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Influence of Conformal Coatings on the EMC Performance of a Printed Circuit Board

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***Abstract*—Conformal coatings are often applied to printed circuit boards to protect the board and its components from environmental factors like moisture, chemicals, and vibration. The impact of a conformal coating on crosstalk and radiated emissions was studied in the following paper. Two coating materials were characterized in terms of their permittivity and permeability. The impact of the conformal coating was evaluated based on the crosstalk between microstrip traces, the radiated emissions from a switch-mode power supply (SMPS), and on coupling from an EMI filter to nearby components. The coatings increased crosstalk between microstrip traces by up to 5 ~ 6 dB, and increased radiated emissions from the SMPS by up to 8 dB. While the coating did not affect the performance of the EMI filter, a 5.5 dB increase in coupling was observed from the filter to nearby components. These effects should be considered if pre-compliance testing is performed before the coatings are applied.**

Keywords—Conformal coating; Crosstalk; Radiated emissions; Testing; Electromagnetic Compatibility

I. Introduction

The reliability of printed circuit boards (PCB) can be affected by moisture, chemicals, and vibration. A conformal coating helps protect a PCB from these factors [1], [2]. A 'thin' coating material can be sprayed onto a board to isolate humidity and chemical stress components. A 'thick' coating material can be applied to tall or fragile components to prevent destabilization due to vibration. While the coating helps to protect the PCB, it can potentially increase the electromagnetic coupling between components, enhance the coupling path for EMI noise, or improve the efficiency of an unwanted antenna. In this work, a study was performed to evaluate the impact of conformal coating on the electromagnetic performance of PCBs.

The impact of two conformal coatings was evaluated by measuring their electromagnetic characteristics and by measuring how they influence the electromagnetic performance of PCBs in "real world" applications. Both a standard 'thin' and 'thick' coating material were evaluated. The dielectric properties of the coatings were extracted experimentally. The impact of the materials was studied on a) crosstalk between two parallel microstrips, b) radiated emissions from an SMPS module, c) coupling across an EMI filter and d) between an EMI filter and nearby components.

Section II of this paper explains the electromagnetic characterization of the materials; Section III details the experimental investigations of the impact of the coatings on crosstalk, radiated emissions, and filter performance; and Section IV shows the impact of cure time on the characteristics of the coating. Results are summarized in Section V.

II. Material Characterization

The coatings chosen for investigation were the DOW 3-1953 and DOW 3-1944 polydimethylsiloxane-based elastomeric coating materials. The DOW 3-1953 is a light yellow transparent 'thin' type coating material. The Dow 3-1944 is a clear transparent gel-type 'thick' coating material. Measurements of Y_{21} between two metal plates with the material sandwiched between were made to extract the dielectric constant of the material [3]. This technique uses two-port measurements to minimize the influence of parasitics. A 49 mm X 29 mm X 5.4 mm mold was built to hold the material as shown in Fig. 1 (a). Electrodes were formed by placing copper tape on the top and bottom of the inside of the mold. The top and bottom sides have a hole at the center to allow for connection from the inner pin of an SMA to the electrodes. The SMA shields ("ground") were left unconnected. The relative permittivity of both coating materials was found to be 2.7 as shown in Fig. 2. Results diverge above roughly 10 MHz because of resonances in the dielectric structure. The permeability of the material was extracted using a toroidal core as shown in Fig. 1 (b). As expected, the relative permeability was found to be approximately 1.

III. Evaluation of Impact on EMC Performance

A. Microstrip Coupling

Microstrips are frequently used on PCBs and may be in close contact with the conformal coating. The increased dielectric constant of the conformal coating compared to air can lead to increased crosstalk between two closely-spaced microstrips and increased EMI noise [4]. Fig. 3 shows two parallel microstrip traces used to study of the impact the conformal coating on crosstalk. Both thin and thick coating materials were applied to the traces. A plastic fixture was built to hold the coating material during application to ensure the coating covered a well-defined portion of the traces and at a consistent 120 mil thickness. Studies were performed with traces that were tightly coupled

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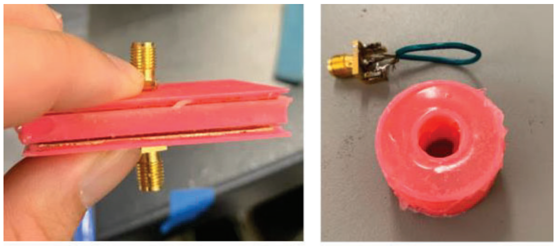


(a) (b)

Fig. 1. Fixtures used to measure the electromagnetic properties of the coating materials: (a) dielectric constant; (b) relative permeability.

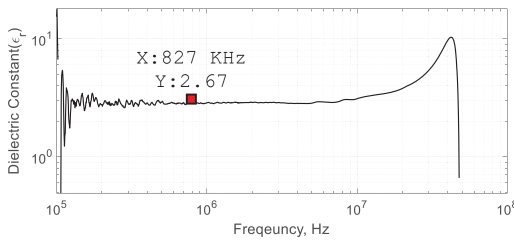


Fig. 2. Measured relative permittivity with frequency.

(trace width = 100 mils, trace separation = 130 mils), were loosely coupled (width = 100 mils, separation = 240 mils), and for a pair of asymmetric traces (width of traces = 100 mils and 40 mils, separation = 155 mils). Measurements of coupling were performed on each trace pair when there was no coating material (denoted as "original"), when they were covered with the thick coating material, and when they were covered with the thin coating material, for a total of 9 cases studied. 4-port S-parameter measurements and simulations were made between the ends of the traces. Simulation and measured results were closely matched. These S-parameters were used to predict coupling to the near-end port when the far end port was left open (i.e., S21 when ports 3 and 4 were open; S41 when ports 2 and 3 were open). The aim of this measurement was to emulate the loading in a real-world product where two microstrips are closely placed but connected to different sources and loads. Fig. 4 shows the far-end coupling at 100 MHz (S41 when ports 2 and 3 are open). Coupling increased by 5-6 dB when the coating was added, likely because of the increased capacitance between the traces, as confirmed by the simulation results.

B. Switched-Mode Power Supply (SMPS)

Switched mode power supplies are common sources of radiated emissions [5]. The emissions from an SMPS were studied with and without conformal coating applied. The thick coating was applied as shown in Fig. 5 to large components like the capacitors and inductors which might require mechanical stabilization. The thin coating was applied on both sides of the entire board. Emissions were measured while the SMPS was used to drive a 6-ohm load.

Measurements were performed before and after applying the coating. Measurements showed no impact from the thin coating on radiated emissions, but the thick coating generally caused radiated emissions to increase as shown in Fig. 6. For example, in the horizontal polarization radiated emissions increased by 6-8 dB at 80 MHz, by several decibels from 110-125 MHz, by

Fig. 3. Microstrip traces covered with the coating material.

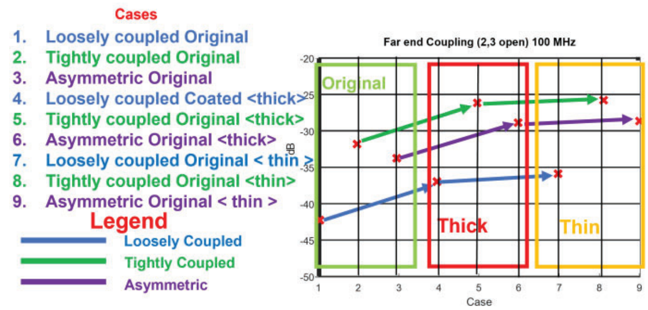
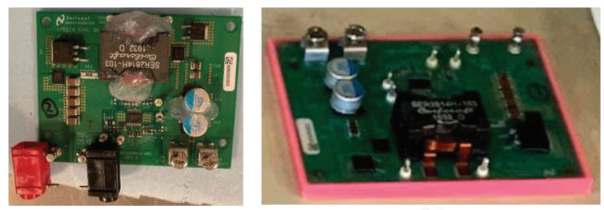


Fig. 4. Far end coupling (S41) at 100 MHz when ports 2 and 3 are open.



(a) (b)

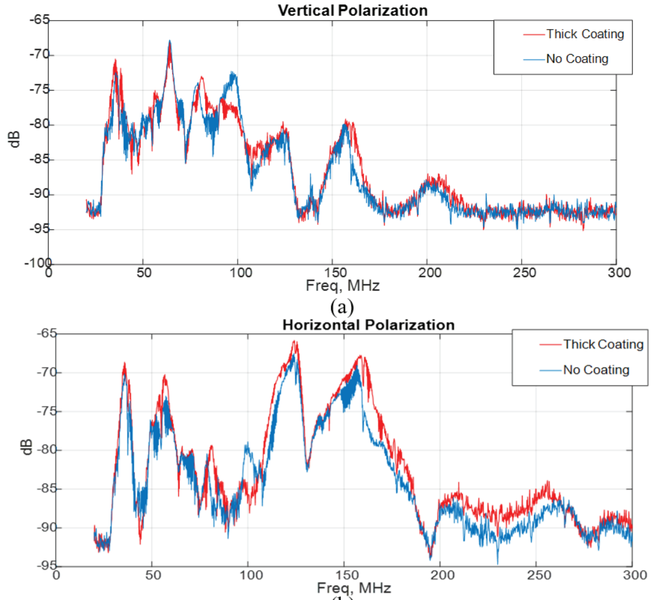
Fig. 5. SMPS board with (a) thick coating applied and (b) thin coating.

2-6 dB from 160-180 MHz, and by 2-3 dB from 200-250 MHz. A modest increase was also observed at some frequencies in the vertical polarization. While emissions decreased around 100 MHz with the coating added, this was the only case where a reduction was observed. Only a small increase was observed overall, in part because the material only modestly increases the capacitively coupling between parts on the board.

C. EMI-Filter

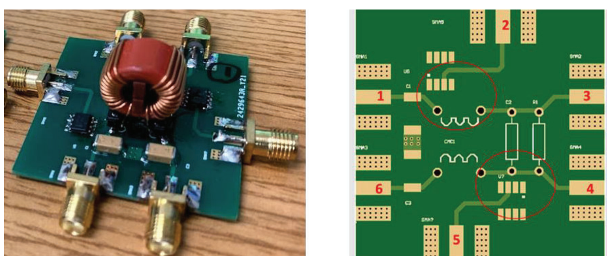
When the thick coating is applied around tall components, it may increase the capacitance between these components and other nearby components. Parasitic capacitive can be particularly important for an EMI filter [6].

The effect of the conformal coating was studied on the EMI filter shown in Fig. 7. An IC with an SOIC8 package was placed near to the filter transformer and capacitors, and an SMA connector was connected to the IC pin closest to the common mode choke to measure the coupling between the filter components and nearby devices. The thick coating was applied to the "large" transformers and capacitors. A second board was also constructed where the thin coating was applied to the entire board, but no thick coating. The coatings had minimal impact on the EMI filter performance, but a roughly 5.5 dB increase



(a) (b)

Fig. 6. Radiated emission from a switched mode power supply with and without thick coating material applied for the (a) vertical and (b) horizontal polarization.



(a) (b)

Fig. 7. EMI Filter board: (a) complete PCB, (b) Layout.

was observed on the coupling from the transformer to a nearby IC when a thick coating was used, as shown in Fig. 8.

IV. Influence of Cure Time

As the conformal coating usually takes several weeks to solidify, EMI measurements are often performed before the coating has fully cured. To show whether the cure time might have an impact on EMI measurements, the S parameters between two microstrip traces were continuously monitored for 10 days after the first application of the coating material. Fig. 9 shows the far-end coupling (S41) at 302 MHz when ports 2 and 3 were open. The variation in the coupling was less than 0.5 dB over the 10 day period, suggesting that the permittivity of the material – and thus the influence on electromagnetic performance – changes little over time. Similar results were observed at other frequencies.

V. Conclusion

The experiments performed here demonstrate that a conformal coating can impact the crosstalk and radiated emissions within electronic products. The addition of the coating material was seen to increase crosstalk between two microstrip

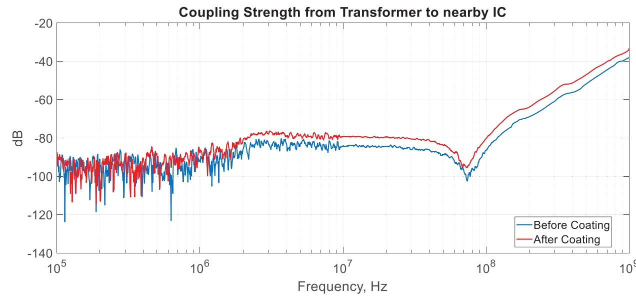


Fig. 8. Coupling from the EMI filter transformer to a pin of a nearby IC.

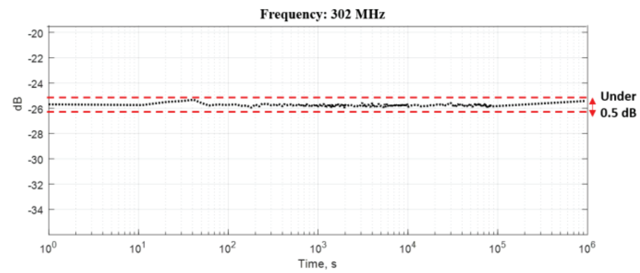


Fig. 9. Far-end coupling as a function of the cure time of the coating material.

traces by 5-6 dB, to increase the radiated emissions from an SMPS by up to 6-8 dB over a broad range of frequencies, and to increase the coupling between an EMI filter and nearby components. While EMI filter performance was not impacted by the coating, the coupling to nearby components might create an unexpected path for radiated emissions. While the observed increase in coupling or radiated emissions was not substantial and the size of the study was limited, results demonstrate that the presence or absence of the conformal coating should be considered when performing pre-compliance tests.

Acknowledgment

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