A Novel Method for Suppression of the Undesired Radiation on the Corrugated DGS

Girae Kim, *Member, KIMICS*

***Abstract*—**The defected ground structure (DGS) for microstrip structure can be used to protect analog/RF signal from SSN interference of digital circuits on PCB with common ground. However, the basic DGS gives rise to undesired emissions that may interfere with nearby circuitry due to the ground discontinuity. In this paper, we have proposed the modified structure, Corrugated DGS and the method to reduce the radiation by adding the lumped resistor on the proposed Corrugated DGS.

***Index Terms*—**EMI, EMC, DGS, Propagation, Radiation, Crosstalk

I. INTRODUCTION

Recently, the digital and analog/RF circuits have been packaged on single Printed Circuit Board (PCB) with common ground for the several reasons in many digital communications. However, since the high speed digital circuits using CMOS tend to produce significant simultaneous switching noise (SSN) levels and generally digital signal contains several spurious harmonic frequencies, they may interfere with main signal of analog or RF circuits when the common ground is used [1]. The high frequency harmonic and non-harmonic components are seldom specified on the assumption that they can be eliminated using conventional EMC techniques such as filtering, grounding and isolating. The high frequency radiation and interference problems due to ground resonance are often discovered during the system EMC and crosstalk measurement. The ground resonance issues must be addressed at early design stages. Otherwise, expensive and time-consuming design iterations are necessary to solve this problem. The method for this problem to split their ground by slot on ground plane was proposed [2]. It makes isolation for AC between digital and analog/RF circuits while leaving only a small DC connection to maintain a common reference potential.

In this paper, we propose the Defected Ground Structure (DGS) [3] as a solution to protect the main signals of analog or RF circuits from SSN interference of digital circuits due to common ground. Even if the basic DGS can be a good solution for SSN problems, it gives rise to undesired emissions that may interfere with nearby circuitry. Therefore, we propose a modified structure, Corrugated DGS, to reduce radiation of the undesired Electromagnetic field in high frequency range while maintaining good isolation between the digital and analog/RF circuitry. It can reduce the radiation due to third harmonic frequency more than the fundamental frequency. Also, we have suppressed the radiation due to the fundamental frequency by adding the lumped resistor on the proposed Corrugated DGS. The results of this paper can be applied to the design of Printed Circuit Board using the high speed mixed signals to improve the EMI characteristic.

II. MODELLING AND CHARACTERISTICS

Fig. 1 shows the three dimensional schematic of the basic DGS for microstrip structure. The equivalent modelling for DGS is represented in Fig. 2 [3-5], and transmission characteristic, S21, of the basic DGS is like as Fig. 3.

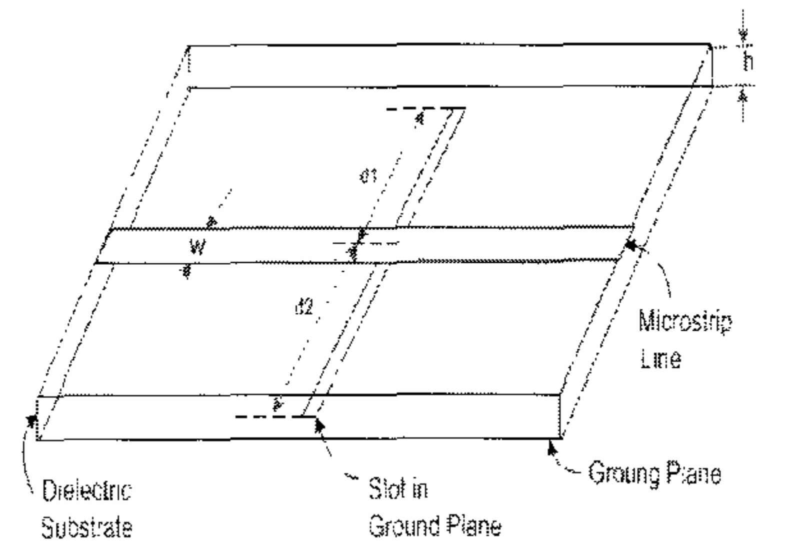


Fig. 1. 3-D view of basic DGS

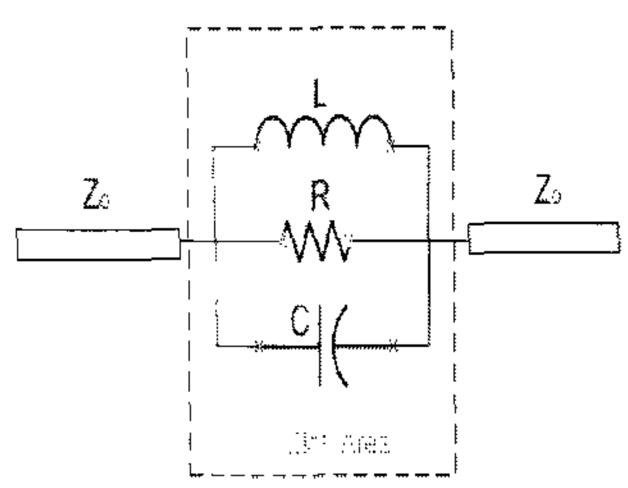


Fig. 2. Equivalent Model

Manuscript received Feb. 9, 2008.

Girae Kim is with the Department of Electronics Engineering, Silla University, Busan, 617-736, Korea, Email: grkim@silla.ac.kr)

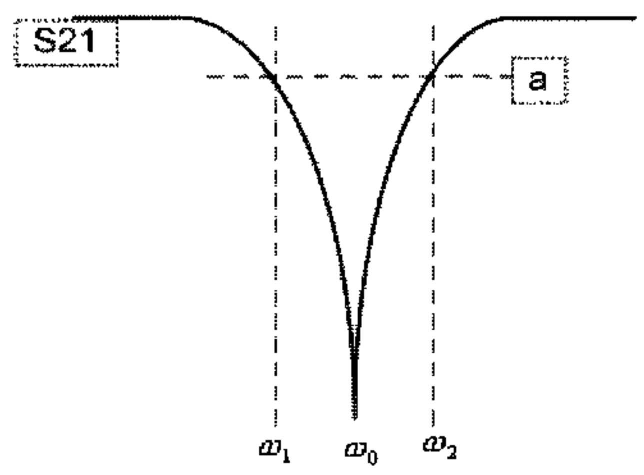


Fig 3. Characteristics, S_{21}

From the parallel RLC network in Fig. 2, S_{21} is as following [6].

$$|S_{21}|^2 = \frac{4Z_o^2[R^2(1-w^2LC)^2 + w^2L^2]}{4Z_o^2R^2(1-w^2LC)^2 + w^2L^2(R+2Z_o)^2} \quad (1)$$

The resistance, R can be obtained from S_{21} at the resonance frequency as

$$R = 2Z_o(\frac{1}{|S_{21}|} - 1)\Big|_{w=w_o} \quad (2)$$

The capacitance, C can also be by choosing the bandwidth ($w_2 - w_1$) with $S_{21} = a$ at $w = w_1 = w_2$,

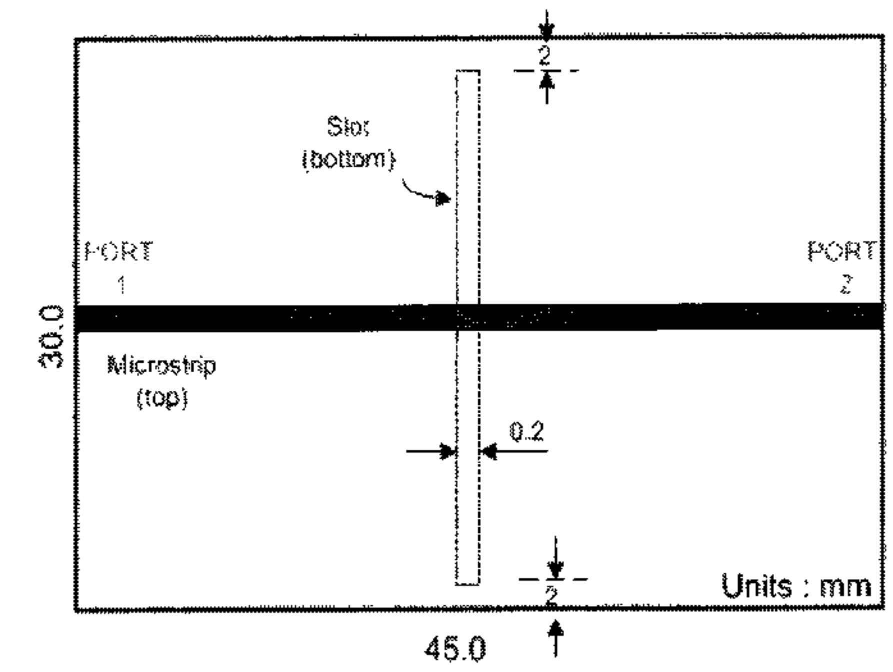
$$C = \frac{\sqrt{a^2(R+2Z_o)^2 - 4Z_o^2}}{2Z_oR\sqrt{1-a^2}(w_2 - w_1)} \quad (3)$$

Then the inductance, L will be calculated by substituting C into the following equation,

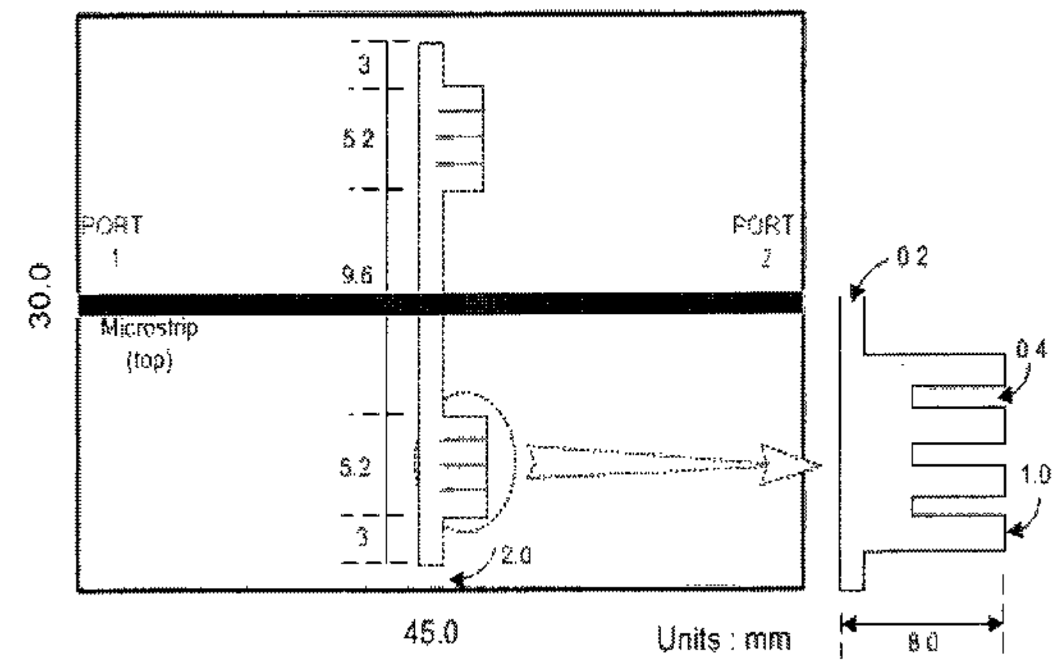
$$L = (w_o^2C)^{-1} \quad (4)$$

III. EXPERIMENTAL RESULTS

All structures in this paper are fabricated on a 45mm by 30mm substrate with ε_r of 2.33, a thickness of 31mil and the microstrip line on the slot has 50ohm characteristic impedance at 5GHz. The simulated results are obtained by using the three dimensional EM simulator, HFSS of Ansoft, and the measured results are obtained from an Agilent 8510C network analyzer. Fig. 4(a) shows the structure of the basic DGS and Fig. 4(b) shows one for the Corrugated DGS that are simulated and measured in this study. Fig. 5 shows the comparison of transmission characteristic between slotted ground structure and Corrugated DGS.

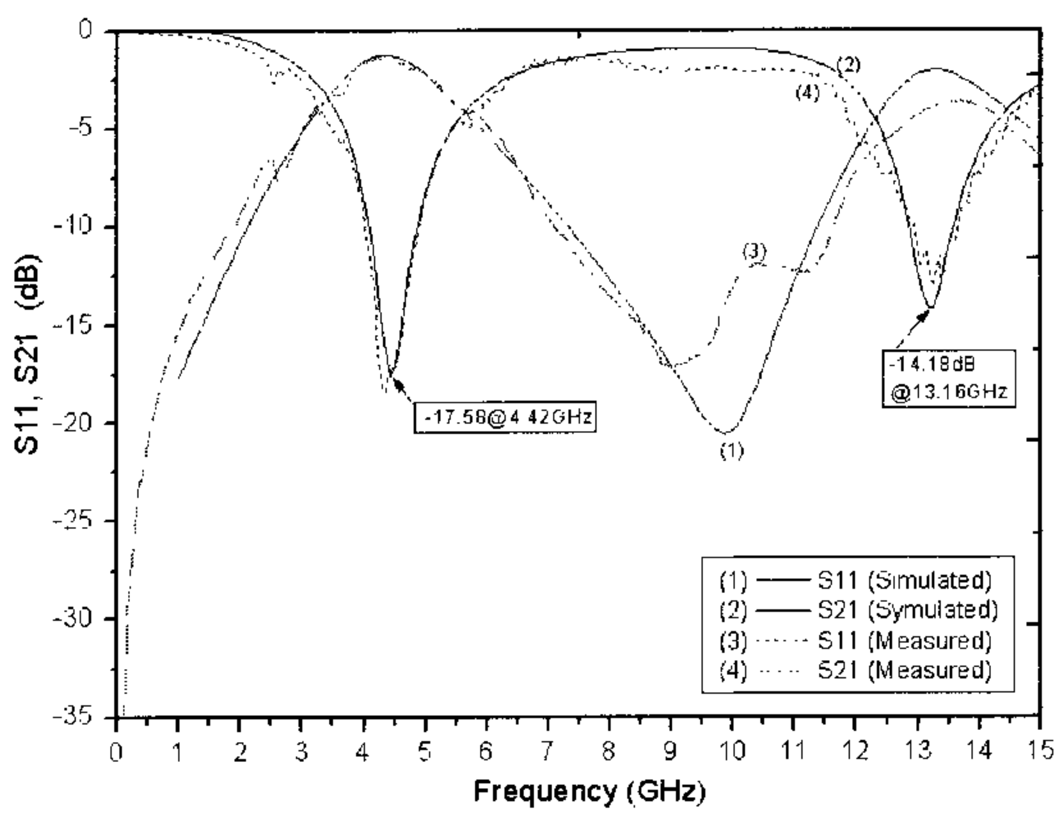


(a) Slotted ground structure (basic DGS)

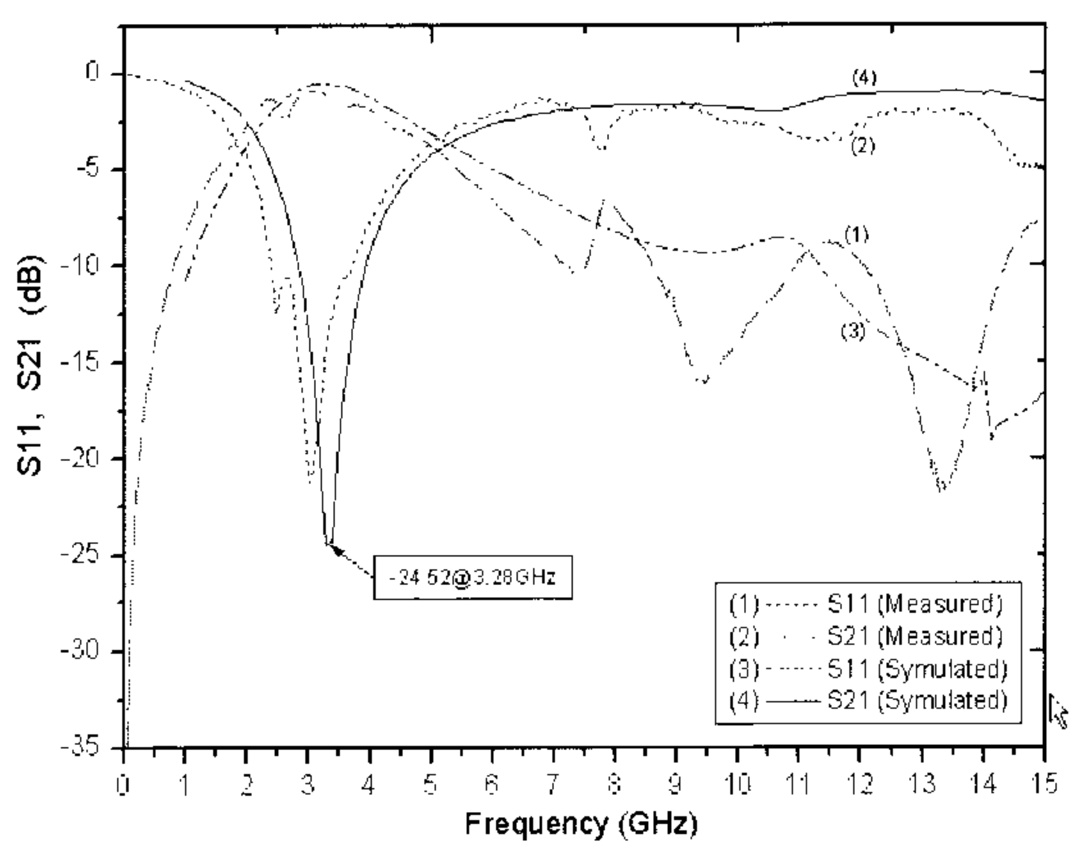


(b) Corrugated DGS

Fig. 4. The structures used in this paper



(a) Slotted ground structure (basic DGS)



(b) Corrugated DGS

Fig. 5. The Characteristics of structures in Fig. 4

When signals are transmitted from port1 to port 2 on microstrip line in the Slotted ground structure, the fundamental frequency at half effective wavelength equals to the slot length and its odd harmonics pass through the slot and radiate. The transmission characteristic, S_{21} is represented in Fig. 5(a). The structure isolates the left side and the right side of slot. In Fig. 5(a), isolation for the fundamental frequency is 17.58dB at 4.42GHz and isolation for the third harmonic is 14.18dB at 13.16GHz. The isolation characteristic for the fundamental frequency can be used to increase isolation between digital circuit and analog/RF circuit, but odd mode harmonics give rise to radiation of unwanted electromagnetic field that may be EMI source. We modified the structure of slot to eliminate the third harmonic of frequency as Fig. 4(b), and we obtained an isolation of 24.52dB at the fundamental frequency 3.28GHz and could eliminate the harmonics as shown in Fig. 5(b). In this structure, the frequency of isolation was shifted lower because the effective inductance was increased. The structure in Fig. 4(a), Corrugated DGS has good isolation at the fundamental frequency. However, it also radiates EMI through the slot. It is necessary to control the isolation characteristic depending on the levels of digital signal. If the isolation is too much, the radiation gets higher at the lower frequency range. We can control the isolation characteristic using the lumped resistor on the slot as shown in Fig. 6. The near field strength for the slotted line structure, Corrugated DGS without a resistor and with a 100ohm resistor are compared by simulation using EM simulator in Fig. 7.

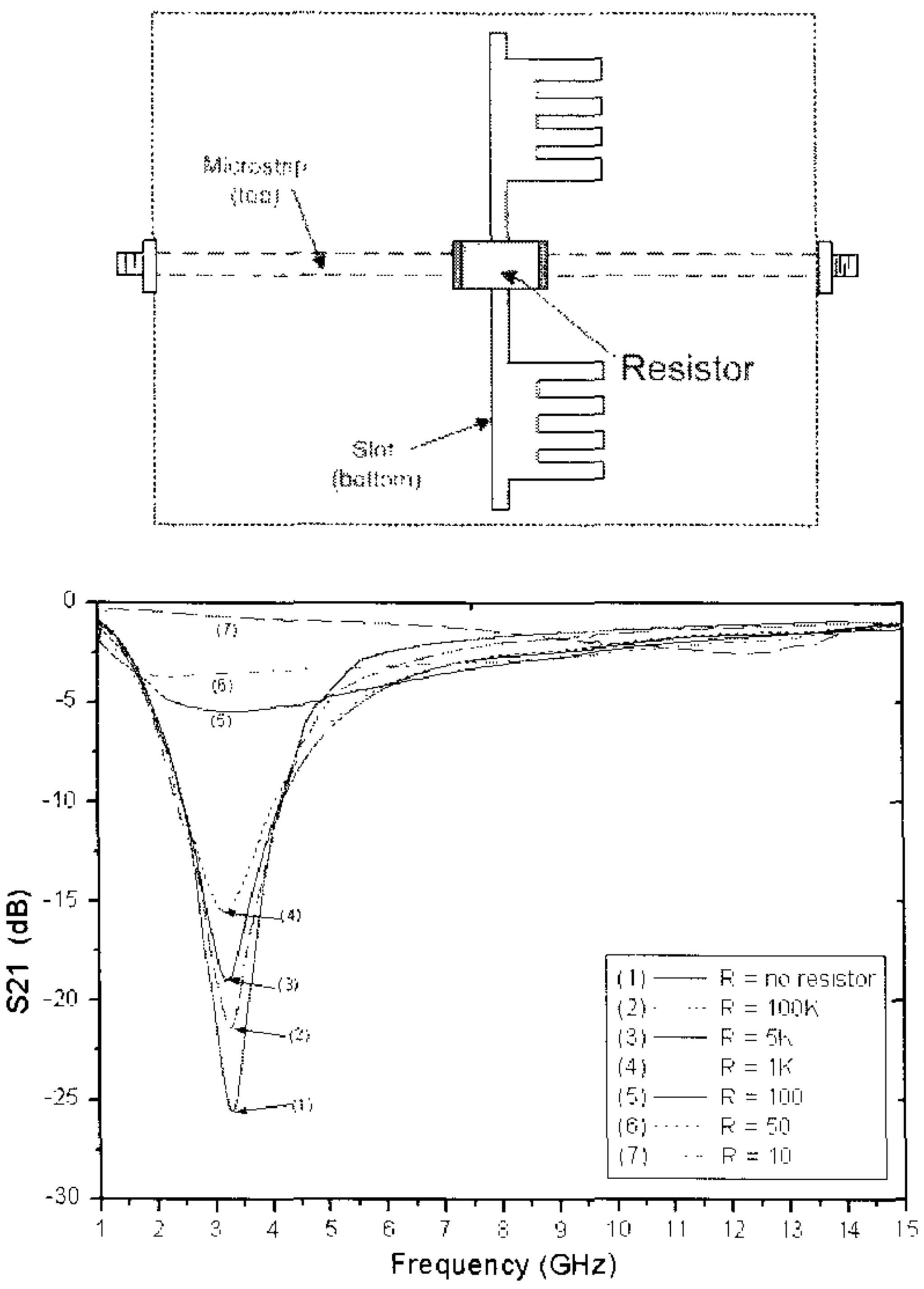


Fig. 6 View and Characteristic for Corrugated DGS with Resistor

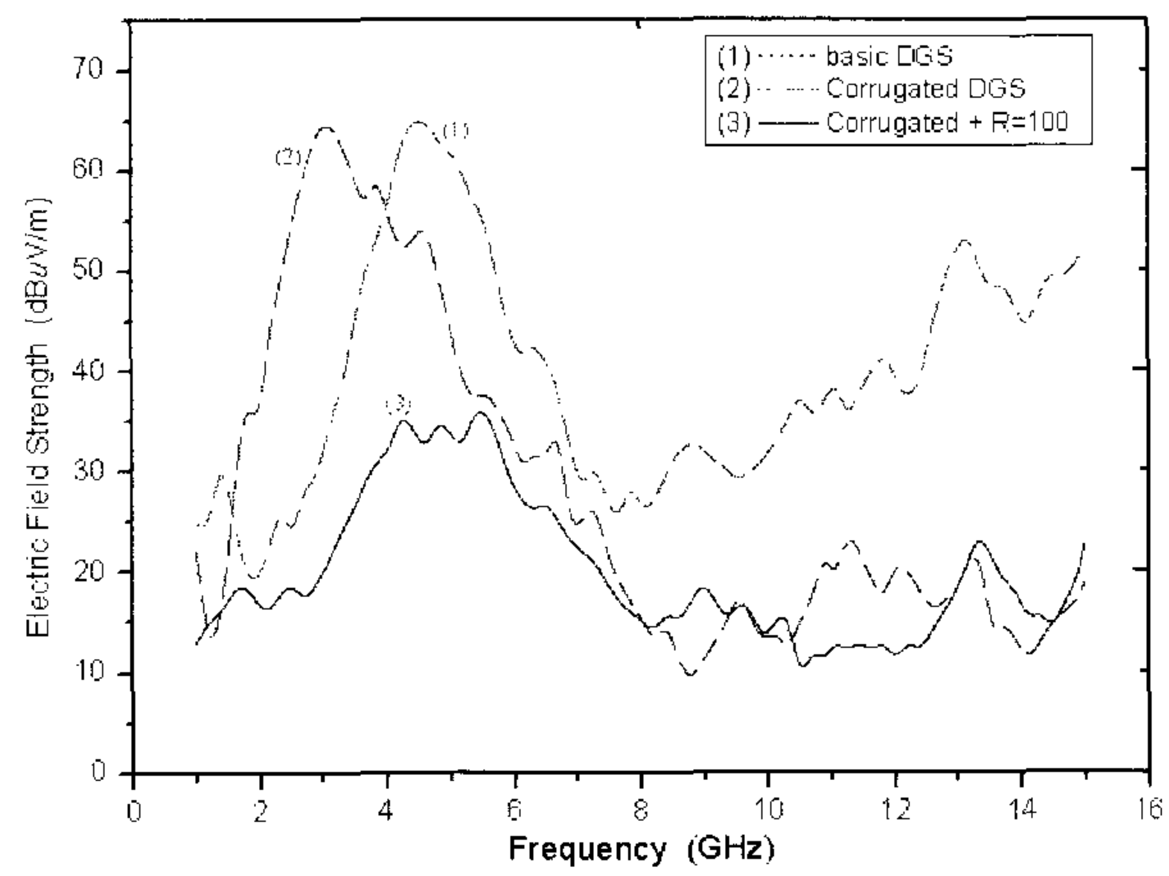


Fig. 7. Calculated Electric Field Strength (dBuV/m)

IV. CONCLUSIONS

The Slotted ground structure of Fig. 4(a) can be used to protect analog or RF signals from SSN interference of digital circuit, but it gives rise to undesired radiation. The electric field strength was about a 65 *dBuV/m* at 4.4GHz due to the fundamental frequency and about a 55 *dBuV/m* at frequency of 13.2GHz due to the third harmonic frequency as shown in Fig. 7. The proposed Corrugated DGS in Fig. 4(b) have reduced the radiation at the high frequency range compared with result of the basic DGS, but the electric field strength for low frequency range does not changed above a 65 *dBuV/m*. We have suppressed radiation above 30 *dBuV/m* for low frequency range using the 100ohm lumped resistor on the slot of the Corrugated DGS. The results of this paper can be applied to the design of Printed Circuit Board that contain digital and analog /RF circuit in order to suppress the EMI and to have good isolation between circuits. Also, we can apply this approach to design of the variable attenuators for specific frequencies by using the result of Fig. 6.

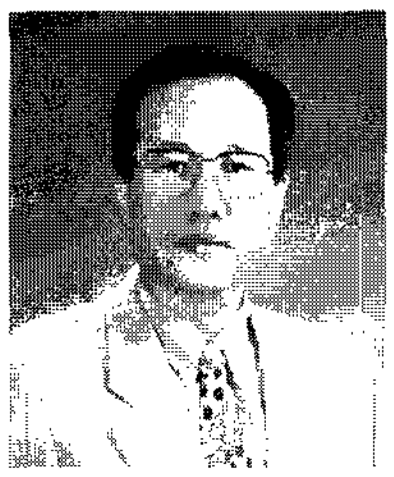
REFERENCES

[1] M. I. Montrose, Printed Circuit Board Design Techniques for EMC Compliance, 2nd edition, IEEE Press, 2000, New York.

[2] Orhanovic, N. Raghuram, R., and Matsui, N., "Signal propagation and radiation of single and differential microstrip traces over split image planes," Electromagnetic Compatibility Symposium, Washington DC, Aug. 2000, pp.339-343.

[3] D. Ahn, J.S. Park, C.S. Kim, J. Kim, Y. Qian, and T. Itoh, "A design of the Low Pass Filter Using the

Novel Microstrip Defected Ground Structure," IEEE Trans. Microwave Theory Tech., vol. 49, No. 1, pp. 86-93, Jan. 2001.
[4] C.S. Kim, J.S. Park, D. Ahn and J.B. Lim, "A novel 1OD periodic defected ground structure for planar circuits," IEEE Microwave Guided Wave Lett., vol. 10,pp.131-133, Apr. 2000
[5] J.S. Lim, Y. T. Lee, J. H. Han, J.S. Park, D. Ahn, and S. Nam, "A technique for reducing the size of amplifiers using defected ground structure," Proc. 2002 IEEE MTT-S Dig., vol. 2, pp. 1153-1156, June 2002.
[6] C. C. Chang, C. Caloz, and T. Itoh, "Analysis of a Compact Slot resonator in the Ground Plane for Microstrip Structure," Proc. APMC 2001, pp.1100-1103.



Girae Kim
received the B.S., M.S. in Electronic Engineering form the Sogang University, Seoul, Korea, in 1986, 1988, respectively. And received Ph. D. from Kyungnam University, Korea in 1999. From 1988 to 1993 he was a researcher in Communication Research Center of Samsung Electronics Co. Ltd. He developed RF and microwave systems such as VSAT and Cellular Base Station. From 1993 to 1999 he worked with Masan College as an assistant professor. He studied the crosstalk and interconnection problem on the multilayer PCB by using FDTD method. Since 1999, he has been on the faculty of Electronics Engineering Department at the Silla University, Busan, Korea. He was joined microwave Lab. of University of California, Los Angeles (UCLA) as Post-Doc. course from July 2002 to August 2003. His areas of interest are microwave integrated circuits, packaging technology, analysis of crosstalk and interconnection problem on the multilayer PCB.