Small Proximity Connector in Two-Dimensional Signal Transmission

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Abstract: In the previous study, we proposed a technology called Two-Dimensional Signal Transmission (2DST) for sensor networking. In 2DST, microwave is localized in a two dimensional medium. Sensor elements located close to the 2DST sheet communicate using the microwave by the proximity connectors. Although the previously reported proximity connector could be put freely on the sheet, one problem was that it needed to have a certain size comparable to the microwave wavelength. In this paper, we propose a new small proximity connector to 2DST sheet. Instead of imposing some limitation on the freedom of the connector position, we can make it smaller than the previous one. We explain the principle of the proximity connector and analyze the efficiency of power transmission and reflection by numerical simulation.

Keywords: two-dimensional signal transmission, sensor network, networked sensing, proximity connector

1. INTRODUCTION

We proposed Two-Dimensional Signal Transmission (2DST) method to realize wireless sensor networks on a thin sheet [1]. The schematic drawing of 2DST sheet is shown in Fig.1. This sheet consists of a ground conductive layer, a meshed conductive layer and a dielectric layer sandwiched between those two conductive layers. Each sensing element is freely put on the sheet and connects to the microwave running inside the 2DST sheet without any electrical contact. The microwave supplies the elements with the electrical power and transmits signals. Using this system, we can construct high density sensor network without batteries on the sensors and complicated wires. Since there is little maicrowave emission to outside, higt speed comunication using wide band will be avairable, free from the radio law. Since the sheet strucutre is simple, we can cover a large area with a low-cost 2DST sheet. Furthermore, we can make the sheet with various materials including flexible and elastic ones.

In this paper, we propose a new small proximity connector with no electrical contact between sensor elements and the sheet. The connector is smaller than the previous one [1], and is realized at a comparable size to the period of the mesh layer in the 2DST sheet by imposing some limitation on the freedom of the connector position. The method enables a large number of small sensor elementss to be located densely. It is fit to the applications such as an artificial skin that uses the flexibility of the 2DST sheet. We explain the basic structure of the proximity connector and, First, We explain the basic structure of the proximity connector. Next, we analyze the efficiency of power transmission by numerical simulation. Finally, we summarize the results and show the future prospects.

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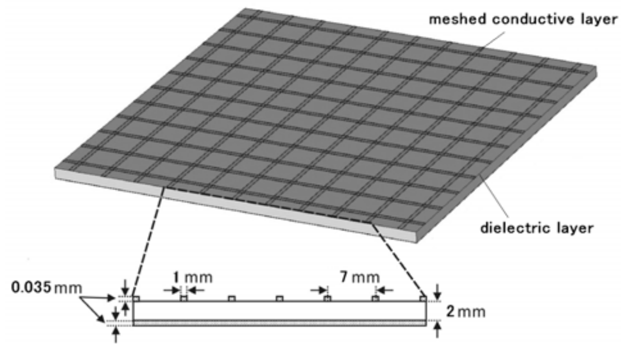

Fig. 1 Schematic drawing of 2DST sheet

2. STRUCTURE OF THE CONNECTOR

The upper side of the conductive layers of 2DST sheet has periodic lattice (mesh) structure as shown in Fig. 1. In the previously reported connector [1], the connector size was larger than the lattice period for obtaining uniformity of connectivity independent on the relative position to the mesh. In that method, the proximity connection was brought by the macroscopic sheet inductance of the mesh layer. The connector size could not be extremely smaller than the wavelength.

In this paper, we design a proximity connector to couple with the microscopic structure of the mesh. The proposed structure of the connector is shown in Fig. 2. The connector is supposed to be located at a fixed position relative to the mesh unit. In the connector, a loop from the cable core to the external conductor is formed. A part of the loop (part I) runs along the conductive part of the mesh layer for inductive coupling while part II is intended to obtain capacitive coupling with the mesh conductor.

In our study, we try various dimensional parameters of parts I and II, and obtain a preferable parameters by numerical simulations.The core and via are embedded in a dielectric.

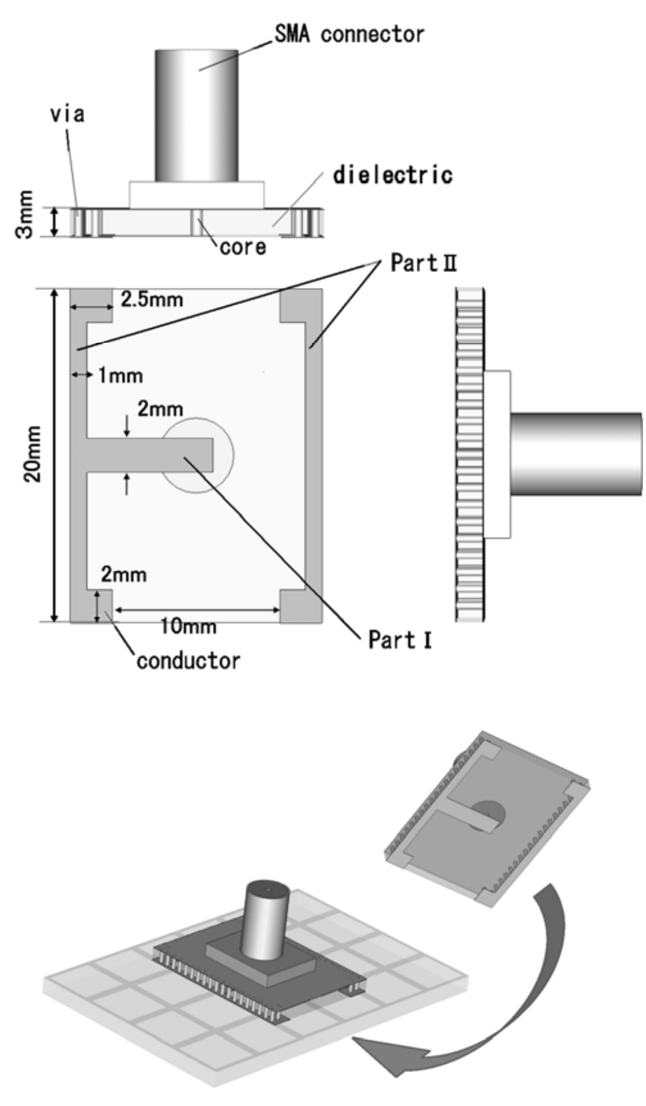

Fig.2 The proposed structure of the connector.

3. EVALUATION OF THE CONNECTIVITY

In the numerical simulation, we suppose the 2DST sheet model shown in Fig. 3. We conducted simulation analyses using the software W-STUDIO (AET Japan, Inc.). We set ports 1 and 3 at the right-and-left ends of the sheet, and port 2 at the proximity connector (Fig.4). An input wave consists of microwave which includes 1.0 ~ 6.0 GHz frequency components.

At the front and back boundary of the sheet, all electric energies can't pass through to the outside. The relative permittivity of the dielectric layer of the sheet is $\varepsilon_r = 1.4$. The thickness of conductive layer and the dielectric layer are 35 µm and 2 mm respectively. The conductive layer and dielectric layer do not have loss by resistance and dielectric respectively. The period of the mesh lattice was 7 mm and the line width of the lattice was 1 mm. The total size of the sheet was 42 mm by 28 mm.

The interval between part II and the sheet is 0.1 mm. The relative permittivity of the dielectric which has the core and via of the connector in itself is ε_r = 2.7. It's dielectric loss is 0.0002 (based on the solid state properties of PTFE).

Under the model, trial and error approach is adopted to obtain preferable parameters. In the evaluation of the connector, we paid attentions to the following two parameters.

$$P_I = 1 - S_{22}{}^2 \quad (1)$$

$$P_O = S_{12}{}^2 + S_{32}{}^2 \quad (2)$$

The parameter S_{12} is the amplitude ratio of the output wave at port1 to the input wave from port2. S_{22} is the reflection coefficient at port2. S_{32} is the amplitude ratio of the output wave at port3 to the input wave from port2. Therefore, the parameter P_I represent the energy of the microwave which is incident on this system, and the parameter P_O represent the energy of the microwave which is going out from the system. So the total energy loss L in this system and transmission efficiency E from the sensor elements to the sheet are calculated as follows,

$$L = P_I - P_o \quad (3)$$

$$E = P_o / P_I \quad (4)$$

A good connector has a small value of L and a big value of E.

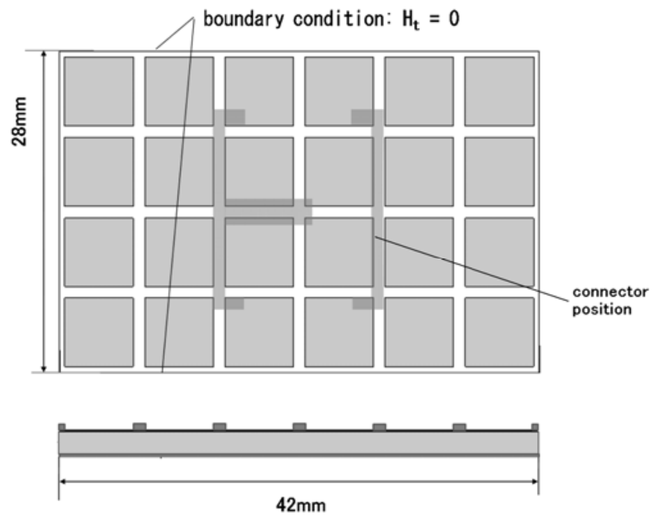

Fig.3 The 2DST sheet model

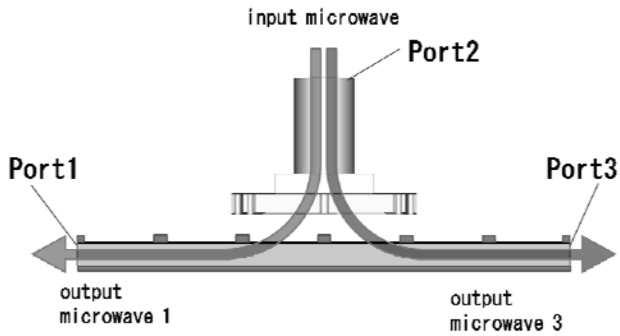

Fig.4 Port setting and energy flow in the system.

4. NUMERICAL SIMULATION

Figure 5 shows a result of the simulation. In a frequency band of 2.4GHz, the value of S_{12} is 0.28, S_{22} is 0.90, and S3 is 0.29. From eq. (1) ~ (4), $L = 0.185$ and $E = 0.879$. In other words this proximity connector can send 88% of the energy that was in the connector into the sheet. Since the value of S_2 is big, a microwave of 81.5 % reflects it. Although it seems to have at a glance a problem for this result, there is no problem adding a circuit muching impedance between the connector and the sensor elements side.

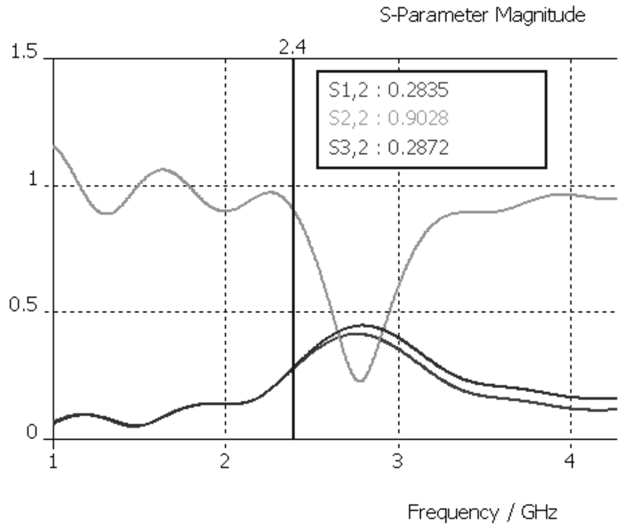

Fig.5 Result of numerical simulation.

5. SUMMARY

In this paper, we showed one configuration of the signal and power transmission connector that works on the 2DST sheet. It works as a proximity connector without electrical contacts to the 2DST sheet. Since the size of this connector depends on the size of periodic lattice (mesh) structure on the 2DST sheet. So proposed connector is smaller than the previous one.

Based on simulation analyses, we confirmed that the power was transmitted by efficiency of 81.5% through the 2DST sheet by 2.4 GHz microwave.

APPENDIX

We designed the proximity connector whose impedance adjusted with sensor element whose impedance 50 Ω by changing connector structure (shown in figure 6). Simulation result is shown in Figure.7.

In a frequency band of 2.4GHz, the value of S_{12} is 0.45, S_{22} is 0.04, and S3 is 0.45. Therefore the reflection ratio of input maicrowave energy is less than 1%. On the other hand, from eq. (1) ~ (4), $L = 0.601$ and $E = 0.41$. The energy loss of this system is 60.1 %.

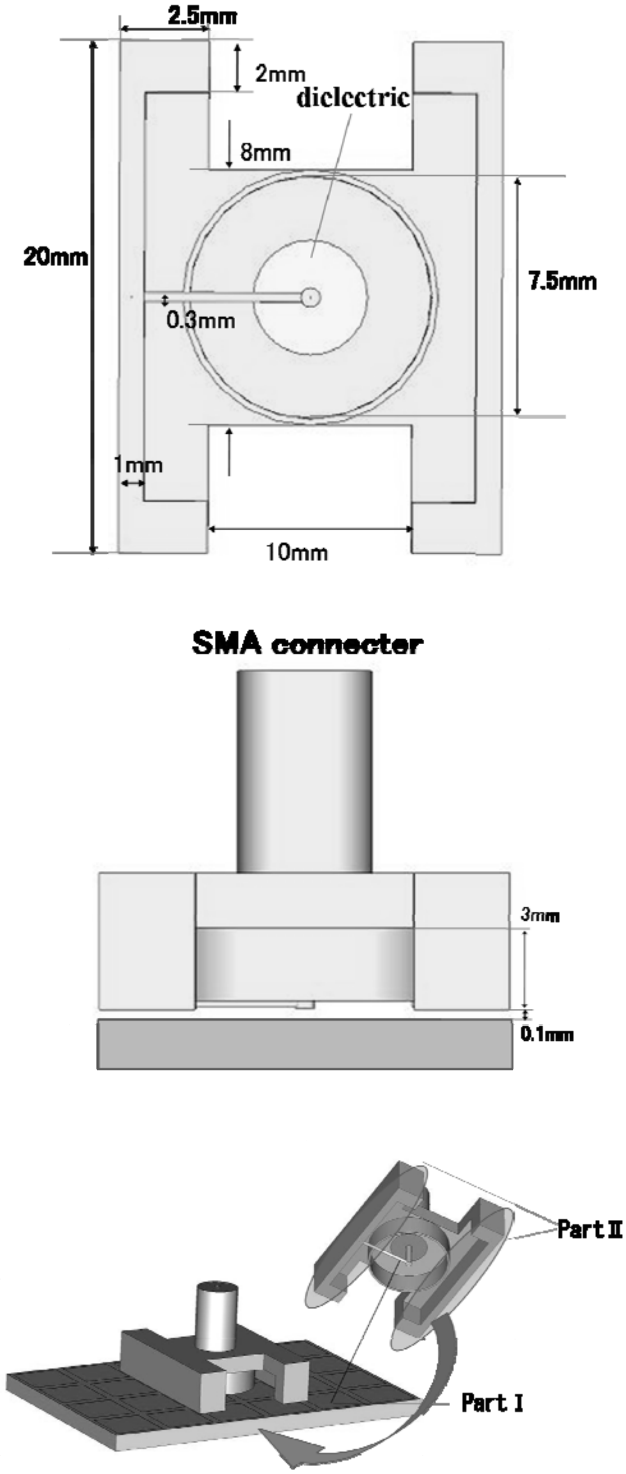

Fig.6 The structure of the connector which adjusted with sensor element impedance.

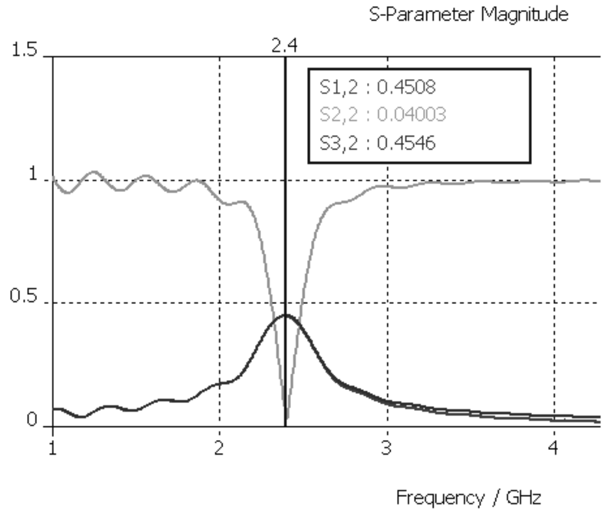

Fig.7 Simulation result of matched connector.

References

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