REDUCTION OF ELECTROMAGNETIC FIELD PENETRATION THROUGH NARROW SLOTS IN CONDUCTING SCREEN BY SHORTING WIRE

Ki-Chai Kim   Woo Jin Kang
School of Electrical Engineering and Computer Science
College of Engineering, Yeungnam University, Kyongsan 712-749, Korea
E-mail   kckim@yu.ac.kr

1. Introduction

The electromagnetic field penetration through an aperture in a planar conducting plane of infinite extent are studied by many researchers [1]-[5]. Even though the problem of penetration of electromagnetic fields through a slot aperture in a conducting screen has been the subject of intensive research for many years, still the reduction problem of the electromagnetic field penetration remains a rather complicated subject. The reduction technique of the penetrated electromagnetic field through a narrow slot using the installing a parallel line when a plane wave is excited into the slot on an infinitely large conducting screen is proposed [6].

In this paper, a reduction characteristics are discussed using the installing a shorting wire on the narrow slot. The integral equation for the electric field on the slot aperture is derived and solved by applying Galerkin's method of moments. When the plane wave is excited into the narrow slot, the aperture electric field is controlled by the shorting wire connected on the slot. The results show that the magnitude of the penetrated electromagnetic field is reduced by installing the shorting wire on the slot. To verify the theoretical analysis, the calculated electric field penetrations are compared with expriments.

2. Theoretical Analysis

Figure 1 shows the coordinate system of the infinitely large conducting screen with a narrow slot. The conducting screen is located in the *xy*-plane with the origin at the center of the slot aperture. The slot aperture is parallel to the *x*-axis. The shorting wire is connected along the *y*-axis by a distance *c*.

The problem can be divided into two regions as illustrated in Fig. 1. Region Ⅰ (z<0) is defined as the half-space containing the incident plane wave and bounded by the conducting screen as shown in Fig. 1. The incident electromagnetic fields is penetrated into Region Ⅱ(z>0). The two regions are assumed to be free-space.

The magnetic current sheet with the width *b* can be replaced by the magnetic current cylinder with the equivalent radius *b/4* when *b* is much smaller than the wavelength. If the plane wave is incident into the narrow slot, the integral equation for the unknown aperture electric field $\boldsymbol{E}_a$ in the narrow slot can be written as

$$\hat{z}\times\left\{(\boldsymbol{H}^{i}+\boldsymbol{H}^{r})+\hat{y}I_{y}\delta(x-c)+\frac{1}{j\omega\mu_{0}}\iint_{S_a'}\overline{\boldsymbol{K}}^{I}_{maa}\cdot\left[\hat{z}\times\boldsymbol{E}_{a}\right]dS_a'\right\}=\hat{z}\times\frac{1}{j\omega\mu_{0}}\iint_{S_a'}\overline{\boldsymbol{K}}^{II}_{maa}\cdot\left[-\hat{z}\times\boldsymbol{E}_{a}\right]dS' \quad (1)$$

where, $\delta(\cdot)$ is the Dirac delta-function, $k=\omega\sqrt{\varepsilon_0\mu_0}$, and ω represents the angular frequency. The time dependence exp(jωt) is assumed and omitted throughout this paper. The superscripts I and II denote region I and region II, respectively. $\hat{y}$ and $\hat{z}$ are a unit vector in the *y* and *z* direction. dS_a' denotes an element of area on the slot aperture. Science the shorting wire is an equivalent to the parallel lines of length $l=0.25\lambda$, the current at the connecting position of the shorting wire is given by

$$I_y=\left.\frac{V_L}{-jZ_c\cot(\beta l)}\right|_{l=\frac{\lambda}{4}} \qquad (2)$$

where V_L is the voltage of loading point, β is the propagation constant of the parallel wires, and Z_c is the characteristic impedance of the two parallel lines. The incident and reflected magnetic fields are expressed as follows.

$$\boldsymbol{H}^{i}=-\hat{x}\frac{1}{Z_0}E_{0y}^{i}e^{-jkz} \quad (3a) \qquad \boldsymbol{H}^{r}=-\hat{x}\frac{1}{Z_0}E_{0y}^{i}e^{jkz} \quad (3b)$$

To solve the integral equation for the unknown, the aperture electric field $\boldsymbol{E}_a$ is expanded as

$$\boldsymbol{E}_a(x)=\hat{y}\sum_{n=1}^{N}V_nF_n(x) \qquad (4)$$

where V_n are coefficients to be determined, and F_n are the piecewise sinusoidal expansion functions. Substituting the assumed basis function into the integral equation (1) and employing Galerkin's method of moments, we obtain a set of linear equations for the unknown expansion coefficients.

When a plane wave is excited toward the narrow slot aperture, the penetrated electric field in region II is obtained by

$$E_y=-\frac{1}{2\pi}\sum_{n=1}^{N}V_n\frac{1}{\sin k\Delta x_n}[S_L+S_U] \qquad (9)$$

where

$$S_L=\int_{x_{n-1}}^{x_n}\frac{\partial}{\partial z}\left(\frac{e^{-jkR}}{R}\right)\sin k(x'-x_{n-1})dx' \quad (10a), \qquad S_U=\int_{x_n}^{x_{n+1}}\frac{\partial}{\partial z}\left(\frac{e^{-jkR}}{R}\right)\sin k(x_{n+1}-x')dx'. \quad (10b)$$

3. Numerical Results and Discussion

The slot used in the calculation is a narrow slot compared to the wavelength. The dimensions of the slot are *a=15* cm and *b=1* mm.

Figure 2 shows the frequency characteristics of the penetrated electric field at *z=5* cm when no shorting wire is present on the slot aperture. As shown in Fig. 2, the maximal penetrated electric fields occur at frequencies of *0.94* GHz and *2.9* GHz. These frequencies correspond to the resonance frequencies of the slot aperture with the length of *15* cm.

Figure 3 represents the electric field distribution on the slot when no shorting wire is present on the slot aperture. These results should be compared to the case of shorting wire is connected on the slot aperture. Figure 4 shows the frequency characteristics of the penetrated electric field at $z=5$ cm when the shorting wire is connected at $c=0$ cm and $c=3$ cm. Also, Fig. 4 shows the penetrated electric field when no shorting wire is present on the slot. As can be seen from the Fig. 4, it is found that the penetrated electric field is reduced by installing the shorting wire on the slot. If the shorting wire is connected on the center of the slot aperture ($c=0$ cm), the magnitude of the penetrated electric field is effectively reduced at frequencies of 1 GHz and 3 GHz. In order to verify the validity of the numerical calculations, the experimental result for no shorting wire is provided [5]. It is shown that the calculated electric fields in Region II are in good agreement to experimental results.

Figure 5 shows the electric field distribution on the slot when fixed $c=0$ cm and $f=1.77$ GHz. As shown in Figs. 3 and 5, it is found that the aperture electric field distribution is effectively controlled and reduced by installing the shorting wire on the slot.

4. Conclusion

This paper described a reduction technique of electromagnetic field penetrations through a narrow slot on a infinite conducting screen, and proposed the use of shorting wire on the slot to reduce a level of penetrated electromagnetic fields. As the results, it is found that the magnitude of the penetrated electromagnetic field can be reduced by loading the shorting wire on the slot aperture. Therefore, connecting the shorting wire on the slot is an effective way to control the level of the electromagnetic field penetration through a narrow slot in a planar conducting screen.

References

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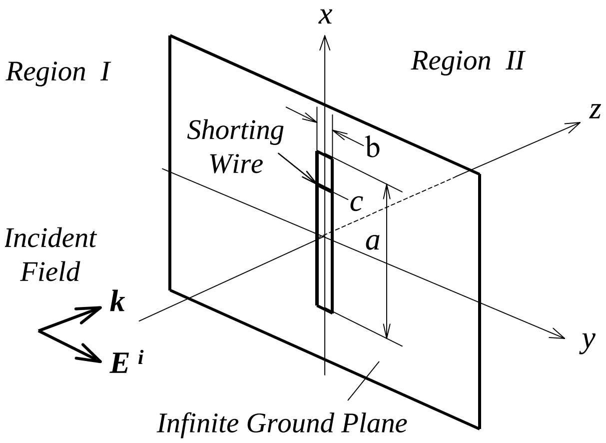

Fig. 1. Aperture in planar conducting screen of infinite extent.

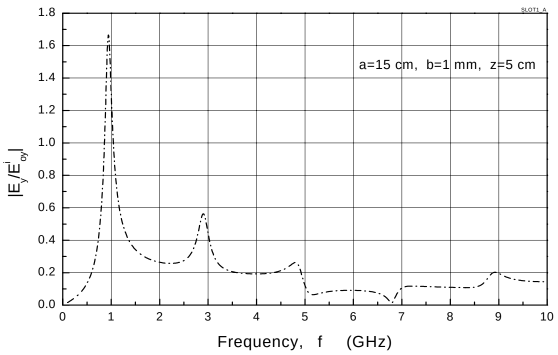

Fig. 2. Frequency characteristics of the penetrated electric fields.

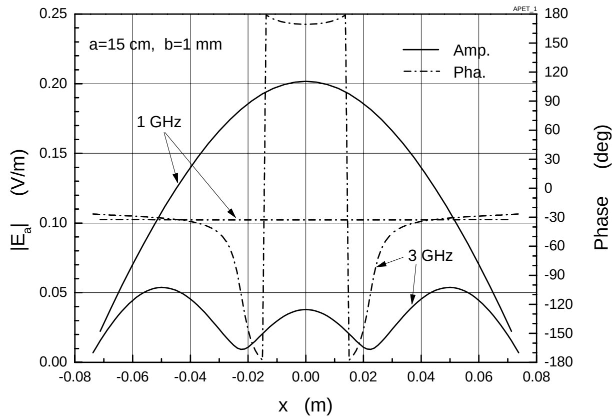

Fig. 3. Aperture electric field distributions.

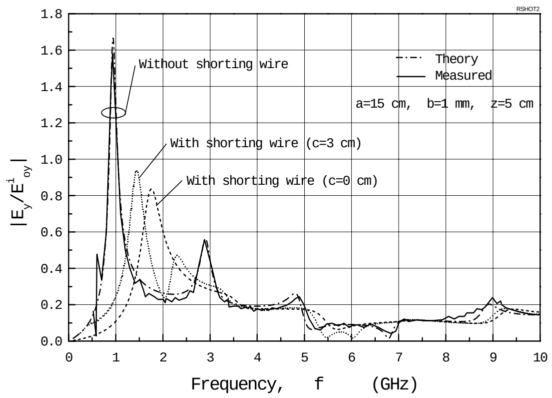

Fig. 4. Frequency characteristics of the penetrated electric fields.

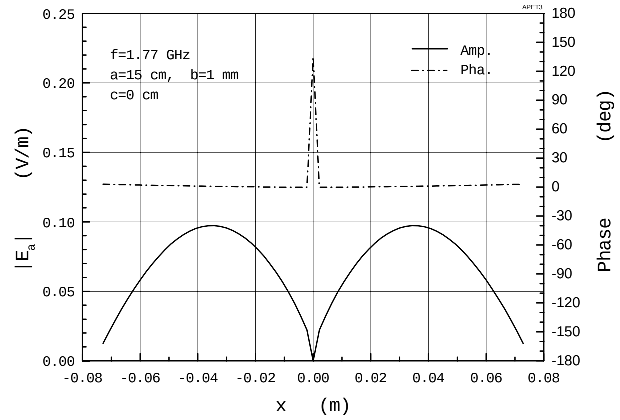

Fig. 5. Aperture electric field distributions.