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Electrical Engineering Community

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How did you get into electronics/engineering and when did you start?

As a physics major in college, I was given the opportunity to work at a storm research lab. This got me into a lab/engineering environment and some contacts there set me up with an internship at an R&D company in Albuquerque, New Mexico. Because I had some familiarity with lightning, I was assigned to work on a couple of projects that were related to electromagnetic pulse (EMP). I gained some valuable experience and worked under some excellent senior-level engineers, but was still struggling trying to figure out what area of electronics to pursue. I got a huge break when I was assigned to work under a senior EMC engineer who was an excellent mentor. I knew the test automation software that he needed to make his measurements, and as a result, I had the privilege of working for him for about six months. During that period, he taught me an immense amount about electromagnetic compatibility. When he left the company, I was asked to take over his position as the resident EMC expert. I certainly was no expert at that time, but from that point on I was doing EMC.

I worked for a couple companies in Albuquerque before relocating to Colorado in 1989 where I began working for Ball Aerospace. I worked on some very interesting projects at Ball and learned a great deal, but wanted to get into the commercial world, so I went to work for a small commercial company. In the meantime, I was experiencing success with "moonlighting" as an EMC consultant, so I formed EMC Integrity, Inc. in November of 1993. When I got laid off from my daytime job in May of 1994, I made the decision to go full time and make it on my own with EMC Integrity.

What was the company like in 1994?

In the beginning EMC Integrity solely did design consulting. That was going very well but we needed a reliable lab to test the designs. There were a lot of requests from our customers to start an engineering lab, which we did in 1995. We later decided to turn it into a full compliance immunity test lab and received our first accreditation in 1997. We could perform immunity testing, engineering troubleshooting, debug, find and fix, and mitigation for clients. EMC Integrity quickly established a reputation for technical excellence and slowly began to increase in market share. However, we were somewhat limited because we could not perform formal emissions

EMC Integrity, Inc. Facility - Longmont, Colorado

testing, so in 1998 we established a relationship with another company and we used their 10-meter chamber on second shift to offer our clients compliance-level emissions testing.

How long did you keep that relationship before you decided that you needed to build your own 10-meter chamber?

It was about 2004 when we decided that it just made sense to have all of the testing done under one roof and we began plans to set up up our own 10-meter chamber. This required building our own facility, which we did. We opened the doors of our new building in February of 2006.

What was your business like after you built your 10-meter and moved to a new space?

When we opened our doors, all we had to do was let the word out. It turns out there were a lot of people that wanted to use EMC Integrity based on our reputation, but did not like the idea of taking their product to an OEM's lab and working second shift. Our clients were very pleased to have emissions and immunity testing under one roof, and business grew pretty dramatically after that.

Our growth has also been spurred by our ability to do International Submittals for the Far East including Korea, Taiwan, Russia, and China. We are able to do this through our Nemko Partner Lab Program. Nemko is a Notified Body for EMC (among other things) in the European Union, and it's great to have access to their expertise. Using their world-wide network, we can get clients' products EMC-approved for anywhere in the world. Since Nemko also offers product safety testing, EMCI can offer clients a virtual one-stop shop for compliance testing.

With the new additions and expansions to your lab, did you have to build another building?

After a few years in our new building, things were already getting crowded and we were working either second shifts or weekends to accommodate clients. After doing some trade-off studies, we determined the most cost-effective approach would be to add on to our existing building.

Our primary need was more bandwidth in our existing 10-meter, so the centerpiece of our expansion was a second 10-meter chamber. However, we didn't simply duplicate what we already had. We built a chamber that would not only increase our bandwidth, but would allow us to test larger products. Thus, our new chamber has a 4-meter turntable, 8' by 10' access doors, much bigger support power, and a 16' by 26' shielded ante-chamber that resides beneath the turntable. This arrangement makes setup of even large, I/O-intensive products much easier.

Do you use more than one antenna mast in the new chamber?

The new chamber has two antenna masts. We have a standard antenna mast that resides at the 10-meter distance covering the frequency range from 30 MHz to 1 GHz. We also have a second boresight antenna mast at the 3-meter distance. Boresight antennas are used for testing above 1 GHz, where signals become more directional. The standard antenna used from 1-18 GHz is a broadband horn. The function of the boresight mast is to keep the antenna pointed at the unit under test as it travels from 1 to 4 meters in height.

What would you recommend to electrical engineers working on products if they wanted to do some work to make sure their products will do well in terms of EMC testing?

Test early. Test as soon as you can. What often happens is that compliance testing is not performed until the end of the product design cycle. The closer you get to product completion, the more the design solidifies. Consequently, your options for change are reduced. A lot of people don't realize that unless a product is designed to meet electromagnetic compatibility requirements, there is about a 95 percent chance that it will fail. There is a huge value in identifying problems earlier in the project development cycle. If you identify a problem early, you can engineer a solution. If you wait until the design cycle is completed, oftentimes you are forced to implement some sort of "band-aid" fix. In addition to being a more cost-effective approach, addressing compliance problems early also greatly reduces the possibility that product shipment schedules will be delayed.

Do you see more problems in radiated immunity or conducted immunity?

I think that it is 50/50. While these tests are related, they are really two different animals. Radiated immunity is higher frequency than conducted immunity. Radiated immunity is a free-field type of test where conducted is lower frequency, and designed to simulate the current that would be induced on cables if they were exposed to a lower frequency EM field. However, a lot of times if you see problems on one, you will see problems on both.

What direction do you see your business heading in the next few years?

The future looks to be quite bright. With our increased throughput capability and our larger chamber, we are very well set to test larger and higher-end information technology equipment, medical systems, measurement systems, and industrial electronics. We have also begun testing intentional transmitters which are devices that intentionally transmit radio frequency energy to other devices. This all presents EMC Integrity with a huge opportunity for growth.

What challenges do you foresee in your industry?

I think one of the biggest challenges faced in not only the compliance industry, but the electronics industry in general, is education. My story of how I got into EMC is very common among EMC engineers. Nearly all of us mentored under EMC gurus who were kind enough to take the time to teach us the fundamentals of the discipline. Most engineers who graduate haven't even heard of electromagnetic compatibility, compliance requirements, or compliance testing. There are a few universities in the country which have introduced EMC courses in their curricula, but the majority of universities only mention EMC in passing, if at all. As a result, most electrical engineers start doing designs at companies with no idea of how to design for compliance. So now you're back to the scenario of having product shipment delayed by compliance issues, band-aid fixes rather than engineered solutions, and the cost overruns associated with both of these. The biggest challenge is definitely education. ■

10 Important Things to Consider Before EMC Testing Your Product

By Vincent Greb

Electromagnetic interference and compatibility (EMI/EMC) is a specialized discipline which can best be described as an esoteric hybrid between physics and electrical engineering. Having devoted nearly my entire career to the field, I find it utterly fascinating. But I have observed that many engineers who are forced to deal with it find the field completely frustrating. It comes complete with its own requirements, test equipment, test methodologies, trouble-shooting techniques, and even has its own vernacular. Because it is such a specialized area, many companies aren't large enough to employ a full-time compliance engineer. Consequently, compliance tasks are often delegated to electrical or mechanical engineers or technicians, many of whom aren't as familiar with the field as they would like to be. As such, they sometimes find it difficult to assess whether or not an EMC test lab will be a good fit for their company's products.

Compounding the problem is the fact that, in my 25 years of experience, I have observed that if a product has been designed without taking EMI/EMC into consideration, there is a 95% probability that the product will fail at least one of the tests required for EMC compliance. Thus, there is a good chance that you will be doing iterative testing at an EMC lab. The better the fit between your company and your test lab, the better for everyone involved.

Many engineers focus primarily on emissions. This is understandable, since the Federal Communications Commission (FCC) only requires compliance with emission limits for sale of digital devices in the United States. However, for sale in other economic areas, most notably the European Union and Korea, compliance with immunity standards is also required. As more countries develop and become larger players in the global economy, they continue to adopt standards requiring compliance with both EMI/EMC emission and immunity. Any product development team should realize that EMC does and will continue to play a more prominent role in global compliance, and they would do well to consider its implications on the cost, schedule, and marketability of their products.

The purpose of this article is as stated in the title: It will give technicians, engineers, engineering managers, and program managers 10 important things to consider before having EMC compliance testing done on their product. These range from assessing the technical capabilities of a lab, to logistical considerations, to common technical oversights made in the EMC design of a product.

I should point out that some of these considerations may not apply to your particular product. Some of these recommendations deal with commercial testing (e.g., FCC, CE Mark), while others will apply to MIL-STD, aerospace, and RTCA testing.

Lab Requirements

Consideration #1. Make sure the EMC lab you are considering is accredited. For EMC test labs in the United States, there are two main laboratory accreditation agencies: National Voluntary Laboratory Accreditation Program (NLVAP) and American Association for Laboratory Accreditation (A2LA). NVLAP is a branch of the National Institute of Standards and Technology (NIST), and is therefore a branch of the U.S. government. A2LA is a private, nonprofit organization. While there are other companies that can audit and accredit labs, NVLAP and A2LA are by far, the most established and recognized names in the U.S. An EMC test lab should be accredited by either NVLAP or A2LA to ISO17025: 2005, which is the ISO standard for test and calibration laboratories.

So what does it mean to have an "accredited lab?" Presumably, you're looking for an EMC test lab as an independent, third-party evaluation of your product to the EMC standards which apply to your product. Well, accreditation is the third-party assessor of the lab. It is a process that provides a degree of insurance that the lab in question has the correct test facilities, test equipment, procedures, processes and personnel to correctly perform the testing in accordance with applicable standards.

Labs should be happy to provide you with two documents to support their claim of being an accredited lab: a certificate and a scope. The certificate is a one-page document which will provide such information as the name of the accrediting agency (NVLAP or A2LA) and the standard to which the lab has been assessed (ISO/IEC 17025: 2005). The scope of accreditation is usually a multi-page document which lists the tests for which the lab has been approved. It is probably a good idea to verify that the tests you are considering are included under the lab's scope.

You can also check out the accreditation status of a lab yourself by going to the appropriate web site. The NVLAP web site lists the accredited labs by state. The A2LA site doesn't provide such a list, but rather allows you to search for a lab by name, area, et cetera. The links to the appropriate page for NVLAP and A2LA are as follows:

NVLAP: http://ts.nist.gov/standards/scopes/ect.htm

A2LA: http://www.a2la.org/dirsearchnew/newsearch.cfm

Is accreditation proof positive that the lab can do your testing? No, but it is a good first step in the right direction.

Consideration #2. For commercial radiated emissions testing, does the lab you are considering use a 10-meter chamber or an open area test site (OATS)? When radiated emissions testing was first required for commercial electronics (around 1980), an OATS was the only approved way to make the measurements. However, as the radio frequency (RF) spectrum became more cluttered, OATS testing became much less reliable. Most notably, the advent of broadband television is spelling the end of many OATS around the country. The advancement of ferrite and anechoic technology has made 10-meter chambers a viable option. So what are "semi-anechoic 10-meter chambers?" A qualified 10-meter chamber will meet all the requirements of an OATS, but is isolated from the external electromagnetic environment. And even though 10-meter chambers are still termed "alternate test sites" by ANSI C63.4, they are much better test sites for five main reasons:

Volumetric site attenuation Open area sites are only required to meet site attenuation at the center of the turntable. Thus, a site can meet its normalized site attenuation (NSA) requirement and still have serious problems with repeatability and reproducibility of data because an NSA is so limited in scope. Chambers, on the other hand, are required to meet volumetric site attenuation, which is a much more stringent requirement. Not only do chambers need to comply with NSA at the center of the turntable, but at the front of the turntable, the left side of the turntable, and the right side of the turntable. This requirement encompasses a volume rather than a line, and indicates how uniform the "quiet zone" of the site is. The ability to meet the volumetric site attenuation requirement is a significant component that contributes to the repeatability and reproducibility of test data.

Reduced test time. Open Area Test Sites (OATSs) have always had the problem of having to determine whether or not an emission is an ambient or actually emanating from your product. To help mitigate this, many open area sites were built in remote areas, which meant increased transit time to and from the facility. However, broadband noise emanating from power lines often makes emission measurements below 200 MHz difficult, and sometimes impossible. In addition, the proliferation of cellular telephones, pagers, and now broadband high-definition television (HDTV) are taking up larger portions of the RF spectrum, and making emissions measurements at many OATSs more time-consuming and less reliable.

Provided that the unit under test can be set up within 30 minutes, a full-compliance radiated emissions scan from 30 MHz to 1 GHz takes only two hours in a correctly configured 10-meter chamber, as compared with six to eight hours at a typical OATS.

Reduced cost. Chambers typically have a higher hourly rate than open area sites. However, the fact that the work can be accomplished in much less time makes the cost of doing emissions testing in a chamber significantly less expensive than an OATS. In performing a cost comparison, don't forget to factor in the extra cost of the time for the personnel to support the testing.

Greater repeatability of test data. Open area sites are subject not only to increasing ambient noise, but also to changes in the physical environment around the site. High humidity, rain, and snow can dramatically alter test results, often making them appear higher (or lower) than they actually are. This can result in increased test time, making the manufacturer spend additional time and money reducing an emission which is being enhanced by the environment at the test site. That simply cannot happen at a qualified indoor chamber, whose measurements are not dependent on the environment. If you see an emission, it is coming from your product or the associated support equipment.

Greater confidence that your product is truly compliant. The basic procedure for radiated electric field emissions testing is as follows: pre-scan, maximization/quasi-peak (QP), cable maximization, final QP. A large part of getting a good set of final data begins with the pre-scan, as this is the basis for the list of frequencies that will be QPed and maximized. The following table compares how the pre-scan in a 10-meter chamber differs from that of an OATS. (See Figure 1)

The pre-scan performed in a 10-meter chamber has eight times the resolution of a typical OATS. Not only do you have a better profile of your product (much faster), this is extremely valuable at frequencies above 500 MHz, where signals become increasingly directional. A highly directional signal could easily be non-compliant if measured, yet it might not even make the final QP list, given the lack of resolution of the OATS pre-scan data.

In addition, when testing at an OATS, the possibility often exists that an emission from your product cannot be measured because it is obscured by the ambient noise. A well-meaning test facility could give you a passing report, however, when self-declaring, it is the manufacturer who has to deal with the implications of selling a non-compliant product. This scenario simply could not happen when using an indoor facility. If you see an emission, you know that it is coming from your product or support equipment and the problem can be dealt with much easier and more directly.

Consideration #3. Assuming the lab you are considering does have a chamber (as opposed to an OATS), will the radiated emissions testing from 30 MHz to 1 GHz be performed at a distance of 10 meters? If you're looking to ship your product globally, the fact is that neither Taiwan nor Korea will accept 3-meter data from 30 MHz to 1 GHz. While other countries may accept 3-meter data, most do so only with caveats that have recently been added to the standards. In addition, in the event of a dispute between 3-meter and 10-meter data, 10-meter will always take precedence because it is closer to a far-field condition.

The biggest problem with 3-meter data is that you're definitely in the near field below 100 MHz,

Parameters	10-Meter	OATS
Azimuth Positions (typical)	8	4
Antenna Heights (typical)	4	1
Polarities (typical)	2	2
Total number of measurement locations for pre-scan	**64**	**8**

Figure 1

which means the emissions will behave more erratically. This is due primarily to the fact that the fields generated by the UUT are interacting more with the receive antenna. The closer you are to far-field conditions, the more consistent your test results will be.

Consideration #4. Verify that the lab you're considering can handle the power requirements of your unit under test, and possibly your support equipment as well. Often the lab will beat you to the punch on this, but if they don't, be sure to bring it up. Many EMC tests require that different sorts of devices be placed in series with the input power to the unit under test. These devices include line impedance stabilization networks (LISNs) and coupling/decoupling networks (CDNs). It could save everyone a lot of time and effort if both you and the lab know whether or not the unit under test exceeds the current rating, voltage rating, or number of phases supported by these devices. A work-around may exist, but this also might entail additional lead time, as the lab may have to rent and/or calibrate special equipment required to do the testing.

Logistical

Consideration #5. If you have a large product, does the test lab have a loading dock? While there will be a number of things to consider when shipping large products to a test lab, whether or not the lab has a loading dock is a good measure of how well-equipped the lab is to test large products. Here are some other related considerations: Does the lab have a fork lift and if so, what is its load rating? Does the lab have ample storage space to store the shipping crates that will sit empty while the unit is being tested? In any event, make sure you coordinate shipping with the lab. If your product is scheduled to arrive prior to testing, make sure the lab is aware of this so they are ready to receive your product.

> The 10 things to consider in this article have been written as an introductory guide to all those individuals who do not have adequate time to devote to the field of EMC, but have nonetheless been tasked with the job of managing product compliance. If at least one of the suggestions given in this article will be of use to part-time compliance professionals, it will have achieved its goal.

Consideration #6. Verify that your hardware is completely functional at your facility prior to packing up and shipping to the test lab. This might sound trivial, but you'd be surprised at the number of times hardware arrives which is not functional because it was not checked out at the manufacturer's location, or because it lacks a cable needed for correct operation. If you check the hardware out at your facility prior to testing, and package up that entire system, you greatly reduce the potential for encountering problems when you arrive at the lab. If you're mailing the product to the lab such that the lab will be testing it without client support, make sure you have included ample instructions on how the unit should be set up and configured for testing. In addition, make sure that the lab has the necessary information to contact someone from your facility in the event that an anomaly is encountered during testing.

Consideration #7. If your product is scheduled to undergo immunity testing, understand that some of this testing may be destructive. The two most common tests where hardware is damaged are surge immunity and electrostatic discharge. Surge immunity is a test designed to simulate the indirect effects of lightning or large switching transients induced on power inputs and possibly long I/O cables connected to the unit under test. Unless the power supply on your product is designed to withstand the energy in the surges that will be applied, it will most likely be damaged.

Electrostatic discharge (ESD)

testing is designed to simulate both direct and indirect effects of this event. The direct effects can either be air or contact. Air discharge testing is performed on user-accessible parts of the product which are non-conductive, while contact discharge testing applies to conductive portions of the product, also user-accessible.

One frequently asked question is, "Are you going to discharge to connector pins?" If the reference standard is IEC 61000-4-2 (aka, EN 61000-4-2), the answer is no. In other words, unless you are testing to some customer-specific requirement, Section 8.3.2 of IEC 61000-4-2 specifically excludes exposed connector pins to direct discharge. If the connector shell is metal, contact discharge is performed only to the shell, and not the connector pins. Similarly, if the connector shell is non-conductive, air discharge may be applied to the connector shell.

Consideration #8. During immunity (or susceptibility) testing, how will your product be exercised and monitored? Many people only think of EMC in terms of emissions, during which a product needs to be continually exercised, but not necessarily monitored for correct performance. In my opinion, however, immunity testing is more important because it adds a lot more value to the product. Immunity testing looks at how the product will respond when exposed to an adverse, externally-impinged electromagnetic environment. This could be a radiated RF field, transients induced on power and I/O cables, or electrostatic discharges. Radiated RF immunity testing can take anywhere from four hours to a couple of days, depending on the test being performed. Watching a product for that period of time is extremely tedious and that prolonged period of boredom could result in the support person missing a problem that occurred during testing. A much more reliable solution to this problem would be to write a script which not only exercises the product, but produces a noticeable error when an out-of-tolerance condition exists. Visual alarms are good, but audible alarms are even better. The few hours dedicated to programming this feature will pay big dividends during the testing.

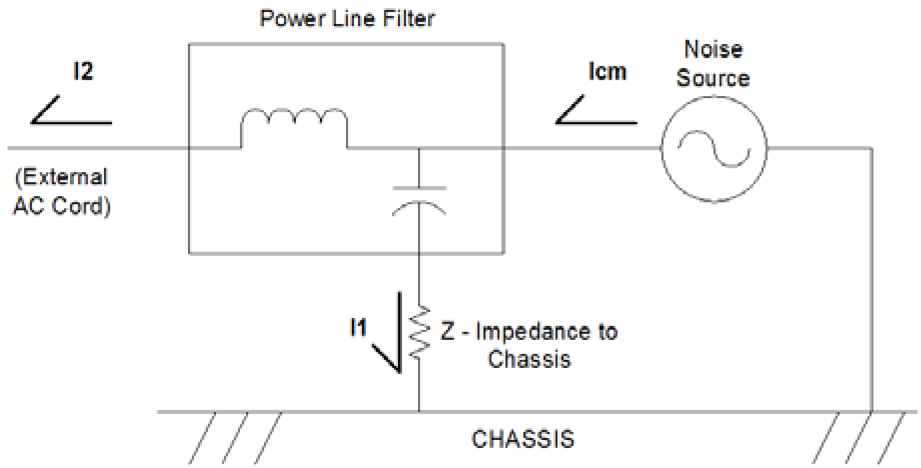


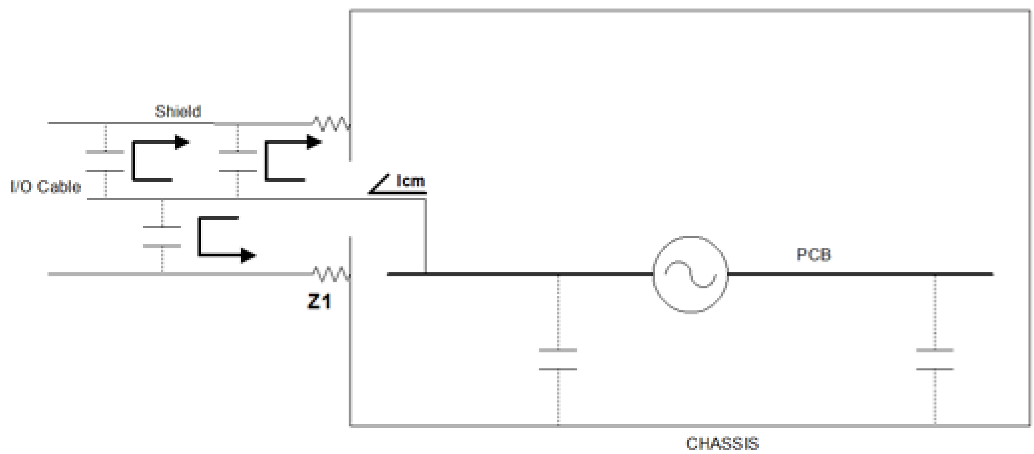
Figure 2: Simplified CM Model for Power Line Filter.

Common Technical Oversights

Consideration #9. If you are using an AC power line filter, make sure that you have installed it correctly. Many times, when trouble-shooting an emissions problem, the primary source of radiation is the AC power cord. Emissions may be related to the power supply, or might be from higher frequency sources within the product (e.g., digital logic, clocks, or processors) Clients are often perplexed that the AC line can be "hot," since they know there is an AC power line filter installed in their product! However, for a filter to work correctly, it must be properly installed.

Nearly all power line filters are designed to filter both differential mode (DM) and common mode (CM) noise. DM noise is line to line, while CM noise is line with respect to some reference. Often, this reference is the chassis. If this is the case, in order for the filter to work effectively, it needs to be installed with a low impedance connection to chassis. If it is installed on a non-conductive surface, this can greatly inhibit filter performance for high frequency (i.e., common mode) noise. A good illustration of this is shown as a very simple common mode model, in Figure 2.

The line to chassis capacitor in this filter is designed to provide a return path for noise currents generated within the chassis. This filter, in



Notes

1. The capacitance between the I/O cable and the shield is distributed capacitance between these two elements.
2. The capacitance between the PCB and the chassis is parasitic (i.e., free space) capacitance.

Figure 3: Simplified CM Model for Shield Termination.

essence, sets up a current divider in which we would like I1 to be very large and I2 to be negligible. However, the higher the impedance between the filter and chassis, the less effective this current divider will be, and the greater the resultant current appearing on the AC power cord will be. The larger the magnitude of CM current on the AC power cord, the higher the radiated electric field emissions are going to be.

A common mistake is to rely on the green wire (i.e., safety) ground for a low impedance return path. Keep in mind that safety ground wires are installed to deal with safety-related problems at power frequencies, typically 50 or 60 Hz. The impedance of the wire is negligible at these frequencies, but since inductive reactance increases proportionally with frequency, it will most likely present an impedance of hundreds of ohms at or above 30 MHz.

Consideration #10. If your product has any shielded I/O cables, make sure that these shields are properly terminated. The typical purpose of a shield is to contain the high-frequency emissions generated on PCBs inside the box, which are propagating on the wires inside the shield. However, in order for the shield to be effective, it must have a low impedance return path to the noise source, which is in many cases, the chassis. If this condition is not present, the CM currents will simply couple to the shield, it will be excited to an RF potential with respect to the chassis, and it will end up radiating instead of the wires. A simplified CM model for this is shown in Figure 3.

Conclusions

Electromagnetic interference and compatibility is a very specialized discipline. However, being both specialized and a support engineering function, unless you work for a company large enough to support an EMC engineer, your company's compliance is probably being handled by a technician or engineer who only deals with EMC as a sideline, as the need arises. The 10 things to consider in this article have been written as an introductory guide to all those individuals who do not have adequate time to devote to the field of EMC, but have nonetheless been tasked with the job of managing product compliance. If at least one of the suggestions given in this article will be of use to part-time compliance professionals, it will have achieved its goal. ■