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마이크로스트립 구조의 신호선에 의한 방사성 간섭 예측모델

Simple RE Prediction Model of the Signal Line of the Microstrip Structure

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Abstract : This work presents the simplified mechanism that the microstrip line generates the radiated emission which is one of the measures on the EMI levels. The electric currents on the metallization of the structure are input to the radiation integrals with the Green's functions being derived to consider the stratification of the microstrip. The simulated results suggest the method of the conceptualization on the RE characteristics of the signal trace in the PCB structure..

Keywords: Microstrip structure, Radiated Emission, Radiation Integral

I. Introduction

Each of many modern communication systems consists of multiple layers of PCBs with increasing frequency in operation and complexity in architecture. The more densely each of the layers is populated, the more care needs taking of to avoid unwanted EMIs. In particular, when it comes to the PCB layouts, a layered structure goes through inhomogeeneity in material and deformation in the uniformity of the geometry with vias and discontinuities, which ends up with radiation.

In the first place, a full-wave analysis method is used to see exactly the electromagnetic physics in the complex layered media without any approximation. It can be chosen from the FDTD, the FEM, the BEM and the like. The Method of Moment is also a good candidate for it. But they are claimed for the long computation time.

This work presents the simplified model where the electric currents on the metallization of the structure are convolved with the Green's functions using the reflection coefficient of stratification in the radiation integral. The simulated results suggest the method of the conceptualization on the RE characteristics of the signal trace in the PCB structure.

II. Theory

Here comes the simple sketch of the microstrip structure.

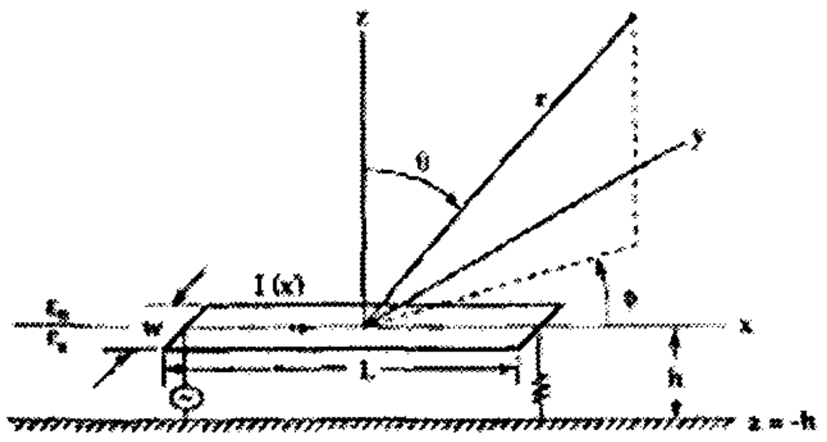

그림 1. 마이크로스트립 구조의 간략도.
Fig. 1. The simplified microstrip structure varactor.

The signal line is above the PEC ground by h. Between the ground and the line, the dielectric is placed as the substrate. $I(x)$ is the horizontal component of the electric current flowing on the line. At this point, it must be noted that the current plays the radiated emission source, corresponding to the common mode type, This RE can be exactly calculated by the radiation integral, but the far-filed approximation is acceptable since the main contribution of the current and field survives the far distance. Therefore, the x-component of the electric filed due to the x-direcrted Hertzian dipole $Io\,\Delta x$ is expressed as

$$E_{B_x}(r) = -j\eta_0 k_0 I_0 \Delta x \frac{e^{-jk_0 r}}{4\pi r} \tag{1}$$

where

$$\eta_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \quad k_0 = \omega\sqrt{\mu_0\epsilon_0}$$

This is concerned with the assumption that the structure is homogeneous with effective permittivity. However, the stacked material shows the different electromagnetic behaviors with reflection coefficients in terms of the polarization, say, for example, TE and TM.

$$\begin{aligned} R_{\mathrm{TE}}(\xi) &= \frac{j\mu\zeta_0 - \mu_0\zeta\cot(\zeta h)}{j\mu\zeta_0 + \mu_0\zeta\cot(\zeta h)} \\ &= \frac{r_{\mathrm{TE}} - e^{-j2\zeta h}}{1 - r_{\mathrm{TE}}e^{-j2\zeta h}} \end{aligned} \tag{2}$$

where

$$\zeta = \sqrt{k^2 - \xi^2} \quad \zeta_0 = \sqrt{k_0^2 - \xi^2} \quad k = \omega\sqrt{\mu\epsilon} = 2\pi/\lambda$$

$$r_{\mathrm{TE}} = \frac{\mu\zeta_0 - \mu_0\zeta}{\mu\zeta_0 + \mu_0\zeta}$$

The TE polarization means the dominant electric field has the direction transverse to the z-axis(direction of layering). Different from the TE, the TM represents the direction of the magnetic field is perpendicular to the z-axis. The reflection coefficient of the TM is as follows.

$$R_{\mathrm{TM}}(\xi) = \frac{-r_{\mathrm{TM}} + e^{-j2\zeta h}}{1 - r_{\mathrm{TM}}e^{-j2\zeta h}}$$

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(3)

where

$$r_{\mathrm{TM}} = \frac{\epsilon_0 \zeta - \epsilon \zeta_0}{\epsilon_0 \zeta + \epsilon \zeta_0}$$

Using these reflection coefficients, the radiated electric field with regard to homogeneous medium is modified as follows.

$$E_\theta^{H}(\bar{r}) = E_{\tilde{H}_x}(r)[1 - R_{\mathrm{TM}}(\theta)]\cos\theta\cos\phi \qquad (4)$$

$$E_\phi^{H}(\bar{r}) = -E_{\tilde{H}_x}(r)[1 + R_{\mathrm{TE}}(\theta)]\sin\phi \qquad (5)$$

Eqn. (4) and Eqn.(5) depict the elevation and azimuth components of the electric field, respectively. Finally, the length of the signal line is taken into account by the 1-D integral along the line with the expressions above as their kernel functions.

$$A_{x,l}(\theta,\phi) \approx \frac{1}{l}\int_{-l/2}^{l/2} e^{j(k_0\cos\psi_x - \beta)x'}\,dx' \qquad (6)$$

III. Radiation Property

The first experiment is to check the radiation resistance versus frequency with varying permittivity. The spacing between the ground and the signal line is 1.5 mm and the signal line stretches 100 mm. And the line is terminated matched.

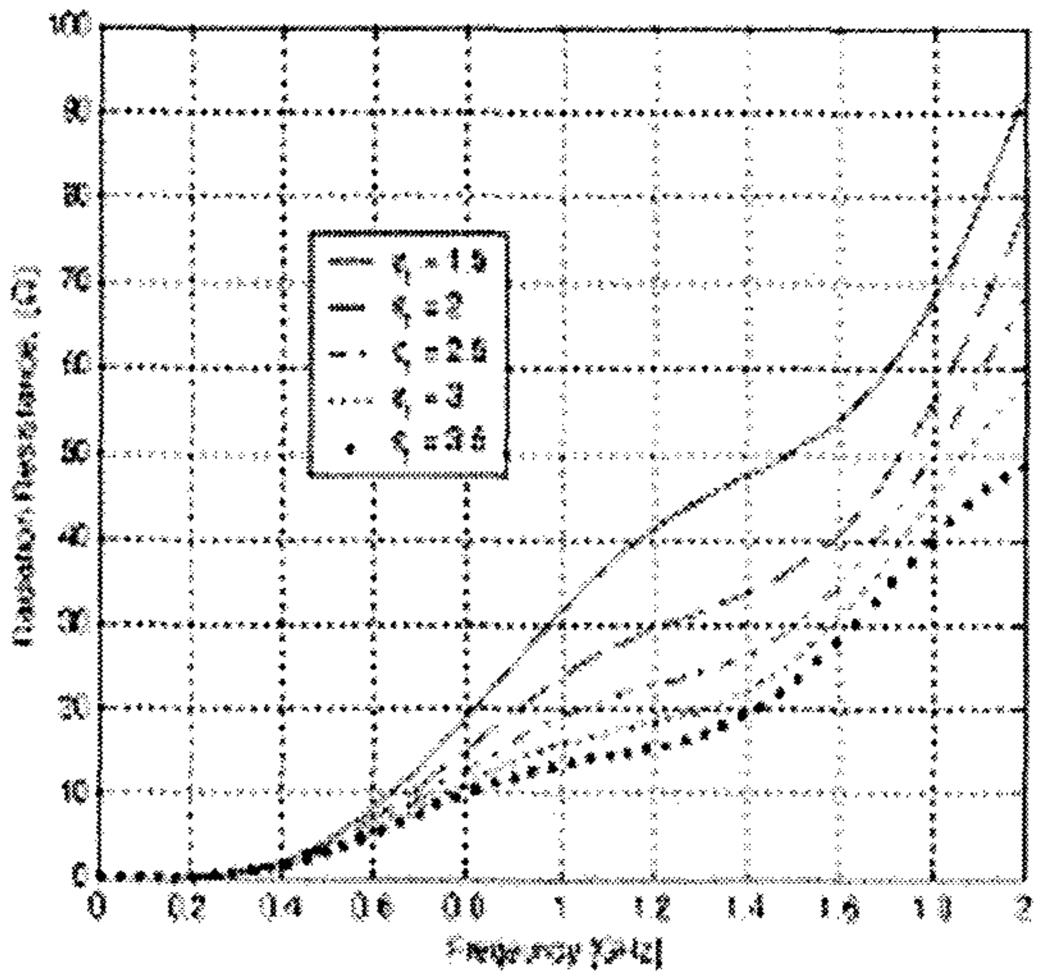

그림 2. 유전율 변화에 따른 복사저항 대 주파수.

Fig. 2. Radiation resistance versus frequency with varying permittivity.

For all the cases of different permittivity numbers, radiation resistance increases. And, it is observed that the higher permittivity corresponds to the curve of the lower radiation resistance. It is compatible to the physical phenomenon that using the substrate of the higher permittivity reduces the radiation and tends to capture energy in the substrate. Next, the spacing is varied to see the relations between the frequency and the radiation resistance.

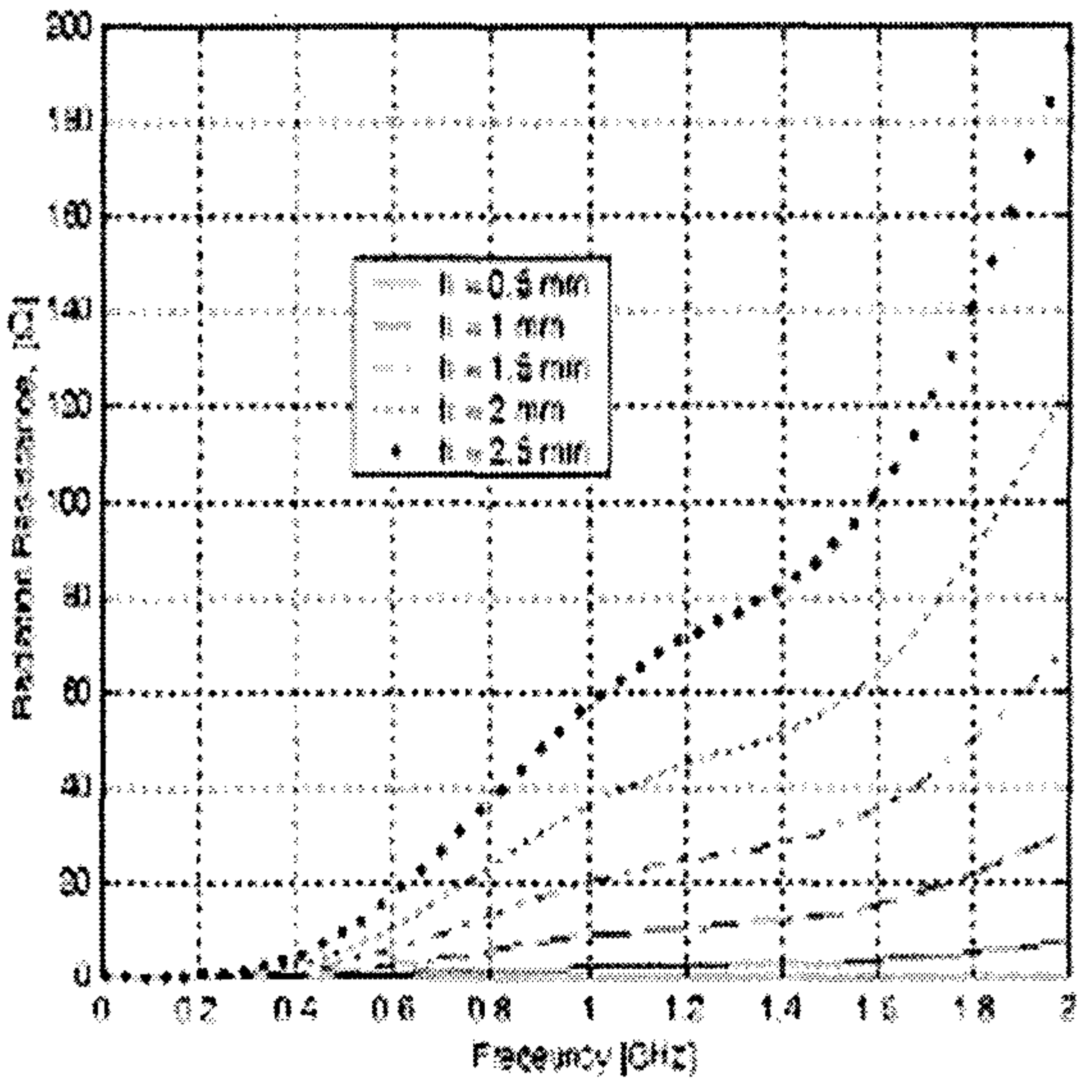

그림 3. 유전체 두께 변화에 따른 복사저항 대 주파수.

Fig. 3. Radiation resistance versus frequency with varying *h*.

As the frequency goes up, the radiation resistance is getting higher regardless of the height. What is noticeable compared to the previous simulation, the higher value of *h* makers the radiation resistance grow. It is explained that as the radiator of the signal line becomes farther away from the substrate, the radiation efficiency gets larger.

VI. 결 론

This work presents the simplified mechanism that the microstrip line generates the radiated emission which is one of the measures on the EMI levels. The electric currents on the metallization of the structure are input to the radiation integrals with the Green's functions being derived to consider the stratification of the microstrip. The simulated results suggest the method of the conceptualization on the RE characteristics of the signal trace in the PCB structure..

참고문헌

[1] D. A. Hill, D. G Camell, K. H. Cavcey, and G H. Koepke, "Radiated emissions and immunity of microstrip transmission lines : theory and reverberation chamber measurements", IEEE Trans. on Electromagnetic Compatibility, vol. 38, no. 2, pp. 165-172, May 1996..

[2] D. M. Pozar, "Rigorous closed-form expressions for the surface wave loss of printed antennas," Electron. Lett., vol. 26, no. 13, pp. 954-956, June 1990...

[3] Luc B. Gravelle and Perry F. Wilson, "EMI/EMC in printed circuit boards - a literature review", IEEE Trans. on Electromagnetic Compatibility, vol. 34, no. 2, pp. 109-116, May 1992.

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