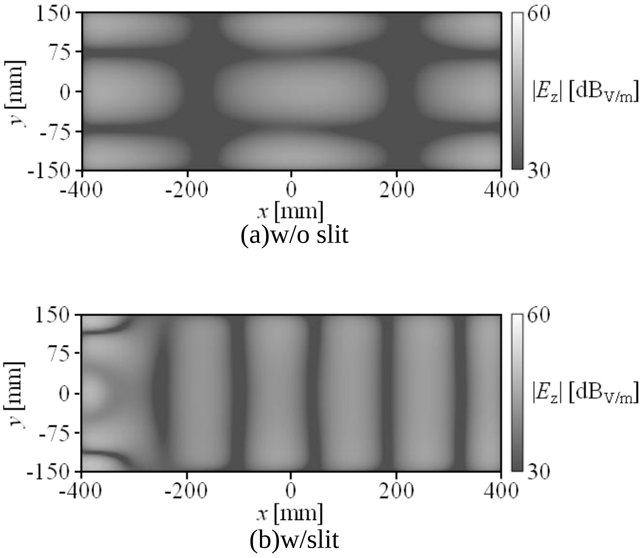

Figure 2. $|E_z|$ distribution on the sheet with open termination

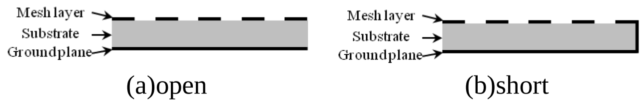

Figure 3. geometry of sheet termination

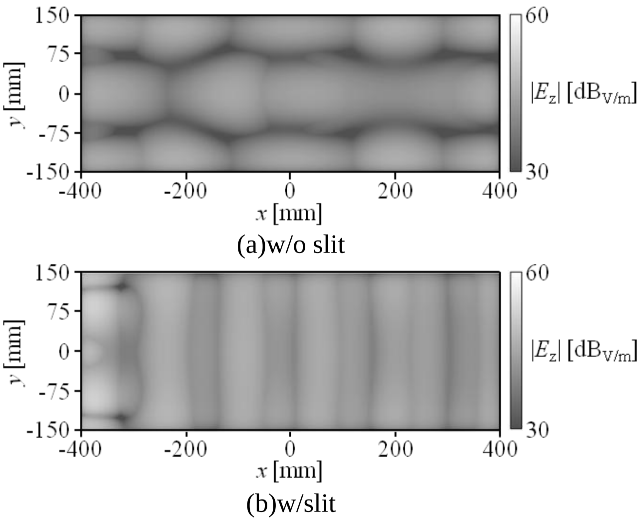

Figure 4. received $|E_z|$ distribution of the sheet using diversity reception

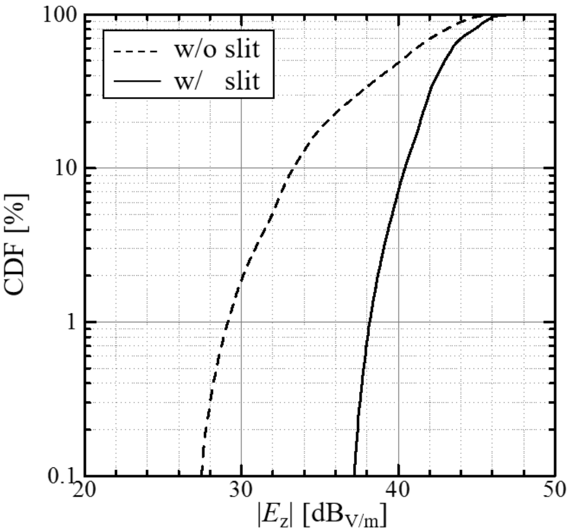

Figure 5. CDF of received $|E_z|$ of diversity reception

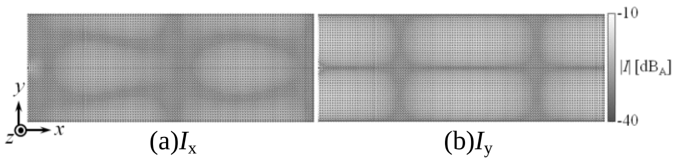

Figure 6. current distribution of the sheet without slits

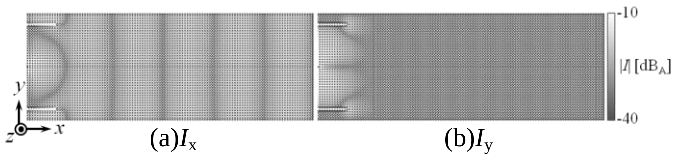

Figure 7. current distribution of the sheet with slits

IV. CONCLUSION

In this paper, the two-dimensional communication sheet with slits has been proposed in order to eliminate the low sensitivity areas in its width direction. Performance of the proposed sheet has been analyzed numerically and the effect of the slits on the electric field distribution of the sheet has been clarified.

It has been found that the y-component of the current distribution is suppressed by loading slits. As a result, the electric field distribution on y-direction of the sheet becomes uniform because the electrical size of the sheet is reduced when the slits are loaded with the sheet. It has been also found that the diversity gain of the system improves when the slits are loaded with the sheet.

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