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EBG 구조를 이용한 전력공급/접지판의 RF 잡음저감 특성

Characteristics of Resonance Suppression of PBS using EBG

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Abstract : 전기전자 장치 내부의 PCB에 존재하는 전력공급/접지판은 RF 공진잡음을 발생시켜 디지틀 신호 품질 저하 및 불요방사의 문제를 일으킨다. 본 논문에서는, 전력공급/접지판의 RF 잡음을 제거하기 위한 방법으로 Mushroom EBG 구조를 사용할 때 이 구조가 가지는 전자기 및 전기적 특성을 모드해석법과 회로이론의 하이브리드화를 통해 예측을 수행한다. 예측을 통해 잡음을 억제할 수 있는 유용한 정보를 얻는다.

Keywords: PBS, EBG

I. Introduction

Communication systems today are typically equipped with stacked PCBs with ascending operating frequency and complexity in their architecture. The more densely each of the layers is populated, the more care needs taking of to avoid unwanted EMIs. In particular, when it comes to the digital functions together with the analog ones for one circuit, a couple of layeres are assigned as power suppliy planes like DC power-bus and ground, and they form cavity-type parallel plates that will possibly leave the system with spurious resonances as in area-fills[1-6].

To take some steps against the resonance, its precise prediction is prerequisite with rigorous analyses of the power-bus structures without any approximation[2,3]. Based upon the results, it needs examining that placing local elements on the power plane and ground affects the initial resonances[2-6]. As the local components, EBG-Equivalent elements are commonly used to circumvent the resonance. However, in a significant number of cases, this is not that effective due to the disturbance of other surface mounting elements or vias.

This paper suggests the full-wave based calculation of the DC power-bus lodaed with EBG-Equivalent elements along with vias in the same structure. Besides the electromagnetic fields and impedance profiles, the correlated influence of the EBG-Equivalent elements and other lumped elements loaded in the structure are given.

II. Theory

The PCB typically holds drivers, traces and receivers. Also, multiple PCBs are stacked, following the design rule to assure required EMC properties. They are connected through vias or isolated between digital and analog functions. Most of them can be considered parallel plates without loss of accuracy in electromagnetic modeling. Particularly, the DC power supply plane and its ground are a good example of parallel planes. In Figure 1, such a structure is illustrated with Wx by Wy by Wz in size. Using the feeding probe denoted as (X_0, Y_0), the current is given and works as the DC supply. The point of field excitation is assumed to coincide with that of the observation at (X_0, Y_0). The intermediate region between the metal planes corresponds to the PCB's substrate and 4.2 and 0.02 are each chosen as its relative dielectric constant and loss tangent, which is confined within the magnetic-walls.

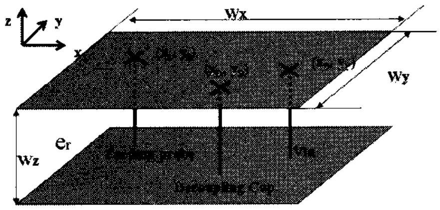


Figure 1. DC power bus modelled as parallel-planes

Outside the planes, air is assumed as the medium. The electromagnetic field(E_z) is expressed as well-known as in [2] and can be converted to the voltage or interpreted as the impedance with no difficulty. Particularly, the impedance is given as follows.

$$Z(X_0,Y_0 \mid X_f,Y_f) = \sum_{m=0}^{\infty}\sum_{n=0}^{\infty}\gamma_{mn}\cdot C_{mn}(X_0,Y_0)\cdot C_{mn}(X_f,Y_f)\cdot W_z$$

$$/[[\varepsilon\mu/Q + j\{\varepsilon\omega - (k_{xm}^2 + k_{yn}^2)/(\omega\mu)\}](W_x W_y)] \tag{1}$$

where

$$C_{mn}(X, Y) = cos(k_{xm}X)\cdot cos(k_{yn}Y)$$

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

$$Q = [\ tan\delta + \{\ 2/(\ \omega\mu_0\kappa W_z^2\ )\}^{0.5}\ ]^{-1}$$

$$\omega_{mn} = \{(k_{xm}{}^2 + k_{yn}{}^2)/(\varepsilon\mu)\}^{0.5}$$

$$G_{mn} = C_0 \cdot \omega_{mn} / Q$$

γ_{mn} is 1 and 4 for ($m = 0, n = 0$) and ($m \neq 0, n \neq 0$) each. With ($m \neq 0, n = 0$) or ($m = 0, n \neq 0$), γ_{mn} is 2. $tan\delta$, ε, μ, f and j denote loss-tangent, permittivity, permeability, frequency and $\sqrt{-1}$, respectively. Eqn. (1) itself does not have terms to consider N_{Lu} loads with the equivalent lump elements(Z_{Lu}) of which can be simply expressed as a series equivalent circuit

$$Z_{Lu} = R_{Lu} + j(\omega L_{Lu} - 1/(\omega C_{Lu})) \tag{2}$$

In order for the loading effect to be included, the following matrices can be used

$$\begin{bmatrix} V_0 \\ [V_{Lu(i)}] \end{bmatrix} = \begin{bmatrix} Z_{00} & [Z_{0,Lu(j)}] \\ [Z_{Lu(i),0}] & [Z_{Lu(i),Lu(j)}^{Int}] \end{bmatrix} \cdot \begin{bmatrix} I_0 \\ [I_{Lu(j)}] \end{bmatrix} \tag{3}$$

And

$$[V_{Lu(i)}] = -[Z^{Ext}_{Lu(i),Lu(j)}]\cdot[I_{Lu(j)}] \quad (4)$$

with

$$Z^{Ext}_{Lu(i),Lu(i)} = Z_{Lu},\ \ Z^{Ext}_{Lu(i),Lu(j)} = 0$$
$$Z^{Int}_{Lu(i),Lu(i)} = Z(X_{Lu(i)},Y_{Lu(i)} \mid X_{Lu(j)},Y_{Lu(j)})\cdot$$
$$Z_{0,Lu(j)} = Z(X_0,Y_0 \mid X_{Lu(j)},Y_{Lu(j)}) \quad ,$$
$$Z_{Lu(i),0} = Z(X_{Lu(i)},Y_{Lu(i)} \mid X_0,Y_0)$$

These are manipulated as

$$Z_{00} \leftarrow Z_{00} - [Z_{0,Lu(i)}]\cdot([Z^{Int}_{Lu(i),Lu(i)}]+[Z^{Ext}_{Lu(i),Lu(i)}])^{-1}\cdot[Z_{Lu(j),0}] \quad (5)$$

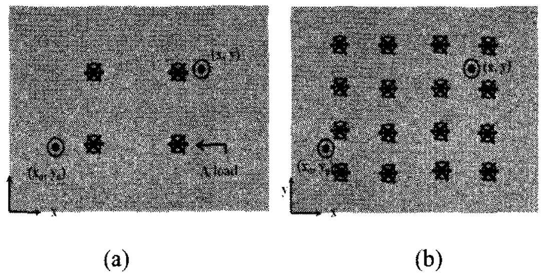
which is the generalized input impedance. The generalized trans impedance can be obtained in a similar manner. If a umped element is placed in the structure for damping the resonance, its values will be substituted for (2).

On account of its denominator's zeroes, the impedance profile in the frequency range shows a spiky behavior as resonance. The resonance points are determined depending on size-related modes, substance and frequency. What is intriguing with the resonance is attributed to the emitted radiation, ground bounce, Delta-I noise, etc that end up with EMIs. Researches have seen the mounted elements on either or both of the parallel planes can change the resonance characteristics. Many such activities have followed the mounting of EBG equivalent local elements to lower the impedance's increase due to the stacked PCB's inductive loop behavior. In addition, other local elements such vias are forced to exist together with the decoupling capacitors in the same power-bus. Since it is easy to guess that they affect each other and the overall resonance characteristcis, both of them need considering for one geometry. In Figure 1, the placement assigns a via and a decoupling capacitor at (X_D,Y_D) and $(X_V,\ Y_V)$, respectivley. These lumped elements' influences are reflected in the field calculation as is in [3].

III. Numerical Results

Before starting to examine the characteristics of a variety of loads, we need to state the following. The number, positions, distribution, equivalent circuit values(R_{Lu} L_{Lu} and C_{Lu}) and combination of EBGS(EBG Structurer) are varied, and the thickness, dielectric constant and loss tangent are changed to quickly see the electromagnetic behaviors of the power-bus. And this is followed by the experiment that includes vias. All the cases go with the observation point (X=144.4mm,Y=100mm) and the feed point at (X_0=44.4mm, Y_0=50mm). The power-bus size amouns to (W_x=200mm,W_y=150mm, W_z=1.5mm).

Firstly, we investigate the impedance of the power-bus when we change the number, distribution and positions of EBGSs. Four cases are dealt with, where 4, 16, 25 and 36 EBGSs are evenly distributed in the power-bus. They look like sqaure matrices of EBGS s' positions. The 4 and 16 EBGSs are placed as follows. For evaluating the impedance between (X_0, Y_0) and (X, Y), all the EBGS s are given 7.3nF as capacitance, 0.5nH as ESL, and 85mΩ as ESR which is commercially availble. Now we compare how the 4, 16, 25 and 36 EBGSs affect the impedance.



(a) (b)

Figure 2. 4 and 16 EBGSs evenly placed in the DC power bus

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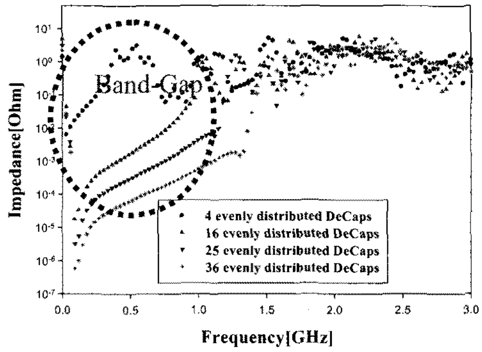
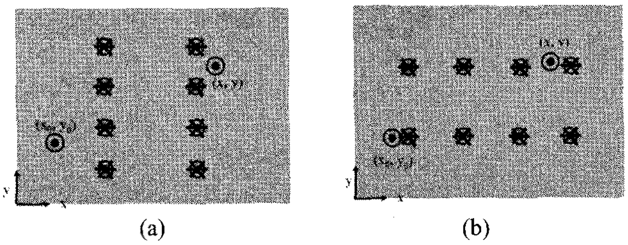


Figure 3. Impedance for the 4 16, 25 and 36 EBGS placement and appearance of the Band-Gap.

Seeing Figure 2, it is obvious the more EBGSs are placed in the power-bus, the wider becomes the resonance-suppressed regime. Particularly, from the use of 16 EBGSs, the impedance can be lowered by over 40dB at 500MHz with respect to the 4 EBGS-case. Next, we are dealing with the rectangular matirces of EBGS positions. Example 1 is to compare 2-by-4 and 4-by-2 rectangular distribution. Each of them has 8 EBGSs in a total. The following shows the illustration of these two ways of placement.



(a) (b)

Figure 4. 2-by-4 and 4-by-2 rectangularly placed EBGSs

When the impedance is calculated, all the EBGSs are assumed the same as those of Figure 3.

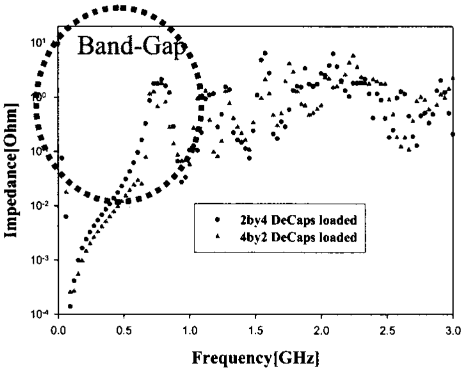
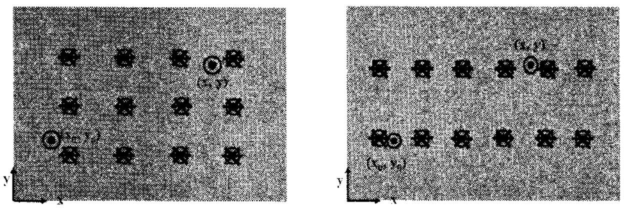


Figure 5. Impedance of the 2-by-4 and 4-by-2 rectangularly placed EBGSs

Example 1 results in not much difference between the two cases, since the density of population is close to each other. However, the 4-by-2 case is superior to the other in noise-suppression around 500MHz, because EBGSs are in the vicinity of both the two ports. Similarly, in Example 2, 12 EBGSs are laid in two distribution cases as 4-by-3 and 6-by-2. They are illustrated as follows.



(a) (b)

Figure 6. 4-by-3 and 6-by-2 rectangularly placed EBGSs

Solving Example 2 on the rectangular matrix of placement, the EBGSs are identical with Figures 3 and 5.

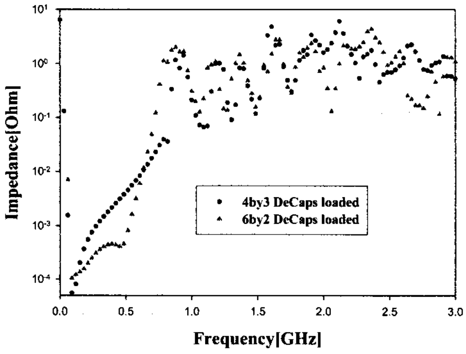


Figure 7. Impedance of the 4-by-3 and 6-by-2 rectangularly placed EBGSs

Figure 7 tells us that both the cases have a similar tendency in the higher frequency regime over 600MHz. However, the 6-by-2 case shows superiority in lowering the impdance at less than 600MHz, to the 4-by-3 case, since the ports of the former case are closer to their adjacent EBGSs, compaerd to the latter. .

IV. Conclusion

Considering the EMI-causing resonance related to the DC power-bus modelled as cavity-type parallel planes, the structure's field and impedance are rigorously evaluated. Based upon this prediction method, positioned values of EBGs are tried in the power-bus to damp the undesirably high impedance with resonance. This can lead to success in suppressing the specific resonance. Particularly, this paper enlightens the way EBGs can be affected by other lumped elements like vias and other physical input-parameters in a variety of manners for coping with better PCB EMC countermeasures. And their LPF and BPF behaviors have been mentioned in terms of pole extraction. .

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