October 24, 2024 WEBINAR SUMMARY

From Theory to Practice: Near-Field EMI Noise Suppression with 3M Solutions

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KEY TAKEAWAYS

- An overview of near-field EMI and common noise sources.
- Using simple calculations to estimate absorber performance.
- Test methods for evaluating EMI absorbers for noise reduction.
- Test methods for comparing absorber performance.
- Demonstrations of EMI noise suppression conducted by 3M.
- Key product characteristics for selecting a 3M EMI Absorber.

OVERVIEW

As electronic devices become increasingly complex, with reduced design footprints, higher operating frequencies, and the proximity of one to another, navigating the challenge of electromagnetic interference (EMI) is a formidable challenge. EMI noise suppression requires precise control and the selection of optimal materials, based on an in-depth understanding of available EMI test methods and key material properties.

3M brings decades of expertise in EMI/RFI management and materials science to help solve complex and dynamic design challenges. With a broad portfolio offering of electrically conductive tapes and gaskets, EMI absorbers, and magnetic shielding materials, 3M products cover a variety of applications. With extensive technical and testing capabilities, including comprehensive material characterization, environmental testing, and modeling and simulation capabilities, 3M can help identify a noise-reduction solution for unique designs.

CONTEXT

Dr. Sergei Manuilov discussed several methods for testing absorber effectiveness and shared results of performance testing of various 3M absorbers in key applications.

KEY TAKEAWAYS

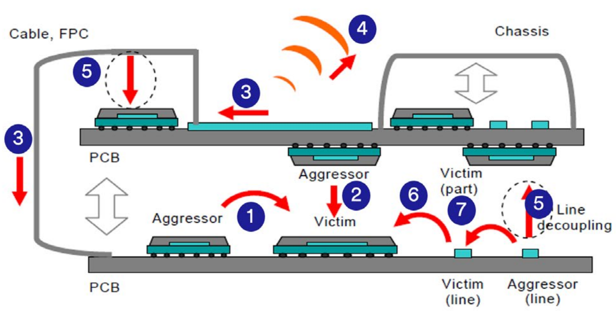
An overview of near-field EMI and common noise sources.

Having multiple interconnected components across more than one PCB board is a common scenario in electronic design. The components induce fields, which will couple to any object in the vicinity, creating a near-field coupling. Depending on the noise sensitivity requirements of the application, it might be necessary to reduce near-field couplings.

Board-level EMI noise sources include inductors and traces, as they can be noise carriers, and active devices such as clock circuits and logic circuits, which can generate noise at a frequency higher than the frequency of the original operation.

Figure 1: Noise suppression effect classified as noise path and NSS position

	Near Field Coupling			Conduction	Radiation
	Part (component)		Line	Line plane	Far-field
	Same side	Opposite side	Line in vicinity		
Part (component)	1 Intra-decoupling	2 Inter-decoupling	5 Line decoupling	3 Transmission attenuation	4 Radiation suppression
Line	6	5 Line decoupling	7		



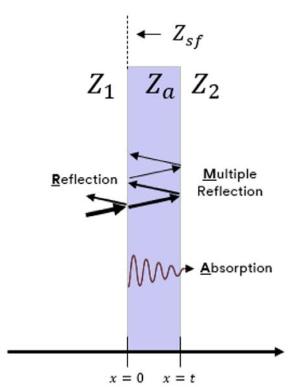
Near-field and far-field absorbers suppress EMI noise, and can be classified by principle of operation:

- **Impedance matched** absorbers reduce electromagnetic (EM) wave reflection and transmission. This requires tuning of permittivity (ε) and permeability (μ) of absorbers to match EM wave impedance to the free space values.
- **Quarter-wavelength** absorbers are widely used. The wave traveling from a noise source hits the absorber and experiences multiple reflections from absorber surfaces, one of which is typically metal (backing). This results in destructive interference and very low signal reflection—most of it is converted to heat by absorber material.
- **Multi-layer systems** use the same principle as quarter-wavelength but a stack absorber is used to achieve broadband performance.
- **Gradient absorbers** use material that enables the wave to go further into the absorber. While the density of the absorber increases, the reflection is reduced through additional absorption.

Using simple calculations to estimate absorber performance.

Estimating far-field quarter-wavelength or multi-layer absorber performance is relatively simple if the permittivity and permeability of materials are known. Below is the classical example of calculations for a quarter-wavelength absorber.

Figure 2: Calculating the far-field EMI wave reflection in a multi-layer system



- **Characteristic impedance of the media:**

$$Z_{1,a,2} = \sqrt{\frac{\mu_0\,\mu_{1,a,2}}{\varepsilon_0\,\varepsilon_{1,a,2}}}$$

- **Propagation constant of the media:**

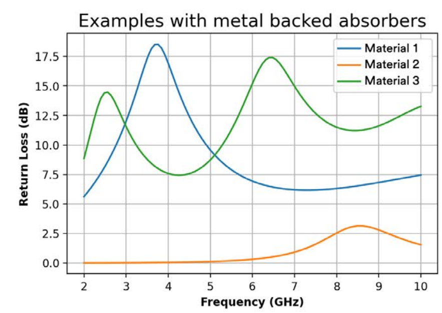
$$k = \omega\sqrt{\epsilon_0\mu_0\varepsilon_{1,a,2}\mu_{1,a,2}}$$

- **Surface impedance**

$$Z_{sf} = Z_a\frac{Z_2 + Z_a\tanh(jkt)}{Z_a + Z_2\tanh(jkt)}$$

- **Return loss – EM wave suppression:**

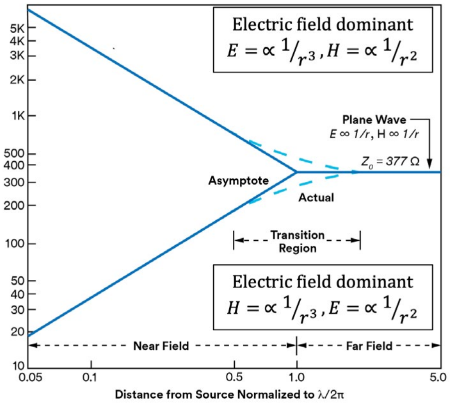
$$RL = -20log_{10}\left(\frac{Z_{sf} - Z_1}{Z_{sf} + Z_1}\right)$$



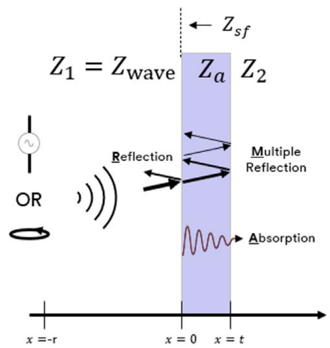
A similar approach can be used to estimate near-field absorber performance. However, near-field calculations must also account for variation in impedance for near-field sources. The example calculation in Figure 3 does not consider non-radiating fields nor consider other electromagnetic modes in the system. As an absorber will also suppress or change other modes, a different calculation may be more appropriate.

> "We had success using this simplistic approach to estimate and understand how new absorbers may work , but [it does] not consider a real-case scenario where the fields might be too complicated and different from this idealistic picture."
>
> *Dr. Sergei Manuilov, 3M*

Figure 3: Calculating near-field EMI absorption



Source. Ott, H. W. (2009). Electromagnetic compatibility engineering. Wiley. Page 241, Figure 6-4.



- **Characteristic impedance of the media:**

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$$k = \omega\sqrt{\epsilon_0\mu_0\varepsilon_{1,a,2}\mu_{1,a,2}}$$

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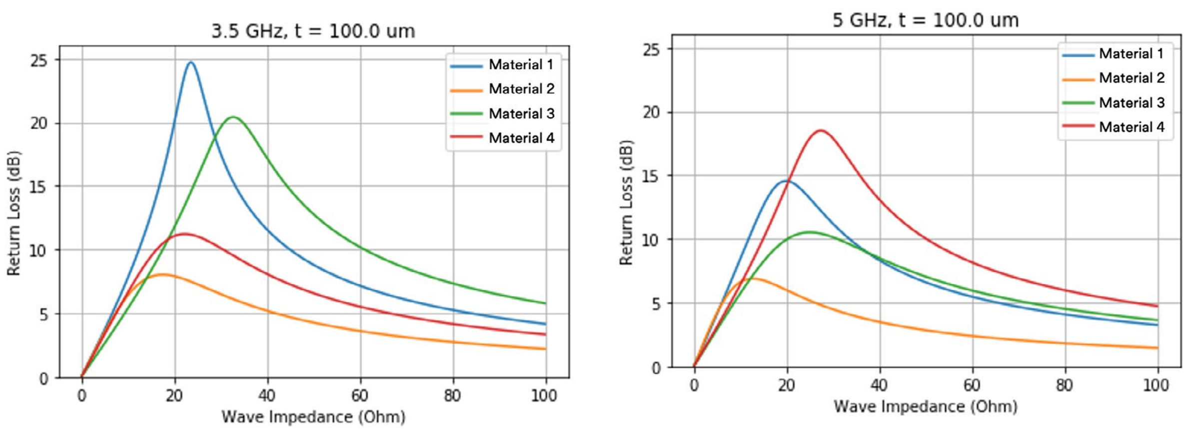
$$Z_{sf} = Z_a\frac{Z_2 + Z_a\tanh(jkt)}{Z_a + Z_2\tanh(jkt)}$$

- **Return loss – EM wave suppression:**

$$RL = -20log_{10}\left(\frac{Z_{sf} - Z_1}{Z_{sf} + Z_1}\right)$$

Figure 4: Reflection loss performance will vary with frequency range and drop with higher impedance.



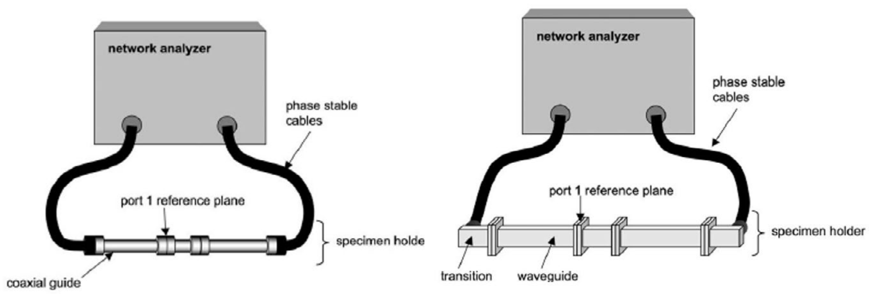
Test methods for evaluating EMI absorbers for noise reduction.

For more accurate calculations, assuming known values for magnetic permeability and dielectric permittivity, there are two methods that can be used to measure intrinsic absorber properties:

- **Waveguide techniques.** Two ASTM test methods are easy to use and relatively inexpensive to implement. Calibration standards are available and relatively small size samples are needed. However, this approach requires special attention to the gap in samples with high permittivity, and gaps in coaxial samples are impossible to remove. Additionally, these methods are destructive, which can be problematic for certain applications.

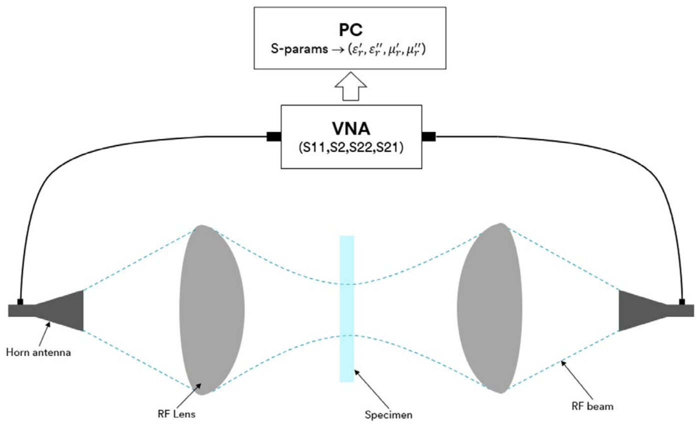
Figure 4: Waveguide techniques for measuring intrinsic absorber properties

ASTM D7449/D7449M – 08 **ASTM D5568 – 08**



- **Free space focused beam.** As with wavelength techniques, the free space focused beam method is easy to use, but this approach overcomes issues around sample size and gaps associated with the ASTM tests. The sample does not have to be cut, nor is a specific size required, though samples must be larger in size than required by the wavelength technique. This method is nondestructive; however, it is relatively expensive.

Figure 5: Free space focused beam for measuring intrinsic absorber properties

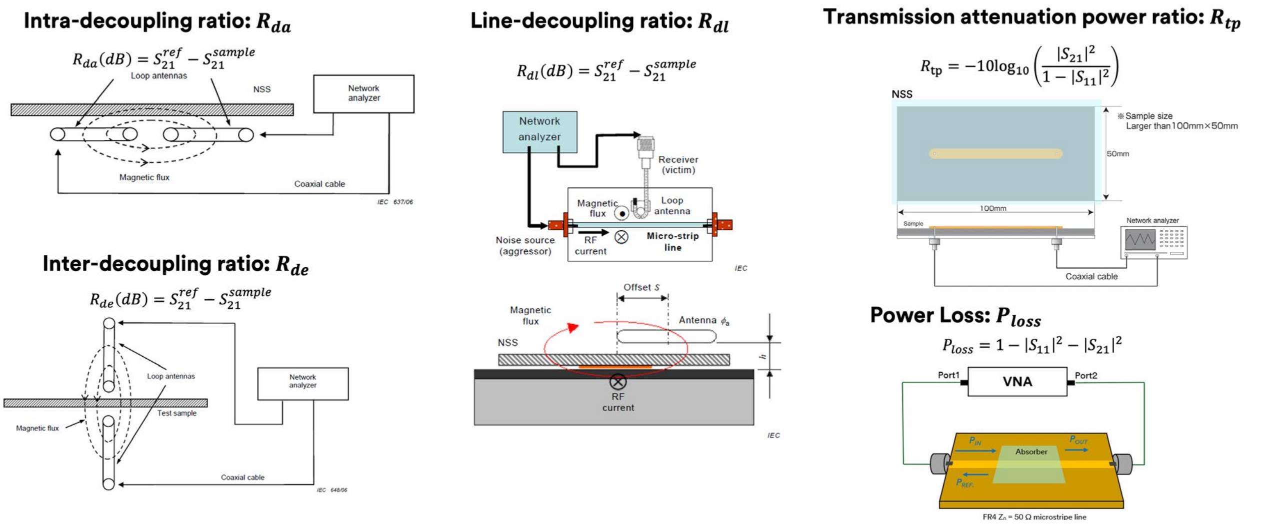


Test methods for comparing absorber performance.

The European Committee for Electrotechnical Standardization (2025) IEC6233-2 standard outlines near-field absorber test methods for quick and easy comparison of absorbers. However, not all methods presented necessarily reflect real scenarios, and the coils required for some tests are challenging to fabricate per standard specifications. 3M does conduct some testing using microstrip line measurements:

- The transmission attenuation power ratio measurement (IEC) measures the signal transmitted and reflected from a sample placed on the microstrip line. The higher the ratio between the two, the better.
- The power loss test method, while not standardized, is used by different industry players. A sample is placed on a microstrip line fabricated with fiberglass substrate, and the system measures reflection and transmission. Assuming no emissions from the system, the measurements can be used to calculate signal loss in the material.

Figure 6: Near-field absorber test methods



Demonstrations of EMI noise suppression conducted by 3M.

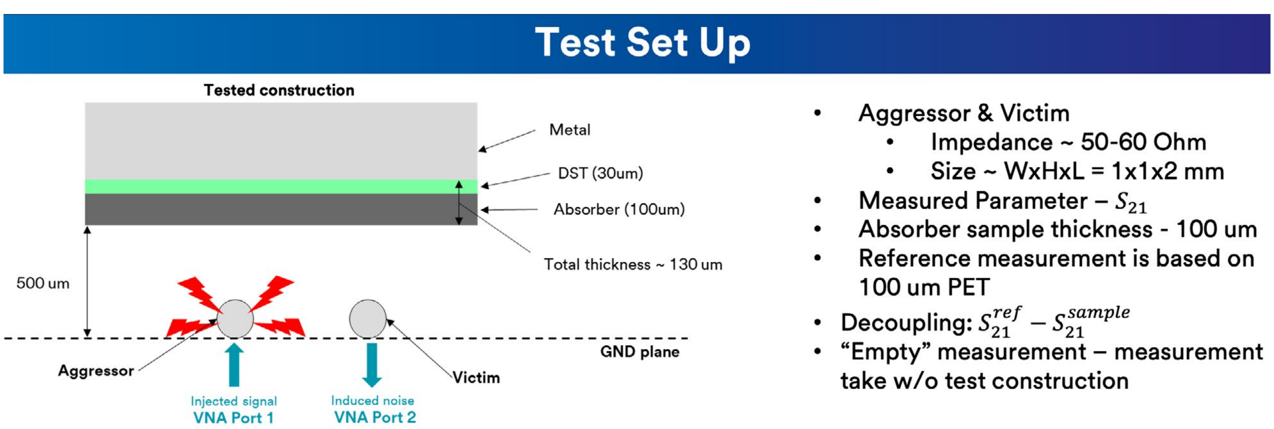
3M constructed tests to mimic real use cases to measure different approaches to noise suppression and to compare the performance of various absorbers in each scenario, including:

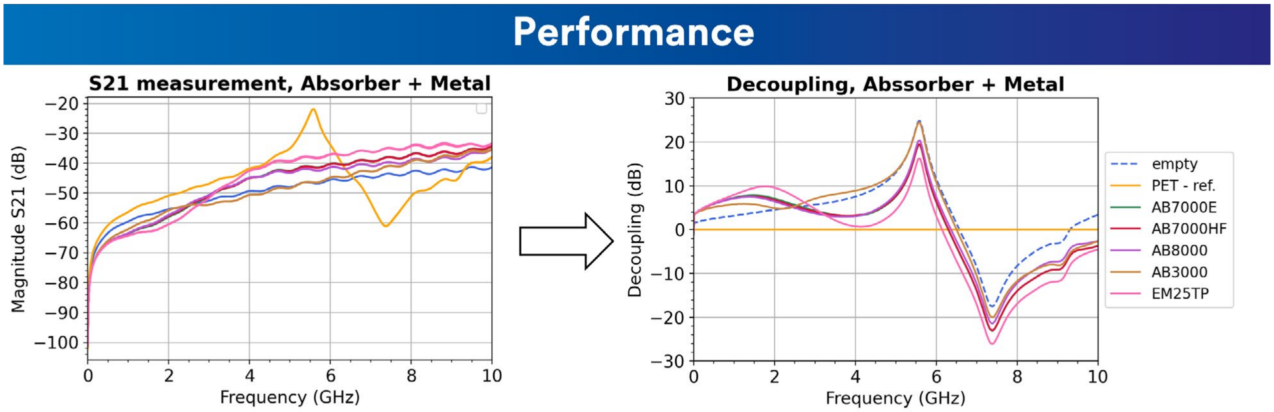
Aggressive Victim Decoupling

A victim and aggressor were placed above ground. The test construction used metal foil, to which an absorber was attached, with noisy components covered. This was placed 500 µm above the source of noise. Signal transfer from the aggressor to the victim was measured. The test also measured signal transfer using PET film instead of the absorber, to provide a reference measurement. A measurement with no test construction (i.e., measuring signal transfer with only victim and aggressor involved) was also taken.

The metal lid resulted in increased coupling between the aggressor and the victim, as well as vivid resonances defined by metal lid lateral dimensions. Adding absorbers resulted in a reduction of the aggressor-victim coupling and amplitudes of resonant peaks. Depending on the frequency, specific absorbers provided better performance. Between 0.3MHz and 3GHz, the EM25TP worked well, while for 2.5GHz to 10GHz, the AB3000 was the preferred choice.

Figure 7: Aggressor victim decoupling (noise suppression demo)



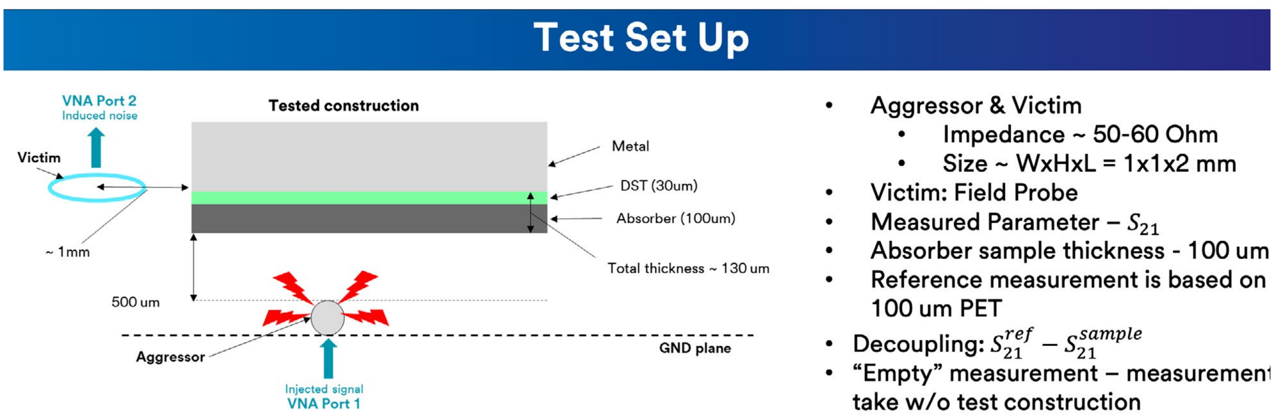


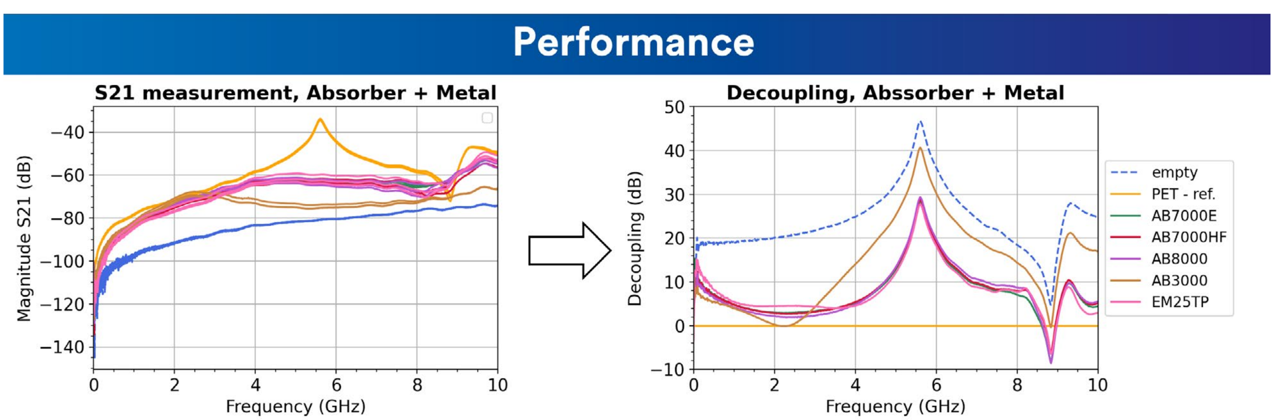
Leakage Reduction

To measure side leakage, the 3M team used a similar setup, but with a field probe at the edge of the test construction to measure how much noise the aggressor induced on the sides. As with the previous test, this test also measured noise using PET film as reference and with no test construction in place.

Using a metal lid in the test resulted in increased side leakage and resonant responses, but results showed that adding absorbers reduced side leakage and suppressed resonant peaks. The recommended absorbers for different frequencies are the same for side leakage reduction in case of aggressor victim decoupling. Side leakage can be reduced further by adding a 3M Conductive Pressure-Sensitive Adhesive (CPSA).

Figure 8: Side leakage reduction (noise suppression demo)



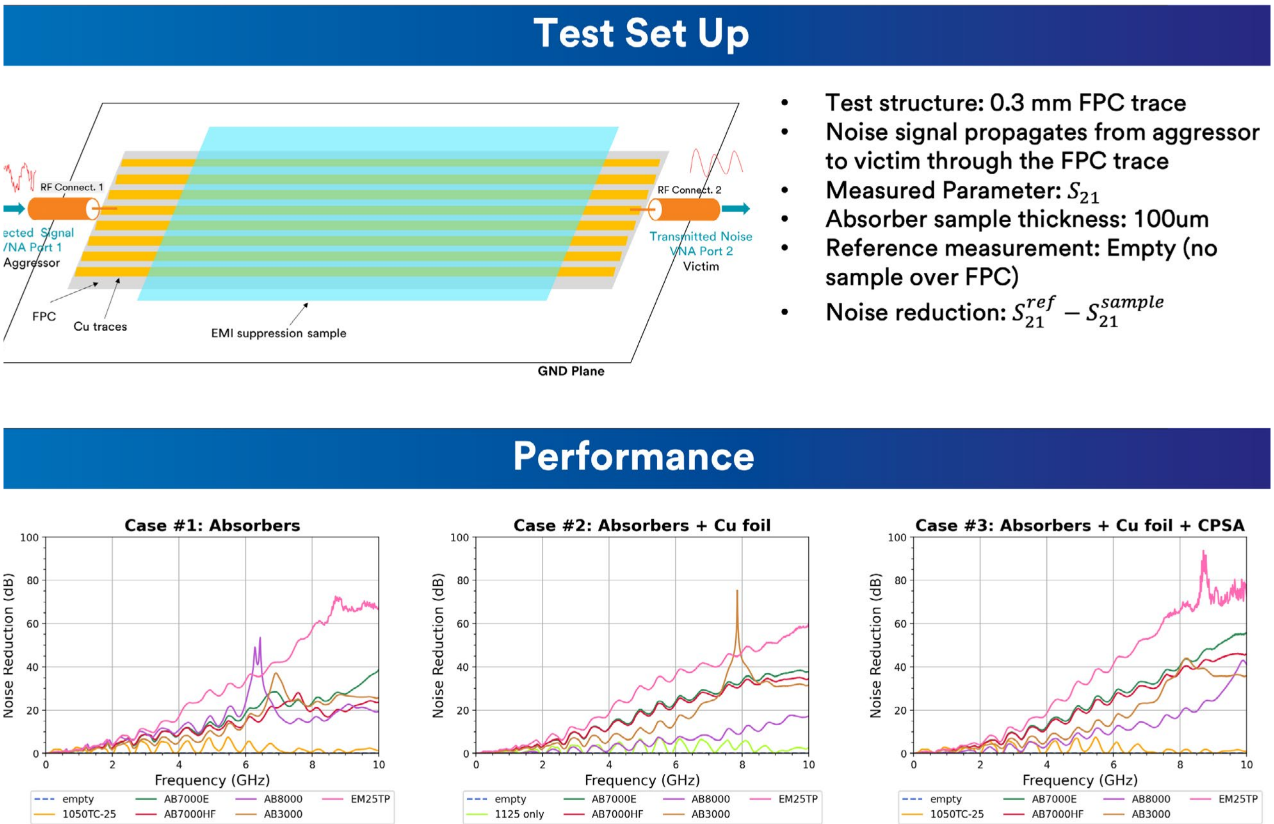


FPC/PCB over trace noise. This test was performed on a 0.3 millimeter FPC trace placed on the aluminum ground and connected to two RF signal lines (one on each side). This replicated a scenario in which signal is injected on one side and travels over the FPC to be picked up on the other side.

To suppress the high-frequency noise, an absorber was placed on top of the FPC. Two other configurations were an absorber placed with copper foil and an absorber placed with copper foil and CPSA (conductive tape).

This configuration achieved high-frequency noise suppression above 2-3 GHz, with the 3M EMI Absorber EM25TP Series performing best in reducing trace noise. The copper foil addition had no significant impact on noise.

Figure 9: FPC/PCB over trace noise (noise suppression demo)

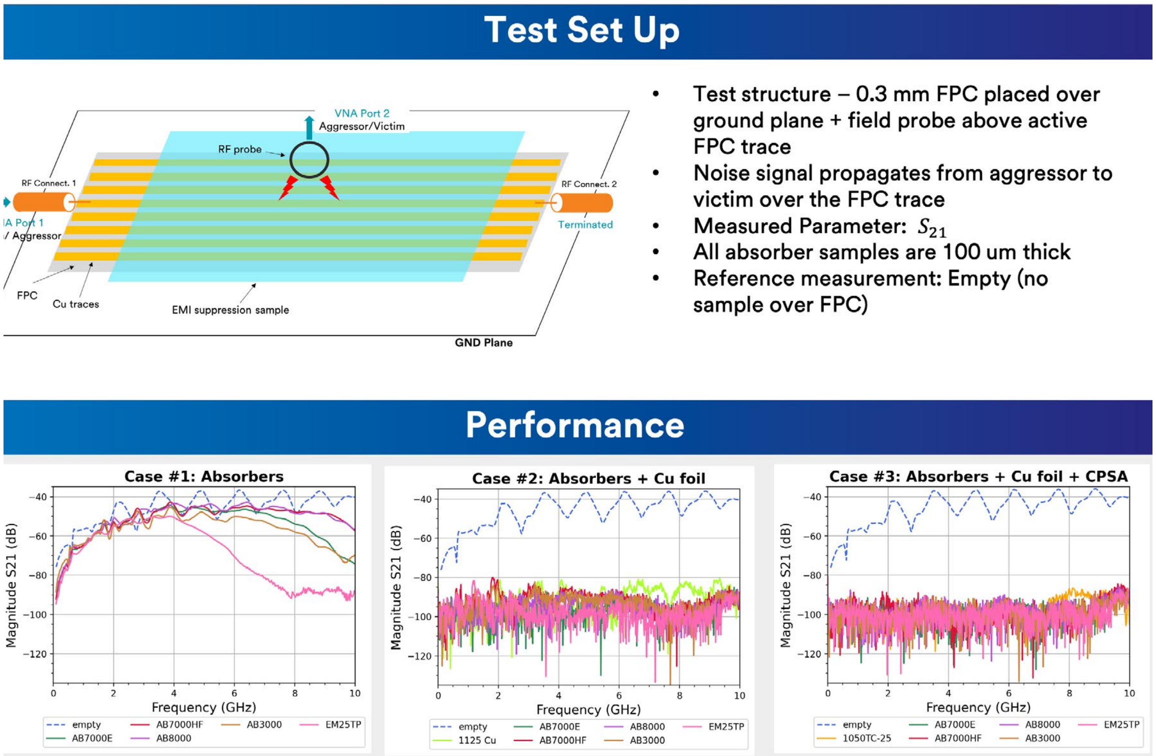


FPC/PCB above trace noise. To test designs in which there is a component near the FPC that can couple into or induce a signal into the trace—or vice versa—an RF probe was used to measure the injected signal on one side and signal transmitted into the probe.

Three configurations were tested over the trace: an absorber alone, an absorber with copper foil, and an absorber with copper foil and copper CPSA. The absorber demonstrated some noise reduction at higher frequencies, but adding the copper layer improved performance in the broad frequency range.

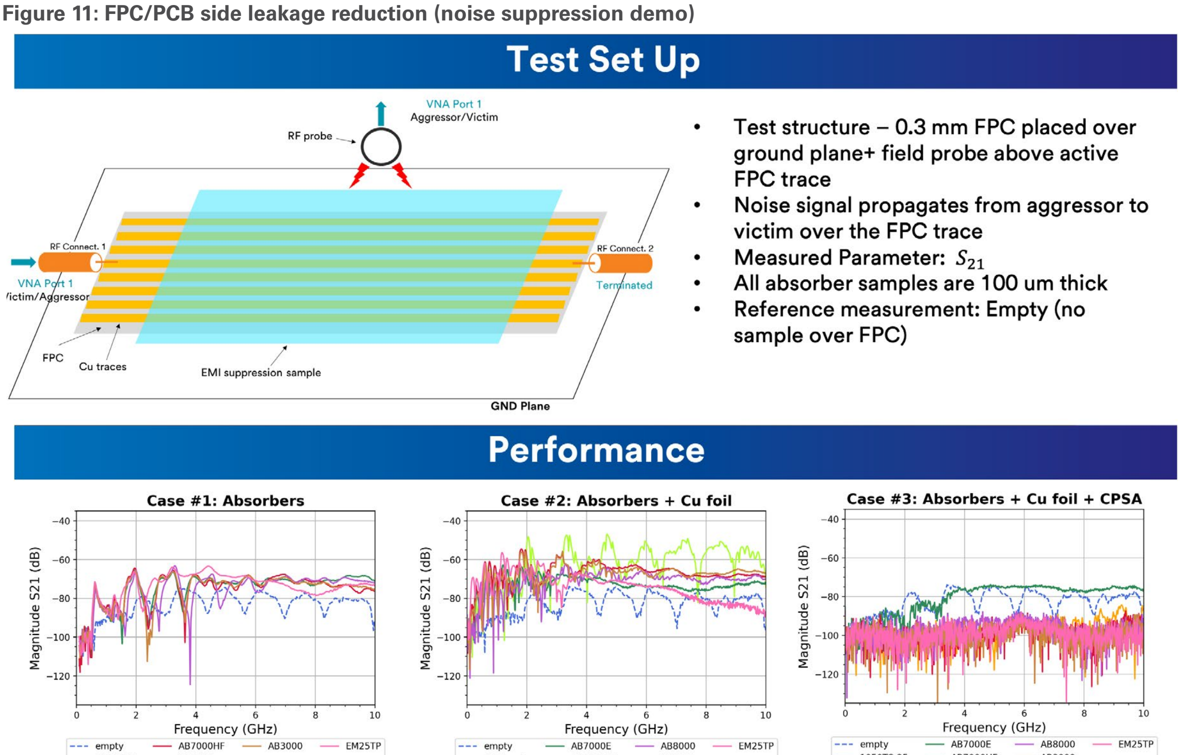
> "If you want to get rid of noise or prevent coupling of a trace to anything above it . . . consider using an absorber plus copper."
>
> *Dr. Sergei Manuilov, 3M*

Figure 10: FPC/PCB above trace noise (noise suppression demo)



FPC/PCB side leakage reduction. Finally, we are testing the impact of different construction on the signal leaking out of the sides. For that the field probe is placed over the edge of tested material construction. It is very similar to the side leakage test shown in Figure 8. In this test, using an absorber plus copper foils and CPSA to seal edges brought everything down to the noise floor. Out of the three tested configurations, this combination achieved optimal performance—reduced over the trace and above trace noise as well as side leakage.

Figure 11: FPC/PCB side leakage reduction (noise suppression demo)



Key product characteristics for selecting a 3M EMI Absorber.

3M produces a wide range of EMI suppression materials. When selecting a 3M EMI absorber for testing, there are several key characteristics to consider to make the best choice for a given application:

- **Permittivity and permeability.** Test various combinations of different materials through simulations and conduct system analysis to determine which absorbers achieve the best performance.
- Perform **attenuation and/or power loss** measurements on the microstrip line.
- Identify and account for **environmental** factors, such as temperature stability (cold and/or hot), thermocycling, and exposure to humidity/water, UV, salt mist, or fire (flammability).
- **Other** application-specific characteristics, such as mechanical (e.g., die cutting, bending), format (e.g., sheet, roll), and adhesive options.

3M's technical data sheets (TDSs) contain information on intrinsic properties, permeability, and permittivity of 3M materials, as well as power loss measurements and Transmission Attenuation Power Ratio. For Power Loss and Transmission Attenuation Power Ratio, 3M provides different thickness dependencies.

TTI and Mouser stock a wide range of 3M EMI/RFI products, ensuring fast and easy access from small sample sizes to rolls for full-scale production.

Figure 12: 3M's portfolio of EMI noise suppression products

3M Composite EMI Absorbers	
3M™ EMI Absorber & Magnetic Shielding Materials	
☆**AB3000** Absorbing frequency - 1GHz – 10GHz Magnetic shielding frequency - 300kHz –15 MHz	Absorber Acrylic adhesive (optional) Release Liner
EM25TP Absorbing frequency: 200MHz – 4GHz Magnetic shielding frequency: 100kHz –3 MHz	
3M™ EMI Absorbers	
☆**AB7000E, AB7000HF** Absorbing frequency – 800MHz – 4GHz	Absorber Acrylic adhesive (*optional) Release Liner *Only some absorbers offer both with and without adhesive.*
☆**AB8000 (high temp)** Absorbing frequency: 300MHz – 4GHz	
AB5000HF, AB5000SHF Absorbing frequency: 300MHz – 2GHz	
3M™ Hybrid Shielding Absorber	
AB6005HF (AL+PET) **AB6005SHF (PET+AL+PET)** Shielding frequency - 10MHz – 18GHz	AL-PET layer Absorber Acrylic adhesive Release liner

BIOGRAPHY

Dr. Sergei Manuilov
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Dr. Sergei Manuilov is an Advanced Product Development Specialist at 3M within the Electronic Materials Systems Division. His expertise lies in developing new material products aimed at electromagnetic interference suppression and control. His research spans across handheld electronic devices and telecom infrastructure. Over his 9-year tenure at 3M, Dr. Manuilov has successfully developed several high-impact products that have effectively addressed complex customer EMI challenges.

Dr. Manuilov earned his PhD from the Royal Institute of Technology (KTH) in Sweden. Following his doctorate, he pursued postdoctoral research at the Gwangju Institute of Technology in South Korea and later at The Ohio State University. He then embarked on his professional journey with 3M.