WHITE PAPER | 2022

WIRELESS POWER TRANSFER (WPT)

SURVIVAL, CHALLENGES AND SOLUTIONS

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INTRODUCTION

As a society, we have fallen out of love with cables – partly because of how inconvenient it is to be tethered in place as we use a device and partly because, as end users, we are now inescapably aware of the fact that there is a better way. Wireless communication between devices is becoming more widespread and more attainable, and its appeal is undeniable.

Wireless communication has many benefits for individuals and society, ranging from a reduction in copper cables (a net gain to the environment) to improved usability for those with limited mobility who might struggle to connect and disconnect cables, to plain old convenience. With cellular devices, we have essentially achieved completely cable-free transfer of data, but the pesky problem remains that communication devices need an energy source to work. A phone or a computer can transmit a staggering amount of information through empty air, but when the battery runs low, the user has no choice but to be tethered to a wall again. Could wireless power transfer (WPT) be the ultimate solution and one day become as ubiquitous as the wireless communication interface?

This paper highlights some of the technology, use cases and regulatory challenges for WPT and where this technology may lead us in the future.

USE CASES FOR WIRELESS POWER TRANSFER (WPT)

Think about all the products plugged into the outlets around your home or office. It's undoubtedly a long list, ranging from objects that never move, like your refrigerator, to objects that never sit still, like your cell phone. It's obvious why WPT is so useful for devices like cell phones, and why cell phones were the first widespread application for wireless charging, but WPT has much wider potential both inside and outside the household. Imagine being able to move countertop appliances around your kitchen as you work, without worrying about short cords or the position of our outlets. Imagine an electric wheelchair that never needs to be plugged in. We have already integrated some forms of WPT into our lives, and it is clear that there are many more cases where WPT would offer significant benefits.

Household

Unlike a refrigerator, countertop kitchen appliances like blenders are often moved from one surface to another in both home and restaurant kitchens. If such appliances could charge wirelessly, it would not only be more convenient, but reduce the risk of snagging, damaging, or tripping on cords when the appliance needs to be moved. Hot plates, which are an electric alternative to tabletop gas burners with open flames, are much safer than their gas counterparts but have the distinct disadvantage of needing to be plugged in. Wireless power transfer could make these appliances the ideal option for cooking at the table, both in homes and restaurants.

It's hard to overstate the convenience of dropping your mobile devices on a table that charges them as if by magic, of course. The first laptops and tablets with rechargeable batteries created a similarly liberating shift in consumer expectations. Wireless charging has advantages beyond convenience, however. Currently, every chargeable device comes with a charger, one which is likely incompatible with all your other devices and which will become defunct if you ever replace your device. Likewise, when you misplace or damage a cord, or if you need to charge a device like a phone in multiple places, you are forced to buy new cables. All of this creates a lot of unnecessary electronic waste. By eliminating the physical link between devices and cords, wireless power transfer systems could be made entirely device-agnostic.

WPT USE CASES

WPT also has applications to help those with disabilities. For people with limited mobility, this technology could remove the need to bend over, move objects, or reach for a wall outlet to plug something in, and for those with limited dexterity, placing a phone or tablet anywhere within range of a WPT device is much easier than plugging in a tiny cord. Devices such as hearing aids would also become significantly more user-friendly with WPT. Changing the tiny batteries in these devices is challenging, but designing a hearing aid with a charging port requires the device to be physically larger. By eliminating charging ports, WPT could also allow the exterior of a medical device to be completely sealed, making them more water-resistant, easier to clean and potentially more comfortable when in contact with the body.

Commercial & Industrial Applications

Modern machines are becoming more autonomous; many can communicate with each other without the need for human input (often called M2M communication), and independently move around complex spaces. These machines require built-in batteries rather than power cables, which of course necessitate periodic recharging. It is much easier and more practical for an autonomous machine to utilize WPT charging than for the same machine to try to plug itself into a wall socket. It is already very common for machines such as robotic vacuum cleaners to charge themselves by stopping on a charging pad with exposed metallic contacts that transfer power. This is an improvement over a plug and socket for this type of device, but WPT offers even greater potential for product improvement.

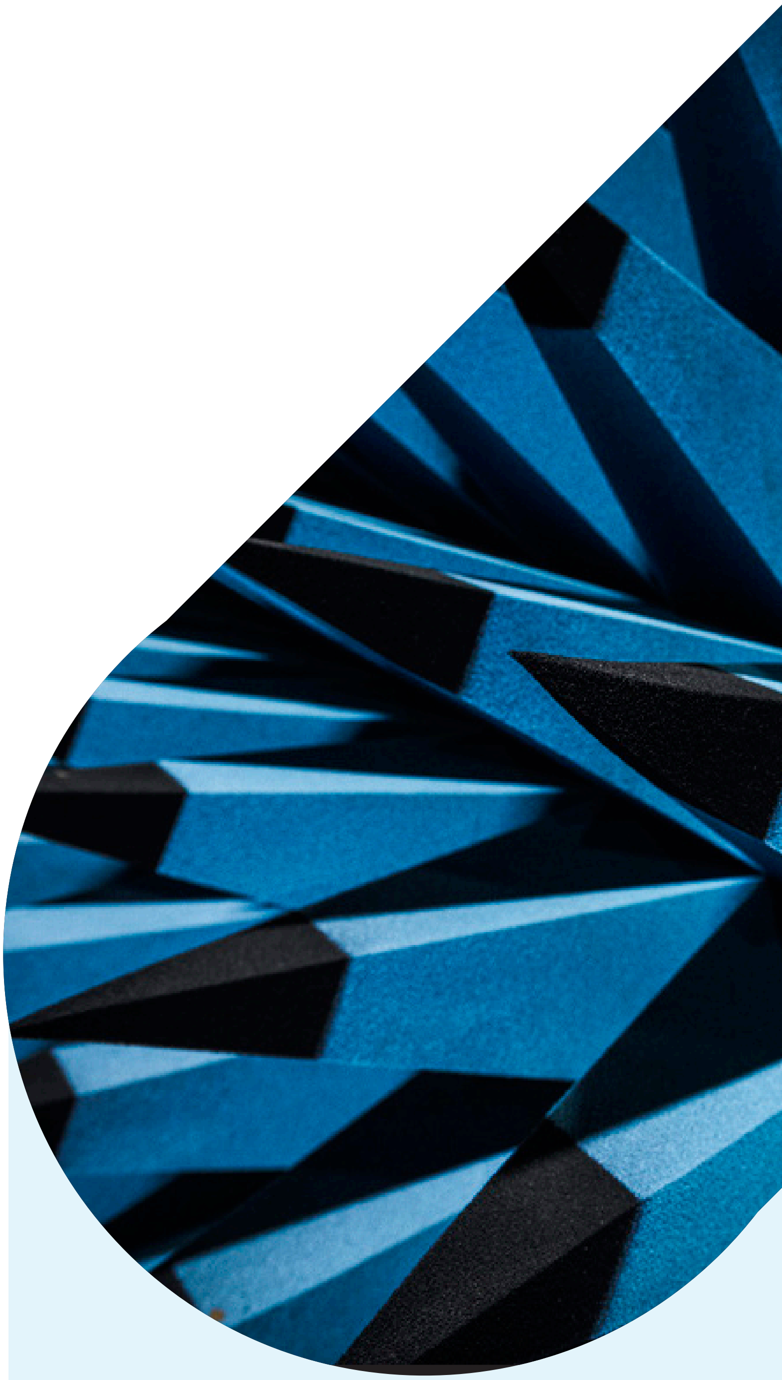
The major drawback of a charging pad in an industrial setting is that the robot has to stop work to charge. One innovative solution would be to embed WPT coils into the most travelled route the robot takes, allowing it to charge frequently or even constantly while continuing to work. This would not only increase productivity dramatically but may allow future robot designs to use smaller, lighter batteries.

Many RFID technologies already integrate a type of WPT that uses passive tags. As the RFID chip is scanned, a high-powered radio frequency (RF) channel provides sufficient energy to power up the tag and transfer the relevant data. The tag then powers down when it is moved away from the scanner. Applications for this type of small-scale WPT are wide and varied. Small tags like this can be used to track commercial laundry, both to monitor its location and to log how many times it has been washed, or to survey objects for shops or hospitals. The potential for general asset tracking is very promising.

“One innovative solution would be to embed WPT coils into the most travelled route the robot takes, allowing it to charge frequently or even constantly while continuing to work.”

Transportation

In the transportation industry, WPT has applications that largely provide improved convenience, but may provide measurable quality of life improvements for some users. By volume, personal vehicles are the largest segment of the transportation industry, and electric vehicles are changing the transportation landscape forever. For many electric vehicle owners, it is no great hardship to plug in a vehicle for charging, but in urban areas, electric vehicle owners rely on street charging. Cables stretched across sidewalks in crowded cities have the potential to become damaged by the environment and may even present a hazard to passers-by. Wireless charging stations could make it possible for vehicle owners to pull up beside a charging area and begin charging their vehicles instantly, without even leaving the car. This is a convenient solution for the average person, but for wheelchair users or other people with limited mobility, it could allow them to travel and accomplish tasks more independently.



With so many applications, what kind of technology supports WPT?

TECHNOLOGY THAT SUPPORTS WPT

Magnetic Induction

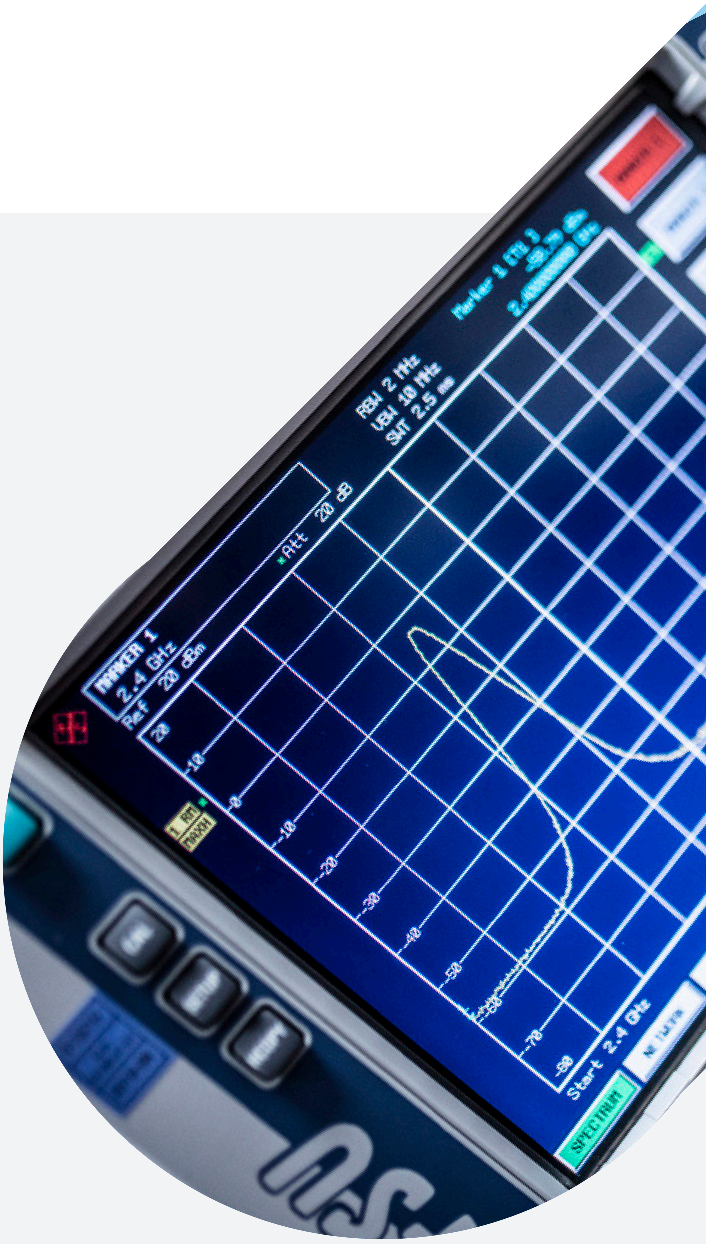
Products like induction cooking burners use an old but reliable technology called magnetic induction. It works on the same principle as a transformer: the current feeds into the primary coil and produces a voltage into the secondary coil, which in turn is used to power the product. In the case of a burner, the secondary coil is a ferrous metal and due to the eddy currents, it produces heat. The heat from the pan is then conductively coupled to the contents of the pan. Traditional magnetic induction systems use the power frequency (50/60 Hz).

Magnetic Resonance

Magnetic resonance systems are more complex than induction since they use switch-mode technology to convert the AC input to a higher frequency (typically a frequency reserved for industrial, scientific, and medical use, or “ISM” band) and gain an efficiency advantage. The receiving coil is tuned to a slightly different frequency than the primary coil to ensure maximum power transfer.

Radio Frequency

RF-based WPT systems are a new generation of wireless power transfer. They essentially work on the same principles as any radio communication system, insofar as transmitter and receiver are tuned to the same frequency. Directional antennas ensure that the energy is focused on a small area. There are a limited number of available frequencies since this type of WPT system (ISM) requires a dedicated frequency to ensure it doesn’t interfere with other communication systems.



THE REGULATORY ENVIRONMENT

A major part of bringing a product to market is ensuring that it meets the market's regulatory requirements. There are many different regulatory approvals in place around the world, but they largely follow one of two models: the North American model or the European model.

Beyond common regulatory requirements such as safety, radio frequency and electromagnetic compatibility regulations are perhaps the biggest hurdles for manufacturers to overcome. This is partly due to contradictory categorization systems in different regions: some consider WPT a type of ISM product, while others consider it radio or wireless equipment.

WPT as an ISM Device

If a WPT product produces a pure radio frequency signal with no modulation, then it is considered an industrial, scientific and medical (ISM) technology. The term ISM originates from the International Telecommunication Union (ITU), which aims to harmonize frequency bands across the world for common uses, thereby reducing variations in products and increasing global trade. The ITU Radiocommunication Sector (ITU-R) has allocated certain frequency bands for ISM use, which include applications such as induction cooking, treatment of materials and the transfer of electromagnetic energy (which includes WPT).

Manufacturers can use ISM bands for communication, but they must do so with the understanding that they are not protected from interference. A manufacturer needs to weigh the potential use of available ISM frequencies against the efficiencies and practicalities of using a particular band. Although ISM bands are sensible for lower-power applications, high-power applications such as electric vehicle charging are more challenging. For efficiency reasons, high-power charging needs to be performed at a low frequency (in the kHz region). There are currently no dedicated ISM frequencies allocated in this range. ITU-R is making progress toward 'recognizing' certain frequencies, but this may not necessarily be accepted throughout the world, leaving it up to individual countries to allow their use or not. This is not ideal for vehicle manufacturers, since it would mean WPT charging is available for some vehicles in some countries but not others.

WPT as a Radio Equipment

In Europe and certain other regions, when a WPT device uses modulation (or any other communication/determination technique) to exchange information with the load at its power frequency, it is considered radio equipment. If the WPT device exchanges information using a form of communication other than the power frequency, such as Bluetooth or ZigBee, the final product is still considered radio equipment, but since the WPT frequency itself is not communicating, it is considered an ISM device.

ISED & FCC GUIDELINES

North America – USA (FCC) / Canada (ISED)

Intentional radiators that transmit information must be certified under the appropriate Federal Communications Commission (FCC) Part 15 Rules, and will generally require an equipment certification. A WPT device may operate in two different modes: charging and communications. It is possible for the device to be approved under Part 18 for the charging mode and Part 15 for the communications mode if the device demonstrably complies with the relevant rule parts and the functions are independent. Part 18 consumer devices can be authorized using either certification or Suppliers Declaration of Conformity (SDoC), once the appropriate RF exposure evaluation has been completed.

A new standard for WPT applications is underway within ANSI (C63.30) and is due to be published in late 2021 or early 2022. While this is still in development, this description presents the current situation with the FCC.

FCC guidelines for Radio Frequency (RF) exposure

The FCC's Knowledge Database (KDB) guideline 680106 states that devices specifically intended for wireless power transfer or inductive charging require FCC guidance for frequency exposure review. This includes Part 18 devices. It may be necessary for the responsible party (in most cases, the manufacturer) to seek support from the FCC on specific WPT devices by submitting a KDB inquiry.

How to proceed with FCC approvals

In the U.S, product manufacturers must seek guidance from the FCC by submitting a wireless charging application inquiry, unless the device meets the requirements per KDB 680160 section 5 outlined in the list below. Medical devices are not covered under KDB 680160, so inquiries for these devices would be needed on a case-by-case basis.

Requirements cited per KDB 680160 section 5:

1. The power transfer frequency is less than 1 MHz.

2. Output power from each primary coil is less than or equal to 15 watts.

3. The transfer system includes only single primary and secondary coils. This includes charging systems that may have multiple primary coils and clients that can detect and allow coupling only between individual pairs of coils.

4. The client device is placed directly in contact with the transmitter.

5. Mobile exposure conditions only (portable exposure conditions are not covered by this exclusion).

6. The aggregate H-field strengths at 15 cm surrounding the device and 20 cm above the top surface from all simultaneous transmitting coils are demonstrated to be less than 50% of the MPE limit.

The inquiry to the FCC should include the following:

- Complete product description, including coil diameters, number of turns and current
- FCC Rule Part(s) the device will operate under and the basis for selecting the Rule Part(s)
- Planned equipment authorization procedure (i.e., SDoC or certification)
- Drawings, illustrations
- Frequency of operation
- Radiated power
- Operating configurations
- Conditions for human exposure

ISED & FCC GUIDELINES

RF exposure guidelines in Canada

Canada takes a different approach to RF exposure for wireless inductive charging devices, separating products and sub-components into three type categories per Radio Standards Specification 216 (RSS-216, Issue 2, Amendment 1, September 2020, Wireless Power Transfer Devices):

- Type 1: Does not transmit any intelligence and does not require certification
- Type 2: Category II Radio - includes modulation on WPT frequency but is certification exempt
- Type 3: Category I Radio - requires certification

WPT devices must also comply with Health Canada's Safety Code 6 for RF exposure. When assessing compliance, all transmitters must be at maximum power. This includes those not used for power transfer.

EMC compliance for wireless charging devices

For the FCC, a radiator would need to be tested and certified under the relevant portion of FCC part 15C (FCC 15.209, FCC 15.225, etc.) if it is intended for telecommunications applications involving the transmission of data. FCC Part 18 is allowed where no intelligence is transmitted, such as in cases where RF is used to perform work heating, welding, treatment of materials, and charging. Only in specific cases, and by very limited means, is charge status (but not temperature) allowed to be transmitted via Part 18.

Requirements cited per KDB 680160 section 2a:

If systems use load impedance, also called load modulation, on the client device's fundamental transfer frequency for the sole purpose of load management, those systems may be authorized under Part 18. The load modulation must be integral to transfer system power management and control and must be used only to the extent necessary to enable safe and efficient operation. Valid applications include rapid shut-down in response to over-voltage conditions, reporting of charging status, and identification of invalid devices.

For devices authorized under Part 18, load modulation may not be used to communicate any other information, such as the device's charging prioritization or the transfer of extended system data, images or music. For devices that perform these functions, both Part 15 and Part 18 requirements must be satisfied for equipment approval. Similarly, devices that use a 680106 D01 RF Exposure Wireless Charging App v03 Page 2 secondary frequency for load management, control and data functions must be authorized according to both Part 15 and Part 18 requirements, as appropriate.

For Canada, per RSS-216, devices without communication capabilities would be tested to ICES-001, which references CISPR 11 group 2. Devices with communication would be tested to the relevant product standard (RSS-210, RSS-310, etc.).

EUROPE – CE MARKING / UKCA

Much like in the US and Canada, a system that performs only wireless power transfer and no other wireless communication transfer would not fall under the EU's Radio Equipment Directive (RED). However, any form of communication, such as load modulation, would fall under the RED.

Products that propagate electromagnetic waves in space, but are not intended for radio communication or radiodetermination are not covered by the RED. Such products include:

- Inductive warming or heating appliances (including cookware)
- Pure wireless power transfer (excluding any communication or radiodetermination)
- High-frequency surgical equipment
- Test equipment, if intended to use radio waves exclusively for testing other devices

This, in turn, affects which standards are used to demonstrate compliance and determines the need for a Notified Body. Products falling under the scope of the EMC Directive/Regulations will assess the product against EN 55011, the European version of CISPR 11. This standard covers ISM products and specifically addresses the requirements for WPT devices that do not communicate. Since products of this type will be classified as ISM products, they either need to operate on an ISM frequency or meet the emission limits for general products. There are a limited number of ISM frequencies throughout the world, however, and they are not truly harmonized, therefore careful consideration of these frequencies is very important.

WPT devices that do communicate on their power frequency are considered radio communication equipment and are therefore subject to a different set of regulatory requirements, although both routes consider harmful interference and safety concerns. The applicable standards are written by the European Telecommunications Standards Institute (ETSI), which is the European standards body for telecommunication equipment. The standards entitled EN 303 417 and EN 300 330 are available for use by manufacturers to demonstrate that they make efficient use of spectrum requirements (Article 3.2). If no standard clearly applies to a manufacturer's specific product, the manufacturer can choose to use the services of a Notified/Designated Body, which will use other methods to demonstrate compliance to the 'essential requirements' of the directive or regulation. This is a more complex process since the manufacturer will need to demonstrate that their product meets essential requirements and can avoid harmful interference without relying on the predetermined set of parameters provided by a standard.

EMC requirements are also applicable, and EN 301 489-1/3 would typically be applied to demonstrate that the product works as intended (i.e. within manufacturer specifications) within its intended electromagnetic environment.

In Europe, RF Exposure considerations fall under safety requirements (as opposed to North America, where they are considered an RF requirement). The device must comply with the requirements of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and must meet Article 3.1a of the Radio Equipment Directive/Regulations. This compliance is typically demonstrated using international standards that have been converted to a European equivalent such as EN 50566, EN 50663, EN62311, or EN62233; the exact standard will depend on the application.

THE FUTURE OF WIRELESS POWER TRANSFER

For more information, please visit **element.com**

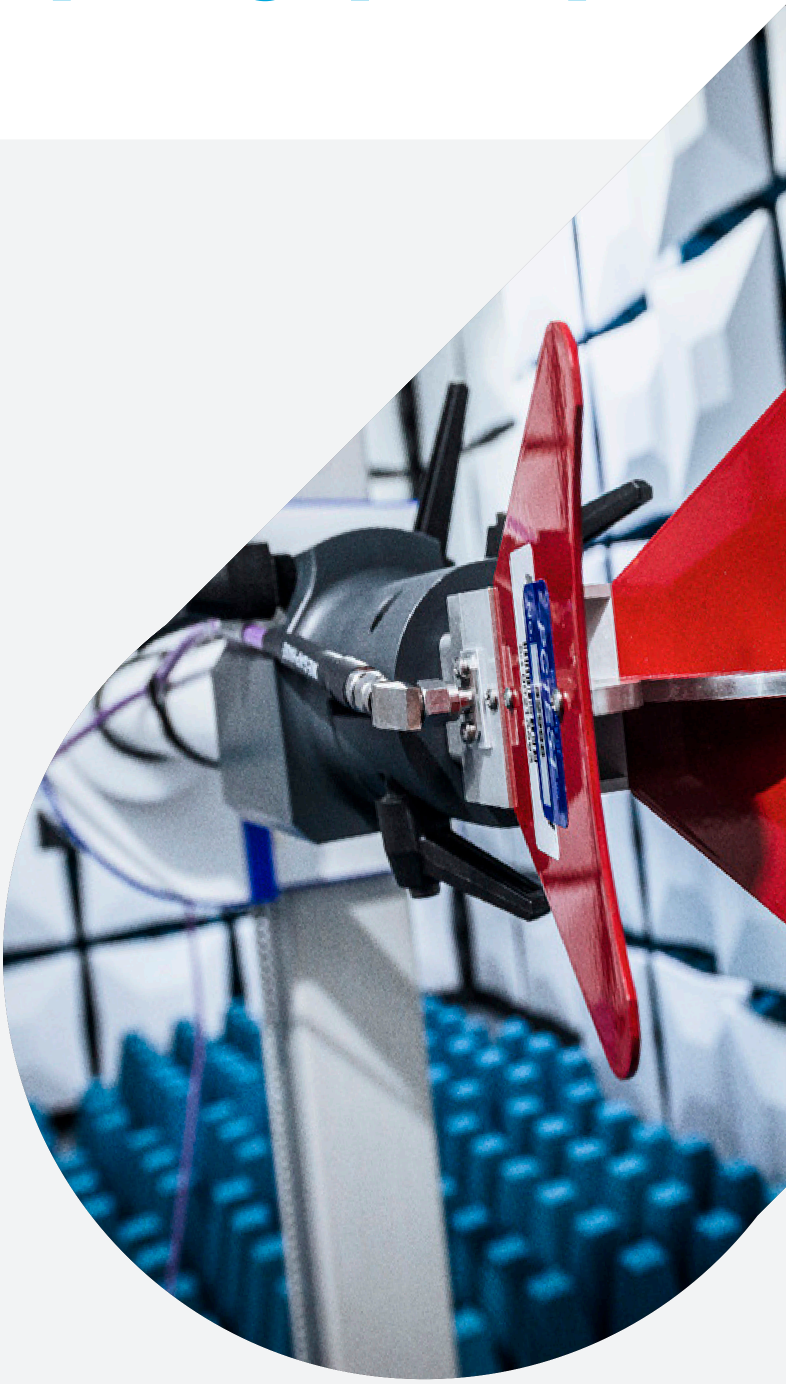
THE FUTURE OF WPT IN THE REGULATORY ENVIRONMENT

Since the regulatory environment for WPT products varies throughout the world, many different regulatory conditions must be fulfilled for a product to be distributed globally. These conditions range from dedicated standards that provide a clear route to compliance to vague and ambiguous requirements. There are also different ways to classify the same technology – is it a radio device or is it an ISM product? Perhaps WPT products will ultimately become their own category.

The ITU-R has taken the lead on trying to establish dedicated frequency bands where none currently exist for WPT. Trying to resolve and designate new frequency allocations without interference to existing allocations and while supporting efficient use of the spectrum is a delicate job. This work is time-consuming and will not conclude for some time, but users want the convenience of WPT technology now.

North America (FCC and ISED) has a clear route to compliance established, but this is only part of a manufacturer's solution to unlock a global market. The European regulations appear more relaxed since the compliance regime is largely based on 'self-declaration,' but manufacturers need to perform a risk assessment and conduct their own studies to ensure that products do not cause harmful interference. This, in turn, leads to different interpretations of what needs to be done and every manufacturer ends up taking a different approach.

ETSI and the CEPT are currently investigating different WPT technologies with co-existence studies, but given the slow process of collecting data and publishing new standards to the satisfaction of the European Commission under the RED, their process will also not conclude for some time. In the interim, Notified Bodies work to monitor the rapidly changing landscape, harmonize requirements and ensure that manufacturers provide evidence of their efficient and effective use of the spectrum (remit of the radio equipment directive).



HOW ELEMENT CAN HELP

LEADER IN CARRIER APPROVALS, REGULATORY CAPACITY AND 5G EXPERTISE

Element is deeply involved with the work of the WPT industry across the world and has positively tested and certified many different types of WPT devices.

Only a small number of third-party labs such as Element have made such investments, driven by developments in 5G technology. The resultant increased knowledge and understanding of complex wireless systems operating in the millimeter wave frequency ranges puts them in a unique position of being able to offer a test service that ensures the product will gain market access and be accepted by the industry as well as the knowledge and skills needed to test other wireless systems operating at higher frequencies.

Contact Element today for WPT testing and much more.

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