Frequency Shift Effects in Potted Modules

The introduction of potting material in automotive electronic modules changes the EMI characteristics of the modules.

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INTRODUCTION

Automotive EMC is an extremely demanding discipline. The environment in which electronic modules must operate can range between extremes in temperature, humidity, rain, dirt, mud, etc. Because of these extreme conditions, modules that are placed in the engine compartment must typically be potted to protect the electronics. Introduction of the potting material changes the EMI characteristics of the modules. It is one of those effects that will be discussed in this paper.

For some time, a frequency shift has been noted in the conducted emission measurements of potted modules versus unpotted modules. There has been much discussion concerning what the mechanism for this shift is. Some recent experimental measurements may shed light on the matter.

These measurements were performed in order to better understand how currents distribute as a function of frequency, conductor topology and dielectric thickness and type. Many measurements were made, examining different conductor layouts and differing dielectric materials. Solid conductive planes were driven with sinusoidal and pulsed waveforms. In addition, several dipole configurations were tried using similar waveforms. These investigations are ongoing and this report is preliminary. The primary purpose of these investigations is to find layout techniques that inherently reduce or redirect noise currents, thereby lowering conducted emission levels. By determining optimum topologies, we may arrive at reduced emission levels at no additional cost.

CURRENT DISTRIBUTION IN A LOOP STRUCTURE

Recently, a large loop structure was measured; the geometry is shown in Figure 1. This loop was driven by single sinusoidal waveforms in the frequency range 25-400 MHz, with an amplitude of 40 mV. The conductive loop was located over an FR4 dielectric (e_r = 4.5) of 0.028-inch thickness. The currents in the loop arms were measured using EMSCAN.[1]

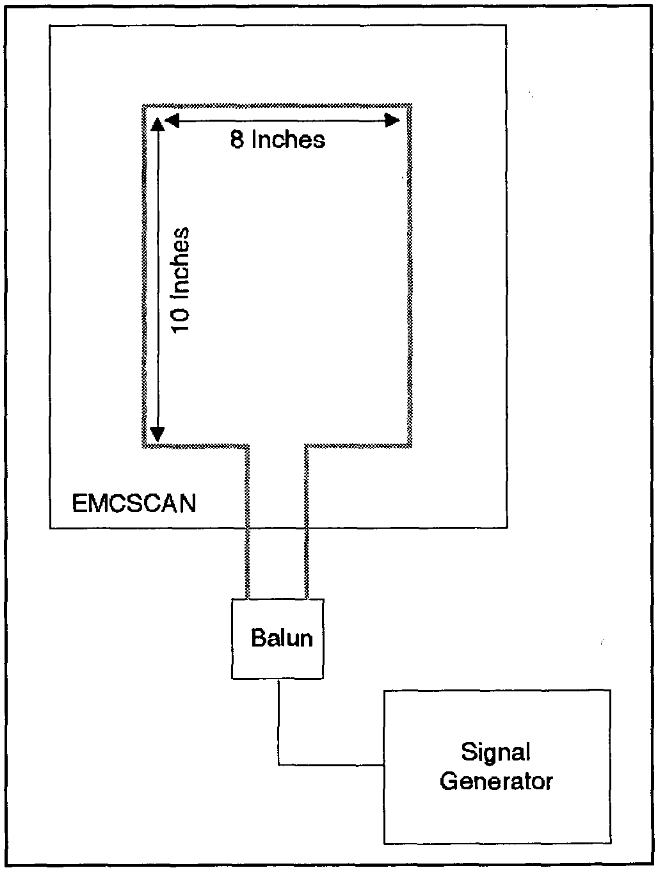

Figure 1. *Geometry of Loop Structure.*

Figure 2 shows the distribution of the currents in the absence of potting material. The z axis is in units of dBV. The x and y axis designators can be ignored. At 25 MHz, we can see that the current distribution is fairly evenly distributed on each of the arms. Figure 3 shows the same configuration at 150 MHz.

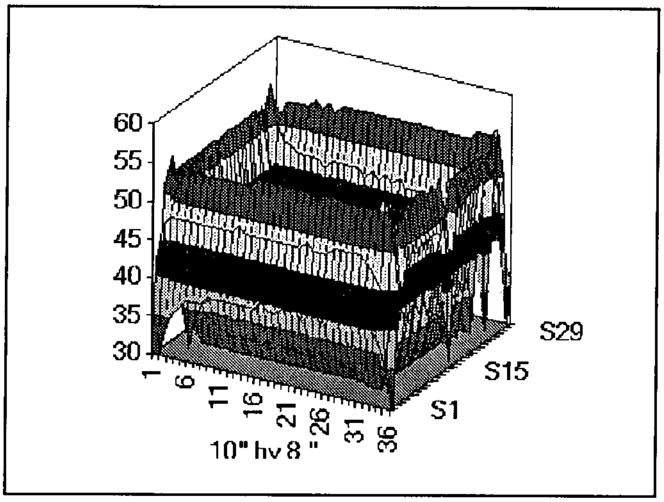

Figure 2. *Distribution of Currents with No Potting Material, where f = 25 MHz.*

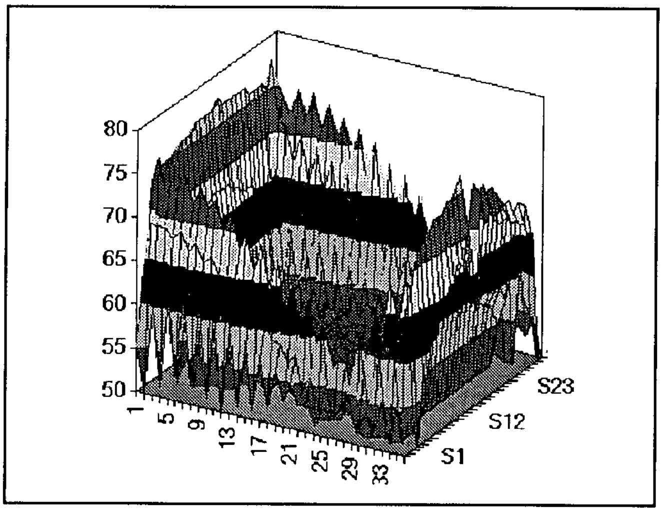

Figure 3. *Distribution of Currents with No Potting Material, where f = 150 MHz.*

A comparison of the two distributions shows that the currents are now gaining some structure. In particular, a current null is seen to be forming, displaced from either end of the side arms of the loop. This can be interpreted as an indication that the loop arm is entering into resonant behavior, where current nulls and current maxima will occur as a function of the RF impedance. The RF impedance is a complex quantity that depends upon the conductor geometry, the dielectric material and the frequency. At nulls, the RF impedance is approaching infinity and at maxima the RF impedance is approaching zero. Figure 4 shows the distribution, again at 150 MHz, but with a 0.5" slab of potting material laid over the loop structure.

Note that the current null has shifted, indicating a change in the RF impedance. This is to be expected since the dielectric slab should change the RF impedance of the entire structure. Figures 5 and 6 show the results at 200 MHz for the same structure, where we see the shift of the null and an enhancement in the maximum level measured, similar to what is seen in actual conducted emission measurements.

Figures 7 and 8 show the calculated distribution of currents in a simulated loop. The software used

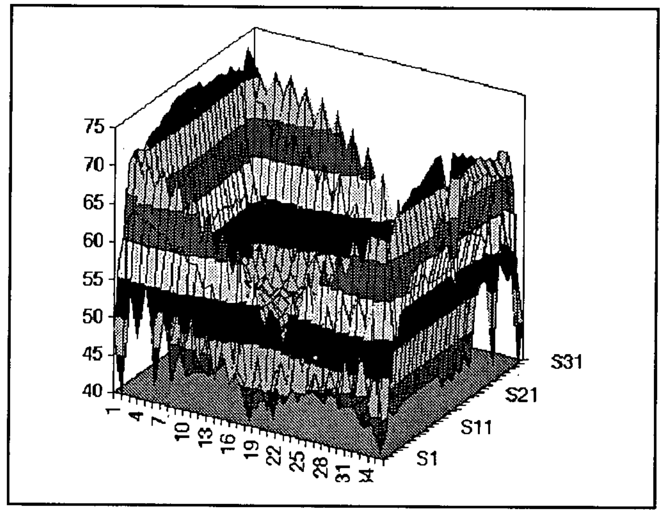

Figure 4. *Distribution of Currents at f = 150 MHz, with 0.5" of Potting Material.*

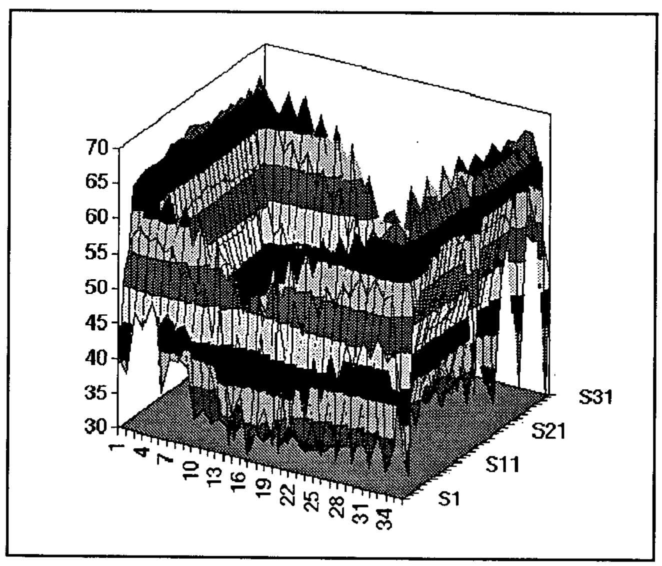

Figure 5. *Null Shift in Distribution Currents at f = 200 MHz.*

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FREQUENCY SHIFT EFFECTS . . . (Continued from page 46)

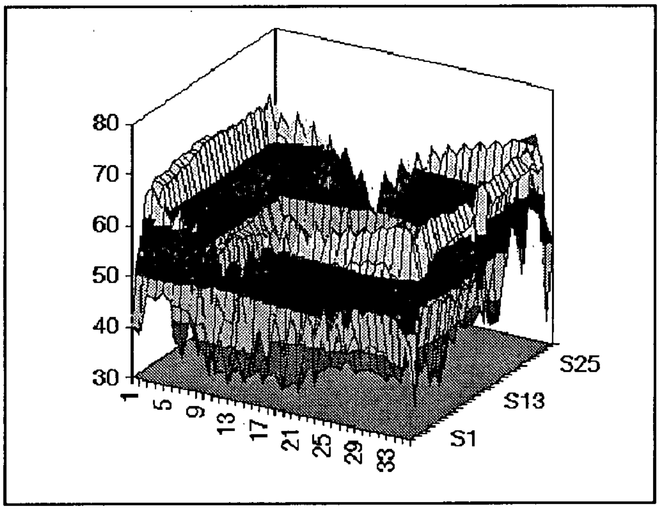

***Figure 6.** Null Shift in Distribution Currents at f = 200 MHz.*

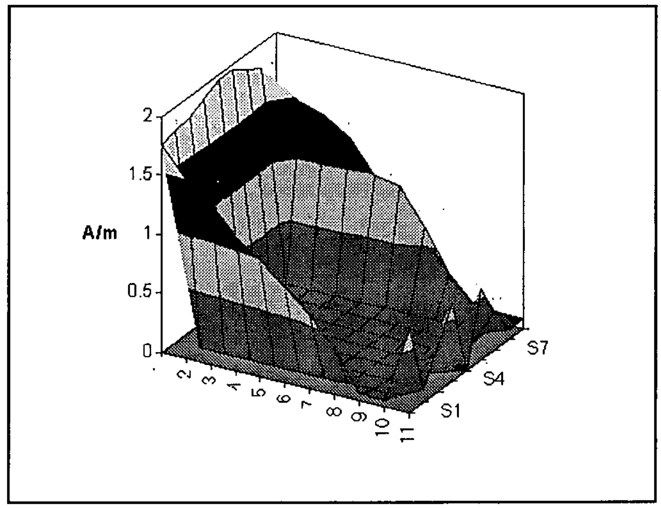

***Figure 8.** Calculated Distribution at f=150 MHz With Potting.*

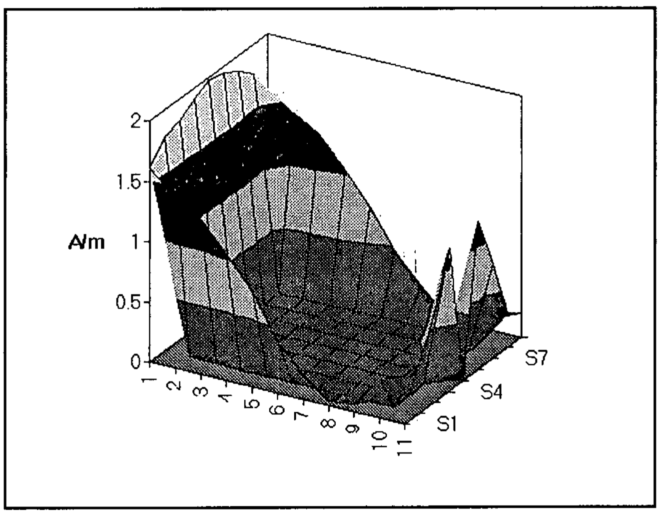

***Figure 7.** Calculated Distribution at f = 150 MHz Without Potting.*

to provide the simulation is commercially available.[2] A comparison of the two plots, with and without potting, shows a result similar to our actual measurements, with the potting causing a shift in the current distribution along the loop arm. Note that the EMSCAN measurements were made with a signal level of 40 mV driving the loop, and the simulation was run with a value of 1.0 V.

Figures 9, 10, and 11 show conducted emission measurements made on an unpotted FCC module and a potted module. Automotive conducted emission measurements are somewhat different than those made for FCC or MIL-STD testing. For automotive measurements, a module is powered, and all I/O pins except those necessary to power the module are left unterminated. Measurements are then made on each pin with a wideband voltage probe. The limits are -60 dBV from 2 to 6 MHz, -70 dBV from 6 to 30 MHz and -80 dBV from 30 to 200 MHz. Additional measurements are made in the .05 to 2 MHz range and the 200 to 500 MHz range.

Comparison of the maximum measured levels over the limit (Figure 9) shows the potted module approximately 8 to 10 dB higher on average, which is in fair agreement with the measurement made using the loop. Also shown is a comparison of the noise density (Figure 10). Noise density is a measure of how widespread the noise is, and is derived by adding all peaks over the limit, in microvolts, and then dividing by the frequency span. Figure 10 indicates broader emissions with the potted version. Finally, a comparison is shown between the frequencies at which the maximum level was recorded (Figure 11). This plot indicates a downward frequency shift of approximately 30 MHz.

CONCLUSION

From these few plots we may infer that the frequency shift is a phenomenon associated with RF impedance loading introduced by the dielectric. If each trace in any given module is assumed to be a summation of elementary dipoles, then by changing the dielectric medium, (i.e., by introducing potting) the RF impedance of that dipole and, therefore, the current distribution along the dipole and the radiation characteristics of the dipole are changed. Having

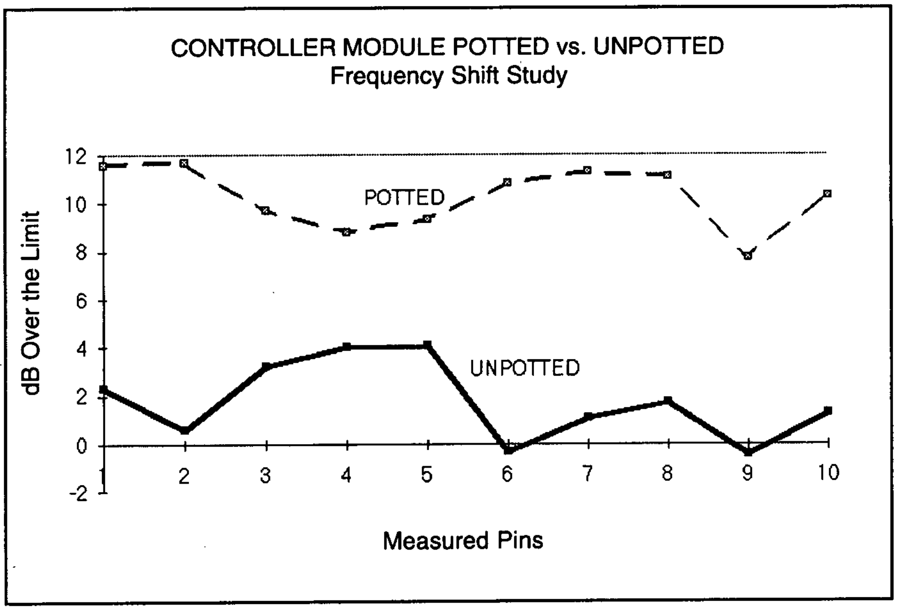

Figure 9. *Maximum Measured Levels.*

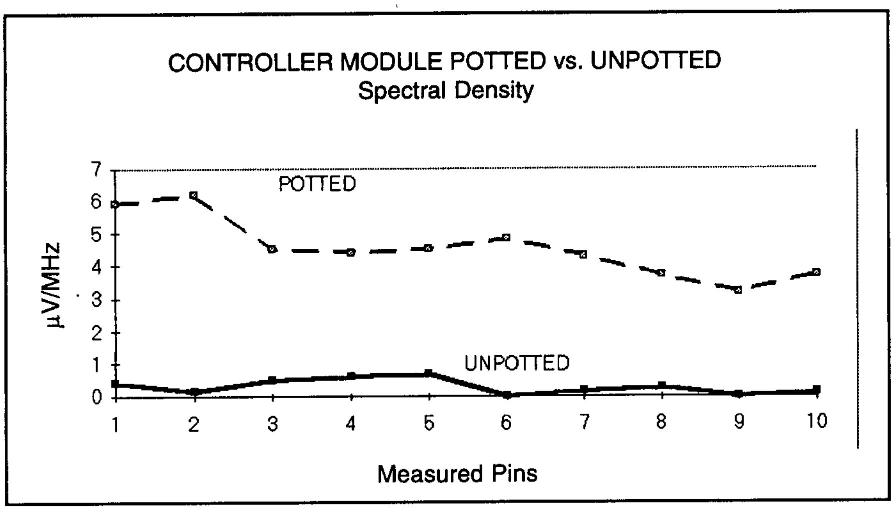

Figure 10. *Noise Density.*

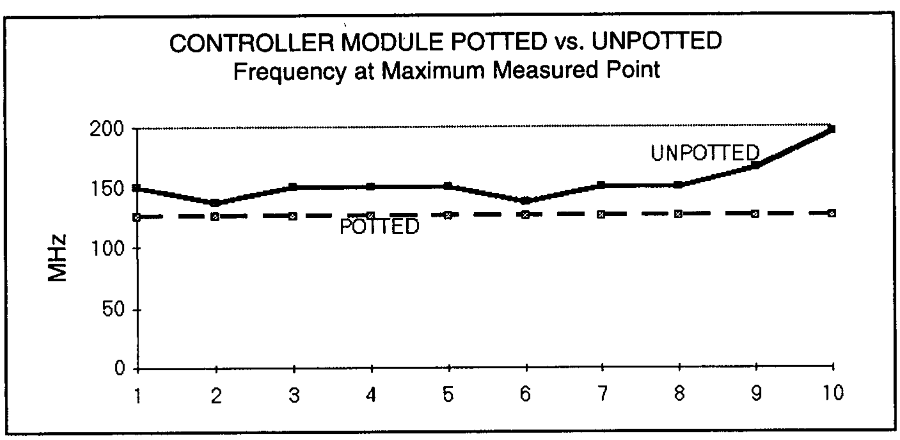

Figure 11. *Frequency Shift Comparison.*

made this assumption, we may then say that the ensemble of all traces is similar to an ensemble of individual dipoles driven at various frequencies, and that we should see a general shift in the frequency characteristics of the aggregate.

Finally, the measurements made with the loop indicate a method whereby the differences between potting materials can be measured, and the effect of different potting materials on the measured noise current frequency distributions can be understood.

REFERENCES

1. S. Xavier, D. James, "EMSCAN™: A Tool for Evaluating the EMC Performance of Printed Circuit Packs," Euro-EMC 91 Conference. EMSCAN is a planar array of 1280 virtually infinitesimal magnetic dipoles. The device allows the near-field measurements of a circuit board or planar structure to be measured. The current distributions are then displayed. Emscan Corporation/ Amplifier Research.

2. Sonnet: 3D Field Simulation of Planar Structures, Sonnet Software, Liverpool, NY. Sonnet is a 3D field simulator. The user defines the number of layers, whether dielectric or metal, the type of metal and various other parameters. The current distributions are then calculated at the frequencies of interest.

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