PCB DC power-bus 로부터의 전파방사에 관한 연구

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A study on the radiated emission from the DC power-bus for the PCB

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Abstract

The DC power-bus' resonance is frequently attributed to EMI sources in the PCBs. Subsequently, it will ruin the digital signal integrity within one system or between adjacent systems in the form of conducted or radiated emission. Hence, since it is of importance to examine the PCB's emission, this paper sheds a light on the radiated emission from the power-bus with regards to its resonance modes. A full-wave analysis method is used to calculate the impedance and radiated electric fields and is validated by physics and an EM analysis tool.

Index terms : Radiated fields, PCB power-bus, full-wave analysis

1. Introduction

The PCBs in a communication system are usually stacked on top of each other for accommodating routes of signal traces, vias, connectors, semiconductor chips and so on. Since the population of the components on each PCB layer is getting more complicated and the space between the layers becomes smaller, it is more likely for the structure to generate EMI noises with increasing clock speed. Especially, cavities like the DC power-bus incur the resonance phenomena over a broader range of spectrum and they end up with non-compliance in radiated as well as conducted emission concerns[1-6].

As stated earlier, the DC power-bus acts like a cavity that is composed of the top and bottom planes as the PEC boundary condition and the PMC walls[2,3]. Along with these boundary conditions, the resonance properties are determined by the feeding point as the source of excitation, the loading element and the size of the DC power-bus. The eletromagnetic fields go highest at each resonance mode, and they propgate past the edges of the planes to the external region. This is radiated emission(RE). The radiated energy from one cavity reaches its upper and lower PCB layers and nearby systems.

In this paper, a full-wave analysis method in Ref.'s [2,3] is adopted to perform the exact calculation of the impedance profile and give the resonance modes' radiated electric field from the DC power-bus. In particular, the present analysis method is validated by a reliable EM tool for the impedance computation.

2. Theory

Lately, the PCB level EMC problems have had much attention, because they have much to do with other levels of EMC concerns bridging the gap between ICs, modules, and systems. Another reason is that a variety of potential noise sources are formed by way of the PCB. One good example regarding this is the stacked planes. The stacking of planes causes energy reactance and resonating properties in between. At the maxima of the energy as the resonance modes, fields propagate and noise currents conduct along the paths out of control. This resonating structure can be illustrated as in Figure 1.

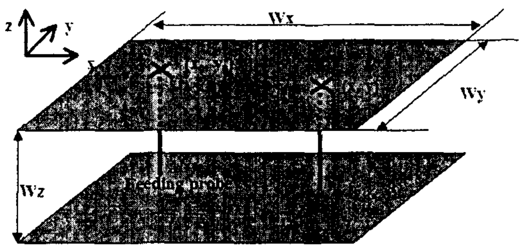


Figure 1. DC power bus modelled as a cavity

The top as the ground and the bottom as the power-plane are identical in size with *Wx* by *Wy* by *Wz*. The DC current is carried along the feeding probe situated at (X_0, Y_0). And it is used as port 1. Port 2 is any arbitrary observation point at (X, Y) where induced voltage is observed. The filling region between the two planes is the dielectric substrate and 4.2 and 0.02 are given as its relative dielectric constant and loss tangent. Respectivley. Referring to the structure's boundary conditions again, the two planes are the PEC and the walls are the PMC. Then, electromagnetic field(E_z) is expressed as in Ref. [2,3] and can be easily interpreted as the voltage-to-current ratio or as the impedance. The expression is guessed to show resonance phenomena when its denominator becomes zero. These resonance frequencies are decided dependent upon the physical size, the filling substance and the boundary conditions.

The field E_z is formed inside the cavity and it goes out of the structure into the outer region. The radiation can be explained as the magnetic current due to E_z is induced on the walls first, and then this fictitious current radiates. For this, the radiation integral in the following is employed[7].

$$\underline{E}=(jk_o W_z e^{jk_o r}/(4\pi r))\int \underline{M}s(\underline{r}')\cdot e^{jk_o \underline{r}'\cdot e_r}\cdot(e_r \times e_l)dl \quad (1)$$

$\underline{M}s(\underline{r}')$ is the induced magnetic current at $\underline{r}'$ on the walls, and e_r and e_l are the normalized position vectors of the observation and source points. k_o is the free-space wavenumber and $j=\sqrt{-1}$. Given that W_z is far less than W_x or W_y equation (1) takes line integral along the periphery instead of the surface integral. Also, the above equation considers the far-zone for simplicity.

3. Numerical Results

First, the impedance profile is obtained through the exact full-wave calculation with respect to the power-bus of 225mm by 150mm by 1.5mm. For this simulation, no loading of local components is considered. And the DC current is fed at (X_0=0, Y_0=0) from bottom to top. The frequency range of interest occupies from 0 through 1GHz. With the identical input parameters as the calculation, a commercial EM analysis tool(FDTD based) is used to validate the present technique.

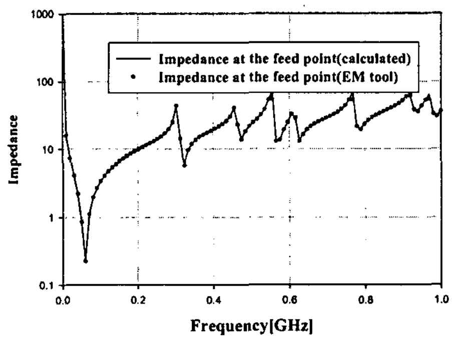
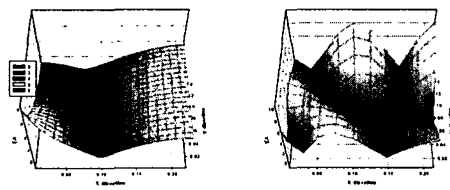


Figure 2. Input impedance profile of the DC power bus without loading(calculated and compared to other method)

Figure 2 shows good agreement between the two methods. Both simulation cases depict the resonance behaviors of the DC power-bus. Beyond 200 MHz, seven peaks correspond to (1,0), (0,1), (1,1), (2,0), (2,1), (3,0) and (0,2) in order. Next, Ez in the DC power-bus is plotted for the frequencies around two resonance modes (1,0) and (3,0).



(a) (b)

Figure 3. Ez over the DC power bus (a) 360MHz (b) 750MHz.

In Figure 3, Ez varies over the planes with the numbers of nulls equivalent to resonance modes. And now the calculated radiated field is visualized at phi =0° and 90° planes with varying theta.

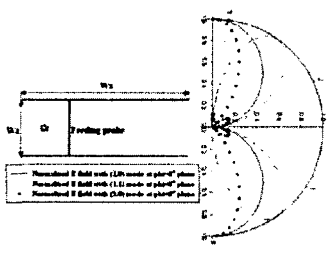


Figure 4(a) Radiated field at phi=0° plane

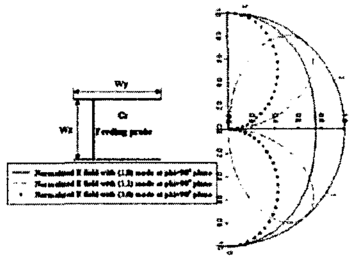


Figure 4(b) Radiated field at phi=90° plane

Figure 4 Radiated field patterns at phi=0° and 90° planes

Each plane's observation deals with three different resonance modes (1,0), (1,1) and (3,0). All the field patterns are normalized since they are alike in magnitude. In the phi=0° plane, (3,0) mode is the weakest of all. (1,1) mode tilts the radiation angle different from the other cases. As for the phi=90° plane's observation, (3,0) mode generates tiny tilted beams and (1,1) mode's beam is still inclined. Combining the two phi-planes, (1,1)- and (3,0) modes radiate mostly vertically and do not emit much of energy in the horizontal direction. However (1,0)-mode causes the horizontal and vertical directed radiation, which is thought to be a significant EMI noise to nearby objects.

4. Conclusion

To diagnose the damaging radiated emission from the DC power-bus, its field and impedance as well as resonance properties are exactly calculated. In particular, a full-wave analysis method is used to calculate the impedance and radiated electric fields and is validated by physics and an EM analysis tool. Through the radiation integral of the induced magnetic current on the walls of the DC power-bus, the radiated field pattern is also computed. It is noteworthy that the dominant (1,0) resonance mode energy reaches any adajacent objects from the edges of the structure.

Acknowledgement

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