SUPPRESSION EFFECT OF THE UNDESIRED EMISSION FROM PRINTED CIRCUIT BOARD WITH A MICROSTRIP LINE USING A FERRITE PLATE

Teruo Tobana*, Qiang Chen**, Kunio Sawaya**, Takayuki Sasamori* and Kohshi Abe*

*Department of Electronics and Information Systems,
Faculty of System Science and Technology,
Akita Prefectural University, Tuchiya, Honjou, 015-0055, Japan

**Department of Electrical and Communication Engineering,
Tohoku University, Aoba-ku, Sendai, 980-8579, Japan

abstract

The effect of suppressing electromagnetic emission from a printed circuit board (PCB) by using a ferrite plate with the Debey dispersion is investigated. The PCB has an infinite ground plane and a microstrip line terminated with an open, short or 50Ω load. The frequency dependent finite different time domain (FD-FDTD) method is used for the numerical analysis. The calculated results show that the suppression effect is achieved by the ferrite plate is placed at a large magnetic field intensity.

1. INTRODUCTION

It is very important to suppress the undesired electromagnetic emission from the electrical and electronic equipment such as a printed circuit board[1]–[3]. One of the effective methods for the suppression of the emission is to place electromagnetic absorber over the circuit such as the materials impregnated with carbon and the ferrite materials. Since the permeability of the ferrite has a strong dispersion, the analysis of the ferrite is not easy. The FD-FDTD method is one of the most powerful techniques to analyze such a dispersive material[4].

In this paper, a numerical analysis of the power radiated from a microstrip line on a PCB is carried out. The PCB consists of an infinite dielectric substrate with an infinite ground plane and a microstrip line terminated by an open circuit, a short circuit or 50Ω resistance, respectively. A ferrite plate as an absorber is placed above the PCB. The FD-FDTD method based on the recursive convolution is applied to the analysis. Numerical results of the radiating power from the microstrip line are shown as a function of frequency. And the suppressive effect of the ferrite plate is demonstrated.

2. FORMULATION OF FD-FDTD METHOD FOR A SPINEL FERRITE

When frequency over several hundred MHz is considered, frequency dispersion of a permeability of the spinel type ferrite is expressed approximately by

$$\mu(\omega) = \mu_0 \left(1 + \frac{\mu_s - 1}{1 + j\omega t_0}\right) \tag{1}$$

where μ_0 is the permeability in free space, μ_s is the static relative permeability at zero frequency, t_0 is the relaxation time and ω is the angular frequency [5]. This equation is the first order Debey dispersion. We can formulate FDTD equation for the medium of spinel ferrite by using Frequency Dependent FDTD (FD-FDTD) method. The FD-FDTD method uses an accumulated variable Ψ in the ordinary FDTD method, where Ψ is a substitution of the integral form of a convolution. The FD-FDTD formulation of ferrite material is given by

$$\boldsymbol{E}^{n+1} = \alpha_e \boldsymbol{E}^n + \beta_e[\nabla \times \boldsymbol{H}^{n+\frac{1}{2}}] \tag{2}$$

$$\boldsymbol{H}^{n+1} = \alpha_h \boldsymbol{H}^n + \beta_h[\nabla \times \boldsymbol{E}^{n+\frac{1}{2}}] + \gamma_h \boldsymbol{\Psi}_h \tag{3}$$

$$\boldsymbol{\Psi}_h^{n+1} = \chi_h \boldsymbol{H}^{n+1} + \xi_h \boldsymbol{\Psi}_h^n \tag{4}$$

where

$$\alpha_e = \frac{\epsilon}{\epsilon + \sigma\Delta t},\ \beta_e = \frac{\Delta t}{\epsilon + \sigma\Delta t}$$

$$\alpha_h = \frac{1}{(1+\chi^0)},\ \beta_h = \frac{\Delta t}{\mu_0(1+\chi^0)},\ \gamma_h = \frac{1}{(1+\chi^0)}$$

$$\chi_h = (\epsilon_s - 1)\left(1 - e^{-\frac{\Delta t}{t_0}}\right)^2,\ \xi_h = e^{-\frac{\Delta t}{t_0}}$$

$$\chi^0 = (\epsilon_s - 1)\left(1 - e^{-\frac{\Delta t}{t_0}}\right).$$

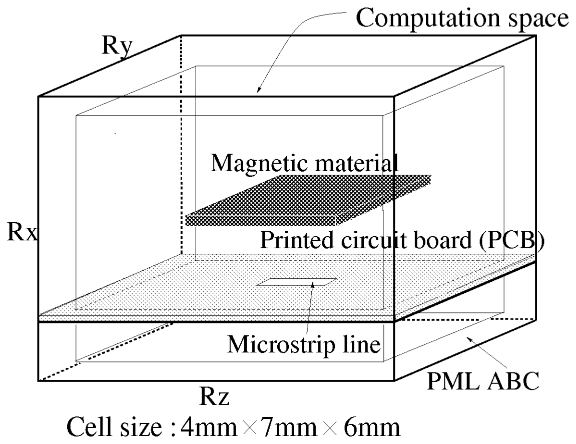

Figure 1: The analysis model in the computation space

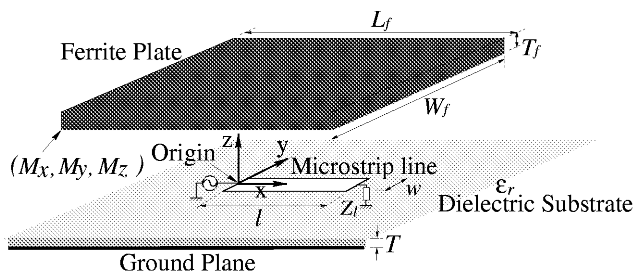

Figure 2: The geometry of the PCB and the ferrite plate

3. ANALYSIS OF RADIATION POWER FROM A MICROSTRIP LINE

3.1 Analysis Model

The analysis model is shown in Fig. 1. As a outer radiation boundary condition, the PML absorbing boundary condition is used. In order to analyze only

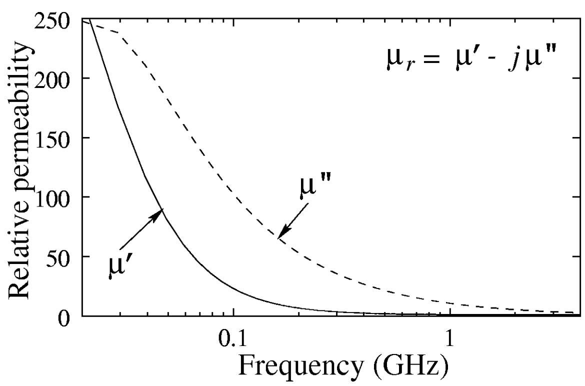

Figure 3: The dispersion of permeability of the ferrite plate, where $\mu_s = 500$ and $t_0 = 7.4 \times 10^{-9}$ in (1)

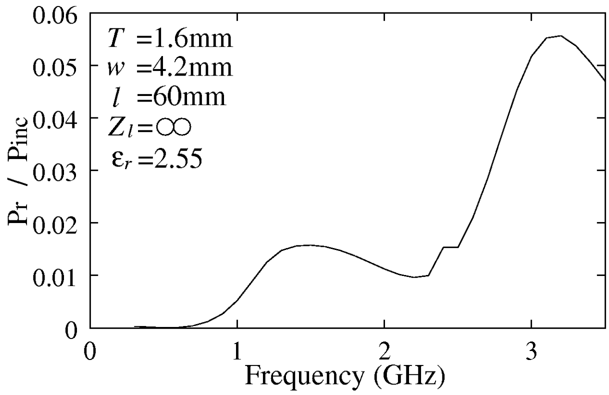

Figure 4: The radiation power from the PCB to connect an open circuit without the ferrite plate

the radiation power from a microstrip line on the PCB, a PCB with an infinite ground plane is assumed. Considering an infinite ground plane, we put the edges of the PCB in the PML layers.

The geometry of the PCB and a ferrite plate for suppressing the radiation power is shown in Fig. 2. The PCB consists of a microstrip line on the dielectric substrate of ϵ_r and thickness T. The microstrip line has the length l and the width w. A signal circuit of output impedance 50Ω is connected to one end of the microstrip line and a load circuit is connected to another end. The load circuit is assumed to be an open circuit, a short circuit or a 50Ω termination. The feeding point at the end of the signal side is made to be the origin of the coordinate. The ferrite plate is rectangular having a size of $L_f \times W_f \times T_f$. The position of the ferrite plate is denoted to the corner point of (M_x, M_y, M_z). The relative permeability dispersion of this ferrite plate is shown in Fig 3. The relative permittivity and the conductivity of the ferrite are $\epsilon_r = 15$ and $\sigma = 2 \times 10^{-3}$S/m, respectively.

The power P_r radiated from the microstrip line is calculated with integrating the Poynting vector over a surface enclosing both of the microstrip line and the ferrite plate. Similarly, the reference radiation power P_0 radiated from a microstrip line without the ferrite plate is also calculated.

3.2 Numerical Results

For $Z_l = \infty$ (open circuit), the radiation power from the microstrip line and the input impedance of the line without the ferrite plate are shown in Fig. 4 and Fig. 5. The radiation power is normalized by the incident power from a source. As can be seen from Fig. 4 and 5, it can be seen that a local maximum of the radiation occurs at the anti-resonance frequency of the microstrip line, because the magnetic field intensity on the center of the microstrip line is largest at the anti-resonance frequency.

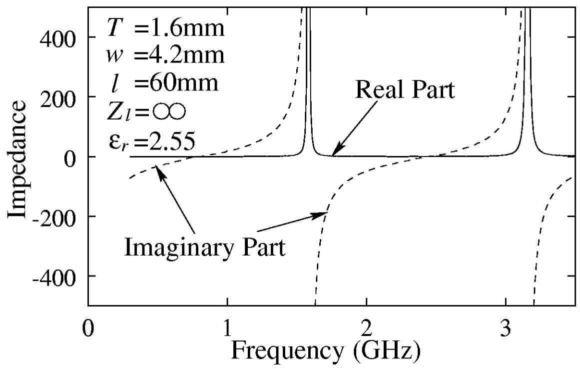

Figure 5: The input impedance of a circuit same as Fig. 4

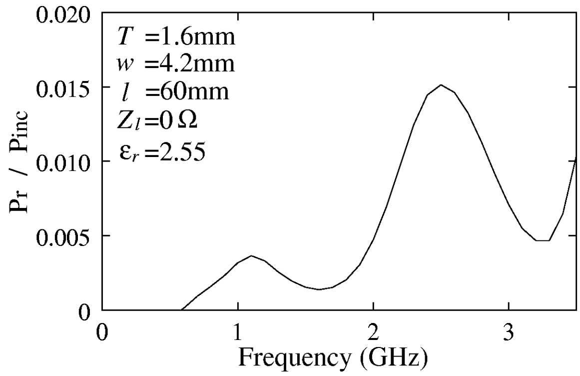

Figure 7: The radiation power from the PCB to connect a short circuit without the ferrite plate

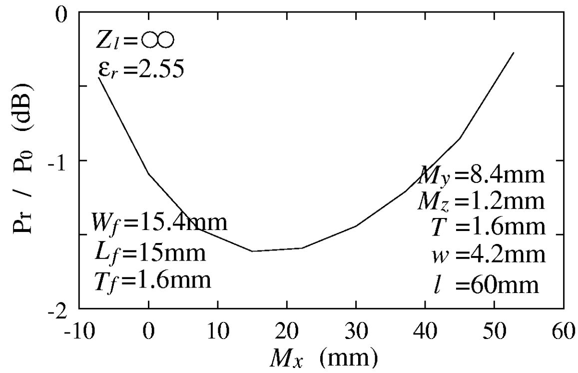

Figure 6: The suppression effect of a ferrite plate as a function of M_x

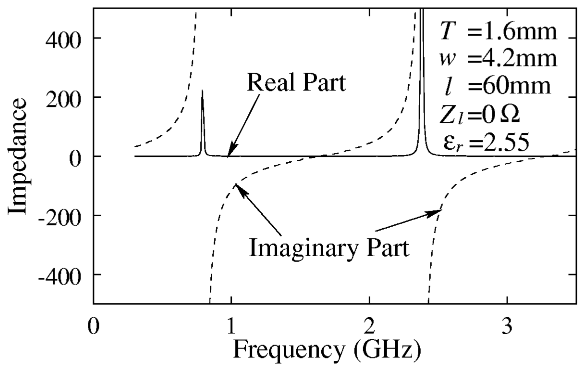

Figure 8: The input impedance of a circuit same as Fig. 7

The ratio of the radiation power with and without the ferrite plate P_r/P_0 at anti-resonance frequency is shown in Fig. 6 as a function of M_x, the position of the ferrite plate. As can be seen in Fig. 6, the largest suppression effect occurs that when the ferrite plate is placed above the center of the microstrip line. Consequently, a large suppression effect is obtained by putting the ferrite plate in region of a large magnetic field intensity.

The normalized radiation power from a microstrip line and the input impedance of the line without the ferrite plate for the case of $Z_l = 0$ (short circuit) are shown in Fig. 7 and Fig. 8. A local maximum radiation occurs at the anti-resonance frequency of the microstrip line similar to the case of the open circuit.

P_r/P_0 at anti-resonance frequency is shown in Fig. 9 as a function of M_x. The largest suppression effect occurs when the ferrite plate is placed above the end of the microstrip line. In the case of the short circuit, it becomes the largest magnetic field intensity on the end of the microstrip line. Consequently, a large suppression effect is obtained by putting the ferrite plate in region of a large magnetic field intensity similar to the case of the open circuit.

Finally, the normalized radiation power from a microstrip line is shown in Fig. 10 for the case of $Z_l = 50\Omega$. As seen in Fig. 10, the normalized radiation power from a microstrip line with termination circuit increases with the increase of the frequency.

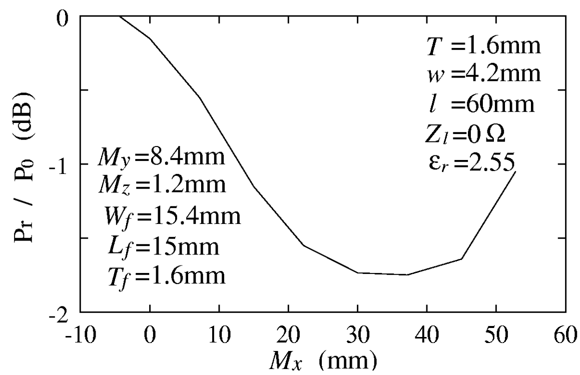

Figure 9: The suppression effect of a ferrite plate as a function of M_x

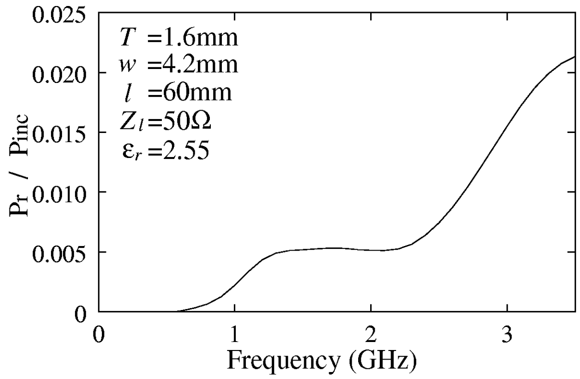

Figure 10: The radiation power from the PCB to connect a termination circuit without the ferrite plate

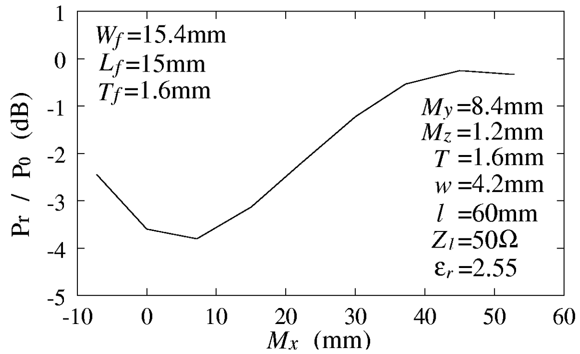

Figure 11: The suppression effect of a ferrite plate as a function of M_x

P_r/P_0 at 1.5GHz is shown in Fig. 11 as a function of M_x. The largest suppression effect occurs when the ferrite plate is located above the feeding point of the microstrip line, since the largest magnetic field intensity occurs on the feeding point of the microstrip line.

Thus, it can be concluded that a large suppression effect is obtained by putting the ferrite plate in a large magnetic field intensity.

4. CONCLUSION

In order to study the suppression effect of the undesired emission with the ferrite plate, the radiation power from a microstrip line on the PCB with an infinite ground plane has been calculated by using FD-FDTD method. The calculated results have shown that a large suppression effect can be obtained by locating the ferrite plate in the region of a large magnetic field intensity.

ACKNOWLEDGMENT

The authors would like to thank Prof. Y. Kami at Univ. of Electro-Communications for his helpful suggestions.

References

[1] M. Costa, T. K. Sarkar, B. J. Strait, and S. Bennett, "On Radiation from Printed Circuits", Proc. 1981 IEEE Int. Symp. Electromagn. Compat., pp.246-249, 1981.

[2] Y. Kami, "Mechanism of Electromagnetic Radiation from a Transmission Line.", IEICE Trans. Commun., Vol. E75-B, No. 3, March 1992.

[3] Y. Katsuyama, J. Hirokawa, M. Ando and N. Goto, "An Analysis of EMI from PCB",IEICE Tech Rept., EMCJ 92-7, pp.7-14, May 1992.

[4] K. S. Kunz, R. J. Luebbers, "The Finite Difference Time Domain Method for Electromagnetics", CRC Press, 1993.

[5] Y. Naito, "A Note on Permeability Dispersion of Spinel Ferrite", IEICE Trans. vol. 56-C, No 2, pp. 113-120, Feb. 1973. (in Japanese)

[6] O. P. Gandhi, G. Lazzi and C. M. Furse, "Electromagnetic absorption in the human head and neck for mobile telephonesat 835 and 1900 MHz", IEEE Trans. Microwave Theory Tech., vol. 44, no. 10, pp. 1884-1896, Oct. 1996.

[7] A. Talfove, "Computational Electrodynamics: The Finite-Difference Time-Domain Method", Norwood. Ma, Artech House, 1995.