Study on Invasiveness and Suppression Effect for Near Electromagnetic Field above PCB by Suppression Material

Takashi Kasuga[1], Yuki Matsumoto, Atsushi Nakajiri and Hidetoshi Nakayama[2]

Nagano National College of Technology
716 Tokuma Nagano-shi, Nagano 381-8550 Japan

[1]kasuga@ee.nagano-nct.ac.jp

[2]nakayama@ec.nagano-nct.ac.jp

Abstract—**This study is to make clear the suppression effect and influence of the near electromagnetic field by the conductive or magnetic plates put on the PCB. The suppression effect and influence by the copper, ferrite and composite material pasted the copper and ferrite plates together are discussed by the measurement and calculation. The suppression effect by the copper plate increases as the frequency shifts higher. The suppression effect by the ferrite plate is corresponded to the frequency characteristics of permeability of the ferrite. The suppression effect by the composite suppression material is large than that of the copper or ferrite plates by itself at all frequency band. As the influence for the near electromagnetic field by the FDTD is calculated, it is appeared that the invasiveness for the near magnetic field is large. As the composite material mc puts on the PCB, the influence with respected to the electric field between PCB and composite material is small. The invasiveness by the copper plate can be suppressed.**

Key words: PCB, composite suppression material, near electro-magnetic field, suppression effect, invasiveness.

I. INTRODUCTION

The information electronic devices such as mobile phone or notebook type personal computer are downsizing and high functionality using the several kinds of the LSI [1]. As the mobile phone and personal computer have a wireless circuit, the countermeasure of the EMI problem caused by the RF radiated own circuit must be needed [2]. For the countermeasure method of EMI and Immunity, it is found to be useful to shield the printed circuit board (PCB) by the conductor plate. However, the increment of the EMI radiation due to the coupling between the PCB and the conductor plane can be possible. To decrease the coupling between the PCB and the conductor plate, the electromagnetic noise is absorbed by the magnetic sheet pasted inside the conductor plate [3].

The suppression method of the electromagnetic noise is used as the conductor plate and the magnetic sheet is put above the PCB or LSI [4-6]. It is clear that the suppression material by the conductor plane and the magnetic sheet can effectively suppress either electric or magnetic field. However, it is not much disputed that the conductor or the magnetic plates make an impact on the near electric and magnetic field.

In this paper, the suppression effect and invasiveness for the near electromagnetic field around the PCB with the noise suppression material is discussed. The noise suppression materials used in this study are copper, ferrite and the composite electromagnetic suppression material pasted between the copper and ferrite plates. The suppression effect is discussed to measure the near magnetic field for cross sectional of the PCB. The invasiveness of the near electromagnetic field is discussed by the FDTD simulation.

II. PCB MODEL, MEASURE AND ANALYSIS CONDITION

A. PCB Model

Figure 1 shows the PCB model used in this study. The length of the board is 300mm, width is 100mm, and thickness is 1.6mm. The dielectric material of the board is glass epoxy, and the relative permittivity is 4.4. The whole background of the PCB is copper plate. The characteristic impedance of the transmission line is 50Ω. The end of the transmission line is terminated by 47Ω chip resistor.

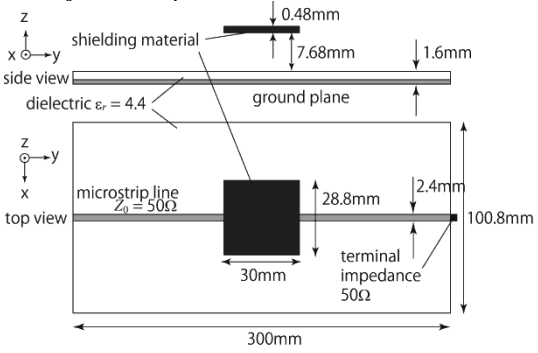

Fig. 1 PCB model under test

Figure 2 shows the suppression materials. The copper plate, ferrite plate and the composite electromagnetic suppression material pasted the copper and ferrite plates together are used. The size of the suppression material is 28 x 28 mm^2. The thickness of the copper plate is 0.5mm, and ferrite is 0.8mm. When the ferrite side of the composite material is turn the PCB, the condition is called "mc". And the copper is turn the PCB, the condition is called "cm". When the suppression material was set at higher than 8mm above the PCB, it was

clear that the characteristic impedance of the transmission line was not varied [4]. In this study, the suppression material is put at 8mm above the PCB.

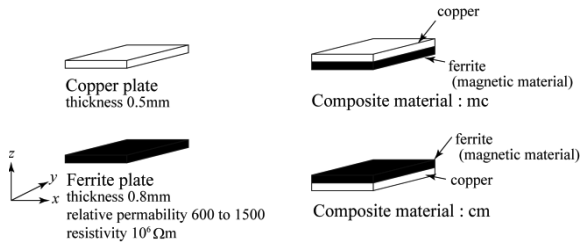

Fig. 2 Electromagnetic suppression material

B. Measurement of Near Magnetic Field

The near magnetic field is measured by the near magnetic field probe MP-10L (NEC) whose frequency band is 150kHz to 1GHz. The output of the magnetic field probe is amplified by the 40dB amplifier (R&K A130), and detected by the spectrum analyzer (Agilent N9320A). The coil height is 16.5mm from the PCB surface. The coil area is 12 x 3mm^2.

The 0dBm voltage signal is applied from TG source of spectrum analyzer. The amplitude of the magnetic field is normalized by the maximum value of the magnetic field for the PCB without suppression material.

C. FDTD Analysis Condition

The suppression effect and influence of the near electromagnetic field by the suppression material are calculated by FDTD simulation. The unit cell sizes are Δx=1.2, Δy=2.5, and Δz=0.48mm. The time step Δt is 1.46ps by Courant stability condition. The signal frequency to calculate the electromagnetic field distribution is 100MHz. The permeability μ' of the magnetic material is assumed 1000, and μ'' is zero. The thickness of the copper plate is modeled by one cell, and that of magnetic suppression material is two cells.

III. Suppression Effect of Near Electromagnetic Field

To discuss the suppression effect of the near electromagnetic field by the copper and magnetic plates, the frequency characteristics of the magnetic field H_x above the printed line, x=0, is shown in Fig. 3. The longitudinal axis of Fig. 3 is normalized by the magnetic field at "elemental PCB" without the suppression material. The magnetic field with suppression materials is decreased with respected to that of elemental PCB. The magnetic field at the copper plate is -5 to -6dB than that of elemental PCB at all frequency bands. Since the specific frequency band of the permeability of ferrite is 1 to 400MHz, the magnetic field of the ferrite plate is decreased less than 400MHz, and is small than that of the copper plate at less than 200MHz. There is not large difference between the magnetic field of the "cm" and "mc". The magnetic fields of the composite materials are decreased than that of the copper and ferrite plates at all frequency bands. The noise suppression effect is large by pasted the copper and ferrite plates which have difference frequency characteristics together.

To discuss the noise suppression effect above the PCB, the magnetic field for the cross sectional distribution at 100 MHz is shown in Fig. 4 and 5. Figure 4 is the magnetic field distributions of the elemental PCB and conductor plate by measurement and calculation. The magnetic field of the elemental PCB by the measurement and FDTD calculation are good agreement. There is difference between calculation and measurement on the magnetic field at conductor plate edge.

Figure 5 shows the measurement results of the magnetic field by the suppression materials. The magnetic field of the copper plate is decreased at 4.6dB than that of the elemental PCB. That of ferrite is 9.8dB, composite material is 11.8dB. On the composite material "cm" and "mc", there is no difference of the magnitude of the magnetic field. However, there is difference above the edge of the composite material. The magnetic field of the composite material "mc" at PCB edge is smaller than that of "cm". As the difference of the layout method of the composite material, the suppression effect is different. The distributions of the ferrite and composite material "mc" are agreement.

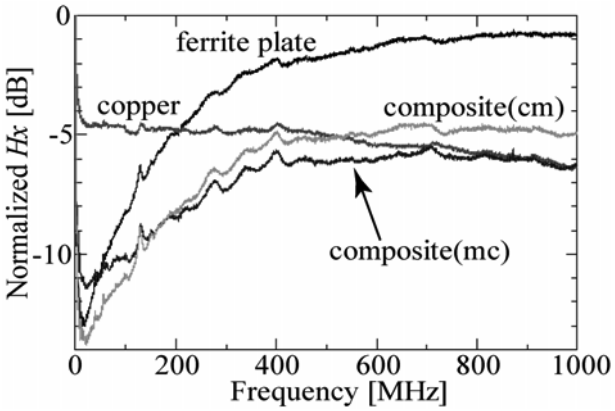

Fig. 3 Frequency characteristic of magnetic field H_x

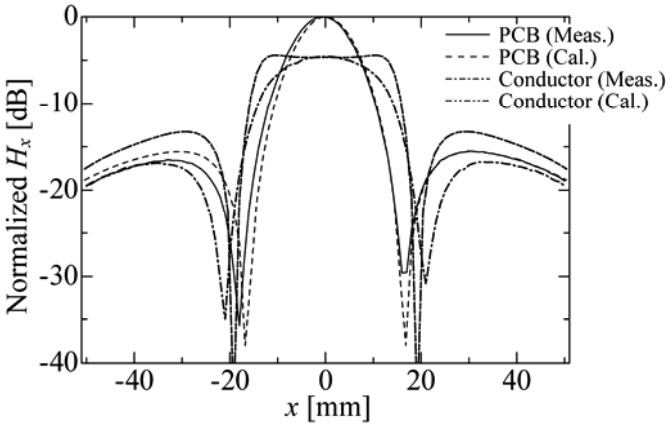

Fig. 4 Cross sectional distribution of magnetic field H_x for the elemental PCB and conductive plate by measurement and calculation.

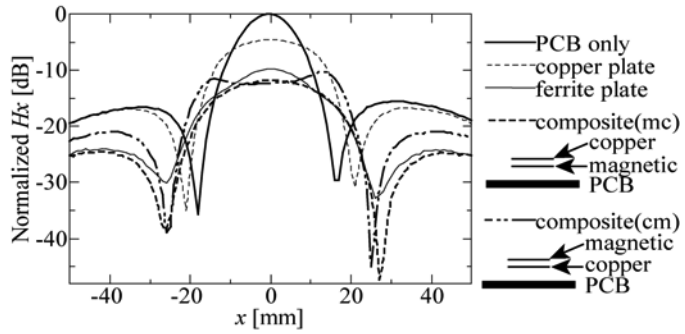

Fig. 5 Cross sectional distribution of magnetic field H_x for the suppression materials.

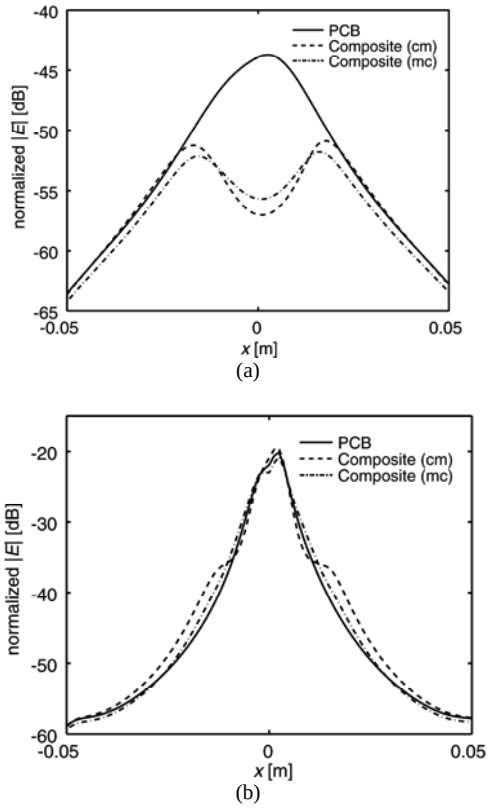

Fig. 6 Cross sectional distribution of electric field $|E|$. (a) is electric field distribution upper side of suppression material and (b) is between PCB and suppression material.

IV. Suppression Effect of Near Electromagnetic Field

The invasiveness for the near electromagnetic field as the suppression material puts on the PCB is discussed using the FDTD simulation. Figure 6 and 7 show the near electric and magnetic field distribution above the PCB. (a) is the electric or magnetic field distribution above the suppression material at z=16.5mm from the PCB surface, and (b) is the distribution of the interval between PCB and suppression material at z=4mm from the PCB surface. The electric and magnetic field are signified by the absolute value. The amplitudes of the electric and magnetic field are normalized by the maximum value of the analysis results.

In Fig. 6(a), the electric field above the suppression material is decreased about 13dB. The shapes of the electric field distribution between the composite material "mc" or "cm" are different, but difference of the amplitude is 1dB. On the electric field distribution between PCB and suppression material in Fig. 6(b), the electric field by the composite material "cm" is varied above the edge of suppression material. On the other hand, the distribution of the composite material "mc" is coincided with that of elemental PCB. As the side of the magnetic material for composite material is turn the PCB, the influence with the near electric field can be decreased.

In Fig. 7(a), the magnetic fields with composite material are decreased at the cross sectional direction of all PCB. The shapes of the distribution by the "cm" or "ms" are different. From results in Fig. 5 and 7(a), since the suppression amount by the "mc" is larger than that of "cm", the suppression effect with the magnetic field is different as the direction of suppression material side. In Fig. 7(b), the magnetic fields of the "cm" and "mc" under the suppression material are coincided with elemental PCB. However, the magnetic fields outside with the suppression material are decreases with elemental PCB. The composite suppression material influences the near magnetic field.

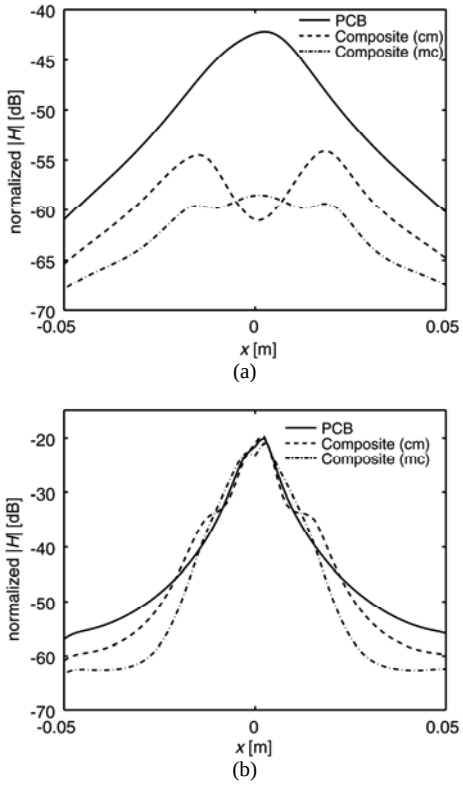

Fig. 7 Cross sectional distribution of magnetic field $|H|$. (a) is electric field distribution upper side of suppression material and (b) is between PCB and suppression material.

To discuss the influence for the near electromagnetic field when the suppression material is set on the PCB, Fig. 8 shows the suppression amount of the electric and magnetic fields when the composite material "cm" put on the PCB with respected to that of the elemental PCB. Figure 8 is the cross sectional view of the PCB, and x=0 and z=0 point is the printed line. The positive value indicates the amount of the suppression, and negative value is that of increase.

The both of the electric and magnetic fields above the suppression material are decreased. On the other hand, the electric and magnetic fields at the edge and center of the suppression material are increased. The cause of the increment of the electromagnetic field is as the current flows the edge of the suppression material. In Figs. 4 and 5, the null points are shifted when the suppression material puts on the PCB. The cause of the null point shifting is the current on the edge of the suppression material.

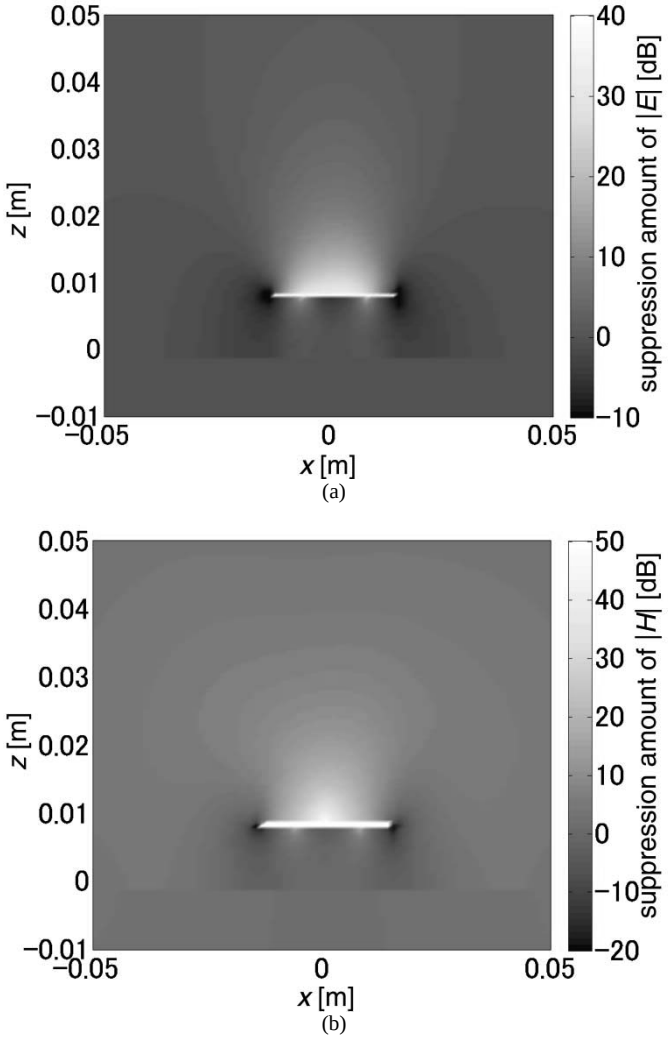

Fig. 8 Amount of the suppression of electric and magnetic field with composite material "cm". (a) is electric field, and (b) is magnetic field.

V. Conclusion

This study is discussed the suppression and influence for the near electromagnetic field when the noise suppression material puts on the PCB. The copper, ferrite and composite material pasted the copper and ferrite plates together are used for the noise suppression material. The suppression effect by the copper plate is increased as the frequency shifts higher. The suppression effect of the ferrite plate relates with the permeability of the ferrite. The amount of the suppression effect for the composite material is decided with the larger suppression amount for either elemental copper or ferrite plates. The suppression effect of the composite material at wide frequency band is larger than that of copper or ferrite plates by itself. At the suppression effect for the cross sectional direction, the electric field is decreased above the suppression material, and magnetic field is decreased in the cross sectional in all PCB.

As the influence of the near electric and magnetic fields by the suppression material, the magnetic field comes under the influence of the suppression material. Since the current is focused on the edge of the suppression material, the electric and magnetic fields are increased at near the edge of the suppression material. When the composite material "mc" is put on the PCB, the electric field under the suppression material is coincided with that of the elemental PCB. The invasiveness by the copper plate can be suppressed.

The invasiveness by some other structures such as cable or near electric and magnetic field probe must be discussed.

Acknowledgments

This study is the Foundation for Technology Promotion of Electronic Circuit Board subsidized 2007 project. The analysis results of this study are calculated used by super computer SX-9 of Cyber science Center Tohoku University.

References

[1] Y. Sugimoto, "RF Analog, and Mixed Digital LSIs for Portable Telephones", Journal of IEICE, vol.84, no.11, pp.796-802, (2001)

[2] T. Harada et.al, "Investigation on EM Interference Measurement and Control Technique in Wireless Equipment", Proceedings of the 2008 IEICE society Conference, BS-3-5, (2008)

[3] H. Ono et.al, "Noise Suppression Sheet for Intra EMC Application", Proceedings of the 2008 IEICE society Conference, BS-3-3, (2008)

[4] M.Tanaka et.al, "Effect of Conductive Sheet Placed over PCB on Electromagnetic Noise Shielding", IEICE trans. on comm. vol.E86-B, No.3, pp.1125-1131, (2003)

[5] T. Kasuga et.al, "A Study on Suppression of Crosstalk between Parallel Transmission Lines at High Frequency Band", proceeding of 2007 IEEE International Symposium on EMC, THPM42, (2007)

[6] K. Nakano et.al, "Study of Reduction in Unwanted Radiation by Layer Stackup Printed Circuit Board with IC", Technical Report of IEICE, EMCJ2002-71, (2002)