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From the Editor

Kenneth Wyatt

Senior Technical Editor / Interference Technology / ITEM Media
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Quoting from Heraclitus (Greek philosopher from Ephesus and influencer of Plato, 535 to 475 B.C.), “There is nothing permanent except change.” And change is in the wind for Interference Technology as many of you may have noticed. I’m excited to be a part of this change.

Interference Technology was first published in 1971 by Robert Goldblum. I started subscribing a year later and was always impressed with the technical content of what was then called Interference Technology Engineers Master (ITEM). The annual Directory and Design Guide (DDG) was a treasured keepsake among engineers and I’ve spoken with several that still have complete collections.



Pictured (L-R) Robert Goldblum, Publisher Emeritus, ITEM Media, and Kenneth Wyatt, Senior Technical Editor sharing some time at the 2016 IEEE EMC Symposium in Ottawa.

Now, we’re continuing the trend of providing industry-leading technical content to the EMC community. You may have seen Interference Technology’s new look. If not, hop on over to www.interferencetechnology.com! New logo, new website, and a load of new resources including a blog updated by some of the industry’s top thought leaders.

A new digital Wireless Interference and RFI guide was recently released (check our site) and new EMC Troubleshooting and Precompliance Testing, Medical EMC, EMC Testing, and EMC Fundamentals digital guides are soon to come. We’ll also be updating last year’s releases, including our Automotive EMC, Filters and Shielding guides. As mentioned, a lot of change!

I see a number of trends in technology that I believe will keep us EMC engineers and product designers busy for years to come. Some of the new technology

includes vehicle wireless and vehicle-to-vehicle systems, continued advances in healthcare instruments and mobile health systems, smart home and Internet of Things (IoT), mobile and wireless systems, and incorporating new instruments and techniques for faster EMI measurements.

Some of these technical advances will be highlighted in our upcoming EMC Live 2017 event, a worldwide three-day web-based series of seminars and product demos that will be hosted by Graham Kilshaw, Chief Media Officer, and myself. Last year, we had over 6000 registrations from over 70 countries. EMC Live is the largest on-line EMC conference in the world. Registration is now open at <http://emc.live>.

This year, our keynote speaker is Ransom Stevens, Ph. D., who will be presenting “The Keys To Innovation: Priming Your Brain to Percolate Brilliant Ideas”. Stevens is a scientist and technologist who has collaborated on major discoveries at international labs. He’s written articles on subjects ranging from neuroscience to quantum physics and his irreverent but accurate look at the neuroscience innovation in art and science makes these complex subjects accessible and funny.

Also new this year, Interference Technology will be broadcasting select presentations from the IEEE Symposium on EMC, live from Washington D.C., August 7 to 11. For more information and to register, go to: <http://www.emc2017online.emcss.org>. As ever, if you’re interested in contributing technical articles to Interference Technology, check out the “Contribute” link at the bottom of our web site for technical details and feel free to drop me an email with your proposal.

May the (electromagnetic) force be with you!

Cheers, Ken

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Input Filters – The Key to Successful EMC Validation

Ranjith Bramanpalli & Steffen Schulze

Würth Elektronik

Input filters are today as ever a requisite factor for successful EMC validation of switching controllers, irrespective of the size of the AC component involved. Switching controllers create conducted EMC interferences due to AC components in their lines, independent of their individual topology and application. Certain component manufacturers have therefore optimized their power modules for a low line-bound and radiated emission of interferences. These types of modules' residual ripple generally exhibits a negligibly low value, meaning that an output filter can be dispensed within most applications. Since the input current at the step-down converter is pulsating, this may generate radio-frequency interferences in the application. Depending on the specific application, the hardware developer decides whether an input filter is necessary directly before the power module or in another position in the switch. The design process of input filters for optimized power modules and the measurement techniques that are used is discussed in this article.

INTRODUCTION

As a starting point it is useful to illustrate how differential mode noises develop in the first place. Differential mode noises are interference signals in a system with a symmetrical current back and forth between the source and the load in the lines of a switching controller.

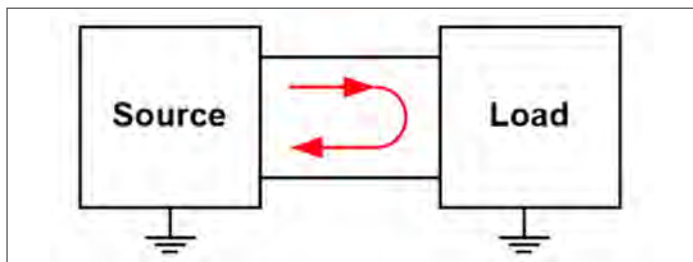


Figure 1. Symmetrical system

In the input circuit, the clock frequency of the power module includes an AC component superimposed over the useful current and is similar in its configuration to the current through the storage inductance of the power module. The input current flows into the input capacitor C_{in} . Real capacitors possess a resistive component, the ESR, and an inductive component, the ESL as shown in Figure 2.

Due to the ESR of the input capacitor and the impedances of the lines of the power module, the AC component produces an undesirable voltage drop.

In this form, the noise voltage shows up as a differential-mode signal. The amplitude of the interference voltage occurring at the input capacitor is essentially dependent on the ESR of the capacitor used. Electrolytic capacitors have a relatively high ESR, the value of which can range between just a few milliohms up to several ohms. As a consequence, the interference voltage can vary between a few millivolts up to several volts. Ceramic capacitors,

on the other hand, have a very small ESR of just a few milliohms and thus result in a noise voltage of a few millivolts. In addition, the circuit-board design of the power module exerts a great effect on the interference voltage.

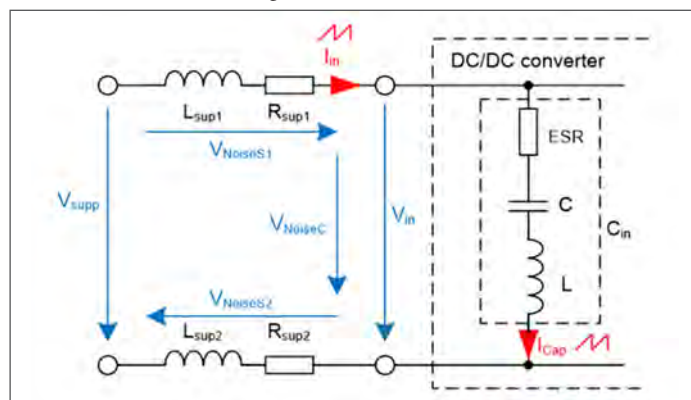


Figure 2. Development of the noise voltage

To reduce differential mode noises, at least one simple LC filter must be fitted at the input of the converter as a measure to minimize the AC component in the line. In high-impedance systems, such an input filter can theoretically produce a voltage attenuation of 40 dB/decade in the stopband. In practice, a lower degree of attenuation is achieved since the terminating impedances are low-ohm in their nature and also because the components themselves exhibit losses. In dimensioning the LC filter a corner frequency f_c is selected that is below the switching frequency f_{sw} of the power module. If the factor is one tenth, theoretically an insertion loss of 40 dB is achieved at the switching frequency at which the highest spectral amplitude occurs.

$$f_c = \frac{f_{sw}}{10} \quad (1)$$

The corner frequency of an LC filter is generally:

$$f_c = \frac{1}{2\pi \sqrt{L_f \cdot C_f}} \quad (2)$$

As an example for the calculation of the filter, an inductance of 10 μH is selected and *equation (2)* is transformed to

$$C_f = \frac{1}{(2\pi \cdot 0.1 \cdot f_{\text{sw}})^2 \cdot L_f} \quad (3)$$

In arranging the filter components, as shown in *Figure 3*, the filter capacitor can be positioned on the side of the voltage source or on the input side of the power module. The decisive factor for the attenuation of the pulsating current drawn from the voltage source is the inductance of the filter inductor.

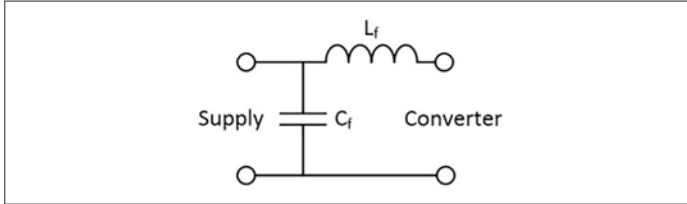


Figure 3. Arrangement of the components of the input filter

When the quality of the filter resonance is too high, oscillations may occur in the event of changes in the input voltage that must be regulated. The stability criterion that applies here is that the output impedance of the input filter $Z_{\text{out,filter}}$ within a broad frequency spectrum has to be lower than the input impedance of the power module $Z_{\text{in,converter}}$

$$|Z_{\text{out,filter}}| < |Z_{\text{in,converter}}| \quad (4)$$

In addition, the corner frequency f_c of the input filter should lie far below the crossover frequency f_{co} of the power module.

$$f_{c,\text{filter}} \ll f_{co,\text{converter}} \quad (5)$$

Figure 4 shows how this is done by placing an attenuating branch parallel to the power module input.

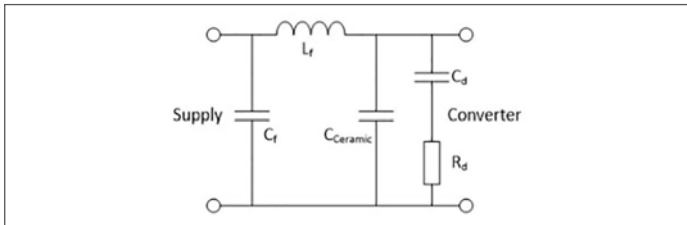


Figure 4. Attenuation of the input filter

The attenuator reduces the quality of the input filter and consequently its output impedance at the resonance frequency. *Equation (6)* can be applied to calculate the attenuation resistance R_d for a filter quality of $Q_f=1$:

$$R_d = \sqrt{\frac{L_f}{C_f}} \quad (6)$$

A value that has established itself in practice as an indicator of the capacity of the attenuation capacitor C_d is the five-to-ten-fold measure of the filter-capacitor capacitance.

$$(5 \cdot C_f) < C_d < (10 \cdot C_f) \quad (7)$$

As an alternative, the filter can be attenuated by selecting an electrolytic capacitor that is switched parallel to the filter output instead of the attenuator. As a rule, the value of the ESR of the electrolyte capacitor is sufficient to attenuate the filter.

SELECTING THE LC FILTER COMPONENTS

Both capacitors and coils show capacitive as well as inductive properties in reality. Filter inductors have their highest filter effect at their self-resonant frequency (SRF). In coils, the SRF is strongly dependent on the inductance and the capacitive coupling between the winding turns. In capacitors, the SRF is strongly dependent on the capacitance and the length of their terminations. When selecting the filter components, it is hence advisable to make sure that the SRF is at the upper end of the frequency range in which the RFI voltage is at its maximum or, respectively, in which the filter is to be active.

The decisive factor for the reduction of the differential-mode noise is the filter inductor, since this is the component that counteracts the rapid rise and drop in the current in the input circuit. *Figure 5* shows the impedance curves of three rod core chokes based on an example of the Würth Electronics WE-SD product family.

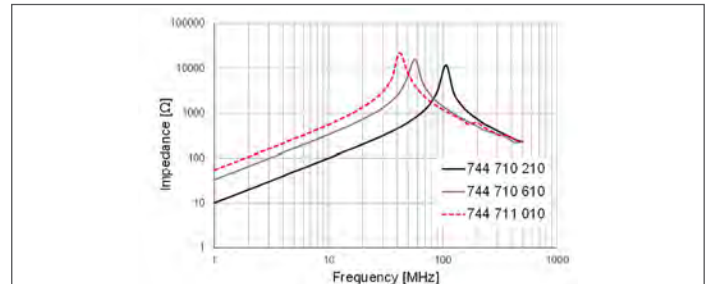


Figure 5. Example of Impedance of one manufacturer's SD rod core chokes

The higher the inductance, the smaller the SRF. It is recommended to select an inductor with an inductance whose numeric value is lower than the capacitance of the filter capacitor. In practice, a filter inductance with a maximum value of 10 μH is selected, since – depending on the design – such an inductance has a self-resonant frequency of approximately 30 MHz.

Exceeding the rated current of the filter inductor may result in damage to the wire winding. Taking the efficiency of the switching controller as a basis, it is possible to calculate the effective input current of the power module using *equation (8)*.

$$I_{\text{in}} = \frac{V_{\text{out}} \cdot I_{\text{out}}}{V_{\text{in}} \cdot \eta} \quad (8)$$

For safety reasons, a larger value should be selected as the rated current of the filter coil.

The filter capacitor may take the form of a liquid electrolyte capacitor, a polymer capacitor, or even a ceramic capacitor. The only aspect that must be considered is that the filter quality at the corner frequency is sufficiently low (see Section 4).

Further measures must be considered when dimensioning a Π filter. In the optimal case, an input filter should be placed as close as possible to the input of the power module. For the case that the input filter is placed further away due to geometric circumstances, the traces may act as an antenna between the input filter and the power module at higher frequencies. The trace inductance can, however, also be used together with a ceramic capacitor to establish an additional LC filter with a higher cut-off frequency (see *Figure 6*). Due to its negligibly low ESR, a ceramic capacitor can swiftly short-circuit

DESIGN

high-frequency voltages to ground with low impedance.

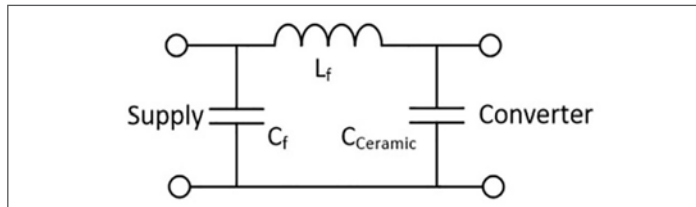


Figure 6. Π input filter

The SRF of the capacitor should roughly lie within the spectrum of the switching frequency of the power module. To illustrate this point, Figure 7 shows impedance curves of Würth Elektronik WCAP-CSGP ceramic capacitors in the 0805 size.

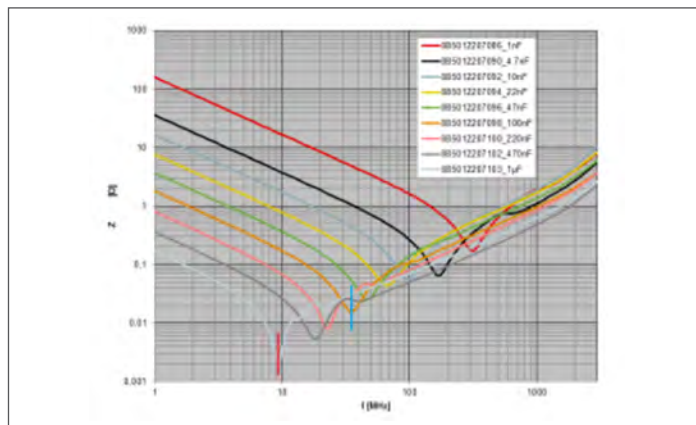


Figure 7. Impedance of ceramic capacitors

Of the components shown in Figure 7, at a clock frequency of 2 MHz, for example, a capacitor with 1 μF would be suitable (resonant frequency marked in red). Even a 100 nF ceramic capacitor (resonant frequency marked in blue), which is used as a blocking capacitor in numerous electronic circuits, would be a suitable candidate at these values; it should be mentioned, however, that compared with the 1 μF version the 100 nF capacitor has an ESR higher by a factor of nine.

DIMENSIONING AN OUTPUT FILTER

Some power modules on the market, such as Würth Elektronik MagI³C power modules, exhibit a negligibly low residual ripple at the output, which is why an output filter is not absolutely necessary. For the case that components supplied by the switching controller decouple interference signals via interfaces (e.g. sensor switches, analog switching circuits), it may be necessary to include an output filter to filter the output voltage.

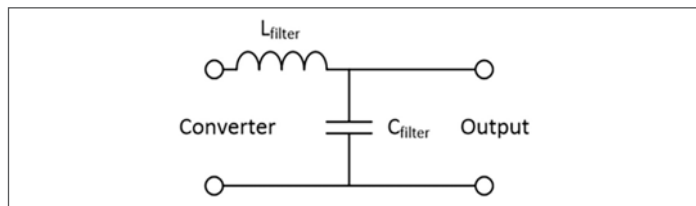


Figure 8. Output filter

The circuit schematic shown in Figure 6 images an output filter as an option comparable to that shown here in Figure 8. It is not generally possible to make a definitive statement on the necessity for

and effectiveness of such an output filter, since this must be dimensioned individually for each specific application. It may be possible to use an output filter to reduce the residual ripple of the power module to an absolute minimum, or otherwise to suppress undesirable subharmonic oscillations. The filter can be dimensioned as already described above in Section 3. Attenuation of the filter resonance is not necessary in this case.

MEASURING THE NOISE VOLTAGE

The noise voltage is measured according to the basic standard IEC CISPR 16-2-1, which describes the types of the interference variables to be measured, the equipment to be used for the various interfaces, and the measurement set-up for table-top and floor-standing devices. The interferences are evaluated in the frequency range from 9 kHz to 30 MHz. The measuring devices include besides the EMI receiver a variety of line impedance stabilizing networks (LISNs), voltage probes, current clamps and capacitive couplers. In a measurement set-up for table-top devices, as shown in Figure 9, the test object (DUT, "device under test") is positioned on a non-conductive table standing on a ground reference plane. The table should be 40 cm in height. In the case that a vertical ground reference plane is also present, the table should be at least 80 cm in height. The LISN must be connected to the ground plane ensuring good conductivity. The DUT itself and any attached cables are to be arranged so that they are 40 cm distant from the ground plane.

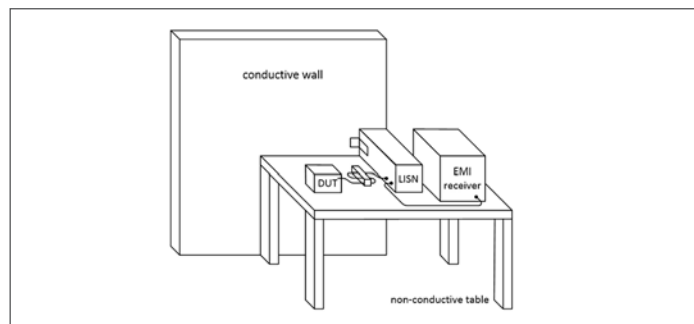


Figure 9. Test set-up for measuring conducted interferences on power-supply lines

The length of the cable between the DUT and the LISN should not exceed 80 cm. The EMI receiver evaluates the asymmetric noise voltage that is decoupled at the LISN for the separate leads of the cable.

MEASURING THE RADIATED NOISE

The method for measuring the radiated noise above 30 MHz is described in the IEC CISPR16-2-3 basic standard. The measurement environment is generally in the form of an anechoic room with a conductive floor or, at a smaller scale, an anechoic chamber. Here, too, the DUT is positioned on a non-conductive table (for portable or table-top devices, see Figure 10) or on the floor. To enable the DUT to revolve on its own axis in its default state during the measurement, it is placed on a turntable. In larger anechoic rooms, the receiving antenna is placed at a distance of 10 m from the DUT and adjusted in its height during the measurement to find the maximum electric field strength at each measurement frequency (peak spectrum). In addition, the orientation of the antenna is altered (horizontal and vertical polarization). In smaller anechoic chambers, the distance between antenna and DUT should be 3 m; since the antenna height needs to be fixed, the height scan is omitted and

the floor between the antenna and the DUT must be covered with absorbing material.

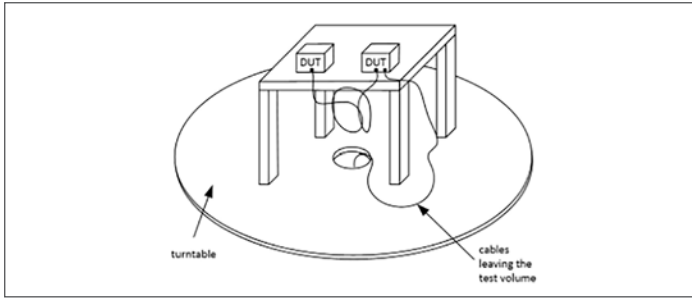


Figure 10. Test set-up for measuring the radiated noise in anechoic rooms or chambers

CASE STUDY - MEASURED NOISE VOLTAGE

The following section describes the measurement of the noise voltage using a Würth Elektronik MagI³C power module evaluation board fitted with a Variable Step Down Regulator Module (171 020 601) as an example.

Already during the preliminary phase it is possible to measure the AC component at the power module's input using an oscilloscope. By running an analysis within the time domain, the anticipated interference spectrum can be estimated at the start of the work on the design of the filter.

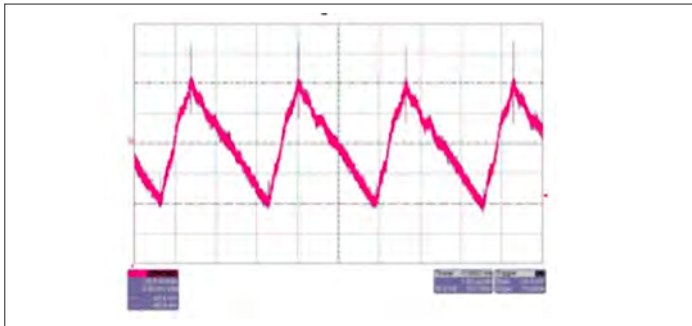


Figure 11. Time-domain signal with a broadband spectral content

Figure 11 shows an AC component of 80 mV, measured at an input voltage of the power module of 7.5 V, an average input current of 1.2 A, and an average load current of 2 A. Switching controllers have the property to show up as a negative differential resistance from the viewpoint of the power supply. The input current rises with decreasing input voltage. For this reason, the noise voltage is measured under "worst case" conditions – minimum input voltage, maximum current.

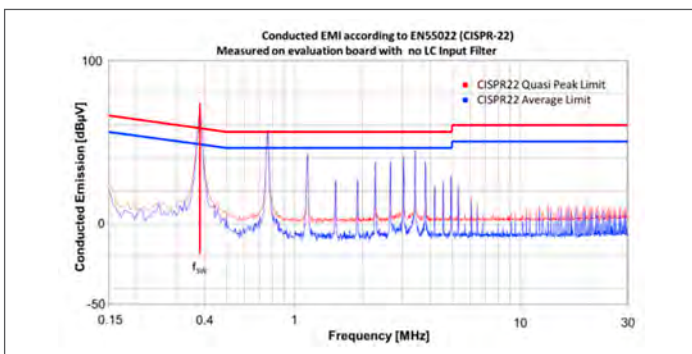


Figure 12. Noise voltage without an input filter

The decisive factor in the analysis of this type of noise emission, however, remains the measurement of noise voltage as can be performed in an EMC laboratory. Figure 12 shows the result of a noise voltage measurement without an input filter.

This power module operates at a clock frequency of 370 kHz. In the interference spectrum, the highest amplitude (red peak: 68 dBμV) can be measured at this frequency. The amplitude density of the noise voltage drops at a rate of approx. 40 dB/decade, meaning that no significant interference level can be seen above the 15th harmonic. Nevertheless, it is only above the 9th harmonic that the interference level is more than 10 dB below the limit for the average detector (dark blue line).

Equation (3) from Section 3 can now be used to calculate a suitable LC input filter. Due to the relatively low switching frequency, an inductor with a low SRF and an inductance of 4.7 μH is selected and the filter capacitance is calculated.

$$C_1 = \frac{1}{(2\pi \cdot 0.1 \cdot 370 \text{ kHz})^2 \cdot 4.7 \mu\text{H}} = 3.9 \mu\text{F} \quad (9)$$

The selected filter capacitor is the one with a little higher capacitance of 10 μF. The maximum input current is calculated using equation (8) from Section 3.

This calculation requires the efficiency of the evaluation board, which is determined by measurement and in this case has a value of 91%

$$I_{in} = \frac{5 \text{ V} \cdot 2 \text{ A}}{6 \text{ V} \cdot 0.91} = 1.83 \text{ A} \quad (10)$$

On the basis of the calculations of the filter inductance and input current, it is now possible to select an appropriate inductor. Picked for the purpose is an unshielded inductor from the Würth Elektronik PD2 series, size 5820. Figure 13 shows the result of the noise voltage measurement with the matched filter.

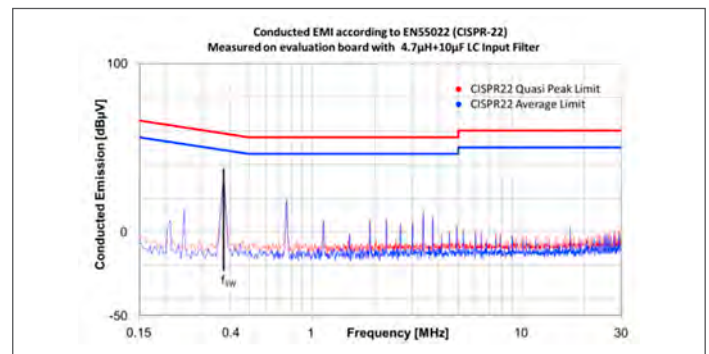


Figure 13. Noise voltage with an input filter

The interference level measured at the 370 kHz switching frequency has a value of 30 dBμV. The levels of all harmonics are lower than 20 dBμV and are thus sufficiently attenuated. The average level at 370 kHz corresponds to the peak level and is 18 dB lower than the average limit of 47 dBμV. In measuring such conducted interferences in the practical context, a signal-to-noise ratio of this dimension is entirely sufficient in order to confirm the conformity of this measurement.

The purpose of the measurement of the noise voltage is to demonstrate the usefulness of an analysis of the interference potential in

DESIGN

the time domain; though an analysis in the frequency domain is still indispensable.

Finally, the equations from Section 3 can be used to calculate an attenuating resistance.

$$R_d = \sqrt{\frac{4.7 \mu\text{H}}{10 \mu\text{F}}} = 0.686 \Omega \quad (11)$$

The higher the value of the attenuation resistance, the higher the attenuation of the filter resonance. In this case, the next higher resistance of the E12 series of 1Ω can be selected.

A value of $47 \mu\text{F}$ is selected for the attenuation capacitor. This may be, for example, a Würth Elektronik eiCap ceramic capacitor of the WCAP-CSGP series.

MEASURING ACCORDING TO IEC CISPR 22

The above measurements were performed according to the IEC CISPR16-2-1 standard, as described in Section 8. The use of a LISN enabled the asymmetric voltage to be decoupled and equated to the asymmetric (common-mode) voltage, which was then compared to the limit, taken from the IEC CISPR 22 standard for devices for private and commercial use (Class B). For power-supply components –

and this includes all types of switching controllers – there is no directly applicable EMC standard. The entire application in which the switching controller is used must be assigned to a specific category of devices and then tested according to the corresponding standard applicable for the product or product family. In this case, the product-family standard IEC CISPR 22 for IT installations was taken only with reference to the limits, which are also given in the IEC 61000-6-3 generic standard. The generic standards can be used in cases for which there is no specific standard for the device in question.

SUMMARY

Irrespective of the size of the AC component involved, an input filter is today as ever a requisite factor for a successful EMC validation of a switching controller. Simple-to-apply equations can be used to calculate such an input filter on an individual basis. Taking the impedances of the filter and the switching controller into account in the equations, this enables oscillations to be avoided and also ensures the control stability of the switching controller itself. A targeted selection of the filter components lays the foundations for an optimal design of the filter. Equipped with an appropriate degree of technical skill in EMC testing methods, the hardware developer can design his switch purposefully and, wherever necessary, make any adjustments to the filter himself.



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Choosing and Using Silicon Protection Devices

Dave Rose

Correctly choosing an external (off chip) Transient Voltage Suppressor (TVS) is not as simple as it once was. Integrated Circuit (IC) feature size is shrinking (Figure 1) and more and more inputs are being exposed to the outside world. Portable consumer devices are everywhere and have more functions in smaller and smaller sizes, necessitating smaller and smaller TVS packaging. At the same time, the demand for bandwidth is sky-rocketing, as witnessed by three popular technologies: Ethernet, HDMI and USB (Figure 2).

SYSTEM LEVEL CONSIDERATIONS

Failure Levels of Unprotected Inputs

The first constraint to be considered is the failure level of the input to be protected. Hopefully, this will be known based on Transmission Line Pulse (TLP) or Human Body Model (HBM) testing, but this is often not the case. If it is not known, and cannot be measured, a reasonable estimate must be made.

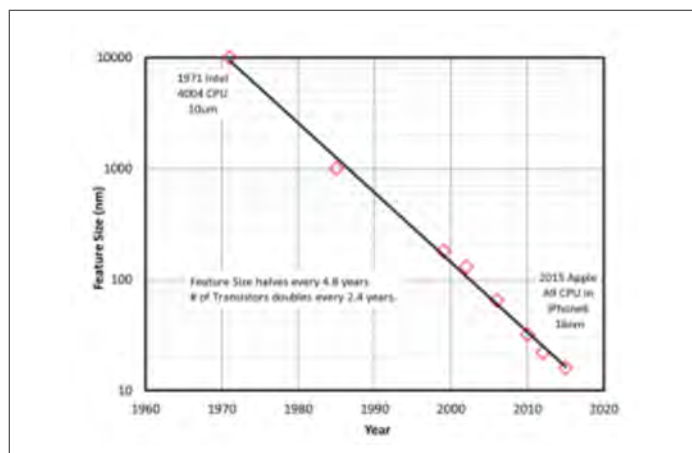


Figure 1: Process Node Trends

Symbol Rate

The symbol rate of the application must be known. This is not always the same as the bit rate. For complex modulation schemes, the number of bits per symbol can be much larger than one. In some simple modulation schemes the number of bits per symbol can be less than one. Typically, the analog bandwidth required for a digital signal is between half the symbol rate and the sym-

bol rate. For example, if a digital protocol requires a symbol rate of 5Gsymbols/s, then the analog bandwidth required is between 2.5GHz and 5GHz depending on channel noise and other factors.

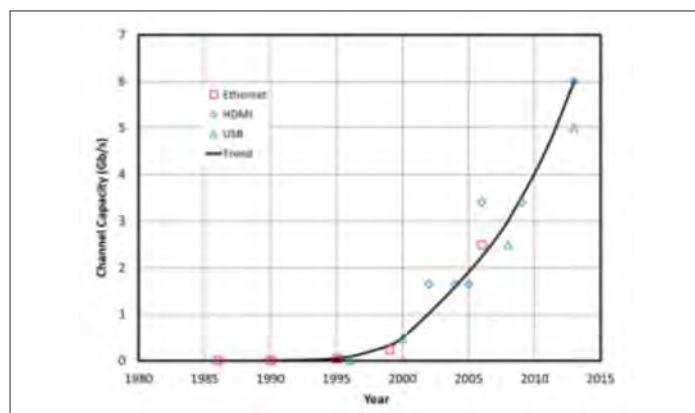


Figure 2: Channel Capacity Trends

System Protection Level Requirements

The requirements for system level protection must be known and understood. There is a huge difference between a person shuffling across a carpet with a smart phone and a 10G Ethernet Inter-Building Cable subjected to a near lightning strike. There are standards available for all likely Electrostatic Discharge (ESD) and surge threats; these should be used along with applicable protection device datasheets to determine a good protection scheme.

PROTECTION DEVICE CONSIDERATIONS

Insertion Loss

Any device added to a communication channel will introduce extra signal losses in that channel. These losses are caused by the

parasitics of the added device. Often, only the capacitance is considered, but especially for low capacitance devices, the stray inductance has a very large effect. Figure 3 shows a comparison between a measured part, a full model simulation for the part, and a simulation using only the part's junction capacitance. It is quite apparent that there is a large difference even well below the -1dB point.

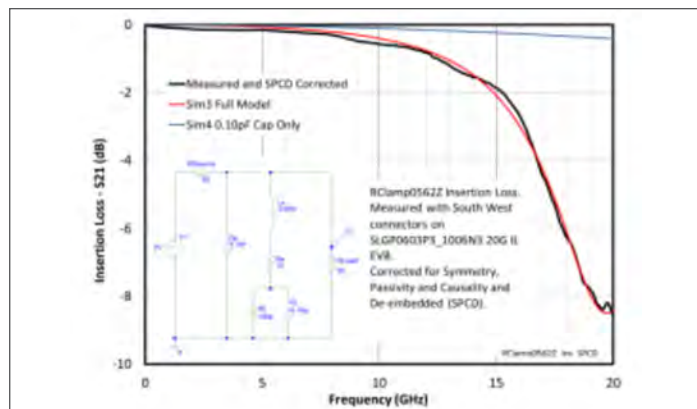


Figure 3: Insertion Loss Comparison

Using Silicon TVS Diodes

Silicon TVS diodes have been used for many years as protection devices. They consist of one or more TVS diodes and possibly one or more steering diodes. Capacitance can cover two orders of magnitude or more; there really is no typical, nor a typical reduction magnitude. The steering diodes are used to reduce capacitance and, in a bridge configuration, allow a uni-directional TVS to symmetrically clamp in a bi-directional fashion.

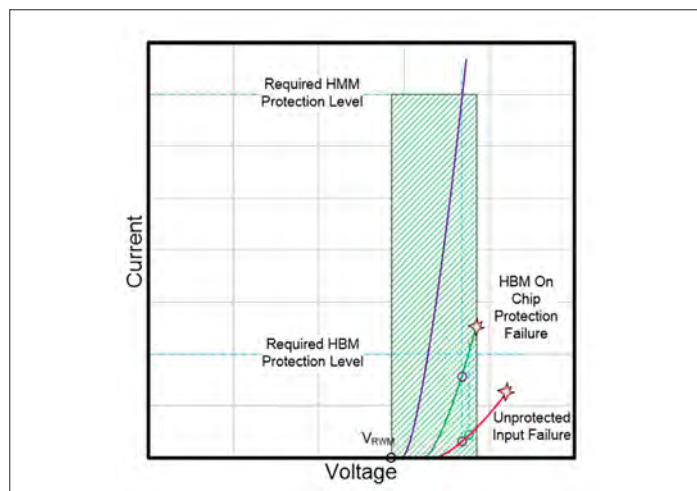


Figure 4: Zener Type Protection

The TLP characteristic of the TVS protection device must include very low leakage at the maximum port voltage (V_{RWM}) and the clamping voltage at the Required Human Metal Model (HMM) protection level must be lower than the Human Body Model (HBM) on-chip protection Failure Voltage, as shown in Figure 4. With increasing frequencies and decreasing on-chip protection levels, it has become more difficult to satisfy both of these criteria while still meeting insertion loss, size and cost requirements.

Using Snap-Back Devices

Snap-back devices can either be of the shallow snap-back or

deep snap-back types. An example of a Shallow Snap-Back device would be a Bipolar Transistor (BJT) especially designed for enhanced collector-emitter punch-through breakdown. These devices exhibit low capacitance for their protection levels and are very good for protection in the 1.5V to 4V working range. Deep snap-back devices are typically a 4-layer PNP SCR type structure. A much larger "window" is available for the external protection device Figure 5.

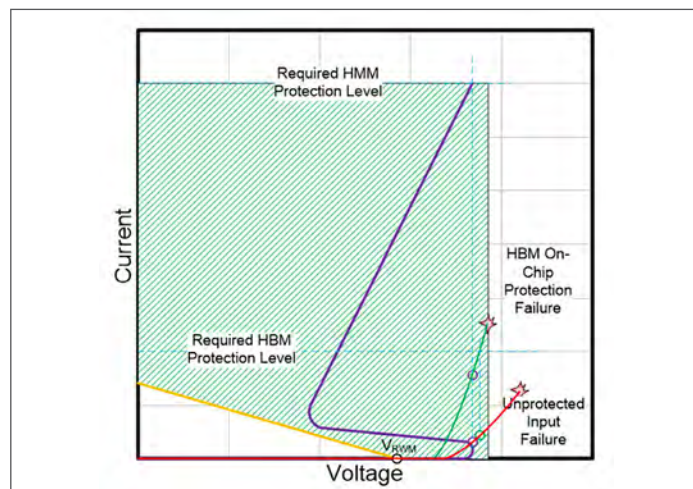


Figure 5: Snap-Back Protection

Avoiding Latch-Up

The major concern for snap-back protection is the avoidance of latch-up. Latch-up can occur if the protection device enters its snap-back region and sufficient DC current is sourced into the protected line to hold it there. Most typically, this occurs due to pull up resistors on the signal line.

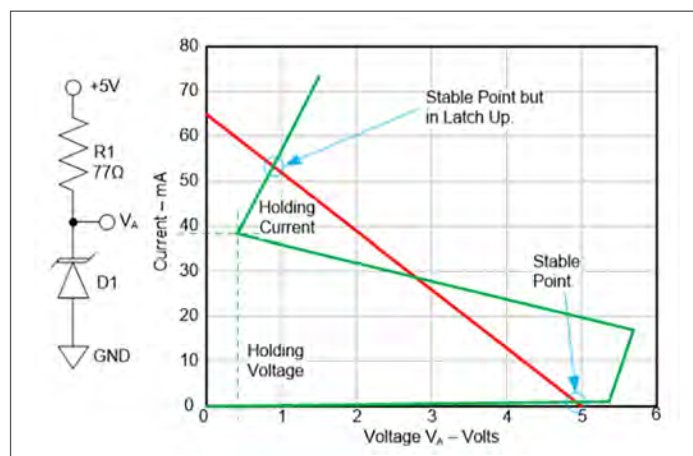


Figure 6: Snap-Back and Load Line

Figure 6 shows an illustration of the problem. The red line is the locus of the operating points of the resistor R1, note that the X-axis is V_A – the voltage at the node where the resistor and protection device connect. The green line is the locus of the operating points of the protection device. There are three points where the loci coincide: The first is just below 5V before the protection device turns on and is the normal maximum operating point; the second is at about 2.8V, but is unstable since the total resistance is negative; and the final point is at slightly less than 1V and is the latch-up point.

DESIGN

When a transient event occurs, a high current pulse will flow through the protection device, as the transient fades, the current in the protection device will fall until it reaches the latch up point and will not be able to fall any further. The input will be latched up and will be unresponsive to normal signals. The only way to get out of latch-up is to momentarily pull the VA node low or to cycle system power.

Latch-up can be avoided with proper design. All that needs to be done is to ensure the second and third crossing points do not exist by careful selection of either pull-up resistor or the protection devices holding current and voltage.

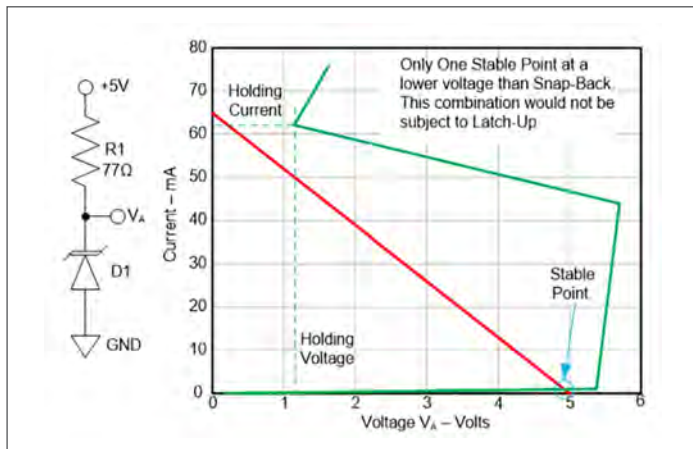


Figure 7: Avoiding Latch-Up

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OTHER CONSIDERATIONS

Board Layout

The best protection device in the world will not be able to do its job properly if the board layout is not optimum. Guidelines for proper board layout include:

1. Protect at the system input, i.e. generally, the protection device should be as close as possible to the connector where any transient event might be injected.
2. Use Kelvin like connections to avoid adding spikes due to parasitic inductance (Figure 8).

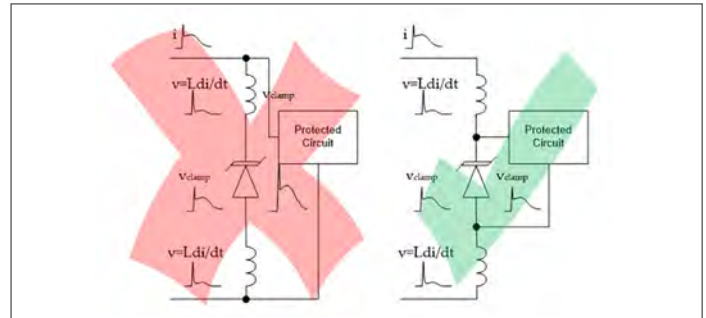


Figure 8: Minimizing parasitic inductance effects

3. Minimize any opportunities for coupling. Avoid routing the protected circuitry close to the protection circuitry. Take care with ground planes to ensure return currents are properly controlled. Minimize loop areas to minimize radiation, pickup and inductance, a good practice in any case.

Multi-Line Protection

Multi-line protection packages are becoming more popular and are generally tailored for a particular application. Of course, the packages are larger and generally have slightly higher inductance than an equivalent single line package. Make sure that this extra inductance will not be detrimental in the intended application. The insertion loss curves in the part datasheet will be helpful here. If possible, the signal lines should be made to "flow through" without major directional changes to help maintain proper signal integrity.

SUMMARY

By using a systematic approach, it is relatively straightforward to choose an optimum protection device for a given application by using knowledge of the system and the detailed protection requirements. In most cases, the application is well known and the protection device manufacturer will have a sub-set of their devices already chosen for the application. This will be a good starting point for protection device selection.

REFERENCES

1. Digital Communications, Andy Bateman, Addison-Wesley 1998, ISBN 0-201-34301-0.
2. Signal and Power Integrity – Simplified 2nd Ed, Eric Bogatin, Prentice Hall. 2010, ISBN 0-13-234979-5.
3. Snap-Back TVS and Load Line Analysis. Dave Rose, Semtech Internal Presentation.
4. TVS35-TVS Technology Theory and Comparison; SCR vs. EPD vs. TVS Diodes. Dave Rose, Semtech Internal App Note.



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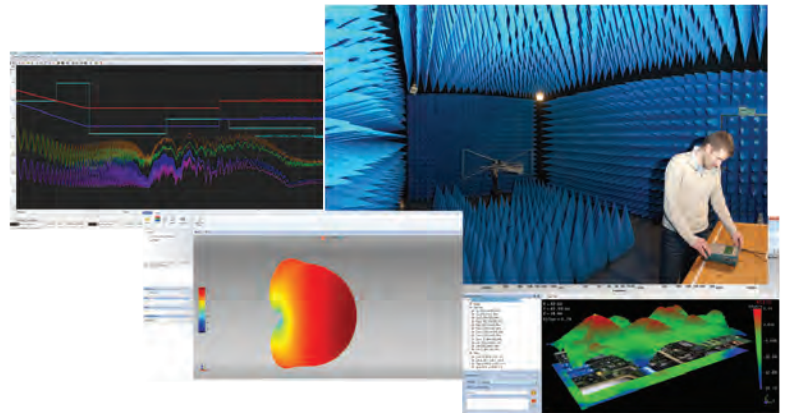
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Selecting the Proper EMI Filter Circuit For Military and Defense Applications

David Stanis

WEMS Electronics, ret.

For questions, contact Mike MacBrair, mmacbrair@wems.com

Insertion loss, the term used to express a filter's ability to reduce or attenuate unwanted signals, has traditionally been measured in a 50 ohm source and 50 ohm load impedance condition, as standardized in MIL-STD-220.

In this matched 50 ohm impedance condition, various types of filter circuit configurations, single capacitor, "L's", "PI's", and "T's", will exhibit the same response for that given circuit regardless of the relationship between the input, output, and RF signal source.

MIL-STD-220 insertion loss tests are well defined, universal, and are excellent for monitoring filter manufacturing consistencies. However, the results can be misleading when it comes to selecting the proper filter circuit that must function in a complex impedance setting.

INTRODUCTION

Passive inductive and capacitive filters are impedance sensitive devices by nature and therefore source and load conditions must be taken into consideration when selecting a filter circuit.

This is particularly true, and becomes more pronounced, when you consider that most EMI line filters are not matched filter networks. That is to say the ideal design value of the individual components that make up the network have been modified, or intentionally mismatched, in order to accommodate operating line voltages, operating line currents, and reasonable packaging schemes.

In most cases the ideal inductor for a given response has been greatly reduced in value to accommodate the operating current and reduce the DCR; therefore the capacitors have to be increased in value to achieve the required insertion loss.

This intentional mismatch, which is widely practiced throughout the industry, only affects the very low frequencies by introducing ripple in the pass-band and has little, if any, negative effect in the reject band.

CIRCUIT CONFIGURATION

EMI line filters are passive devices and their effect are bidirectional. They are all low-pass brute force networks, passing DC and power line frequencies with very low losses while attenuating the unwanted signals at higher frequencies.

They do not differentiate between EMI generated inside or outside the subsystem or system. They are equally effective in reducing EMI emissions as well as protecting a device from unwanted EMI entering via the power lines.

Each additional element improves the slope of the insertion loss

curve. That is, the reject-band will be reached must faster with each section, or element, added. Increasing or decreasing the individual elements values does not change the slope of the curve but does affect the cutoff frequency.

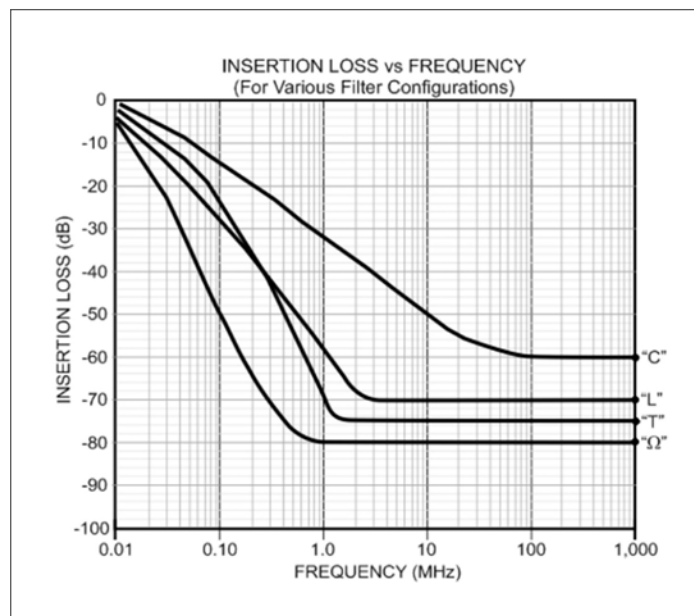


Figure 1. Insertion Loss vs Frequency Curves

More importantly, when the source and load impedance of the circuit changes, the slope of the insertion loss curve also changes. A "PI" circuit type filter, for example, is best suited when the source and load impedances are of similar values and relatively high. As these impedances become lower, the insertion loss for the "PI" filter also becomes lower. The reverse is true for "T" circuits.

If the circuit impedances varies with frequency, as most circuits do, then it is advantageous to use multiple element filters such as a "PI" or "T" circuit. In the case of a "PI" circuit that exhibits

maximum or load impedance is reduced the filter still has two active elements. For all practical purposes it becomes an “L” circuit. Additionally, the amount of filtering achievable is limited by the inductance (ESL) and resistance (ESR) in the capacitor and the parasitic capacitance in the inductors. The results are that the insertion loss curves “levels off” at approximately 80 to 90 dB.

The following is a brief description of the most popular types of EMI Filter circuits and their application. It should be pointed out that these are only general guidelines due to the fact that most impedance conditions and EMI profiles are dynamic, complex, and change with frequency.

- **Feedthrough Capacitor** – A single element shunt feedthrough capacitor has attenuation characteristics that increases at a rate of 20 dB per decade (10 dB at 10 kHz, 30 dB at 100 kHz). A feedthrough capacitor filter is usually the best choice for filtering lines that exhibit very high source and load impedances.
- **L-Circuit Filter** – A two element network consisting of a series inductive component connected to a shunt feedthrough capacitor. This type of filter network has attenuation characteristics that increases at a rate of 40 dB per decade (20 dB at 100 kHz, 60 dB at 1MHz). An “L” circuit filter is best suited for filtering lines when the source and load impedances exhibit large differences. For most applications this type of network provides the greatest performance when the inductor is facing the lower of the two impedances.
- **PI-Circuit Filter** – This is a three element filter consisting of two shunt feedthrough capacitors with a series inductive component connected between them. This three element filter has attenuation characteristics that increases at a rate of 60 dB per decade (20 dB at 15 kHz, 80 dB at 150 kHz). A “PI” circuit filter is usually the best choice when high levels of attenuation are required and when the source and load impedances are of similar values and relatively high.
- **T-Circuit Filter** – This also is a three element filter consisting of two inductive components with a single shunt feedthrough capacitors connected between them. Like the “PI” circuit filter, this device has attenuation characteristics that also increase at a rate of 60 dB per decade (20 dB at 15 kHz, 80 dB at 150 kHz). A “T” circuit filter is the best choice when high levels of attenuation are required and when the source and load impedances are of similar values and relatively low.
- **Double Circuits** – Double “L’s,” double “PI’s,” and double “T’s” consisting of four and five elements are best suited when extremely high levels of attenuation are required. Double “L’s” have a theoretical attenuation of 80 dB per decade, while double “PI’s” and double “T’s” have a theoretical attenuation of 100 dB per decade. The source and load impedance conditions that apply to the single circuit devices apply to the double circuit filters.

The following table summarizes the various source and load impedance settings and the proper filter circuit for that condition.

Table 1

High Impedance	Circuit	Load Impedance
High	“C”	High
Low*	“L”	High
High	“L”	Low*
High	“Pi”	High
Low	“T”	Low
High / Low	“Double”	High / Low

*The inductor facing the lower of the two impedances

MISMATCHING

As previously stated, most EMI line filters are intentionally mismatched for ease in manufacturing. A typical example of this industry wide practice is a cylindrical style filter.

The military specifications for this particular filter are:

Operating Voltage: 70 VDC

Operating Current: 5 ADC

Circuit Configuration: “PI”

DC Resistance: .015 ohms maximum

Case Diameter: .410 inches maximum

Full Load Insertion Loss per MIL-STD-220 (50 ohms):

150 kHz	300 kHz	1 MHz	10 MHz	100 MHz
16 dB	38 dB	75 dB	80 dB	80 dB

Based on a source and load impedance of 50 ohms, MIL-STD-220, a properly designed Butterworth filter (a filter network that has a maximum flat pass-band with average cutoff frequency to reject-band ratio), would produce the following element values in order to satisfy the minimum insertion loss requirements:

$$C_1 = .0769 \mu\text{fd}$$

$$L_2 = 385 \mu\text{Hy}$$

$$C_3 = .0769 \mu\text{fd}$$

The theoretical MIL-STD-220 insertion for a “PI” filter of these values is as indicated below:

150 kHz	300 kHz	1 MHz	10 MHz	100 MHz
33 dB	51 dB	83 dB	>100 dB	>100 dB

The capacitance values for C1 and C3, .0769 μfd , are acceptable for a 70 VDC rated filter and are easily manufactured. However, L2 must be 385 μHy in order to satisfy the insertion loss requirements.

DESIGN

In order to achieve 385 μH at 5 ADC, allow for core saturation (the change in incremental permeability of the core material with DC bias), and comply with the .015 DC resistance requirement, the diameter of the inductor would be in excess of 2.0 inches. This inductor would obviously not fit a case with an outside diameter of .410 inches.

By simply reducing the inductor to a realistic value and increasing the value of C1 and C3, we can achieve the required insertion loss in the reject-band with a design that can easily be manufactured. The typical values for this application would be:

$$C_1 = .70 \mu\text{fd}$$

$$L_2 = 5 \mu\text{Hy}$$

$$C_3 = .7 \mu\text{fd}$$

The theoretical MIL-STD-220 insertion for this modified filter is:

150 kHz	300 kHz	1 MHz	10 MHz	100 MHz
25 dB	50 dB	83 dB	>100 dB	>100 dB

As previously stated, this practice of intentionally mismatching the element values will introduce a substantial amount of ripple, as much as 10 to 20 dB, in the pass-band. However, at frequencies below 1 KHz, the response is normally flat to within ± 1 dB.

Figure 2 depicts the MIL-STD-220 insertion loss characteristics for the ideal filter network and the modified design as compared to the specification requirements.

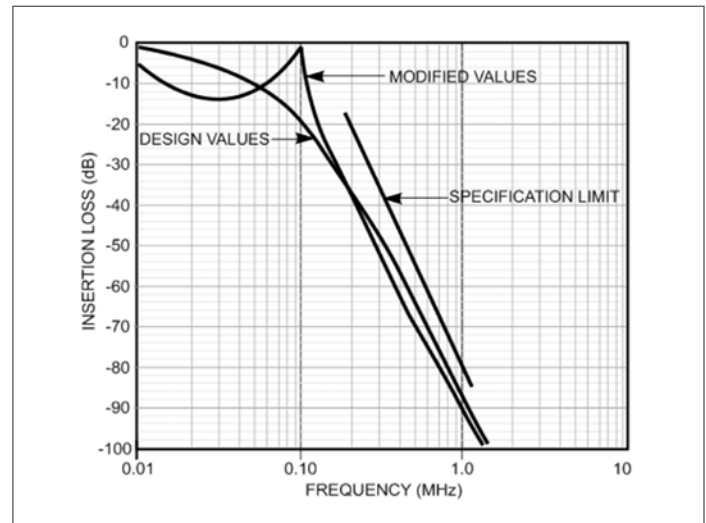


Figure 2. MIL-STD-220 insertion loss characteristics for ideal filter network and modified design compared to specification requirements.

MIL-STD-220 INSERTION LOSS VERSES MIL-STD-461 EMI TESTING

The majority of EMI filters are employed in order to cause system compliance to one of various military or commercial EMI/EMC specifications.

The most widely references military EMI/EMC specification is Military Specification MIL-STD-461 (462,463). This document specifies the allowable amount of conducted and radiated emissions that a subsystem or system can generate.

Conducted emissions is interference that is present, or 'conducted' on primary power lines (AC or DC) and/or signal lines as detected by a current probe or other means.

Radiated emissions is interference, both 'E' and 'H' fields, that is being transmitted or radiated from the total system as detected by a receiving antenna.

In addition, MIL-STD-461 also delineates a series of tests that subject the device under test to various types of conducted and radiated interference to determine the survivability of the device when exposed to a harsh EMI environment. This series of tests is referred to as conducted and radiated susceptibility.

Conducted emission requirements and test methods are referred to as "CE". The numbers that follow refer to the applicable frequency range and whether it pertains to input power lines or signal lines. (i.e., CE03 establishes test methods and maximum allowable interference that can be present on AC and DC power lines over the frequency range of 15 kHz to 50 MHz.)

Similarly, "CS" stands for Conducted Susceptibility, "RE" for Radiated Emission, and "RS" for Radiated Susceptibility.

As previously stated, EMI filters being bidirectional devices not

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only help to reduce the amount of conducted emissions generated within, but also protect the system from unwanted interference entering via the power lines and signal lines.

To some degree EMI filters also help to reduce the radiated interference. This is due to the fact that the power lines and signal lines can act as 'transmitting antennas' if too much EMI is present. However, the majority of radiated problems are system configuration related (i.e., improper grounding, shielding, lack of EMI gaskets, the choice of materials in the case of "H" fields, etc.).

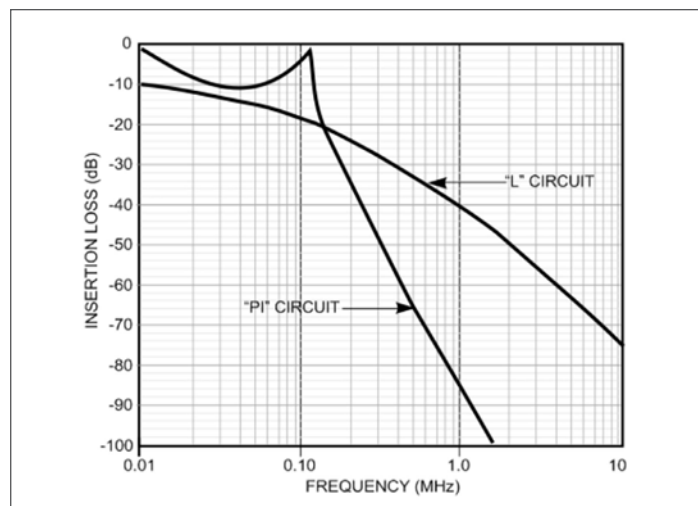


Figure 3. comparison of theoretical MIL-STD-220 50 ohm insertion loss of a "PI" filter and a "L" filter

The EMI profiles, and impedance, of any device is very complex and will change drastically over a given frequency range. It's this phenomenon that makes selecting an EMI filter based solely on 50 ohm insertion loss data difficult.

Figure 3 compares the theoretical MIL-STD-220 50 ohm insertion loss of a "PI" filter and a "L" filter comprised of the following components.

"PI" Circuit:

$$C_1 = .70 \mu\text{fd}$$

$$L_2 = 5 \mu\text{Hy}$$

$$C_3 = .70 \mu\text{fd}$$

"L" Circuit:

$$C_1 = .70 \mu\text{fd}$$

$$L_2 = 5 \mu\text{Hy}$$

Looking at this comparison, and if size was not an issue, one would have a tendency to choose the "PI" circuit over the "L" circuit based on performance. At 1 MHz the "PI" circuit provides 80+ dB of insertion loss where the "L" circuit only provides 40+ dB.

However, MIL-STD-461 conducted emission tests are not per-

formance under 50 ohm source and load conditions.

Figure 4 illustrates a typical MIL-STD-461 conducted emissions test configuration.

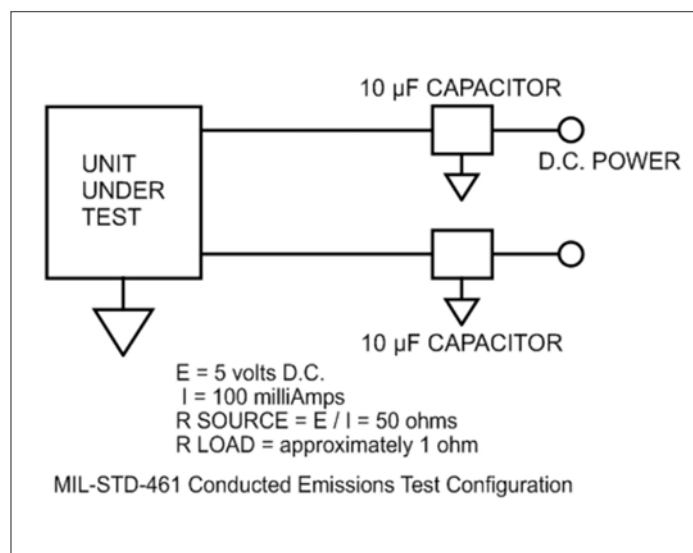


Figure 4. MIL-STD-461 Conducted Emissions Test Configuration

Not knowing the EMI source impedance (the device under test), we will assume ohms law. In this case 50 ohms. We don't know what the load impedance is, however, due to the 10 μfd line stabilization capacitors (required by MIL-STD-461 as part of the test configuration), we can assume it is low compared to the source impedance. In this case, we will theorize 1 ohm.

In this more realistic setting, 50 ohm source and 1 ohm load, the "L" circuit performs almost as well as the "PI" circuit as illustrated in Figure 5. By slightly increasing the values of C1 and L2 in the "L" circuit, a response identical to the "PI" circuit can be achieved.

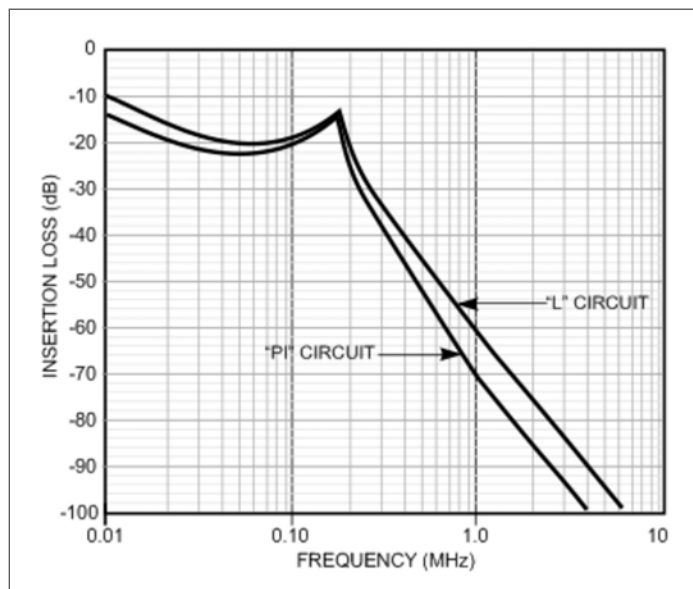


Figure 5. Performance of "L" and "PI" circuits for 50 ohm source and 1 ohm load

In the above example we were only concerned with EMI emanating from the test sample. If we were also concerned about protecting against unwanted interference entering the device then

DESIGN

a “T” circuit would be the filter of choice. In essence, by using a “T” circuit we have two “L” circuits with the inductor facing the lower impedance.

If the “T” circuit consisted of L1 facing the unit under test and, L3 facing the load with C2 in the middle, then for conducted emissions the “L” circuit is comprised of C2 and L3. For conducted susceptibility, if we assume the unit under test to be the lower of the two impedances, the “L” circuit is comprised of C2 and L1. In both instances the secondary inductor will provide some additional filtering. However, its contribution is relatively small compared to the other two components.

There are an infinite number of source and load impedance combinations for signal line applications where the 10 μ fd line stabilization capacitors are not required as part of the test configuration. For these situations the theoretical insertion loss can be calculated by varying RS and RL in the equations.

Although the circuits that we have been discussing only address common mode (interference which is present as a common potential between ground and all power lines) EMI, the same philosophies apply when selecting differential mode (interference which is present as a potential between individual power lines) EMI filtering elements commonly found in multicircuit filter assemblies, or “Black Box”.

CONCLUSION

Selecting the proper EMI filter circuit is not a difficult task provided, that as a minimum, the following parameters are taken into consideration:

- The EMI source impedance
- The EMI load impedance
- The EMI propagation mode (common mode, differential mode or both)
- Conducted emission requirements
- Conducted susceptibility requirements

Other considerations that are not readily apparent are the effects caused by mismatching; performance at full load; and the inability to achieve the theoretical insertion loss due to the inductance (ESL) and resistance (ESR) in the capacitor, and the parasitic capacitance in the inductors.

For more information about EMI Filters and Filter Connectors, please contact:

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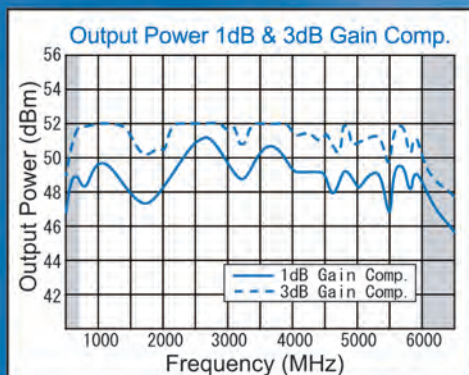
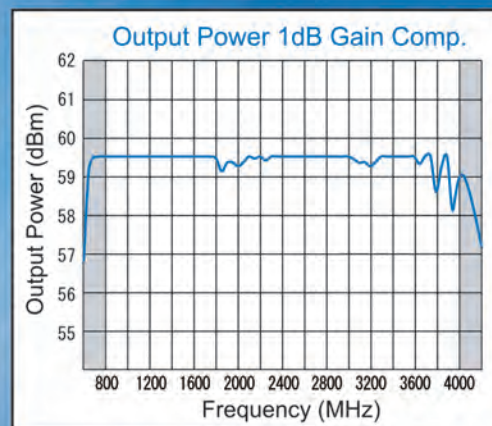
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Top Three EMI and Power Integrity Problems with On-Board DC-DC Converters and LDO Regulators

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Modern devices are continuing a long-term trend of squeezing more electronics into smaller packages, while also increasing system performance, data rates and operating efficiency. Higher efficiencies are often achieved by implementing faster silicon MOSFETs or even faster eGaN FETs while size is reduced by increasing switching frequencies and replacing aluminum and tantalum capacitors with smaller ceramic devices. One result of this trend is that there is greater interaction between the disciplines of EMI, signal integrity (SI) and power integrity (PI).

INTRODUCTION

EMI is a measure of the electromagnetic emissions produced by the high-speed current and voltage signals the system creates. Power integrity is a measure of the power quality at the device that being powered. This means that the power supply voltages must be maintained within the allowable operating voltage range of high-speed devices. Devices, such as modems, reference clocks and low noise amplifiers (LNAs) are all sensitive to noise on the power rails, which results in timing jitter, spurious responses reduced data channel eye openings, and degraded signal-to-noise ratio (SNR). This too, is a measure of power integrity. The power supply itself is a noise source and the noise sources generated by the power supply must be kept from propagating through the system.

This article discusses the three most common causes of EMI and power integrity issues while providing tips for how to avoid or minimize them in your design.

1. **Ringing** on switched waveforms causes broad resonant peaks in the emission spectrum.
2. **DC-DC converters generate noise** at the switching frequency, and because of high speed switching devices, can generate broadband switching harmonics well into the GHz.
3. **Power plane resonance** in DC-DC converter or LDO regulators due to high-Q capacitors resonating with power planes.

RINGING AND RADIATED EMISSIONS

Any ringing on the switched waveform (fairly common) can lead to broadband resonances in the resulting RF spectrum. Resonant frequencies resulting from DC-DC converters or low

dropout (LDO) linear regulators can be as low as a few kHz while resonance due to the PDN with switching devices, such as MOSFETs can be in hundreds of MHz or higher.

The harmonic energy resulting from this switching is “captured” by the PDN and device resonances, evident as ringing in the time domain. The current and voltage of this ringing produces EMI. The magnitudes of the ringing and EMI are related to the quality factor (Q) and characteristic impedance of the resonance and the harmonic energy produced by the switching.

As an example, the switching waveform on a DC-DC buck converter demo board was measured with a Rohde & Schwarz RTE 1104 oscilloscope and Rohde & Schwarz RT-ZS20 1.5 GHz active probe (Figure 1).

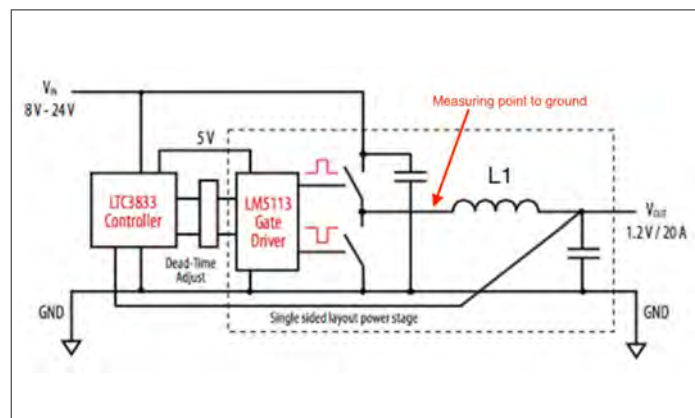


Figure 1. Diagram showing the measuring point at the switch device junction (on the left side of $L1$) to ground return.

There was a very large ringing superimposed on the switched waveform of 216 MHz. This can be seen clearly in Figure 2.

A Fischer Custom Communications F-33-1 current probe was used to measure both the input power cable common mode current (violet trace) and output load differential mode current (aqua trace). See Figure 3. Note the broad resonant peaks at 216 MHz (marker 1) and the second harmonic at 438 MHz (marker 2).

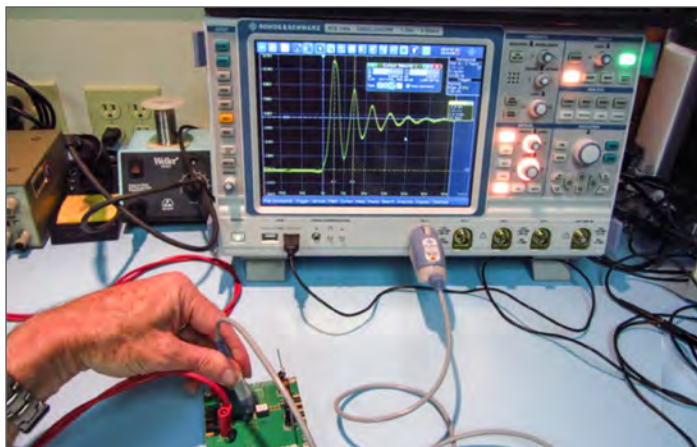


Figure 2. Measuring the rise time and ringing on a DC-DC converter. Notice to strong ringing at 216 MHz.

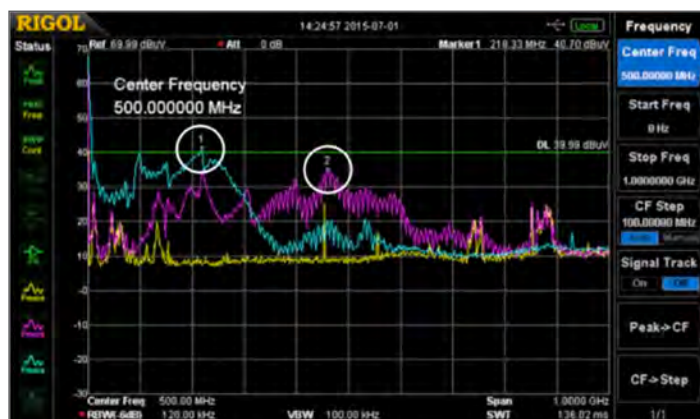


Figure 3. Resulting resonances from the 216 MHz ring frequency (marker 1) and second harmonic at 438 MHz (marker 2).

Remediation Tips - There are several ways to improve the design to minimize the resonances, ringing and therefore EMI. Since the energy is related to the switching frequency, rise time of the switching, characteristic impedance, and Q of the resonances, these factors are also the paths to mitigation.

- Slower edges will degrade operating efficiency but reduce high frequency energy
- Careful PCB design and capacitor selection will minimize the characteristic impedance and Q
- Keep traces short and wide and dielectrics thin.
- Keep all the switching circuitry on one side of the board, preferably with a thin dielectric to the respective ground return plane.
- Use of a snubber circuit, damping of resonances using controlled ESR capacitors, or redesign of the inductor for lower leakage inductance.

For additional detail on measuring ringing refer to Reference 1.

FAST EDGES CREATE BROADBAND NOISE AT GHZ FREQUENCIES

Today's on-board DC-DC converters use switching frequencies as high as 3 MHz. This is an advantage because it allows for physically smaller inductor and filter components, as well as increased efficiency. However, the fast edge speeds create broadband harmonic energy. The bandwidth of this harmonic energy is related

to the voltage and current rise time. A 1ns edge speed can produce harmonic energy up to 3 GHz, or more.

These broadband harmonics are the cause of radiated emissions failures and also can affect the receiver sensitivity of any on-board telephone modems or other wireless systems, such as GPS. Figure 4 shows how a typical DC-DC converter circuit can be characterized using an H-field probe connected to a spectrum analyzer.

It's also possible to connect the probe to an oscilloscope and hold it near each DC-DC converter to get some idea of the ringing, if any, without disturbing the circuit.

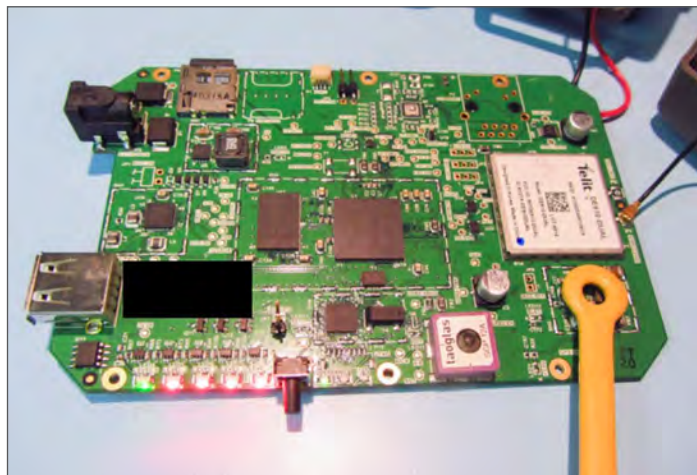


Figure 4. Probing DC-DC converter noise sources on a typical wireless device.

Figure 5 shows the resulting measurement of a couple DC-DC converters. The yellow trace is the ambient noise floor of the measurement system and is always a good idea to record for reference. The aqua and violet traces are the two converter measurements. Note that both produce broadband noise currents out to 1 GHz, with the converter in violet out to beyond 1.5 GHz. Note the violet trace is 20 to 50 dB higher than the ambient noise floor.

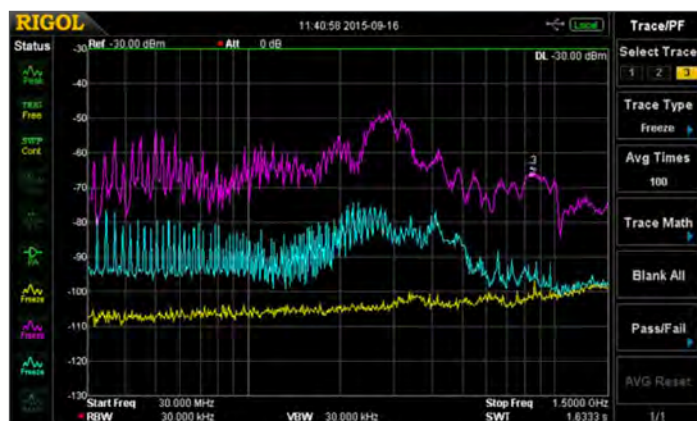


Figure 5 - In this example, we're looking from 30 MHz to 1.5 GHz to generally characterize the spectral emissions profile of a couple of on-board DC-DC converters. Both will potentially cause interference to mobile phone bands in the 700 to 950 MHz region. The one with the violet trace is over 30 dB above the ambient noise level in the mobile phone band.

Remediation Tips - To reduce the risk of self-interference to on-board mobile phone modems and wireless systems, the product design must start off with EMC in mind and with no corners cut.

DESIGN

This will consist of:

- A near perfect PC board layout
- Filtering of DC-DC converters
- Filtering of any high frequency device
- Filtering of the radio module
- Local shielding around high noise areas
- Possibly shielding the entire product
- Proper antenna placement

The PC board layout is critical and is where most of your effort should reside. An eight or ten layer stack-up will provide the most flexibility in segregating the power supply, analog, digital, and radio sections and provide multiple ground return planes, which may be stitched together around the board edge to form a Faraday cage. Care must be taken to avoid return current contamination between sections – especially in the ground return planes. For wireless products, the power plane for the radio modem section should be isolated (except via a narrow bridge) from the digital power plane. All traces to this isolated plane should pass over the bridge connecting the two. This can provide up to 40 dB of isolation between the digital circuitry and radio.

It is vital that the power and ground return planes be on adjacent layers and ideally 3-4 mils apart at the most. This will provide the best high frequency bypassing. All signal layers should be adjacent to at least one solid ground return plane. Clock, or other high-speed traces, should avoid passing through vias and should not change reference planes.

Power supply sections should be well isolated from sensitive analog or radio circuitry (including antennas). Be aware of primary and secondary current loops and their return currents. These return currents should not share the same return plane paths as digital, analog, or radio circuits. Remember that high frequency return currents want to return to the source directly under the source trace.

For more details on resolving DC-DC converter noise issues with wireless radio modems, refer to Reference 2.

PC BOARD PLANE RESONANCE AND THE EFFECT ON RADIATED EMISSIONS

Noise propagation in a simple system can be represented by three elements, the voltage regulator, the printed circuit board planes with decoupling capacitors (PDN) and the device being powered (load).

Each of these three elements is comprised of resistive, inductive and capacitive terms. Even “noise free” low dropout (LDO) regulators can be highly inductive (Reference 3). The resistive, inductive and capacitive terms can resonate amplifying the noise signals created by the power supply and the load as they travel across the PDN creating EMI. The harmonics of the switching frequency and the switch ringing discussed earlier excite these PDN resonances (Reference 4). As stated previously this noise can degrade and interfere with on-board wireless modems, as well as resulting radiated and conducted emissions.

A short video helps explain the basic principles of PDN design (Ref-

erence 5). The radiated EMI of a LTC3880 DC-DC converter measured near the input plane using an H-field probe is seen in Figure 6.

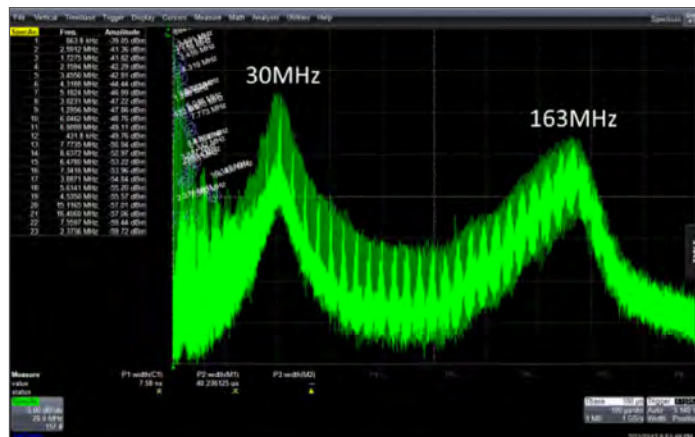


Figure 6. Spectrum analyzer display showing the 30 MHz and 160 MHz resonances detected near the input power connections of a DC-DC converter.

The 163 MHz is attributed to the ringing of the switches as seen in Figure 7. This ringing is caused by the inductance of the upper MOSFET bond wires, pins and circuit board planes, ringing with the lower MOSFET and PC board capacitance.

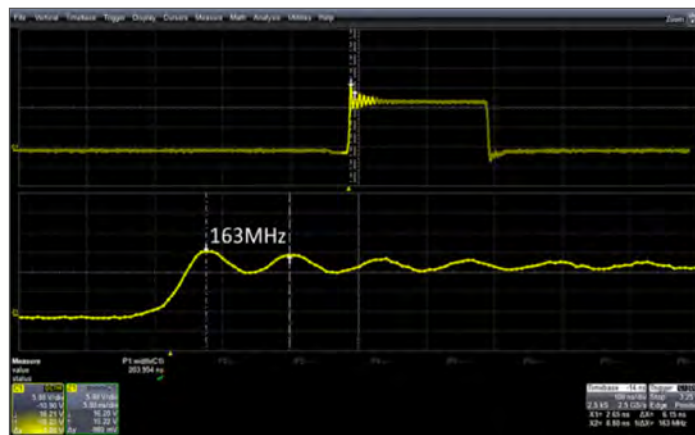


Figure 7. The 163 MHz EMI is easily explained by the ringing at the switch device, as discussed earlier.

The input ceramic decoupling capacitor resonates at approximately 30 MHz, as seen in Figure 8 and results in the large 30 MHz EMI signature.

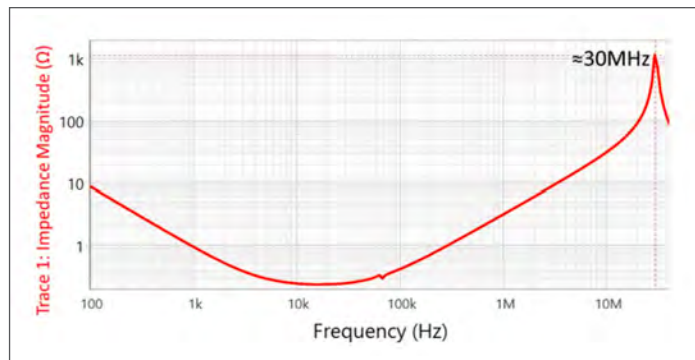


Figure 8. The larger 30 MHz emission is identified as a printed circuit board resonance using an H-field probe and confirmed by a 1-port reflection impedance measurement at the input capacitor.

The input power plane section of the DC-DC converter (measured in Figure 6) is shown in Figure 9 with schematic representations of the component, PC board and external connections.

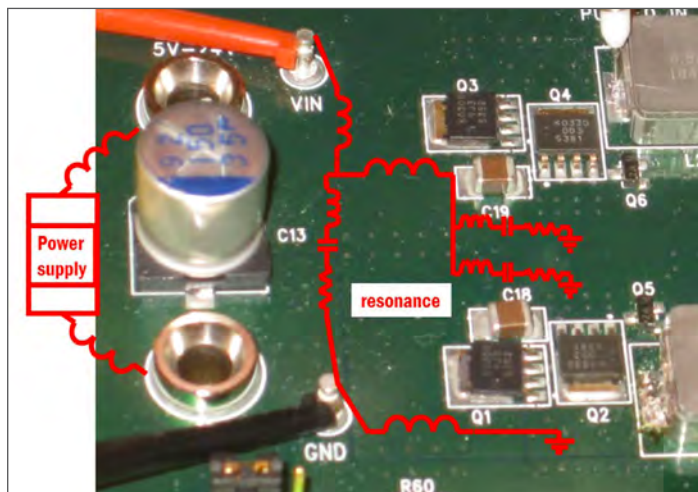


Figure 9. The power plane section of the DC-DC converter (measured in Figure 6) with schematic representations of the component, PC board and external connections.

A very simple simulation example can be used to illustrate these impedance resonance effects. Consider a simple DC-DC converter as shown in Figure 10.

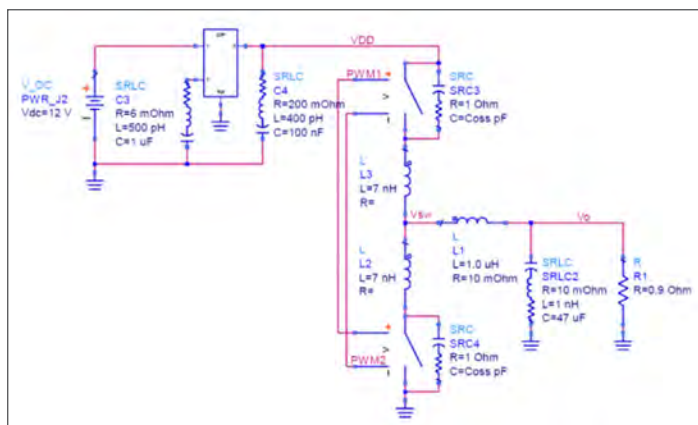


Figure 10. A simple DC-DC converter for illustration of plane resonance EMI. The "FET" switches include lead inductance and drain capacitance (Coss). A small PC board and two ceramic capacitors are included.

Designers frequently place the FET switches on one side of the board with power entry on the opposite side of the PC board. The small PC board plane used in this example has power entry through a pair of pins and no interconnect inductance is added to connect power to the PC board. A large 47 μF ceramic capacitor is placed on the top side of the PC board, while a smaller, 0.1 μF ceramic capacitor is placed very close to the FET switches on the bottom side of the PC board. Two parallel vias connect power and ground from the top side of the PC board to the bottom side as seen in Figure 11.

The simple model is used to simulate the harmonic current in the input connector, which is directly related to conducted and radiated emissions. Two simulations are performed; one with low ESR ceramic capacitors and the other with a lower Q controlled ESR ceramic replacing the 0.1 μF capacitor close to the FET switches. Both simulations are shown together in Figure 12.

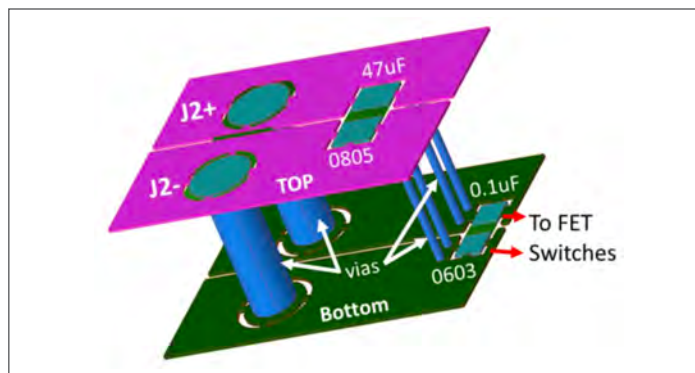


Figure 11. The large round pins on the left are the input power connector, J2. The larger capacitor on the top side is an 0805 sized 47 μF and the smaller capacitor on the bottom side is an 0603 sized 0.1 μF .

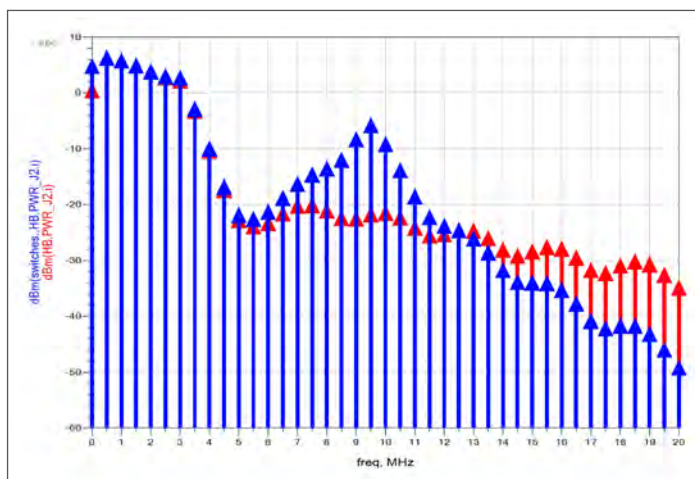


Figure 12. Spectral simulation of the input power lead shows the high Q ceramic (10 $\text{m}\Omega$ blue) has a clear peak near 10 MHz that is eliminated using a controlled ESR ceramic (200 $\text{m}\Omega$ red)

The simulated impedance, measured at the smaller capacitor in Figure 13 shows the corresponding plane resonance with a clear 10 MHz peak using the high Q ceramic capacitor (blue) and the peak is eliminated using the controller ESR ceramic capacitor (red).

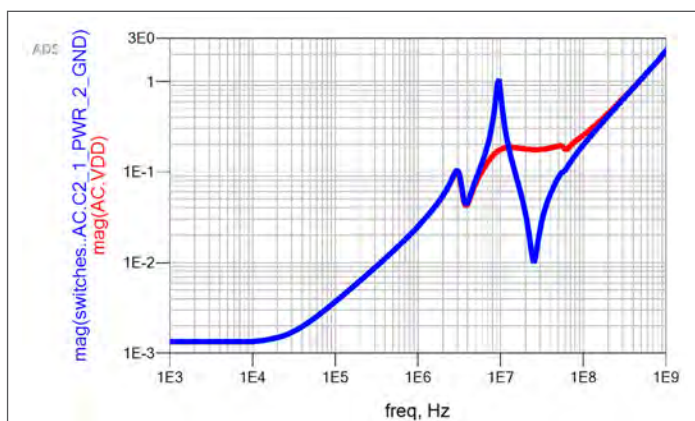


Figure 13. The simulated impedance at the 0.1 μF capacitor using high Q ceramic (10 $\text{m}\Omega$ blue) and a controlled ESR ceramic (200 $\text{m}\Omega$ red)

Remediation Tips – To minimize PDN resonances, the complete system of voltage regulator, PDN and the load need to be carefully balanced. Damping resistance must be included to eliminate or minimize the existence or Q of resonances. This will consist of:

DESIGN

- Short, wide power planes
- Keep the layout as small as possible to minimize inductance
- Thinner PC board dielectric layers, closer to the surface
- Incorporate EM simulation to identify and minimize PDN resonances
- Keep capacitors on one side of the PC board to the extent possible
- Low-Q or ESR controlled capacitors reduce Q
- Choose voltage regulators and output capacitors for good control loop stability
- Don't place cutouts or holes in ground plane layers below the power plane
- Ferrite beads are a very common cause of PDN resonances
- Be aware of inductive interconnects bringing power to the system.

Printed circuit board design and decoupling is critical and “rules-of-thumb” generally don't work well in high speed circuits. The design of the circuit board and capacitor decoupling always involves trade-offs, but the impacts on resonances need to be weighed carefully. A multi-frequency harmonic comb generator can be extremely helpful for quickly identifying PDN resonances (Reference 3).

SUMMARY

As you can see, designing DC-DC converters, LDOs, and PDNs with today's high-speed technology nearly always requires careful circuit design, adequate filtering, simulation of the PDN, very careful circuit board layout, and use of controlled-ESR filter capacitors. Poor designs can result in:

- Ringing in power supply switches (or other fast-edged digital switching) resulting in associated radiated or conducted emissions resonant peaks at the ring frequency and harmonics.
- High frequency broadband noise well beyond 1 GHz, resulting in self-interference to radio modems.
- Poor stability and resonances in un-damped power distribution networks, leading to instability, spectral resonances, and associated radiated and conducted emissions.

REFERENCES

1. Wyatt, GaN Technology and the Potential for EMI (EDN), <http://www.edn.com/electronics-blogs/the-emc-blog/4439839/GaN-technology-and-the-potential-for-EMI>
2. Wyatt, Platform Interference (EDN), <http://www.edn.com/electronics-blogs/the-emc-blog/4441086/Platform-interference>
3. Wyatt, Review: Picotest J2150A Harmonic Comb Generator <http://www.edn.com/electronics-blogs/the-emc-blog/4440532/Review--Picotest-J2150A-harmonic-comb-generator>
4. Sandler, The Inductive Nature of Voltage Control Loops, <http://www.edn.com/electronics-blogs/impedance-measurement-rescues/4438578/The-inductive-nature-of-voltage-control-loops>
5. Sandler, How to Design for Power Integrity: Finding Power Delivery Noise Problems (Video), https://www.youtube.com/watch?v=oL6qjhJH_m4&t=4s&list=PLtq84kH8xZ9HIYg-BYDsP7TbqBpftidzI8&index=4



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Cost-Effective Applications of EMI Gaskets

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EMI gaskets are used extensively by the electrical/electronic industry to assist in complying with the various EMI radiated emission requirements. These requirements include compliance to DoD TEMPEST and EMI, and FCC and EU EMI test limits. As a rule of thumb the radiated emission TEMPEST requirements are about two orders of magnitude (40 dB) more stringent than the DoD EMI requirements, and the DoD EMI radiated emission requirements are about two orders of magnitude (40 dB) more stringent than the FCC and EU EMI requirements. This means that in terms of difficulty, complying to the FCC and EU requirements is relatively easy. However, the expense can be high in terms of the percentage increase in the cost of manufacturing the equipment. The FCC requires that the manufacturers of the equipment that falls under their jurisdiction be responsible for compliance throughout the life of the equipment. As such, the cost of not complying for the life span of the equipment can be very costly (i.e., redesign and retrofit can become a catastrophic cost).

INTRODUCTION

The cost of complying with the FCC (as well as DoD, EMI and TEMPEST) radiated emission requirements can be reduced to within acceptable limits by understanding the problems associated with the radiation and suppression of radiated electromagnetic waves. Because of the relatively low FCC compliance EMI radiated emission suppression levels, EMI gaskets are not always needed. However, the proper selection and use of EMI gaskets can often significantly reduce the expense associated with compliance costs. A significant aspect associated with the proper selection and use of EMI gaskets is to be prepared to use them if they are needed. If one is not prepared, then the driving force in selecting a gasket is the least cost to add the gaskets after the fact. In such cases, the cost can be, and usually is, exceedingly high. The paragraphs that follow describe the generation and propagation of electromagnetic (EM) waves from wires, the method used to shield the fields, low cost methods of implementing EMI gaskets and problems associated with obtaining reliable shielding throughout the life of the equipment.

THE GENERATION, PROPAGATION AND SHIELDING OF EM WAVES

The equipment covered by FCC and EU requirements contains circuits, which generate RF energy that falls within the bandwidth of radios and other communication equipment. This energy travels on wires from one circuit to another, where the wires connecting the two circuits act as antennas. The energy emanating from the wires is transmitted out of the equipment in the form of electromagnetic (EM) waves. When the magnitude of the waves are a higher amplitude than is allowed by the specification limits we call it electromagnetic interference or EMI.

The fields, which radiate from wires are similar to the fields which radiate from electric dipole antennas. Figure 1 illustrates an EM field emanating from a transmission line pair.

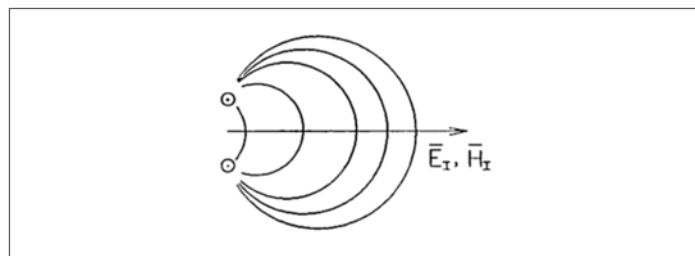


Figure 1. EM field emanating from a transmission line pair.

We know from antenna theory that the impedance of the wave is equal to \bar{E}/\bar{H} where the relationship of \bar{H} to \bar{E} is approximately equal to the following:

$$\bar{H} \cong \frac{2\pi\bar{E}R}{377\lambda} \left(R < \frac{\lambda}{2\pi} \right)$$

$$\cong \frac{\bar{E}}{377} \left(R < \frac{\lambda}{2\pi} \right)$$

$$\text{where: } \lambda = 3 \times 10^8 / f \text{ (meters)}$$

R = Distance from radiating wire to point in question (meters)

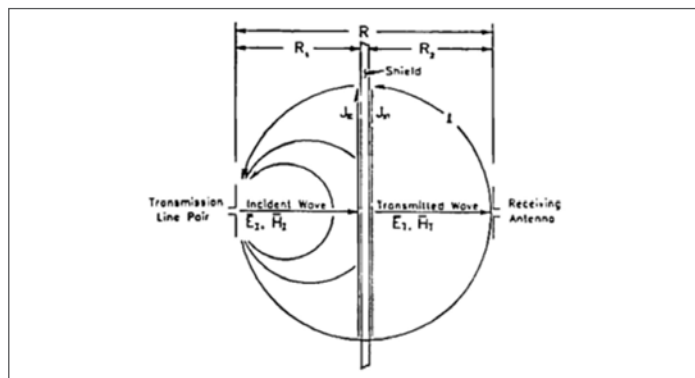


Figure 2.

When the wave of *Figure 1* strikes a shielding barrier, a current J_{SI} (i.e., surface current density on the incident side) is generated on the shield as illustrated in *Figure 2*. The current is equal to approximately two times the value of H in amperes/meter of the incident field (the field that radiates from the wire and strikes the barrier). The current in turn is attenuated by the skin depth of the barrier where the current on the transmitted side, J_{ST} , will generate another EM field. The magnitude of the "E" field in volts/meter emanating from the barrier will be J_{ST} (current density in amperes/meter on the secondary side) times the impedance of the barrier in ohms. The secondary field is what is detected by the test antenna.

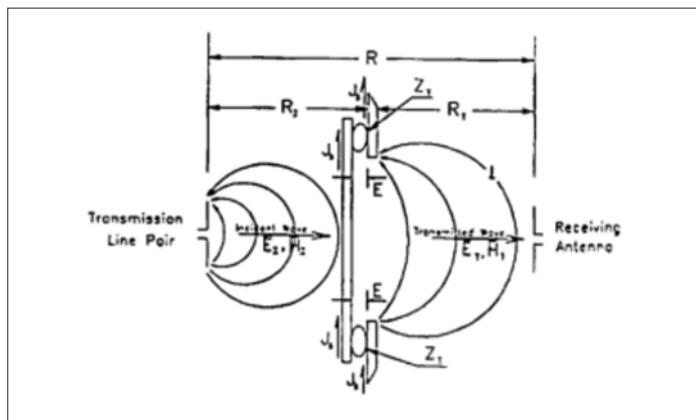


Figure 3.

If the shielding barrier has a joint in it, the current will flow across the joint creating a voltage which is equal to J_{SI} times Z_T (the current in amperes/meter times the transfer impedance of the joint in ohm-meters). A field will radiate from the joint as illustrated in *Figure 3* and is observed by the test antenna. If the field so detected is above the limits specified by the requirements we must reduce the transfer impedance (Z_T) of the joint. This can be accomplished by the use of additional fasteners or by the use of EMI gasket material.

COST EFFECTIVE USE OF GASKETS

Commercial electronic equipment is generally housed in non-conductive die-cast or molded plastic cabinets. The cabinets are coated with a conductive material to provide the required shielding for compliance to FCC or VDE limits. This is usually accomplished by plating the inside of the cabinet with an electroless coating (aluminum, nickel, copper, tin, etc.) or with a conductive paint. This coating will reduce the EM fields penetrating the cabinet walls to within acceptable levels. However, the joints of the cabinet provide a convenient path for the EM fields to penetrate the cabinet. These fields are reduced to acceptable levels by providing conductive paths between the joint surfaces of the cabinet. This can be performed by the use of additional fasteners or by the use of EMI gasket material. The use of EMI gasket material can be a very cost effective means of obtaining the shielding at the joint surfaces. The cost of using EMI gasket material can be significantly less than the cost of using fasteners. However, to obtain the cost effective advantage, provisions must be made in the die or mold to provide room for the gasket material and methods of holding the gasket material in place.

There are two kinds of EMI gasket material that are recommended

for cost effective use. These are as illustrated in *Figures 4 and 5* and are as follows:

1. Commercial grade convoluted spring EMI gasket material. The material is made from low cost stainless steel, and can be purchased in cut-to-size lengths for pennies per inch. The material can provide an EM bond of one milli-ohm per meter length, and can be held in place by the use of pinch bosses or retaining holes.

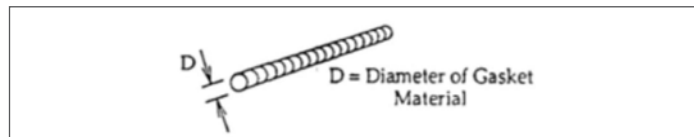


Figure 4.

2. The commercial grade convoluted spring gasket material attached to a neoprene sponge elastomer. An adhesive backed tape is supplied with the elastomer, where the purpose of the elastomer and tape is to hold the EMI bonding material in place.

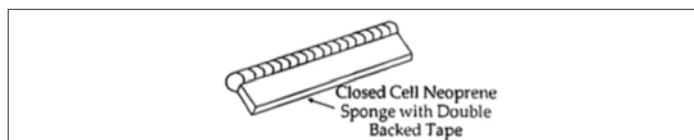


Figure 5.

In using the convoluted spring gasket material, (or any similar EMI gasket material), a groove must be provided in the die or mold to house the gasket. The recommended groove is illustrated in *Figure 6* where the width of the groove is about 35% wider than the gasket material and the depth is about 75% of the width (diameter) of the gasket material. *Figure 7* also illustrates a method, which has been effectively used to protect the gasket.

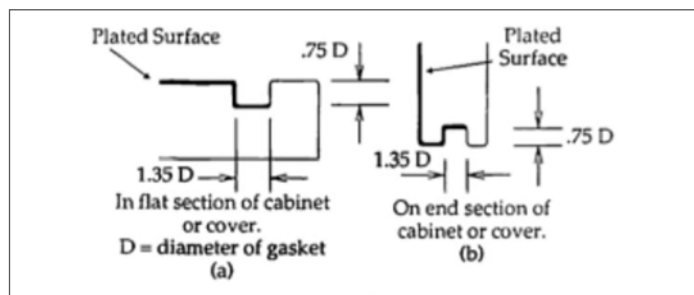


Figure 6.

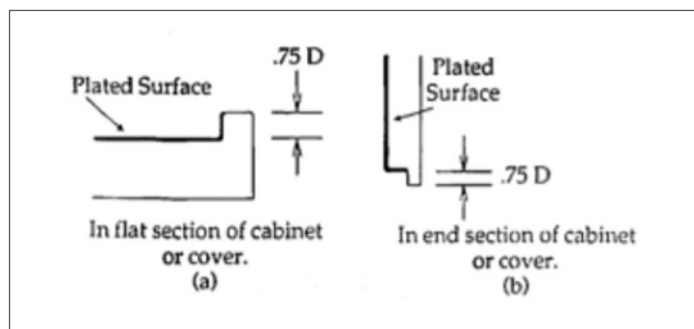


Figure 7.

The recommended diameter of the gasket material is between

DESIGN

0.06 and 0.15 inches (1.5 mm to 3.8 mm). Assuming a 25% maximum deflection of the gasket, this will accommodate a 0.015 to 0.037 inch gap (or unevenness) between the joint surfaces to be EM bonded. Please note! The purpose of the gasket is to provide a conductive path between the separate parts of the case. Therefore, care must be exercised to ensure that the conductive plating on the separate parts interface with the gaskets.

The grooves or configurations of *Figures 6 and 7* provide a place for the gaskets to sit. However, provisions must be made to hold the gasket materials in place. This is accomplished by providing pinch bosses or retaining holes along the groove. The pinch bosses are illustrated in *Figure 8* and retaining holes in *Figure 9*. Because the requirements are relatively easy to comply with, continuous gasketing throughout the length of the joint is not required (i.e., small segments along the length of the joint can be used effectively). The actual optimal length and number of segments of EMI gasket material will not be known until the EMI testing on a finished prototype equipment is completed. One (1) to 1-1/2 inch segments on one (1) or two (2) of the four (4) sides of a small cover is often sufficient. The grooves of *Figure 6 and 7* must be placed in the die or mold during the early design phases. The pinch bosses or retaining holes can be placed in the die or mold after the EMI testing is completed and optimal required gasketing is known.

Please note! During EMI testing, the segments of EMI gasket material can be held in place using tape or other non-destructive methods of retainment.

In applying the gasket material to the unit case the following considerations should be applied.

1. Pinch bosses

- Cut the gasket material to the appropriate length (outside-to-outside distance between pinch bosses).
- Push one end of the gasket material between one set of pinch bosses.
- Stretch the gasket about 5% (to put the gasket under slight tension) and push the loose end into the other set of pinch bosses.

2. Retaining hole

- Cut the gasket material to the appropriate length (distance between holes plus 0.4 inches).
- Insert one end of the gasket into one hole.
- Holding the inserted end in the hole stretch the gasket and insert the gasket into the other hole all the way to the bottom.
- Release holding devices (i.e., fingers, etc.).

Note: A silicone RTV adhesive can be used to positively secure the two ends inside the hole.

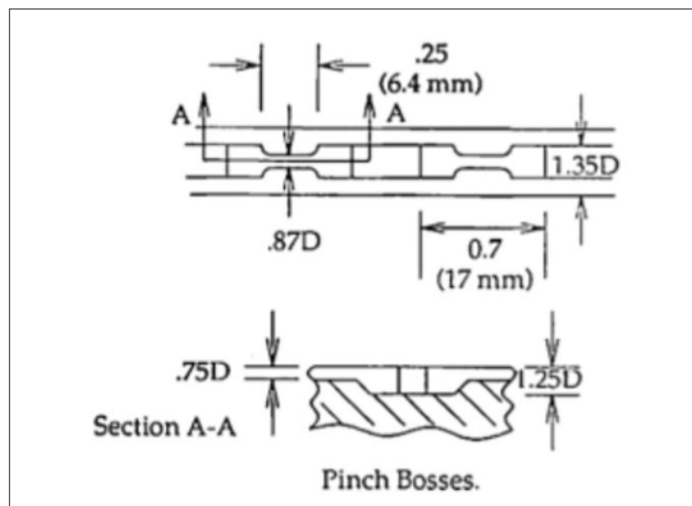


Figure 8.

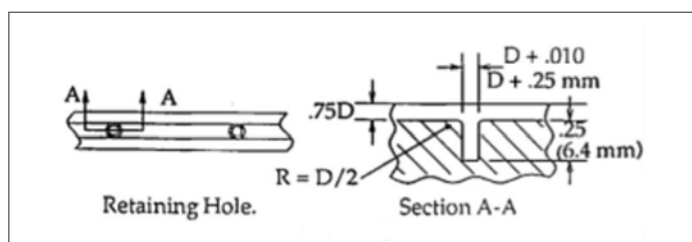


Figure 9.

The EMI gasket strip material that is attached to the neoprene sponge elastomer of *Figure 2* uses adhesive backed tape to hold it in place. The standard thickness of the material is either 1/16, 3/32 or 1/8 inch. The recommended segments or lengths of gasket material are 1 to 1 1/2 inches long. The specific placement of the gasket segments can be determined during the EU or FCC EMI testing. However, provision must be made in the design of the cabinet to provide the required space for the gasket strip. *Figures 10 and 11* illustrate two methods that have proven successful.

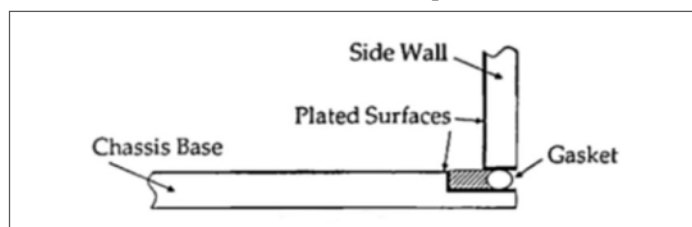


Figure 10.

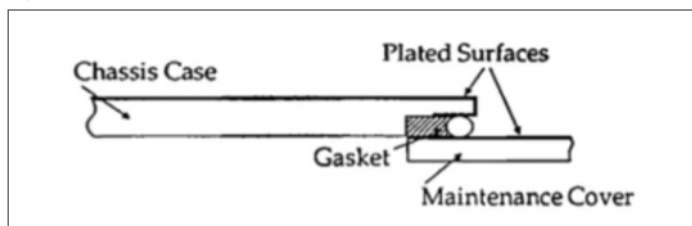


Figure 11.

RELIABILITY OF GASKETED JOINT

The FCC and EU require that compliance to the specification limits be for the life of the equipment. If a problem with a piece of equipment is detected and is proven to be due to inadequate de-

CONCLUSION

The use of EMI gasket material can significantly reduce the cost of complying with the FCC and EU EMI radiated emission limits. The reduced cost results from using EMI gasket material in place of fasteners, where the EMI gasket material can cost as little as pennies per inch.

To use the gasket material in a cost effective means, provisions to hold and protect the gasket material must be designed into the mold or die.

These provisions consist of: (1) O-ring grooves and pinch bosses or retaining holes when using the convoluted spring gasket material; or (2) providing space between the various case sections to be EM bonded together when using the EMI strip gasket material.

SELECTED BIBLIOGRAPHY

1. Groshart, G., "Corrosion Control in EMI Design", Symposium & Exhibition, Montreux, Switzerland, July 1977.
2. Hellen, E., "Electromagnetic Theory", John Wiley & Sons, New York, 1962.
3. IT&T Corp., "Reference Data for Radio Engineers", Stratford Press Inc., New York, 1964.
4. Kunkel, G.M., "Introduction to Shielding of Electromagnetic Fields and the Application to EMI/RFI Gaskets", IEEE International Symposium on EMC, October 1975.
5. Kunkel, G.M., "An Overview of Problems Associated with the Design of Electromagnetic Shields", IEEE International Symposium on EMC, Washington D.C., July 1986.
6. Madle, P.J., "Transfer Impedance and Transfer Admittance Measurements on Gasketed Panel Assemblies, and Honeycomb Air Vent Assemblies", IEEE 1977 International Symposium on EMC, Washington D.C., July 1976.
7. Ott, H.W., "Noise Reduction Techniques in Electronic Systems", John Wiley & Sons, New York, 1976.
8. White, D.R.J., "Electromagnetic Shielding Materials and Performance", Don White Consultants, Inc., Maryland 1975.

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Personal Protective Equipment (PPE) Evaluation Methods of Static Control Gloves for ESD Integrity

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SME Electrostatics for Aerospace & Defense / RMV Technology Group, LLC / A NASA Industry Partner

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Static Control gloves can be classified as Personal Protective Equipment (PPE) to reduce the risk of electrostatic discharge (ESD). There are several types of ESD Gloves: Nitrile, Vinyl, Latex, Rubber and humidity independent conductive carbon/nylon yarn gloves as illustrated in *Figure 1*.



Figure 1.

Due to an astounding rise in the number of non-compliant and suspect counterfeit products, the author has found (in the testing of electrostatic materials) that a significant number of today's OEMs, CMs, and suppliers either manufacture and/or use many ESD safe products that do not meet current ANSI/ESD or Military Standards. Suspect counterfeiting is no longer limited to cosmetics, watches and hand bags; this problem extends to the cordless wriststrap, soldering irons, ionizers, static shielding bags and other static control products.

Since 2007, non-compliant or suspect counterfeit materials have infiltrated the supply lines of Federal agencies and the commercial sector. First to present and publish on ESD Materials and Packaging used in the DoD supply chain, the author spoke before the 2010 NASA Quality Leadership Forum, Cape Canaveral prior to Industry awareness of suspect counterfeit static control products found in manufacturing.

Today's manufacturing sector requires ESD protection of ultra-sensitive electronic Class 0A sensitive devices at <125 volts. ESD handling protocols are also required with medical devices, small satellites (CubeSats), pharmaceutical delivery, touch screen displays, consumer electronics and aerospace & defense.

Following a formalized materials qualification process is critical in sourcing of ESD materials from the manufacturing floor to long term storage, transport and staging. Moreover, the end user must take a "Trust but Verify" posture and require evaluation samples from suppliers for qualification testing.

This article does not address cleanroom gloves. In the handling of sensitive devices, some people are latex intolerant and others may be allergic to antistatic gloves that could contribute to skin irritation. Moreover, migration of topical surfactants could pose issues with circuit card polycarbonate incompatibility, mirror fogging, solderability and crazing or stress cracking¹. For this evaluation, the ergonomically designed and breathable static control gloves prevent profuse sweating, are washable and maintain ESD safe properties at low RH.

As of 2016, the highest transistor count in a commercially available Intel 22-core Xeon Broadwell-EP is now over 7.2 billion transistors equivalency compared to Intel's 2300 transistors in 1971² (*Table 1*). Simply put, speed kills. ESD procedures for the protection of ultra-sensitive devices are necessary to prevent damage or

yield loss in the field after release of the final product.

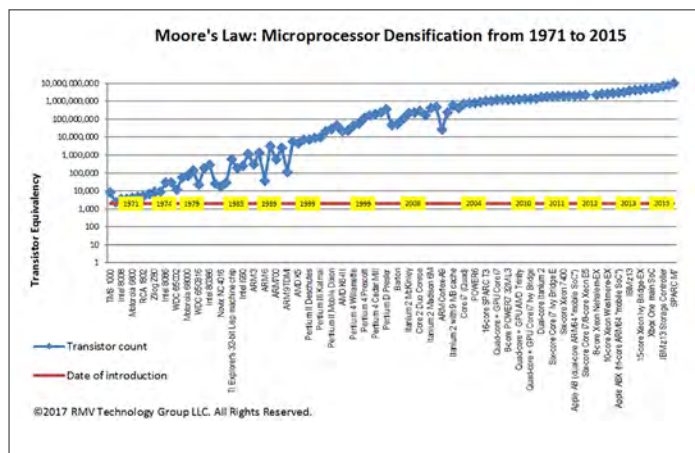


Table 1.

During assembly, ANSI/ESD S20.20-2014 ESD protocols are now being implemented so that supplier products will provide traceability with recent testing requirements.

How does one evaluate static control PPE gloves? There are two basic testing methods, ANSI/ESD SP15.1-2011 and MIL-STD-3010C, Method 4046 (modified).

Two testing methods are commonly utilized in Aerospace & Defense, Semiconductor, Disk Drive, Medical Device and the Automotive sector. One method is ANSI/ESD SP15.1-2011 (Café) that measures a glove's resistance when worn by an individual (*Figure 2, left*); the second method is electrostatic decay testing at ± 1000 volts to ± 100 or less (*Figure 2, right*).



Figure 2.

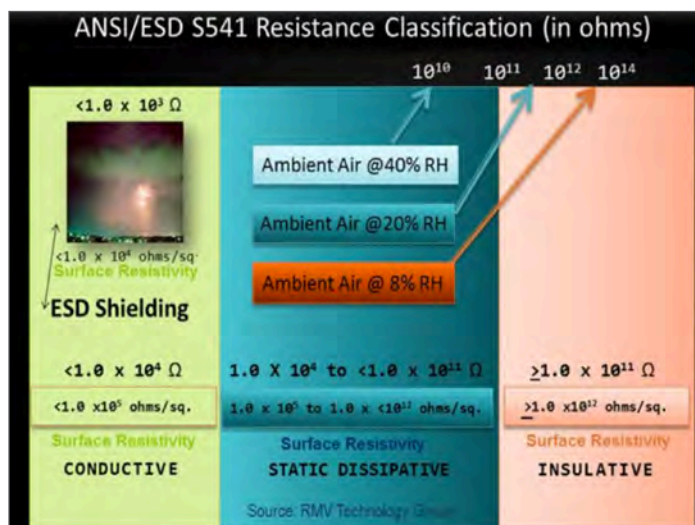


Illustration 1.

As the reader can see from the Illustration in *Illustration 1*, there is a relationship between relative humidity (RH) and surface resistance. Most organizations follow the ANSI/ESD S541-2008 surface resistance cut-off limit of $<1.0 \times 10^{11}$ ohms for ESD PPE gloves that serves as the benchmark for performance.

A cut-off of <2.0 seconds is a well accepted limit for electrostatic decay testing that can be traced back to EIA 541, Appendix F (1988). In this case, the test setup is positioned at +/-1000 volts for decay down to +/-10 volts.

One advantage of the ANSI/ESD SP15.1 Café resistance testing method is the measurement of multiple contact points with (10) per pairs of static control gloves (little finger to thumb) as illustrated below in *Figure 3*.



Figure 3.

ANSI/ESD SP15.1 provides an evaluation method to analyze how gloves will interact when worn by testing six pairs. In this test setup, gloves were evaluated at 12%+/-3%RH and 50%+/-3%RH after 48 hours of preconditioning as illustrated in *Table 6*. **Note:** Due to limited space, *Data Tables 2 – 5 have been intentionally omitted*. The full article can be viewed on-line at on-line at: <https://interferencetechnology.com/category/digital-magazines/>

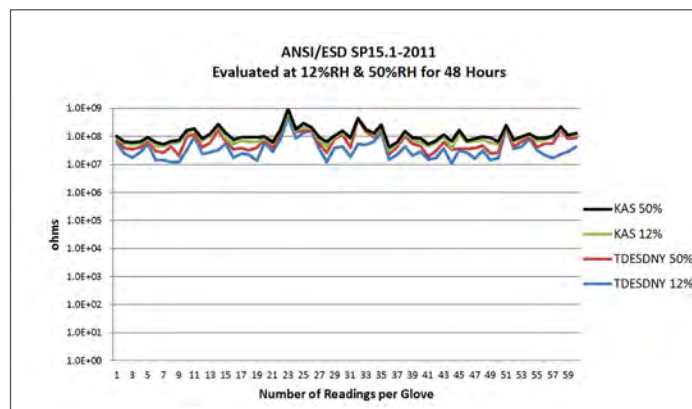


Table 6.

The reader can observe in *Table 6*, that the static control PPE gloves performed under the upper limit of $<1.0 \times 10^{11}$ ohms. Some companies that test for Charge Device Model (CDM) safety set a

target range between 1.0×10^6 ohms to 1.0×10^9 ohms in which the gloves in this article under test achieved.

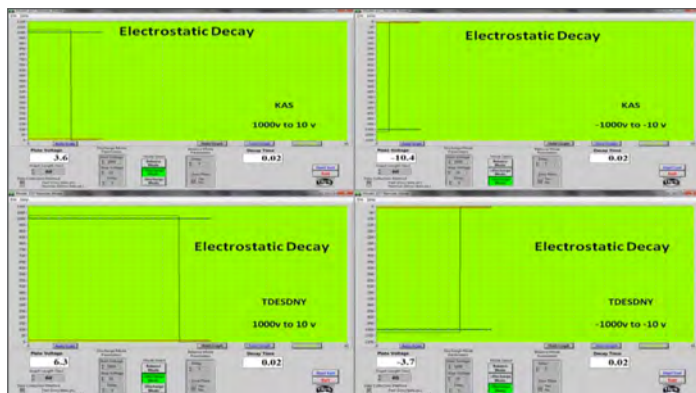


Figure 4.

A second method utilized for Static Control PPE verification is to conduct charge decay tests for six gloves at 12%RH+/-3%RH after 48 hours of preconditioning. For this test, a grounded evaluator wears the gloves making intimate contact with a 6" x 6" stainless steel plate charged to +/-1.0kV then initiating decay for a cut-off of +/-10 volts. In each case, the decay measured less than 2.0 seconds and can be viewed in *Tables 7 – 8*.



Figure 5.

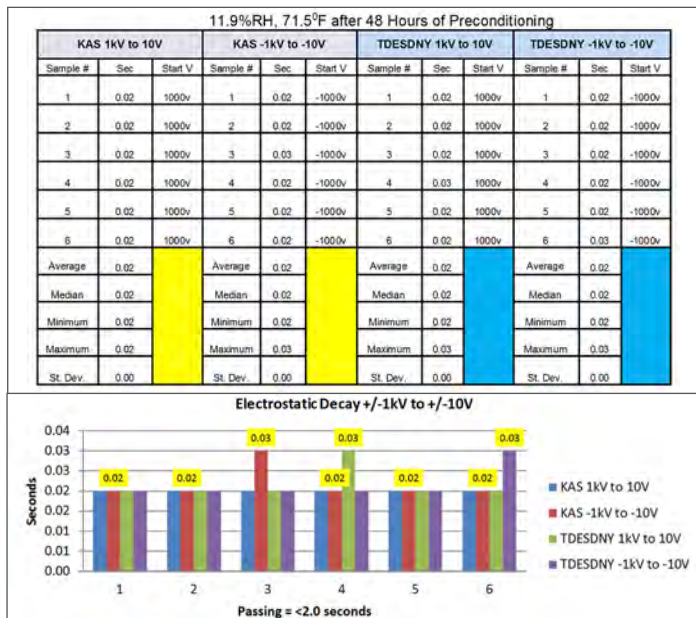


Table 8.

In short, if the reader utilizes both the ANSI/ESD SP15.1 and Electrostatic Decay per MIL-STD-3010C, Method 4046 (Modified), then one can be assured that 3rd party or in-house testing results will confirm a supplier product claims and reduce the risk of suspect counterfeit static control products in the supply chain.

Special Acknowledgement: A special thank you to Duncan Caselman (Duncanc@qrp-gloves.com) who generously provided samples of QRP KAS & TDES DNY gloves for this article.

Bob Vermillion, CPP, Fellow, is a Certified ESD & Product Safety Engineer-iNARTE with proven subject matter expertise in the mitigation of Triboelectrification for Space, Lunar and Mars surfaces and troubleshooting of robotics, systems and materials for aerospace & defense, hand held devices, wearables, medical device, pharmaceutical, automotive and semiconductor sectors. Bob has co-authored several ANSI level ESD documents and is the former Vice-chair of the ESDA Aerospace & Defense under the leadership of NASA-Langley. Vermillion formerly served on the BoD with iNARTE until its merger with RABQSA. Since 2014, Bob is an active contributor with the NASA IAWG for ESD.

On January 26, 2017, Bob was a Special Guest Speaker for the Annual Joint Audit Planning Committee (JAPC) by special invitation from NASA to present a white paper on Materials Validation and CubeSats. On September 26, 2016, Bob presented before the NASA Academy of Aerospace Quality Workshop, Auburn University upon recommendation by NASA. On 21-25 March 2016, Bob trained the NASA Subject Matter Experts (SMEs) for ESD Control, including JPL and UC Berkeley Space Science Laboratory. Speaking engagements include Suspect Counterfeit Training Presentations/Seminars for NASA, DOE, Aerospace & Defense, California Polytechnic University, Loyola University, and, most recently, the NASA Ames GIDEP Conference on 4 April 2016. Vermillion is Founder and CEO of RMV Technology Group, LLC, a NASA Industry Partner and 3rd Party ESD Materials Testing, Training and Consulting Company. Bob Vermillion can be reached at bob@esdrmv.com or 650-964-4792. You can also visit our websites at www.esdaerospacestraining.org and www.esdrmv.com

REFERENCE

1. ANSI/ESD SP15.1-2011
2. MIL-STD-3010C, Method 4046
3. ANSI/ESD S20.20-2014
4. ANSI/ESD S541-2008 LATEX ALLERGY OVERVIEW, AAAAI, <http://www.aaaai.org/conditions-and-treatments/allergies/latex-allergy>

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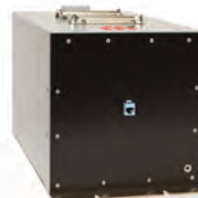
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TEM Cell



CISPR 22 / EN 5022 Solutions



Surge CDN

Applications Mil-Std 461/462, CISPR, FCC, VDE, IEC 61000-4-5, IEC 61000-4-6, ESD, HIRF, TREOP Bellcore, SAE J15447, RTCA DO-160

How to Perform a Manual Radiated Emissions Test

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Oftentimes when a new person is hired to perform radiated emissions testing in a laboratory they know little about EMC and even less about how to perform a test. There is a training period where they will learn how to perform a test using whatever software the lab has been using. They may be well trained in how to perform the test with the automation working, but, what if the control computer fails and the test must be performed? What now?

Try putting yourself in the position of having to perform a radiated emissions test by hand. Once the testing is complete, reduce the data to see if the product passed or failed. Do you know how to do this? Do the people in your laboratory know how to do this?

More importantly, ISO/IEC 17025:2005 requires that software be validated to show that it performs correctly and provides the right answers. If you don't know how the test is actually performed, how do you know that the software is doing it correctly? To quote a line from the second Star Trek movie (The Wrath of Khan), "You've got to know how things work on a Star Ship." Likewise here, you've got to know how to perform the test by hand to know if the software is lying to you.

HOW DO YOU RUN THE TESTS?

What steps should you take to perform the test? What data should you record while running the test? What do you do with the results once you have measured them and run the calculations? Why did that computer have to quit and make me do all this work by hand?

In this article, we'll walk you through the steps, show you what data to collect and what to do with the data. As to why the computer quit and made you do this by hand? You'll need to work on that yourself. I can't help you there.

At each measurement frequency you will need to record the frequency, receiver reading, antenna height, turntable position and antenna polarity. Some labs record separate tables for vertical and horizontal polarities. Some labs do not. Make sure you record this, regardless of how the data is presented. Some labs might do a full test at one polarity and then the other. Others might find the frequencies being emitted by the EUT and check both, one after the other. The choice is up to you, either works.

You should record the antenna height and turntable position where the maximum signal was obtained for future reference. They aren't important for the pass/fail determination, but they can be helpful in the future..

Set up the EUT in the laboratory in accordance with the test standard's requirements. You will need to do this regardless of whether or not the laboratory automation is working. Install the appropriate antenna on the antenna mast, turn on the receiver or spectrum analyzer and give it time to stabilize. Some labs never

turn their receivers or spectrum analyzers off to ensure that they remain stable.

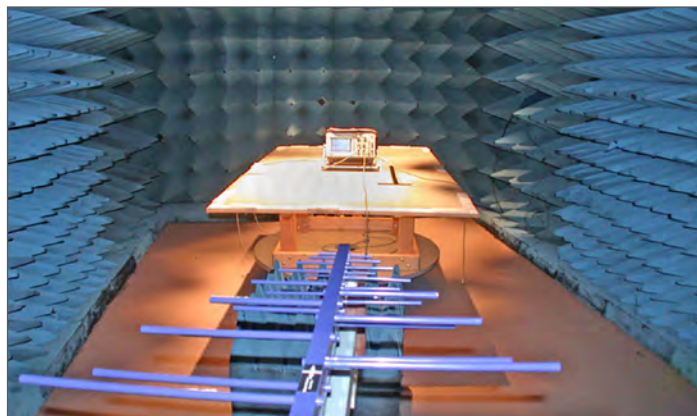


Figure 1 - Setup of equipment under test in a 3m semi-anechoic chamber.

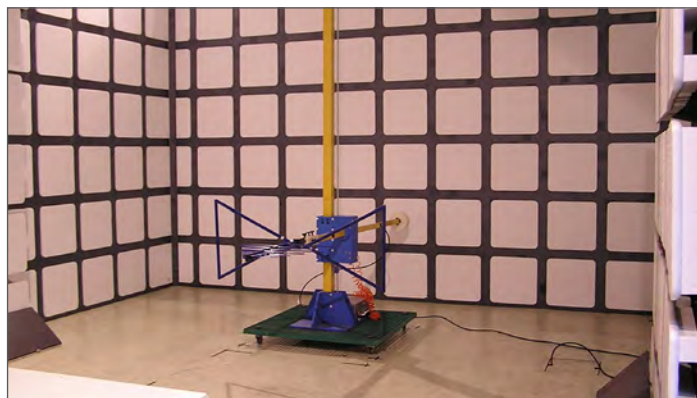


Figure 2 - Hybrid antenna (30 MHz to 1 GHz) on an antenna mast for height scan and both polarities

Most commercial radiated emissions tests start at 30 MHz and end at either 1 GHz or sometimes as high as 6 GHz, depending on the highest internal clock frequencies. Start at 30 MHz and tune through the spectrum, up to the maximum frequency of the antenna in use or the maximum frequency of the measurement, whichever is lower. Change antennas as necessary until the entire frequency range to be tested has been measured. Do the whole process listed below one antenna at a time to cover the desired spectrum.

This sounds simple, except you also need to spin the turntable and vary the height of the receive antenna. When the automation was working, it did this for you. Pre-scans to find emissions from the EUT need to cover the frequency range, various turntable positions, antenna heights and both antenna polarities to make sure that all emissions are found. How many turntable positions and antenna heights? Let's talk about that.

A common step size for turntable positions at frequencies below 1 GHz is 45 degrees. Why 45 degrees? It seems about right. Take a few representative systems, use a spectrum analyzer to sweep a range of frequencies, set the antenna to about 2 meters and spin the table. Do this for

both polarities. How quickly does the amplitude of the signal change as the turntable rotates? Does it ever drop out of sight completely? Probably not. In this initial process you are trying to find frequencies of interest. You are not looking for the maximum reading. 45 degrees has been shown over the years to be generally adequate for ensuring that emission frequencies are identified for going to the next step. Above 1 GHz you may need more turntable positions due to narrower beam widths of emissions from the EUT.

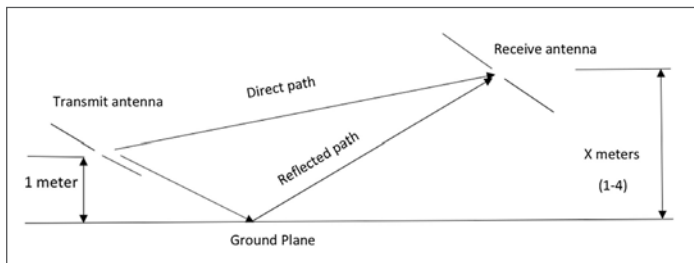


Figure 3 - Diagram showing the direct and reflected waves being detected by the receiving antenna.

Likewise, what antenna heights are needed? Keep in mind that the reason we vary the height of the antenna is that we have two paths at an OATS (and in a good RF semi-anechoic chamber) that RF will follow from the EUT to the antenna. The direct path and a reflected path bouncing off the ground plane. These two paths are different lengths. We vary the height of the antenna to find, ideally, the position where these two waves arrive in phase and give us a maximum reading. This height will change as a function of frequency as the wavelength changes with frequency. At 30 MHz we will find that we get the maximum vertically polarized level with the antenna at 1 meter (the minimum height used) above the ground plane. At this frequency the maximum horizontally polarized signal will be found at 4 meters above the ground plane. As we tune higher

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in frequency the height for the maximum changes. You can sit on a single frequency and watch the amplitude of the received signal change as antenna height changes, sometimes so severely that the signal drops into the receiver noise. Due to these nulls it is important that pre-scans be done at a variety of antenna heights to avoid missing a signal.

One way to avoid the problem of step size determination is to perform the pre-scans with a spectrum analyzer. Set the analyzer to MAX HOLD as you scan a range of frequencies. While it is scanning, spin the turntable and scan the antenna heights. Repeat for the other polarity. When you are finished the spectrum analyzer should give a clear indication of the frequencies that require more detailed study.

Now that you have a list of frequencies (within the limitations of the spectrum analyzer to discriminate while scanning) you can go back to each. Tune in the first frequency on the list to find its actual center frequency. Set the receiver to the appropriate detector and bandwidth. Scan the antenna height and turntable positions to find the maximum reading. Take the reading with the appropriate detectors and record the result. Repeat for the other polarity, or as suggested earlier, wait until all signals have been measured and repeat for the other polarity. Now tune to the next frequency on the list and repeat.

OK, NOW YOU HAVE THE MEASUREMENTS. WHAT NEXT?

Once you have measured all the frequencies of interest go back to the first one and calculate the field strength using *Equation 1*. Compare the results against the limit. If the signal isn't above the limit, it passes. Go to the next frequency measured and repeat. How do you do all this? Where do you get the other numbers needed?

You have a data sheet full of readings. Frequencies and receiver readings. You have a table showing the gain of your pre-amplifier (assuming you used an external pre-amplifier) as a function of frequency. You have another table showing your cable loss, again as a function of frequency. And, finally, you have tables showing the antenna factors of your antennas as a function of frequency. Your receiver readings are in dBμV and the limits are in dBμV/m. How do you get from the receiver readings to the field strength to compare with the limit?

“Back in the day” this was always done by hand. There was no other way. A simple equation is used to convert the receiver reading to a field strength, knowing the other inputs. This equation is:

$$E_{dB\mu V/m} = V_{dB\mu V} - G_{dB} + CL_{dB} + AF_{dB/m} \quad (1)$$

where: $E_{dB\mu V/m}$ is the field strength in dBμV/m

$V_{dB\mu V}$ is the receiver reading in dBμV

G_{dB} is the gain of the external pre-amplifier in dB

CL_{dB} is the loss in the antenna cable in dB

$AF_{dB/m}$ is the antenna factor in dB/m

Each of these values is different at each measurement frequency, so you have to have them all. Notice that you subtract the pre-amplifier gain as the input will be lower than the output going to the receiver and you add the cable loss and antenna factors.

You might start out with a table that looks something like the following:

Table 1 - Example of a data table	
Frequency (MHz)	30.0
	44.3
Receiver Reading (dBμV)	45.3
	34.9
Pre-amp Gain (dB)	26.1
	25.2
Cable Loss	1.0
	1.2
Antenna Factor	10.0
	11.2
Field Strength (dBμV/m)	30.2
	-
Antenna Height (m)	1.00
	1.30
Turntable Position (degrees)	150
	170
Polarity (V/H)	V
	V
Limit (dBμV/m)	30
	30

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The first six columns look familiar, don't they? They're just from the equation above, along with a notation of the frequency. But the next three weren't included in the equation. Why are they important? The last item is the limit. You need to compare the field strength with the limit to see if the product passed or failed. You get this number from the standard or regulation you are testing against. Remember, the limit is a function of frequency. You might put this in the table in column 7 and move the other items one column to the right if you like. The other three (antenna height, turntable position and antenna polarity) are useful for reference, but aren't key to determining if this data set shows pass/fail for the EUT.

In filling out this table enter the frequency of the measurement into the first column. Then enter your receiver reading into the second column. Look up the pre-amplifier gain in a table and enter it in the third column. This assumes that the pre-amplifier was calibrated at a frequency near the measurement frequency and its gain doesn't change that much between calibration points. If it does change significantly you might interpolate the gain between the two calibration frequency points that straddle your measurement frequency. A simple formula for interpolation is *Equation 2*.

$$Gm = \left(\frac{F - CF1}{CF2 - CF1} \right) * (G2 - G1) + G1 \quad (2)$$

Where: F is the measurement frequency

CF1 is the calibration frequency below the measurement frequency

CF2 is the calibration frequency above the measurement frequency

G1 is the calibrated gain at Cal Frequency 1

G2 is the calibrated gain at Cal Frequency 2

Gm is the gain at the Measurement Frequency

If the gain at 30 MHz was 26 dB, the gain at 50 MHz was 27 dB and the measurement frequency was 40 MHz, what would the gain be, assuming that the gain changed smoothly with frequency? Plug the numbers into the equation above and see what you get. The answer is at the end of this article. How did you do? And, no, these are not the numbers shown in *Table 1*.

You would calculate the cable loss and antenna factors in the same manner. Look them up in a table as a function of frequency and interpolate if necessary.

Once you have the receiver reading, pre-amplifier gain, cable loss and antenna factor for the frequency of the measurement you can plug them into *Equation 1* to find the field strength at the measurement frequency. Enter this number in the column in the table for Field Strength. Compare that against the limit at the frequency and you have a Pass/Fail determination.

Table 1 shows a complete line of data in the first line. Frequency, receiver reading, preamplifier gain, cable loss, antenna factor,

field strength (calculated), antenna height, turntable position, polarity and limit. The second line has all the information that you would have taken in the measurement (frequency, receiver reading, antenna height, turntable position and polarity), along with the preamplifier gain, cable loss and antenna factors after looking them up or interpolating them. All that remains is to use *Equation 1* to fill in the remaining blank. What should that value be? Did you get it right? The limit shown is from CISPR 22 or CISPR 32, Class B for measurements at 10 meters. Did the product pass or fail?

THAT WAS A LOT OF WORK!

You bet it is. That's why automating the tests is important. However, somewhere along the line (and maybe more often than once) you will need to perform some measurements on a device to provide a baseline to check that the software is operating properly and providing acceptable results. An accredited laboratory will have to do this. As you can see, performing radiated emissions testing by hand is a time consuming and somewhat tedious process. But when the automation quits, or you have to demonstrate that the automation is performing the test correctly, you must know how the tests are performed and be able to do them manually. Train your laboratory personnel on how to do the measurements by hand. Normally they won't have to do this, but wouldn't it be nice to know that they know how?

Answers:

Gain is 26.5 dB $26.5 = ((40 - 30) / (50 - 30)) * (27 - 26) + 26$

Field strength for the second line is 22.1 dBμV/m

$$22.1_{\text{dB}\mu\text{V/m}} = 34.9_{\text{dB}\mu\text{V}} - 25.2_{\text{dB}} + 1.2_{\text{dB}} + 11.2_{\text{dB/m}}$$

The product failed. It is 0.2 dB over the limit at 30 MHz.

AUTHOR

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Simulating EM Shielding for Aeronautical Applications

Dr. David Johns

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The airframe of an aircraft can provide some measure of shielding against high-intensity radiated fields (HIRF), but this is compromised by doors, windows, seams, access panels and components interfaced to the airframe such as antennas used for communication and navigation. Composite materials are increasingly used in aeronautical applications due to their relatively light weight, but their unique electromagnetic properties create additional challenges for maintaining shielding integrity. This article will explore the electromagnetic simulation of shields at both the component and airframe level, while demonstrating how special modeling techniques applied in the 3D TLM method can be used to improve the efficiency of capturing the important coupling mechanisms.

INTRODUCTION

Aircraft are subject to a range of environmental electromagnetic effects (E3), such as lightning strikes, electromagnetic pulses (EMP) and high-intensity radiated fields (HIRF), which can pose a risk to the safe performance of avionics. Shielding can mitigate these risks and protect electronic systems. However, shielding effectiveness may be compromised by aperture leakage or diffusion, allowing fields to penetrate.

This means that when developing shielding, the aircraft engineer has to balance several contradictory design requirements. In the name of weight reduction, material use should be minimized, but making shields thinner can increase leakage. This is made more complex by the increasing use of lightweight composite materials in the airframe, which have different electromagnetic properties to the conventionally used metals, and by the need to include doors, windows and cables in the aircraft (Figure 1).

Electromagnetic simulation offers an effective way to investigate these effects during the design process. Simulation allows the effect different configurations and material properties to be assessed easily and field visualization helps engineers to identify the coupling paths that lead to field penetration.

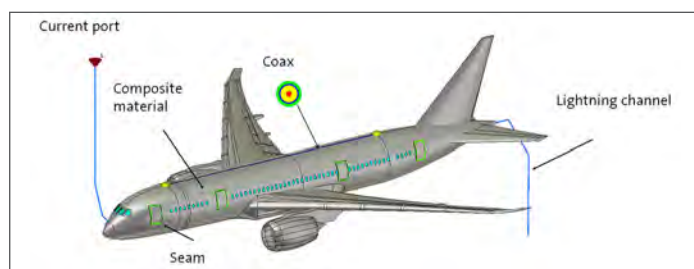


Figure 1. Simulation setup for a lightning strike on an airliner, showing some critical points in the shielding. These include cables, door seams and composite materials.

E3 SCENARIOS

There are a range of different scenarios that need to be considered for shielding analysis, including HIRF, EMP, lightning strike, electrostatic discharge (ESD) and radiated emissions from onboard devices. With the right simulation setup, these can all be assessed with virtual prototypes.

As these are all usually broadband or transient phenomena, a time domain approach is usually the best choice. With time domain simulation, the entire frequency spectrum of interest can be covered by a single simulation. External fields can be modeled using plane waves for external effects such as HIRF and EMP, or using near field sources drawn from simulation or measured data and placed within the aircraft. Using field sources can reduce the complexity of simulation, replacing detailed models with more efficient representations of the source of emissions.

For lightning strike analysis, lightning channels can be modeled as wires connecting the aircraft to a current source. Lightning attachment zones can first be predicted using electrostatic simulation [1].

SKIN EFFECT AND COMPOSITE MATERIALS

The penetration of fields through solid material is limited by the skin effect. High frequency current does not flow uniformly throughout the cross-sectional area of a conductor. Instead, the current flows in a thin layer just underneath the surface, and the thickness of the conduction layer is defined by the skin depth at that frequency. The skin depth is defined as the depth at which field intensity has reduced to $1/e$ or 37%.

In metals, which have high conductivity and often also high permeability, the skin depth is very short. Aluminum has a conductivity of around 35 MS/m, and the skin depth at 1 MHz is around 0.085 mm. At these frequencies, any diffusion through typical metal thicknesses would be negligible.

However, because of their light weight and strength, carbon fiber composite (CFC) materials are increasingly used in aircraft, with some modern airliners being over 50% composites. These materials are significantly less conductive, and provide less shielding. Carbon fiber has a conductivity of around 104 to 105 S/m with corresponding skin depths at 1 MHz ranging between 1.6 and 5 mm – orders of magnitude greater than aluminum. This will result in significantly greater field diffusion through the material.

An additional complication is that CFC materials often have a complex structure giving them anisotropic EM properties. Multiple layers of fibers are stacked to form a laminate, and the fiber direction can vary from ply to ply.

Figure 2 shows how this can significantly affect the shielding performance of the material. In this simulation, a broadband diagonally polarized plane wave is incident on a sheet of CFC laminate. In one variant, the fibers in each ply are all aligned in the same direction (uni-directional or UD). In the other, each layer is rotated sequentially (quasi-isotropic or QI). As the results show, the QI laminate attenuated the fields by a similar amount in both x and y directions. However, the UD laminate shows very different results, with around a 50 dB difference in field transmission between the two components.

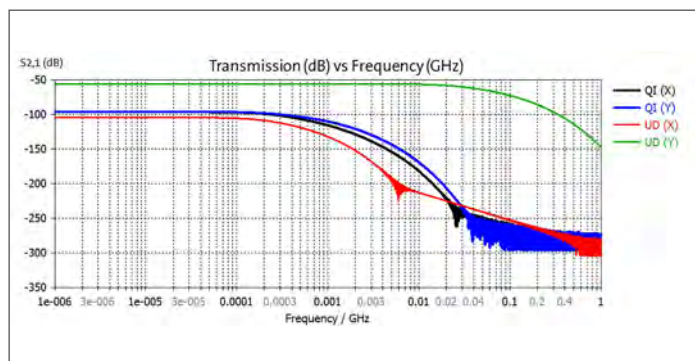


Figure 2. Simulated transmission of a diagonally-polarized plane wave incident on an 8 ply CFC laminate 1.6 mm thick.

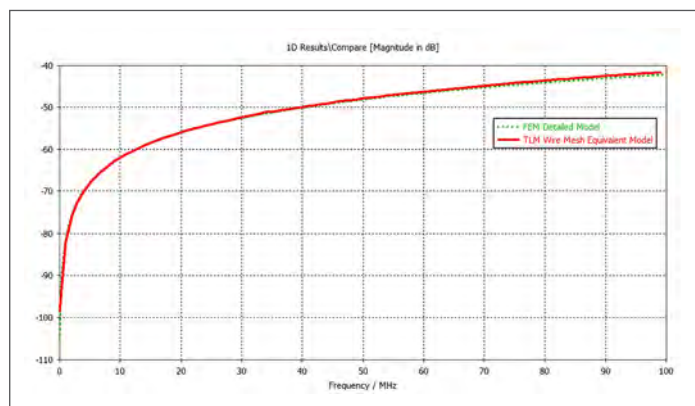


Figure 3: (left) Agreement between simulated transmission results for a detailed wire mesh model and an equivalent model. (right) Agreement between analytic transmission results for stacked graphite layers and a simulation with an equivalent model.

Because CFC materials offer less shielding, especially at low frequencies, they can be supplemented with wire mesh. This creates a Faraday cage that can significantly increase shielding and light-

ning protection. Both CFCs and wire meshes contain fine detail, and this can be simulated much more effectively using equivalent models rather than modeling individual wires or fibers. The examples in this article were simulated using the multi-layer (stacked) thin panel material and wire mesh material in CST STUDIO SUITE®. These offer extremely close agreement to more detailed models and to the expected analytical results (Figure 3).

FINE DETAILS

Any practical shield will have some gaps in it; for example, vents, windows, joints and seams. Fields can penetrate through these – even very fine seams can compromise shielding if the length of the seam corresponds to the resonant frequency of the incident radiation (Figure 4). This means that modeling all this fine detail is essential for the accurate simulation of shielding performance, and special simulation methods are required in order to perform these calculations in a practical length of time.

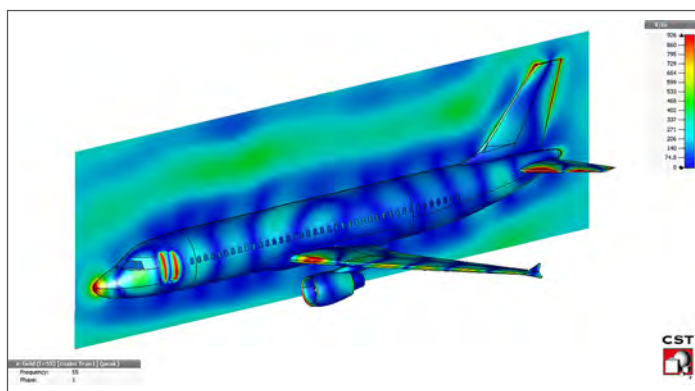


Figure 4. Induced fields and currents on an aircraft subject to HIRF at 55 MHz. There is a considerable resonance in the seam around the front door frame.

For E3 simulations, the time domain transmission line matrix (TLM) solver is often a very efficient tool. The TLM solver is broadband, and it can also model transient effects such as lightning strikes directly. In addition, the TLM solver also supports octree meshing, with a very fine mesh around small details and a sparser mesh in open space. This can significantly reduce simulation run times compared to other solver types, especially when combined with high-performance GPU computing.

In addition, many fine details from the CAD data can be replaced with compact models. For example, simulating the shielding performance of an avionics box that includes a ventilation panel in 3D would mean that each individual hole needs to be modeled and meshed, increasing simulation time. The vent can therefore be replaced by a compact model containing an analytic representation of the vent's transmission properties, which is much faster to simulate – the mesh can be larger than the aperture size, which not only reduces the number of mesh cells needed but also allows a larger time step for a shorter simulation. Figure 5 shows the implementation of a compact vent model for simulating an electronics enclosure. Using the compact model reduced simulation times by 25% compared to a 3D model with a rough mesh, and by 85% compared to a more accurate fine mesh. The simulated compact model results also agreed closely with measured results, demonstrating the viability of simulation for virtual prototyping.

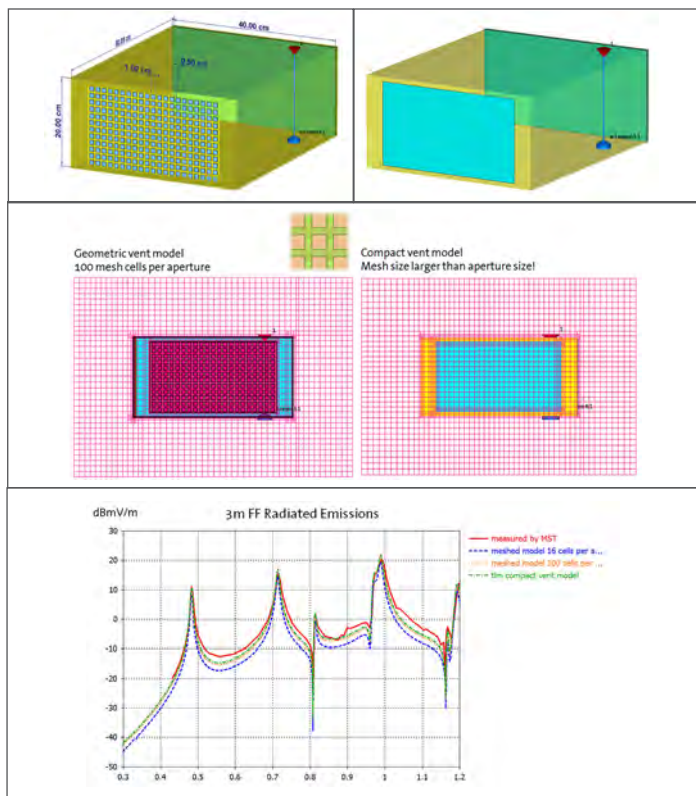


Figure 5. Detailed (top left) and compact (top right) models of a vent on an enclosure, showing the 3D model (middle) and mesh (bottom) with simulated and measured far field results at 3 m. Measured data from [3]

Similarly, an equivalent model can be used to simulate leakage through slot/seam apertures or fasteners. This is demonstrated below where a direct electrostatic discharge (ESD) onto the front panel of a box is simulated. The ESD is simulated by modeling a laboratory ESD test setup, allowing direct comparison of measured and simulated data (Figure 6).

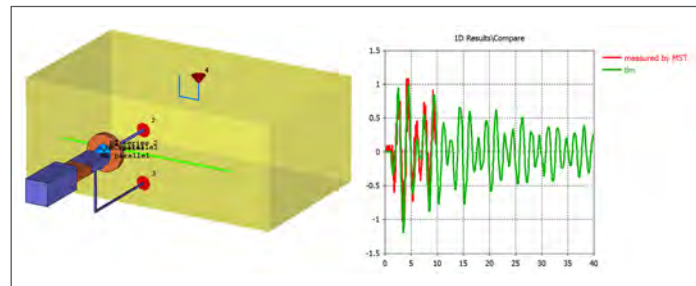


Figure 6: Comparison of simulation and measurement of an ESD shielding test scenario, showing excellent agreement between measured and simulated data [2].

Finally, an aircraft will contain many kilometers of cabling, mostly bound into complex cable harnesses. Cables are a significant factor in electromagnetic susceptibility – fields can couple into cables and cable shields and then be reradiated elsewhere. Again, the complexity and size of cables means that they are much more efficiently simulated with hybrid methods, combining full-wave 3D and analytic approaches.

CONCLUSION

Implementing simulation in the design process gives engineers greater capacity to analyze and optimize EM shielding at an early stage. Simulated and measured results complement each other: replicating common test scenarios with virtual prototypes allows changes to be implemented and assessed without the time and money costs associated with a physical prototype.

REFERENCES

1. Kunze, Marco, "Supporting Future Aircraft Certifications with EM Simulations", In Compliance, Dec 2015
2. F. Centola et al., "ESD Excitation Model for Susceptibility Study," Proceedings of the IEEE International Symposium on EMC, Aug 2003
3. Li, Min; Nuebel, J.; Drewniak, James L.; Hubing, Todd H.; DuBroff, Richard E.; and Van Doren, Thomas, "EMI reduction from airflow aperture arrays using dual-perforated screens and loss", IEEE Transactions on EMC, Aug 2000

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2017 Calendar of Events

The following is a partial listing of major EMC-related conferences planned for 2017. If your conference is not listed, please contact: info@interferencetechnology.com.

THE 20TH ANNUAL DOD (E3) PROGRAM REVIEW

April 3 – 7, 2017

San Antonio, Texas

The Program Review is an information exchange forum for DoD Components, the Federal Government, and Industry E3 and Spectrum Management professionals to collaborate, network, and meet to discuss policy and regulations, acquisition trends, operational supportability, and emerging technology. It also features dozens of technical presentations, several training seminars, and many working groups, ad hoc meetings, and exhibitions. The proposed theme of this year's event is Joint Electromagnetic Spectrum Operations (JEMSO).

<https://www.fbcinc.com/e/dode3/attendeeereg.aspx>

THE BATTERY SHOW EUROPE 2017

April 4 – 6, 2017

Stuttgart, Germany

The Battery Show Europe Exhibition & Conference is a showcase of advanced battery manufacturing and technology for electric & hybrid vehicles, utility & renewable energy support, portable electronics, medical technology, military and telecommunications.

<http://www.thebatteryshow.eu/>

EMC LIVE 2017

April 25 – 27, 2017

Online

Join the fastest growing online EMC event of the year. EMC Live teaches the latest in practical solutions to electromagnetic interference (EMI) challenges – all for FREE, and all LIVE. Learn directly from industry professionals during 3 days of technical webinar presentations, product demonstrations, and an abundance of resources from whitepapers to application notes. Several electromagnetic compatibility (EMC) topics will be covered, including shielding, ground filtering, standards, pre-compliance, and testing, all applicable to electronics, design, and test engineers working in any industry. Enjoy from the comfort of your office chair!

<http://emc.live/>

RF AND MICROWAVE PACKAGING (RAMP) CONFERENCE 2017

April 26 – 27, 2017

Paris, France

The objective of the RF and Microwave Packaging Workshop is to provide a unique forum that brings together scientists, engineers, manufacturing, academia, and business people from

around the world who work in the area of RF and Microwave packaging technologies. This workshop enables discussion and presentation of the latest RF and Microwave technology. To help bring together the international community, this workshop is being co-sponsored by IMAPS-France and will be the continuation of a series of joint workshops on RF and Microwave packaging between IMAPS and IMAPS-France and UK Chapters.

<http://www.imaps.org/rf/>

DGCON 2017

May 15 – 17, 2017

Herzliya, Israel

The Hardware Design Practices of today require the possession of vast ranges of expertise. The main reason for this requirement is the constantly evolving Data Transfer Rates. In addition to the “Legacy” practices, the “New-Age” Hardware Designer needs to hold a vast knowledge expertise in the field of Signal Integrity & Power Integrity, RF and EMC. DGCON, initiated by Dgtronix, is the main Israeli Conference targeted to provide the necessary Technical Knowledge, covering many aspects of Hardware Design including Simulations and Advanced Simulation Tools, IC & Passive Interconnects Modeling, Ultra-High-Speed SERDES and Interfaces, Test & Measurement Tools, Advanced Board Design and PCB Layout Methodologies, and Modern PCB Materials & Manufacturing.

<https://www.dgcon.info/>

59TH ELECTRONICS MATERIALS CONFERENCE

June 28 – 30, 2017

Notre Dame, Indiana

The Electronic Materials Conference (EMC) is the premier annual forum on the preparation and characterization of electronic materials. The conference will be held at the University of Notre Dame in South Bend, Indiana. The conference features a plenary session, parallel topical sessions, a poster session and an industrial exhibition.

<https://www.mrs.org/59th-emc>

5TH ADVANCED ELECTROMAGNETICS SYMPOSIUM (AES 2017)

July 26 – 28, 2017

Incheon, South Korea

Be a part of AES 2017, the 4th Advanced Electromagnetics Symposium and take the opportunity to meet, interact and network with the experts of Electromagnetics. The program will facilitate discussions on various relevant topics of the subject among the participants in a dynamic setting. The program will also feature

keynote and invited speakers addressing the most pressing issues of the subject and best practices to inspire the participants. Additionally, through its unique from-Conference-to-Journal-Publication concept, AES offers an opportunity for authors to submit their papers to a special issue in Advanced Electromagnetics journal. <http://mysymposia.org/index.php/AES17/AES17>

IEEE EMC+SIPI 2017 INTERNATIONAL SYMPOSIUM

August 7 – 11, 2017

National Harbor, Maryland

The 2017 Symposium on EMC+SIPI is the leading event to provide education of EMC and Signal and Power Integrity techniques to specialty engineers. The Symposium features five full days of innovative sessions, interactive workshops/tutorials, experiments and demonstrations, and social networking events. Join your colleagues August 7 – 11, 2017 at the EMC + SIPI Symposium in National Harbor, Maryland just outside of Washington D.C.

<http://www.emc2017.emcss.org/>

EMC EUROPE 2017

September 4 – 8, 2017

Angers, France

EMC Europe 2017 focuses on the high quality of scientific and technical contributions as well as the fruitfulness of exchanges among EMC researchers and practitioners from all over the world, in a spirit of openness and conviviality. The conference will cover the whole spectrum of EMC topics, including emerging trends. Special sessions, workshops, tutorials and a large exhibition will be organized along with regular sessions.

<http://emceurope2017.org/>

EDI CON USA

September 11 – 13, 2017

Boston, Massachusetts

EDI CON USA is first industry event in the USA to bring together RF, microwave, EMC/EMI, and high-speed digital design engineers and system integrators for networking, product demonstrations, training, and learning opportunities. Got a design challenge? Bring it to EDI CON USA and ask your peers and industry experts about it. Chances are, you'll come away with an

entirely new perspective on the problem, and some immediate ways to move forward.

<http://www.ediconusa.com/>

THE BATTERY SHOW 2017

September 12 – 14, 2017

Novi, Michigan

The Battery Show Exhibition & Conference is a showcase of advanced battery technology for electric & hybrid vehicles, utility & renewable energy support, portable electronics, medical technology, military and telecommunications.

<http://www.thebatteryshow.com/>

EMC TURKEY 2017

September 24 – 27, 2017

Cankaya Ankara, Turkey

After three successful EMC Turkiye Conferences we are glad to inform you that everything is ready for the take off EMC Turkiye 2017, The Fourth International EMC Conference to be held in Middle East Technical University (METU) Ankara between Sep 24 – 27, 2017, with the sponsorships of the IEEE EMC Society and the IEEE AP Istanbul Chapter. The official conference website is www.emcturkiye.org. All papers will be listed in the IEEE Xplore and in IEEE digital library.

<http://www.emcturkiye.org/index.php?page=home>

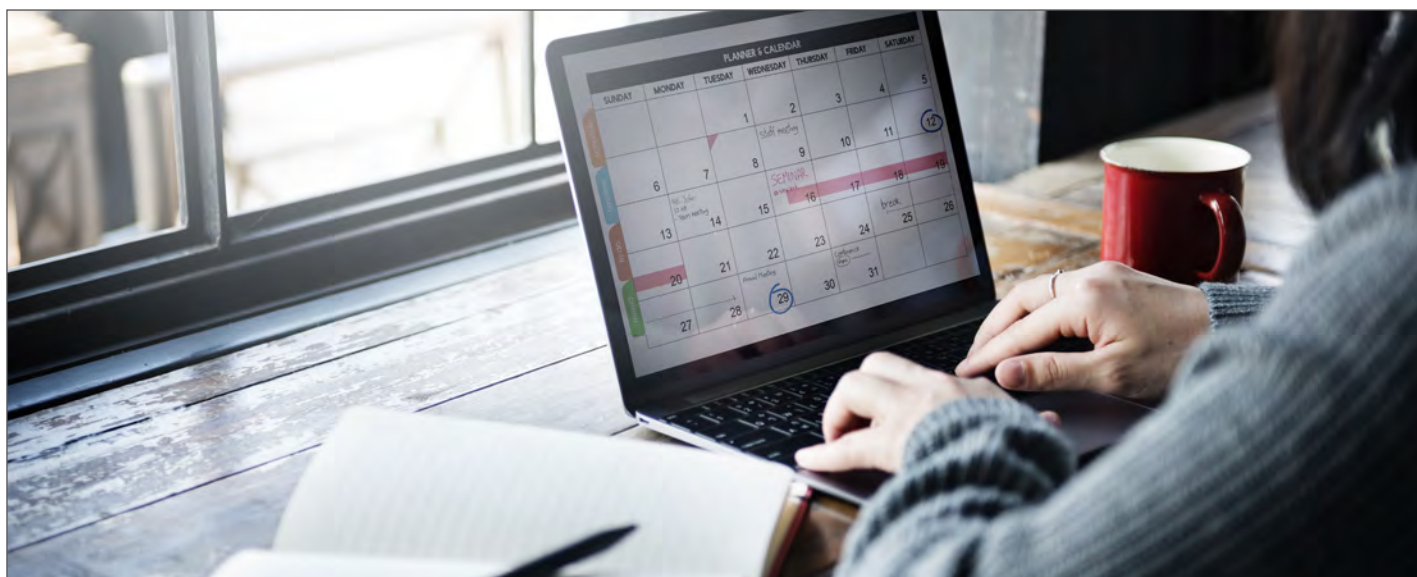
AUTOMOTIVE TEST EXPO 2017

October 24 – 26, 2017

Novi, Michigan

At the thirteenth Automotive Testing Expo USA you can see the very latest technologies and services that are designed to ensure that the highest standards are met in terms of product quality, reliability, durability and safety. Over 300 exhibiting companies will be out to demonstrate that their products are able to help with the ultimate aim of ELIMINATING RECALLS. These must surely be the drivers of any successful car industry; they represent fundamental features that are uppermost in customers' minds, and are essential for brand loyalty and brand protection as well as global sales success.

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DGCON, is the main event of Israel in the field of Signal & Power Integrity and EMC. The 4th DGCON gathers world-renowned SI / PI gurus along with Israeli Engineers. The Conference is targeted to provide the necessary Technical Knowledge covering various aspects of Hardware / ASIC Design.

www.dgcon.info



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2016/2017 Standards Review

Compliance with standards makes or breaks the launch of any new product. This section recaps new and revised national and international EMC standards over the last 12 months. The information below has been featured in our weekly Interference Technology eNews. Just go to InterferenceTechnology.com, subscribe to the eNews, and you'll be updated on important changes in EMC standards weekly.

RADIO EQUIPMENT DIRECTIVE, 2014/53/EU

February 1, 2017

Note: The Radio Equipment Directive (RED), 2014/53/EU, must be used for new products manufactured after June 13, 2016 and becomes mandatory for all products June 13, 2017.

Abstract

This article provides an update on changes occurring as a result of the new Radio Equipment Directive (RED) 2014/53/EU which can be used from June of 2016. It looks at the changes in the product and regulatory landscape and at what it means to equipment manufacturers. More detail on the history of the RED can be found in the article, Radio Equipment Directive, in the Interference Technology 2015 EMC Directory and Design Guide.

To read the full article, <https://interferencetechnology.com/radio-equipment-directive-201453eu/>

REVIEW OF IEC 60601-1-2: 2014 (4TH EDITION)

February 22, 2017

IEC 60601-1-2:2014 Edition 4 was published February 2014 and replaces IEC 60601-1-2 Edition 3 published on 2007. It pertains to EMC for medical electrical equipment and medical electrical systems. The European version (EN60601-1-2:2015) is identical to its IEC counterpart with exception of references to the EN versions of the 61000-4-x series and the addition of an Essential Requirements annex.

The motivation behind the 4th edition was to create a safety standard that pertains to electromagnetic disturbances in order to align with the general requirements of IEC 60601-1 Edition 3. The previous version of IEC 60601-1-2 did not adequately address the safety aspects as related to electromagnetic interference. In addition, the differences between edition 3 and 4 with respect to immunity are substantial.

To read the full article, <https://interferencetechnology.com/review-iec-60601-1-2-2014-4th-edition/>

CISPR 35 PUBLISHED – MULTIMEDIA IMMUNITY

September 7, 2016

Blog post by Ghery Pettit

Now that CISPR 35 is finally published, the questions that you want answered are: What is the same as CISPR 24? What has changed? What is new? To read the full blog post, [click here](#).

EMF DIRECTIVE – WORKPLACE HEALTH AND SAFETY IN ELECTROMAGNETIC FIELDS

August 10, 2016

As of July 1, 2016, all EU member states are required to have implemented Directive 2013/35/EU for the protection of persons from electromagnetic fields (EMF) in the workplace in national laws. As a consequence, companies throughout Europe must now ensure that their employees are not exposed to fields greater than the exposure limits, some of which have been newly defined. This requires monitoring and minimizing risk through preventive measures where necessary.

The underlying EMF Directive defines “Minimum health and safety requirements regarding the exposure of workers to the risks arising from the physical effects of electric, magnetic, and electromagnetic fields in the frequency range between 0 Hz and 300 GHz”. Its limit values are primarily based on the recommendations of ICNIRP, the International Commission for Non-Ionizing Radiation Protection. They have been reworked in line with the latest scientific findings and refer exclusively to the proven direct short term effects on the human body.

The new feature of the EMF Directive is the requirement that employers must now assess the risk separately for each workplace. The responsibility of ensuring that the limit values for workers are not exceeded means that every risk has to be assessed first and then the actual exposure levels recorded in a way that complies with the Directive. The emission specifications of device manufacturers or computed values can be used for this, particularly in areas such as offices and laboratories where only low-current equipment is used. For certainty, measurement is now required everywhere else where a higher local EMF exposure level is suspected, such as in metal industry production plant, welding or smelting equipment.

This new set of rules stipulates that specialist personnel should record the field values at regular intervals and then document these in traceable form for this purpose.

For more, <https://www.narda-sts.com/en/company/press/>

FDA FINALIZES GUIDANCE IN SUPPORTING CLAIMS OF EMC

July 20, 2016

The U.S. Food and Drug Administration (FDA) has issued final guidance in supporting claims of electromagnetic compatibility (EMC) of medical devices. The document is recommended for use in conjunction with consensus standards, as well as other FDA guidance documents pertaining to specific devices.

Typically, the FDA reviews EMC information based on the risk of device malfunction and/or degradation if the device is exposed to electromagnetic interference by other devices near its intended electromagnetic environment. The proliferation of smartphones, wearables, home appliances, and other electronic devices poses a threat to safe performance of medical devices, and the FDA wants manufacturers to follow established standards and guidance documents to mitigate risks.

Manufacturers are recommended to follow device-specific guidance, such as one issued for Infusion Pumps Total Product Life Cycle, and cross-cutting guidances, such as Design Considerations for Devices Intended for Home Use.

In addition to following these FDA-recognized standards and guidance documents, and in order to support a claim of electromagnetic compatibility in premarket submissions, the FDA recommends in the final guidance that manufacturers include several items of information. The final guidance document applies to premarket approval (PMA) applications, humanitarian device exemption (HDE) applications, premarket notification [510(k)] submissions, investigational device exemption (IDE) applications, and de novo requests.

To learn more, <https://www.fda.gov/ucm/groups/fdagov-public/@fdagov-meddev-gen/documents/document/ucm470201.pdf>

FCC RELEASES UPDATED LED LIGHTING EMC GUIDANCE

July 14, 2016

(June 17, 2016) Effective June 17, 2016, all RF LED lighting devices, including those that have been considered to operate on frequencies below 1.705 MHz, are now required to have Radiated Emissions measurements performed at a minimum from 30 MHz to 1000 MHz.

Radio frequency (RF) light-emitting diode (LED) lighting products are subject to FCC rules to ensure that devices do not cause harmful interference to radio communications services. This KDB publication clarifies how the FCC rules apply to these products, and outlines manufacturers' responsibilities for controlling interference. This publication does not address older legacy lighting technologies such as incandescent, fluorescent, and high intensity discharge (HID) lighting products.

For more, https://apps.fcc.gov/kdb/GetAttachment.html?id=K-0pZdRE7biF3aagO4XZ8cw%3D%3D&desc=640677%20D01%20RF%20LED%20LIGHTING%20v01&tracking_number=20518

ETSI RELEASES DRAFT STANDARD FOR LOW POWER MEDICAL IMPLANTS

July 14, 2016

(July 1, 2016) The present document together with ETSI EN 301 489-1 [1] covers the assessment of all radio transceivers associated with inductive Ultra Low Power Active Medical Implant (ULP-AMI) transmitters and receivers operating in the range from 9 kHz to 315 kHz and any associated external radio apparatus (ULP-AMI-Ps) transmitting in the frequency range of 9 kHz to 315 kHz including external programmers and patient related telecommunication devices in respect of ElectroMagnetic Compatibility (EMC). Non-radio parts of the above equipment may be covered by other directives and/or standards when applicable.

To download the draft, http://www.etsi.org/deliver/etsi_en/5C301400_301499/5C30148931/5C02.01.00_20%5Cen_30148931v020100a.pdf

IEC 60601-1-9 – ENVIRONMENTALLY CONSCIENCE DESIGN FOR MEDICAL EQUIPMENT

July 6, 2016

The standard for environmentally conscious design, IEC 60601-1-9, was published in 2007 (amended in 2013) as a collateral standard to IEC 60601, the widely accepted series of international standards for the basic safety and essential performance of medical electrical equipment. Compliance with the IEC 60601 series is required by regulatory bodies responsible for electrical medical equipment in many countries.

The requirements of IEC 60601-1-9 are based on practical experience made by reputable medical manufacturers which showed that the application of the standard may result in cost savings and marketing benefits.

Clients continue to increase pressure on manufacturers to develop medical devices with an environmentally conscious design, as it is seen as an aspect of an overall good design practice.

For more, <http://www.intertek.com/medical/iec-60601-1-9/>

MIL-STD-464C REVISION PROCESS UNDERWAY

May 26, 2016

US DoD has begun the process to revise MIL-STD-464C.

Industry comments are welcome, and should be funneled through the two industry reps to the DoD Tri-Service Working Group: ken.javor@emccompliance.com and briand.lessard@lmco.com.

Format for comment submission is very specific and must be adhered to rigorously. The comment should provide change from, change to, and rationale. A suitable form is available from ken.javor@emccompliance.com.

ASSIST IS OFFICIAL ARCHIVE FOR MIL-STD DOCUMENTS

May 18, 2016

ASSIST is a web site used by standardization management to develop, coordinate, distribute, and manage defense and federal

STANDARDS REVIEW

specifications and standards, military handbooks, commercial item descriptions, data item descriptions, and related technical documents prepared in accordance with the policies and procedures of the Defense Standardization Program (DSP).

Besides DoD-prepared documents, ASSIST also has selected international standardization agreements, such as NATO standards ratified by the United States and International Test Operating Procedures.

Since it always has the most current information, ASSIST is the official source for specifications and standards used by the Department of Defense.

Find all archived copies of MIL-STD-461, http://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=35789

TRANSITIONING TO NEW EMC DIRECTIVE 2014/30/EU

May 10, 2016

Now that the new EMC Directive 2014/30/EU is mandatory and in effect as of April 2016, what do manufacturers need to do to ensure continued compliance?

Elite Electronics Engineering has a five-step plan that explains the recommended steps involved. As a minimum, Elite recommends the following steps to ensure continuing compliance with European EMC requirements:

1. Check revision dates of the harmonized standards and update any technical reports
2. Review Annex IV and update the Declaration of Conformity (DoC) by updating the EMC Directive reference to 2014/30/EC, listing all current revisions of the harmonized standards applied, and clearly identifying the apparatus in the DoC to allow traceability.
3. For self-declared products, update technical documentation as specified in Annex II (3).
4. Review the CE label and confirm it's correctly applied.
5. Confirm the operator's information and technical instructions comply with Article 18.

For a copy of 2014/30/EU or questions concerning the new EMC Directive, file:///Users/itemmedia/Downloads/EMC%20Q&A%20on%20EMCD_%20FINAL_2%202028-04-2016%20(5).pdf

NEW EUROPEAN EMC DIRECTIVES PUBLISHED

May 4, 2016

Three new Directives for the electrical sector have been published: the EMC Directive (2014/30/EU), the Low Voltage Directive (2014/35/EU) and the Radio Equipment Directive (2014/53/EU).

Two of these, the EMC Directive and Low Voltage Directive, are now in effect and are mandatory. When comparing these directives to the previous version you will find that many changes were made, particularly to the Radio Equipment Directive and its applicability to certain product families.

WHAT'S NEW: IEC 61000-4-5 SECOND EDITION VS. THIRD EDITION

April 28, 2016

by Jeff Gray, Chief Technology Officer, Compliance West USA

Introduction

IEC 61000-4-5 is part of the IEC 61000 series, which describes surge immunity testing caused by over-voltages from switching and lightning transients. The second edition of IEC 61000-4-5 was released in 2005 and has been in use for many years. The third edition was released as an EN standard in 2014. The general philosophy of the third edition is unchanged from the second edition. However there have been a number of refinements to the standard: additional explanation to clear up ambiguities, new descriptions that were not included in the second edition, and new (informative) Annexes that can be used to help in the application of the standard. The purpose of this article is to outline the changes and additions that are now part of IEC 61000-4-5 3rd edition.

Critical Transition Dates

Transition from the second edition to the third edition is already taking place within the EU according to the following dates:

- 19 Mar. 2015 – Date of Publication (dop): The third edition has to be implemented by publication of an identical national standard by CENELEC member countries.
- 19 June 2017 – Date of Withdrawal (dow): National standards that conflict with the third edition must be withdrawn (i.e. the second edition can no longer be used).

To read the full article, <https://interferencetechnology.com/whats-new-iec-61000-4-5-second-edition-vs-third-edition/>

HOW TO SELECT THE RIGHT EMC STANDARD FOR YOUR PRODUCT

April 20, 2016

Many companies developing products find it difficult to determine the appropriate EMC standard to comply with. The IEC (International Electrotechnical Commission) has developed a web page that explains EMC and offers a tabbed selection method for determining the right standard that applies to your product family.

You can then go to their web store and purchase downloadable standards applicable to your product.

For more information, http://www.iec.ch/emc/emc_prod/prod_main.htm

HOW THE IEC IS ORGANIZED FOR EMC

April 20, 2016

International EMC standards can be confusing to the newcomer. The IEC has posted a chart as to how the various standards organizations are organized.

The first level of organization is the committees, such as TC77, CISPR, and various product committees. These committees have liaisons with associated standards organizations, such as ISO, ITU, CENELEC, and many others. Many of these groups have working relationships with national, regional, and international

organizations. In the U.S., for example, one of the primary standards organizations is ANSI.

For more information, http://www.iec.ch/emc/iec_emc/

MIL-STD-461G: THE "COMPLEAT" REVIEW

April 15, 2016

Ken Javor, EMC Compliance January 2016

MIL-STD-461G was released on 11 December 2015 and will become contractually obligatory on programs initiated after that date.

This account is more than a simple laundry list arrived at by performing a side-by-side "F" vs. "G" comparison. Instead, it is an insider account into the issues with which the Tri-Service Working Group (TSWG) was grappling, and the thought processes behind the changes, as well as, of course, the changes themselves. It also lists some of the issues brought to the table that were not incorporated in MIL-STD-461G, and why. It will greatly assist the reader if a copy of MIL-STD-461G is available as this account unfolds.

To read the full article, <https://interferencetechnology.com/mil-std-461g-compleat-review/>

WHY IS THERE AIR (IN MIL-STD-461G)?

April 14, 2016

Ken Javor, EMC Compliance January 2016 As noted in Javor's MIL-STD-461G review (<https://interferencetechnology.com/mil-std-461g-compleat-review/>), SAE Aerospace Information Report (AIR), AIR 6236, In-House Verification of EMI Test Equipment was written specifically to support MIL-STD-461G. Specifically, section 4.3.11 Calibration of measuring equipment has been reduced in scope to devices such as EMI receivers and spectrum analyzers, oscilloscopes and (RS103) electric field sensors. Section 4.3.11 now says, "After the initial calibration, passive devices such as measurement antennas, current probes, and LISNs, require no further formal calibration unless the device is repaired. The measurement system integrity check in the procedures is sufficient to determine acceptability of passive devices." AIR 6236 was written to support the verification of proper operation of such devices in the EMI test facility using only test equipment commonly available in an EMI test facility. The idea behind the AIR was that if a measurement system integrity check was problematic, the AIR 6236 measurements would demonstrate whether or not there was a problem with a transducer. AIR 6236 was published in December 2015. Also, the procedures in the AIR can be used in-house to routinely self-check EMI test equipment, if desired.

This synopsis, by the AIR's author, discusses what's in it, and why, and includes a test procedure for one piece of equipment that was left out of the AIR.

The Introduction says that the AIR provides guidance on how to self-check the devices listed below, using equipment commonly found in EMI test facilities. The purpose is not to calibrate these devices, but to check that they have not varied significantly from manufacturer's specifications.

To read the full article, <https://interferencetechnology.com/air-mil-std-461g/>

BLUE GUIDE FOR EU PRODUCT RULES AVAILABLE

April 12, 2016

The European Union's (EU) "Blue Guide" describes general rules for placing electronic products on the market within the EU.

It describes how the EU regulates the free movement of goods, when the harmonization rules apply, the product supply chain and their obligations, product requirements, conformity assessment, and accreditation. The document goes on to describe how market surveillance works and includes several informative annexes.

To download the guide, <http://ec.europa.eu/DocsRoom/documents/18027>

CISPR PROVIDES STANDARDS FOR SMARTGRID

April 5, 2016

CISPR's (International Special Committee on Radio Interference) primary role is standardization in the field of control of emissions above 9 kHz from devices, and as such has published various standards that cover or can be applied to SmartGrid system emission measurements and control.

To ensure protection of the radio frequency spectrum, emissions must be addressed effectively if the SmartGrid is to achieve its potential and provide benefits when deployed without interference complaints. A significant additional requirement is that SmartGrid systems must be immune to sources of interference from a wide array of wanted RF signals and RF disturbances and other events which occur at SmartGrid component installations. Controlling emissions and ensuring an adequate level of immunity must both be taken on board. CISPR has prepared a Guide to EMC in Smart Grid which gives further insight into issues which should be taken into consideration when designing and developing equipment for connection and inter-operation with the Smart Grid.

NEW RADIO EQUIPMENT DIRECTIVE

March 30, 2016

As more products include wireless technology, designers need to specify wireless modules that meet the new Radio Equipment Directive (RED) 2014/53/EU, which was published on April 16, 2014. On June 13, 2016, the new Directive will become law and all products within its scope must meet the RED.

To learn more, <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014L0053>

EMC DIRECTIVE 2014/30/EU BECOMES MANDATORY APRIL 2016

February 23, 2016

Elite Electronic Engineering highlights some of the changes between the current EMC Directive 2004/30/EC and the new EMC Directive 2014/30/EU in a white paper published October 14, 2014.

It's time for manufacturers, importers, and distributors to adapt their CE Marking conformity assessment processes to the new directive by April 2016. The new directive will be required for all

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EMC compliance files, and declarations referencing 2004/108/EC will no longer be valid.

Elite reports, "For the most part, compliance with the new directive 2014/30/EC will not significantly impact conformity assessment. The essential requirements listed in Annex I of the directive remain the same as before and continue to be stated in very general terms. The requirements limit electromagnetic emissions to a level that will not affect telecommunications or other equipment and require products to have immunity to electromagnetic disturbances. For permanently fixed installations, Annex I still specifies applying good engineering practices to assess compliance."

The EN harmonized standards in the Official Journal don't change as a result of the recast directive, so the technical requirements used previously will remain the same going forward. However, all harmonized standards are regularly updated as they evolve to adapt to new technology.

Some of the more significant changes in the recast 2014/30/EU relate to the operations of Notified Bodies and other practices that may not immediately impact manufacturers. Annex VII in the new Directive provides a helpful correlation table that relates requirements in 2004/108/EC to 2014/30/EC.

For more, <http://www.elitetest.com/blog/2014-10/transitioning-new-emc-directive-201430eu>

CISPR PROVIDES "GUIDE TO EMC IN SMART GRID"

February 23, 2016

CISPR has prepared a "Guide to EMC in Smart Grid", which gives insight into issues which should be taken into consideration when designing and developing equipment for connection and inter-operation with the Smart Grid.

SmartGrid systems must be immune to sources of interference from a wide array of wanted RF signals and RF disturbances and other events which occur at SmartGrid component installations.

Among the issues that must be addressed is EMC, which is the ability to withstand the electromagnetic (EM) environment (have sufficient immunity) without causing interference (disturbances) primarily to radio reception, but also to other digital/electronic devices.

Electromagnetic disturbances of various types, from a variety of sources, have been reported and have caused performance degradation, outages, shutdowns and even large scale system failure to the power grid. EMC is thus an important factor for consideration in standards relating to the IEC SmartGrid program.

The SmartGrid needs to function properly and have full interoperability, with other electrical and electronic systems. To ensure this these systems and their components must be designed with due consideration for conducted electromagnetic emissions injected into the grid and for immunity to various electromagnetic phenomena originating from the grid. This needs to include devices that will be mounted on the outside of buildings and homes as well as in newly designed "SmartGrid enabled" appliances.

For more, and a copy of the grid, <http://www.iec.ch/emc/smartgrid/>

A2LA AND ANSI RECOGNIZED BY NIST TO ACCREDIT NOTIFIED BODIES

February 16, 2016

A2LA and ANSI (American National Standards Institute) have been formally recognized by the National Institute of Standards and Technology (NIST) as an Accreditation Body offering Notified Body (NB) accreditation under ISO/IEC 17020:2012, ISO/IEC 17025:2005, and ISO/IEC 17065:2012. Currently, A2LA is the only accreditation body recognized by NIST to offer accreditation to all three conformity assessment standards.

These standards form the basis for NB accreditation based on Section 4 of NIST's Requirements & Application for U.S. Conformity Assessment Bodies Seeking EU Radio Equipment Directive (RED) 2014/53/EU Notified Body Status and Requirements & Application of U.S. Conformity Assessment Bodies Seeking Electromagnetic Compatibility (EMC) Directive 2014/30/EU Notified Body Status, which both state that "The [organization] shall obtain formal accreditation for its Notified Body activities."

The newly published Directives become effective in a relatively short window of time, at which point the NB accreditation requirements come into place -April 20, 2016 for the EMC Direc-

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tive, and June 13, 2016 for the RED.

To see more, https://www.ansi.org/news_publications/news_story?menuid=7&articleid=5b8ca79c-a953-43b5-a1e5-009b28b9805f

ACMA RELEASES PRODUCT COMPLIANCE GUIDANCE FOR EMC

February 10, 2016

The electromagnetic compatibility (EMC) regulatory arrangements impose compliance labelling and record-keeping requirements for the supply of an extensive range of electrical and electronic products, vehicles and products with internal combustion engines. The Australian Communications and Media Authority (ACMA) has detailed new requirements in the:

- **Radiocommunications Labelling (Electromagnetic Compatibility) Notice 2008** (<https://www.legislation.gov.au/Series/F2008L00262>) (the EMC LN) made under section 182 of the Radiocommunications Act 1992.

The objective of the arrangements is to minimise the risk of unintentional electromagnetic interference from products which may affect the performance of other electrical products or disrupt radiocommunications services.

The EMC LN specifies, among other things, the form and placement of the compliance label, the compliance level, the applicable EMC testing and record-keeping requirements. The Radiocommunications (Electromagnetic Compatibility) Standard 2008 (<https://www.legislation.gov.au/Series/F2008L00261>) (the EMC Standard) specifies the technical standards that apply to a device. The EMC regulatory arrangements require that, prior to supplying a product to the Australian market, a supplier must:

- **Assess applicability** – establish whether the product is subject to the EMC regulatory arrangement (refer to Part 2 in the EMC LN) (<https://www.legislation.gov.au/Series/F2008L00262>)
- **Identify the applicable standards** – identify the applicable EMC standard/s (<http://www.acma.gov.au/Industry/Suppliers/Equipment-regulation/EMC-Electromagnetic-compatibility/emc-standards-list>) as listed on the ACMA website.
- **Demonstrate compliance** – ensure the product complies with the applicable standard/s at the specified compliance level (refer to section 4.3 of the EMC LN). Compliance can be demonstrated through testing and/or assessment of supporting documentation.
- **Complete a Declaration of Conformity (DoC) and maintain compliance records** – the DoC (<http://www.acma.gov.au/>) is a declaration made by, or on behalf of the supplier that all products comply with the applicable standard/s. A compliance record (<http://www.acma.gov.au/Industry/Suppliers/Equipment-regulation/EMC-Electromagnetic-compatibility/emc-record-keeping-requirements>) is a collection of documents (that may include the DoC and test reports) that support the supplier's claim the product complies with the standard/s (refer to section 4.3A and Part 5 of the EMC LN).
- **Register on the national database** – a supplier must register on the national database (<https://equipment.erac.gov.au/>

Registration/) before affixing a compliance label to a compliant product (refer to sections 4.2 and 4.2A of the EMC LN).

- **Apply a compliance label** – a compliance label indicates the device complies with the applicable standards (refer to Part 3 of the EMC LN). The compliance label consists of the Regulatory Compliance Mark (RCM).

The EMC LN (<https://www.legislation.gov.au/Series/F2008L00262>) and its associated explanatory statement is available on the Federal Register of Legislative Instruments through the ComLaw website.

For more info, <http://www.acma.gov.au/Industry/Suppliers/Product-supply-and-compliance/Steps-to-compliance/emc-regulatory-arrangements>

FCC TO CHANGE EMC APPROVALS PROCESS

February 1, 2016

Ghery Pettit Consulting reports a change in the FCC approvals process starting July 13, 2016.

Up until now, manufacturers have had the choice of using “FCC Listed” test labs or “FCC Recognized Accredited Test Laboratories.” After that date, only the latter test labs – and ONLY those located in countries with mutual recognition agreements (MRAs) with the FCC may be used for the “Certification” approval process. Countries with current MRAs include Australia, Canada, the EU, Hong Kong, Israel, Japan, South Korea, Singapore, and Taiwan. The country with the biggest impact will be those test labs in China, where an MRA does not yet exist.

These test labs (and others located in countries lacking an FCC MRA) will only be able to test products to the FCC’s “Verification” process.

For more information, <http://pettitemcconsulting.com/what-has-changed-with-fcc-approvals/>

GUIDE TO CISPR COMMITTEES

January 26, 2016

The International Special Committee on Radio Interference (CISPR) has several subcommittees working on various CISPR standards. The IEC offers a guide to these various subcommittees, along with their the scope of work.

In addition, there are useful downloadable guides for users of CISPR standards and standardization policy.

FUNCTIONAL SAFETY STANDARD IEC 61508

January 26, 2016

With more electronic systems controlling human-machinery interfaces, functional safety for EMC is becoming an important consideration.

IEC 61508 addresses functional safety for industrial-process measurement, control and automation. This standard was developed by IEC SC 65A and you can read various comments and changes by leading experts.

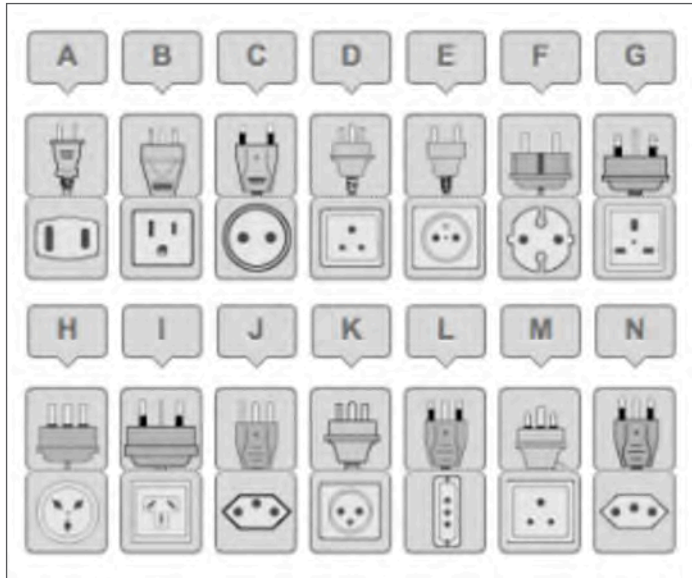
For more, <http://www.iec.ch/functionalsafety/?ref=extfooter>

STANDARDS REVIEW

DIRECTORY OF WORLD POWER PLUGS FOR TRAVELERS

January 26, 2016

There are 14 commonly-used power line plugs used in over 200 countries. The IEC has made available a useful directory of power line plug styles used across the world. This handy guide (<http://www.iec.ch/worldplugs/?ref=extfooter>) for travelers is tabulated by country or by clicking on a world map.



C63 COMMITTEE STANDARDS INCORPORATED BY FCC

January 11, 2016

IEEE, the world's largest professional organization dedicated to advancing technology for humanity, today announced that two Accredited Standards Committee on Electromagnetic Compatibility (ASC-C63[®]) standards have been 'incorporated by reference' into the updated U.S. Federal Communications Commission (FCC) rules by which telecommunications certification bodies (TCBs) authorize radio-frequency (RF) equipment.

The FCC's reference of the two ASC C63[®] standards impacts the work of wireless-device manufacturers, test laboratories, and trade associations globally. The two ASC C63[®] standards referenced in FCC 14-208, 'Authorization of Radiofrequency Equipment' (<https://www.federalregister.gov/documents/2015/06/12/2015-14072/authorization-of-radiofrequency-equipment>), propose procedures for testing the compliance of a wide variety of wireless transmitters. ANSI C63.4-2014 (<http://standards.ieee.org/findstds/standard/C63.4-2014.html>), American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz, defines measurement

procedures for unintentional radiators such as computers and various digital electronic devices. ANSI C63.10-2013 (<http://standards.ieee.org/findstds/standard/C63.10-2013.html>), American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices, for intentional radiators such as remote controls, cordless phones, hands-free microphones, some medical

devices, security devices, and other unlicensed wireless devices.

'The rules we are adopting will facilitate the continued rapid introduction of new and innovative products to the market while ensuring that these products do not cause harmful interference to each other or to other communications devices and services,' as taken from FCC 14-208, which became effective 13 July 2015. Its rules in July 2016 will become mandatory for RF devices used in the United States.

For more, <http://c63.org/news.htm>

STANDARD FOR SPECTRUM CHARACTERIZATION AND OCCUPANCY SENSING

January 6, 2016

The IEEE has initiated a new standards working group, P802.22.3, whose purpose is to specify the operating characteristics of the components of a system to characterize and sense the occupancy of the radio spectrum.

Formore, <https://standards.ieee.org/develop/project/802.22.3.html>

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Professional Societies

IEEE ELECTROMAGNETIC COMPATIBILITY SOCIETY

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Website: www.emcs.org

The Institute of Electrical & Electronics Engineers (IEEE), the world's largest professional engineering society, is a global organization of individuals dedicated to improving the understanding of electrical and electronics engineering and its applications to the needs of society. The parent organization has over 360,000 members, approximately 70 percent of whom belong to technical groups such as the EMC Society.

The EMC Society, which enjoys a membership of over 5000, functions through a Board of Directors elected by the Society membership. The Board includes 20 members-at-large who serve staggered 3-year terms. The Executive Board consists of the President, President-Elect, Immediate Past President, Secretary, Treasurer, and five Vice Presidents, who oversee the activities of standing and technical committees. The officers are elected by the Board of Directors. The annual IEEE International Symposium on Electromagnetic Compatibility is sponsored by the Board of Directors, which also coordinates activities of standing technical and ad hoc committees. Recently, the EMC Society has included the topic of Signal Integrity.

EMC Society publications include Transactions on EMC, a quarterly journal which features state-of-the-art papers on interference technology and EMC, and the EMC Society Newsletter, a quarterly newsletter of society activities, industry developments, practical papers, and notices of meetings, regulations, and new publications.

The EMC Society also has a group of distinguished lecturers who are available to present talks to IEEE and other organizations. The society subsidizes the lecturers' expenses, and organizations are encouraged to contact the society for further details.

IEEE PRODUCT SAFETY ENGINEERING SOCIETY

While product safety had been addressed in various committees over the years, there was never a professional society or symposium solely devoted to product safety engineering as a discipline until recently. The IEEE Product Safety Engineering Society (PSES) began operation on 1 January 2004.

The field of interest of the Society is the theory, design, devel-

opment and implementation of product safety engineering for electronic and electro-mechanical equipment and devices. This includes the theoretical study and practical application of analysis techniques, testing methodologies, conformity assessments, and hazard evaluations.

The society's mission is to strive for the advancement of the theory and practice of applied electrical and electronic engineering as applied to product safety and of the allied arts and sciences.

The society provides a focus for cooperative activities, both internal and external to IEEE, including the promotion and coordination of product safety engineering activities among IEEE entities. In addition, the Society will provide a forum for product safety engineering professionals and design engineers to discuss and disseminate technical information, to enhance personal product safety engineering skills, and to provide product safety engineering outreach to engineers, students and others with an interest in the field. The Society is accepting members at any time during the calendar year, both full IEEE members and affiliate members. Membership is available at www.ieee.org/services/join/.

The IEEE Product Safety Engineering Society works closely with various IEEE Societies and Councils that also include product safety engineering as a technical specialty.

Every year, the PSES hosts a Symposium on Product Compliance Engineering. Symposia will consist of Technical Sessions, Workshops, Tutorials and Demonstrations specifically targeted to the compliance engineering professional. Attendees will have the opportunity to discuss problems with vendors displaying the latest regulatory compliance products and services. For more information, visit www.psessymposium.org. Past papers from the Symposia are available in IEEE Xplore or on CD (for a fee).

In addition to hosting an annual conference, the PSES provides the opportunity for product safety engineers to publish technical papers in a newsletter. See <http://www.ieee-pses.org/newsletters.html>.

For further information visit www.ieee-pses.org.

DB SOCIETY

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This unique, interesting, and exclusive fraternity of EMC engineers was founded in 1975 by 10 eminent EMC engineers. The purpose of the dB Society is to open doors within the EMC community.

SOCIETIES

Its primary objectives are to greet and to welcome new engineers, suppliers, vendors, and manufacturers to the EMC community and to assist them in establishing contacts in the EMC field.

The following membership requirements are unique and rigidly enforced:

Ten years of service to the EMC community, Five years of service to a recognized professional, EMC organization, Sponsorship by two Duo-Decade members, Favorable recommendations by three other recognized individuals in the EMC community, and Acceptance by the Admissions Board.

Business meetings and informal, relaxed get-togethers take place during major EMC functions. A formal evening social function is the highlight of each year and is usually conducted during the IEEE EMC Symposium. All meetings are for members and their spouses, only.

U.S. membership is limited to 100 EMC engineers. There are society affiliates in the United Kingdom, India, and Israel.

ESD ASSOCIATION

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Founded in 1982, the ESD Association is a professional voluntary association dedicated to advancing the theory and practice of electrostatic discharge (ESD) avoidance. From fewer than 100 members, the Association has grown to more than 2,000 members throughout the world. From an initial emphasis on the effects of ESD on electronic components, the association has broadened its horizons to include areas such as textiles, plastics, web processing, cleanrooms, and graphic arts. To meet the needs of a continually changing environment, the Association is chartered to expand ESD awareness through standards development, educational programs, local chapters, publications, tutorials, certification, and symposia.

Electromagnetic Discharge (ESD) Technology Roadmap

In the late 1970s, electrostatic discharge, or ESD, became a problem in the electronics industry. Low-level ESD events from people were causing device failures and yield losses. As the industry learned about this phenomenon, both device design improvements and process changes were made to make the devices more robust and processes more capable of handling these devices. With devices becoming more sensitive through the year 2010, it is imperative that companies begin to determine the ESD capabilities of their handling processes. The ESD Technology Roadmap can be downloaded at: www.esda.org

ANSI/ESD S20.20 Control Program Standard and Certification

A primary direction for the association is the continued implementation of a facility certification program in conjunction

with ISO registrars. With the association's ESD control program standard, ANSI/ESD S20.20: Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices), the Association offers a means of independently assessing a company's ESD control program and of issuing a formal ANSI/ESD S20.20 certification.

The ANSI/ESD S20.20 standard covers the requirements necessary to design, establish, implement, and maintain an ESD control program to protect electrical or electronic parts, assemblies and equipment susceptible to ESD damage from Human Body Model (HBM) discharges greater than or equal to 100 volts. Developed in response to the Military Standardization Reform Act, ANSI/ESD S20.20 has been formally adopted for use by the U.S. Department of Defense.

Symposia, Tutorials, and Publications

As part of its commitment to education and technology, the association holds the annual EOS/ESD Symposium, which places major emphasis on providing the knowledge and tools needed to meet the challenges of ESD. Scheduled for June 30-July 3, 2015, at the Conference Center, COEX in Seoul, KOREA, the annual Symposium attracts attendees and contributors from around the world. Technical sessions, workshops, authors' corners, seminars, tutorials, and technical exhibits provide a myriad of opportunities for attendees to expand their knowledge of ESD.

In addition to tutorials and seminars, the association offers a number of publications and reference materials for sale. These range from proceedings of past EOS/ESD Symposia to textbooks written by experts in the field of ESD.

SOCIETY OF AUTOMOTIVE ENGINEERS

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SAE International is a professional society of engineers dedicated to a broad spectrum of engineering disciplines within the aerospace and automotive fields. Under the SAE Aerospace Council, technical standards committees address disciplines ranging from electrical power to multiplex signal characteristics — and from fiber optic data transmission to electromagnetic compatibility. The many elements of EMC are handled by SAE Committee AE-4, Electromagnetic Compatibility, which was organized in 1942 under the Aerospace Council. The committee is composed of technically qualified members, liaison members, and consultants —all of whom are responsible for writing standards on electromagnetic compatibility.

Committee AE-4 provides assistance to the technical community through standardization, improved design and testing methodology, and technical forums for the resolution of mutual problems. Engineering standards, specifications, and technical reports are developed by the Committee and are issued by the Society for industry and governments worldwide. Objectives of Committee AE-4 are to advance the state of technology, to stabilize existing technology, to obtain a uniformity of EMC requirements among government agencies, and to further the interests

of the EMC technical community. The theme of “design before the fact” for EMC is a guiding concept. Special attention is given to maintenance of EMI control requirements consistent with the rapidly advancing state-of-the-art.

The following is a partial list of documents that have been issued to assist in implementing SAE objectives. For a complete list, visit the SAE website at www.sae.org or call SAE Customer Service at 724-776-4841.

Aerospace Recommended Practice (ARPS)

ARP	935A	Control Plan/Technical Construction File
ARP	936A	Capacitor, 10 mF for EMI Measurements
ARP	958C	Electromagnetic Interference Measurement Antennas, Standard Calibration Method
ARP	958D	Electromagnetic Interference Measurement Antennas, Standard Calibration Method
ARP	1172	Filters, Conventional, EMI Reduction, Specifications
ARP	1173	Test Methods for EMI Gasketing
ARP	1267	EMI Measurement of Impulse Generators, Standard Calibration Requirements and Techniques
ARP	1481A	Corrosion Control and Electrical Conductivity in Enclosure Design
ARP	1705	Coaxial Test Procedure to Measure the RF Shielding Characteristics of EMC Gasket Materials
ARP	1870	Aerospace Systems Electrical Bonding and Grounding for Electromagnetic Compatibility and Safety
ARP	1972	Recommended Practices and Procedures for EMC Testing
ARP	4043A	Flightline Bonding and Grounding of Aircraft
ARP	4242	Electromagnetic Compatibility Control Requirements, Systems
ARP	4244	Recommended Insertion Loss Test Methods for EMI Power Line Filters
ARP	5416A	Aircraft Lightning Test Methods

Aerospace Information Reports (AIRS)

AIR	1147	EMI on Aircraft from Jet Engine Charging
AIR	1209	Construction and Calibration of Parallel-Plate Transmission Lines for EMI Susceptibility Testing
AIR	1221	EMC System Design Checklist
AIR	1255	Spectrum Analyzers for EMI Measurements
AIR	1394A	Cabling Guidelines for Electromagnetic Compatibility
AIR	1404	DC Resistivity vs. RF Impedance of EMI Gaskets
AIR	1423	EMC on Gas Turbine Engines for Aircraft Propulsion
AIR	1425A	Methods of Achieving EMC of Gas Turbine Engine Accessories, for Self-Propelled Vehicles
AIR	1499	Recommendations for Commercial EMC Susceptibility Requirements
AIR	1662	Minimization of Electrostatic Hazards in Aircraft Fuel Systems

AIR	1700A	Upper Frequency Measurement Boundary for Evaluation of Shielding Effectiveness in Cylindrical Systems
AIR	4079	Procedure for Digitized Method of Spark Energy Measurement

SAE AE-4 Electromagnetic Environmental Effects (E3 or EMC) Committee

The SAE AE-4 E3 Committee provides a technical, coordinating, and advisory function in the field of E3. The focus is on problem areas in which committee expertise can be effectively applied at the national and international levels. Electrical and electronic accessories are studied for compatibility within systems and with various communications media. Engineering standards, specifications, and technical reports are developed and are issued for the general information of industry and government.

In the past, subcommittees have included AE-4R, Aircraft Radiated Environments, and AE-4H, High Power RF Simulators and Effects. AE-4 E3 holds national meetings in conjunction with the IEEE EMC Society Symposium, usually held in August at various locations. Additional information about meetings or more specific information on the activities of the committee can be obtained by contacting the world headquarters at 1-724-776-4841. Visit the SAE's Technical Standards Committee Forum website at <http://forums@sae.org>.

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iNARTE, Inc. (The International Association for Radio, and Telecommunications and Electromagnetics, Inc.) was founded as a non-profit membership/certification organization in 1982. With the advent of deregulation and the Federal Communications Commission's “encouragement/urging” private industry to establish certification standards to fill the licensing void, iNARTE initiated and developed a comprehensive certification program for telecommunications engineers and technicians.

In 1988, a Command of the United States Navy, seeking a credible and respected certification entity, selected iNARTE as the administrative agent for the certification of engineers and technicians in the field of electromagnetic compatibility (EMC).

ACIL—THE AMERICAN COUNCIL OF INDEPENDENT LABORATORIES

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The American Council of Independent Laboratories (ACIL)

SOCIETIES

is the trade association representing independent, commercial engineering, and scientific laboratory, testing, consulting, product certifying and R&D firms; manufacturers' laboratories; related non-profit organizations; and consultants and suppliers to the industry. The organization was founded in 1937. All ACIL activities focus on its mission: to enhance members' success by providing advocacy, education, services, and mutual support and by promoting ethics, objectivity, independence, and free enterprise.

ACIL is a voluntary, non-profit membership organization. Programs are determined by members, administered by an elected Board of Directors, and supported by a professional staff operating from headquarters in Washington, D.C.

ACIL's Conformity Assessment Section

ACIL's Conformity Assessment Section consists of firms with wide and varied interests, all performing testing, listing, or labeling in accordance with applicable safety and performance standards, and/or materials testing and resolution of product and structural problems. Several committees have evolved within the Section to meet the needs of its diverse membership, including the EMC Committee, the U.S. Council of EMC Laboratories, and the Third-Party Product Certifiers Committee. In January 2005, the section sponsored a booth at the Consumer Electronics Show that advocated the advantages of independent third-party testing and the capabilities of ACIL member EMC laboratories.

ACIL's EMC Committee

ACIL's EMC Committee was established in 1996 to address the common concerns of the ACIL EMC community. The Committee sponsors educational sessions at ACIL meetings that include both technical and policy issues such as mutual recognition agreements (MRAs). The Committee updates members on the latest developments, upcoming requirements, and activities in the field—both domestic and international.

In January 2002, ACIL published a 143-page document, Technical Criteria for the Accreditation of Electromagnetic Compatibility (EMC) and Radio Testing Laboratories, a checklist to assist both assessors and laboratories.

The Committee also formed the U.S. Council of EMC Laboratories (USCEL) in an effort to aid U.S. laboratories in addressing technical issues arising from the U.S./EU MRA and other global concerns. As the USCEL Secretariat, ACIL provides staff and supports volunteers active in this important area.

U.S. Product Certifiers

Key U.S. product certifiers are ACIL members and are reaping many benefits, such as participation in the ACIL Third-Party Product Certifiers Committee (3P²C²). This Committee provides a forum for members to discuss and to act upon various issues of common interest. This committee formed the American Council for Electrical Safety to serve as a forum among testing laboratories, regulators, and electrical inspectors.



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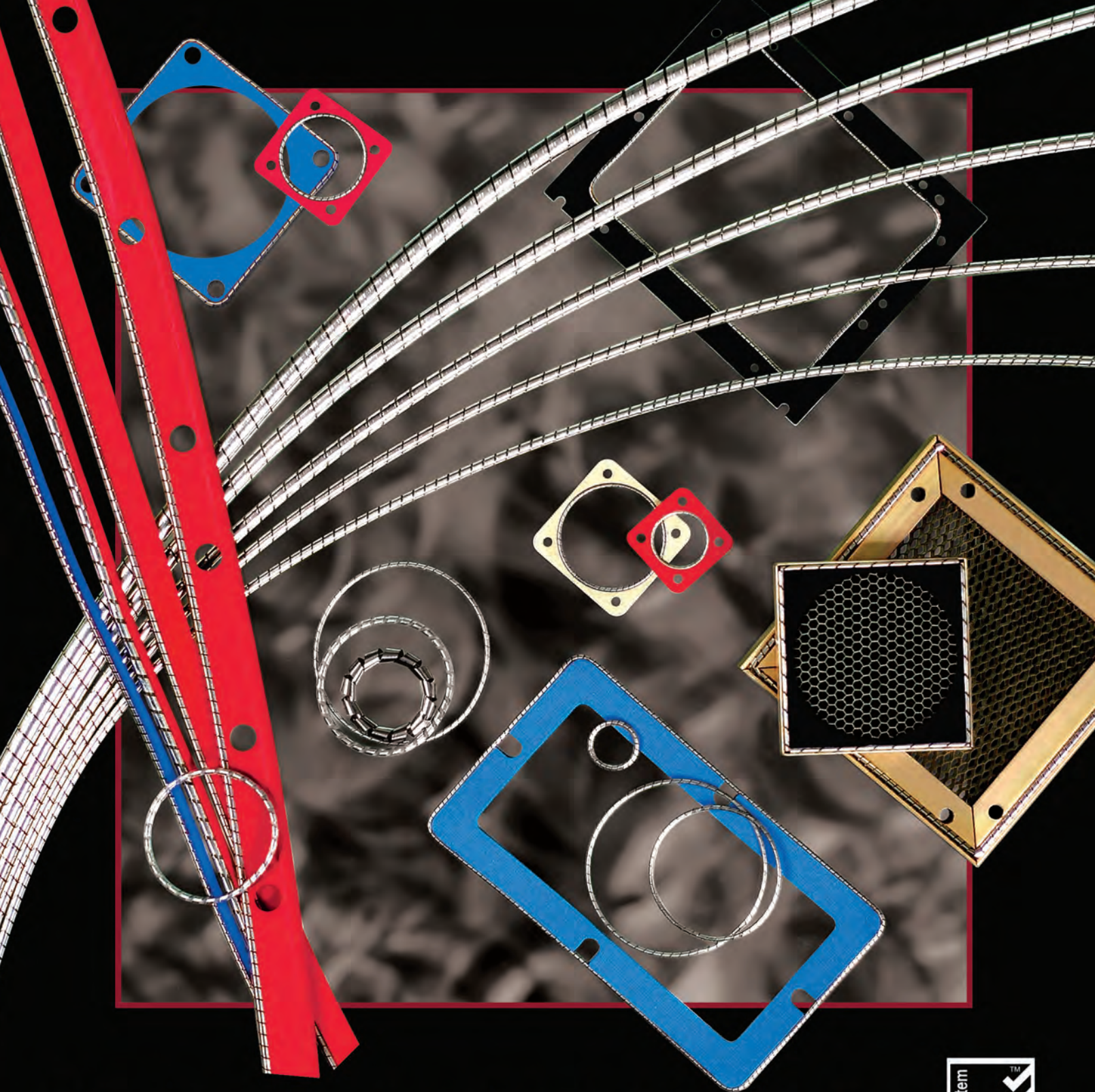
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Visit our EMC military channel at;
www.interferencetechnology.com for more information.

If you wish to be included in the government directory please email us with your name, title, phone number, and desired location in directory. If you are currently listed in this directory and wish to update your contact information please contact info@item.media.

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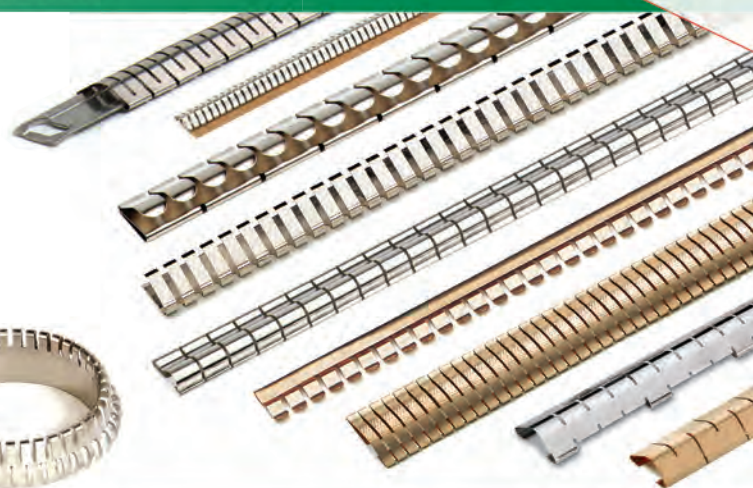
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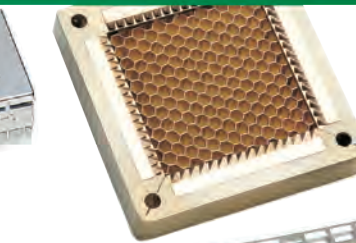
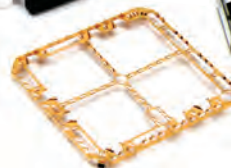
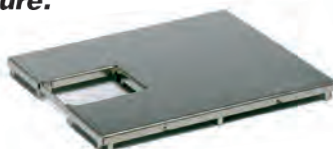
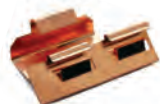


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For 2017, we have changed the location of our full supplier directory from this print edition to our online directory at buyersguide.interferencetechnology.com - where information on products and contacts is now updated daily. In this section, we provide a quick guide to some of the top suppliers in each EMC category - test equipment, components, materials, services, and more. To find a product that meets your needs for applications, frequencies, standards requirements, etc., please search these individual supplier websites for the latest information and availability. If you have trouble finding a particular product or solution, email info@item.media for further supplier contacts.

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