NOVEMBER 2020

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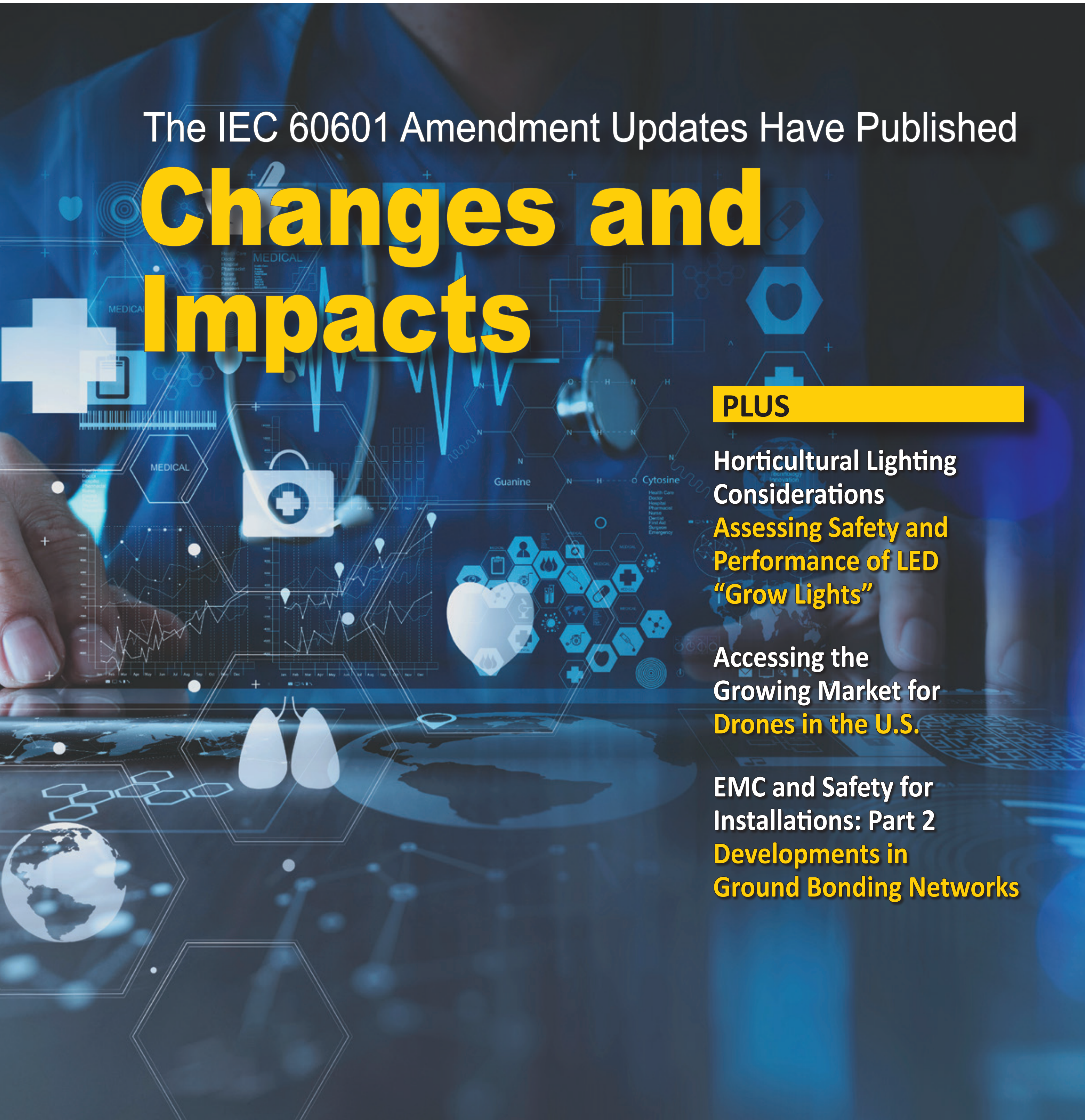

The IEC 60601 Amendment Updates Have Published

Changes and Impacts

PLUS

Horticultural Lighting Considerations
Assessing Safety and Performance of LED "Grow Lights"

Accessing the Growing Market for Drones in the U.S.

EMC and Safety for Installations: Part 2
Developments in Ground Bonding Networks

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NOVEMBER 2020 CONTENTS

Volume 12 | Number 11

FCC Moves to Free Up More Spectrum for 5G Deployment

As part of its ongoing effort to free up spectrum for the nationwide deployment of 5G technology, the U.S. Federal Communications Commission (FCC) has proposed to allocate a portion of mid-band spectrum for 5G use.

The Commission's Report and Order and Further Notice of Proposed Rulemaking lays the groundwork for making 100 megahertz of spectrum in the 3.45-3.55 GHz band available for 5G use. Specifically, the Report and Order adopts a 2019 FCC proposal to remove secondary, non-federal allocations from the 3.3-3.55 GHz band as a first step to facilitate spectrum sharing between federal incumbents and commercial operations.

The Further Notice of Proposed Rulemaking proposes: 1) allocation changes to the band to enable future commercial use; 2) coordination between future commercial users and federal incumbents that remain operational within the band; 3) relocation logistics for non-federal secondary users; and 4) technical, licensing and operating rules to foster a successful coordinator of band use between the parties.

FDA Issues Guidance Documents on Pilot Accreditation Scheme

The U.S. Food and Drug Administration (FDA) has issued three final guidance documents in support of a pilot program that would allow accredited testing laboratories to assess medical devices for compliance with certain FDA-recognized standards. The three final guidance documents issued by the FDA include:

- "The Accreditation Scheme for Conformity Assessment (ASCA) Pilot Program"—This guidance describes how the Pilot accreditation program was designed and how accreditation bodies, testing laboratories and device manufacturers can participate in the program.
- "Basic Safety and Essential Performance of Medical Electrical Equipment, Medical Electrical Systems, and Laboratory Medical Equipment – Standards Specific Information for the Accreditation Scheme for Conformity Assessment (ASCA) Pilot Program"—This guidance provides information specific to the basic safety and essential performance of standards in the Pilot program. Specifically, the guidance addresses which standards are eligible for inclusion in the Pilot, ASCA program specifications for those standards, and recommended premarket submission contents specific to those standards when testing is conducted by an ASCA-accredited testing laboratory.
- "Biocompatibility Testing of Medical Devices – Standards Specific Information for the Accreditation Scheme for Conformity Assessment (ASCA) Pilot Program—This guidance provides information on the biological evaluation of medical device standards and test methods in the ASCA Pilot. Similar to the previously referenced guidance, this guidance discusses the standards and test methods eligible for inclusion in the program, program specifications for those standards, and recommended contents specific to those standards.

Required under the 2017 FDA Reauthorization Act, the FDA's pilot accreditation program would help to facilitate a more efficient review process for certain types of medical devices, allowing device manufacturers to bring new and innovated products to market more quickly.

Vintage TV Identified as Source of Broadband Outage

Residents of a small village in rural Wales can now breathe a sigh of relief after engineers identified a source of interference that resulted in the regular shutdown of the community's broadband internet service.

According to a report posted last month to the CNN website, the village of Aberhosan was experiencing daily internet service outages every morning around 7 am for a period of 18 months. Repeated investigations by network operators turned up little that could explain the daily outages, and even replacing cables that serviced the area did not mitigate the problem.

Finally, Openreach, the company that runs the digital network in the United Kingdom, deployed their chief engineering team to investigate whether the source of the problem might be a single high-level impulse noise (SHINE), a form of electrical interference emitted from certain appliances that impact broadband signals. Using spectrum analyzers, engineers walked throughout the village to identify a potential source for the noise.

The investigation ultimately led to a vintage television in the home of a village resident, who habitually turned on the set every morning at 7 am, resulting in the shutdown of broadband services.

Openreach reports that the owner has "retired" the vintage television and that there have been no subsequent broadband outages in Aberhosan.

FCC Grants ARRL Waiver Request for Fire Emergencies, Hurricanes

The U.S. Federal Communications Commission (FCC) has granted a request from the American Radio Relay League (ARRL) to temporarily waive symbol rate limits for amateur radio communications used during hurricane and wildfire relief efforts.

Symbol rates are the rates at which carrier waveform amplitude, frequency and/or phase is varied to facilitate the transmission of information. Under current FCC rules, symbol rates applicable to high frequency (HF) amateur radioteletype (RTTY/data transmissions are limited to 300 bauds for frequencies less than 28 MHz and 120 bauds in the range between 28-29.7 MHz.

The ARRL submitted a petition to the FCC in 2016 to remove the symbol rate limitations due to advances in modulation techniques. While a decision on that petition is still pending, the ARRL also sought an emergency waiver of the symbol rate limits for licensees supporting hurricane and wildfire relief efforts via HF using PACTOR 4 modems, which permit relatively high-speed data transmission rates.

The FCC approved the temporary waiver requested by the ARRL expressly for emergency relief communications using PACTOR 3 and PACTOR 4 emissions within the U.S. and its territories. The period of the waiver is limited to 60 days from the date of the FCC's order, September 17, 2020

FDA Issues Guidance on Recognition of Voluntary Consensus Standards

The U.S. Food and Drug Administration (FDA) has issued a guidance on how the agency addresses requests for recognition of a voluntary consensus standard for use in the assessment of medical devices.

Issued in mid-September, the guidance, "Recognition and Withdrawal of Voluntary Consensus Standards," details the procedures the agency's Center for Device and Radiological Health (CDRH) follows in evaluating potential consensus standards and sets forth the principles it uses to recognize a standard wholly, partially or not at all. The guidance also provides information on the reasons or rationale behind decisions to withdraw a consensus standard.

Voluntary consensus standards that have been "recognized" by the FDA have been evaluated and determined as appropriate for use by medical device manufacturers in demonstrating conformity with the FDA's relevant requirements. Frequently, consensus standards recognized by the FDA can also be used to demonstrate conformity with requirements in other jurisdictions, such as the European Union's Medical Device Regulation (MRD).

You Can't Make This Stuff Up: 2020 Ig Nobel Prizes Announced

And now for a bright spot in our chaotic world…

The 30th First Annual (not a typo!) Ig Nobel Prize ceremony was held virtually last month. Not to be confused with the Nobel Prizes being announced this week in Stockholm, Sweden, the Ig Nobel Prizes are intended to "honor achievements that first make people laugh and then make them think."

This year's Ig Nobel Prize award winners include:

- For physics, a team of researchers from Australia, Ukraine, France, Italy, Germany, the United Kingdom and South Africa for determining experimentally what happens to the shape of a living earthworm when the earthworm is vibrated at a high frequency;
- For acoustics, researchers from Austria, Sweden, Japan, Switzerland and the U.S. for inducing a Chinese alligator to bellow in an airtight chamber filled with helium-enriched air;
- For economics, researchers from the United Kingdom, Poland, France, Brazil, Chile, Columbia, Australia, Italy and Norway for their efforts to quantify the relationship between different countries' national income inequality and their average amount of mouth-to-mouth kissing;
- For psychology, Canadian and U.S. researchers for devising a method to identify narcissists by examining their eyebrows
- And finally, for peace, researchers from India and Pakistan for having their diplomats ring each other's doorbells in the middle of the night, and then run away before anyone had a chance to answer the door.

PCB RETURN-CURRENT DISTRIBUTION IN A MICROSTRIP LINE

By Bogdan Adamczyk

In [1] the return path of high-frequency current was discussed for a two-layer PCB configuration shown in Figure 1a.

It was shown that at high frequencies the return current takes the path of least inductance, which is directly underneath the top trace, because this represents the smallest loop area (smallest impedance). This is shown in Figure 1b.

This article discusses the distribution of a PCB return current underneath top trace for the microstrip configuration. Next month's article will discuss the distribution for the stripline configurations.

RETURN CURRENT DISTRIBUTION IN A MICROSTRIP CONFIGURATION

Consider a typical microstrip configuration in a four-layer PCB, shown in Figure 2.

Figure 3 shows a single trace on a signal layer carrying a forward current and the associated fields.

Figures 4 and 5 on page 10 show the CST Studio simulations of the ***E*** and ***H*** fields, respectively [2].

If the trace carries a forward current then the return current will flow on the adjacent reference plane underneath the trace where the electric field lines terminate. The reference plane could be a ground plane (signal V_1 and the adjacent plane) or a power plane (signal H_2 and the adjacent plane), as shown in Figure 6 on page 10.

Let's stop here for a minute and answer this important question: *How is it possible for the return current to flow on the power plane?*

This seems to contradict what we have learned in a basic circuit course. In a "classical" circuit course we

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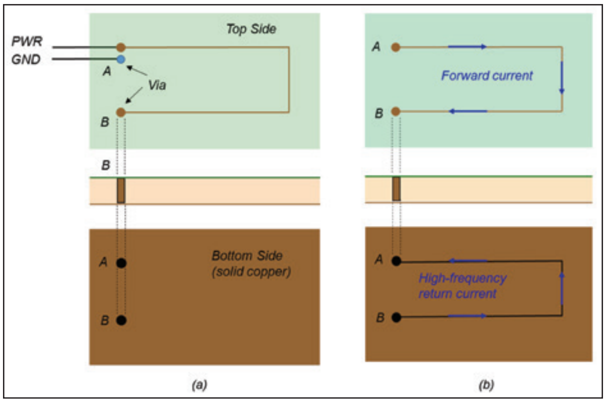

Figure 1: Two-sided PCB with a solid ground plane

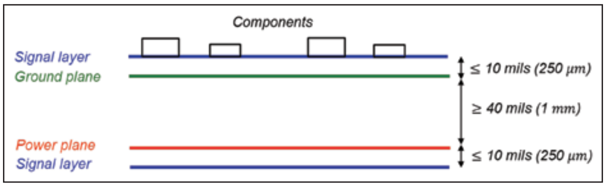

Figure 2: Microstrip configuration is a four-layer PCB

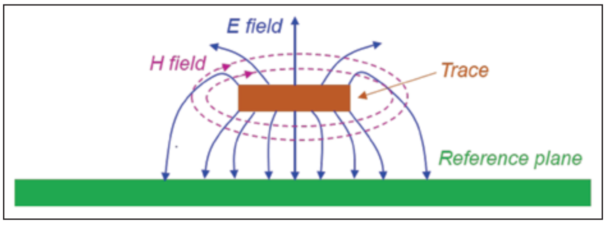

Figure 3: Microstrip line and the surrounding fields

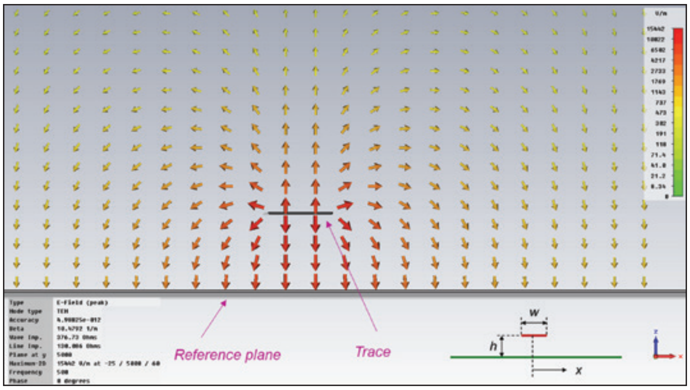

Figure 4: Microstrip line - simulated ***E*** field

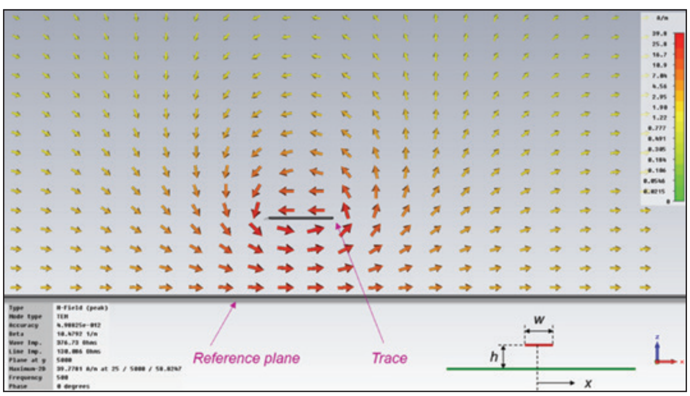

Figure 5: Microstrip line - simulated ***H*** field

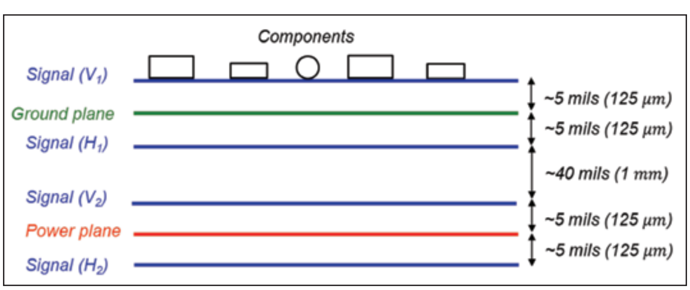

Figure 6: Reference planes in a six-layer PCB configuration

always assumed that the current flows out of the positive terminal of the source, flows along the forward path, through the load, and returns to the source on the return (ground) path (conductor or plane).

This is true for pure DC currents where we model the current flow as moving charges along the conductor, flowing with a drift velocity proportional to the voltage of the source. We often ignore the drift velocity and assume that there is no time delay in the current flow and the voltages and currents appear instantaneously everywhere in the circuit when the source is connected to it.

Pure AC current (regardless of its frequency) does not involve the charges moving along a conductor; it is modeled as the charges oscillating back and forth (with respect to their original position) as the polarity of the source changes. This ac model is valid for the *functional*, i.e., intentional ac currents. When analyzing such circuits, we still assume that the current flows from the positive terminal of the source, along the forward conductor to the load, and returns to the source along the return (ground) path (conductor or a plane). And again, we often ignore the time delay.

Now, the situation is quite different for high-frequency *noise* currents. Actually, for any-frequency noise currents, but we usually ignore the low-frequency noise and focus on high-frequency noise currents. These high-frequency noise currents, (created for instance, during the switching of the DC voltage levels) are superimposed on the existing functional DC or AC currents. In understanding their impact, it helps to think of them as the electromagnetic

Figure 7: High-frequency return currents

waves traveling on the surface of the conductor. These waves disturb the functional behavior of the charges moving in a conductor, *regardless of what DC potential the conductor is at*! These high-frequency noise waves (current) will "flow" on any conducting surface, regardless of whether it is a ground or power plane!

Now, having established the fact that the high-frequency noise current can flow on either the ground or power plane, let's look into more details of such a flow. The high-frequency current flows within a few skin depths of the reference plane surface, as shown in Figure 7.

Figure 8 shows the fields and the current density inside the current carrying conductor (see [3] for more details).

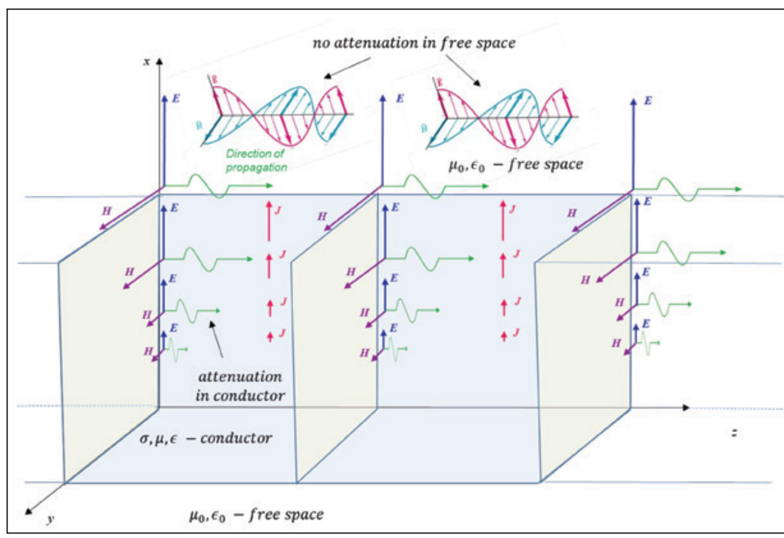

Figure 8: Fields and current density inside a conductor

Since the current density decays to virtually zero within a few skin depths in a conductor, the high-frequency currents are often considered to be the surface currents. Consequently, the reference plane can be considered as two different conductors. The high-frequency current flowing on the top surface is different from the high-frequency current flowing on the bottom surface. This is illustrated in Figure 9.

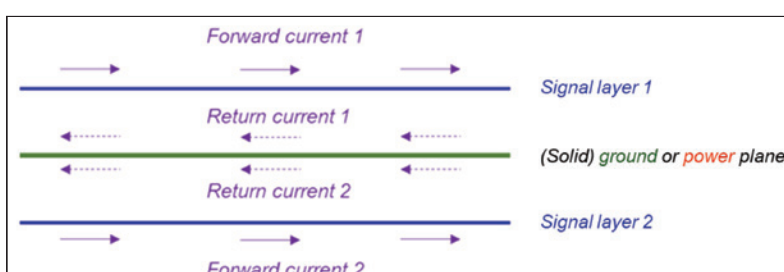

Figure 9: Currents on both sides of the reference plane

Let's turn our attention to the return current distribution in the reference plane underneath the forward trace. Consider the microstrip line geometry shown in Figure 10, where the trace of width *w* is at a height *h* above a reference plane; *x* is the distance from the center of the trace.

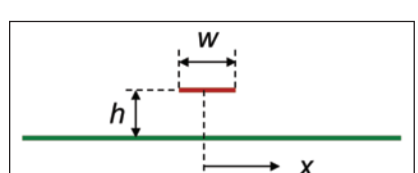

Figure 10: Microstrip line geometry

The current distribution on the reference plane underneath the trace is described by its current density [4] *J(x)*:

$$J(x) = \frac{I}{w\pi}\left[\tan^{-1}\left(\frac{2x-w}{2h}\right) - \tan^{-1}\left(\frac{2x+w}{2h}\right)\right] \quad (1)$$

where *I* is the total current flowing in the loop. The current density underneath the center of the trace is

$$J(0) = \frac{I}{w\pi}\left[\tan^{-1}\left(\frac{-w}{2h}\right) - \tan^{-1}\left(\frac{w}{2h}\right)\right] \quad (2)$$

Figure 11 on page 12 shows the Matlab plot of (normalized) current density underneath a trace as a function of *x/h*.

Observations: 1) Majority of the return current flows relatively close to the center of the trace. 2) as the distance from the center increases, the curve flattens. Therefore, there is still some return current beyond the distance ±5*x/h* from the center.

Figure 12 shows the CST Studio simulation of the current density underneath the trace.

Figure 13 shows the % of the total microstrip return current contained in the portion of the plane between ±*x/h* of the centerline of the trace.

Observations: 1) 50% of the current is contained within a distance ±1*x/h*. 2) 80 % of the current is contained within a distance ±3*x/h*. 3) 97% of the current is contained within a distance ±10*x/h* [x].

Table 1 shows more detailed results for other distances from the centerline underneath the trace [x].

The highlighted row in Table 1 shows that if a microstrip trace is located 10 mils above a reference plane, then 97% of the return current will flow in the portion of the plane that is 200 mils to the left and right of the trace centerline.

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2. Scott Piper, *CST Microwave Studio Simulations*, Gentex Corporation, 2012
3. Bogdan Adamczyk, "Skin Depth in Good Conductors," *In Compliance Magazine*, February 2020.
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x/h	% of Current
1	50
2	70
3	80
5	87
10	94
20	97
50	99
100	99.4
500	99.9

Table 1: Cumulative current in % underneath a microstrip trace

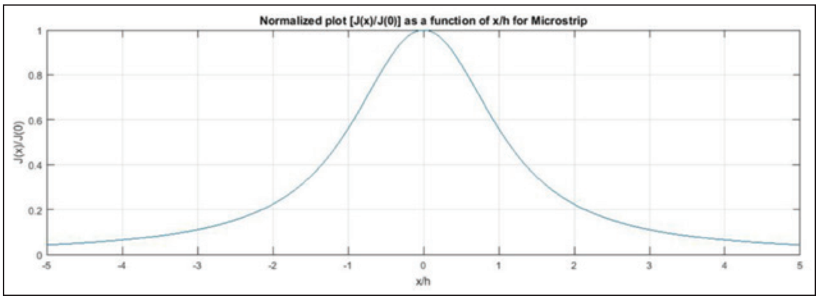


Figure 11: Current density underneath a microstrip trace (Matlab)

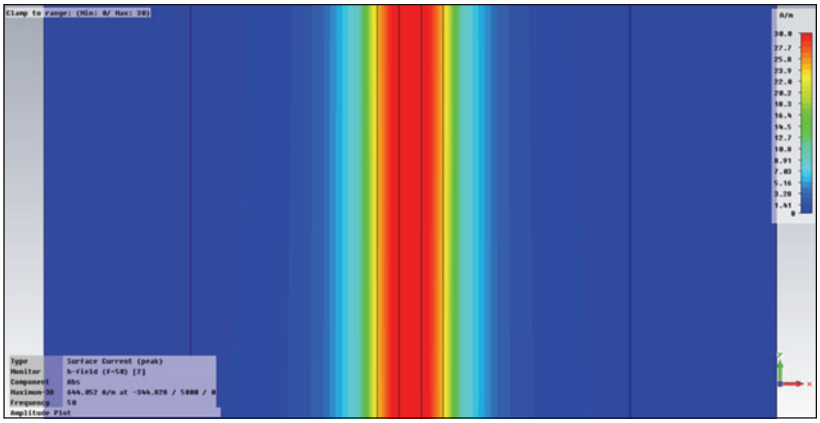


Figure 12: Current density underneath a microstrip trace (CST Studio)

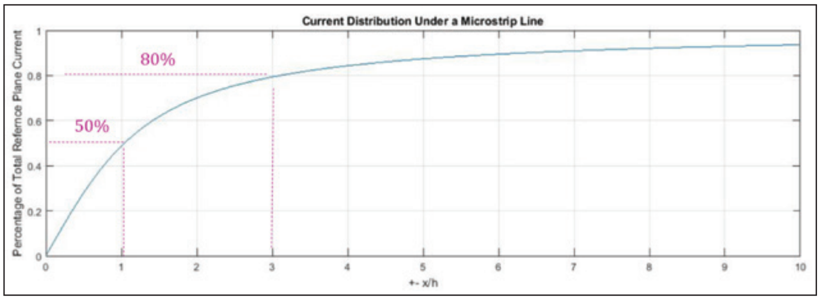


Figure 13: Cumulative distribution of the return current

THOSE SEMICONDUCTOR DATASHEET ABSOLUTE MAXIMUM RATINGS (AMR) ARE CRITICAL

Following them properly is for your benefit!

By Stevan Hunter for EOS/ESD Association, Inc.

Stevan Hunter, PhD, has 42 years experience in semiconductor engineering and holds certifications as Lean Six Sigma Blackbelt, Reliability Engineer, and ESD Factory Control Manager. Stevan currently focuses on his university teaching, as Faculty Associate at Arizona State University, BYU-Idaho and University of Maryland CALCE. He is a Senior Member of IEEE and ASQ, and member of IMAPS, SRE, AVS, ASEE and ATD.

Founded in 1982, EOS/ESD Association, Inc. is a not for profit, professional organization, dedicated to education and furthering the technology Electrostatic Discharge (ESD) control and prevention. EOS/ESD Association, Inc. sponsors educational programs, develops ESD control and measurement standards, holds international technical symposiums, workshops, tutorials, and foster the exchange of technical information among its members and others.

This article is a follow-up to "What's the trouble with AMRs?" In Compliance Magazine*, January 2020.*

The purpose of AMR is to warn "customers" who use the semiconductor product that there are physical limits that must not be violated if reliability is to be preserved. Each manufacturer decides how to determine appropriate AMR and how and what to publish on the product datasheet. The "Transient AMR" working group of the Industry Council on ESD Target Levels has submitted their report. The main points are summarized below.

A semiconductor industry survey in 2019 obtained responses from representatives of some 18 different semiconductor manufacturers and 61 different semiconductor "customers". 97% of manufacturer responses indicated that they expect product reliability to be jeopardized if an electrical AMR is ever violated for any length of time. In general, manufacturers agree with the guidance of IEC standard 60134, which has stated the "hard line" definition of Absolute Maximum Ratings (AMR) since 1961. Nearly half of these responders said they would consider the semiconductor product warranty void for AMR violation if it were known. Manufacturers do *not* typically publish "transient" AMR information, allowing certain transients to exceed the basic AMR without jeopardizing the reliability. One responder indicated that such transient information is sometimes specified, with the assumption that customers who expose the product to transients are careful to prevent a violation. Manufacturers continue to receive "customer returns" failed units with evidence of electrically induced physical damage, EIPD, that of course wasn't present when the product originally shipped as a new qualified unit. Many of these returned units are badly damaged, indicating that the electrical overstress (EOS) was well beyond AMR, though the cause remains unknown.

Most "customer" survey respondents indicated that they take datasheet AMR quite seriously, while 13% think of AMR more loosely. Half of the customers indicated that AMR must never be exceeded because physical damage is expected. Another third of the customers think that semiconductor AMR defines the limits beyond which reliability may be jeopardized, a softer but still serious definition. Five customers thought that AMR are standardized limits for semiconductor use and expect that some products have more margin beyond AMR than others. Three customers responded that AMR are just "guidelines", implying that excessive excursions beyond AMR should be avoided. Some customers indicated that they only intentionally violate AMR if the time beyond AMR is short enough to not cause damage – they want manufacturers to provide applicable limits for transients. Certain customers who are especially concerned about the reliability of their own products ensure that electrical stresses are kept far below AMR. Overall, it seems that more customer education may

The "Transient AMR" working group recommends that the development of a standard for determining and reporting AMR would be useful in the industry, and a standard may contribute to a reduction in customer returns as awareness increases regarding the seriousness of AMR as reliability limits.

be necessary before there is a universal understanding that AMR are serious limits.

No discussions of AMR were found in the literature search, though there are many papers and even books on the topic of EOS. AMR are safety limits, not meant to be precise or accurate for a given semiconductor unit. There is no industry standard on how to determine and report electrical AMR. A few examples of product datasheets were found that include transient AMR for permitted overshoot on input pulses.

The working group acknowledges the fact that manufacturers don't typically characterize products "beyond AMR" because there is no apparent return on investment for this. Products are meant to be operated only within maximum operating limits (MOL), where functionality and reliability are guaranteed.

Those customers who request "permission" to exceed AMR for short transients must discuss directly with the manufacturer. The customer may need to provide additional support to justify the characterization and reliability tests involved in developing special AMR for certain transients, keeping in mind that unless you have a method to detect latent damage, there will still be a risk that product reliability can be jeopardized unknowingly.

Figure 1 is a "transients" modification of the EOS and AMR relationship figure of "Understanding Electrical Overstress (EOS)", JEP174, following the concept that the shorter the pulse, the more power is required to cause EOS and physical damage, jeopardizing reliability.

Semiconductor manufacturers characterize and stress test each element type in an IC to define a

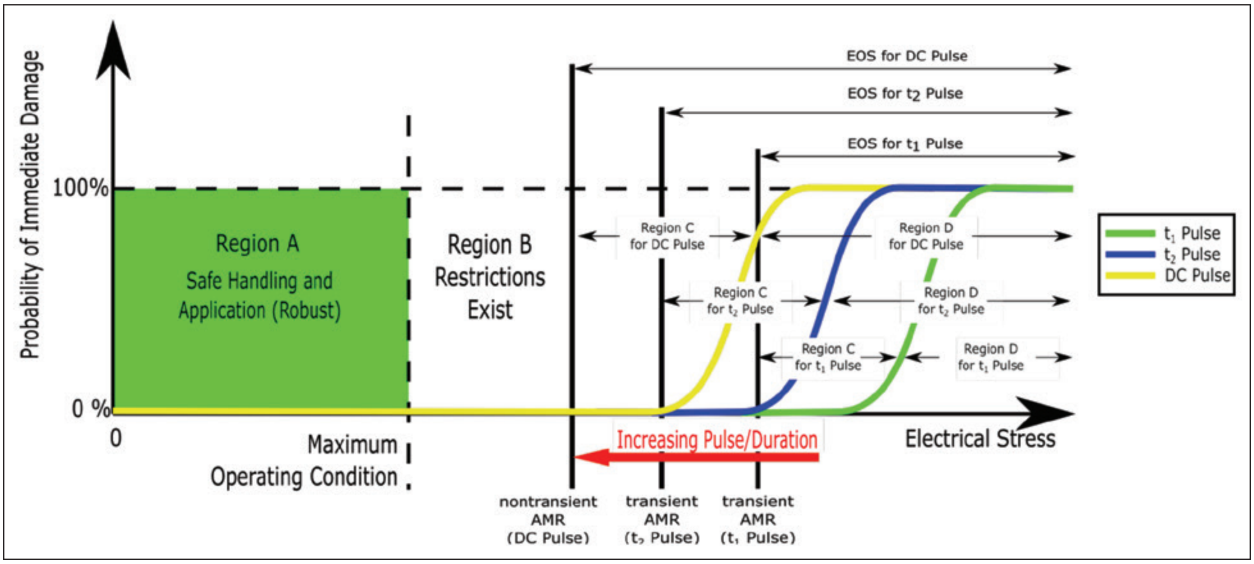


Figure 1: A proposed graphical depiction of how Transient Absolute Maximum Ratings should be interpreted. The green, blue, and yellow lines represent cumulative probability distributions of a component suffering immediate, catastrophic EOS damage due to t_1, t_2 and DC pulses respectively, where pulse width or duration obeys $t_1 < t_2 <$ DC inequality. [Valeriy Khaldarov]

safe operating area (SOA) for each stress type. This results in datasheet MOL and the formal reliability expectation. Accelerated life tests for reliability qualification stress the product beyond MOL, going into "region B" of the figure based on the well known mathematical models for each wearout mechanism, but products are not typically stressed to fail. Only ESD and Latch-up are specifically stressed to immediate fail, "region D" of the figure. Establishing datasheet AMR is more about safety margin to help the customers avoid latent damage of "region C".

Reliability stress testing to establish limits for various types of transient EOS pin by pin would be expensive and time-consuming. But we note that software has been developed for simulating circuit behavior, including robustness or weakness against ESD or EOS pulses in general, pin by pin. Simulation methodology has been demonstrated in the literature to be of great use to semiconductor designers and board and system designers. Simulations during product design can potentially be a means for semiconductor manufacturers to quickly identify weak pins or circuit elements, and also lead to increased confidence and accuracy in determining AMR.

The "Transient AMR" working group recommends that the development of a standard for determining and reporting AMR would be useful in the industry, and a standard may contribute to a reduction in customer returns as awareness increases regarding the seriousness of AMR as reliability limits. A "phase 2" of the Transient AMR project is proposed to include a combination of simulation and physical testing of ICs to seek best practice methods in determining and reporting AMR that could include further detail regarding specific transients of concern to customers. If you have any interest or comments regarding the project, please contact Ashok Alagappan (ashok.alagappan@ansys.com).

Banana Skins

Numbers 295 - 298 are taken from the Appendix to MIL-STD-464A dated 18 March 1997. (MIL-STD-464A is entitled "Department of Defense — Interface Standard —Electromagnetic Environmental Effects — Requirements for Systems".

295 From MIL-STD-464A A.5.7.2 "Precipitation static (P-static)"

A.5.7.2 A fighter aircraft was experiencing severe degradation of the UHF receiver when flying in or near clouds. Investigation revealed that the aircraft was not equipped with precipitation static dischargers. Installation of these devices solved the problem.

An aircraft had a small section of the external structure made of fiberglass. Post-flight inspections required personnel to get in close proximity to this non-conductive structural component. On several occasions, personnel received significant electrical shocks which caused them to fall from ladders and be injured. Corrective action was easily accomplished be applying a conductive paint to the surfaces exposed to airflow and personnel contact.

Static discharges from the canopy were shocking pilots on a fighter aircraft during flight. Charges accumulating on the outside of the canopy apparently migrated slowly through the dielectric material and discharged to the pilot's helmet when sufficient charge appeared on the inside surface. A grounded conductive finish on the inside of the canopy fixed the problem. Experience with an ungrounded conductive finish aggravated the problem.

When an aircraft was flying in clouds during a thunderstorm, the pilot was unable to transmit or receive on the communications radio. Further investigations were performed with the most reasonable conclusion that the radio blanking was caused by electrostatic discharge. Several incidents were also reported where pilots and ground crews received shocks due to static discharges from aircraft canopies. These incidents occurred on the carrier deck after the aircraft had been airborne for several hours.

It was discovered on an aircraft that was experiencing p-static problems that the static dischargers had been installed using an adhesive that was not electrically conductive.

Coordination between structural and electrical engineer personnel is necessary to ensure that all required areas are reviewed. For example, a structural component on an aircraft was changed from aluminum to fiberglass and experienced electrostatic charge buildup in flight which resulted in electrical shock to ground personnel. The structural engineer made this change without proper coordination, which resulted in an expensive modification to correct the shock problem.

296 From MIL-STD-464A A.5.7.3 "Ordnance subsystems"

Explosive subsystems have been initiated by ESD caused from human contact or other sources of ESD.

297 From MIL-STD-464A A.5.8.3 "Hazards of electromagnetic radiation to ordnance (HERO)"

Several incidences onboard Navy ships involving the inadvertent firing of rockets and missiles have resulted in catastrophic loss of life and equipment. There have been numerous explosive mishap reports involving RF induced, uncommanded actuation of automatic inflators worn by aircrew personnel both on flight decks and in-flight while launching from and landing on the carrier. These problems pose a tremendous hazard to aircrews, especially those in-flight at the time of occurrence.

298 From MIL-STD-464A A.5.11.1 "Aircraft grounding jacks"

Aircraft fuel fires have been attributed to electrostatic discharge. Precisely demonstrating that an electrostatic discharge caused a mishap is usually not possible due to difficulty in reproducing conditions that were present.

Grounding jacks on aircraft in the field have been found to be electrically open-circuited with respect to the aircraft structure due to corrosion. It is important that corrosion control measures be implemented at the time of installation.

299 Patriot system interference blamed for shooting down UK fighter plane

The latest Patriot scandal concerns the deaths of the crew of Yahoo 76, a British Tornado GR-4 that was shot down by a Patriot air and missile defences unit over Kuwait on 22 March last year as it descended with another Tornado in a pre-planned "safe" corridor towards its home base west of Kuwait City.

What the data shows is that the Patriot did not initially identify the Tornado as a target at all, and that the "missile" it registered was in fact a "ghost" – an illusion probably generated by electronic interference from other nearby Patriot units. Furthermore, the Patriot detected this false target 15 kilometres east of the approaching Tornados, heading not towards the Patriot but towards a troop encampment roughly 15 kilometres to the north. If it had been heading towards the Patriot, the battery's weapon control computer would have classified it as an Air Threat Category 1. Instead, it classified it as a Category 9, a threat level so low that the computer did not even mark it for engagement.

The Patriot's crew, believing they were under attack, launched an Interceptor missile at the false target, which by this stage had "moved" into the vicinity of the Tornados. In the absence of any other target, the interceptor's radar homed in on one of the planes.

(Taken from: "Unfriendly Fire", *by Theodore Postol, Professor of Science, Technology and National Security Policy at the Massachusetts Institute of Technology, New Scientist, 2 October 2004, page 23, http://www.newscientist.com.)*

300 Electromagnetic effects due to UFOs

Reports of anomalous aerial objects (AAO) *(UFOs to the rest of us – Editor)* appearing in the atmosphere continue to be made by pilots of almost every airline and air force of the world in addition to private and experimental test pilots. This paper presents a review of 56 reports of AAO in which electromagnetic effects (E-M) take place on-board the aircraft when the phenomenon is located nearby but not before it appeared or after it had departed. These effects are not related to the altitude or airspeed of the aircraft. The average duration of these sightings was 17.5 minutes in the 37 cases in which duration was noted.

There were between one and 40 eye witnesses (average = 2.71) on the aircraft. Reported E-M effects included radio interference or total failure, radar contact with and without simultaneous visual contact, magnetic and/or gyro-compass deviations, automatic direction finder failure or interference, engine stopping or interruption, dimming cabin lights, transponder failure, and military aircraft weapon system failure. There appears to be a reduction of the E-M energy effect with the square of increasing distance to the AAO. These events and their relationships are discussed. This area of research should be concentrated on by other investigators because of the wealth of information it yields and the physical nature of AAO including wavelength/ frequency and power density emissions.

(As usual, we celebrate another *hundred Banana Skins with something a little more unusual, tongue-in-cheek, or just plain funny. Make up your own mind about which category this one falls into. It was taken from the Abstract for* "Fifty-six Aircraft Pilot Sightings Involving Electromagnetic Effects", *by Richard F. Haines, Ph.D, Copyright 1992, 16 Jun 03.)*

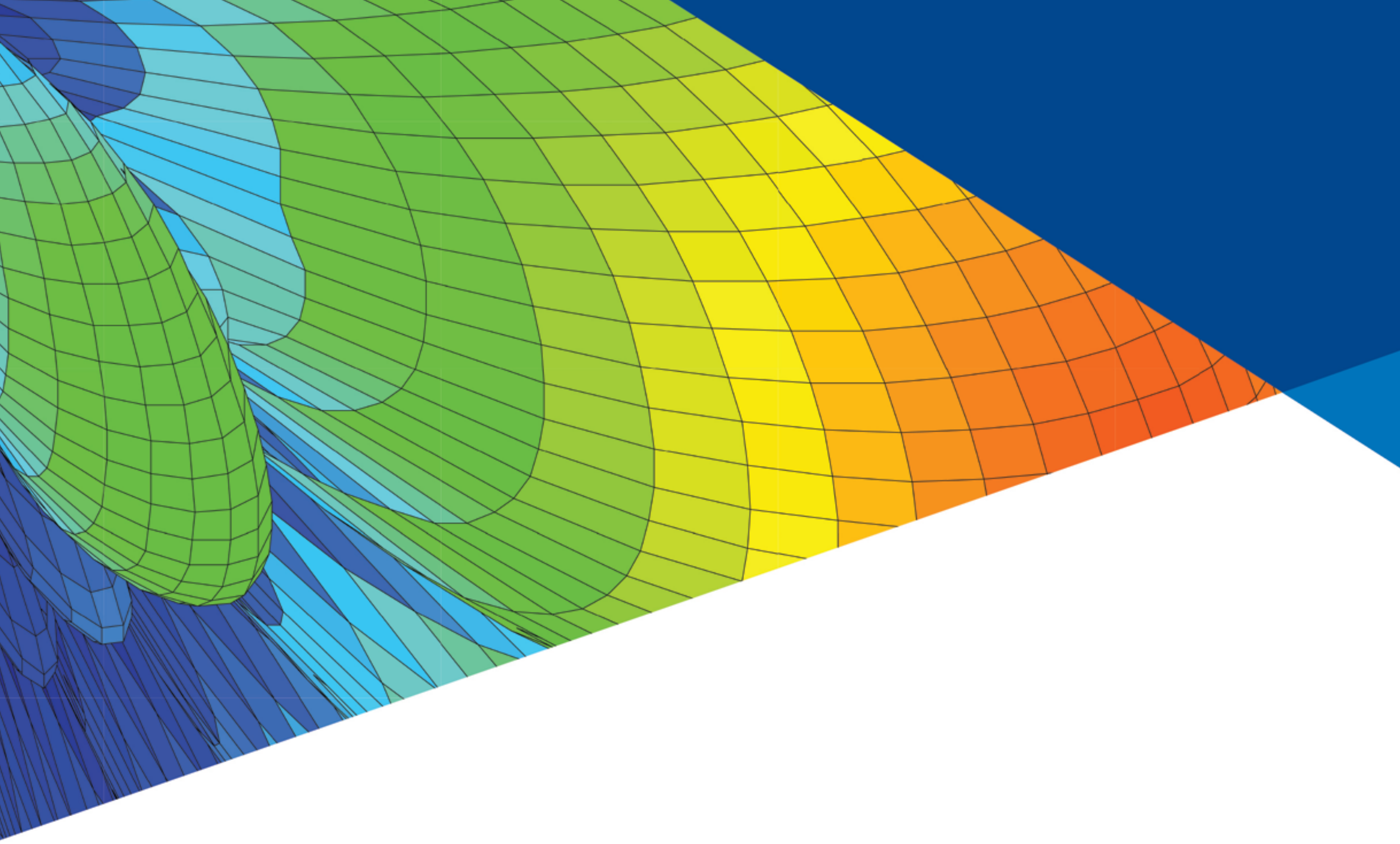
301 Immunity to interference degrades over time

EMI hardness evaluations under the Navy's Air Systems' EMI Corrective Action Program (AEMICAP) have shown that the hardness of aircraft is degraded over time. Electrical inspections have shown numerous instances of foreign object damage, excessive chaffing of wires, and improper splicing and terminations. Bonding measurements performed over a ten year period on a Navy fighter aircraft indicates 10-15% out of specification conditions on a new aircraft, 40-60% out of specification conditions on a five year old aircraft and 70-80% out of specification conditions on a ten year old aircraft. These out of specification bonding conditions result in inadequate termination of shields and boxes and degrade shielding effectiveness.

During EMC tests, the effects of corrosion and maintenance practices on the EMC design have been noted. For example, composite connectors were incorporated in the pylons of a Navy attack aircraft to correct a severe corrosion problem on the existing aluminum connectors. The composite connectors are more resistant to the corrosion than aluminum. They do, however, oxidize and produce a powdery residue on the connector. The maintenance personnel would then wire brush this residue, thereby eliminating the outer conductive coating, severely degrading the connector conductivity, and introducing potentially more severe corrosion problems.

(Taken from MIL-STD-464A, Appendix A.5.9 "Life cycle, E3 hardness." *'HERO' stands for Hazards of Electromagnetic Radiation to Ordnance.)*

The regular "Banana Skins" column was published in the EMC Journal, starting in January 1998. Alan E. Hutley, a prominent member of the electronics community, distinguished publisher of the EMC Journal, founder of the EMCIA EMC Industry Association and the EMCUK Exhibition & Conference, has graciously given his permission for In Compliance to republish this reader-favorite column. The Banana Skin columns were compiled by Keith Armstrong, of Cherry Clough Consultants Ltd, from items he found in various publications, and anecdotes and links sent in by the many fans of the column. All of the EMC Journal columns are available at: https://www.emcstandards.co.uk/emi-stories, indexed both by application and type of EM disturbance, and new ones have recently begun being added. Keith has also given his permission for these stories to be shared through In Compliance as a service to the worldwide EMC community. We are proud to carry on the tradition of sharing Banana Skins for the purpose of promoting education for EMI/EMC engineers.



How Do You Prepare For 5G?

Since 5G mmWave measurements add substantial complexity, understanding the challenges of radiated test solutions is key to being prepared for 5G.

ETS-LINDGREN
An ESCO Technologies Company

Responsible for 80% of CTIA Authorized Test Labs (CATLs)

A trusted advisor for any mmWave emissions solution

Over 10,000 test and measurement projects delivered worldwide

What considerations should device manufacturers weigh as 5G technologies become more prevalent in the market?

There is an important distinction between 5G devices that transmit in the newly designated Frequency Range 2 (FR2) band and those that will only use the traditional bands below 6 GHz (FR1). The FR2 band will be deployed on products that require massive data throughput, but isn't practical for most machine-to-machine data transfers. If your product design does utilize FR2, plan for the radio conformance to essentially triple because each band is tested independently and the interplay between the two bands is also tested. Radiated emissions tests for devices transmitting in the FR2 band expand significantly as well with FCC Part 30 requiring testing up to 200 GHz.

As a test engineer, how will 5G projects differ from past cellular generations?

The ability of devices to combine bands complicates the testing substantially. The latest revisions of LTE and all 5G capable devices will aggregate carriers, sometimes separated widely in frequency. Predicting the source of transmission harmonics or stray emissions and mitigating them will be very challenging when so many combinations of channel and bandwidth are possible. 5G FR2 capable devices have a non-stand alone mode where a transmission is happening in both FR1 and FR2 at the same time. Expect some rather complicated tests to be added to ensure these transceivers work well inside the band and protect adjacent transmission bands.

What should lab managers take into account when restructuring their business models around testing the new 5G technologies?

James Young
Director
Business Development
ETS-Lindgren

"With our expertise in EMC and wireless measurements, we are uniquely qualified to help our customers meet today's 5G test challenges."

Lab managers face issues balancing the price charged for extended frequency tests with the time, equipment, and personnel needed to make them. The 40 GHz upper frequency line has held well for decades, but 5G and future processor speeds move the minimum higher. The impact will be higher-priced more advanced test systems. mmWave emissions drive complexity and costs at every stage. The RF receiver path must shrink considerably and utilize fragile connectors, extensive amplification, and external frequency converters. Measurement equipment must be moved inside the chamber and connected to no less than four additional antenna/frequency converter combinations (40-60, 60-90, 90-120, 120-220 GHz) for the FCC Part 30 measurement case. mmWave tests have the potential to bust budgets if not carefully planned.

THE IEC 60601 AMENDMENT UPDATES HAVE PUBLISHED: CHANGES AND IMPACTS

Make Plans Now to Start Your Gap Assessment

Leonard (Leo) Eisner is principal medical device product safety and regulatory consultant at Eisner Safety Consultants. Eisner's focus is on medical electrical equipment (IEC 60601 series). He has over 35 years' experience in product safety. Eisner routinely speaks and writes as an international expert on the topic of IEC 60601 series. Eisner is the manager of the LinkedIn discussion group IEC 60601 Series – Medical Electrical Equipment. He can be reached at Leo@EisnerSafety.com.

By Leonard (Leo) Eisner

Over the many years of my career, I have noticed that standards keep changing at an ever-increasing rate. Most recently, I have been involved in four of the standards committees dedicated to IEC 60601-1, Medical electrical equipment, one of eight standards in the IEC Amendments Project. Part of our work is reflected in the recently released Ed. 3.2 of IEC 60601-1.

Medical device standards are being developed more and more rapidly and some existing standards are being updated in shorter time frames (i.e., the rules for IEC standards development has changed to allow for shorter development cycles), and national medical device regulations (including guidances) keep changing at a faster pace. As a result, it is becoming more difficult for medical device manufacturers as well as medical device consultants to keep up to date with the proliferation of changes. Ultimately, this impacts the manufacturer's quality systems and technical documentation, increases product development cycle times, and stretches out product time to market.

This article will focus on the IEC 60601 series of medical electrical standards, and specifically on the IEC Amendments Project, a project that was completed under Sub Committee 62A (SC62A). The article provides a summary of some of the changes from the previous version of the standards impacted by the Amendments. There are literally hundreds of changes in these standards, and it would be impossible to adequately provide details on all of these changes. But we'll do our best in the pages that follow.

ABOUT THE IEC AMENDMENTS PROJECT

The Amendments Project under SC62A covers the general standard (IEC 606011) and most of the collateral standards (IEC 606011XX, except for IEC 6060113). (For background on the Amendments Project, refer to my previous article, "The Future of the IEC 60601 Series: An Update," published in the *In Compliance* 2020 Annual Reference Guide.) Six of the standards that fall under the Amendments Project were published in July 2020, and IEC 60601-1 was published in August. IEC 60601-1-2, the remaining standard of the Project was published in September. IEC 60601-1-3 is not part of the Amendments Project. It is expected that IEC 60601-1-3 will be published around September 2021 to align with the Amendments Updates. See Table 1 on page 22 for publication dates.

It is important to understand that the particular standards of IEC 60601-2-XX / IEC/ISO 80601-2-XX have not yet been updated to align with the Amendments. If the particular standard applicable to your device has not yet been updated to align with edition 3.2 of the general standard, you can continue to use edition 3.1. However, the new versions of collateral standards (e.g., IEC60601-1-2 ed 4.1) may still apply because of new regulatory requirements.

Some particular standards in the series are likely to be updated fairly quickly, while others may take up to three or more years before they are published. This extended timeline may determine when manufacturers begin the process of transitioning from IEC 60601-1, Ed. 3.1, and the applicable collateral and particular standards to the pertinent Amendments.

The decision to transition may be impacted by additional factors such as:

- Transition dates of national certifiers such as UL, CSA, BSI;
- National regulators transition periods;
- New product being ready for market or legacy product lines;

- Regulatory approvals;
- Existing safety certifications;
- Business, regulatory, quality system strategy and impact.

Therefore, it is important for device manufacturers to initiate a full gap assessment as soon as possible to understand the consequence of the anticipated changes, as they are likely to impact design requirements, testing laboratory approvals, regulatory approvals, and more.

Each of the IEC standards of the Amendments Project were concurrently voted on by CENELEC for adoption and final approval as European standards (EN Norms). These EN Norms are not currently harmonized under either the EU's Medical Device Directive (MDD) or the EU's Medical Device Regulation (MDR). Therefore, it will be up to the national standardization bodies (NSBs) throughout EU Member States to issue their own versions of the European equivalent standards. These delays are likely to further complicate an already challenging process for obtaining device approval under the EU's MDR.

Standard	Current Version	Amended Version	Date Published/ Expected Publication	Types of changes Major/Minor/Editorial
IEC 60601-1	Edition 3.1	Edition 3.2 = 3rd ed. + A2 Medical electrical equipment	2020-08-20	Major
IEC 60601-1-2	Edition 4.0	Edition 4.1 = 4th ed. + A1 Electromagnetic disturbances – requirements & tests	2020-09-01	Major
IEC 6060601-1-3	Edition 2.1	Edition 2.2 = 2nd ed. + A2 Radiation protection in diagnostic X-ray equipment	Est'ed: 2021-09	Not Determined - In process still
IEC 60601-1-6	Edition 3.1	Edition 3.2 = 3rd ed. + A2 Usability	2020-07-22	Minor Editorial Changes: Terms & referenced standards. Transition to IEC 62366-1.
IEC 60601-1-8	Edition 2.1	Edition 2.2 = 2nd ed. + A2 Alarm Systems in MEE & MES	2020-07-23	Major
IEC 60601-1-9	Edition 1.1	Edition 1.2 = 1st ed. + A2 Environmentally conscious design	2020-07-22	Minor Editorial Changes: Referenced standards No Technical Changes
IEC 60601-1-10	Edition 1.1	Edition 1.2 = 1st ed. + A2 Physiologic closed-loop controllers	2020-07-22	Major
IEC 60601-1-11	Edition 2.0	Edition 2.1 = 2nd ed. + A1 Home healthcare environment	2020-07-22	Minor
IEC 60601-1-12	Edition 1.0	Edition 1.1 = 1st ed. + A1 Emergency medical services environment	2020-07-22	No Technical Changes

Table 1: Current status of IEC 60601 Amendments

THE SCOPE OF CHANGES

We had a variety of changes between all these documents. The majority of changes fall under one of the following issues:

- Some of these changes were intended to align the standards with regulatory requirements and with the updates to ISO 14971, IEC 62366-1 and IEC 62304 to facilitate the regulatory approval process:
  - IEC 60601-1, 60601-1-2, 60601-1-6 and 60601-1-10 refer to the most recent standard ISO 14971:2019 Medical devices - Application of risk management to medical devices standard.
  - IEC 60601-1-6, 60601-1-8, 60601-1-10, & 60601-1-11 refer to the most recent standard IEC 62366-1:2015 + A1:2020 for Medical devices - Part 1: Application of usability engineering to medical devices. Note that IEC 60601-1 refers bibliographically to IEC 62366-1:2015 as an informative reference, not as a normative standard.
  - IEC 60601-1 refers to the current IEC 62304:2006 + A1:2015. It was hoped that IEC 62304 2nd edition would have been published but that edition had issues in committee and has not yet been published. So the Amendments Project couldn't wait any longer to align with the anticipated IEC 62304 2nd edition requirements. We will have to live with this version for now.
- Updates to key standard references - Normative references that were updated in IEC 60601-1, Ed. 3.2 include the following standards (a number of which will be discussed later in this article):
  - IEC 60601-1-2:2014 + A1:2020, EM disturbances
  - IEC 60601-1-3:2008 + A1:2013, Diagnostic X-ray equipment
  - IEC 60601-1-6:2010 + A1:2013 +A2:2020, Usability
  - IEC 60601-1-8:2006 + A1:2012 + A2:2020, Alarm systems
  - IEC 60747-5-5:2007 or later, Optoelectronic devices – Photocouplers
  - IEC 60825-1:2014, Safety of laser products - Part 1: Equipment classification and requirements
  - IEC 60950-1:2005 + A1:2009 +A2:2013, Information technology equipment
  - IEC 62133-2, Lithium systems
  - IEC 62368-1:2018, Audio/video, information and communication technology equipment
  - ISO 7010:2019 Safety signs
  - ISO 15223-1:2016, Medical devices— Symbols to be used with medical device labels, labelling and information to be supplied

- New or updated terms in IEC 60601-1 and some of the other standards. Some of the terms come from the regulatory standards. IEC 60601-1 has two new definitions internal to the standard itself.
- IEC 60601-1 required a significant number of clarifications, as did several other standards. The primary reason for these clarifications stemmed from:
    - Safety gaps identified by WG14 decisions, many of which are published in IEC TR 60601-4-3:2018 (2nd Ed) Guidance and interpretation - Considerations of unaddressed safety aspects in the third edition of IEC 60601-1 and proposals for new requirements
    - Inconsistencies within a standard
    - Technical errors which generated new and updated test requirements

The following sections detail the changes of significance found in IEC 60601-1, Ed. 3.2.

Clause 8 & Annex A, Clause 8

IEC 62368-1:2018 is being used as an alternative solution for means of operator protection (MOOP) to IEC 60950-1, which was the only other option in IEC 60601-1, Ed. 3.0 and 3.1 for MOOP. (Note that one level of means of patient protection (MOPP) of IEC 60601-1 can't be always be provided by the lower level of two levels of MOOP's detailed in either IEC 60950-1 or in IEC 62368-1.)

We found some drawbacks with IEC 62368-1:2018 when we did our analysis for an alternative option to IEC 60601-1. There are areas where voltages for 2 MOOP don't meet the requirements for 1 MOPP, so manufacturers should carefully read and evaluate the examples and extensive details included in Clause 8 of Annex A (Guidance & Rationale) to determine if they apply to a given device or component, such as switch mode power supplies.

In many cases, working voltages that are above 354Vdc/250Vrms become problematic for double insulation for 2 MOOP for air clearance for IEC 62368-1:2018 as it may not necessarily meet the needed 1 MOPP for air clearance. Similar to IEC 62368-1, IEC60950-1:05, A1:09, A2:13 working voltages that are above 707Vdc/500Vrms in many cases become problematic for double insulation for 2 MOOP for air clearance as it may not necessarily meet the needed 1 MOPP for air clearance. Adding in IEC 62368-1 was not originally part of IEC 60601-1, Ed. 3.2 but was inserted into the project given the anticipated shortage of IEC 60950-1 certified power supplies in the near future.

If you can't you use an IEC 62368-1 switch mode power supply, here are some other options:

1. Substitute an IEC 60601-1 and IEC 60601-1-2 compliant power supply. This is our recommendation to clients anticipating FDA review and since reviewers may have concerns about the use of a power supply intended for ITE applications.
2. Look at the isolation in your overall device/system and determine if you can add additional isolation that will get you the isolation needed. This may mean a redesign and additional testing, and could add cost and testing time.

Another piece of the puzzle is that EN 60950-1 (the CENELEC equivalent of IEC 60950-1) will be withdrawn as of 12/20/2020, and will no longer qualify as a harmonized standard under the EU's Low Voltage Directive (LVD). Therefore, EN 62368-1 is probably the best alternative as it remains a harmonized standard under the LVD, and it enables you to use an ITE type (non-medical) power supply for MOOP.

The changes also relate to other components that provide MOOP isolation on the mains side of power isolation of medical devices, as well as system requirements related to monitors, keyboards, computers, printers, etc. The updates to IEC 60601-1, Ed. 3.2 reflect these considerations.

Alarms and Indicators (Table 2)

The revised Table 2 of the standard represents a significant improvement over that found in the prior edition of the standard. This updated table was generated by the Joint Working Group on Alarms IECSC62A JWG2 (the Committee which also developed the alarm system standard IEC 60601-1-8). The revised table shows much more clearly and precisely what is expected for indicators (warnings & cautions) and alarms. The most significant change is the addition of more detailed specifications regarding alarms. This is especially important since it may encourage the inclusion of alarm systems that conform with the requirements of IEC 60601-1-8 in the design of medical devices (new and existing).

Detachable Power Cords (Clause 8.6.4)

Prior to the release of the updated edition of IEC 60601-1, testing laboratories were required to use a 3 meter power cord consistent with the requirements of Clause 8.11.3.3 and Table 17 in cases where a device manufacturer neither provided nor specified one. But testing laboratories don't typically stock power cords, so this requirement wasn't always tested consistent with the requirements. The updated edition of the standard now includes new requirements that specify that testing to be carried out "using a DETACHABLE POWER SUPPLY CORD as provided or specified (length and cross-sectional area) by the MANUFACTURER." This means that device manufacturers may either provide samples of all variations of power cords intended for use with their device or specify in their IFU the length and cross-sectional area of each power cord. Providing cord samples to the test lab for this requirement can add time to testing and increase the cost.

Table 2 – Colours and meanings of indicator lights and alarm indicator lights for ME EQUIPMENT

Name	On when	Indicator light [a]	Alarm indicator light	Accompanied by sound	Operator requirement
Warning [b]	HAZARDOUS SITUATION is to be avoided	Red, not flashing	–	– [c]	Avoidance of a HAZARDOUS SITUATION which could cause death or serious injury
Caution [b]	HAZARDOUS SITUATION is to be avoided	Yellow, not flashing	–	–	Avoidance of a HAZARDOUS SITUATION which could cause minor or moderate injury or equipment damage
Ready for use	ME EQUIPMENT is ready for use	Green	–	–	–
HIGH PRIORITY ALARM CONDITION	Interruption of current workflow is needed	–	Red, flashing [d]	Typically [d]	Immediate action to prevent injury
MEDIUM PRIORITY ALARM CONDITION	Re-planning of current workflow is needed	–	Yellow, flashing [d]	Typically [d]	Prompt action to prevent injury
LOW PRIORITY ALARM CONDITION	Planning of future workflow is needed	–	Yellow or cyan, not flashing [d]	Optional [d]	Awareness for future action
Other	Situations other than that of red, yellow or green	Any colour other than red, yellow, cyan or green	–	–	–

[a] These indicator lights are INFORMATION SIGNALS and IEC 60601-1-8 requires that they be perceived as different than visual ALARM SIGNALS.

[b] Such warnings and cautions are frequently accompanied by a SAFETY SIGN.

[c] Sound may be utilized, but IEC 60601-1-8 requires that it be perceived as different than auditory ALARM SIGNALS.

[d] As specified in IEC 60601-1-8.

Table 2: Color and meanings of indicator lights and alarm indicator lights for medical electric equipment (Table reproduced with permission of the IEC)

Conductive Coating (New Clause 8.9.1.16)

A new requirement was added to the standard, even though most test houses have applied this requirement for many years. The requirement involves confirmation that flaking or peeling of conductive coatings doesn't reduce spacings. If compliance can't be verified by an examination of construction and available data, the appropriate testing of the coating must be conducted. UL 746C has always served as the default standard for such testing, but the updated IEC 60601-1 now includes references to UL 746C as well as ISO 2409 and ISO 4624.

IEC 62133-2 for Secondary (Rechargeable) Lithium Batteries (Clause 15.4.3.4)

IEC 62133-2 has been added as an alternative to the older IEC 62133 standard. But if your testing lab/regulator (i.e., EU Notified Body) or customer expects you to meet the newer IEC 62133-2 standard, you'll need to retest in order to obtain a new test report and CB certificate. The implication is increased test costs, additional test samples, project delays and potential redesign of batteries/battery packs to meet the new requirements. The two standards (IEC 62133 vs IEC 62133-2) don't have identical tests between them.

IEC 60747-5-5:2007 or later for Optoelectronic devices, Photocouplers (Clause 8.5.1.2)

An added requirement in Clause 8.5.1.2 (MOPP) recognizes that opto-couplers found compliant with IEC 60747-5-5:2007 or later editions are considered acceptable, assuming that their dielectric voltage withstand are acceptable for the given application, and that the air clearance and creepage distances at the outside of the opto-coupler meet the requirements. Opto-couplers complying with IEC 60747-5-5:2007 or later are considered equivalent to the requirements of solid insulation (Clause 8.8.2) and insulating compounds (Clause 8.9.3).

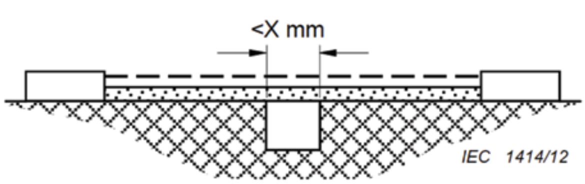
Small Spacings (Clause 8.9.4 and Figure 23)

Not all testing laboratories are involved in the development of the interpretations (WG14). So they may be unaware of the change to the minimum X mm away vs. the 1 mm gap in some of the creepage and air-clearance limits illustrated in Figures 23–25 and 27–31 of the standard. These changes could have impact primarily on PCB layouts and their spacings. For example, Figure 1 (Figure 23 in the standard) shows X mm (underlined), while Ed. 3.1 uses 1 mm.

Figure 23 was the only one in the series of figures in the standard that had a 1 mm instead of X mm in the figure when the previous update was made. The X mm rules in Clause 8.9.4 had to be updated slightly to align properly but have been in the standard since Ed. 3.1.

ISO 14971:2019

As detailed in IEC 60601-1, essential performance requirements are directly connected to risk analysis. So certification to IEC 60601-1 is based in part on demonstrating compliance with the requirements of ISO 14971, the standard addressing risk management issues. There are no significant changes to risk management within IEC 60601-1, Ed. 3.2, but many of the ISO 14971:2019 terms that are referenced in the standard have been updated. These updates may necessitate updating the content of your risk management files in advance of resubmitting devices for testing.



Condition: Path under consideration includes a parallel- or converging-sided groove of any depth with a width less than <u>X mm</u>.

Rule: CREEPAGE DISTANCE and AIR CLEARANCE are measured directly across the groove as shown.

Figure 23 – CREEPAGE DISTANCE and AIR CLEARANCE – Example 2

Figure 1: Creepage and air clearance examples (Figure 23 in the standard)

The goal of the Amendments Project was to make the more immediately needed changes to the IEC 60601-1 series of standards in advance of efforts to develop a 4th Edition of the standard, expected to begin by about 2025.

OTHER CHANGES IN STANDARDS IN THE AMENDMENT PROJECT

Changes of significance for IEC 60601-1-2, Ed. 4.1

Conducted emissions (CISPR 11) now test at minimum and maximum rated voltage versus the single voltage test previously used. Note that this change may affect RF emission levels.

New tests Table 11, Clause 8.11 immunity to proximity magnetic fields. Two of the three tests per Clause 8.11 (134.2 kHz @ 65A/m and 3.56Mhz @ 7.5A/m) are from the AIM 7351731 standard. The third test (30kHz @ 8A/m) is for the home healthcare environment (radiant cooktops).

The Guidance section on the application of risk management with regard to electromagnetic disturbances has been totally rewritten to clarify risk management references in the standard.

Changes of significance for IEC 60601-1-8, Ed. 2.2

Clause 6.3.3.1 references Annex G – new sound files. These are new, optional audio sound files for alarms in addition to the previously listed sound files. The Alarms committee is considering making Annex G mandatory in the next revision of 60601-1-8.

Clause 6.3.3.2 – The test set-up and configuration has been changed to correct references to figures and tables in ISO 3744. This means test source and locations (based on figures) will change. Therefore, the test results may vary from past results.

Added new distributed Alarm systems requirements in Clause 6.11.1.

WRAPPING UP

I'm continually being asked by manufacturers about the expected timeline for the adoption of these standards by national regulators. Each of the standards in the Amendments Project includes a recommendation for a three year transitional period from the date of each standard's publication. I checked with the Standards and Conformity Assessment program of the U.S. Food and Drug Administration's CDRH, and they confirmed that internal discussions are already underway regarding the recognition and transition period for these standards. They are anticipating adopting the three-year transition period recommended in the standards in the Fall of 2020.

What is not clear is how long it will take the FDA to "recognize" the particular standards (IEC 60601-2-XX & IEC/ISO 80601-2-XX) once they are aligned with the Amendments Project. I recommend that device manufacturers take a "state of the art" approach and apply the latest version of each standard when designing their devices, recognizing at the same time that this approach has limitations in cases where regulatory authorities have requirements that reference earlier editions of a given standard (i.e., MDD Harmonized Standards) and insist on using these outdated standards.

The goal of the Amendments Project was to make the more immediately needed changes to the IEC 60601-1 series of standards in advance of efforts to develop a 4th Edition of the standard, expected to begin by about 2025. We believe that the work of the Amendments Project will help clarify many important issues around the current use of IEC 60601-1 and its collateral standards, and make it easier to use the standard in the near term. At the same time, the changes are likely to result in some additional work, as device manufacturers will need to conduct a gap assessment and review their documents and systems to determine what needs to be updated before they resubmit to their test laboratories and regulators to meet these revised requirements.

HORTICULTURAL LIGHTING CONSIDERATIONS

Assessing Safety and Performance of LED “Grow Lights”

Brett Alsop is the North America Lighting Safety Technical Lead at Intertek. He has more than 25 years' experience in product testing and serves on many technical panels for standard writing. Alsop can be reached at brett.alsop@intertek.com.

By Brett Alsop

The use of horticultural lighting or "grow lights" has been common in the industry for years, allowing plant growth in controlled environments. These products are defined as luminaires intended to be installed in a horticultural application either above the canopy or within it. In recent years, products using light-emitting diode (LED) technology have become increasingly popular, as they offer the potential for better energy-efficiency as well as better plant growth. In fact, the global market for LED horticultural luminaires is an expanding market, on pace to grow more than 18% in the next decade, reaching $20.3 billion by 2030.[1]

The growth of LED horticultural lighting products is fueled by expanding global population, urbanization and increasing disposable incomes, all of which increase the demand for food products to be produced with less space.[1] This, in turn, drives the demand for agriculture to take place in controlled environments. However, the very nature of these controlled environments means there are special considerations for ensuring the safety and performance of these products, and they cannot be tested to the same standards as general lighting. The industry is responding to these needs, and applicable standards are emerging and evolving. It is important to know what is required and what is on the horizon for this expanding market.

SAFETY CONSIDERATIONS

In August 2019, the harmonized standard ANSI/CAN/UL 8800 was published for the U.S. and Canada to support manufacturers in certifying and selling lighting products and accessories such as wire harnesses for horticultural lighting applications. ANSI/CAN/UL 8800 is the primary North American safety standard for horticultural lighting.

ANSI/CAN/UL 8800 applies to horticultural lighting installed in accordance with the U.S. National Electrical Code (ANSI/NFPA 70) and/or Part 1 of the Canadian Electrical Code. The scope and compliance requirements of this include considerations for the intended environment and use of these products. It also provides guidance on cautionary markings and instructions.

Photobiological Safety Requirements

Photobiology concerns itself with the relationship between light's radiation and living organisms exposed to the light. It is an important consideration for these products, as many humans will be exposed to the lights as part of their work environments. As such, they must be assessed according to IEC 62471, Photobiological safety of lamps and lamp systems, and classified into an applicable risk group from the IEC standard.

The acceptable risk group classifications for grow lights when assessed to the IEC standard are: Risk Group 0 (Exempt, or no photobiological hazards); Risk Group 1 (no photobiological hazard under normal behavioral limitations); or Risk Group 2 (does not pose a hazard due to aversion response to bright light or thermal discomfort). Risk Group 3 (Hazardous even for momentary exposure) is not permitted for horticultural lighting under ANSI/CAN/UL 8800.

Elevated Ambient Requirements

It is common for horticultural luminaires to be used in elevated ambient conditions, such as those found in greenhouses. These warmer temperatures naturally result in a unique environment in which these lighting products will exist. As such, the standard requires that temperature testing be conducted at the anticipated ambient rating for the product, instead of 25˚C as is typically done for an LED luminaire, hardware or system.

Similar to the high temperatures one would anticipate in a grow light setting, it is also inevitable that these products will encounter moisture and humidity, as water is a critical component of horticulture.

The standard requires that all horticultural luminaires comply with the following:

- Be subjected to the temperature test of ANSI/UL 1598 / CSA C22.2 No. 250.0;
- Be subjected to the abnormal temperature test of ANSI/CAN/UL 8800 (units with motors);
- Be marked in accordance with Table 20.1.1, Item 1.6 of ANSI/UL 1598/ CSA C22.2 No. 250.

Humidity Requirements

Similar to the high temperatures one would anticipate in a grow light setting, it is also inevitable that these products will encounter moisture and humidity, as water is a critical component of horticulture. As such, horticultural luminaires must be rated suitable for "damp" or "wet" environments in accordance with ANSI/UL 1598/CSA C22.2 No. 250.0 for fixed luminaires.

Ingress Protection Requirements

An ingress protection (IP) rating refers to the degree of protection an electronic or electrical enclosure provides against external dust, fluid or other objects that may pass through or into the product. As outlined above, it can be expected that grow lights will be exposed to water and, as such, all luminaires must be rated "damp" or "wet" and must comply with both the rain and sprinkler tests of Clause 13.4.8 of ANSI/UL 1598. This includes the following requirements:

- Based on installation type, the luminaire needs to comply with requirements of location designations in ANSI/UL 1598: LOC-3, for ceiling-mounted recessed lights; LOC-4 for wall-mounted surface lights; LOC-5 for wall-mounted recessed lights; or LOC-6 for surface and pole- or post-electric parts.
- A luminaire exposed to dust and water can be marked with an IP code of IP 54 or higher per IEC 60598-1.

Enclosure UV Exposure Requirements

An additional consideration unique to horticultural lighting is exposure to UV for polymeric enclosures or components. These take into account the unique setting and role of grow lights to ensure the materials are suitable for such use and will endure the UV exposure. ANSI/CAN/UL 8800 includes the following requirements:

- Horticultural LED luminaires utilizing polymeric enclosures must comply with the requirements of ANSI/UL 1598/CSA C22.2 No. 250.0 for fixed luminaires or UL 746C/CSA C22.2 No. 0.17 for polymeric materials used in electrical devices.
- Horticultural luminaires utilizing polymeric material for a water shield need must use shields made with UV-rated material.

Supply Connection Requirements

The standard also includes several provisions for supply connections. Per the requirements, horticultural luminaires are to be provided with an outlet box for fixed wiring applications, with a cord or provision to a proprietary wiring system. Use of a plug would be dependent on electrical codes, such as NFPA 70, Article 410.16, and local jurisdictions. When used, the plug must be suitably rated for the environment. Finally, considerations should be made for elevated ambient conditions, corrosion, and high humidity for these components, just as for the luminaire itself.

PERFORMANCE CONSIDERATIONS

Safety is just one concern for horticultural luminaires. As seen with other electrical products, performance is another factor that must be considered. If a product is relative safe but performs poorly and does not function well, the product will not fill the need or be successful. While the ANSI/UL/CAN safety standard addresses one side of this coin, several industry associations are developing voluntary standards to address performance of horticultural and agricultural lighting applications.

American Society for Agricultural and Biological Engineers (ASABE)

ASABE has several performance standards that can be used when developing grow lights. The scope of these documents is as follows:

- **ASABE S640 - Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms).** Published in July of 2017, this standard provides definitions and descriptions of metrics used for radiation measurements for plant growth and development. A key factor to a successful grow light is ensuring it emits the right amount of the proper kind of light to aid in photosynthesis. This standard addresses the needs of plants, defining 33 electromagnetic radiation types, including ultraviolet, photosynthetic, far-red and spectral ranges.
- **ASABE S642 – Recommended Methods of Measurements and Testing for LED Radiation Products for Plant Growth and Development Standard.** ASABE's second standard, published in October of 2018, provides guidance on methods for testing and measuring LED packages and arrays/modules, LED lamps, and any other LED devices used for plant growth and development. This standard specifically targets products with a spectral range between 280 and 800 nanometers (nms).
- **ASABE X644 - Performance Measures of Electromagnetic Radiation Systems for Plants**. This draft standard is intended to establish appropriate performance criteria of luminaires designed for horticultural applications, as well as installed systems that use such devices. The primary focus of the standard includes electromagnetic output and efficacy. It recommends minimum and advanced

As the demand for efficient grow lights continues to increase and the industry looks for ways to accommodate these needs, ensuring the safety and performance of these products is essential.

criteria, plant spectral response characteristics, and methodologies to compare the plant growth and energy performance between alternative devices and installed systems when applied to diverse horticultural operations.

The DesignLights Consortium® (DLC)

The DLC, which focuses on energy optimization through interconnected lighting solutions, has a vested interest in ensuring that energy efficient options like LEDs are utilized in horticultural and agricultural applications. The DLC Horticultural Lighting program is a suite of tools and resources designed to encourage and enable widespread adoption of LED technology in the horticultural lighting sector. It includes technical requirements and a listing of qualified products that meet these requirements.

The DLC program includes output characteristic requirements for reported metrics, which includes metrics for photosynthetic photon flux (PPF), far-red photon flux (PFFR), spectral quantum distribution (SQD) and photosynthetic photon intensity distribution (PPID). It also includes required minimums for photosynthetic photon efficacy (PPE) (μmol/J), photon flux maintenance, photosynthetic (PFMP), and photon flux maintenance, far-red (PFMFR). There are also requirements to have appropriate horticultural lighting safety certification by an OSHA NRTL or SCC-recognized body.

The program also includes requirements for efficacy, long-term performance, warranty, driver testing to real-world applications or In-SITU temperature measurement testing (ISTMT), electrical performance/power quality, safety, and tolerances. Supporting documentation under the program includes test reports from an accredited lab, application forms, marketing materials, specification sheets and applicable certifications.

Regardless of the standards manufacturers elect to use or programs in which they'd like to enroll, it is important to understand the requirements and build a test plan that can be used throughout the product development process. Doing so will also require knowledge of other applicable standards referenced in these requirements, from general electrical safety to requirements specific to the settings where these luminaires will be used. It will also be important to work with a knowledgeable party to conduct testing. In some cases, testing conducted by a DLC-approved lab will be required.

As the demand for efficient grow lights continues to increase and the industry looks for ways to accommodate these needs, ensuring the safety and performance of these products is essential. The industry will undoubtedly continue to evolve, introducing and modifying standards, making it necessary to keep up to date with these changes. Working with a trusted partner to stay informed, creating a test plan and conducting the necessary testing will be essential to bringing these in-demand products to market.

SOURCE

1. "Horticulture Lighting Market to Generate $20.3 Billion by 2030," on Account of Population Boom: P&S Intelligence. Globe News Wire. March 24, 2020. https://www.globenewswire.com/news-release/2020/03/24/2005242/0/en/Horticulture-Lighting-Market-to-Generate-20-3-Billion-by-2030-on-Account-of-Population-Boom-P-S-Intelligence.html. Accessed 6.10.2020

ACCESSING THE GROWING MARKET FOR DRONES IN THE U.S.

The Regulatory Landscape

David Schramm has more than 20 years' experience in medical, ITE, industrial, appliances, test and measurement, audio and regulatory wireless. He specializes in EMC, wireless and SAR testing including Wifi, Bluetooth, low power (unlicensed), short range devices and RFID. Schramm is also specialized in licensed devices, including LTE mobile phones and PTT. He sits on both ANSI C63.10 and ANSI C63.26 working groups, and has co-authored several articles, including one published in the IEEE Publication Journal. Schramm can be reached at david.schramm@sgs.com.

By David Schramm

It was recently reported that one U.S. retailer had been ordered to pay a fine of nearly $3 million in connection with the marketing of drone transmitters that operated in unauthorized radio frequency bands. The severity of the fine demonstrates why manufacturers and retailers of drones need to be certain that the products they place on the market are safe and comply with relevant legislation.

DRONE MARKET GROWTH

The "anthropause" – the period when many countries have gone into lockdown because of COVID-19 – has been a chance for all of us to re-evaluate our lives. Many of us have appreciated the temporary respite from the noise, pollution and congestion of modern life. And, as our lives slowly begin to return to normal, we are wondering if technology can be used to make these changes more permanent.

One area that has shown considerable promise in recent years has been the expanded use of unmanned aircraft systems (UAS), more commonly known as drones. Until recently, commercially available drones were little more than toys. But that has all changed. By the time the COVID-19 lockdown began, drone technology had advanced to a point where it could successfully and safely deliver life-saving medicines to hospitals while allowing the operators to maintain strict social distancing rules.

Utilizing drones in this way is not just a response to the COVID-19 Pandemic. Indeed, these developments have been in the works for a number of years. One multinational company is so keen to exploit the potential of drones for delivering packages that they already have drone development sites operating in the U.S., United Kingdom, Austria, France and Israel.

Companies are keen to exploit the utility and cost-effectiveness of drones in a number of different theaters. Photography was the initial commercial use because it allowed companies to take photographs in places that would have previously been either prohibitively expensive or impossible. Since then, commercial drone use has expanded to include surveying and mapping, inspecting pipelines, gathering data, search and rescue, tracking criminals, and for checking insurance claims. The agricultural sector has been particularly keen to exploit this technology, using it to monitor animal health, determine weight and movement, survey crops, plan irrigation schemes, and manage pasture and hydration.

Demonstrative of the growth of commercial drone use is the fact that the U.S. Federal Aviation Authority (FAA) originally estimated it would take until 2022 to reach 450,000 commercial drones in the U.S. a number that was actually matched and exceeded by 2019. Contributing factors towards the exponential growth of this emerging technology include:

- Rapid technological advances mean drone users have been able to quickly exploit different commercial opportunities;
- Compactness and relative simplicity make them an attractive option for businesses operating in a wide variety of environments; and
- Cost-effective – analysts have estimated cost savings could easily reach $100 billion.

It is hardly surprising therefore that the market for commercial drones is predicted to grow from $4 billion to $40 billion in the next five years.

NEED FOR REGULATION

In recent years, the drone industry has received unwelcome attention because of the actions of a few individuals. As often happens with many emerging technologies, the fast pace of development means legislation and regulation often fail to keep pace.

There are several ways drones have been misused, including spying, flying contraband over borders or into prisons, and damaging property. What really brought drone misuse to the attention of the public, however, was the threat they present to commercial airplanes. Stories of drones being used to disrupt airports have appeared in newspapers all over the world, for example, Newark Airport (U.S.) in January 2019 and Heathrow Airport (UK) in September 2019.

In response to this threat, several countries have introduced, or are preparing to introduce, regulations to curb this misuse. In June 2019, the European Union (EU) became the first region to publish a comprehensive set of rules for ensuring the safe, secure and sustainable use of drones. Regulation (EU) 2019/945 and Implementing Regulation (EU) 2019/947 cover both commercial and leisure use. And, while they do cover product safety, they are equally concerned with the operational use of the drone.

This is something that we see in a number of markets – the conjunction of regulations to control use with additional safety and performance requirements. Perhaps this is a characteristic of all emerging technologies as advances in capability initially outstrip the ability of jurisdictions to regulate them. In many ways, what we are seeing is that these concerns are not related to technology but rather to how the technology is being used. Rather than abandon the technology, we need to rewrite the instruction manual!

It is clear that the authorities drafting regulations have been unable to match the fast rate of growth in the drone sector. For manufacturers of drones looking to operate in these markets, it should be understood that any review of the current regulatory landscape is just a snapshot. As the technology transforms and advances, we can expect new regulations to be introduced to define what is a safe product, and what represents safe and sustainable use.

U.S. DRONE MARKET

Greater commercial use has been the driving force behind the U.S. drone market's exponential growth. We, therefore, need to start by looking at workplace requirements applicable to drones.

In the U.S., workplace health and safety are controlled and monitored by the Occupational Safety and Health Administration (OSHA). OSHA has the right to enter any business and can if its inspectors deem the workplace to be unsafe, close it with immediate effect.

When OSHA investigates a business, among the things they will want to see is whether all electrical products are certified by a Nationally Recognized Testing Laboratory (NRTL). However, while the U.S. does have a standard for drones – UL 3030 – it has not yet been adopted by OSHA.

Further, drones do not currently fall under the scope of the Consumer Product Safety Commission (CPSC). However, it is a salutary lesson for drone manufacturers and suppliers to remember that, until a few years ago, hoverboards were also not covered by the CPSC. It then began to emerge that hoverboards were the cause of multiple incidents, including burns and, in one particularly awful incident, a house fire that caused the death of a young girl. It is now a mandatory requirement of the CPSC that all hoverboards supplied in the U.S. must conform to UL 2272.

Therefore, it is not impossible to imagine that the CPSC may require compliance with UL 3030 at some point in the future. At the moment, though, this seems unlikely because much of the debate surrounding drones relates to usage and not product safety.

FAA REGULATIONS

Since many of the reported drone incidents relate to misuse, it is probable that any immediate regulatory interdictions relating to drones would come via the FAA. Part 107 of FAA regulations relates to UAS, covering drones weighing less than 55 pounds but excluding model aircraft. These are operational requirements and include conditions relating to:

- Flying safely
- Minimum visibility when flying

When looking at drone regulations, the problem we have is that the history of this technology is defined by rapid advances that outpace the ability of authorities to regulate. In essence, they are always playing catchup.

- Maximum speed
- Maximum height

The regulations make it clear that drones must be flown within unaided sight.

Part 107 also covers drone registration, but it does not include requirements that are directly relevant to manufacturers, beyond the limitations it places upon operators in terms of maximum and minimum capabilities.

FCC REGULATIONS

The only regulatory requirements with which a manufacturer or importer must conform for access to the U.S. market come from the Federal Communications Commission (FCC) and are related to radio frequency functions. And, as the nearly $3 million fine levied on the retailer we referenced at the beginning of this article demonstrates, the cost of failing to conform to these requirements can be high.

In that case, the FCC found that the video link between the drone and the operator functioned outside of the frequency bands designated for amateur use. The FCC's investigation found that the company had marketed at least 65 different transmitter models, none of which had been certified. These products were found to be operating in restricted frequencies, which could cause interference with critical FAA systems. In addition, some models were also found to operate at power levels that exceeded FCC limits, meaning they could interfere with FAA terminal doppler weather radar.

The FCC prohibits drones from using the following radio frequency technologies:

- 6 GHz U-NII devices (a new frequency band, similar to WLAN 5 GHz)
- Ultra-wideband and wideband transmission systems
- 57-71 GHz and 92-95 GHz frequency bands

The most commonly used radio frequency technologies used in drones for the U.S. market are:

- ISM bands: 915 MHz, 2.4 GHz, 5.8 GHz
- GPS
- Wi-Fi (WLAN 2.4 GHz and 5 GHz)
- Bluetooth and other 2.4 GHz technologies

Additionally, it should be noted that radio frequency technologies using UHF 433 MHz, 1.3 GHz, 3.4 GHz, require the operator to hold an amateur (HAM) radio license.

LOOKING TO THE FUTURE

It is always dangerous to try to predict the future. Who, for example, would have predicted a global pandemic shutting down entire countries back in October 2019? It is always safer to look at the here and now. When looking at drone regulations, the problem we have is that the history of this technology is defined by rapid advances that outpace the ability of authorities to regulate. In essence, they are always playing catchup.

However, manufacturers should consider two important points when trying to predict the future direction of regulations in relation to this emerging technology. First, much of the growth in this sector is related to commercial operations and this brings it closer to being adopted by OSHA. Second, as the example of the hoverboard demonstrates, it is not without precedent that the CPSC will mandate a standard if it should prove necessary to protect consumers. In either of these scenarios, it is easy to see that UL 3030 (a standard we currently recommend to clients) might well become mandatory.

UL 3030

Published in September, 2018, UL 3030:2018, Standard for Unmanned Aircraft Systems, covers the electrical system of unmanned aircraft systems used in flight for commercial applications or flight incidental to business applications for both the U.S. and Canadian markets. The drones covered by the standard are intended for use by certified UAS pilots, as identified in Federal regulations.

UAS, or drones, are defined in the standard as being:

- For outdoor use;
- Less than 55 lbs. (24 kg);
- Provided with an internal lithium ion battery that is charged from an external source; and
- Operating at a voltage of no greater than 100 V dc

Commercial applications include, but are not limited to:

- Agricultural applications
- Scientific or research applications
- Government or local police applications
- Search and rescue applications
- Video applications for the film industry or news broadcasts

A subset of commercial applications, "flight incidental to business," covers things like roof inspections by insurance agents or construction workers, or real estate photography.

UL 3030 does not cover:

- Model or hobby UASs which are marketed to and intended to be operated by the general public;
- Aspects of control associated with the human pilot (pilot error), UAS handling, contact or impact of the UAS with external objects, people or structures, adverse weather conditions such as high winds that may affect operation, or the general airworthiness of the aircraft;
- The ability of the UAS to correctly or adequately perform its intended operation;
- The ability of the UAS to land safely if the battery is discharged in flight;
- Physiological effects associated with the use of UASs;
- Devices intended for use in hazardous (classified) locations, which are subject to additional requirements to mitigate risks of fire and explosion;
- UASs used for any military or similar tactical operations;
- The efficacy of UAS communications or the effects of the loss of UAS communication during flight.

The standard covers the requirements associated with electrical shock, fire and explosion hazards relating to the inherent features of the UAS, as well as the battery and charger system combinations provided for recharging the UAS.

BATTERY REQUIREMENTS

UL 3030 allows for UAS batteries to be provided as either individual cells, configured around the design of the UAS, or as complete battery packs. The standard provides the following provisions:

- Section 17.2.2 – Individual lithium ion or other lithium-based cells must comply with the requirements for secondary lithium cells in UL 2580, Standard for Batteries for Use in Electric Vehicles, or UL 1642, Standard for Lithium Batteries
- Section 17.2.3 – Battery packs must conform to one of the following:
  - UL 2580 – Standard for Batteries for Use in Electric Vehicles
  - UL 2271 – Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications
  - UL 62133 – Standard for Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made from Them, for Use in Portable Applications

Manufacturers should also note that, if the battery pack can be replaced by the user or can be removed for charging, it must be marked or designed to ensure that the battery can only be replaced in one direction. If this is not the case, then an internal battery reverse polarity test must be performed (Section 32.5).

MOTOR REQUIREMENTS

According to UL 3030, the motor in a UAS must be safe under normal conditions and should not be hazardous under overload conditions. It must be capable of carrying the maximum normal anticipated load without exceeding temperatures on insulation and windings as determined during the temperature test.

UL 3030 states that motors located in hazardous voltage circuits must comply with the requirements of both of the following standards:

- UL 1004-1 – Standard for Rotating Electrical Machines – General Requirements
- CSA C22.2 No. 100 – Motors and Generators

"Hazardous voltage" is defined as voltage exceeding 30 V rms/42.4 V ac peak or 60 V dc.

Motors that are located in low voltage circuits should either comply with the requirements of UL 3030 or either of the above standards.

In addition to these provisions, UL 3030 also covers a wide range of other construction criteria, including:

- Metallic and non-metallic materials
- Enclosures
- Assembly
- Internal wiring and terminals
- Chargers
- Insulation levels and protective grounding
- Protection circuits and safety analysis
- Printed wiring boards
- Spacings and separation of circuits
- Fuses

As a comprehensive standard, UL 3030 also contains provisions relating to performance testing:

- Temperature test (charging and flying)
- Dielectric voltage withstand
- Isolation resistance
- Capacitor discharge
- Vibration
- Strength of enclosures
- Water exposure
- Motor overload

There are also a wide variety of provisions relating to abnormal operations including, inter alia, overcharge, disconnected fans/blocked vents, relay and solenoid burnout, and imbalanced charging.

MOVING FORWARD

The global COVID-19 Pandemic has helped to highlight the benefits of commercial drone use in terms of cost effectiveness and utility. As we return to normality, it is clear this is an emerging technology that has proven itself and is here to stay.

The U.S., like other countries, may soon find that their current legislation is inadequate for this growing market. Its mandatory FAA and FCC requirements only relate to operation and radio frequency technology, but it is possible to see that, as the market expands and new suppliers come online, product safety may become an issue that requires more comprehensive regulation.

UL 3030 is currently only a recommended standard for manufacturers operating in the United States. But there is a real possibility that growth in commercial drone use may lead to its adoption by OSHA. If this happens, then all drones used in the workplace would require NRTL certification.

In theory, this would not affect the sale of non-commercial drones because OSHA has no jurisdiction over the home or the retailer. However, the boundaries between home and workplace are increasingly becoming blurred and electrical products sold in the high street can often be found in both settings. If a non-commercial drone is accidentally supplied for commercial use, then it would need to be NRTL certified and it does not matter where it was purchased.

Manufacturers are therefore advised to consider adopting the UL 3030 standard as part of a pre-emptive risk management strategy to avoid possible future legislative non-compliance.

EMC AND SAFETY FOR INSTALLATIONS: PART 2

Developments in Ground Bonding Networks

Editor's Note: In this article, the words "ground," "grounded" or "grounding" are used interchangeably with "earth," "earthed," or "earthing."

The first part of this article (see *In Compliance Magazine*, October 2020) introduced the first protective equipotential bonding/grounding systems, which only had requirements for human safety. It showed how – as electronics became more commonplace and more interconnected and variable-speed motor drives increased in power – these early structures developed into bonding networks (BNs) to protect electronics from damage due to insulation failures and lightning surges. Site-wide BNs are costly

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By Keith Armstrong

to create, so in those early days it was common to only provide BNs for the parts of a site where electronic equipment was installed. This led to the development of the isolated bonding network (IBN), which is where this Part 2 picks up.

ISOLATED BONDING NETWORKS (IBNS)

An IBN is a BN that is isolated from the rest of the protective equipotential bonding system, except for at one single point of connection (SPC) (see Figure 1).

The idea of the IBN is that when fault or lightning currents occur in the rest of the building (or vehicle), their isolation prevents those currents from flowing through the nice low impedance created within the IBN, helping to protect the equipment it contains.

The usual guidance is that – with all of its mains power supplies isolated at the IBN's distribution cabinet(s) and any uninterruptible power supplies (UPSs) switched off, and then its SPC temporarily disconnected – an IBN should be able to withstand a voltage of at least 10kVDC with respect to the rest of the building's protective equipotential bonding system for at least one minute, without any current flowing in "sneak paths," including via corona discharges, arcs or sparks, once the IBN's stray capacitances have been charged up.

(It should go without saying that if an IBN is constructed where there could possibly be a potentially flammable or explosive atmosphere, its isolation should never be tested with high voltages as described above! Also, always remember to reconnect SPCs after successful voltage withstand tests, and do not reconnect the mains power supplies to any equipment within an IBN until after its SPC has been properly reconnected.)

Never rely on simply switching off the items of equipment within an IBN individually before testing its isolation as briefly described above. This is because all items of electronic equipment are fitted with EMI/RFI filters that "leak" milliamps of stray currents into the protective grounding conductor in their mains leads, and it does not take many such items for these leakage currents to build up to lethal levels. The EMI filters in high-power variable speed drives (VSDs) and other switching power converters can individually leak hundreds of mA, even Amps, into their protective ground.

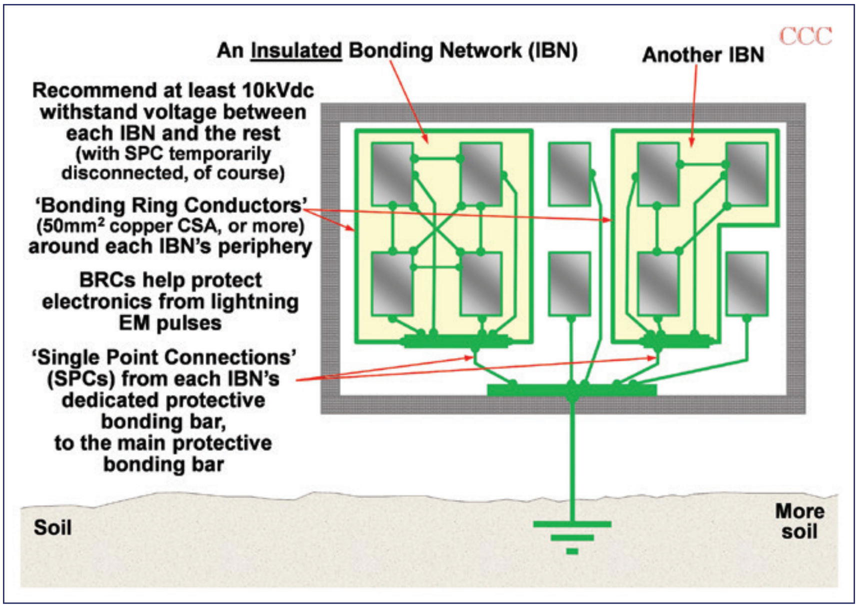

Figure 1: A sketch of two Isolated Bonding Networks (IBNs)

These filters are usually fitted before the mains on/off switch, so they remain powered up and leaking current when the equipment has apparently been switched off using its own controls. This is why, before testing the voltage isolation of an IBN, all of its mains power supplies (there may be more than one) must be isolated at the IBN's power distribution cabinet(s), and any uninterruptible power supplies (UPSs) within the IBN switched off.[1]

In the old days, each commercial or industrial building had a dedicated electrical manager, a skilled electrical engineer who ensured that no one compromised its protective equipotential bonding system or did anything else that might cause fires, shocks, unreliability, etc., and also supervised any/all upgrades and modifications. These knowledgeable professionals maintained the electrical drawings and knew them like the backs of their hands.

But these days it is much more common not to employ an electrical manager. Instead, suitably skilled subcontractors are hired when upgrades and modifications are done, or for annual inspections. Of course, they may not be familiar with a particular building's electrical installation, or its history. And, if my experience is any guide, the building's owners or operators may not have ensured that its electrical drawings have been kept up-to-date, and may not even know where they are, or which subcontractor had them last!

In such situations, it is possible for very-carefully-designed IBNs to be seriously compromised by changes and modifications made by people who are unaware of their importance (or even existence). I have seen it happen even in major national infrastructure plants. All it takes to compromise an IBN is for a person to string an Ethernet cable from their office outside an IBN to a computer inside an IBN. The consequences for equipment damage, and even for significant fire and shock hazards, especially during a thunderstorm, can be very severe indeed.

So, it is good general safety and reliability guidance to use CBNs, and not to use IBNs unless the building or site has 24/7/365 supervision by permanently-employed competent electrical engineers or technicians who understand where all the IBNs are and how (and why) to keep them isolated. These engineers or technicians should also approve any changes to any wiring (even Ethernet cables) and supervise all maintenance.

COMMON BONDING NETWORKS (CBNS)

A CBN is a single BN that is "common" to an entire building (see Figure 2).

The big advantage of a CBN is that signal/data cables may be run around anywhere in the building – ideally strapped to bonding conductors/metalwork along their entire lengths to use them as PECs – without having to make any alterations to its protective equipotential bonding system. This makes adding new equipment in the future easy to do and relatively inexpensive.

The previous discussion has only concerned human safety as regards electric shock hazards, and the protection of electronics from damage by surge transients caused (indirectly) by lightning. However, all conductive items behave like "accidental antennas".[2] This fact means that for good EMC, all conductors and any pieces of metal – that are not functional

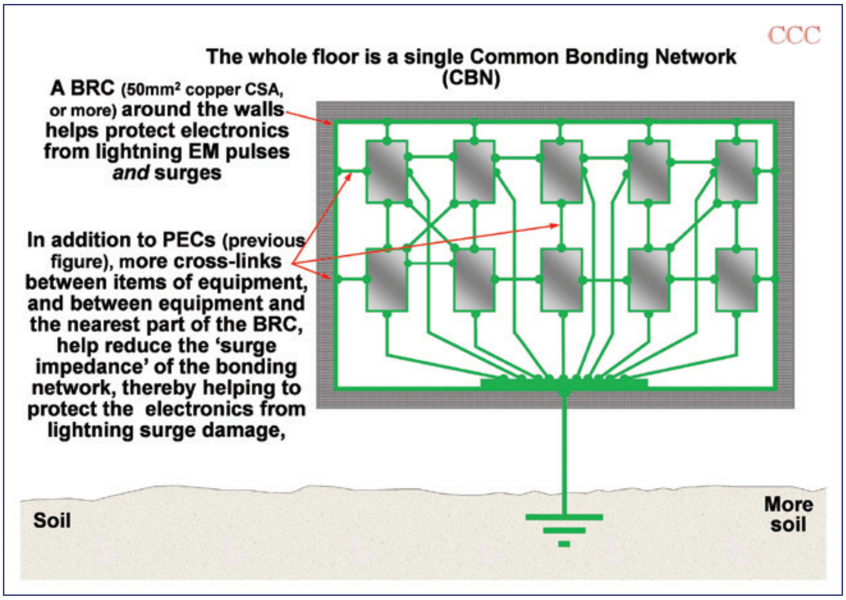

Figure 2: A sketch of a Common Bonding Network (CBN)

conductive parts in any electrical/electronic circuits, of course – should be interconnected so as to be integral parts of any BNs, IBNs or CBNs – whether these conductors or pieces of metal have anything to do with electrical safety or not.

MESHED BNS, IBNS AND CBNS

Computer electronics initially used circuits operating from 5VDC power rails, and with such low-voltage signals/data the "equipotential" voltages considered acceptable between "touchable" points during faults and thunderstorms in protective equipotential bonding systems were much too high. But the cost of fitting suitably rated insulation/isolation to every data cable regardless of how short it was would have been totally ridiculous.

So, when computer rooms and digital telephone exchanges (called Central Offices in the U.S.) started to be built in the 1970s, they invented much cheaper solutions: MESH-BNs, -IBNs and -CBNs. The word MESH in the acronym refers to the fact that multiple cross-bonds are needed to reduce the inductances in the protective equipotential bonding systems by enough to reduce the exposure of digital electronics to lightning surge damage, and (in the 1990s, when the European Union's EMC Directive loomed) to help achieve EMC for systems and installations.

Generally, these structures take the physical form of regular "grids" or "meshes" of bonding conductors – hence their name (see Figures 3 and 4).

Initially, these meshed conductive structures were called SRPPs (for system reference potential planes), BMs (for bonding mats) or a wide variety of jargon or proprietary terms that can be found in computer and telecom system installation guidance documents from the 1970s, 80s and 90s.[3]

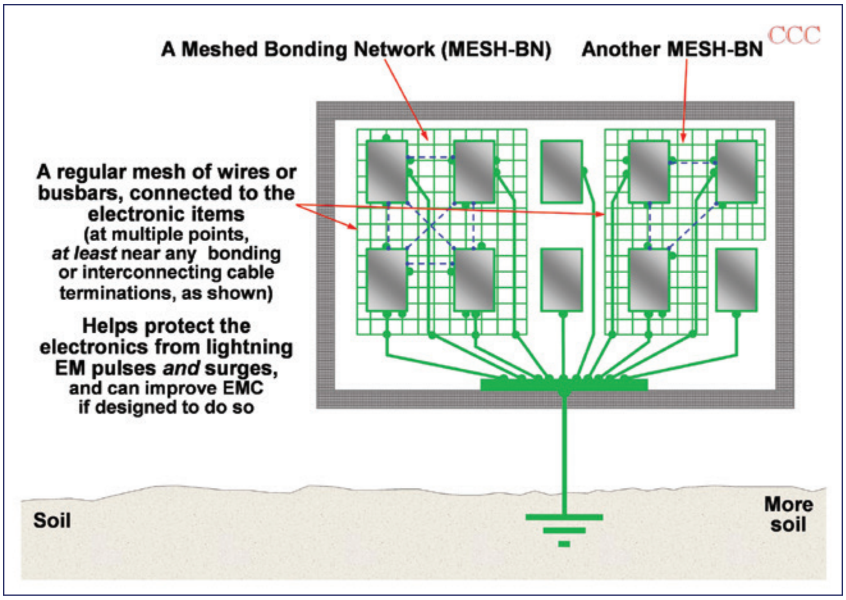

Figure 3: A sketch of a two MESH-BNs

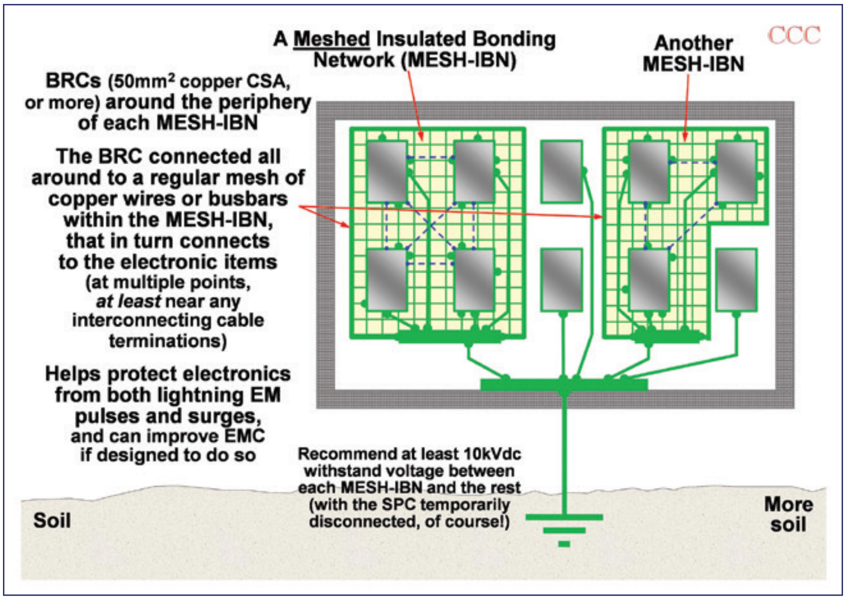

Figure 4: A sketch of two MESH-IBNs

Figure 5 shows the sort of SRPP design that was often used. The conductors used for the mesh were usually 6mm diameter copper, soldered at their joints, but some preferred to use wide copper "lightning tape" because of its lower inductance and ease of jointing using the clamps used for that purpose when constructing LPSs. Some computer/telco system installers used "natural metalwork" instead of installing a copper mesh, either by using the metal framework that supported the computer false-floor tiles as the mesh, or interconnecting the metal backs of the computer floor tiles. Figure 6 shows a modern proprietary development of the latter approach.

As time went on, these computer systems grew to occupy more than one room, so the rooms' individual MESH-BNs or MESH-IBNs had to be mesh-bonded together to reduce the "surge impedance" of the new combined BNs or IBNs being created.

Remember that when the $Z = \sqrt{[R^2 + (2\ L)^2]}$ expression was introduced in Part 1 of this article, I mentioned that this was only relevant for conductors well-below their first quarter-wave resonance. We now need to correlate this with mesh dimensions.

Most lightning energy is contained in the spectrum below 1MHz, but it is still considered to have significant amount of energy up to 10MHz. The wavelength in air of 10MHz is 30 metres, making its first quarter-wavelength resonance 7.5m. So, a mesh size of 5m or less on a side (in air) is considered effective against all lightning frequencies, and the smaller the mesh size the lower its inductance between any two points and the lower the surge transient voltages that can arise due to induced lightning currents.

For good EMC, we may want our meshes to be smaller, either to control higher frequencies than 10MHz due to speedier computer data, or to provide lower impedances below 10MHz due to high-power VSDs. For example, 30MHz was a common goal in early computer systems and required mesh dimensions

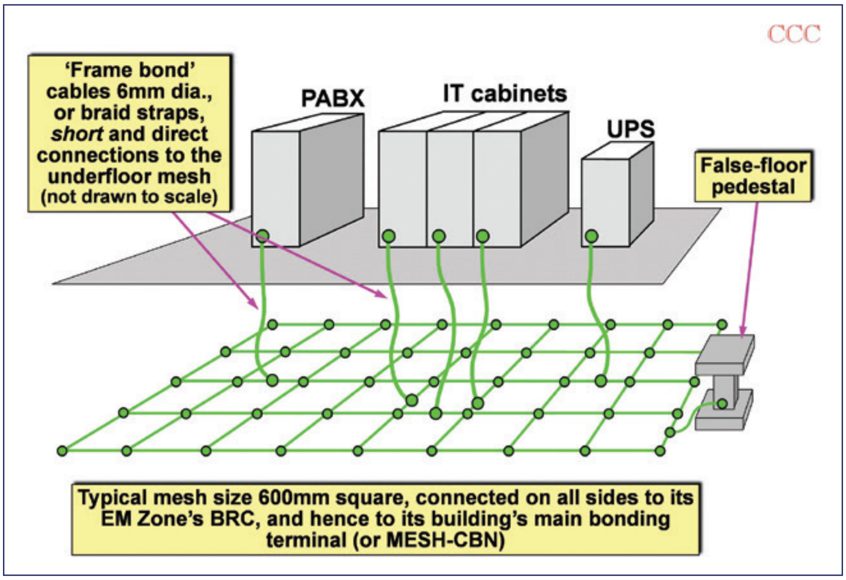

Figure 5: Example of constructing an SRPP, from the 1990s

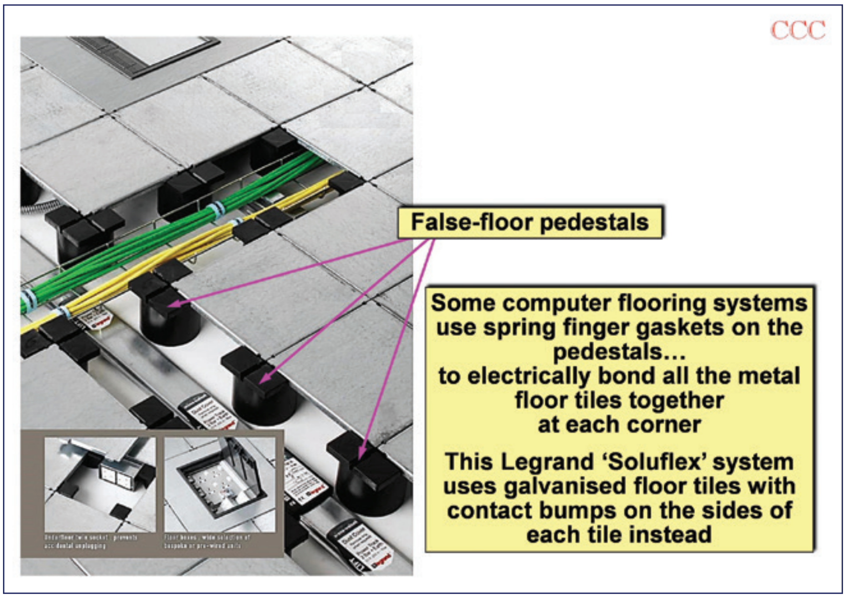

Figure 6: A proprietary system for constructing SRPPs using false-floor tiles themselves

Modifying existing installations to create meshed bonding networks for new equipment can easily cost more than the new equipment itself!

of around 600mm on a side, as shown in Figure 8. Modern computer systems may require meshes to control 100MHz or more.

The VSD technology that was new in the early 1990s could excite structural resonances in installations up to a few MHz, and this frequency has been steadily rising as power switching devices have developed. These frequencies are lower than those used by computer data, but on the other hand, their levels are much higher, so the sizing of a mesh size could depend more on the VSDs used on the site than on its computers. This issue will become much more important as the next generation of power switching devices replaces IGBTs and silicon powerFETS during the 2020s.[4]

Clearly, to be able to easily and quickly install new electronic systems or VSDs these days, it helps if you don't have to first modify a building's protective equipotential bonding structure (whether it is grounded to rods in the soil, or not) to create MESH-BNs, IBNs or CBNs. Modifying existing installations to create meshed bonding networks for new equipment can easily cost more than the new equipment itself! After all, you often have to cut into floors or walls to get at the conductors that need to be meshed together.

Also, in industrial applications it has long been a simple matter to use existing metal cable support structures and/or cable armor as PECs. But this clever cost-saving measure is very vulnerable to changes and modifications being carried out by people who are not aware that these metal structures have any functionality other than mechanical. Creating a well-meshed CBN helps avoid problems of unreliability and/or EMC arising for such reasons.

So, since the mid-1990s, the general recommendation for all systems or installations is that "new-builds" should install MESH-CBNs right from the start. It is also generally recommended that legacy buildings convert to MESH-CBNs as soon as practical, usually a gradual process as new equipment is installed.

These recommendations are set to become much more important during the next few years, as the new generation of power switching converters and variable-speed motor drives based on HEMTs and SiC powerFETS discussed in Part 1 of this article become readily available in high power ratings.

Figure 7 shows a MESH-CBN covering an entire floor of a building, but of course, we may need to extend them in three dimensions to other floors too,

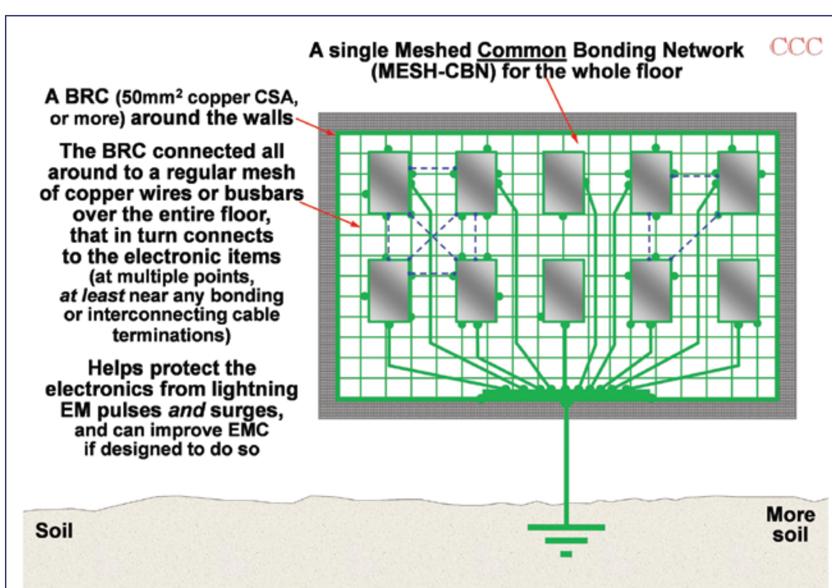

Figure 7: A sketch of a MESH-CBN

and Figures 8 - 10 are copies of relevant slides from my training course on EMC for Systems and Installations.[5]

SPECULATION ON 3G, 4G, 5G, ETC., AND FIBRE-OPTICS

What if low-cost high-rate digital wireless comms had been available back in the 1970s? Even 3G cellular systems would have made data cables unnecessary back then, making BNs, IBNs and CBNs unnecessary. As the complexity of the electronic systems grew, wireless datacomms would have kept pace, first with 4G and then 5G.

Perhaps when 5G is mature and proven to be robust in industrial applications (despite the high levels of interference often associated with industrial processes), we will simply be plugging 5G modems into USB 3 sockets to carry industrial Ethernets, with no longer any need for data cables, hence no need for costly MESH-BNs, -IBNs, or -CBNs. Protective equipotential bonding/grounding networks would still be required for human safety, but nothing more complex than the original types sketched in Figure 1 of Part 1 of this article – a big reduction in the use of costly copper.

A similar speculation concerns low-cost fibre-optics. If we had had modern low-cost fibre-optics running at 25Mb/s in the 1970s, they would have been preferable to copper cables (with all the EMC problems created by their unavoidable "accidental antenna" behaviours).

These days, when people ask me for help in fixing data interference problems with cables between items of equipment in scientific/industrial systems/installations, I am increasingly recommending that they replace their copper data cables with fibre-optic "modems" connected by (metal-free) fibre-optical cables. The cost of fibre-optic systems is steadily falling, and their data rates are steadily increasing, and

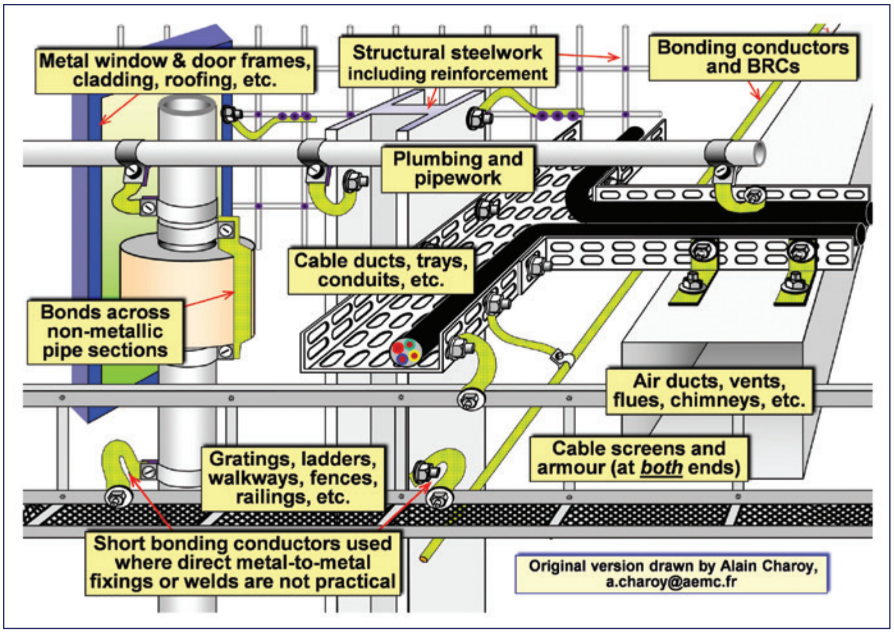

Figure 8: Using "natural" metalwork in a building-wide 3-D MESH-CBN

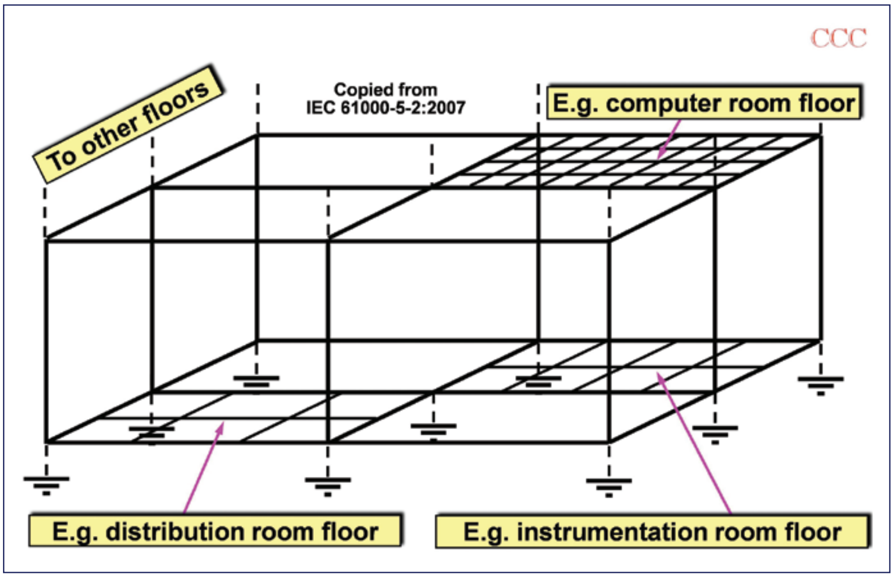

Figure 9: A sketch developed from a Figure in IEC 61000-5-2, showing the vertical bonding between MESH-CBNs on different floors of a building

Generally speaking, for the best EMC with the lowest overall costs, now and in the future, copper cables should only be used for (well-filtered!) AC or DC power.

using them instead of copper cables avoids the need to create MESH-BNs, -IBNs, or -CBNs.

Even though the cost of a fibre-optic solution may be a few hundred or thousand U.S. dollars, very little time is required for installation. Although creating a MESH-BN, MESH-IBN, or MESH-CBN might appear at first to cost less, it will almost certainly cost a lot more overall when labour costs are taken into account, never mind the costs of the lost production while these intrusive modifications are being undertaken.

Also, while the fibre-optic solution is almost guaranteed to work first time (no one with any real experience ever guarantees anything where EMI is concerned!), converting a legacy installation into a MESH-BN, -IBN, or -CBN can be a bit of a gamble. Installing meshed bonding in legacy buildings is very labor intensive and time consuming, but going for a least-cost option might well only result in having to do it all over again! For example, the mesh size depends upon how low the overall impedance needs to be, and the highest frequency it needs to control, and these are often not understood as well as they might be.

Also, will the resulting meshed structure be future-proof, or will it need to be modified again when the existing equipment is upgraded or replaced, or when new equipment is installed nearby in a few years' time? Even replacing failed equipment with new versions of the exact same product from the same manufacturer inevitably causes ever-increasing noise problems at ever-higher frequencies.

This problem arises because the newer versions inevitably use newer power switching devices and newer microprocessors that switch more quickly – whether we want or need them to, or not! The original, slower semiconductors are simply no longer available to manufacturers, whose products therefore tend to become ever noisier at ever-increasing frequencies – even when they remain fully compliant with the relevant emissions standards.

Generally speaking, for the best EMC with the lowest overall costs, now and in the future, copper cables should only be used for (well-filtered!) AC or DC power. And all signals, data, and controls should use either (metal-free) fibre-optic cables or proven-industrially-robust and reliable wireless datalinks.

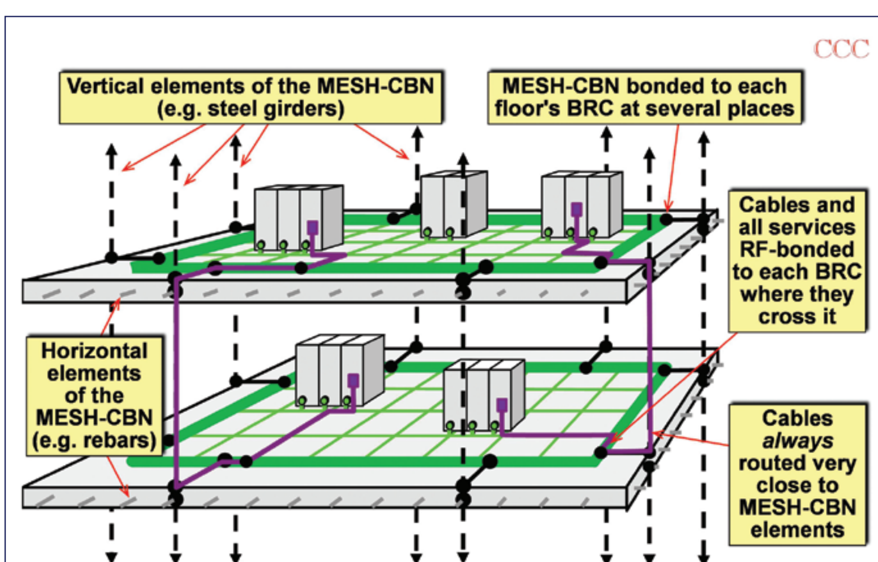

Figure 10: A sketch of using "natural" metalwork to vertically bond between MESH-CBNs on different floors of a building

ENDNOTES

1. It is always a problem in a brief article like this for an author to know how far to go into the detail, especially where safety issues are concerned. I have to assume that my readers understand that testing an IBN by isolating it and charging it up to 10kVDC has the potential to injure people due to electric shock – therefore such tests should only be carried out by people independently certified as being competent to perform them, and who regularly perform such tests. The high-voltage test generators must be current-limited to help prevent dangerous shocks, and the area of the IBN and near to it kept reliably off-limits to all personnel not directly involved.
2. All conductors (including any metalwork) are "accidental antennas," whether we want them to be or not. See https://www.emcstandards.co.uk/the-physical-basis-of-emc for more details on this.
3. For example, I have seen such a guide from the 1970s that said the SRPP for a computer room had to maintain an 'equipotential voltage' from one corner to another that should not exceed 0.7V at frequencies up to 30MHz.
4. This article is not the place to discuss mesh sizing in detail. But, for more information about EMC, see *EMC for Systems and Installations*, Tim Williams and Keith Armstrong (available at https://www.emcstandards.co.uk/emc-for-systems-and-installations). Also see section 5 of "Good EMC Engineering Practices for Fixed Installation" at https://www.emcstandards.co.uk/good-emc-engineering-practices-for-fixed-instal2 for information on using rebar meshes and the like to help protect installations from the powerful electromagnetic pulses (EMP) that can be created by lightning and nuclear explosions (e.g.: LEMP, HEMP, NEMP, etc.).
5. Available at https://www.emcstandards.co.uk/good-enc-engineering-practices-for-electricalel.

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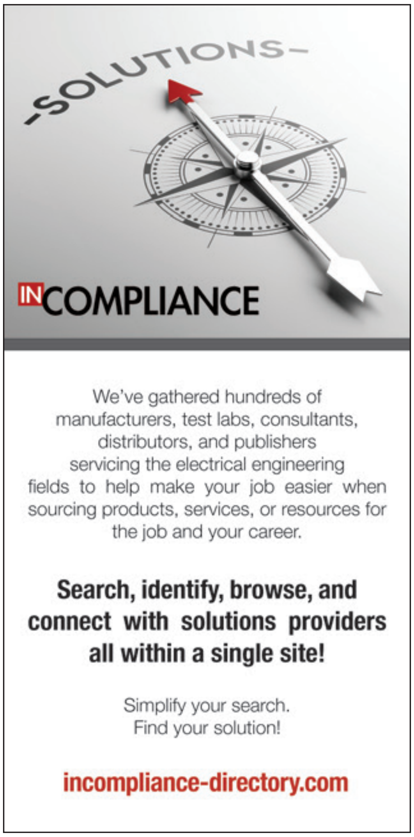

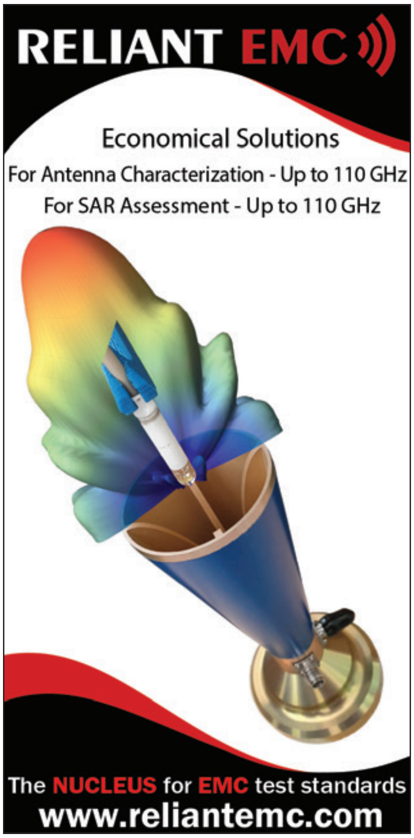

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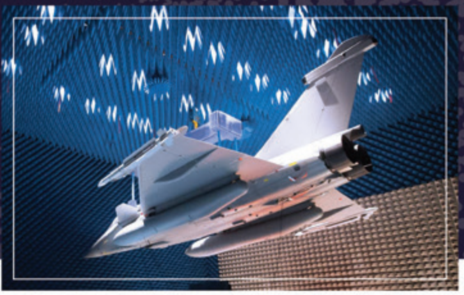

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