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정확한 Full-Wave 해석방법을 이용한 차동모드 급전을 가지는 PCB Power-Distribution Network에서의 슬릿에 의한 영향 연구

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On the Effects of the Slits in the PCB Power-Distribution Network with the Differential-Mode Signaling using a Rigorous Full-Wave Method

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Abstract - This study investigates the performances of the signaling techniques including differential signals for the power-distribution network(PDN)s with and without the slit, using a rigorous evaluation method, validated by the FDTD simulation up to 5 GHz.

1. Introduction

The power- and ground planes in PCBs are called the power-distribution network(PDN) and are known for causing cavity-mode resonance and possibly noise in the related system. T. Okoshi uses a modal sum expressions to characterize the structure[1]. Expanding the circuit concept, M. Hampe et al examines the effect of loads like DeCaps on the power-bus resonance[2]. Lately, S. Kahng presented the performance of differential signaling in the PDN and the advantage in reducing the number of resonance frequencies and impedance level[3]. However, a question can be raised if the differential signaling will work well in the power-bus with a geometrical change like having slits shown in Z. Wang's work[4]. This study investigates the performances of the differential signal feeding between the power-bus with and without the slit, using a rigorous evaluation method, which is validated by the FDTD application of [3].

2. Theory

The slit power-bus structure can be modeled as a cavity having the PEC power- and ground planes and the PMC walls.

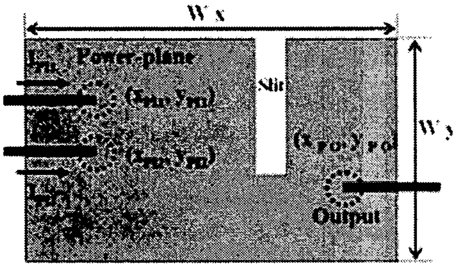


Fig. 1. Top view of a slit PDN

Fig. 1 is the top-view of the PDN structure where 2 feeds provide currents I_{PI1} and I_{PI2}, passing the structure through the holes at (X_{PI1}, Y_{PI1}) and (X_{PI2}, Y_{PI2}). The output port is placed at (X_{PO}, Y_{PO}). Excluding the slit, the size of the power-bus is W_x*W_y*W_z. The sandwiched substrate is featured by W_z, 4.2 and 0.02 given as its thickness, relative dielectric constant and loss tangent[1-4]. Regarding the feeds, when I_{PI1} and I_{PI2} are in-phase and the same in magnitude, it is the common-mode signaling. Out-of -phase, they are the differential-mode signals. Ahead of working on the differential signaling with 2 feeds, the 1-feed case needs to be addressed as the basics. For this, a rigorous evaluation method is adopted, shown as follows[1-3].

$$Z(f, X_f, Y_f) = \sum_{m=0}^{\infty}\sum_{n=0}^{\infty} \frac{\gamma_{nm} \cdot c_{mnii} \cdot c_{mnff} \cdot W_z / (W_x W_y)}{\varepsilon\omega / Q + j(\varepsilon\omega - \frac{k_{xm}^2 + k_{yn}^2}{\omega\mu})} \quad (1)$$

where

$c_{mnii}=cos(k_{xm}X_i)\cos(k_{yn}Y_i)sinc(k_{xm}P_{xi}/2)sinc(k_{yn}P_{yi}/2)$

$k_{xm}=m/\ W_x,\ k_{yn}=n/W_y,\ =2\ f$

$$Q = [\tan\delta + \sqrt{2/\omega\mu_0\kappa W_z^2}\,]^{-1}$$

This 1-feed case can be expanded to the differential and common-mode signaling by the superposition principle[4]. Furthermore, the slit structure can be solved by the segmentation scheme as done in [3] and details are not repeated here.

3. Results for validation

Firstly, the impedance is evaluated on the power-bus structurewith the differential signals so as to verify whether Eqn. (1) is numerically well-implemented. For the same environment as [3], Eqn. (1) and the FDTD approaches are used and compared. Stating again the structure, the geometry and frequency range are the same as [3], where 54mm33.5mm1.1mm, (27mm, 17.2mm), (27mm, 16.3mm), (41.8mm, 27.4mm) are given to $W_xW_yW_z$, (X_{PI1}, Y_{PI1}), (X_{PI2}, Y_{PI2}), and (X_{PO}, Y_{PO}).

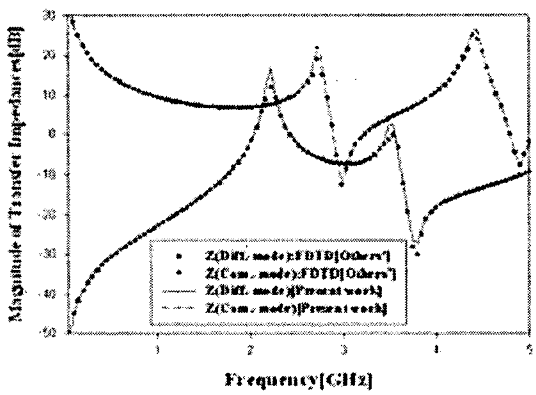


Fig. 2. Differential & Common-mode signaling for the PDN with out a discontinuity

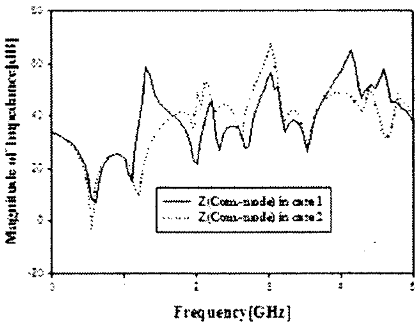
The results are in good agreement between the present method and FDTD[3]. It is noticed that the differential signals lower the impedance level and outperforms the common-mode signals. As of now, a slit is considered starting from Fig. 3.

(a) Port configuration case 1 with Differential & Common-mode signaling for the PDN

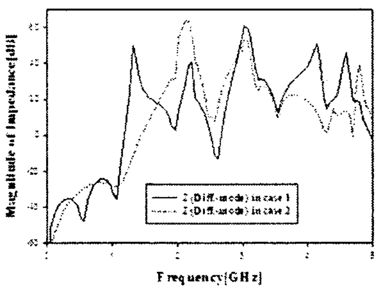
(b) Port configuration case 3 with Differential & Common-mode signaling for the PDN

Fig. 3. Three port configuration cases of Differential & Common-mode signaling for the PDN with a discontinuity

Case 1 has (27mm, 17.2mm)~(27mm, 16.3mm), and case 2 has (18mm, 17.2mm)~(18mm, 16.3mm) for feeding with (41.8mm, 27.4mm) as (X_{PO}, Y_{PO}) in common. Xs=36mm, Ls=10mm and Ws= 2mm are given to the slit. Also test case 3 is with (14mm, 7.9mm), (14mm, 6.9mm) and (41.8mm, 7.5mm) as (X_{PI1}, Y_{PI1}), (X_{PI2}, Y_{PI2}), and (X_{PO}, Y_{PO}) in order.

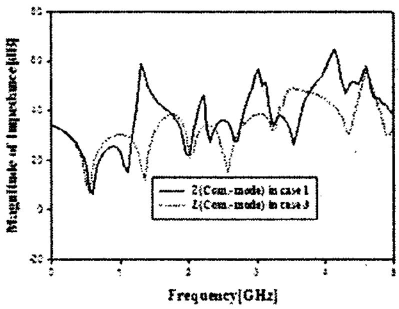


(a) Resultant Impedance profile of cases 1 & 2 with Common-mode signaling for the PDN



(b) Resultant Impedance profile of cases 1 & 2 with Differential-mode signaling for the PDN

(c) Resultant Impedance profile of cases 1 & 3 with Common-mode signaling for the PDN



(d) Resultant Impedance profile of cases 2 & 3 with Differential-mode signaling for the PDN

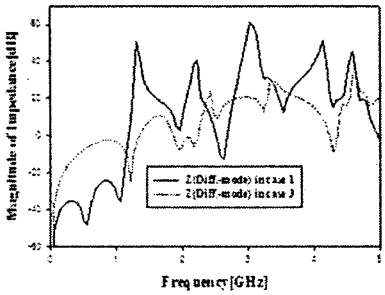


Fig. 4. Three cases of impedance profiles on Differential & Common-mode signaling for the PDN with a slit as a discontinuity

Compared to Fig. 2(without the slit), cases land 2 have an increased level of impedance with more resonance points despite the differential feeding, because the slit makes the current path longer and imbalance between 2 feeding paths. Lastly, differential feeding can be much improved by selecting case 3-scheme. Seeing Fig. 4(d), the performance is remarkably improved with (14mm, 7.9mm), (14mm, 6.9mm) and (41.8mm, 7.5mm) as (X_{PI1}, Y_{PI1}), (X_{PI2}, Y_{PI2}), and (X_{PO}, Y_{PO}), because the current path is placed so that fed signals be not disturbed by the slit.

4. Conclusion

The discontinuity of a slit is considered and its influence is rigorously analyzed on the differential signaling in the power-distribution network. And an effective way has been suggested to improve the performance.

[참 고 문 헌]

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