Reduction of Coupling between a Monopole Antenna and a Strip Line in a Shield Case

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1 Introduction

In a wireless terminal such as a portable telephone, problems are often caused by coupling between an antenna of the terminal and strip lines in circuits. Therefore, the amount of the coupling should be decreased to the level where these problems are not caused. Covering the circuits with the shield case is often used as the technique to reduce the amount of coupling with the antenna. However, it has difficulty in manufacturing a complete shielding structure, where some gaps cannot be avoided between the ground of the circuits and the shield case. Therefore, some coupling is caused through these gaps. It is important to design the shield case and the circuits to estimate the amount of coupling.

Although some reports about above theme have been published [1,2], there has been no paper on quantitatively evaluating the shield effect of the shield case in the viewpoint of the coupling between the antenna and the lines. This paper presents the quantitative evaluation of the coupling between the antenna and the strip line in the shield case. The dependence of the coupling on the length of gaps and the length of the antenna is clarified. The coupling is calculated by using FDTD method together with electromotive force (EMF) method[3]. Using both methods together improves the calculation efficiency because re-calculation using FDTD method is unnecessary for the change of parameters about the strip line. The validity of the calculation is confirmed by comparison between the calculated and measured results.

2 Calculation model and formulation

The calculation model is showed in Figs. 1 and 2. The amount of the coupling between the monopole antenna outside the shield case and the strip line inside it is calculated. In this paper, both ends of strip line are terminated by 50 [Ω] because the object of calculation is assumed to be RF circuit. The shield case covers the strip line with gaps. The length of each gap depends on the division number N. The gaps are divided into N pieces in y direction. The detail definition of N ($N = 0, 1, 2, 4, 8$) is as follows. First of all, the case with no shield case is defined as $N = 0$. Next, the case with shield case and four short circuited lines at each corners is defined as $N = 1$. In the cases of $N = 2, 4, 8$, the shield case is connected to the ground of the strip line at some points to divide the gaps into N pieces in y direction, that is longitudinal direction. In addition to that, the gaps are divided into 2 pieces in x direction for $N = 8$. The monopole antenna with length L is set up on the outside of the shield case with delta gap voltage source.

The amount of coupling S_{21} is given as follows

$$S_{21} \simeq \frac{R_L|Z_{21}|^2}{Re\{Z_{11}\}|Z_{22}+R_L|^2}|T_1| \qquad (1)$$

where Z_{11} and Z_{22} are self-impedance of the monopole antenna and the strip line, respectively. Further, Z_{21} is mutual impedance, R_L is load connected to the strip line and T_1 is reflection loss between monopole antenna and its feed circuit. Z_{11} and T_1 can be calculated by FDTD method. Z_{22} and R_L are 50 [ohm] in this case. Z_{12} can be expressed as follows.

$$Z_{21} = -\frac{1}{I_1 I_2^*}\int \boldsymbol{E}_1 \cdot \boldsymbol{J}_2^* dV \tag{2}$$

where $\boldsymbol{E}_1$ is electric field in the shield case caused by the monopole antenna obtained by FDTD method. $\boldsymbol{J}_2$ is current distribution on the strip line that is assumed to be uniform.

3 Calculation and measurement results

Figures 3(a) and (b) show the change of S_{21} when the directions of the strip line are x and y, respectively. The position of the strip line changes in y direction from the bottom to the top of the shield case. Figure 3 roughly shows that S_{21} increases as the strip line approaches the top or the bottom. Moreover, it can be confirmed that S_{21} decreases with increase in N. S_{21} of the strip line in y direction is larger than that in x direction.

Figure 4 shows the calculated and the measured results of the relationship between N and S_{21}. This figure shows that the ratio of decrease in S_{21} is steep when N changes 0 to 1, and is gradual when N is greater than 1.

Figure 5 shows the calculated and measured results of S_{21} when L is changed. In this figure, S_{21} is defined without $|T_1|$ that varies much as L changes. This figure shows that S_{21} decreases as L approaches about $\lambda/2$. The calculated result shows that S_{21} with $L \simeq \lambda/2$ is 8[dB] smaller than that with $L \simeq \lambda/4$. The reason is that the monopole antenna with $L \simeq \lambda/2$ causes little current on the box on which the antenna is set up [4]. The electric field inside the shield case, that is the coupling S_{21}, is caused when the gaps exist so as to interrupt the current that flows on the outside of the shield case. In other words, the amount of coupling becomes small if the absolute value of the current outside the shield case becomes small. The measured results are included in the figures. The correspondence shows the validity of calculation.

4 Conclusion

The amount of the coupling between the antenna and the strip line in the shield case has been calculated by using FDTD method together with EMF method. The relationship between the division number N, the length of the antenna L and the coupling S_{21} was clarified. The above results showed that the amount of coupling S_{21} was able to be reduced by increasing N and setting $L \simeq \lambda/2$. In addition, the validity of the calculation has been confirmed by comparison between the calculated and measured results.

References

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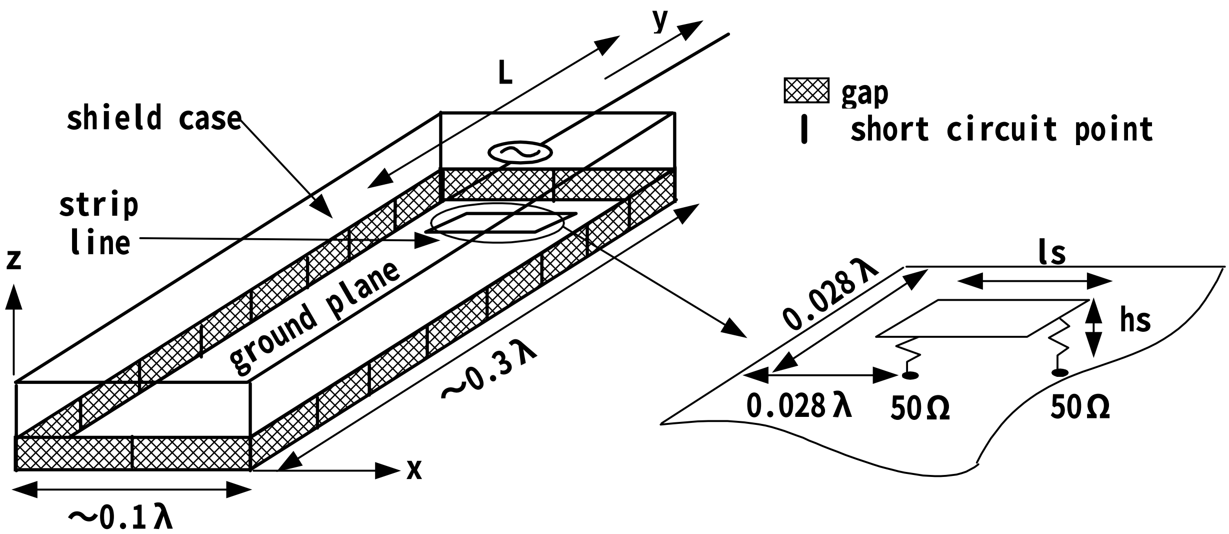


Fig.1 Calculation model (with N=8)

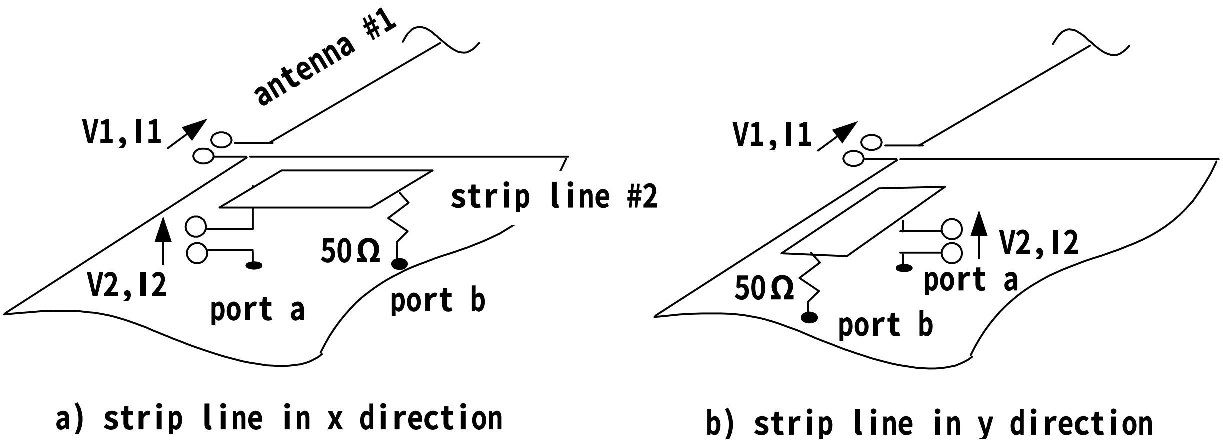
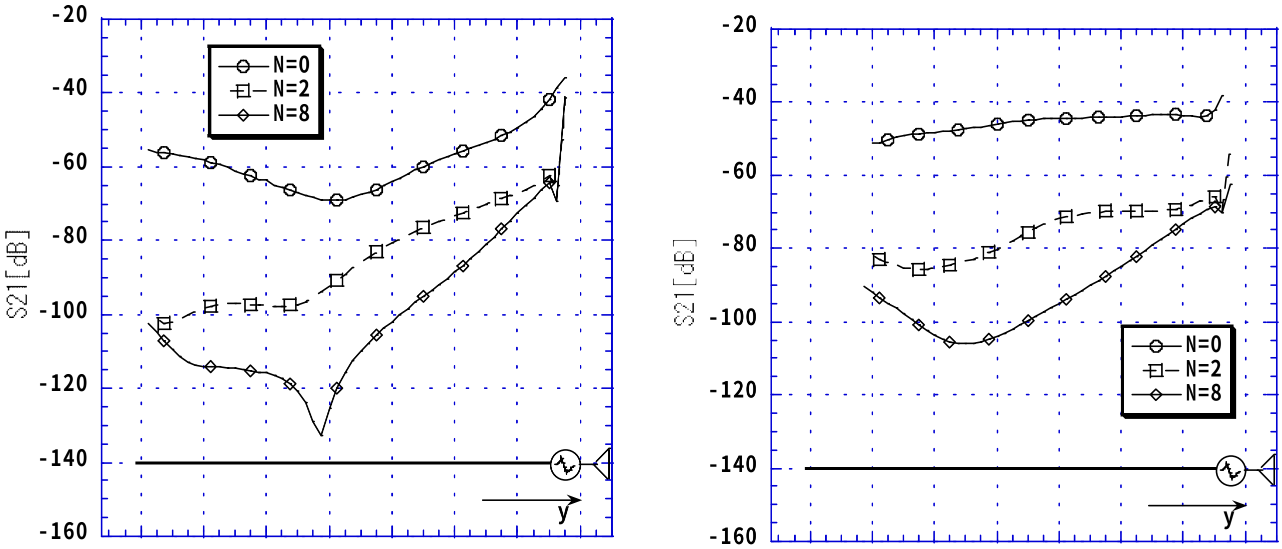


Fig.2 Modeling of the antenna and the strip line



a) strip line in x direction

b) strip line in y direction

Fig.3 Change of S21 as a function of position (cal.)

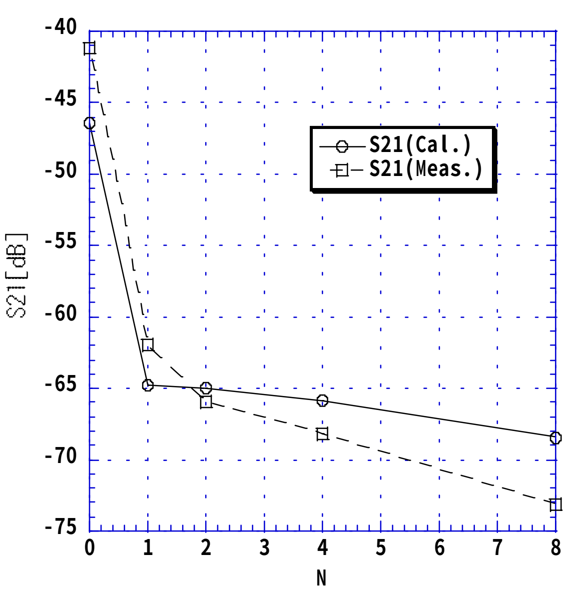


Fig.4 Change of S21 as a function of N (cal. and meas.)

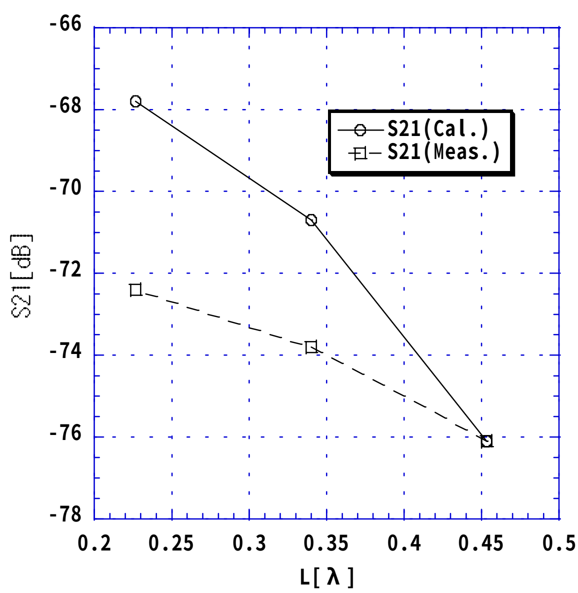


Fig.5 Change of S21 as a function of L (cal. and meas.)