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STANDARDS UNIVERSITY

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Conformity Assessment and Compliance

IN THIS ISSUE

Introduction: Conformity Assessment & Compliance

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Technical standards are formal documents that establish uniform engineering or technical criteria, methods, processes and practices developed through an accredited consensus process. The purpose of this publication is to help raise awareness of standards, show the importance of standards, present real-world applications of standards, and demonstrate the role you can play in the standards development process. Knowledge of standards and standards activities can help facilitate your professional engineering practice and improve technological developments to meet the needs and improve the lives of future generations.

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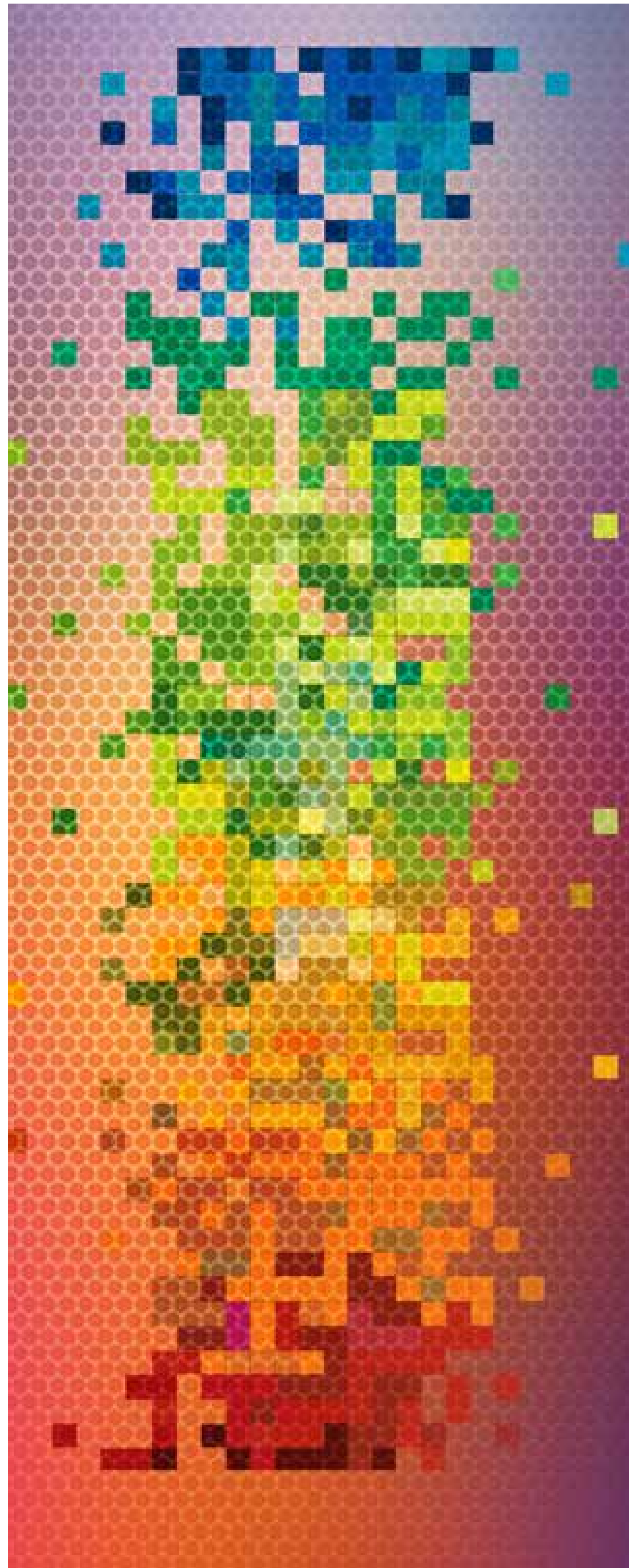
Letter from the Editor



Sometimes it is easier to let the expert explain a topic – be it a concept, a process, a product or a service. The focus topic for this issue is Conformity and Compliance, and have we got a treat for you! Don Heirman, a member of the eZine Editorial Board, past President of IEEE Standards Association, and an expert in the field of electromagnetic compatibility (EMC) offered to put together this issue with the help of other experts in the field. How could I have chosen any response other than "please, will you? …

Without further ado, this is Don's "dynamite eZine ssue" (his own words!). Start with his Introduction article and follow the order he has presented. Hope you enjoy reading this issue, and please share your comments with us about conformity and compliance in your field of work.

Yatin Trivedi, Editor-in-Chief, is a member of the IEEE Standards Association Board of Governors (BoG) and Standards Education Committee (SEC), and serves as vice-chair for Design Automation Standards Committee (DASC) under Computer Society. Yatin served as the Standards Board representative to IEEE Education Activities Board (EAB) from 2012 until 2017. He also serves as the Chairman on the Board of Directors of the IEEE-ISTO.

Yatin currently serves as Associate Vice President for semiconductor design services at Aricent Inc. Prior to his current assignment, Yatin served as Director of Strategic Marketing at Synopsys where he was responsible for corporate-wide technical standards strategy. In 1992, Yatin co-founded Seva Technologies as one of the early Design Services companies in Silicon Valley. He co-authored the first book on Verilog HDL in 1990 and was the Editor of IEEE Std 1364-1995™ and IEEE Std 1364-2001™. He also started, managed and taught courses in VLSI Design Engineering curriculum at UC Santa Cruz extension (1990-2001). Yatin started his career at AMD and also worked at Sun Microsystems.

Yatin received his B.E. (Hons) EEE from BITS, Pilani and M.S. Computer Engineering from Case Western Reserve University. He is a Senior Member of the IEEE and a member of IEEE-HKN Honor Society.

Introduction: Conformity Assessment and Compliance

by Don Heirman

In this issue, we look at two different aspects of product compliance. With videos, we show the role of conformity assessment in ensuring that products meet design standards and regulatory compliance. We also provide insight into what is involved in actual testing to demonstrate compliance to design standards and meet regulatory requirements in both North America and the European Union (EU) as two major regions of the world. We discuss in this article not only the role of testing but also acceptance of products based on the manufacturer indicating that the product was designed for its purpose of use and is safe. We have invited several contributors to cover conformity assessment and regulatory compliance as well as the testing needed to show compliance. You will find articles on these subjects from the following authors:

- Bill Hurst, US Federal Communications Commission (FCC)—comments by a regulator on meeting regulations that apply to all products operating with microprocessors, including those that communicate via wireless media; see requirements for digital devices in this section
- Ray Klouda, Elite Electronic Engineering—the role of a testing laboratory to show compliance with regulations
- Ben Gorini, Nokia—a look at international approaches to providing standards to meet regional regulations; see this link for the EU Standardization Organizations
- Todor Cooklev, Purdue University—an example of standards application for wireless products that meet standards and regulations;
- Antonio Farone, Motorola Solutions—an explanation of why wireless products need to meet human RF exposure requirements and what this entails
- H. Stephen Berger, TEM Consulting—a view of consumer reaction to the need for products to truly meet regulations and in fact work as advertised; see this link for the Hearing Industry Association noting news articles the US Food and Drug Administration (FDA) clearing the way for at-home hearing tests.
- Ghery Pettit, Pettit EMC Consulting—an overview of key U.S. and international standards development organizations along with examples of significant standards they have developed; see this link for the IEC organization that developed emission standards.
- Andrew Myles, Cisco—a discussion of the trade-off between innovation and regulation in unlicensed spectrum.

We also offer a three-part series of videos:

- Conformity Assessment: A Process by Rudi Schubert, IEEE
- The Value of Conformity Assessment for Different Players by Yatin Trivedi, Aricent, Inc.
- Conformity Assessment: Perspective of Product Designers by Gordon Gillerman, NIST

Virtually all products either have a microprocessor control (which emits incidental or unintended signals) or transmit wirelessly, if not both. Hence every manufacturer is concerned with this aspect of regulation compliance, as are the end users/customers. The manufacturer is also concerned that its products meet a need functionally. There are also requirements for all electronic products to meet a variety of regulations including safety [both from electrical shock and human exposure to radio frequency (RF) energy], interoperability with other devices/systems, RF emissions to control interference with other electronic products, and, in some countries, immunity to the RF environment at the typical location where the product is used. How then are these aspects assessed to be true? Both conformity assessment and regulatory compliance testing play a role here.

Government agencies around the world regulate products to ensure they do not interfere with radio services and actually work in the environment in which they are used. Our regulatory story was provided by the U.S. FCC and by a standards manager highly active in European Committee for Electrotechnical Standardization

(CENELEC) which supports compliance requirements and the standards needed to show such compliance. The European Union is a major player in interference control as is the FCC. Interference is generated from products that have unwanted and operational signals that could disturb other products. The Voluntary Control Council for Interference (VCCI) of Japan is another body that has recognition much like a regulatory authority and as such establishes requirements to control interference. They reference primarily standards produced by the International Electrotechnical Commission (IEC) on how to measure emissions as well as the limits to be met.

In North America, the limits are set only by regulatory bodies and are not included in US measurement standards. While conformity to IEC standards and most others is voluntary, observance of these standards becomes mandatory when regulators reference them in their "rules" to show product compliance. Thus, emission limits are established globally as there is a worldwide need to protect radio services from the interference generated by electronic devices.

Immunity (the ability to withstand interference from other sources that emit radio signals), however, is not regulated internationally. In the United States, for example, immunity is addressed by the Food and Drug Administration (FDA) for medical devices. The FCC however does not address immunity for digital devices (sometimes called unintentional radiators), as they rely on manufacturers themselves to determine what immunity levels should be used to reduce customer complaints and show the quality of their products. In the European Union, immunity is addressed for most commercial products as this requirement is called out in an EU Directive. Hence there may be different test levels required worldwide that must be taken into account in performing immunity compliance testing.

In addition, safety is also regulated worldwide, as it is in the United States by the Occupational Safety and Health Administration (OSHA). For safety with RF fields, human exposure must be measured for all products that transmit signals, such as mobile and smart phones (the IEEE 802 series of standards generally covers wireless transmitter design requirements). The compliance test is quite complex to show adherence to FCC and other similar limits, such as those of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), are strictly enforced in most parts of the world.

Major manufacturers also have internal compliance testing capability. For instance, CISCO Systems and Apple have well established testing capabilities. Third-party testing is available in the marketplace to cover manufacturers that do not have such compliance testing capability or that simply want to have an independent check on the internal lab results. Fortunately, there are many third-party electromagnetic compatibility (EMC) testing organizations. EMC covers both emission and immunity testing. In the United States, the American Council of Independent Laboratories (ACIL), a major trade organization of EMC testing labs, is a good contact for manufacturers seeking such third-party testing as they can put them in contact with competent test laboratories.

Another important aspect is ensuring that compliance measurements are conducted at a high level of competency by the testing laboratories. Most third-party testing organizations and some manufacturers' labs are assessed by accrediting bodies. These accreditation bodies assess the quality of both testing facilities and the competency of the test engineers performing compliance tests. In the United States, there are two major accrediting bodies which are recognized internationally as well. They are the National Voluntary Laboratory Accreditation Program (NVLAP) operated by the U.S. National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, and the American Association for Laboratory Accreditation (A2LA) operating out of Frederick, Maryland.

Many accrediting bodies worldwide are members of the International Laboratory Accreditation Cooperation (ILAC), and both NVLAP and A2LA are ILAC members. ILAC membership is important for international recognition as ILAC members assess and accredit conformity assessment bodies (to relevant international standards) among those that sign a mutual recognition agreement.

These assessments are generally conducted every two years but can be more frequent if any significant deficiency is found needing immediate attention. We also need an organization that speaks to user confidence. In the realm of hearing aids, there is the Hearing Industry Association (HIA), which advocates at times for their user community. We welcome feedback from this or any other consumer group on their view that products they use meet regulatory compliance. One of the articles in this issue provides more details about such customer expectations based on the author's experience with HIA.

There is always the need for feedback from regulatory authorities and perhaps the end users of products that presumably meet compliance requirements. Most customers see labels on products and assume that placing them on the product is tantamount to "automatic" compliance with regulatory needs. However, if you examine the exterior of an ac/dc converter that powers your laptop computer, you will see a myriad of labels from all over the world that presumably show compliance with the requirements of the countries whose labels are shown. But is this true in all cases? Manufacturers bear responsibility for verifying the truth of this, a task they take seriously. It would be good to hear the views of product regulators in many countries that products are truly complying with regulations. This is a sensitive subject as the premise is that all comply; however, we know from field complaints that some do not, thus disrupting the operation of adjacent equipment (now usually called a "disturbance") and radio services, or even affecting the user's electronic products. The FDA and FCC have a complaint mechanism in place for reporting such problems. But the time and budget of these organizations to sample compliance with products in the marketplace are extremely limited. Reported problems have been published in trade magazines, and such incidents can be searched for and even cited. In summary, enjoy the breath of videos and articles included in this edition of the e-zine on the use of a conformity assessment scheme, showing compliance with regulations, and the integral part that standards play in compliance assessment, particularly in performing compliance and conformity measurements.

Donald Heirman is president of Don HEIRMAN Consultants, LLC, which is a training, standards, and educational electromagnetic compatibility (EMC) consultation corporation. Previously he was with Bell Laboratories for over 30 years in many EMC roles, including Manager of Lucent Technologies (Bell Labs) Global Product Compliance Laboratory, which he founded, and where he was in charge of the corporation's major EMC and regulatory test facility and its participation in ANSI accredited standards and international EMC standardization committees. He chairs or is a principal technical contributor to U.S. and international EMC standards organizations, including ANSI ASC C63® (immediate past chairman and chairman of the C63.4 working group), the Institute of Electrical and Electronics Engineers, and the International Electrotechnical Commission's (IEC) International Special Committee on Radio Interference (CISPR). He was CISPR chairman between 2007 and 2016. He has been the chairman of the IEC's Advisory Committee on EMC (ACEC) since July 2013. He is also a member of the Technical Management Committee of the U.S. National Committee of the IEC. In November 2008, he was presented with the prestigious IEC Lord Kelvin award at the IEC General Meeting in Sao Paulo, Brazil. This is the highest award in the IEC and recognizes his many contributions to global electrotechnical standardization in the field of EMC. He is a life fellow of the IEEE and an honored life member of the IEEE EMC Society, past member of its Board of Directors, chair of its technical committees on EMC measurements and Smart Grid, former Vice President for Standards, past EMCS president, and past chair of its standards development committee. He is also the former president of the IEEE Standards Association (SA) and past member of the SA Board of Governors and the IEEE's Board of Directors and Executive Committee. He was the Associate Director for Wireless EMC at the University of Oklahoma Center for the Study of Wireless EMC. He now teaches the practical application of EMC compliance measurements at Purdue University, West Lafayette, Indiana, USA. He has also a special collection of his career EMC-related papers in the Purdue Library Archives. This was established for researchers in the area of EMC standardization. Access is available online (see URL home page). He is a voting member of the U.S. Smart Grid Interoperability Panel (SGIP) (now called the Smart Electric Power Alliance) and its Testing and Certification Committee. In addition, he is chairman of the SGIP Electromagnetic Interoperability Issues Working Group, which is providing EMC recommendations for Smart Grid equipment and systems. He also serves as the consultant on Smart Grid matters for the Conformity Assessment section of the American Council of Independent Laboratories.

Government Agencies that Regulate Products (and set limits) Going into the Marketplace

by Bill Hurst

A wide variety of radiofrequency (RF) devices are subject to Federal Communications Commission (FCC) technical and equipment authorization requirements in order to minimize the risk of harmful interference with radio services and to meet other statutory and policy objectives. Section 302 of the Communications Act of 1934, as amended, authorizes the FCC to make reasonable regulations governing the interference potential of devices that emit RF energy and can cause harmful interference to radio communications.

The FCC generally implements this authority by establishing technical rules for RF devices. For example, Part 15 of the Commission's rules sets forth the technical requirements for unlicensed devices—intentional and unintentional radiators; Parts 22, 24, and 27 present the technical requirements for transmitters used in various commercial mobile radio services; and Part 90 specifies the technical requirements for transmitters used in private land mobile radio services.

FCC rules are adopted through an open rulemaking process in which the FCC gives the public notice that it is considering adopting or modifying rules on a particular subject and seeks the public's comments. The Commission then considers the comments received in developing final rules.

Comments can be filed electronically using the Internet by accessing the Commission's Electronic Comment Filing System, ECFS. All comments and documents related to a rulemaking proceeding can be viewed online.

One of the primary ways in which the Commission ensures compliance with the technical rules is through the equipment authorization program for RF devices, which is codified in Part 2 of the FCC rules. This program ensures that RF devices comply with the Commission's technical and equipment authorization requirements before they can be imported to or marketed in the United States. The Office of Engineering and Technology (OET) administers the day-to-day operation of the equipment authorization program.

The Enforcement Bureau (EB) is the primary FCC unit responsible for enforcing the provisions of the Communications Act as well as the Commission's rules, orders, and various licensing terms and conditions. The FCC has an online Consumer Complaint Center to enable interested parties to file complaints. The Enforcement Bureau's Spectrum Enforcement Division, in conjunction with regional and field offices, is responsible for responding to interference complaints involving FCC licensees.

The Commission has established an experimental licensing program to provide for the introduction of new and innovative products prior to final equipment authorization. Each year, the Office of Engineering and Technology typically grants more than 2,000 experimental licenses. Many of the services and technologies deployed today were first tested under the experimental licensing program. Moreover, many experimental licenses are currently supporting work aiming towards the introduction of next-generation 5G services. New types of experimental licenses have been established to allow greater flexibility for parties—including universities, research labs, health care facilities, and manufacturers of radio frequency equipment—to develop new technologies and services while protecting incumbent services against harmful interference.

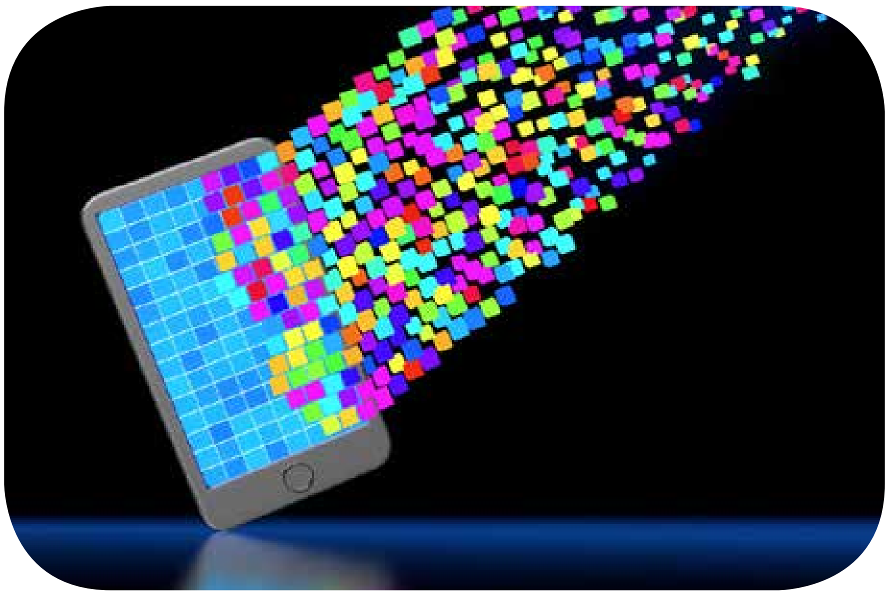
The FCC provides a number of resources to help educate and answer questions that consumers and the telecom industry may have regarding FCC requirements.

- The Commission has a Knowledge Database (KDB) that provides information on equipment authorization requirements. Interested parties can submit inquiries concerning equipment authorization matters (FCC rules Part 2, Part 15, etc.) to the FCC Office of Engineering and Technology (OET) Laboratory Division. The OET publishes equipment authorization procedures and measurement guidance in the form of FCC Public Notices and Knowledge Database (KDB) publications.
- Information about general FCC matters beyond equipment authorization is available at the FCC Consumer and Governmental Affairs Bureau (CGB) Consumer Help Center.
- Questions about wireless transmitting station licensing matters can be submitted at the FCC Wireless Telecommunications Bureau (WTB) Support site.
- For information and questions about RF radiation safety and health concerns for antennas installed on buildings, towers, and cluster sites, please see the FCC OET RF Safety FAQ site.

Bill Hurst is Chief of the Technical Research Branch, Laboratory Division, Office of Engineering and Technology of the Federal Communications Commission (FCC). His responsibilities at the FCC include technical research, support for the Commission's equipment authorization program, participation on domestic and international standards committees, accreditation activities, and coordination with other government agencies and groups concerned with conformity assessment policies and rules. He is involved with international trade issues including technical barriers to trade (TBT) and various trade agreements. To facilitate the acceptance of testing and certification of telecommunication products by the Commission, he oversees the implementation of Mutual Recognition Agreements (MRAs) between the United States and the European Union, Japan, Canada, Mexico, Israel, the Asia-Pacific Economic Cooperation (APEC), and the Inter-American Commission for Telecommunications (CITEL).

Test Labratories for Compliance Testing

by Raymond J. Klouda



Most standards and regulations rely on testing and measurement to demonstrate compliance with their requirements. These standards have requirements for the test facilities to be used when testing products for compliance. In order to properly evaluate any product, tests and measurements must be performed in a well-equipped laboratory and under conditions described and specified in the standards. The staff must be well trained and have experience with the particular measurement techniques. For example, for radiated emission measurements, a large absorber-lined shielded enclosure (ALSE) or Open Area Test Site (OATS) is required. The test site must be designed and built to meet rigorous site attenuation requirements. The measurement receiver should be equipment with specified bandwidths and detector functions. Measurement antennas are listed and must be characterized for the frequency range. The equipment must be maintained and calibrated with traceability to a national standard. A properly equipped and staffed laboratory is essential for demonstrating that a product is compliant with the standards and regulations.

Manufacturers may choose to have their own internal laboratory or use one of the many independent laboratories for their compliance testing. In either case, to insure the quality of the test, the laboratory will need to be accredited. Typically, these laboratories are required to be accredited according to the ISO/IEC 17025 standard, which specifies the general requirements for the competence of testing laboratories. These laboratories can be expensive to build and maintain, so many manufacturers will rely on independent third-party laboratories to meet their needs. Test lab trade organizations such as the American Council of Independent Laboratories (ACIL) would be a good source to contact for such third-party testing options. Sometime a manufacturer will have what is known as a "pre-compliance" laboratory inside its facilities and use an outside third-party laboratory for official measurements. A pre-compliance laboratory might not be accredited nor meet the rigorous requirements in the standard but will be useful for experimenting with the product in its development stage so that it will likely meet the requirements when presented to the compliance laboratory for official tests.

Raymond J. Klouda has been with Elite Electronic Engineering, Inc., since 1981 and serves as President and Senior EMC Engineer. Mr. Klouda has been active in the related fields of electromagnetic compatibility (EMC) and RF shielding design since 1981. He is proficient with military and commercial EMC specifications, including Mil-Std-461, RTCA-DO160, FCC rules, Canadian regulations, CE marking, and international compliance, including CISPR and IEC/ISO specifications. As a technical reviewer, he evaluates and approves radio devices under the Telecommunication Certification Body program. In addition, he leads the team responsible for the administration of Elite's ISO 17025 quality system and ISO 17065 certification systems. Ray lives in Lisle, IL, USA. He enjoys gardening and traveling. Mr. Klouda received his electrical engineering degree from the University of Illinois at Champaign-Urbana B.S.E.E. (1981) and graduated with honors (Tau Beta Pi and Eta Kappa Nu honor societies). He is an iNARTE-certified EMC engineer and a licensed professional engineer in the state of Illinois. He is an active member of the IEEE EMC Society and the IEEE EMC Chicago Chapter, and has served on the Executive Committee since 1989 in various roles (secretary, chair, and member). He was also Technical Program Chair for both the 1994 and 2005 International EMC symposiums held in Chicago, IL, USA.

Compliance View from a Major Region of the World

by Raymond J. Klouda

In the European Union, EMC requirements are covered by the EMC directive 2014/30/EU, but for some products, these requirements are covered by specific directives such as the Radio Equipment Directive 2014/53/EU.

In order to demonstrate compliance with the essential requirements listed in the directives, EMC European Norms (EN) are prepared by CENELEC and ETSI under the mandate of the European Commission. Once these CENELEC and ETSI EN standards are published and the EU Commission notified, they are cited in the EU Official Journal as "harmonized standards," signifying compliance with the specific directives. For each EN, the EU Official Journal also includes the transition period between the new standard and the one it replaces. Therefore, by the date of cessation of the superseded standard, manufacturers must show they conform to the specifications of the new EN in force.

The European Norms on EMC for radio equipment and telecommunication network equipment are produced by ETSI while all other EMC standards are produced by CENELEC. CENELEC and ETSI ENs, together with EMC requirements, refer to the basic standards produced by the IEC (e.g., 61000-4-x series) or CISPR (e.g., 16-x-y series) and adopted in the European Union as European Norms (for instance, in the EU, IEC 61000-4-2 has been adopted as EN 61000-4-2 and CISPR 16-2-3 as EN 55016-2-3). Similarly, the EMC generic and product family standards are, in most cases, the IEC standards adopted in the European Union as ENs (e.g., IEC 61000-6-1 became EN 61000-6-1 and CISPR 32 became EN 55032). When no EMC product standards are available from the IEC or CISPR, then CENELEC and ETSI produce specific ENs; an example is the standard EN 50 561-1, Power Line Communication Apparatus Used in Low-Voltage Installations, where an equivalent IEC or CISPR standard does not exist.

In some cases, the IEC/CISPR standards are adopted in the European Union with some modifications. These modifications are quoted in the "Foreword" of the EN. Furthermore, in recent EU ENs, there is an Annex section that defines the relationship between the requirements in the EU directives and the specific technical requirements defined in the standard that should be applied by manufacturers to demonstrate compliance.

Information on the latest harmonized standards produced by CENELEC and ETSI for the EMC directive 2014/30/EU can be found at https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/electromagnetic-compatibility_en. Information on the latest CENELEC and ETSI standards harmonized with EMC requirements for the Radio Equipment Directive 2014/53/EU can be found at http://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/rtte_en.

Beniamino Gorini
Alcatel-Lucent (Nokia)

International standardization bodies

- Since 1991 Alcatel (now Alcatel-Lucent) representative in ETSI EMC TB and later Vice-chairman of ERM-EMC WG. Project Leader for various EMC standards for telecommunication and radio equipment.
- Since 1991 member of ETSI TC-EE with role of rapporteur of some environmental standards
- Since 1995 national representative in CENELEC TC210 "EMC standards".
- Since 1996, national delegate in CISPR SC A "EMC test methods & instrumentation", SC H "EMC Generic standards and Emission limits" and SC I "EMC standards for ITE/MME"
- Since 1998 member of ITU-T SG5 "EMC of telecommunication systems & hazard to human beings" (now "Environment and climate change")
- Since 2000 secretary of CISPR SCA/WG2 "EMC test methods" and in September 2006 appointed convenor of this WG
- From 2000 until 2008 Convener of the Joint Task Force IEC 77B/WG10 & CISPR SC/A for "Uniform measurement test arrangement"
- From 2003 until 2012, member of IEC SC77B/WG10 "Immunity basic standards"
- From 2004 until 2010, member of IEC SC106/WG5 "generic EMF standards"
- Since 2004, national delegate and ETSI TC-EE liaison person in CENELEC TC111X/WG3 "Standardization programme for the Energy using Product" directive

Standards, Regulation, and Compliance

by Todor Cooklev

To say that spectrum is critically important is an understatement. The relevant industries generate trillions of dollars in annual revenue.

Because spectrum is so important to the public welfare, regulations established by government agencies are necessary. In the United States, the rules that govern the radio spectrum are laid out in Title 47 of the Code of Federal Regulations. These rules include measures to protect environmental and other types of resources, and compliance with them is mandatory.

Standards are produced by standards-developing organizations (SDOs) and typically refer to the operation of a particular product. Compliance with standards for electromagnetic interference is mandatory, but compliance with standards such as Wi-Fi and LTE is entirely voluntary. However, the successful standards have created huge market opportunities, and compliance with these standards has become, in most cases, a de facto requirement for commercial success. Prior to selling equipment, equipment manufacturers must receive certification that their devices comply with government (in the United States, FCC) regulations. Thus, these devices undergo[KZ1] [KZ2] interoperability testing, as established by the relevant standard. Devices are fielded only after they have passed these tests. Standards may include performance criteria that incorporate relevant regulations, and in these cases, compliance with the standard can mean compliance with the regulations.

Currently, the FCC first "allocates" a band of frequencies, specifying power limits and, in some cases, determining the specific service to be used. There are several different licensing schemes: (1) exclusive, usually for a limited geographic area; (2) non-exclusive; (3) unlicensed; and (4) special, meaning a site-based license. For example, cellular service providers have exclusive licenses. Wi-Fi is using unlicensed and, more recently, non-exclusively licensed spectrum, or licensed spectrum that is otherwise unoccupied. Unlicensed devices must accept whatever interference they receive and must not cause harmful interference. Exclusive licenses can be obtained primarily through competitive bidding and guarantee license holders the right to call federal marshals to tear down transmitters that cause "harmful interference" to the license holder.

The central technical concept is what constitutes "unacceptable interference." Interference to a receiver depends mainly on the distance from that receiver to the unwanted transmitter compared to the distance to the intended transmitter, and the power levels of these transmitters. There is no such thing as interference-free wireless transmission, or rather reception. Every receiver must tolerate some level of interference.

For a long time, spectrum was considered a resource, similar to land or oil, albeit "infinitely renewable," with several dimensions—time, frequency, and location. The licensing system is effectively parceling spectrum in frequency, in location, and, more recently, in time. The problem with this is that signals can overlap in all three of these dimensions and still be non-interfering, using techniques such as spread-spectrum and ultra-wide band (UWB). Since two people cannot plough the same plot of land at the same time, the resource analogy has limitations.

Therefore, the technology evolution not only leads to new regulations and standards but also improves our understanding of "spectrum" and "interference," the very concepts with which these regulations and standards operate.

Todor Cooklev is Harris Professor of Wireless Communication and Applied Research at Purdue University in Fort Wayne, Indiana. He has contributed to the development of a number of communications standards, including Bluetooth, DSL, Wi-Fi, cellular, and military radio systems, serving at times in leadership positions in standardization organizations such as ITU-T, IEEE 802, and 3GPP. His research interests include most aspects of wireless standards. Dr. Cooklev has contributed to more than 100 publications.

Human Exposure Compliance

by Antonio Farone

National and international regulations that address radio-frequency exposure safety refer, for the most part, to the exposure guidelines established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which are substantially harmonized with the C95.1-2005 standard promulgated by the IEEE. A few relevant exceptions are regulations from the United States, Canada, South Korea, India, and Bolivia, which mostly rely on 1986 guidance by the U.S. National Council on Radiation Protection and Measurements (NCRP). A common trait of these guidelines is the definition of the specific absorption rate (SAR) (i.e., the time-rate of radio-frequency power dissipation in tissue) as the primary metric for quantifying exposure from portable wireless communication devices operated close to the body. Additional common traits are the definition of separate sets of limits for workers and for the general public (e.g., consumers) as well as the definition of time-averaging provisions in the application of exposure limits.

Under the current regulatory frameworks worldwide, before their market introduction, wireless devices such as smartphones and tablets, laptop computers, and portable radios are subject to routine compliance evaluations, which for the most part rely on SAR measurements performed according to international standards defining accurate and efficient testing methods. In particular, IEEE 1528, IEC 62209-1, and IEC 62209-2 form the backbone of internationally accepted SAR testing guidelines. These standards are continually updated to reflect the rapid progress of technology—for instance, the transition from single to multiple transmitter devices, from narrow-band to broadband waveforms, and from handheld to wearable devices. For SAR test data to be considered of acceptable quality, regulators frequently require test labs to be accredited according to the ISO/IEC 17025 standard, which specifies general requirements for demonstrating competence to carry out tests and/or calibrations, thereby ensuring personnel competency and operations reliability.

Dr. Antonio Faraone received the Ph.D. in applied electromagnetics from the University of Rome "La Sapienza" in Italy. In 1997 he joined Motorola, Inc., and currently serves as the Chief EME (Electromagnetic Energy) Scientist at Motorola Solutions, Inc., with documented expertise in RF dosimetry, antenna R&D, theoretical electromagnetics, and EME standards and regulations. He is a Motorola Dan Noble Fellow and Master Innovator with 29 U.S. patents, and has co-authored 35 peer-reviewed articles. Dr. Faraone is a recipient of the IEC 1906 Award and was recently elected to the AdCom of the IEEE International Committee on Electromagnetic Safety (ICES).

Customer Reaction and Needs for a Compliant Product

by H. Stephen Berger

Standards are essential tools for implementing conformity assessment systems. A conformity assessment system seeks to evaluate compliance of a product or service with requirements. Customers buying products have expectations which in their minds and, not infrequently, in reality are also requirements. Customers may not be aware of it, but they depend on standards and the conformity assessment processes that use them to provide them with products that meet their needs. It is probably hard to think of a product that does not have customer expectations, which can be viewed as customer requirements. A hearing aid is a good example, but only one of many that we could discuss. Hearing aid wearers expect that a hearing aid will help compensate for their hearing loss. One particular situation in which hearing aid wearers want the device to work is when making a phone call. Customers expect their hearing aid to work no matter whether it is a wireline call, a cellular call, a cordless call, a VoIP call, or any other kind of phone call. Customers don't what to have to deal with the underlying technology. They just want to make a phone call and be able to understand the person they are talking to. In this case, there is a TIA standard covering wireline and cordless phones and an ANSI standard covering cellular and VoIP. These standards translate the hearing aid users' expectation into technical requirements that the Federal Communication Commission (FCC) requires phone manufacturers to meet.

One challenge is that customer expectations are thought of in the way we commonly speak, but to be evaluated, requirements must be technically precise. A translation must be made from plain language into technical specifications. What does it mean to be able to "use the phone" or "hear the other person?" These needs are easily understandable but are not evaluable. How many dB SPL of audio volume equates to "hear the other person?" At what point is the volume so low that it can be determined the user cannot "hear the other person"? Is volume the only requirement? How about distortion, noise, and fidelity? Is the real technical requirement a single parameter or multiple parameters? Standards translate plain language requirements into technically precise, evaluable specifications.

As we go deeper into the conformity assessment process, we can say that what a laboratory assessor needs to explore is the ability of a laboratory to do a test correctly.

Once evaluators see that a laboratory has the equipment, processes, and appropriately skilled staff to do a test correctly, they turn their attention to the laboratory's management and quality systems. Having seen that a laboratory can do a test correctly, they then look for evidence that the laboratory can be expected to do the test correctly every time. This process of laboratory assessment relies on standards, foundationally ISO 17025, the laboratory evaluation standard, to convert these requirements into specific, evaluable specifications.

Customers have little interest in the details of how laboratories or lab assessors do their work. What they care about is the end result. If a person uses a hearing aid, he or she wants to be able to use the phone, every time, no matter what kind of phone it is. All of us want to be able to fill a prescription and have confidence that the medicine we take is what the doctor ordered. When we go to a restaurant, we do not want to wonder if the food we are eating is safe. All these user needs rely on standards to convert easily understood expectations into technically precise and evaluable requirements that laboratories can follow and lab assessors can confirm are being routinely followed. In this way, we can rely on products and services to meet the requirements we have and count on them to provide.

H. Stephen Berger
President, TEM Consulting, LP

Mr. Berger is president of TEM Consulting, an engineering services and consulting firm in Georgetown, TX. He provides leadership in areas of unlicensed spectrum, standards, regulatory approvals and public policy, data collection, analysis, and interference mitigation techniques. Among his current standards projects, he is co-chair of both:

- The ANSI C63.27 working group developing standard test methods for wireless coexistence.
- The AAMI TIR-69 working group developing guidance on evaluating the risk associated with the use of wireless in a medical device or healthcare delivery system.

Standards Bodies that Provide Measurement Techniques to show Compliance

by Ghery Pettit

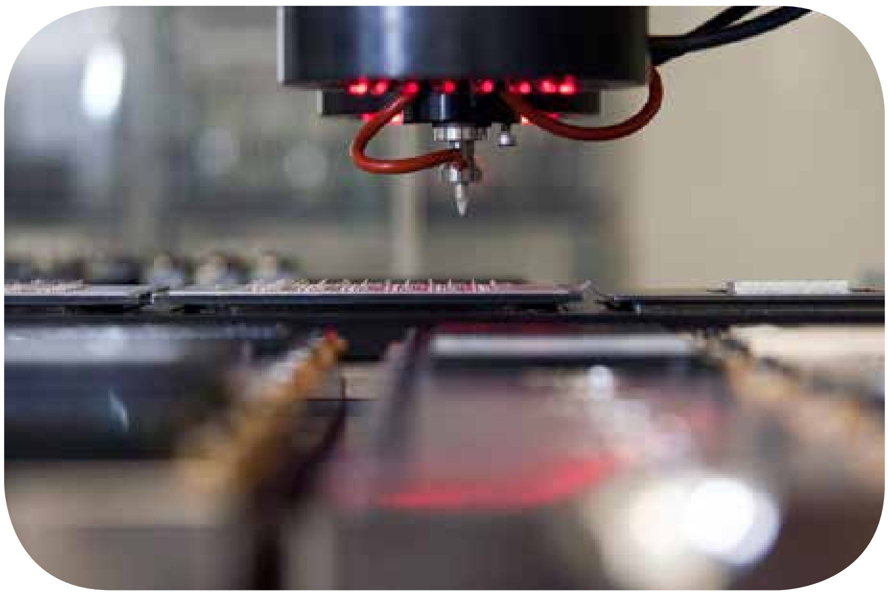
Standards Development Organizations (SDO) exist in various parts of the world, and some are involved in writing EMC standards. The two major organizations writing standards upon which other standards are based are the Accredited Standards Committee (ASC) C63® in the United States and the International Electrotechnical Commission (IEC).

C63® is most notably responsible for C63.4, the American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz. C63® is also responsible for a number of other American national standards that cover a variety of EMC matters.

The IEC, headquartered in Geneva, Switzerland, has a number of Technical Committees (TC), Subcommittees (SC), and special committees (Comité International Spécial des Perturbations Radioélectriques—CISPR) that generate EMC standards. The most noteworthy of these are CISPR and TC77 (and its subcommittees—SC77A, SC77B, and SC77C). These TCs, SCs, and special committees write the basic standards and product family standards that are then incorporated into various national standards and referenced in national regulations. For example, CISPR SC I has published CISPR 32, Electromagnetic Compatibility of Multimedia Equipment-Emission Requirements, and CISPR 35, Electromagnetic Compatibility of Multimedia Equipment-Immunity Requirements. CISPR 35 then uses a number of basic standards written and published by SC77B to describe how the various immunity tests are to be performed.

In the European Union, the standards used for EMC are largely written by CENELEC, the European Committee for Electrotechnical Standardization. CENELEC generally creates its standards in parallel with work in the IEC and votes on their standards at the same time as CISPR (parallel voting). Thus, Euro norms such as EN 55032 are oftentimes identical to IEC standards—in this case, CISPR 32. Any differences are included in the EN document as common modifications and shall be implemented when the EN is used for compliance with European regulations.

Japan, although active in CISPR and other IEC committees, writes its own EMC requirements documents through the VCCI Council. VCCI is a trade association, not a governmental body. Its standards are very similar those of CISPR but are not necessarily identical. Being a trade association, their "regulatory" impact is a bit different. In order to place the VCCI mark on a product, a manufacturer must be a member of the VCCI, and members are obligated to place the mark on all products they market in Japan. Non-VCCI members may not use the mark on their products.



Finally, the IEEE also writes standards relating to EMC. IEEE has dual publishing agreements with the IEC so that an IEEE standard that addresses a subject not covered by an IEC standard can have the standard marked as both an IEEE and an IEC standard. IEEE standards without both marks are still available as voluntary standards for use throughout the world. Most, but not all, IEEE standards dealing with EMC are products of the IEEE EMC Society.

Ghery S. Pettit received the BSEE degree from Washington State University in 1975. He has worked in the areas of TEMPEST and EMC for the past 40 years, starting at the Naval Electronic Systems Engineering Center, Vallejo, where he joined the Field TEMPEST Team. In this position he performed instrumented TEMPEST surveys on ships and shore installations for the US Navy. In the fall of 1979 he joined Martin Marietta Denver Aerospace where he worked on what became the Peacekeeper missile system, as well as other projects, providing TEMPEST and EMC design and analysis support. In October 1983 he joined Tandem Computers in Cupertino, California. While at Tandem he provided EMC design, troubleshooting and EMC compliance testing services to a number of projects. He oversaw the construction of Tandem's 30 meter Open Area Test Site (OATS) and 10 meter RF semi-anechoic chamber while also providing full EMC support for Tandem's new top end mainframe system, the Nonstop Cyclone. In early 1995 Ghery took a position with Intel Corporation. Initially this was in Oregon where he aided in the construction of Intel's first 3 meter RF semi-anechoic chamber and oversaw the design and construction of a 10 meter OATS facility. While in Oregon he led the work to design and build Intel's EMC test facilities (a 3 meter RF semi-anechoic chamber and 10 meter OATS) in DuPont, Washington. He moved to DuPont in 1996 and served as the lead engineer in the laboratory until moving to the Corporate Product Regulations and Standards (CPRS) department in 2000. While in CPRS he served as the focal point within Intel for EMC standards and regulations, represented the company on various industry committees and national and international standards development organizations, provided EMC design and troubleshooting support for various business units in the company and, when needed, made trips to customer sites around the world to aid in resolving EMC problems with customer designs that utilized Intel silicon products. Since retiring from Intel he is now continuing his work on national and international standards development organizations and consulting in the areas of EMC design, troubleshooting, testing, standards interpretations and laboratory design.

Mr. Pettit is presently serving as Chair of CISPR SC I. He was a member of the USNC IEC / CISPR G TAG from 1998 until Subcommittee G (ITE) was merged with Subcommittee E (broadcast receivers) to form Subcommittee I (multimedia equipment) in 2001 whereupon he became a member of the USNC IEC / CISPR I TAG, on which group he continues to serve. He was a member of the US delegation to the CISPR G and CISPR I meetings from 2000 to 2015. He is also a member of the USNC IEC / SC77B TAG. He is a member of CISPR SC I WG2 (emissions standards) and CISPR SC I WG4 (immunity standards). Ghery was a member of CISPR SC I WG3 from the formation of SC I in 2001 until WG3 was dissolved at the end of 2012. He served as the Convener (chairman) of this WG from 2007 through the end of 2012. He is also a member of ASC C63® SC 1. Ghery served as the Chairman of the Information Technology Industry Council's (ITI) committee on EMC (TC5) from 1999 until he retired from Intel in 2015. He served as a member of that committee first as a representative from Tandem Computers and then Intel Corporation starting in the late 1980s. From 1999 to 2005 he served on the Panel for Electronics and Electrical Engineering, Board on Assessment of NIST Programs for the National Research Council, reviewing and reporting on the activities of the RF laboratory at NIST in Boulder, Colorado.

Ghery has been active in the IEEE EMC Society for over 30 years. He has served as a chapter officer in three chapters, Littleton Colorado, Santa Clara Valley and Seattle. He served as an officer in the Santa Clara Valley Section of the IEEE from 1991 through 1995. He served on the Board of Directors of the IEEE EMC Society as a Director at Large from 1999 to 2004 and 2006 to 2011. During this time he served as the Chapter Coordinator from 1999 to 2005. From 2003 to 2008 he was the Vice President for Communications Services. In 2009 and 2010 he was the Vice President for Conference Services. He served as President Elect for the IEEE EMC Society in 2011, President in 2012 and 2013 and Immediate Past President in 2014 and 2015.

Ghery has written 8 papers and articles for publication and contributed a chapter for the 2nd Edition of the ARRL's Radio Frequency Interference Handbook. He is a member of the dB Society and serves as a Technical Advisor for the ARRL in the area of EMC.

The Trade-Off Between Innovation and Regulation is Unlicensed Spectrum

by Andrew Myles

Way back in 1985, the FCC in the United States made the momentous decision to open up the 2.4GHz band for unlicensed use. The 2.4 GHz band is often called the "junk band" because it also contains emissions from everything from RF welders to microwave ovens. The associated rules imposed few restrictions and opened up the band as one great big experimental platform that would determine if unrelated users could coexist together in unlicensed spectrum in a useful way.

The freedom to communicate wirelessly without a license attracted a wide variety of potential users. In 1990, the IEEE 802.11 Working Group formed to develop a new WLAN standard to take advantage of this amazing opportunity of free spectrum for everyone. It took seven years to complete the first ratified version of the IEEE 802.11 standard, but the result provided the basis for the socioeconomic goliath now known as Wi-Fi. In 2017, more than half the world's IP traffic is carried over Wi-Fi, making use of more than nine billion Wi-Fi devices, with more than three billion new devices sold annually. Wi-Fi initially was focused on connecting laptops to the Internet. It is now used for everything from industrial machines to laptops to phones to bathroom scales. As a guest worker in Dubai recently noted to the author, "Wi-Fi is life!" because it allowed her daily access to her family in the Philippines.

One question often arises: why was the FCC's experiment to allow anyone to use the 2.4 GHz band so successful? Generally, if you allow anyone to do anything, they usually do, and chaos often ensues. If chaos had occurred in the 2.4 GHz band, Wi-Fi today would not allow "anyone, anytime, anyplace to set up a network that just works well enough," adding hundreds of billions of dollars to the worldwide GDP annually. On the other hand, if the experiment had led to chaos, then the global community would have not been any worse off than the status quo; it would have simply been a missed opportunity.

One possible answer is that it was just chance that the unlicensed wireless market generally converged without much oversight on a single solution based on the IEEE 802.11 standard, which uses a relatively conservative Listen Before Talk (LBT) protocol, with distributed control. This approach inherently gives everyone roughly equal access. It was also probably fortuitous that the Wi-Fi Alliance formed in 1999 to prove interoperability, using[KZ1] certification tests that effectively used sharing as a proxy for interoperability. The efforts of the IEEE 802.11 Working Group and the Wi-Fi Alliance working with a homogeneous sharing mechanism meant that fair coexistence in the 2.4 GHz band came for free.

Wi-Fi is not the only wireless network using the 2.4GHz band. Both Bluetooth and Zigbee have a significant presence in the band too. However, again the global community was fortunate. Rather than attempting to make quite different systems coexist, both Bluetooth and Zigbee were designed so that they could, for the most part, avoid operating in the same channels as Wi-Fi. Instead, they often focus on the space between or beyond Wi-Fi channels in the 2.4 GHz band.

Wi-Fi's early success meant that the spare capacity of the 2.4 GHz band quickly diminished. Regulators around the world had the foresight to recognise this possibility and started identifying additional spectrum in the 5 GHz band for non-licensed use from about 1998. The available 5 GHz channels have varied by country and over time, but one common characteristic has been that Wi-Fi often has to share the channels with primary users such as satellites and radar. The need to share with primary users means that Wi-Fi is required to limit its output power in some channels to avoid interfering with satellites, and to not use some channels at all when radar is detected. Deferring to primary users is in everyone's best interest; no one wants Wi-Fi to interfere with the weather radar at the airport that is helping your plane to land safely. The fortune of the 2.4 GHz band has extended into the 5GHz band insofar as fair coexistence between users of Wi-Fi systems can almost always rely on the distributed sharing enabled by the LBT protocols used by the IEEE 802.11a/n/ac amendments.

A few years ago, operators using LTE in licensed spectrum discovered the benefits of unlicensed spectrum: access to capacity they did not have in licensed spectrum, and for free! Some operators utilized Wi-Fi with various degrees of integration with their licensed systems. More recently, efforts have started to focus on the use of LTE-based mechanisms in the 5 GHz band. The LTE-U Forum developed LTE-U, 3GPP developed LAA, and the MulteFire Alliance developed MulteFire. These new systems have raised serious coexistence questions for Wi-Fi and more broadly for the global community that depends on Wi-Fi's socioeconomic benefits.

LTE-U is a system that decides on what is "fair" on behalf of the Wi-Fi systems operating in the same channel. This centralized approach is quite different from the distributed approach used successfully by Wi-Fi for so many years. The threat to fair coexistence led to significant debate in the United States, with the FCC and even committees of Congress becoming involved. It was a very painful process for all parties, particularly the FCC, which preferred that the market decide as it had in the past. Eventually, the Wi-Fi Alliance facilitated the development of a test plan that would identify the worst violations of fair coexistence by

LTE-U. While this is helpful, it provides no guarantees because its use is not mandatory. Ultimately, LTE-U is not expected to have a significant market impact, so any associated coexistence issues will be limited.

LAA (and MulteFire) is a system that is based on an LBT protocol, like Wi-Fi. Interestingly, this design choice was heavily influenced by European regulatory requirements for LBT and a desire to deploy LAA globally. These same requirements mean LTE-U cannot operate in Europe, which is part of the reason LTE-U is unlikely to have longevity in the market. The use of LBT by LAA should result in some degree of fair coexistence with Wi-Fi. Unfortunately, it is not guaranteed because LAA uses a different form of listening to Wi-Fi. Whereas Wi-Fi detects preambles at -82 dBm and energy at -62 dBm to determine whether the medium is busy, LAA uses only energy at -72 dBm. Because this asymmetry will inevitably cause problems in certain environments, it is the subject of continuing discussions by standards organizations and regulators.

Going forward, there are a number of unanswered questions. What is the correct balance between allowing innovation of the nature that allowed Wi-Fi to emerge in 1999 and protecting the socioeconomic benefits of Wi-Fi that exist today? Is the laissez-faire approach of the United States or the light touch regulation of the Europeans better? Will the use of different sharing mechanisms allow for sufficiently fair coexistence between LAA/MulteFire and Wi-Fi? If not, is there a case for even tighter regulation? Or should we just let innovation rule, always letting the market decide?

In 1985, the FCC started a very successful experiment to make use of the 2.4 GHz band. In 2017, it appears a new experiment is being run in the United States and Europe to find the right balance between innovation and regulation in unlicensed spectrum. However, in contrast to the original experiment that was conducted in an environment with no significant stakeholders, the latest experiment brings together two economic juggernauts: the Wi-Fi industry and the LTE industry. The IEEE 802.11 Working Group, 3GPP, Wi-Fi Alliance, MulteFire Alliance, LTE-U Forum, and regulators are all stakeholders, along with everyone who uses Wi-Fi today. Let's just hope this experiment turns out as well as the original, with only winners. Only time will tell!

Dr. Andrew Myles has a B.Sc./B.E. (Hons. I) from the University of Sydney and a Ph.D. from Macquarie University. He has worked in higher education, industry research, management consulting, and industry for 30 years. He is currently employed at Cisco. For the last 17 years, his focus has been on standards work related to Wi-Fi, including in the IEEE 802.11 Working Group, Wi-Fi Alliance, ISO/IEC JTC1/SC6, and ETSI BRAN, both in technical and governance/leadership roles. When asked what sort of engineering he does, he now answers that he is a political engineer.

Funny Pages

Standard Fare

by Rick Jamison