Pre-compliance Validation of EESeal® in Your Application

WHITEPAPER

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Pre-compliance Validation of EESeal® in Your Application

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As previous Quell EESeal® whitepapers and case studies *[Ref 1,2,3,4]* have demonstrated, the performance and benefits of a drop-in/in-connector filter cannot be overstated. These filters are extremely valuable when used to mitigate non-compliance found during EMC qualification testing or in the field.

Here, the case will be made for "pre-compliance testing" and evaluation of the EESeal® in order to elevate the chance of success of a compliance pass at the first test event. This process will also reduce the risk of discovering events while in the field. It is a compelling tool in the arsenal of the EMC engineer to persuade diversely-skilled members of the design team or organizational structure and to overcome barriers of cognitive dissonance *[Ref 5]*.

The value and process of pre-compliance testing has been well-documented in the IEEE EMC Society Annual Symposium recurring workshop "EMC Consultant's ToolKit" over the past decade *[Ref 6]*, as well as the 2020 workshop on "Basic Laboratory Measurements" *[Ref 7]*. There, one uses modest and/or Do-it-Yourself (DIY) test equipment, readily available to the typical design engineer, to gauge the system performance in non-laboratory environments.

This has been discussed in multiple industry publications as well as the personal blog and YouTube videos of Ken Wyatt, a founding member of the ToolKit workshop *[Ref 8]*. Thus here, we directly present a specific pre-compliance verification application, relying on the reader to review the references.

SPECIFYING THE EESEAL®

Emissions are a constant, critical concern. The ever-growing application of switch-mode power conversion technology as well as more efficient and higher-speed semiconductor technologies like GaN and SiC have created more challenges *[Ref 9]*. While the most cost-effective location for emissions control measures is at the switching circuit and PCB level, that has its limitations. Often, one still needs a "final filter" on the cable "antennas." The EESeal® is an excellent match for this task.

When faced with multiple cables, one may be concerned about having to filter all of them. In severe situations, that may be necessary. Luckily, as Henry Ott advises, often there is a Dominant Mechanism – or one cable *[Ref 10]*. Using the clamp-on RF current probe and spectrum analyzer, one may Pareto or Triage the cables to efficiently find a dominant emissions source. Although the RF current readings are relative to radiated signal field intensities, a worst-case estimate expression of 14 dBuA can be considered as the limit line for an FCC Class B device. That has general applicability across many equipment and industry requirements.

To specify an EESeal®, you need to provide the voltages and data rates on each pin as well as any transient requirements, and the target frequencies that need to be mitigated.

PRE-COMPLIANCE/BENCH-TOP "COLD" VERIFICATION

A pre-compliance approach can verify EESeal® filtering in-situ/unpowered in a device. The signal from a Tracking Generator excites the wires inside the Device Under Test (DUT), close to the inner side of the connector. The associated Spectrum Analyzer then measures the Common Mode RF current on external cables by a clamp-on current probe. The relative dB loss from inserting the EESeal® vs. frequency is compared to the laboratory radiated non-conformance shortfall amounts.

Alternatively, a Conducted Method forgoes the above multi-thousand dollar investment. Rather, use an affordable Nano Vector Network Analyzer (NanoVNA) *[Ref 11]* to measure transmission attenuation (S-parameter S21) before the EESeal® is inserted, then again after insertion. Although it does not directly measure the common mode current reduction, it gives a reliable 50 Ohm to 50 Ohm attenuation picture.

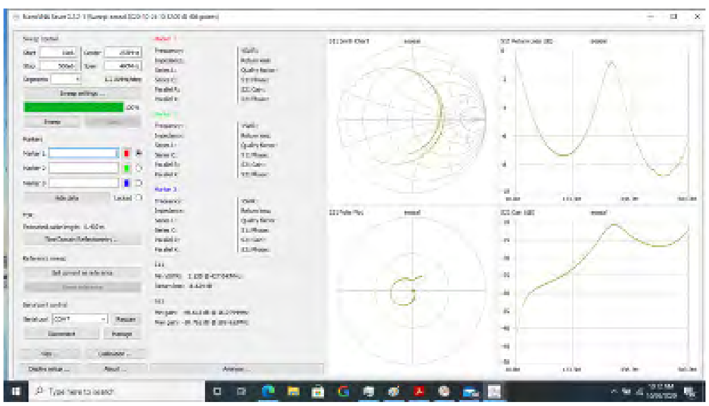
SIMPLIFIED DEMONSTRATION

Figure A shows the NanoVNA setup for S21 where a cast metal box emulates the DUT. It is fitted with a DB15 male pin connector, the typical sample supplied by Quell. The VNA Port 0 signal source is well attached to the DB15 connector pin 1 inside the shielded box by a semi-rigid coax cable whose shield is also well bonded to the box.

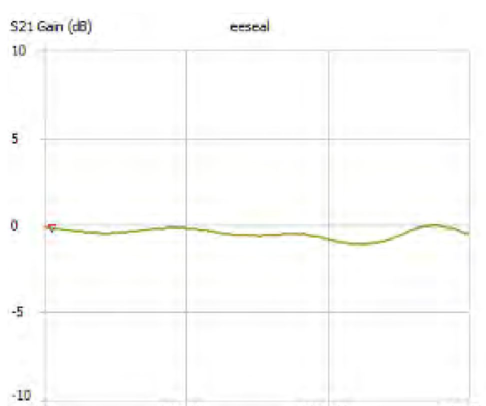
The external mating female DB15 connector pin 1 and shell is "pigtail" attached to a coaxial cable, ultimately to the NanoVNA Port 1. Additional clamp-on ferrites on the coaxial cables help assure the measurements are not corrupted by the possible parasitic return path through the NanoVNA itself. The "NanoSaver" Application on a Personal computer controls, displays, and stores instrument measurements for more detailed analysis and presentation.

Figure A : NanoVNA , Port0 to interior of pseudo or artificial DUT shielded enclosure DB15 connector pin 1, Port 1 flexible coax to removable DB15 connector. USB cable to Personal Computer running NanoSaver control Application software.

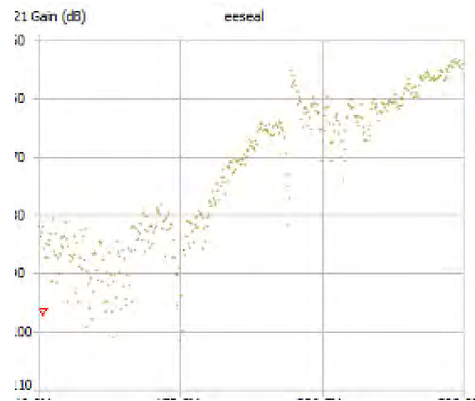
The NanoSaver Application software sets frequency range and plots S11 & S21 in polar and rectangular coordinates.



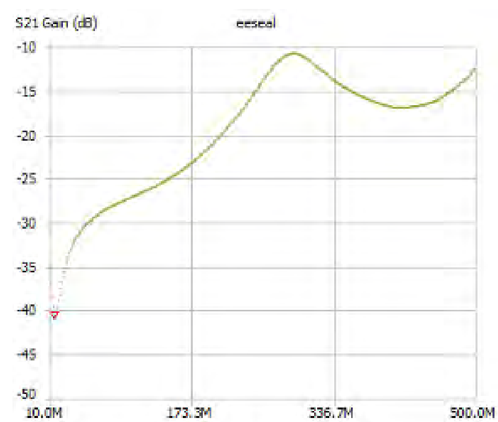
After the usual Open-Short-Load calibration of the basic VNA, the through Gain/Loss S21 with mated connectors BUT no EESeal®, verifies correct RF continuity through the fixture and connectors. Loss and variation in the 2dB range is well within acceptable boundaries.



Next, the ultimate isolation is verified by separating the mated DB15 connectors. Attenuation ranging from 100 to 55 dB is within expectations for a simple setup. It exceeds the measured attenuation by a comfortable margin.



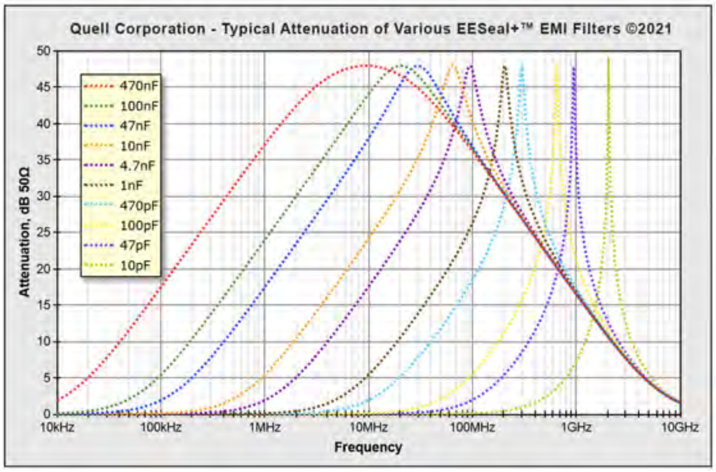
The standard EESeal® sample D-Sub-15.139 has 47 nF capacitors connected by fine spring wires to pins 1,4,8,10 and 13 and the ground shell. Only Pin 1 was evaluated. In Figure D, the resonant dip of 41 dB attenuation is acceptably close to the published typicals. The published dip at 20 MHz was measured at 14 MHz. The 13 dB attenuation at 500 MHz is close to the typical 15 dB at 600 MHz. The degraded attenuation of 11 dB near 300 MHz is likely a resonance in the coax cable “pig-tail” connection to the exterior mating connector. This is still an acceptable experimental variance from the ideal.



Next, the EESeal+™ with new conductive polymer connection system was substituted. Type DSub-15.180FC has the same 47 nF capacitance and pin population. Again, only pin 1 was evaluated. The maximum attenuation was 42 dB – having slightly higher attenuation then the standard EESeal® version. The resonant maximum attenuation dip moved up almost 2:1 higher to 24 MHz. Nominal capacitor tolerance is +/- 20 % and would not cause such a frequency shift.

Resonant frequency depends on the square root of the L-C product. Thus, all things being equal, a 4:1 capacitance change is required for a 2:1 frequency shift. So one may attribute the higher frequency to lower connection (partial) inductance from the potentially wider, thicker and multiple connections in the EESeal+™ polymer conductor system.

The ultimate attenuation is roughly the same and may be dominated by the capacitor's intrinsic Equivalent Series Resistance (ESR). One may intuit that the resistance of the EESeal+™ conductive polymer or the original's wires resistances may be similar and also much lower than the capacitor ESR. In any event, the happy outcome for the polymer EESeal+™ is 11 dB better attenuation than the original in the 300 MHz range fly-back peak and 15 dB better at 500 MHz, with a higher frequency for the maximum attenuation.



CONCLUSIONS

The EESeal® filter system can be evaluated by a pre-compliance methodology to determine its potential dB improvement in a product's cable RF Emissions. That provides a very compelling persuasive demonstration very quickly, with very low risk. An inexpensive VNA approach was demonstrated with good correlation to Quell published "Typical Attenuation".

The new EESeal+™ with polymer conductors showed approximately 10+ dB better attenuation at higher frequencies and the maximum attenuation occurs at an advantageous higher frequency compared to the existing wire interconnect technology.

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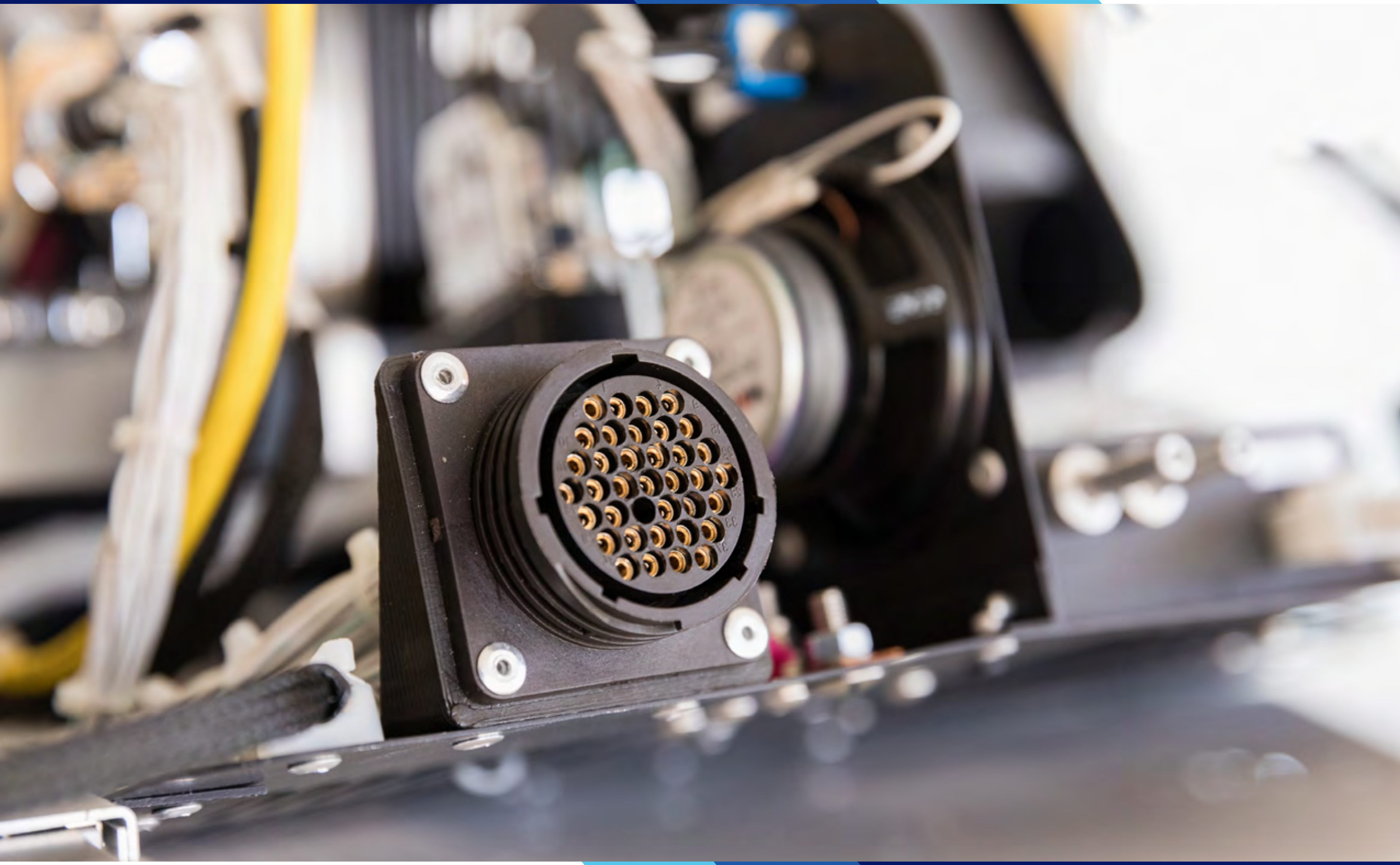

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