Study on the Effect of Metal-Wall Loading on the DC Power-Bus

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Abstract

The DC power-bus for the PCB is loaded with metal walls on its selected sides and is characterized electromagnetically. This is a novel concept of approach to mitigate the spurious resonance and finally signal integrity problems. In particular, the peak at DC, which is always in the way to secure parallel-plates' EMC, can be completely removed by the proposed method. Through the findings of this study, the effect of metal-loading of the power-bus will be presented along with the impression that the suggested technique can tackle the headaches of signal integrity, ground bounce, EMIs.

Key words : DC Power-Bus, DC-Surge, Signal Integrity, Spurious Resonance, Metal-Loading, EMI.

I. Introduction

Almost every modern communication system comprises multiple layers of PCBs with increasing frequency in operation and complexity in 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 layers are assigned as power supply planes like DC power-bus and ground, and they form cavity-type parallel plates that will possibly leave the system with spurious resonance as in area-fills[1]~[5].

In the first place, a full-wave analysis method is used to see the accurate resonance points in the power-bus structures without any approximation[1]. Based upon the analysis, secondly, it is investigated that local(distributed) or global loading of the plane with lumped elements or material sheet, respectively disturbs the initial resonance[4],[5]. In line with this, much of the similar research has shown the importance of predicting the resonance frequencies and the possibility of enhancing the EMI matters.

This paper proposes the metal walls are loaded on the sides of the DC power-bus planes and work in a fairly good manner to change the original resonance's characteristics. Especially, the DC-peak will disappear with this idea. Counting on the choice of the feed and output points, the resonance will be more mitigated. This is beneficial in that we do not need to return to the certain manufacturing stages for the power-bus when it necessitates boring via holes and placing lumped components at the test procedure. Instead, metal walls are adopted. The effect of this scheme is verified through comparing the DC power-supply planes with and without the metal walls.

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 plates. In Fig. 1, such a structure is illustrated with w_x by w_y by w_z in size.

Using the feeding probe denoted as (X_0, Y_0), the current is given and works as the DC supply. The field is excited and the voltage is detected at the observation point (X, Y). The intermediate region between the plates corresponds to the PCB's substrate and 4.2 and 0.02 are

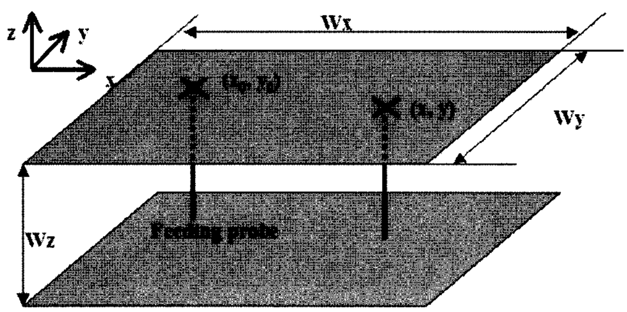

Fig. 1. DC power-bus modeled as parallel-plates.

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each chosen as its relative dielectric constant and loss tangent, which is confined within the boundary. Outside the plates, 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. For the factors in the expression, see Ref. [2].

$$Z = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \frac{r_{mn} \cdot C_{mn}(X_0, Y_0) \cdot C_{mn}(X, Y) \cdot W_z/(W_x W_y)}{\varepsilon\omega/Q + j[\varepsilon\omega - (k_{xm}^2 + k_{yn}^2)/(\omega\mu)]} \quad (1)$$

On account of its denominator's zeroes, the impedance profile in the frequency range shows a spiky behavior as resonances. 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 plates can change the resonance characteristics. Many such activities have inspired the following study. Clearly, changing the boundary conditions will disturb the initial resonance. So, selective sides of the power-supply planes are loaded with electric conductors as is done in Fig. 2.

If metal walls need implementing after the conventional fabrication, copper ribbons or similar others can be adopted and placed along the substrate's periphery. And the conductor on the walls should have spacing from the top and bottom plates. Though metal-coated walls are separated from the conducting plates, they are electromagnetically connected for the A.C. For this to be considered in the field expression, $\sin(k_{xm}X_0)$ and $\sin(k_{xm}X)$ will be substituted for $\cos(k_{xm}X_0)$ and $\cos(k_{xm}X)$ of $Cmn(X_0, Y_0)$ and $Cmn(X, Y)$ with the field expression in [4] with $k_{xm} = m\pi/W_x$ and $k_{yn} = n\pi/W_y$, in order to meet the boundary conditions for Fig. 2.

Ⅲ. Numerical Results

Firstly, the field distribution needs taking into account for the original structure of Fig. 1. For the sake of convenience in investigation, its physical size is left with 400 mm by 300 mm by 1.5 mm. As a comment on its size, the height of the substrate(ε_r=4.2, $\tan\delta$=0.02) is conventionally employed. (X_0, Y_0) is placed at the center of the plates and frequency is 500 MHz. For the calculation, modes (m, n) are considered upto (400, 400) in the framework of the modal-type Green's function calculation.

All the sides are equivalent to the perfect magnetic conductor where E_z takes its maximum. Source and edge conditions are met, as physics is checked. Taking a gander at Fig. 3, the field's high intensity is, except for two nulls, spread all over the area. Especially, when the resonance of the source occurs and the observation point is nearby, they get affected. Therefore, if a way is sought to lower the intensity above by a simple loading method, it will be good enough. Giving this a thought, two sides of the plates are selected and replaced by conductor. In the second example, they are implemented at the two ends in x-direction of the DC power-bus.

The frequency and the structure for this simulation are the same as Fig. 1 except that it is facilitated with conductors. It is noteworthy that the field intensity has been reduced quite much over the whole area except for the unchanged source. Specifically, the edges parallel with y-direction have completely zero, since E_z is short-circuited. It can be interpreted that the resonance frequencies have been moved away from the original ones. This is verified by the impedance profile calculated and measured in the frequency domain. In order to get the 2-port characteristics on the basis of the input and trans-impedance observed at an upper-edge point (X=200 mm, Y=150 mm) as port 2, with respect to port 1 located at the center. Besides, for the experiment, copper planes and teflon substrate are used.

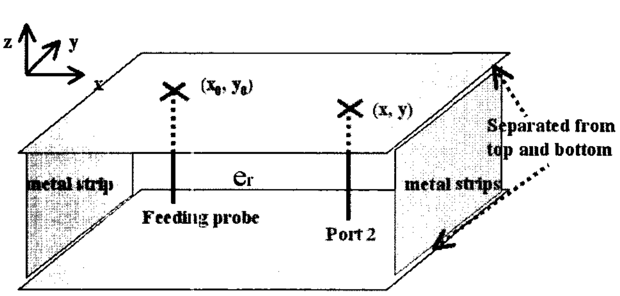


Fig. 2. Metal-wall loaded DC power-bus.

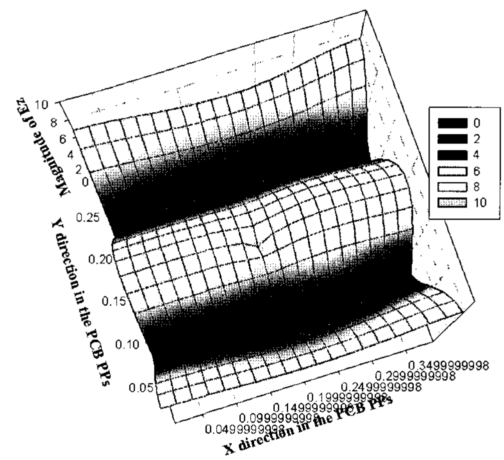


Fig. 3. Field distribution on the DC power-bus of Fig. 1.

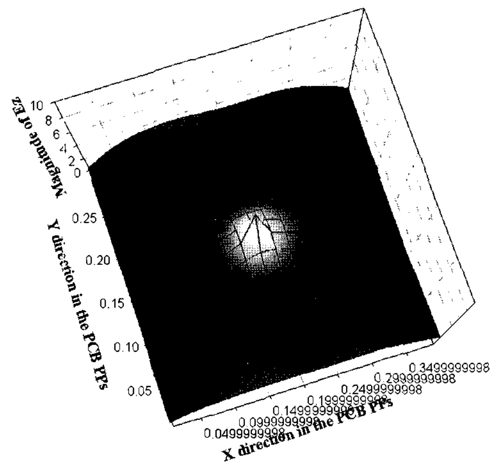
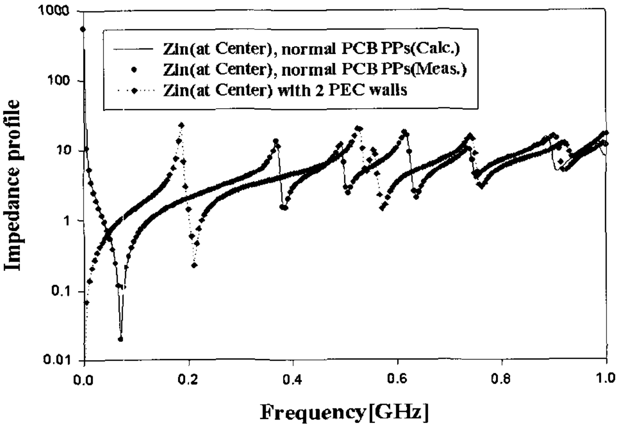
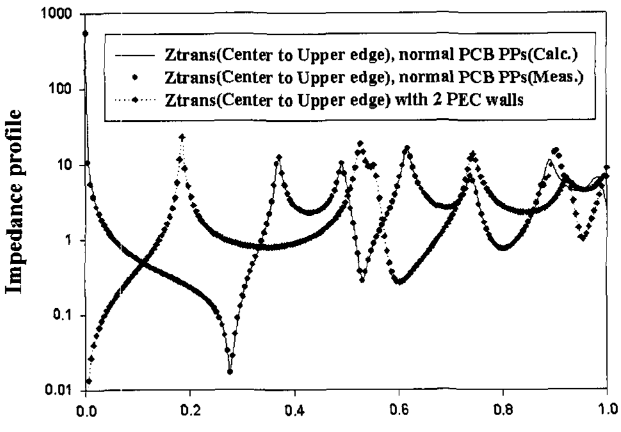


Fig. 4. Field distribution on the DC power-bus of Fig. 2.



(a) Input impedance(fed at the center of the planes)



(b) Trans-impedance at (X=200 mm, Y=150 mm)

Fig. 5. Impedance profiles of the DC power-bus with and without metal walls.

In the first place, the calculation shows good agreement with the experiment for the conventional power-bus structure, though there occurs discrepancy for the higher frequency. It is clear that the frequencies of resonance have varied in a positive way from the solid line(DC power-bus without metal walls) to the dotted line(with metal walls). Namely, the resonance modes (0, 0), (0, 1) and (2, 1) of the power-supply planes have been removed or shifted. Conspicuously, the DC-peak has disappeared, since the inherited capacitance of the plates has been cancelled, and this will be useful in taking measures to damp the DC-surge. On the other hand, mode (2, 0) is common in both of the two cases. And, an additional resonance is created around 180 MHz and calls for a decoupling capacitor to mitigate it, which is no big a deal because the proposed method has already reduced the number of resonance peaks of the original structure. Last but not least, the position of port 2 where elements such as chips or other electric sources are laid decides the impedance and field distribution, and port 2 needs to placing at the area of dampened E_z. In accordance with this, the relations between the source and output must be kept in designers' mind.

Ⅳ. Conclusion

In the PCBs for a system, the power-supply plane and the ground are indispensable to DC/digital circuitry along with analog components. Before considering the EMI-causing resonance related to the DC power-bus modeled as cavity-type parallel plates, the structure's field and impedance are calculated. And then, the metal walls are attached on the sides of the plates to circumvent the undesired resonance. This results in the decrement of the field intensity over the plates and leads to avoiding resonance, particularly at DC which is a potential cause of DC-surge noise. This is due to the changed boundary conditions to short-circuiting and relations between the source and the output port, examining the electromagnetic behavior in the DC power-bus.

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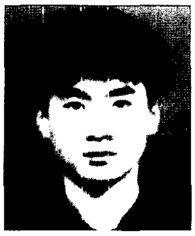

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