

# Emission from PCB with a Conducting Wire for Microstrip Line Placed Various Positions

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## 1. Introduction

Recently, with the progress of information processing technology the fundamental and its harmonics frequency of a clock pulse of an electronics device such as personal computer becomes very fast. Moreover, the clock pulse used in such fast equipment becomes faster. Consequently the problem of undesired emission from such fast electronics device is emphasized. Moreover by the increases of the equipment which operates in low voltages the susceptibility increases. The disturbed electromagnetic field of the former is generated from the microstrip line and the ground plane on a printed circuit board (PCB) included in equipment and it radiates through opening apertures and power cables on the equipment.

Though there are many factors as cause for radiated emission from the PCB, one of the most critical causes is the common mode current. The common mode current relatively smaller than the differential mode current flowing on the PCB, but due to the relatively large electrical extent of the external common mode current path, emission of the common mode current often becomes dominant [1]. The common mode current is generated at discontinuity in the PCB, on cables attached the PCB to outside and so on. Then various methods for estimating amount of the common mode current are reported and studied [2]-[4]. It easily becomes possible by using these techniques to derive common mode current.

In these cases conducting wire is connected only at the center of the edge of the ground plane and its direction is parallel to the PCB. The position of the junction of the conducting wire and its direction are important in a practical PCB design. Therefore it is necessary to understand clearly the relation between the common mode current and the conducting wire which connected at various locations on the ground and directed to any direction. Also because the wavelength at the frequency in which exceeds 1GHz is smaller than 30cm, it is considered that large electromagnetic radiation is occurred due to resonance when PCB and wires in equipment have the size of several centimeter. Therefore we focus on frequency band 1~3GHz, the PCB and wires whose sizes is about several centimeter.

In this paper, in order to clarify the relation between the conducting wire, which is connected to an edge of the ground plane of a PCB, and emission, we analyze the radiation power from the PCB for various directions of the conducting wire and positions of a microstrip line. As the numerical analysis method the Finite Different Time Domain (FDTD) method is used. Then in order to prove validity of calculated radiation power by attaching the conducting wire, we measure the radiation power from a PCB.

## 2. Analysis of Radiation Power from PCB

### 2.1 Analysis Model

The analysis model is shown in Fig.1. The model shows that the PCB arranged one microstrip line is connected to the conducting wire at the edge of the ground plane. The PCB is composed of Teflon laminated circuit board (relative permittivity  $\epsilon_r=2.3$ ) of thickness  $T=1.6$ mm and the ground plane, which has the width  $W=30.4$ mm and the length  $L=65.6$ mm. The microstrip line arranged on the PCB has the width  $w=4.8$ mm and the length  $l=40$ mm, and its characteristic impedance is about  $50\Omega$ . The signal source which has supply voltage  $V_0=1$ V and internal resistance

$R_0=50\Omega$  is connected to one end of the microstrip line as feeding point and a load resistance is connected to the other end. The conducting wire of the length  $l_c=30\text{mm}$  is connected to the ground edge parallel to  $x$  axis direction. The center of the ground plane of the PCB is made to be the origin of the coordinate.  $X$  axis is defined parallel to the microstrip line and  $z$  axis is defined vertical axis to the PCB respectively. The position of junction of the ground plane and the conducting wire is  $(x_c, y_c, 0)$ , and the position of the microstrip line is the center point of it  $(l_x, l_y, 1.6\text{mm})$ .

As the numerical analysis method, we use the FDTD method, which is well suited to EMI resulting from the PCB geometries [5]. Yee cells whose size is  $0.4\text{mm} \times 0.4\text{mm} \times 0.2\text{mm}$  are used in computational region. As the boundary condition, Perfectly Matched layers (PML) is used in the FDTD analysis. The radiation power  $P_r$  from the PCB is calculated to integrate real part of Poynting vector over closed box surrounding the PCB. The normalized power  $P_r/P_{inc}$  which is normalized by incident power  $P_{inc}$  is used as an evaluation parameter. Then,  $P_{inc}$  is the incident power when the microstrip line is matched to signal source whose supply voltage is  $V_0$  and internal resistance is  $R_0$ , and it is given by

$$P_{inc} = \text{Re} \left( \frac{|V_0|^2}{4R_0} \right)$$

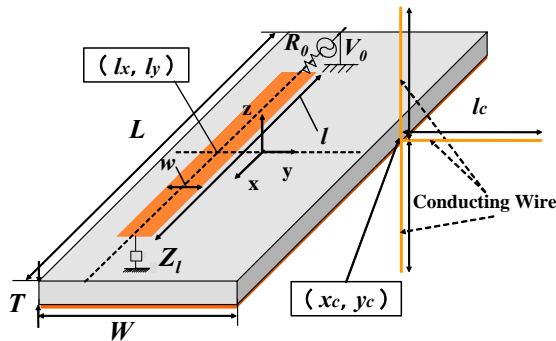


Fig.1 Configuration of PCB and conducting wire

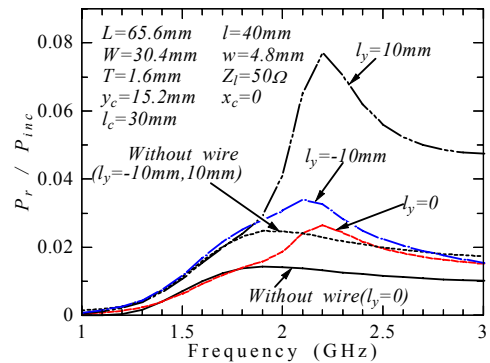


Fig.2 Normalized power from PCB with or without conducting wire (+z direction)

## 2.2 Numerical Results

Normalized radiation power from the PCB attached the conducting wire is analyzed for various position of the microstrip line. The direction of the conducting wire is  $+z$  axis. The microstrip line centered lengthwise ( $l_x=0$ ) and centered ( $l_y=0$ ) or separated from center  $l_y=-10\text{mm}$  or  $10\text{mm}$  widthwise and the load resistance is  $Z_l=50\Omega$ . The position of the junction between the ground plane and the wire is the center of the ground edge ( $x_c=0, y_c=15.2\text{mm}$ ).

Numerical results of the normalized radiation power from the PCB with the conducting wire for the microstrip line placed center ( $l_y=0$ ) or near the edge ( $l_y=-10\text{mm}, 10\text{mm}$ ) is calculated and shown in Fig.2. The radiation power from the PCB without the conducting wire is also plotted as reference. Fig.2 shows that the radiation power from the PCB without wire becomes large when the microstrip line placed near the edge of the ground plane [6]. The radiation power from the PCB with the conducting wire is larger than the others especially for the microstrip line placed to  $l_y=10\text{mm}$ . In addition, the radiation power from the PCB with the conducting wire is the largest at the  $2.2\text{GHz}$ . Since the distance between the microstrip line and the conducting wire is the smallest in the case  $l_y=10\text{mm}$ , the electrical coupling between them becomes the largest. Therefore the large radiation power occurs because the large common mode current excited in the conducting wire [4]. Moreover it is considered that since the resonance happens when the length  $l_c$  of a conducting wire is about  $1/4$  wavelength at  $2.2\text{GHz}$  the radiation power becomes the maximum.

In order to research the relation for the radiation power versus the position of the microstrip line ( $l_y$ ), the radiation power for various directions of the wire is plotted in Fig.3 as a function of  $l_y$  at frequency in which the radiation power is the maximum. The radiation power without wire is also plotted as reference. The directions of the wire are  $y$  axis,  $+z$  axis or  $-z$  axis. As seen in Fig.3, the radiation power is largest for  $l_y=12\text{mm}$  and it decreases with the increase of the distance between the microstrip line and the edge of the PCB until  $l_y=0$ , in which the radiation power is smallest in spite of the direction of the wire.

Also for the case of the PCB without the wire the radiation power for the case of the microstrip line located near the edge is large and it for the case of the microstrip centered is the smallest [6]. Similarly, for the case of the PCB with the wire when the distance between the microstrip line and the edge connected to the wire is sufficiently small it is large especially for the case of the wire directed to  $+z$  axis. As the  $l_y$  decreases the radiation power increases for  $l_y < 0$  and reaches the local maximum value at  $l_y = -12\text{mm}$ . But, this value is smaller than that at  $l_y = 12\text{mm}$  since the contribution of the radiation power from the wire is small. Moreover at  $l_y = -12\text{mm}$ , the difference of the radiation power according to the direction of the wire is very small.

Numerical results of the radiation power for various  $x_c$  which is the position of the junction are shown in Fig.4. The microstrip line is centered or separated from center at  $l_y = -10\text{mm}$  or  $10\text{mm}$  widthwise. The radiation power is normalized by that from the PCB without wire at frequency in which the radiation power is the maximum. Fig.4 shows that the radiation power decreases with distance between  $x_c = 0$  and the junction of the wire and becomes the minimum when the junction is on the corner.

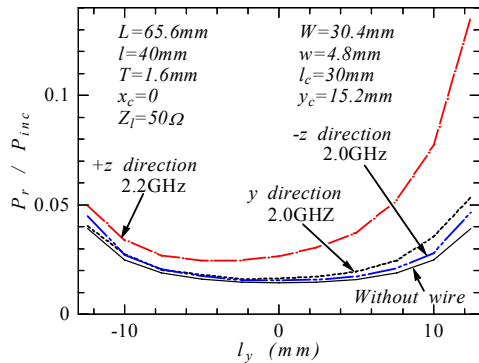


Fig.3 Normalized radiation power versus  $l_y$

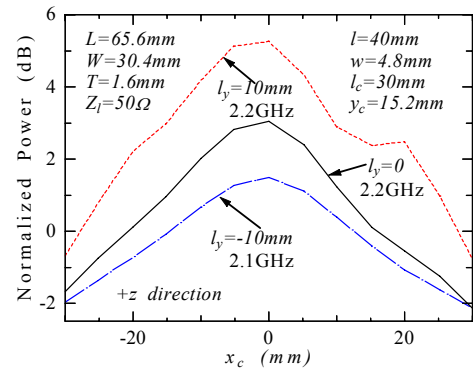


Fig.4 Normalized radiation power versus  $x_c$

### 3. Measurement Result

#### 3.1 Measurement Method

We measure the maximum received power from the PCB with or without a conducting wire in the small anechoic chamber. The maximum received power  $P_{max}$  is normalized by the received power from the PCB without wire. We measured only upper hemisphere area, which is the microstrip line side ( $z > 0$ ) of the PCB, because the radiation power of the ground side ( $z < 0$ ) is smaller than the other side. Since the maximum received power of the  $\theta$  polarization and  $\varphi$  polarization is nearly equal, the only  $\theta$  polarization is used as the received power.

The PCB which has one microstrip line on the one side of the dielectric substrate ( $\epsilon_r = 2.3$ ) of  $W = 30\text{mm}$ ,  $L = 66\text{mm}$  and  $T = 1.6\text{mm}$  and the ground plane on the other side is used. The microstrip line with  $w = 4.8\text{mm}$  and  $l = 40\text{mm}$  is terminated with the load resistance of  $50\Omega$  and centered lengthwise and centered or separated from center at  $l_y = -10\text{mm}$  or  $10\text{mm}$  widthwise. The copper wire with  $l_c = 30\text{mm}$ , and the diameter  $d = 1\text{mm}$ , is used as the conducting wire and soldered to the ground edge of the PCB ( $x_c = 0$ ,  $y_c = 15\text{mm}$ ).

#### 3.2 Measurement Result

The maximum received power from the PCB with the conducting wire which directed to  $+z$  direction is measured, when the position of the microstrip line is  $l_y = -10\text{mm}$ ,  $0$  or  $10\text{mm}$  widthwise. This measurement result is shown in Fig. 5. It shows that the maximum received power of the case of the microstrip line separated from center at  $l_y = 10\text{mm}$  is largest in other positions at the  $2.25\text{GHz}$  and its value is about  $4\text{dB}$  relative to the case of the PCB without the wire. At this frequency the direction of the maximum received power, which is  $l_y = -10\text{mm}$ ,  $0$  and  $10\text{mm}$ , is almost about  $\theta = 90^\circ$  and  $\varphi = 270^\circ$ . It is consider that since for this frequency range the length of the conducting wire is corresponding to about  $1/4$  wavelength the resonance occurs and the wire operates as the monopole antenna. Moreover as the distance between the microstrip line and the wire decreases the received power increases for frequencies larger than  $2\text{GHz}$ . This measured result indicates that the received power depends on the distance between the microstrip line and the wire, so we regard the analysis and measurement results as similar tendency.

When the conducting wire attaches to  $+z$  direction with  $l_y=10\text{mm}$ , measurement results of the maximum received power for various  $x_c$  which is the position of the junction are shown in Fig.6. AS seen in Fig.6, in the case of the conducting wire attached to  $x_c=0$  at the 2.25GHz, the radiation power is largest and becomes the minimum when the junction is on the corner. When the conducting wire attached to  $x_c=30\text{mm}$ , the radiation power increases at the 1.55GHz. It is considered that since the length  $L$  of the PCB plus  $l_c$  of the conducting wire equals about  $1/2$  wavelength at 1.55GHz the resonance happens and the radiation power increases consequently. This measured result indicates to consistent with the numerical analysis results.

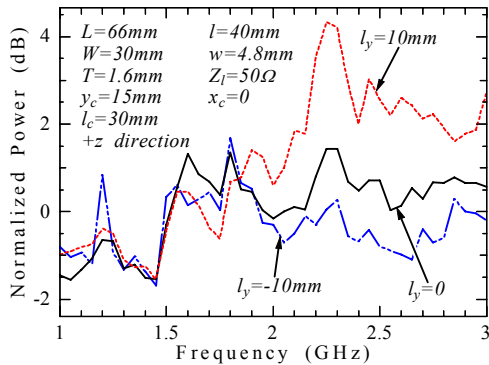


Fig.5 Measured power from PCB with  $l_y=-10\text{mm}$ , 0 and  $10\text{mm}$  ( $+z$  direction)

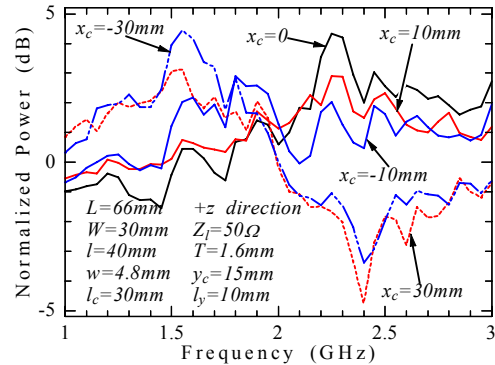


Fig.6 Maximum received power with  $x_c=-30\text{mm}\sim 30\text{mm}$  ( $l_y=10\text{mm}$ )

## 4. Conclusion

In this paper to demonstrate the relation between emission from the PCB and the attached conducting wire, we analyzed the normalized radiation power using the PCB which placed one microstrip line and connected the conducting wire to the edge of the ground plane. Numerical results of the radiation power showed that in case of the microstrip line separated from center  $l_y=10\text{mm}$  widthwise the radiation power is the largest at the 2.2GHz. For the position of the microstrip line when the microstrip line is located at the center of the PCB the radiation power is the smallest and when it is located near the edge attached wire the radiation power is the largest since the distance between the microstrip line and the wire is sufficiently small. From the measurement results radiation power from the PCB with conducting wire shows a similar tendency with the analysis results. We honestly showed that as the distance between the microstrip line and the conducting wire decreases the radiation power increases.

## References

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