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| U.S. Radiocommunications SectorFact Sheet |
| **Working Party:** ITU-R WP 1A | **Document No:** USWP1A23\_13\_FS – PDR Report SM.2392 for Beam WPT on ISM Frequencies |
| **Ref:** Report on the first 2019-2023 meeting of Working Party 1A **–** Annex 08- Preliminary draft revision of Report ITU-R SM.2392-0 - Impact studies and human hazard issues for wireless power transmission via radio frequency beam | **Date:** 27 January 2021 |
| Document Title: Revision to “Preliminary draft revision of Report ITU-R SM.2392-0 - Applications of wireless power transmission via radio frequency beam”,  |
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| **Purpose/Objective:** Proposal add additional bands for consideration |
| **Abstract:** This input will proposed edits to include new bands for beam WPT in two existing ISM bands: 24.125 GHz ± 125.0 MHz and 61.25 GHz ± 250.0 MHz. The 6 US companies developing beam WPT have told FCC in Docket 19-226 comments that they “support allowing WPT on all ISM frequencies”  |

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| **Radiocommunication Study Groups** |  |
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| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R SM.[WPT.BEAM.IMPACTS] |
| Impact studies and human hazard issues for wireless power transmission via radio frequency beam |

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# 1 Introduction

Wireless Power Transmission (WPT) technology is used to transfer power wirelessly from power sources to devices that use or consume power. Significant innovations in WPT can free users from needing electric power cords or changing batteries if electric power is supplied wirelessly. There are two major categories in WPT technologies. One of them is non-beam WPT technology, which transfers power to devices using magnetically, capacitively or inductively coupled means in the near field region and is typically used to charge devices, such as mobile phones and electric vehicles. The other category of WPT is beam WPT, which transfers power wirelessly using radio waves over longer distances (several meters or more, and the potential to cover wider areas).

Beam WPT regulations, standards, and operational guidelines are currently being developed at national, regional, and international levels for wireless charging technologies of mobile/portable and IoT sensor devices for applications of WPT via radio frequency beam. Report [ITU-R SM.2392](http://www.itu.int/pub/R-REP-SM.2392/en) “Applications of wireless power transmission via radio frequency beam” indicates diverse applications and technologies of beam WPT in the future. The Report focuses on applications of WPT technologies using radio frequency beam and highlights that such devices may be classified as Industrial, Scientific, Medical (ISM) or short-range devices (SRD). While both ISM and SRD Beam WPT devices are addressed in Report ITU-R SM.2392, Report [ITU-R SM.1896](https://www.itu.int/rec/R-REC-SM.1896/en) provides a list of frequency ranges for global and regional harmonization of SRDs in its annexes, and Radio Regulations footnote **5.150** provides a list of frequency ranges for ISM devices. To mitigate the impact of WPT devices on the operation of radiocommunication services as finding increasing technology and spectrum demand, some solutions that utilize frequency bands designated for ISM applications and other solutions for spectrum sharing with the incumbent radiocommunication services are discussed. In order to commercialize these WPT technologies, studies on the impact of WPT systems on radiocommunication systems are necessary.

The purpose of this Report is to indicate the possibilities of coexistence with radiocommunication systems by conducting impact studies and demonstrating compliance with international and/or national radio frequency regulations and RF exposure guidelines even in the proposed beam WPT operation conditions. It is also intended to provide guidance to the administrations wishing to allow implementation of beam WPT technologies in the proposed frequency ranges in order to minimize the potential impact of beam WPT on radiocommunication services. Furthermore, this Report is expected to contribute to discussions towards international frequency ranges and regulations for beam WPT applications.

National regulations, such as those in the United States, offer reasonable protection against harmful interference from these devices in a residential installation, but such limits do not guarantee that interference will not occur in a particular instance. However, as demonstrated in the studies contained in this document, Beam WPT technologies have the benefit of causing little to no harmful interference to other devices at distances equal to or less than 30 cm. Any harmful interference that does exist can easily be mitigated by the user moving the charging device and/or affected device. As such, users are encouraged to try to correct any such interference.

# 2 Radio characteristics of beam WPT

This section provides examples of the characteristics of the beam WPT system.

TABLE 1

Examples of radio characteristics of beam WPT systems

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| System | System 1 | System 2 | System 3 | System 4 | System 5 | System 6 | System 7 | System 8 |
| Frequency | 915-921 MHz | 915-921 MHz | 915-921 MHz | 917-920 MHz | 2.410-2.486 GHz | 5.738-5.766 GHz | 24.1 – 24.15 GHz | 61 – 61.5 GHz |
| Output Power | 4 W  | 15 W  | Up to 50 W | 1 W | 15 W | 32 W | CW | CW |
| Antenna gain | 7 dBi | 8.24 dBi | Not to exceed e.i.r.p. | 6 dBi | 24 dBi | 25 dBi | # | # |
| e.i.r.p. | 20 W  | 100 W  | 300 W  | 36 dBm | 65.8 dBm | 70 dBm | 50 W | 50 W |
| Modulation | CW | CW | CW | CW or Other modulation | CW | CW |  |  |
| Bandwidth | 500 kHz | 500 kHz | 500 kHz | 200 kHz | - | - | 10 MHz | 10 MHz |
| Beacon signals | Other wireless systems | Other wireless systems | Other wireless systems | Other wireless systems | Other wireless systems | Beam-WPT dedicated wireless system |  |  |
| Antenna | Wide-beam | Wide-beam | Wide-beam | Wide-beam | Beam forming | Beam forming | Near field beam focusing | Near field beam focusing |
| Applications | Wireless Charging of Mobile/Portable Devices Wireless Powered & Charging of Sensor Networks |
| Note: The technical specifications contained in this table describe some of the characteristics used in the respective studies, and are not meant to be interpreted as regulatory limits, as there may be other Beam WPT systems with higher power than those listed.# For these units the transmitting antenna has a focal point in its near field. As a result, e.i.r.p. is not a meaningful concept and does not act as a predictor of distant field strengths |

# 3 Studies on the impact to the incumbent systems

#  The possible incumbent systems that may require impact studies are as follows:

– Wireless LAN (2.4 GHz, 5.6 GHz band);

– DSRC (5.8 GHz band);

– IMT (900 MHz band);

– MCA (920 MHz band);

– LPWA (920 MHz band);

– RFID (920 MHz band);

– Amateur radio (2.4 GHz band, 5.7 GHz band);

– Radar (5.6 GHz band);

– Microwave link (5.9 GHz band);

– N-STAR (Mobile satellite communication system) (2.5 GHz band);

– Radio astronomy (920 MHz band, 2.3 GHz band, 2.7 GHz band, 4.8 GHz band etc.), adjacent 23.6 – 24.0 GHz

– EESS (active) (co-frequency 5 470-5 570 MHz, adjacent 5 250-5 470 MHz);

– EESS (passive) adjacent 23.6 – 24.0 GHz

* Amateur/Amateur-Satellite, adjacent 24.0-24.05 GHz

– etc.

## 3.1 Study A

An over-the-air, distance charging transmitting device (DUT) operating between 915 MHz and 921 MHz was tested for impact to demonstrate interoperability with wireless devices and technologies operating in the same band. The DUT operates on a single channel with a bandwidth less than 400 kHz and maximum declared conducted average power of 37.4 dBm. The DUT is designed to charge other devices at a distance of up to 30 cm. Additionally, the DUT is compliant with Title 47, Chapter I, Subchapter A, Part 15 of the United States Electronic Code of Federal Regulations, which, inter alia, requires that devices cause no harmful interference and accept interference caused by the operation of an authorized radio station, by another intentional or unintentional radiator, by industrial, scientific and medical (ISM) equipment, or by an incidental radiator.

The tests were performed in two separate rooms. The first was a real-world test performed in a regular room and on a wooden countertop where other signals were present, as illustrated in Figure 1. As an example of the types of signals present, a nearby train station regularly emits 900 MHz signals that are detectable in the room. The second room was an anechoic chamber, as described in ETSI EN 302 208 V3.1.1 (2016-11) Annex B.1.2 and as illustrated in Figure 2. This anechoic chamber was used to demonstrate whether the results found in the regular room were repeatable in a free-space environment and whether any degradation of signal was due to the noisy environment. The tests were performed in the exact same manner, detailed further below, in each room. The results from each of the tests did not have any discrepancies; as such, only one set of results is presented below.

Figure 1

Test setup in room 1, open area



Figure 2

Test setup in room 2, anechoic chamber



Tests were performed on the following types of wireless devices:

Table 2

Types of devices used, frequencies, and distances in Study A

|  |  |  |  |
| --- | --- | --- | --- |
| No. | Type of device | Frequency range (MHz) | Distances tested (cm) |
| 1 | Cellphone | Uplink: 888.0-915.0Downlink: 925.2-960.0 | 0, 10, 20, 30, 40, 50, 70, 100  |
| 2 | Cellphone | Uplink: 888.0-915.0Downlink: 925.2-960.0 | 0, 10, 20, 30, 40, 50, 70, 100 |
| 3 | Cellphone | Uplink: 888.0-915.0Downlink: 925.2-960.0 | 0, 10, 20, 30, 40, 50, 70, 100 |
| 4 | Cellphone | Uplink: 888.0-915.0Downlink: 925.2-960.0 | 0, 10, 20, 30, 40, 50, 70, 100 |
| 5 | Wireless Microphone and base station | 904.45-927.45User Selectable | 0, 10, 30, 100, 200 |
| 6 | Assisted listening device | 863.25-864.75 User Selectable | 0, 10, 30, 100, 200 |
| 7 | Assisted listening device | 904.65-926.85User Selectable | 0, 10, 30, 100, 200 |
| 8 | RFID reader | 903-927Hopping | 0, 10, 30, 100, 200 |
| 9 | RFID reader | 865-868Hopping | 0, 10, 30, 100, 200 |

**Cellphone**. The DUT was placed 100 cm from a mobile phone simulating a desktop environment. The cell antenna, cabled to base station simulator, was placed 3 m from the DUT and mobile phone devices. A call from the mobile phone was established to the callbox in the GSM 900 Band, on a specific frequency. After the call was established, the DUT was switched on at 917.5 MHz. The charging signal was verified with a spectrum analyzer positioned in the test area. The call was monitored for 60 seconds. After which the call state was logged (call maintained, or call dropped.). The distance between the DUT and mobile phone was decreased incrementally until the mobile phone was touching the DUT, measured at 0 cm. Testing was performed using 5 different channels.

Figure 3

Cellphone impact test setup



Figure 4

 Other In-band device impact test set up



The results demonstrated that all phones were able to operate without harmful interference on at least one channel and on all channels when separated by 1 m or more from the DUT.

**Wireless Microphone and base station**. The base-station (receiver) was placed 30 cm from the DUT, and the Microphone (Transmitter) moved through the test distances. Subsequently, the Microphone (Transmitter) was placed 30 cm from the DUT, and the Base-station (receiver) was moved through the test distances.

Setting the audio device frequency away from that of the DUT resulted in little to no harmful interference. When operating at or close to the transmit frequency of the DUT, the devices suffered harmful interference.

**Assisted listening device**. The Transmitter was placed 30 cm from the DUT, and the Receiver was moved through the test distances. Following this, the Receiver was placed 30 cm from the DUT, and the Transmitter was moved through the test distances.

Setting the audio device frequency away from that of the DUT resulted in little to no harmful interference. When operating at or close to the transmit frequency of the DUT, the devices suffered harmful interference.

**RFID reader**. For the first device, scans were performed at 903.250; 904.250; 915.250; 915.750; 920.250; 926.750; and 927.250 MHz. The software transmitting setting was set to 30 dBm. RFID tags were then placed 30 cm from the DUT. For the second, scans were performed at 865.00; 866.00; 867.00; and 868.00 MHz with default settings. RFID tags were then placed 30 cm from the DUT.

At separation distances of 1 m or greater between the DUT and RFID reader and tags, the readers worked without error.

## 3.2 Study B

A single client RF near-field contact charger, the device under testing (DUT), that operates when a receiving device is placed on the charger surface was tested for impact to demonstrate interoperability with other wireless devices and technologies. The DUT used Bluetooth Low Energy (BLE) to pair with the receiving device and transmitted a continuous carrier wave signal adjustable between 915 MHz and 921 MHz. The maximum declared average power was 33.0 dBm per port, with a measured ERP of 1.0 W, and EIRP of 1.64 W. The DUT is designed to charge other devices that rest on its surface. Additionally, the DUT is compliant with Title 47, Chapter I, Subchapter A, Part 15 of the United States Electronic Code of Federal Regulations, which, inter alia, requires that devices cause no harmful interference and accept interference caused by the operation of an authorized radio station, by another intentional or unintentional radiator, by industrial, scientific and medical (ISM) equipment, or by an incidental radiator.

The tests were performed in two separate rooms. The first was a real-world test performed in a regular room and on a wooden countertop where other signals were present, as illustrated in Figure 5. As an example of the types of signals present, a nearby train station regularly emits 900 MHz signals that are detectable in the room. The second room was an anechoic chamber, as described in ETSI EN 302 208 V3.1.1 (2016-11) Annex B.1.2 and as illustrated in Figure 6. This anechoic chamber was used to demonstrate whether the results found in the regular room were repeatable in a free-space environment and whether any degradation of signal was due to the noisy environment. The tests were performed in the exact same manner, detailed further below, in each room. The results from each of the tests did not have any discrepancies; as such, only one set of results is presented below.

Figure 5

Test setup in room 1, open area



Figure 6

Test setup in room 2, anechoic chamber



Tests were performed on the following types of wireless devices:

Table 3

Types of devices used, frequencies, and distances in Study B

|  |  |  |  |
| --- | --- | --- | --- |
| No. | Type of device | Frequency range (MHz) | Distances tested (cm) |
| 1 | Cellphone | Uplink: 888.0-915.0Downlink: 925.2-960.0 | 0, 10, 20, 30, 40, 50  |
| 2 | Cellphone | Uplink: 888.0-915.0Downlink: 925.2-960.0 | 0, 10, 20, 30, 40, 50 |
| 3 | Cellphone | Uplink: 888.0-915.0Downlink: 925.2-960.0 | 0, 10, 20, 30, 40, 50 |
| 4 | Cellphone | Uplink: 888.0-915.0Downlink: 925.2-960.0 | 0, 10, 20, 30, 40, 50 |
| 5 | Wireless Microphone and base station | 904.45-927.45User Selectable | 0, 30, 100, 200 |
| 6 | Assisted listening device | 863.25-864.75 User Selectable | 0, 30, 100, 200 |
| 7 | RFID reader | 903-927Hopping | 0, 10, 30, 100 |
| 8 | RFID reader | 865-868Hopping | 0, 10, 30, 100 |
| 9 | Smart hub | 903-914 | 10, 30, 100 |
| 10 | Push button | 916 | 10, 30, 100 |

Note: The smart hub (device no. 9) and push button (device no. 10) use LoRa technology and were tested together.

**Cellphone**. The DUT was placed 50 cm from a mobile phone. A call to the mobile phone was setup to the callbox in the GSM 900 band on a specific frequency. The call box antenna was placed 50 cm away from the mobile phone. A call was setup between the callbox and the mobile phone under test. Then the DUT was turned on and set to a specific frequency. The call was monitored for 60 seconds. After which the call state was logged (call maintained or call dropped.). The DUT was then moved 10 cm closer to the mobile phone and the process repeated. This was continued until the DUT was touching the mobile phone (distance = 0 cm).

No harmful interference was observed for any of the test configurations.

**Wireless Microphone and base station**. Four sets of tests were performed. For the first two, the base station (receiver) was placed 30 cm from the Charger, and the Microphone (Transmitter) was moved through the test distances. The DUT operated at 918 MHz for the first test, then 917.5 MHz for the second. For the third and fourth tests, the Microphone (Transmitter) was placed 30 cm from the Charger, and the base station (receiver) was moved through the test distances. Again, the tests were performed once with the DUT at 918 MHz then once at 917.5 MHz.

The microphone did not experience noticeable harmful interference except when it operated at 917.65 MHz; when the DUT operated at 918 MHz, this harmful interference was only experienced when the Microphone was within 30 cm of the DUT.

**Assisted listening device**. Four sets of tests were performed. For the first two tests, the Transmitter was placed 30 cm from the Charger, then the Receiver moved through the test distances. The DUT operated at 918 MHz for the first test, then 917.5 MHz for the second. For the third and fourth tests, the Receiver was placed 30 cm from the Charger, then the Transmitter was moved through the test distances. Again, the tests were performed once with the DUT at 918 MHz then once at 917.5 MHz.

The tests show that the assisted listening device was not affected by the DUT due to the frequency offset between the two devices.

**RFID reader**. The first device, scans were performed at 903.250; 904.250; 915.250; 915.750; 920.250; 926.750; and 927.250 MHz. The transmit settings was set to 30 dBm in software, and the receive was set to 0 dBm. The RFID tag was placed 30 cm from the DUT, with its operating frequencies at 918 MHz then 917.5 MHz. The second reader was set to scan at 865.00; 866.00; 867.00; and 868.00 MHz. Default settings were used for the tests. The RFID tag was placed 30 cm from the DUT, with its operating frequency set to 918 MHz.

The results show that the RFID devices operated without significant degradation at separation distances greater than 30 cm.

**Smart hub with push button**. The smart hub and push button were operated using default settings, with the smart hub placed 30 cm from the DUT. The results demonstrated that the smart hub with push button operated without degradation under all of the configurations assessed.

## 3.3 Study C

## 3.3.1 Radiocommunication systems and services considered in the study

This section shows the frequency and protection criteria for radiocommunication systems and considered in the study.

## 3.3.1.1 902-928 MHz (ISM in Region 2)

## 3.3.1.2 917-920 MHz (non-ISM)

917-920 MHz (non-ISM) radiocommunication systems and services considered in the study show Table 4.

TABLE 4

917-920 MHz (non-ISM) radiocommunication systems and services considered in the study

| System | Frequency | Protection criterion | References |
| --- | --- | --- | --- |
| Digital MCA Service | 930 MHz – 940 MHz (up) | TBD | −108.8 dBm/MHz (in band)−51 dBm (out of band)ARIB\*1 STD-T85(Japan) |
| 940 MHz – 945 MHz (down) |
| Advanced MCA Service | 895 MHz – 900 MHz (up) | −110.8 dBm/MHz (in band)−44 dBm (out of band, 12.5 MHz separation) | 3Gpp TS36 104 ｖ8.3.0 (2008-9) |
| 850 MHz – 860 MHz(down) | −119 dBm/MHz (in band)−43 dBm (out of band, modulation)−15 dBm (out of band, CW) | 3Gpp TS36 104 ｖ8.3.0 (2008-9) |
| LTE-A (Band 8) | 900 MHz – 915 MHz (up) | −110.8 dBm/MHz (in band)−44 dBm (out of band, 12.5 MHz separation) | 3Gpp TS36 104 ｖ8.3.0 (2008-9) |
| 945-960 MHz (down) | −119 dBm/MHz (in band)−43 dBm (out of band, modulation)−15 dBm (out of band, CW) | 3Gpp TS36 104 ｖ8.3.0 (2008-9) |
| RFID (Passive) | 916.7 MHz – 923.5 MHz | TBD | −81 dBm/MHz (in band)−30 dBm (out of band, 2 MHz separation)ARIB STD-T106ARIB STD-T107(Japan) |
| RFID (Active) | 915.9 MHz – 929.7 MHz | TBD | −127 dBm/MHz (in band)−80 dBm (out of band)ARIB STD-T108(Japan) |
| Radio astronomy | 1 400 MHz – 1 427 MHz | −197.4 dBm/MHz | ITU-R RA.769-2 |
| \*1: Association of Radio Industries and Businesses (<https://www.arib.or.jp/english/>) |

## 3.3.1.3 2 400-2 500 MHz (ISM)

## 3.3.1.4 2 410-2 486 MHz (non-ISM)

2 410-2 486MHz (non-ISM) radiocommunication systems and services considered in the study show Table 5.

TABLE 5

2 410-2 486 MHz (non-ISM) radiocommunication systems and services considered in the study

| System | Frequency | Protection criterion | References |
| --- | --- | --- | --- |
| Wireless LAN  | 2 400 MHz – 2 497 MHz | −92 dBm (co channel)−66 dBm (adjacent channel),−50 dBm (alternate adjacent channel) | IEEE Std.802.11-2016 |
| Premises radio  | 2 400 MHz – 2 483.5 MHz | TBD | −98 dBm(including 11 dBi antenna gain)ARIB RCR STD-1ARIB RCR STD-29(Japan) |
| Unmanned mobile image transmission system (Wireless system for drones and other unmanned vehicles) | 2 483.5 MHz – 2 494 MHz | TBD | −98 dBm (co channel)−72 dBm (adjacent channel),−56 dBm (alternate adjacent channel)(including 6 dBi antenna gain)Report on MIC Advisory No. 2034(Japan) |
| Geostationary Mobile Satellite Service | 2 500 MHz – 2 535 MHz | TBD | −124.9 dBm/MHz (in band)−41 dBm(out of band, 10-25 MHz separation)Report on MIC Advisory No. 2032(Japan) |
| Non-Geostationary Mobile Satellite Service | 2 483.55 MHz – 2 500 MHz | TBD | −119.4 dBm/MHzReport on MIC Advisory No. 82(Japan) |
| Broadcasting Service: Field Pickup (FPU)  | 2 330 MHz – 2 370 MHz | TBD | −102 dBm/MHz(mobile relay Uplink)Report on MIC Advisory No. 2024(Japan) |
| Radio astronomy | 2 695 MHz | −187 dBm/MHz | ITU-R RA.769-2 |
| Amateur radio | 2 400 MHz – 2 450 MHz | TBD | −110.83 dBm/MHzJARL\*2 requirement |
| \*2: The Japan Amateur Radio League, Inc. (https://www.jarl.org/English/0-2.htm) |

## 3.3.1.5 5 470-5 770 MHz (ISM)

## 3.2.1.6 5 738-5 766 MHz (non-ISM)

5 738-5 766 MHz (non-ISM) radiocommunication systems and services considered in the study show Table 6.

TABLE 6

5 738-5 766 MHz (non-ISM) radiocommunication systems and services considered in the study

| System | Frequency | Protection criterion | References |
| --- | --- | --- | --- |
| Wireless LAN (W56) | 5 470 MHz – 5 730 MHz | −63 dBm (adjacent channel),−47 dBm (alternate adjacent channel) | IEEE Std.802.11-2016 |
| Dedicated Short Range Communication (DSRC) | 5 770 MHz – 5 850 MHz | TBD | −42 dBm(class-2, spurs response rejection),−100 dBm (class-2)ARIB STD-T75(Japan) |
| Broadcasting Service: Studio to Transmitter Link (STL) & Transmitter to Transmitter Link (TTL) | 5 850 MHz – 5 925 MHz | TBD | −101.6 dBm(equivalent thermal noise level)ARIB\_STD-B22(Japan) |
| Broadcasting Service: Field Pickup (FPU) & Transmitter to Studio Link (TSL) systems | 5 850 MHz – 5 925 MHz | TBD | −89.4 dBm(FPU fixed relay station)ARIB STD-B33(Japan) |
| Unmanned mobile image transmission system (Wireless system for drones and other unmanned vehicles) | 5 650 MHz – 5 755 MHz | TBD | −98 dBm (in-band),−72 dBm (adjacent channel),−56 dBm (alternate adjacent channel)Report on MIC Advisory No. 2034(Japan) |
| Weather radar | 5 250 MHz – 5 372.5 MHz | −120 dBm (noise), −40 dBm (CW) | ITU-R M.1849-2 |
| Radio astronomy | 4 700 – 5 140 MHz, 3 000 MHz – 14 000 MHz | −187 dBm/MHz | ITU-R RA.769-2 |
| Amateur radio | 5 650 MHz – 5 850 MHz | TBD | −110.83 dBm/MHzJARL requirement |

## 3.3 Study D

## 3.3.1 Radio services considered in the study

This section shows the frequency and protection criteria for systems and considered in the study. This study deals with use of segments the longstanding ISM bands at 24.0-24.250 GHz and 61.0- 61.5 GHz for beam WPT. Because of the small wavelength in these bands, multiple element antennas have modest size and can effectively focus power on the intended destination with absorption of the transmitted power exceeding 90% of the transmitted power.

## 3.3.2 Considerations for 24.1 – 24.15 GHz and 61.0- 61.5 GHz in USA

In USA these two bands are identified for ISM use with explicit out-of-band emission limits. For transmitter powers less than 500 W, these limits are 25 V/m at 300m measured over a 1 MHz bandwidth.

The technology being considered at these frequencies involves close to CW transmission. The maximum 10 MHz bandwidth comes from three sources: phase noise of the frequency source, incident random phase modulation on the transmitted signal from continuous minor adjustments of the phase shifters in the antenna elements to maintain focus on the intended destination, and low index modulation of the CW carrier for communications between the transmitter and power destination used to both maintain a tight focus of the band on the destination and to implement active safety features that decrease power when an object or a human or pet approach the high pfd volume near the intended destination.

ITU-R RS.2017-0(08/2012) gives the interference criteria for satellite passive remote sensing. For the passive band in 23.6-24 GHz that is near the 24.1-24.15 GHz band being considered for WPT the maximum interference level from all sources is -166 dBW measured over 200 MHz and the percentage of area or time permissible interference level may be exceeded is 0.01%. The closest passive band to 61.0-61.5 GHz that is protected by **5.340** is the 52.6 - 54.25 GHz allocation to EARTH EXPLORATION-SATELLITE (passive) and SPACE RESEARCH (passive) which is 6.75 GHz away or 11% of the ISM band lower frequency. This is presumed to be too far away for out-of-band emissions to be of concern for a near CW signal. But the much closer spacing between 23.6-24 GHz passive band and the 24.1-24.15 GHz band being considered for WPT is discussed below.

## 3.3.3 Impact of 24.1 – 24.15 GHz beam WPT on 23.6-24 GHz passive allocation

Well-designed wireless power transfer devices operating in the 24GHz band do not pose an interference issue to EESS passive satellites. Their operation differs markedly from the operation of other radio devices such as vehicular radar systems or 5G IMT transmitter operating in the vicinity of the 23.6-24GHz band because well-designed, focusing WPT devices are different in the following ways: (1) unlike the others, WPT devices are operated indoors – if not exclusively – in the vast majority of practical use cases (e.g. in homes, offices, and commercial buildings). (2) The signal is a very narrow-band, essentially unmodulated CW signal, as no or insignificant data is being transmitted, unlike for typical radio applications. Finally, (3) these systems use technology related to phased arrays to focus power close to the antenna in order to operate efficiently as a device to transfer wireless power. As a result, the spatial distribution of potential OOBE power is narrowly limited and makes it unlikely that any given device in the viewing points at the satellite receiving antenna.

To estimate the power reaching a satellite, we perform the following calculation:

where

|  |  |  |
| --- | --- | --- |
| Parameter | Description | Assumed value |
|  | EIRP OOBE emission at 24GHz band-edge, integrated over 1MHz, in dBm | -27dBm (value allowable in USA for ISM devices) |
| -30dB | Conversion from dBm to dBW | Factor 1,000 = 30dB |
|  | Free space pathloss |  at 850km (without atmospheric absorption) |
|  | Maximum EESS (passive) satellite antenna gain | 40 dB to 52dB |
|  | Loss from building absorption due to indoor use case | 25dB |
|  | Number of devices in the satellite viewing area | Varies |
|  | OOBE roll-off factor due to narrow-band emission over 200MHz (from 24GHz band-edge to 23.8GHz) | -4.1dBRoll-off is higher from 23.6-23.8GHz |
| 23dB | Bandwidth adjustment from 1MHz resolution BW (typically used for equipment authorization) to 200MHz  | Factor 200 = 23dB |
|  | Beamwidth factor due to narrow beamwidth of WPT device | 3.3o WPT beam angle translates to -30.8dB (area ratio of 3dB beamwidth solid area over total spherical area)  |

To provide additional detail, the surface area on a sphere of a conical cap of width is given by

where is the (beam-width) angle (to wit: for the factor is ½ which is half the area of a sphere). The WPT 3dB beam-width for a device using 256 antenna elements is 3.3o, resulting in a factor of 0.000829 or 30.8dB attenuation as most devices will not be pointing at the satellite where OOBE is strongest).

The roll-off factor LBW is the effective attenuation of the OOBE emission over the 200MHz BW as OOBE emissions roll-off as the inverse of the square of the offset frequency in the region of interest. Since the OOBE is expected to be most severe at the band-edge at 24GHz, it has to be met there (in a 1MHz BW typically for regulatory requirements), but rolls off due to its origin from oscillator phase noise.

Building loss occurs because the signal will experience appreciable attenuation inside the building as it’s reflected and transmitted through walls, ceilings, floors and furniture. Estimates here are based on data in [P.2040-1](https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.2040-1-201507-I%21%21PDF-E.pdf). As the devices typically operate looking downwards, and as the viewing angle from the satellite is typically at a range of 45o-55o, we assume that 2-3 reflections/transmission have to occur resulting in a conservatively estimated loss of 25dB.

Free-space path loss is given by or 178.5dB for a path of 850km and a wavelength of 1.27cm, conservatively ignoring atmospheric absorption.

Assuming 1,250 devices per square kilometer (a very large number of devices!), an EESS passive satellite receive antenna gain of 52dB (in the worst case), a viewing area of 216km2 (resulting in N=270,000 devices in the area), and a maximum OOBE power of -27dBm EIRP produced by the WPT devices, using the above calculation, we estimate an interference signal strength of

at the satellite in the 23.8-24GHz band in this worst case compliant with RS.2017 limits.

Thus, we believe that well-designed, narrow-band, focusing WPT devices for indoor use do not pose an interference risk to EESS passive satellites.

## 3.3.4 Human hazard issues for 24.1 – 24.15 GHz and 61.0- 61.5 GHz WPT

## Technology being considered for these bands used phased array multiple element beams to focus power on a small area for efficient power transfer. This creates a high power flux density (pfd) at and near the power receiving area that could violate applicable safety standards. This situation is avoided by active measures that detect the presence of objects near the high pfd volume and reduces or ceases power transmissions when such objects are detected.

The strategy being followed is to make sure applicable safety standards are met: Systems will employ multiple, independently operating and independently testable safeguards that will ensure that exposure requirements are met. Examples of these are the ability to evaluate the orientation of the device being charged, including whether it is moving, fixed, or set on a stable surface; the ability to passively sense nearby movement and beam interruption; and the ability to detect Doppler signals from the device being charged or people that are moving. In this way, the distances between the beam, the charging device, and any people located in the vicinity can be calculated in milliseconds, ensuring that the power transfer will cease before a person enters the path of a beam. These independent safety features are all native to the WPT system, meaning that they are inherent in the function of the beam formation apparatus of the WPT system.

## 3.3.5 Summary of the studies on the impact of beam WPT on radio services

This section summarizes study results on the impact of beam WPT per each proposed operation frequency range to radiocommunication services and systems considered.

## 3.3.5.1 Studies in Japan

A study on the impact of Beam WPT technologies operating in 920 MHz band, 2.4 GHz band, and 5.7 GHz band to the incumbent radiocommunication systems and services was performed in Japan in 2020 for the purpose of new rulemaking. Summary is described below.

System parameters used for the study are shown in Table 7. Detailed results are found in Annex 2.

TABLE 7

Expected specifications of beam WPT commercial systems in 2020 (Step 1)

|  |  |  |  |
| --- | --- | --- | --- |
| System | System 1 | System 2 | System 3 |
| Spec. | Frequency | 920 MHz band(915-930 MHz) | 2.45 GHz band(2.40-2.499 GHz) | 5.7 GHz band(5.470-5.770 GHz) |
| Output Power | 1 W | 15 W | 32 W |
| Antenna gain | 6 dBi | 24 dBi | 25 dBi |
| e.i.r.p. | 36 dBm | Max. 65.8 dBm | Max. 70 dBm |
| Modulation | Not specified | NON | NON |
| Place of use | Indoor | Indoor | Indoor |

The standard wall loss is defined in Section 3 of Recommendation ITU-R P.2109-1 “Prediction of building entry loss” and can be calculated using the Building entry loss model. is there.

Since the passage loss value depends on the outer wall material, the model offers two types of outer wall "Thermally efficient" that uses heat shield and heat insulating material with high electromagnetic wave reflection characteristics and "Traditional" that does not use them. , It is possible to find the median loss. The calculation formula of the loss model is shown below. Moreover, since the loss also depends on the frequency, the formula also considers the frequency dependence.

 in the calculation formula is the median path loss, *r*, *s*, and *t* are the constants shown in Table 4.2, and *f* is the path frequency (GHz). Table 4.3 shows the calculation results for the representative frequencies of the three frequency bands used in the spatial transmission wireless power transmission system.

The "Thermally efficient" model has a large loss of about 15 dB compared to "Traditional", but it is unlikely that heat insulating and heat insulating materials are used for all outer walls, so the pathing loss to be used is. The examination was based on the value of the "Traditional" model.

Table 8

Constants used for loss model in ITU-R P.2109-1

|  |  |  |  |
| --- | --- | --- | --- |
| Item | *r* | *s* | *t* |
| Traditional | 12.64 | 3.72 | 0.96 |
| Thermally efficient | 28.19 | –3.00 | 8.48 |

Table 9

Calculation results for the three frequency bands used in beam WPT

|  |  |  |  |
| --- | --- | --- | --- |
| Item | 920 MHz | 2 450 MHz | 5 750 MHz |
| *Lh* (Traditional) | 12.5 dB | 14.2 dB | 16.0 dB |
| *Lh* (Thermally efficient) | 28.3 dB | 28.3 dB | 30.8 dB |

Table 10

Wall loss used for of the studies on the impact of beam WPT

|  |  |  |  |
| --- | --- | --- | --- |
| Item | 920 MHz | 2.4 GHz | 5.7 GHz |
| Wall loss | 10.0 dB | 14.0 dB | 16.0 dB |

Radiocommunication services and systems considered for the study were shown below.

– 920 MHz band (915-930 MHz)

• Digital MCA (Multi-Channel Access radio system): Relay station and mobile station

• MCA (Multi-Channel Access radio system): Mobile station

• MCA (Multi-Channel Access radio system): Base station

• Mobile communication system (LTE): Base station and mobile terminal station

• RF-ID system

• Radio astronomy

– 2.4 GHz band (2.400-2.499 GHz)

• Wireless LAN systems

• Premises Radio Stations and Specified Low Power Radio Stations

• Unmanned mobile image transmission system (Wireless system for drones and other unmanned vehicles)

• Mobile satellite communication system: N-STAR

• Mobile satellite communication system: Globalstar

• Broadcasting: Field Pickup Unit (FPU) system

• Radio beacon

• Radio astronomy

• Amateur radio

– 5.7 GHz band (5.470-5.770 GHz)

• Wireless LAN systems

• Dedicated Short Range Communication (DSRC) system

• Broadcasting Service: Studio to Transmitter Link (STL) & Transmitter to Transmitter Link (TTL) systems

• Broadcasting Service: Field Pickup (FPU) & Transmitter to Studio Link (TSL) systems

• Unmanned mobile image transmission system (Wireless system for drones and other unmanned vehicles)

• Weather radar

• Radio astronomy

• Amateur radio

For the WPT systems intended the operation 920 MHz band, the system parameters assumed for the impact study (See Table 4.1) were compliant with the radio regulation including transmission intervals for the RF-ID systems currently operated in the same frequency range. Minimum separation distances were derived in accordance with the Beam WPT characteristics for the case geographical separation distance is necessary to regulate. In addition, Monte-Carlo system-level simulation was performed to assess interfering likelihood from Beam WPT to LTE and MCA mobile communication networks. Furthermore, a comprehensive Beam WPT management rule regarding WPT operation environment and WPT radio frequency EMFs was defined and can be applied specific use cases using the band to abide by Radio-Radiation Protection Guidelines. Thus, required technical requirements and operational conditions (See Annex [2] for details) not to cause harmful impact to the existing systems and services were determined.

For the Beam WPT systems intended for the operation in 2.4 GHz band and 5.7 GHz band, the study was conducted with the system parameters (See Table 4.1) to determine required technical requirements and operational conditions under the current radio regulation including frequency allocation and operational conditions. Study results in 2.4 GHz band and 5.7 GHz band are summarized as follows:

1 A comprehensive Beam WPT management rule regarding WPT operation environment and WPT radio frequency EMFs was defined and applied to abide by Radio-Radiation Protection Guidelines.

2 Carrier sensing mechanism shall be adopted to coexist with WLAN systems and / or Specified Low Power Radio Stations. It turned out that WLAN system performance such as throughput can be maintained without harmful interference by adding carrier sensing mechanism.

3 For radioastronomy, weather radar, and Radio Beacon services, minimum separation distances were specified.

4 For broadcasting systems, mobile satellite communication systems, and Dedicated Short Range Communication (DSRC) system, minimum separation distances were specified. In addition, operational coordination was addressed for the case Beam WPT causes harmful interference.

5 For unmanned mobile image transmission system (i.e., a wireless communication system for drones and other unmanned vehicles), studies assuming practical use cases showed that spectrum sharing without causing harmful impact was possible by operational coordination as needed between WPT systems and unmanned mobile image transmission systems.

6 For amateur radio services, Beam WPT installation conditions for spectrum sharing were specified. In addition, Beam WPT systems shall not use the frequency band for Earth-Moon-Earth (EME) systems and repeater systems. Operational coordination is undertaken between WPT systems and amateur radio systems.

### 3.3.5.1.1 917-920 MHz (non-ISM)

Radio characteristics example of beam WPT (non-ISM) is shown on Table 1.

(1) Digital MCA Service

We referred to the examination in the past shared report with RFID. This is because it uses almost the same technology as RFID.

(2) Advanced MCA Service

WPT can be shared by the control station (base station: downlink) by considering vertical directivity.

The mobile station (upstream) can be shared when both systems do not exist in the same room by Monte-Carlo simulation using the extended Hata formula (300 m or less).

In the case of the same room, the required improvement amount is about 10 dB, but it can be shared because it is expected to be attenuated by obstacles and the human body in the room.

However, regarding the use with the WPT system in the same room, the WPT users will be alerted by giving cautions to the instruction manual.

(3) LTE-A (Band 8)

The WPT system can be shared in a general environment even when there is no transmission time limit. On the other hand, the WPT system can be shared in the management environment by limiting the transmission time (stopping transmission for 50 msec within 4 seconds of the transmission time).

(4) RFID (Passive)

The WPT system and RFID system can be shared on the same channel if a separation distance of about 6 m is secured. If the separation distance cannot be secured, the channel can be changed or sharing by shielding with a wall.

(5) RFID (Active)

The WPT system can be shared by operating in accordance with the RFID band operation rules.

(6) Radio Astronomy

The separation distance was calculated with free space loss model to be 37.5 km using the spurious ability value (-60.5 dBm / MHz). The WPT system has set that distance from radio astronomy as a restricted installation area.

### 3.3.2.1.2 2.410-2.486 GHz (non-ISM)

Radio characteristics example of beam WPT (non-ISM) is shown on Table 1

(1) Wireless LAN

The simulation using the carrier sense mechanism on the beam WPT system was conducted to study the impact to the Wi-Fi devices located outside of the WPT controlled environment. The decline of the throughput of those Wi-Fi devices could be suppressed with appropriate parameters of carrier sense mechanism, compared with the case when another Wi-Fi AP was operated at the same location instead of the beam WPT inside the WPT controlled environment.

(2) Premises Radio

Within the beam WPT controlled environment the operation of the premises radio can be managed and controlled by the same operator as for the beam WPT. Moreover, within the 84.9 m from the beam WPT location it can be suppressed the transmission with the carrier sense mechanism when premises radio is transmitting.

(3) Unmanned mobile image transmission system

In the study separation distance was calculated with extended Hata model and it is 3.6 km on co channel from the beam WPT to the Unmanned mobile image transmission system outdoor. However, since the system is usually operated outside the cities and the usage time and places are planned, the harmful interference can be avoided by the coordination procedure.

(4) Geostationary Mobile Satellite Service

In the study separation distance was calculated with worst case scenario of out of band interference, where antenna directivity direction of the GEO MSS receiver was perfectly matched to the beam direction of the beam WPT. It is 30 m in the northern part of Japan. With the separation distance and coordination procedure if necessary, harmful interference can be avoided.

(5) Non-Geostationary Mobile Satellite Service

In the study separation distance was calculated of in band interference with extend Hata model and it was 0.96 km. Since Non-Geostationary Mobile Satellite Service is generally used in the location where cellular mobile system cannot be reached in Japan and the beam WPT does not possibly exist, the harmful interference can be avoided.

(6) Broadcasting Service: Field Pickup

In the study separation distance was calculated in various scenarios and systems and with the antenna directivity it does not cause harmful interference with 10 m separation distance outside the WPT controlled environment.

(7) Radio Astronomy

In the study separation distance was calculated for each radio astronomy site operating 2 695 MHz considering clutter loss. The separation distances are 5.7 km or 1.6 km depending on the environment of the site. To avoid the harmful interference to radio astronomy restricted area around the sites are set with those separation distances.

(8) Impact study for Radio Amateur

In the study separation distance was calculated considering clutter loss. 2 out of 4 frequencies of beam WPT are co-channel with Radio Amateur, which need 4.4 km separation distance with 18 dBi Radio Amateur antenna. Considering antenna directive loss and using adjacent band if necessary, the harmful interference can be avoided.

### 3.3.2.1.3 5.738-5.766 GHz (non-ISM)

Radio characteristics example of beam WPT (non-ISM) is shown on Table 1

(1) Wireless LAN

Simulation was conducted to study the impact of the beam WPT system to the Wi-Fi system that operate outside the WPT controlled environment. When carrier sense mechanism with appropriate parameters was applied to the beam WPT system, the impact to the Wi-Fi throughput was equivalent to the case when another Wi-Fi system existed instead of the beam WPT system.

(2) Dedicated Short Range Communication (DSRC)

Study on separation distance was made for the worst case scenario, where antenna directivity of the DSRC system perfectly matched to the beam direction of the beam WPT system. The separation distance was calculated with free space loss model to be 2.6 km from the beam WPT system to the DSRC Class 2 base station. Propagation loss due to building wall and directivity loss of DSRC antenna can be expected to further avoid harmful interference.

(3) Broadcasting Service: Studio to Transmitter Link (STL) & Transmitter to Transmitter Link (TTL)

Separation distance was calculated with free space loss model to be 836 m for out band noise signal from the beam WPT to the STL/TTL base station. When difference in height is more than 5 m, 20 dB of directivity loss of STL/TTL antenna can be expected to further avoid harmful interference.

(4) Broadcasting Service: Field Pickup (FPU) & Transmitter to Studio Link (TSL) systems

Separation distance was calculated to be 80 m for out band noise signal from the beam WPT to the FPU base station. When difference in height is more than 25 m, more than 14 dB of directivity loss of FPU antenna can be expected to further avoid harmful interference.

Separation distance was calculated with free space loss model to be 1 485 m for out band noise signal from the beam WPT system to the TSL base station. When difference in height is more than 7 m, 20 dB of directivity loss of STL/TTL antenna can be expected to further avoid harmful interference.

(5) Unmanned mobile image transmission system

Separation distance was calculated with free space loss model to be 23 km on co-channel and 185 m on the alternate adjacent channel from the beam WPT system to the unmanned mobile image transmission system outdoor, respectively. However, since the system is usually operated outside the cities and the usage time and places are scheduled, harmful interference can be avoided by such as coordination procedure.

(6) Weather radar

Separation distance was calculated with free space loss model to be 3 308 m for out band noise signal from the beam WPT system for each weather radar site. To avoid the harmful interference, separation distance should be kept.

(7) Radio Astronomy

Separation distance was calculated with free space loss model to be 1.1 km or 1.7 km for 4 995 MHz and 10 650 MHz radio astronomy sites. To avoid the harmful interference, separation distance should be kept.

(8) Impact study for Radio Amateur

Separation distance was studied considering clutter loss. The calculated separation distance with free space loss model was 1.5 km and 262 m for 30 dBi and 15 dBi Radio Amateur antennas, respectively. Antenna directivity and coordination procedure can avoid harmful interference.

# 4 Human hazard issues

Human exposure to electromagnetic fields (EMF) is addressed by a number of regulatory agencies as well as international expert organizations such as the World Health Organization (WHO), the Institute of Electrical and Electronics Engineers (IEEE), and the International Commission on Non Ionizing Radiation Protection (ICNIRP). The determination of EMF safety limits is addressed by these groups and are not in the scope of ITU-R’s work. There are a number of different guidelines on human exposure to EMF that have been published by these organizations, across several frequency ranges. These guidelines include: ICNIRP guidelines of 1998, 2010, and 2020 and IEEE C95.1-2019 - IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz. Many Administrations have or may at some point adopt these guidelines or modified/updated guidelines based on their own experts’ studies. System designers, manufacturers, and operators of WPT equipment should consider steps to adequately protect the public from the hazardous effects of EMF and should consider these limits in their planning and deployment of WPT systems.

Unlike non-beam WPT, beam WPT in the practical implementation would employ microwave transmission systems using 920 MHz band, 2.4 GHz band, and 5.7 GHz band to transmit the power. Microwaves may be beamed from an antenna, by way of point-to-point or point-to-multipoint, over a distance of several meters or more. Unlike wireless communication uses, the level of transmitted electromagnetic power required for commercial implementation of beam WPT could be greater to some extent or substantial. It is deemed appropriate that a human (including medical devices) exposure to beam WPT EMF should be assessed and managed with additional measures to be compliant with the current guidelines in the beam WPT planning and operation.

To cope with above-mentioned unique and standing technical requirements, some current beam WPT implementations are considering adoption of human body detection mechanisms in the area with expecting greater RF exposure than the guidelines to cease power transmission and / or steer the power beam direction when detected. To facilitate implementation such technical measures and ensure compliance with the guidelines, study on regulatory environmental conditions for beam WPT is also undertaken in some administrations. See Annex 1 for details.

# 5 Summary

[*Editor’s note: The following text summarizes the results of Studies A and B. A paragraph summarizing the results of study C is expected to be provided at the next meeting of WP 1A.*]

The studies presented in this document demonstrate that the impact of Beam WPT systems on other wireless devices and technologies depends on factors such as the output power of the beam WPT, the distance between devices, and whether the same operating frequencies are being used. For Beam WPT systems operating in the 915-921 MHz band, results from the studies demonstrate that in most cases their operation is feasible and causes little to no interference to the following types of devices: IMT user terminals, wireless microphones and base stations, assisted listening devices, RFID readers, door/window sensors, smart hubs, and smart power outlets.

Annex 1

RF exposure environmental control to comply with
the Radio Protection Guidelines

# 1 Beam WPT installation environments

Information and Communication Council of the Ministry of Internal Affairs and Communication (MIC) of Japan defined the WPT indoor installation environments by the names of the WPT controlled environment and the WPT general environment to manage and control radiofrequency EMF exposure generated from the beam WPT system to human bodies in the operation of Japanese 920 MHz band (915-930 MHz), 2.4 GHz band (2.400-2.499 GHz), and 5.7 GHz band (5.470-5.770 GHz) to comply with their Radio Protection Guidelines (the Guidelines, thereafter) as follows.

## 1.1 WPT controlled environment

The WPT controlled environment is summarized as shown below:

– It is categorized as indoor and closed space for beam WPT operation

– In the environment, WPT radio frequency EMF levels meet the allowable range specified for the controlled environment in the Radio Protection Guidelines. (Power transmission shall be ceased when detecting an individual entering the area where EMFs surpass the limits of the controlled environment specified in the Guidelines.)

– When a beam WPT system is operated in the WPT controlled environment, for the purpose of avoiding and mitigating harmful effect to other radiocommunication systems, the WPT system installation personnel, the WPT system operator, the WPT licensee, and other authorized personnel shall be able to manage and control the use of other radiocommunication systems and device installation conditions in an integrated manner.

– When the concerned WPT controlled environment is bordering other indoor space (e.g., side-by-side rooms or upper-and-lower floors), WPT radio frequency EMF levels shall meet the allowable range of specified spectrum sharing conditions with the other radiocommunication systems even in those indoor spaces, or the identical WPT manager to the concerned indoor WPT controlled environment shall be able to manage the coordinated spectrum sharing in the integrated manner. (This clause is applied to the 2.4 GHz and 5.7 GHz bands operation only)

## 1.2 WPT general environment

The WPT general environment is one of the categories of WPT indoor installation environment and means a WPT use environment that does not fulfil the definition of the WPT controlled environment. (e.g., wireless power transmission to quality management sensors in a logistics warehouse (920 MHz band application only), wireless power transmission to observation sensor devices in an elder nursing care facility (920 MHz band application only).

# 2 Compliance with the Radio Protection Guidelines

## 2.1 Separation distance

To comply with the radio frequency EMF exposure requirements in the Radio Protection Guidelines, the following separation distances were derived and specified.

Table [A-01-1 ]

Separation distances to meet the RF exposure limits of the Radio Protection Guidelines

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Environmental condition defined in the Radio Protection Guidelines | Reflection coefficientK = 1(\*1) | Reflection coefficientK = 2.56(\*2) | Reflection coefficientK = 4(\*3) | Adding 6 dB to EMF strength(\*4) |
| Reflection coefficientK = 2.56 | Reflection coefficientK = 4 |
| 920 kHz band | Controlled environment | 0.102 m | 0.163 m | 0.203 m | 0.325 m | 0.4065 m |
| General environment | 0.227 m | 0.364 m | 0.456 m | 0.727 m | 0.912 m |
| 2.4 GHz band | Controlled environment | 2.45 m | 3.92 m | 4.90 m | 7.82 m | 9.80 m |
| General environment | 5.48 m | 8.76 m | 10.95 m | 17.49 m | 21.90 m |
| 5.7 GHz band | WPT controlled environment | 4.00 m | 6.40 m | 8.00 m | 12.80 m | 16.00 m |
| WPT general environment | 9.00 m | 14.30 m | 17.80 m | 28.50 m | 35.70 m |
| (\*1) No reflections counted.(\*2) Reflections from the ground counted.(\*3) Reflections from the water surface and from those other than the ground counted.(\*4) 6 dB is added in the case greater reflection is expected to observe due to buildings such as an office building nearby the evaluation point.  |

## 2.2 Directions

The beam WPT systems being considered for the operation in the 920 MHz band, the separation distance to meet the limits in the Guideline is comparatively short; and therefore, it is possible for them to operate in the WPT general environment.

Those for the 2.4 GHz band and the 5.7 GHz band assume adoption of human body detection mechanisms in the area expecting greater RF exposure than the limits of Guidelines to cease power transmission when detected. In addition, the systems are to take safety measures to ensure correct functioning of the detect and protect mechanism. Moreover, some alert such by indicating attentional area and setting a fence is conducted, too.

Beam WPT transmitters are not used at a very close proximity (within 20 cm) from the human body according to use case scenarios and also taking appropriate safety measures mentioned above. Therefore, study on specific energy absorption rate (SAR) for the human body nearby is not necessary.

Annex 2

Impact Studies in Japan for beam WPT

# 1 Introduction

This Annex provides impact studies carried out in the process toward new regulation for beam WPT systems using 920 MHz band, 2.4 GHz band, and 5.7 GHz band in Japan. The study was conducted by a working group (WG), which was established under the Advisory Board subcommittee of the Ministry of Internal Affairs and Communications (MIC), Japan. The WG consisted of technology experts and representatives in the related fields including WPT industries, intended incumbent radio systems, EMC, radio wave exposure and academia. The study results were published as a report “The technical conditions for beam WPT on the premises” after deliberation by the Advisory Board, and will be incorporated into Japanese radio regulation and guidelines for WPT operation after going through the institutionalization procedure.

# 2 System specifications for beam WPT

The system specifications for beam WPT reported in “The technical conditions for beam WPT on the premises” shown in Table ANX2-1. The system specifications System 1, Systems 2, and System 3, shown in Table ANX2-1 are supposed the first commercial systems with practical application objectives in 2020 (Step 1).

The System 1 is mainly used in WPT for wireless-powered sensor network. The System 1 is used in indoor and controlled environment where WPT equipment is controlled by managers of factories, nursing homes and so on. The power consumption of the sensor is about several hundred mWs or less.

The System 2 and the System 3 are mainly used in WPT for small displays in addition to the application of the System 1. The System 2 and the System 3 are used in indoor and controlled environment where WPT equipment is controlled by managers of factories, plants, warehouses and so on. The power transmission to the receiver devices requires up to several watts.

TABLE Anx2-1

Expecting specifications of beam WPT commercial systems in 2020 (Step 1)

|  |  |  |  |
| --- | --- | --- | --- |
| System | System 1 | System 2 | System 3 |
| **Spec.** | Frequency | 920 MHz band(915-930 MHz) | 2.45 GHz band(2.40-2.499 GHz) | 5.7 GHz band(5.470-5.770 GHz) |
| Output Power | 1 W | 15 W | 32 W |
| Antenna gain | 6 dBi | 24 dBi | 25 dBi |
| e.i.r.p. | 36 dBm | Max. 65.8 dBm | Max. 70 dBm |
| Modulation | Not specified | NON | NON |
| Place of use | Indoor | Indoor | Indoor |

“WPT controlled environment” and “WPT general environment” are defined. “WPT controlled environment” is defined as,

– Indoor and closed area,

– Environment where limits of Japanese radio exposure guidelines in controllable area can be cleared, and/or the manager/administrator can cut off power transfer of beam WPT systems when limits of Japanese radio exposure guidelines in controllable area are happened to be not cleared,

– Environment where the manager/administrator can manage and control both of beam WPT systems and incumbent radio communication services in order to avoid or reduce harmful interference from beam WPT systems.

“WPT general environment” are defined as the other environment where the above conditions cannot be met.

# 3 Use case scenarios and conditions for Impact Studies on beam WPT

In the WG for beam WPT systems, impact to several incumbent systems are studied. Table Anx2‑2 shows the use case scenarios and conditions for Impact Studies on beam WPT systems used for impact studies.

TABLE Anx2-2

Use case scenarios and conditions for beam WPT systems

|  |  |  |  |
| --- | --- | --- | --- |
| beam WPT system | 920 MHz band | 2.4 GHz band | 5.7 GHz band |
| Usage environment  | Factory (Indoor), nursing home, etc. | Factory (indoor), plant (indoor), warehouse, etc. | Factory (indoor), plant (indoor), warehouse, etc. |
| Application | Charging and power supply to sensor network | Charging and power supply to sensors, display and information devices | Charging and power supply to sensors, display and information devices |
| Number of receiving devices per one WPT transmitter | 5 to 10 devices(Simultaneous reception) | 1 to several tens devices(Successive or sequential reception) | 1 to several tens devices(Successive or sequential reception) |
| Power range | Several μW to several hundreds μW | 50 mW to 2 W | Several mW to several hundreds mW |
| Power transfer distance | Less than 5 m | Less than 10 m | Less than 10 m |
| Coexistence with other wireless systems | Feasible. Take appropriate interference mitigation and radio protection measures | Feasible. Take appropriate interference mitigation and radio protection measures | Feasible. Take appropriate interference mitigation and radio protection measures |
| Power transfer while human bodies exist | Possible to transfer under the condition that limits of national radio exposure guidelines are cleared  | Off | Off |

Table Anx2-3, and Figures Anx2-1, Anx2-2 and Anx2-3 shows the specification of beam WPT systems used for impact studies.

TABLE Anx2-3

Specifications of beam WPT systems used for impact studies

|  | 920 MHz band | 2.4 GHz band | 5.7 GHz band |
| --- | --- | --- | --- |
| Transmitter antenna output power  | 1W (30 dBm) | 15W (41.8 dBm) | 32W (45.0 dBm) |
| Frequency channels  | 918.0, 919.2 MHz(2 channels) | 2 412、2 437, 2 462, 2 484 MHz(4 channels) | 5 740, 5 742, 5 744, 5 746, 5 748, 5 750, 5 752, 5 758, 5 764 MHz(9 channels) |
| e.i.r.p | 36 dBm Max. | 65.8 dBm Max. | 70.0 dBm Max. |
| Tolerance of occupied bandwidth | 200 kHz | Not specified | Not specified |
| Transmitter antenna directive gain | 6.0 dBi | 24.0 dBi | 25.0 dBi |
| Location and height of transmitter antenna | Located indoor area | Located indoor area and set on ceiling to look down | Located indoor area and set on ceiling to look down |
| 2.5 m above floor | 5.0 m above floor | 4.6 m above floor |
| Transmitter antenna directive pattern | Figure ANX2-1 | Figure ANX2-2 | Figure ANX2-3 |
| Usage environment | Indoor | Indoor | Indoor |
| WPT controlled environmentand/or WPT genral environment | WPT controlled environment | WPT controlled environment |
| Modulation | Not specified | N0N | N0N |
| Propagation loss due to building wall | 10.0 dB | 14.0 dB | 16.0 dB |

FIGURE ANX2-1

Transmitter antenna directive pattern for 920 MHz band



FIGURE ANX2-2

Transmitter antenna directive pattern for 2.4 GHz band



FIGURE ANX2-3

Transmitter antenna directive pattern for 5.7 GHz band



# 4 Results of Impact Studies by the beam WPT

## 4.1 Summary

Tables Anx2-4, Anx2-5 and Anx2-6 summarize the results of impact studies for each beam WPT band.

TABLE Anx2-4

Results of impact study for beam WPT using 920 MHz band

| Incumbent system | Results of impact study |
| --- | --- |
| Digital MCA (Multi-Channel Access radio system):Relay station and mobile station | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by accounting the separation distance, the adjustment of setting conditions, measures to mitigate interferences and propagation loss due to building walls.  |
| MCA (Multi-Channel Access radio system):Mobile station | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference. Administrators should call attention to the possibility of interfering to MCA mobile stations in the same indoor environment.  |
| MCA (Multi-Channel Access radio system):Base station | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference. |
| Mobile communication system(LTE):Base station and mobile terminal station | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference. |
| RF-ID system | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference in the condition that WPT systems comply the regulation of passive RF-ID systems. |
| Radio astronomy | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance. |

TABLE Anx2-5

Results of impact study for beam WPT using 2.4 GHz band

| Incumbent system | Results of impact study |
| --- | --- |
| Wireless LAN system | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by adding the carrier sensing function. WPT systems should be used in "WPT controlled environment".  |
| Premises Radio Station, Specified Low Power Radio Station |
| Unmanned mobile image transmission system(Wireless system for drones and other unmanned vehicles) | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference. If necessary, the operational coordination is performed between WPT systems and unmanned mobile image transmission systems.  |
| Mobile satellite communication system:N-STAR | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance. If necessary, the operational coordination is performed between WPT systems and mobile satellite communication systems.  |
| Mobile satellite communication system:Globalstar | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference. If necessary, the operational coordination is performed between WPT systems and mobile satellite communication systems.  |
| Field Pickup (FPU) system | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance and by meeting the installation conditions. |
| Radio beacon | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance. |
| Radio astronomy | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance. |
| Amateur radio | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by meeting the installation conditions. If necessary, the operational coordination is performed between WPT systems and amateur radio systems.  |

TABLE Anx2-6

Results of impact study for beam WPT using 5.7 GHz band

|  |  |
| --- | --- |
| Incumbent system | Results of impact study |
| Wireless LAN system | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by adding the carrier sensing function. WPT systems should be used in "WPT controlled environment".  |
| Dedicated Short Range Communication (DSRC) system | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance. When harmful interferences happen, the operational coordination should be performed between WPT systems and DSRC systems.  |
| Broadcasting Service:Studio to Transmitter Link (STL) & Transmitter to Transmitter Link (TTL) systems | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance and by meeting the installation conditions. |
| Broadcasting Service:Field Pickup (FPU) & Transmitter to Studio Link (TSL) systems | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance and by meeting the installation conditions. |
| Unmanned mobile image transmission system(Wireless system for drones and other unmanned vehicles) | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance or by the operational coordination between WPT systems and unmanned mobile image transmission systems. |
| Weather radar | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance. |
| Radio astronomy | Impact from beam WPT systems is on an acceptable level and does not cause harmful interference by keeping the necessary separation distance. |
| Amateur radio | WPT systems do not use the frequency band for Earth-Moon-Earth (EME) systems and repeater systems. The operational coordination is performed between WPT systems and amateur radio systems.  |

## 4.2 Results of impact study for beam WPT using 920 MHz band

## 4.3 Results of impact study for beam WPT using 2.4 GHz band

## 4.4 Results of impact study for beam WPT using 5.7 GHz band

# 5 Regulation issues for the beam WPT

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 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 to protect human bodies from harmful effects of RF exposure to beam WPT radio waves, which may include human body detection when transmitting, transmission interruption, safety instruction and mechanism, and further protection measures to keep off the people from local transmission region observing higher RF exposure level than the restriction defined in the Radio Protection Guidelines.

A stepwise approach to achieve above is taken in the rulemaking process. The 1st Step studies impact to the existing radiocommunication systems; and then, it provides technical conditions intended for the use in occupational environments and/or general public environments under specified exposure control mechanisms. The Report (in Japanese) regarding the 1st Step released in July 2020 [xx] describes technical conditions operating in 920 MHz band, 2.4 GHz band, and 5.7 GHz band for the use indoors (e.g., factories) with human body protection requirements from RF exposure. The 2nd and later Steps further extend studies for the use outdoors and higher power transmission including new technology development, applications, commercialization, effective spectrum sharing, noise suppression, and etcetera.