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Description	

An Experiment Study of Electromagnetic Field Distribution over 2D Communication System

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***Abstract* — This paper presents a novel two-dimensional communication system (2DCS), in which a 2D sheet allows the coupler-attached devices that are placed on the surface of the 2D sheet to provide data transmission and power supply concurrently. The electromagnetic waves that propagate inside the 2D sheet can produce a standing wave, which is the resultant of the reflected waves and the original wave. The anti-reflection edge is mounted at the sides of the 2D sheet in order to diminish the impact of the standing wave. In this paper, we investigate the electromagnetic field characteristics of the 2D sheet, which is conjoined with the 3-side and 4-side of anti-reflection edge. Measurement results reveal that the average magnetic field strength decreases about –8dB and –17dB for the 3-side and 4-side of anti-reflection edge, respectively.**

***Index Terms* — 2D Communication System, Evanescent Wave, Standing Wave, Reflection Wave.**

I. INTRODUCTION

Recently much attention has been paid for the ubiquitous communication. The 2D communication system has a huge potential as the most-challenging technology for realizing the ubiquitous communication, because the novelty of 2D communication system combine the best features of both wired and wireless communications. The 2D communication system (hereinafter we call it as 2DCS) comprises of two components: a connector (coupler) and a 2D sheet. The connector that is embedded or attached into the device is used to extract the electromagnetic wave from the 2D sheet and also to inject the electromagnetic wave into the 2D sheet. However, the 2D sheet that acts like a transmission medium can provide the gigabit data transmission and the power supply to devices that are placed on the top of the surface of the 2D sheet. The devices may include laptops, personal digital assistants (PDAs), mobile phones, home appliances, sensors, and other types of device habitually placed on the surface of the 2D sheet. One example of 2DCS applications is a wired-free meeting table that linked laptops at the workplace.

A dearth of research has been published in relation to the surface as a medium for power and networking. The core idea was first inspired by Scott et al. in October 1998 at the Laboratory for Communications Engineering, Cambridge University. Scott et al. [1] named their idea as 'Networked Surface.' The Networked Surface is primarily aimed at connection of higher-end computational devices (e.g., handhelds and laptops) that are placed on the top of the surface such as desk or table. However, Lifton and Paradiso [2] use the surface with pushpins and layered conductive sheets, where direct contact to the conductive layers in the board is used to obtain power, whereas the networking is established via infrared. To envisage high-speed networking capabilities, Laerhoven et al. [3] proposes that the conductive layer can be used as a bus topology network for pins. Instead of using pin-shaped connectors, Minamizawa et al. [4] introduces a proximity (non-contact) connector that touches the surface for both power and networking. In this paper, we called the construction of sheet and connector that proposed by [4] as 2DCS.

This new form of 2DCS is not just able to provide the data transmission and the power supply between two devices, but it also can provide accurate estimation of device location. In order to inspire the position estimation in the 2DCS as published in [5], the impact of the standing wave inside the 2D sheet should be reduced. One of the solutions is that we can use the anti-reflection edge, which is mounted at the sides of the 2D sheet in order to absorb the energy of the reflected waves. In this paper, our aim is to measure the electromagnetic field distribution and strength of the 2D sheet, which is conjoined with 3-side and 4-side of anti-reflection edge. The rest of this paper is organized as follow. Section II describes a brief principle of the design of anti-reflection edge. Section III gives the experiment setup, layout, and measurement results. Section IV explains the analysis and discussion of measurement results. Finally, the last section concludes the paper.

II. PRINCIPLE OF THE DESIGN OF ANTI-REFLECTION EDGE

The fundamental structure of the 2DCS, which consists of two components: 2D sheet and connector is described in [6]. Suppose the electromagnetic wave travels through the 2D sheet, the electromagnetic wave is bounded for the 4-side of 2D sheet. A portion of electromagnetic energy is seeped out from the sides of 2D sheet whereas the rest of portion of electromagnetic energy is reflected back into the 2D sheet.

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We define that the bounded wave after the original electromagnetic wave as a 'reflected wave.' Inside the 2D sheet, a 'standing wave' that remains in a constant position can arise as the result of combination between the reflected waves and the original electromagnetic wave. In other words, the standing wave in 2D sheet is a wave in which the distribution of field strength is formed by the superposition of reflected waves and original wave propagating in either opposite or other directions. As a result, a contour of nodes (zero displacement) and anti-nodes (maximum displacement) at fixed points of the 2D sheet is formed. The distribution of standing wave depends on 2D sheet size, electromagnetic wavelength, object placement on the top of 2D sheet, and reflection wave absorber at the sides of 2D sheet. In this paper, we use an anti-reflection edge as wave absorber to minimize the impact of the standing wave of the 2D sheet. The main function of the anti-reflection edge is to absorb the electromagnetic energy and converts it to heat. This can lead to the amplitude of the reflected wave becomes smaller. Thus, the resultant of the standing wave becomes smaller too. The anti-reflection edge is mounted on the edge of 2D sheet as illustrated in Fig. 1.

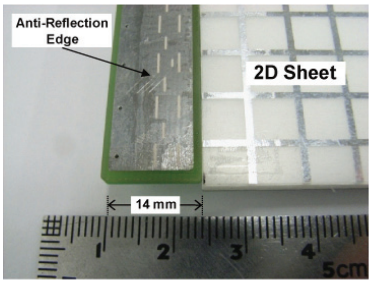


Fig. 1. Anti-reflection edge.

III. EXPERIMENTAL STUDY

We conduct a few experiments for measuring the magnetic field strength of the 2D sheet with or without the anti-reflection edge. We use a set of instruments such as a signal generator, a magnetic field probe, a power amplifier, a spectrum analyzer, and a personal computer in an anechoic room. Figure 2 and 3 show the layout and setup view of the experiment. The input signal is generated from the AGILENT signal generator whereby the input frequency and power is set to 2.4 GHz and 10 dBm (or it is equivalent to 10 mW), respectively. The input signal is sent to the clip type connector via a coaxial cable. The clip type connector that is developed by Cellcross Co. Ltd. is directly pinned at the middle of one side of the 2D sheet. The clip type connector has the impedance of 50 Ω so that the input signal can be optimally extracted out from the coaxial cable to the 2D sheet. The 2D sheet that fabricated by Teijin Fibers Ltd. is used for this experiment. The measured raw data is sensed and taken by the NEC CP-2S probe. Since the measured signal is very weak, the power amplifier is used to scale up the measured signal in order to fit into the readable range of the spectrum analyzer. After processing it, the measured data of the spectrum analyzer are sent to the personal computer via a GP-IB interface.

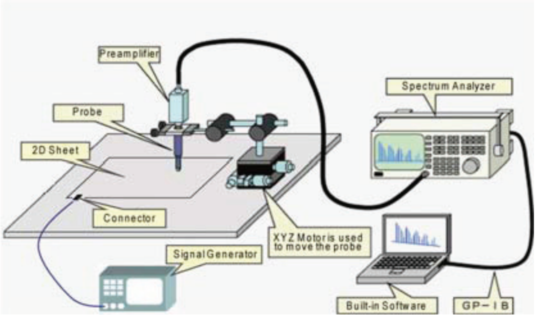
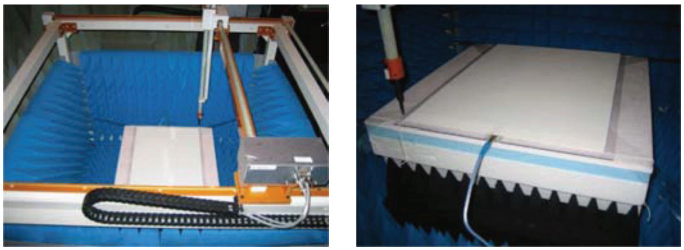


Fig. 2. Experiment layout.



Top View

Side View

Fig. 3. Experiment setup.

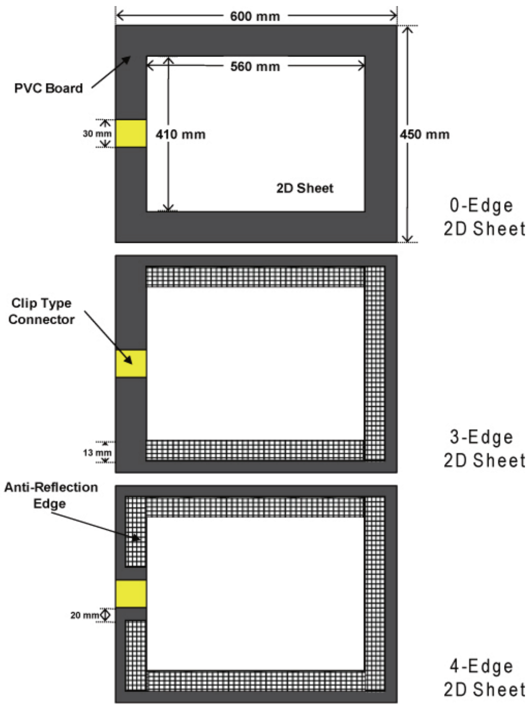


Fig. 4. Types of 2D sheet for this experiment study.

The planar scanner is used to move the probe within the limited measurement range of 100 cm × 100 cm × 50 cm with the measurement speed of 5~15 mm/s in the X-, Y-, and Z-axes, respectively. The 4-side of planar scanner is placed with the wave absorbers to avoid undesired reflection waves that released from the sides of 2D sheet to be sensed by the probe. Therefore, the measured signal that sensed by the probe is assumed to be purely the emitted signal from the 2D sheet. The basic size of the 2D sheet is 56 cm × 41 cm × 2.3 mm. In our experiments, two different measurement sizes are prepared. The first one is 56 cm × 41 cm × 2.3 mm for 2D sheet with no anti-reflection edge (simply named as 0-edge 2D sheet). However, the second one is 58 cm × 44.5 cm × 2.3 mm for 2D sheet with 3-side mounted anti-reflection edge or 4-side mounted anti-reflection edge (hereinafter we called them as 3-edge 2D sheet or 4-edge 2D sheet, respectively). These types of 2D sheet are shown in Fig. 4. The other experiment parameters and settings are listed in Table 1.

TABLE I
EXPERIMENT PARAMETERS AND SETTINGS

Planar scanner model	DEVICE DM3472AV1
Magnetic field probe model	NEC CP-2S
Spectrum analyzer model	ADVANTEST R3273
Signal generator model	AGILENT E4438C
Power amplifier model	HEWLETT PACKARD 11975A
Power reflection meter	ROHDE & SCHWARZ NRT
SMA connector impedance	50 Ω
Preamplifier gain	10 dB
Signal frequency	2.4 GHz
Input power	10 dBm

A. Measurement Results

Since the entire 2D sheet cannot be placed horizontally flat on the top of measurement area, we measure the height that is the distance in between the bottom of probe and the top of 2D sheet, at the nine points include: top left, top middle, top right, left center, center, right center, bottom left, bottom middle, bottom right. Therefore, the average height of 0-edge, 3-edge, and 4-edge 2D sheet is Z = 1.56 mm, Z = 2.28 mm, and Z = 1.83 mm, respectively. In these experiments, the probe is moved with the measurement step of 10 mm for both X- and Y- axes. To reduce the spurious radiation from the probe structure, we measure the magnetic field strength along the X-direction and Y-direction (by just turning the probe with 90 degree). Then, we compute the resultant of magnetic field strength from both X-direction and Y-direction.

Figure 5, 6, and 7 show the magnetic field distribution of the 0-edge, 3-edge, and 4-edge 2D sheets, respectively. In Fig. 5, the measurement results show that it is clearly identified the pattern of mesh structure of 2D sheet based on the magnetic field contour. We can observe obviously the standing wave from the X-Z viewpoint however it is difficult to identify the standing wave from the Y-Z viewpoint. This is because the energy flow of reflected waves is in parallel to the input direction of electromagnetic wave. From X-Z viewpoint in Fig. 5, the maximum displacement of standing wave is intuitively about 5 cm. The average magnetic field strength for 0-edge 2D sheet is about 96.43 dBμA/m.

Figure 6 and 7 show the magnetic field distribution of the 3-edge 2D sheet and 4-edge 2D sheet, respectively, in which both 2D sheets are mounted by the anti-reflection edge. As we can see from the measurement results, the overall magnetic field strength has been reduced. For example, the average magnetic field strength for 3-edge 2D sheet is about 88.65 dBμA/m, which is about 8dB lower than the 0-edge 2D sheet. Similarly, the average value for 4-edge 2D sheet is about 79.08 dBμA/m, which is about 17dB lower compared to the 0-edge 2D sheet. Figure 7 shows the amplitude of maximum displacement becomes smaller and this leads to the standing wave becomes steady. One main reason is the high-impedance of anti-reflection edge successfully absorbed the energy of reflected wave and dissipated it as heat. As a result, the amplitude of reflected wave becomes smaller and the entire standing wave also becomes smaller inside the 2D sheet.

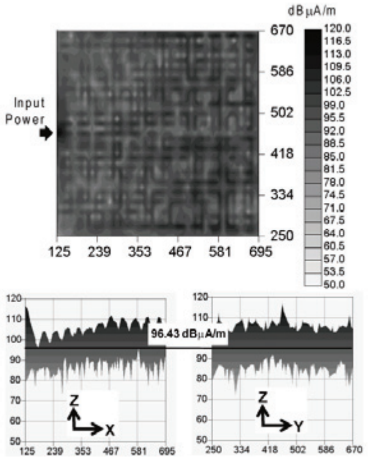


Fig. 5. Magnetic field distribution of 0-edge 2D sheet.

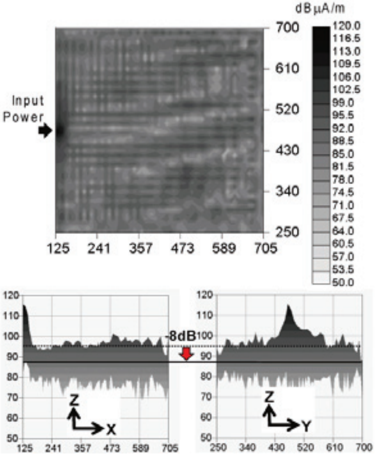


Fig. 6. Magnetic field distribution of 3-edge 2D sheet.

IV. ANALYSIS AND DISCUSSION

Besides examining the average magnetic field strength, Figure 8 shows the comparison of minimum and maximum magnetic field strength for three types of 2D sheet. The maximum magnetic field strength for 0-edge, 3-edge, and 4-edge 2D sheets is about 116.52 dBμA/m, 115.75 dBμA/m, and 98.42 dBμA/m, respectively. However, the minimum magnetic field strength for 0-edge, 3-edge, and 4-edge 2D sheets is about 71.92 dBµA/m, 68.39 dBµA/m, and 57.0 dBµA/m, respectively. In regards to these results, we can conclude that the anti-reflection edge is capable to reduce the entire magnetic field strength inside the 2D sheet.

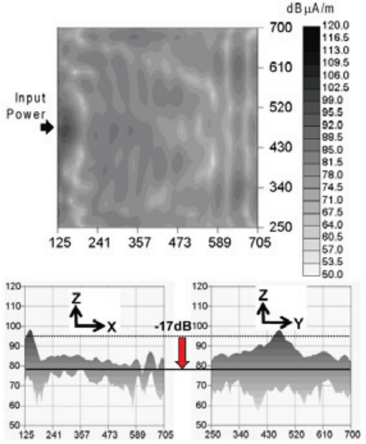


Fig. 7. Magnetic field distribution of 4-edge 2D sheet.

To further analyze the measurement results, we classify the magnetic field strength into several intervals with an interval of 10-dBµA/m as illustrated in Fig. 9. Figure 9 shows the most frequent value for 0-edge, 3-edge, and 4-edge 2D sheets is 90~99 dBµA/m, 80~89 dBµA/m, 70~79 dBµA/m, respectively. There is a shift toward the left direction of 10-dBµA/m and 20-dBµA/m for 3-edge 2D sheet and 4-edge 2D sheet, respectively. Furthermore, we can see more narrowly distribution spread for 4-edge 2D sheet compared to the 0-edge 2D sheet. This is because the standard deviation of magnetic field strength for 0-edge is about 5.84 dBµA/m, which is higher than the standard deviation of magnetic field strength for 4-edge 2D sheet (4.53 dBµA/m). The small standard deviation means that many measured signals are close to the average magnetic field strength as in the case of 4-edge 2D sheet.

We divide the 2D sheet into nine sectors as shown in Fig. 10. As a matter of fact, this chart reveals that the anti-reflection edge absorbs more energy at the S8 sector compared to other sectors. This is because the original wave experiences the most energy absorption at the side of S8 before the first reflected wave is produced. On the other hand, the lowest energy absorption is at the S2 sector. This is because the S2 sector is the only entrance for the original wave to flow into the 2D sheet.

V. CONCLUDING REMARKS

In this paper, we introduced the novel technology of 2DCS and described the principle of the anti-reflection edge. We also investigated the magnetic field strength over the 2D sheet with and without the anti-reflection edge. Measurement results reveal that the average magnetic field strength losses about 8dB and 17dB for the 3-edge 2D sheet and 4-edge 2D sheet, respectively compared to 0-edge 2D sheet. From this study it can be concluded that reducing the energy of reflected waves can improve the position estimation in 2DCS. Further experiment is required to investigate the electric field distribution and strength of 2DCS with or without the anti-reflection edge.

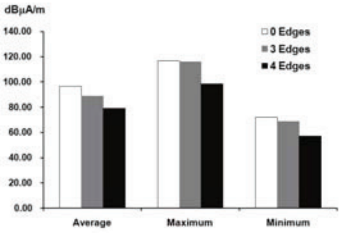


Fig. 8. Comparison of average, maximum, and minimum of magnetic field strength.

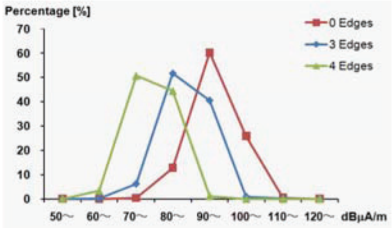


Fig. 9. Distribution of magnetic field strength.

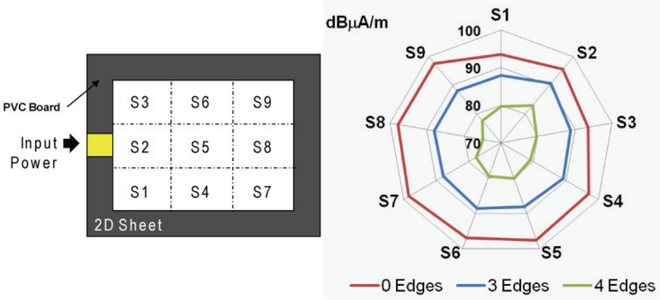


Fig. 10. Magnetic field strength for different sector in the 2D sheet.

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