Electromagnetic Field Measurement of an Object over 2D Communication System

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1. Introduction

Today both wired and wireless communications are part of everyone's daily life. However, the state-of-the-art technology, 2D communication system is becoming one of the most-challenging technologies for the gigabit communication and the power supply simultaneously to devices. The 2D communication system (hereinafter we call it as 2DCS) consists of two components: a connector (coupler) and a 2D sheet. A connector that embedded 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. The details of 2DCS can be found in [1, 2]. The electromagnetic wave that is confined into the thin 2D sheet still can be seeped out from the surface of the 2D sheet. Therefore, it is important to examine the effect and characteristic of electromagnetic field, which is reflected off the surface of 2D sheet experimentally, because it has been raised in view of human health. Furthermore, the radiation of electromagnetic wave can lead to the malfunctioning of other sensitive electrical and electronic equipment. In order to pursue these issues, an experiment is conducted inside an anechoic room to investigate the electromagnetic field distribution and strength of the 2D sheet. So far, we have conducted two experiments on the 2D sheet with and without the anti-reflection edged in [1] and [2], respectively. In this paper, we further examine the electromagnetic field characteristic when an object is placed on the top of the 2D sheet. The rest of this paper is organized as follow. Section 2 gives the experimental setup. Section 3 explains the measurement results and discussions. Finally, the last section concludes the paper.

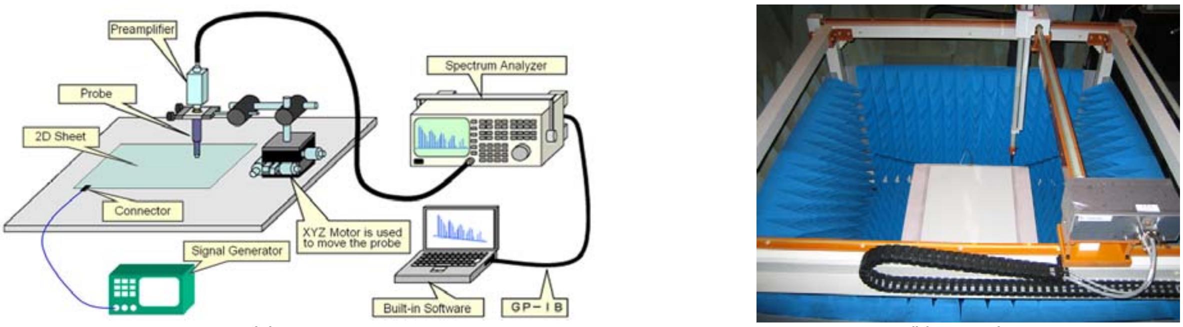
2. Experimental Setup

We conduct a few experiments for examining the effect and characteristic of electromagnetic distribution when an object is placed on the top of the 2D sheet. The experiment is conducted using a set of instruments such as a signal generator, a magnetic field probe, a power amplifier, a spectrum analyzer, and a personal computer in a shielded room. Figure 1(a) and 1(b) show the experiment layout and setup, respectively.

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 is directly pinned at the middle of side edge 2D sheet as shown in Figure 2. The clip type connector has an impedance of 50 Ω so that the input signal can be optimally extracted out from the coaxial cable into the 2D sheet. The measured raw data is sensed and obtained by a 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 GP-IB interface.

The planar scanner is used to move the probe within the limited measurement range of 1 m×1 m×0.5 m with the measurement speed of 5~15 mm/second in all X-, Y-, and Z-axes. The fourside of planar scanner is placed with the wave absorber to avoid undesired reflection waves that released from the edge of 2D sheet to be sensed by the probe. Therefore, the measured signal that is sensed by the probe is assumed to be purely the emitted signal from the surface of the 2D sheet. The size of 2D sheet is 56 cm×41 cm×2.3 mm. The anti-reflection block is placed at the edge of 2D sheet that is shown in Figure 2. We summarize the experiment parameters and settings in Table 1.

Since the entire 2D sheet cannot be placed completely flat on the top of measurement area, we measure the height, a distance in between the bottom of probe and the surface of the 2D sheet, at the nine points include: top left, top middle, top right, left center, center, right center, bottom left, bottom middle, bottom right. By this way, we can obtain the average height of 2D sheet. For example, the average height is about 2 mm when we conduct the experiment for 2D sheet with no object. In our experiments, we consider three objects: a copper plate, a material with the relative static permittivity of 12 (Er12), and a water-contained glove. The size of copper plate is 10 cm×10 cm×1 mm. The copper plate is a reddish-colored metal and it has the second highest electrical and thermal conductivity after silver. The average height is about 2 mm when we conduct the experiment for the copper plate. The size of Er12 plate is 10 cm×10 cm×8 mm. Examples of Er12 material are polymer, salt, graphite, and black lead. The average height is about 1 cm when we conduct the experiment for the Er12 plate. We fill a 180-milliliter of pure water into a plastic glove (hereinafter we called it as water-contained glove). The average height of the probe is about 2 cm for conducting the experiment for the water-contained glove that is placed on the top of 2D sheet. For all the experiments, the probe is moved with a 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.



(a) Layout (b) Top View

Figure 1: Experiment Setup

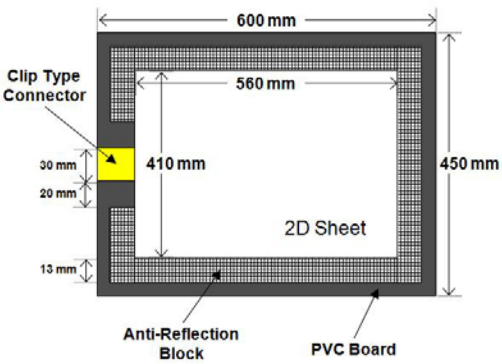


Figure 2: 2D Sheet for the Experiment

Table 1: Experiment Parameters and Settings

2D sheet size	X, Y, Z = 56 cm, 41 cm, 2.3 mm
Planar scanner	DEVICE DM3472AV1
Magnetic field probe	NEC CP-2S
Spectrum analyzer	ADVANTEST R3273
Signal generator	AGILENT E4438C ESG vector
Power amplifier	HEWLETT PACKARD 11975A
Power reflection meter	ROHDE & SCHWARZ NRT
SMA connector impedance	50 Ω
Preamplifier gain	10 dB
Input signal frequency	2.4 GHz
Input signal power	10 dBm

3. Measurement Results and Discussions

Figure 3 shows the magnetic field distribution of 2D sheet for no object, copper plate, Er12 plate, and water-contained glove. In Figure 3(a), the measurement results show that it is clearly identified the pattern of standing wave based on the magnetic field contour. From XY viewpoint, the maximum displacement of standing wave is intuitively about 6 cm and the average magnetic field strength for 2D sheet with no object is about 79.1 dBµA/m. Figure 3(b) shows that the average magnetic field strength for the copper plate is about 78.6 dBµA/m or simply 0.6% lower than the 2D sheet with no object. This indicates that the use of copper plate does not influence the magnetic field of 2D sheet.

As we can see from the measurement results in Figure 3(c) and 3(d), the overall magnetic field strength has been increased for the Er12 plate, meanwhile the overall magnetic field strength has been reduced for the water-contained glove. The average magnetic field strength for the Er12 plate is about 82.2 dBµA/m. This value is about 4% higher than the 2D sheet with no object. However, the average value for the water-contained glove is about 77.2 dBµA/m that is about 2.3% lower than the 2D sheet with no object.

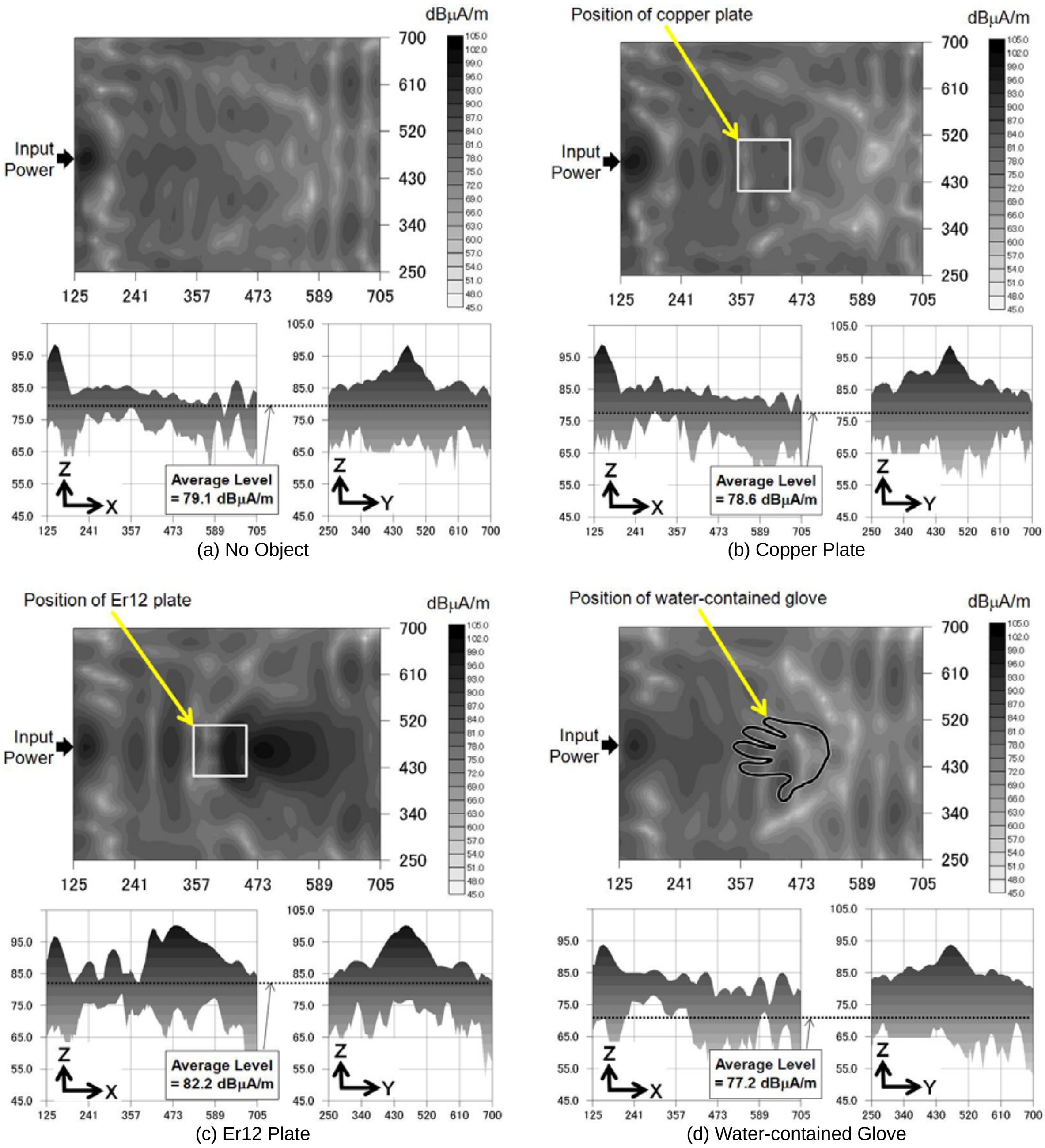


Figure 3: Magnetic Field Distribution and Strength

In Figure 3, we discussed the magnetic field distribution with no object when the probe is placed at the height of 2 mm. This leads to the unfair analysis for the Er12 plate and the water-contained glove, in which the probe of their experiments is placed at the height of 1 cm and 2 cm, respectively. To validate the measurement results above, we compare separately the magnetic field strength along the X-direction only for the objects depending on the probe height. Table 2 lists the comparison of average, standard deviation, maximum, and minimum of the magnetic field strength for all the objects when the probe is placed at three difference heights from the surface of 2D sheet. The average magnetic field strength for the Er12 plate is about 78.14 dBµA/m, which is about 4.53% higher than the 2D sheet with no object. However, the average value for the copper plate and the water-contained glove is about 74.51 dBµA/m and 73.31 dBµA/m, respectively, which is about 0.16% and 1.61% lower compared to the 2D sheet with no object. We verify that the Er12 plate does increase the average magnetic field strength of 2D sheet. Due to the dielectric properties, the Er12 plate concentrates the radiated energy from the surface of 2D sheet and it becomes the source of radiation emission. In contrast, the water-contained glove does decrease the average magnetic field strength of 2D sheet. This is because the inside of the plastic glove is water, which absorbs the radiated energy from the surface of 2D sheet. Then, the water converts the absorbed energy to heat. At last, the copper plate does not give any effect on the change of magnetic field strength.

Table 2: Magnetic Field Strength (dBµA/m) Comparison

When the probe is placed at about 2 mm			
Parameter	No Object	Copper Plate	Change
Average	74.63	74.51	–0.16%
Standard deviation	5.17	5.77	+11.58%
Maximum	93.98	94.27	+0.31%
Minimum	43.99	43.70	–0.66%
When the probe is placed at about 1 cm			
Parameter	No Object	Er12 Plate	Change
Average	74.76	78.14	+4.53%
Standard deviation	5.10	6.35	+24.32%
Maximum	92.35	96.02	+3.98%
Minimum	46.22	48.45	+4.82%
When the probe is placed at about 2 cm			
Parameter	No Object	Water-contained Glove	Change
Average	74.51	73.31	–1.61%
Standard deviation	5.77	5.89	+2.13%
Maximum	94.27	89.75	–4.79%
Minimum	43.70	43.13	–1.30%

4. Concluding Remarks

In this paper, we measured and investigated the effect and characteristic of magnetic field strength when objects are placed on the top of the 2D sheet. Measurement results reveal that the average magnetic field strength drops about 1.61% when the water-contained glove put on the 2D sheet. However, the average magnetic field strength increases about 4.53% when the Er12 plate put on the 2D sheet. Interestingly, the copper plate does not give any effect on the change of magnetic field strength.

References

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