# IEEE Standards Education e-Magazine

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# The IEEE Standards Education e-Magazine
## *Wireless Power Transfer and related standards, Vol. 6, No. 2*

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**What are Standards?**
Technical standards are formal documents that establish uniform engineering or technical criteria, methods, processes and practices developed through an accredited consensus process.
Standards are:

- developed based on guiding principles of openness, balance, consensus, and due process;
- established in order to meet technical, safety, regulatory, societal and market needs;
- catalysts for technological innovation and global market competition.

Knowledge of standards can help facilitate the transition from classroom to professional practice by aligning educational concepts with real-world applications.
Join us as we explore the dynamic world of standards!

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# Letter from the Editor-in-Chief

Yatin Trivedi, David Law

**"Look Ma, No Hands, No Wires!"**

Today, most of us take access to Wi-Fi (IEEE Std. 802.11n™) for granted. That's what makes our daily lives go-around at home, in the office or on the road with access to information across the Internet. Compared to the 'tethered' internet access of a few years ago, we became so much more mobile, and productive now having "cut the cord." But one aspect of our technology usage that is still tied to cords is the need for power even when you have battery operated devices. Think about all of the devices in our lives that require batteries to be recharged: wireless phones, laptops, electric vehicles, medical devices, all the fun wearables and so much more. What if you didn't need to plug in a device to recharge its battery or what if your device didn't even need a battery for its power supply? There are a number of standards currently available and in development that support just that through Wireless Power Transfer (WPT) that can allow us to "cut the cord" to traditional power sources.

WPT can help make our lives much easier and can help support cleaner, greener energy options. There is a lot to consider in this area such as: compatibility, spectrum availability, and health/safety concerns. The articles in this issue of the IEEE Standards Education eMagazine explore the work that has been done and is currently taking place around the world for WPT standards in a variety of fields.

In consumer electronics, there are currently a number of competing standards for WPT, even within the same Standards Development Organization (SDO). The question is then raised for manufacturers as to which standard they should choose for their products? This is a critical decision that can affect how well a product may do in the market and be adopted by consumers. Similar concerns arise for car manufacturers as the technology needs to be compatible and work properly with devices installed at charging locations. Applications of WPT are numerous and go beyond what has already been seen on the market today. Understanding the role of standards in this area can help to facilitate advancements in current and new technologies.

As you can see, industry agreement on standards plays a critical role in the development of technologies that will work as promised and be successfully accepted by consumer markets. Our hope is that as you read this quarterly issue of the IEEE Standards Education eMagazine, you'll learn about the importance of collaboration in standards development in wireless power transfer, the impact of standards on these technologies, and why education about standards is critical for moving technologies in this area forward. If you are wondering how WPT affects you, just think about the recharging convenience offered at your favorite coffee shop, or the time you forgot the charger for your phone. If you are among those who drive/own an electric vehicle, you know the need for recharging your vehicle's batteries. Wouldn't it be great if you could recharge while you are driving (dynamic wireless charging)? In order to make these applications possible, the industry needs standards and products built on (in compliance with) these standards.

As always, we have included funny pages, featured courses highlighting Practical Ideas from Professors, a featured video on the author of the book, *Modern Standardization* as well as a review of that same book, and links to a number of public articles and other information that you may find useful. A fascinating student paper which explores wireless power systems in underwater probe is also featured.

Happy reading!

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Yatin Trivedi, Editor-in-Chief, is Director of Standards and Interoperability Programs at Synopsys. He is a member of the IEEE Standards Association Board of Governors (BoG), Standards Board (SASB) and Standards Education Committee (SEC), vice chair of the Corporate Advisory Group (CAG), chair of the Industry Connections Committee (ICCom) and serves as vice-chair for Design Automation Standards Committee (DASC) under Computer Society. Since 2012 Yatin has served as the Standards Board representative to IEEE Education Activities Board (EAB). He represents Synopsys on the Board of Directors of the IEEE-ISTO and on the Board of Directors of Accellera. He represents Synopsys on several standards committees (working groups) and manages interoperability initiatives under the corporate strategic marketing group. He also works closely with the Synopsys University program.

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 the M.S. Computer Engineering from Case Western Reserve University, Cleveland. He is a Senior Member of the IEEE and a member of IEEE-HKN Honor Society.

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## Meet the Author-Ron Schneiderman

The IEEE.tv Meet the Author Series offers one-on-one interviews with leading experts in the field. Meet the authors of conference papers, technical articles, IEEE books and eBooks. In this featured video, you'll meet Ron Schneiderman, the author of the book, "Modern Standardization: Case Studies at the Crossroads of Economics, Technology and Politics."

*Videos will launch in YouTube or IEEE.tv*

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# DEVELOPMENTS IN WIRELESS POWER TRANSFER STANDARDS AND REGULATIONS

31 May 2016
Christos Kalialakis, Nuno Borges Carvalho, Naoki Shinohara, Apostolos Georgiadis, David Law

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Selected Developments in Wireless Power Transfer Standards and Regulations

**Abstract**
Selected advances in the use and development of wireless power transfer (WPT) standards and regulations in Europe and Japan are reported. The European research program COST-WiPE (European cooperation in science and technology–wireless power transmission for sustainable electronics) is described as a means to enhance interaction between research and standardization. WPT electronics are also reviewed in terms of frequency based on recent publications. Furthermore, activities in the context of the International Telecommunications Union (ITU) and especially recent Japanese contributions with a focus on far field systems are given.

**I. Introduction**
Wireless Power Transfer (WPT) is gaining traction in many application domains because it offers the possibility of batteryless operation and wireless charging. Although wireless charging frequently gets the attention of the media, batteryless operation can bring major benefits for the environment and the massive deployment of wireless sensors in the Internet of Things (IoT) [1], [2].

It is generally agreed that WPT devices operate in two fundamental ways: the so-called near field and far field. These terms refer to the region of the electromagnetic field which interacts with the receiver. Near field is associated with induction whereas far field is associated with radiation.

Any wireless device in the real world operates in a densely populated frequency spectrum. Standards and regulations ensure that any new technology is conditioned properly in order to be marketed commercially. Two of the most important parameters in terms of standards and regulations are frequency and power. Both of these parameters affect nonionizing radiation safety [8] and electromagnetic compatibility. Thus it is vital that any research is done with the standards in mind [7], [9]. However, the regulatory framework for WPT is complicated because of the large number of organizations involved, the interactions among them [3], and the uneven stage of research and development (R&D) in different parts of the world.

In Section II, a current European research program that takes into account standards and regulations is described, highlighting the necessity to diffuse knowledge to researchers and back into regulators. A brief survey of published WPT systems show that these operate in specific frequency bands (Section III). Although, near field systems seem to be gaining more commercial momentum, the field of WPT-FF (wireless power transfer-far field) [4] can offer substantial applications and benefits. Recent developments in the context of the ITU are given in Section IV.

## II. The European COST Program WiPE

In the European Union, a well-known research framework is COST (European cooperation in science and technology) [5]. The COST Association is an International not-for-profit association that integrates all management, governing, and administrative functions necessary for the operation of the framework. The COST Association currently includes 32 member countries. Its programs act as focal points on currently important topics in order to facilitate exchange among research partners.

In the area of WPT, the program Wireless Power Transmission for Sustainable Electronics (WiPE) [6] was begun in mid-2013 with a completion date of mid-2017. WiPE aims to address efficient WPT circuits, systems, and strategies especially tailored for batteryless systems. Battery-free sensors, passive RFID, and near field communications (NFC) are systems that make use of WPT and energy harvesting to remotely power up mobile devices or to charge batteries.

There are five research workgroups (WGs) each dedicated to a specific area of importance. These are

- Far field WPT systems;
- Near field WPT systems;
- Novel materials and technologies ;
- Applications (space, health, agriculture, automotive systems, home appliances);
- Regulation and societal impact.

The first two workgroups follow an effective classification of WPT systems in terms of engineering operation. The other three WGs are looking at WPT from a higher level and cut across all WPT systems. WPT and its related applications are new technologies which generate substantial market interest. This fact presents additional challenges: (1) researchers should know about standards and regulations such as exposure limits for electromagnetic fields, e.g., specific absorption rates in the human body, and to follow the development of new regulations; and (2) standards and regulation bodies should be informed about research efforts in this field, especially on the issues of preferred spectrum bands, potential interference with other wireless communication systems, and radiation safety studies.

Such a standards aware research approach offers a plausible way to enhance the education of engineers (in a senior undergraduate or graduate level) through research-led teaching [10]. The term research-led is centered around the notion that research results should not be cut out from teaching and instead should provide opportunities to enrich and differentiate the material given to the aspiring engineer. In this way, standards and regulations can be more easily integrated into coursework instead of teaching a general course dedicated to standards and regulations (Fig. 1).

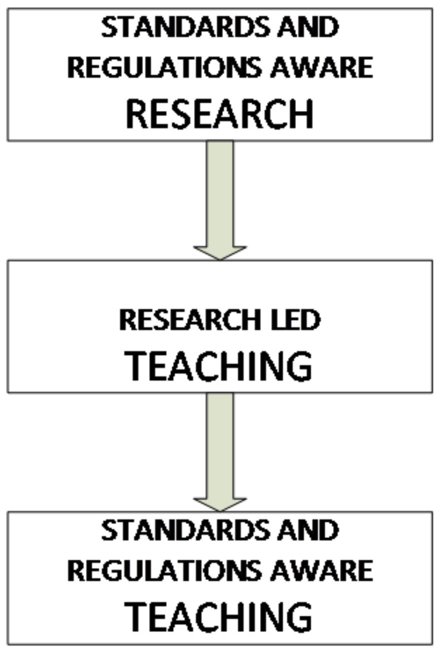


Fig. 1. A possible scheme for enhancing the diffusion of standards and regulations into teaching.

**III. Utilization of ISM and Other Frequency Bands**

Frequencies are not given for free. In fact, spectrum as a scarce resource is quite expensive, and in most cases frequencies are licensed with a substantial fee. However, when the interference potential of a device is low (e.g., a short range device) then this device can operate as a secondary user without paying frequency fees. There are some specific frequency bands that are intended for industrial, scientific, and medical (ISM) uses. The use of these frequencies requires no licensing, is in general straightforward, and thus popular. On the other hand, as frequency of operation goes higher, the interference potential gets stronger, and subsequently an allocation of a frequency band for dedicated use as a separate service becomes necessary. Many recent realizations of WPT circuits are in ISM frequency bands. A brief survey of publications in IEEE and other journals reveals a preference for the lower frequencies up to 13.56 MHz (Table I).

**Table I**
Most popular frequency bands in use by WPT systems.

| No | Frequency(MHz) |
|---|---|
| 1. | 0.020 |
| 2. | 0.125 |
| 3. | 0.200 |
| 4. | 6.78 |
| 5. | 13.56 |
| 6. | 27.12 |
| 7. | 40.68 |
| 8. | 433.92 |
| 9. | 915 |
| 10. | 2,450 |
| 11. | 5,800 |

## IV. Developments for WPT Devices in the ITU

The ITU is the global ICT regulator. Whenever a new wireless technology appears, frequency allocation is the most important issue to consider. This allocation is greatly facilitated by the input of interested stakeholders and countries that develop these technologies. For example, countries with a large automotive industry (Japan and Korea in particular) have already developed national standards and regulations for near field systems [*3*]. A global frequency allocation goes through the ITU and in specific ITU-R (radio communications), one of the three ITU divisions. A global effort is necessary for spectrum harmonization across the globe, which greatly facilitates economies of scale.

ITU-R deals with new technologies by employing specialized teams of experts called study groups (SGs). WPT matters fall under the jurisdiction of SG1 (study group 1). In order to expedite the developments, subgroups are formed whose task is to answer specific mandates of a formal document called *Question*. In the case of WPT, this *Question* bears the code 230/1 and was issued in 2012 to be handled by technical subgroup working party 1A. The proceedings of this ongoing effort can be found online [12].

A *Question* is considered resolved when recommendations and reports are developed. The text with the regulatory force is the recommendation, with much more technical detail given in an associated report. In the area of near field (or non-beam as they are termed by the ITU), the ITU report has now been published [13]. Recent contributions are aiming toward a report and a recommendation for FF, e.g. see [12], [14], [15], and [16] from Japan. The input from industry and research institutes is significantly eased by alliances such as the Wireless Power Transfer Consortium for Practical Applications (WiPoT) of Japan [17].

**Table II**
Applications of wireless power transfer in far field and potential frequency bands [14].

| ID | Application | 2.45 GHz band | 5.8 GHz band | 900 MHz band |
|---|---|---|---|---|
| 1. | Wireless Powered Sensor Network | | | ● |
| 2. | Wireless Charger of Mobile Devices | ● | | |
| 3. | WPT in a Metal Pipe | ● | | |
| 4. | Microwave Buildings | ● | | |
| 5. | 2D (Surface) WPT | ● | ● | |
| 6. | Wireless Charging for Electric Vehicles | ● | ● | |
| 7. | Point-to-Point WPT | ● | ● | |
| 8. | WPT to Moving/Flying Target | ● | ● | |
| 9. | Solar Power Satellite | | ● | |

Besides charging, there are many interesting applications in the far field which cannot be covered by near field, e.g., the possibility of a space solar power satellite [11], as well as other possibilities which are shown in Table II**.** The preferred frequency bands of interest for WPT-FF are 2.45 GHz and 5.8 GHz.

## Conclusion

There are a multitude of parallel activities in the regulatory and standards organizations in the field of WPT. Diffusion of these activities and awareness in research programs in the field of WPT is necessary. EU COST program WiPE was described as a case study of how standards and regulations can be explicitly integrated in research. Furthermore, it was stressed that WPT-FF requires more standardization work and regulations that in turn need to be informed by research studies. Contributions by Japan in the area of far field WPT have been described in the context of recent ITU regulatory activities.

## Acknowledgment

The work of C. Kalialakis, N. Carvalho, and A. Georgiadis was supported by EU COST Action IC1301 WiPE. The work of C. Kalialakis and A. Georgiadis was further supported by EU H2020 Marie Sklodowska-Curie grant agreements No. 661621 and No. 654734.

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# SAE PUBLISHES TIR J2954, WIRELESS POWER TRANSFER EV/PHEV

31 May 2016
Jesse Schneider, David Law

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In 2010, SAE International launched its Wireless Power Transfer (WPT) task force for light duty EVs and PHEVs for the purpose of standardizing both the vehicle and ground assembly infrastructure to enable commercialization. The task force, chaired by Jesse Schneider (BMW), published its first document SAE TIR J2954 on May 31st, 2016 called "Wireless Power Transfer for Light-Duty Plug-In/ Electric Vehicles and Alignment Methodology."

A link to download SAE TIR J2954 is found below:
http://standards.sae.org/j2954_201605/

The SAE WPT task force is comprised of multiple automakers, EV infrastructure companies, local and national governments, laboratories, universities, wireless technology suppliers, and OEM (original equipment supplier) first tier suppliers (Tier 1) from around the globe (EU, Asia, North America, etc.) as shown in Fig. 1.

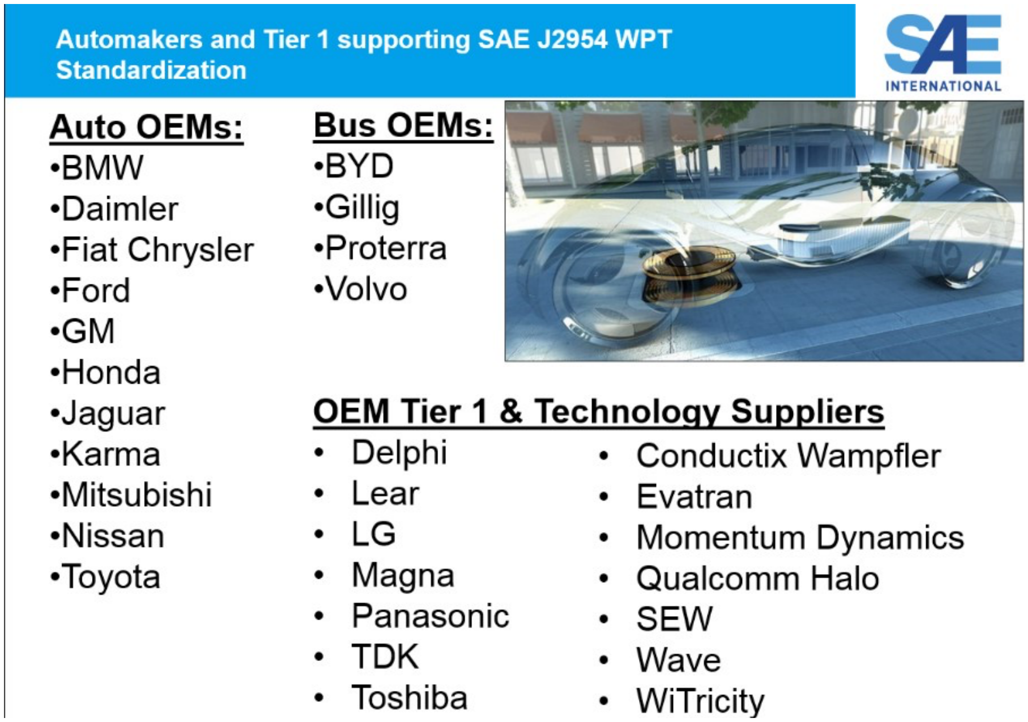


**Figure 1**

Wireless charging is starting to become mainstream for consumer electronic devices in low power applications. This technology has also the potential to transfer high power in the *kilowatt* range to enable charging of electric and plug-in electric vehicles. In order to achieve this commercially, standardization is needed.

Wireless power transfer using inductive charging enables electrified vehicles to be seamlessly and automatically charged without operator interaction. Essentially, the two coils from the vehicle and ground need to be aligned to a minimum degree (by parking properly in a spot) to transfer energy through inductance. The customer can charge the vehicle by simply parking an electric vehicle in a SAE J2954 WPT parking space. No additional action is required of the customer to charge as everything is automated. This could be very attractive to electric vehicle (EV/PHEV–plug-in hybrid electric vehicle) customers, by offering charging along with high efficiencies similar to conductive charging (above 85%).

As an analogy to conductive charging (e.g. SAE J1772), wireless charging can be interoperable and charge using the SAE J2954 specified common specific frequency band, coil guideline and topology with a high coupling factor. The components needed to make this happen wirelessly from the vehicle to the ground assemblies are shown in Fig. 2.

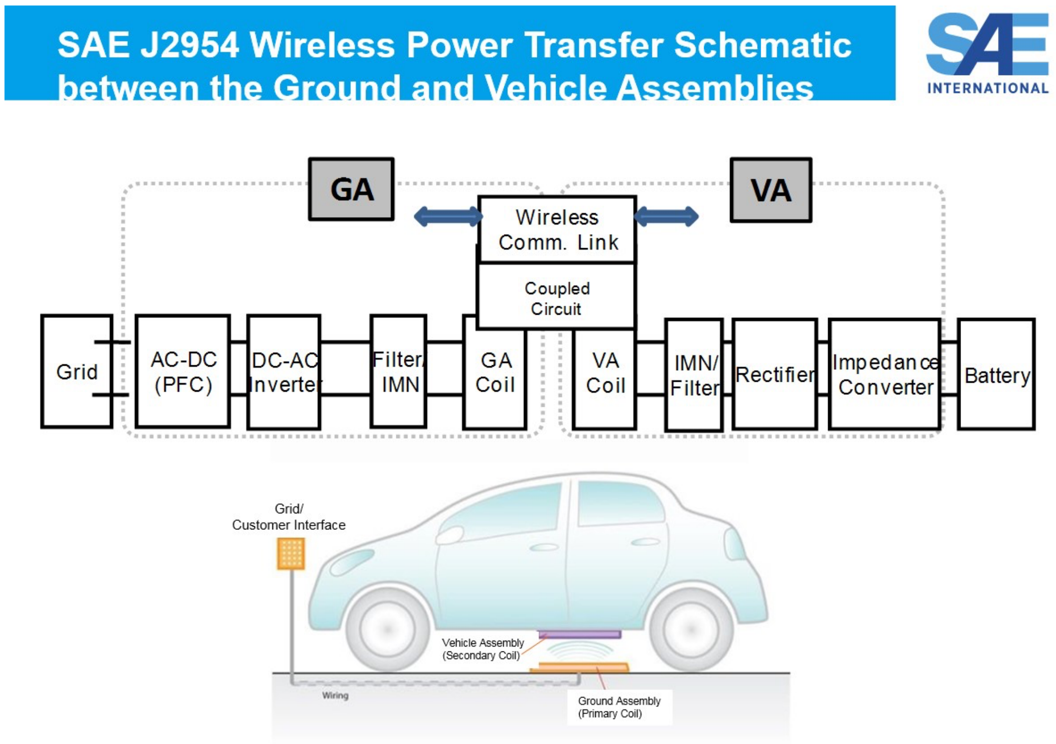


**Figure 2**

The TIR J2954 guideline establishes guidance for the inductive coils, electromagnetic limits, and interoperability for the *testing and demonstration phase* of the technology. This entails specifying a common frequency of operation at the 85 kHz band (81.39 kHz–90 kHz) for interoperability. In addition, there are power levels in four classes up to 3.7 kW (WPT 1), 7.7 kW (WPT 2), 11 kW (WPT 3), and 22 kW (WPT 4).

In order to harmonize electromagnetic field (EMF) limits, the latest international levels for electric and magnetic fields limits from ICNIRP (International Commission on Non-Ionizing Radiation Protection) were utilized. The American Association of Medical Instrumentation (AAMI) has also been consulted regarding EMF compatibility related to medical devices such as pacemakers. The EMF limits published in TIR J2954 have been harmonized by combining the AAMI limits with ICNIRP values.

One of the key components of standardization is the inductive coil geometry and topology specification for both the vehicle assembly (VA), mounted under the vehicle pan, and the ground assembly. The inductive vehicle/ground coil *set* enables a performance-based interoperability and reference point for charging that is automated for the customer.
The SAE J2954 task force found consensus to develop a common coil geometry specification and circuit specification for both the vehicle and ground assembly coil set to ensure interoperability of wireless charging. The team has already established a close to commercial *master* vehicle/ground assembly coil set for the WPT 1 (3.7 kW) power class as a baseline for both the OEMs and infrastructure providers. For the WPT 2 (7.7 kW) power class, the SAE J2954 team has created two reference coil options for the testing phase of the SAE J2954 guideline.

The SAE J2954 team developed a testing protocol for safety and performance of wireless charging using a standardized test stand for bench and full vehicle testing (Fig. 2). The SAE J2954 testing procedure confirms the system electromagnetic field limits, power transfer performance, and safety levels (such as ICNIRP magnetic field levels and temperature limits).

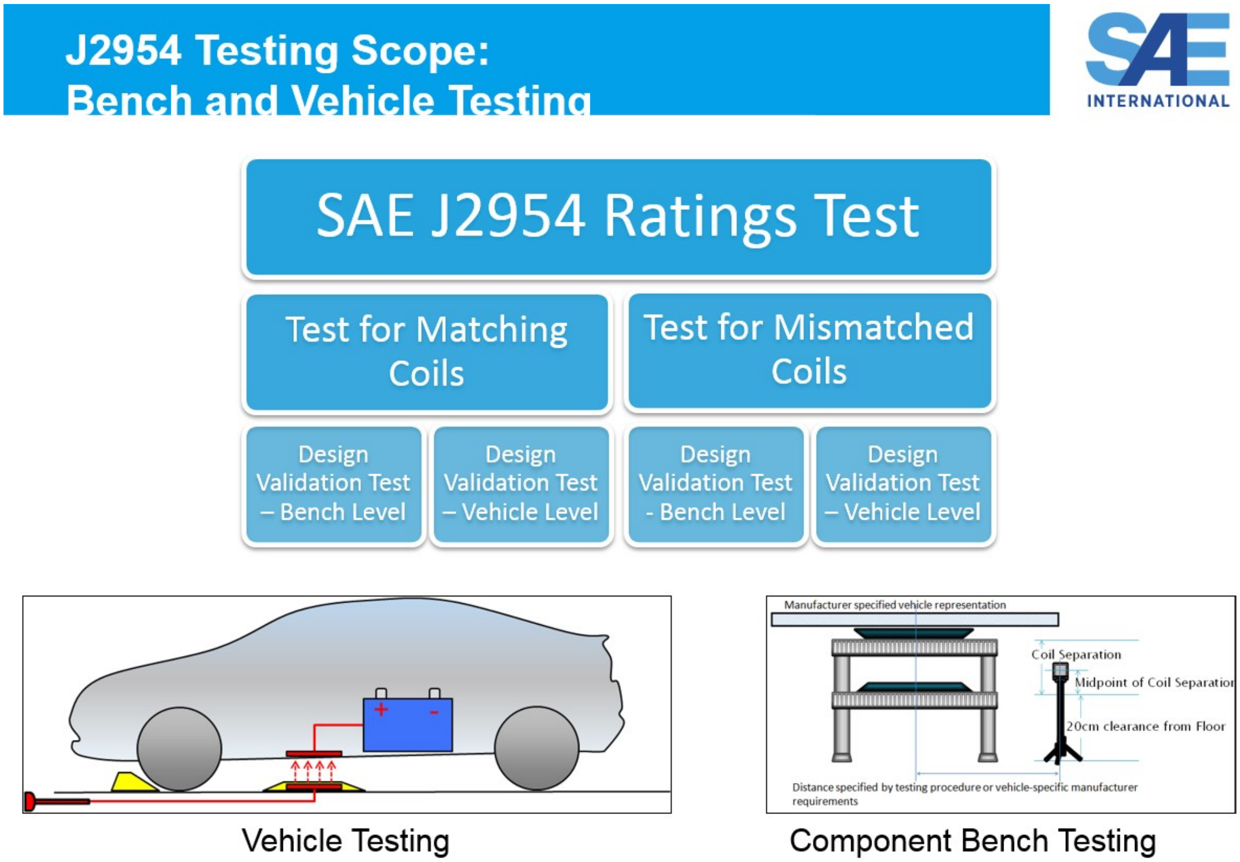


**Figure 3**

The SAE Wireless Power Transfer task force is working very closely with the U.S. Department of Energy (DOE) in relation to testing of both the bench and vehicle systems (Fig. 3). The US DOE has assigned a number of its laboratories (Idaho National Lab, Argonne National Lab, etc.) to assist in the data validation projects to test industry equipment.

In addition, the SAE J2954 team is in close contact with the U.S. Federal Communications Commission (FCC) in regard to frequency and EMC levels, as well as the international task force CISPR (International Special Committee on Radio Interference) group. The Draft ANSI C63.30 team, which is being led by the FCC, is also aligned with the SAE team, which references the charging coils from J2954. Draft ANSI C63.30 is the American national standard of EMC procedures for compliance testing of wireless power transfer products.

For the next standardization phase, planned in 2017, there will be a SAE J2954 WPT recommended practice, which will include a refined definition of the master and reference coils.

In order to support the impending wireless charging vehicle and infrastructures roll out worldwide (slated for 2020), SAE J2954 will be finalized as a standard in 2018 using the results of both the bench testing and actual vehicle field testing.

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Jesse Schneider's work has led to a number of firsts to further electric and fuel cell vehicles such as establishing the emergency response guide, fueling validation, and numerous standards. For over 20 years, he worked in both the U.S. and Germany in automotive management ranging from conventional series development to electric and fuel cell electric vehicles.

At BMW North America, he is the manager of fuel cell, electric vehicle development. He relocated from the Munich office of BMW, where he was the first program manager of the hydrogen storage system, as well as requirements management.
Mr. Schneider established the SAE wireless power transfer standardization for the PHEVs team in 2010 and continues to chair the task force.

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# WIRELESS CHARGING OF CONSUMER ELECTRONICS: RUBBISH HEAP OR MASS ADOPTION?

31 May 2016
John Perzow, David Law

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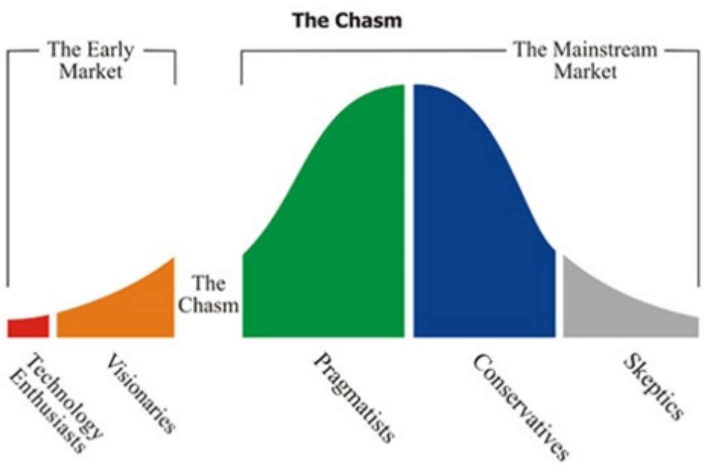
**Wireless Charging of Consumer Electronics: Rubbish Heap or Mass Adoption? *(Reprint)*** *

Remember Digital Audio Tape (DAT)? How about the Apple Newton? Whatever happened to Betamax?

While these disruptive technologies all seemed like great ideas at the time, today they exist mostly in museums or landfills. For a variety of reasons – they were too expensive, something better came along, they were poorly marketed or executed – they never 'crossed the chasm' from early the adopters to mainstream consumers. Today, wireless charging for mobile consumer devices is a technology that is receiving a lot of attention. Some are asking if is this just a nice option or something now so fundamental so as to be included in the must-have feature-list.

Let's answer the question by first looking at the adoption rate of similar consumer technologies that successfully went mainstream, and then comparing the growth profile to the wireless charging market adoption rate.




**Crossing the chasm**[1]

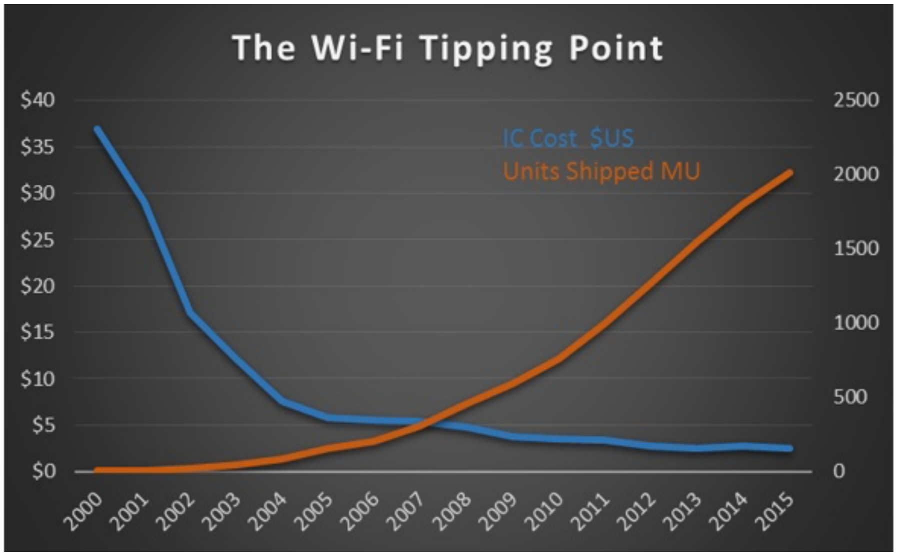
It may seem like a basic technology-marketing truism, but market adoption of disruptive technology usually follows a predictable pattern. First, the initial product launches in its rudimentary form and is generally first adopted by visionary and early adopter individuals who understand the innovation, appreciate the technical contribution, and are not dissuaded by high initial pricing.

These early adopters are often in markets where the benefits are particularly valuable. Think of GPS, which was created for military use, then quickly found its way into new and higher-volume applications as cost came down and new uses were made possible. At a point called critical mass[2], the annual growth rate exceeded 50 percent and the technology became self-sustaining.

**The Tipping Point**

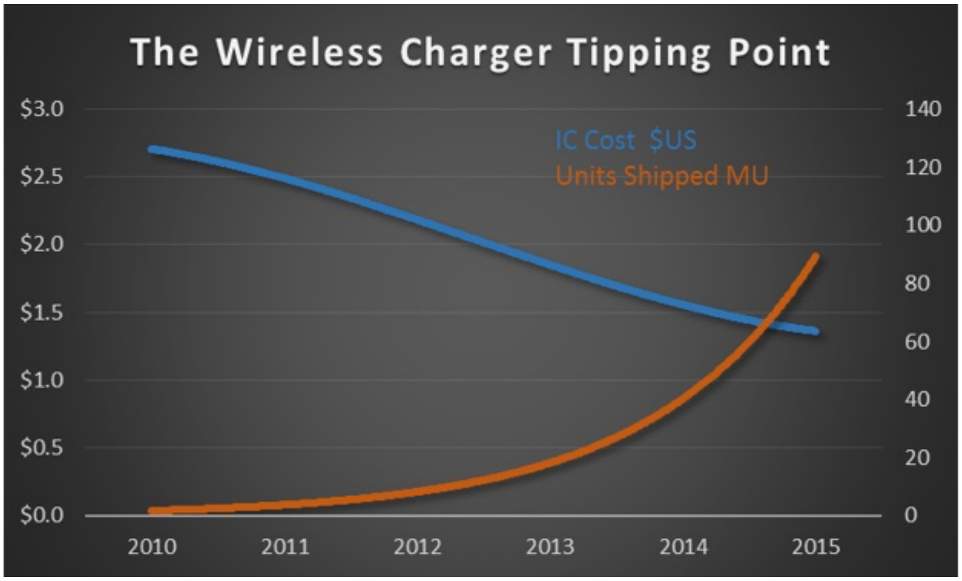
The tipping point into mass adoption occurs when critical mass is achieved and the cost of the function drops to the level the mainstream market deems appropriate for the benefit. In the following chart, we can see the tipping point for Wi-Fi. Complex consumer devices depend on the application-specific integrated circuits (ASIC) that support the function, and because cost and volume data are available, the ASIC is used as a proxy for system price and volume. We can see that IC price-drops led shipment increases by about 18 months.

Anticipated volume often drives pricing just as lower prices enable newer, higher-volume and more cost-sensitive applications. Buoyed by $5 ASIC costs, the tipping point for Wi-Fi occurred in 2007 and 2008, when shipments grew at 51 and 50 percent respectively. Interestingly, Wi-Fi didn't achieve 50 percent penetration until 2013[3].




**The Tipping Point for Wireless Charging**

The figure below[5,6] charts the shipments and ASIC cost for wireless charging receivers (cell phones, cases, digital cameras, wearables, etc.). Wireless charging ASIC cost dropped below the $2 point in early 2012 and because volumes started doubling in 2013, wireless charging may be said to have achieved critical mass. I should note here that this is an analysis of 5 watt wireless power systems, which represent all present CE wireless charging products now in the market. Wireless charger ASICs are largely power management devices and power management ICs do not scale with smaller IC feature size. Therefore, the 15 watt ASICs that support the >5W chargers now being introduced will have a higher average selling price for the increased power they offer. The higher power ICs enable wireless fast-charging, so the added cost will be more than offset by the added benefit. The first phone with integrated wireless charging receivers was launched in 2011, which was the LG-Revolution. With the launch of the Samsung Galaxy S6 and S6 edge in March 2015, we witnessed the migration of embedded wireless charging from high-end smartphones and accessories to high-volume mainstream smartphones.




There are now more than 80 models of phones that have embedded Qi wireless charging or have wireless charging accessories specifically designed for that phone (e.g., a case or card that is added beneath the back cover of the phone). The installed base of wireless charging products is now over 160M[7] units, which is still below the 50 percent target-market penetration point necessary to declare that the technology has become a mainstream requirement. Given the fact that wireless power has hit critical mass (shipments have exceeded 50 percent every year since 2012), it is easy to understand why Juniper Research predicts >40 percent penetration into all U.S. households by 2021[8].

Probably the best leading-indicator that wireless charging is becoming an indispensable feature in cell phones, wearables and other CE devices is the rate at which the automotive sector has embedded wireless charging into new cars and trucks. The automotive market tends to be late (conservative) adopters. This is for good reason as new technology must be thoroughly vetted for value, safety and reliability before it is designed into a "consumer device" that has a 10-to 15-year lifetime. Auto makers want to know that a feature that occupies some of the most valuable real estate inside the cab, the center console, will continue to add value in five or ten years. As of January 31, 2016, thirty-two models of cars offered wireless charging as either standard-equipment or a factory option and all but one of the top auto makers worldwide had at least one model of car available with wireless charging. It appears that the automotive industry has placed a bet that wireless charging is here to stay.

**Part of our daily journey**

It is clear that wireless charging is well on its way to becoming a must-have consumer feature in consumer electronics, cars and many public locations such as hotels, airports and restaurants. Wireless charging has crossed the chasm into mainstream adoption. Shipments have been growing at a 50 percent clip or greater since 2012. All but one of the world's top car manufacturers have designed wireless charging into at least one model of car despite this industry's normal behavior to adopt new technology later then other market segments. However, less than 50 percent of the target market has adopted wireless charging to date.

The reasons for this level of consumer adoption are 1) the convenience of easy charging, 2) the elimination of proprietary chargers, and 3) the new business-to-consumer benefits that wireless charging enables. Wireless power should be designed for the consumer's daily journey. The auto maker's vision for wireless charging is that the driver and passengers can customize their experience when they place their phone in the charging area. Restaurateurs and hoteliers share the vision that wireless charging enables guests to interact with their environment in ways that were not otherwise possible. As is typical with new technology, use cases are emerging that were unimagined when the technology was first introduced. For all these reasons, it's safe to say that wireless charging is fast becoming a permanent, ubiquitous aspect of our daily journey.

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**John Perzow**
Wireless Power Consortium

John Perzow is the vice president, market development for the Wireless Power Consortium. Prior to joining the WPC, John was the marketing director for Analog Devices Power Management group, the marketing director and product line manager for the power group of Broadcom Corp. and marketing director for National Semiconductor power group. John began his career as part of the start-up team of Comlinear Corporation, which designed high-speed amplifiers and data converters. He holds a BS in Electrical Engineering Education from Colorado State University and an MBA from the University of Colorado.

John is co-named in six patents in power electronic circuit design, a guest lecturer and a member of the Industrial Advisory Board of the Electrical and Computer Engineering department at Colorado State University.

The Wireless Power Consortium is the not-for-profit, IEEE standards group that created Qi, the global wireless charging standard.

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# CHOOSING A STANDARD FOR PORTABLE WIRELESS CHARGING SYSTEMS DESIGN

31 May 2016
Alan Li, David Law

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**Which Standard Should You Consider When Designing Portable Wireless Charging Systems?**

**Introduction**
Smartphone technologies are the key indicators of consumer electronic trends. New technologies and features continue to emerge such as USB type C, 4K video, and immersive VR gaming. Wireless charging is one of these technologies that has been in use since late 2000, but is still not used by the masses in smartphones. The industry generally agrees that the reason behind it is the eco-system; the standard. There are multiple standards in the world, but their technologies are incompatible at present.

**The Standards**
Currently there are two global organizations, but three standards for mainstream consumer electronics. In 2008, the Wireless Power Consortium (WPC) established the Qi wireless power standard based on Magnetic-Induction (M.I.) power transfer technology. The Power Matter Alliance (PMA) established the PMA standard based on a very similar M.I. technology. All For Wireless Power (A4WP) established a standard based on a different Magnetic-Resonant (M.R.) power transfer technology.

PMA and A4WP merged in 2015 and was named the Airfuel Alliance in early 2016. Despite the merger, the Airfuel Alliance continues to have two incompatible standards: Airfuel-Inductive and Airfuel-Resonant.

As of April 2016, WPC has 226 members with 844 certified products. Over 30 countries have deployed Qi products including China, Taiwan, Hong Kong, North America, Europe, South Korea, and Japan. The Airfuel Alliance has 149 members and 62 certified products. The main players in the Airfuel Alliance are located in North America and South Korea.

**The Technologies**

The Qi and Airfuel-Inductive standards both use M.I. technology that relies on tight coupling coils of magnetic fields transfer. They are very similar except for the operating frequencies and communication protocols for wireless power transfer operations. The Qi operating frequency is between 110 kHz and 205 kHz and the Airfuel-Inductive frequency is between 235 kHz and 275 kHz.  The Airfuel-Resonant standard employs a different M.R. technology that is characterized as loosely coupled coils of magnetic fields transfer operated at 6.78 MHz.

Despite the name difference, M.I. and M.R. technologies are similar in many ways, which should become clearer later in this paper. Both technologies use transmitter and receiver antennas called *Tx* and *Rx* coils, and rely on an alternating magnetic field generated in the *Tx* coil coupling into the *Rx* coil for wireless power transfer in close proximity. Both technologies fall under the inductive coupling and near-field power transfer categories. As shown in Fig. 1, the alternating current first conducts in the transmitter coil and infinite imaginary magnetic fields loop around it. With a receiver coil in close proximity, some of these magnetic fields are captured into the *Rx* coil. This action induces the alternating current in the receiver coil, which is known as the wireless power transfer.

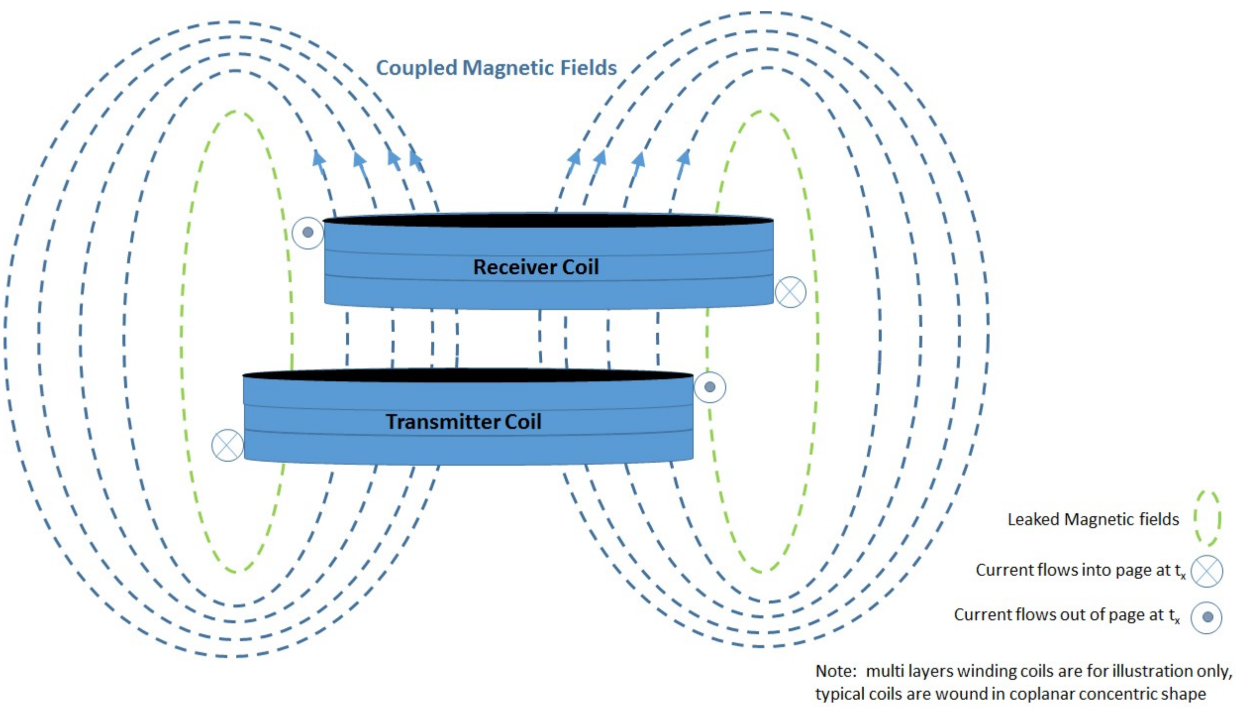


Fig. 1. Conceptual wireless power transfer.

Magnetic flux is a measurement of how much magnetic field passes through the *Tx* and *Rx* coils. The higher the magnetic field passing through the *Tx* and *Rx* coils, the higher the flux that enhances the power transfer. Near-field wireless power transfer technologies apply the same principle of the ideal transformer for power transfer without the metal core, which confines the magnetic field transfer from the primary to the secondary side winding. It is therefore the challenge for the wireless power technology to capture as much magnetic field in the air between the *Tx* and *Rx* coils as possible in order to increase the magnetic flux for optimizing the power transfer.

Wireless power is a complex subject; the numbers of variables that the designers need to deal with can be overwhelming. Some variables are inversely related and some have nonlinear effects. The variables that affect wireless power transfer efficiency are the size of the *Tx* and *Rx* coils, their positions and gap, the coil material, diameter, length, number of turns, number of layers, the tuning capacitor value and the capacitance coefficient, the resonant frequency, skin effect, proximity effect, magnetic shielding materials and configurations, temperature, and more. These variables relate to the coils' DC and AC resistances, which are the self and mutual inductances that dictate the power transfer performance. Fortunately, all of these variables can be summed up by two important factors, which are the Coupling factor *k* and the Quality factor *Q*. It can be proven that near field inductive coupling power transfer efficiency [1] is

$$\eta = \frac{k^2 Q_1 Q_2}{\left(1+\sqrt{1+k^2 Q_1 Q_2}\right)^2}$$

(1)

where *k* is the coupling factor between the *Tx* and *Rx* coils, and $Q_1$ and $Q_2$ are the Quality factor of the *Tx* and *Rx* coils, respectively.

The *k* and *Q* factors are figure-of-merit because if we can make the term $k^2Q_1Q_2$ much larger than 1, then the power transfer efficiency approaches 1. It is virtually impossible to achieve 100% due to the numerous variables described. The *k* and *Q* factors apply to both M.I. and M.R. technologies with different degrees of influence on power transfer efficiencies. An example of measured k factors is presented in [2]. The Q factor can be measured in certain LCR meters. In practice, *k* and *Q* are usually estimated.

The Coupling factor *k* is unit-less, with the greatest number of 1 when all the magnetic fields pass through the *Tx* and *Rx* coils in maximum strength. As seen in Fig. 1, some of the magnetic fields cannot be captured by effects such as coil alignment and gap. Some fields travel longer distances than others because their magnetic field strengths are relatively weak. In M.I. technology, the *Q* factor, which will be explained later, is essential, but the *k* factor is far more important than the *Q* factor. In general, the coupling factor is best when the *Tx* and *Rx* coils' shapes and sizes are matched, coils are aligned, and are in a close gap within 10 mm in the *x*, *y* and *z* directions or tighter. Currently, M.I. technology for smartphone applications reaches about 80% efficiency from AC input to DC output.

The Quality factor *Q* is also dimension-less. High *Q* indicates a low rate of energy loss relative to its stored energy in the power coil. Typical *Q* in M.I. designs is between 30 and 50, and typical Q in M.R. designs is between 50 and 100. The *Q* factor increases in frequency, peaks at the resonant frequency, then falls sharply and equals to 0 when it reaches the self-resonant frequency. Further increases in frequency alters the coils' inductive characteristic to capacitive. Optimum frequency for the maximum *Q* occurs at the resonant frequency. Since the coil is inductive, it is best use a tuning capacitor to tune the LC to the resonant frequency. Also, *Tx* and *Rx* coils are rarely identical nor perfectly aligned, and the *Q* factor is unique to each coil.

In M.R. technology, the *k* factor is generally not at its optimum since the coils' alignment and gap requirements are looser. On the other hand, the *Q* factor is critical. M.R. coils generally have few windings and also require a gap between adjacent coils, as shown in Fig. 2, to reduce the proximity effect. The proximity effect is a phenomenon in high frequency operation such that the influence of the adjacent conductor can reduce the effective cross-sectional area of the measuring conductor for the flow of the current; it therefore increases the AC resistance that affects the power transfer. In addition, it can be proven that the optimum *Tx* coil radius *R* is

$$R = D \qquad (2)$$

where *D* is the distance between the transmitter and receiver coils for optimum near field inductive coupling power transfer [1]. Since the goal of M.R. technology is to achieve spatial freedom with looser coil alignment and proximity, M.R. coil size is generally larger than the M.I. coils. Figure 2 shows tri-mode coils where the inner and outer coils are for M.I. and M.R. technologies, respectively. Since M.I. relies on tight coupling coils in close distance, equation (2) does not affect M.I. technology as much as it affects M.R. technology.

M.R. coupling also allows a single transmitter to conduct power transfer to multiple receivers. In principle, M.R. technology can yield satisfactory power transfer, but the design challenge is very high because of the narrow range of optimum Qs.

**Development**

In M.I. and M.R. technologies, semiconductor makers are mainly from the US, Japan, Europe, Taiwan, and Hong Kong. Since different and incompatible wireless power standards exist, few semiconductor companies develop multimode transmitter and receiver ICs. Dual-mode devices include Qi + Airfuel-Inductive transmitters and receivers. Currently, Tri-mode devices are Qi + Airfuel-Inductive + Airfuel-Resonant receivers only. Multimode wireless power solutions address the dilemma of multiple standards. On the other hand, M.I. and M.R. technologies employ unique coil designs where the coils cannot be shared. [refer to the Tri-Mode Wireless Power Coils in Fig. 2 (courtesy of TDK).] The center coil is used for both Qi and Airfuel-Inductive standards for 5 W operations. The outer coil is dedicated to the Airfuel-Magnetic standard for 6.5 W operation. The coil module dimension is 75 mm x 60 mm. The multimode operation increases the complexity and cost of the coil and system designs.

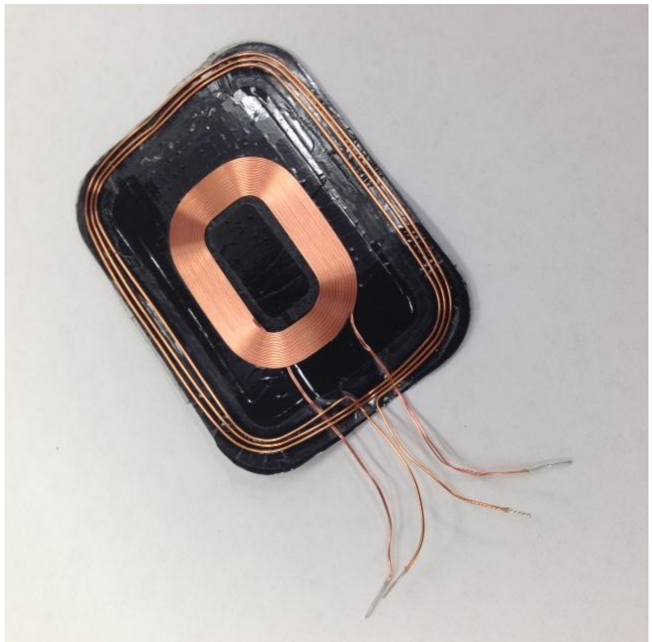

Fig. 2. Tri-mode wireless power coils, where the inner coil is for M.I. Qi and Airfuel-Inductive operations and the outer coil is for M.R. Airfuel-Magnetic operation (courtesy of TDK who provided the tri-mode wireless power coils picture).

Other new developments in wireless power technology include phase-shift control. Driving *Tx* and *Rx* coils involves inductive switching with the AC voltage leading the AC current to a maximum of 90 degrees. Researchers are working on phase-shift control in order to align the AC voltage and current waveforms for optimizing the power transfer efficiency.

WPC also has several new developments. It has a task force working on publishing the resonant extension in the Qi specification. Their goal is to use the same M.I. *Tx* and *Rx* coils for M.R. applications at low frequencies to leverage system designs. WPC also adds a Shared Mode extension to allow multiple receivers to be powered by a single transmitter. In addition, WPC is also working on a 60 W–200 W version of wireless power transfer for power tools, drones, and laptop computer applications.

In Airfuel-Resonant technology, at least one company has been proposing GaN FET to replace MOSFET in the transmitter inverter design to reduce the loss in the switching circuit.

In the future, a wireless power transceiver (transmitter and receiver combined) IC is a possibility. Applications include a battery bank where the battery is a receiver when it is being charged from a transmitter base. The battery becomes a transmitter when it is used to charge a receiver device.

**Reliance by employers on complying with standards for introducing their products to the marketplace**

Companies who embrace wireless charging usually adhere to standards. Standards enable the expansion of the eco-system that can lead to the mass adoption of the technology. In addition, researchers, semiconductor companies, and coil makers designing wireless power solutions and contributing to the standards have spent years understanding the dynamics of the technology. As a result, companies who follow the standards and apply reference designs not only avoid reinventing the wheel, but also increase the chance of design success.

Toshiba semiconductor has been providing wireless power solutions since 2012. The company follows the Qi standard and has just launched its fourth-generation chipset, the TC7718FTG transmitter and TC7766WBG receiver, for Qi 15W wireless power applications.

**Summary**

Standards enable the development of the eco-system. It is imperative that users be able to charge their phones in places like airports or coffee shops seamlessly without understanding the standards issue. Given time, the market should self-regulate such that wireless power standards should converge.

Any wireless power technologies offer convenient wireless charging possibility. However, there is no one-size-fits-all wireless power technology exists that meets all the system cost, size, and efficiency requirements and yet offers the ultra-convenient feature of wireless charging from a distance. As a result, the standard selection depends on the application requirement. For applications that demand maximum efficiency and a tighter design footprint, Qi and Airfuel-Inductive are the standards. For applications that demand charging without strict *Tx* and *Rx* coil alignment and allow for a few centimeters coil-to-coil gap freedom, the Airfuel-Resonant coupling is the standard at present and perhaps Qi resonant in the future.

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**Alan Li** graduated from Florida International University with a BSEE degree. He started his applications engineer career at National Semiconductor, which was later spun off as Fairchild Semiconductor. Alan has also worked at Analog Devices and Intersil in applications and marketing roles. Currently Alan is a senior business development manager at Toshiba Semiconductors where he is responsible for wireless power, motor control, and a variety of analog products for the American market. Alan has over 20 years of analog semiconductor experience in which he defined numbers of analog products such as DAC, digital potentiometers, LED drivers, and power management ICs for the industry. Alan has also published a number of articles and application notes in digital-to-analog converter and digital potentiometers applications.

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# INCOMPATIBLE IN MOBILE CHARGERS – NEED BASED OR STRATEGIC?

30 May 2016

Dr. Stephen K. Kwan, Nitin Aggarwal, David Law

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**Case Study: Incompatible in Mobile Chargers – Need based or Strategic?*** 

Figure 1: Steve Wozniak, Apple's co-founders, backpack. Image Source: Gizmodo.com

Jim is a Silicon Valley tech professional who, like many others, carries multiple electronic devices. Along with personal devices like a smart phone, a tablet, and an e-reader, Jim also carries a laptop, a portable hard drive, a personal hotspot, and a small camera. This is typical of many average Americans, who according to a recent survey by Sophos[3], carry on an average three electronic devices, including smart phones, tablets, mp3 players, and e-readers. This might not sound a lot, but considering that personal carry on space is extremely limited and inconvenient, especially for the travelers, people like Jim pay careful attention to selecting how many and what devices to carry, usually based on size, weight, and functionality. For example, Jim ditched his iPod for the built in MP3 player in his smart phone and is now getting ready to dump his portable hard-drive in favor of cloud storage. "Phone chargers to be standardized in 2011[1]", read Jim on a fine Sunday afternoon in January 2011. The news got him excited. He had been waiting for this for so long that he couldn't even remember. Jim researched more to confirm and came across several other articles boldly claiming the same; "Universal Phone Chargers Coming in 2011: Samsung, Apple, Nokia, RIM Commit To MicroUSB Standard[2]," "Apple, others agree to universal cell phone charger standard in Europe." Jim rejoiced and felt a sigh of relief.

Personal carry on space is not just limited but also extremely saturated. There are already devices specialized to handle everything from trading stocks to hiring a cab to measuring how many steps we take in a day. It is a market with high barriers to entry. It is not only difficult to introduce new products in this domain, but also difficult to change people's habits and make them switch. Imagine how difficult it is to convince someone to move their entire music collection to a different platform. Manufacturers are mindful of these limitations and compete fiercely to bring innovative products to the market – products that are smaller, lighter, and more convenient to use. Unfortunately, one thing that gets overlooked, both by consumers and by the manufacturers, is that each device needs its own charger. Manufacturers oblige by providing a charger, usually, compatible only with the specific device that was sold. That would be just fine if the consumer was carrying only one device, but unfortunately for people like Jim, who carry multiple devices; consumers are forced to carry as many chargers as there are devices. Not just that, every time a Jim buys a new phone, he is paying for a new charger as well. This is a problem not just for him, but also for the environment. Annually, 51,000 metric tons of electronic waste from chargers ends up in landfills just in Europe with worldwide figures crossing few hundred thousand metric tons.


Figure 2: Jim's universal charger purchased at – http://www.amazon.com/Xcessor-Universal-Charger-BlackBerry-Ericsson/dp/B006L9XHHW

Jim gets frustrated dealing with all these chargers. At home, with family, there were more chargers than there were wall sockets, and while traveling, chargers took up lot of space in his bag. Every once in a while he forgot one at home rendering his device useless. On several occasions he had to buy an expensive replacement costing him a lot of money. His make shift solution of dumping all his chargers and buying a universal charger with 10 different tips was as frustrating as dealing with the chargers themselves. Matching the tips was a pain and the cables would just tangle with each other. Moreover, if one tip failed, it meant Jim had to replace the entire universal charger. Luckily, airports, coffee shops, and few other establishments started providing cell charging stations at least for the two most popular platforms; Apple and Micro USB. While a welcome initiative, it falls short of being an ideal solution, considering that there are more than 100 different cellular phone manufacturers[4], 6000 different cell phone models, and over 30 different types of chargers in the market[5]. It was just one big inconvenience. Jim always wondered why mobile device manufacturers don't standardize on a single charger. He strongly believed that the manufacturers should not even include a charger with their product. Once the chargers are standardized, a consumer can just buy their own charger and it will be compatible with all devices they own even when they upgrade saving hassle and keeping tons out of landfills. The benefits were enormous both for the consumers and for the environment.

The long wait was over. At last, it was happening. Jim's wish was coming true. It only took an entire European Union to convince the top 14 manufacturers, with a combined market share of more than 80% of the market, to agree on a standardized charger for smart phones. Apple, Emblaze Mobile, Huawei Technologies, LGE, Motorola, NEC, Nokia, Qualcomm, Research in Motion (RIM), Samsung, Sony, Ericsson, TCT Mobile (ALCATEL), Texas Instruments and Atmel signed an European Commissions memorandum of understanding, for Micro USB based Common External Power Supply specifications, for use with data-enabled mobile phones sold in European Union. While the initiative was a far cry from a real world wide universal charger for all cellular phones, it was the first step in gaining consensus.

Three years since signing of MOU, Jim is still carrying as many chargers as he was when the initiative was first announced. Jim was very disappointed and wondered what happened. First, the MOU was only limited to European Union, even though the scope was defined in global context, leaving out 93% of the world's population. Second, United States, China, and other major countries did not have or were not interested developing a similar mandate officially. Third, manufacturers, by themselves, did not have an incentive to consensually agree on a universal standard. Fourth, the European Union consensus standards only applied to data-enabled smart phones which had a combined market share of 25%, in 2010, leaving the remaining 75% market still unstandardized. Finally, the standard left out other small personal carry on devices, like hard drives, MP3 players, GPS, non-smart phones, resulting in, lack of interest from manufacturers [6]. According to Stephen Russell, ANEC secretary General,

"*The standard undoubtedly holds some benefits for consumers and the environment. But its limited scope is extremely disappointing. Most consumers do not buy data-enabled smartphones and it is hard to understand why buyers of more conventional mobile phones will not be able to benefit from the common charger. We feared this might be a consequence of the voluntary agreement reached between the European Commission and mobile phone producers in June 2009. ANEC had been seeking a more interventionist stance from the Commission. The ambition must now be to include all mobile phones and other small consumer multimedia electronic devices within the scope of this or similar standards. We will look to the Commission for action if the industry does not make a commitment to do so in the very near future."*

The consumer organizations criticized the initiative claiming it will stifle innovation, slow down research, limit manufacturers' ability to innovate, and limit the functionality of the devices. The biggest blow to the effort came when Apple introduced their new proprietary lightening connector in 2012 suggesting that they were not interested in honoring their agreement with the EU or in cooperating with other manufacturers. To please the European Commission, Apple introduced a Micro-USB to lightening adapter sold exclusively in Europe. Ok, thought Jim, so why did Apple retract on its own promise and why manufacturers are disinterested in extending their cooperation worldwide?

Incompatibility exists in almost all industries. For example, printers have proprietary ink; game consoles have proprietary games and controllers, and likes. Sometimes incompatibility is due to unique requirements of a product which cannot be addressed by an existing technology, while at other times, incompatibility is due to strategic reasons. Sometimes compatibility is required for an industry to function properly, for example, agreements on weights and measures, data exchange, and language, while at other times compatibility is not required but desired for convenience and overall societal good. The decision to maintain compatibility is usually dependent on whether companies want to compete in the market or for the market. Question then is; is the incompatibility in mobile phone chargers due to unique requirements of the manufactures or is it strategic in the sense that it gives them competitive advantage and source of additional revenue?

Unlike parameters like spectrum and networking protocols, chargers have always been viewed as an accessory for mobile phones, incompatibility of which is inconsequential to the normal operations of the phone[7]. This is because the actual charging mechanism is built into the cell phone while the charger basically serves as a power adapter which converts 110-220V alternate current to 5 -5.5V direct current[8]. Thus, at least on the face of it, compatibility may be desired, for example, to address Jim's inconvenience and to reduce landfills, but it is definitely not required. By this logic, it seems like Apple's incompliance with the European MOU is a testament that Apple views their chargers as either technically superior or as a source of competitive advantage.

A Micro USB cable has the capability to charge and sync at the same time. The cable itself is relatively cheap because there are thousands of manufacturers churning out millions of them simply by following the industry standards. Apple's lightening charger, on the other hand, is said to have a proprietary chip that provides additional functionality to the iDevices[9]. The same functionality can be achieved using Micro USB standard and some workarounds, but it looks like Apple is not interested in compromises. The proprietary chip ensures that the imitation is minimal, and authorized reproduction generates royalties. This allows Apple to charge premium on their cables with revenues exceeding 100 million dollars by some estimates[10]. The proprietary technology also allows Apple to charge huge royalties from third party accessories manufacturers bringing in almost $5.5 Billion dollars in 2012, some of which can be directly attributed to accessories using lightening connectors. With these kinds of revenue, it is highly unlikely that Apple will voluntarily adopt Micro USB standards, ever.

This case study was originally written, with the support of NIST grant in 2012, for wired charging standards. Just when it seemed that the industry was deadlocked into competing standards for wired charging, technological advancements in the form of wireless charging provided hope for universally compatible solution by making the needs obsolete. Wireless charging promised to be the solution for all wired problems. It was going to revolutionize the mobile charging and eliminate the need for having charging cables all together. Starbucks already committed to installing Powermat wireless charging stations in its stores all across the United States.

However, four years later, it looks like nothing has changed. The problems and arguments in this article are as valid in the case of wireless charging standards as they were in the case of wired charging standards. Unfortunately, when there are billions of dollars at stake, it is never easy to convince competitors to agree on a technology. Just like multiple charging tips, there are multiple wireless charging standards; Powermat from Power Matters Alliance (PMA), Qi specification from Wireless Power Consortium (WPC), and Rezence by Alliance for Wireless Power (A4WP). And then there is Apple which holds patents and is working on its own proprietary wireless charging solution. It looks like there may never be a single mobile charging standard.

Meanwhile Jim is still hopeful. Three years since the original MOU between 14 companies in EU, European Commission has voted on an updated Radio Equipment Law[11]. All mobile devices sold in the EU member nations will have to be Micro USB compliant by 2017, including iDevices. Jim knows that United States will not follow suit and mandate compliance to the manufacturers. However, Jim is hopeful that the manufacturers will see the benefits to the European consumers and may extend the courtesy in other countries. Meanwhile, Jim continues to carry his big bag full of chargers (in addition to multiple charging matts) hoping against all hopes that one day he will not have to carry anything.

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[10] http://chargeall.com/why-is-apple-still-using-proprietary-connectors/
[11] https://www.gov.uk/government/consultations/radio-equipment-directive-proposal

**This case study was prepared as a basis for discussion rather than to illustrate either effective or ineffective handling of a business scenario and/or leadership/role behavior. This case study was part of a project undertaken with the support of a research grant from NIST Measurement Science and Engineering, Standards Services Group, and the Lucas College of Business at San José State University.* 

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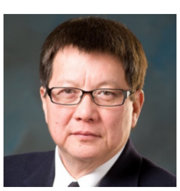

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Dr. Stephen K. Kwan is Lucas Professor of Service Science in the Lucas College and Graduate School of Business at San José State University, USA. He is currently the Associate Dean of Graduate Business Programs. He was the founding chair of the MIS department and had served as the Senior Associate Dean of the College. He is actively involved in research, teaching, and community activities in Service Science, Management, Engineering, and Design (SSMED). He is a recipient of multiple IBM Faculty Awards, and grants from the National Science Foundation (NSF), and National Institute of Standards and Technology (NIST). He had also worked on projects with TOTVS, Sun Microsystems, Cisco, Microsoft, HP, the State of California, the US Army, etc. His current research interests include Standards Education, Global Trade in Services, Service Systems & Service Value Networks, and Design Thinking for Service System Innovation. He had published in the areas of Service Science, Queueing Systems, Database Management, E-Commerce, Standards Education and Standards Policy. He received a B.S. and M.S. in Computer Science from the University of Oregon, and a Ph.D. in Management from UCLA.

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# IEEE BRINGS STANDARDS EDUCATION TO THE CAPSTONE DESIGN CONFERENCE

24 May 2016

Jennifer McClain, David Law

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The Capstone Design Conference, held every two years, offers a forum for faculty, administrators, industry representatives, and students to share ideas about improving design-based capstone courses. Capstone courses, also referred to as senior design courses, are for undergraduate engineering students in their last year of study.

The IEEE Standards Education Committee (SEC) sponsored panel sessions at the last two Capstone Conferences in 2012 at the University of Illinois at Urbana–Champaign and at The Ohio State University in Columbus, Ohio, in 2014. The upcoming conference on 6-8 June 2016, is once again at The Ohio State University, and this time IEEE will run a very unique workshop for attendees.

On Monday, 6 June 2016, IEEE is offering a *Workshop on Technical Standards and Consensus Building*. Representatives of the IEEE SEC will facilitate an interactive consensus-building exercise in which attendees take on the roles of different members of a standards working group tasked with developing a new technical standard. The workshop aims to demystify how standards are developed and used, and will provide ideas on how capstone instructors can bring industrial standards that students are likely to encounter in the workplace into classroom and design experiences.

These workshops have been run seven times over the past few years with mostly university undergraduate and graduate students in attendance. This will be the first time the workshop is tailored specifically for educators who may want to use the exercise to teach about standards as part of their coursework.

**Workshop Objectives:**

- To facilitate a better understanding of the importance of standards to industry and demonstrate the fundamentals of standards development.
- To provide specific ideas for using standards and standards development in capstone courses.
- To discuss new ways for meeting some key Accreditation Board for Engineering and Technology, Inc. (ABET) criteria, including:
    - an ability to function on multidisciplinary teams;
    - an understanding of professional and ethical responsibility;
    - the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
    - a recognition of the need for, and an ability to engage in, life-long learning;
    - a knowledge of contemporary issues.
- To provide information on new standards education tools.
- To enable a fuller understanding of the economic, political, and technical realities of standards development.
- To put participants into the role of a working group member and to enable a better appreciation and understanding of motivation and dynamics in that environment.

**Workshop Outcomes:**

At the end of the workshop, participants will:

- Have a better understanding of the importance of standards to industry, and see industrial standards as catalysts for technological innovation and global market competition.
- Have specific ideas for how to incorporate new standards education tools into capstone coursework.
- Have a better understanding of how these tools can help meet certain ABET criteria.

Facilitators:

- James Irvine, Ph.D., Reader in the EEE Department at Strathclyde University, Glasgow, UK
- Jennifer McClain, Senior Manager, IEEE Standards Education & Business Development
- Susan Tatiner, Director, Standards Education Programs, IEEE Standards Association
- James P. Olshefsky, Director, External Relations, ASTM International

At the end of this interactive workshop, participants will have acquired a fuller understanding of how standards are developed, and specific ideas for how to incorporate new standards education tools into capstone coursework. According to Susan Tatiner of the IEEE Standards Association, “It is exciting for us to enable educators, as well as students, to gain a better understanding of how valuable standards are to industry. Standards are incredible teaching tools, and the more students know about them the better prepared they will be when starting out in their careers. Industrial standards serve as catalysts for technological innovation and global market competition, which are important themes we also see in capstone projects.”

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Jennifer began her career at the IEEE in 1997 as Associate Editor for IEEE Transactions on Plasma Science and IEEE Transactions on Magnetics. She spent eight years with the IEEE Standards Association editing standards, aiding working groups with the standards development process, and as the Managing Editor of the Standards Information Network, publishing handbooks and guides to help with the implementation and understanding of standards. Now with IEEE Educational Activities, she manages all functions related to the Standards Education Programs and Committee, and as part of the business development team develops opportunities for IEEE Educational Activities.
Jennifer holds a B.A. with History and English Majors from Western Michigan University, Kalamazoo, MI, and attended the Masters of Education in Social Studies program at West Chester University, West Chester, PA, obtaining a Pennsylvania Secondary Education Teaching Certificate in Social Studies.

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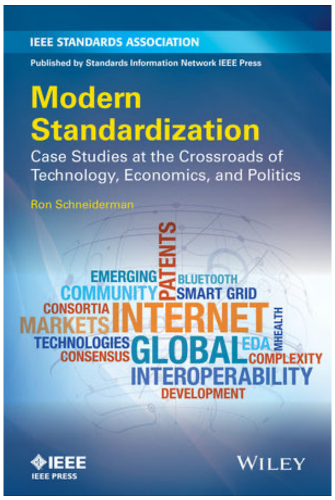
# BOOK REVIEW: MODERN STANDARDIZATION

23 May 2016
Dr. Ahmed S. Khan, David Law

**Book Review:**
***Modern Standardization: Case Studies at the Crossroads of Technology, Economics and Politics* by Ron Schneiderman**




In today's global economy, the importance of the formal study of standards has been highlighted by the new demands of international trade. Politics of standards development and adoption is becoming a complex affair in an era of intellectual property rights. In today's global market place, the major challenges are: How do standards development organizations (SDOs) keep pace with the creation and development of products driven by new and emerging technologies? How to teach engineering and technology workforce and students the importance and applications of standards?

Globally, more than a half a million engineering and technology standards are considered as the basic building blocks for the development of new products that help drive the processes of compatibility and interoperability. Standards make it easier to compare competing products. As new standards are developed and adopted, they promote international trade and allow technical cooperation between organizations and countries.

Recently published book *Modern Standardization — Case Studies at the Crossroads of Technology, Economics, and Politics* by Ron Schneiderman (published by IEEE Press/Wiley) address these key challenges. It was written as a result of efforts by the IEEE Standards Education Committee (SEC) to gain a better understanding of what products and services would be useful for standards education at the university level. The book covers up-to-date issues related to ethics, policies, and business strategies in standards developments.

The book is a useful resource for faculty, students, engineers and entrepreneurs. The major strength of the book is its collection of standards-specific case studies which offer an opportunity to combine professors' teaching preferences with real-world insights into the technical, political, and economic domains of engineering. Students can appreciate how standards experts and SDO working groups institute policies, procedures, and guidelines to develop and establish standards. Students can learn how to select and apply standards in new product design and service. The book is primarily designed to be used as a supplemental resource for a course in standards. There is a curriculum guide available for educators to help them design and implement courses effectively.

The book is also a good reference resource for engineers and entrepreneurs, as it covers a survey of national and international standards development needs for a wide array of technologies such as smart energy grid, cyber security, wireless technologies, vehicles' black box, electronic design automation (EDA), the Internet and Internet of Things (IoT), and explores the push for open standards. The book presents a discussion on the collaboration efforts between U.S. and European standards organizations for promoting trade through Transatlantic Trade and Investment Partnership (TTIP).

In short, the book is a welcome addition to standards literature and serves as an important resource for standards stakeholders in academia and industry. It informs them how standards experts and SDO working groups establish the policies, procedures, and guidelines to ensure the integrity of the standards development process, thus enabling organizations to develop new products and promote global trade.

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Dr. Ahmed S. Khan is a Professor of Electronics and Electrical Engineering in the College of Engineering and Information Sciences at DeVry University, Addison, Illinois. Dr. Khan has Thirty-two years of experience in research, instruction, curricula design, development, evaluation, implementation and program accreditation, management and supervision. Dr. Khan received an MSEE from Michigan Technological University, an MBA from Keller Graduate School of Management, and his Ph.D. from Colorado State University. His research interests are in the areas of Nanotechnology, and Social and Ethical Implications of Technology. He teaches Wireless Engineering, Network Engineering, Fiber Optic Communications, Science Technology and Society (STS), and Project Management. He also advises students on their senior design projects. He is the author of many educational papers and presentations. He has authored/coauthored many books, including the most recent "Nanotechnology: Ethical and Social Implications," CRC Press (2012).
Dr. Khan is a senior member of the Institute of Electrical and Electronics Engineering (IEEE), and a member of American Society of Engineering Education (ASEE), and has been listed in Who's Who among America's Teachers. Dr. Khan has been serving as the faculty adviser to the student chapter of IEEE at DeVry, Addison, IL since its inception in 1986. Dr. Khan also serves as an ETAC program evaluator for the ABET.

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# STUDENT APPLICATION PAPERS

20 May 2016
David Law

Student application papers applying industry standards are papers submitted by students, or their faculty mentors on their behalf, in which an industry technical standard(s) was applied (analyzed and implemented). Each paper highlights specific design choices in the application of various technical standards and describes the resulting product, process, or service. Click on the title to view the full paper.

> **Implementation of a QI Compliant Wireless Power System for an Underwater Probe (PDF, 1.5 MB), by Heitor M. Santos, Luiz F. O. Chamon, and Cassio G. Lopes, Signal Processing Lab, Electronic Systems Engineering Department, University of Sao Paulo, Brazil**

# IMPLEMENTATION OF A QI COMPLIANT WIRELESS POWER SYSTEM FOR AN UNDERWATER PROBE

*Heitor M. Santos, Luiz F. O. Chamon, and Cássio G. Lopes*

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## ABSTRACT

Underwater sensing probes are used in a myriad of applications, for instance, oceanographic profiling. These probes present a design challenge as they are submitted to harsh marine environments and large pressures, which makes their waterproofing intricate. A solution to this issue would be to completely and permanently seal the probe's shell. This, however, complicates the access to the internal circuit, which poses the problem of how the equipment's batteries would be charged. This work addresses this issue by implementing a Qi-compliant wireless power transfer system. Introducing a layer model of the standard, each part of the power transmitter and receiver modules are designed, mounted, and tested. Even though the purposes of this system is battery charging, the wireless power modules described in this white paper could also be used in other applications.

## 1. INTRODUCTION

Oceanographic research is paramount to the preservation of coastal biomes, also contributing to economic and military interests. In this endeavor, a myriad of sensing instruments are used to map and monitor oceans and lakes, the CTD (Conductivity, Temperature, and Depth) being one of the most commonly used. This equipment is composed of a waterproofed probe equipped with conductivity, temperature, and pressure sensors. The probe is usually attached to a boat by a steel cable and dives sampling these variables at different depths. From these measurements, scientists can obtain the profile of several quantities of interest for their research, such as salinity and water density [1].

The CTD was initially developed in 1960 by the electrical engineer Neil Brown, from Bissett-Berman Corporation. It has since evolved into a more feature-rich equipment, including different sensors (light, current velocity, etc.) and automatic profiling capabilities [2]. Still, some issues have yet to be fully addressed, one of the most important being waterproofing. The use of these instruments in great depths requires costly sealing solutions that can deal with large pressure, since any infiltration, no matter how small, can permanently damage the instrument.

Our laboratory proposed permanently sealing the CTD probe as a solution to this problem. This could be achieved, for example, by making use of an acrylic cast which fully impermeabilizes the internal circuitry. Nevertheless, this raises two additional problems: data access and powering. The former can easily be dealt with using any of the countless wireless communication systems available nowadays. The latter, on the other hand, is more demanding. Even though most probes already rely on batteries to operate, these are usually recharged using a specific connector on the probe's shell, which defies our fully sealed probe solution.

This work addresses this issue by recharging the batteries via wireless power (WP) transfer (inductive charging), allowing the probe's shell to be completely and permanently sealed [3]. This white paper starts giving an overview of WP transfer and the available standards for it. A layer implementation of the Qi standard is then introduced, which has the advantage of facilitating development and increasing the system's robustness. Finally, implementation details are presented and testing results are analyzed and discussed.

## 2. WP TRANSFER

WP transfer is useful in situations where wiring is inconvenient or even impossible. It consists of supplying energy to a device using air as a conductive medium, by means of electromagnetic waves or magnetic fields. The current application is justified by the inaccessible nature of the batteries due to the permanent sealing of the underwater probe.

The development of WP transfer can be traced back to Nikola Tesla. Though scientists had been studying electromagnetic induction since the early 18th century, Tesla was the first to demonstrate its use for transmitting power wirelessly. In 1891, he lighted a lamp without connecting wires to it, later patenting several other applications of WP [4].

Slow progresses were made in the field of WP during the 1900s, such that in the beginning of the 21th century there

**Table 1**. Market assessment of WP standards [5]

| | WPC | PMA | A4WP |
|---|---|---|---|
| Member Companies | 140+ members | 80+ members | 40+ members |
| Specification Published | Yes (WPC1.1), public | Yes (PMA 1.1), members only | Yes (v1.0), members only |
| Approved Tx Types | $> 20$ | In development | In development |
| Certified Products | 160 | In development | In development |
| IC Solution Available | Yes (5 suppliers) | Two in development | None public |
| Regulatory Approvals | Yes | Yes | No |
| Infrastructure Play | U.S., Japan, Europe | U.S., Europe | None |

were only a few consumer products employing this technology. This scenario, however, is rapidly changing and the WP market has shown a significant growth in recent years. An increasing number of companies have been interested in WP and the development of several WP standards (Section 2.1) has been fundamental in this process [5].

Even though this work is applied to the charging of an underwater probe's battery, WP can be applied to countless electronic consumer products, such as mobile phones, MP3 players, laptops; medical devices, like pacemakers [6]; and even electric vehicles [7].

### 2.1. WP Standards

Currently, there are three main organizations [5] developing WP transfer standards: the Wireless Power Consortium (WPC), responsible for the Qi standard (see Section 2.2); the Alliance for Wireless Power (A4WP); and the Power Matters Alliance (PMA). So far, only the Qi standard is ready and freely available to the community on the WPC website [8]. A4WP and PMA standards are still under development and are only available to members of the respective groups. Comparisons between the three standard can be found on Table 1.

### 2.2. Qi WP Standards

WPC is the largest group involved in the creation of WP standards (more than 140 members), presenting the most developed standard so far: the Qi standard [5,9].

Developed since 2008, the Qi standard is based on inductive coupling and magnetic resonance. The current version (1.1) aims at low power devices, defining close-proximity power transfers up to 5W. The standard was named after the Asian philosophy's term "Qi", meaning *vital energy* (referring to the power flow that allows devices to work) [6,9].

## 3. THE QI LAYER MODEL

The Qi standard does not define the structure of the power transmitters and receivers, only their specifications. In this work, we introduce a layer model for the Qi standard (Figure 1) in order to facilitate the development of the system. Layer designs are considered robust, since each layer can be implemented independently, and have been used in several applications, such as the OSI model and the World Wide Web [10].

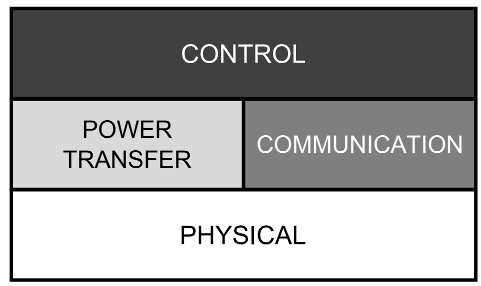



**Fig. 1**. Qi layer model

### 3.1. Physical Layer

This layer is responsible for the transduction of electric to magnetic energy. The physical layer is the actual gateway to WP transfer, though it is also involved in the exchange of messages between Qi devices.

The Qi standard describes several transmitter/receiver sets that are adequate for different applications [9]. In this work, a 24 $\mu$H and a 15.3 $\mu$H coil were chosen for the transmitter and receiver respectively. Cylindrical helical coils with air cores were chosen due to their ease of construction and well-known behavior. The inductors' design was based on Nagaoka's model,

$$L = \pi \mu N \frac{R^2}{\ell} K$$

where $L$ is the self-inductance of the coil, $\mu$ is the magnetic permeability of the medium, $R$ is the radius of the coil, $N$ is the number of turns, $\ell$ is the length of the coil and $K$ is the Nagaoka's factor [11].

### 3.2. Power Layer

The power layer is responsible for performing the conversions necessary to transfer power, i.e., it is responsible for DC-to-AC conversion in the transmitter and AC-to-DC conversion in the receiver. This layer connects directly to both the source and the load, thus being the layer that indeed retrieves energy from the source and delivers it to the load.

The power layer is also responsible for the sensing of the physical layer. For the purposes of this implementation, it is sufficient to measure the current going through the coils, since the voltage is known a priori. These measurements are required by the Communication layer to receive messages from the receiver module and by the Control layer to adjust the transmitted power.

The Qi standard determines that the operation frequency should be within a 100–205 kHz range [9]. The nominal frequency must corresponds to the resonance of the transmitter-receiver pair, so as to allow for maximum power transfer. This work adopts a nominal frequency of 100 kHz.

In order to adjust the resonant frequency of the transmitter-receiver coils, suitable series capacitors were selected. Using the resonant frequency relation for series LC circuits, namely

$$f = \frac{1}{2\pi\sqrt{LC}} \Rightarrow C = \frac{1}{L(2\pi f)^2}$$

Taking $L_{TX} = 24\mu$H and $L_{RX} = 15.3\mu$H, the inductance of the transmitter and receiver coils, yields

$$C_{TX} = \frac{1}{L_{TX}(2\pi 100 \cdot 10^3)^2} \Rightarrow C_{TX} = 105.54 \text{ nF}$$
$$C_{RX} = \frac{1}{L_{RX}(2\pi 100 \cdot 10^3)^2} \Rightarrow C_{RX} = 165.56 \text{ nF}$$

These values were adopted as an initial estimate of the necessary capacitance. Tuning of capacitors values was later performed in-circuit to improve the resulting resonance.

### 3.3. Communication Layer

The Qi standard defines a one-way communication protocol from the receiver to the transmitter module. Hence, the receiver can send identification and control messages to the transmitter, but the latter has no way to respond except by controlling the power being transferred. Communication between the modules is used to ensure Qi compliance, determine the device's power requirements, and control the power transfer [9].

The communication protocol relies on a biphase differential signaling. In this scheme, each bit is transmitted in two clock periods [9]. Zeros are encoded using the same level in both periods, whereas ones perform a transition after the first period (Figure 2). The advantage of this coding system is that the message is invariant to polarity inversions: even if the modulated signal is inverted, the received message remains the same.

The message bits are grouped in bytes of 11 bits (Figure 2) consisting of a start bit (0), 8 information bits (from least to most significant), a parity bit (even), and a stop bit (1). These bytes are, then, transmitted in packets described below (Figure 3):

- **Preamble:** sequence of 11 to 25 bits 1 used for synchronization purposes;
- **Header:** one byte that determines the packet type and, implicitly, the message size;
- **Message:** up to 27 bytes carrying the actual information of the packet, i.e., the payload;
- **Checksum:** single byte resulting of the exclusive or of the message and header bytes.

The packets are transmitted using amplitude modulation by switching a capacitive and/or resistive dummy load on the receiver side (Figure 4). The modulation frequency defined by the Qi standard is 2 kHz, i.e., the differential signaling clock is 4 kHz [9].

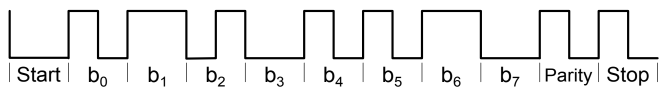



**Fig. 2**. A Qi byte (0x35) [9]

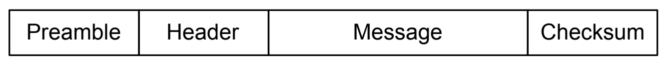



**Fig. 3**. Configuration for a packet of bytes

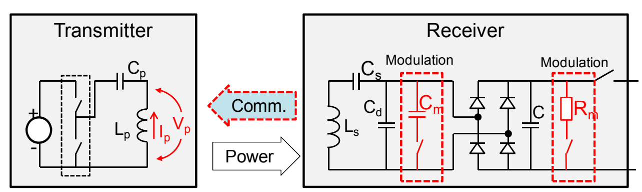



**Fig. 4**. Diagram of the capacitive dummy load modulator [12]

### 3.4. Control Layer

The Control layer coordinates the whole WP transfer. It has different roles in the receiver and transmitter. The receiver Control layer is responsible for the messages that the Communication layer delivers to the transmitter. It also compares the current sensing data from the Power layer with the load set point to generate error value messages. The transmitter Control layer manages the WP transfer. It checks the compliance of the receiving device, gathers its identification and configuration informations, and uses the error value messages received to feed a PID controller that adjusts the power sent by the Power layer.

The Qi standard defines a four-phases WP transfer (Figure 5) [9]:

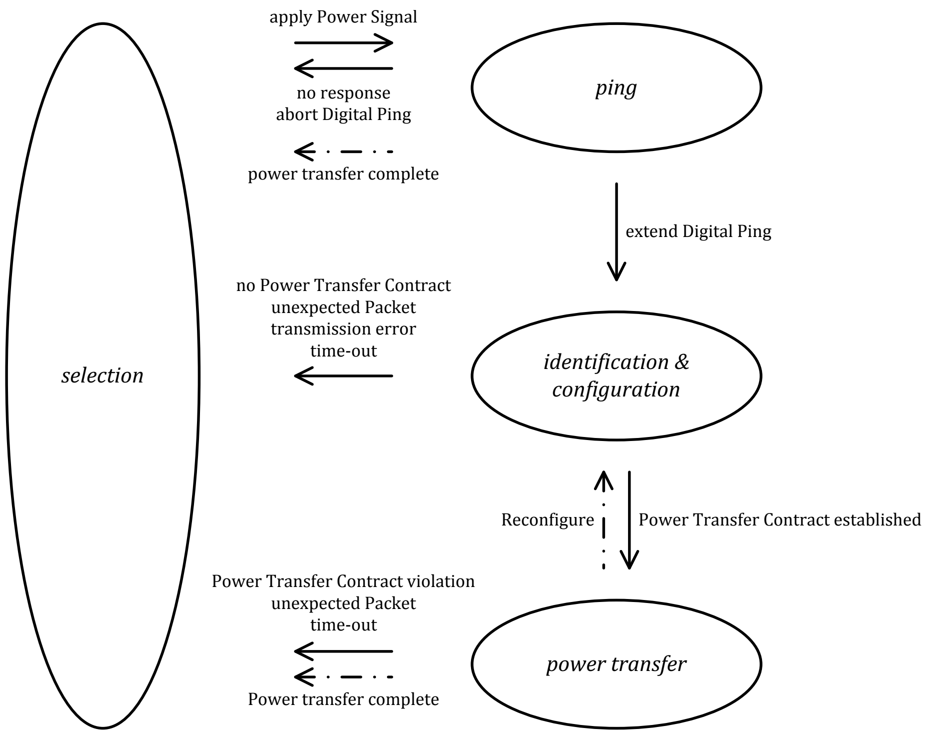



**Fig. 5**. Phases of the power transfer process and control protocol [9]

- **Selection:** during this initial phase no power is transferred. The transmitter recurrently checks for the presence of an object, usually using short power bursts. As soon as an object is detected, the process follows to the next phase. Whenever the WP transfer is interrupted, the system returns to this phase;
- **Ping:** the transmitter checks if the detected object is a Qi compatible device. To do so, the transmitter starts sending power at a nominal level and waits for a predefined packet. If this packet is not received within a certain time limit, the transmitter aborts the WP transfer;
- **Identification & Configuration:** in this phase, the receiver sends all the information necessary to start a WP transfer. The transmitter can check if it supports the device's version and required power and choose to abort or proceed with the transfer ;
- **Power Transfer:** this is the phase when the actual power transfer takes place. The power is controlled using error value messages from the receiver and adjusting the inverter's operating frequency.

## 4. IMPLEMENTATION

During the implementation of the Qi standard, the layer design model introduced in the last section was extensively used. All circuits and firmwares were independently developed and tested relying only of their interfaces to other layers. A final integration step was then performed so as to produce the final prototype.

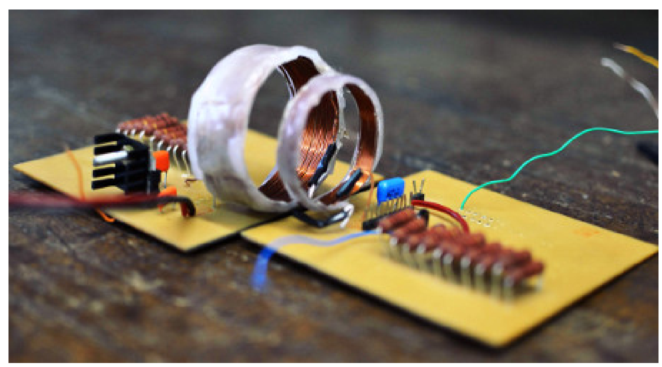


**Fig. 6**. WP transfer system prototype

The final prototype can be seen in Figure 6 and a detailed block diagram is presented in Figure 7. In the following sections, the implementation of the aforementioned layers is described in more details.

### 4.1. Microcontroller

In this work, the microcontroller adopted to implement the Qi protocol was the Texas Instruments MSP430. The MSP430 is

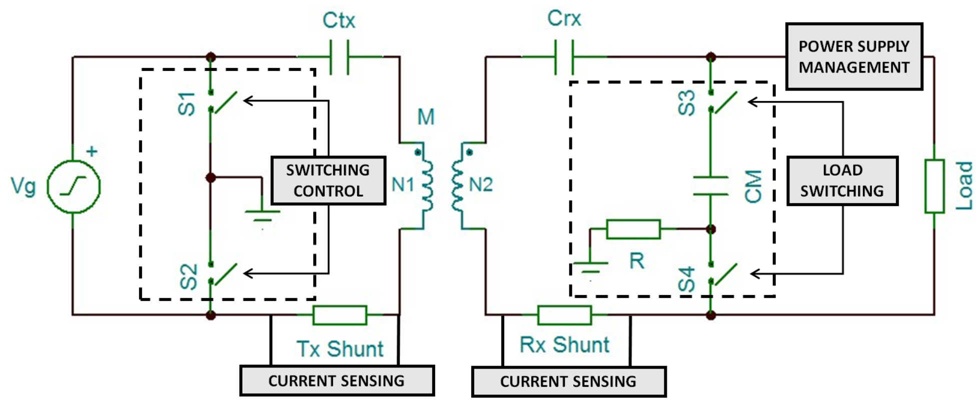



**Fig. 7**. WP transfer system overview

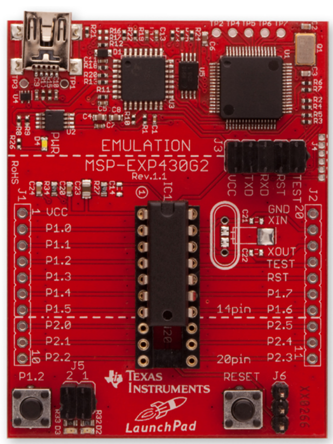


**Fig. 8**. Texas Instruments' MSP430 LaunchPad

a low power 16-bit RISC microcontroller with embedded 10-bit ADCs, timers, PWM, and UART [13], making it appropriate for the present implementation. Another advantage of this microcontroller is the MSP430 LaunchPad board [14], an evaluation/development module which facilitates its use and test in prototypes (Figure 8).

### 4.2. Physical Layer

The helical coils constructed for the WP transfer modules can be seen in Figure 6. Their characterization is presented in Table 2, where the theoretical values evaluated in Section 3.1 are compared to measurements of the actual coils. The latter were obtained using a 1 V signal at 100 kHz.

Given the values obtained, the coupling coefficient can be evaluated. Explicitly,

$$k = \frac{M}{L_{TX} L_{RX}} \approx 0.3,$$

where $k$ is the coupling coefficient and $M$ is the mutual inductance of the coils.

**Table 2**. Comparison between calculated and measured inductance values

| Module | Theoretical $L$ ($\mu$H) | Measured $L$ ($\mu$H) | Measured $M$ ($\mu$H) |
|---|---|---|---|
| Transmitter coil | 25.4 | 25.309 | 5.518 |
| Receiver coil | 14.3 | 14.193 | 5.518 |

**Table 3**. Characterization of the capacitors of the WP transfer coils

| Module | Theoretical $C$ (nF) | Nominal $C$ (nF) | Measured $C$ (nF) |
|---|---|---|---|
| Transmitter coil | 105.54 | 120 | 113.19 |
| Receiver coil | 165.56 | 180 | 179.40 |

### 4.3. Power Layer

So as to guarantee the resonant frequency chosen in Section 3.2, the capacitance was tuned according to the coils inductances. To do so, the theoretical values previously determined were approximated by standardized capacitor values and simulated using SPICE. The selected capacitors are characterized in Table 3 and the assembled circuit frequency response is illustrated in Figure 9. Again, the impedance measurements were performed using a 1 V signal at 100 kHz.

The power layer is also responsible for DC-to-AC and AC-to-DC conversions in the transmitter and receiver modules, respectively. The transmitter inverter produces a square wave from a DC voltage by switching the load between VCC and ground (see *Switching Control* in Figure 7). To do so, this implementation relied on an H-bridge driver IC, which has the advantage of requiring a single signal from the microcontroller and taking care of PWM dead time internally [15]. Hence, the MSP is relieved of this task, simplifying the firmware.

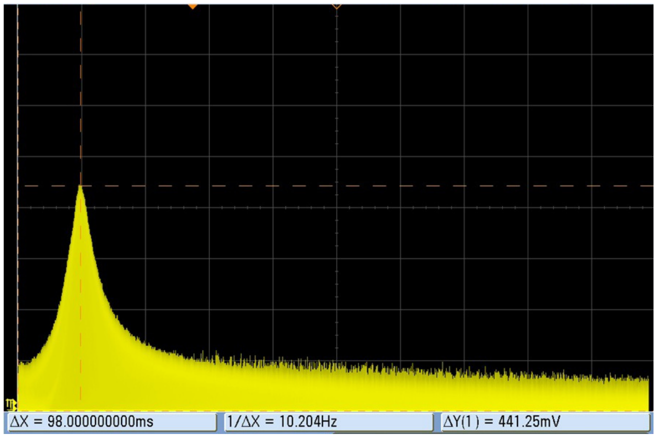



**Fig. 9**. Frequency response of the transmitter/receiver pair: measured using a sine sweep from 50 to 550 kHz (0.5 kHz/ms). Resonance = 99 kHz

Due to high quality factor of the LC filter formed by transmitter/receiver pair (see Figure 9), the received voltage is approximately sinusoidal. Before it can be delivered to the load, it must therefore be rectified. As a proof of concept, this work adopts a full-bridge diode rectifier. Though there are more efficient solutions, such as those based on silicon-controlled rectifiers (SCR) or switch-mode supplies [16], the diode rectifier is simpler and sufficient for this implementation's purposes.

Finally, this layer must also perform the task of sensing current on both modules. In this development, a low side 1 Ω shunt resistor was used to simplify the design. Even though high side measurements are more reliable in many applications, there would be little gains in this case. Furthermore, high side current sensing requires a more costly differential amplifier to deal with the larger common mode voltages. Before entering the microcontroller's AD converter, the current sensor signal passes through a peak hold to facilitate its amplitude measurements.

### 4.4. Communication Layer

Contrary to the previous layers, which were implemented mainly in hardware, the communication layer has both hardware and firmware components. This section first describes the receiver side, which from the communication viewpoint transmits messages, then discussing the reception of these messages by the transmitter.

The receiver firmware starts by mounting the packets, appending start, stop, and parity bits to the message, constructing the preamble and the header, and calculating the checksum. Using an interrupt routine, the receiver sends the packet by modulating the dummy load (see Figure 7) using the MOSFET switches shown in Figure 10. This bootstrap circuit is only necessary when the MOSFET transistors' gates are not

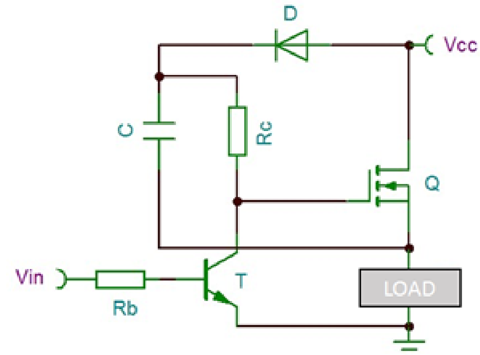



**Fig. 10**. Bootstrap circuit with MOSFET transistor

logic level, i.e., they cannot be triggered by typical logic voltages. Here, a BJT, which is able to turn on at lower voltages, is used to control the charge and discharge of diode/capacitor voltage doubler, thus enabling the MOSFET to act as a switch. The biphase differential signaling is implemented by the interrupt routine during the load modulation.

The communication layer on the transmitter module is firmware-only, since current sensing information are already captured by the Power layer. The demodulation routine, however, is not as straightforward as the modulation one. While the transmitter is waiting for a message, it samples the current level at approximately 8 kHz, i.e., twice the preamble frequency. As soon as it detects a level shift, the firmware samples the channel at higher speed (about 50 kHz) so as to determine the bit period and align its measurements to a preamble edge (Figure 11a). The firmware then synchronizes to the middle of the bit and starts sampling at normal pace (Figure 11b). The demodulation occurs at the same time as the sampling, so that the transmitter records the demodulated bits.

After the header has been acquired, the transmitter can evaluate the number of bytes in the message. It then proceeds to capture the message and compare the checksums. If the reception is successful, the header and message become available to the Control layer. Otherwise, the Communication layer will reset the process immediately.

Figure 11c illustrates the communication of three packets (ping, identification, and configuration) between the Qi modules.

### 4.5. Control Layer

The first role of the control layer is that of controlling the WP transfer process flow, i.e., going through the phases described in Section 3.4. The receiver firmware goes straightforwardly through all phases as long as it is receiving power. The transmitter, on the other hand, has the more complicated task of constantly checking whether all requirements of one phase were met before proceeding to the next one. Both flow control were implemented using an array of function pointers traversed by a variable that tracked the current phase. In case of errors (wrong message header, time out, incompatible device etc.), the transmitter microcontroller was reset, thus ending the power transfer and restarting the phases cycle.

The transmitter's control layer has the additional task of adjusting the inverter frequency to control the amount of power transferred to the receiver. To do so, the transmitter uses error messages from the receiver and a PID controller. Explicitly,

$$P(i,j) = e(i,j)$$
$$I(i,j) = \min[\, I(i,j-1) + e(i,j)\cdot t\,;\, I_{\max}\,]$$
$$D(i,j) = \frac{e(i,j) - e(i,j-1)}{t}$$
$$PID(i,j) = [K_P P(i,j) + K_I I(i,j) + K_D D(i,j)]\, S_v$$

where $i$ indexes the outer loop (which starts upon receiving a new error message) and $j = 1, \ldots, J$ indexes the inner loop; $e(i,j)$ is the error, with $e(i,1)$ being the first value received from the power receiver module and $e(i,0) = e(i-1,J)$; $K_P$, $K_I$, and $K_D$ are the proportional, integral, and derivative gains, respectively; $S_v$ is the control gain which converts the PID update to the control signal; $t$ is the time it takes for the inner loop to execute; $I_{\max}$ is used to avoid integral windup issues; $I(i,0) = I(i-1,J)$ represent the value of the integral term at the end of the last outer loop iteration [9,17]. The Qi standard suggests that the proportional term alone would be sufficient for this type of implementation [9].

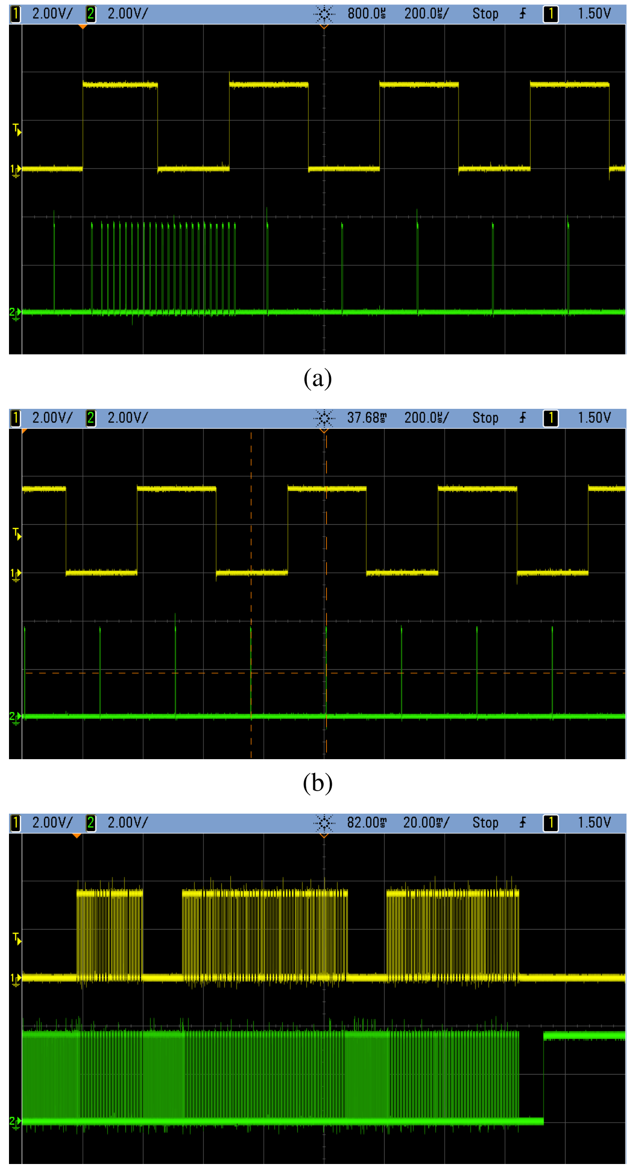
Though the control layer has been fully implemented, the PID controller parameters still requires adjustments to function properly. So far, it has only been validated in debugging simulations.

### 4.6. Power Supply Management

The WP receiver module is responsible for charging the lithium-polymer (LiPo) battery used to power the underwater probe. This type of battery, however, requires care since its life cycle may be reduced if it is fully discharged or charged too quickly. In some cases, LiPo batteries can incinerate and even explode.

Several dedicated ICs are available to manage this kind of battery. In this work, Microchip's MCP73831 was used [18]. A typical configuration of this IC is introduced in Figure 12.

As the figure shows, the output of the Power layer on the receiver module is connected to one side of the IC, while the battery is connected to the other. Instead of an LED, the STAT pin is used by the microcontroller to determine when it should request the power transfer to end. The 2 kΩ resistor on the PROG pin sets the constant-current charge mode of the IC to 500 mA. If necessary, this pin can be used to manually disable the charging at any moment. Here, however, the receiver module can rely on the undervoltage lock out of the IC.




(a)

(b)

(c)

**Fig. 11**. Communication: receiver message (upper yellow curves) and transmitter sampling (lower green curves). The transmitter first synchronizes using the preamble **(a)** and then proceeds to the message **(b)**. Ping, identification, and configuration packets are illustrated in **(c)**.

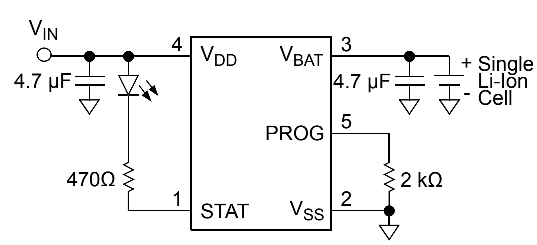



**Fig. 12**. MCP73831 for LiPo battery charging [18]

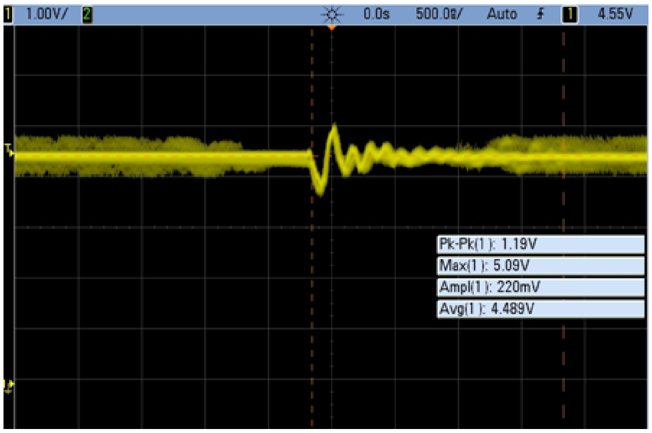



**Fig. 13**. Rectified received voltage on a 1 $\Omega$ dummy load. Power = $20.15$ W

### 4.7. Integration and PCB design

This last step consists of integrating the layers and making the necessary adjustments to the interfaces so as to enable WP transfer. Since the layers were carefully designed and tested, interfacing them was straightforward. However, tuning the modules parameters is a non-trivial task that depends on a myriad of factors extrinsic to the circuit design, such as components tolerances, parasitics etc. Though the design allowed most adjustments to be made in the firmware, some hardware would, nevertheless, be necessary.

The transmitter and receiver modules printed circuit boards (PCBs) were designed so that the MSP430 Launchpad could be easily connected to them. This was done so as to facilitate system debugging. Once assembled (Figure 6), the system was tested using a 1 $\Omega$ dummy load. In this test, the input voltage was increased up to the point where the circuit started to overheat. The implemented system was able to supply more than 20 W to the receiver module using a 20 V input (Figure 13). Hence, this implementation can perform well above the 5 W required by the Qi standard v1.1. Still, efficiency could be increased by improving the performance of some of the system components (e.g., the coils).

## 5. CONCLUSION

This white paper details the implementation of a Qi compliant WP transfer device. This device was designed to be used as a charger for the batteries of an underwater probe, though it could easily be adapted to serve other purposes. It starts by describing the main characteristics of the standard and introducing a layer model of the system. The implementation of each layer was then detailed, along with the result of their testings. Though all layers were individually functional, the integration step was only concluded for the Physical, Power, and, partially, for the Control layer. Future works include tuning of the Communication layer and the PID controller parameters; optimization of the coils design to increase the WP transfer efficiency; improvement of the receiver's rectifier to reduce losses; and development of a more precise current sensor.

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# FEATURED COURSES

19 May 2016

David Law

Practical Ideas from Professors: Standards Education in Your Courses

# Teaching Standards in Electromagnetic Compatibility

## About the School of Engineering and Sustainable Development at De Montfort University

The School of Engineering and Sustainable Development is one of three schools in the faculty of Technology; the other two are the School of Computer Science and Informatics, and the Leicester Media School. As well as a strong general engineering focus, the School of Engineering and Sustainable Development also has a research focus on sustainability, with a broad spectrum of related research, including energy economics. The undergraduate curriculum of the school is mechanical engineering, mechatronics, electronic engineering, and physics. The electronic engineering, mechatronics, and physics students share a number of courses, one of which is the course on electromagnetics.

## Using Standards in Technical Field Courses:

De Montfort University was incorporated as a university in 1992; immediately prior to that it was a polytechnic (Leicester Polytechnic). One aspect of polytechnic education that is still strong is the emphasis on skills development for the next phase of students' lives—whether that is a research career or an industrial one. Should students progress along the research path, an increasing emphasis in the United Kingdom is placed on the demonstration that the research has impact outside a purely research environment.

Prof. Alistair Duffy

Alistair Duffy has worked at De Montfort University in Leicester, United Kingdom, since 1994; prior to this he read for degrees at University College Cardiff, the University of Wales, and the University of Nottingham, and also worked in industry. He currently leads two research groups: the Centre for Electronic and Communications Engineering and the Advanced Manufacturing Processes and Mechatronics Centre. He has served two terms as a director-at-large of the IEEE Electromagnetic Compatibility (EMC) Society, and he is currently the chair of the EMC Society's Standards Development and Education Committee (SDECom). Alistair's research work has contributed to IEEE 1597.1™, IEEE Standard for Validation of Computational Electromagnetics, Computer Modeling and Simulations.

Practical Ideas from Professors: Standards Education in Your Courses

# Teaching Standards in Electromagnetic Compatability

## Using Standards in Technical Field Courses (continued):

One vehicle for this is through the incorporation of that work in recognized standards. Should students follow an industrial career, they will need to understand the role of standards in their particular fields, and be aware of the importance of contributing to the development of these standards to ensure that their voices, or the voices of their employers (or industry groups), are heard. As a result, standards are introduced in the degree program simply as another technical resource, and not via formal lectures. This way, it is intended that any concerns individuals may have with the perceived amount of time and effort required for using potentially large documents to guide working practices can be overcome.

The electromagnetics module runs throughout the academic year (starting in October, with the final assessment in May). It is weighted 50:50 between the final examination and coursework. There are several components to the coursework, but the main component is a technical paper that is written following the IEEE Journals template. There are two parts to this coursework element. The first is focused on problem-based learning and requires students to develop knowledge and skills in electromagnetic simulation and the use of vector network analyzers and spectrum analyzers for various measurement tasks. The second part to the coursework is project-based learning, for which a design problem is set. Recent design problems have included planar Yagi-Uda arrays and Branch Line Couplers. The students are expected to design the components using full wave electromagnetic simulation software, to build the device, and then to compare the measurements against the predictions from the simulation software. It is in undertaking this comparison that standards are introduced.

One important question when comparing the real measurements with the simulations is: "How good is the agreement?" The second important question is: "How do you know?" It is as a means of answering these questions that IEEE Std 1597.1 is introduced. This standard addresses the comparison of simulated and measured data, primarily for the purpose of validation. The marking scheme for the final paper includes how the process of comparison has been performed and the critical analysis of the final designs and practical devices.

Practical Ideas from Professors: Standards Education in Your Courses

# Teaching Standards in Wireless Communications

## About the School of Electrical Engineering, Information Technology, and Physics at Technische Universität Braunschweig

Technische Universität Braunschweig, founded in 1745, is one of the oldest Universities of Technology in Germany. Electrical Engineering and Information Technology at Technische Universität Braunschweig are taught in three 3-year bachelor and five 2-year master programs to approximately 1600 students, many of whom are studying toward joint degrees with computer science, mechanical engineering, or industrial engineering. The school has a long-standing tradition in standardization, as demonstrated by the technical leadership in the development of Digital Video Broadcast (DVB) by TU Braunschweig faculty member, Professor Ulrich Reimers. The school is also closely cooperating with the Braunschweig-based Physikalisch-Technische Bundesanstalt (PTB), Germany's national metrology institute and highest authority when it comes to correct and reliable measurements.

Prof. Dr.-Ing. Thomas Kürner

I am a university professor specializing in mobile radio systems at the Institute for Communications Technology at Technische Universität Braunschweig in Germany. My reseach areas are: indoor channel characterisation and system simulations for high-speed short-range systems including future terahertz communications systems; propagation, traffic and mobility models for automatic planning and self-organization of cellular radio networks; vehicle-to-X communications; as well as accuracy of satellite navigation systems. Currently, I am chair of the IEEE 802.15 Task Group 3d, chair of the IEEE 802.15 Interest Group THz, and vice-chair of the IEEE 802.15 Task Group 3e.

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Practical Ideas from Professors: Standards Education in Your Courses

# Teaching Standards in Wireless Communications

Technische Universität Braunschweig

## Using Standards in Wireless Communications Courses:

Typically, communication systems are set up by a huge number of components and entities, which are provided by a large number of different manufacturers. Interworking of all these components does not work without standardization. Furthermore, requirements coming from the economy of scale make it mandatory to have the same *standardized* systems globally wherever possible. As a consequence, when teaching communications engineering, education covering the overall design of communications systems is impossible without considering the standards behind these systems.

Teaching about standards is an integral part of my lectures: "Principles in Wireless Communications" and "Advanced Topics in Mobile Radio Systems." The first lecture considers in its second half complete wireless communications systems. The teaching on these systems covers the most relevant standards developed by 3GPP and IEEE 802®. The latter lecture includes systems at 60 GHz and beyond, where a lot of especially in IEEE 802 is ongoing. Each year, the lecture is updated with recent developments in IEEE 802.11™ and IEEE 802.15.3™. Master theses are often related to standards and include the implementation of standards into simulation tools. For example, the IEEE 802.11p™ standard has been implemented into the physical layer simulator developed by my group.

The market success of a specific wireless communications system does not only depend on its specific scientific and technical merits but is also significantly influenced by economic, political, and regulatory factors. These factors also heavily impact the standardization process. From my point of view, education on the interplay of these aspects is essential in order to prepare the students for the "real life" that is awaiting them after their time at the university. In my professional career, I have participated in many decisions in the area of standardization and regulation, which enables me to provide students with first-hand experience and information about how and why certain decisions have been made.

For more information on Standards and Standards development, visit www.standards.ieee.org

Practical Ideas from Professors: Standards Education in Your Courses

# Teaching Standards in Engineering Technology

## About the Department of Engineering Technology at Prairie View A&M University

Prairie View A&M University is located in eastern Texas, north of the city of Houston. The Department of Engineering Technology at Prairie View A&M offers educational programs and experiences designed to prepare students to meet the challenging demands of industry, society, and the nation as a whole. The goal of the department is to produce technology professionals capable of applying engineering principles in design, construction, and maintenance of electrical and computer systems. The Department of Engineering Technology offers two degree programs: Computer Engineering Technology (CPET) and Electrical Engineering Technology (ELET). Both these programs are accredited by the Engineering Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (ETAC of ABET). Each program prepares students to work as engineering technologists capable of applying engineering principles to design, construction, operation, and industrial production.

## Using Standards in Engineering Technology Courses:

It is valuable to include standards in engineering technology courses, such as CPET 4063 Data Communications Methods and CPET 4363 Computer Networking, because standards are used in industry, and they help students to bridge the real world and academia. I also use standards to evaluate student performance in my courses, analyze outcomes, and for ABET accreditations.

Dr. Sarhan M. Musa

As director of the Prairie View A&M University Avaya Networking Academy (PVNA), a senior member of IEEE, and a professor with sixteen years experience teaching data communications and networking for academia and industry, my goal is to prepare students for professional engineering practice. Since my involvement with Avaya, I have been exposed to Shortest Path Bridging (SPB), which is a technology detailed in an IEEE standard. Thus, I decided to teach my students about IEEE standards in my courses, focusing on the IEEE 802.1aq™ standard.

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# Teaching Standards in Engineering Technology

## Using Standards in Engineering Technology Courses (continued):

For example, I might assign students to groups, and have each group select two students to deliver a presentation on IEEE 802.1aq (SPB) following the guideline below:

1. Define IEEE 802.1aq standard
   a. Sponsoring organization/Key stakeholders
   b. Competition/Conflicts of interest
   c. Evolving concerns
   d. International concerns
2. Purpose of standard
   a. Why was the standard needed?
   b. Testing and evaluating standard guidelines
   c. Expanded product applications of standard
   d. Provide an executive summary
3. Competing standards
   a. Who? What? Why? When?
   b. Competing standards
4. Outlook
   a. Current and future outlook of network challenges and supporting standards and certifications
5. Presentation requirements
   a. Minimum of 10 slides
   b. Minimum of 20 minutes/Maximum of 30 minutes
   c. Ability to organize and plan, and design, prepare, and use appropriate visual aids for communication/presentation
   d. Ability to articulate subject knowledge (technical content)
   e. Appearance and ability to provide good oral delivery
6. Identify references/resources

Students need to be aware of standards due to rapid changes in technology today. Today's network, as shown in Figure 1, is consistent and complex due to multiple segments, multiple protocols, multiple resiliency constructs, box-by-box configuration, and manual device configuration. But, there is a better way to build today's networking, as shown in Figure 2, using the IEEE 802.1aq standard (SPB) through Fabric Connect's one network, one protocol, one active-active resiliency model, automatic core configuration, automatic device configuration, and IP extension.

Industry is always looking for young engineers who know about the advanced technology, such as Shortest Path Bridging.

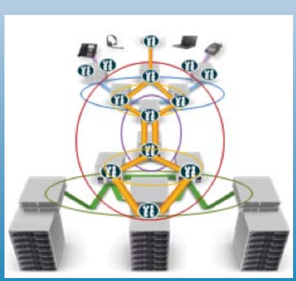

Figure 1

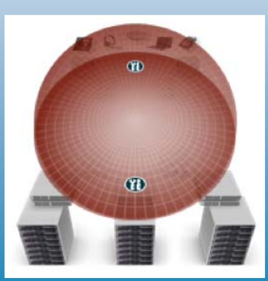

Figure 2

IEEE

Practical Ideas from Professors: Standards Education in Your Courses

# Teaching Standards in History & Technology Studies

## About the Program in Science & Technology Studies at Stevens Institute of Technology

Stevens Institute of Technology is a technology-centric university located in Hoboken, New Jersey, directly across the Hudson River from midtown Manhattan. The Program in Science & Technology Studies (STS) at Stevens is an interdisciplinary program within the College of Arts & Letters, an academic unit that oversees humanities and arts instruction for all Stevens undergraduates. STS, as a field of study, examines the feedback loops between science, technology, and society: both the social forces that shape scientific knowledge and technical practice, as well as the social consequences of research, innovation, and engineering.

## Using Standards in History & Technology Studies Courses:

History is the study of change over time in human societies; a recurring theme in most history courses is the tension between diversity and uniformity. For students who take history at the university level, learning about standards is akin to seeing human societies in microcosm. The standards-setting process demands that people with different interests and backgrounds work together toward a common end. There is always competition, and there is always cooperation. The process always generates winners and losers, and the divergent fates of groups and individuals often mirror their social standing and relative positions of power. There are many striking parallels between standards-setting processes and political history—such as constitutional conventions, multilateral agreements, and behind-the-scenes dealmaking. Standards, like politics, illuminate the subtleties and nuances of human behaviour.

Andrew L. Russell, Ph.D.

Associate Professor of History and Director of the Program in Science & Technology Studies at Stevens Institute of Technology in Hoboken, New Jersey. Russell is the author of *Open Standards and the Digital Age: History, Ideology, and Networks* (Cambridge University Press, 2014), a book about the emergence of the voluntary consensus approach to standards-setting for information and computing technologies. Russell earned a Ph.D. in the History of Science and Technology from Johns Hopkins University, and has been awarded fellowships from Duke University's John Hope Franklin Humanities Institute, the Charles Babbage Institute at the University of Minnesota, the Association for Computing Machinery History Committee, and the IEEE Life Members' Committee.

Practical Ideas from Professors: Standards Education in Your Courses

# Teaching Standards in History & Technology Studies

## Using Standards in History & Technology Studies Courses (continued):

At Stevens, we offer an entire course on standards within our STS curriculum. The course, titled "Standards and Society," provides an interdisciplinary overview of the place of standardization in modern societies. Students explore how standards play important roles in shaping their lives as consumers and citizens. Readings, lectures, and class discussions will consider the past, present, and future of standards-setting regimes in industrial, governmental, and international arenas through examples such as standards for computing, automobiles, food, medicine, and education. At the same time, students learn how they might participate in the development and use of standards in technical and social fields. Many of our students major in STEM fields, so they have already encountered standards in their technical classes. Moreover, they are very likely to encounter standards in their work after they graduate from Stevens.

One innovative aspect of our curriculum is our extensive use of simulation exercises. In these exercises, we introduce students to an imaginary technology—such as 3D printed devices, or sensor-filled wearable technologies—and assign them to play specific roles in the standards-setting process. Some students adopt the role of the safety-obsessed public servant; others adopt the role of a stodgy incumbent firm or a nimble, ambitious entrepreneur. The exercises generate a remarkable depth of discussion, insight, and learning that they do not experience in traditional lecture or seminar formats.

Another important consideration is to structure class assignments around subjects with which students already have a personal connection. All our students, for example, take standardized tests and are compelled to take part in course assessment procedures. These rituals, which are grounded in the desire to enhance fairness and effectiveness in education, are often confusing and opaque. Like all standards, educational standards are the products of complex social processes—in other words, they are reservoirs of endless teachable moments.

Practical Ideas from Professors: Standards Education in Your Courses

# Teaching Standards in Electronics & Communication Engineering

## Electronics & Communication Engineering Program at SSN

The Department of Electronics & Communication Engineering at the SSN College of Engineering, located in Tamil Nadu, India, offers an undergraduate program in the area of electronics and communication, and graduate and doctoral programs in the areas of communication systems, applied electronics and VLSI. In their final years, graduate students undertake individual projects, while undergraduate students undertake group projects in these areas. Recently, the department has initiated review of these projects by engineers from industry. Research within the department focuses on electromagnetics and antennas, image and speech processing, wireless communication networks and VLSI and MEMs.

## Using Standards in Technical Field Courses:

Measurements are fundamental to the advancement of technology. The practical requirement that measurement results be widely understandable requires the use of units, and hence standards [1]. This requirement is at a rather fundamental level, and plays an implicit but extremely important role in any measurement, but especially in measurements undertaken to validate engineering designs. This means that standard test procedures are available, so the results can be understood across countries. In antenna measurements, an area of my work, for example, in measuring the gain of a test antenna using the reference antenna method, a standard antenna is always required to be part of the measurement system.

**Dr. Krishnasamy Selvan**

Prior to teaching, Dr. Selvan was with a government microwave research and development organization for seventeen years. He began teaching in 2005 and focuses on electromagnetics and antennas to undergraduate and graduate students, and supervises masters' and doctoral research. As a member of the IEEE Antennas and Propagation Society's Education Committee, he has special interest in electromagnetic education. In his teaching, Dr. Selvan gives particular importance to measurement methods, and emphasizes the importance of developing an understanding of uncertainty in measurements, a key aspect of metrology and standards.

# Teaching Standards in Electronics & Communication Engineering

## Using Standards in Technical Field Courses (continued):

A statement of uncertainty is expected to be included in reporting any professional measurement result. For example, such a statement is required for measurements related to quality control, basic research and calibrating standards [2]. This requirement applies to many fields, including electronics and communication engineering [3]. Therefore, I think it is an important requirement that engineering students develop a good understanding of this topic.

For the courses on radiation systems, both at undergraduate and graduate levels, I discuss the standard antenna gain measurement procedures and the importance of uncertainty estimation in measurements. When possible, I make a short presentation on my work in the area (for example [4]). As part of an assessment, I ask students to submit a written assignment on the topic, discussing the importance and methods of uncertainty estimation in general, and in antenna measurements in particular. I advise project students also to become aware of the importance of this topic.

I think it may be a good idea to ask students to determine the uncertainty in making their laboratory measurements. While this may not be feasible for every measurement, if they can do it at least for one specific measurement, they can gain a good understanding of the topic.

Given that standards are "documented agreements containing technical guidelines to ensure that materials, products, processes, representations and services are fit for their purpose," [5] included within their purview are measurement methods and references, among others. In my teaching of antenna measurements, standard methods are covered. These include the so-called reference antenna gain measurement method, where a reference antenna is part of the measurement setup.

### Benefits for Students

As discussed in [5], there is a unique relationship between standards and innovation. Gaining a decent level of understanding of the role standards play in science and engineering will certainly help students to be better engineers and scientists in industry, and in fact in any organization.

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Practical Ideas from Professors: Standards Education in Your Courses

# Teaching Standards in Electromagnetics & Communication

## The Engineering Program at CentraleSupélec

In 2010 the Department of Electromagnetics of Supélec (CentraleSupélec since 2015), a Grande Ecole graduate school of engineering located in the Île-de-France region of France, successfully implemented a graduate course entitled Human Exposure and Electromagnetic Field Measurement. This course, which is proposed within the Electromagnetics and Communication program, is taken during the last year of the 3-year engineering curriculum.

## Program Details:

The aim of the Human Exposure and Electromagnetic Field Measurement course is to provide a sound knowledge of: the problem of human exposure to electromagnetic fields, the currently applied standards and exposure limits, and the methodology for the evaluation of the exposure. It appeared natural to incorporate international guidelines, recommendations and standards related to electromagnetic field exposure in this course.

Prof. Vikass Monebhurrun

Professor Vikass Monebhurrun has been actively participating in French National Research Programs on dosimetry since 1998. His research has contributed to the international standardization committees of CENELEC, IEC, and IEEE. He is author or co-author of about 100 peer-reviewed conference and journal papers and he holds three international patents on antennas for mobile communications. He actively participates in several international standardization committees on numerical and experimental dosimetry, namely IEEE 1528™, IEC 62209, IEC 62232, and IEEE/IEC 62704. He currently chairs the IEEE Antennas and Propagation Standards Committee as well as the IEEE/IEC 62704-3 Standardization Committee.

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# Teaching Standards in Electromagnetics & Communication

CentraleSupélec

## Using Standards in Electromagnetics and Communication

The course starts with an introduction to commonly encountered wireless communication systems and standards, e.g., IEEE 802.11™. Following a historical review of how the problem of electromagnetic field exposure was addressed in different countries—dating back to the use of radars by the military during World War II—the need for a consensus-based document, i.e., a standard, elaborated by a committee of recognized experts is demonstrated. One of the references for the definition of the electromagnetic field exposure limits is IEEE C95.1™. There are also references to similar documents proposed by other national or international committees to emphasize the importance of developing harmonized standards to ensure worldwide acceptance.

Once the exposure limits are defined, the standards applied to demonstrate product compliance—prior to the marketing of the handsets and the installations of the base station antennas—are presented. For example, the measurement procedure for the Specific Absorption Rate (SAR) evaluation of handsets, as described in IEEE 1528™, is detailed. As an application example, the step-by-step design of a mobile phone is considered: it is verified that the prototype mobile phone complies with both performance and SAR standards. The students further learn that if a standardized measurement procedure is enforced, it guarantees that the results can be replicated by another test laboratory, within a given measurement uncertainty. Since a standard dosimetric test facility is also available in the laboratory, the students can follow a demonstration of the measurement procedure used to show the SAR compliance of a mobile phone.

Since there are multiple bodies—national as well as international—developing standards for different electrical engineering applications, it is expected that, following this course, the student is able to find the right standard for a given purpose once he/she starts to work as a professional engineer.

# NEWS AND FURTHER READING

19 May 2016
David Law

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**NEWS AND FURTHER READING**

**Light Could Become the Dominant Form of Heat Transfer**
By Dexter Johnson, *IEEE Spectrum*, Posted 1 Apr 2016

**Automotive Industry Driving Wireless Charging into Mainstream Adoption**
By John Perzow, Wireless Power Consortium
Published 9 March 2016

**Scientists propose high-efficiency wireless power transfer system**
January 26, 2016 by Lisa Zyga, Phys.org

**IEC Developing Test Standards for Wireless Power Transfer Products in Two Committees**
Published by Compliance Today on 18 January 2016

**IEEE Communications Magazine Special Issue on Wireless Powered Communications Networks: Architectures, Protocol Designs, And Standardization**
Published: April 2016

**EVENTS**

**Complimentray Webinar: Review of Recent Advance in Dynamic and Omnidirectional Wireless Power Transfer**
Sponsored by IEEE Industry Applications Society
8 June 2016, 11:00am EDT

**2016 IEEE Transportation Electrification Conference and Expo (ITEC)**
Sponsored by IEEE Power Electronics Society, IEEE Industry Applications Society, IEEE Power & Energy Society
Dates: 27 Jun – 29 Jun 2016
Location: Knoxville, TN, USA

**2016 IEEE PELS Workshop on Emerging Technologies: Wireless Power Transfer (WoW)**
Sponsored by IEEE Power Electronics Society
Dates: 20 Jul – 22 Jul 2016
Location: Dearborn, MI, USA

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# FUNNY PAGES

19 May 2016
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# A NIST INDUSTRY-ACADEMIC WORKSHOP: 8-9 SEPTEMBER

18 May 2016
David Law

**A NIST Industry-Academic Workshop:** ***Standards and the Digital Economy – Implications for Teaching and Policy***

***Dates: 8-9 September 2016***
***Location: Gutman Conference Center, Harvard University, Boston, MA, USA***

Management, engineering, economics, law and policy courses covering the Digital Economy often miss an essential strategic and competitive element – emerging interoperability *standards*.

This 1.5 day industry-academic workshops will explore what these standards are, how they are developing and how the topic can be addressed in teaching. Speakers, panelists and discussion leaders will include representatives from academia, government, and standards developers and participants will work through an interactive simulation exercise.

***You should attend if you are:***

- *Teaching faculty and academic researchers focused on policy, strategic planning, economics, operations, marketing, or engineering design. Students working with participating faculty are also welcome.*
- *Managers, standards setters, and government policy makers at the operational and strategic levels.*

**For more information and to register:** http://gsi.nist.gov/global/index.cfm/L1-4/L2-14/A-794

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**About NIST Industry Academic workshops**
Since 2014 NIST Industry Academic workshops have addressed the underlying role of standards and standardization in rapidly evolving business and industry sectors. Earlier workshops held at Northwestern University, UCLA, University of Pittsburgh and Georgetown University focused on smart systems including smart grid, cloud, smart manufacturing; cybersecurity; and supply chain operations, strategy and infrastructure development.

This event is sponsored by the National Institute of Standards and Technology's Standards Coordination Office in collaboration with the Harvard Kennedy School, and Northwestern University and with hospitality hosted by IEEE.

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# CALL FOR IEEE STANDARDS EDUCATION EMAGAZINE CONTRIBUTIONS

17 May 2016 | David Law

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The IEEE Standards Education eZine Editorial Board invites contributions from industry practitioners, educators and students on topics related to education about technical standards. Interested parties may submit an inquiry or article abstract for consideration to the Editorial Board at any time throughout the year via email to: ezine-eb@listserv.ieee.org. Abstracts should be no longer than 500 words and final articles should be no more than 2,000 words. Particular areas of interest include, but are not limited to:

- impact and development of standards in various regions of the world;
- reliance by employers on complying with standards for introducing their products to the marketplace
- best practices and ideas for incorporating standards into the classroom and curricula

Final contributions should include a 100 word biography of the author(s) and a high-resolution (JPEG) picture. All illustrations must be provided in a high-resolution (JPEG) format. References to all copyrighted material must be properly cited.
**The theme of the 4th quarter 2016 issue is Smart Cities. Articles for the 4th quarter issue will be due by 15 September 2016.**

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# ABOUT THE IEEE STANDARDS EDUCATION E- MAGAZINE

**A PUBLICATION FOR THOSE WHO LEARN, TEACH, USE, DEPLOY, DEVELOP AND ENJOY STANDARDS!**

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. Standards are:

- developed based on guiding principles of openness, balance, consensus, and due process;
- established in order to meet technical, safety, regulatory, societal and market needs;
- catalysts for technological innovation and global market competition.

- Knowledge of standards can help facilitate the transition from classroom to professional practice by aligning educational concepts with real-world applications.

IEEE is committed to:

- promoting the importance of standards in meeting technical, economic, environmental, and societal challenges;
- disseminating learning materials on the application of standards in the design and development aspects of educational programs;
- actively promoting the integration of standards into academic programs;
- providing educational materials about standards needed in the design and development phases of professional practice.
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Serving the community of students, educators, practitioners, developers and standards users, we are building a community of standards education for the benefit of humanity. Join us as we explore the dynamic world of standards!

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