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Effect of Dissipative Edge Terminations on the Radiation from Power/Ground Planes

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Abstract: The paper examines the effect of using dissipative edge terminations between power and ground planes on the radiation from a printed circuit board. Basically, this consists of resistive loading of the edges of the power/ground plane structure. These edges constitute the main radiating sources for the dominant resonant mode. This has been found to be effective in reducing the impedance at resonant frequencies. This paper examines the effect on the radiation. The analysis is based on a full wave moment method solution combined with a multi-port network formulation. Numerical results are presented and discussed.

Introduction

Power/Ground plane design in printed circuit boards and multi-chip modules for mitigating SI and EMI problems has been tackled by exploiting the inter-plane capacitance, and by the judicious placement of de-coupling capacitors [1]. Increasing the inter-plane capacitance, for example, by reducing the spacing between the two planes decreases the radiation efficiency of the resulting antenna structure. This leads to a lower impedance as well as lower radiation [2]. On the other hand, use of de-coupling capacitors can either increase the resonant frequency, or decrease the impedance at resonance or result in a combination of both and has much the same desirable effect. Basically, there are two ways to render a resonant antenna inefficient, namely, by introducing losses, or an impedance mismatch. Since the primary radiating edges for the dominant resonant modes are at the boundary, use of a Dissipative Edge Termination (DET) has been known to smoothen the resonant peaks of the impedance profile [3]. In the present paper, we examine the effect on radiation.

To evaluate the effect of resistive terminations, one considers a parallel plate geometry consisting of two rectangular planes separated by the dielectric substrate. The impedance of this structure can be determined by reducing it to an equivalent circuit consisting of a mesh of short transmission lines, or by using analytical formulas [4]. The value of the input impedance at any location, or the transfer impedance between any two points on the plane as a function of the frequency, gives an indication of its effectiveness in de-coupling as well as reducing the voltage drop that leads to common mode radiation. Smaller the magnitude of this impedance, smaller is the voltage drop and more effective is the de-coupling. This has led to the definition of a frequency dependent parameter called the "target impedance" [5]. Future, high performance printed circuit board designs require target impedances of less than a milli Ohm. In a realistic board situation, the parallel plate waveguide, or the radial transmission line gets excited by currents flowing through ground/power vias and this also leads to simultaneous switching noise. The currents flowing through signal vias connecting traces can also cause a similar excitation and it is this particular case that is considered in the present paper.

Formulation

The geometry considered is shown in Fig. 1. A short microstrip trace and a square power plane are stacked on the top of a ground plane. The trace is excited at one end and terminated at the other end in a matched load, both of which are connected to the ground plane. Two dielectric layers exist between the trace and the power plane, and the power plane and the ground plane. The analysis is carried out using a rigorous Mixed Potential Integral Equation technique. To enable use of Green's functions, we let the transverse dimensions of the dielectric layers and the ground plane extend to infinity [2]. Lumped loads are treated by an application of multi-port network theory. From the current distribution on the trace and the power plane, the far field radiation is computed in the upper hemisphere and the maximum of the two perpendicular components is recorded as a function of the frequency. This is termed the emission level and is translated to a 3 meter measurement distance.

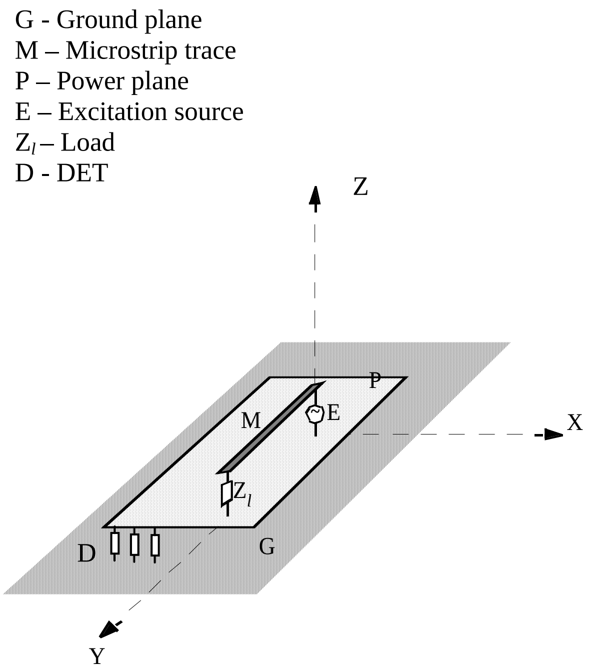

Figure 1: Geometry

The values of the termination resistors required can be calculated from the equivalent transmission line circuit as described in [3]. They are simply made equal to the characteristic impedance of the short transmission lines in the equivalent circuit. An analysis of the tolerance in the values of the resistors has shown a weak effect implying that the precise value is not very important.

Results and Conclusion

For the illustration the microstrip trace is 2.3 mm wide and 25.3 mm long as in reference [6]. It is excited at one end with a frequency independent voltage source of amplitude 0.2V and terminated at the other end in a 50 Ω load. The power plane is square patch of side length = 48.3 mm and is centered underneath the trace. The thickness of the dielectric layer between the trace and the power plane is 1.57 mm. The spacing between the power plane and the ground plane is taken as 1.57 mm. These values are chosen primarily to show the effects clearly. In the first example (a), the edges of the power plane are left open. In the second example (b), 30 Ω resistors are placed 4.4 mm apart all along the square boundary. The reference radiation is taken to be the differential mode radiation from the trace alone. This is computed by placing the trace on an infinite ground plane with a dielectric thickness of 1.57 mm. FR4 is assumed as the dielectric in all cases. The radiation from the composite structure is a combination of the trace radiation and the power plane radiation. It can be seen from Fig. 2a that the presence of the power plane increases the emission levels significantly, in particular at resonance.

An examination of the current distribution on the power plane in the case (a) shows a strong excitation of the

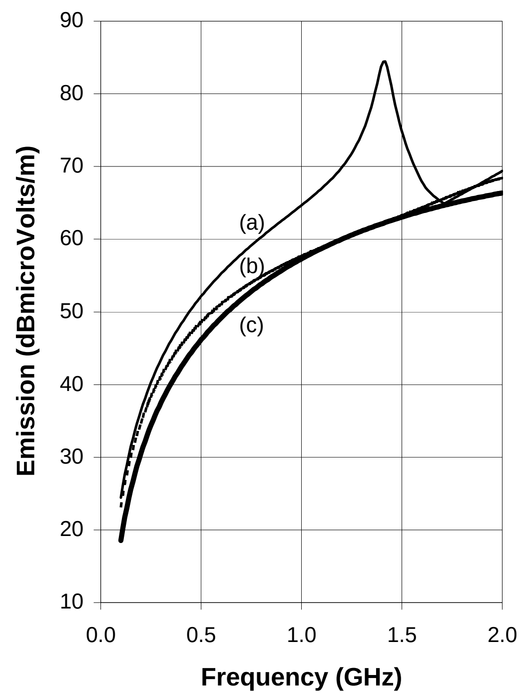

Figure 2: Computed radiation in free space

dominant patch resonant mode at 1.41 GHz. The radiation from the power plane alone exceeds that of the trace. In case of (b), the losses in the same resonant mode are significantly increased, resulting in absorption. Note that the resistive terminations render the structure non resonant and is also one of the reasons why the precise value of the resistance is not critical. Therefore, by using DET, the power plane simply becomes an inefficient radiator and the overall emission level is reduced significantly at resonance. As a result, the radiation begins to approach that of the reference case (c).

An experiment was carried out on an example board consisting of two plane layers without any traces. The board measured 10 x 10 inches with a 31 mils thick FR4 as the dielectric substrate. It was excited in the center and the emission level was measured in a semi-anechoic chamber. The board was placed horizontally at a height of 1.5 meters and the receiving antenna was at the same height and at a distance of 3 meters and was vertically polarized. Measured results are shown in Fig. 3. The relative field strength with edges of the printed circuit board left open is shown in Fig.3a. Note that the high emission level at 565 MHz which corresponds to the full wave resonance can be clearly seen. The emission result with the edges of the board terminated in 5.1 Ohms/inch resistors along the periphery is shown in Fig. 3b for the same orientation. A ~25 dB reduction in the peak emission level can be seen. For several other orientations of the board, a similar reduction of the emission level was observed.

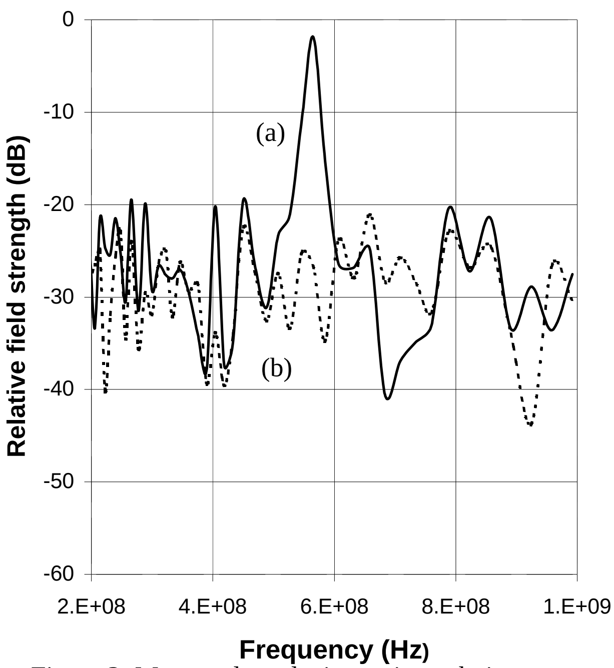

Figure 3: Measured results in semi-anechoic

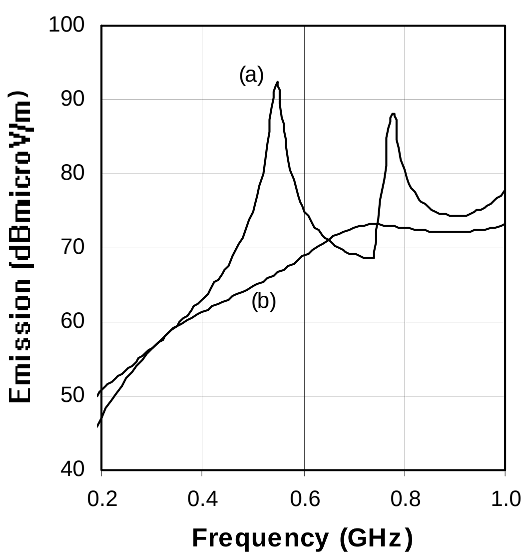

Figure 4: Computed radiation in free space

Computed results for this geometry are shown in Fig. 4. Once again, 4a corresponds to the case without any DET and 4b is that with DET. In the illustration, the maximum free space radiation over the upper hemisphere was calculated as in Fig. 1. The reduction in emission at the first resonance is in good agreement with the measured results. The second peak in the emission level of Fig. 4a was not so clearly seen in the measured results for the particular board orientation. These results indicate that the use of a dissipative edge termination can prove to be effective in reducing the radiation at the resonant frequencies of the power/ground planes in printed circuit boards.

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