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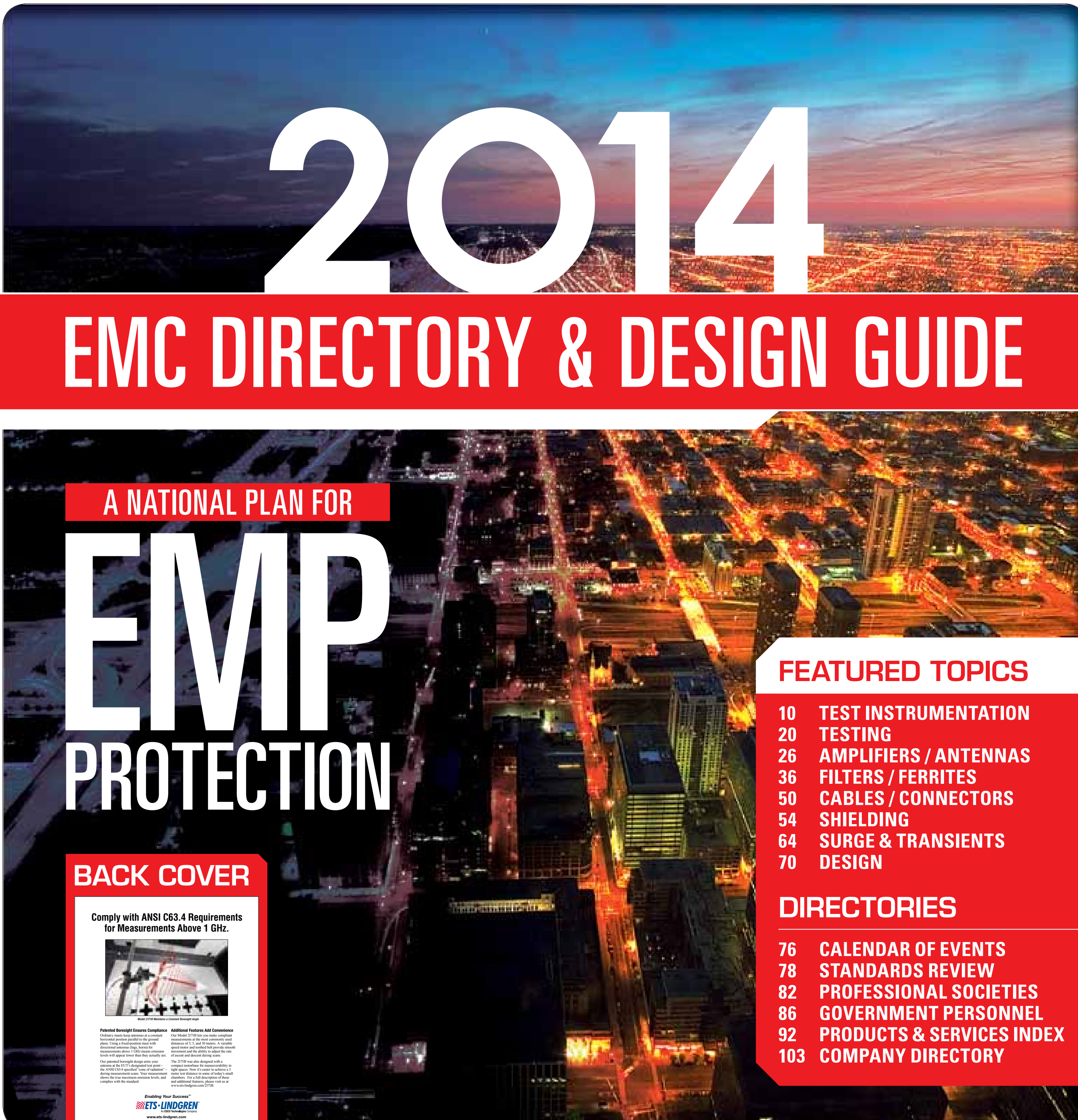

2014 EMC DIRECTORY & DESIGN GUIDE

A NATIONAL PLAN FOR EMP PROTECTION

FEATURED TOPICS

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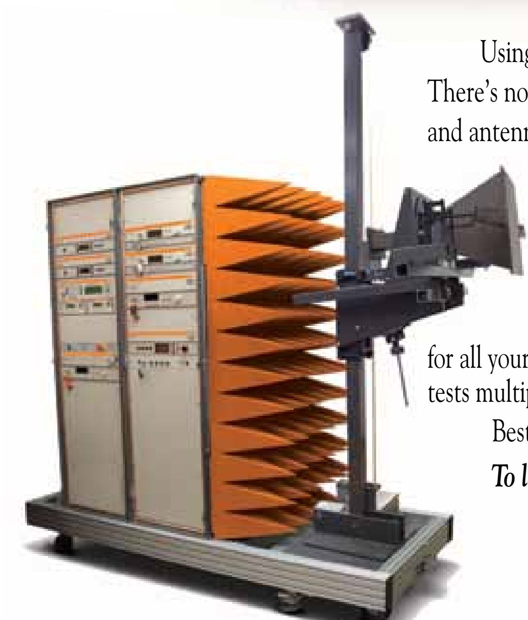
Comply with ANSI C63.4 Requirements for Measurements Above 1 GHz.

System Components From Multiple Sources Can Be A Real Horror



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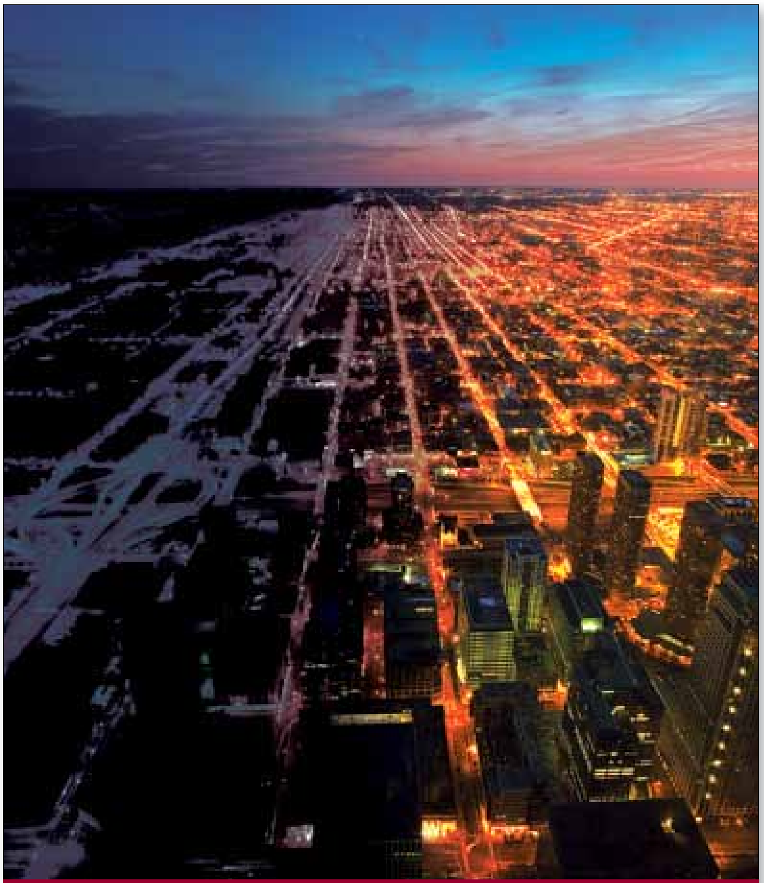

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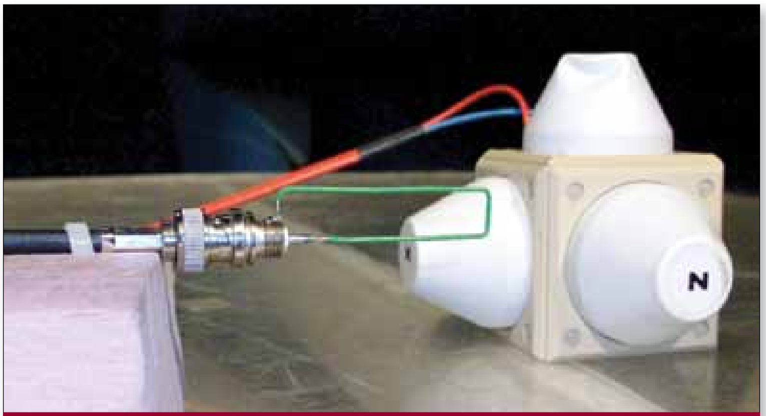

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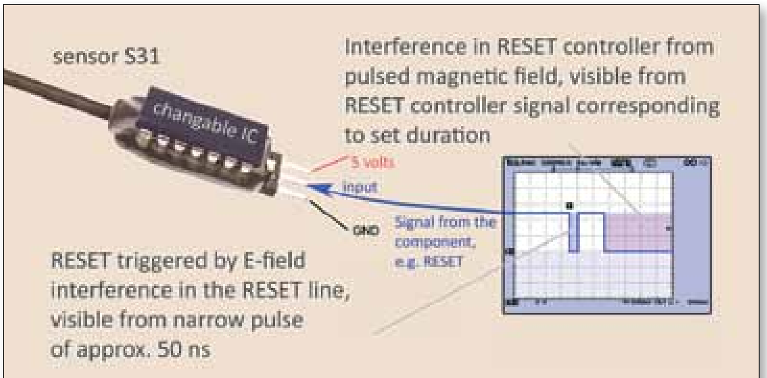

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EMC Needs Engineers

THE FIELD OF EMC could be at risk, as a profession, if we do not begin to address the question of EMC education. The phenomena of EMI is not going away any time soon. So what happens if plans are not made to address the ever decreasing pool of skilled labor?

On one hand, as our more seasoned engineers have begun retiring, we need more students and young professionals to rise up and join the ranks. And on another hand, the accessibility of continuing educational opportunities for today's engineers is also an issue - for example, ever decreasing corporate budgets are increasingly limiting the opportunity for EMC engineers to travel to seminars, symposia etc. This is a very real problem, and one that looms larger as the years tick by. So let's make a start by having a real dialog, and taking a look at the initiatives in the community already.

Last year, our marketing department began reaching out to schools and universities across the US that offer electronics engineering programs, to introduce *Interference Technology* to them. It's going to take a long time, but we've made a start, and so far we've reached about 200 hundred colleges, professors and students. We hope that the field will attract students to look at EMC engineering as a possible future career. We also hope that if they aren't already aware of this industry, they will be now. But then we ask, what else can we do with regard to higher education to make our program better? We welcome your suggestions. Is your company involved in the promotion of the field? We'd love to hear about your initiatives and share them with our community as a way to get this dialog going and to inspire others.

A few years ago, we could blame the economy as the reason why companies did not send their EMC engineers to conferences and industry events. But as the economy has recovered, companies are still not sending as many engineers out for training. Companies have become used to doing more with less, and this is the new reality we face. But *online* education has grown dramatically in recent years, in the form of webinars, video conferencing, conference calls, and more. Last year, we introduced our first series of webinars for EMC, and thousands of you signed up and attended for an hour at a time to listen, learn and ask questions. They were a great success and we believe this is the shape of things to come.

Interference Technology will be doing more webinars this year, targeting our topics to appeal not only to the experienced engineer, but also covering the basics to appeal to the new engineers and also to regular EEs, who need a primer or two. Keith Armstrong will present 'PCB Suppression of ICs with BGA or Multiple Power Rails' June 25 and 'Cost-Effective Use of HDI (microvia) PCB Technology for SI, PI and EMC' Sept. 17. If you've missed any webinars, click the 'webinars' tab on our site to watch the archived presentations.

Most notably, this fall, we are taking our education initiative one step further. In October 2014, we are launching *EMC Live* - a multi-day, online, educational experience of webinars, roundtables, videos and networking, with real practical material for the everyday engineer, covering standards updates, design techniques, and test set ups for the military, aerospace, consumer and automotive markets, among other topics. This is an exciting opportunity for you to connect with your colleagues around the world and watch and learn from interactive presentations from some of the most practical EMC minds in the world today. And tell your boss that you don't have to pack your bags or travel anywhere, and there's no cost to attend! Visit www.emclive2014.com for more information.

What we are doing is just a start and is certainly not a complete solution. And for many, reading this printed form of Interference Technology, is still one of the best forms EMC education around - at least that's what you tell us year after year. We'd like to hear more of your thoughts about the education needs of our community, and encourage you to create a dialog with your colleagues that will inspire others to do more too. Please send me your comments and suggestions at bstas@interferencetechnology.com. I look forward to hearing from you.

Belinda Stasiukiewicz
Editor

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ITEM MEDIA

USA
1000 Germantown Pike, F-2
Plymouth Meeting, PA 19462
Phone: (484) 688-0300
Fax: (484) 688-0303
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info@item-media.net
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CHINA, TAIWAN, HONG KONG
ACT International
Mainland China - Linda Li, +86-21-62511200
Email: lindaL@actintl.com.hk
Hong Kong - Mark Mak, +85-22-8386298
Email: markm@actintl.com.hk

JAPAN
e-OHTAMA, LTD.
Miho Toshima, +81-44-980-2092
E-mail: m-toshima@e-ohtama.jp

Mitigating Excessive Emissions, 2nd Edition

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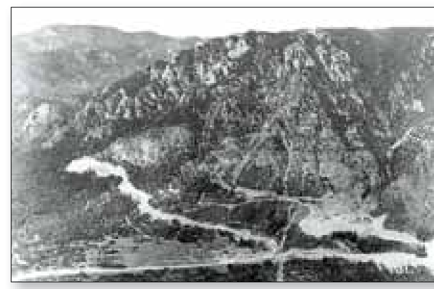
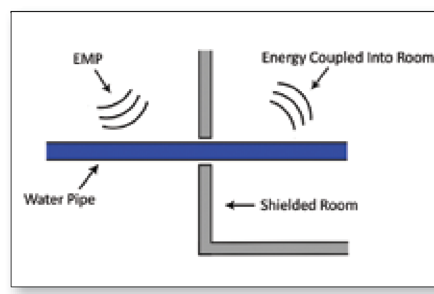


Cheyenne Mountain Colorado



Water Pipe Allowing EMP Energy to Enter the Room

MITIGATING excessive emissions was originally written in 1988 and presented at the IEEE EMC Symposium in Atlanta Georgia. The concept and paper have been used by the author hundreds, if not thousands, of times to illustrate what he calls "The Barbell Model". This illustrates, in very simple terms, how radiation can be properly confined by terminating shielded cables properly, filtering wires, adding filter capacitors and even decoupling integrated circuits. The original paper is being updated to give additional background about how the concept was used to evaluate a mountain against EMP and how the concept applies to susceptibility, as well as to update many of the drawings.

I understand many years ago when Cheyenne Mountain was evaluated for nuclear hardness to EMP, (the Electro Magnetic Pulse when a nuclear weapon is detonated) a similar concept was used. When you realize the difficulty of doing real life testing of a nuclear blast on a mountain you can appreciate the advantages of using a simpler technique. I understand that in the process of the evaluation, an EMP weakness was found where a water pipe entered a shield room without being terminated. As you read through this paper, you will learn that this is the worst case termination possible, none at all! (See figures above.)

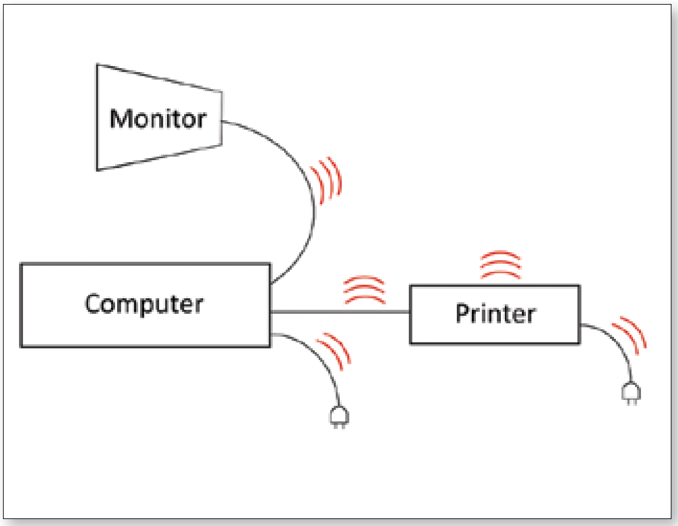


FIGURE 1A: The Problem Today.

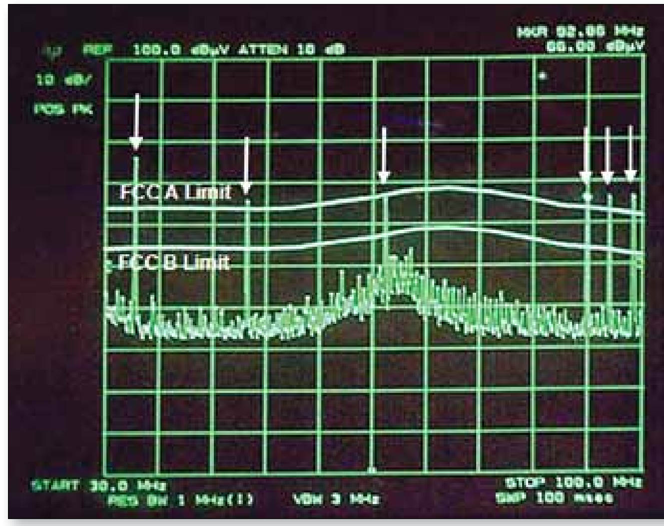


FIGURE 1B: Out of FCC Limit.

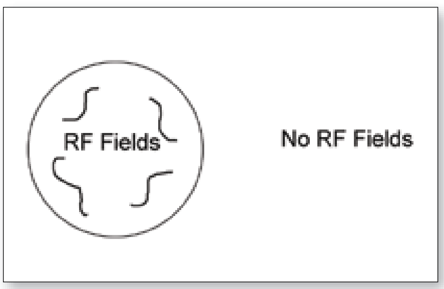


FIGURE 2: The Electronic Product Represented by a Conductive Sphere.

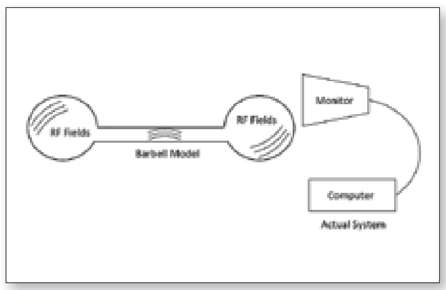


FIGURE 3: Interconnected Components Represented as a Barbell.

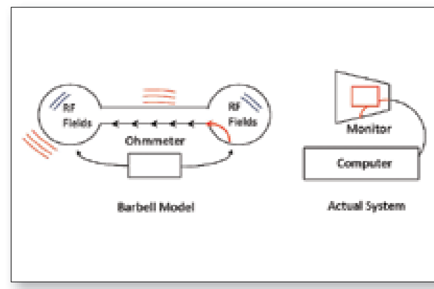


FIGURE 4 Improper Connection Using an Internal Pigtail.

Often, when communication is required between electronic devices, unwanted RF energy is combined with it. This unwanted RF energy can be controlled or reduced by proper consideration being given to the topology of the system. The following explains many of the ways in which this unwanted RF energy can be controlled or mitigated and describes some of the ways in which the control may be compromised.

The number one problem in electromagnetic compatibility (EMC) has always been radiation from external cables. The materials needed to solve this problem are generally present, but are not being used properly.

Figures 1A and 1B show a typical computer system as it often arrives at a test facility. The interconnecting cables and even some of the peripherals are emitting RF energy. Throughout this discussion, an analogy is used where the electronic product is represented as a conductive sphere (the ball of what will become our barbell) connected by the handle or shield of the cable as shown in Figure 3.

Obviously if electromagnetic fields were kept inside of a conductive sphere, there would be no unwanted RF energy on the outside. (See Figure 2) This containment, however, is impractical since wires, such as ac power, keyboard communication and data via parallel and serial interfaces must pass in and out of the sphere. Thus, the spheres need a way to communicate while inhibiting unwanted emission.

One way to accomplish this protected path is to build one circuit in a sphere and communicate via a hollow bar to another sphere, thus expanding the analogy to a barbell. The spheres in Figure 3 represent a personal computer (PC), and the hollow bar represents an interconnecting shield to a monitor with the two circuits communicating with no external fields. The spheres and interconnecting passage allow communications inside the barbell. This concept can be used at any level of complexity.

The barbell is a difficult way of actually connecting two circuits, but this concept will be used to develop a more practical approach. Figure 4 is the barbell model showing the way shielded cables are often improperly connected to equipment.

The bar, which is the shield on the cable, is connected to one of the spheres with an internal pigtail. A pigtail is a short length of wire used to terminate a shield. The resistance of the internal pigtail may not greatly exceed that of the connection of an ideal barbell model, but the internal pigtail acts as a receiving antenna and couples the RF energy outside of the sphere, via the bar. The bar and the second sphere now radiate the RF energy which was originally inside the first sphere.

An example of improper use occurred when a manufacturer used an 8-inch wire as a pigtail, which caused his

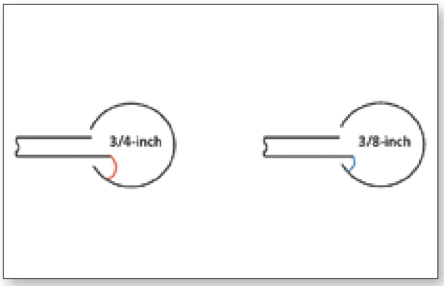


FIGURE 5: Reducing Emissions by Shorting the Pigtail.

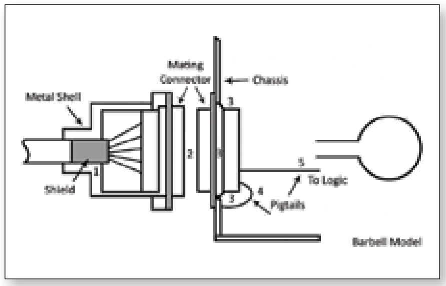


FIGURE 6: Ideal Termination.

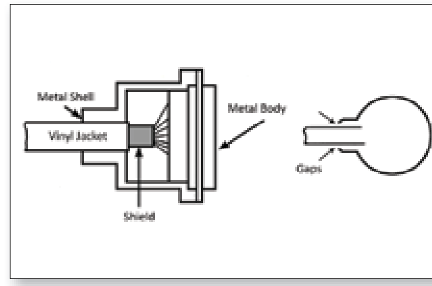


FIGURE 7A: Improper Shield Termination.

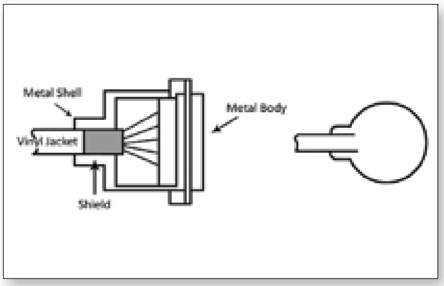


FIGURE 7B: Proper Shield Termination.

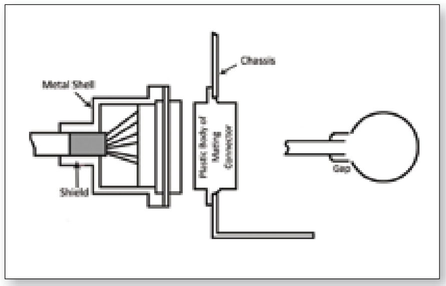


FIGURE 8: Improperly Used Plastic Connector.

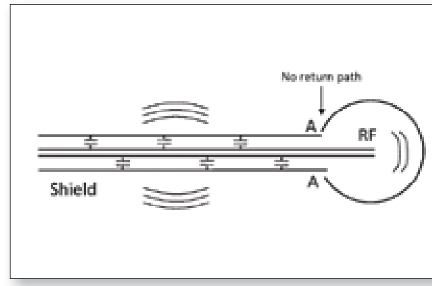


FIGURE 9: RF Emissions Resulting From a Gap.

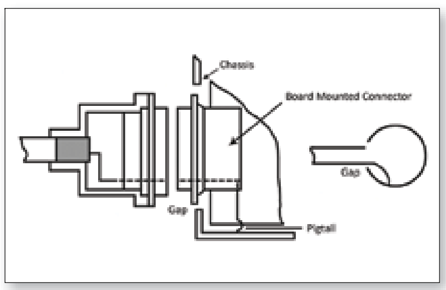


FIGURE 10 A: Improper Termination Using Non-bulkhead Connectors.

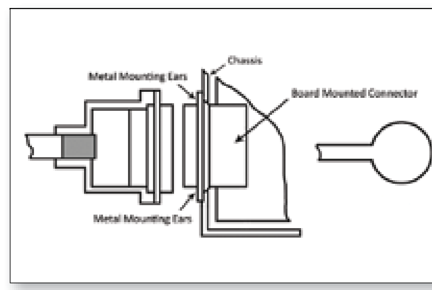


FIGURE 10 B: Proper Termination With Metal Mounting Ears on Connectors.

equipment to be out of limit. Shortening the pigtail to 1 inch brought the system into compliance. Another example of improper use was a pigtail ¾-inch long tying the shield of an RS232 connector to a metal chassis (Figure 5). The unit was at the limit of RF emissions until the wire was shortened to ⅜ inch. Measured emission dropped by 6 dB which can be calculated using: 20 Log (L1 /L2) or 20 Log (0.75/0.375) = 20 Log 2 = 6 dB

I have seen testing to 200 V/m with a cable terminated with a 20 inch pigtail. In this case, we are not radiating energy, but just the opposite. The energy from the transmitting antenna is being picked up by the pigtail as if it were a receiving antenna causing the energy to enter inside the device. With 200 V/m it is very unlikely a system could ever pass radiated susceptibility under these conditions. (See the section SUSCEPTIBILITY LESSONS LEARNED near the end of this article.)

The ideal way to terminate is to connect the bar to the ball of the barbell using a 360-degree connection as shown in Figure 6. In this figure, the shield makes 360-degree contact to the metal shell at point 1. The metal shell makes a 360-degree contact to the mating connector at point 2, as does the mating connector to the chassis at point 3. This arrangement can be seen using the barbell model as a continuous connection. The barbell model can be compromised with pigtails and logic grounds as shown at points 4 and 5. The potential for emissions at points 1 through 5 are now considered in detail.

IMPROPER CABLE TERMINATIONS IN COMMON USE

The ideal termination in Figure 6 is often compromised in one of five ways.

1. Failure to tie the metal shell to the shield (see Point 1, Figure 6).

To be properly terminated, the metal shell of the connector must contact the shield. In Figure 7A, the shell is insulated from the shield by the vinyl jacket of the cable. The vinyl creates a small gap. Emission resulting from gaps is examined in **2.** below. In Figure 7B, the vinyl has been partially removed to enable direct contact between the shell and the shield, thus providing a continuous confinement of RF field.

2. Use of plastic mating connectors (See Point 2, Figure 6 and Figure 8).

Plastic should not be used on the body of the mating connector because it prevents electrical connection between the metal shell and the metal chassis, thus creating a small gap. Both mating connectors should have metal or at least conductive shells.

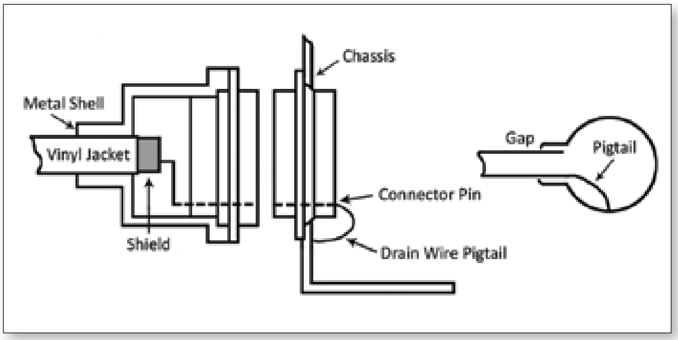


FIGURE 11: Improper Use of Drain Wire.

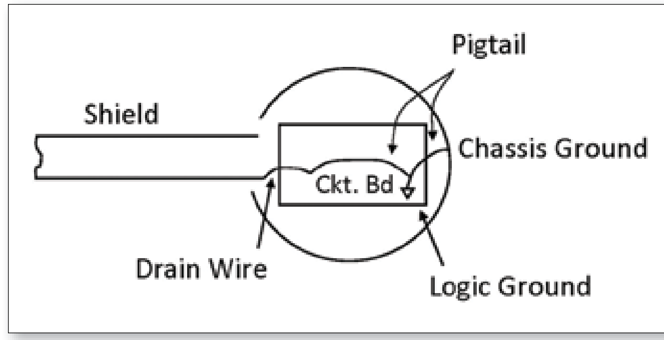


FIGURE 12: Worst-Case Use of a Drain Wire.

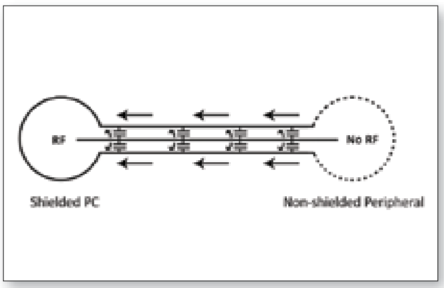


FIGURE 13: Proper Use of a Shield Cable as a Filter.

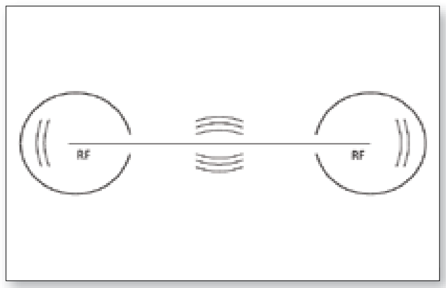


FIGURE 14: Barbell Without a Bar or Filter.

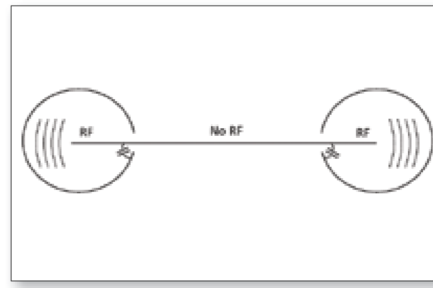


FIGURE 15: Barbell Without a Bar and With a Filter Capacitor.

One might conclude that the small gaps at Points 1 and 2 of Figure 6 would not cause a problem because so little energy can seemingly exit from a small gap. However, RF energy is induced on the wire inside the sphere (Figure 9). This energy then passes through the shielded cable on its wires and is coupled to the shield by stray capacitance. Since the energy has no path to return to the sphere because of the gap at A, the energy flows out onto the shield and radiates.

3. Use of non-bulkhead, board mounted connectors (See Point 3, Figure 6 and Figures 10a & b).

A major compromise in many designs is the use of board-mounted connectors without contact to a chassis. This condition, as shown in Figure 10A, is in effect, a pigtail from the shield to the chassis. In a correct installation, the connector would have metal mounting ears, which are terminated to the chassis as shown in Figure 10B.

4. Incorrect use of drain wire (See Point 4, Figure 6 and Figure 11).

As shown in Figure 11, a drain wire is sometimes used improperly to terminate the shield to the chassis when the shield does not connect to the metal shell of the connector. This arrangement should be avoided, especially at higher frequencies, since the drain wire forms a pigtail similar to that in Figure 4. This pigtail picks up and couples energy through the pin of the connector out onto the shield from which it radiates.

5. Use of drain wire to logic ground (See Point 5, Figure 6 and Figure 12).

In Figure 12, the drain wire from the shield is connected directly to logic ground. This is improper in that it forms a pigtail, which may not reach the chassis except through the power supply. In an installation like this, the logic ground circuit is continuously injecting RF current into the pigtail. This indirect route makes the pigtail the longest of all the examples and possibly the worst case discussed.

FILTERING AS A WAY OF CONFINEMENT

The following are three ways in which the continuous metal shield can be removed from portions of the barbell model without increasing emissions.

1. Filtering with Shielded Cable to a Non-shielded Peripheral.

A system such as a PC, which is completely shielded, can be connected to a poorly shielded device such as a printer and still pass emission requirements. This is explained by the capacitance between the shield and the internal conductors as seen in Figure 13. While the energy is passing through the wires in the shielded cable, it is being continuously removed and returned to the PC through the shield. This capacitance often acts as an adequate filter to remove RF, enabling a non-shielded peripheral to meet emission requirements. It will only work if the connection at the source end (PC) is well terminated.

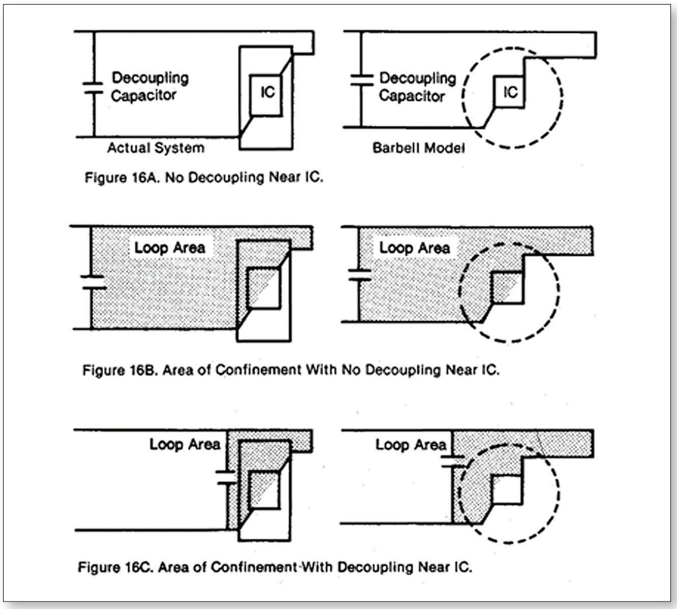


FIGURE 16: Area of Confinement Versus Decoupling Location.

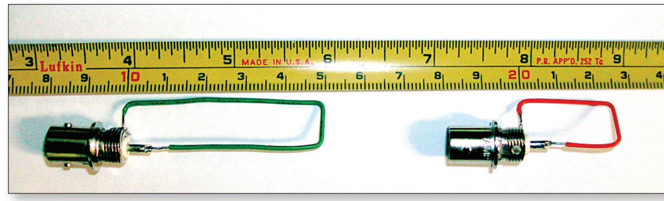


FIGURE 17: The two loops used in the test.

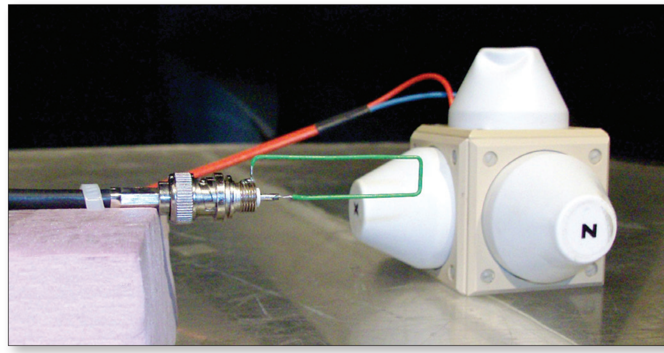


FIGURE 18: Here we see the 1cm by 5 cm loop and the field sensor for E fields.

2. Filtering with a Capacitor.

The next step in examining the barbell analogy is to remove the bar from the model completely, thus eliminating the shielding on the cable. The bar can be removed if all RF is eliminated from the wires before they leave the sphere. RF can be removed by a filter where the signals exit the sphere.

Figure 14 represents a non-shielded cable with RF riding on it. The confinement of the RF field has been compromised to a point where there is no shielding over the wires. The RF needs to be confined in the spheres. This confinement of the RF should not prevent the communication. The goal of confining RF and allowing communications can be accomplished by providing an RF short circuit at the point where the wire exits the sphere as shown in Figure 15.

This shortening of the wire differs from a pigtail in that a pigtail is an extension of the shield and is not RF shortened as it enters or exits the sphere.

The RF shortening of the wire is accomplished by using a properly selected capacitor as a filter at the point of exit. This capacitor must allow the intended communications to pass and short RF to the sphere. The capacitor can take several forms, such as a discrete capacitor, a connector with a capacitor built into each connection, or a feed-through capacitor. The highest quality of these three would be the feed-through capacitor. The choice of capacitor is determined by the frequency to be filtered, the number of connections, and the cost. Filtering with capacitors as described can be used for signal wire and for power cords. It must be noted that the capacitor is much like a pigtail in that its wire lengths are critical. Since there is inductance in the leads of the capacitor, the ideal length of the leads would be 0, or as close as possible to 0. If a single capacitor does not work, a combination of capacitors and inductors can be added to build an L, T, or Pi filter that should solve the problem.

3. Filtering by Decoupling.

The barbell analogy can be applied to an integrated circuit, which needs its energy confined with a decoupling capacitor as seen in Figure 16A. Figure 16B shows the large loop area of poorly confined RF energy when the decoupling capacitor is placed at a great distance from the integrated circuit. In Figure 16C, the area of confinement is greatly reduced by moving the decoupling capacitor near the integrated circuit.

SUSCEPTIBILITY LESSONS LEARNED

The original Mitigating Excessive Emissions paper was an explanation of how emissions are generated by a current flowing in a loop and how the levels of emissions are very dependent on the area of the loop as well as the current level.

Since then, the concept has been explained to probably thousands of people over the years. One of the worse situations I can rememberwas a product that was required to meet 200 V/m. When the product failed, we examined it and found there were a number of communication links with 20 inch pigtails. The question has always been in my mind, "How much voltage is being induced with a 20 inch pigtail?"

Since the author has always wanted to apply the barbell concept to susceptibility using scientific experimentation, he generated two tests with the same area but different wire lengths, and presents data from three experiments to show real numbers of the voltage picked up when doing susceptibility testing.

TABLE 1: INDUCED VOLTAGE INTO 5cm SQUARE LOOP					Transducer	
Axis	Frequency	Field Strength (V/m)	Antenna Distance	Induced Voltage (dBuV)	(Cable / Atten. dB)	Net Voltage (dBuV)
Y-Axis	10MHz	200	1 meter	89.44	0.4	89.84
Z-Axis	10MHz	200	1 meter	93.55	0.4	93.95
Y-Axis	30MHz	200	1 meter	92.3	1.3	93.6
Z-Axis	30MHz	200	1 meter	92.49	1.3	93.79
Y-Axis	100MHz	200	1 meter	93.6	22.3	115.9
Z-Axis	100MHz	200	1 meter	93.8	22.3	116.1
Y-Axis	200MHz	200	1 meter	95	23.4	118.4
Z-Axis	200MHz	200	1 meter	95	23.4	118.4

TABLE 2: INDUCED VOLTAGE INTO 2.5cm SQUARE LOOP					Transducer	
Axis	Frequency	Field Strength (V/m)	Antenna Distance	Induced Voltage (dBuV)	(Cable / Atten. dB)	Net Voltage (dBuV)
Y-Axis	200MHz	200	1 meter	89.1	23.4	112.5
Z-Axis	200MHz	200	1 meter	89	23.4	112.4

AS WE SEE FROM THE TABLE ABOVE:

A. There is a voltage induced into the connector from 89.84 dBuV to 118.4 dBuV or .031 V to .831 V. It does not take much imagination to realize voltages of ~ .831 may cause upset.

B. We also see from the bottom 4 rows, when we replaced the 5 cm^2 loop with a 2.5 cm^2 loop, the voltage dropped from 118.4 dBuV to 112.4 dBuV, 6 dB just as was described in the paper.

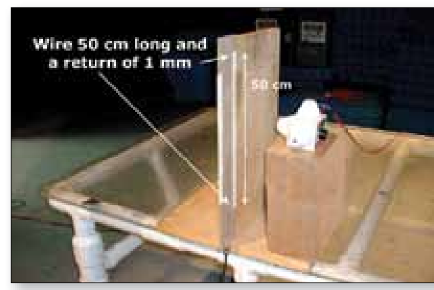


FIGURE 19: 20 Inch Long Loop with a 1 mm Return in Z Axis.

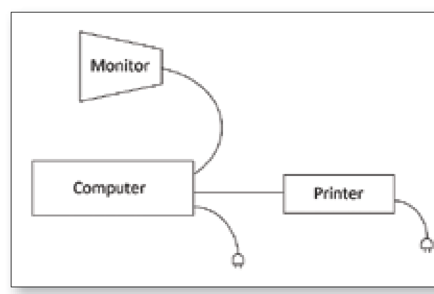


FIGURE 20A: Today's Solution.

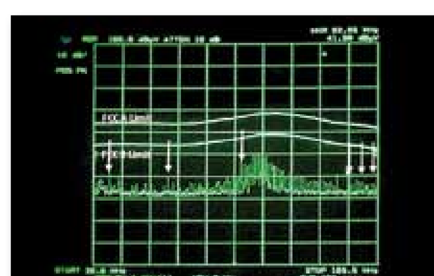


FIGURE 20B: Product meeting the FCC A and B Limit.

TABLE 3: INDUCED VOLTAGE INTO 5cm SQUARE LOOP					Transducer	
Axis	Frequency	Field Strength (V/m)	Antenna Distance	Induced Voltage (dBuV)	(Cable / Atten. dB)	Net Voltage (dBuV)
Y-Axis	10MHz	200	1 meter	61.4	39.8	101.2
Z-Axis	30MHz	200	1 meter	85.7	40.6	126.3
Y-Axis	100MHz	200	1 meter	96.1	41.5	137.6
Z-Axis	200MHz	200	1 meter	91.8	42.5	134.3

AS WE SEE FROM THE TABLE ABOVE:

A. There is a voltage induced into the connector from 101.2 dBuV to 137.6 dBuV or .115 V to 7.59 V. It does not take much imagination to realize voltages of 7.59 volts will cause upset in most circuits.

B. We can see that the longer wire is indeed a much better E-Field pickup. About 20 dB higher.

1. Measuring the induce voltage using a 20 inch pigtail as a square loop 5 cm by 1 cm

The assumptions:

The pigtail is 20 inches or 50 cm

The return is 1 mm away (the thickness of the insulation)

The loop area is .1 cm by 50 cm = 5 cm^2

We will use a loop of 5 cm by 1 cm

Load used would be the input impedance of the instruments (50 Ohms)

This experiment was done twice, once with an area of 5 cm^2 as described above and again with an area of 2.5 cm^2 which is ½ of both the area and the length of the previous experiment. See Figures 17 and 18 and the data in Tables 1 and 2 that show a 6 dB difference at 200 MHz.

When applying the concept to susceptibility, it turns out to be more of an E-Field pickup than a current loop emissions problem. You will see that with the same 5 cm^2 loop area we get far different results using the two approaches.

2. Using a 20-inch pigtail as a wire 50 cm long and its return 1 mm away.

We have the same area but a far different wire length. The original thinking of using a pigtail was to demonstrate emissions, which are caused by current flowing in a loop and is thus area dependent. Since we were trying to demonstrate pickup from an E-Field, it became apparent the length of the pickup antenna (pigtail) would be important not just the area. We tested a loop made from a 20-inch wire with the same effective loop area.

The assumptions:
The pigtail is 20 inches or 50 cm
The return is 1 mm away (the thickness of the insulation)
The loop area is .1 cm by 50 cm = 5 cm^2
We will use a loop of 50 cm by 1 mm
Load used would be the input impedance of the instruments (50 Ohms)

Using the same 5 cm^2 loop area as in Table 1 but a much different pig tail length of 20 inches (see figure 19) we get a much higher induced voltage as shown in Table 1 and 3 at 200 MHz Z-Axis.

SUMMARY

Today a major EMC compliance problem is radiation from cables. A model has been developed which allows an understanding of how RF energy needs to be confined. This confinement is sometimes compromised by an open circuit, a gap, or a pigtail. The barbell model shows how the energy can be confined by properly terminating shielded cables, filtering wires, adding filter capacitors, and decoupling the power and ground of integrated circuits. If you use this process to analyze your system and make the necessary adjustments, you will have fewer problems involving RF radiation (see figures 20A and 20B).

Experimental data was generated where both the wire length and area was changed by ½ and the energy picked up changed by 6 dB (compare Table 1 and Table 2 at 200 MHz).

Experimental data was also shown using the same loop area but dramatically different wire lengths. From this data one can conclude with long pigtails (20 inches) one could not expect to pass 200 V/m susceptibility testing as shown in Table 3 at 200 MHz.

Remember that the ideal length of a pigtail is "zero."

ACKNOWLEDGEMENT

The author's concept of the barbell was developed from personal conversations with Dr. Werner Graf who had previously presented a paper by E. F. Vance and F. M. Tesche entitled "Shielding Topology in Lightning Transient Control," NASA Conference Publication 2128 FAA-RD-80-30. Thank you to Tim Lusha of D.L.S. Electronic Systems, Inc. for running the experiment using the 5 and 2.5 cm loops.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EMC War Stories: Letters from Home

CANDACE SURIANO
Consultant
Suriano Solutions

JOHN SURIANO
Consultant
Suriano Solutions

PART 1: MY CELL PHONE CAN TALK TO ME IN STEREO

DEAR JOHN,

I am snowed in here at home with the kids, you may be in an EMC lab solving some tough issues, but I've been very busy here at home with some interesting problems of my own. We've been bothered by the behavior of our computer speakers. Periodically my cell phone I keep on the shelf talks to me on the computer speakers about 8 feet away. No, it doesn't use words that I can understand; instead it talks in some pulsed sort of buzzing noise that reminds me of Morse code.

Yes, I'm still using my "stupid" phone; I know you want me to switch to a smart phone. It's a GSM phone operating at 1.9GHz. I have done some simple tests that led me to some remarkable conclusions. I think they nicely illustrate some of the fundamental principles of EMC.

First I made some basic observations. The phone makes a noise on the speaker periodically. I held the phone up to the speakers, made a call and sent a text with the phone (see Figure 1). Both actions resulted in the noise. I concluded that the noise is not related to the ringer or the vibrator in the phone.

Every so often the cell phone sends a signal to let the network know where it is located. So I know that the cell phone was just calling its home (not ours), when it makes the periodic noise. There doesn't appear to be much difference in the interference when it was calling its home or making a normal call.

The signal from the phone is transmitted in bursts. The repetition rate of the bursts is on the order of milliseconds as shown in Figure 2. Each burst contains 1.9GHz modulated waves. The information is encoded in phase modulation. A spectrum analyzer set to zero span at 1.9GHz would show the burst signals as a pulsed waveform as shown in Figure 3.

Then I stole/borrowed our daughter, Frances' speakers from her (Figure 4) to find out if they also had a susceptibility to the cell phone signal. The noise also was on these speakers. I started to probe her speaker circuit board with my old Velleman PC


MXE

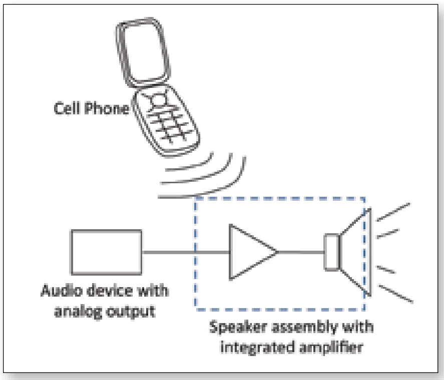

FIGURE 1: Cell phone interference with computer speaker

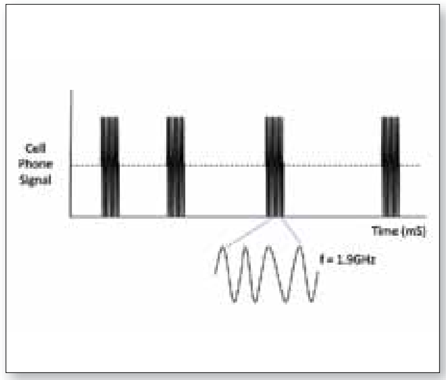

FIGURE 2: Cell phone transmission comprised of bursts of 1.9GHz signals

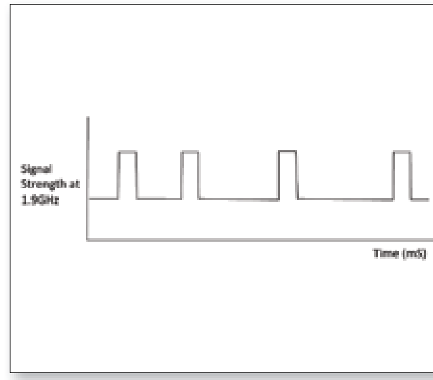

FIGURE 3: Signal at 1.9GHz

scope. Figure 5 is the signal I saw measured at one of the output pins of the speaker driver IC while the cell phone was communicating. The speaker IC is a commercially available stereo amplifier comprised of cascaded operational amplifiers.

One of the primary building blocks of an operational amplifier is the emitter follower circuit. A typical emitter follower circuit is shown in Figure 6. I wondered if this simple circuit is influenced by the cell phone. How else to do this but I did it with our old 20 in 1 Electronic Project Kit shown in Figure 7. With the cell phone nearby to the circuit, the emitter follower circuit did indeed pick up the noise.

The voltage at the emitter from the cell phone is seen in Figure 8. It seems like the emitter follower circuit is susceptible to the signal my old phone puts out just like the speaker circuit. This is actually an example of a basic susceptibility problem. An RF signal from an intentional or unintentional radiator can produce a DC voltage in a transistor circuit. The cell phone sends out bursts of

FIGURE 4: Cell phone and computer speakers (with cover removed)

FIGURE 5: Voltage at output of speaker amplifier during cell phone transmission

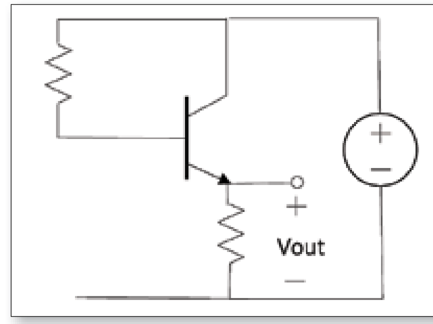

FIGURE 6: Emitter follower circuit: basic transistor circuit building block

1.9GHz signals. Every time a transmission is made by the phone it causes an offset in the voltage output of the transistor. This means the speaker electronics act as an envelope detection circuit for the cell phone output. Since the repetition rate of the communication bursts is in on the order of milliseconds, the voltage offsets from the transmission results in audible frequency noise in the amplifier circuit. Thus the noise is in the audible range because the speaker electronics are picking up the pauses between the bursts of data.

A longer continuous wave signal produces a longer offset of the voltage output. I tried the same experiment with one of our hand held mobile radio transmitters instead of the cell phone. Figure 9 shows how the voltage offset is present when the radio transmit key is depressed. Therefore the speaker electronics still couple into the emitter follower circuit, but not in the audible range.

Clearly RF transmissions can cause excitement and problems in all sorts of electronic equipment. An RF signal can result in a DC voltage in transistor circuits affecting the operation of the equipment. This is why susceptibility tests include various tests of immersion in RF fields. As shown in Figure 10 the cell phone can induce RF current in the transistor circuit. The RF current is rectified by

FIGURE 7: 20 in 1 Electronic Project Kit emitter follower implementation

FIGURE 8: Voltage offset in emitter follower circuit due to cell phone transmission

the transistor and a DC voltage drop is produced between the base and collector. This alters the bias of the transistor and results in lower output voltage of the circuit.

This is very disconcerting to me. I can't imagine how pervasive this problem could be. No wonder they don't like cell phones in hospitals and airplanes! It's a good thing that a lot of electrical equipment is tested for radiated susceptibility.

I am planning to keep my old cell phone, but I want to get rid of this annoying noise from our household speakers! I first used foil to shield the phone from the speaker and speaker signal wire. When the speaker and speaker signal wire was shielded from the signal, the speaker did not emit noise. If I put a piece of foil behind or around the phone, there is a shield and the phone does not couple into the speaker's electronics. However, this is not a great way to shield the phone because our children do not want to

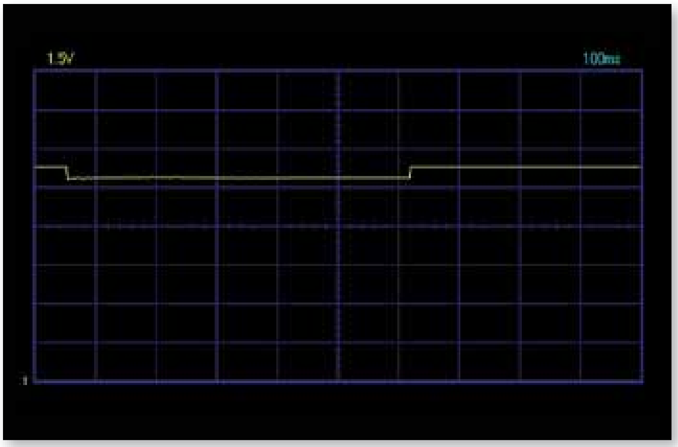

FIGURE 9: Voltage drop during key-on of hand-held transmitter

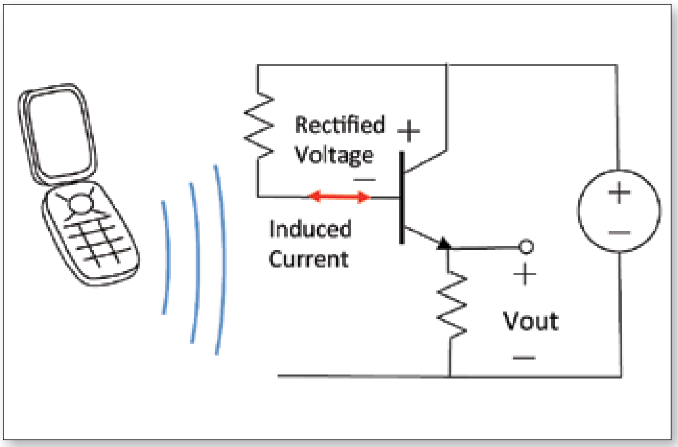

FIGURE 10: Cell phone transmission producing rectified voltage offset

hang around a mom with a shinny foil covered phone. The kid's new smart phones do not cause the speakers to emit an audible noise. Part of their silence is because they use the wireless in the house when they make their calls. However, when they disabled the wireless communication they still did not couple into the emitter follower circuit audibly. This is because their phones do not transmit in bursts like the older phones. When I watched their smart phones' transmission on the scope, their phones transmitted in an initial burst and then continuously, perhaps that transmission waveform is because they are 4G. They may generate do generate a DC offset in the amplifier that is not pulsed.

Well that's enough for now. I included some helpful references for you at the end of the letter. Don't forget to write.

Love,
Candace

ABOUT THE AUTHOR

Candace Suriano *is a graduate of GMI Engineering & Management Institute (BSME) and has graduate degrees from Purdue University (MSME, MSE) and the University of Dayton (Ph.D.). She is the author of numerous papers and articles on electromagnetic compatibility and chaired an antennas and probes workshop at several IEEE EMC symposia. Candace is currently working to encourage young people to explore electrical engineering by organizing Library Kit donations and demonstrations by groups from the Southeastern Michigan IEEE. Her interests are in the areas of electromagnetic compatibility and electromagnetic modeling. Candace is a mom with interests in MOM.*

John Suriano *is a graduate of GMI Engineering & Management Institute (BSEE) and has graduate degrees from Purdue University (MSME, Ph.D.). John is the author of numerous papers and articles on electromagnetic compatibility and motor design. He supervises an EMC laboratory for Nidec Automotive Motor Americas in Auburn Hills, Michigan. He has interests in electric motors and electromagnetic modeling.*

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- [1] Paul Horowitz and Winfield Hill, The Art of Electronics, Cambridge University Press, New York, 1980.
- [2] Victor Grinich and Horace Jackson, Introduction to Integrated Circuits, McGraw Hill, U.S.A., 1975.

Risk of ESD Sensitive Devices in Proximity to ANSI/ESD STM2.1 Compliant Garments by Field Induced Model Discharge

BOB VERMILLION
CPP/Fellow
Certified, ESD Engineer-iNARTE
RMV Technology Group, LLC
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DURING ESD assessments, it is not uncommon to see personnel wearing wool, silk, cotton, polyester blends and static control overalls (ESD Garments). Some ESD garment types consist of an embedded conductive grid network (Figure 1) in combination with cotton or polyester blends as seen under a digital microscope (Figure 1, left). Despite favorable cuff-to-cuff (Figure 2 right) or sleeve-to-sleeve resistance (Figure 2, left) to ANSI/ESD STM2.1-2013 (see Table 2), some ESD garment types are charge generating. So, is a conductive grid network embedded in ESD garments (Figure 1) adequate for the prevention of Triboelectrification or charge generation? Note: This article does not address disposable garments.

ANSI/ESD STM2.1 establishes requirements for taking point-to-point measurements as illustrated in Figure 2. One method utilizes special stainless steel garment clip electrodes (Figure 2, left) or two 5-pound NFPA electrodes (Figure 2, right) also illustrated in ANSI/ESD STM2.1.

Recent testing by the Author found that although some ESD garments measured within the acceptance range of ANSI/ESD S20.20 for electrical resistance, electrostatic fields were still measured by a grounded operator wearing an ANSI/STM2.1 compliant garment. Based upon these findings for ESD garments, one may ask if there is a risk of ESD fabric charging in proximity to Ultrasensitive ESD devices (HBM Class 0) under 50 volts? Will an electrostatic field facilitate an ESD event when con-

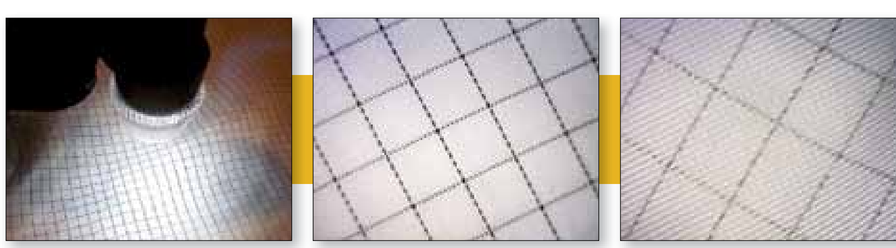

FIGURE 1

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FIGURE 2

FIGURE 3

TABLE 2 SOURCE: ANSI/ESD STM2.1

Common Industry Description / use of Garment System	Garment Categories	Recommend Resistance Values
Garments with some electrical field suppression properties	ESD Category 1 Static Control Garments	<1.0 x 10^{11} ohms
Garments with a designated grounded point	ESD Category 2 Groundable Static Control Garment	<1.0 x 10^{9} ohms
Garment in continuous electrical path with a person; however, not the primary ground path	ESD Category 2 Groundable Static Control Garment	<1.0 x 10^{9} ohms
Grounded with dual paths to ground via continuous monitoring equipment that requires two separate paths to ground	Gar ESD Category 3 Groundable Static Control Garment System (Garment in Combination with a Person)	<3.5 x 10^{7} ohms
Grounded through a single wire constant monitor system[1]	Gar ESD Category 3 Groundable Static Control Garment System (Garment in Combination with a Person)	<3.5 x 10^{7} ohms
Garment used as primary grounding path for personnel	Gar ESD Category 3 Groundable Static Control Garment System (Garment in Combination with a Person)	<3.5 x 10^{7} ohms

[1]Some single wire constant monitor systems measure parameters other than resistance.

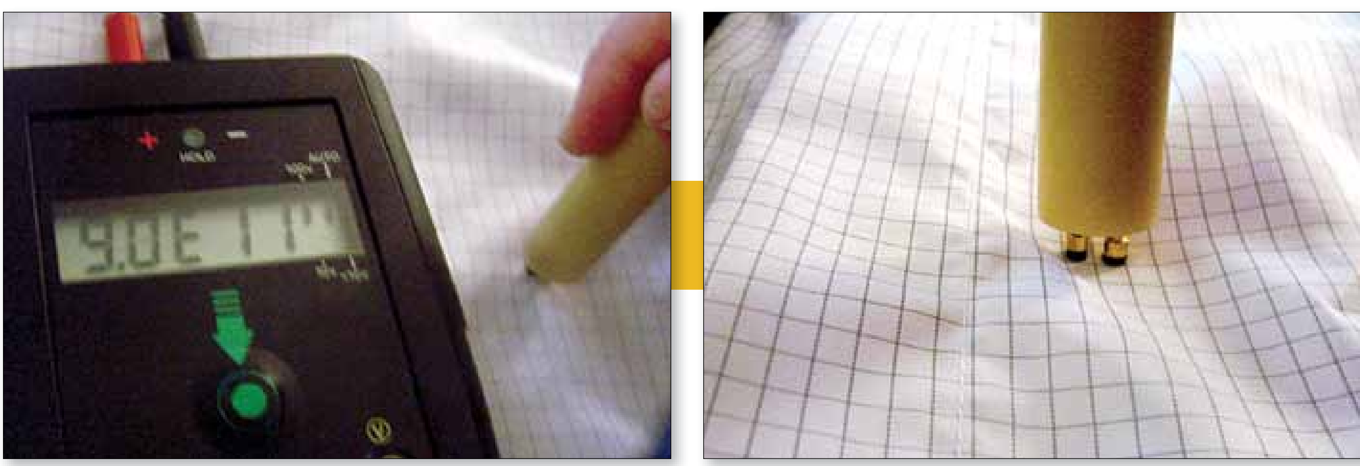


FIGURE 4

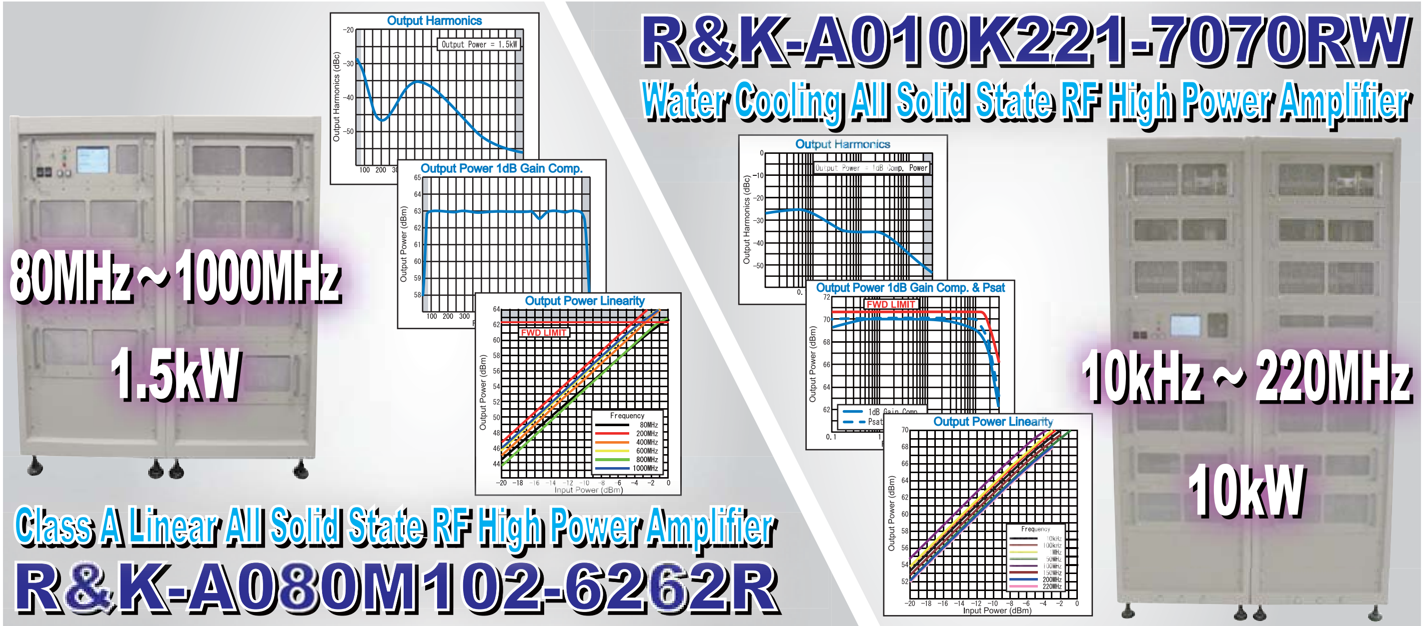
tact is made by a grounded operator touching a circuit card or components with metal tweezers? Table 2 highlights the resistance requirements for ANSI/ESD STM2.1.

Three factors are necessary to produce an ESD event:

1. Charge Generation
2. Charge Accumulation
3. Rapid Discharge

Therefore, it is important that a path to ground exists between a grounded operator and an ESD garment.

A few years ago, this same probe (as photographed in Figure 3) measured an operator wearing an ESD garment and conductive footwear on a conductive floor. Less than 50 volts was generated (Figure 3, right). A non-contact voltage probe is utilized to determine peak electrostatic voltage.



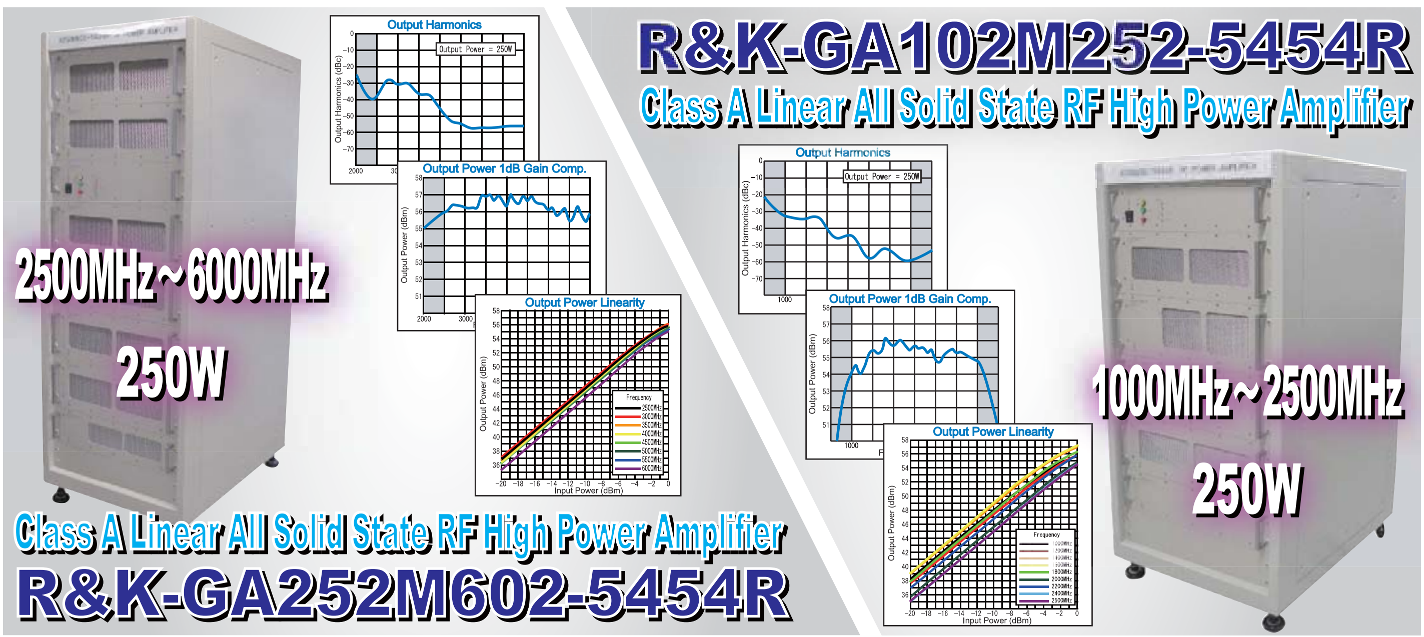


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FIGURE 5

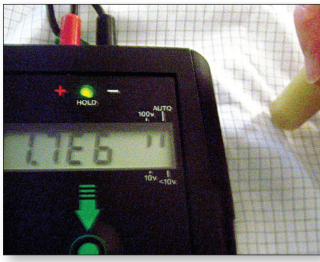

FIGURE 6

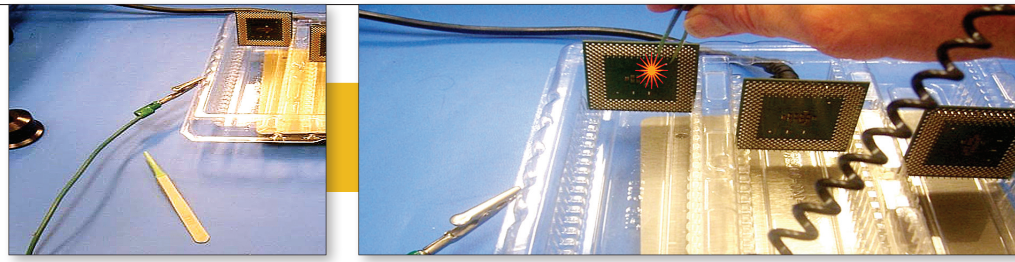

FIGURE 7

TABLE 3

Garment	ANSI/ESD STM2.1 ESD Garments (Ω) Limit: <1.0E+11 ohms	ANSI/ESD STM11.13 ESD Garment Grid Patten (Ω) (Inside Grid Pattern, Figure 4)	ANSI/ESD STM11.13 ESD Garment Grid Patten (Ω) (On Grid Pattern, Figure 6)
Wool Sweater - Figure 5, Left Note: No Field Suppression	1.3E + 12	NA	NA
ESD Garment - Figure 5, Center Laundered Cotton & Carbon Grid Pattern	7.0E + 10	3.2E + 10	2.4E + 08
Polyester & Carbon Grid Pattern Figure 5, Center-Right	9.0E + 05	9.0E + 11	1.7E + 06
Black Cotton Short Sleeve Shirt - Figure 5, Far Right Note: No Field Suppression	6.2E + 10	NA	NA

Resistance Values Note: Red = failure

TABLE 4 ANSI/ESD STM11.13 FOR 48 HOURS AT 12.4%RH

2-Point Resistance Inside			2-Point Resistance Outside		
Tray	**STM11.13**	**C.V.**	**Tray**	**STM11.13**	**C.V.**
1	3.40E+08	100v	1	4.51E+08	100v
2	3.21E+08	100v	2	4.89E+08	100v
3	4.24E+08	100v	3	4.34E+08	100v
4	3.54E+08	100v	4	4.66E+08	100v
5	3.70E+08	100v	5	4.37E+08	100v
6	3.52E+08	100v	6	4.03E+08	100v
Average	3.60E+08	Inside Base	Average	4.30E+08	Outside Base
Median	3.53E+08		Median	4.36E+08	
Minimum	3.21E+08		Minimum	3.89E+08	
Maximum	4.24E+08		Maximum	4.66E+08	
St. Dev.	3.53E+07		St. Dev.	2.90E+0	

For this article, the computer interfaced, non-contact probe system was positioned on an ESD safe workstation (Figure 3, left). During testing, the laptop computer (Figure 3, left) was moved 3' away from the probe set-up so as not to influence the readings. The temperature and relative humidity (RH) measured 73°F and 37%RH respectively. The Workmanship NASA-STD 8739.6 Page 16, Section 6.1 calls out the following:

6.1 Temperature and Relative Humidity (RH)

6.1.1 Temperature and relative humidity (RH) shall be monitored in the processing area and maintained within the following limits (Requirement):

a. For temperature: 18° - 30° C (65° - 85° F)
b. Maximum relative humidity: 70 percent RH
c. For ESD-sensitive hardware, minimum humidity: 30% RH
d. For ESD-sensitive hardware, HBM Class 0, minimum humidity: 40% RH

ANSI/ESD STM2.1 & ANSI/ESD STM11.13 RESISTANCE:

A wool sweater, polyester blend ESD garment, ESD cotton garment and cotton shirt were benchmarked (Figures 4 and 5) to determine the fabric resistance properties. The need to differentiate a myriad of factors that

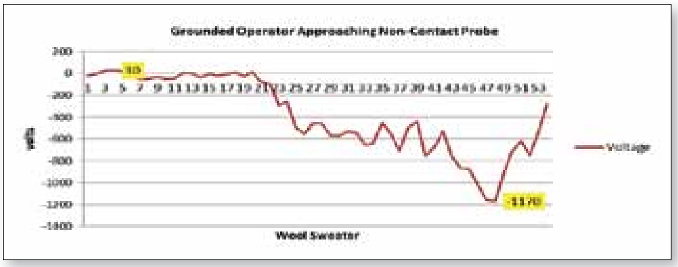

FIGURE 8a

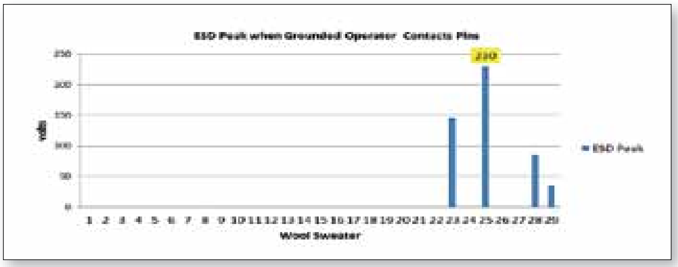

FIGURE 8b

can occur with different types of ESD garments should be of interest to the reader. Table 3 provides a summary of the results.

In Figure 7, the antistatic tray was hand treated and produced a 2-point average resistance measuring 3.6 x 10^8 ohms for the inside cavities and 4.3 x 10^8 on the bottom (Table 4). The tray was set atop a charge plate to confirm that the overhead 3-fan ionization unit had neutralized the charge to <5.0 volts. An alligator clip was attached to the tray to insure a path to ground. An ESD event antenna was positioned one foot from the ESD sensitive device. While the operator was grounded (wearing a wriststrap), a stainless steel tweezer made direct contact with the pins of the ESD sensitive device (metal-to-metal). Consequently, the test was conducted first wearing a wool sweater, second an ESD cotton blend & carbon grid garment, third, an ESD Polyester blend & carbon grid garment, and finally, a black cotton short-sleeve shirt.

The next step constitutes a grounded operator approaching a computer interfaced, non-contact voltage probe. The results are illustrated in Figures 8 to 11.

Within seconds after approaching the non-contact voltage probe and ESD event antenna, the grounded operator wearing the various apparel for each material type, made direct metal-to-metal contact with the ESD sensitive device. Consequently, an electrostatic field in proximity to an ESD sensitive device produced a field induced model discharge (FIM) when metal-to-metal contact was made in the presence of an electrostatic field as illustrated in Tables 4 and 5.

DEFINITION OF CDM & FIELD INDUCTION:

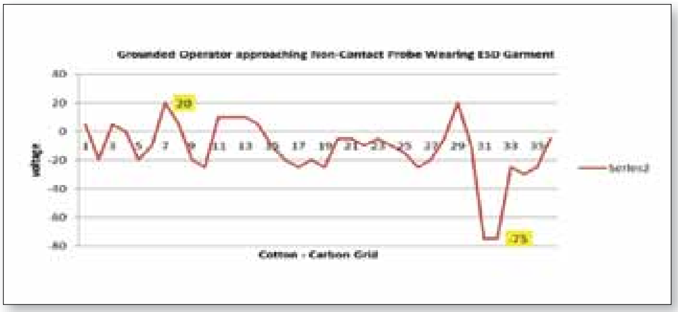

FIGURE 9a

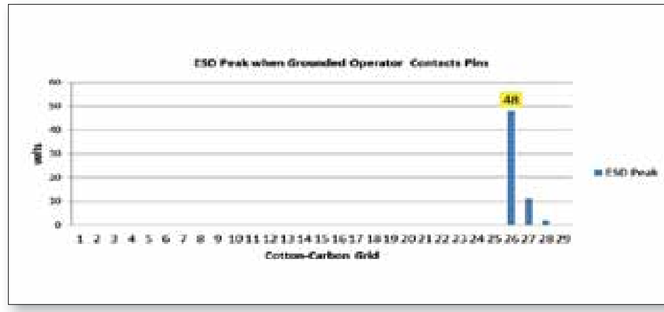

FIGURE 9b

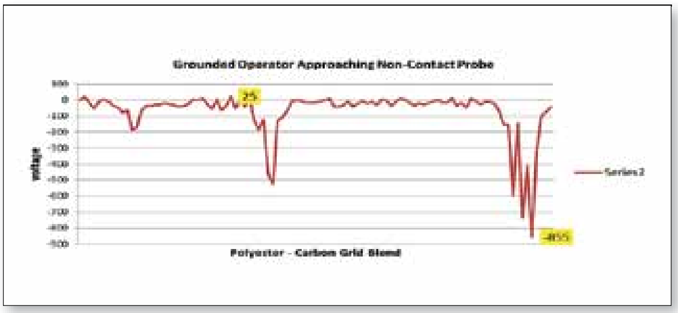

FIGURE 10a

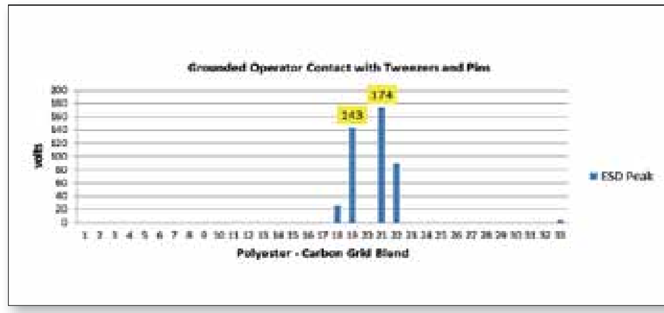

FIGURE 10b

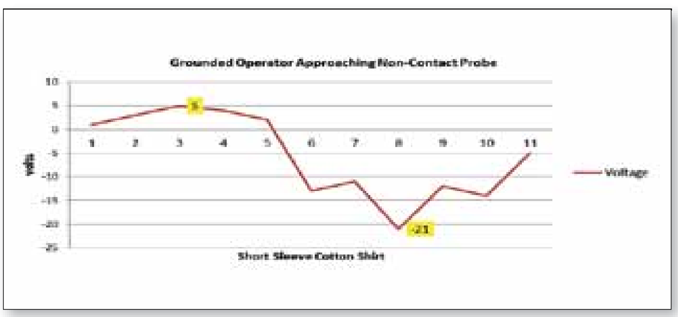

FIGURE 11a

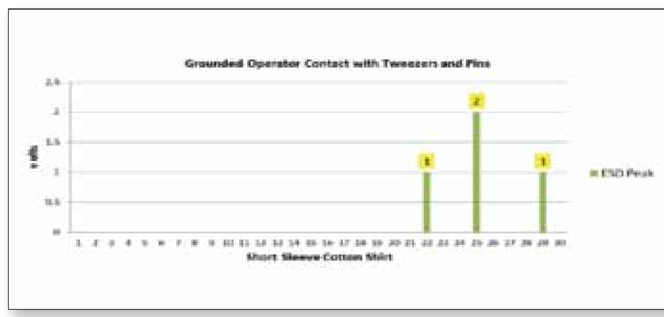

FIGURE 11b

As a device contacts a conducting surface, discharge to the surface can be very rapid and cause device damage known as CDM (Charge Device Model) Hazard or Field Induced Model Discharge.

Induction is caused by one object or person transferring a charge to another surface. At the point of surface contact, a charge will rapidly discharge onto a conductive surface such as tweezer contact with component pins.

In summary, charge contribution by ESD garments should be considered when handling Ultrasensitive ESD devices under 50 volts or as required by the user. The ESD garment standard test method, ANSI/ESD STM2.1, provides an effective cuff-to-cuff or sleeve-to-sleeve measurement technique as an indicator of resistance performance. Moreover, it was found that without ionization, some fabrics (with and without conductive grids) generated both electrostatic fields that fueled ESD events when metal tweezers made contact with component pins by a grounded operator. In conclusion, this article outlines preliminary findings whereby more research at lower relative humidities and additional testing will be required for a later study.

ABOUT THE AUTHOR

Bob Vermillion, *CPP/Fellow, is a Certified ESD & Product Safety Engineer-iNARTE with subject matter expertise in advanced materials testing and evaluation, troubleshooting robotics and electronic systems for aerospace, disk drive, medical device, pharmaceutical, automotive and consumer electronics. As a member of the ESD garment working group, Bob also serves on the ESDA Standards Committee. Bob is a member of the SAE G-19 & G-21 Committees. Speaking engagements include ESD Seminars in the USA and abroad including guest lecturer seminars for California State Polytechnic University, San Jose State University, University of California at Berkeley and Clemson University. Bob is CEO & Founder of RMV Technology Group, LLC, a NASA Industry Partner and 3rd Party ESD Materials and Systems Level Testing Lab, Training and Consulting Company. You can reach Bob at 650-964-4792 or bob@esdrmv.com.*

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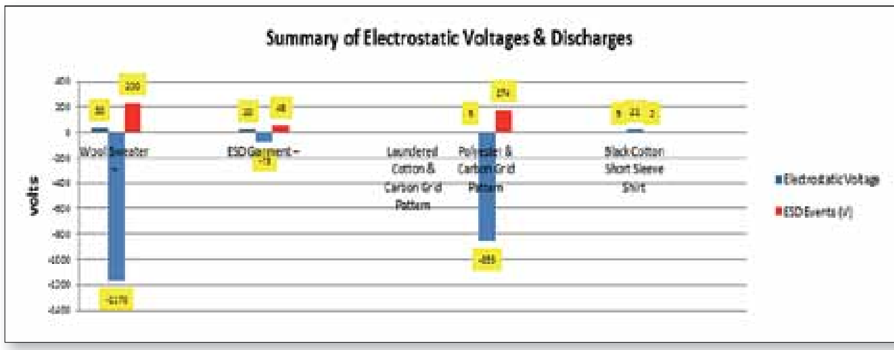
TABLE 5 SUMMARY OF ELECTROSTATIC VOLTAGE & DISCHARGE

Test	Electrostatic Voltage		ESD Events (V)
Wool Sweater - Figure 5, Left	30	-1170	230
ESD Garment - Figure 5, Center Laundered Cotton & Carbon Grid Pattern	20	-75	48
Polyester & Carbon Grid Pattern Figure 5, Center-Right	5	-855	174
Black Cotton Short Sleeve Shirt - Figure 5, Far Right	5	21	2

Note: Ionizer was turned off after each neutralization phase.



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Part 2 - EMP Protection of Buildings

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PART 1 OF THIS ARTICLE (in *Interference Technology's* EMC Test & Design Guide) addressed a Proposed *National Plan* for EMP Protecting the U.S. Part 2 of the article presents methods and techniques for EMP protection of buildings, solar rooftops and other structures. As such, Part 2 covers details of shielding, bonding, grounding, and cable or device surge suppression and filtering. These apply to structures from sheds and rooms to small and large homes, and to commercial and industrial buildings less than about five floors in height.

8 SHIELDING A HOME & BUILDING BEFORE A SOLAR ROOFTOP

Electromagnetic shielding works from a combination of (1) radiated emission reflection loss at the metal shield and (2) metal absorption loss. The first component develops from the ratio of the arriving wave impedance and that of the metal. The second comes into play when the skin depth of the metal exceeds about 50% of the metal thickness.

8.1 Shielded Building, Rooms& Cabinets

Figure 8 illustrates that there exists three levels (possibly more) of shielding. The benefit of shielding the entire building to 80 dB (amount discussed earlier) means that nothing else inside needs to be shielded. So existing climate controls, cell phones, iPhones, iPads, laptop computers, peripherals, and all the rest of electrical and electronic devices can continue to be used. However, shielding a building to 80 dB in some cases become expensive (for example, more than 10% of the entire building cost).

Consequently, one or more internal shielded rooms could be added where the more sensitive items would be located, and the entire building shielding can be correspondingly reduced. For example, suppose aluminum foil or sprayed copper paint on the outside walls, ceiling and floor (bonded and secured) are used to produce 45 dB shielding. This reduces the needs of the remaining shielded rooms, cabinets or enclosures to 35 dB as shown in Figure 8.

However, if the same skin shielding were applied to the inside of the outer

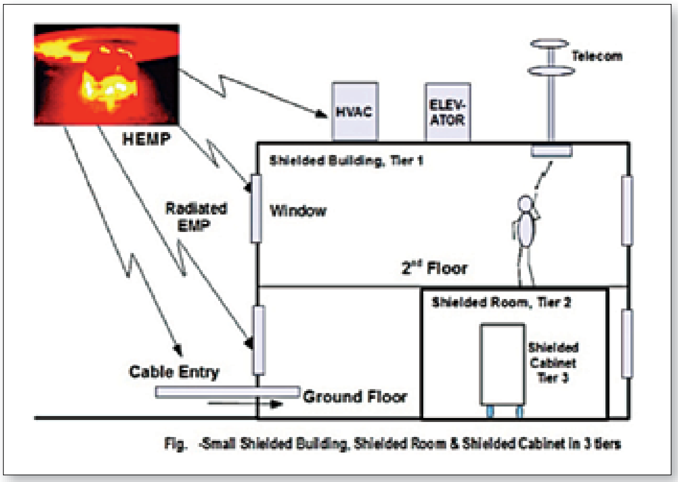

FIGURE 8: Three tiers of shielding: shielded building, shielded room and shielded cabinet or box.

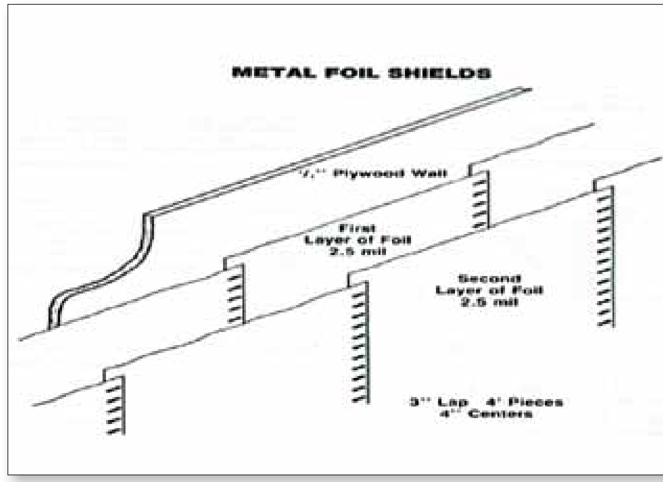

FIGURE 9: Two layers of foil overlap to ensure against handling and aging effects

walls, this would not work as the electrical wiring in the outside walls is still not protected.. ***Thus, apply the shield to the outer building skin.***

If the internal building items have a certified radiated susceptibility limit of 10 V/m (the assumed typical conditions), the remaining shielding required can be achieved in an internal screen room or cabinet or box size, as applicable. Shielded rooms of the quality offered by the EMC manufacturers are shielded to about 120 dB and represent a huge overkill in performance and price, and therefore, would not be used here.

The applied shielded building skin is therefore placed on the outside with sheet metal building walls bonded where joined. Each of the six sides of the building (roof, basement floor, and four sides) is bonded along its entire length.

Figure 8 shows that the windows, rooftop elevator shack, A/C heat exchanger, and all cable shields penetrating the building must not have SE less than 80dB below 64 MHz. (See Figure 17.)

8.2 Shielding of the Building Facade

How to shield the building facade (outer skin)? What constitutes the basic material under the building skin or envelope, such as with vinyl siding? In the U.S., it is typically a plywood lath sheathing in the North and concrete blocks (stuccoed over) for residential in the South. For commercial it may be aluminum composite panels, copper or stainless steel sheets, weather-board, etc. These and other materials are dependent on whether or not the building already exists or has not yet been designed or built. Most specifics of this discussion are beyond the scope here and involve important architectural matters.

If the facade of the existing building permits the direct addition of an aluminum foil, then the household, 1 mil (= 0.001 inches = 0.0254 mm) or a more ruggedized version (for example, 3 mils) of aluminum foil provides all the shielding needed.

One mil of aluminum foil provides 96 dB of shielding. So there exists sufficient shielding. But how are sheets of foil to be bonded to their mounting material siding? Also, how are they mated together at their edges?

Basically, an adhesive spray is made on the mounting material back and the foil is placed thereon. However, the foil overlap should approximate one inch (2.5 cm), as shown in Figure 9, and a masking tape used to secure the

FIGURE 10: Many different electrical gaskets available for selection of the correct type for any particular application. Right central wire mesh type for window sills.

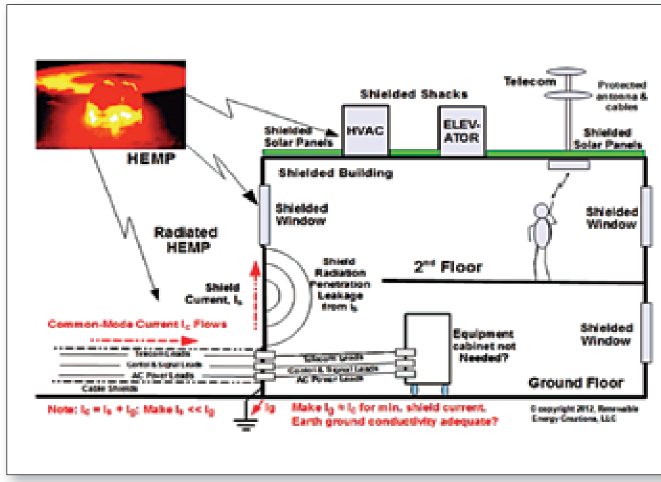

FIGURE 11: Shielded Building and Grounding Compromises

overlap junction. Do not spray the foil adhesive in the 2.5 cm region as ***metal must be bonded to metal*** without any other material in between to ensure a high conductivity and good shielding.

The foil must end at each window sill or outside door sill or frame as the window/door will receive its own shielding. An electrical bonding agent or gasket (described below) is used to electrically connect the building facade with each window and door periphery.

One possible option to the above foil is to use copper or aluminum paint, applied by brush, roller or spray. A finishing non-conductive protection coat of latex paint is applied. One major benefit of the paint approach is the relatively easy application by spraying and the avoidance of foil overlaps, and electrical gaskets except at windows, doors, etc. described below.

How to close this gap? There are different methods, but they go beyond the level of this article. Of course, to a new building just being planned or being built, this is not an issue as the bottom floor shield is extended beyond

FIGURE 12: Wire mesh, shielded windows

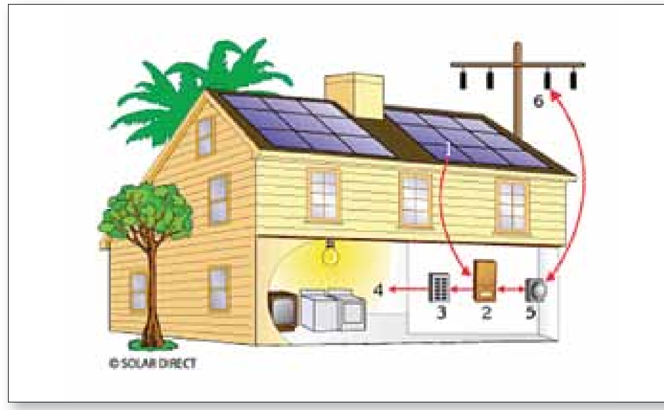

FIGURE 13: A typical EMP Unprotected Solar Rooftop Installation.

outer frame footprint to be bonded to outside shielding.

Regarding electrical gaskets used to seal the adjoining metal sides, Figure 10 shows options available from companies like Tech-Etch for the engineering community. The figure also shows other electrical gaskets use in bonding other types of mating electrical parts.

8.3 Grounding of Shielded Building

Figure 11 shows the shielded building including building skin, shielded windows, shielded HVAC and elevator shacks and other external elements. The shielded building could float in space without grounding, and the shield works fine. No grounding is required. However, there are other concerns such as if the shield becomes charged up to any voltage above ground level due to whatever stray radiations (or accidental connection of a hot AC lead to building skin), it constitutes a shock hazard to entering and exiting people. Also, lightning control must be considered. That's why the building skin must be grounded (earthed) to satisfy the National Electrical Code.

Also, as shown at the lower left, Figure 11, telecom leads, control and signal leads, and AC power leads must enter the building. These cables must also be shielded. Since the cable shield and the building shield may be at a different voltage, the entering cable shield must be bonded to the building shield (usually a metal plate. The object is to divert the EMI (induced electromagnetic interference shield currents) and grounded to earth, where they are harmlessly dissipated. But the devil is in the details.

The sketch of Figure 11 illustrates the situation repeated thousands of times throughout a state or a country of a developed nation. Radiated EMI (or EMP) is coupled to a cable shield where EMI surface, common-mode currents, Ic, are grounded at the shielded building entrance (assuming a best case in which the building is shielded). It is typically assumed that the EMI currents will flow down the ground rod(s) (see I_g) and dissipate harmlessly into the absorbing earth. Some EMI currents (I_S), however, still flow on the building shield (that skin current is capacitive coupled back to ground to close the loop). Those currents may then penetrate into the building skin where they can upset or burnout internal victims. So, how successful (e.g., how low?) is the low-impedance quality of each? Also, how much attention has been paid to pertinent details?

Remember, the only shield current that should flow is from the terminated, direct radiated EMI onto the building shield, per se. It should not contain additional currents that come from any cable entry ground which can exceed the terminated EMI surface current on the building by large amounts. The degree to which it is exceeded is a direct mea-

FIGURE 14: Shielded Inverter Cabinets

FIGURE 15: Two different types of Many hardened surge suppressors

sure of the reduction loss in building shielding effectiveness.

If the building were built on sand or some non-moisture holding soil, or a drought existed in the area, then the grounding system will not work as well (or poorly). If the ground Fargo clamps eroded out or became disconnected, then what? (Note: *Measurement of Soil Resistivity*, in MIL-HDBK-419 speaks in detail to the number of ground rods, ground wells and earth electrode subsystem necessary to achieve the grounding objectives).

Can you testify if your own facilities or other installations are properly grounded? What criteria or standard do you use? Who signed off on the inspection? It is still “grounded” five years later?

As it develops, the entire discussion may be academic from an EMP point-of-view since few non-government buildings are EMP protected (shielded) in the first place today. For those situations, all the interior electronics are fried in an EMP event – grounded or not.

EMP, lightning and EMI won't go away. Grounding is an important part of the protection system, but shielding and filtering are of equal concern.

8.4 Shielding Windows, Doors & Other Building Skin Leakage

Windows cannot employ electrochrom glass as this blocks light with little shielding, nor can one have a few microns (very thin film) of vapor-deposited metal on the window as a shield since one could not then see through the window. Although a one micron (very thin film) of silver deposited on glass offers an RF shielding effectiveness of 80 dB, it also blocks the optical transmission.

Therefore, a metal screen mesh (Figure 12) is considered for covering the windows which passes almost all the light (optically) but blocks the EMP radiated transmissions by 80 dB below 12 MHz (depends on the mesh screen spacings). The required screen mesh element separation distance, d, to achieve this shielding, is calculated by:

$$SE_{dB} = 20Log_{10}(150 / (d * f_{MHz}) = 80 \text{ dB}$$

where: f_{MHz} = 12 MHz from the geometric mean of the first and second corner frequencies in the Bode Fourier frequency plot corresponding to the 5 nsec rise time of

FIGURE 16: Wire screen mesh covered, shielded meters

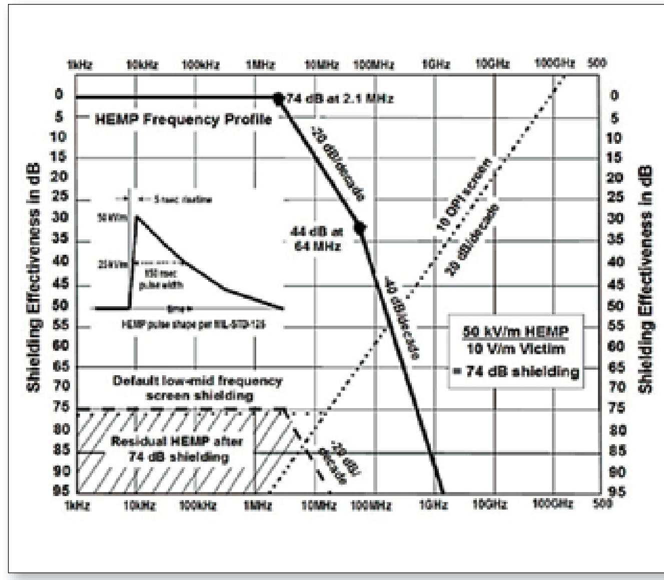

FIGURE 17: Shielding effectiveness Requirements for EMP protection..

the standard 150 nsec EMP pulse.

Solving the equation for mesh separation, d, produces a distance of d = 1.29 mm. This corresponds to 25.4/1.29 or 20 wire mesh openings per inch (OPI). This OPI is mentioned since mesh shielding is usually reported in OPI by manufacturers, and is available up to 100 OPI.

For shielding solar panels, do not use higher OPI as the light transmissivity begins to suffer and this will adversely affect the solar panel efficiency of converting sunlight into electricity.

8.5 Shielded External Doors

One or more doors permit entry into and exit from the shielded building. For each such door, a vestibule must be generated such that a set of two doors is used with interlocks so that not more than one door can be opened at any time. This will avoid a fortuitous situation in which both doors are temporarily open at the moment an EMP incident occurs, which would otherwise compromise the entire integrity of the building shielding effectiveness.

8.6 Shielded Wires and Cable Entries

As shown in Figure 11 earlier, three cable and wire classes enter nearly every building: (1) telecom (telephone, Ethernet, and other hard-wire communications) leads, (2) control and signal leads for controlling certain activities and reporting back elsewhere with status data, and (3) AC power mains to supply 120 VAC, 240VAC or other voltage to run the building's many operational loads previously discussed. Unless the cables are already placed in conduit, buried and/or shielded, their shields must provide the required 80 dB shielding below 64 MHz isolation to the entering leads.

The interconnecting wiring between and among all solar panels, inverter (if micro-inverters are not used) and the down conductors to the service entrance panels must also be shielded to 80 dB. A solid thin wall copper tubing can also be used as the shield. However, to ensure the benefits of flexibility, knitted-wire mesh shielding can be used on all cabling instead. All shielding must have an overcoat of weather sealant or outer jacket if not placed inside a conduit.

As explained above, the cable shields are bonded to the building shield usually at a metal grounding plate welded to the building shield at cable entrance (see above discussion on building grounding).

9 ADDING A SHIELDED SOLAR ROOFTOP

An EMP unprotected solar rooftop typically consists of panel mounting racks, solar panels, interconnecting cables, one inverter (or a micro-inverter at each panel), down conductor cables to a power-select transfer switch (connects utility power or solar panels), and backup batteries. Batteries are used for nighttime power and overcast days when the solar panel power output is insufficient. Generators are not normally used since unless protected they would burnout in an EMP burst, and they require fuel which may not be available after an EMP incident.

Solar panels usually contain 1st generation silicon solar cells (the work horse for generation of space electricity for 40 years) which have the highest light conversion efficiency. The panel frame usually measures about 3 feet (0.91 meters) x 5 feet (1.52 meters) and produces an output of about 200 watts with a 22±% light-conversion efficiency. Increasing in popularity is CaTu, a second generation, thin-film, solar cells costing significiently less (First Solar of Tempe, AZ has produced these at a reported production cost as low as $0.52/watt), but they have a conversion efficiency of about 65% of silicon.

The average home size in the U.S. is 2,300 sq. ft (214

sq. meters). A one floor house will have a roof of about 2,700 sq ft (252 sq. m). If about half is facing roughly south and 80% is useful to hold the solar panels, then up to 72 solar panels can be mounted.

Because the solar panels are not pointing at the sun (i.e., fix mounted with no tracker, such as the trackers used in solar farms) during the rotation of the earth, the average power output over a 10-hour period may be about 10 kW. If the home has two floors, then available roof provides about half this or about 5 kW. By adding a typical garage, this may add another kW. The average house in the U.S. requires about 8 kW to handle the A/C, hot water, clothes washer/drier, appliances, lighting and other loads.

The average of 5 kW applies for about five hours per day and falls off as the sun moves toward the horizons. In the northern hemisphere, there is less in winter and higher latitudes and more in summer and lower latitudes. The above assumes no blockage due to the shadows of other buildings and trees.

Of course, a solar installation would be instantly burned out in an EMP incident, so the entire installation must be EMP protected.

9.1 Adding Shielding to Solar Panels

After mounting the framework racks on the building roof, the shielded solar panels are then affixed thereto. The shielding is to provide the required nominal 80 dB solar panel shielding:

Shield the panels completely inside of the solar glass window face and bond them to the frame which provides complete metallic coverage of the other five sides. The solar screen may be 20 OPI (openings per inch). welded screen mesh, previously mentioned. This shielding is to be done back at the factory where the panels are manufactured for quality control and long-life performance. The screen will reduce the light transparency by roughly 15%.

9.2 Adding Shielded Micro-inverters or Inverter (shield only)

The micro-inverter is a small DC-AC converter which takes a typical 12 VDC output from a solar panel and converts it to 120 VAC or other user load value. As appropriate, the panels are connected in series and/or parallel to produce the desired load voltage. A small micro-converter can be built into the shielded solar panel near its output connector (this is to be done at the time of solar panel assembly back at the factory) or mounted separately next to the panel. Unless the entire solar rooftop assembly is to be shielded separately, the shielded unit requires an HV surge suppressor at the cable connectors.

Micro-inverters have several advantages over conventional central inverters. Even small amounts of shading debris or snow lines on any one solar panel, or a panel failure, does not disproportionately reduce the output of an entire array. Each micro-inverter obtains optimum power by performing maximum power point tracking for its connected panel.

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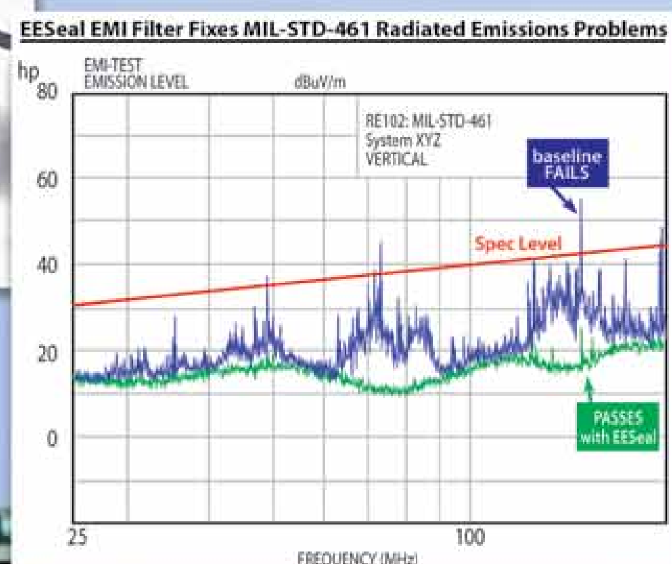

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Their primary disadvantages are that they have a higher equipment initial cost per peak watt than the equivalent power in a central inverter, and micro-inverters are normally located near the solar panel, where they may be harder to maintain. These issues are usually surpassed by micro-inverters having higher durability and simplicity of initial installation.

When the total rooftop solar load exceeds about 10 kW, micro-inverters are usually not used and the inverter takes over. The photo in Figure 14 shows three inverter sizes ranging from 10 kW to 500 kW. If they were located outside the EMP shielded building they would have to have cabinet shielding of 80 dB plus cable surge suppressors and shielded cabling. To avoid this, if possible, they should be placed inside the 80-dB shielded building (e.g: garage) and existing models used with no further shielding retrofit required.

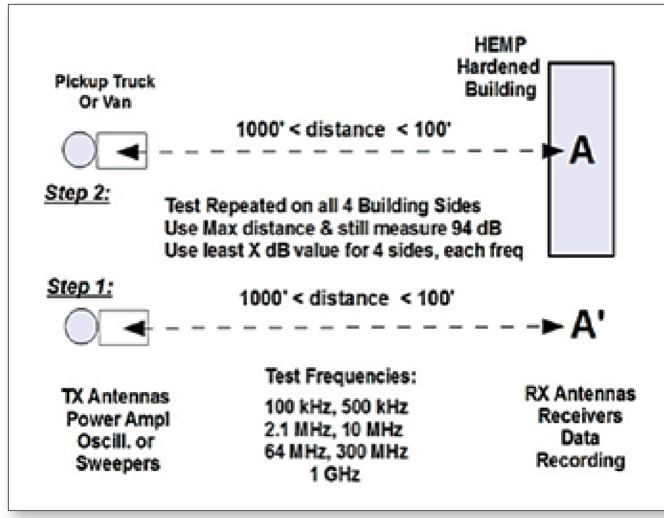


FIGURE 18: Test setup for determining shielding performance.

9.3 Adding EMP Surge Suppressors and Filters

Commercial electronic surge suppressors used for lightning control do not clamp fast enough (clamp >100 nsec for lightning); need to clamp less than 5 nanoseconds for EMP, to protect against the near instantaneous effects of an EMP. Some also may not have great enough current carrying capacity. So it is important that already existent EMP surge sup-pressors be used for any exterior wire/cable entrance from the outside world to the inside of the EMP-shielded building.

Figure. 15 shows two of several HV EMP surge suppressors available for addressing the wide variety of needs and applications. (The surge suppressors that are sometimes used for high voltage transformers in substations to address the geomagnetic storm needs are altogether different and are not shown here)

9.4 Adding the Shielded Smart Meter

A smart meter (Figure 16) is usually an electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes.

Smart meters enable two-way communications between the meter and the central system. Unlike home energy monitors, smart meters can gather data for remote reporting. Such an advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter. Some are also equipped to do much more.

Since the smart meter is mounted on the outside of a building, it will have to be shielded to 80 dB to match the EMP threat. This can be accomplished by using the same 20 OPI wire mesh screen engulfing the entire meter on the front and back as discussed earlier for windows and panels.

Note that smart meters are more EMI susceptible than their replaced older meters. So the smart grid is more susceptible if it is using on-line digital generation and computation of data.

10 EMP TEST AND CERTIFICATION

10.1 Testing the Solar Installation

Contractually, it is necessary in performance tests to demonstrate EMP-protection compliance with the 80-dB shielding requirements over the designated frequency spectrum.

While the building EMP and solar EMP compliance tests can be done simultaneously, in the early stages it may be best to do each separately. This will facilitate diagnostics-and-fix as needed. The building compliance test must be done first. Details are beyond the level of this article and will not be discussed here.

10.2 EMP Test and Certification

How does one know if the installed EMP pro-tection will work (cause no electronic failures) if or when an EMP burst happens? Was an installation over or under protected and by how much? Of course, without an insitu testing, it may never be known. One does not want to pay for something if it cannot be demonstrated to work.

Instead of a simulated EMP burst, seven or more test frequencies are used in accordance with the Bode Plot shown in Figure 17. Otherwise, testing would be impossible since all other devices in the area would be burned out.

As mentioned in MIL-STD-188-125, the EMP pulse in the time domain (X-axis is time) has an amplitude of 50 kV/m, a rise time of 5 nsec and a pulse width at the half amplitude of 150 nsec. This is shown in the insert at the left within Figure 17 and represents the test specifications for EMP testing and compliance.

Figure 17 also depicts the frequency-domain (X-axis is frequency) manifestation of the time-domain pulse just mentioned. It is presumed here that all electrical and electronic devices comply with European Union (CE mark) or other test compliance of radiation susceptibility limits of 10 V/m. (For example, the European Union specifies in EN61000-4-3 that equipment subject to Level 3 requirements shall not be susceptible to a field strength 10 V/m over the frequency range 80 MHz to 1 GHz.

While testing details are beyond the scope of this article, in concept testing is quite simple. A small van or pickup truck at the left in Figure 18 contains a scanning oscillator or sweeper which feeds a power amplifier which drives radiating test antennas pointing at the building to the right. Inside the building is a tracking receiver driven by matching pickup antennas.

The test configuration is first calibrated as a reference with both transmitter and receiver configurations on the outside (step 1). Tests are made at the seven frequencies indicated in the drawing, and the RF attenuator settings recorded. Then, maintaining the same distance between transmitter and receiver, both are moved as shown in step 2 with the receiver configuration moved mostly to the middle of the building and attenuator settings again recorded to get the same levels as in step 1. The difference between the attenuator settings in step 1 and step 2 constitutes the building shielding in dB.

The tests are repeated for the other remaining three (or more) sides of the building, recording the shielding effectiveness of each side for all seven frequencies. Then for each frequency, the corresponding four side shielding effectiveness are compared and the smallest dB value selected. These results constitute the building EMP shielding effectiveness. They are compared with the Figure 15 Bode plot to determine compliance.

There is a more automated procedure than just explained. It is discussed elsewhere. Also, if the building is large (several floors or acres in size), the transmitter may be located in a helicopter or blimp.

10.3 Maintenance Considerations

Everything ages, including all buildings and their contents. For the outside, the more severe the climate and weather, the more rapid degradation and variance in performance is expected. In addition to shock safety, building grounding will determine how well the building EMP shielding has held up. As stated earlier, the soil loaminess (somewhat dark, and good for growing grass or other vegetation) makes for good grounding as it holds moisture. Arid soil like sand is very poor and low on conductivity. It may need to be impregnated with bauxite (an aluminum base particulate) or proprietary grounding compounds to permit better earthing into a much lower impedance sink.

As observed, testing for grounding effectiveness will show up in the above open air shielding effectiveness tests. So a building's earth and grounding should be tested by a licensed and certificated technician to add to the insurance protection in some periodic basis. Initially, use every two years as a default period.

SUMMARY

This article, *A National Plan for EMP Protection*, has been presented in two parts. Part 1 addressed a plan to EMP protect communities, villages, towns and small cities in sufficient quantities and sizes to maintain some defined semblance of our civilization lifestyle following an EMP burst. This is to be contrasted to an EMP survivalist who survives but surrenders his lifestyle.

The second part, Part 2, addresses the shielding of small buildings up to large houses, small and large commercial shopping malls and industrial manufacturing and big box replenishment structures. Details including shielding, bonding, grounding, surge suppression and filtering were covered. These actions generate new products and services, new markets and create millions of new jobs.

ABOUT THE AUTHORS

Don White, *registered professional engineer, retd., holds BSEE and MSEE degrees from the University of Maryland. He is past CEO of three Electro-magnetic Compatibility companies in metro Washington, D.C.*

White has written and published 14 technical books over a span of 30 years. His last book was ***The EMC, Telecom and Computer Encyclopedia****, an 800-page compendium.*

At Don White Consultants, he published a bimonthly trade journal called EMC Technology magazine circulated over four continents. He was the technical editor and wrote many of the tutorial articles. White is past president of IEEE Electromagnetic Compatibility Society. He may be reached at DonWhite@emp-safeguard.com or drjw9@aol.com.

Jerry Emanuelson *holds a BSEE degree from the University of Colorado. He began his career as an audio and video test engineer for Ampex Corp., the manufacturer of audio and video tape recorders. He later became the Transmitter Supervisor for a broadcasting company with transmitter locations on mountaintops, subject to severe lightning and significant EMI problems due to many types of closely packed transmitters.*

He is the leading EMP Internet author with scores of EMP related subjects. He is a former member of IEEE Broadcast Society, and is now part-time electronics consultant and a part-time non-fiction science writer.

Emanuelson can be reached at emp@futurescience.com

EMC Practice – Measurement Under Interference

CLEAN TRANSMISSION OF SIGNALS FROM THE EUT

JÖRG HACKER
Engineer
Langer EMV-Technik GmbH

IT IS UNCOMMON to use an oscilloscope to monitor signals from the EUT when testing immunity to interference. The complicated environmental conditions in the anechoic chamber during RF irradiation or burst and ESD tests lead to measuring errors and unwanted interference in the EUT. Modifications to the EUT are accordingly done by "trial and error".

These difficulties can be overcome by careful measurement using small and interference-immune measuring systems. Causes for malfunction are quicker to find this way.

1 AIM OF THE MEASUREMENTS:

1.1 Detect Interference

Interference is traditionally detected by observing the EUT. The subjective nature of this observation introduces inaccuracies. Automatic testing procedures are not possible. Electronic display monitoring or measurement of output signals from the EUT can help in this situation.

1.2 Trace Back Disturbed Signals

EMC practice is often complex. Interferences in EUT can occur simultaneously at different places via different modes of action. To eliminate errors effectively, it is crucial to analyse disturbed signals from the EUT. This concerns the disturbance of signals in both digital and analogue systems.

These measurements allow conclusions to be drawn as to the cause of error as well as an evaluation of the effectiveness of EMC measures directly at the site of interference.

2 REQUIREMENTS FOR MEASURING EQUIPMENT:

2.1 General Requirements

Injecting disturbances, e.g. using a line impedance stabilization network on the burst test station, produces physical quantities in the EUT such as current, voltage, magnetic field and electric field. Their spatial distribution, intensity and orientation are determined by the geometric structure of the metallic system of the EUT and measuring station. They are almost impossible to predict given the complexity of the EUT.

These quantities also act on the measuring equipment, such as the probe tip and measuring lines, but must not be

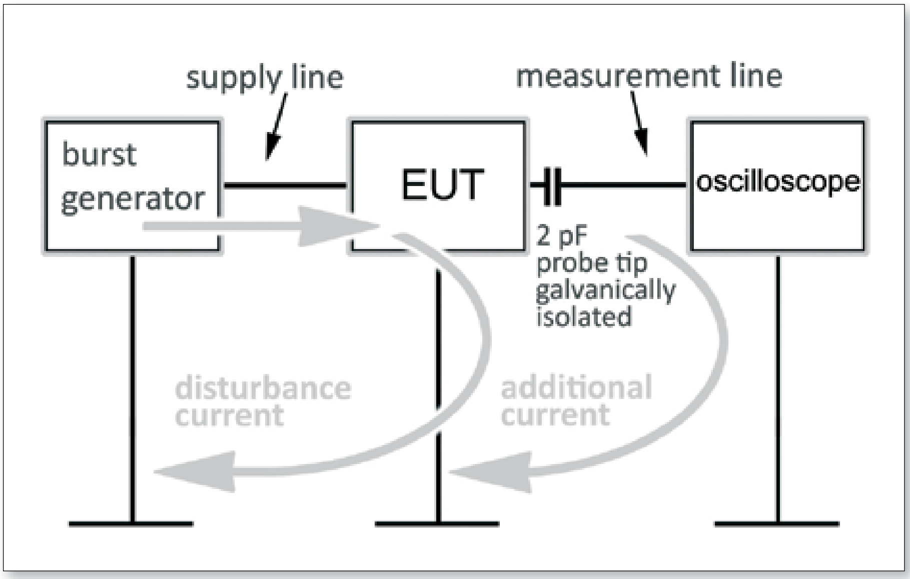


FIGURE 1: Disturbance current flows through a galvanically isolated probe tip.

allowed to cause false readings. What field strengths must the measuring equipment be able to withstand?

In the case of ESD, the entire disturbance voltage can exist between the metallic housing and the PCB insulated against it. At a distance of 5 mm, 5 kV ESD creates a field strength of 1 kV/mm, i.e. 1 MV/m! The disturbance current flowing through the EUT produces magnetic fields in the range of several milliteslas.

The field strengths are much lower for RF irradiation, and reach up to about 200 V/m, depending on the test requirements.

To achieve error-free measurements under these conditions, the EUT and measuring equipment must be galvanically isolated. Only then will the path of the disturbance current in the EUT not be impermissibly modified. It must be noted here that an optocoupler, for example, used for galvanic isolation possess a parasitic capacity of a few pF between the primary and secondary side. It depends on the EUT construction as to how much this capacity will transmit impermissible disturbance current (Figure 1). Optimally, the measurement should be done using fibre optics, since then hardly any parasitic capacity exists at all. It also rules out any change in the disturbance fields by additional cables. It does, however, require a probe tip that converts the signal to be measured into a light signal and which is itself so small that it does not impermissibly deform the disturbance fields.

2.2 Measuring Analogue Aignals

2.2.1 Mechanism of Interference

Especially critical for analogue systems are RF irradiation via the antenna and RF coupling in the lines. Most analogue systems are resistant to burst/ESD errors, since there band with is not high enough to detect these short disturbance pulses.

High-frequency electric and magnetic fields are coupled into the EUT from the electromagnetic field through the EUT surface or via connected leads. These fields produce disturbance voltages on signal lines and in the GND system. Modulation of the RF disturbance field is especially problematic. The standard demands the carrier frequency be modulated to 80% AM at 1 kHz. The RF can be demodulated at pn junctions, e.g. in operational amplifiers. As a consequence, a voltage with a frequency of 1 kHz arises, which superimposes itself over the useful signal and is carried over into the analogue signal path.

2.2.2 Requirements For The Measuring System Bandwidth

For troubleshooting, it is usually sufficient to measure the demodulated 1 kHz signal in the EUT. The RF carrier itself need not be measured. This means a small and low-cost measuring system can be used. With the help of a small probe tip with an A/D-converter, the 1 kHz error signal is converted into digital light signals and transmitted from the EUT over fibre optic cable without feedback (Figure 2).

The measuring signal in the EUT is generally superimposed with RF voltages. Upon measurement, these voltages are applied to the probe tip, i.e. the probe tip must be immune to interference at field strengths of up to 200 V/m.

MEASUREMENT RANGE:

Practically required measurement ranges are between 5 mV (audio equipment and sensors) and 50 V (automation equipment, ASI bus, vehicle on-board wiring system). A high dynamic range is preferable. Limits are set by the small size,

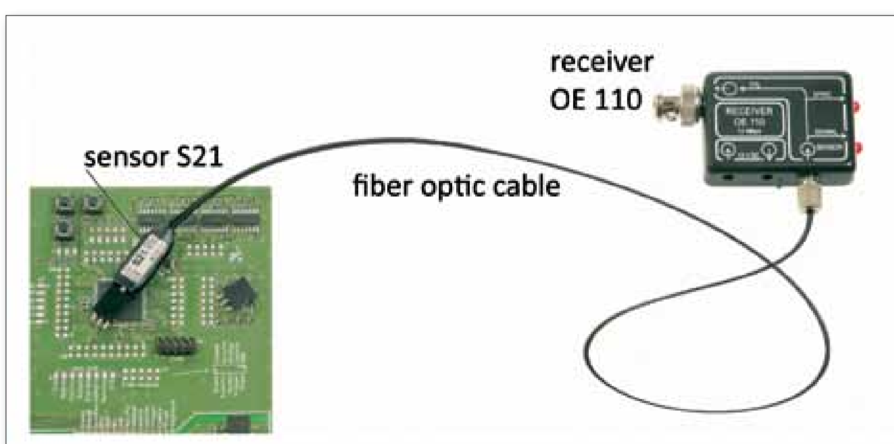


FIGURE 2: System for transmitting signals over fibre optics.

the transmission capacity of serial transmission and the power draw of the probe tip.

2.3 Measuring digital signals

2.3.1 Mechanism of interference

Short disturbance pulses such as burst and ESD are especially critical for digital circuits. Every IC input evaluates the disturbance voltage pulse at its input with its dynamic input switching threshold. When its switching threshold is exceeded, this pulse is converted to a logical signal and fed into the program sequence. This then triggers very specific functional errors, depending on the EUT.

The interference immunity of the EUT is essentially determined by the sensitivity of the IC. The definition of a sensitivity parameter is a crucial for coping with the interference processes. It depends on the IC technology (HC, AC, VHC, etc.), on the shrink and therefore on the IC manufacturer. The scatter range of IC sensitivity for all modern IC families lies at a factor of 10. The resulting deviation of burst immunity can lie within the kV range.

2.3.2 Requirements for the measuring system

It is difficult to produce a probe tip at reasonable cost that, on the one hand, is small enough not to interfere with the EUT and, on the other hand, transmits the rapid disturbance voltage pulses over fibre optic cable error-free at the given field strengths. It is, however, possible to introduce a special probe tip (which we will refer to from here on as a sensor) into the EUT. This sensor possesses a digital IC of known sensitivity. When this IC recognizes, with its dynamic input threshold, a voltage pulse (or disturbance voltage pulse), it emits a defined light pulse. In this way, it reproduces the interference threshold of the electronic device. A light pulse thus signifies: "A disturbance pulse has occurred in the EUT on the tested circuit that is large enough to disturb the device's function."

2.4 Potential measurement

By transmitting signals over fibre optic cable, these systems

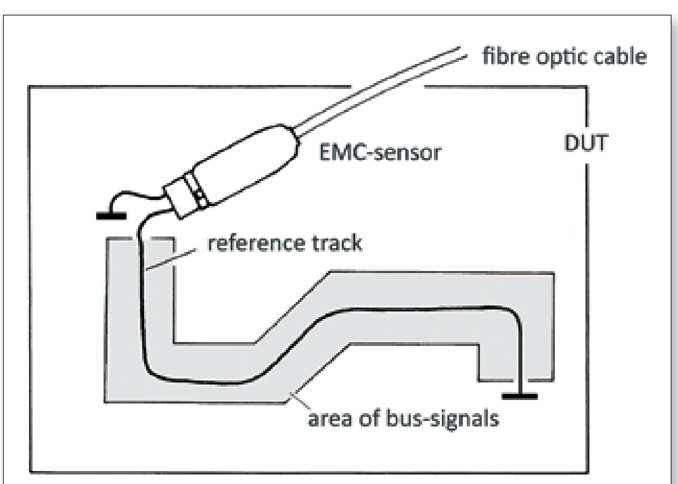


FIGURE 3: Measuring voltage differences over the GND system

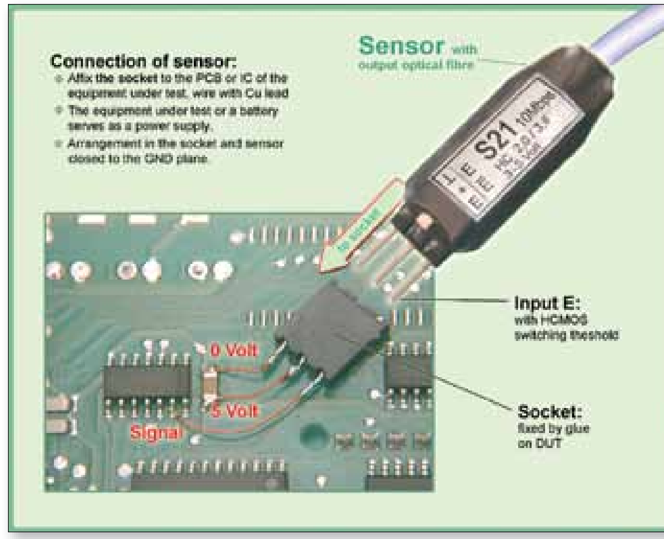


FIGURE 2a: How to connect the sensor in the DUT.

are also in principle suitable for potential measurement. The only thing to ensure is the power supply of the probe tip is made potential-free, e.g. using a battery module.

This is useful for measuring, for example, transients in the intermediate circuit voltage of pulse inverters.

3 MEASURING STRATEGIES

3.1 Measuring disturbances

A reference interference threshold is created using a sensor and a conductive trace on the Device Under Test (Figure 3).

With the conductive trace, the sensor taps voltage differences over the GND system of the EUT that are caused by disturbance current in the GND system (Figure 3). When the sensor's interference threshold is exceeded, it emits a light signal over a fibre optic cable. This is a quick way to evaluate the effectiveness of countermeasures.

This method is mainly employed for dimensioning connector systems, shields, filters and current leakage paths. It can also be employed during the developmental phase, when the EUT itself is not yet functional but information is already needed on the design of housing and filters.

3.2 Measuring static signals

When troubleshooting, it is useful to monitor certain signals in order to learn the instantaneous state of the EUT. Of interest are signals such as INT, RESET or PFI, which are also transmitted by a sensor from the EUT over a fibre optic cable. A counter (event counter) can summate the light pulses and thereby serve as a memory. That means continuous, concentrated monitoring of a display is no longer necessary – modifications can be made freely while the measurement is still running.

The origin of the interference can often be learnt by monitoring the signals on an oscilloscope (via fibre optics): In Figure 5, a short disturbance pulse on the RESET line of a processor signifies direct interference on this line, while a pulse in the millisecond range is caused by interference on the RESET component.

3.3 Measuring periodic signals

3.3.1 Monitoring the EUT

Often, it cannot be determined whether the EUT is still running during interference immunity tests. For example, the controller may have long since crashed while the LCD display still shows the correct data. The transmission of characteristic signals from the EUT is helpful in such cases. A signal such as Chip Select, for example, shows that the processor is still working.

3.3.2 Signal monitoring

If the disturbances are coupled into the bus system, for example, then it is possible to detect disturbance pulses on the oscilloscope. Measurements are done with sensors via fibre optics, with triggering over the pulse width of the measured signal. The pulse width of the useful signal is typically larger than that of the disturbance pulses. If the oscilloscope does not have such a triggering option, or if the data and interference signal are almost equally long, then one can trigger the disturbances manually using a burst detector.

3.4 Analysing operating behaviour

Frequently, the data on bus systems give an indication of the operating state of the EUT. Precisely analysing the data on an oscilloscope or logic analyser is laborious in such cases. One quick option is to monitor the data stream with a counter. Naturally, given the changing data content and lack of synchronization between counter and data packets, one does not always obtain a constant numeric value on the counter. Mostly, however, specific operating states are assigned specific numeric values. The developer can therefore recognize, for example, specific pulse sequences during system start-up after RESET and infer the current operating state of the EUT. When testing immunity using this simple analytical system, it can

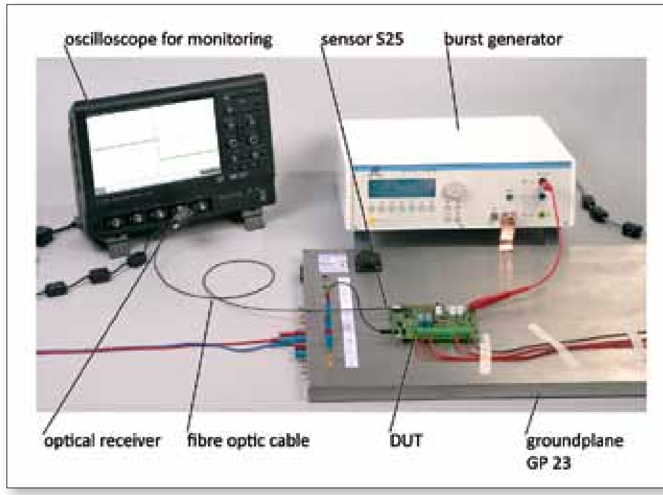


FIGURE 4: Signal measurement over fibre optic cable.

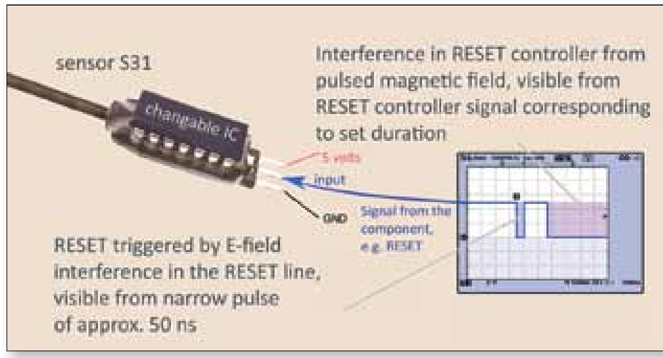


FIGURE 5: RESET monitoring using a sensor S31: The sensor-IC is exchangeable – in case of an overload the user can exchange the damaged IC by himself.

be discerned whether, for example, the system is restarting due to interference, or whether data are being retransmitted at unusual frequency, etc.

3.5 Analogue signals

Especially in systems that use analogue data acquisition and digital processing, it is important to verify whether the disturbance lies in the analogue quantity or in the digital processing.

Figure 6 shows the output voltage of an operational amplifier that has RF coupled into its input, which demodulates and amplifies the 1 kHz signal. This demodulation can occur at practically every pn junction. The degree of disturbance is affected by the extent to which the EUT itself amplifies the demodulated disturbance voltage.

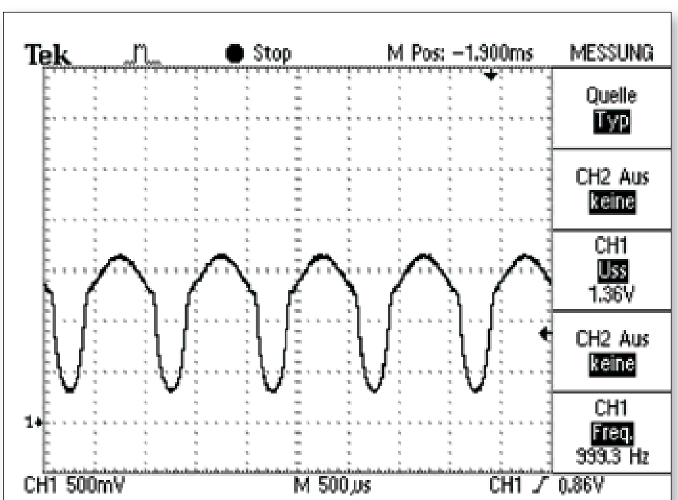


FIGURE 6: Demodulated 1 kHz interference signal at the output of an op-amp

4 SUMMARY

Using fibre optic technology and small, interference-immune sensors, it is possible to measure signals in the EUT without feedback or error during interference immunity testing. In the case of digital systems, a simple counter is often sufficient for evaluating the behaviour of the EUT and detecting interference.

Inexpensive Radiated Immunity Pre-Compliance Testing

KENNETH WYATT
Senior EMC Engineer
Wyatt Technical Services

AS AN EMC consultant, it seems that lately I've run into many client projects where radiated immunity has cropped up as the major issue. One reason for this may be the trend in using digital and analog circuits that are powered by 3.3 volts, and lower, which decreases noise margins significantly. Sensitive analog circuitry is also greatly affected.

The compliance testing for radiated immunity for most commercial products is based on the international standard, IEC 61000-4-3, and is usually performed from 80 to 1000 MHz (sometimes to 2000 MHz) at E-field levels from 3 to 20 V/m, depending on the product environment or application. Some military, vehicular or aerospace applications require testing to 200 to 1000 V/m, and frequencies up to 18 GHz or more.

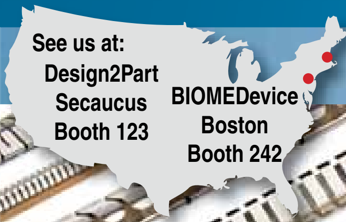
The RF signal is generally modulated by a 1000 Hz AM sine wave modulation set to 80% for commercial testing, and short duration (as little as 1%) pulsed modulation for military and aerospace testing. The modulation is designed to test for "audio rectification" issues. For example, if the 1000 Hz modulation is rectified by semiconductor junctions, or in audio or other analog circuitry, it could cause bias upsets, or otherwise upset sensitive analog circuitry. For military applications, the pulse modulation serves to simulate radar interference. Strong external RF fields can:

- Reboot the system
- Disrupt of analog or digital circuitry
- Create false readings on displays
- Cause loss of data
- Halt, slow or disrupt data transfer
- Cause high bit errors (BER)
- Cause a change of state in the product (mode, timing, etc.)
- Introduce noise in measurements
- Cause a loss of sensitivity of measurement systems or receiver systems (radios)

In this article, I'd like to describe several low cost methods for creating strong localized fields, which may be used to characterize the RF susceptibility of your product.

EMI Shielding Solutions

Standard Spring Finger Gaskets



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Device	Approx Freq	Max Power	Approx V/m at 1m
Citizens Band	27 MHz	5W	12
FRS	465 MHz	500 mW	4
GMRS	462 MHz	1 to 5W	5.5 to 12
3G Mobile Phone	830 MHz / 1.8 Ghz	400 mW	3.5

TABLE 1: A listing of commonly available (mostly license-free) transmitters that may be used to simulate high RF fields during limited radiated susceptibility testing.

Pout (W)	V/m at 1m	V/m at 3m	V/m at 10m
1	5.5	1.8	0.6
5	12.3	4.1	1.2
10	17.4	5.8	1.7
25	27.5	9.2	2.8
50	38.9	13.0	3.9
100	55.0	18.3	5.5
1000	173.9	58.0	17.4

TABLE 2: A chart of calculated E-fields in V/m (assuming an antenna gain of 1).

LICENSE-FREE RADIO TRANSMITTERS

One low-cost technique for quick troubleshooting is to use one of the license-free portable Family Radio Service (FRS) FM two-way radios to transmit close to the sensitive areas of the product (Figure 1). These radios transmit near 465 MHz with a power level of ½ Watt. While limited in frequency range, many RF susceptibility problems have been located and resolved using this simple tool.

Other (mostly) license-free tools would include a portable CB radio (27 MHz) and a transmitting cellular (or PCS) mobile phone (varies from 700 to 1900 MHz). Table 1 lists several (mostly) license-free transmitters that may be used to test radiated susceptibility in select frequency bands. The GMRS transmitter requires a license.

Using Equation 1, we can calculate the expected E-field level in volts/meter given the transmitter output power in watts. Table 2 indicates some E-field levels for various power levels.

$$V/m = \frac{\sqrt{30 * Pout * Gain_{Numerical}}}{meters} \qquad \textbf{Equation 1}$$

BENCH TOP RF GENERATORS

Another very good troubleshooting technique that's tunable over a range of frequencies is to obtain a bench top RF generator and connect this to a small E-field or H-field loop probe (Figure 2). Generators that can produce at least +10 to +20 dBm work the best – the higher, the better. A plus would be the ability to apply 80% AM-modulation to the RF at 1000 Hz. This will more closely match the requirements of the immunity standard. This will produce an intense RF field (up to 10 V/m, or more), which may then be probed around cables, connectors or internal circuitry. You'll need some way to monitor the proper operation of your product. Watch for disruptions during the probing.

If the small loop probes cause no susceptibility to the product, try taking a longer piece of wire and wrapping it with loose turns around and along the length of each I/O or power cable to couple in the RF more efficiently. Then connect this wire to the RF generator output.

FIGURE 1: In a pinch, try transmitting using one of the low-cost and license-free FRS two-way radios.

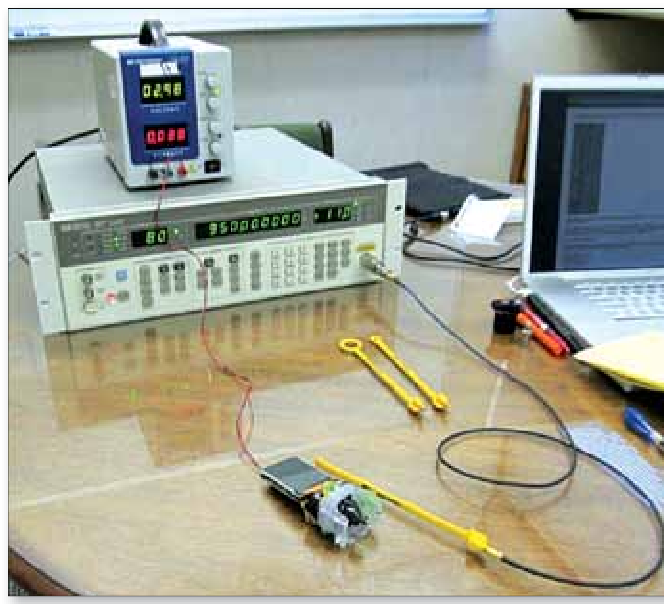

FIGURE 2: One of the best troubleshooting setups for radiated susceptibility is an RF generator connected to a small H-field probe. The probe will quickly identify sensitive areas or cables of your product. By adjusting the generator frequency and RF output level, you may be able to zero in very quickly. With this small medical product, we were able to identify a single ribbon cable (of several) that was susceptible at about 950 MHz.

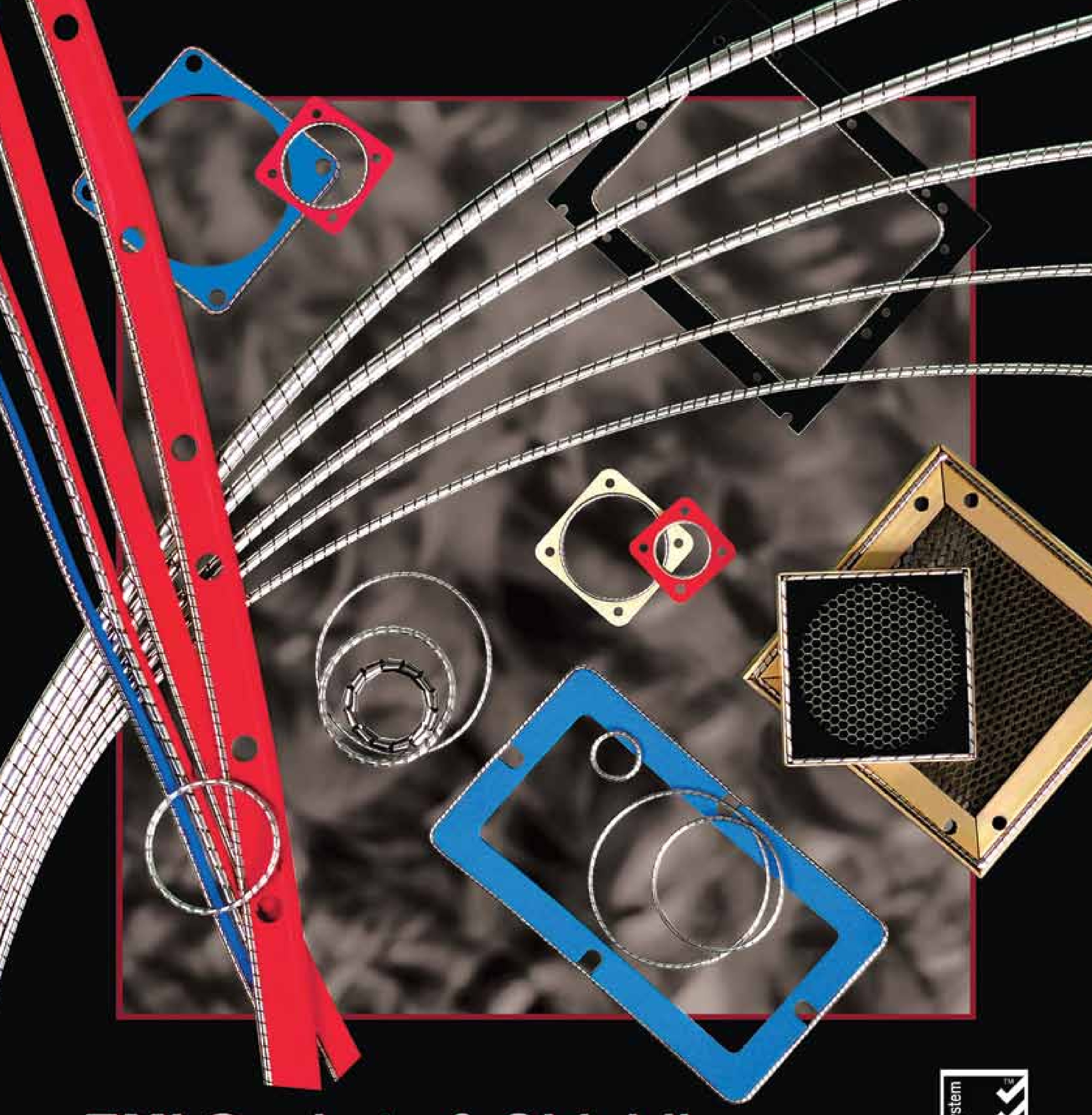

FIGURE 3: The TPI Synthesizer from Trinity Power is about 2 by 3.5 inches and can produce up to +17 dBm from 35 to 4400 MHz.

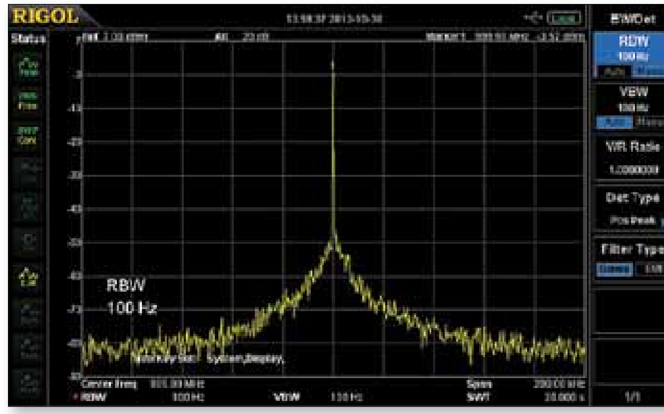

FIGURE 4: The RF output from the TPI Synthesizer is fairly low in phase noise, but the higher order harmonics are only 10 dB down from the fundamental.

While I've seldom needed it, in extreme cases, you may need to obtain a 10 to 20 W broadband power amplifier to boost the RF output from the generator. You could use a simple dipole antenna, such as a TV rabbit ears or DIY dipole antenna made from two lengths of wire cut to the approximate quarter wavelength (each side) of the frequency band that may be an issue and connect one side to the shield and one to the center wire of a coax cable.

Note that this test with the power amplifier should be performed in a shielded room to prevent interference to existing communications or broadcast services.

USB-CONTROLLED RF SYNTHESIZERS

Recently, there have been a handful of small USB-powered RF synthesizers available at low cost. One affordable solution is the "TPI Synthesizer" from Trinity Power, Inc. (http://www.rf-consultant.com). This small module can produce up to +17 dBm and can tune from 35 to 4400 MHz in user definable steps of as little as 1 kHz. It is USB-controlled and includes PC software that controls frequency, sweep limits, step size and three levels of power output. You can also control or sweep the power level in definable steps. I've successfully used the software with my Windows 8.1 OS operating under Parallels 9 on my Macbook Pro laptop.

Because the output from this synthesizer begins to taper down to about +10 dBm output starting at 3000 MHz, the company sells a "calibrated" synthesizer with a flatter frequency response that produces +10 dBm.

Another good option is the Windfreak Technologies "SynthNV" shown in Figure 5 (http://www.windfreaktech.com), which also includes the means to AM or pulse-modulate the RF. This RF generator tunes from 35 to 4400 MHz in 1 kHz steps and can produce up to +19 dBm output into 50 Ohms. While more than double the cost of the TPI Synthesizer, it also has the means to measure RF power levels and can be configured as a simple network analyzer. The RF output is also variable up to +19 dBm (almost 100mW).

It is also USB-controlled using provided software based on National Instruments Labview. The Labview "engine" is provided at no extra charge. There's also a simple controller software available based on the Android OS.

FIGURE 5: The Windfreak Technologies model SynthNV RF generator is USB-controlled and tunes from 35 to 4400 MHz. It can also AM-modulate the RF output at 1 kHz, according to the radiated immunity standard IEC 61000-4-3. Image courtesy of Windfreak Technologies.

FIGURE 6: The well laid out control panel for the SynthNV RF synthesizer.

FIGURE 7: The control panel for the RF sweeper function allows setting of lower and upper frequency limits, as well as step size of 1 kHz to 100 MHz.

The SynthNV uses basically the same Analog Devices ADF4351 PLL synthesizer IC as the TPI Synthesizer, so the RF output and higher order harmonics look much the same.

As mentioned in the caption of Figure 4, one potential disadvantage of both these synthesizers is that the second order harmonic is just 10 dB down from the fundamental, so during immunity testing, you're effectively testing at a couple frequencies simultaneously – the fundamental at, say +19 dBm and the second harmonic at +9 dBm. Admittedly, this is a 10:1 power ratio, so may not be that much an issue. The third harmonic (and higher order) is another 8 dB down (or more), so probably doesn't enter into the equation.

By attaching an H-field or E-field probe to the output, you can probe interior areas of your product's PC board and discover sensitive areas that may need filtering or shielding. The nice thing about adding 1000 Hz 80% AM modulation is that it can help reveal "audio rectification" issues (generally in analog circuitry). This occurs when semiconductor junctions act as detectors and rectify the modulated RF, causing bias changes in op-amps, for example.

One thing I noticed during my testing and review of the SynthNV is the regular narrow glitches occurring

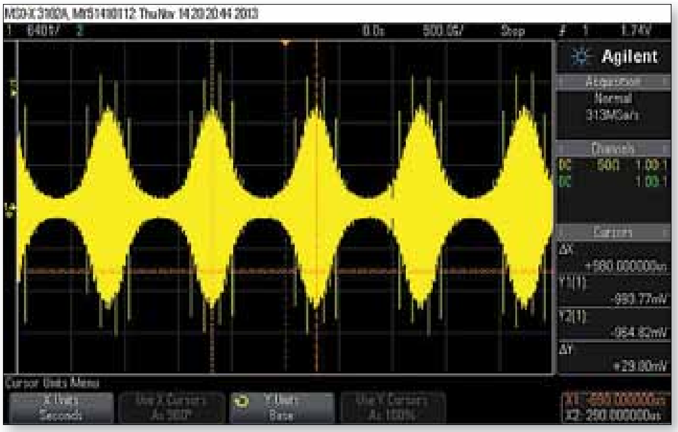

FIGURE 8: The 80% AM-modulated RF output from the SynthNV showing some periodic glitches. While the designer is looking into that, I don't believe these should be of much issue as far as troubleshooting immunity.

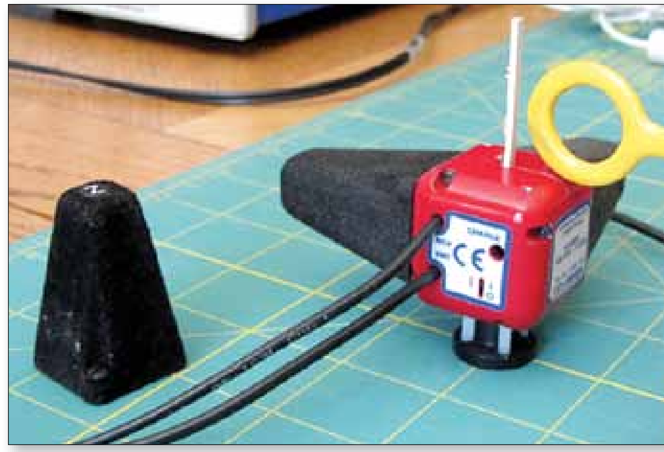

FIGURE 9: The simple setup used to measure several near field probes. The protective shroud around the "Z-axis" antenna was removed to allow the probe to come within 2mm of the antenna element. This helped simulate applying RF fields close to a circuit trace.

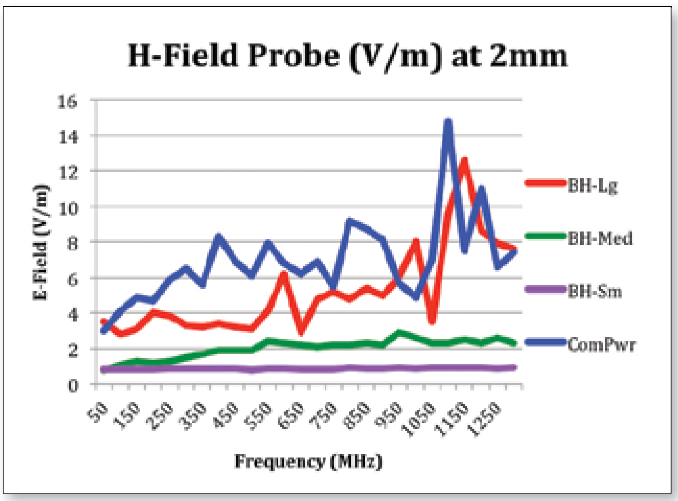

FIGURE 10: The E-field levels from several H-field probes. "BH"=Beehive Electronics (Large, Medium, and Small). Both the large Beehive and Com-Power probes appeared to resonate above 1000 MHz.

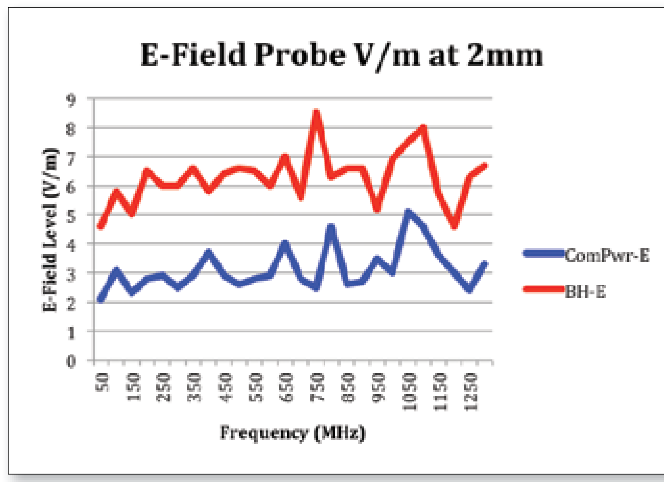

FIGURE 11: The Com-Power and Beehive E-field probes were both measured versus frequency. The field level was much flatter than the H-field probes.

during the peak modulation cycles. These can only be seen on a very fast oscilloscope (1 GHz bandwidth). I suspect, however, these glitches would not be a real issue during immunity troubleshooting. If anything, they may "over-test" the product being characterized. The designer is looking into this anomaly.

I might also point out that due to the "fractional-N" PLL, it's not possible to exactly tune the modulation frequency to 1000 Hz. The closest it will get is 1008 Hz.

MEASUREMENT OF NEAR FIELD PROBES

To help characterize the expected E-field levels from various near field probes (both E-field and H-field), they were measured using an ETS-Lindgren field sensor. The probes were either driven by the TPI Synthesizer or SynthNV synthesizer at the full power of each (+17 to +19 dBm output).

The three sizes of Beehive Electronics H-field and the Com-Power H-field probes were measured at various frequencies from 50 to 1300 MHz. See Figure 10.

The E-field probes were a bit flatter in response, as you might expect, because they don't have much of an effective L-C network, being essentially electrically short monopole antennas. See Figure 11.

The advantage of the near field probes is that the field level falls off rapidly with distance, thus it's easier to evaluate separate sections of your circuitry to determine the precise areas of susceptibility. See Figure 12 for a plot of field level versus distance. By 3 to 4 cm, the field is essentially 1 V/m, or less.

Figure 13 shows me probing a Raspberry PI embedded processor. By sweeping the probe around the PC board and I/O cables at various frequencies, you can be fairly sure your product will operate OK during the actual compliance testing. If you're wondering, the Raspberry PI was immune to the RF levels I was able to introduce.

In summary, these simple and low cost tools can help you perform a pre-qualification assessment on your prod-

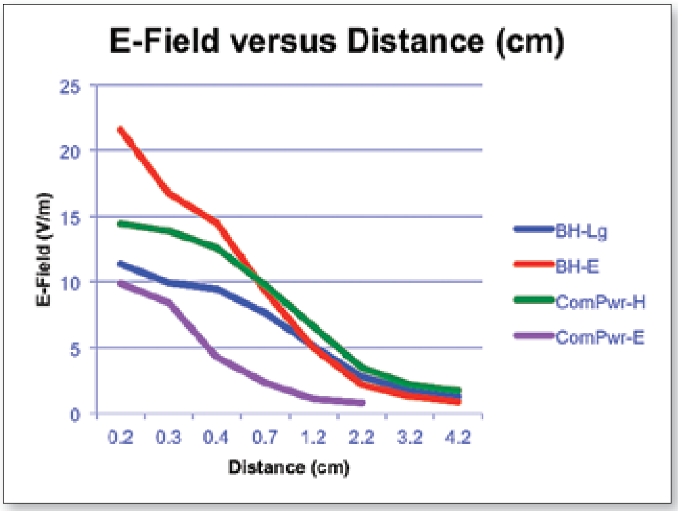

FIGURE 12 – E-field level of several near field probes versus distance. The highest field levels occur within about 1cm from the probe tip.

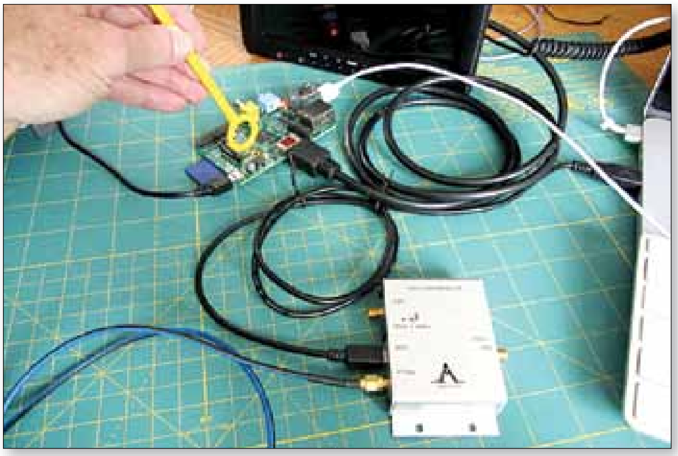

FIGURE 13: Using the SynthNV from Windfreak Technologies to evaluate the Raspberry PI embedded processor.

uct well prior to taking it out for compliance testing. This could save you a lot of time and money. In brief:

- RF generators can drive near E-field or H-field probes to create strong localized E-fields for pre-compliance testing.
- There are low-cost RF synthesizers available now that may replace larger bench top instruments.
- Localized RF fields of 2 to 15 V/m may be generated to help diagnose radiated immunity issues with a product.

ABOUT THE AUTHOR

Kenneth Wyatt, Sr. *EMC Engineer, Wyatt Technical Services, LLC, holds degrees in biology and electronic engineering and has worked as a product development engineer for 10 years at various aerospace firms on projects ranging from DC-DC power converters to RF and microwave systems for shipboard and space systems. For over 20 years, he worked as a senior EMC engineer for Hewlett-Packard and Agilent Technologies in Colorado Springs where he provided comprehensive EMC design and troubleshooting services and managed the product compliance test facility. During that time, he provided EMC training and corporate leadership for EMC.*

A prolific author and presenter, he has written or presented topics including RF amplifier design, RF network analysis software, EMC design and troubleshooting of products and use of harmonic comb generators for predicting shielding effectiveness. His specialty is EMI troubleshooting and is a co-author of the popular EMC Pocket Guide. He has been published in magazines such as Interference Technology, RF Design, Test & Measurement World, EMC Design & Test, Electronic Design, EDN, InCompliance, Microwave Journal, HP Journal and several others. He coauthored The EMC Pocket Guide (SciTech Publishers) and writes The EMC Blog for www.EDN.com.

Wyatt is a senior member of the IEEE and a long time member of the EMC Society where he served as their official photographer for 10 years. He may be contacted at ken@emc-seminars.com or www.emc-seminars.com.

Potential Impacts of Electromagnetic Weapons on the Critical Infrastructures (View from 2012)

DR. WILLIAM A. RADASKY
President and Managing Engineer
Metatech Corporation
IEEE Life Fellow

WHAT IS IEMI?

IN RECENT YEARS Hollywood has indicated that criminals and terrorists could use electromagnetic weapons to black out a portion Las Vegas (Ocean's 11) or take down a counterterrorism computer center (24). Is this fact or fiction? It turns out that Hollywood in this case is leading the public and police agencies in understanding the possibilities of this threat. As with fiction, however, these two examples are extreme in the sense that they either used a large generator to connect to the wiring of a power substation or an explosive device in the trunk of an automobile. Neither of these situations are the most likely ways that EM weapons would be used against the critical infrastructures.

In the late 1990s two respected International scientific and engineering organizations took initial steps to understand the threat of electromagnetic weapons on society. In 1999 URSI (International Union of Radio Science) passed a resolution at their General Meeting in Ottawa, Canada recommending that scientists and engineers take this threat seriously and work to protect against it. In the same year, IEC SC 77C expanded their scope of work to begin to write reports and standards dealing with what was originally called EM Terrorism, but was later renamed as Intentional Electromagnetic Interference (IEMI). IEMI has been formally defined as: "Intentional malicious generation of electromagnetic energy introducing noise or signals into electric and electronic systems, thus disrupting, confusing or damaging these systems for terrorist or criminal purposes."

The reason that this threat has emerged in recent years is two fold. First, powerful solid-state electronics allow the development of electromagnetic weapons that produce high levels of peak power in very short time domain pulses; as the objective of these weapons is to produce high peak electric and magnetic fields, the energy contained in the pulses is not as important. This allows the use of a small energy source to power the weapons. Second, modern commercial electronics and computers operate with microprocessors with clock speeds in the GHz range and at low internal operating voltages, making them potentially more susceptible to interference and damage to EM threats in this same frequency and voltage range.

A few cases of IEMI threats/attacks have been well documented, but many more are not discussed in public due to the embarrassment of those attacked or for security reasons. Here are a few illustrative examples.

1. In Japan, two Yakuza criminals were caught using an EM weapon on a Pachinko (gaming) machine to trigger a false win.
2. In St. Petersburg, Russia, a criminal used an EM weapon to disable a security system at a jewelry store, so that he could commit a robbery.
3. In London a city bank was the target of blackmail attempt whereby the use of an EM weapon was threatened against the bank's systems.
4. In Moscow a Telecommunications center was targeted and was put out of commission for 24 hours, denying service to 200,000 customers.
5. In early March 2011, the city of Seoul, Korea sustained an electronic jamming attack that disabled a large number of GPS systems used in industry. In addition the South Korean military indicated that some of their systems had been adversely affected. In early 2012, it was also reported that GPS systems in the region of the Incheon International Airport in South Korea were being jammed and that airlines were warned about this situation.

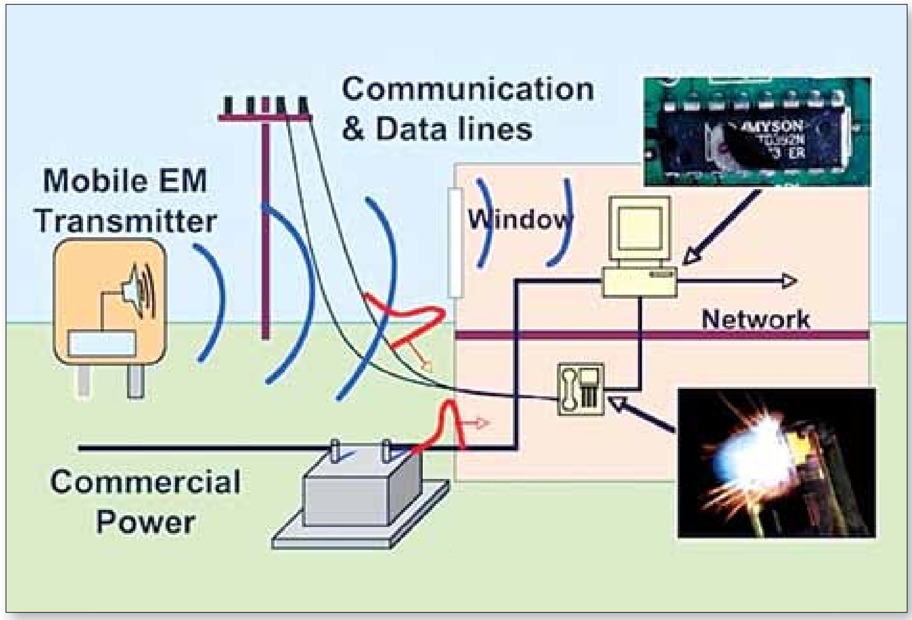

FIGURE 1: One scenario for IEMI interactions. Image: Metatech

INTRODUCTION

Electromagnetic weapons consist of two categories: radiated and conducted. Both types possess an energy source (such as a battery), a solid state generator that produces high output voltages with a rapid variation in time, and either an antenna that is designed to propagate these fields some distance away from the weapon (radiated fields) or a means to connect to wiring of a system (conducted voltages). The radiated fields are more flexible (for the attacker) but they decrease rapidly with distance from the weapon. The conducted weapons require a connection to power or data lines outside of a building, but their entire output is transmitted to the circuits they are attacking. One would think that the conducted threat is not important, however, buildings have been found to have unprotected data cabinets and external power plugs outside of the building. In addition, those with power system experience can connect to the low voltage outputs of transformers leading into buildings.

Figure 1 illustrates the basic process for "coupling" radiated fields from an EM weapon into a building. The electromagnetic fields will induce voltages and currents on both external and internal wiring (for the internal wiring the shielding properties of the building are important). These voltages will lead to electronic equipment that often cannot tolerate the levels entering the equipment. Providing line protection (surge arresters/filers) at the entrance of external building cables and providing some electromagnetic shielding in the building walls will provide some protection against this threat (discussed later).

As for the critical infrastructures such as the power, telecommunications, financial, water, natural gas, etc., nearly all of these infrastructures are controlled by computers with more and more sophistication each year. For example the power systems in developed areas of the world are installing digital smart power meters at homes and businesses along with communications systems to interpret the data. In addition, distributed renewal power systems require additional sensors to determine their operating status so the grid can operate efficiently. The increase in the amount of information to be processed and the accompanying communications requirements make the system more vulnerable to those who wish to create problems (whether they be hackers, criminals or terrorists).

While security is always an important consideration for the critical infrastructures, it must be noted that locked doors or even fences are not an impediment to EM weapons. In addition an attacker can try to disrupt a facility over and over until they succeed, as no one will know that they are under attack until computer problems are noticed.

TECHNICAL BACKGROUND

EM Weapon Characteristics

In order to understand the threats to electronic equipment, it is necessary to understand the different types of electromagnetic environments that can be produced and that can create operational problems for exposed equipment. There are two basic categories of EM environments of concern: narrowband and wideband. Also as mentioned earlier, there are also two major ways for this power to be delivered to a system: through a radiated and conducted process.

A narrowband waveform is nearly a single frequency (typically a bandwidth of less than 1% of the center frequency) of power delivered over a fixed time frame (from 100 nanoseconds to microseconds). Some of the environments in this category include modulation of the sine waves, shifting frequencies and even repetitive applications. This category of threat is usually referred to as high power microwaves (HPM), although this term is used loosely to include frequencies outside of the microwave range.

FIGURE 2: The JOLT generator produces a peak range times electric field product of 5.3 MV, a pulse width of 1 ns and a repetition rate of 600 pulses per second.

A wideband waveform (sometimes referred to as ultrawideband – UWB or short pulse – SP) is usually one in which a time domain pulse is delivered, often in a repetitive fashion. The term "wideband" usually indicates that the power in the waveform is produced over a substantial frequency range relative to the "center frequency". Of course many pulse waveforms do not have an explicit center frequency and the technical community decided that there was a need for better definitions relating to this problem. The IEC has defined new terms to describe wideband waveforms including mesoband, subhyperband and hyperband [61000-2-13].

In terms of system vulnerabilities, the narrowband threat is usually one of very high power, since the electrical energy is delivered in a narrow frequency band. It is fairly easy to deliver fields on the order of thousands of volts/meter at a single frequency. Often the malfunctions observed in testing equipment with narrowband waveforms are those of permanent damage.

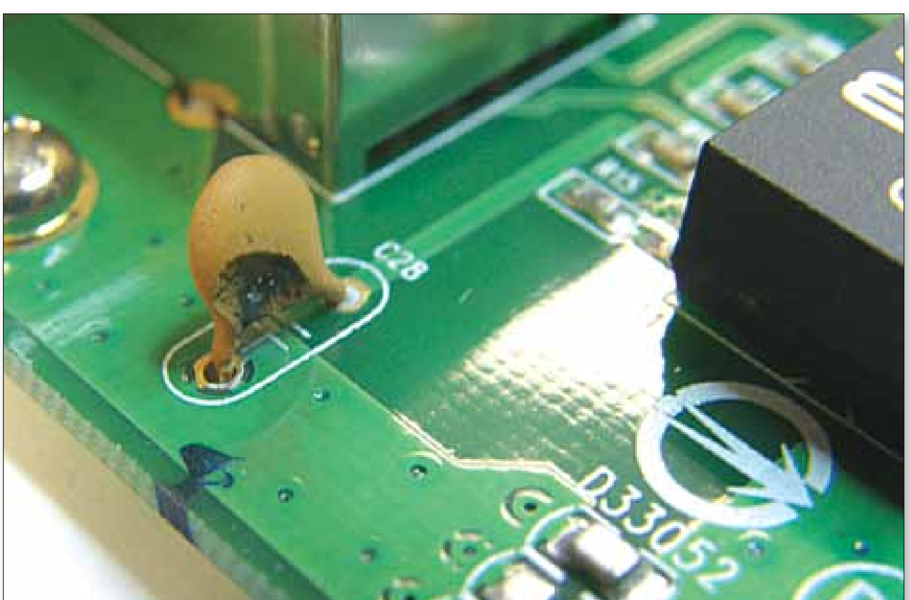

FIGURE 3: Damaged capacitor on a network interface card

The wideband threat is somewhat different in this respect. Since a time domain pulse produces power over many frequencies at the same time, the power produced at any single frequency is much less. This means that damage is not as likely as in the narrowband case. Sources that have been built can produce repetitive pulses up to 1 million per second and can continue for many seconds or minutes, thereby increasing the probability of producing a system upset. Some of these upsets can interfere with the communications of data, thus providing a different way of denial of service.

One example of an extremely powerful wideband generator was developed by the U.S. Air Force for research purposes. It is known as the JOLT simulator and its capabilities were published in the IEEE Proceedings in July 2004. A photograph of the generator is shown in Figure 2.

Vulnerability of Commercial Electronics

Over the past fifteen years there have been significant experiments that have tested the response of commercial equipment to narrowband and wideband threats similar to those expected from IEMI. In general this testing has emphasized personal computer equipment (including networks) since they are in wide usage in many different industries. In addition testing has included cash machines, industrial control equipment, power supplies, Ethernet components, WIFI networks, automobiles, GPS electronics, cellular phones, PDAs and different types of sensors. Many journal articles and conference papers have dealt with the details of these experiments, and therefore we will only summarize the results here.

SHIELDING MEASUREMENTS		
Nominal Shielding, dB	**Room**	**Shielding, dB**
0	All wooden bldg	2
5	Room under wood roof	4
	Wood bldg-room 1	4
	Concrete - no rebar	5
	Wood bldg-room 2	6
10	Conc. +rebar-room 1	7
	Conc. +rebar-room 2	11
	Conc. +rebar-room 3	11
20	Conc. +rebar-room 4	18
30	Metal bldg	26
	Conc. +rebar-well prot. room	29

TABLE 1: Shielding effectiveness measurements for various power system buildings and rooms between 1 MHz and 5 GHz

Modern computers and other types of equipment using microprocessors appear to be vulnerable to malfunction from radiated narrowband fields above 30 V/m, although newer high-speed PCs have higher susceptibility levels (~300 V/m). There appear to be large variations in the responses of equipment due to the specific experiment setups and the quality of the equipment enclosures that are used. In addition, tests performed over the range of 1 – 10 GHz seem to indicate that malfunctions occur at lower field levels at lower frequencies.

Wideband radiated-field testing has also been performed by Russian, Swedish, German and U.S. scientists. Testing of computer-sized electronic equipment indicates that peak electric field levels of ~2 kV/m for pulses with pulse widths on the order of 200 ps create upset in the electronics (requiring a power reset), with damage occurring in the 5 kV/m range. An example of circuit board damage caused by a pulsed voltage that represents coupling to a metallic Ethernet cable is shown in Figure 3.

One should note that these experiments are usually performed by directly exposing the equipment under test within line of sight of a radiating antenna. Of course if the equipment is inside a building or in a room without a window, there will be a reduction of the incident field from outside to inside (depending on the type of wall construction). Also most experiments have not carefully examined the polarization and angle of incidence aspect thoroughly (due to time and expense aspects), and therefore most of the effects noted during testing can occur at even lower field levels when an optimum coupling geometry is considered.

For conducted IEMI threats, it seems clear that if attacker access to external telecom or power cables is not prevented, it is fairly easy to inject harmful signals into a building. For pulsed waveforms, it appears that pulse widths on the order of 100 microseconds can create damage to equipment power supplies and to interface circuit boards at levels as low as 500 volts, but more typically at levels of 2 – 4 kV.

Relationship to IEC EMC Immunity Standards

While these failure values may seem to be low with respect to the capabilities of EM weapons, they should not be a surprise. When one examines the everyday electromagnetic compatibility (EMC) test requirements for immunity in the IEC, it is unusual to see a narrowband radiated field level immunity requirement above 10 V/m (for frequencies above 80 MHz). Higher levels are not recommended for home or factory applications because of the expense of providing the increased protection.

For wideband-conducted transients, most of the lightning and electric fast transient tests for EMC are performed for levels up to 2 kV. Only in special cases, such as for equipment in a power generating facility or a substation, will the immunity test levels be higher. The typical EMC conducted wideband test waveforms (such as the EFT) have rise-times as fast as 5 ns and pulse widths as long as 700 microseconds (e.g. 61000-4-5). The narrowest pulse width for EMC is 50 ns, which is much wider than the typical IEMI threat.

It is therefore clear that the EMC immunity levels of commercial electronics are low compared to their apparent susceptibility levels to IEMI electromagnetic environments. This indicates that normal EMC immunity protection will not be sufficient for the IEMI problem. In addition, when a generator like JOLT is used, it can produce 50 kV/m at a range of 100 meters distance. This exceeds the damage level for most unprotected electronics by a factor of 10!

PROTECTION APPROACH

The basic IEMI protection approach for a building housing sensitive electronics consists of ensuring that all cables entering a building from the outside are protected at their entrance with filters and surge protection devices with a good low inductance grounding system. This is necessary since the frequency content of the coupled disturbances will be above 100 MHz and a simple cable ground will have a high impedance. The second approach is to reduce the external fields from penetrating the building without any attenuation. For the fields that do penetrate, there are ways to deal with the internal electromagnetic fields.

FIGURE 4: Example of an IEMI detector

Several options for mitigation include:

1. Better electromagnetic building shielding. Increase the quality of the shielding effectiveness of the building in the frequency range of importance. For example, windows are leaky to high frequency EM fields, and should be covered over with metal sheeting.
2. Increase the possible weapon standoff distances using physical security, such as fencing, to keep assailants far away, in order to take advantage of the 1/R falloff in electric field from an antenna.
3. Use EM alarms to monitor the EM environment – watch for the start and continuation of an IEMI attack.
4. If high levels of IEMI fields can get into the facility and couple to network cabling, then an effort must be made to either reduce the coupling to the cables or restrict the effects of the coupled signals. Approaches to accomplish this include:

- Layout cables along metallic surfaces.
- Use shielded cables and connectors.
- Use ferrites on metallic cables.
- Use surge protection devices at the equipment connection.
- Use optical cabling without metal to replace metallic cable.

Building Shielding

Depending on the strength of an IEMI weapon and its location relative to the electronics, it is conceivable that the external peak electromagnetic fields will be greater than 10 kV/m. These fields may not be attenuated very much in the range of 1 MHz to 5 GHz, depending on the natural shielding provided by typical construction methods. Table 1 shows the results of measurements at buildings with different types of construction materials. It is clear that there is a strong variation in attenuation. The far right column indicates the measurement values obtained, while the first column places the measurements into approximate categories.

There are two approaches in dealing with the building itself. First one could improve the shielding effectiveness by covering open windows, if present, covering the external surfaces of the building with metallic material, adding metallic materials to the internal walls of the building (metallic wallboard), or replacing the existing building with an all metal building (clearly the most expensive option). In addition, irrespective of the approach taken, any external power, communications and control cables must be grounded at the building entrance with low inductance techniques (plates not wires).

Electromagnetic Alarms

Since in many cases EM weapons may create major interference with computers and other electronics only while the weapon is transmitting, there is some value in using a detector to determine if a continuous IEMI source is operating nearby. Even if the attack were short in duration, a detector would be useful from a forensic point of view. Because of the wide range of EM environments (from narrowband to hyperband), it is not easy to build detectors that can cover a large range of frequencies and time intervals, but Figure 4 shows one example of a portable detector (it has been calibrated up to 8 GHz). Other detectors can be installed permanently near sensitive electronics.

PROTECTION ACTIVITIES

As indicated in the introduction of this article, after the URSI resolution, the IEC started its standardization work dealing with IEMI in earnest. This then led to activities within the IEEE, ITU-T and Cigré as indicated below:

- IEC IEMI standards development began in 1999.

- The IEEE EMC Society Transactions Special Issue on IEMI was published in August 2004.
- The ITU-T Recommendation for the protection of telecommunications systems from HPEM (IEMI), K.81 was published in 2009.
- The IEEE EMC Society Standard Practice P1642 under development to protect publicly accessible computers from the threat of IEMI is planned for publication in early 2013.
- A Cigré C4 Brochure is under development for the protection of high-voltage power substation control electronics from IEMI and is planned for publication by the end of 2012.

In addition to standardization activities, the Federal Energy Regulatory Commission and the Department of Energy have evaluated the impact of severe electromagnetic threats on the power industry, and the House of Representatives has introduced the SHIELD Act, HR 668, which if passed into law will require the protection of the bulk power electric infrastructure against the threats of natural and man-made electromagnetic pulse. IEMI is one of these man-made threats.

CONCLUSIONS

While electromagnetic weapons may seem to be something conjured up by Hollywood for entertainment, they are clearly threats to modern electronic systems due to the advances in both solid state electronics for producing small advanced weapons and also due to the increased efficiency of electronics operating at lower and lower voltages (increasing their sensitivity).

From the brief overview presented here, it is clear that the international technical community has evaluated the situation and feels that IEMI is a real threat to our critical infrastructures. Through research and engineering studies, several ways have been revealed to make our society less vulnerable to this threat. The challenge for the future is to determine the most cost-effective approaches for protection that include physical protection, electromagnetic protection and finally electromagnetic detection. In addition the education of facility operators is an important goal, which hopefully is promoted by this article.

FOR FURTHER READING

Standards produced by IEC SC 77C dealing with HPEM and IEMI (www.iec.ch)

"Special Issue on High-Power Electromagnetics (HPEM) and Intentional Electromagnetic Interference (IEMI)", IEEE Transactions on Electromagnetic Compatibility, Volume 46, No. 3, August 2004.

"High-power electromagnetic immunity guide for telecommunication systems," Telecommunication Standardization Sector of ITU, ITU-T, K.81, November 2009.

ABOUT THE AUTHOR

Dr. Radasky received his Ph.D. in Electrical Engineering from the University of California at Santa Barbara in 1981. He has worked on high power electromagnetics applications for more than 44 years. He has published over 400 reports, papers and articles dealing with electromagnetic environments, effects and protection during his career. In recent years he has worked extensively in performing assessments for critical infrastructures to the threats of HEMP, IEMI and severe geomagnetic storms. He is Chairman of IEC SC 77C (EMC: High Power Transient Phenomena), Chairman of IEEE EMC Society TC-5 (High Power EM), and a Working Group Convener for Cigré C4. He founded Metatech Corporation in 1984 in California and is the president and managing engineer.

Dr. Radasky is active in the field of electromagnetic compatibility (EMC) standardization, and he received the Lord Kelvin Award from the IEC in 2004 for outstanding contributions to international standardization. He is an IEEE Life Fellow and a registered Professional Engineer in electric engineering.

A Design Review of the Automotive Radiated Emissions Test Fixture

TOM MULLINEAUX
RF ENGINEER

FROM A COLD, dispassionate RF engineering perspective, the automotive radiated test set-up is a strange looking transmit/receive arrangement, with the cable harness of the equipment under test (EUT) suspended above a large copper sheet acting as the transmitter, and a huge antenna close to the chamber floor, and partly in the shadow of the copper sheet, acting as the receiver.

In the guise of a design review[1], this article examines the working of the harness/antenna pair design. After the examination it then suggests possible improvements, particularly as regards symmetry of field emanation and thereby symmetry of antenna illumination.

Setting the Scene

To make for an open mind generally, and in an effort to discourage the surfacing of long-held reader prejudices, we shall name parts by their function. Also, to allow the exercise to fit within an article of reasonable length, we will 1) limit the review to the transmitter and receiver parts of the test system, and 2) frame the review with rules and assumptions. We start by renaming the parts of interest. For the purposes of this article we shall use initials for some of the longer part names.

The Field Emanating Fixture

A much simplified layout of the test set-up highlighting the cable harness/copper sheet arrangement is shown in Figures 1(a) and 1(b).

The figures show the 2m long EUT cable harness (in yellow) held 5cm above the copper sheet by insulated pillars. This will be referred to as the Field Emanating Fixture (FEF). Auxiliary components such as LISNs and representative loads required by the test are shown to the left of the dotted line. We shall regard these as supporting components only, and concentrate on the parts to the right of the dotted line.

The E-Field Sensor (Figure 2)

It can be argued that the bi-conical antenna positioning and proximity means it is not behaving as an antenna as is commonly understood (no longer a doughnut shaped radiation pattern, etc), and therefore can simply be regarded as an arrangement of vertical conducting rods, unevenly loaded, and unevenly illuminated. So to allow for the widest

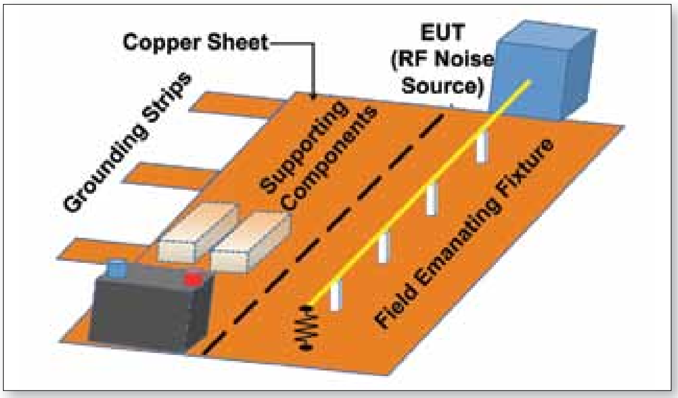

FIGURE 1a: Simplified Field Emanating Fixture seen from Above

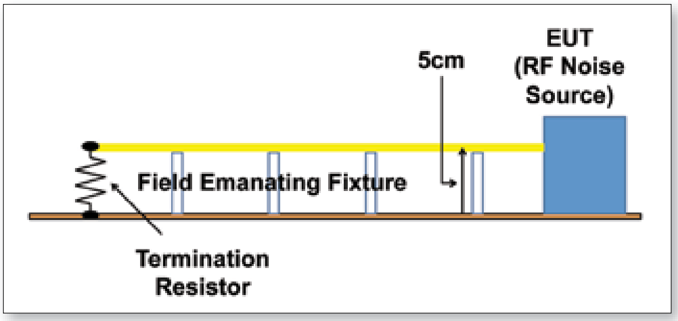

FIGURE 1b: Simplified Field Emanating Fixture seen from Front

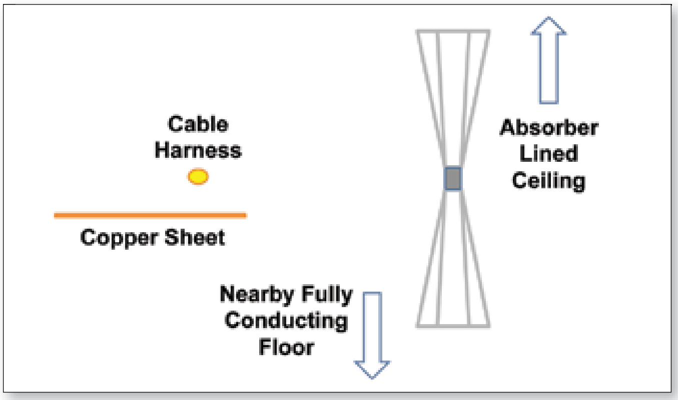

FIGURE 2: E-Field Sensor close to Fixture and Chamber Floor

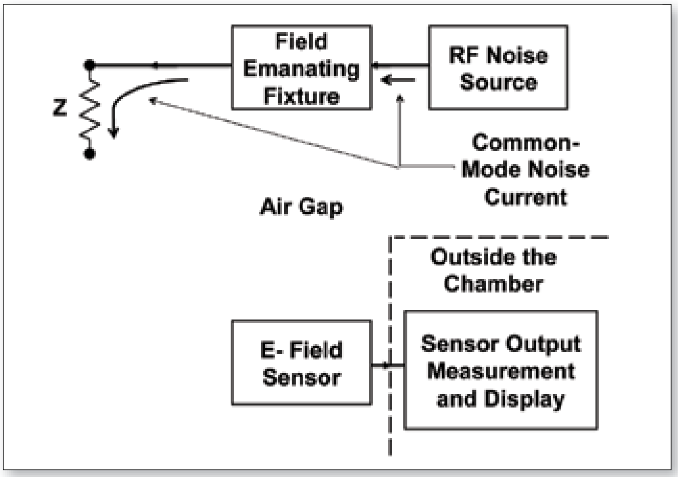

FIGURE 3: Simplified Schematic Showing Renamed Parts

interpretation, and since we shall be limiting the review to E-Field measurements, we shall call it the E-Field Sensor.

Continuing with the naming by functionality, we will refer to the EUT as the RF Noise Source.

A simplified schematic showing the renamed parts is shown in Figure 3.

Framing the Design Review

As with all well run design reviews, strict rules and assumptions are imposed. These are imperative if solid forward progress is to be made, and if the review meeting is to be completed in a reasonable time.

The rules. These are listed in Table 1. The ones that are not self explanatory are referred to within the main body of the article, and so the list needs only a cursory glance before proceeding.

The assumptions. These are listed in Table 2. Again, these need only a cursory glance at this time.

With the rules and assumptions in place, we are now in a position to begin the review. For our purposes this is the first review of the design (that is, a review of the designer's first shot at a solution).

Four steps are taken. First the designer provides a description of the proposed design to the review panel. This is followed by reviewer questions to ensure everyone at the table fully understands the working of the design. Then the reviewers identify, and home in on possible shortfalls in the design. Finally suggestions are made that address any shortfalls.

Although suggestions on possible approaches are given, care is taken to ensure no detailed design work takes place during the review, as this is not the purpose of the meeting. The meeting minutes record the list of development tasks to be completed, and list the data to be gathered ready for presentation at the second review.

THE DESIGN REVIEW

The Test Set-Up Description

The test set-up is designed to measure the level of radiated emissions caused when a subject EUT is connected to a wiring harness. It is assumed that when fitted in the vehicle the vast majority of the emitted fields will emanate from the connected wiring harness as opposed to the EUT itself.

The set-up has two key roles. The first is to emit as RF fields, any RF noise injected onto the harness by the EUT. The second is to measure the strength of the emitted fields.

The emitter role is achieved by using a field emanating fixture (FEF) comprised of 2 meters of the wiring harness suspended over a copper sheet. Measurement is achieved by use of a vertically orientated biconical antenna. The antenna is 1 meter away and centered on the harness.

Although somewhat similar to a cable harness fitted to an automobile chassis, the FEF arrangement was in fact borrowed from an aerospace RF emissions test set-up. The cable and sheet act as a transmission line in a similar fashion to a microstrip

TABLE 1: THE RULES	
Rule #1	The frequency range in question is limited to the bi-conical antenna operating frequency of 20-200MHz.
Rule #2	We take no account of the auxiliary equipment (LISNs etc). We focus instead on the performance of the Field Emanating Fixture / E-Field Sensor pair.
Rule #3	The wiring harness over the copper sheet is deemed equivalent to a 'single wire over conducting plane' transmission line.
Rule #4	No account is taken of the insulation around wires or of multi-wire bundles. This is for simplicity, and as will be seen during the review, these are not seen as significant game changers.
Rule #5	ZFEF ≠ ZIN_SITU. Although somewhat similar in layout, at no time do we consider the characteristic impedance of the Field Emanating Fixture ZFEF to be the same as the characteristic impedance ZIN_SITU of an actual cable harness fitted (in-situ) to the chassis of an automobile.
Rule #6	ZFEF ≠ ZS. Consistent with Rule #5, there is no reason to believe the characteristic impedance of the FEF is the same as Zs, the characteristic impedance of the RF Noise Source.
Rule #7	No standing wave exists on the FEF (for simplicity and in order to assess the true performance of the FEF, we will do so under matched termination resistor conditions).
Rule #8	We will only refer to E-Field emissions.
Rule #9	There are no copper sheet effects (resonances).
Rule #10	There is no chamber floor effect in the suggestion stage of the review (we will fit ferrite tile/absorber as required).
Rule #11	The following do not significantly affect the performance of the test system: the test table supporting the test set-up, the 5cm pillars holding the wiring harness, any discontinuity in the FEF (resistor termination method, etc), or the proximity of the semi-anechoic chamber walls.

TABLE 2: THE ASSUMPTIONS	
Assumption #1	We assume at all times that the RF emission levels from the 2m long FEF dominate any 'over the air' RF emissions emitted by the EUT box itself.
Assumption #2	We assume all noise currents emitted by the RF Noise Source are common mode. That is they travel in the same direction along all wires in the harness and return via the copper sheet.
Assumption #3	Any fields caused by DC currents in the wiring harness will be static and hence unseen by the E-Field Sensor
Assumption #4	20-200MHz oscillating RF Fields, whether they turn out to be propagating or not, will be sensed at 1 meter distance by the E-Field Sensor.

transmission line. The strong similarity can be seen in Figure 4, where sketches are shown of the E-Field distribution of a microstrip line and of a wire over a conducting plane transmission line. Using one of the free calculators available on-line[2] the characteristic impedance of a single 1.5mm diameter wire over the conducting plane was determined as 300 ohms. If correct, this could make sense from a historical perspective as folded dipoles and the old type valve tuners use 300 ohms. However the actual characteristic impedance of the FEF has not been confirmed by measurement.

The sketches in Figure 4 show the E-field concentrated in the gap immediately below the upper conductor (the closer the lines of force, the stronger the field), while fringe fields that weaken with distance emanate to the sides.

Since the noise currents are at RF frequencies, Mother Nature contrives to make the length of the loop as short as possible (loop

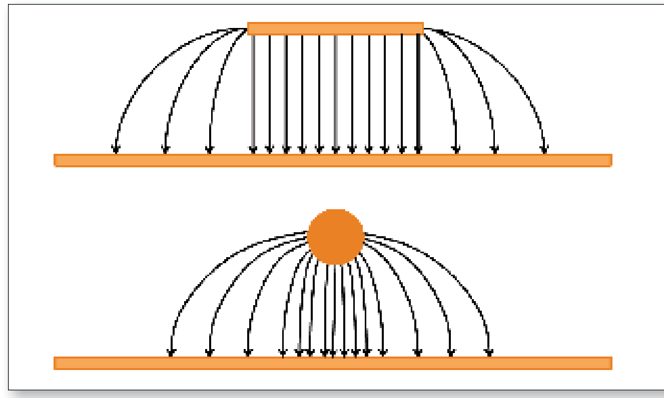

FIGURE 4: Sketches of the E-Fields in microstrip (dielectric removed for simplicity) and a single wire over a ground plane

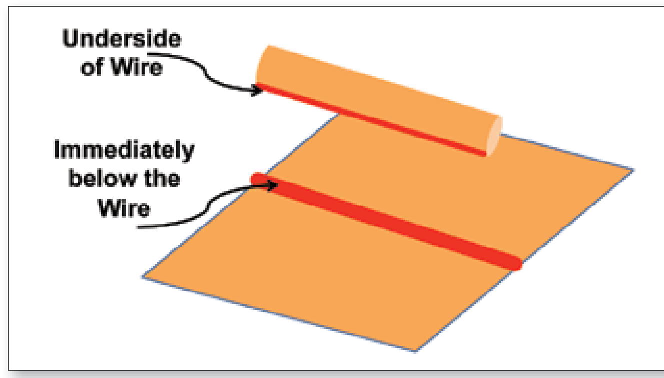

FIGURE 5: The Route taken by the RF Currents

area correspondingly as small as can be). This happens when the currents follow a path on the underside of the wire and return immediately below the wire on the surface of the copper sheet, as shown in Figure 5.

The receiver role is played by a biconical antenna. For these frequencies (20-200MHz), the antenna is necessarily large[3]. Ideally no fields emanate from the underside of the FEF, so the only illumination of the antenna is from the upper side of the FEF. This makes for unequal illumination as shown in Figure 6.

The asymmetric illumination casts severe doubt on the continued usefulness of calibration data provided with the antenna, but at least as with any field strength transducer, the output will likely increase with increasing field strength. For this reason we will call the antenna an E-Field sensor.

At only 1 meter distance and with the relatively long wavelengths in question the E-Field sensor picks up all fields, propagating and non-propagating.

The present termination resistor is 120 ohms (inherited), and so standing waves will likely exist on the FEF as the RF noise currents bounce to and fro between the mismatch at the termination and the mismatch at the FEF/EUT interface. This creates confusion as to whether the E-Field sensor is measuring fields at points of maximum, minimum, or somewhere in between.

Review Panel Questions Stage

Clarification was given as follows:

The characteristic impedance of the actual cable harness that

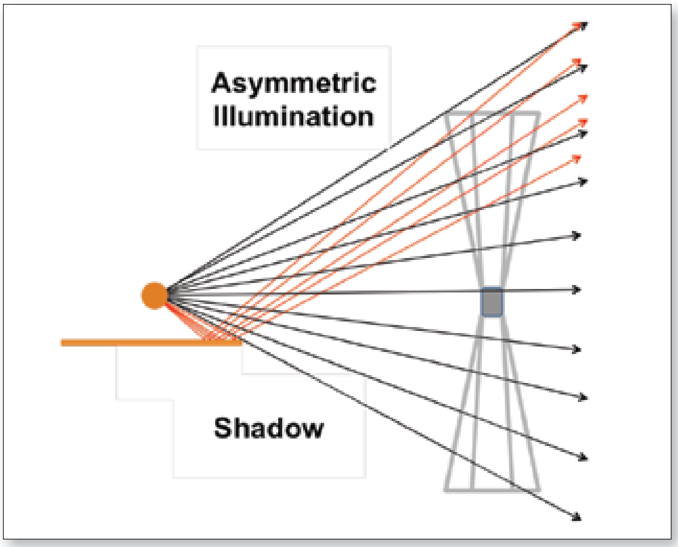

FIGURE 6: Asymmetric Illumination of the Antenna

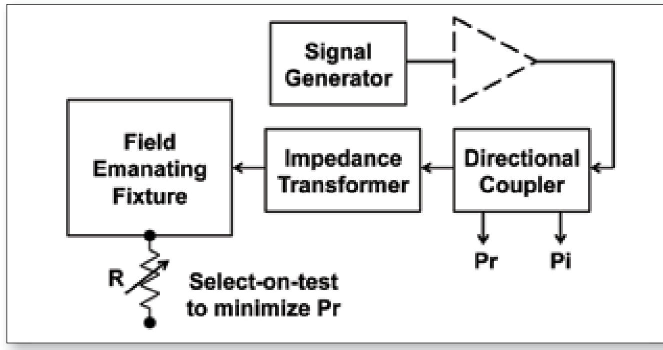

FIGURE 7 Characterizing the FEF

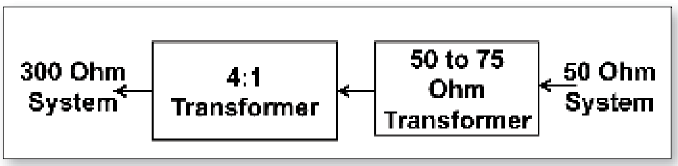

FIGURE 8: 50 Ohm to 300 Ohm Impedance Transformer

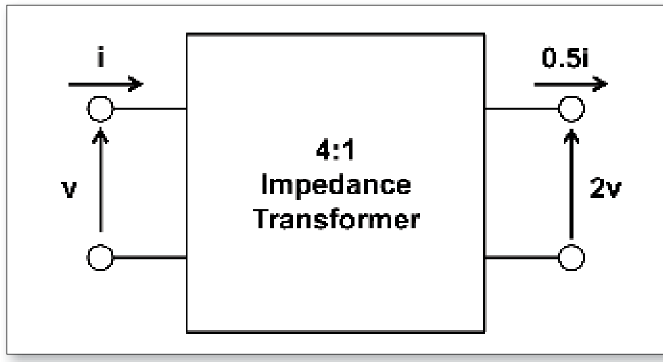

FIGURE 9: 4:1 Impedance Transformer

the EUT will be attached to is not known beforehand since the EUT may be supplied to several auto manufacturers, and even if supplied to only one, the EUT may be installed into many different models.

Even though in some respects the EUT connected to the wiring harness over the copper sheet looks representative of a real installation (except for being held 50mm (originally 2 inches?) above the car chassis), it is in fact a time proven test fixture, representative of an historic aircraft installation set-up.

In the main, the real wiring harness will be attached to the metalwork of the car and so on average the distance between the wires and the metalwork will likely be less than 50mm, with correspondingly lower characteristic impedance.

Although transmission lines tend to be reasonably low loss (otherwise they would not be regarded as transmission lines), the historic FEF is deemed to be leaky enough for reliable field measurement purposes.

The FEF could be made intentionally leakier by for instance increasing the harness height, or by deliberate removal of some of the copper sheet, for instance by cutting out a segment below the center of the harness to increase the fringing field strength.

The source impedance of the RF Noise Source is unknown, and so there could be a bad match between it and the FEF, preventing efficient transfer of the noise signals onto the FEF. It is possible that when the EUT is installed in real life, that the match could improve and efficient transfer of noise onto the harness could take place.

Shortfall Identification Stage

The outcome of the design shortfall identification stage was as follows:

1. Although design re-use is encouraged, this only happens where the design is proven and supported with performance data. There seems to be no supporting data with the inherited FEF. To pass this review, data characterizing the proposed FEF must first be obtained.

2. The presence of standing waves in an open, locally unshielded set-up such as this does not make for a well behaved RF system. Therefore, to pass this review, all efforts must be made to prevent them.

3. The E-Field sensor illumination is asymmetric. In the main, field sensors are intended to be fully immersed in the field they are expected to measure. Without this, in-house calibration data must be obtained.

Review Panel Suggestions

The suggestions put forward for the designer to consider were as follow.

1. Characterizing the FEF could be achieved by using a signal generator as the RF Noise Source to provide signals of known frequency and power level, and a single 1.5mm diameter wire can be used as the wiring harness. The signal generator power level can be amplified as necessary. Figure 7 shows the general idea. A 50 Ohm to 300 Ohm transformer is used to assure efficient injection of the test signal. The impedance transformer stages are shown in Figure 8. The transformer uses two very common components in the world of power RF, a 50 Ohm to 75 Ohm transformer followed by a 4:1 transformer. The 4:1 transformer doubles the voltage and halves the current to create four times the impedance of the input impedance as shown in Figure 9. The incident

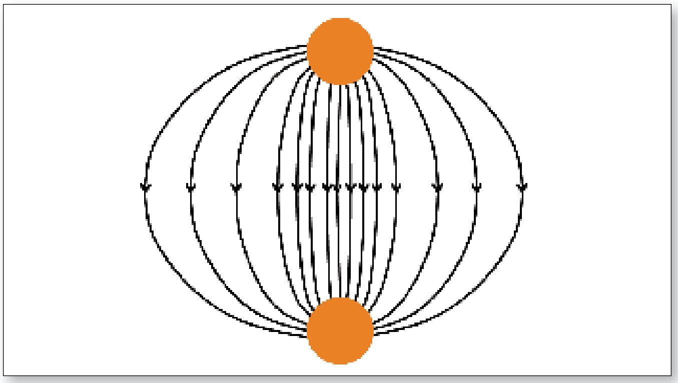

FIGURE 10: 2-Wire Symmetric E-Field Distribution

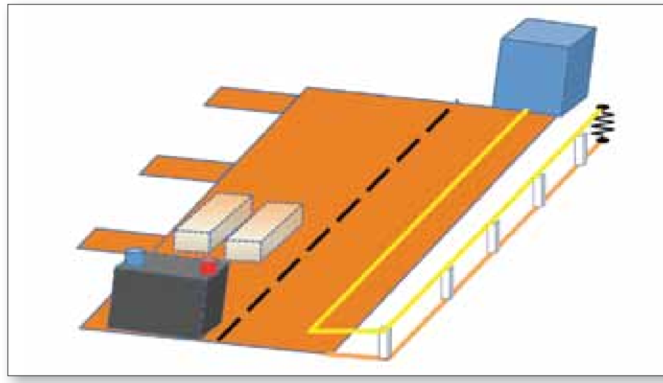

FIGURE 11: 2-Wire FEF for Consideration by the Design Engineer

power (Pi) and reflected power (Pr) are monitored using a directional coupler. The resistor value is selected on test to minimize the reflected power and thereby match the load to the FEF characteristic impedance. In fact the designer could stipulate this method to match the wiring harness to the load prior to actual EUT test runs. The designer is now in a position to fully characterize the FEF/E-Field sensor pair.

2. Given the FEF is not truly representative of the wiring harness in-situ, then any leaky transmission line could be used as the FEF. For instance, symmetry of the emanated fields could be achieved by using a 300 Ohm 2- wire transmission line. The symmetrical field distribution is shown in Figure 10. The 2- wire could be formed from the wiring harness and a strip of the copper sheet. With this arrangement the E-Field Sensor would be immersed in a symmetric field, especially if the designer insisted the biconical antenna was isolated from the chamber floor (antenna and test FEF raised, floor lined). Food for thought is given in Figure 11, where the idea is that the harness attached to the copper sheet is more representative than the 50mm high harness. However this could create issues of it's own and so can be dispensed with and the RF Noise Source can be connected directly to the 2-wire FEF. The design engineer is at liberty to experiment using the characterization set-up described above.

3. The issue of the propensity of the RF Noise Source to inject noise currents onto a wiring harness of different characteristic impedance is still unresolved. This is crucial and must be resolved for the test-system design to pass this review process.

CONCLUSION

Although deliberately short on detail, the hope is that readers can see that the application of standard engineering management practices as used daily in commercial enterprises, may be used to generate new ideas to address known weaknesses in current test set-ups. And the incorporation of these ideas might in turn be considered by the standards setting bodies to improve consistency and thereby confidence in product compliance testing.

NOTES

1. Many people still think of a design review as just a progress check and an opportunity to discuss snags. In fact with the emergence of the new product introduction (NPI) methodology, design reviews are a key component where, as well as ensuring the design is on track, 'gates' must be passed before the release of further resource/funding for a project. As a program manager I was very familiar with this methodology, and often wondered how the design of the subject radiated emissions arrangement would fare if put through a formal design review. Hence this article. The intention was to invite input from EMC experts, but they seemed too attached to the existing set-up to look at the design in a dispassionate way, so I decided against this. Although a mock review, the review and outcome is very similar to what I would expect to take place under real commercial conditions.

2. http://www.eeweb.com/toolbox/wire-microstrip-impedance. Height above plane 50mm, single wire diameter 1.5mm, substrate dielectric 1

3. The bottom of the antenna is close to the fully conducting chamber floor. Meantime the top of the antenna is some distance away from the lined chamber ceiling. This makes for imbalance in the 'loading' of the antenna.

AUTHOR NOTE

The article is not a paper requiring copious results or even references, it is an appeal for change. My point is that dyed in the wool EMC engineers with an encyclopedic knowledge of standards, their history, and their implementation are ill suited to push for change, even when they are aware that test set-ups have serious flaws. Independent review using the methods used by the commercial sector is in my view the best way to get through the barricade formed by the experts.

To learn more, visit Interference Technology's EMC Zone, where Mullineaux blogs regularly.

ABOUT THE AUTHOR

***Tom Mullineaux** is an RF engineer experienced in engineering management and technical sales management. He is currently a freelance author and technical writer.*

Calendar

EUROPEAN CONFERENCE ON ANTENNAS & PROPAGATION (EUCAP) 2014

April 6-11, 2014, The Hague, The Netherlands

The 8th annual European Conference on Antennas & Propagation provides a forum for the exchange of scientific and technical information on the latest results and developments in antenna theory and technology, electromagnetic wave propagation and antenna measurement techniques. Members of both Industry and academia are welcome to attend.

www.eucap2014.org

MIL-STD-461F TRAINING COURSE

April 15-18, Jul 15-18, Oct. 14-17, 2014, Baltimore, MD

The MIL-STD-461F will be introduced, including the new/modified test methods and test article configurations. This course offers critical information for military compliance professionals, testing industry professionals, and developers involved with electronics systems development .

www.wll.com

EUROPEAN WIRELESS 2014

May 7-9. 2013, Braintree, MA

This course covers the methodology of designing an electronic product to minimize the possibilities of having problems of electromagnetic interferences (EMI) or Electromagnetic Compatibility (EMC). Useful techniques for troubleshooting an EMI/EMC problem are presented to help in products where problems exist. The basics of designing electronic products with EMI and EMC in mind are introduced in a very understandable and entertained style. The course presents the ways in which an electronic system can generate and/or receive EMI causing failure to meet EMC regulations. A practical approach with many real world examples, techniques, simulation and hardware tools for EMI design will be explained to minimize costs, production and marketing delays considering EMI in the design phase.

www.besserassociates.com

"EMC ESSENTIALS" DESIGN AND TROUBLESHOOTING WORKSHOP

May 8-9, 2014 , Milpitas, Calif.

Join Ken Wyatt for a two day course hosted by SIEMIC Global Testing & Certifications. The price is $1,295 and includes seminar notes, lunch and snacks

Day 1: EMC Theory (Part 1) - Attendees will be introduced to units of measurement, time and frequency domain, differential and common mode currents, radiated emissions, ESD, PC board layout and shielding/bonding. Day 1 is crucial to understanding the Day 2 presentation, as it will also include demonstrations of many of the basic principles.

Day 2: EMC Theory (Part 2), plus Bench Top Measurements and Troubleshooting - Continue with ESD and system design, followed up with practical tools and techniques that can be used for pre-compliance measurements as well as troubleshooting EMC problems in a more formal setting. We will include the popular "Top Ten EMC Issues" and will demonstrate several probing and analysis techniques that will identify EMC issues quickly. Several case studies will also be described.

www.emc-seminars.com

EMC 2014 TOKYO

May 12-16, 2014, Tokyo, Japan

The "2014 International Symposium on Electromagnetic Compatibility" (EMC'14/Tokyo) will be held at "Hitotsubashi Hall (National Center of Sciences)," Chiyoda, Tokyo, from May 13 to 16, 2014. EMC'14/Tokyo is the 7th "International Symposium on Electromagnetic Compatibility" organized by "The Institute of Electronics, Information and Communication Engineers, Communications Society" (IEICE-CS). We would like to invite all engaged in research and development in the various fields of electromagnetic compatibility to participate in this symposium.

www.ieice.org

DESIGN FOR EMC

May 13-15, 2014, Fareham, Hampshire

This EMC training course will cover design to meet the compliance requirements of the European EMC Directive, as well as other commercial and military requirements. Good EMC design gives you a product that is more reliable and better fitted for its environment. The course is structured to achieve the maximum learning potential from a combination of tutorial and case study exercises. It emphasises the underlying physics of interference generation and coupling and how it affects design methods, without resorting to complex mathematics.

www.tuv-sud.co.uk

EUROPEAN WIRELESS 2014

May 14-16, 2014, Barcelona, Spain

The European Wireless Conference focuses on all aspects of telecommunications, including ongoing research, new products and technology. This year's conference will focus on "Energy- and Spectrally-Efficient Broadband Communication Systems."

www.ew2014.org

"WEBINAR: 'PCB SUPPRESSION OF ICS WITH BGA OR MULTIPLE POWER RAILS'

June 25, 2014, Online

Keith Armstrong will present a webinar: 'PCB Suppression of ICs with BGA or Multiple Power Rails.' Registration will open June 11.

Overview: Most EMC design textbooks that cover printed circuit board (PCB) design and layout – including mine – do not cover the special EMC issues associated with Ball Grid Array devices (BGAs), so this webinar covers PCB design techniques that will reduce their emissions and increase their immunity. In particular, how to get good plane meshes under them, and how to deal with their multiple power planes.

www.interferencetechnology.com/webinar-series

2014 IEEE EMC INTERNATIONAL SYMPOSIUM

Aug. 3-8, 2014, Raleigh, NC

The Electromagnetic Compatibility Society is the world's largest organization dedicated to the development and distribution of information, tools and techniques for reducing electromagnetic interference. The society's field of interest includes standards, measurement techniques and test procedures, instrumentation, equipment and systems characteristics, interference control techniques and components, education, computational analysis, and spectrum management, along with scientific, technical, industrial, professional or other activities that contribute to this field. This is the largest event of the year.

www.emc2014.org

EMC EUROPE 2014

Sept. 1-4, 2014, Gothenburg, Sweden

EMC Europe is the leading EMC Symposium in Europe and the 2014 edition will be held at The Swedish Exhibition & Congress Centre in Gothenburg, Sweden, They wish to invite and encourage all those working in the field of electromagnetic compatibility to participate in this prestigious event.

www.emceurope2013.eu

INNOVATIVE SMART GRID TECHNOLOGIES (ISGT) EUROPE 2014

Oct. 12-15, 2014, Istanbul, Turkey

The 5th European Innovative Smart Grid Technologies (ISGT) Conference will provide participants from industry and academia with the opportunity to discuss the cutting-edge development of smart grid technologies and the associated solutions related to increased penetration of renewables and distributed energy resources in the power system.

www.ieee-isgt-2014.eu

EUROPEAN MICROWAVE WEEK 2014

Oct. 5-10, 2014, Rome, Italy

European Microwave Week is the premier event of its kind in Europe and its conferences are set to be even more cutting edge and ground breaking in 2013 than in previous years. The European Microwave Week consists of three conferences: The European Microwave Conference (EuMC); The European Microwave Integrated Circuits Conference (EuMIC); The European Radar Conference (EuRAD).

www.eumweek.com

EMC LIVE 2014

Oct. 14-16, 2014, Online

EMC LIVE is a brand new, online multi-day event hosted by *Interference Technology.* This event will feature roundtables, webinars and panels on everything EMC-related and there's no cost to attend. Check out our website to see more information as it becomes available.

www.emclive2014.com

Consultant Services

Standards Recap

Compliance with standards makes or breaks the marketing of any new product. This section recaps new and revised national and international EMC standards. 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.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

299.1-2013 - Measuring the Shielding Effectiveness of Enclosures and Boxes Having All Dimensions between 0.1 m and 2 m - *7/10/2013*

This standard provides uniform measurement procedures for determining the shielding effectiveness of electromagnetic shielding for a variety of enclosures and boxes having all dimensions between 0.1 m and 2 m in the radio frequency range not addressed by IEEE Std 299(TM)-2006. This standard is divided into two distinct parts: Part I, which covers 0.75 m to 2 m and Part II, which covers physically small (< 0.75 m) but electrically large enclosures. A number of annexes are included to address physically small and electrically small enclosures, electrically small enclosures in reverberation chambers, rationale, mathematical formulas, selection of measurement techniques, preliminary measurement and repairs, wall-mounted monopoles, impedance mismatch correction and using isolated monopoles in outer reverberation chambers.

1309-2013 - Standard for Calibration of Electromagnetic Field Sensors and Probes (Excluding Antennas) from 9 kHz to 40 GHz - *11/22/2013*

This standard provides consensus calibration methods for electromagnetic (EM) field sensors and probes. In addition, data recording and reporting requirements are given, and methods for estimating measurement uncertainty are specified.

1528-2013- Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques - *9/6/2013*

This standard specifies protocols and test procedures for the measurement of the peak spatial-average SAR induced inside a simplified model of the head of users of certain handheld radio transceivers. These transceivers operate in the 300 MHz to 6 GHz frequency range and are intended to be used for personal wireless communications services and to be operated while held against the ear.

The results obtained by following the protocols specified in this recommended practice represent a conservative estimate of the peak spatial-average SAR induced in the head of a significant majority of persons, subject to measurement and other uncertainties that are defined in this recommended practice. The results are representative of those expected during conditions of intended use of a handheld wireless device. It is not the intent of this recommended practice to provide a result representative of the absolute maximum SAR value possible under every conceivable combination of head size, head shape, handset orientation and spacing relative to the head.

Body SAR measurements typically required for wireless handsets and the measurement of SAR induced in the external tissues of the head, e.g., the external ear (pinna), are not addressed in this document.

C63.10-2013 - American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices - *9/13/2013*

This standard covers the procedures for testing the compliance of a wide variety of unlicensed wireless transmitters (also called intentional radiators and license-exempt transmitters) including, but not limited to: remote control and security unlicensed wireless devices, frequency hopping and direct sequence spread spectrum devices, antipilferage devices, cordless telephones, medical unlicensed wireless devices, Unlicensed National Information Infrastructure (U-NII) devices, intrusion detectors, unlicensed wireless devices operating on frequencies below 30 MHz, automatic vehicle identification systems and other unlicensed wireless devices authorized by a radio regulatory authority. This standard excludes test procedures for unlicensed wireless devices already covered in other published standards (e.g., Unlicensed Personal Communication Services (UPCS) devices).

C63.17-2013 - American National Standard Methods of Measurement of the Electromagnetic and Operational Compatibility of Unlicensed Personal Communications Services (UPCS) Devices - *10/9/2013*

This standard establishes specific test procedures, including applicable regulatory requirements regarding radio-frequency emission levels and spectrum access procedures, for verifying the compliance of unlicensed personal communications services (UPCS) devices (including wideband voice and data devices).

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60255-26:2013 - Measuring Relays and Protection Equipment – Part 26: Electromagnetic Compatibility Requirements - *5/24/2013*

IEC 60255-26:2013 is applicable to measuring relays and protection equipment, taking into account combinations of devices to form schemes for power system protection including the control, monitoring, communication and process interface equipment used with those systems. This standard specifies the requirements for electromagnetic compatibility for measuring relays and protection equipment. The requirements specified in this standard are applicable to measuring relays and protection equipment in a new condition and all tests specified are type tests only. This new edition includes the following technical changes with respect to the previous edition:

- definition of test specifications, test procedures and acceptance criteria per phenomena and port under test in one document;
- extension of radiated emission measurement for frequencies above 1 GHz;
- limitation of radiated emission measurement at 3 m distance for small equipment only;
- addition of zone A and zone B test level on surge test;
- extension of tests on the auxiliary power supply port by a.c. and d.c. voltage dips, a.c. component in d.c. (ripple) and gradual shut-down/start-up;
- harmonization of acceptance criteria for immunity tests.

IEC 60358-3:2013 - Coupling Capacitors and Capacitor Dividers – Part 3: AC or DC Coupling Capacitor for Harmonic-Filters Applications - *11/27/2013*

IEC 60358-3:2013 applies to AC or DC single-phase coupling capacitors with rated voltage higher than 1,000 V that are connected line-to-ground with the low voltage terminal either permanently earthed or connected to a tuning device for harmonic-filters applications. It replaces Clause 1 of IEC 60358-1:2012.

IEC 60384-14:2013 - Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification – Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains - *6/5/2013*

IEC 60384-14:2013 applies to capacitors and resistor-capacitor combinations that will be connected to an a.c. mains or other supply with nominal voltage not exceeding 1,000 V a.c. (r.m.s.) or 1,000 V d.c. and with nominal frequency not exceeding 100 Hz. This fourth edition cancels and replaces the third edition published in 2005 and constitutes a technical revision.

IEC 60512-28-100:2013 - Connectors for Electronic Equipment Tests and Measurements – Part 28-100: Signal Integrity Tests Up to 1,000 MHz on IEC 60603-7 and IEC 61076-3 Series Connectors - Tests 28a to 28g - *2/6/2013*

IEC 60512-28-100:2013 specifies the test methods for transmission performance for IEC 60603-7 and IEC 61076-3 series connectors up to 1,000 MHz. It is also suitable for testing lower frequency connectors; however the test methodology specified in the detailed specification for any given connector remains the reference conformance test for that connector. The test methods provided include insertion loss, return loss, near-end crosstalk (NEXT), far-end crosstalk (FEXT), transverse conversion loss (TCL) and transverse conversion transfer loss (TCTL). For the transfer impedance (ZT) test, see IEC 60512-26-100. For the coupling attenuation, see IEC 62153-4-12.

IEC 61000-3-3:2013 - Electromagnetic Compatibility (EMC) – Part 3-3: Limits – Limitation of Voltage Changes, Voltage Fluctuations and Flicker in Public Low-Voltage Supply Systems for Equipment with Rated Current ≤16 A Per Phase and Not Subject to Conditional Connection - *5/14/2013*

IEC 61000-3-3:2013 is concerned with the limitation of voltage fluctuations and flicker impressed on the public low-voltage system. It specifies limits of voltage changes, which may be produced by equipment tested under specified conditions, and gives guidance on methods of assessment. It is applicable to electrical and electronic equipment with an input current equal to or less than 16 A per phase that is intended to be connected to public low-voltage distribution systems of between 220 V and 250 V line-to-neutral at 50 Hz and not is subject to conditional connection. IEC 61000-3-3 has the status of a product family standard within the IEC 61000 series. This third edition cancels and replaces the second edition published in 2008. This edition constitutes a technical revision which takes account of the changes made in IEC 61000-4-15:2010.

IEC 61587-3:2013 – Mechanical Structures for Electronic Equipment – Tests for IEC 60917 and IEC 60297 Part 3: Electromagnetic Shielding Performance Tests for Cabinets and Subracks - *2/6/2013*

IEC 61587-3:2013 specifies the tests in the frequency range of 30 MHz to 3,000 MHz for empty cabinets and subracks concerning electromagnetic shielding performance. Stipulated attenuation values are chosen for the definition of the shielding performance level of cabinets and subracks for the IEC 60297 and IEC 60917 series. The shielding performance levels are chosen with respect to the requirements of the typical fields of industrial application. They will support the measures to achieve electromagnetic compatibility but cannot replace the final testing of compliance of the equipped enclosure. This second edition cancels and replaces the first edition issued in 2006 and constitutes a technical revision.

IEC 61788-16:2013 - Superconductivity – Part 16: Electronic Characteristic Measurements – Power-Dependent Surface Resistance of Superconductors at Microwave Frequencies - *1/16/2013*

IEC 61788-16:2013 involves describing the standard measurement method of power-dependent surface resistance of superconductors at microwave frequencies by the sapphire resonator method. The measuring item is the power dependence of Rs at the resonant frequency. This method is applicable for a frequency in the range of 10 GHz and for an input microwave power lower than 37 dBm (5 W). The aim is to report the surface resistance data at the measured frequency and that scaled to 10 GHz.

IEC 62037-5:2013(E) - Passive RF and Microwave Devices, Intermodulation Level Measurement – Part 5: Measurement of Passive Intermodulation in Filters - *1/16/2013*

IEC 62037-5:2013(E) defines test fixtures and procedures recommended for measuring levels of passive intermodulation generated by filters typically used in wireless communication systems. The purpose is to define qualification and acceptance test methods for filters for use in low intermodulation (low IM) applications.

IEC 62037-6:2013(E) - Passive RF and Microwave Devices, Intermodulation Level Measurement – Part 6: Measurement of Passive Intermodulation in Antennas - *1/16/2013*

IEC 62037-6:2013(E) defines test fixtures and procedures recommended for measuring levels of passive intermodulation generated by antennas typically used in wireless communication systems. The purpose is to define qualification and acceptance test methods for antennas for use in low intermodulation (low IM) applications.

IEC 62153-4-3:2013(E) – Metallic Communication Cable Test Methods – Part 4-3: Electromagnetic Compatibility (EMC) – Surface Transfer Impedance – Triaxial Method - *10/22/2013*

IEC 62153-4-3:2013(E) determines the screening effectiveness of a cable shield by applying a well-defined current and voltage to the screen of the cable and measuring the induced voltage in order to determine the surface transfer impedance. This test measures only the magnetic component of the transfer impedance. This second edition cancels and replaces the first edition published in 2006 and constitutes a technical revision. This edition includes the following significant technical changes with respect to the previous edition:

- three different test configurations are now described;
- formulas to calculate the maximum frequency up to which the different test configurations can be used are included;
- the effect of ground loops is described.

IEC/PAS 62825:2013 - Methods of Measurement and Limits for Radiated Disturbances from Plasma Display Panel TVs in the Frequency Range 150 kHz to 30 MHz - *1/10/2013*

IEC/PAS 62825:2013(E), which is a Publicly Available Specification (PAS), applies to plasma display panel TVs intended for use in residential or commercial environments that have a visible display area with a diagonal dimension of 1 m or greater and are within the scope of CISPR 13 or CISPR 32. This specification covers emission requirements related to radiated radio-frequency (RF) disturbances in the frequency range 150 kHz to 30 MHz. It specifies suitable limits and methods of measurement for the assessment of radiated RF disturbances. The requirements specified in this specification are essential EMC requirements that should be met in order to protect radio reception in the frequency range up to 30 MHz at locations where these display devices are operated in the field. While application of this specification is recommended, the comprehensive set of normative EMC emission requirements can also be found in CISPR 13 or CISPR 32. Use of this specification does not remove the obligation to apply any other CISPR publication. The objectives of this specification are to establish supplementary requirements that provide an adequate level of protection of the radio frequency spectrum, allowing radio reception as intended in the frequency range 150 kHz to 30 MHz, and to specify procedures to ensure the reproducibility of measurement and the repeatability of obtained results.

IEC 62215-3:2013 – Integrated Circuits – Measurement of Impulse Immunity – Part 3: Non-Synchronous Transient Injection Method - *7/17/2013*

IEC 62215-3:2013 specifies a method for measuring the immunity of an integrated circuit (IC) to standardized conducted electrical transient disturbances. The disturbances, not necessarily synchronized to the operation of the device under test (DUT), are applied to the IC pins via coupling networks. This method enables understanding and classification of interaction between conducted transient disturbances and performance degradation induced in ICs regardless of transients within or beyond the specified operating voltage range.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO) / IEC

ISO 11451-4:2013 - Road Vehicles: Vehicle Test Methods for Electrical Disturbances from Narrowband Radiated Electromagnetic Energy – Part 4: Bulk Current Injection (BCI) - *3/25/2013*

ISO 11451-4:2013 specifies bulk current injection (BCI) test methods for testing the electromagnetic immunity of electronic components for passenger cars and commercial vehicles, regardless of the propulsion system (e.g. spark-ignition engine, diesel engine, electric motor) installed. The electromagnetic disturbance considered in ISO 11451-4:2013 is limited to continuous narrowband electromagnetic fields.

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE (CISPR)

CISPR 15:2013 - Limits and Methods of Measurement of Radio Disturbance Characteristics of Electrical Lighting and Similar Equipment - *5/8/2013*

CISPR 15:2013 applies to the emission (radiated and conducted) of radio frequency disturbances from the following:

- all lighting equipment with a primary function of generating and/or distributing light for illumination purposes and intended either for connection to the low voltage electricity supply or for battery operation;
- the lighting part of multi-function equipment where one of the primary functions of this is illumination;
- independent auxiliaries exclusively for use with lighting equipment;
- UV and IR radiation equipment;
- neon advertising signs;
- street/flood lighting intended for outdoor use;
- and transport lighting (installed in buses and trains).

Lighting equipment for aircraft, airports and apparatuses for which the electromagnetic compatibility requirements in the radio-frequency range are explicitly formulated in other CISPR standards are excluded from the scope of this standard. The frequency range covered is 9 kHz to 400 GHz. This eighth edition cancels and replaces the seventh edition published in 2005, its Amendment 1 (2006) and Amendment 2 (2008).

CISPR 20:2006+A1:2013 - Sound and Television Broadcast Receivers and Associated Equipment - Immunity Characteristics - Limits and Methods of Measurement - *10/29/2013*

CISPR 20:2006+A1:2013 applies to television broadcast receivers, sound broadcast receivers and associated equipment intended for use in the residential, commercial or light industrial environment. This standard describes the methods of measurement and specified limits applicable to sound and television receivers and to associated equipment with regard to their immunity characteristics to disturbing signals. This standard is also applicable to the immunity of outdoor units of direct-to-home (DTH) satellite receiving systems for individual reception. Immunity requirements are given in the frequency range 0 Hz to 400 GHz. Radio-frequency tests outside the specified frequency bands or concerning other phenomena than given in this standard are not required.

The objective of this standard is to define the immunity test requirements for equipment defined in the scope in relation to continuous and transient, conducted and radiated disturbances, including electrostatic discharges. These test requirements represent essential electromagnetic immunity requirements. Test requirements are specified for each port (enclosure or connector) considered. The environments encompassed by this standard are residential, commercial and light-industrial locations, both indoor and outdoor. Locations that are characterized by their mains power being supplied directly at low voltage from the public mains are considered to be residential, commercial or light industrial. The following list, although not comprehensive, gives an indication of locations that are included:

- residential properties, e.g. houses, apartments, etc.;
- retail outlets, e.g. shops, supermarkets, etc.;
- business premises, e.g. offices, banks, etc.;
- areas of public entertainment, e.g. cinemas, public bars, dance halls, etc.;
- outdoor locations, e.g. petrol stations, car parks, amusement and sports centers, etc.;
- light-industrial locations e.g. workshops, laboratories, service centers, etc.;
- car and boat.

EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI)

EN 301 489-34 - EMC and Radio Spectrum Matters (ERM); EMC Standard for Radio Equipment and Services; Part 34: Specific Conditions for External Power Supply (EPS) for Mobile Phones - 5/23/2013

EN 301 489-34 contains electromagnetic compatibility requirements for the common external power supply (EPS) for use with data-enabled mobile telephones as described in EN 62684 and M/455. Product dependent arrangements that are necessary to perform the EMC tests on dedicated types of radio communications equipment, and the assessment of test results, are detailed in the appropriate product related parts of EN 301 489. In case of differences (for instance concerning special conditions, definitions and abbreviations) between the present document and EN 301 489-1, the provisions of EN 301 489-34 take precedence. The environment classification and the emission and immunity requirements used in the present document are as stated in EN 301 489-1, except for any special conditions included in the present document.

EN 301 489-50 - EMC and Radio Spectrum Matters (ERM); EMC Standard for Radio Equipment and Services; Part 50: Specific Conditions for Cellular Communication Base Station (BS), Repeater and Ancillary Equipment - *3/12/2013*

EN 301 489-50, together with EN 301 489-1, covers the assessment of digital cellular base station equipment, repeaters and associated ancillary equipment in respect of ElectroMagnetic Compatibility (EMC), including individually and combinations of:

- IMT-2000 CDMA Direct Spread (UTRA and E-UTRA, i.e. LTE);
- IMT-2000 CDMA Multi-carrier;
- GSM equipment meeting Phase 2, and Phase 2+ requirements;
- IMT Multi-Standard Radio (MSR);
- IMT OFDMA TDD WMAN (Mobile WiMAX).

Technical specifications related to the antenna port and emissions from the enclosure port of radio equipment (base station (BS), and repeaters) are not included in this standard. Such technical specifications are found in the relevant product standards for the effective use of the radio spectrum. Examples of base station equipment covered by the present document are given in annex A. In case of differences (for instance concerning special conditions, definitions, abbreviations) between the present document and EN 301 489-1, the provisions of EN 301 489-50 take precedence. The environmental classification and the emission and immunity requirements used in the present document are as stated in EN 301 489-1, except for any special conditions included in the present document.

EN 302 065-1 - EMC and Radio Spectrum Matters (ERM); Short Range Devices (SRD) using Ultra-Wideband Technology (UWB) for Communication Purposes; Harmonized EN Covering the Essential Requirements of Article 3.2 of the R&TTE Directive; Part 1: Requirements for Generic UWB Applications - *2/7/2014*

EN 302 065-1 applies to transceivers, transmitters and receivers utilizing Ultra WideBand (UWB) technologies and used for short range applications. The present document applies to impulse, modified impulse and RF carrier based UWB communication technologies. The present document applies to fixed (indoor only), mobile or portable applications, e.g.:

- stand-alone radio equipment with or without its own control provisions;
- plug-in radio devices intended for use with, or within, a variety of host systems, e.g. personal computers, hand-held terminals, etc.;
- plug-in radio devices intended for use within combined equipment, e.g. cable modems, set-top boxes, access points, etc.;
- combined equipment or a combination of a plug-in radio device and a specific type of host equipment.

As per the ECC/DEC/(06)04 and Decision 2007/131/EC and its amendment, the UWB transmitter equipment conforming to the present document is not to be installed at a fixed outdoor location, for use in flying models, aircraft and other forms of aviation. The present document applies to UWB equipment with an output connection used with a dedicated antenna or UWB equipment with an integral antenna.

EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN)

EN 12016:2013 - Electromagnetic Compatibility Product Family Standard for Lifts, Escalators and Moving Walks – Immunity - *8/31/2013*

EN 12016:2013 specifies the immunity performance criteria and test levels, including the basic safety requirements in regard to their electromagnetic environment, for apparatuses used in lifts, escalators and moving walks that are intended to be permanently installed in buildings. These levels represent essential EMC requirements. The standard refers to EM conditions as existing in residential, office and industrial buildings. This standard addresses commonly-known EMC related hazards and hazardous situations relevant to lifts, escalators and moving walks when they are used as intended and under the conditions foreseen by the lift installer or escalator and/or moving walk manufacturer. However, the performance criteria and test levels for apparatuses/assembly of apparatuses used in general function circuits does not cover situations with an extremely low probability of occurrence. This standard does not apply to other apparatus already proven to be in conformity to the EMC Directive and not related to the safety of the lift, escalator or moving walk, such as lighting apparatus, communication apparatus, etc. This standard does not apply to electromagnetic environments such as radio-transmitter stations, railways and metros, heavy industrial plants, or electricity power stations, which require additional investigations. This standard is not applicable to apparatuses that were manufactured before the date of its publication as EN 12016.

EUROPEAN COMMITTEE FOR ELECTROTECHNICAL STANDARDIZATION (CENLEC)

EN 50413:2008/A1:2013 - Basic Standard on Measurement and Calculation Procedures for Human Exposure to Electric, Magnetic and Electromagnetic Fields (0 Hz – 300 GHz) - *9/2/2014*

EN 50413:2008/A1:2013 gives elements to establish methods for measurement and calculation of quantities associated with the assessment of human exposure to electric, magnetic and electromagnetic fields (EMF) in the frequency range from 0 Hz to 300 GHz. The major intention of this basic standard is to give the common background and information to relevant EMF standards. This basic standard does not go into details extensively due to the broad frequency range and the huge amount of possible applications. Therefore, it is not possible to specify detailed calculation or measurement procedures in this Basic Standard. This standard provides general procedures only for those product and workplace categories for which there do not exist any relevant assessment procedures in any existing European EMF basic standard. If there exists an applicable European EMF standard focused on specific product or workplace categories, then that standard supersedes this one. If an applicable European EMF standard does not exist, but an applicable assessment procedure in another European EMF standard does exist, then that assessment procedure should be used. This standard deals with quantities that can be measured or calculated in free space, notably electric and magnetic field strength or power density, and includes the measurement and calculation of quantities inside the body that forms the basis for protection guidelines. In particular the standard provides information on:

- definitions and terminology
- characteristics of electric, magnetic and electromagnetic fields
- measurement of exposure quantities
- instrumentation requirements
- methods of calibration
- measurement techniques and procedures for evaluating exposure
- calculation methods for exposure assessment.

EN 50566:2013 - Product Standard to Demonstrate Compliance of Radio Frequency Fields from Handheld and Body-Mounted Wireless Communication Devices Used by the General Public (30 MHz – 6 GHz) - *2/11/2014*

EN 50566:2013 covers any electromagnetic field-emitting device intended to be used with the radiating component in close proximity to the human body (i.e. less than 20cm), including devices operated in front of the face. The frequency range is 30 MHz to 6 GHz.

SOCIETIES

Professional Societies

IEEE ELECTROMAGNETIC COMPATIBILITY SOCIETY (S-27)

IEEE Operations Center
445 Hoes Lane, P.O. Box 6804
Piscataway, NJ 08855-1331
Phone: 732-981-0060
Website: www.emcs.org
President: J. Roberto B. de Marca

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.

Membership in the IEEE is on a qualified basis, with a basic annual fee of between $140 and $180 depending on the region of the world. The U.S. fee is $183. The Institute offers major medical and life insurance at low group rates, and each member receives a copy of the monthly publication, Spectrum. Affiliate, associate, and student memberships are available for those who do not qualify for regular membership; and special arrangements are provided for those temporarily out of work. Members may join one or more of the 39 technical societies by paying the additional individual society fee(s). The EMC Society has an annual fee of $30. Student memberships are $15.

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.

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.

Chairmen of these committees welcome assistance and indications of interest in committee activities from the EMC Society membership. EMC Society activities are provided by 54 chapters with members in 61 countries worldwide.

A committee directory, listing officer, board, committee, and chapter contacts' names, addresses, and telephone numbers, is available on the IEEE EMC Society website at www.emcs.org.

The EMC Society is also active in technical conferences and symposia through its sponsorship of the annual International Electromagnetic Compatibility Symposium and participation in other worldwide symposia. Symposia and conferences are announced in the EMC Society Newsletter.

The IEEE Symposium on Electromagnetic Compatibility will be held in Long Beach, Calif. USA from August 14-19, 2011. Visit the Symposium website at www.emc2011.org.

The EMC Society has published a number of standards. For information on EMC Society and other IEEE standards, contact the IEEE Operations Center.

2014 EVENTS

- **IEEE EMC Society Board of Directors Meetings**
  Aug. 3 and 7, 2014, Raleigh, North Carolina
- **IEEE EMC Chapter Colloquium and Exhibition "Table-Top Shows"**
  March 20 - Seattle, Washington
  The Reverb Chamber, Anechoic Chamber and OATS Users Group Meeting
  Marriott Seattle Waterfront Hotel
  Downtown Seattle, Washington
  Janet O'Neil
  Email: janet.oneil@ets-lindgren.com

  May 6 - Chicago, Illinois
  Speakers and topics to be announced
  Itasca Country Club, Itasca, Illinois
  Frank Krozel, Electronic Instruments
  Email: frank@electronicinstrument.com
  www.emcchicago.org

  May 8 - Detroit, Michigan
  Speaker and topic to be announced
  Canton Summit on the Park
  Scott Lytle, Yazaki North America
  Email: scott@emcsociety.org
  www.EMCSOCIETY.org/emcfest

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, development and implementation of product safety engineering for electronic and electromechanical 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. The next conference will be in Portland, Oregon, USA on November 5-7, 2012. The Symposium 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 http://www.ieee-pses.org/symposium/. 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

22117 NE 10th Place
Sammamish, WA 98074
Fax: 425-868-0547
Email: j.n.oneil@ieee.org

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. 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 only.

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

ESD ASSOCIATION

ESD Association
7900 Turin Road, Building 3
Rome, NY 13440-2069
Phone: 315-339-6937
Fax: 315-339-6793
Email: info@esda.org
Website: www.esda.org

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.

ELECTROSTATIC 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.

Although ESD programs have been part of some ISO 9000 audits in the past, the assessment frequently has been cursory and actual judgment of the program has been left to the individual auditor. ANSI/ESD S20.20 provides a formal, consistent process standard that can be audited. It provides a single, auditable ESD standard for OEM's, suppliers, and contractors. To date, there are approximately 132 facilities in 13 countries that have become ANSI/ESD S20.20 certified.

Accredited registrars conduct the actual assessments of the companies. The association has developed a training program for the registrars and supervises registrar witness audits. This independent assessment of a company's ESD control program could be performed as part of the company's ISO 9000 surveillance audit or as a separate audit. Currently, there are 161 trained auditors in 13 countries who have been certified to conduct ANSI/ESD S20.20 audits.

In addition, the ESD Association offers an ESD program documentation review service. For a fee of $1,500 (US), members of the ESD Association's Facility Certification committee will review your ESD program documentation and will compare it to the requirements listed in ANSI/ESD S20.20-2007. Facilities that choose to become certified will use the ANSI/ESD S20.20-2007 standard as the basis for their certification. A report will be provided that describes the areas that need to be improved for documentation to be compliant with ANSI/ESD S20.20-2007. This service should be considered a MUST for any company that is preparing for facility certification based on ANSI/ESD S20.20-2007.

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 September 9-14, 2012, at the Westin Tucson, La Poloma, Arizona, USA, 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.

TECHAMERICA ELECTROMAGNETIC COMPATIBILITY COMMITTEE

1401 Wilson Blvd., Suite 1100
Arlington, VA 22209
Phone: 703-284-5344
Website: www.geia.org

TechAmerica is the association that was created by the merger of AeA and ITAA. Earlier in 2008, ITAA and GEIA merged. The result of these mergers is an organization that is the leading voice for the U.S. technology industry, which is the driving force behind productivity growth and jobs creation in the United States. TechAmerica is the technology industry's only grassroots-to-global advocacy network. With nearly 1200 member companies, 20 regional councils and offices in Beijing and Brussels, the association represents the full spectrum of the technology industry.

TechAmerica is the technology industry's only grassroots-to-global advocacy network. The organization has expanded initiatives in areas such as information Assurance / Information Security, Identity Management, Cloud Computing, Global Sourcing / Globalization, Intelligence agencies, Department of Defense & NASA, and State & Local programs and public policy advocacy.

TechAmerica provides programs for business development, networking and market intelligence in the Federal arena, dealing with government entities such as Department of Defense, Homeland Security, Federal Communications Commission, Federal Trade Commission, Congress, as well as with state and local governments.

TechAmerica has a team of public policy professionals at state, federal and international levels that allow the organization to successfully influence legislative and regulatory issues that affect member companies.

In addition, TechAmerica offers an active standards development program to provide industry with proven solutions to business process challenges. The program is nationally and internationally recognized for its leadership and expertise in the development of standards. Configuration Management, Systems Engineering, Systems Safety, Earned Value Management, Logistics, Reliability and Electromagnetic Compatibility (EMC) area where TechAmerica is involved in standard.

The Electromagnetic Compatibility (EMC) Committee (formally known as G-46) deals with the system-oriented discipline that ensures electromagnetic compatibility in electronics design. The Committee develops technical criteria and procedures to guide the design engineer. Its work also includes spectrum management and conservation; secure communications; and electromagnetic emissions, susceptibility, control, and characterization.

The EMC Committee was established to provide an industry/user position on government specifications, regulations, and standards. Participation has expanded to include G-46 representation on the various committees drafting government specifications and standards. For example, G-46 participated on the working committees for MIL-STD-464A and MIL-STD-461E and provided update recommendations to MIL-STD-461F. The scope of G-46 activities has expanded to foster and facilitate the EMC discipline for the benefit of TechAmerica member companies.

Committee activities include spectrum management and conservation; personnel safety; and health care electronics design, usage and installation in terms of regulated and non-regulated electromagnetic (EM) emissions and immunity. Inter- and intra-environmental areas as they affect systems, subsystems and equipment, subassemblies, and components are also areas of concern. In addition to other activities, committees:

- Review, assess, advise and coordinate related activities of organizations/individuals in government, industry, and technical societies.
- Assure that EMC legislation, regulations, specifications, standards, requirements, and evaluation procedures are adequate for procurement and application.
- Assure that EMC legislation, regulations, specifications, standards, requirements, and evaluation procedures are harmonized with their commercial counterparts to the maximum extent practical for procurement and application.
- Propose and recommend action and provide support to other organizations, as deemed desirable.
- Coordinate and promulgate information to facilitate advancement of the state-of-the-art.

Additional information on TechAmerica and the EMC Committee (G-46) can be obtained at (703) 284-5315, phyllis.call@techamerica.org, or via the GEIA website at http://www.geia.org.

SOCIETY OF AUTOMOTIVE ENGINEERS

400 Commonwealth Drive
Warrendale, PA 15096-0001
Phone: 724-776-4841

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 PRACTICES (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.**

iNARTE

Ste. 301, 600 N. Plankinton Ave.
Milwaukee, WI 53201
Phone: 888-722-2440
Fax 414-765-8661
Email: service@inarte.us
Website: www.inarte.org

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).

In 1993, iNARTE, certified by the Federal Communications Commission (FCC) as a Commercial Operators License Examination Manager (COLE Manager), was authorized to administer all examination elements for FCC licensure (formally an FCC responsibility).

In 1994, the ESD Association selected NARTE to implement and administer a certification program for Electrostatic Discharge Control Engineers and Technicians.

During 1997, two nations, China and Japan, requested iNARTE assistance in the establishment of specific in-country certification programs comparable to and able to meet iNARTE certification standards.

In 2000, iNARTE established the Unlicensed Wireless Systems Installer certification to identify fully qualified design and installation personnel. This certification accredits professionals who design and install wireless systems that do not require a license from the FCC —including information systems, security systems, and transportation systems.

In 2001, iNARTE developed an Agreement with the IEEE EMC Society for the co-promotion of awareness and education in EMC/EMI fields. Today the EMC Society is the keeper of the body of knowledge from which the iNARTE examinations are derived.

In 2003 iNARTE, together with specialist partners, developed the Product Safety certification program. The Product Safety program accredits professionals who use hazard-based analysis to identify and develop solutions to eliminate or minimize safety hazards. In 2004 iNARTE signed an Agreement with the IEEE Product Safety Engineering Society, PSES, to co-promote awareness and education in Product Safety. Today, technical experts within the PSES assist iNARTE in the development of the examination question pools.

In 2006 iNARTE executed Agreement with ANSI ASC 63, the Accredited Standards Committee on EMC, for the purposes of joint cooperation and promotion in education and technical achievement in EMC engineering.

By 2007, the global interest and participation in iNARTE Certification programs had resulted in almost one quarter of members being from overseas countries. In recognition of this, the iNARTE Board of Directors voted unanimously to change the association name to the, "International Association for Radio. Telecommunications and Electromagnetics, iNARTE."

As iNARTE, an agreement of mutual support and cooperation was signed with the ESD Association in 2007. The ESDA will assist iNARTE in formulating and maintaining the question pools from which certification examinations are derived

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ACIL—THE AMERICAN COUNCIL OF INDEPENDENT LABORATORIES

1875 I Street, NW, Suite 500
Washington, DC 20006
Phone: 202-887-5872
Fax: 202-887-0021
Email: Info@acil.org
Website: www.acil.org

The American Council of Independent Laboratories (ACIL) 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.

Over the past several years, ACIL has administered round robin proficiency testing programs with two artifacts allowing laboratories to make both AC line conducted and radiated emissions measurements over the frequency range of 0.15–30 MHz and 30 MHz–1 GHz, respectively.

While continuing the round robins in the frequencies noted above, ACIL has launched another round robin with a new test artifact. This artifact will allow participating laboratories to demonstrate proficiency for radiated emissions measurements in the frequency range of 1–18 GHz. Emissions measurements above 1 GHz are becoming increasingly common with the advent of fast processors and wireless devices in the 2.4- and 5-GHz bands.

ACIL also was instrumental in the formation of the Telecommunication Certification Body Council (TCBC). New rules establishing TCBs were adopted by the FCC in December 1998, providing more options for manufacturers—they can now choose to have their product certified by either the FCC or a private certification body (TCB). A TCB may approve equipment subject to certification (e.g., transmitters, telecom terminal equipment, or scanning receivers). The TCB Council addresses the specific concerns of the TCB community and all constituent bodies are permitted to participate.

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 ($3P^2C^2$). 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.

Government Directory

The following is a list of the principal government personnel involved in EMC/EMI. This list is based upon best available data at the time of publication. Additions, deletions and corrections for any facility may be updated at any time by e-mailing your changes to bstas@interferencetechnology.com.

DEPARTMENT OF DEFENSE

Defense Spectrum Organization
DSO Director: Stuart F. Timerman 703-325-2567
Stuart.Timerman@disa.mil
DSO Dep Dir: Mr. Ralph Puckett. 703-325-2874
Ralph.Puckett@disa.mil

Strategic Planning Office (SPO)
SPO Director 703-325-0435
Internat'l Team Lead: Mr. Chris Hofer 703-325-2876
EST Team Lead: Ms. Mary Lin 703-325-0136
National Team Lead: Mr. Dan O'Neill 703-325-2606

Joint Spectrum Center (JSC)
2004 Turbot Landing, Annapolis, MD 21402-5064
Tel: 410-293-4957, Fax: 410- 293-2631
Commander, JSC (J00):
COL John J. Hickey Jr., USA 410- 293-2450
John.Hickey@jsc.mil
Commander's Group: commander@jsc.mil
Technical Director (J01):
Mr. Mike Williams 410- 293-2457
mike.williams@jsc.mil
Executive Officer (J02):
CDR Robert "Jeff" Lamont, USN 410- 293-2452
Jeff.Lamont@jsc.mil

Operations Division (J3)
Chief: LTC Kevin T. Laughlin 410-293-9813
Kevin.Laughlin@jsc.mil
Senior Engineer: Mr. Robert Lynch 410-293-9816
robert.lynch@jsc.mil
RD&A Division (J5):
Mr. Robert Schneider. 410-293-4958
robert.schneider@jsc.mil
Senior Engineer: Mr. Marcus Shellman. . . . 410-293-4959
marcus.shellman@jsc.mil
Team Lead: Mr. Matthew Grenis 410-293-9264
matthew.grenis@jsc.mil
R&D Team Lead: Mr. Serey Thai 410-293-9263
Serey.Thai@jsc.mil

Spectrum Management Information Technology Division (J6)
Acting Chief: Mr. Joseph Whitworth 410-293-9822
Plans and Resources Division (J7):
Chief: Mrs. Joanne F. Sykes 410-293-2356
joanne.sykes@jsc.mil
Applied Engineering Division (J8):
Chief: Aaron Leong, Lt Col, USAF. 410- 293-2682
Aaron.Leong@jsc.mil
Senior Engineer: Mr. Irving Mager. 410- 293-2103
irving.mager@jsc.mil
Chief, DSRMA: Mr. Ted Grove 410- 293-2222

Joint Frequency Management and Spectrum Engineering Office, Atlantic (JFMO LANT)
Director JFMO LANT (USJFCOM/J63)
1562 Mitscher Ave., Ste. 200
Norfolk, VA 23551-2488
Tel.: 757-836-8006 Fax: 757-836-8022

UNITED STATES AIR FORCE

Aeronautical Systems Center (ASC) ASC / ENAC
2145 Monahan Way
Wright-Patterson Air Force Base, OH 45433-7101
Fax: 937-255-5305
E3 Technical Advisor
Mr. Manny Rodriguez. 937-255-6957
manuel.rodriguez@wpafb.af.mil
EMI/EMC Tech Expert
Mr. Joseph M. DeBoy, ...937-255-6995
joseph.deboy@wpafb.af.mil
EMI/EMC Engineer
Mr. Brian M. Lezanic 937-255-9051
brian.lezanic@wpafb.af.mil

Aeronautical Systems Center (ASC) ASC / ENAC
2145 Monahan Way
Wright-Patterson Air Force Base, OH 45433-7017
Fax: 937-255-5305
Electromagnetic Environmental Effects (E3) Engineer
Mr. Jose Pabon Soto 937-255-7676
jose.pabon-soto@wpafb.af.mil

Aeronautical Systems Center (ASC) ASC / WKE
2590 Loop Rd. West
Wright-Patterson Air Force base, OH 45433-7142
Fax: 937-255-7749
Electromagnetic Environmental Effects (E3) Engineer
Ms. Natalia Bartholomew. 937-255-3451
natalia.bartholomew@wpafb.af.mil

Air Force Research Laboratory Headquarters
Bldg 15 Room 225
1864 Fourth Street
WPAFB, OH 45433-7132
Mr. Joe Harrington. .937-656-4636
joseph.harrington@wpafb.af.mil
Aeronautical Systems Center (ASC)
312/326 AE SW (Fighter Bomber Wing)
702 AE SG (B-2)
2690 C St., B556
Wright-Patterson AFB, OH 45433-7424
Dr. Phil Beccue 937-255-6881
Philip.Beccue@wpafb.af.mil

Aeronautical Systems Center (ASC)
312/326 AE SW (Fighter Bomber Wing)
651 AE SS (B-52)
2690 C St., B556
Wright-Patterson AFB, OH 45433-7424
FAX (937) 656-4621
Mr. Jeremy Burns . . . .(937) 255-7025
jeremy.burns@wpafb.af.mil

HQ Air Force Material Command (AFMC) AFMC / EN P
Bldg. 262/Rm N145/Post116D
Wright-Patterson AFB, Ohio 45433
Fax: 937-656-4183
Mr. John S. Welch 937-255-0651
john.welch@wpafb.af.mil

Aeronautical Systems Center (ASC)
516 AE SW (Mobility)
836 AE SG (Tankers)
2530 Loop Road West,
Wright-Patterson AFB, Ohio 45433
Mr. Robert Rosengarten . . . .(937) 255-3451
Robert.Rosengarten@wpafb.af.mil

Air Force Research Laboratory, Sensors Directorate AFRL/RYWD
2241 Avionics Circle
Bldg 620, Rm 1DG106
Wright-Patterson Air Force Base, OH 45433
EMI Laboratory
Fax: 937-656-9047
Mr. Steven Coffman. 937-528-8673
steven.coffman.ctr@wpafb.af.mil
Mr. John Zentner 937-528-8677
john.zentner.ctr@wpafb.af.mil

Aeronautical Systems Center Reconnaissance Systems Wing
303 AE SG (Global Hawk)
2640 Loop Road West
Wright-Patterson Air Force Base, OH 45433-7106
Mr. Dave Osborn. 937-255-7437
david.osborn@wpafb.af.mil

Air Force Space Command (AFSPC)
85th Engineering Installation Squadron
85 EIS/SCYM
670 Maltby Hall Drive, Ste.234
Keesler AFB, MS 39534-2633
85.eis.scym@keesler.af.mil
Specialized Engineering Flight:
Mr. George R. McNeer, SCY 228-377-1037
Electromagnetics Section Chief:
Mr. Frederick G. Blache, SCYM 228-377-3926
frederick.blache@us.af.mil
E3 Engineers:
Mr. Randal Blanchard, SCYT. 228-377-1068
randal.blanchard@us.af.mil
Captain Micah Coplan 228-377-1035
micah.coplan@us.af.mil
Ms. Kristen M. Corrigan 228-377-1073
kristen.corrigan@us.af.mil
Mr. Edward Crum, SCYM 228-377-1096
edward.crum@us.af.mil
Mr. Stephen L. Dabney 228-377-1074
stephen.dabney@us.af.mil
Mr. Tim O. Hillman 228-377-1278
timothy.hillman@us.af.mil
Mr. Justin L. Johnston. 228-377-3041
justin.johnston.4@us.af.mil
Mr. Carlton L. Jones. 228-377-1088
carlton.jones@us.af.mil
Mr. James W Laycock 288-377-1035
james.laycock@us.af.mil
Mr. Tom Lipski 228-377-1084
thomas.lipski@us.af.mil
Captain Arris Pineda 228-377-1126
arris.pineda@us.af.mil
Mr. Alton J. Richards III 228-377-1079
alton.richards@us.af.mil
Captain Jason R. Seyba. 228-377-1085
jason.seyba@us.af.mil
Mr. Gregory P. Smith 228- 377-1083
gregory.smith.7@us.af.mil

Mr. Jessie Thomas III. 228- 377-4601
jessie.thomas.2@us.af.mil
Mr. Phi D. Tran. 228- 377-1062
phi.tran@us.af.mil
Mr. Truong X. Vu 228- 377-1866
truong.vu@us.af.mil
Mr. Brandon Walker. 228- 377-1048
brandon.walker.1@us.af.mil
Sr. Electronics Engineer:
Mr. Robert (Nick) Wilson 228- 377-1047
robert.wilson.6@us.af.mil

UNITED STATES ARMY

U. S. Army Research, Development and Engineering Command (RDECOM)
Attn.: AMSRD-AAR-AEP-F
Bldg. 3208
Picatinny Arsenal, NJ 07806-5000
Fax: (73-724-3025
Mr. Tom Crowley, Supvr. 973-724-5678
thomas.m.crowley@us.army.mil
Mr. Daniel Gutierrez, Sr. Proj. Engr. 973-724-4667
daniel.gutierrez@us.army.mil
Mr. Paul Lee, Proj. Engr.. 973-724-4584
paul.m.lee@us.army.mil

Army Research, Development, and Engineering Command (RDECOM)
Attn: RDMR-AES-E3
Building 4488
Redstone Arsenal, AL 35898-5000
Fax: 256-313-3194
E3 for Army Aircraft Airworthiness
E3 Branch Chief:
Mr. Dave Lewey. 256-313-8464
dave.lewey@us.army.mil
E3 Team Lead, Attack/Recon/Cargo Team:
Ms. Karen Compton .256-313-8437
karen.compton@us.army.mil
E3 Team Lead, Utility/Fixed Wing/SOA Team:
Mr. Duane Driver 256-313-8447
duane.driver@us.army.mil
Mr. Dale Heber 256-313-2229
dale.heber@us.army.mil
Mr. Bruce Hildebrandt 256-313-8457
bruce.hildebrandt@us.army.mil
Mr. Elliot Croom 256-842-5387
Elliot.croom@amrdec.army.mil
Mr. Abner Merriweather. 256-313-8470
abner.merriweather@us.army.mil
Mr. Brian Smith,iNCE, iNCT 256- 313-8484
brian.smith42@us.army.mil
Mr. John Trp . . . .
256-313-3148
john.trp@us.army.mil
Mr. Mike Dreyer 256-313-6384
michael.dreyer@us.army.mil
Mr. Dan Hinton 256-313-8497
daniel.w.hinton@us.army.mil
Mr. David Alan Landrith. 256-313-9102
david.landrith@amrdec.army.mil
Mr. Roy Lawson 256-313-8454
roy.lawson@us.army.mil
Mr. Chris Myers 256-842-3197
Christopher.myers@amrdec.army.mil
Mr. Thad Paone. 256-842-1387
Thad.paone@us.army.mil
Attn.: AMSAM-RD-MG-SD

Army Test and Evaluation Command (ATEC) United States Army Aberdeen Test Center (ATC) Electromagnetic Interference Test Facility (EMITF)
Attn.: TEDT-AT-C4
400 Colleran Road, Building 456
Aberdeen Proving Ground, MD 21005-5059
Fax: 410- 278-0579
EMITF Supervisor:
Mr. Michael C. Geiger 410- 278-2598
michael.c.geiger.civ@mail.mil
Senior Electrical Engineer:
Mr. Clinton Sienkiewicz. 410- 306-1334
clifton.j.sienkiewicz.civ@mail.mil
Electronic Technicians:
Mr. Duane Buono 410- 278-3005
duane.buono.ctr@mail.mil
Mr. Emmanuel Hammett 410- 278-3161
Emmanual.hammett.ctr@mail.mil
Mr. Mark Connor. 410- 278-3189
Mark.j.connor3.ctr@mail.mil
JR Gildeleon 410- 278-3008
john.r.gildeleon.ctr@mail.mil
Mr. Todd Holman 410- 278-3022
richard.t.holman.ctr@mail.mil
Mr. Harry Giles 410- 278-3232
Harry.j.giles.ctr@mail.mil
Mr. Nate Reyerson 410-278-3176
Nathan.p.reyerson.ctr@mail.mil

Army Center for Health Promotion & Preventive Medicine (CDR USACHPPM)
Radiofrequency/Ultrasound Program
Attn.: MCHB-TS-ORF
5158 Blackhawk Road
Aberdeen Proving Ground, MD 21010-5403
Mr. John J. DeFrank. 410-436-3353

Bureau of Medicine and Surgery (M3F72)
2300 E. St., N.W.
Washington, DC 20372-5300
Fax: 202-762-0931

Army Engineer Research and Development Center - Construction Engineering Research Laboratory
Attn.: CEERD-CF-F
P.O. Box 9005
Champaign, IL 61826-9005
Dr. William J. Croisant 217-373-3496
william.j.croisant@erdc.usace.army.mil

Army Electronic Proving Ground Test Engineering Directorate
Laboratory Division
Attn.: TEDT-EP-TEL
Fort Huachuca, AZ 85613-7110
Div. Chief Mr. Rafael Anton. 520- 538- 4916
rafael.anton@us.army.mil

E3 Test Facility/Blacktail Canyon
Mr. James Smith 520- 538-5188
james.a.smith4@us.army.mil
Ms. Rachel Blake 520- 538-2818
rachel.m.blake@us.army.mil
Mr. David Seitz 520- 533-5819
david.seitz3@us.army.mil

Antenna Test Facility
Technical Lead: Mr. Doug Kremer 520-533-8170
douglas.kremer@us.army.mil

Army Intelligence and Security Command G-4, Technical Support Division
Attn.: IALO-T
8825 Beulah St.
Ft. Belvoir, VA 22060-5246
Tel.: 703-428-4479 (DSN: 328-4479)
Fax: 703-428-4911 (DSN: 328-4911)
Ms. Anne Bilgihan
anne.g.bilgihan.civ@mail.mil

Army Nuclear and Chemical Agency (USANCA)
7150 Heller Loop, Ste. 101
Springfield, VA 22150-3198
Mr. R. Pfeffer. 703-806-7862

Army Research Laboratory (ARL)
Survivability/Lethality Analysis Directorate (SLAD)
Bldg 1628, AMSRD-ARL-SL-ES WSMR, NM 88002
575-678-7650
jose.reza@us.army.mil

White Sands Test Center
Attn.: TEDT-WSV-E (S Jesson)
Building 21225
White Sands Missile Range, NM 88002-5158
Ms. Stephanie Jesson. 575-678-6107
Stephanie.s.jesson.civ@mail.mil
Ms. Janet Danneman 575-678-6307
Janet.danneman.civ@mail.mil
Mr. Gustavo Sierra 575-678-2038
Gustavo.l.sierra.civ@mail.mil
Mr. John Chavarria. 575-678-1993
John.p.chavarria.civ@mail.mil

Army Test and Evaluation Command (ATEC United States Army Electronic Proving Ground (EPG) Enterprise Test Services Directorate Electromagnetic Environmental Effects/TEMPEST and Antenna Division
ATTN: TEDT-EP-SEA
2000 Arizona Street
Fort Huachuca, AZ 85613-7063
E3/TEMPEST
Test Officers
Mr. James A. Smith .520-538-5188
james.a.smith4.civ@mail.mil
Mr. Thomas Q. Markham 520-538-1802
thomas.q.markham.civ@mail.mil
Mr. Fulton K. Woo. 520-533-8266
Fulton.k.woo.civ@mail.mil
Mr. David L. Seitz 520-533-7529
david.l.seitz14.civ@mail.mil
Mr. Garrett V. Rude. .520-538-5623
garrett.v.rude.civ@mail.mil
Antenna Technical Lead
Mr. Douglas P. Kremer 520-533-8170
douglas.p.kremer.civ@mail.mil
Test Officer
Mr. Anthony C. Sanchez 520-533-9874
anthony.c.sanchez.civ@mail.mil
Ms. Rachel M. Blake 520-538-0726
rachel.m.blake.civ@mail.mil

UNITED STATES MARINE CORPS

Marine Corps Operational Test and Evaluation Activity (MCOTEA)

3035 Barnett Ave., Quantico, VA 22134, Chief of Test (703) 432-0927, Marine Corps Systems Command (MCSC), Attn.: Mr. Praful Bharucha (C4II/ACENG), 2000 Lester Street, Quantico, VA 22134-5010
E3 Control Program Sponsor
Mr. Praful Bharucha .703-432-3806
praful.bharucha@usmc.mil

UNITED STATES NAVY

MID-LANT Area Frequency Coordination Office; Naval Air Warfare Center Aircraft Division

Code 5.2.2.2
23013 Cedar Point Road, Unit 4, Building 2118
Patuxent River, MD 20670-1183
Fax: 301- 342-1200
Mr. Robert Tate. 301- 342-8632
robert.d.tate1@navy.mil
Mr. John Tonello 301- 342-2158
john.tonello@navy.mil
Mr. Thierry Wandji 301-342-3297
ketchiozo.wandji@navy.mil

Naval Air Warfare Center Aircraft Division

Electromagnetic Interference Lab, 5.4.4.9
Patuxent River, MD, Fax: 301- 342-5390
EMI Lab
EMC Branch Head: Mr. Mark Mallory . . . 301-342-1663
Mark.Mallory@navy.mil
Mr. Omar Ali 301-342-7814
Omar.Ali@navy.mil
Mr. Rich Andrusko 301-342-7810
Richard.Andrusko@navy.mil
Mr. Mike Clelland 301-342-8605
Michael.Clelland@navy.mil
Mr. Jack Farren. 301-342-7816
Jack.Farren@navy.mil
Mr. John Finley 301-342-4855
John.Finley@navy.mil
Ms. Xuyun Gan 301-757-8725
Xuyun.Gan@navy.mil
Mr. Donald Goddard. 301-342-7786
Donald.I.Goddard@navy.mil
Ms. Tonja Goldring 301-342-6108
Tonja.Goldring@navy.mil
Mr. Scott Graham. 301-342-7809
Scott.Graham@navy.mil
Mr. Matt Griffith. 817-777-4256
Matthew.Griffith@navy.mil
Mr. Remash Guyah. 301-342-8681
Remash.Guyah@navy.mil
Mr. Scott Halt 301-342-7575
Scott.Halt@navy.mil
Mr. Ryan Hanks 301-342-7785
Ryan.Hanks@navy.mil
Mr. Danny Johnson 301-342-7811
Daniel.r.Johnson@navy.mil
Mr. Jim Lewis 301-342-5845
James.g.Lewis@navy.mil
Mr. Jeff Miller. 301-757-0019
Jeffrey.C.Miller@navy.mil
Mr. Tim Moynihan .301-342-7846
Timothy.Moynihan@navy.mil
Mr. Mike Nahaj 301-342-3554
Michael.Nahaj@navy.mil
Mr. Sam Niebauer 301-757-0016
Samuel.Niebauer@navy.mil
Mr. Chris Theofilis 301-342-1667
Chris.Theofilis@navy.mil

Naval Air Warfare Center Training Systems Division (NAWCTSD)

Code 6.7.2.3
12350 Research Parkway, Orlando, FL 32826-3275

Space and Naval Warfare Systems Center, Charleston (SPAWAR SYSCEN, Charleston)

P.O. Box 190022
North Charleston, SC 29419-9022
Fax: 843-218-4238
Electromagnetic Environmental Effects (E3) Branch, Code 5610
Branch Hd.: Mr. Wayne Lutzen. 843-218-5723
Wayne.lutzen@navy.mil
E3 Engineers
Reco Baker. 843-218-3988
Reco.baker@navy.mil
Mr. Frederic Duffy .843-218-4363
Frederic.duffy@navy.mil
Mr. Michael Hanna. .843-218-4039
Michael.a.hanna@navy.mil
Mr. Guillermo Leiva 843-218-7129
Guillermo.leiva@navy.mil
Mr. Thomas Sessions. 843-218-6331
Thomas.sessions@navy.mil

Space and Naval Warfare Systems Center Pacific, Pacific C4ISR Department

(SSC PAC, PAC C4ISR DEPT)
2293 Victor Wharf Access Road, Pearl City, HI 96782-3356
Fax: (808) 474-5511
Ms. Candice Saka. 808-471-4028
Candice.saka@navy.mil
Mr. Jack Munechika. 808-471-1976
Jack.munechika@navy.mil
Mr. Randy Yamada .808-474-6061
Randy.yamada@navy.mil
Mr. Lloyd Hayashida. 808-474-1967
Lloyd.hayashida@navy.mil
Mr. Laine Murakami. 808-471-0366
laine.murakami@navy.mil

SPAWAR Systems Center - Pacific (SSC-Pacific)

53560 Hull St., San Diego, CA 92152-5001
Fax: 619- 553-3791
Applied Electromagnetics Branch, Code 5541
Branch Hd.: Dr. John Meloling 619-553-2134
john.meloling@navy.mil
Mr. Jeffrey C. Allen .619-553-6566
jeffrey.allen@navy.mil
Ms. Carol Becker 619-553-1033
carol.becker@navy.mil
Mr. David C. Dawson 619-553-4075
david.c.dawson@navy.mil
Mr. David Hurdsman 619-553-4261
david.hurdsman@navy.mil
Mr. Lance Koyama .619-553-3784
lance.koyama@navy.mil
Mr. Ahn Lee 619-553-3426
ahn.lee@navy.mil
Mr. P. Michael McGinnis 619-553-5092
mike.mcginnis@navy.mil
Ms. Nazia Mozaffar 619-553-2593
nazia.mozaffar@navy.mil
Mr. Rick Nielsen 619-553-6015
rick.nielsen@navy.mil
Ms. Jeanne Rockway 619-553-3886
jeanne.rockway@navy.mil
Mr. Kianoush Rouzbehani 619- 553-3134
kian.rouzbehani@navy.mil
Raquel Sanchez-Karem 619-553-5876
raquel.sanchez-karem@navy.mil
Ricardo Santoyo-Mejia 619-553-6139
ricardo.santoyomejia@navy.mil
Anirudha Siripuram 619-553-8749
anirudha.siripuram@navy.mil
Ron Thompson 619-553-0457
ron.thompson@navy.mil
Electromagnetics Technology Branch, Code 5542
Branch Head: Matt Osburn 619-553-5941
matthew.osburn@navy.mil
Dr. Rich Adams 619-553-4313
rich.adams@navy.mil
Mr. Jim Birkett 619-553-3586
jim.birkett@navy.mil
Mr. Jose L. Chavez .619-553-5075
jose.chavez@navy.mil
Dr. Will Cronyn 619-553-5084
will.cronyn@navy.mil
Mr. Chris Dilay. 619-553-3794
chris.dilay@navy.mil
Mr. Vincent V. Dinh 619-553-7255
vincent.v.dinh@navy.mil
Ms. Silvia Goodman, Secretary 619-226-5953
silvia.goodman@navy.mil
Mr. David Hilton 619-553-2666
david.r.hilton@navy.mil
Mr. Carl P. Kugel 619-553-3066
carl.kugel@navy.mil
Ms. Wendy Massey. 619-553-9711
wendy.massey@navy.mil
Mr. Daniel Meeks 619-553-6753
daniel.meeks@navy.mil
Dr. John D. Rockway 619-553-5438
john.rockway@navy.mil
Mr. Alberto Rodriguez 619-553-5697
alberto.rodriguez2@navy.mil
Advanced Electromagnetic Technology Branch, Code 5546
Branch Hd.: Jodi McGee 619-553-3778
jodi.mcgee@navy.mil
Diana Arceo. 619-553-6344
diana.arceo@navy.mil
Lam T. Bui. 619-553-6038
lam.bui@navy.mil
Jennifer Edwards 619-553-5428
jennifer.edwards@navy.mil
Daniel R. Gaytan. 619-553-7461
daniel.gaytan@navy.mil
John L. Hunter. 619-553-5086
john.hunter@navy.mil
Lillie Jackson, Secretary 619-553-5076
lillie.jackson@navy.mil
Dr. Burt Markham. .619-553-6082
burt.markham@navy.mil
Mr. Marcus Maurer .619-553-3797
marcus.maurer@navy.mil
Mr. Aldo Monges 619- 553-6129
aldo.monges@navy.mil
Mr. Filemon Peralta 619-553-3043
filemon.peralta@navy.mil
Mr. Hoa Phan. 619-553-0148
hoa.phan@navy.mil

Mr. Randall Reeves 619-553-1032
randall.reeves@navy.mil
Mr. Anthony Ton 619-553-5428
anthony.ton@navy.mil
Mr. Daryl W. Von Mueller 619- 553-6527
daryl.vonmueller@navy.mil
Mr. Benton Wong 619-553-3043
benton.wong@navy.mil
Chief of Naval Operations
Code NC-1, PT-5451, N6F13
2000-Navy Pentagon, Washington, DC 20350-2000
Fax: (703) 601-1323
Spectrum Electromagnetic Environmental Effects (E3) & EMP Policy & Programs
Head: Mr. Dave D. Harris. . . . . (703) 601-3968
dave.harris@navy.mil
Naval Ordnance Safety and Security Activity (NOSSA)
NAVORDSAFSECACT INDIAN HEAD
Electrical Explosives Safety
Code N84
Farragut Hall, Bldg. D323, 23 Strauss Ave.
Indian Head, MD 20640-5035, Fax: 301- 744-6088
Weapons Assessment (N8)
Director: Charles Denham. 301- 744-4447
charles.denham@navy.mil

Naval Research Laboratory

Code 5348
4555 Overlook Ave., S.W., Washington, D.C. 20375-5320
Tel.: 202-404-7726, Mr. Larry Cohen
Lawrence.Cohen@nrl.navy.mil
Naval SeaSystems Command (NAVSEA)

Force Electromagnetic Environmental Effects (E3) and Spectrum Management Warfare Systems

Engineering Directorate (SEA 06)
1333 Isaac Hull Ave., S.E., Stop 5011, Washington Navy Yard, DC 20376-5011, Fax: (202) 781-4568
Force E3 and Spectrum Management Branch
Branch Head: Mr. J. Don Pierce 202-781-4214
james.d.pierce@navy.mil

Naval Surface Warfare Center, Crane Division (NSWC Crane)

Code GXS
300 Highway 361, Bldg. 3287E, Crane, IN 47522
Fax: 812-854-3589
Mr. Larry McKibben 812-854-5107
Lawrence.McKibben@navy.mil
Naval Surface Warfare Center
Dahlgren Division
5493 Marple Road, Suite 156, Dahlgren, VA 22448-5153
Electromagnetic Effects Division, Code Q50
Electromagnetic Effects Division
Chief Engineer:
Mr. Jason Bardine 540-653-7450
Jason.bardine@navy.mil
NAVSEA E3 Technical Warrant Holder:
Mr. Kurt Mikoleit. 540-653-3425
Kurt.mikoleit@navy.mil
E3 Spectrum Supportability Branch, Code Q51
Branch Head:
Mrs. Amy Sunshine Smith-Carroll 540-653-1694
amy.smith-carroll@navy.mil
E3 Spectrum Supportability Branch, Code Q51
Operations and Spectrum Support Group Lead:
Mr. Mark Flenner 540-653-7892
Mark.l.fleener@navy.mil
E3 Spectrum Supportability Branch, Code Q51
Spectrum Engineering Group Lead:
Ms. Margaret Neel. 540-653-8021
Margaret.neel@navy.mil
E3 Spectrum Supportability Branch, Code Q51
Electromagnetic Pulse Group Lead:
Mr. Blaise Corbett 540-653-2104
Blaise.corbett@navy.mil
E3 Assessment & Evaluation Branch (Q52)
Branch Head:
Mr. William T. Lenzi 540-653-3444
william.lenzi@navy.mil
E**3 Assessment & Evaluation Branch (Q52)**
EMC/EMV Evaluation Group Lead:
Mr. James McGinniss 540-653-0489
james.mcginniss@navy.mil
E3 Assessment & Evaluation Branch (Q52)
RADHAZ Program Manager:
Mr. Richard Magrogan. 540-653-3445
richard.magrogan@navy.mil
E3 Assessment & Evaluation Branch (Q52)
Weapons System E3 Group Lead:
Mr. Michael Miller 540-653-3460
michael.d.miller4@navy.mil
E3 Assessment & Evaluation Branch (Q52)
EMI/461 Lab Group Lead:
Mr. Carl Hager. 540-653-9501
carl.hager@navy.mil
E3 Assessment & Evaluation Branch (Q52)
Test Operations Group Lead:
Mr. Matthew Curtis 540-653-3439
matthew.a.curtis@navy.mil
E3 Assessment & Evaluation Branch (Q52)
Science & Technology Applications Group Lead:
Mr. Michael Slocum .540-653-2212
michael.slocum@navy.mil
E3 Assessment & Evaluation Branch (Q52)
RADHAZ Environment Characterization Group Lead:
Ms. Tamera Hay 540-653-1419
tamera.hay@navy.mil
E3 Assessment & Evaluation Branch (Q52)
Surface Maritime Sensors Group Lead:
Mr. Michael Workman. 540-653-4646
michael.l.workman@navy.mil
E3 Platform Integration Branch (Q53)
Branch Head:
Mr. Kenneth D. Larsen 540-653-3476
kenneth.d.larsen@navy.mil
E3 Platform Integration Branch (Q53)
Senior Scientist:
Dr. Greg Balchin 540-653-6037
gregory.a.balchin@navy.mil
E**3 Platform Integration Branch (Q53)**
MAAC Group Lead:
Mr. Greg Brobjorg 540-653-7075
greg.brobjorg@navy.mil
E3 Platform Integration Branch (Q53)
Combatant Group Lead:
Mr. Reza Biazaran. 540-284-0595
reza.biazaran1@navy.mil
E3 Platform Integration Branch (Q53)
CVN Group Lead:
Mr. Tim Baseler. 540- 653-0741
timothy.baseler@navy.mil
E3 Platform Integration Branch (Q53)
Computational Electromagnetics Group Lead:
Mr. Bryan Wagaman 540- 653-3430
bryan.wagaman@navy.mil
E3 Systems Interoperability Branch, Code Q54
Branch Head:
Mr. Rich Link 540- 653-8907
rich.link@navy.mil
E3 Systems Interoperability Branch, Code Q54
Shipboard EMC Improvement Program Lead:
Mr. Mark Hamer 540- 284-0711
mark.hamer@navy.mil
E3 Systems Interoperability Branch, Code Q54
Force E3 Interoperability Group Lead:
Mr. John "Bart" Barbee 540- 653-3483
john.s.barbee@navy.mil
E3 Systems Interoperability Branch, Code Q54
Communication Systems E3 Interoperability Group Lead:
Mr. Cris Lake 540- 653-5087
cristopher.lake@navy.mil
E3 Systems Interoperability Branch, Code Q54
Radar Systems E3 Interoperability Group Lead:
Mr. Al Pitts. 540- 653-6268
albert.pitts@navy.mil
E3 Systems Interoperability Branch, Code Q54
Electronic Warfare Systems E3 Interoperability Group Lead:
Mr. Brad Conner 540- 653-0610
bradley.conner@navy.mil

Naval Undersea Warfare Center (NUWC)

1176 Howell St.
Newport, RI 02841-1708
Submarine Electromagnetic Environmental Effects (E3) Branch, Code 3431
Branch Head, 401- 832-5542
Branch Head: Mr. Craig F. Derewiany 401-832-5542
craig.derewiany@navy.mil
Mr. Scott Albert 401-832-4122
scott.albert@navy.mil
Mr. Jon Bond. 401-832-6480
jon.bond@navy.mil
Mr. Michael J. Carpenter 401-832-5540
michael.j.carpenter@navy.mil
Mr. Douglas L. DeAngelis 401- 832-5872
douglas.deangelis@navy.mil
Mr. Jamie A. Donais. 401-832-3603
jamie.donais@navy.mil
Mr. Anthony Francis. 401-832-5493
anthony.francis1@navy.mil
Mr. Edward R. Javor. 401-832-5546
edward.javor@navy.mil
Mr. Alan T. McHale. .401-832-5635
alan.mchale@navy.mil
Mr. Michael P. Martin 401-832-5630
michael.p.martin@navy.mil
Mr. Paul D. Opperman 401-832-4092
paul.opperman@navy.mil
Mr. Fredric A. Stawarz. 401-832-5550
fredric.stawarz@navy.mil
Mr. John L. Thibeault 401-832-5551
john.thibeault@navy.mil
Mr. Richard L. Thibeault. 401-832-5552
richard.thibeault@navy.mil
Mr. Oleg Volchansky 401-832-5399
oleg.volchansky@navy.mil
Mr. Oscar R. Zelaya .401-832-5597
oscar.zelaya@navy.mil
EMC Laboratory 401-832-5554
OPNAV N2N6F1221

Spectrum Management and Electromagnetic Environmental Effects Office Net-Centric Capabilities/Strategic and Tactical Communications Branch Information Dominance Directorate
2511 Jefferson Davis Highway, Arlington, VA 22244-0001,
Tel: 703-601-1414; Fax: 703-601-1323
Director: Mr. D. Mark Johnson 703-601-1414
david.m.johnson4@navy.mil

OTHER UNITED STATES AGENCIES

Dept. of Health & Human Services - Food and Drug Administration
Center for Devices and Radiological Health
12725 Twinbrook Pkwy. (HFZ 133), Rockville, MD 20852
Tel.: 301- 827-4944
Electrophysics Branch, Div. Physical Sciences
Mr. Howard I. Bassen, Chief
Mr. Paul S. Ruggera
Mr. Donald Witters

U.S. Environmental Protection Agency (EPA)
Office of Radiation and Indoor Air (ORIA)
Radiation Protection Division (6608J)
1200 Pennsylvania Ave., N.W., Washington, DC 20460
Fax: 202-343-3204
Director: Mr. Jonathan Edwards 202-343-9437
edwards.jonathan@epa.gov
Mr. Norbert Hankin .202-343-9235
hankin.norbert@epa.gov

Federal Aviation Administration
Headquarters- ATC Spectrum Engineering Services, AJW-6
800 Independence Avenue, S.W.
Washington, DC 20591
Spectrum Assignment & Engineering Office, AJW-1C2
Manager: Mr. Timothy Pawlowitz 202-267-9720
timothy.j.pawlowitz@faa.gov
Spectrum Planning & International Office, AJW-1C3
Manager: Mr. Robert A. Frazier 202-267-9722
Robert.Frazier@faa.gov
Federal Aviation Administration
FAA Aviation Safety (AMN-110N)
1601 Lind Ave. S.W., Renton, WA 98057
Fax: 425-917-6590
Chief Scientific & Technical Advisor - Aircraft EMC:
Mr. David Walen. 425-917-6586
dave.walen@faa.gov

Federal Communications Commission
445 12th Street, SW, Washington, DC 20554, Office of Engineering & Technology, Tel.: 202-418-2470
Chief: Julius P. Knapp
Deputy Chiefs.: Mr. Ira Keltz, Ronald Repasi, Alan Stillwell;
Associate Chief: Bruce Romano
Policy & Rules Division
Tel.: 202-418-2472
Chief: Geraldine Matise
Deputy Chief: Mark Settle
Spectrum Policy Branch
Chief: Mr. Jamison Prime
Technical Rules Branch
Chief: Ms. Karen Ansari
Spectrum Coordination Branch
Chief: John Kennedy
Electromagnetic Compatibility Division
Tel: 202-418-2475
Chief: Walter Johnston
Technical Analysis Branch
Chief: Mr. Robert Weller
Experimental Licensing Branch
Chief: Mr. James Burtle

Federal Communications Commission Laboratory
7435 Oakland Mills Rd., Columbia, MD 21046
FCC Laboratory Division
Dr. Rashmi Doshi, Chief 301-362-3011
Mr. Jim Szeliga 301-362-3051
Mrs. Pat Wright 301-362-3001
Equipment Authorization Branch
Mr. Joe Dichosco, Chief. 301-362-3024
Ms. Evelyn Cherry 301-362-3022
Mr. Steve Dayhoff 301-362-3027
Mr. Tim Harrington. 301-362-3039
Mr. Andrew Leimer 301-362-3049
Mr. Stanley Lyles 301-362-3047
Ms. Diane Poole 301-362-3034
Audits and Compliance Branch
Mr. Raymond Laforge, Chief. 301-362-3041
Mr. David Galosky 301-362-3290
Ms. Katie Hawkins. 301-362-3030
Ms. Phyllis Parrish 301-362-3045
Mr.Martin Perrine. 301-362-3025
Mr. Richard Tseng. 301-362-3054
Mr.Samuel Uganzenwoko. 301-362-3033
Technical Research Branch
Mr. William Hurst, Chief 301-362-3031
Mr. Kwok Chan 301-362-3055
Mr. James Drasher. 301-362-3047
Mr. Steve Jones 301-362-3056
Mr. Steve Martin 301-362-3052
Mr. Tom Phillips. 301-362-3044
Mr. George Tannahill 301-362-3026
Customer Service Branch
Mrs. Sandy Haase, Chief. 301-362-3013
Ms. Bessie Bordenave. 301-362-3046
Ms. Linda Elliott 301-362-3032
Mr. Tim Jamerson 301-362-3014
Mr. Ken Reitzel 301-362-3015
Ms. Bette Taube 301-362-3028
Mrs. Joycelyn Walls 301-362-3017

Goddard Space Flight Center
Greenbelt, MD 20771
Code 565 Electrical Systems Branch
Code 549.0, Electromagnetic Systems Engineering
Mr. Todd Bonalsky, PhD, lead engineer 301-286-1008
Todd.M.Bonalsky@nasa.gov

National Aeronautics and Space Administration - Kennedy Space Center
Kennedy Space Center, FL 32899
EMC Engineers
Team Lead: Ms. Dawn Trout (VA-F3), ... 321-867-5366
dawn.h.trout@nasa.gov
Mr. Ron Brewer (Analex) 321-867-5329
ronald.w.brewer-1@nasa.gov
Ms. Janessa Burford (VA-H3). 321-867-5333
janessa.l.burford@nasa.gov
Mr. Tung Doan. 321-867-5330
tung.m.doan@nasa.gov
Mr. Paul Edwards 321-867-8927
paul.edwards@nasa.gov
Mr. Gabriel Vazquez Ramos, (VAH3) 321-867-3374
gabriel.vazquezramos-1@nasa.gov
Mr. Noel Sargent (Analex). 216-433-3395
noel.b.sargent@nasa.gov
Mr. James Stanley 321-867-1991
james.e.stanley@nasa.gov
Mr. Jarek Tracz 321-867-2780
jarek.a.tracz@nasa.gov
EMC Test Engineer Manager:
Pete Aragona (NEE10) 321-867-1027
peter.s.aragona@nasa.gov

National Aeronautics and Space Administration - Langley Research Center
5 North Dryden St., Bldg. 1202, Hampton, VA 23665
Fax: 757-864-9884
EMC Test Facility (MS 130)
Ms. Courtney Rollins 757-864-7814
c.h.rollins@larc.nasa.gov
HIRF Laboratory (MS 130)
Mr. Jay J. Ely. 757-864-1868
j.j.ely@nasa.gov
Mr. Truong X. Nguyen 757-864-7528
t.x.nguyen@larc.nasa.gov
EMI/EMC Analysis and Troubleshooting (MS 488)
Dr. Arthur T. Bradley. 757-864-7343
arthur.t.bradley@nasa.gov

National Aeronautics and Space Administration - John H. Glenn Research Center
21000 Brookpark Road, Cleveland, OH 44135

National Aeronautics and Space Administration – Lyndon B. Johnson Space Center
2101 NASA Parkway, Houston, TX 77058-3696
Electronic Design & Manufacturing Branch
Branch Chf: Ms. Darilyn Peddie 281-483-8279
Deputy Branch Chf: Ms. Denise Romero . . 281-483-8056
E3 Group Lead: Dr. Robert Scully 281-483-1499
EMC Test Facility Lab Mgr: Mr. Rick Deppisch 281-483-0475

National Aeronautics and Space Administration - George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812
Spectrum Manager: Terry Luttrell 256-544-0130
Terry.Luttrell@nasa.gov
EMC Engineers (M/S ES42/4708)
Division Chief: Mr. Tony Clark. 256- 544-2394
Tony.Clark@nasa.gov
Branch Chief: Mr. Jeff Wesley 256- 544-3393
Jeff.Wesley@nasa.gov
Team Lead: Mr. Mark Krome 256- 544-5635
Mark.Krome@nasa.gov
Mr. Michael Crane (ERC) 256- 544-7259
Michael.G.Crane@nasa.gov
Mr. Tim Dew (ERC) 256- 544-3718
Timothy.M.Dew@nasa.gov
Mr. Ross Evans (Dynetics). 256- 961-2305
Ross.W.Evans@nasa.gov
Ms. Tammy Flowers. 256-961-0508
Tammy.D.Flowers@nasa.gov
Mr. Truman Glasscock (Triumph) 256-544-5318
Truman.G.Glasscock@nasa.gov
Mr. Kenneth Gonzalez (Qualis) 256- 544-1658
Kenneth.P.Gonzalez@nasa.gov
Mr. Steve R Jones 256-544-4373
Steve.Jones@nasa.gov
Mr. Steve Linthicum (Dynetics). 256-544-5312
Steven.E.Linthicum@nasa.gov

Mr. Jonathan Mack 256-544-3599
Jonathan.D.Mack@nasa.gov
Mr. Matthew McCollum 256-544-2351
Matt.Mccollum@nasa.gov
Mr. Matthew McGrath (Dynetics) 256- 544-3051
Matthew.M.McGrath@nasa.gov
Mr. Tom Perry (Jacobs) 256-544-0744
Thomas.A.Perry@nasa.gov
Mr. Glenn Shelby 256-544-0694
Glenn.Shelby@nasa.gov
EMI Test Facility 256-544-8121

National Institute of Standards and Technology

Electromagnetics Division, 687, Boulder, CO 80305
Div. Chief: Dr. Michael H. Kelley. 303-497-4736
michael.kelley@boulder.nist.gov
Secretary: Ms. Mary Filla . . . . (303) 497-3132
mary.filla@boulder.nist.gov
RF Fields Group 687.02
Group Leader: Dr. Perry F. Wilson 303-497-3406
pfw@boulder.nist.gov
Secretary: Mr. Gian Aparicio 303-497-3321
aparicio@boulder.nist.gov
Antenna Parameters (687.02 Project)
Mr. Jeffrey Guerrieri 303-497-3863
guerrieri@boulder.nist.gov
Wireless Systems (687.02 Project)
Dr. Kate Remley 303-497-3652
kate.remley@boulder.nist.gov
Field Parameters and EMC Applications (687.02 Project)
Galen Koepke 303-497-5766
koepke@boulder.nist.gov
Quantum Measurement Division, 684
Gaithersburg, MD 20899
Div. Chief: Dr. Carl Williams 301- 975-3531
carl.williams@nist.gov

National Telecommunications and Information Administration (NTIA)

U.S. Department of Commerce
1401 Constitution Ave., N.W., Washington, DC 20230
202-482-1850
Emergency Planning Subcommittee Chairman
Chief: Mr. Stephen R. Veader 202-482-4417
sveader@ntia.doc.gov
Spectrum Planning Subcommittee Chairman
Chief: Mr. Stephen Butcher. 202-482-4163
sbutcher@ntia.doc.gov
Institute for Telecommunications Sciences (ITS)
325 Broadway, Boulder, CO 80305-3328
Exec. Officer: Mr. Brian Lane 303-497-3484
blane@its.bldrdoc.gov
Director: Mr. Al Vincent. 303-497-3500
avincent@its.bldrdoc.gov
Spectrum & Propagation Measurements Division
Mr. Eric D. Nelson. 303-497-7410
enelson@its.bldrdoc.gov
Telecommunications & Information Technology Planning Division
Mr. Jeffrey R. Bratcher 303-497-5132
jbratcher@its.bldrdoc.gov
Telecommunications Engineering, Analysis & Modeling Division
Ms. Patricia Raush 303-497-3568
praush@its.bldrdoc.gov
Telecommunications Theory Division
Mr. Frank Sanders 303-497-7600
fsanders@its.bldrdoc.gov

TEMPEST CONTACTS

Army Electronic Proving Ground Enterprise Test Services Directorate

Mr. Alan Morris, Driector
Attn.: TEDT-EP-SE
2000 Arizona Street, Fort Huachuca, AZ 85613-7110
520- 533-8275
Floyd.a.morris10.civ@mail.mil

Electromagnetic Environmental Effects/ TEMPEST & Antenna Division

Attn.: TEDT-EP-SEA
2000 Arizona Street, Fort Huachuca, AZ 85613-7110
E3 Test Facility/Blacktail Canyon
Mr. James A. Smith .520-538-5188
james.a.smith4.civ@mail.mil
Mr. David Seitz. 520-533-5819
david.l.seitz14.civ@mail.mil
Mr. Garrett Rude 520-533-2818
garrett.v.rude.civ@mail.mil
Mr. Fulton Woo. 520-533-5819
fulton.k.woo.civ@mail.mil
Antenna Test Facility
Technical Lead: Mr. Doug Kremer 520-533-8170
douglas.p.kremer.civ@mail.mil
Mr Anthony Sanchez 520-533-9874
anthony.c.sanchez.civ@mail.mil
Ms. Rachel Blke 520-538-0726
rachel.m.blake.civ.mail.mil

BELGIUM

Belgian Naval Headquarters

Project Office, Kwartier Koningin Elisabeth
1 Everestraat, 1140 Brussels, Belgium
Tel.: +32-2-7013334, Fax: +32-2-7014786

CANADA

Aerospace Engineering Test Establishment (DND)

PO Box 6550, Cold Lake, AB T9M 2C6, Canada
Tel.: 780-840-8000
Mr. Serge Couture ext. 7511
serge.couture@forces.gc.ca

DENMARK

Naval Materiel Command Denmark

Danneskiold-Sasoees Alle 1 Copenhagen K 1434 Denmark
Tel.: +45-32-663266
FAX: +45-32-663299
http://smk.svn.dk

GERMANY

Bundesministerium der Verteidigung

Arbeitsbereich 2
Stauffenbergstr. 18
10785 Berlin
Tel: +49 (0) 18 88 -242424
Fax: 49 (0) 18 88-248520
bmvgprinfoab2@bmvg.bund.de

Wehrtechnische Dienststelle für Fernmeldewesen und Elektronik (WTD 81)

Center of Competence EMC
91171 Greding
Germany
Tel: +49-8463-652-0
Fax: +49-8463-652-607
www.bwb.org/wtd81

GREECE

Ministry of National Defence

Hellenic Navy Research Center (GETEN)
229 Messogion Ave.
Hollargos 155-60
Greece
Tel.: +30-210-6598100-200

ITALY

Ministry of Defense

Centro Interforze Studi per le Applicazioni Militari (CISAM)
Via della Bigattiera 10, San Piero a Grado, 56010 San Piero a Grado (Pisa), Italy
Fax: +39 050-961001
Director:
Amm. Isp. Giordano Cottini. . . . .+39 050-964200

MARITELERADAR - Instituto per le Telecomunicazioni e l'Elettronica della Marina Militare

"Giancarlo Vallauri", Viale Italia, 72-57126 Livorno, Italy
E-mail: mariteleradar@marina.difesa.it
EMC Dept.
Ric. Ing. Giancarlo Misuri. . . . . +00-39-0586-238208
EMC Section/Laboratory
Cdr. Roberto Desideri. . . . . +00-39-0586-238153
C.T.E.R. Salvatore Trovato . . . . +00-39-0586-238153

NETHERLANDS

Royal Netherlands Navy

Naval Establishment
Division Special Product/Consultancy
P.O. Box 1000
1780 CA Den Helder
The Netherlands
Tel.: +31-223-656124
Fax: +31-223-656467

Ministry of Defense - Directorate of Materials RNI Navy, Department of Naval Architecture & Marine Engineering

P.O. Box 20702
2500 ES The Hague
The Netherlands
Tel.: +31 70 3162335
Fax: +31 70 3163131

UNITED KINGDOM

Defence Science & Technology Laboratory

Headquarters
Porton Down
Salisbury, Wiltshire
SP4 0JQ
Tel.: +44 (0) 1980 613000

Product & Services Index

INTERFERENCE TECHNOLOGY'S 2014 EMC Products & Services Index contains approximately 250 different categories to help you find the equipment, components, and services you need. Locate additional product information by consulting the Advertiser Index on page 120. Full details of all the suppliers listed within each category can be found in the Company Directory, starting on page 103.

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AMPLIFIERS

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Innco Systems GmbH
Instruments for Industry (IFI)
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Next Generation Power Amplifiers
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Quarterwave Corporation
R A Mayes Company, Inc.
R&K Company Limited
Richardson RFPD
Silicon Labs
Teseq
Test Equipment Connection
TREK, INC.

AUDIO BAND POWER AMPLIFIERS

AE Techron, Inc.
TREK, INC.

MICROWAVE POWER AMPLIFIERS

Advanced Test Equipment Rentals
AR RF/Microwave Instrumentation
Empower RF Systems
Giga-tronics/Ascor Inc.
Instruments for Industry (IFI)
MCL Inc. TWT Amplifiers
MILMEGA
MITEQ
Quarterwave Corporation
R&K Company Limited
Test Equipment Connection
Vectawave

RF POWER AMPLIFIERS

Advanced Test Equipment Rentals
AR RF/Microwave Instrumentation
BONN Elektronik GmbH
Electronic Instrument Associates Central, Inc.
Empower RF Systems
Instruments for Industry (IFI)
Laplace Instruments Ltd.
Lionheart Northwest
MILMEGA
MITEQ
Next Generation Power Amplifiers
Noise Laboratory Co., Ltd.
Ophir RF Amplifiers
R A Mayes Company, Inc.
R&K Company Limited
Richardson RFPD
Teseq
Test Equipment Connection
Vectawave

SILICON CARBIDE UHF AMPLIFIERS

MILMEGA

SOLID STATE AMPLIFIERS

AE Techron, Inc.
AR RF/Microwave Instrumentation
Cree, Inc.
BONN Elektronik GmbH
Empower RF Systems
Instruments for Industry (IFI)
MILMEGA
MITEQ
Next Generation Power Amplifiers
Ophir RF Amplifiers
R&K Company Limited
Vectawave

TRAVELING WAVE TUBE (TWT) AMPLIFIERS

Applied Systems Engineering, Inc.
AR RF/Microwave Instrumentation
BONN Elektronik GmbH
CPI (Communications & Power Industries)
Instruments for Industry (IFI)
MCL Inc. TWT Amplifiers
Ophir RF Amplifiers
Quarterwave Corporation
TMD Technologies Ltd.

ANTENNAS

ANTENNA FILTERS

Captor Corp.
Fotofab
Spectrum Advanced Specialty Products

ANTENNA MASTS

ETS-Lindgren
Innco Systems GmbH

ANTENNAS

Aaronia AG
A.H. Systems, Inc.
Advanced Test Equipment Rentals
Applied Electromagnetic Technology LLC
AR RF/Microwave Instrumentation
ARA Technologies
Beehive Electronics
Com-Power Corp.
Dynamic Sciences International, Inc.
Electro-Metrics Corp.
ETS-Lindgren
Fotofab
germania elektronik GmbH
Instruments for Industry (IFI)
Laird Technologies
Liberty Labs, Inc.
Lubrizol Engineered Polymers
Noise Laboratory Co., Ltd.
Q-par Angus Ltd.
R A Mayes Company, Inc.
Spectrum Advanced Specialty Products
Sunol Sciences Corp.
TDK Corp.
TDK RF Solutions
Teseq

BICONICAL ANTENNAS

A.H. Systems, Inc.
ETS-Lindgren
Instruments for Industry (IFI)
Liberty Labs, Inc.
Teseq

E-FIELD ANTENNAS

A.H. Systems, Inc.
Advanced Test Equipment Rentals
ETS-Lindgren
Instruments for Industry (IFI)
Langer EMV-Technik GmbH

EMI TEST ANTENNAS

A.H. Systems, Inc.
Advanced Test Equipment Rentals
AR RF/Microwave Instrumentation
ETS-Lindgren
Fotofab
Instruments for Industry (IFI)
Laird Technologies
Laplace Instruments Ltd
TDK RF Solutions

H-FIELD ANTENNAS

A.H. Systems, Inc.
AR RF/Microwave Instrumentation
ETS-Lindgren
Instruments for Industry (IFI)
Langer EMV-Technik GmbH

HORN ANTENNAS

A.H. Systems, Inc.
Advanced Test Equipment Rentals
AR RF/Microwave Instrumentation
ETS-Lindgren
Instruments for Industry (IFI)
Liberty Labs, Inc.
Teseq

LOG PERIODIC ANTENNAS

Aaronia AG
A.H. Systems, Inc.
Advanced Test Equipment Rentals
ETS-Lindgren
Instruments for Industry (IFI)
Liberty Labs, Inc.

MONOPOLE ANTENNAS

ETS-Lindgren
Instruments for Industry (IFI)
Noise Laboratory Co., Ltd.

TEST ANTENNAS

Advanced Test Equipment Rentals
A.H. Systems, Inc.
AR RF/Microwave Instrumentation
Electro-Metrics Corp.

germania elektronik GmbH
Instruments for Industry (IFI)
R A Mayes Company, Inc.
Teseq

CABLES AND CONNECTORS

CABLES & CONNECTORS

AEF Solutions
Americor Electronics, Ltd.
Amphenol Industrial Operations
Brim Electronics, Inc.
Calbrooke Marketing Inc.
Captor Corp.
Carlisle Interconnect Technologies
CONEC Corp. - USA
Electri-Flex Company
ETS-Lindgren
Federal-Mogul Corporation Systems Protection
EMI Solutions Inc.
Fischer Connectors Inc.
Fotofab
Harwin
Heilind Electronics
Hi-Tech Controls
Hi-Voltage & EMI Corp.
ITT Interconnect Solutions
Ja-bar Silicone Corporation
Lutze Inc.
Megaphase
Onanon Connectors
PennEngineering
Positronic Industries
Potters Industries, Inc.
PSC Electronics
Qualtek Electronics Corp.
Quell Corp.
RIA CONNECT
Schurter Inc.
Sealcon
Spectrum Advanced Specialty Products
Swift Textile Metalizing LLC
Teledyne Reynolds
Wilcoxon Research
Wurth Electronics Midcom Inc.

FIBER OPTIC CABLES

Carlisle Interconnect Technologies
ETS-Lindgren
FiberPlex Technologies, LLC
Langer EMV-Technik GmbH
Ross Engineering Corp.

FILTER CONNECTORS

AEF Solutions
API Technologies - Spectrum Control
Carlisle Interconnect Technologies
Captor Corp.
Curtis Industries / Filter Networks
EMCCons Dr. Rasek GmbH & Co
Glenair Inc.
Heilind Electronics
Kensington Electronics Inc.
Marcom Coordinator
RF Immunity
Spectrum Advanced Specialty Products
Spectrum Control
Schurter Inc.

FILTER PIN CONNECTORS

Captor Corp.
Carlisle Interconnect Technologies
EMI Solutions Inc.
Fischer Connectors Inc.
Kensington Electronics Inc.
Onanon Connectors
Phoenix of Chicago
Spectrum Advanced Specialty Products

RETROFIT FILTERS & CONNECTORS

EMI Solutions Inc.
Quell Corporation
Schurter Inc.

CONDUCTIVE MATERIALS

CONDUCTIVE ADHESIVES, CAULKS, EPOXIES & ELASTOMERS

ARC Technologies, Inc.
Creative Materials, Inc.
Dontech, Inc.
EEMCCOIMEX
Feuerherdt GmbH
germania elektronik GmbH
HITEK Electronic Materials Ltd
Ja-bar Silicone Corporation
Leader Tech, Inc.
Master Bond
Metal Textiles Corp.
Parker Chomerics
P&P Technology Ltd.
Silicone Solutions
Sunkyoung S.T.
VTI Vacuum Technologies, Inc.
Sealing Devices Inc.
Seal Science West
Tech-Etch, Inc.

CONDUCTIVE CLOTH

ARC Technologies, Inc.
Dontech, Inc.
Eeonyx Corporation
Ja-bar Silicone Corporation
JEMIC Shielding Technolgy
Jinan EMI Shielding Technology Co., Ltd.
LBA Group Inc.
Less EMF Inc.
Marktek Inc.
Sealing Devices Inc.
Swift Textile Metalizing LLC
The Zippertubing Company

CONDUCTIVE COATINGS

ALX Technical
Amstat Industries, Inc.
Conductive Compounds Inc.
Dontech, Inc.
Ja-bar Silicone Corporation
Master Bond
Nolato Silikonteknik AB
Plastic-Metals Technologies, Inc.
Randolph Products
Sealing Devices Inc.
Sulzer Metco (Canada) Inc.
Swift Textile Metalizing LLC
VTI Vacuum Technologies, Inc.

CONDUCTIVE CONTAINERS

Custom-Pak
MµShield Company, Inc.
Swift Textile Metalizing LLC
VTI Vacuum Technologies, Inc.

CONDUCTIVE LAMINATES

Dontech, Inc.
Insul-Fab, a Div. of Concote Corporation
Ja-bar Silicone Corporation
Marian Inc.
Parker Chomerics
Polymer Science Inc.
Sealing Devices Inc.
Sulzer Metco (Canada) Inc.
Swift Textile Metalizing LLC

CONDUCTIVE MATERIALS

3M Electronics Markets
Adhesives Research, Inc.
Alchemetal
Antistatic Industries of Delaware
ARC Technologies, Inc.
Caprock Mfg.
Cool Polymers, Inc.
Creative Materials, Inc.
Desco Industries Inc.
Device Technologies, Inc.
Dontech, Inc.
EEMCCOIMEX
Eeonyx Corporation
ElectriPlast Corporation
Federal-Mogul Corporation
HITEK Electronic Materials Ltd
Intermark USA, Inc.
Ja-bar Silicone Corporation
Less EMF Inc.
LGS Technologies
M&C Specialties
Marktek Inc.
Master Bond
Metal Textiles Corp.
MTI - Microsorb Technologies, Inc.
Mueller Corp.
Nolato Silikonteknik AB
Oak-Mitsui Technologies
Optical Filters Ltd
Parker Chomerics
P&P Technology Ltd.
Premix Oy
Progressive Fillers International
Sealing Devices Inc.
Sulzer Metco (Canada) Inc.
Swift Textile Metalizing LLC
Tech-Etch, Inc.
THEMIX Plastics, Inc.
Venture Tape Corp.
VTI Vacuum Technologies, Inc.

CONDUCTIVE PAINT

Dontech, Inc.
LBA Group Inc.
Randolph Products
Parker Chomerics
Sealing Devices Inc.
Sulzer Metco (Canada) Inc.
Swift Textile Metalizing LLC

CONDUCTIVE PARTICLES

Ja-bar Silicone Corporation
Sulzer Metco (Canada) Inc.

CONDUCTIVE PLASTICS

CAPLINQ Corp.
Cool Polymers, Inc.
Dexmet Corporation
Dontech, Inc.
ElectriPlast Corporation
Optical Filters Ltd.
Parker Chomerics
Premix Oy
Sealing Devices Inc.
THEMIX Plastics
VTI Vacuum Technologies, Inc.

CONDUCTIVE PLATING

Dontech, Inc.
ElectriPlast Corporation
Ja-bar Silicone Corporation
Sealing Devices Inc.
Sulzer Metco (Canada) Inc.
Swift Textile Metalizing LLC
VTI Vacuum Technologies, Inc.

CONDUCTIVE TAPES

Bystat International Inc.
Dontech, Inc.
HITEK Electronic Materials Ltd
Intermark USA, Inc.
ITW/Pressure Sensitive Adhesives & Components
Ja-bar Silicone Corporation
M&C Specialties
P&P Technology Ltd.
Polymer Science Inc.
Swift Textile Metalizing LLC

FILTERS AND FERRITES

ABSORPTIVE FILTERS

Dontech, Inc.
Instruments for Industry (IFI)
TDK-EPC Corp

ACTIVE FILTERS

LCR Electronics, Inc.
Q-Filter Products
Richardson RFPD
Schaffner EMC, Inc.
VPT, Inc.

COAXIAL FILTER CONNECTORS

Captor Corp.
EMC Eupen, A Div. of I2R Corp.
Kensington Electronics Inc.
NexTek, Inc.
Soshin Electronics Europe GmbH
Spectrum Advanced Specialty Products

DISCOIDAL CAPACITORS

Pacific Aerospace and Electronics
Union Technology Corp.

FEED-THROUGH FILTERS

Captor Corp.
Genisco Filter Corp.
Instec Filters
LCR Electronics
NexTek, Inc.
Radius Power, Inc.
Pacific Aerospace and Electronics
Radius Power

RF Immunity Ltd.
Spectrum Advanced Specialty Products
Syfer Technology Limited
TDK-EPC Corp.
Tri-Mag, Inc.

FERRITE BEADS & CORES

AEM, Inc.
Allied Components International
Cosmo Ferrites Limited
Dexter Magnetic Technologies
EMC Solutions USA LLC
Fair-Rite Products Corp.
Ferronics, Inc.
KOA Speer Electronics
Leader Tech, Inc.
Magnet Industry Ltd.
MEC Kitagawa
National Magnetics Group, Inc.
TDK-EPC Corp.
THORA Elektronik GmbH
Vishay Intertechnology, Inc.

FERRITE SUPPRESSION COMPONENTS

ARC Technologies, Inc.
Fair-Rite Products Corp.
Spectrum Advanced Specialty Products

FERRITES

Adams Magnetic Products Co.
AEM, Inc.
Allied Components International
ARC Technologies, Inc.
Dexter Magnetic Technologies
EMC Component Group, Inc.
Fair-Rite Products Corp.
Intermark USA, Inc.
KOA Speer Electronics
Leader Tech, Inc.
Magnet Industry Ltd.
MEC Kitagawa
Spectrum Advanced Specialty Products
Taiyo Yuden (U.S.A.) Inc.

FILTER ARRAYS

Captor Corp.
Fotofab
LCR Electronics
Syfer Technology Limited
TDK-EPC Corp
Spectrum Advanced Specialty Products

FILTER CAPACITORS

API Technologies - Spectrum Control
AVX Corporation
Beijing Tempest Electronics Technologies Co. Ltd.
Captor Corp.
LCR Electronics, Inc.
NexTek, Inc.
Pacific Aerospace and Electronics
Radius Power, Inc.
Spectrum Advanced Specialty Products
Syfer Technology Limited
Synergistic Technology Group
TDK-EPC Corp.
X2Y Attenuators LLC

FILTER CHOKES

Block USA
Captor Corp.
Datatronics
Fair-Rite Products Corp.
LCR Electronics, Inc.
Radius Power, Inc.
Schaffner EMC, Inc.
Schurter Inc.
TDK-EPC Corp

FILTER COILS

Captor Corp.
Communication Coil, Inc.
Curtis Industries / Filter Networks
LCR Electronics
Radius Power, Inc.
Schaffner EMC, Inc.
Schurter Inc.
TDK-EPC Corp

FILTER MODULES

Block USA
Captor Corp.
Curtis Industries / Filter Networks
Elite EMC Ltd.
LCR Electronics
Q-Filter Products
Radius Power, Inc.
Schurter Inc.
Spectrum Advanced Specialty Products
VPT, Inc.

FILTER PINS

EMI Filter Company
Spectrum Advanced Specialty Products
Syfer Technology Limited

FILTER SEAL INSERTS

Kensington Electronics Inc.

FILTERED POWER ENTRY MODULES

Advanced Conversion Technology
Americor Electronics, Ltd.
API Technologies - Spectrum Control
Block USA
Captor Corp.
Curtis Industries / Filter Networks
Filter Concepts, Inc.
Interpower Corporation
LCR Electronics
Marcom Coordinator
Qualtek Electronics Corp.
Radius Power, Inc.
Schaffner EMC, Inc.
Schurter Inc.
Spectrum Advanced Specialty Products
Tri-Mag, Inc.

FILTERS

Advanced Conversion Technology
Advanced Monolythic Ceramics, Inc.
Aerodev Electronmagnetic Tech
Amphenol Canada Corp.
API Delevan
Arcotronics, Inc.
Aries Electronics
AVX Corporation
Block USA
Capcon International, Inc.
Captor Corp.
Cre8 Associates Ltd.
Curtis Industries / Filter Networks
E3 Displays
EESeal
Electrocube, Inc.
Elite EMC Ltd.
EMI Filter Company
EMI Solutions Inc.
EPCOS, Inc.
ETS-Lindgren
Fil-coil
Filter Concepts, Inc.
Filtronica, Inc.
Fotofab
Fuss-EMV
Genisco Filter Corp.
Gowanda Electronics
Heilind Electronics
High & Low Corporation
Instruments for Industry (IFI)
Integrated Microwave Corp.
Instec Filters
Jiangsu WEMC Technology Co.
Johanson Dielectrics, Inc.
Kensington Electronics
LCR Electronics, Inc.
Marcom Coordinator
Mercury United Electronics Inc.
MPE Limited
Murata Electronics North America
NexTek, Inc.
Oxley Developments Company Ltd.
Pacific Aerospace and Electronics
Panasonic Electronic Components
Quell Corporation
Radiotechnika Marketing Sp. z o.o.
Radius Power, Inc.
RF Immunity
RFI Corp.
Roxburgh EMC
Sabritec
Schaffner EMC, Inc.
Schurter Inc.
SiTime Corp.
Souriau PA&E
Spectrum Advanced Specialty Products
Spectrum Control
Suppression Devices
Syfer Technology Limited
Synergistic Technology Group, Inc.
TDK-EPC Corp
Texas Spectrum Electronics
Tri-Mag, Inc.
Tyco Electronics
V Technical Textiles, Inc.
View Thru Technologies, Inc.
Vishay Intertechnology, Inc.
VPT, Inc.

INDUCTORS

API Delevan
Asia Market Access (HK) Ltd . Taiwan Branch
BI Technologies
Block USA
Captor Corp.
CET Technology LLC
Curtis Industries / Filter Networks
Frontier Electronics, Corp.
Gowanda Electronics
Kensington Electronics Inc.
KOA Speer Electronics
LCR Electronics
Micrometals, Inc.
Schaffner EMC, Inc.
Schurter Inc.

MICROWAVE FILTERS

Cobham Microwave
EMI Filter Company
Instec Filters
Instruments for Industry (IFI)
Q-Filter Products
Spectrum Advanced Specialty Products
Syfer Technology Limited

POWER LINE FILTERS

Advanced Conversion Technology
ASIA & EMC CONSULTANCY, Rudolfstetten/Switzerland
Asia Market Access (HK) Ltd . Taiwan Branch
Block USA
Captor Corp.
Curtis Industries / Filter Networks
DNB Engineering, Inc.
Elite EMC Ltd.
EMC Solutions USA LLC
Emission Control, Ltd.
Filter Concepts, Inc.
Genisco Filter Corp.
High & Low Corporation
Instec Filters
JINAN Filtemc Electronic Equipment Co., Ltd.
LCR Electronics
Marcom Coordinator
MPE Limited
Radiotechnika Marketing Sp. z o.o.
Radius Power, Inc.
Reliant EMC LLC
RF Immunity
Roxburgh EMC Filters and Lighting Protectors
Schaffner EMC, Inc.
Schurter Inc.
Syfer Technology Limited
TDK-EPC Corp.
Tri-Mag, Inc.

PRINTED CIRCUIT BOARD (PCB) FILTERS

Captor Corp.
Curtis Industries / Filter Networks
LCR Electronics
Radius Power, Inc.
Schurter Inc.
Schaffner EMC, Inc.
Spectrum Advanced Specialty Products
Syfer Technology Limited
Tri-Mag, Inc.

RETROFIT FILTERS & CONNECTORS

Elite EMC Ltd.
Quell Corporation
RF Immunity
Schaffner EMC, Inc.
Schurter Inc.
Sealcon

SHIELDED ROOM FILTERS

Captor Corp.
Dontech, Inc.
Elite EMC Ltd.

EMC Solutions USA LLC
ETS-Lindgren
LCR Electronics
MPE Limited
TDK-EPC Corp.

SIGNAL LINE FILTERS

Block USA
Captor Corp.
Curtis Industries / Filter Networks
EMI Filter Company
ETS-Lindgren
Genisco Filter Corp.
LCR Electronics
Radiotechnika Marketing Sp. z o.o.
Spectrum Advanced Specialty Products
Syfer Technology Limited
TDK-EPC Corp.
WEMS Electronics

SPREAD SPECTRUM PRODUCTS

Mercury United Electronics Inc.
Silicon Labs
SiTime Corp.

SUPPRESSORS

AMETHERM, Inc.
ARC Technologies, Inc.
Bourns
Captor Corp.
Dexter Magnetic Technologies
Fair-Rite Products Corp.
Intermark USA, Inc.
MCG Surge Protection, Inc.
NexTek, Inc.

TEMPEST FILTERS

Captor Corp.
Curtis Industries / Filter Networks
Dontech, Inc.
FiberPlex Technologies, LLC
Filter Concepts, Inc.
LCR Electronics
MPE Limited
NexTek, Inc.
Radius Power, Inc.
Syfer Technology Limited
Spectrum Advanced Specialty Products

WIRE & CABLE FILTERS

Advanced Conversion Technology
Captor Corp.
LCR Electronics
Spectrum Advanced Specialty Products

SHIELDING

ANECHOIC CHAMBER CALIBRATION TO IEC 80-3

ETS-Lindgren
Panashield Inc.

ANECHOIC CHAMBERS

Albatross Projects GmbH
Comtest Engineering B.V.
Dutch Microwave Absorber Solutions
Electronic Instrument Associates Central, Inc.
ETS-Lindgren
MVG-EMC
Panashield, Inc.
Universal Shielding Corp.
Videon Central Inc.

ANECHOIC CHAMBERS – FIRE PROTECTION

ETS-Lindgren
Panashield, Inc.

ANECHOIC MATERIALS

Dutch Microwave Absorber Solutions
ETS-Lindgren
Fair-Rite Products Corp.
Panashield, Inc.

ARCHITECTURAL SHIELDING PRODUCTS

Alco Technologies, Inc.
LBA Technology Inc.
Swift Textile Metalizing LLC

BACKSHELLS, SHIELDED ASSEMBLIES, TERMINATIONS

Northern Technologies Corp.

BOARD LEVEL SHIELDS

3Gmetalworx World
Laird
Leader Tech, Inc.
Mech-Tronics
Photofabrication Engineering Inc.
Precision Photo-Fab, Inc.
Prismier - Board Level Shielding
Swift Textil Metalizing LLC
Tech-Etch, Inc.
United Western Enterprises, Inc
W. L. Gore & Associates, Inc.

BRAID

Alco Technologies, Inc.
Calmont Wire & Cable, Inc.
Syscom Advanced Materials

CABINETRY & HARDWARE

FIBOX Enclosures
Fotofab

CONDUIT, ELECTRICAL, SHIELDED, MAGNETIC & RF

Federal-Mogul Corporation Systems Protection
Ja-bar Silicone Corporation
Saint-Gobain Performance Plastics, Seals Group
Sealing Devices Inc.
VitaTech Electromagnetics
Zero Ground
The Zippertubing Company

CRT ELECTRO-OPTICAL SHIELDS

Dontech, Inc.
MµShield Company, Inc.

DIE CUT SHIELDING MATERIAL

Apex Die & Gasket Inc.
Dontech, Inc.
W. L. Gore & Associates, Inc.
Greene Rubber
Identification Products Corp.
Insul-Fab, a Div. of Concote Corporation
Ja-bar Silicone Corporation
Orion Industries Inc.
P&P Technology Ltd.
Schlegel Electronic Materials
Sealing Devices Inc.
Spira Manufacturing Corp.
Tech-Etch, Inc.
Temas Engineering

EMI GASKETS

ACS Industries, Inc.
Boyd Corporation
CGS Technologies
E-Song emc co., ltd.
Connors Company
Fabritech, Inc.
GETELE
Greene Rubber
Insulfab
Intermark USA, Inc.
Ja-bar Silicone Corporation
JEMIC Shielding Technolgy
Kemtron Ltd.
Laird
LCR Electronics
Leader Tech, Inc.
Marian Inc.
Nolato Silikonteknik AB
Parker Chomerics
P&P Technology Ltd.
Plastic-Metals Technologies, Inc.
Prismier - Board Level Shielding
Rubbercraft
Schlegel Electronic Materials
Sealing Devices Inc.
Spira Manufacturing Corp.
STACEM
Stockwell Elastomerics, Inc.
Swift Textile Metalizing LLC
Tech-Etch, Inc.
Temas Engineering
THEMIX Plastics
United Seal and Rubber Co., Inc.
VTI Vacuum Technologies, Inc.
W. L. Gore & Associates, Inc.

FACILITIES & SHIELDED ENCLOSURE SERVICES

AR Tech Engineered Fabric Products
CCPartners, Ltd.
Compac Development Corp.
DNB Engineering, Inc.
ETS-Lindgren
Panashield, Inc.
Rittal Corp.

FINGERSTOCK

Feuerherdt GmbH
Ja-bar Silicone Corporation
Kemtron Ltd.
Leader Tech, Inc.
Parker Chomerics
P&P Technology Ltd.
Sealing Devices Inc.
Tech-Etch, Inc.

GTEM CELLS

ETS-Lindgren
Instruments for Industry (IFI)
Laplace Instruments Ltd
Noise Laboratory Co., Ltd.

HARNESSES

Captor Corp.

HONEYCOMB SHIELDING

ETS-Lindgren
Ja-bar Silicone Corporation
Kemtron Ltd.
Leader Tech, Inc.
P&P Technology Ltd.
Spira Manufacturing Corp.
Tech-Etch, Inc.

IRON CORE POWDERED MAGNETIC MATERIALS

Fair-Rite Products Corp.

MAGNETIC SHIELDING

Ad-Vance Magnetics
ElectriPlast Corporation
Dexter Magnetic Technologies
Integran
Less EMF Inc.
VTI Vacuum Technologies, Inc.

MAGNETIC SHIELDING GASKETS

Kemtron Ltd.
Spira Manufacturing Corp.
STACEM
VTI Vacuum Technologies, Inc.

MAGNETIC SHIELDS

Ad-Vance Magnetics
Integran
Prismier - Board Level Shielding
VTI Vacuum Technologies, Inc.

MICROWAVE ABSORBERS

ARC Technologies, Inc.
Dutch Microwave Absorber Solutions
ETS-Lindgrenhielded
EMI Technologies, Inc.
Intermark USA, Inc.
Laird
Marktek Inc.
MVG-EMC
Parker Chomerics
Select Fabricators, Inc.
SOLIANI EMC
Source1 Solutions
Sulzer Metco (Canada) Inc.
Swift Textile Metalizing LLC

MRI SHIELDING

Dontech, Inc.
ETS-Lindgren
MµShield Company, Inc.
MVG-EMC
Panashield, Inc.
Select Fabricators, Inc.
Shielding Resources Group
Universal Shielding Corp.

RF SHIELDING GASKETS

ARC Technologies, Inc.
Delcross Technologies
Greene Rubber
Insul-Fab, a Div. of Concote Corporation

Ja-bar Silicone Corporation
Marian Inc.
Parker Chomerics
P&P Technology Ltd.
Richardson RFPD
Schlegel Electronic Materials
Sealing Devices Inc.
Spira Manufacturing Corp.
STACEM
Swift Textile Metalizing LLC
Tech-Etch, Inc.
Temas Engineering
VTI Vacuum Technologies, Inc.
W. L. Gore & Associates, Inc.

RF SHIELDING MATERIAL

Axonics, Inc.
CCPartners, Ltd.
Cybershield
Dexmet Corporation
E-Song emc co., ltd.
Federal-Mogul Corporation Systems Protection
Feuerherdt GmbH
germania elektronik GmbH
Intermark USA, Inc.
Ja-bar Silicone Corporation
Marktek Inc.
Parker Chomerics
P&P Technology Ltd.
Precision Manufacturing Group
Saint-Gobain Performance Plastics, Seals Group
Spira Manufacturing Corp.
Sulzer Metco (Canada) Inc.
Swift Textile Metalizing LLC
Tech-Etch, Inc.
THEMIX Plastics
TWP Inc.
Universal Shielding Corp.
W. L. Gore & Associates, Inc.

SCIF DESIGN CONSTRUCTION & MAINTENANCE

ETS-Lindgren
K-Form Shielded Rack Enclosures and Design
Krieger Specialty Prodcuts
Panashield, Inc.

SHIELDED AIR FILTERS

ETS-Lindgren
Ja-bar Silicone Corporation
Parker Chomerics
P&P Technology Ltd.
SOLIANI EMC
Spira Manufacturing Corp.
Tech-Etch, Inc.

SHIELDED BUILDINGS

ETS-Lindgren
Panashield, Inc.

SHIELDED CABINETS & HARDWARE

FIBOX Enclosures
K-Form Shielded Rack Enclosures and Design
MµShield Company, Inc.
Panashield, Inc.
Swift Textile Metalizing LLC

SHIELDED CABLE ASSEMBLIES & HARNESSES

Binder-USA
Brim Electronics, Inc.
Captor Corp.
Federal-Mogul Corporation Systems Protection
Fischer Connectors Inc.
Interpower Corporation
Lapp USA
MegaPhase LLC
Phoenix of Chicago
Sealcon
Swift Textile Metalizing LLC
The Zippertubing Company

SHIELDED COMPONENTS

CET Technology LLC
Federal-Mogul Corporation Systems Protection
Ja-bar Silicone Corporation
Northern Technologies Corp.
Richard Wöhr GmbH
Saint-Gobain Performance Plastics, Seals Group
Schurter Inc.
Spira Manufacturing Corp.
Swift Textile Metalizing LLC
VTI Vacuum Technologies, Inc.

SHIELDED CONDUITS

ANAMET Electrical, Inc.
Custom-Pak
Electri-Flex Company
Federal-Mogul Corporation Systems Protection
Zero Ground LLC

SHIELDED CONNECTORS

Binder-USA
Fischer Connectors Inc.
Ja-bar Silicone Corporation
Kycon
Lutze Inc.
Nolato Silikonteknik AB
Onanon Connectors
PennEngineering
Prismier - Board Level Shielding
Schurter Inc.
Sealcon
Southwest Microwave, Inc.

SHIELDED DOORS

Comtest Engineering B.V.
Dontech, Inc.
ETS-Lindgren
Krieger Specialty Prodcuts
Panashield, Inc.
Shielding Resources Group
Swift Textile Metalizing LLC

SHIELDED ENCLOSURES

ClickFold Plastics
Custom-Pak
Electrorack Enclosure Products
EMP-tronic AB
E-Song emc co., ltd.
FIBOX Enclosures
HITEK Electronic Materials Ltd
IMS Engineered Products
JEMIC Shielding Technolgy
K-Form Shielded Rack Enclosures and Design
LBA Technology Inc.
Modpak, Inc.
MµShield Company, Inc.
R A Mayes Company, Inc.
Richard Wöhr GmbH
Roxburgh EMC Filters and Lighting Protectors
Select Fabricators, Inc.
Shielding Resources Group
Universal Shielding Corp.
VTI Vacuum Technologies, Inc.

SHIELDED FANS

ETS-Lindgren
Spira Manufacturing Corp.

SHIELDED FUSE HOLDERS

Schurter Inc.

SHIELDED ROOM FILTERS

Captor Corp.
Dontech, Inc.
ETS-Lindgren
JiangSu WEMC Technology Co., Ltd.
Panashield, Inc.
TDK-EPC Corp.

SHIELDED ROOMS

Comtest Engineering B.V.
ETS-Lindgren
Holland Shielding Systems BV
I. Thomas GmbH
Krieger Specialty Prodcuts
Lionheart Northwest
Panashield, Inc.
R. A. Mayes Company, Inc.
Select Fabricators, Inc.
SOLIANI EMC

SHIELDED ROOMS, ACCESSORIES

Audivo GmbH
Ad-Vance Magnetics, Inc.
Dontech, Inc.
ETS-Lindgren
Gaven Industries Inc.
Leader Tech, Inc.
Panashield, Inc.
Shielding Resources Group, Inc.
Swift Textile Metalizing LLC

SHIELDED ROOMS & ENCLOSURES

Albatross Projects GmbH
Alco Technologies, Inc.
Allied Moulded Products, Inc.
AR Tech
Bud Industries
Captor Corp.
Comtest Engineering bv
E&C Anechoic Chambers Asia Ltd.
EMI Technologies, Inc.
EMP-tronic AB
ETS-Lindgren
Frankonia EMC
Global EMC Ltd.
Holland Shielding Systems BV
IMS Engineered Products
Instruments for Industry (IFI)
K-Form, Inc.
Marktek Inc.
Modpak, Inc.
Noise Laboratory Co., Ltd.
ORBIT Advanced Electromagnetics, Inc. (AEMI)
R. A. Mayes Company, Inc.
Rainford EMC Systems Ltd.
Select Fabricators, Inc.
Source1 Solutions
Spira Manufacturing Corp.
Stahlin Enclosures
Swift Textile Metalizing LLC
Videon Central Inc.
VTI Vacuum Technologies, Inc.

SHIELDED ROOMS, LEAK DETECTORS / MONITORS

ETS-Lindgren

SHIELDED SCANS, MONITORS & CRTS

Dontech Incorporated
Optical Filters Ltd

SHIELDED SWITCHES

Schurter Inc.

SHIELDED TRANSPARENT WINDOWS

CCPartners, Ltd.
Dontech, Inc.
Instrument Plastics Ltd.
Optical Filters Ltd.
Parker Chomerics
P&P Technology
Sealing Devices Inc.
Tempest Security Systems Inc.

SHIELDED TUBING

Federal-Mogul Corporation Systems Protection
Ja-bar Silicone Corporation
MµShield Company, Inc.
Sealing Devices Inc.
Zippertubing Company

SHIELDING

3M Electronics Markets Materials Division
A&R Tarpaulins, Inc.
Ad-Vance Magnetics
Alco Technologies, Inc.
Amuneal Manufacturing Corp.
ANAMET Electrical, Inc.
ARC Technologies, Inc.
Autosplice, Inc.
Axonics, Inc.
Bal Seal Engineering, Inc.
Binder-USA
Calmont Wire & Cable, Inc.
Central Coating Company
Chomerics, Div. of Parker Hannifin Corp.
ClickFold Plastics
Cima NanoTech, Inc.
Connors Company
Dexmet Corporation
Dontech, Inc.
East Coast Shielding
Ed Fagan Inc.
Electri-Flex Company
ElectriPlast Corporation
Emerson & Cuming Microwave Products, Inc.
E-Song emc co., ltd.
ETS-Lindgren
Fabritech, Inc.

SHIELDING COMPONENTS

SHIELDING FOILS

SHIELDING MATERIAL, MAGNETIC FIELD

SIGNAL LINE ISOLATION TRANSFORMERS

TEM CELLS

SURGE AND TRANSIENTS

ANTISTATIC COATINGS

ANTISTATIC MATERIALS

ELECTROSTATIC DISCHARGE (ESD) GENERATORS

ELECTROSTATIC DISCHARGE (ESD) SIMULATORS

EMP GENERATORS

EMP SIMULATORS

GROUNDING SYSTEMS

POWER LINE DISTURBANCE MONITOR

POWER LINE ELECTRONICS

STATIC CONTROL MATERIALS & EQUIPMENT

SUPPRESSORS

SURGE & TRANSIENTS

SURGE PROTECTION

TRANSIENT DETECTION & MEASURING EQUIPMENT

TRANSIENT GENERATORS

TRANSIENT SUPPRESSORS

UNINTERRUPTED POWER SYSTEM

TEST INSTRUMENTATION

ABSORBER CLAMPS

BIDIRECTIONAL COUPLERS

BROADBAND EMI DETECTORS

COUPLING-DECOUPLING NETWORKS

CURRENT PROBES

DESIGN SOFTWARE

AR RF/Microwave Instrumentation
AWR Corporation
CST of America, Inc.
EM Software & Systems
Integrated Engineering Software
Moss Bay EDA
Remcom Inc.
Sonnet Software, Inc.

ELECTROSTATIC CHARGE / DECAY METERS

Amstat Industries, Inc.
TREK, INC.

ELECTROSTATIC DISCHARGE (ESD) SIMULATORS

Advanced Test Equipment Rentals
CST of America, Inc.
EM Test USA
EMC Partner AG
Fischer Custom Communications
HV Technologies, Inc.

EMI RECEIVERS

AFJ Instruments srl
Agilent Technologies Inc.
AR RF/Microwave Instrumentation
GAUSS Instruments
Inceleris
Laplace Instruments Ltd.
Narda Safety Test Solutions S.r.l.

FCC PART 68 TEST EQUIPMENT

EMC Partner AG
HV Technologies, Inc.
Retlif Testing Laboratories

FIBER OPTIC SYSTEMS

Accurate Controls Ltd.
Audivo GmbH
D.A.R.E!! Consultancy
Fischer Custom Communications
Michigan Scientific Corp.
Micronor Inc.
MITEQ

FIELD INTENSITY METERS

EMC Test Design
ETS-Lindgren
Instruments for Industry (IFI)
Narda Safety Test Solutions S.r.l.
Potomac Instruments Inc.
SRICO, Inc.
TREK, INC.

GROUND RESISTANCE TESTERS

AEMC Instruments, Inc.

HELMHOLTZ COILS

ETS-Lindgren

HIGH VOLTAGE PULSE TRANSFORMERS

CET Technology LLC
Pearson Electronics, Inc.

IMPULSE GENERATORS

AMETEK Compliance Test Solutions
AR RF/Microwave Instrumentation
ASIA & EMC CONSULTANCY, Rudolfstetten/Switzerland
Compliance West, USA
EMC Partner AG
EM TEST USA
High Sierra Microwave
HV Technologies, Inc.
Ion Physics Corp.
Langer EMV-Technik GmbH
Montena Technology SA

INDUCED CURRENT METERS & PROBES

AR RF/Microwave Instrumentation
ETS-Lindgren

INSERTION LOSS TEST NETWORKS

Captor Corp.

INTERFERENCE GENERATORS

EMC Partner AG
High Sierra Microwave
HV Technologies, Inc.

ISOTROPIC FIELD SENSORS

D.A.R.E!! Consultancy
ETS-Lindgren
Instruments for Industry (IFI)
Narda Safety Test Solutions S.r.l.

LIGHTNING GENERATORS

Advanced Test Equipment Rentals
Avalon Test Equipment Corp.
EM Test USA
EMC Partner AG
HILO-TEST
HV Technologies, Inc.
Lightning Technologies, Inc.

LIGHTNING SIMULATORS

Advanced Test Equipment Rentals
EM Test USA
EMC Partner AG
HV Technologies, Inc.

LISNS

AFJ Instruments srl
ETS-Lindgren
Fischer Custom Communications
Laplace Instruments Ltd.

MAGNETIC FIELD METERS

Combinova AB
Ergonomics, Inc.
Less EMF Inc.

MAGNETIC FIELD PROBES

Agilent Technologies, Inc.
AR RF/Microwave Instrumentation
ETS-Lindgren
Langer EMV-Technik GmbH

NETWORK ANALYZERS

Advanced Test Equipment Rentals
Agilent Technologies, Inc.
AMETEK Compliance Test Solutions
ETS-Lindgren
LBA Technology Inc.

PORTABLE TEST EQUIPMENT

A.H. Systems, Inc.
Agilent Technologies Inc.
ETS-Lindgren
HV Technologies, Inc.
Instruments for Industry (IFI)
MITEQ
MPB Srl
Prostat Corp.
Rigol Technologies

RADIATION HAZARD METERS

ETS-Lindgren
Narda Safety Test Solutions S.r.l.

RADIATION HAZARD PROBES

ETS-Lindgren
Instruments For Industry (IFI)

RF POWER COMPONENTS

Cree, Inc.
EM Test USA
MCL Inc. TWT Amplifiers
MKS Instruments
MITEQ
Richardson RFPD

RF POWER METERS

Agilent Technologies, Inc.
Anritsu Company
AR RF/Microwave Instrumentation
ETS-Lindgren
Test Equipment Connection

SIGNAL GENERATORS

Agilent Technologies, Inc.
Anritsu Company
AR RF/Microwave Instrumentation
High Sierra Microwave
Laplace Instruments Ltd
Praxsym, Inc.
Rigol Technologies
York EMC Services Ltd.

SIMULATION SOFTWARE

Agilent Technologies Inc.
Ansys
CST of America Inc.
Delcross Technologies
EM Software & Systems
EMS-Plus
Integrated Engineering Software
Polymer Portal
Remcom Inc.

SPECTRUM ANALYZERS

Aaronia AG
Agilent Technologies, Inc.
Anritsu Company
Rigol Technologies
ValueTronics International, Inc.

TELECOMMUNICATIONS TEST NETWORKS

Agilent Technologies, Inc.
HV Technologies, Inc.

TEMPEST TEST EQUIPMENT

A.H. Systems, Inc.
Fischer Custom Communications

TEST ACCESSORIES

AR RF/Microwave Instrumentation
Audivo GmbH
CST of America, Inc.
EM Test USA
EMC Partner AG
EMCO Elektronik GmbH
ETS-Lindgren
Fischer Custom Communications
Innco Systems GmbH
Instruments for Industry (IFI)
TDK-Lambda Americas

TEST CAPACITORS

Captor Corp.

TEST EQUIPMENT, LEASING & RENTAL

A.H. Systems, Inc.
Advanced Test Equipment Rentals
AR RF/Microwave Instrumentation
Instruments for Industry (IFI)

TEST EQUIPMENT, REPAIR & CALIBRATION

A.H. Systems, Inc.
Adler Instrumentos SL
Agilent Technologies, Inc.
AMETEK Compliance Test Solutions
D.A.R.E!! Consultancy
Electronic Instrument Associates
Embassy Global, LLC
EMC Partner AG
EMSCAN
ETS-Lindgren
Fischer Custom Communications
Instruments for Industry (IFI)
Restor Metrology
Ross Engineering Corp.
Seibersdorf Labor GmbH

TEST INSTRUMENTATION

A.H. Systems, Inc.
Aaronia AG
Accurate Controls Ltd.
Adler Instrumentos SL
Advanced Test Equipment Rentals
Aeroflex
Agilent Technologies, Inc.
All-Spec Industries
Alltest Instrument, Inc.
AMETEK Compliance Test Solutions
Amstat Industries, Inc.
Anritsu Company
Apogee Labs Inc.
APREL Laboratories
AR RF/Microwave Instrumentation
ASR Technologies Inc.
Audivo GmbH
AWR Corporation
Barth Electronics, Inc.
Bird Technologies Group / TX RX Systems
Circuit Insights LLC
Combinova AB
Compliance West, USA
CST of America, Inc.
D.A.R.E!! Consultancy
D.A.R.E!! Instruments
Ecliptek Corp.
EM Software & Systems
EM Test USA
Embassy Global, LLC
EMC Partner AG

TEST SOFTWARE

TRANSIENT DETECTION & MEASURING EQUIPMENT

TURNTABLES

VOLTAGE PROBES

TESTING

ANECHOIC CHAMBER TESTING

AUTOMOTIVE TESTING

BELLCORE TESTING (SEE TELCORDIA)

CALIBRATION SERVICES

CALIBRATION TESTING

CERTIFICATION SERVICES

COMPETENT/CERTIFIED ACCREDITING BODIES TESTING

COMPUTER-AIDED ANALYSIS SERVICES

DIRECT LIGHTNING TESTING

ELECTROSTATIC DISCHARGE (ESD) TESTING

EMISSIONS TESTING

EMP, SGEMP SYSTEM ASSESSMENT

EMP/LIGHTNING EFFECTS TESTING

ENVIRONMENTAL TESTING

EUROPEAN CERTIFICATION TESTING

FCC PART 15 & 18 TESTING

Telcron LLC
TUV SUD America Inc.

FCC PART 68 TEST EQUIPMENT

HV Technologies, Inc.
Global Testing
Retlif Testing Laboratories

IMMUNITY TESTING

A.H. Systems, Inc.
AMETEK Compliance Test Solutions
BEC Inc.
CKC Laboratories, Inc.
Compliance Engineering Pty Ltd - Australia
D.L.S. Electronic Systems, Inc.
Electronics Test Centre (Kanata)
EMC Integrity, Inc.
F2 Labs
H.B. Compliance Solutions
LEDE-SIECIT
LS Research, LLC
Next Generation Power Amplifiers
Nemko USA - Tampa
Philips EMC Center
QAI-EMC
Radiometrics Midwest Corp.
Reliant EMC LLC
Retlif Testing Laboratories
Spitzenberger & Spies Power Amplifiers and EMC test systems
Teseq
TUV SUD America Inc.
Washington Laboratories

ISO 9000 TESTING

Electronics Test Centre (Kanata)
Swift Textile Metalizing LLC
TUV SUD America Inc.

LIGHTNING STRIKE TESTING

D.L.S. Electronic Systems, Inc.
Elite Electronic Engineering Co.
Pearson Electronics, Inc.
Radiometrics Midwest Corp.
Retlif Testing Laboratories
TUV SUD America Inc.

MIL-STD 188/125 TESTING

Little Mountain Test Facility

MIL-STD 461 / 462 TESTING

Advanced Compliance Solutions, Inc.
AMETEK Compliance Test Solutions
CKC Laboratories, Inc.
D.L.S. Electronic Systems, Inc.
DNB Engineering, Inc.
Electronics Test Centre (Kanata)
EMC Compliance
EMC Partner AG
Environ Laboratories
Little Mountain Test Facility
Harris Corp (GCSD)
MET Laboratories, Inc.
National Institute for Aviation Research
NU Laboratories
Parker Chomerics
Retlif Testing Laboratories
Radiometrics Midwest Corp.
TUV SUD America Inc.
Wyle

NAVLAP / A2LA APPROVED TESTING

A2LA
ATLAS Compliance & Engineering
Bay Area Compliance Labs Corp.
Cascade TEK
CKC Laboratories, Inc.
Core Compliance Testing Services
Compliance Management Group
Compliance Worldwide
D.L.S. Electronic Systems, Inc.
Electronics Test Centre (Kanata)
Elite Electronic Engineering Co.
Environ Laboratories
International Certification Services, Inc.
Liberty Labs, Inc.
MET Laboratories, Inc.
Northwest EMC Inc.
NU Laboratories
Radiometrics Midwest Corp.
Telcron LLC
TUV SUD America Inc.

PRODUCT SAFETY TESTING

D.L.S. Electronic Systems, Inc.
Electronics Test Centre (Kanata)
Elite Electronic Engineering Co.
F2 Labs
Eurofins Product Service GmbH
Global Testing
MET Laboratories, Inc.
Montrose Compliance Service
Nemko USA - Tampa
Professional Testing (EMI), Inc.
Retlif Testing Laboratories
R.N. Electronics Ltd.
Timco Engineering, Inc.
TUV SUD America Inc.
Washington Laboratories

RADHAZ TESTING

DNB Engineering, Inc.
Electronics Test Centre (Kanata)
Retlif Testing Laboratories

RS03 > 200 V / METER TESTING

CKC Laboratories, Inc.
D.L.S. Electronic Systems, Inc.
DNB Engineering, Inc.
Electronics Test Centre (Kanata)
Elite Electronic Engineering Co.
Radiometrics Midwest Corp.
Retlif Testing Laboratories
TUV SUD America Inc.

RTCA DO-160 TESTING

Advanced Compliance Solutions, Inc.
AE Techron
AMETEK Compliance Test Solutions
Cascade TEK
CKC Laboratories, Inc.
D.L.S. Electronic Systems, Inc.
DNB Engineering, Inc.
Electronics Test Centre (Kanata)
Elite Electronic Engineering Co.
EMC Partner AG
Environ Laboratories
Eurofins Product Service GmbH
National Institute for Aviation Research
Pacific Power Source, Inc.
Radiometrics Midwest Corp.
Retlif Testing Laboratories
TUV SUD America Inc.

SHIELDING EFFECTIVENESS TESTING

D.A.R.E!! Calibrations
D.L.S. Electronic Systems, Inc.
Dontech, Inc.
Electronics Test Centre (Kanata)
Elite Electronic Engineering Co.
EMC Integrity, Inc.
ETS-Lindgren
Federal-Mogul Corporation Systems Protection
MET Laboratories, Inc.
National Institute for Aviation Research
Radiometrics Midwest Corp.
Retlif Testing Laboratories
TUV SUD America Inc.

SITE ATTENUATION TESTING

D.A.R.E!! Calibrations
D.L.S. Electronic Systems, Inc.
Electronics Test Centre (Kanata)
ETS-Lindgren
Radiometrics Midwest Corp.
Retlif Testing Laboratories
Wave Scientific Ltd

SITE SURVEY SERVICES

D.A.R.E!! Calibrations
D.L.S. Electronic Systems, Inc.
Electronics Test Centre (Kanata)
Elite Electronic Engineering Co.
EMF Testing USA
ETS-Lindgren
F2 Labs
Kimmel Gerke Associates, Ltd.
Radiometrics Midwest Corp.
Retlif Testing Laboratories
Wave Scientific Ltd.

TELCORDIA TESTING

D.L.S. Electronic Systems, Inc.
Electronics Test Centre (Kanata)
Radiometrics Midwest Corp.

TEMPEST TESTING

National Technical Systems
Storm EMC Services Ltd

TESTING

3C Test Ltd. - EMC Testing
A.H. Systems, Inc.
A2LA
Acme Testing Company
Advanced Compliance Solutions, Inc.
Advanced Testing Services
AERO NAV Laboratories
AE Techron, Inc.
AHD EMC Lab / Amber Helm Development L.C.
Alion Science and Technology
American Environments Co., Inc.
Apache Design Solutions, Inc.
Applied Physical Electronics, L.C.
ATLAS Compliance & Engineering
BEC Inc.
Blackwood Labs
Blue Guide EMC Lab
Braco Compliance Ltd.
Bureau Veritas (formerly Curtis-Straus)
Cascade TEK
CertifiGroup
CETECOM Inc.
CKC Laboratories, Inc.
Communication Certification Laboratory
Compatible Electronics, Inc.
Compliance Certification Services
Compliance Engineering Pty Ltd - Australia
Compliance Engineering Ireland Ltd.
Compliance Management Group
Compliance Testing LLC
Compliance Worldwide
Core Compliance Testing Services
Cranage EMC Testing Ltd.
Criterion Technology, Inc.
CSA International
Custom Assembly LLC
D.A.R.E!! Calibrations
D.L.S. Electronic Systems, Inc.
Dayton T. Brown, Inc.
dBi Corp.
Diversified T.E.S.T. Technologies
DNB Engineering, Inc.
Don HEIRMAN Consultants
E.F. Electronics Co.
E-Labs Inc.
ElectroMagnetic Investigations, LLC
Electro Magnetic Test, Inc.
Electro Rent Corporation
Electronics Test Centre
Elite Electronic Engineering Co.
EM Software & Systems
EMC Compliance
EMC Cons Dr. Rasek GmbH
EMC Integrity, Inc.
EMC Technologies Pty Ltd.
EMC Tempest Engineering
EMC Testing Laboratories. Inc.
EMCMCC
EMF Testing USA
EMField
EMITECH
Enerdoor Inc.
Engineered Testing Systems
Environ Laboratories, LLC
ETS-Lindgren
Eurofins Product Service GmbH
Fabreeka International, Inc.
Federal-Mogul Corporation Systems Protection
Global Advantage
Global Certification Laboratories, Ltd.
Global Testing
Green Mountain Electromagnetics, Inc.
GTN GmbH & Co. KG
H.B. Compliance Solutions
Harris Corp (GCSD)
Hermon Laboratories
HILO-TEST
iNARTE, Inc.
Ingenium Testing, LLC
International Certification Services, Inc.
International Compliance Laboratories, LLC
Intertek Testing Services
IQS, a Div. of The Compliance Management Group
ITC Engineering Services, Inc.
Jacobs Technology Inc.
JS TOYO Corporation (Shenzhen) Ltd.
Keystone Compliance
Kimmel Gerke Associates, Ltd.
L.S. Research
L-3 Communications Cincinnati Electronics
Laboratory Testing Inc.
Langer EMV-Technik GmbH
L F Research EMC

Liberty Labs, Inc.
Little Mountain Test Facility
Mesago Messe Frankfurt GmbH
MET Laboratories, Inc.
MIRA Ltd.
National Technical Systems
Naval Air Systems Command
Naval Air Warfare Center
NCEE Labs
Nemko USA
Northwest EMC, Inc.
NU Laboratories
Pacific Power Source, Inc.
Paladin EMC
Parker Chomerics
Parker EMC Engineering
Peak Electromagnetics Ltd.
Pearson Electronics, Inc.
Percept Technology Labs, Inc.
Philips Applied Technologies - EMC Center
Philips Innovation Services-EMC Center
Pioneer Automotive Technologies, Inc. - EMC Lab
Power-Electronics Consulting
Product Safety Engineering Inc.
Protocol Data Systems Inc.
Pulver Laboratories Inc.
QinetiQ
Qualtest Inc.
Radiometrics Midwest Corp.
Radiotechnika Marketing Sp. z o.o.
Remcom Inc.
Restor Metrology
Reliant EMC LLC
Retlif Testing Laboratories
RF Exposure Lab, LLC
RFI Global Services Ltd.
RFTEK
Rhein Tech Laboratories, Inc.
Richardson RFPD
Rogers Labs, Inc.
Rubicom Systems, A division of ACS
SAE Power
Seven Mountains Scientific, Inc. (ENR)
SGS
SIEMIC
Southwest Research Institute
SPAWAR Systems Center Atlantic
Swift Textile Metalizing LLC
Sypris Test and Measurement
TEMPEST Inc.
Teseq
Test Site Services Inc.
The Compliance Management Group
Timco Engineering, Inc.
TRaC Global
Trialon Corp.
TUV Rheinland Of North America
TUV SUD America Inc.
TÜV SÜD Product Service Ltd.
TÜV SÜD SENTON GmbH
Ultratech Group of Labs
Underwriter's Laboratories Inc.
Walshire Labs, LLC
Washington Laboratories, Ltd.
White Sands Missile Range
Willow Run Test Labs, LLC
Wyle
Yazaki Testing Center
D.A.R.E!! Instruments

TESTING LABORATORIES

Alion Science and Technology
AT4 Wireless
Blue Guide EMC Lab
CKC Laboratories, Inc.
Compliance Testing LLC
Compliance Worldwide
Core Compliance Testing Services
D.A.R.E!! Instruments
D.L.S. Electronic Systems, Inc.
Diversified T.E.S.T. Technologies
DNB Engineering, Inc.
Don HEIRMAN Consultants
Electro Magnetic Test, Inc.
Electronics Test Centre (Kanata)
Elite Electronic Engineering Co.
EMC Integrity, Inc.
EMC Technologies Pty Ltd.
F2 Labs
H.B. Compliance Solutions
International Compliance Laboratories, LLC
Jakob Mooser GmbH
Keystone Compliance
Laboratory Testing Inc.
Langer EMV-Technik GmbH
Liberty Labs, Inc.
Little Mountain Test Facility
MET Laboratories, Inc.
National Technical Systems
Northwest EMC Inc.
Partnership for Defense Innovation
Percept Technology Labs
Professional Testing (EMI), Inc.
Qualtest Inc.
Radiometrics Midwest Corp.
Retlif Testing Laboratories
Richardson RFPD
RMV Technology Group, LLC
SDP Engineering Inc.
SIEMIC
Sprinkler Innovations
Stork Garwood Laboratories Inc.
Test Site Services Inc.
Timco Engineering, Inc.
Tranzeo EMC Labs Inc.
TÜV SÜD America Inc.
TÜV SÜD Product Service Ltd.
TÜV SÜD SENTON GmbH
Wave Scientific Ltd.
World Cal, Inc.

OTHER PRODUCTS AND SERVICES

BOOKS

Cherry Clough Consultants Ltd
Henry Ott Consultants
ITEM Media
Montrose Compliance Service

CHAMBERS REVERB

ETS-Lindgren

CONSULTANTS

Captor Corp.
Cherry Clough Consultants Ltd
D.A.R.E!! Instruments
D.L.S. Electronic Systems, Inc.
DNB Engineering, Inc.
Don HEIRMAN Consultants
Elite Electronic Engineering Co.
EM Software & Systems
EMC Cons Dr. Rasek GmbH
EMC Management Concepts
EMCMCC
EMF Testing USA
EMITEMC
Equipment Reliability Institute
ERA Technology Ltd. Trading as Cobham Technical Services
ETS-Lindgren
Henry Ott Consultants
Hoolihan EMC Consulting
ITEM Media
Jakob Mooser GmbH
Kimmel Gerke Associates, Ltd.
Lawrence Behr Associates Inc.
Montrose Compliance Service, Inc.
MOOSER Consulting GmbH
NewPath Research L.L.C.
Paladin EMC
Power & Controls Engineering Ltd.
Power Standards Lab (PSL)
Radiometrics Midwest Corp.
Retlif Testing Laboratories
Storm EMC Services Ltd
TUV SUD America Inc.
Wyatt Technical Services LLC

STANDARDS TRANSLATIONS

Advanced Programs, Inc.
ANDRO Computational Solutions
Electronics Test Centre (Kanata)
PGMC Ltd
TUV SUD America Inc.

TRAINING, SEMINARS & WORKSHOPS

A2LA
AMETEK Compliance Test Solutions
Andre Consulting, Inc.
Cherry Clough Consultants Ltd.
CST of America, Inc.
Delcross Technologies
D.L.S. Electronic Systems, Inc.
Don HEIRMAN Consultants
EM Software & Systems
EMC Engineering and Safety
EMC Goggles Ltd.
Euro EMC Service (EES)
Fotofab
Gaddon Consultants
Henry Ott Consultants
Hoolihan EMC Consulting
Integrated Engineering Software
Jastech EMC Consulting, LLC
Langer EMV-Technik GmbH
M.MARDIGUIAN, EMC Consulting
Montrose Compliance Service
QEMC - Engenharia, Qualidade e Compatibilidade Eletromagnética Ltda.
Retlif Testing Laboratories
SIEMIC
Simberian Inc.
Spec-Hardened Systems
Stephen Halperin & Associates
Storm EMC Services Ltd
Teseq
TUV SUD America Inc.

ITEM™ interference technology THE INTERNATIONAL JOURNAL OF ELECTROMAGNETIC COMPATIBILITY

Company Directory

Manufacturers, consultants, and service organizations active in the electromagnetic interference field are listed in this directory. To learn how to be included in this directory, or for any corrections. e-mail bstas@interferencetechnology.com.

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3C Test Ltd. - EMC Testing
Silverstone Technology Park, Silverstone Circuit, Towcester, Northampton NN12 8GX, UK
+44-1327-857500; Fax: +44-1327-857747
sales@3ctest.co.uk; www.3ctest.co.uk

3Gmetalworx World
2 - 90 Snow Boulevard, Concord, Ontario L4K 4A2, Canada 888-965-3634; sales@3gmetalworx.com
www.3gmetalworx.com

3M Electronics Markets Materials Division
6801 River Place Boulevard, Austin, TX 78726-9000, US
800-245-0329; Alex.Gwin@kolarmail.com
www.3M.com/electrical

7Layers AG
Borsigstrasse 11, Ratingen 40880, Germany; 49-210-27490; www.7layers.com

A

A&R Tarpaulins, Inc.
16246 Valley Boulevard, Fontana, CA 92335 US
909-829-4444; mail@artech2000.com; www.artarps.com

A.H. Systems, Inc.
9710 Cozycroft Avenue, Chatsworth, CA 91311 US
818-998-0223; Fax: 818-998-6892
sales@ahsystems.com; www.AHSystems.com

AL	T & M Solutions	770-973-7492
AR	Southwest Electronic Industries, Inc.	972-523-0017
GA	T & M Solutions	770-973-7492
LA	Southwest Electronic Industries, Inc.	972-523-0017
OK	Southwest Electronic Industries, Inc.	972-523-0017
TN	T & M Solutions	770-973-7492
TX	Richardson, Southwest Electronics Industries	972-523-0017
INTERNATIONAL		
AUS	Test & Measurement Australia PTY Limited	61-2-4739-9523
AUT	Pro Nova Elektronik GmbH	49-7141-2858-20
BEL	EEMCCOIMEX	31-320-295-395
BOL	Rentametric International, Inc.	305-767-4000
BUL	Test Solutions	359-2-970-1990
CHN	Beijing Twenty First Century Co., Ltd., Beijing	86-10-8267-5757
CHN	Compliance Direction Systems, Beijing	86-10-6846-0592
COL	Rentametric International, Inc.	305-767-4000
CRC	Rentametric International, Inc.	305-767-4000
ECU	Rentametric International. Inc.	305-767-4000
ESA	Rentametric International, Inc	305-767-4000
ESP	Wavecontrol	34-93-320-8055
FRA	AR France	33-147-91-7530
GER	Pro Nova Elektronik GmbH	49-7141-2858-20
GRB	SystemWare Europe	44-1462-734777
GRE	Vector Technologies	30-210-68-58008
GUA	Rentametric International, Inc	305-767-4000
HON	Rentametric International, Inc	305-767-4000
INA	Singapore Technologies Ltd.	65-6413-3119
IND	Technocomm Instruments Private Ltd.	91-80-25731009
ISR	WAVE Components Ltd	972-9-764-4878
ITA	Narda Safety Test Solutions; Segrate	39-02-269 98702
ITA	TESEO S.p.A; Druento	011-39-99-41-911
JPN	Techno Science Japan Co	81-3-5717-6130
KOR	Taehung Trading Inc.	82-2-541-2825
LUX	EEMCCOIMEX	31-320-295-395
MAS	Singapore Technologies Ltd.	65-6413-3119
NCA	Rentametric International, Inc	305-767-4000
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POL	AM Technologies	48-22-53-22-801
ROU	Celesta Comexim	4021-410-30-64
RUS	Sernia Ltd.	7-495-225-40-14
SIN	Singapore Technologies Ltd.	65-6413-3119
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THA	Singapore Technologies Ltd.	65-6413-3119
TUR	Norana	90-232-464-0011
TPE	Superlink Technology Corp.	886-2-2698-3456
VZL	Rentametric International, Inc	305-767-4000

A2LA - American Assoc. for Lab. Accreditation
5301 Buckeystown Pike, Frederick, MD 21704 US
301-644-3248; Fax: 301-454-9449
info@A2LA.org; www.A2LA.org

Aaronia AG
Gewerbegebiet Aaronia AG, Strickscheid, DE-54597 Euscheid, Germany;
49-6556-93033; Fax: 49-6556-93034
www.aaronia.de

Accurate Controls Ltd.
25 Cowley Rd., Nuffield Industrial Estate, Poole, Dorset, UK
44-1202-678108; www.accurate-controls.ltd.uk

ACL Inc.
1960 East Devon Avenue, Elk Grove Village, IL 60007 US
847-981-9212; 800-782-8420; marykay@aclstaticide.com
www.aclstaticide.com

ACL Staticide
840 West 49th Place, Chicago, IL 60609
847-981-9212; 847-981-9278
info@aclstaticide.com; www.aclstaticide.com

ACS Industries, Inc.
One New England Way, Lincoln, RI 02865 US
401-769-4700; Fax: 401-333-2294
jbuckler@acsind.com; www.acsindustries.com/products/industrial-applications/EMI-RFI_Shielding/default.html

Adams Magnetic Products Co.
807 Mantoloking Road, Suite 203, Brick NJ 08723 US
732-451-0123; www.adamsmagnetic.com

Adhesives Research, Inc.
400 Seaks Run Road, P.O. Box 100, Glen Rock, PA 17327 US
717-235-7979; 800-445-6240; Fax: 717-235-8320
jgumerlock@arglobal.com; www.adhesivesresearch.com

Adler Instrumentos SL
C/ Antonio de Cabezon, 83, Madrid, Madrid 28034 Spain
34-91-358-4046; Fax: 34-91-358-1383
info@adlerinstrumentos.es; www.adler-instrumentos.es

Ad-Vance Magnetics, Inc.
625 Monroe Street, P. O. Box 69, Rochester, IN 46975 US
574-223-3158; Fax: 574-223-2524;
rick@advancemag.com; www.advancemag.com

Advanced Compliance Solutions
284 West Drive, Ste. B, Melbourne FL 32907 US;
321-951-1710; info@acstestlab.com; www.acstestlab.com

Advanced Monolythic Ceramics, Inc.
3101 Constitution Avenue, Suite 100, Olean, NY 14760 US
716-372-5225; Fax: 716-372-5467;
info@sc.rr.com; www.amccaps.com

Advanced Programs, Inc.
7125 Riverwood Drive, Columbia, MD 21046 US
410-312-5800; Fax: 410-312-5850;
service@advprograms.com; www.advprograms.com

Advanced Test Equipment Rentals
10401 Roselle Street, San Diego, CA 92121 US
888-554-2832; Fax: 858-558-6570;
rentals@ATECorp.com; www.ATECorp.com

Advanced Testing Services
9420 San Mateo Boulevard NE, Suite C, Albuquerque, NM 87113 US; 505-292-2032; Fax: 505-237-8430
sales@advanced-testing.com; www.advanced-testing.com

AE Techron, Inc.
2507 Warren Street, Elkhart, IN 46516 US
574-295-9495; Fax: 543-295-9496;
sales@aetechron.com; www.aetechron.com

AEF Solutions
Unit 46, Thomas Way, Lakesview Business Park, Hersden Canterbury Kent CT3 4JJ, UK
44-1227-711455; Fax: 44-2380-455022
info@aefsolutions.com; www.aefsolutions.com

AEM, Inc.
6610 Cobra Way, San Diego, CA 92121 US
858-481-0210; Fax: 858-481-1123;
hrcsales@aem-usa.com; www.aem-usa.com

AEMC Instruments, Inc.
200 Foxborough Boulevard, Foxborough, MA 02035 US
508-698-2115; Fax: 508-698-2118; www.aemc.com

AERO NAV Laboratories
14-29 112 Street, College Point, NY 11356 US
718-939-4422; 800-680-6608; Fax: 718-539-3719;
aeronavlabs@aeronavlabs.com; www.aeronavlabs.com

Aerodev Electronmagnetic Tech
No.59, Lane 1985, Chunshen Road, Shanghai, China;
86-21-5439-9971, 86-215-439-9973; Fax: 86-215-439-9974
www.aerodev.com

Aeroflex
35 South Service Road, P.O. Box 6022, Plainview, NY 11803 US
516-694-6700; 800-843-1553; Fax: 516-694-2562
info-test@aeroflex.com; www.aeroflex.com

AFJ Instruments Srl
Via Corno di Cavento 5, Milan 20148, Italy
+39-02-91434850;
info@afj-instruments; afj-instruments.com

Agilent Technologies, Inc.
5301 Stevens Creek Boulevard, Santa Clara, CA 95051 US
800-829-4444; www.agilent.com

AHD EMC Lab /Amber Helm Development L.C.
92723 Michigan Highway 152, Sister Lakes, MI 49047 US
269-429-8352; 888-847-8027; Fax: 269-429-9016
ghelm@ahde.com; www.ahde.com

Albatross Projects GmbH
Daimlerstraße 17, 89564 Nattheim, Germany
49-7321-730510; Fax: 49-7321-730590
info@albatross-projects.com; www.albatross-projects.com

Alchemetal
3327 80 Street, Suite 2, New York, NY 11372 US
917-297-3560; egreenwood@alchemetal.com;
www.alchemetal.com

Alco Technologies, Inc.
1815 West 213th Street #175, Torrance, CA 90501 US;
310-328-4770; Fax: 310-328-1262; alcotech@alcotech.com;
www.alcotech.com

Advanced Conversion Technology, Inc.
2001 Fulling Mill Rd. Middletown PA 17057 US; 717-939-2300; www.actpower.com; SALES@ actpower.com

Alion Science & Technology
20 Clipper Road, West Conshohocken, PA 19428 US; 610-825-1960; Fax: 610-825-1684; contact@alionscience.com; www.alionscience.com

All-Spec Industries
5228 US Highway 421 N, Wilmington, NC 28401 US
800-537-0351; 910-763-5664; sales@allspec.com;
www.all-spec.com

Allied Components International
14712 Sinclair Circle, Tustin, CA 92780 US
714-665-1140; Fax: 714-665-1150
ac@alliedcomponents.com; www.alliedcomponents.com

Allied Moulded Products, Inc.
222 North Union Street, Bryan, OH 43506 US
419-636-4217; sales@alliedmoulded.com
www.alliedmoulded.com

Alltec Corp.
64 Catalyst Drive, Canton, NC 28716 US; 828-646-9290; Fax: 828-646-9527; marketing@allteccorp.com
www.allteccorp.com

Alltest Instrument, Inc.
500 Central Avenue Farmingdale, NJ 07727 US;
732-919-3339; Fax: 732-919-3332; sales@alltest.us
www.alltest.us

ALX Technical
630 Rivermede Road, Unit 9, Concord, Ontario, L4K 2H7 Canada; 905-761-0370; Fax: 905-761-0371;
www.alxtechnical.com; info@alxtechnical.com

American Environments Co., Inc.
17 Commercial Boulevard, Medford, NY 11763 US; 631-736-5883; Fax: 631-736-5272; online@aeco.com;
www.aeco.com

Americor Electronics, Ltd.
675 South Lively Boulevard, Elk Grove Village, IL 60007 US;
847-956-6200; Fax: 847-956-0300;
www.americor-usa.com

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AMETEK Compliance Test Solutions
52 Mayfield Avenue, Edison NJ 08837 US; 732-417-0501;
Fax.: 732 417 0511; dan.odum@ametek.com; www.emtest.com

AMETHERM, Inc.
916 Fairview Drive, Carson City, NV, 89701 US
775-884-2434
www.ametherm.com; info@ www.ametherm.com

Amphenol Canada Corp.
605 Milner Avenue, Toronto, Ontario M1B 5X6, Canada; 416-291-4401; Fax: 416-292-0647
sales@amphenolcanada.com; www.amphenolcanada.com

Amphenol Industrial Operations
40-60 Delaware Avenue, Sidney, NY 13838 US; 888-364-9011; Fax: 520-397-7169; www.amphenol-industrial.com;
tech@amphenol-aio.com

AMS
9119 Cross Park Drive, Knoxville, TN 37923 US; 865-691-1756; Fax: 865-691-9344; info@ams-corp.com;
www.ams-corp.com

Amstat Industries, Inc.
3012 NORTHLake Terrace, Glenview, IL 60026 US; 847-998-6210; Fax: 847-998-6218; Larry Jacobson,
amstat@sbcglobal.net; www.amstat.com

Amuneal Manufacturing Corp.
4737 Darrah Street, Philadelphia, PA 19124 US; 215-535-3000; 800-755-9843; Fax: 215-743-1715; info@amuneal.com;
www.amuneal.com

ANAMET Electrical, Inc.
1000 Broadway Avenue East, P.O. Box 39, Mattoon, IL 61938 US; 800-230-3718; Fax: 800-677-2706; info@anametelectrical.com; www.anametelectrical.com

Andre Consulting, Inc.
12812 NE 185th Court, Bothell, WA 98011 US; 206-406-8371;
Fax: 425-485-8153; help@andreconsulting.com; andreconsulting.com

ANDRO Computational Solutions, LLC
Beeches Professional Campus, Bldg 2 Suite 1,
7902 Turin Road, Rome, NY 13440 US
315-334-1163; Fax: 315-334-1397
androcs@androcs.com; www.androcs.com

Anritsu Company
1155 East Collins Boulevard, Suite 100,
Richardson, TX 75081 US;
972-644-1777; 800-267-4878; Fax: 972-671-1877
www.us.anritsu.com

Antistatic Industries
224 Pegasus Avenue, Northvale, NJ 07647 US;
201-660-7800; Fax: 201-784-0620;
info@antistaticindustries.com; www.antistaticindustries.com

Apache Design Solutions
2645 Zanker Road, San Jose, CA 95134 US;
408-457-2000; Fax: 408-428-9569;
apache_sales@apache-da.com; www.apache-da.com

APC by Schneider Electric
132 Fairgrounds Road, West Kingston, RI 02892 US
877-272-2722; www.apc.com

Apex Die & Gasket Inc.
1155 West 23rd Street #3A, Tempe, AZ 85282 US
480-894-1112; 888-937-3907;
dave@apexdc.com; www.dieandgasket.com

API Delevan
270 Quaker Road, East Aurora, NY 14052 US
716-652-3600 Fax: 716-652-4814
apisales@delevan.com; www.delevan.com

API Technologies - Spectrum Control
4705 South Apopka Vineland Road, Suite 210,
Orlando, FL 32819 US;
855-294-3800; www.apitech.com

Apogee Labs Inc.
210 South Third Street, North Wales, PA 19454 US
215-699-2060; Fax: 215-699-2061; www.apogeelabs.com

Applied Electromagnetic Technology LLC
P.O. Box 1437, Solomons, MD 20688 US
410-326-6728; Fax: 410-326-6728;
info@appliedemtech.com; www.appliedemtech.com

Applied Physical Electronics, L.C.
P.O. Box 341149, Austin, TX 78734 US; 512-264-1804; Fax: 512-264-1784; info@apelc.com; www.apelc.com

Applied Systems Engineering
7510 Benbrook Parkway, Fort Worth, TX 76126 US
817-249-4180; Fax: 817-249-3413,
bjostrand@applsys.com; applsys.com

APREL Laboratories
303 Terry Fox Drive, Suite 102, Kanata, Ontario
K2K 3J1, Canada
613-435-8300; Fax: 613-435-8306
info@aprel.com; www.aprel.com

AR Receiver Systems
160 School House Road, Souderton, PA 18964 US
800-933-8181; Fax: 818-882-3981; info@arworld.us
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AR RF/Microwave Instrumentation
160 School House Road, Souderton, PA 18964 US
215-723-8181; 800-933-8181
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DC	Delmarva Engineering	410-990-9000
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ID	Syntek	503-614-3403
IL	Electronic Instrument Associates, Inc	630-924-1600
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MD	Delmarva Engineering	410-990-9000
ME	R.J. Sickles Associates	781-214-1002
MI	Delta Technology Solutions LLC	810-815-2174
MN	Electronic Instrument Associates, Inc	612-695-4055
MO	KJS Marketing Inc	314-469-4544
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MT	Syntek	503-614-3403
NC	Delmarva Engineering	410-990-9000
ND	Electronic Instrument Associates, Inc	612-695-4055
NE	KJS Marketing, Inc	816-578-4751
NH	R.J. Sickles Associates	781-214-1002
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NM	Technical Marketing Specialists	505-286-0079
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NY	GSC Representatives; East Rochester	585-385-1170
OH	Delta Technology Solutions LLC	810-815-2174
OK	Testech	405-202-2203
OR	Syntek	503-614-3403
PA	Advanced Technical Marketing	973-683-1411
PA	Delta Technology Solutions LLC	810-815-2174
RI	R.J. Sickles Associates	781-214-1002
SC	Brennan Associates	770-736-4199
TN	Brennan Associates	770-736-4199
TX	Testech	512-350-3778
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VA	Delmarva Engineering	410-990-9000
VT	R.J. Sickles Associates	781-213-1002
WA	Syntek	425-822-7777
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INTERNATIONAL		
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AUS	Faraday Pty Ltd	61-3-9729-5000
AUT	EMV GmbH	49-89-614-1710
BLG	AR Benelux B.V	31-172-423000

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GUA	Sistemas Ingenieria de EMC	52-55-21632148
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KOR	EMC Solutions	82-070-7805-5100
MAS	Precision Technologies PTE, Ltd.	65-6-2734573
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MEX	Sistemas e Ingenieria de EMC	52-55-2168-2148
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POL	Urzadzenia Elektroniczne Import	48-022-313-1735
PRT	Wavecontrol, S.L.	34-933-208-055
ROM	Comtest SRL	4021-2110883
RSA	Protea Technology Ltd.	27-11-719-5791
RUS	Radiant-Elcom	7495-725-0404
SIN	Precision Technologies PTE, Ltd	65-6-2734573
SAF	Protea Technology, Ltd	27-11-719-5791
SPA	Wavecontrol, S.L.	34-933-208-055
SWE	CE-BIT Elektronik AB	46-8-735-7550
SWZ	Emitec Messetchnik AG	41-41-748-6010
TAI	Evergo Microwave, Inc	886-2-2752-0767
THA	Precision Technologies PTE, Ltd.	65-6-2734573
TUR	Orko Mumessillik	90-312-438-2213
UK	AR UK Ltd	441-908-282766

AR Tech
16246 Valley Blvd, Fontana, CA 92335 US
909-829-4444; www.artech2000.com

ARA Technologies
P.O. Box 226, Smithtown, NY 11787 US
631-724-4619; Fax: 631-361-8691
emc@aratech-inc.com; www.aratech-inc.com

ARC Technologies, Inc.
11 Chestnut Street, Amesbury, MA 01913 US
978-388-2993; Fax: 978-388-6866
sales@arc-tech.com; www.arc-tech.com

Aries Electronics
2609 Bartram Road, Bristol, PA 19007 US
215-781-9956; Fax: 215-781-9845
info@arieselec.com; www.arieselec.com

ASIA & EMC Consultancy
Am Mühlebach 27, 8964, Switzerland
415-66-311767

Asia Market Access Ltd.
413 Rui Guang Road, 6th Floor, Neihu District,
Taipei City 114, Taiwan
886-2-8752-5151; www.asiamarketaccess.com

ASR Technologies, Inc.
332 Crestview Road, Ottawa Ontario K1H 5G6 Canada
613-737-2026; Fax: 613-737-3098
Dr. Andrew Podgorski, a.podgorski@ieee.org
www.asrtechnologiesinc.com

AT4 Wireless
Parque Tecnologico de Andalucia, C/ Severo Ochoa,
2, 29590 Malaga, Spain
+34-95-261-91-00
infoLAB@at4wireless.com; www.at4wireless.com

ATLAS Compliance & Engineering
1792 Little Orchard Street, San Jose, CA 95125 US
408-971-9743; Fax: 408-971-9783
info@atlasce.com; www.atlasce.com

Audivo GmbH
Irrenloher Damm 17, Schwarzenfeld D 92521, Germany
49-9435-54190; Fax: 49-9435-541919
info@audivo.com; www.audivo.com

Austest Laboratories
9 Packard Avenue, Unit 2, Castle Hill NSW 2154, Australia
+61-2-9680-9990; Fax: +61 (0)2 9882 6600
martin@austest.com.au; www.austest.com.au

Autosplice, Inc.
10121 Barnes Canyon Road, San Diego, CA 92121 US
858-678-3119; Fax: 858-535-0130
kkozicki@autosplice.com; www.autosplice.com

Avalon Equipment Corp.
2453 Cades Way, Suite B, Vista, CA 92081 US
760-536-0191; 888-542-8256; Fax: 760-536-0184
sales@avalontest.com; www.avalontestequipment.com

Averna
87 Prince St., Suite 510, Montreal, Quebec, H3C 2M7, Canada
514-842-7577; 877-842-7577; Fax: 514-842-7573
www.averna.com

AVX Corp.
One AVX Boulevard, Fountain Inn, SC 29644 US; 864-967-2150; gib@avxcorp.com; www.avx.com

AWR Corp.
1960 East Grand Ave., Suite 430, El Segundo, CA 90245 US
310-726-3000; Fax: 310-726-3005
info@awrcorp.com www.awrcorp.com

Axonics, Inc.
20 Post Lane North, Suffern, NY 10901 US
845-228-8924; Fax: 914-652-2489
info@axonics.net; www.axonics.net

B

Bal Seal Engineering, Inc.
19650 Pauling, Foothill Ranch, CA 92610 US; 800-366-1006; 949-460-2100; Fax: 949-460-2300; sales@balseal.com; www.balseal.com

Barth Electronics, Inc.
1589 Foothill Drive, Boulder City, NV 89005 US; 702-293-1576; Fax: 702-293-7024; beisales@barthelectronics.com; www.barthelectronics.com

Bay Area Compliance Labs Corp.
1274 Anvilwood Avenue, Sunnyvale, CA 94089 US; 408-732-9162; Fax: 408-732-9164; sales@baclcorp.com; www.baclcorp.com

BEC Inc.
970 East High Street, Pottstown, PA 19464 US; 610-970-6880; Fax: 610-970-8381; sales@bec-ccl.com; www.bec-ccl.com

Beehive Electronics
8555 Lawrence Lane, Sebastopol, CA 95472 US; 707-824-9206; Fax: 707-581-1955; info@beehive-electronics.com; www.beehive-electronics.com

BI Technologies Corp.
4200 Bonita Place, Fullerton, CA 92835 US; 714-447-2300; 714-447-2345; Fax: 714-447-2400; www.bitechnologies.com

Binder-US
3903 Calle Tecate, Camarillo, CA 93012 US; 805-437-9925; Fax: 805-383-1150; sales@binder-usa.com; www.binder-usa.com

Bird Technologies
30303 Aurora Road, Solon, OH 44139 US; 440-248-1200; 866-695-4569; Fax: 440-248-5426; www.bird-technologies.com

Blackwood Labs
Unit 8 Woodfieldside Business Park, Pontllanfraith, Blackwood, NP12 2DG, UK; +44 (0) 1495-229-219; Fax: +44 (0) 1495-228-331; blackwoodenquiries@kiwa.co.uk; www.blackwood-labs.co.uk

Block USA
1370 Bowes Road Suite 110, Elgin IL , 60123, US; 847-214-8900; 847-628-0606; paul.ganvik@block-trafo.com; www.block.eu/en_US/home/

Blue Guide EMC Laboratory
Joseph Cardijnstraat 21, B-9420 Erpe-Mere, Belgium; 32 (0) 53-60-16-01; Fax: 32 (0) 53-70-78-99; info@bgemc.com; www.bgemc.com

BONN Elektronik GmbH
Ohmstr. 11, DE-83607 Holzkirchen, Germany; 49-8024-608830; Fax: 49-8024-6088310; info@bonn-elektronik.com; www.bonn-elektronik.com

Bourns Inc.
1200 Columbia Avenue, Riverside, CA 92507 US; 951-781-5500; www.bourns.com

Boyd Corp.
600 So McClure Road, Modesto, CA 95357 US; 209-491-4797; 800-554-0200; customerservice@boydcorp.com; www.boydcorp.com

Braco Compliance Ltd.
P.O. Box 31188, Ilam, Christchurch 8444, New Zealand; 64-21-208-4303; enquiries@bracocompliance.com; www.bracocompliance.com

Brim Electronics, Inc.
120 Home Place, Lodi, NJ 07644 US; 201-796-2886; Fax: 973-778-2792; info@brimelectronics.com; www.brimelectronics.com

Bud Industries
4605 East 355th Street, Willoughby, OH 44094 US; 440-946-3200; Fax: 440-951-4015; saleseast@budind.com; www.budind.com

Bureau Veritas
1601 Sawgrass Corporate Parkway, Suite 400, Fort Lauderdale, FL 33323 US; 954-236-8100; Fax: 954-236-8108; www.bureauveritas.com

Bystat International Inc.
2630 Sabourin Street, Ville Saint-Laurent, Québec, H4S 1M2, Canada; 514-333-8880; 800-361-6777; Fax: 514-333-8885; static@bystat.com; www.bystat.com

C

Calbrooke Marketing Inc.
P.O. Box 39, Arthur, ON N0G 1A0, Canada; 519-848-3810; sales@calbrooke.com; www.calbrooke.com

Calmont Wire & Cable, Inc.
420 East Alton Avenue, Santa Ana, CA 92707; 800-905-7161; Fax: 714-549-4028; calsales@calmont.com; www.calmont.com

CAP Wireless
950 Lawrence Drive, Newbury Park, CA 91320 US; 805-499-1818; Fax: 805-499-6649; info@capwireless.com; www.capwireless.com

Capcon International, Inc.
120 Craft Avenue, Inwood, NY 11096 US; 516-371-5600; Fax: 516-239-5481; info@capconemi.com; www.capconemi.com

CAPLINQ Corp.
957 Snowshoe Crescent, Orléans, Ontario K1C 2Y3, Canada; 613-482-2215; Fax: 702-995-1235; info@caplinq.com; www.caplinq.com

Caprock Mfg.
2303 120th Street, Lubbock, TX 79423 US; 806-745-6454; Fax: 806-745-5963; caprock@caprock-mfg.com; www.caprock-mfg.com

Captor Corp.
5040 South County Road 25A, Tipp City, OH 45371 US; 937-667-8484; Fax: 937-667-5133; sales@captorcorp.com; www.captorcorp.com

Carlisle Interconnect Technologies
102 W. Julie Drive, Tempe Arizona 85283 US; 480-730-5700; Fax: 480-730-5800; www.carlisleit.com

Cascade TEK
5245 Northeast Elam Young Parkway, Hillsboro, OR 97124 US; 888-835-9250; Fax: 503-648-1798; info@cascadetek.com; www.cascadetek.com

CCPartners, Ltd.
8390 E. Via De Ventura, Suite F-110, Scottsdale, AZ 85258; 480 778 0122 Ext. 102; www.ccpartnersltd.com

Central Coating Company
165 Shrewsbury Street, West Boylston, MA 01583 US; 508-835-6225; Fax: 508-835-6228; info@centralcoating.com; www.centralcoating.com

CertifiGroup
901 Sheldon Drive, Cary, NC 27513 US; 800-422-1651; info@certifigroup.com; www.certifigroup.com

CETECOM Inc.
411 Dixon Landing Road, Milpitas, CA 95035 US; 408-586-6200; Fax: 408-586-6299; info@cetecom.com; www.cetecomusa.com

CET Technology LLC
27 Roulston Rd. Windham, NH, 03087 US; 603-894-6100 www.cettechnology.com

CGS Technologies
1801 West Parkside Lane, Phoenix, AZ 85027 US; 623-869-0600; Fax: 623-582-4813; info@cgstech.com; www.cgstech.com

Cherry Clough Consultants Ltd.
9 Bracken View, Brocton, Stafford, Staffs ST17 0TF, UK; 44-1785-660-247; Fax: 44-1785-660-247; Keith Armstrong, keith.armstrong@cherryclough.com; www.cherryclough.com

Chomerics
77 Dragon Court, Woburn, MA 01888 US; 781-935-4850; Fax: 781-933-4318; chomailbox@parker.com; www.chomerics.com; www.chomericstest.com

Cima NanoTech, Inc.
1000 Westgate Drive, Suite 100, St. Paul, MN 55114 US; 651-646-6266; Fax: 651-646-4161; www.cimananotech.com

Circuit Insights LLC
3744 Valley Lights Drive, Pasadena, CA 91107 US; 626-201-0488; Fax: 626-466-4448; sales@loopslooth.com; www.loopslooth.com

CITEL Inc.
11381 Interchange Circle South, Miramar, FL 33025 US; 954-430-6310; 800-248-3548; Fax: 954-430-7785; info@citel.us; www.citelprotection.com

CKC Laboratories, Inc.
5046 Sierra Pines Drive, Mariposa, CA 95338 US; 209-966-5240; Fax: 866-779-9776; www.ckc.com

ClickFold Plastics, Inc.
2900 Westinghouse Boulevard, Suite 118, Charlotte, NC 28273 US; 866-649-8665; info@clickfold.com; www.clickfoldplastics.com

Cobham PLC
Brook Road, Wimborne, Dorset BH21 2BJ, Kingdom; www.cobham.com

Combinova AB
Domkraftsvägen 1, S-197 40 Bro, Sweden; 46-8-627-93-10; Fax: 46-8-29-59-85; sales@combinova.se; www.combinova.se

Communication Coil, Inc.
9601 Soreng Avenue, Schiller Park, IL 60176 US; 847-671-1333; Fax: 847-671-9191; info@communicationcoil.com; www.communicationcoil.com

Compac Development Corp.
1460 North Clinton Avenue, Suite O, Bay Shore, NY 11706 US; 631-585-3400; Fax: 631-585-3534; sales@compac-rf.com; www.compac-rf.com

Compatible Electronics, Inc.
102 Olinda Drive, Brea, CA 92823 US; 714-579-0500; Fax: 714-528-1992; www.celectronics.com

Compliance Certification Services
47173 Benicia Street, Fremont, CA 94538 US; 510-771-1000; Fax: 510-661-0888; www.ccsemc.com

Compliance Engineering Pty Ltd - Australia
1, 70 Rushdale Street, Knoxfield, Australia 3180; +613 9763 3079; www.compeng.com.au

Compliance Engineering Ireland Ltd.
Clonross, Dunshaughlin, Co. Meath, Ireland; 353-1-8017000; Fax: 353-1-8256733; www.cei.ie

Compliance Management Group
257 Simarano Drive, Marlborough, MA 01752 US; 508-460-1400; www.cmgcorp.net

Compliance Testing, LLC
3356 North San Marcos Place, Suite 107, Chandler, AZ 85225 US; 480-926-3100; 866-311-3268; Fax: 480-926-3598; info@compliancetesting.com; www.compliancetesting.com

Compliance West, US
650 Gateway Center Drive, Suite D, San Diego, CA 92012 US; 619-878-9696; 858-481-6454; Fax: 858-481-8527; sales@compwest.com; www.compwest.com

Compliance Worldwide
357 Main Street, Sandown, NH 03873 US; 603-998-3903; Fax: 603-887-6445; www.complianceworldwide.com

Com-Power Corp.
114 Olinda Drive, Brea, CA 92823 US; 714-528-8800; Fax: 714-528-1992; sales@com-power.com; www.com-power.com

Comtech PST Corp.
105 Baylis Road, Melville, NY 11757 US; 631-777-8900; Fax: 631-777-8877; info@comtechtel.com; www.comtechpst.com

Comtest Engineering B.V.
Industrieweg 12, 2382NV Zoeterwoude, The Netherlands; 31-71-5417531; Fax: 31-71-5420375; info@comtest.eu; www.comtest.eu

Conductive Compounds Inc.
17 Hampshire Drive, Unit 8, Hudson, NH 03051 US; 603-595-6221; Fax: 603-595-6228; sales@conductivecompounds.com; www.conductivecompounds.com

CONEC Corp. - US
343 Technology Drive, Garner, NC 27529 US; 919-460-8800; Fax: 919-460-0141; info@conec.com; www.conec.com

Connors Company
P.O. Box 807, Carver, MA 02330 US; 508-272-1500; Fax: 508-866-5393; Brian Connors, brian@connorsrep.com; connorsrep.com

Cool Polymers, Inc.
51 Circuit Drive, North Kingstown, RI 02852 US; 401-667-7830; 888-811-3787; sales@coolpolymers.com; www.coolpolymers.com

Core Compliance Testing Services
79 River Road, Hudson, NH 03051 US; 603-892-0620; Kenneth L. MacGrath, khcmacgrath@aol.com; www.corecomplianceetesting.com

Cosmo Ferrites Limited
Jabli, Solan, Himachal Pradesh 173209, India; 91-1792-277231; Fax: 91-1792-277234; sales@cosmoferrites.com; www.cosmoferrites.com

CPI
Communications & Power Industries
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CPI - Communications & Power Industries
607 Hansen Way, Palo Alto, CA 94304 US; 650-846-2900; Fax: 650-846-3276; www.cpii.com

U.S. Mid-Atlantic	George Oliver	732-920-0130
U.S. Northeast	George Oliver	732-920-0130
U.S. Southeast	Sharon Altimari	813-977-6590
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INTERNATIONAL		
AUS	Peter Kirkwood	61-2-9987-0666
BEL	Claude Van Daele	32-14-43-1140
CAN	Tom Sertic	905-702-2228
CHN	Patrick Zhou Ning	86-10-8497-7470
ESP	Paolo Ruella	39-011-771-4765
FRA	Laurence Leveau	33-0-1-39-43-8450
GBR	Robin Stewart	44-1932-256-930
GER	Roman Jaresch	49-89-4587-370
IND	Arun Mohindru	91-11-2614-6716
ISR	Shiraz Dewji	41-41-560-7550
ITA	Paolo Ruella	39-011-771-4765
JPN	Ray King	65-6225-0011
KOR	Ray King	65-6225-0011
MEX	Esteban Luna	321-454-3698
PAK	Miro Antelj	41-41-560-7550
SUI	Miro Antelj	41-41-560-7550

Cranage EMC Testing Ltd.
Stable Court, Oakley, Market Drayton, Shropshire TF9 4AG, UK; 44-1630-658568; Fax: 44-1630-658921; info@cranage.co.uk; www.cranage.co.uk

Cree, Inc.
4600 Silicon Drive, Durham, NC 27703 US; 866-924-3645; media@cree.com; www.cree.com

Cre8 Associates Ltd.
Bruntingthorpe Proving Ground, Bath Lane, Lutterworth, Leicestershire LE17 5QS, UK; 44-1162-479787; enquires@cre8-associates.com; www.cre8-associates.com

Creative Materials, Inc.
12 Willow Road, Ayer, MA 01432 US; 978-391-4700; 800-560-5667; Fax: 978-391-4705; info@creativematerials.com; www.creativematerials.com

Criterion Technology, Inc.
1350 Tolland Road, P.O. Box 489, Rollinsville, CO 80474 US; 303-258-0100; Fax: 303-258-0775; critech@criteriontech.com; www.criteriontech.com

CSA International
178 Rexdale Boulevard, Toronto, Ontario M9W 1R3, Canada; 416-747-400; 800-463-6727; www.csa-international.org

CST

CST of America, Inc.
492 Old Connecticut Path, Suite 500, Framingham, MA 01701; US; 508-665-4400; Fax: 508-665-4401; info@us.cst.com; www.cst.com

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CA	CST of America, Inc., El Segundo,	310-606-2607
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GER	CST AG; Munich	49-89-2420828-0
IND	Mr. Pandurangan K	91-44-32551460
ITA	CST AG	39-0363-3512-42
JPN	AET, Inc.	81-44-980-0505
KOR	CST of Korea, Inc.	82-31-781-6866
MAL	Computer Simulation Technology Malaysia Sdn. Bhd.	60-3-7496-6595
TPE	CST Taiwan	886-3-5332541
IND	CST AG	91 44 32551460
SIN	CST South East Asia Pte. Ltd.	65-6562-8705

Cuming-Lehman Chambers Inc.
5800 Cumberland Highway, Chambersburg, PA 17202 US; 717-263-4101; Fax: 717-263-4102; cuminglehman.com

Curtis Industries
2400 South 43rd Street, Milwaukee, WI 53219; 414-649-4200; 800-657-0853; Fax: 414-649-4279; sales@curtisind.com; www.curtisind.com

Custom-Pak
86 16th Ave. N. Clinton, IA, 52732 , US; 563-242-1801; www.custom-pak.com

Cybershield
308 Ellen Trout Drive, Lufkin, TX 75904 US; 936-633-6387; Fax: 936-633-6398; sales@cybershieldinc.com; www.cybershieldinc.com

D

D.A.R.E!! Consultancy
Vijzelmolenlaan 7, Woerden, Utrecht NL-3447GX, The Netherlands; +31 348 430 979; Fax: +31 348 430 645; consultancy@dare.nl; consultancy.dare.nl

D.L.S. Electronic Systems, Inc.
1250 Peterson Dr., Wheeling, IL 60090 US; 847-537-6400; Fax 847-537-6488; jblack@dlsemc.com; www.dlsemc.com

Datatronics
28151 Highway 74, Menifee, CA 92585 US; 951-928-7700; Fax: 951-928-7701; ddisles@datatronics.com; www.datatronics.com

Dayton T. Brown, Inc.
1175 Church Street, Bohemia, NY 11716-5031 US; 631-589-6300; Fax: 631-589-3648; test@dtbtest.com; www.dtbtest.com

dB Control
1120 Auburn Street, Fremont, CA 94538 US; 510-656-2325; Fax: 510-656-3214; marketing@dbcontrol.com; www.dBControl.com

dBi Corp.
216 Hillsboro Avenue, Lexington, KY 40511 US; 859-253-1178; Fax: 859-252-6128; jrbarnes@iglou.com; www.dbicorporation.com

Delcross Technologies
3015 Village Office Place, Champaign, IL 61822 US; 217-363-3396; contact@delcross.com; www.delcross.com

Delta Electronics
4405 Cushing Parkway, Fremont, CA 94538 US; 1-510-668-5100; Fax: 1-510-668-0680; www.delta.com.tw

Desco Industries Inc.
3651 Walnut Avenue, Chino, CA 91710 US; 909-627-8178; Fax: 909-627-7449; www.DescoIndustries.com

Device Technologies, Inc.
155 Northboro Road, Unit 8, Southborough, MA 01772 US; 508-229-2000; Fax: 508-229-2622; Nick Petri, Director of Sales & Marketing, npetri@devicetech.com; www.devicetech.com/shielding/default.asp

Dexmet Corp.
22 Barnes Industrial Road South, Wallingford, CT 06492 US; 203-294-7867; Fax: 203-294-7898; k.mull@dexmet.com; www.dexmet.com

Dexter Magnetic Technologies
1050 Morse Avenue, Elk Grove Village, IL 60007 US; 847-956-1140; info@dextermag.com; www.dextermag.com

Diversified T.E.S.T. Technologies
4675 Burr Drive, Liverpool, NY 13088 US; 315-457-0245; Fax: 315-457-0425; annelle@dttlab.com; www.dttlab.com

DNB Engineering, Inc.
3535 W. Commonwealth Avenue, Fullerton, CA 92833 US; 800-282-1462; 714-870-7781; Fax: 714-870-5081; Tony Piraino, tonyp@dnbenginc.com; www.dnbenginc.com

Don Heirman Consultants
143 Jumping Brook Road, Lincroft, NJ 07738 US; 732-741-7723; Fax: 732-530-5695; Don Heirman, d.heirman@ieee.org; www.DonHeirman.com

Dontech Inc.
700 Airport Boulevard, Doylestown, PA 18902 US; 215-348-5010; Fax: 215-348-9959; Jeff Blake, info@dontech.com; www.dontech.com

Dynamic Sciences International, Inc.
6130 Variel Av., Woodland Hills, CA 91367 US; 818-226-6262; 800-966-3713; Fax: 818-226-6247; market@dynamicsciences.com; www.dynamicsciences.com

Dutch Microwave Absorber Solutions
Industrieweg 12, 2382NV Zoeterwoude, The Netherlands; 31-71-5012526; info@dmas.eu; www.dmas.eu

E

E3 Displays
21050 N. 9th Place, Suite 309, Phoenix, AZ 85024 US; 602-288-9758; Fax: 602-288-9762; info@e3displays.com; www.e3displays.com

E&C Anechoic Chambers NV
Nijverheidsstraat 7A, B-2260 Westerlo, Belgium; 32-14-59-58-00; Fax: 32-14-59-58-01; info@ecanechoicchambers.com ; www.ecanechoicchambers.com\\

E.F. Electronics Co.
217 West Mill Street, Montgomery, IL 60538 US; 630-897-1950; EFEMCTEST@aol.com

East Coast Shielding
1090 RT 19, Johnsonburg, NJ 07846 US; 908-852-9160; Fax: 908-852-9163; mike@eastcoastshielding.com; www.eastcoastshielding.com

Ecliptek Corp.
3545-B Cadillac Avenue, Costa Mesa, CA 92626 US; 714-433-1200; Fax: 714-433-1234; customersupport@ecliptek.com; www.ecliptek.com

Ed Fagan Inc.
769 Susquehanna Avenue, Franklin Lakes, NJ 07417 US; 201-891-4003; 800-335-6827; Fax: 201-891-3207; sales@edfagan.com; www.edfagan.com

EEMCCOIMEX
Apolloweg 80, Lelystad Flevoland 8239 DA Netherlands; 31 3202 95395; Fax: 31-3204-13133; A.J.J. Naus, info@eemc.nl; www.eemccoimex.nl

Eeonyx Corp.
750 Belmont Way, Pinole, CA 94564 US; 510-741-3632; Fax: 510-741-3657; info@eeonyx.com; www.eeonyx.com

EESeal
5639 B Jefferson NE, Albuquerque, NM 87109 US; 505-243-1423; Fax: 505-243-9772; eeseal@quell.us www.eeseal.com

E-Labs Inc.
5150 Lad Land Drive, Fredericksburg, VA 22407 US; 540-834-0372; Fax: 540-834-0373; info@e-labsinc.com; www.e-labsinc.com

Electri-Flex Company
222 W. Central Avenue, Roselle, IL 60172 US; 800-323-6174; 630-529-0482; mktg@electriflex.com; www.electriflex.com

Electrocube, Inc.
3366 Pomona Boulevard, Pomona, CA 91768 US; 909-595-4037; 800-515-1112; Fax: 909-595-0186; ecubesales@electrocube.com; www.electrocube.com

ElectroMagnetic Investigations, LLC
20811 NW Cornell Road, Suite 600, Hillsboro, OR 97124 US; 503-466-1160; 888-466-1160; Fax: 503-466-1170; www.emicomply.com

Electro Magnetic Test, Inc.
1547 Plymouth Street, Mountain View CA 94043 US; 650-965-4000; Fax: 650-965-3000; info@emtlabs.com; www.emtlabs.com

Electro-Metrics Corp.
231 Enterprise Road, Johnstown, NY 12095 US; 518-762-2600; Fax: 518-762-2812; sales@emihq.com; www.electro-metrics.com

Electro Rent Corp.
6060 Sepulveda Boulevard, Van Nuys, CA 91411 US; 877-581-3384; 818- 787-2100; sales@electrorent.com; www.ElectroRent.com

Electronic Instrument Associates
P.O. Box 6487, Bloomingdale, IL 60108-6487 US; 630-924-1600; Fax: 630-477-0321; frank@electronicinstrument.com; www.electronicinstrument.com

Electronics Test Centre Kanata
302 Legget Drive, Suite 100, Kanata K2K 1Y5, Canada; 613-599-6800; Fax: 613-599-7614; Lynn Diggins, sales@etc-mpb.com;

Electronics Test Centre Airdrie
27 East Lake Hill, Airdrie, Alberta T4A 2K3, Canada; 403-912-0037; Fax: 403-912-0083; www.etc-mpb.com

Electrorack Enclosure Products
1443 South Sunkist Street, Anaheim, CA 92806 US; 714-776-5420; 800-433-6745; Fax: 714-776-9683; www.electrorack.com

Element Materials Technology
15062 Bolsa Chica St, Huntington Beach, CA 90660 US; 714-892-1961; 888-786-7555; Fax: 714-892-8159; info.hb@element.com; www.element.com

Elite Electronic Engineering Inc.
1516 Centre Circle; Downers Grove, IL 60515-1082 US; 800-ELITE-11, 630-495-9770, ext. 119; Fax: 630-495-9785; sglaya@elitetest.com; www.elitetest.com

Elite EMC Ltd.
12 Station Road, Marston Green, Birmingham, West Midlands B37 7AS, UK; 44 121 288 0543; Fax: 44 121 288 0543; David Hobbs, sales@eliteemc.com; www.eliteemc.com

EM Software & Systems-SA Pty Ltd.
P.O. Box 1354, Stellenbosch, 7599, South Africa; 27 21 880 1880; Fax: 27 21 880 1936; Celeste Mockey, info@emss.co.za; www.feko.info

EM Software & Systems US Inc.
100 Exploration Drive, Suite 310-B, Hampton, VA 23666 US; 866-419-FEKO; www.emssusa.com
INTERNATIONAL

CHN	EM Software & Systems China, Shanghai	21-50116635
DEU	EM Software & Systems GmbH, Böblingen	49-07031-714-5200

Embassy Global, LLC
PO Box 105, Orchard Park, NY 14127-0105 US; 800-309-6150; Fax: 716-706-1248; inquiries@embassyglobalpr.com; www.embassyglobalpr.com

EMC Compliance
P.O. Box 14161, Huntsville, AL 35815-0161 US; 256-650-5261; Ken Javor, ken.javor@emccompliance.com; www.emccompliance.com

EMC Component Group, Inc.
2901 Tasman Drive, Suite 211, Santa Clara, CA 95054 US; 408-330-9216; Fax: 408-330-0012; sales@emccomponent.com; www.emccomponent.com

EMC Engineering and Safety
Haifa, Israel; 972-528396080

EMC Eupen, A Div. of I2R Corp.
5033 Industrial Road, Bldg. 6, Farmingdale, NJ 07727 US; 732-919-1100; Fax: 732-919-7196; sales@emceupen.com; www.emceupen.com

EMC Goggles Ltd.
P.O. Box 130, Cwmbran, Torfaen NP44 9BT, UK; 44 0 7506015791; John Davies, info@emcgoggles.com; www.emcgoggles.com

EMC Integrity, Inc.
1736 Vista View Drive, Longmont CO 80504 US; 888-423-6275; Fax: 303 776-7314; guyd@emcintegrity.com; www.emcintegrity.com

EMC Management Concepts
46603 Kingschase Court, Sterling, VA; 703-864-7023; Fax: 801-849-3516; bfarmer@emcmanagement.com; www.emcmanagement.com

EMC Partner AG
Baselstrasse 160, Laufen 4242, Switzerland; 41 61 775 2030; Fax: 41 61 775 2059; Nicholas Wright, sales@emc-partner.ch; www.emc-partner.com
INTERNATIONAL

AU	Sydney, Test & Measurement	6-2-4739-9523
AR	Buenos Aires, Mannos	54-11-5258-0259
BE	Berchem-Ste-Agathe, Decatel	32-2-469-00-90
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CZ	Praha, Tectra	420-281-921-650
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SG	Singapore, Precision Tech	65-6273-4573
TR	Istanbul, Aktif Neser	90-216-577-6999
TW	Taipei, Precision International	886-2-8512-4888
US	Manassas, HV Technologies	703-365-2330
ZA	Bramley, Protea Electronics	27 11 719 57 00

EMC Solutions USA LLC
390 North Orange Ave., Suite 2300, Orlando, FL, 32801, US; 407-982-7724; www.totalemc.com

EMC Technologies Pty Ltd.
176 Harrick Road, Keilor Park Victoria 3042 Australia; 61393651000; Fax: 61393317455; Chris Zombolas, chris@emctech.com.au; www.emctech.com.au

EMC Tempest Engineering
2190 East Winston Road, Anaheim, CA 92806 US; 714-778-1726; rbc@emctempest.com; www.emctempest.com

EMC Test Design
PO Box 600532, Newton, MA; 508-292-1833; exid@emctd.com; www.emctd.com

EMC Testing Laboratories, Inc.
2100 Brandon Trail, Suite 101, Alpharetta, GA 30004 US; 770-475-8819; Fax: 770-475-2011; Gene Bailey, gbailey@emctesting.com; emctesting.com

EMCC Dr. Rasek
Moggast, Boelwiese 8, Ebermannstadt 91320 Germany; 1 49 9194-9016; Fax: 1 49 9194-8125; Irmhild Helldoerfer, emc.cons@emcc.de; www.emcc.de

EMCMCC
Sedanlaan 13a, Eindhoven N.Br. 5627MS the Netherlands; 31-40-2927936; Fax: 31-40-2927481; Mart Coenen, mart.coenen@emcmcc.nl; www.emcmcc.nl

EMCO Elektronik GmbH
Bunsenstraße 582152, Planegg, Germany; 49-89-8955650; Fax: 49-89 -895 90 376; www.emco-elektronik.de

Emerson & Cuming Microwave Products, Inc.
28 York Avenue, Randolph, MA 02368 US; 781-961-9600; 800-650-5740; Fax: 781-961-2845; sales@eccosorb.com; www.eccosorb.com

EMF Testing US
11236 Harrington Street, Fishers, IN 46038-3208 US; 800-862-9655; info@emftesting.net; www.EMFTESTING.net

EMField
Rua Nicarágua 962, salas 12/13, CEP 82510-170, Bacacheri, Curitiba, PR, Brazil; 55 041 - 3044 0197; Fax: 55 041 - 3044 0197; emfield@emfield.com.br; www.emfield.com.br

EMI Filter Company
12750 59th Way, North Clearwater, FL 33760 US; 727-585-7990; 800-323-7990; Fax: 727-586-5138; sales@emifilter-company.com; www.emifiltercompany.com

EMI Shielding
1160 South Cameron Street, Harrisburg, PA 17104 US; 717-232-1030; dietrich@jemic.com ; www.jemic.com

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2200 N. Telshor Blvd, Las Cruces, NM 88011 US; 575-532-9190; Fax: 575-532-0884; Joe Alvarez, joea@emitechnologies.com; www.emitechnologies.com

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12704 W. Arden Place, Butler, WI 53007 US; 262-790-0092; Fax: 262-790-0095 ; sales@emissioncontrol.com; www.emissioncontrol.com

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3 Rue des Coudriers, ZA de l'Observatoire, Montigny le BX, Ile de France 78180, France; 33 1 30 57 55 55; Fax: 33 1 30 43 74 48; l.beauvais@emitech.fr; www.emitech.fr

EMITEMC
Arroyo de la China 3510 Rio Negro, Bariloche, Argentina; 54 29 44 52 7498; Hernan Sineiro, hsineiro@emitemc.com;

EMP-tronic AB
Box 130 60, SE-250 13 Helsingborg, Sverige; 46 42 23 50 60; Fax 46 42 23 51 82; Lars Günther, lars@emp-tronic.se; www.emp-tronic.se

EMS-PLUS
PO Box 1265, Four Oaks, NC 27524 US; sales@ems-plus.com; www.ems-plus.com

Empower RF Systems, Inc.
316 W. Florence Avenue, Inglewood, CA 90301 US; 310-412-8100; FAX: 310-412-9232 sales@empowerrf.com; www.empowerrf.com

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emscreen GmbH
Wallbergstraße 7, Taufkirchen , Bavaria 82024, Germany; 49 89 614171 -0; Fax: 49 89 61471-71; info@emscreen.de; www.emscreen.de

EMSS Consulting Pty Ltd.
3 Meson Avenue., Technopark, Stellenbosch, Western Cape 7600, South Africa; 27 21 880 1880; bbosch@emss.co.za; www.emssixus.com

emv - Elektronische Meßgeräte Vertriebs GmbH
Wallbergstraße 7, Taufkirchen, 82024, Germany; 49 0 89614243; Fax: 49 0 89614282; info@emvgmbh.de; www.emvgmbh.de

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75 Industrial Way, Portland, ME 04103 US; 207-210-6511; 877-778-2875; Fax: 207-210-6512; stefano.medved@enerdoor.com; www.enerdoor.com

Engineered Testing Systems
1711 West 15th Street, Indianapolis, IN 46202 US; 317-396-0573; Fax: 317-536-8006; golten@engineered-testing.com; www.engineered-testing.com

Environ Laboratories, LLC
9725 Girard Avenue, South Minneapolis, MN 55431 US; 952-888-7795; ejb@environlab.com ; www.environlab.com

EPCOS, Inc.
485-B Route 1 South Suite 200, Iselin, NJ 08830 US; 732-906-4300; Fax: 732-906-4395; sales.usa@epcos.com; www.epcos.com/emc

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1520 Santa Rosa Avenue, Santa Barbara, CA 93109 US; 805-564-1260; tustin@equipment-reliability.com; www.equipment-reliability.com

ERA Technology Ltd.
Leatherhead, Surrey, UK; +44 (0) 1372 367 345 www.era.co.uk

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324 Second Street Pike, Unit 3, Southampton, PA 18966 US; 215-357-5124; Fax: 215-364-7582; info@ergonomicsusa.com; www.ErgonomicsUS.com

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1301 Arrow Point Drive, Cedar Park, TX 78613 US; 512-531-6400; Fax: 512-531-6500; info@ets-lindgren.com; www.ets-lindgren.com

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EU Compliance Services, Inc.
7580 St. Clair Avenue, Mentor, OH 44060 US; 440-918-1425; Fax: 440-918-1476; emcjanki@aol.com; www.eucs.com

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Dr. D.Hansen Bahnhofstr. 39 POB 84 Berikon AG CH-8965 Switzerland; 41 566 33 73 81; Fax: 41 566 33 73 81; Dr. Diethard Hansen, euro.emc.service@swissonline.ch; www.euro-emc-service.de

Eurofins Product Service GmbH
Storkower Str. 38C Reichenwalde 15526 Germany; +49 33631 888 801; Fax: +49 33631 888 660; mc@eurofins.com; www.eurofins-reichenwalde.de

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F2 Laboratories
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Ferronics, Inc.
45 O'Connor Road, Fairport, NY 14450; 585-388-1020 Fax: 585-388-0036; odavies@ferronics.com www.ferronics.com

Feuerherdt GmbH
Motzener Str. 26b, Berlin 12277 Germany; 49307109645-52; Fax: 49307109645-99; emc@feuerherdt.de; www.feuerherdt.de

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2624 Rousselle Street, Santa Ana, CA 92707 US; 714-545-7003; Fax: 714-545-4607; John Erwin, info@filterconcepts.com; www.filterconcepts.com

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Frankonia EMC
Industrie Strasse, 16, Heideck, D-91180, Germany; 49 91 77-98 500; www.frankonia-emc.com

Frontier Electronics, Corp.
667 E. Cochran Street, Simi Valley, CA; 805-522-9998; Fax: 805-522-9989; frontiersales@frontierusa.com; www.frontierusa.com

F-Squared Laboratories
26501 Ridge Road, Damascus, MD 20872 US; 301-253-4500; Fax 301-253-5179; kdevore@f2labs.com; www.f2labs.com

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Johann-Hittorf-Strasse 6, 12489 Berlin, Germany; 49 30 - 6331319100; info@fuss-emv.de; www.fuss-emv.de

G

Gaddon Consultants
18 New Royd, Millhouse Green, Sheffield, South Yorkshire S36 9NW, UK; 01226-766999; info@gaddon.co.uk; www.gaddon.co.uk

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Agnes-Pockels-Bogen 1, Munich 80992, Germany; 49-89-54-04-699-0; Fax: 49-89-54-04-699-29; info@tdemi.com; www.gauss-instruments.com

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Gutenbergring 41, 22848 Nordenstedt, Germany; 49-40-593-558-0; 49-40-593 558-29; http://www.germania-elektronik.com

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1211 Air Way, Glendale, CA 91201 US; 818-247-6000 Fax: 818-500-9912; sales@glenair.com; www.glenair.com

Global EMC Ltd.
Prospect Close, Lowmoor Road Industrial Estate, Kirkby-in-Ashfield, Nottinghamshire NG17 7LF, UK 44-1623-755539; Fax: 44-1623-755719 info@globalemc.co.uk; www.globalemc.co.uk

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219 Blake Roy Road, Middlebury, VT 05753 US; 802-388-3390; Fax: 802-388-6279; gme@gmelectro.com; www.gmelectro.com

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NAVAIR E3 Division - Code 4.1.13, Bldg. 4010, Room 134, 48187 Standley Road, Patuxent River, MD 20670 US; 301-342-1660; Fax: 301-757-2381; Mike Squires, E3 Division Manager, michael.squires@navy.mil; www.navair.navy.mil

NAVAIR 5.4.4.5
Aircraft Division - E3 Branch Code 5.4.4.5 Hangar 144, Suite 3B, Unit 5, 48202 Standley Road, Patuxent River, MD 20670-1910 US; 301-342-1663; Fax: 301-342-6982; www.navair.navy.mil

NCEE Labs
4740 Discovery Drive, Lincoln, NE 68521 US; 402-472-5880; 888-567-6860; Fax: 402-472-5881; dkramer@nceelabs.com; www.nceelabs.com

NEDC Fabricating Solutions
42 Newark Street, Haverhill, MA 01832; 978-374-0789; www.nedc.com

Nemko-CCL, Inc
1940 West Alexander Street, Salt Lake City, UT 84119 US; 801-972-6146; Fax: 801-972-8432; Tom Jackson, tom.jackson@nemko.com; www.cclab.com

Nemko US
2004 Chelam Way, Brandon, FL 33511 US: 813-528-1261; Andrew Robbins, Andrew.robbins@nemko.com; www.nemco.com

NewPath Research L.L.C.
2880 South Main Street, Salt Lake City, UT 84115 US; 801-573-9853; mahagmann@newpathresearch.com; www.newpathresearch.com

NEXIO
46 Avenue du General de Croutte, Toulouse 31300, France; 33-5-61-44-02-47; Fax: 33-)5-61-44-05-67; sales@nexio.fr; www.nexio.fr

Next Generation Power Amplifiers
316 West Florence Avenue, Inglewood, CA 90301 US; 310-412-8100; Fax: 310-412-9232; www.empowerrf.com

Nextek
2 Park Drive, Building 1, P.O. Box 385, Westford, MA 01886 US; 978-486-0582; Fax: 978-486-0583;sales@nexteklightning.com; www.nexteklightning.com

Noise Laboratory Co., Ltd.
1-4-4, Chiyoda, Chuo-ku, Sagamihara City, Kanagawa Pref 252-0237, Japan; sales@noiseken.com; www.noiseken.com
NY Shinyei Corp. of America; New York..............917-484-7893
INTERNATIONAL
AUS DHS Elmea Tools GmbH................................ 41-1-813-5380-0
BRA T&M Instruments...55-11-5092-5229
CHN Corad Technology Ltd.; Hong Kong.................852-27930330
CHN Corad Technology Ltd.; Shenzhen..............86-755-83761117
CHN Shenzhen HaoGu Technology Co., Ltd.; Shenzhen 86 0755 8398 8565
CHN Rico Tools Trading Ltd.; Shenzhen 86-755- 83600838
CHN Nihon Denkei Co., Ltd.; Shenzhen 86-755-8209-6179
CHN Rico Kohki (Shanghai) Co., Ltd.; Shanghai . 86-21-63537223
CHN Shanghai Sanki Electronics Industries Co., Ltd.; Shanghai.... 86-21-6257-4333
CHN Nihon Denkei Co., Ltd.; Shanghai 86-21-5820-9710
CHN Nihon Denkei Co., Ltd.; Dalian ....86 -411-8762-2136
CHN Nihon Denkei Co., Ltd.; Tianjin 86-22-8386-5887
CHN Nihon Denkei Co., Ltd.; Beijing 86-10-5131-1181
CHN Nihon Denkei Co., Ltd.; Dongguan 86-769-2202-6986
GER Rodemark, DHS Elmea Tools GmbH 49-6074-9199080
IDN Jakarta, Nihon Denkei Co. Ltd. 62-21 8087-1621
IND MEL Systems and Services Ltd.; Chennnai........................... 91-44-2496-1903
IND Complus Systems Pvt. Ltd.; Bangalore..... 91-80-4168-3883
IND Nihon Denkei India Private Ltd. Bangalore91-80-4093-5381
ISR IES Electronics Agencies (1986) Ltd. 972-3-7530751
ITA TESEO SpA...39-11-994 1911
KOR Seoul, Noise Technology Co. Ltd. 82-31-781-7816
MAS Nihon Denkei (Malaysia) Sdn Bhd ; Kuala Lumpur 60-3-2283-5702
MAS AMPTRONIC (M) SDN.BHD.; Selangor Daurl Ehsan 60-3-5632-8411
PHL Nihon Denkei Co., Ltd. 63-2-8452638
SIN NihonDenkei Co. Ltd. 65-6355-0851
THA Nihon Denkei Co. Ltd.; Bangkok 66-2-675-5688
THA Industrial Electrical Co., Ltd.; Bangkok 66-2-642-6700
TPE Precision International Corp......................... 886-2-8512-4888
VIE Nihon Denkei Co., Ltd.. 84-4-951-6505

Nolato Silikonteknik AB
Bergmansv 4, Hallsberg 69491, Sweden; 46-582-88900; www.nolato.se/silikonteknik

Northern Technologies Corp.
95 Konrad Crescent, Markham, Ontario L3R 8T8, Canada; 905-475-9320; 800-456-1875; Fax: 905-475-5719; chrismarshall@northerntech.com; www.northerntech.com

Northwest EMC, Inc.
22975 Northwest Evergreen Parkway, Suite 400, Hillsboro, OR 97124 US: 503-943-3122; www.nwemc.com

NP Technologies, Inc.
2393 Teller Road #108, Newbury Park, CA 91320 US; 805 376-9299; Fax: 805 376-9288; sales@nptrf.com; www.nptrf.com

Nu Laboratories, Inc.
312 Old Allerton Road, Annandale, NJ; 908-713-9300; Fax: 908-713-9001; webmaster@nulabs.com; www.nulabs.com

O

Oak-Mitsui Technologies
80 1st Street, Hoosick Falls, NY 12090 US; 518-686-8088; Fax: 518-686-8080; john.andresakis@oakmitsui.com; www.oakmitsui.com

Okaya Electric America, Inc.
52 Marks Road, Suite 1, Valparaiso, IN 46383 US; 800-852-0122; Fax: 219-477-4856; ross@okaya.com; www.okaya.com

Omicron Electronics GmbH
Oberes Ried 1, Klaus 6833, Austria; 43- 5523-507; Fax: 43-5523-507 -999; info@omicron.at; www.omicron.at

Onanon Connectors
720 South Milpitas Boulevard, Milpitas, CA 95035 US: 408-262-8990; Fax: 408-262-2901; www.onanon.com

OPHIR RF
5300 Beethoven Street, Los Angeles, CA 90066 US; 310-306-5556; Fax: 310-821-7413; info@ophirrf.com; www.ophirrf.com

Optical Filters Ltd.
13447 South Mosiertown Road, Meadville, PA 16335 US: 814-333-2222; Fax: 814-333-4338; www.opticalfiltersusa.com

Orbel Corp.
2 Danforth Drive, Easton, PA 18045 US; 610-829-5000; Fax: 610-829-5050; lgiralico@orbel.com; www.orbel.com

ORBIT Advanced Electromagnetics, Inc.
P. O. Box 711719, Santee, CA 92072-1719 US; 619-449-9492; Fax: 619-449-1553; www.aemi-inc.com

Orion Industries Inc.
One Orion Park Drive, Ayer, MA; 978-772-6000; Fax: 978-772-0021; www.orionindustries.com

Oxley Developments Company Ltd.
Priory Park, Cumbria, Ulverston LA12 9QG, UK; 44 0 1229 840519; Fax: 44 0 1229 870451; m.blows@oxley.co.uk; www.oxleygroup.com

P

P & P Technology Ltd.
Finch Drive, Springwood Industrial Estate, Braintree, Essex, CM7 2SF, UK; 44-1376-550525; Fax: 44-1376-552389; info@p-p-t.co.uk; www.p-p-t.co.uk

Pacific Aerospace & Electronics, Inc.
434 Olds Station Road, Wenatchee, WA 98801 US; 509-285-5299; Fax: 509-663-5039; sales@pacaero.com; www.pacaero.com

Pacific Power Source, Inc.
17692 Fitch, Irvine, CA 92614; 800-854-2433: 949-251-1800; Fax: 949-756-0756; sales@pacificpower.com; www.pacificpower.com

Paladin EMC
65 Buckwheat Avenue, Portsmouth, RI 02871 US; 401-924-3700; spence@paladinemc.com; www.paladinemc.com

Panashield, Inc.
185R West Norwalk Road #R, Norwalk, CT 06850-4312 US; 203-866-5888; Fax: 203-866-6162; help@panashield.com; www.panashield.com

Panasonic Electronic Components
Three Panasonic Way, 7H-2, Secaucus, NJ 07094 US; 1-800-344-2112; Fax: 201-348-7393; industrial@us.panasonic.com; www.panasonic.com/industrial/electronic-components/

Parker Chomerics
77 Dragon Court, Woburn, MA 01888 US; 781-935-4850; Fax 781-933-4213; chomailbox@parker.com ; www.chomerics.com

Parker EMC Engineering
15246 Daphne Avenue, Gardena, CA 90249-4122 US; 310-323-4188; Fax: 310-323-4188; parkeremc@worldnet.att.net; parkeremc.mustbehere.com

Partnership for Defense Innovation
1104 Civil Court, Fayetteville, NC 28303 US; 910-307-3060; Fax: 910-307-3070; info@ncpdi.org; www.ncpdilab.org

Pasternack Enterprises
17802 Fitch, Irvine, CA 92614 US; 1-866-727-8376; Fax: 949-261-7451; sales@pasternack.com; www.pasternack.com

Peak Electromagnetics Ltd.
139 Bank Street, Macclesfield, Cheshire SK11 7AY, UK; 44-0162-5269808; sales@peak-em.co.uk; www.peak-em.co.uk

Pearson Electronics, Inc.
4009 Transport Street, Palo Alto, CA 94303 US; 650-494-6444; Fax: 650-494-6716; sales@pearsonelectronics.com; www.pearsonelectronics.com
INTERNATIONAL
BRA , WEBTRADE ENTERPRISES CORP...............305-374-7576
CAN ACA TMETRIX...800-665-7301
CHE Telemeter Elect.. 41-71-6992020
CHN Corad Technology Ltd.; T&M.................................852-2793-0330
DEU Nucletron Vertriebs GmbH 49-89-14900220
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GBR Alrad Instruments 44-1-635-30345
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ITA Hi-Tec S.R.L...39-2-39266561
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KOR Blue & Green Trading Co..82-2-2026-4444
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PL Warsaw, NDN.. 226416196
SAU Denver Technology Products. 27-11-626-2023
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SWE Trinergi AB...46-19-18-86-60
TH Singapore, Genetron Singapore Pte Ltd............5-6841-2818

PennEngineering
5190 Old Easton Road, Danboro, PA 18916 US; 215-766-8853; Fax: 215-766-3633; info@pemnet.com; www.pemnet.com

Percept Technology Labs, Inc.
4888 Central Ave Suite #110, Boulder, CO 80301 US; 303-444-7480; martyb@percept.com; www.percept.com

PGMC Ltd.
4 Pondholton Drive, Witham, Essex , CM8 1QG, UK; Tel: 44-2071-93 1730; Pablo Garcia, pablog@o2.co.uk

Philips Innovation Services - EMC center
High Tech Campus 7, 5656 AE Eindhoven, The Netherlands; 31-40-27-48060; emc.testlab@philips.com; www.emc.philips.com

Phoenix Company of Chicago Inc.
600 Wheat Lane, Wood Dale, IL 60191 US; 630-595-2300; 800-323-9562; Fax: 630-595-6579; sales@phoenixofchicago.com; phoenixofchicago.com

Phoenix Contact
586 Fulling Mill Road, Middletown, PA 17057 US; 717-944-1300; Fax: 717-944-1625; info@phoenixcon.com; www.phoenixcontact.com/usa_home

Photofabrication Engineering Inc.
500 Fortune Boulevard, Milford, MA 01757 US; 508-478-2025; Fax: 508-478-3582; pei@photofabrication.com; www.photofabrication.com

Plastic-Metals Technology Inc.
7051 SW Sandburg Road, Suite 400, Tigard, OR 97223 US; 503-684-0725; Fax: 503-684-0735; info@p-mtinc.com; www.p-mtinc.com

Polymer Science Inc.
2787 S. Freeman Rd. Monticello, IN 47960; www.polymer-science.com

Positronic Industries
423 North Campbell Avenue, Springfield, MO 65806 US; 800-641-4054; Fax: 417-866-4115; info@connnectpositronic.com; www.connectpositronic.com

Potters Industries, Inc.
P.O. Box 841, Valley Forge, PA 19482 US; 610-651-4700; Fax: 610-408-9724; www.pottersbeads.com

Power & Controls Engineering Ltd.
4 Foothills Drive, Ottawa, Ontario K2H 6K3, Canada; 613-829-0820; Fax: 613-829-8127; mail@pcel.ca; www.pcel.ca

Power Products International Ltd.
Commerce Way, Edenbridge, Kent TN8 6ED, UK; 44-1732-866424; Fax: +44-1732-866399; info@ppi-uk.com; www.ppi-uk.com

Power Standards Lab (PSL)
2020 Challenger Drive #100, Alameda, CA; 510-522-4400; Fax: 510-522-4455; sales@powerstandards.com; www.powerstandards.com

PPM (Pulse Power & Measurement) Ltd.
65 Shrivenham, Hundred Business Park, Watchfield, Swindon, Wiltshire, SN6 8TY, UK; 44-1793-784389; Fax: 44-1793-784391; sales@ppm.co.uk; www.point2point.co.uk

Praxsym, Inc.
120 S. Third Street, P.O. Box 369, Fisher, IL 61843 US; 217-897-1744; sales@praxsym.com; www.praxsym.com

Precision Photo-Fab, Inc.
4020 Jeffrey Boulevard, Buffalo, NY 14219 US; 716-821-9393; Fax: 716-821-9399; www.precisionphotofab.com

Prismier
10216 Werch Drive, Suite 118, Woodridge, IL 60517 US; 630-592-4515; Fax: 630-214-4099; websales@prismier.com; prismier.com

Product Safety Engineering Inc.
12955 Bellamy Brothers Boulevard, Dade City, FL 33525 US; 352-588-2209; Fax: 352-588-2544; hwatkins@pseinc.com; www.pseinc.com

Professional Testing (EMI), Inc.
1601 N. A.W. Grimes Boulevard, Suite B, Round Rock, TX 78665 US; 512-244-3371; Fax: 512-244-1846; info@ptitest.com; www.ptitest.com

Progressive Fillers International
2404 East 28th Street, P.O. Box 72709, Chattanooga, TN 37407 US; 423-629-0007; 888-988-0007; Fax: 423-629-0444; support@pfillers.com; www.progressivefillers.com

Prostat Corp.
1072 Tower Lane, Bensenville, IL 60106 US; 630-238-8883; Fax: 630-238-9717; www.prostatcorp.com

Protection Technology Group
10701 North Airport Road, Hayden, ID 83835 US; 208-772-8515; 800-882-9110; Fax: 208-762-6133; www.protection-group.com/Home

Protek Test and Measurement
40 Boroline Road, Allendale, NJ 07401 US; 201-818-9300

Protocol Data Systems Inc.
4741 Olund Road, Abbotsford, British Columbia V4X 2A1, Canada; 604-218-1762; info@protocol-emc.com; www.protocol-emc.com

PSC Electronics
4400 NE 77th Ave #225, Vancouver, WA 98662 US; 360-735-1010; 800-654-1518; Fax: 360-735-1020; e.morris@emailpsc.com; www.pscelex.com

Pulver Laboratories Inc.
320 North Santa Cruz Avenue, Los Gatos, CA 95030-7243 US; 408-399-7000; 800-635-3050; Fax: 408-399-7001; Lee.Pulver@PulverLabs.com; www.PulverLabs.com

Q

QAI Laboratories
211 Schoolhouse Street, Unit 16, Coquitlam, British Columbia V3K 4X9, Canada; 877-461-8378; 604-527-8378; Fax: 604-527-8368; qai.org

QEMC
Rio de Janeiro, Brazil; 5521-8111-6661; menna@qemc.com.br; www.qemc.com.br

Q-Filter Products
35 Water St., Amesbury MA, 01913, 978-388-0085, qfilter-products.com

QinetiQ
Cody Technology Park, Ively Road, Farnborough, Hampshire GU14 0LX, UK; 44-843-658-4668; www.QinetiQ.com/emc

Q-par Angus Ltd.
Barons Cross Laboratories, Leominster, Herefordshire HR6 8RS, UK; 44-1568-612138; Fax: 44-1568-616373; info@q-par.com; www.q-par.com

Qualtek Electronics Corp.
7675 Jenther Drive, Mentor, OH 44060 US; 440-951-3300; Fax: 440-951-7252; mailbox@qualtekusa.com; www.qualtekusa.com

Qualtest Inc.
5325 Old Winter Garden Road, Orlando, FL 32811 US; 407-293-5844; Fax: 407-297-7376; info@qualtest.com; www.qualtest.com

Quarterwave Corp.
1300 Valley House Drive, Suite 130, Rohnert Park, CA 94928 US; 707-793-9105; Fax: 707-793-9245; engineering@quarterwave.com; www.quarterwave.com

Quell Corp.
5639-B Jefferson NE, Albuquerque, NM 87109 US; 877-730-1669; 505-243-1423; Fax: 505-243-9772; eeseal@quell.us; www.eeseal.com

R

R. A. Mayes Company, Inc.
10064 Deerfield Road, Franktown, CO 80116 US; 800-761-9447; 303-761-5067; Eric Evans; sales@ramayes.com; www.ramayes.com

Randolph Products
33 Haynes Circle, Chicopee, MA 01020 US; 413-592-4191; www.randolphproducts.com

R & K Company Ltd.
721-1 Maeda, Fuji, Shizuoka 416-8577, Japan; 81-545-31-2600; Fax: 81-545-31-1600; info@rkco.jp; www.rk-microwave.com

Radiometrics Midwest Corp.
12 East Devonwood Drive, Romeoville, IL 60446 US; 815-293-0772; Fax: 815-293-0820; Dennis Rollinger, CEO; sales@radiomet.com; www.radiomet.com

Radiotecknika Marketing Sp. Z o.o.
20 Fabryczna Street, Pietrzykowice 55-080, Poland; 48-71-327-0700; www.radiotechnika.com.pl

Radius Power, Inc.
22895 Eastpark Drive, Yorba Linda, CA 92865 US; 714-289-0055; Fax: 714-289-2149; sales@radiuspower.com; www.radiuspower.com

Rainford EMC Systems Ltd.
Haydock Lane, St. Helens, Merseyside WA11 9TN, UK; 44-1942-296190; sales@rainfordemc.com; www.rainfordemc.com

Ramsey Electronics
590 Fishers Station Drive, Victor, NY 14564 US; 585-924-4560; Fax: 585-924-4886; www.ramseytest.com

REMCOM, Inc.
315 S. Allen Street, Suite 416, State College, PA 1680 US; 814-861-1299; 888-773-6266; Fax: 814-861-1308; sales@remcom.com; www.remcom.com

Restor Metrology
921 Venture Avenue, Leesburg, FL 34748 US; 877-220-5554; 888-886-0585; www.restormetrology.com

Reliant EMC LLC
6501 Crown Boulevard, Suite 106A9, San Jose, CA 95120 US; 408-600-1472; contact@reliantemc.com; www.reliantemc.com

Retlif Testing Laboratories
795 Marconi Avenue, Ronkonkoma, NY 11779 US; 631-737-1500; Fax: 631-737-1497; sales@retlif.com; www.retlif.com

CT	Mantec, Inc./Peter Mann	860-774-1551
VA	Retlif Testing Laboratories	703-533-1614
NC	Retlif Testing Laboratories	704-909-2840
NH	Retlif Testing Laboratories	603-497-4600
PA	Retlif Testing Laboratories	215-256-4133

RF Exposure Lab, LLC
802 North Twin Oaks Valley Road, Suite 105, San Marcos, CA 92029 US; 760-471-2100; Fax: 760-471-2121; www.rfexposurelab.com

RF Immunity Ltd.
36 Hayarkon Street, Yavne 81227, Israel; 972-73-2331300; Fax: 972-73-2332325; sales@rfimmunity.co.il; www.rfimmunity.com

RFI Controls Company
341 Village Lane, Los Gatos, CA 95030 US; 408-399-7007; Fax: 408-399-7011; info@rficontrols.com; www.rficontrols.com

RFI Corp.
100 Pine Aire Drive, Bay Shore, NY 11706-1107 US; 631-231-6400; Fax: 631-231-6465; rfisales@rficorp.com; www.rficorp.com

RFTEK
5103 Duntrune Court, Raleigh, NC 27606 US; 919-622-4088; info@rftek.net; www.rftek.net

Rhein Tech Laboratories, Inc.
360 Herndon Parkway, Suite 1400, Herndon, VA 20170 US; 703-689-0368; Fax: 703-689-2056; www.rheintech.com

Richard Wöhr GmbH
Gräfenau 58-60, D-75339 Höfen/Enz, Germany; 49-7081-9540-0; 49-7081-9540-90; info@engl@woehrgmbh.com; www.woehrgmbh.com

Richardson RFPD, Inc.
40W267 Keslinger Road, P.O. Box 307, LaFox, IL 60147, US; 630-208-2700; Fax: 630-208-2662; sales@richardsonrfpd.com; www.richardsonrfpd.com/Pages/home.aspx

Rigol Technologies
7401 First Place, Suite N, Oakwood Village, OH 44146 US; 440-232-4488; info@rigol.com; www.rigolna.com

Rittal Corp.
1 Rittal Place, Urbana, OH 43078 US; 937-399-0500; 800-477-4000; Fax: 937-390-5599; customerservicefax@rittal.us; www.rittal-corp.com

RMV Technology Group, LLC
NASA-Ames Research Center, Bldg. 19, Suite 1073, MS 19-46C, P.O. Box 1, Moffett Field, CA 94035 US; 650-964-4792; Fax: 650-964-1268; Renee Mitchell, renee@esdrmv.com; www.esdrmv.com

R.N. Electronics Ltd.
Arnolds Court, Arnolds Farm Lane, Brentwood, Mountnessing, Essex, CM13 1UT, UK; +44 1277 352219; www.RNelectronics.com

Rogers Labs, Inc.
4405 West 259th Terrace, Louisburg, KS 66053 US; 913-837-3214; Fax: 913-837-3214; info@rogerslabs.com; www.rogerslabs.com

Rohde & Schwarz GmbH & Co. KG
Muehldorfstrasse 15, 81671 Munich Germany , +49 89 4129 12345; /www.rohde-schwarz.com; customersupport@rohde-schwarz.com

ROHDE & SCHWARZ USA, Inc.
6821 Benjamin Franklin Drive, Columbia, MD 21046, US; 410-910-7800; Fax: +1 410 910-7849
www.rohde-schwarz.com/USA; info@rohde-schwarz.com

Ross Engineering Corp.
540 Westchester Drive, Campbell, CA, 95008 US; 408-377-4621; www.rossengineeringcorp.com; info@ www.rossengineeringcorp.com

Roxburgh EMC
Deltron Emcon House, Hargreaves Way, Sawcliffe Industrial Park, Scunthorpe, North Lincolnshire, DN15 8RF, UK; 44-1724-273200; Fax: 44-1724-280353; sales@dem-uk.com; www.dem-uk.com/roxburgh

Roxtec
10127 East Admiral Place, Tulsa, OK 74116 US; 918-254-9872; 800-520-4769; Fax: 918-254-2544; info@us.roxtec.com; www.roxtec.com

RTP Company
580 East Front Street, P.O. Box 5439, Winona, MN 55987 US; 507-454-6900; 800-433-4787; Fax: 507-454-2041; rtp@rtpcompany.com; www.rtpcompany.com

Rubbercraft
3701 Conant Street, Long Beach, CA 90808 US; 562-354-2800; Fax: 562-354-2900; info@rubbercraft.com; www.rubbercraft.com

S

Sabritec
17550 Gillette Avenue, Irvine, CA 92614 US; 949-250-1244; Fax: 949-250-1009; www.sabritec.com

SAE Power
950 S Bascom Avenue, San Jose, CA 95128 US; 408-808-6496; sales@saepower.com; www.saepower.com

Saelig Company
71 Perinton Parkway, Fairport, NY 14450 US; 888-772-3544; Fax: 585-385-1768; info@saelig.com; www.saelig.com

Safe Engineering Services & Technologies
3055 Boulevard Des Oiseaux, Laval, Quebec H7L 6E8, Canada; 800-668-3737; 450-622-5000; Fax: 450-622-5053; info@sestech.com; www.sestech.com

Safety Test Technology Co., Ltd
Pu Tian Science Park B415, 28 Xin Jie Kou Wai Da Jie, Xicheng District, Beijing, 100088 P.R. China; 86-10-51654077; www.instrument.com.cn

Saint-Gobain Performance Plastics
7301 Orangewood Avenue, Garden Grove, CA 92841 US; 1-800-833-5661; Fax: 1-714-688-2701; http://www.plastics.saint-gobain.com/Default.aspx

SAS Industries, Inc.
939 Wading River Manor Road, Manorville, NY 11949 US; 631-727-1441; Fax: 631-727-1387; info@sasindustries.com; www.sasindustries.com

Schaffner EMC, Inc.
52 Mayfield Avenue, Edison, NJ 08837 US; 800-367-5566; 732 225 9533; Fax: 732-225-4789; usasales@schaffner.com; www.schaffnerusa.com

AR Carlton Bates	800-482-9313
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MA Sager Electronics	800-724-3780
MA Norris Associates Inc	781-749-5088
MD Phoenix Sales and Marketing, Inc	410-247-8505
MN Digi-Key	218-681-6674
MN, Grissinger-Johnson Sales	763-544-5451
MN Rockford Controls of Minnesota	763-557-2801
MN Werner Electric	651-458-3701
MO Connector Technology LLC	636-561-3543
NC Aurora-Tech Marketing	800-995-1970
NJ Industrial Components & Engineering, LLC	609-371-5950
NJ State Electronics	800-631-8083
NJ Synergy Sales	732-751-1700
NY Equiptex Industrial Products Corp	800-352-5090
NY Masline Electronics	585-546-5373
NY Net Sales Inc	585-924-1844
NY Powertech Controls	631-368-6678
OH Allied Einterprises, Inc	440-808-8760
OR Globale, Inc	503-590-2325
PA Rumsey Electric Supply Co.	610-832-9000
PA Colrud Lowery	610-338-0606
PA, Cusick Electrical Sales, Inc	215-659-6666
TX Allied Electronics	800-433-5700
TX Kruvand	972-437-3355
TX Mouser Electronics	817-804-3888
TX Smith Power Systems, Inc.	972-690-1500
WA WESCO Sales Group, Inc	425-941-6681
WI, Bunell and Associates	262-784-0994
WI Revere Electric	262-369-7100
WI Taylor Industrial Electronics	262-241-4321
WI Werner Electric	920-729-4500
INTERNATIONAL	
BRA Arrow Brazil	55-11-3613-9300
BRA Farnell-Newark	55-11-4066-9400
BRA LC Overdata Representação e Comércio Exterior Ltda.	55-11-2842-6842
CAN E-Cubed Components Inc	905-791-0812
CAN Powerco Canada, Inc	403-252-2444
CHI Conecta S.A.	56-2-669-79-13
MEX Kuvand de Mexico	01152-33-3671-4159

Schlegel Electronic Materials
1600 Lexington Avenue, Rochester, NY 14606 US; 1-585-643-2000; Fax: 1-585-427-7216; schlegelemi.na@schlegelemi.com; www.schlegelemi.com

Schurter, Inc.
447 Aviation Boulevard, Santa Rosa, CA 95403 US; 707-636-3000; Fax: 707-636-3033; info@schurterinc.com; www.schurterinc.com

SDP Engineering Inc.
17 Spectrum Pointe #508, Lake Forest, CA 92630 US; 949-588-7568; Fax: 949-588-8871; www.sdpengineering.com

Seal Science
Seal Science West: 17131 Daimler Street, Irvine, CA 92614 US; 949-253-3130; Fax: 949-253-3141; westernsales@sealscience.com; Seal Science East: 1160 Win Drive, Bethlehem, PA 18017; 610-868-2800; Fax: 610-868-2144; easternsales@sealscience.com; www.sealscience.com

Sealcon
14853 East Hinsdale Avenue, Centennial, CO 80112 US; 800-456-9012; 303-699-1135; Fax: 303-680-5344; info@sealconusa.com; www.sealconusa.com

Sealing Devices Inc.
4400 Walden Avenue, Lancaster, NY 14228 US; 716-684-7600; 800-727-3257; Fax: 716-684-0760; www.sealingdevices.com

Seibersdorf Laboratories
Forschungszentrum, 244 Seibersdorf, Austria; -43-50550-2500; Fax: 43-50550-2502; office@seibersdorf-laboratories.at; www.seibersdorf-laboratories.at

Select Fabricators Inc.
5310 North Street Bldg. 5, P.O. Box 119, Canandaigua, NY 14424 US; 585-393-0650; 888-599-6113; Fax: 585-393-1378; www.select-fabricators.com

Sensor Products Inc.
300 Madison Avenue, Madison, NJ 07940 US; 973-884-1755; 800-755-2201; Fax: 973-884-1699; sales@sensorprod.com; www.sensorprod.com

Seven Mountains Scientific, Inc. (ENR)
913 Tressler Street, P.O. Box 650, Boalsburg, PA 16827 US; 814-466-6559; Fax: 814-466-2777; www.7ms.com

SGS
1 Place des Alpes, P.O. Box 2152, Geneva 1211, Switzerland; 41-22-739-91-11; Fax: 41-22-739-98-86; www.ee.sgs.com

Shieldex Trading
4502 Route31, Palmyra, NY 14522 US; 315-597-1674; Fax: 315-597-6687;whoge@rochester.rr.com; www.shieldextrading.net

Shielding Resources Group, Inc.
9512 East 55th Street, Tulsa, OK 74145; 918-663-1985; 888-895-3435; Fax: 918-663-1986; www.shieldingresources.com

Siemic Laboratories
775 Montague Expressway, Milpitas, CA 95035 US; 408-526-1188; Fax: 408-526-1088; www.SIEMIC.com

Silicon Labs
400 West Cesar Chavez Street, Austin, TX 78701 US; 512-416-8500; 877-44-3032; Fax: 512-416-9669; susan.nayak@silabs.com; www.silabs.com

Silicone Solutions
1670-C Enterprise Parkway, Twinsburg, OH 44087 US; 330-920-3125; Fax: 330-920-3126; www.siliconesolutions.com

SILENT Solutions
10 Northern Boulevard, Suite 1, Amherst, NH 03031 US; 603-578-1842; Fax: 603-578-1843; Lee Hill, LHill@silent-solutions.com; www.silent-solutions.com

Simberian Inc.
3030 S. Torrey Pines Drive, Las Vegas, NV 89146 US; 401-627-7706; Fax: 702-482-7903; info@simberian.com; www.simberian.com

SiTime Corp.
990 Almanor Avenue, Sunnyvale, CA 94085 US; 408-328-4400; Fax: 408-328-4439; info@sitime.com; www.sitime.com

Solar Electronics Co.
10866 Chandler Boulevard, North Hollywood, CA 91601 US; 818-755-1700; 800-952-5302; Fax: 818-755-0078; sales@solar-emc.com; www.solar-emc.com

Soliani EMC SRL
Via Varesina 122, 22100 Como, Italy; 39-031-5001112; Fax: 39-031-505467; info@solianiemc.com; www.solianiemc.com

Sonnet Software, Inc.
100 Elwood Davis Road, North Syracuse, NY 13212 US; 315-453-3096; Fax: 315-451-1694; info@sonnetsoftware.com; www.sonnetsoftware.com

Soshin Electric Co., Ltd.
No. 3-13-16 Mita, Minato-ku, Tokyo 108-8322, Japan; 81-3-5730-4500; Fax: 81-3-5730-4504; oversea@soshin.co.jp; www.soshin-ele.com

Southwest Microwave, Inc.
9055 S. McKemy Street, Tempe, AZ 85284 US; 480-783-0201; Fax: 480-783-0360; www.southwestmicrowave.com

Southwest Research Institute
6220 Culebra Road, P.O. Drawer 28510, San Antonio, TX 78228 US; 210-684-5111; www.swri.com

Source1 Solutions
4675 Burr Drive, Liverpool, NY 13088 US; 315-730-5667; Fax: 315-457-0428; Steve Frierson, sf@source1compliance.com; www.source1compliance.com

Souriau PA&E
434 Old Station Road, Wenatchee, WA 98801 US; 855-285-5200; Fax: 509-663-5039; sales@pacaero.com; www.pacaero.com

SPAWAR Systems Center Atlantic
P.O. Box 190022, North Charleston, SC 29419 US; 843-218-4000; 843-218-3390; www.public.navy.mil/spawar/Atlantic/Pages/AboutUs.aspx

Spec-Hardened Systems
119 Larkwood Drive, Rochester, NY 14626 US; 585-225-2857; Fax: 585-225-2857; Anthony A. DiBiase, shsesc@aol.com

Specialty Silicone Products
Corporate Technology Park, 3 McCrea Hill Road, Ballston Spa, NY 12020 US; 518-885-8826; 800-437-1442; Fax: 518-885-4682; www.sspinc.com

Spira Manufacturing Corp.
12721 Saticoy Street South, North Hollywood, CA 91605 US; 818-764-8222; Fax: 818-764-9880; sales@spira-emi.com; www.spira-emi.com
AL, FL, GA, MD, MS, NC, SC, TN, VA Raleigh, NC;
Electronic Marketing Associates, Inc. 888-942-1555
INTERNATIONAL
AUT, GER, SUI Tricom Mikrowellen GMBH..... 011-49-8161-86066
CHN IES Technologies Inc 630-632-5941
FRA Getelec 011-33-146-44-6891
JPN Kitigawa Industries Co., Ltd. 011-81-587-34-3761

Sprinkler Innovations
95 Ledge Road, Suite 4, Seabrook, NH 03874 US; 800-850-6692; Fax: 603-468-1031; Jim Beers, jbeers@sprinklerinnovations.com; www.sprinklerinnovations.com

Spitzenberger & Spies GmbH & Co. KG
Schmidstraße 32, 94234 Viechtach, Germany; 49-9942-956-0; info@spitzenberger.de; www.spitzenberger.de

SRICO, Inc.
2724 Sawbury Boulevard, Columbus, OH 43235 US; 614-799-0664; Fax: 614-799-2116; sri@srico.com; www.srico.com

STACEM
Za Kerovel 56390 Grandchamp 56390 France; +33 2 97 66 75 97; www.stacem.com; contact@stacem.fr

Stahlin Enclosures
500 Maple Street, Belding, MI 48809 US; 616-794-0700; Fax: 616-764-3378; www.stahlin.com

Stephen Halperin & Associates, Ltd.
1072 Tower Lane, Bensenville, IL 60106 US; 630-238-8883; Fax: 630-238-9717; info@halperinassoc.com; www.halperinassoc.com

Stockwell Elastomerics, Inc.
4749 Tolbut Street, Philadelphia, PA 19136 US; 215-335-3005; Fax: 215-335-9433; service@stockwell.com; www.stockwell.com

Storm EMC Services Ltd.
14 Willersey Road, Cheltenham, Gloucestershire GL51 6NN, UK; 0117-230-3627; enquiry@stormemc.co.uk; www.stormemc.co.uk

Sulzer Metco Inc.
Zürcherstrasse 12, 8401 Winterthur, Switzerland; 41-52-262-11-22; Fax: 41-52-262-01-01; www.sulzer.com/en/About-us/Our-Businesses/Sulzer-Metco

Sunkyoung S.T.
Hwaseong-Si Gyeonggi-Do, Jangan-myeon Suchon-ri, Korea; 031-351-8171; Fax: 031-351-8174; www.sunkyoungst.com

Sunol Sciences Corp.
6780 Sierra Court, Suite R, Dublin, CA 94568 US; 925-833-9936; Fax: 925-833-9059; emc@sunolsciemces.com; www.sunolsciences.com

Suppression Devices
Unit 8, York Street Business Centre, Clitheroe, Lancashire BB7 2DL, UK; 44-1200-444497; Fax: 44-1200-444330; sales@suppression-devices.com; www.suppression-devices.com

Suzhou 3CTEST Electronic Co., Ltd.
Unit 2, Anda Industrial Park, No.198 Jinshan Rd, SND, Suzhou 215011, China; 86-512- 66389987; 86-512-68077661; Fax: 86-512- 66384886; emitest@188.com; www.3ctest.cn

Swift Textile Metalizing LLC
23 Britton Drive, P.O. Box 66, Bloomfield, CT 06002 US; 860-243-1122; Fax: 860-243-0848; sales@swift-textile.com; www.swift-textile.com

Syfer Technology Ltd.
Old Stoke Road, Arminghall, Norwich, Norfolk, NR14 8SQ, UK; 44-1603-723300; 44-1603-723310; Fax: 44-1603-723301; sales@syfer.co.uk; www.syfer.com

Synergistic Technology Group, Inc.
2490 North Buttercup Drive Tucson, AZ 85749 US; 520-760-0291

Syscom Advanced Materials
1275 Kinnear Road Columbus OH 43212 US; 614-487-3626; Fax: 614-487-3631; www.metalcladfibers.com

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Tapecon, Inc.
701 Seneca Street, Suite 255, Buffalo, NY 14210 US; 716-854-1322; 800-333-2407; Fax: 716-854-1320; www.tapecon.com

Taiyo Yuden (U.S.A.) Inc.
10 North Martingale Road, Suite 575, Schaumburg, IL 60173 US; 800-348-2496; 630-237-2405; Fax: 847-240-1715; www.t-yuden.com

TDK Corp.
475 Half Day Road, Lincolnshire, IL 60069 US; 847-699-2299; Fax: 847-803-6296; www.tdk.com

TDK-EPC Corp.
485B Route 1 South, Suite 200, Iselin, NJ 08830 US; 732-906-4300; Fax: 732-906-4395; sales.usa@epcos.com; www.epcos.com

TDK-Lambda Americas
3055 Del Sol Boulevard, San Diego, CA 92154 US; 619-575-4400; 800-526-2324; Fax: 619-429-1011; us.tdk-lambda.com/lp/

TDK RF Solutions, Inc.
1101 Cypress Creek Road, Cedar Park, TX 78613 US; 512-258-9478; 800-254-9478; Fax: 512-258-0740; info@tdkrf.com; www.tdkrfsolutions.com

Tech-Etch, Inc.
45 Aldrin Road, Plymouth, MA 02360 US; 508-747-0300; Fax: 508-746-9639; websales@tech-etch.com; www.tech-etch.com
AK Tech-Etch, Inc. 508-747-0300
AL Cornerstone Sales, LLC....................................... 256-430-8000
AR Centramark.. 972-414-8188
AZ Moss Marketing 602-828-1461
CA Motion Components 714-255-1080
CA Ross Marketing 650-691-0119
CO Moss Marketing 800-980-8812
CT Brandon Associates, Inc 610-738-8500
DE Brandon Associates, Inc. 610-738-8500
DC Eastern Tech Corp. 410-715-2100
FL Cornerstone Sales, LLC 321-765-4862
FL Cornerstone Sales, LLC 727-789-4802
GA Cornerstone Sales, LLC 770-638-8998
HI Tech-Etch, Inc. 508-747-0300
ID Technical Marketing Inc.................................. 509-991-5664
IL EMT Engineering Sales.................................... 847-481-7403
IN Frederic Ohmer & Associates.......................... 937-434-1454
IN Midtec Associates, Inc. 913-541-0505
KS Midtec Associates, Inc. 913-541-0505
KY Frederic Ohmer & Associates.......................... 937-434-1454
LA Centramark 713-771-1500

MA	Connors Co., Inc.	508-866-5392
MD	Eastern Tech Corp.	410-715-2100
ME	Connors Co.. Inc.	508-747-0300
MI	Frederic Ohmer & Associates	937-434-1454
MN	EMT Engineering Sales.	952-888-1020
MO	Midtec Associates, Inc.	314 839-3600
MS	Tech-Etch, Inc.	508-747-0300
MT	Technical Marketing Inc.	509-991-5664
NE	Midtec Associates, Inc	913-541-0505
NC	Cornerstone Sales, LLC	919-834-2677
ND	EMT Engineering Sales	952-888-1020
NH	Connors Co., Inc.	508-866-5392
NJ	Brandon Associates, Inc.	610-738-8500
NM	Moss Marketing	800-980-8812
NV	Ross Marketing Associates	650-691-0119
NY	Brandon Associates, Inc.	610-738-8500
NY	Brandon Associates, Inc.	610-738-8500
NY	Brandon Associates, Inc.	610-738-8500
OH	Frederic Ohmer & Assoc	937-434-1454
OK	Centramark	972-414-8188
OR	Technical Marketing, Inc.	503-627-9000
PA	Brandon Associates, Inc.	610-738-8500
RI	Connors Co, Inc.	508-866-5392
SC	Cornerstone Sales, LLC	919-834-2677
SD	EMT Engineering Sales	952-888-1020
TN	Cornerstone Sales, LLC	770-638-8998
TN	AL Cornerstone Sales, LLC	256-430-8000
TX	Centramark	817-498-5818
TX	Centramark	972-414-8188
TX	Centramark	512-795-0966
TX	Centramark	713-771-1500
UT	Moss Marketing	801-947-0169
VA	Eastern Tech Corp	410-715-2100
VT	Connors Co., Inc.	508-866-5392
WA	Technical Marketing, Inc. .	425-739-4600
WA	Technical Marketing, Inc.	509-481-5715
WI	Mequon, EMT Engineering Sales	262-236-4001
WV	Tech-Etch, Inc.	508-747-0300
WY	Moss Marketing	800-980-8812
INTERNATIONAL		
BEL	HF Technology	3175-6283717
CAN	The ID Group Inc.	514-575-8044
CHN	Mindar China Co. Ltd.	8610-64680338
DNK	Bomberg EMC Products	454-814-0155
FRA	Yelloz Components	330164466968
GBR	TBA Electro Conductive Products	441706-647718
GER	Feuerherdt GmbH	49-30-710-96-45-53
ISR	Maham Fasteners	972 3 9626516
ITA	Sirces SRL Italy	390-255-231395
JPN	Taiyo Wire Cloth Co.	81-334-937051
NOR	EG Components	472-325-4600
KOR	Eretec Inc.	82-31-436-1100
SGP	Glocom Marketing PTE, Ltd.	65-6873-0933
TPE	TennMax, Inc.	886-2269-54137
RSA	Actum Electronics	27-11-608-3001

Telcron LLC
Harleysville, PA 19438 US; 310-492-5035:
info@telcron.net; www.telcron.net

Teledyne Reynolds
Navigation House, Canal View Road, Newbury, Berkshire, RG14 5UR, UK; 44-1635-262-262; Fax: 44-1635-521936; trlsales@teledyne.com; www.teledynereynolds.co.uk

Temas Engineering
Via Milano 72, 22070 Bregano CO, Italy; 39-031-772348; Fax: 39-031-773897; info@temas.it; www.temas.it

TEMPEST Inc.
11654 Plaza America Drive, P.O. Box #134, Reston, VA 20190 US; 703-836-7378; info-2013@tempest-inc.com; www.tempest-inc.com

Tempest Security Systems Inc.
2855 Kensington Court, Troy, OH 45373 US; 937-335-5600; Fax: 937-335-0018; info@tempestusa.com; www.tempestusa.com

TESEO
Corso Alexander Fleming, 25/27/29, 10040 Druento, Torino, Italia; 39-011-9941-911; Fax: 39-011-9941-900; info@teseo.net; www.teseo.net

Teseq
52 Mayfield Avenue, Edison, NJ 08837 US; 732-417-0501; 888-417-0501; Fax: 732-417-0511; www.teseq.com

AL	Testrack	239-691-6117
AK	TESEQ	888-417-0501 x239
AR	Kemp Instrument	469-233-7288
AZ	Aztec Enterprizes	480-858-9511
CA	Comply Tek	858-674-6155
	TechDream	408-800-7362
CT	Scientific Devices	508-528-2458
CO	Azetec Enterprizes	800-304-3565
DC T	Technical Representatives, Inc	703-675-6723
DE	Technical Representatives, Inc.	609-313-3045
FL T	Testrack	941-720-0673
GA	Testrack	704-905-8628
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	Test Midwest West	816-866-0360
ID	PSI Solutions	503-233-8100
IL	Test Midwest North	262-521-3056
	Test Midwest Central	847-282-0360
	Test Midwest South	314-246-0360
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KS	Test Midwest	816-866-0360
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MD	Technical Representatives, Inc	703-675-6723
ME	Scientific Devices	603-672-1198
MI	Micro Sales	614-792-9117
MN	Test Midwest	612-460-0360
MO	Test Midwest East	314-246-0360
	Test Midwest West	816-866-0360
MS	Testrack	239-691-6117
MT	PSI Solutions	253-838-9263
NC	Testrack	704-905-8628
ND	Test Midwest	612-460-0360
NE	Test Midwest	816-866-0360
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	Comply Tek	858-674-6155
NY	Contech Marketing	732-634-5501
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OH	Micro Sales	614-792-9117
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PA	Micro Sales	614-792-9117
	Contech Marketing	732-634-5501
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SD	Test Midwest	612-460-0360
TN	Testrack	704-905-8628
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WV	Technical Representatives, Inc	703-965-4150
WI	Test Midwest	262-521-3056
WY	Atzec Enterprizes	801-546-9570
INTERNATIONAL		
AUS	Westek Electronics Pty. Ltd.	61-3-9369-8802
BRA	Campinas; EMCert Consultoria	19-3243-9371
CAN	Montreal; Testforce	514-856-0970
IND	Rohde & Schwarz India Pvt. Ltd.	91-11-4254-5422
MEX	TESEQ	888-417-0501 x239
POL	Astat Sp. Z o.o.	48-61-849-80-61
RUS;	St. Petersburg; ZAO NFP Dipaul Ltd.	7-812-325-1478

Test & Measurement Australia Pty Ltd.
P.O. Box 197, Blaxland, NSW 2774 Australia; 612-47399523; Fax: 612-47399524; sjb@TandM.com.au; www.TandM.com.au

Test Equipment Connection
30 Skyline Drive, Lake Mary, FL 32746 US; 407-804-1299; 800-615-8378; Fax: 800-819-8378; sales@testequipment-connection.com; www.testequipmentconnection.com

Test Site Services
30 Birch Street, Milford, MA 01757 US
508-634-3444; Fax: 508-634-0388
lab@testsiteservices.com; testsiteservices.com

Texas Spectrum Electronics
120 Regency Drive, Wylie, TX 75098 US; 972-296-3699; Fax: 972-296-7881; sales@texasspectrum.com; www.texasspectrum.com

The Compliance Management Group
257 Simarano Drive, Marlborough, MA 01752 US; 508-460-1400; Eric L. Wilbur, ewilbur@cmgcorp.net; www.cmgcorp.net

THEMIX Plastics, Inc.
621-D East Lake Street, Lake Mills, WI 53551 US; 920-945-0599; Fax: 1-920-945-0596; info@themixplastics.com; www.themixplastics.com

Thermo Fisher Scientific
81 Wyman Street Waltham, MA 02454 US; 781-622-1000; 800-678-5599; Fax: 781-622-1207; www.thermofisher.com/global/en/home.asp

THORA Elektronik GmbH
Esbacher Weg 13, D-91555 Feuchtwangen, Germany; 0-98-52-6-10-79-0; Fax: 0-98-52-6-10-79-50; service@thora.com; www.thora.com

Timco Engineering, Inc.
849 NW State Road 45, P.O. Box 45 370, Newberry, FL 32669 US; 352-472-5500; 888-472-2424; Fax: 352-472-2030; info@timcoengr.com; www.timcoengr.com

TMD Technologies Ltd.
Swallowfield Way, Hayes, Middlesex UB3 1DQ, UK
44-20-8573-5555; Fax: 44-20-8569-1839; heather.skinner@tmd.co.uk; www.tmd.co.uk

TRaC Global
100 Frobisher Business Park, Leigh Sinton Road, Malvern, Worcestershire, WR14 1BX, UK; +44 (0) 1684 571700; Fax: +44 (0) 1684 571701; emc@tracglobal.com
www.tracglobal.com/content/emc-testing

Transient Specialists, Inc.
7704 S. Grant Street, Burr Ridge, IL 60527 US
866-364-7368; laura@transientspecialists.com; www.transientspecialists.com

Tranzeo Wireless Technologies Inc.
19473 Fraser Way, Pitt Meadows, British Columbia V3Y 2V4, Canada; 604-460-6002; 604-460-6366; Fax: 604-460-6005; sales@tranzeo.com; www.tranzeo.com

TREK, Inc.
11601 Maple Ridge Road, Medina, NY 14103 US; 585-798-3140; 800-367-8735; Fax: 585-798-3106; sales@trekinc.com; www.trekinc.com

Trialon Corp.
1465 Walli Strasse Drive, Burton, MI 48509 US; 810-742-8500; 800-847-8111; Fax: 810-742-8512; trialon@trialon.com; www.trialon.com/test_engineering.html

Tri-Mag, Inc.
1601 North Clancy Court, Visalia, CA 93291 US; 559-651-2222; Fax: 559-651-0188; sales@tri-mag.com; www.tri-mag.com

TUV Rheinland of North America
12 Commerce Road, Newtown, CT 6470 US; 203-426-0888; 888-743-4652; Fax: 203-426-4009; www.tuv.com

TÜV SÜD America Inc.
1775 Old Highway 8 NW, Suite #104, New Brighton, MN 55112 US; 651-631-2487; Fax 651-638-0285; info@tuvam.com; www.TUVam.com

TÜV SÜD Product Service Ltd.
Octagon House, Concorde Way, Segensworth, North Fareham, Hampshire PO15 5RL UK; 44-1489-558100; Fax: 44-1489-558101; info@tuv-sud.co.uk; www.tuv-sud.co.uk/uk-en

TÜV SÜD Senton GmbH
Äußere Frühlingstraße 45, Straubing 94315 Germany; 49-9421-5522-22; Fax: 49-89-5155-1813; senton@tuev-sued.de; www.tuev-sued.de/industry_and_consumer_products/about_tuev_sued_senton

TWP Inc.
2831 Tenth Street, Berkeley, CA 94710 US; 510-548-4434; 800-227-1570; Fax: 510-548-4434; sales@twpinc.com; www.twpinc.com

Tyco Electronics Co.
1050 Westlakes Drive, Berwyn, PA 19312 US; 610-893-9800

U

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3000 Bristol Circle, Oakville, Ontario L6H 6G4, Canada; 905-829-1570; Fax: 905-829-8050; vic@ultratech-labs.com; www.ultratech-labs.com

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Vacuum Schmelze GmbH & CO. KG
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1675 Cambridge Drive, Elgin, IL 60123 US; 800-552-8258; 847-468-8258; Fax: 847-717-6121; Wade Chase, Sales Manager, wcc@valuetronics.com; www.valuetronics.com

Vanguard Products Corp.
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Vectawave
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Vermillion, Inc.
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View Thru Technologies, Inc.
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W

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Walshire Labs, LLC
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Washington Laboratories, Ltd.
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Wavecontrol
Pallars 65-71, 08018 Barcelona, Spain; 34-933208055; Fax: 34-933208056; www.wavecontrol.com

Wave Scientific
61 Livingstone Road, Hove, East Sussex BN3 3WN, UK; 44-1273-906022; info@wave-scientific.com; www.wave-scientific.com

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121 Airport Drive, Watertown, SD 57201 US; 605-886-4385; Fax: 605-886-4486; midcom-us@we-online.com; www.we-online.com

Wyatt Technical Services, LLC
56 Aspen Drive, Woodland Park, CO 80863 US; 719-310-5418; Fax: 877-443-9275; Kenneth Wyatt, ken@emc-seminars.com; www.emc-seminars.com

Wyle Laboratories
1960 East Grand Avenue, Suite 900, El Segundo, CA 90245 US; 310-563-6800; Fax: 310-563-6850; service@wyle.com; www.wyle.com

X

X2Y Attenuators LLC
2730-B West 21st Street, Erie, PA 16506 US; 814-835-8180; Fax: 814-835-9047; www.x2y.com

Y

Yazaki Testing Center
6800 North Haggerty Road, Canton, MI 48187 US; 734-983-6012; Scott Lytle, scott@yazakiemc.com; www.yazakiemc.com

York EMC Services Ltd.
Market Square, University of York, Heslington, York YO10 5DD, UK; 44-1904-324440; Fax: 44-1904-324434; www.yorkemc.co.uk

Z

Zero Ground LLC
3392 Hillside Court, Woodridge, IL 60517 US; 866-937-6463; Fax: 630-968-1200; service@zero-ground.com www.zero-ground.com

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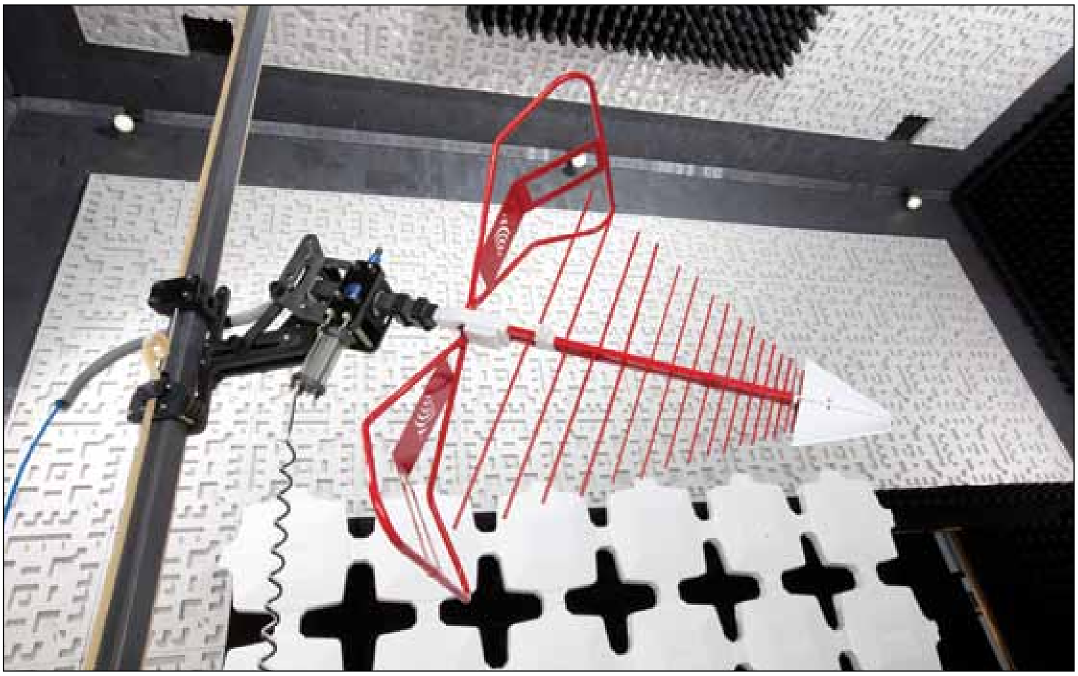

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