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## 저항을 이용한 주름진 DGS에서 불요 전자파 방사의 억압 방법

## (A Suppression of the Undesired Radiation on the Corrugated DGS by using Resistor)

金紀來 \*

(GIRAE KIM)

## 요약

마이크로 스트립 선로 구조에서 접지면에 슬롯을 갖는 DGS는 디지털 회로의 스위칭 모드 잡음에 의한 영향으로부터 아날로그/RF 회로를 보호할 수 있다. 그러나 기본적인 구조는 접지면의 불연속에 의해 불요 전자파를 기준값 이상으로 방사하여 전자파 장애를 일으킬 수 있다. 본 논문에서 제안된 구조인 주름진 DGS는 전자파 방사를 상대적으로 억압할 수 있으며 또한 슬롯에 저항을 두고 이를 이용하여 전자파 방사의 억압을 제어할 수 있다.

## 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.

**Keywords** : DGS, SSN, EMI/EMC

## 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<sup>[1]</sup>. 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.

\* 正會員, 新羅大學校, 컴퓨터工學科

(University of Silla, Busan, Dept. of Computer and Information Engineering)

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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<sup>[2]</sup>. 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)<sup>[3]</sup> 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 Characteristic

Fig. 1 shows the three dimensional schematic of the basic DGS for microstrip structure. The equivalent modelling for DGS is represented in Fig. 2, and transmission characteristic, S<sub>21</sub>, of the basic DGS is like as Fig. 3.

From the parallel RLC network in Fig. 2, S<sub>21</sub> is as following<sup>[4]</sup>.

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

The resistance, R can be obtained from S<sub>21</sub> at the

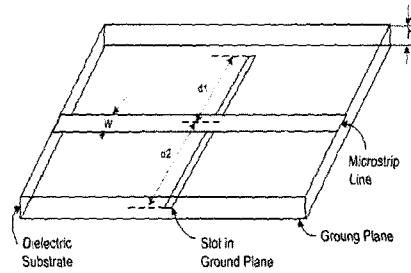


그림 1. 기본 DGS의 구조도  
Fig. 1. 3-D view of basic DGS.

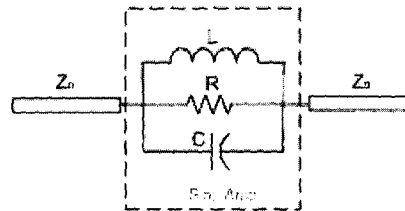


그림 2. DGS의 집중소자 등가 모델  
Fig. 2. Lumped Equivalent Model.

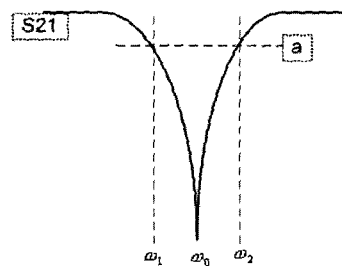


그림 3. DGS의 전송 특성  
Fig. 3. Characteristics of Transmission.

resonance frequency as

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

The capacitance, C can also be by choosing the bandwidth (ω<sub>2</sub> - ω<sub>1</sub>) with S<sub>21</sub> = a at ω = ω<sub>1</sub> = ω<sub>2</sub>,

$$C = \frac{\sqrt{a^2 (R + 2 Z_o)^2 - 4 Z_o^2}}{2 Z_o R \sqrt{1 - a^2} (\omega_2 - \omega_1)} \quad (3)$$

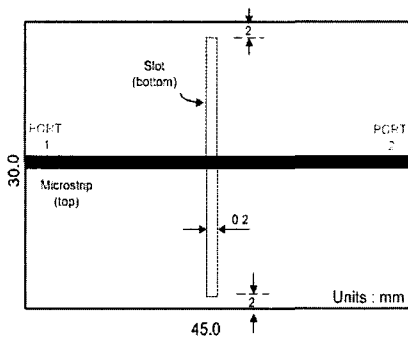
Then the inductance, L will be calculated by substituting C into the following equation,

$$L = \frac{1}{w_o^2 C} \tag{4}$$

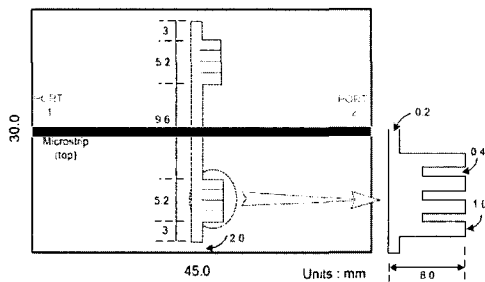
### III. Measured and Simulated Results

All structures in this paper are fabricated on a 45mm by 30mm substrate with  $\epsilon_r$  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.

When signals are transmitted from port1 to port 2

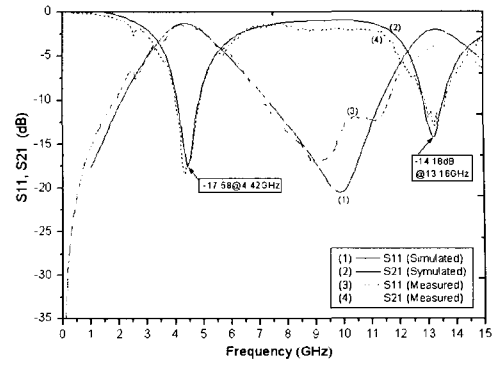


(a) Slotted ground structure(basic DGS)

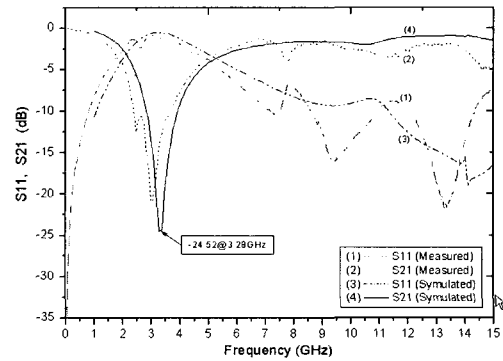


(b) Corrugated DGS

그림 4. 기본 DGS(a)와 주름진 DGS(b)  
Fig. 4. The structures used in this paper.



(a) Slotted ground structure(basic DGS)



(b) Corrugated DGS

그림 5. <그림 4>의 DGS에 대한 전송 특성  
Fig. 5. The Characteristics of structures in Fig. 4.

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.

#### IV. Conclusion

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.

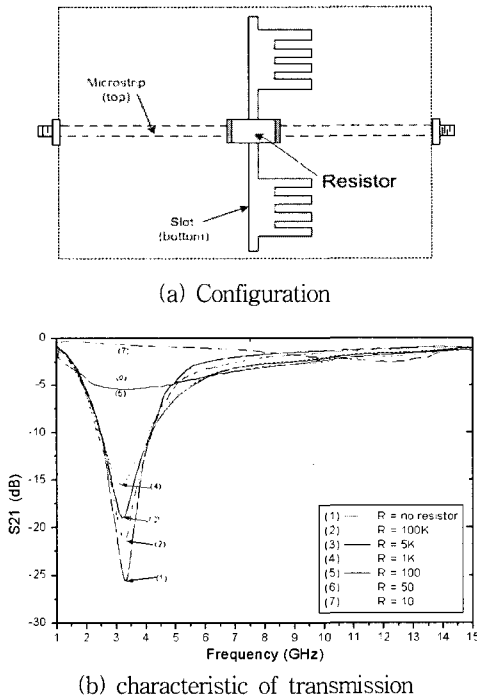


그림 6. 저항을 갖는 주름진 DGS  
 Fig. 6. Corrugated DGS with Resistor.

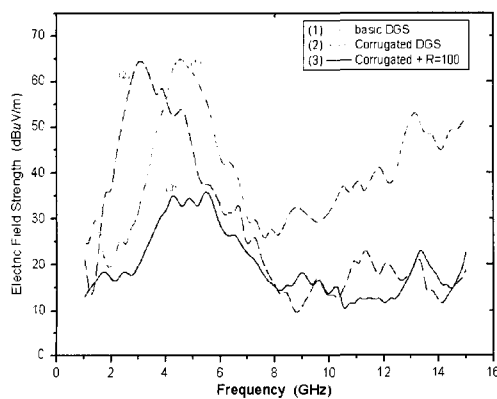


그림 7. 전계강도의 비교  
 Fig. 7. Calculated Electric Field Strength(dBuV/m).

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## 저 자 소 개



金 紀 來(正會員)

1986년 2월 : 서강대학교 전자공학과(학사). 1988년 2월 : 서강대학교 대학원 전자공학과(공학석사). 1998년 2월 : 경남대학교 대학원 전자공학과(공학박사). 1988년~1993년 : 삼성전자(주) 통신연구소 선임연구원. 1993년 3월~1999년 2월 : 마산대학 정보통신과 조교수. 1999년 3월~현재 : 부산 신라대학교 컴퓨터정보공학부 조교수. 2002년 7월~2003년 7월 : 미국 UCLA 마이크로파 연구실 방문연구교수. <주관심분야 : 마이크로파 회로, MMIC 패키징 해석, 전자파해석, 다층기판 Cross-talk 해석, Interconnection 해석, 소출력 무선통신>