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Radio frequency beam wireless power transfer (WPT) for mobile devices

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Radio frequency beam wireless power transfer (WPT) for mobile devices

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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CONTENTS

FOREWORD ... 3
1 Scope ... 5
2 Normative references ... 5
3 Terms and definitions ... 5
4 Introduction to RF beam WPT ... 5
4.1 Overview of the RF beam WPT type ... 5
4.2 Requirements for RF beam WPT ... 6
4.2.1 General ... 6
4.2.2 Power transfer system design of RF beam WPT ... 7
4.2.3 Available candidate frequencies of RF beam WPT ... 8
4.2.4 Operating principle of omnidirectional RF beam WPT ... 8
4.2.5 Operating principle of directional RF beam WPT ... 9
4.3 Operating scenario of RF beam WPT ... 11
4.3.1 Possible requirement for RF beam WPT ... 11
4.3.2 Operating scenario of omnidirectional RF beam WPT ... 12
4.3.3 Operating scenario of directional RF beam WPT ... 12
5 Trends in standards, regulations, and technologies related to RF beam WPT ... 14
5.1 Trends in standards related to RF beam WPT ... 14
5.2 Trends in regulations related to RF beam WPT ... 15
5.3 Trends in global products related to RF beam WPT ... 19
6 Summary ... 22

Figure 1 – TX and RX structures of RF beam WPT ... 7
Figure 2 – Beam pattern diagram of omnidirectional RF beam WPT ... 8
Figure 3 – Example of high-output omnidirectional RF beam WPT in the space ... 9
Figure 4 – Beam pattern diagram of directional RF beam WPT ... 9
Figure 5 – Electromagnetic wave transmission/reception at each pattern antenna of directional RF beam WPT ... 10
Figure 6 – Direction RF beam WPT (a) description on delay generation at each pattern antenna (b) delay adjustment method to transmit desired signals ... 10
Figure 7 – Example of beam pattern formation by the delay and direction adjustment of the transmission signals of each antenna ... 11
Figure 8 – Expected operating scenario of omnidirectional RF beam WPT ... 12
Figure 9 – Expected operating scenario sequence of directional RF beam WPT – Pilot signal transmission from the single RX in case of an obstacle ... 13
Figure 10 – Expected operating scenario sequence of directional RF beam WPT – Directional WPT to the single RX in case of an obstacle ... 13
Figure 11 – Expected operating scenario sequence of directional RF beam WPT – Directional WPT from multiple TXs to multiple RXs in case of an obstacle ... 14

Table 1 – Overview of the RF beam WPT type ... 6
Table 2 – Characteristics of candidate frequencies for RF beam WPT ... 8
Table 3 – Activities of domestic/overseas standardization organizations related to RF beam WPT ... 15
Table 4 – Major recommendations and regulations of standardization organizations related to WPT for mobile devices ... 16

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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RADIO FREQUENCY BEAM WIRELESS POWER TRANSFER (WPT) FOR MOBILE DEVICES

FOREWORD

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IEC TR 63239, which is a Technical Report, has been prepared by technical area 15: Wireless power transfer, of IEC technical committee TC 100: Audio, video and multimedia systems and equipment.

The text of this Technical Report is based on the following documents:

Draft TR	Report on voting
100/3212/DTR	100/3317/RVDTR

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

RADIO FREQUENCY BEAM WIRELESS POWER TRANSFER (WPT) FOR MOBILE DEVICES

1 Scope

This Technical Report presents the surveyed technologies, product development trends, international standards, and regulation trends of RF beam WPT. This report can be used for the research and analysis of projects that apply small-output remote WPT to mobile devices, such as smartphones, Internet of Things (IoT) devices, and ultra-small sensors.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
IoT
Internet of Things
service-based facilities to provide advanced services by connecting the various things of the physical world and the virtual world based on information communication technology

Note 1 to entry: Infrastructure computing devices for realizing ubiquitous space are embedded in environments and things to make them intelligent and to expand the machine-to-machine (M2M) concept, which is capable of intelligent communication between humans and things or between things to the internet.

Note 2 to entry: The concept has evolved into a concept that interacts with all the information of reality and the virtual world as well as things. The major technologies of IoT include sensing technology, wired and wireless communication and network infrastructure technology, IoT interface technology, and service technology through IoT.

3.2
Wi-Fi
Wireless-Fidelity
certification mark provided to products compatible with the regulations determined by the wireless LAN (WLAN) specifications (IEEE 802.11b) using 2,4 GHz

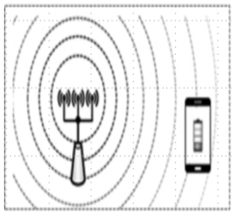
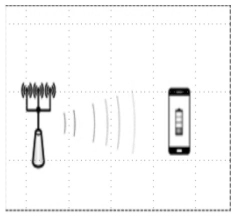
Note 1 to entry: Among the products manufactured in accordance with these specifications, the ones that passed the test of the Wireless Ethernet Compatibility Alliance (WECA), a group founded by wireless-network-related companies, can have this mark.

4 Introduction to RF beam WPT

4.1 Overview of the RF beam WPT type

RF beam WPT performs remote WPT using omnidirectional or directional antenna beam patterns. This type is divided into the omnidirectional type, in which electromagnetic waves are radiated in all directions to achieve constant radiation intensity in any direction, and the directional type, in which radio waves are transmitted in a certain direction. Table 1 shows the Overview of the RF beam WPT type.

Table 1 – Overview of the RF beam WPT type

	Electromagnetic waves	
	Omnidirectional	**Directional**
Representative figure		
Operating principle	Electromagnetic wave radiation	
Electric field intensity	Pt (Pt: transmitting power)	Pt X Gt (Gt: Antenna Gain by beamforming)
Efficiency	Small in proportion to Gt compared to directional RF beam WPT	Large in proportion to Gt compared to omnidirectional RF beam WPT
Transfer distance	Long distance (up to ~m)	Long distance (transfer up to the ~m unit is possible if Line of Sight (LOS) is secured)
Mobility	Possible	Possible
Safety	There are issues on human safety. Human body protection should be considered.	There are issues on human safety. Human body protection should be considered.
Used frequency	RF (Hundred MHz, Several GHz)	RF (Hundred MHz, Several GHz)
Standardization trend	No standard	No standard

4.2 Requirements for RF beam WPT

4.2.1 General

RF beam WPT radiates electromagnetic waves and is significantly different from the two following two non-beam types in the operating principle for transferring power. The magnetic induction and magnetic resonance types use non-radiation WPT and transfer power between TX(Transmitter) and RX(Receiver) in close proximity using the magnetic lines of force and resonance generated by alternating current (AC). On the other hand, RF beam WPT can transfer power by radiating electromagnetic waves through an antenna as in wireless communication. TX transmits the power of an electromagnetic wave oscillator using a directional antenna while RX receives microwaves using an antenna and converts it to a direct current (DC) power source through a rectifier to obtain power.

While RF beam WPT has a benefit in the charging distance because it enables remote charging for multiple devices at the same time, it may affect the human body and exhibits very low power efficiency. The recent technology achieved the power efficiency of very low power at the distance of several meters, but studies to verify and avoid its effects on human health are considered essential for the commercialization of RF beam WPT in the future. It is important to note that the beam WPT needs to arrange conditions for sharing the frequency with existing radio stations because it has the property of radiating the beam into space and transmitting power. In this Subclause 4.2, the system design of the RF beam type, candidate frequencies, and the operating principles of the omnidirectional and directional RF beam types are discussed.

4.2.2 Power transfer system design of RF beam WPT

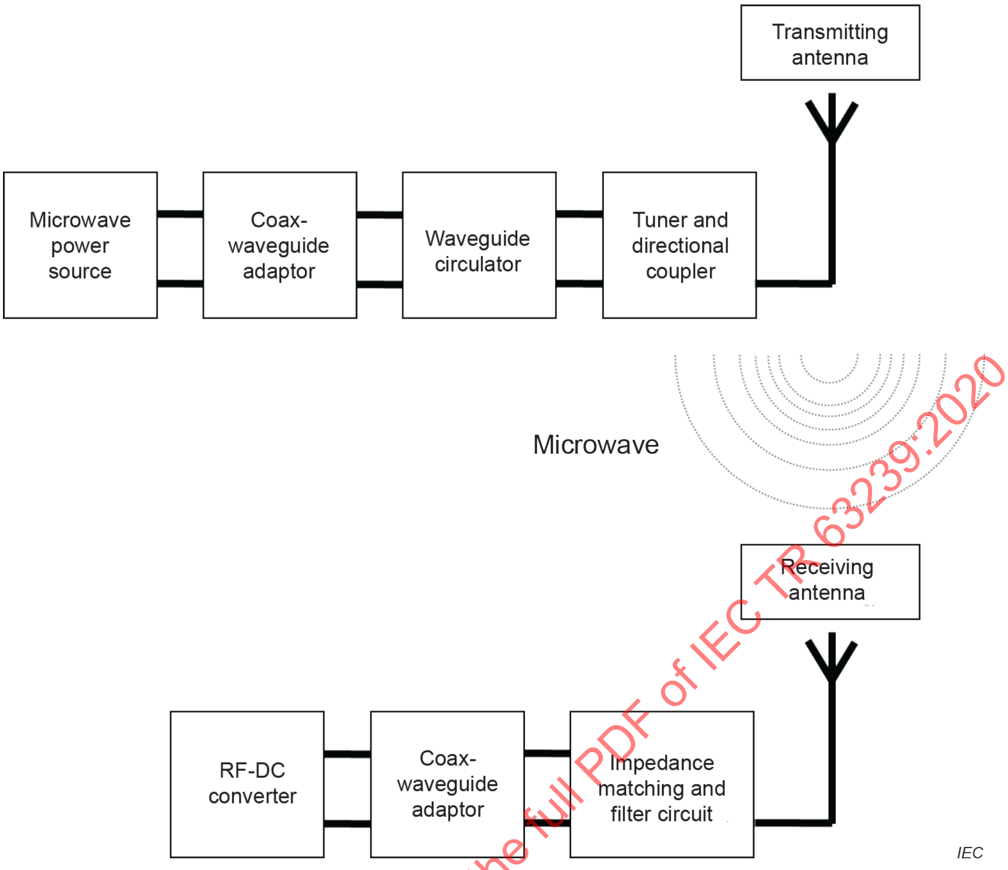


Figure 1 – TX and RX structures of RF beam WPT

Figure 1 shows the TX and RX circuit diagrams of RF beam WPT. In a WPT system, TX consists of a microwave power source, a waveguide circulator, a waveguide adaptor, and a tuner and directional coupler. The microwave power source generates an amplified signal for signal control. The waveguide circulator and adaptor are required to generate specific required frequencies such as GHz through signal response and adjustment. The tuner and directional coupler filters unrequired frequencies as well as noise and matches the transmitter impedance for the transmitting antenna.

RX consists of an impedance matching and filter circuit, a coax-waveguide adaptor, and an RF-DC converter. The impedance matching and filter circuit matches the receiver impedance for the receiving antenna, and the coax-waveguide adaptor extracts specific required frequencies through signal response and adjustment. Finally, the RF-DC converter converts the received electromagnetic waves into DC power.

Since the purpose of RF beam WPT systems is to radiate power wirelessly, it is necessary to design systems focusing on the transfer distance, spatial loss, power consumption of RX, and RF-DC rectification efficiency. In RF beam WPT systems, the magnitude of the spatial loss of power according to the distance is given by the Friis equation and its value is determined by the three major elements, which are the used frequency, transferred power, and transfer distance. Equation (1) shows the Friis equation.

$$P_{RX} = P_{TX} G_{TX} G_{RX} \left(\frac{\lambda}{4\pi r} \right)^2 \tag{1}$$

where P_{RX} is the power input to the receiving module, P_{TX} the power produced by the transmitting antenna of the transmission module, G_{TX} and G_{RX} the gains of the transmitting and receiving antennas, λ the wavelength of the used frequency, and r the distance between the transmitting and receiving modules.

4.2.3 Available candidate frequencies of RF beam WPT

Electromagnetic radiation technology uses GHz frequencies with short wavelengths for long-distance wireless power transfer. Long-distance power transfer using high-output electromagnetic waves in the industrial, scientific, and medical (ISM) bands such as 900 MHz, 2,4 GHz, and 5,8 GHz (900 MHz for the United States), may cause problems in terms of efficiency and human health effects. Table 2 shows the characteristics of some candidate frequencies for RF beam WPT. Whether RF beam WPT is ISM equipment or not is currently being examined in ITU-R, and no conclusion has been obtained yet. Generally, in order to share a frequency, coordination with radio stations that already use the frequency is required.

Table 2 – Characteristics of candidate frequencies for RF beam WPT

Candidate frequency		Characteristics
900 MHz	Pros	More robust, less prone to interference Lower attenuation, travels further through more obstacles
	Cons	Components are larger at lower frequencies
2,4 GHz	Pros	Wi-Fi facility can be used if possible Components are smaller, cheaper
	Cons	Congested band due to abundance of Wi-Fi, Bluetooth, microwaves, cordless phones Attenuates much more quickly, will not pass through metal
5,8 GHz	Pros	Less congested, few RF devices in this band
	Cons	Low transmit power limitations High attenuation in cables, requires very high gain antennas

4.2.4 Operating principle of omnidirectional RF beam WPT

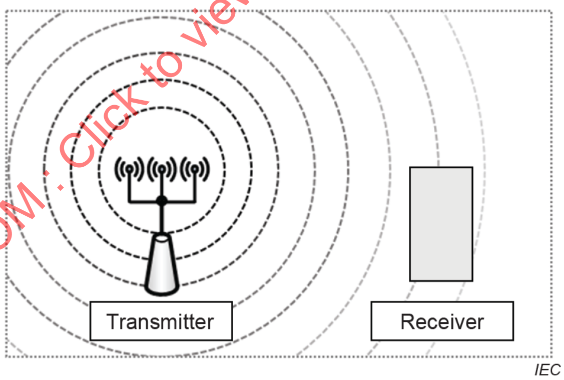


Figure 2 – Beam pattern diagram of omnidirectional RF beam WPT

Figure 2 shows a brief diagram of a beam pattern diagram of omnidirectional RF beam WPT. Omnidirectional RF beam WPT mainly transfers power to a remote distance by radiating electromagnetic signals from a transmitting antenna to all directions through the air using the electromagnetic waves of several GHz or higher. This type is capable of long-distance transmission and reception because it uses high frequencies such as GHz and THz frequencies. Its operating principle can be briefly introduced as follows. First, TX transmits electromagnetic waves using a frequency with high energy. RX then receives the waves using a rectenna (in which an antenna and a rectifier are combined) and converts them into DC power. If approximately 5 W power is radiated from TX, RX receives only 2 mW to 4 mW of power (less than 1 % efficiency). The power received by RX causes no human safety problem because it is too small, but serious human safety problems may occur near TX with high output. Currently, there is no efficient method capable of using this type, but technologies for high-output WPT have been devised to be used in outer space in the future. Figure 3 shows an example of high-output omnidirectional RF beam WPT in outer space.

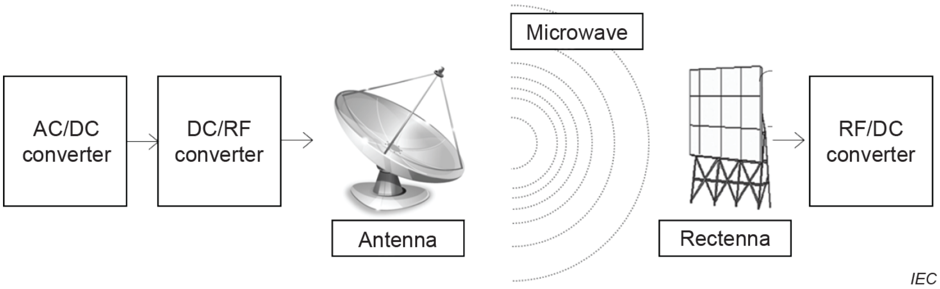


Figure 3 – Example of high-output omnidirectional RF beam WPT in space

4.2.5 Operating principle of directional RF beam WPT

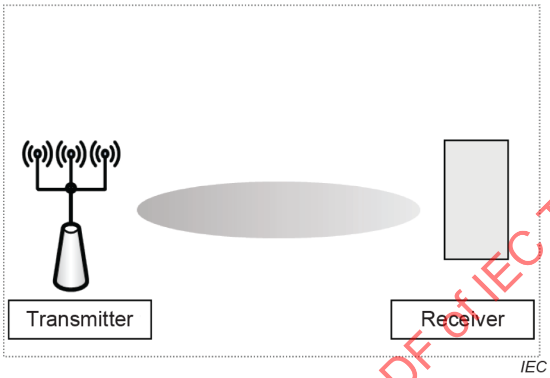


Figure 4 – Beam pattern diagram of directional RF beam WPT

Directional RF beam WPT has the same effect as the spotlight shed on an actor on stage. In an antenna array, the signals of each antenna are filtered or added depending on the frequencies of adjacent signals. TX transfers power to limited targets by forming directional beam patterns using constructive interference or destructive interference at certain angles. Figure 4 shows a beam pattern diagram of directional RF beam WPT. Directional RF beam WPT may occur at TX or RX to achieve spatial selectivity. It is different from omnidirectional transmission and reception in that signals can be directional.

The signal radiation principle of directional RF beam type can be briefly summarized as matching phases between the radiating signals of adjacent antennas. Each antenna offsets signals in unwanted directions for radiating signals in a desired direction. Each antenna is designed to control the direction of signals to obtain the antenna gain of the signals in a desired direction. Figure 5 shows electromagnetic wave transmission/reception at each pattern antenna of directional RF beam WPT. For example, each antenna pattern is designed to be a constant pattern so that it could be half the used electromagnetic wave frequency. In this way, when electromagnetic waves are transmitted, the delay between the transmitted signals becomes a fixed value, making it possible to control the signals generated by all antennas. By adjusting the phase of each antenna in this way, the transmission direction and magnitude of the entire beamforming signals of an array antenna system can be controlled. Figure 6 shows the direction RF beam WPT description on delay generation at each pattern antenna and Figure 7 shows an example of beam pattern formation by the delay and direction adjustment of the transmission signals of each antenna.

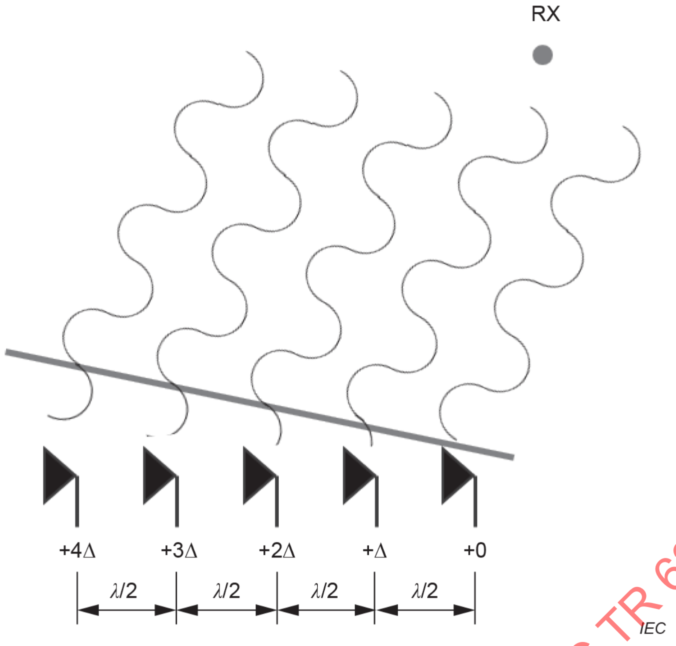
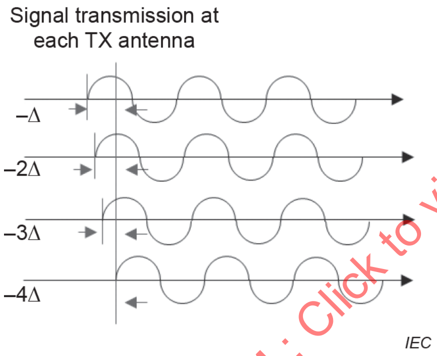
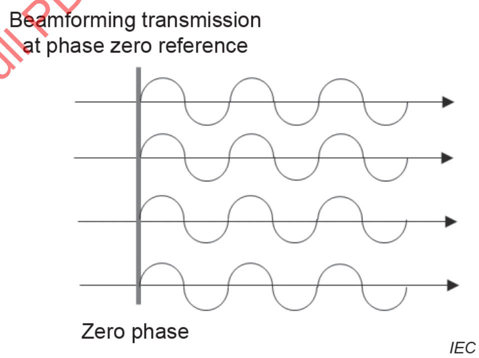


Figure 5 – Electromagnetic wave transmission/reception at each pattern antenna of directional RF beam WPT



a)



b)

Figure 6 – Direction RF beam WPT (a) description on delay generation at each pattern antenna (b) delay adjustment method to transmit desired signals

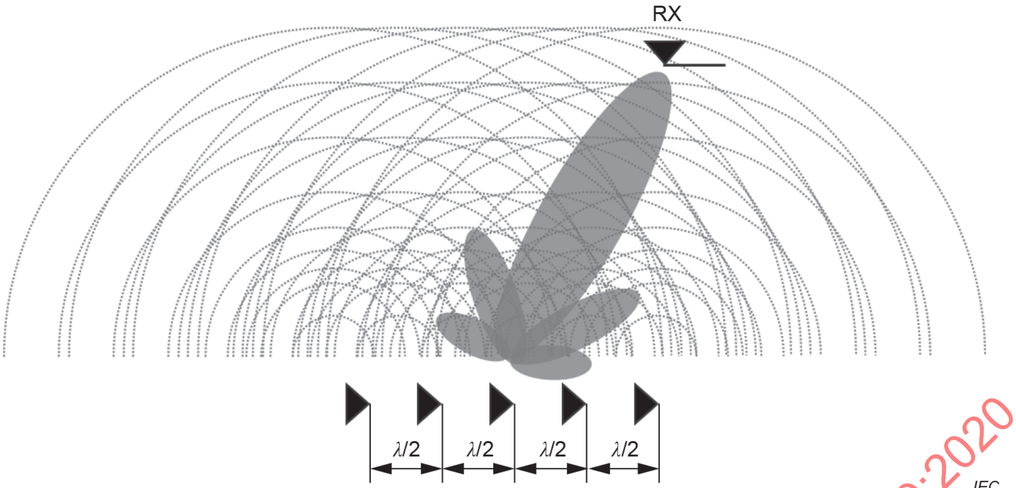


Figure 7 – Example of beam pattern formation by the delay and direction adjustment of the transmission signals of each antenna

4.3 Operating scenario of RF beam WPT

4.3.1 Possible requirement for RF beam WPT

In Subclause 4.3, the operating scenario of charging mobile devices using RF beam WPT is discussed. The operating scenario of charging devices using RF beam WPT is described in this Subclause 4.3. The environment assumed in the operating scenario is as follows.

a) Operating distance: 4 m (15 feet)
b) Charged devices: smartphone and wearable devices
c) Transmission power of each antenna: 23 dBm (transmission power used in wireless communication; selected as it is considered harmless to human health)
d) Used frequency: 2,4 GHz or 5,8 GHz, which is used in Wi-Fi wireless communication
e) Charging method: RF beam WPT area at bus or subway stations

As described in the operating scenario of this document, the output of the transmitter installed in the omnidirectional RF beam WPT area is considered harmless to human health because it uses 23 dBm that satisfies human safety regulations. In addition, as power is radiated through the RF beam type, more TXs can perform WPT to more RXs. The frequency used by TX shall be determined after discussion with each device manufacturer. Frequencies of 2,4 GHz or 5,8 GHz, however, are considered for use with Wi-Fi, which is applied to all IoT devices. In this case, there seems to be no problem with the sizes of the antennas included in each device. Using these frequencies, however, may involve problems such as collision with communication that uses the same frequency. Therefore, it is necessary to use WPT that does not cause collisions with wireless communication, such as frequency occupancy (e.g. RF beam WPT using the first or the last frequency band not used by wireless communication).

4.3.2 Operating scenario of omnidirectional RF beam WPT

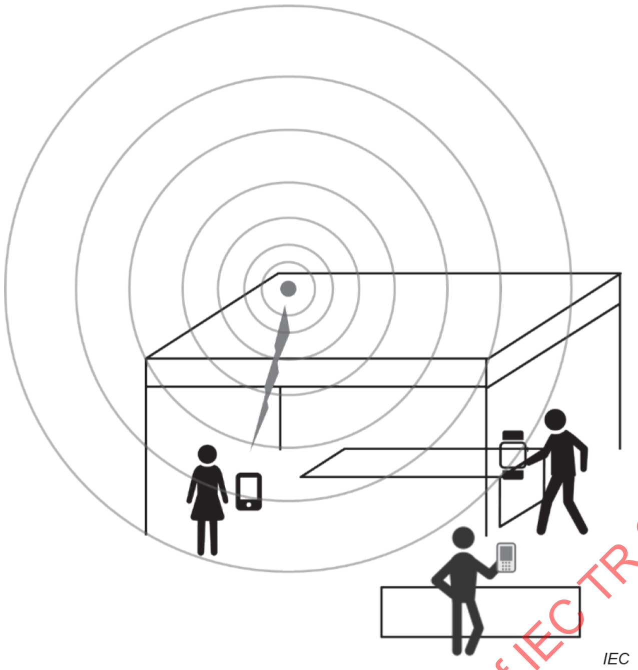


Figure 8 – Expected operating scenario of omnidirectional RF beam WPT

Figure 8 shows an expected operating scenario of omnidirectional RF beam WPT. When device A possessed by a user having a smartphone arrives at a bus stop, it recognizes that it is in the RF beam WPT area. The user activates the function of the TX of omnidirectional RF beam WPT using an application. This process can be performed automatically under the assumption that the user wants wireless power reception when the application is operating. For WPT between the smartphone of the user and TX, first the required information (e.g. essential information for safe power reception such as the rectifier voltage information of the device, desired voltage, and battery status) is exchanged. When WPT is approved finally, TX radiates power in the form of electromagnetic waves and RX finishes preparation for receiving power. Now, the RF beam WPT area is activated, and if device B possessed by another user approaches the area, TX determines whether power is also transmitted to device B through the same certification procedure as that for device A. If device B does not want to receive power, device B can cut off the circuit to receive the RF beam WPT because omnidirectional RF beam WPT is activated in the area.

4.3.3 Operating scenario of directional RF beam WPT

Since directional RF beam WPT focuses power on a certain point or device using multiple antennas, its operating scenario is somewhat different from that of omnidirectional RF beam WPT. Although the output radiated by each antenna is identical due to human health problems, technologies required to perform directional WPT with high efficiency are described.

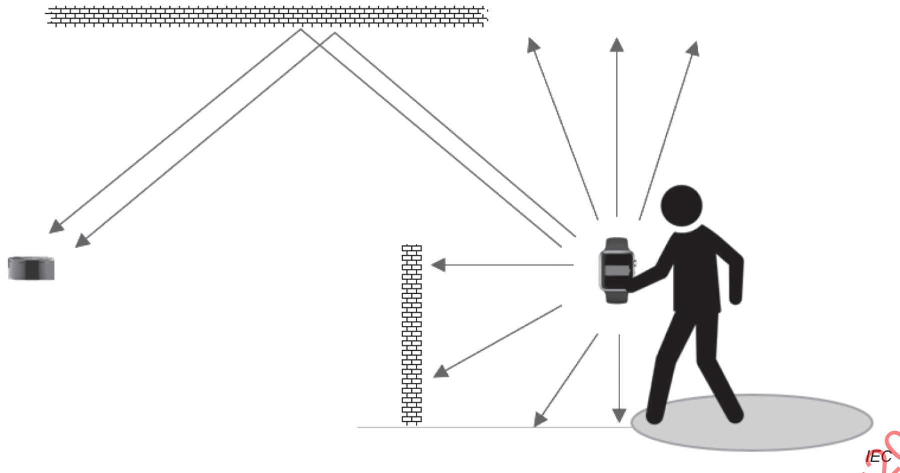


Figure 9 – Expected operating scenario sequence of directional RF beam WPT – Pilot signal transmission from the single RX in case of an obstacle

Figure 9 shows expected operating scenario sequence of directional RF beam WPT – Pilot signal transmission from the single RX in case of an obstacle. Smart watch A, which is RX, executes an application and transmits omnidirectional pilot signals to inform TX of its location and direction, but some of the signals are blocked by an obstacle. The signals are received by some of the multiple antennas present in the TX of directional RF beam WPT, and each transmitting antenna that received the pilot signals through multiple paths estimates the location of RX by analysing the information of the signals.

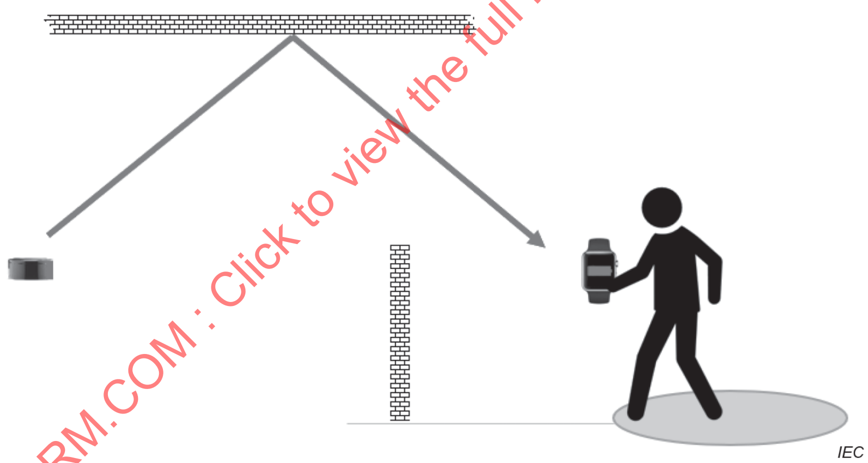


Figure 10 – Expected operating scenario sequence of directional RF beam WPT – Directional WPT to the single RX in case of an obstacle

Figure 10 shows the expected operating scenario sequence of directional RF beam WPT – Directional WPT to the single RX in case of an obstacle. After each antenna that received the pilot signals analyzes the information of RX and acquires the information that there is no human within the location of RX, each antenna transmits directional power in an amount that ensures human safety to the analyzed location of RX. In this case, TX shall monitor the pilot signals from RX in a time unit close to real time and perform WPT only when there is no human or substance between TX and RX.

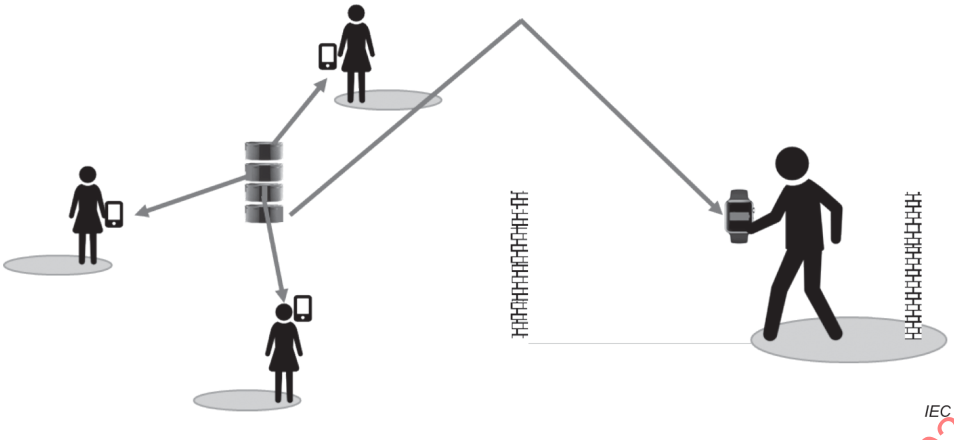


Figure 11 – Expected operating scenario sequence of directional RF beam WPT – Directional WPT from multiple TXs to multiple RXs in case of an obstacle

Figure 11 shows the expected operating scenario sequence of directional RF beam WPT – Directional WPT from multiple TXs to multiple RXs in case of an obstacle. Applying this method, multiple TXs, which can transmit multiple directional RF beam WPT signals, identify the locations of RXs requesting power transfer by analyzing their pilot signals and transmit the required power to each device. In this case, if an obstacle (human) appears in the electromagnetic wave path between each TX and RX, WPT is stopped immediately.

5 Trends in standards, regulations, and technologies related to RF beam WPT

5.1 Trends in standards related to RF beam WPT

International standardization organizations for WPT include International Telecommunication Union Radio Communication Study Group 1 (ITU-R SG1), Asia Pacific Telecommunity Wireless Group (AWG), China Japan Korea-Wireless Power Transfer (CJK-WPT), and International Electronical Committee TC 100 (IEC TC 100). And there are two major de-facto standardization groups as well as Wireless Power Consortium (WPC) and AirFuel Alliance.

AWG and CJK-WPT have published WPT-related technical reports and survey reports, such as policy trends. ITU-R/SG1/WP (Working Party) 1A is preparing recommendations for frequency and technical criteria on WPT. In addition, IEC TC 100 is not only preparing survey reports but also developing standards for specific technologies. Table 3 summarizes the activities of domestic and overseas standardization organizations related to RF beam WPT.

Table 3 – Activities of domestic/overseas standardization organizations related to RF beam WPT

Category	Organization		Standardization status
International (formal)	IEC	TC 100	Founded WPT TA 15 in 2014 and enacted multiple WPT-related international standards. NP ("Parasitic communication protocol for radio-frequency wireless power transmission") related to omnidirectional RF beam WPT was approved in January 2018, and a project is under way.
	ITU-R	SG1 WP1A/1B	Based on Question ITU-R 210-3/1 approved in 2012, the category of WPT, the radio frequency bands for WPT, and the methodologies and requirement to protected the other radio communication services from WPT operations, are being studied. In ITU-R, WPT is separated into two categories, Non-Beam WPT (including magnetic coupling and capacitive coupling WPT) and Beam WPT (WPT via radio frequency beam). The mission of WP 1A is to develop reports and/or recommendations on technical and operational characteristics of WPT. On the other hand, the mission of WP 1B is to discuss regulatory and spectrum management issues for WPT regarding WRC-19 urgent study items. After WRC-19, all discussion items for WPT will be concentrated in WP 1A.
	APT	AWG	TG-WPT was established under WG-TECH in AWG-12, 2012. APT Report and/or APT Recommendation for Non-Beam WPT and Beam WPT are discussed in TG-WPT. Regarding APT Recommendation for WPT, agreement from WG-SPEC is also necessary.

5.2 Trends in regulations related to RF beam WPT

Trends in international regulations and policies on WPT can be largely classified into frequency recommendations and output restrictions, frequency interference regulations, and human health influence regulations. In terms of the frequency recommendations and output restrictions, ITU-R is preparing recommendations for frequencies available globally for automobiles and mobile devices. In terms of the frequency interference regulations, the International Special Committee On Radio Interference (CISPR) has performed a revision task since 2014 to establish standards on electromagnetic compatibility (EMC) by 2019. In terms of the human health influence regulations, the human body protection standards are following the standards established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Federal Communications Commission (FCC), but there is no international standard for detailed measurement assessment methods. Table 4 summarizes the activities of domestic and overseas regulation, development, and standardization organizations.

Table 4 – Major recommendations and regulations of standardization organizations related to WPT for mobile devices

Category	Organization and national trend		Major recent recommendations and national regulations
Frequency allocation/ output restriction	International standardization organization	ITU-R SG1	ITU-R is one of the three organizations constituting ITU, a UN agency, and manages the communication protocols radio spectrum for radio frequency bands allocate the bands of the RF spectrum, allot and register the RF and coordinate efforts in order to avoid harmful interference between radio stations of different countries. [for non-beam WPT] Report ITU-R SM.2303 for non-beam WPT was finalized and approved in 2014, and was revised in 2015 and 2017, respectively. Report ITU-R SM.2303 covers technologies, applications and status of regulations and standards for Non-Beam WPT. Recommendation ITU-R SM.2110 was approved and published in 2017. In this Recommendation, the frequency ranges for Non-Beam WPT for mobiles devices, 6,78 MHz band, is listed. Report ITU-R SM.2451 was finalized and approved in 2019. This Report focuses on impact study for WPT systems for electric vehicles (EVs). Report ITU-R SM.2449 was finalized and approved in 2019. This Report focuses on impact study for WPT systems for mobile devices using 100 kHz to 148,5 kHz. Draft New Recommendation ITU-R SM.[WPT_MOBILE] "Guidance on frequency ranges for operation of non-beam WPT systems for mobile and portable devices" was agreed for approval, in 2019. Draft Revision Recommendation ITU-R SM.2110 "Frequency ranges for operation of non-beam WPT systems" was agreed to input to procedure for adoption and approval. In this Draft Revision Recommendation, the frequency ranges for Non-Beam WPT for EVs are listed. Development for Preliminary Draft New Recommendation ITU-R SM.[WPT-EMISSIONS] "Limits and Measures to mitigate disturbances from WPT systems to radio. systems operating below [30 MHz]" is ongoing.
			[for beam WPT] Report ITU-R SM.2392 was finalized and approved in 2016. This Report focuses on applications of Beam WPT. Currently, development towards Preliminary Draft New Report SM.[WPT.BEAM.IMPACTS] "Impact study and human hazard issues for WPT via radio frequency beam", Preliminary Draft New Recommendation ITU-R SM.[WPT.BEAM.FRQ] "frequency ranges for operation of WPT systems via radio frequency beam" and Preliminary Draft Revision Report SM.2392 "Applications of WPT via radio frequency beam" is ongoing.
	National trend	United States	[for non-beam WPT] The FCC of the United States have certified products that use the ISM band (6,765 MHz to 6,795 MHz) and WPC products (110 kHz to 205 kHz), among W PT products, and regulated them by applying the regulation items of CFR 47 Part 15 and 18.
			[for beam WPT] The FCC has given certification to a few products of beam WPT in applying the regulation CFR 47 Part 15 or 18. However they were investigated on a case by case basis.
		Europe	[for non-beam WPT] Currently applying the ETSI EN 300 and 330-1 regulations, and authorizes W PT for the frequencies of 19 kHz to 21 kHz, 59 kHz to 61 kHz, 79 kHz to 90 kHz, 100 kHz to 300 kHz, and 6,765 MHz to 6,795 MHz.

Category	Organization and national trend		Major recent recommendations and national regulations
			[for beam WPT] (TBD)
		Korea Republic of	[for non-beam WPT] In the case of WPT devices with less than 200 W power consumption, products meeting electromagnetic compatibility are excluded from frequency licensing (revised in March 2015)
			[for beam WPT] (TBD)
		Japan	[for non-beam WPT] The new rules concerning the "type specification" for the operation of WPT technologies have become effective in March 2016. In these new rules, the following three frequency ranges are identified to be used for non-beam WPT: (1) Magnetic resonance type 6,765 kHz to 6,795 kHz for mobile device application, (2) Electric field resonance type 400 kHz band for mobile device applications, (3) Magnetic resonance type 79 kHz to 90 kHz for WPT for EVs. The use of devices with below 50 W input is allowed exceptionally even if they have negligible amount of data communication for in-band control function.
			[for beam WPT] The current Radio Law allows experiment with beam type WPT by obtaining a license of the experimental radio station operation. Discussion of the new regulatory framework is underway towards the commercialization of BEAM WPT technologies. The work has been started in an Advisory Board of the Ministry of Internal Affairs and Communications and is in progress since 2018. Beam WPT supplies electric power over the space intentionally by transmitting radio waves using antenna system, which is different from non-beam WPT. An Advisory Board on the effective use of radio waves in Japan considered a possible regulatory framework for Beam WPT and concluded that Beam WPT should be basically regulated as the "radio equipment" category as those used for radiotelegraphy, radio telephony, or any other electric equipment for the transmission or reception of radio waves because it would require frequency assignments, licensed operators and regulations to operate transmitting/receiving devices. In implementing the regulation for BEAM WPT technologies, the following should be noted and taken into consideration: – Regulatory framework for treating BEAM WPT equipment as "radio frequency transmission equipment", qualification category of the operator, and regulatory type of radio stations since the current regulation system has not fully envisaged WPT. – Technical requirements for the BEAM WPT receiving device based on the study of impacts to other radiocommunication stations, considering high level unwanted emission even from the receiving unit in case of receiving high electric power. – New safety measures for protecting human bodies from exposure to BEAM WPT radio waves, which does not mean installing safety fences but supposes the case that radio waves are emitted from the transmitting device nearby a human body. Currently, on the basis of the notes above, discussions for a new regulation for Beam WPT is underway at the Advisory Board subcommittee of Ministry of Internal Affairs and Communications. The candidate frequency ranges for Beam WPT are 920 MHz, 2,4 GHz, or 5,7 GHz.

Category	**Organization and national trend**		**Major recent recommendations and national regulations**
RF interference	International standardization organization	CISPR	It is a standardization organization for frequency influence protection of radio communication systems and EMC requirements, founded in 1934. Currently, all mobile WPT devices must meet the international EMC standards specified by CISPR. [for non-beam WPT] It is revising the EMC regulations (CISPR 14-1) for magnetic-induction WPT devices for homes. The Standards CISPR 11, 14-1, 15 or 32 may be applied for non-beam WPT equipment. However, the revisions of each standard are under way.
			[for beam WPT] A working team in CISPR/B has been established in order to develop a Working Document on the WPTAAD (At A Distance). CISPR/Steering is still discussing whether beam WPT should be considered radio equipment or ISM equipment. Generally, in order to share a frequency, coordination with radio stations that already use the frequency is required.
	National trend	United States	[for non-beam WPT] In accordance with the FCC rules and regulations, regulation is performed by applying the regulation items of CFR 47 Parts 15 and 18.
			[for beam WPT] (TBD)
		Europe	[for non-beam WPT] EN 55011 standards are applied to devices without communication functions while EN 301 489-1/3 is applied as EMC requirements to devices with communication functions.
			[for beam WPT] (TBD)
		Korea Republic of	[for non-beam WPT] KN 17, an electromagnetic compatibility standard, was newly applied to mobile devices with less than 10 W in 2017. Developing regulations on large-capacity devices with more than 10 W is being discussed.
			[for beam WPT] (TBD)
		Japan	[for non-beam WPT] The new rules concerning the "type specification" for the operation of WPT technologies have become effective in March 2016. In these new rules, the following three frequency ranges are identified to be used for non-beam WPT: (1) Magnetic resonance type 6,765 kHz to 6,795 kHz for mobile device application, (2) Electric field resonance type 400 kHz band for mobile device applications, (3) Magnetic resonance type 79 kHz to 90 kHz for WPT for EVs. In the rules, CISPR standards mainly referred to in making emission limits. Assessment methodologies for compliance demonstration of human body protection from WPT RF exposure of the WPT technologies are specified as well.