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| U.S. Radiocommunications Sector  Fact Sheet | |
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| **Ref:** Report ITU-R SM.2303-2 | **Date:** 7 July 2021 |
| Document Title: Working document towards a preliminary Draft Revision to Report ITU-R SM.2303-2 - Wireless power transmission using technologies other than radio frequency beam | |
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| **Purpose/Objective:** Align Report ITU-R SM.2303-2 with the proposed additional frequency ranges in Recommendation ITU-R SM.2129 for non-beam wireless power transmission systems for mobile and portable devices. | |
| **Abstract:** This input contribution proposes to incorporate the frequency ranges included in Recommendation ITU-R SM.2129 for non-beam WPT induction technologies into Report ITU-R SM.2303. In addition, this contribution may provide updates to the technologies and use cases, if required. | |

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| Wireless power transmission using technologies other  than radio frequency beam | |

**Introduction**:

Report ITU-R SM. 2303-2 provides administrations background information, case studies and national examples of non-beam wireless power transmission applications. The report is currently under revision to accommodate changes in technical standards and new applications for WPT technology.

**Background**:

Consumer demand for wireless charging devices has increased with the expansion of various mobile devices including smartphones, tablets, and wearables. Additional frequency ranges for non-beam inductive WPT applications are now in use and should be considered in relevant ITU-R reports and studies, facilitating global harmonization of these applications that are already on the market. Harmonization benefits both manufacturers and consumers by enabling global use and trade of the devices.

Since 2019, more devices have become available that use other frequency ranges than those originally included in Report ITU-R SM.2303. The revisions provided in this input contribution include references to these new frequencies and emerging frequencies of interest for future non-beam WPT applications for mobile and portable devices.

**Proposal**: The United States proposes Working Party 1A continue working toward a revision of Report ITU-R SM.2303 that includes additional frequency ranges used by non-beam WPT systems for mobile and portable devices. Pursuant to the request of the Chairman after the most recent meeting of Working Party 1A, only changes to Section 7 of the Report are proposed at this time.

**Attachment**: Draft Revision to Section 7 of Report ITU-R SM.2303-2.

[USA Editor’s Note: The Chairman of WP1A requested that only changes to Section 7 of Report ITU-R SM.2303-2 be submitted for the next meeting. In accordance with this request, only Section 7 is included in this draft contribution. No changes to other sections of the Report are proposed.]

# 7 Impact studies between WPT and radiocommunication services

This chapter details the status of impact studies between WPT and radiocommunication services, including the radio astronomy service[[1]](#footnote-1).

## 7.1 Study results and ongoing activities in some administrations

In light of the high field strengths that can be produced by WPT systems, there is the potential for interference to communications signals operating in nearby bands. A determination of the required characteristics of WPT RF signals must be based on studies of potential interference from WPT to other services. Such studies and the resultant determination of characteristics must be completed prior to the designation or assignment of frequencies for WPT.

Figures 12 and 13 show the WPT spectrum designated or under considerations in Japan and assigned in Korea [1]. Additional spectrum may also be used for WPT, pursuant to Recommendations ITU-R [SM.2110](https://www.itu.int/rec/R-REC-SM/recommendation.asp?lang=en&parent=R-REC-SM.2110) ‘Guidance on frequency ranges for operation of non-beam wireless power transmission for electric vehicles’ and [SM.2129](https://www.itu.int/rec/R-REC-SM/recommendation.asp?lang=en&parent=R-REC-SM.2129) ‘Guidance on frequency ranges for operation of non-beam wireless power transmission systems for mobile and portable devices.’ Spectrum sharing studies should be performed between the concerned systems with WPT systems to clarify the availability of coexistence. Some WPT equipment are classified into ISM equipment which shall not cause harmful interference nor claim protection from other stations. Table 17 shows spectrum use of incumbent wireless systems below 1.6 MHz, which should be considered in impact studies for WPT systems for EVs.

TABLE 17

Spectrum use of incumbent wireless systems

| Radio systems | | Frequency bands | Communication technologies | Remarks |
| --- | --- | --- | --- | --- |
| Standard frequency and time signal service | | 19.95 kHz – 20.05 kHz (20 kHz, Global) 39 kHz – 41 kHz (40 kHz, Japan) 49.25 kHz – 50.75 kHz (50 kHz, Russia) 59 kHz – 61 kHz (60 kHz, UK, US and Japan) 65.85 kHz – 67.35 kHz (66.6 kHz, Russia) 68.25 kHz – 68.75 kHz (68.5 kHz, China) 74.75 kHz – 75.25 kHz (75 kHz, Switzerland)  77.25 kHz – 77.75 kHz (77.5 kHz, Germany) 99.75 kHz – 102.5 kHz (100 kHz, China)  128.6 kHz – 129.6 kHz (129.1 kHz, Germany) 157.5 kHz – 166.5 kHz (162 kHz, France) | Amplitude modulation,  Binary Coded Decimal (BCD) | The clocks and watches that periodically receive digital signals of the standard time transmitted from the standard-time-signal transmitting stations to synchronize and adjust own time. |
| Ripple Control Service | | 128.6 kHz – 129.6 kHz (129.1 kHz, Europe) 138.5 kHz – 139.5 kHz (139 kHz, Europe) | － | Load/demand management system for power plants and their electric power network |
| Train radio systems | Automatic Train Stop Systems (ATS) Systems | 10 kHz – 250 kHz (Japan) | － | Telecommunication system that applying electric current to coils installed along with railroad track and detects electric current carried through coils which are installed on train vehicles on the rail to control trains. |
| 425 kHz – 524 kHz (Japan) |
| Inductive Train Radio Systems (ITRS) | 100 kHz – 250 kHz (Japan) | － | Signal transmission system which uses inductive coupling between transmission line which is installed along with the railroad track and so forth and antenna that is installed on train vehicles. |
| 80 kHz, 92 kHz (Japan, only one station) |
| Amateur radio | | 135.7 kHz – 137.8 kHz | Amplitude modulation, frequency modulation, SSB etc. | Radio service with transmitter and receiver devices used for technology research and training of amateur radio operators. |
| 472 kHz – 479 kHz |
| Maritime radio | | 90 kHz – 110 kHz (LORAN) | Pulse, FSK etc. | Radio system that secures safety of vessel operation which is used at port and harbor or on the sea. |
| 424 kHz, 490 kHz, 518 kHz (NAVTEX) |
| 495 kHz – 505 kHz (NAVDAT) |
| Sound broadcast | | 148.5 kHz – 283.5 kHz (Region 1) 525 kHz – 526.5 kHz (Region 2) 526.5 kHz – 1606.5 kHz (Global) 1605.5 kHz – 1705 kHz (Region 2) | Amplitude modulation/DRM | Audio broadcasting service with receiver devices which use medium wave band. |

FIGURE 12

WPT spectrum considered and incumbent systems (10-300 kHz)



FIGURE 13

WPT spectrum considered and incumbent systems (400 kHz-13.56 MHz)



In China, different kinds of high power WPT devices have been invented, which include WPT for home appliance operating frequency ranges of 47-53 kHz and WPT for light and heavy duty vehicles operating working frequency ranges of 37-43 kHz and 82-87 kHz. Facing the market requirement, sufficient coexistence research before relevant frequency planning is urgent and necessary. Considering current national frequency planning, the wireless communication system which has been put into practice and other wireless communication requirements, the coexistence studies including dedicated frequency band, shared frequency band, separation distance and so on are ongoing. CCSA TC5 WG8 will initiate a new project to study the coexistence issues of WPT with incumbent radio-communication systems in 2015. Partial research results will be completed in 2016.

In Japan, target WPT systems and candidate proposed frequency ranges with fundamental parameters are summarized as shown in Table 18.

TABLE 18

WPT technologies considered in Japan MIC WPT Working Group discussion

| Target WPT applications | (a) WPT for EVs | (b) WPT for mobile and portable devices (1) | (c) WPT for home appliances and office equipment | (d) WPT for mobile and portable devices (2) |
| --- | --- | --- | --- | --- |
| WPT technology | Magnetic field power transmission (inductive, resonance) | | | Capacitive coupling |
| Transmission power | Up to approx. 3 kW  (max 7.7 kW) | Several W – approx.100 W | Several W-1.5 kW | Approx. 100 W |
| Candidate WPT frequency ranges | 42-48 kHz  (45 kHz band),  52-58 kHz  (55 kHz band),  79-90 kHz  (85 kHz band),  140.91-148.5 kHz  (145 kHz band) | 6 765-6 795 kHz | 20.05-38 kHz,  42-58 kHz,  62-100 kHz | 425-524 kHz |
| Transmission distance | 0 – approx. 30 cm | 0 – approx. 30 cm | 0 – approx. 10 cm | 0 – approx. 1 cm |
| The information in this Table may be changed by the domestic and global standardization trend of WPT. | | | | |

### 7.1.1 Japan

For spectrum sharing and coexistence studies, the WPT-Working Group (WG) under MIC’s Committee on Electromagnetic Environment for Radio-wave Utilization picked up many possible and practical combinations of the incumbent radio systems and the target WPT systems which might cause a harmful interference event in specific use cases. In such an event, the fundamental WPT radio wave may fall in the same spectrum of the incumbent radio systems when located within the minimum required separation distance from the WPT device or when an appropriate power attenuation measure is not taken. In another case, a WPT harmonic wave might fall into the spectrum of the incumbent radio system to cause degradation of signal quality at the incumbent radio receiver. Seeing varieties of concerned events, the WG defined the worst case conditions to assess the impact of WPT. Usage scenarios have been reviewed; and then, simulations and field experiments have been performed. The coexistence conditions, which gives a criteria of the use of a WPT system together with the incumbent systems, were defined by the WG based on the current receiver sensitivities and actual use cases assumed.

In December 2014, 6.78 MHz magnetic coupling WPT and capacitive coupling WPT demonstrated coexistence in the defined conditions.

6.78 MHz magnetic coupling WPT device coexistence with the public radio systems using small frequency segments in the range of 6.765-6.795 MHz were assessed. The maximum transmission power of 100 W was assumed. Specific emission limits (see Table 12) were derived and specified per a small segment in the range to meet coexistence requirements.

Capacitive coupling WPT device coexistence was assessed by theoretical calculation and field experiments. The results showed much lower magnetic emission strength than the emission limit requirement to coexist with the concerned incumbents. Accordingly, coexistence of a capacitive coupling WPT device with transmission power less than 100 W was proved. It should be noted that, however, frequency ranges used for maritime radio devices and amateur radio devices were excluded from the candidate operation frequency ranges as international spectrum usage is taken into consideration.

Another magnetic coupling WPT technology using kHz range for home appliances has still not demonstrated coexistence for all the defined test cases in the assessment.

WPT for EV applications using 79-90 kHz demonstrated coexistence with standard clock radio devices, AM broadcast devices, and Amateur radios. Those using candidate frequency ranges other than 79-90 kHz have still not met the requirements. Thus, candidate frequency ranges for EV have converged to 79-90 kHz.

The WG performed further assessment to prove coexistence with railway wireless systems, namely Automatic Train Stop Systems (ATS) deployed all over the railway networks in Japan and Inductive Train Radio Systems (ITRS) for very specific actual use cases. The WG finally agreed on the technical requirements on coexistence with railway wireless systems.

As a result of coexistence studies, Japan would like to add emphasis to global attention to coexistence study with railway wireless systems in particular ATS. Today, ATS is operated around 100 kHz and is deployed not only in the Japanese railway network but also in many countries and regional railway networks of the globe. In the future, it may happen that many countries deploying ATS face the same issue to prove coexistence with WPT systems to ensure the safety of the passengers. This study should be taken into global consideration, not in a country specific approach. Japan believes that ITU-R is invited to take action on this study in collaboration with CISPR.

Railway wireless systems by electro-magnetic control mechanism are absolutely crucial for secure operation. Robustness of the systems against unwanted radio waves is a critical measure and may have independent characteristics from one by one. Accordingly, coexistence criteria for the systems differs from one country or one region to another. Therefore, emission limits to specify in CISPR should take account of such variety and reliability of the systems.

The WG concluded that WPT systems for EVs in the frequency range of 79-90 kHz for 3 kW and 7.7 kW power classes can be used without causing harmful interference to the selected incumbent systems and services under practical conditions. The new rules of WPT systems for EVs, 6.78 MHz magnetic coupling WPT and capacitive coupling WPT, were published and put into force in March, 2016.

Table 19 (A), (B), (C) and Table 20 summarize results of coexistence studies.

TABLE 19

Summary of WPT for mobile and home appliance coexistence study results in Japan

(A) Coexistence with Standard Clock Radio Devices, Automatic Train Stop Systems and Inductive Train Radio Systems

| WPT for mobile and  home appliances | | Incumbent systems | | |
| --- | --- | --- | --- | --- |
| Technologies | Candidate frequency ranges | Standard Clock Radio Devices (SCRD) (\*1)  (40 kHz, 60 kHz) | ATS (\*2)  (10-250 kHz) | ITRS (\*3)  (10-250 kHz) |
| Magnetic coupling  (low power for mobile devices) | 6.765- 6.795 kHz | N/A | N/A | N/A |
| Magnetic coupling  (low-high power for home appliances) | 20.05-38 kHz | Meets coexistence conditions with the notes below:  • The 2nd and 3rd harmonics shall not fall in the SCRD operation bands.  • Inviting users’ attention to the possibility of interference to the SCRDs | Further assessment necessary for coexistence.  • Need to derive required separation distance not to cause harmful interference | Meets coexistence conditions |
| 42-58 kHz | Meets coexistence conditions |
| 62-100 kHz | Further assessment necessary.  • Need to derive required separation distance not to cause harmful interference |
| Capacitive Coupling  (low power for mobile devices) | 425-524 kHz | N/A | Meets coexistence conditions by reducing magnetic field strength by 12 dB achieved | N/A |
| Coexistence conditions in assessment:  (\*1) Standard clock radio devices: WPT devices shall not cause harmful interference in simulated use cases.  • Separation distance of 10 m was used as a coexistence criterion. In addition to the fundamental wave characteristics, integer harmonics was examined as well when they fall into the Standard clock radios operation bands.  • Additional measure on operation time condition is considered since WPT operation of home/office equipment is not expected or observed less frequently in midnight when Standard clock radios receive their signals frequently. Advertisement of radio hazard from WPT for home appliances may lead to less interference to share the same spectrum as utilization time is not overlapped entirely.  • WPT harmonics generated fundamental waves of 20.05 kHz and 30 kHz fall into the Standard clock radios operation spectrum. This is critical to ensure non-harmful interference.  (\*2) (\*3) ATS and ITRS: WPT devices shall not cause harmful interference in the actual use cases in operation. The criteria for coexistence are:  • WPT frequency band should not be overlapped with those used for the train signalling communication systems including ATS, or  • The separation distance to the ATS/ITRS devices, in which a WPT device does not cause harmful interference, should be less than the most critical threshold (approx. 1.5 m) specified in the train systems building standards.  • Above shall be met with all types of railways building layout in Japan. | | | | |

(B) Coexistence study with AM broadcast and Maritime radio devices

| WPT for mobile and  home appliances | | Incumbent systems | |
| --- | --- | --- | --- |
| Technologies | Candidate frequency ranges | AM broadcast (\*1)  (526.5-1 606.5 kHz) | Maritime radio devices (\*2)  (405-526.5 kHz) |
| Magnetic coupling  (low power for mobile devices) | 6.765- 6.795 kHz | N/A | N/A |
| Magnetic coupling  (low-high power for home appliances) | 20.05-38 kHz | Not meet coexistence conditions as found required separation distance far exceeding 10 m as the target requirement | N/A |
| 42-58 kHz | N/A |
| 62-100 kHz | Meets coexistence conditions with  the following  • Avoiding the use of WPT systems emitting power in the LORAN-C frequency range (\*3) |
| Capacitive coupling  (low power for mobile devices) | 425-524 kHz | Meets coexistence conditions with  the following notes.  • Inviting users’ attention to the possibility of interference to the AM radio devices.  • If harmful interference observed, WPT devices shall take appropriate measures | Meets coexistence conditions with  the following.  • Avoiding the use of WPT systems emitting power in the frequency ranges of NAVTEX and NAVDAT |
| Coexistence conditions in assessment:  (\*1) AM Broadcast: A WPT device shall not cause harmful interference to an AM broadcast receiver at least 10 m distance based on the CISPR residential environment. Multiple number of WPT devices and an indoor AM-radio receiver is assumed in the system model. Field tests were performed in agreed worst use case conditions with variables of frequencies, number of WPT devices, separation distances, and high and low background city noise level areas. CISPR 11 Group 2 Class-B was referred as well.  (\*2) Maritime radio devices: A WPT device shall not cause harmful interference. Assessment showed that the proposed WPT system has possibility substantially to coexist with the maritime radio systems. However, it is worth noting that the following frequencies in the frequency range in this study are used for secure marine navigation safety. Therefore, the same frequencies have been deleted for the use. (i) NAVTEX: 518 kHz (424 kHz, 490 kHz) (ii) NAVDAT: 495-505 kHz. In addition, harmonics should not fall into the Marine VHF radio band (156-162 MHz) used internationally.  (\*3) LORAN-C, eLORAN (90-100 kHz): Maritime radiocommunication operators commented that this spectrum should not be arranged for the use of WPT. | | | |

(C) Coexistence Amateur radio devices and Public radio systems

| WPT for mobile and home appliances | | Incumbent systems | |
| --- | --- | --- | --- |
| Technologies | Candidate frequency  ranges | Amateur radio devices (\*1)  (135.7-137.8 kHz, 472-479 kHz) | Public radio systems (\*2) (6,765-6,795 kHz) |
| Magnetic coupling (low power for mobile devices) | 6.765-6.795 kHz | Meets coexistence conditions with the following  • Avoiding the use of WPT systems transmitting power in the amateur radio frequency ranges | Meets coexistence conditions with specific emission limits provided |
| Magnetic coupling (low-high power for home appliances) | 20.05-38 kHz | NA |
| 42-58 kHz | NA |
| 62-100 kHz | NA |
| Capacitive coupling (low power for mobile devices) | 425-524 kHz | NA |
| Coexistence conditions in assessment:  (\*1) Amateur radio devices: For capacitive coupling, 472-479 kHz band is an in-band case (sharing the same spectrum). For amateur radios, no official interference level requirements or rules from other systems are found. However, an agreement was to exclude this band allocated to Amateur Radios in the WPT operation frequency range and to set appropriate frequency offset.  (\*2) Public radio systems: 6 765-6 795 kHz is not designated as an ISM band in Japan. However, the regulations’ provisions allow the use for WPT applications in the band. New emission limits for WPT products in this band have been agreed, which may allow coexistence with the incumbent systems and higher transmission power in this band. | | | |

TABLE 20

Summary of WPT for EV coexistence study results in Japan

| WPT for EV | Incumbent systems | | | | |
| --- | --- | --- | --- | --- | --- |
| Candidate frequency ranges | SCRD (\*1)  (40 kHz, 60 kHz) | ATS (\*2)  (10-250 kHz) | ITRS (\*3)  (10-250 kHz) | AM broadcast (\*4) (526.5- 1 606.5 kHz) | Amateur radio devices (\*5) (135.7- 137.8 kHz) |
| 42-48 kHz | Not meet coexistence conditions | Not assessed since another condition did not meet | Meets coexistence conditions | Meets coexistence conditions with the following notes.  • Inviting user’s attention to the possibility of interference to AM broadcast radio receivers.  • If harmful interference observed, WPT devices shall take appropriate measures | Meets coexistence conditions with the following note.  • Avoiding the use of WPT systems transmitting power in the amateur radio frequency ranges |
| 52-58 kHz | Not meet coexistence conditions | Not assessed since another condition did not meet | Meets coexistence conditions |
| 79–90 kHz | Meets coexistence conditions with the following note.  • Inviting user’s attention to the possibility of interference to Standard Clock radio devices | Meets coexistence conditions with the following requirement.  • Minimum separation distance from the rail of 4.8 m shall be kept | Meets coexistence conditions with the following requirement.  • Minimum separation distance from the rail of  45 m shall be kept.  • Only one rail track operation uses 80 kHz and 92 kHz where this technical requirement shall be applied |
| 140.91- 148.5 kHz | Not assessed since another condition did not meet | Not meet coexistence conditions |

TABLE 20

*Notes to Table 20:*

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| Coexistence conditions in assessment  (\*1) Standard clock radio devices: WPT devices shall not cause harmful interference defined by *C*/*I* ratio derived from the minimum receiver sensitivity of the Standard clock radio devices in agreed use cases. Separation distance of 10 m was used as a coexistence criterion. Additional measures on operation time non-overlapping between WPT and Standard clock radio, radio propagation direction variation, and possible performance improvement were taken into consideration.  (\*2) (\*3) ATS and ITRS: WPT devices shall not cause harmful interference in the actual use cases in operation. The criteria for coexistence is: (i) WPT frequency band should not be overlapped with those used for the train signaling communication systems including ATS, or (ii) The separation distance to the ATS/ITRS devices, in which a WPT device does not cause harmful interference, should be less than the most critical threshold (approx. 1.5 m) specified in the train systems building standards. These (i) and (ii) shall be met with all types of railways building layout in Japan.  (\*4) AM Broadcast: A WPT device shall not cause harmful interference to an AM broadcast receiver at least 10 m distance based on the CISPR residential environment. Field test by WPT transmitter and receiver on a mock wagon was performed in agreed worst use case conditions in which WPT’s 7th harmonics of *Fc* = 85.106 kHz falls into 594 kHz AM broadcasting service channel covering wide area of Kanto-region of Japan. Hearing assessment was performed as well.  (\*5) Amateur radio devices: This is an out-band case (not sharing the same spectrum). Candidate frequency ranges for WPT for EVs have appropriate offset frequencies (guard band) to detune in the amateur radio bands. Therefore, receiver sensitivity suppression (out-of-band) by interference is not taken but radiated emission levels of harmonics (spurious emissions) from WPT devices are counted in the case they fall into the amateur radio bands. Referring to the emission level regulations in the Japan Radio Law and other related rules as the criteria, currently the assumptions of WPT systems for EVs show acceptable system parameters to demonstrate possible non-harmful interference to the amateur radio devices. |

### 7.1.2 Korea

In Korea, it uses 19-21 kHz and 59-61 kHz for heavy-duty vehicle WPT system since 2009. The power level is around 100 kW for charging wirelessly electric buses. From 2011, Korea supplies expansion to variable regional cities such as Seoul (Seoul Grand Park shuttle bus), Daejeon (KAIST shuttle bus), Sejong (New administrative intra-city bus) and Gumi city (Industrial complex intra-city bus) and so on. In addition, Korea government has distributed the frequency band (19-21 kHz and 59‑61 kHz) to frequency application equipment included WPT (Wireless Power Transfer) technology in May, 2011 and has supported the relevant impact study to protect preexistence frequency resource and/or frequency services of adjacent band.

The test result based on the already proposed measurement method under real operating sites is shown in Annex 4. This result of Annex 4 indicates the *in-situ* test output under every 10 m, 30 m, 50 m and 100 m from the fixed bus-charging station (around 100 kW).

In addition, Impact Study for Japan’s 60 kHz Radio clock and EBU LF band (148.5-283.5 kHz) is also reported to same condition under real commercial sites.

In conclusion, it is so hard to detect direct correlation interferences between the fixed heavy-duty WPT system and Japanese radio clock, EBU LF band in the case of far-away 100 m distance. This 100 m means a traditional measurement technic of electric field and it also refers the Radio law to protect any other frequency services. Therefore, it must adhere strictly to the separation distance if it uses the fixed high power WPT system.

In Annex 5, Korean mobile WPT devices in the frequency range100-300 kHz are specified as one of weak electromagnetic field strength devices according to the Radio Waves Act. To launch WPT devices using 100-300 kHz into the Korean market, products have to comply with the corresponding regulatory requirements to prevent any harmful interference with other systems. Essentially, any WPT frequency including 100-300 kHz will be allowed as long as it meets the regulatory requirements as a weak electromagnetic filed strength device except for some specific prohibited frequencies.

Annex 5 provides the measured data of electromagnetic radiation disturbance from the WPT system for mobile devices using magnetic induction technology and its compliance to the European standards and CISPR 11 requirements as well as Korea regulations.

### 7.1.3 Germany

Germany performed measurements on a WPT system for the charging of cars in an anechoic chamber and provided the results in January 2016. The field strength of the WPT system operated at 85 kHz was measured in the range 20 kHz up to about 1.5 MHz and compared with the limits in ETSI EN 300 330-1 for inductive SRDs.

The measurements were taken in different polarization planes, with only the results from the plane exhibiting maximum emissions considered. To allow direct comparison with the limits in ETSI EN 300 330, only the measurement results for 10 m distance are taken into account, because this is the normative distance defined in that standard.

The measurement results at 10 m distance show the following:

– In general, the spurious emissions are slightly higher when the vehicle is not positioned exactly over the centre of the charging coil (max offset). The difference, however, is less than the difference when considering different measurement directions (front/back/left/right).

– Spurious emission levels are generally higher to the front and back than sideways.

– The field strength (carrier power) inside the tested channel is around 71 dBuA/m (no offset) to 75 dBuA/m (max offset). This exceeds the limits of ETSI EN 300 330-1 by 4 and 8 dB respectively. ETSI has published EN 303 417 “Wireless power transmission systems, using technologies other than radio frequency beam in the 19-21 kHz, 59‑61 kHz, 79-90 kHz, 100-300 kHz, 6 765-6 795 kHz ranges; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU”..

– The spurious emission levels in the frequency range of the standard time signals (below 85 kHz) are well below the limit from ETSI EN 300 330-1, typically by 20 dB.

– The spurious emission levels at the harmonic frequencies below 1.5 MHz exceed the limit of ETSI EN 300 330-1 by as much as 20 dB. It should be noted that the WPT system tested was a prototype setup which is still under development and may therefore not represent the final production design.

## 7.2 Ongoing WPT studies and results on the impact to broadcasting services

The broadcasting service has the following Primary allocations in the LF and MF bands:

148.5-283.5 kHz in Region 1

526.5-1 606.5 kHz in Regions 1 and 3

525-1 705 kHz in Region 2

Both allocations are used for AM sound broadcasting and/or for DRM (Digital Radio Mondiale).

For co-existence between WPT systems and broadcasting services, the impact to broadcasting services should be discussed in any radio environments, such as rural, residential and urban areas.

Subsection 7.2.1 contains a study based on an analytical approach using the protection criteria of broadcasting service from ITU-R Recommendations and reports. It derives the maximum tolerable magnetic field from WPT at the broadcasting receiver in the LF and MF bands. The derived maximum tolerable magnetic field strengths are almost at same level as the environment noise level in quiet rural areas as described in Recommendation [ITU-R P.372](https://www.itu.int/rec/R-REC-P.372).

Subsection 7.2.2 describes a study on the impact in urban and suburban areas conducted by a committee of the administration of Japan. Basic requirement for co-existence between WPT systems and broadcasting services in this study is that the emission level at broadcasting receivers from WPT is lower than environmental noise in “city” environment described in Recommendation ITU-R P.372. The radiated emission limits for the MF broadcasting band at 10 meters from WPT receivers are determined by a different approach from the analytical study above. The approach includes emission measurements and audibility tests of interferences to broadcasting service in an emission test site.

### 7.2.1 Analysis of the impact of WPT systems to broadcasting services

#### 7.2.1.1 Protection criteria and acceptable interference

Recommendation [ITU-R BS.703](https://www.itu.int/rec/R-REC-BS.703/en) ‒ *Characteristics of AM sound broadcasting reference receivers for planning purposes* sets the minimum sensitivity of an AM sound broadcasting sound receiver for planning purposes as:

– Band 5 (LF): 66 dBµV/m

– Band 6 (MF): 60 dBµV/m

Recommendation [ITU-R BS.560](https://www.itu.int/rec/R-REC-BS/recommendation.asp?lang=en&parent=R-REC-BS.560) ‒ Radio-frequency protection ratios in LF, MF and HF broadcasting, outlines applicable protection ratios for interference between AM broadcast signals. Although WPT is not a broadcast signal, it may take the form of a (mostly) unmodulated carrier and to that extent is actually very similar to a broadcast AM signal, during a pause or quiet passage as presented to the receiver. These protection ratios can therefore be considered to be a good basis for deriving radiated emission limits from WPT.

#### 7.2.1.2 Derivation of the maximum tolerable H field at the broadcasting receiver from WPT installations

Part of any emission limit is the specification of the distance from the interfering source at which a particular field strength limit should apply. This issue can be dealt with completely separately from the question of what the limit should be:

– The first step in the derivation is to consider the wanted and interfering field strengths at the broadcasting receiver, whatever the distance this happens to be from the interfering source. Where distances are mentioned, we do so only in order to establish the field strength that was present.

– The second step is to consider what assumptions are necessary about the separation distance and the factors affecting the propagation between the interference source and the broadcasting receiver, as well as the scenarios for WPT use cases (from low power chargers for mobile phones etc. up to high power chargers for Heavy Electric Vehicles).

The limits may then be derived in the first step above for WPT interference falling in the band of an AM signal.

Importantly, radiated disturbances caused by WPT equipment can occur on:

– harmonics of a fundamental WPT frequency; for example a WPT EV charger using a frequency in the 79 to 90 kHz band can generate harmonics falling in the LF broadcasting band (148.5 to 283.5 – second harmonic) and in the MF broadcasting bands (526.5 to 1 606.5 kHz and 525 to 1 705 kHz – sixth harmonic and above) or,

– the fundamental of the WPT itself; for example a WPT mobile phone charger using a frequency in the LF Broadcasting Band in Region 1 (148.5 to 283.5 kHz).

Starting from the recommended planning considerations and protection criteria given in Recommendations ITU-R BS.703 and ITU-R BS.560 and noting that broadcast receivers used in the home commonly use ferrite-rod antennas that respond to the magnetic-field component H of the wave, it is convenient to use the corresponding H-field strengths when considering emission limits on WPT equipment. Assuming far-field free-space conditions (which will apply to the received broadcast signal at the receiver antenna) the relationship between the electric and magnetic fields (from Maxwell’s equations) is:

Where μ0 is the permeability of free space and ε0 it the permittivity of free space.

This means that the following conversion factors apply:

which may be expressed as:

So, the receiver sensitivities at LF and MF (in § 7.2.1.1) can also be expressed as 14.5 and 8.5 dBµA/m respectively.

The protection ratios for AM broadcasting comprise two components:

– the “co-channel” protection ratio (PR) needed when the interferer and wanted signal carrier are on essentially the same frequency (so any beat between them is of a frequency below the audible range; in this case the modulation of the interferer is the dominant cause of audible disturbance);

– the additional “relative PR” that must be added when the wanted and interfering signals have a frequency difference, which then gives rise to a continual audible beat tone; this correction depends on the frequency offset, primarily because the frequency response of the human ear is far from ‘flat’.

Unless WPT device frequencies are carefully aligned with the broadcast frequency raster, the additional relative PR for non-co-channel operation will need to be added. Assuming the WPT frequency to be uncontrolled, we may assume that the worst case occurs. Figure 1 of Recommendation [ITU-R BS.560](https://www.itu.int/rec/R-REC-BS/recommendation.asp?lang=en&parent=R-REC-BS.560) shows that the greatest relative PR is approximately 16 dB, which corresponds to frequency offsets of around 2 kHz.

For the worst case, this relative PR must be added to the co-channel PR of 40 dB to give an overall PR for WPT interference to AM broadcasting of (40 + 16) = 56 dB.

It therefore follows that the maximum acceptable WPT field strength, at the broadcast receiver location, is given by subtracting this PR from the receiver sensitivity.

The maximum acceptable WPT H field at the broadcast receiver location is therefore:

– Band 5 (LF): (14.5 – 56) = –41.5 dBµA/m

– Band 6 (MF): (8.5 – 56) = –47.5 dBµA/m.

It will be seen that these values are smaller than:

– the man-made and external-noises at LF; see Recommendation ITU-R P.372 radio‑noise; and

– the –15 dBµA/m at 10 m, in a 10 kHz bandwidth, recommended for SRDs operating in the range 148.5 kHz – 5 MHz in ERC Recommendation [70-03](https://docdb.cept.org/download/25c41779-cd6e/Rec7003e.pdf) [3] Annex 9.

However, there are good reasons for this:

– the beat-tone caused when the carrier of an interferer lies at a frequency offset from that of the broadcast signal being received is more disturbing than the same level of noise; this is clear in comparing the recommended protection ratios quoted above with the carrier-to-noise ratios considered acceptable for AM broadcasting (see Note below);

– these same protection ratios are applicable to other potentially-interfering broadcast signals in broadcast planning (see Annex 6) – it would not be acceptable to apply less-stringent conditions to non-broadcast (non-licensed) interferers than to broadcasts which have primary allocation in this frequency range in Region 1;

– noise levels at LF vary widely with location on the globe, seasons and time of day, so Recommendation ITU-R P.372 needs very careful interpretation; LF broadcasting is used in those parts of the world where the noise levels are acceptable (e.g. use of LF broadcasting does not occur in the Tropics);

– the limits for SRDs in ERC Recommendation [70-03](https://docdb.cept.org/download/25c41779-cd6e/Rec7003e.pdf) [3] (relevant to Europe) would have been derived under assumptions as to the separation from broadcast receivers which would be expected for the SRD types then considered, together with the likely intermittency of their use; these assumptions need revision for ubiquitous household devices used in the home for significant periods.

NOTE – The signal strength of an AM radio transmission is defined as the strength of the carrier. Recommendation [ITU-R BS.703](https://www.itu.int/rec/R-REC-BS/recommendation.asp?lang=en&parent=R-REC-BS.703) effectively sets the minimum carrier level which can be considered as providing a service and therefore defines boundary of the service area. Indeed, broadcasters and frequency planners use this figure to make this definition. It is based on a wanted audio signal to random noise ratio of 26 dB. The modulation gives rise to only a small amount of additional energy in (information carrying) sidebands. If an rms modulation depth of 0.2 (20%) is assumed[[2]](#footnote-2) the power in the carrier is around 14 dB greater than the modulation power in the sidebands. By comparison with the carrier, the sideband power is negligible adding less than 4% overall. Taking this typical sideband to carrier relationship into account, Recommendation ITU-R BS.560 specifies the protection ratio that a given service should have from an interferer as 40 dB. If the carriers are on the same frequency and it is assumed that the modulation depth of the two programmes is the same, this in turn defines the wanted audio signal to unwanted audio signal (from the interfering station) ratio as 40 dB. Clearly this is somewhat higher than the wanted signal to random noise ratio, the reasons being that an unwanted audio signal represents a greater intrusion into the wanted audio and that the signals in the upper and lower sidebands are correlated; whereas random noise is not.

This in turn means that at the fringe of the service area, as defined by the minimum sensitivity requirement for planning purposes, the unwanted signal should be 40 dB lower. In the MF case this is therefore 60 dBμV/m (from § 7.2.1.1 above – expressed as a voltage) minus 40 dBμV/m = 20 dBμV/m. If there is an offset between the carriers, the carrier component itself becomes a much more pernicious interferer as it is 14 dB stronger than the modulation and is much more audibly intrusive. As stated above, any modulation becomes negligible in this situation and can be ignored. Recommendation ITU-R BS.560 recognizes this requires up to an additional 16 dB of protection from a single sine wave. For all practical purposes, single tone interference from WPT equipment will appear to the receiver to be the same as another interfering carrier, potentially offset in frequency, and should be treated as such. The fact that it is not modulated is irrelevant as it would be for another radio service.

#### 7.2.1.3 Consideration of distance and propagation related factors

A categorization of WPT chargers is needed in terms of:

– Use (ranging from low power chargers for mobile phones etc. up to high power chargers for heavy duty Electric Vehicles)

– Indoor versus outdoor use

– Power output

– Coupling mechanism

– Residential versus non-residential use.

This would help in defining the most appropriate assumptions about minimum separation distance and propagation related factors.

For example, low power domestic mobile phone chargers and LF/MF broadcast receivers are both intended to be used in domestic environments, foreseeably within the same room. Therefore large separation distances cannot be achieved. It is therefore proposed that the H field limits given above should apply at a distance from the WPT device of 1 m. As another example, a separation distance of 10 m would be a more reasonable assumption between a WPT bus charger and a domestic broadcast receiver, noting however that in a large bus terminus there are likely to be several (many) charging systems operating at the same time, each contributing to the underlying noise environment; the cumulative effect needs to be considered as well.



The image shows the lower floors of an apartment block in South East London. It can be seen that the ground floor is given over to garages with apartments immediately above. The height of the garage ceilings is about 2.3 metres. It could reasonably be assumed that a radio receiver being operated in one of the lowest level apartments might be no more than 3 metres above the floor of the garage and hence no more than 3 metres away from at least one WPT charger which was intended for charging cars in the garages. There could be three chargers within 3 metres and several more within 10 metres. Other scenarios can be envisaged where a car could be being charged and the distance between the charger and a receiver in a neighbour’s apartment of house might be no more than 3 metres. Magnetic field reduces with the inverse cube of the distance from the source and conversely increases with proximity to the source. The ratio of H fields at 3 m and 10 m is therefore (10/3)3 = 37.0. In dBuA/m terms this is a difference of 20.log10(37) = 31 dB. So, to give an equivalent field strength at 10 metres, a correction factor of 31 dB would have to be applied. In the case of a charger intended for a car. The tolerable magnetic field strength at 10 metres from the charger would have to be 31 dB smaller than the value calculated to protect the receiver. Other distances and other correction factors would have to be used for other scenarios.

Brief experiments (reported in August 2015) have confirmed interference from WPT devices to reception of broadcasting does occur, even with WPT of lower power.

#### 7.2.1.4 Mitigation Strategies

Very clearly there is a wide disparity between the levels of interference that a broadcast receiver can tolerate, and the levels allowed for ISM devices. This is not usually a problem because such devices are operated under controlled conditions and physically separated from broadcast receivers (or any other radio receiver) that might be affected. Steps can be taken to ensure that licensed radio services are not affected. In the case of WPT chargers for vehicles, controlled use is more difficult to guarantee. It seems unlikely that stray radiation from a WPT device can be brought down to the levels necessary to protect the broadcasting service and so an alternative strategy needs to be found.

As a starting point, the receiver protection levels can be relaxed by 16 dB (the relative protection ratio) if the source of interference, including all the relevant harmonics, can be arranged to sit on the carrier frequencies of the MF transmissions. In ITU Regions 1 and 3 LF and MF transmission carrier frequencies lie on a fixed raster with each frequency being a multiple of 9 kHz. In Region 2, MF transmission carrier frequencies lie on a fixed raster with each frequency being a multiple of 10 kHz. If therefore the charging frequencies are themselves made to be multiples of 9 kHz or 10 kHz respectively, they and all of their harmonics will automatically lie on the broadcast frequency raster.

While this may be sufficient on its own in some cases, it will probably not be enough to narrow the gap between the requirements of the broadcast receiver and, for example, a vehicle charger in a domestic environment. This can again be addressed by careful choice of the operating frequency of the WPT device but now, as well as placing this frequency and (importantly) its harmonics on the broadcast raster, these must also be set such that they are well separated (spectrally) from the frequencies used by broadcast services in the area where the WPT device is operating. In effect the frequencies used for the WPT devices would have to be ‘planned’ on the same basis as broadcast transmissions which would otherwise interfere with each other. It is important to note that this strategy is very much simplified if the WPT frequencies follow the same raster as the broadcast frequencies. A description of the broadcast transmission planning process is given in Annex 6.

#### 7.2.1.5 Further Work

The mitigation techniques described in the previous section form the basis of a ‘toolbox’. This ‘toolbox’ would need to be developed with a lot more detail which has yet to be finalized. Areas that would need to be covered include:

Frequency Accuracy and Stability – Ideally, the frequency of the WPT device would be precisely and consistently on the 9 kHz or 10 kHz raster as appropriate to ensure that it and its harmonics were accurately aligned with the frequencies of the broadcast stations. In practice it is likely that a small amount of static and dynamic variation could be tolerated but exactly what the tolerances are would need to be established. There are two factors involved here. First, it is essential that any frequency offset did not give rise to ‘beat tones’ that were within the audible range. A ‘beat would occur at the difference frequency between the WPT and the broadcast station and the bottom end of the audible range would be partly determined by the audio filtering in the receiver. In practice it is possible that there will be some variation in the operating frequency of the WPT device because it has to optimize itself to cope with inaccurate physical alignment between the charger and the item being charged.

Modulation of the Charging ‘Field’ – This follows on from the previous point. It is suggested that the WPT charger could be used to transfer data to the item being charged by modulating the charging (magnetic) ‘field’ in some way. Communication in the other direction would need a separate system. Any attempt to modulate the charging ‘field’ would manifest itself as sidebands. Limits would need to be placed on this sideband energy because it would have the potential to interfere with broadcast services even if the basic frequency was accurately on the raster. It is necessary to look at the modulation schemes envisaged. In the case of a high power charger it would be logical to imagine that there are easier ways to communicate over very small distances than to modulate the high power charging ‘field’.

Database of Available Frequencies – In any one geographical location, the range of LF and MF broadcasts that can be received will be different from another geographical location. For this reason the range of available (non-interfering) frequencies for the WPT charger will be different in different locations. The charger will therefore have to know where it is (geographically) and have access to a database of usable frequencies. It will, of course, also require a degree of frequency agility.

Use of ‘Off-Raster’ Frequencies – Given a knowledge of its location and the LF or MF broadcasting environment, it might be possible to use frequencies that are not on the broadcast raster provided that the drawbacks of doing this are recognized and the field power is kept within appropriate limits. Of particular interest might be the frequencies at the mid-point between the frequencies on the broadcast raster. Even harmonics would all lie on the raster and odd harmonics would lie on the boundary between adjacent broadcast channels; a point at which the receiver filtering might well reduce the audible impact.

Control of Harmonics – In the MF band, certainly at the higher frequency end, it is likely that only the higher order harmonics of the charging frequency will generate interference. The better the energy in these higher order harmonics is controlled, the easier it will be to find a suitable operating frequency for the WPT device.

### 7.2.2 Japan's study on the impact to and compatibility with broadcasting services in urban and suburban areas

While § 7.1.1 provides outlines of spectrum sharing and coexistence studies taken in Japan’s new rule making process, this section describes details of the methodology taken in the study on the impact of WPT for EVs to the broadcasting services and assessment results. The study was performed by the WG and approved by MIC’s Committee (see § 7.1.1).

#### 7.2.2.1 Japan’s points of view for impact study

Japan’s approach taken in the impact study emphasizes the following points:

1) WPT system compatibility with the incumbent radiocommunication services in urban areas may be a priority concern.

WPT systems for EVs will be commercialized mainly from urban areas. Therefore, radio environment and usage models in urban areas should carefully be considered to demonstrate ability to coexist without causing problems. The radiated emission limits in Japan’s new regulation on WPT were determined by the results of the impact study focusing on urban areas.

For the impact study to protect broadcasting services, the radiated emission limits from WPT systems should be lower than the environment noise level as described in Recommendation ITU-R P.372, where different environment categories are defined, “City”, “Residential”, “Rural”, and “Quiet rural”. It is assumed that the separation distance in suburban and rural areas is larger than in urban areas while man-made-noise level in suburban and rural areas goes lower.

Detailed conditions for assessment were assumed, which include:

– Required separation distance for assessment between WPT systems and the closest AM broadcast receiver: 10 m (referring to CISPR Standards, others).

– Propagation loss due to house/building walls:10 dB (from Japanese study results).

– Self-interference (the WPT system interferes to owner’s wireless devices): not considered.

2) Radiated emission limits for WPT systems in the broadcasting service frequency range consistent to the existing living regulations

Since inductive cooking heaters conforming to international standards such as CISPR 11, Group 2, Class B, and/or CISPR 14-1 have been already commercialized and are widely spread, any harmful disturbances and troubles to other wireless systems from inductive cooking heaters have not been reported. This situation is same in many countries and regions. To prevent generating harmful interference in the frequency range of AM broadcasting services from WPT equipment, the target radiated emission limits in the range were determined by referring to the existing emission limits. The emission limits were agreed among broadcast representatives and WPT proponents to be specified in the regulation.

3) Assessment in suburban and rural areas and protection of incumbent radio systems through regulations

Due to various physical constraints for measurements in the study, the WG has not come to a conclusion that the impact to medium-wave broadcast receivers is acceptable to coexist when the receivers are used in wooden houses located in medium and low environmental noise areas. However, even in those situations, the above mentioned does not mean that the WPT system causes harmful interference at every WPT operation time and at consistent basis to the receivers located nearby when taking account of the following statistics: average time for operation of the WPT systems for EV (e.g. less than one hour), relatively high proportion of users who prefer short-time charging (e.g. several tens of minutes) after returning home, and the WPT frequency to be determined within a certain band based on the environment and installation condition.

Given the considerations above, it is deemed that substantial problems to the reception of broadcasting service may not be probable even when the required condition for coexistence cannot be achieved in some cases. A cautionary statement such as “This equipment may cause harmful interference to medium wave broadcast receivers” attached to the WPT system user instruction and/or the product can remind the users of possible harmful interference to the receivers.

WPT industries should continuously take appropriate interference mitigation measure to reduce the interference to lower than the allowable level in order to avoid harmful disturbance to broadcasting services in suburban and rural areas.

If the WPT system should cause unacceptable interference to the receivers, radio administrations shall provide necessary regulatory measures/orders to stop WPT system operation causing harmful interference to the other incumbent radio systems.

#### 7.2.2.2 Power transmission specifications for measurement

Specifications of WPT systems for EVs were determined as follows:

– WPT technology: Magnetic coupling (resonant magnetic coupling)

– Application: Electric passenger vehicle charging while parking (Static)

– Frequency range: 79‑90 kHz (so-called 85 kHz band)

– 79-90 kHz range was selected as the primary frequency range by referring to Japan domestic impact study results and IEC and SAE discussion results in the view of global harmonization.

– Transfer power range: 3 kW-class and 7.7 kW-class; Classes are assumed for passenger vehicles

#### 7.2.2.3 Emission limits for assessment

The target emission limits in the power transmission frequency ranges for the studies of WPT systems was assumed by referring to the emission limits of FCC Part 18. The target emission limits out of the power transmission frequency range were assumed by referring to one of Japan’s radio regulations for inductive cooking heaters. As to the frequency range over 150 kHz, CISPR 11 Group 2 Class B was referred to. The assumed target emission limits of magnetic field are described below:

a) WPT frequency range (frequency range used for power transmission)

68.4 dBμA/m @ 10 m for 3 kW Tx Power

72.5 dBμA/m @ 10 m for 7.7 kW Tx Power

b) Frequency range from 526.5-1 606.5 kHz (AM broadcasting frequency range):

−2.0 dBμA/m @ 10 m

c) Frequency range except for the above frequency range:

23.1 dBμA/m @ 10 m

The above target emission limits were settled firstly, in the frequency ranges both under 526.5 kHz and over 1 606.5 kHz. However, in later stages the Committee concluded to adopt the limits of CISPR 11 Group 2 Class B in the frequency range over 150 kHz except for AM broadcasting frequency ranges.

**7.2.2.4 Analytical study**, measurement results and audibility test WPT systems for EVs shall not cause harmful interference to an AM broadcasting receiver located at least within 10 meters distance from the systems based on the target radiated emission limits. Emission measurements using a WPT transmitter and WPT receivers on a mock wagon were performed under the agreed worst use case conditions, where the rotation angle of AM broadcasting receivers was selected and set to null direction to receive broadcasting signal considering antenna directive patterns. In addition, the AM receivers were located on the axis at which the strongest WPT unwanted emission waveform arrives considering WPT coil emission patterns. WPT’s 7th harmonic of *Fc* = 85.106 kHz falls into 594 kHz AM broadcasting channel, which covers a wide area of Kanto-region of Japan. Hearing (audibility) assessment was performed as well. A criterion for satisfactory mitigation of the impact of WPT for EVs to AM broadcasting was confirmed.

Details are described below:

a) Basic conditions of the impact study

At first, the WPT-WG of MIC clarified the following conditions and use cases for the impact study.

– Acceptable maximum emission (the target emission limit) is –2.0 dBμA/m @ 10 m which follows the existing emission limit for inductive cooking heaters in the 526.5‑1 606.5 kHz range (AM broadcasting frequency range)

– Self-interference is out of scope of this impact study. Self-interference means that an owner’s WPT system interferes to the same owner’s AM broadcasting receiver.

– AM broadcasting receivers are located inside houses or buildings. On the other hand, a WPT system for EVs is located outside of the houses or buildings. Propagation loss due to house walls should be considered.

– Separation distance between a WPT system and an AM broadcasting receiver is 10 m, under assumption that the nearest neighborhood house is located more than 10 m apart from the WPT owner’s house.

– Receivers are assumed to be located in a high-field strength area (receiving electric field strength is more than 80 dBμV/m), and a medium-field strength area (66 dBμV/m). The protection for the broadcast reception users in a low–field strength area (48 dBμV/m) is also important. However, the impact study in the WG focused on high-field strength and medium-field strength areas, because WPT systems are expected to gain in popularity in urban areas in the initial stage and then spread over other areas.

b) Analytical study

In the next step, the impact of WPT for EVs on AM broadcasting was studied by an analytical approach. In this step, the following criteria were agreed and taken.

– Acceptable radiated emission limits should be lower than environmental noise level in a particular area. An emission limit of 26.0 dBμV/m at 594 kHz is adopted by referring to the environmental noise of “City” described in Recommendation ITU-R P.372. This electric field strength (26.0 dBμV/m) is converted to magnetic field strength   
(–25.5 dBμA/m) as the acceptable maximum unwanted emission at the receiver.

– Propagation loss due to walls of houses and buildings between a WPT system and an AM broadcasting receiver is assumed to be 10 dB by referring to the reported results of MIC’s round-table conference concerning MF broadcasting pre-emphasis (Dec. 1983).

This analysis intended to assess the impact to the AM receiver in terms of magnetic-field emission by calculation when a measured unwanted emission strength was given and applied. For that purpose, the system model simulated the condition in (a) and other conditions were agreed; and then, unwanted emission strength at the receiver location was calculated. It was assumed that a WPT system for EV was located 10 m apart from the nearest neighbourhood house in which the receiver was located. Furthermore, an AM broadcasting receiver was located at 50 cm inside from windows of the house. The WPT parameters such as radiated emission strength (i.e., –15.6 dBμA/m) and necessary conditions were the same as the WPT system shown as “Test Equipment B” for EVs described in Annex 3.

The following points were suggested in this analytical study:

– Calculated emission strength derived with the measured emission strength satisfies the acceptable unwanted emission strength.

– The measured emission strength used for calculation is lower than the target emission limit of –2.0 dBμA/m by more than 10 dB, which shows substantial clearance for emission to the limit. This number was supported because industries sensibly and commonly take account of uncertainty budget by 10 dB or more for their emission performance margin in their design and test stages.

– In practical condition, unwanted emission strength from WPT systems reaches to –25.6 dBμA/m (= –15.6 dBμA/m – 10 dB), which is nearly or less than the acceptable unwanted emission strength, –25.5 dBμA/m.

The above consideration was accepted by the WPT-WG of MIC. Thereafter, the agreed target emission limit of –2.0 dBμA/m in the AM broadcasting frequency range in Japan was confirmed to be the acceptable number and then approved as a new regulation concerning WPT.

c) Magnetic field emission measurement

In order to confirm the result of the analytical study above, emission measurement using WPT test equipment and AM broadcasting receivers was performed. Conditions and methods were as follows:

i) Measurement set up

As mentioned above, the “Test Equipment B” for EVs, described in Annex 3, was used in this experimental test. The WPT frequency of the Test Equipment was 85.106 kHz. The transfer power was 3 kW at the input port of the transmission coil. The 7th harmonic of this WPT equipment was 595.742 kHz. Measured radiated emission levels of the WPT frequency and harmonics of “Test Equipment B” are plotted in Fig. 14.

FIGURE 14

Measured magnetic field strength of “Test Equipment B” (Quasi-peak value)



Note: The 6th harmonic is not plotted as can be plotted below the bottom of the y-axis scale.

d) Audibility test

i) AM broadcasting receiver selection

Several types of AM broadcasting receivers, including high-end type and portable type were prepared for this experimental test.

ii) Date and place

Date of this experimental test is from 1st July to 2nd July, 2014. Open area test site of Telecom Engineering Center (TELEC) Matsudo Laboratory was used for this experimental test. TELEC Matsudo Laboratory is located in a general residential suburb area nearby Tokyo.

iii) Broadcasting service channel and frequency

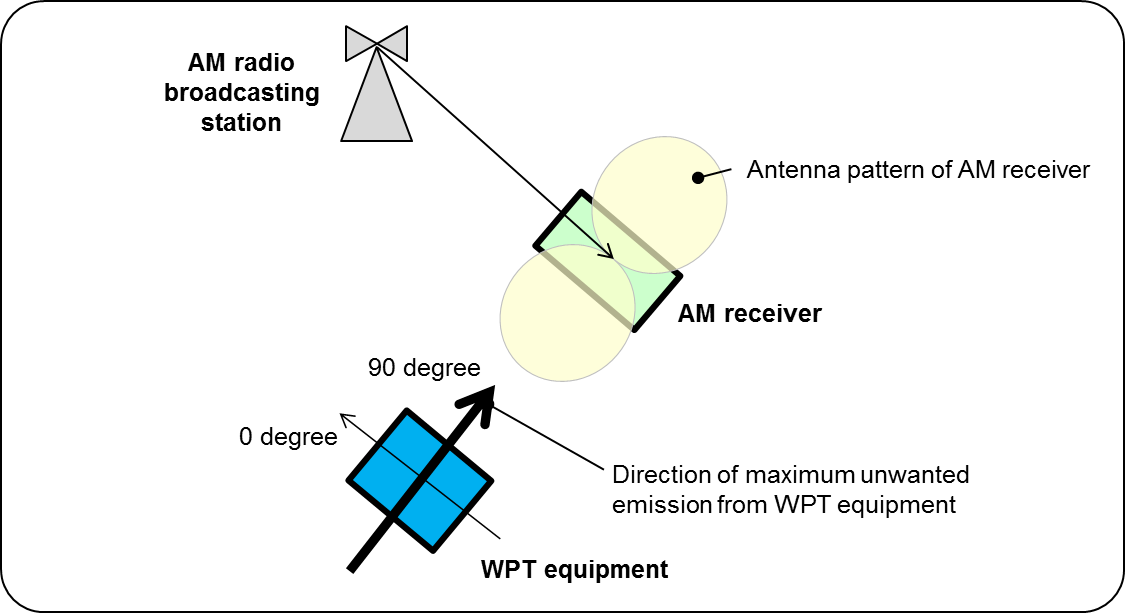
In the Tokyo area, there is an AM broadcasting channel of NHK Radio 1 at 594 kHz. The frequency difference between NHK Radio 1 and the 7th harmonic of “Test Equipment B” is about 1.7 kHz. If the 7th harmonic of “Test Equipment B” is larger than environmental noise, we can hear noise of 1.7 kHz.

Test procedure was as follows:

• At first, received field strength of AM broadcasting, radiated emission strength of harmonics of WPT equipment and environmental noise level were measured by using a spectrum analyzer. In the measurement, the receiving antenna received vertical and horizontal directions of H-field. The WPT equipment was placed at the 90 degrees rotated direction which maximizes the received unwanted emission strength. From these checking operations which consider the polarization and the radiated emission directivity from the WPT equipment, the maximum unwanted emission strength can be realized. Figure 15 shows the condition of the worst case which demonstrates the maximum impact to broadcasting receivers from the WPT equipment in this experimental study. This Figure illustrates the location of the AM radio broadcasting station, AM radio receivers and the WPT equipment, and also describes the relationship between the antenna pattern of radio receivers and the direction of the maximum emission from the WPT equipment.

FIGURE 15

Measurement condition of audibility test



• Next, an audibility test was performed by the participants listening to the broadcasting programs at several different locations separated by different distances including 10 m and 3 m from the WPT equipment. In this audibility test, the separation distance of 10 m matches the required conditions for this impact study. The test of 3 m separation distance was done only as reference. In this test, the face direction and the rotation angle of broadcasting receivers were selected at the worst condition for broadcasting reception considering antenna directive patterns and polarizations of those receivers. At the same time, the face direction and the rotation angle of broadcasting receivers were also adjusted to maximize the interference emission from the WPT equipment.

iv) Test results

The measurement results of received electric field strength are shown in Fig. 16. The field strength of AM broadcasting was about 100 dBμV/m and the environmental noise level was about 60 dBμV/m, which are much higher than the assumption described in (a). In this Figure, electric field strengths where the WPT equipment is ON and OFF are described. The difference between the WPT equipment of ON and OFF conditions is not clearly found in this Figure, because the environmental noise level is slightly higher than the 7th order harmonic from the WPT equipment.

The results of this audibility test were as follows:

• AM broadcasting receivers located at 10 m from WPT equipment

The tone noise could be recognized as a very small sound only in very silent broadcasting programs but never in normal audio programs. In general, the tone noise under this test condition deems not to disturb general broadcasting listeners listening radio programs.

• AM broadcasting receivers located at 3 m from WPT equipment

The tone noise can be easily caught when broadcasting programs are relatively silent, such as news programs. On the other hand, when broadcasting programs are busy, such as music programs, the tone noise cannot be easily caught.

#### 7.2.2.5 Assessment of study results

Under agreed test conditions and use cases assumed in urban area, magnetic field emission strength derived by analytical study and also that measured by a WPT-EV test equipment in a field measurement site showed acceptable (= non-harmful) level of emission received while settling the emission limit –2.0 dBμA/m in the AM broadcasting frequency range. In audibility assessment, It was confirmed that the tone generated by the WPT 7th harmonic falling in an AM broadcast channel in MF band was indistinct while listening to radio programs or obscurely audible during very quiet programs. It demonstrated little impact and no harmful interference to the AM broadcasting service. From this result, Japan's new regulations for WPT systems adopted this limit in the frequency range of AM broadcasting service.

This methodology for measurement and assessment must be useful for radio regulators who intend new rule making for WPT for EVs in urban area where Environment Category “City” in Recommendation ITU-R P.372 can be applied.

FIGURE 16

Measured electric field strength of an AM broadcasting channel when WPT is ON and OFF



## 7.3 Frequency ranges 100/110-300 kHz for WPT

The LF and VLF ranges are being promoted for WPT use by Standards Developing Organizations (SDOs) industry alliances and manufacturers; the frequency range 100/110-300 kHz is also under consideration in the present studies. There are concerns on

* The use of LF frequencies adjacent to or overlapping the Region 1 LF broadcasting band, 148.5-255 kHz; and
* Adverse impact on radiocommunication and radionavigation services making use of the LF bands.

[*USA Editor’s Note: the placement of these sections may need to be reassessed as the content develops. Additional contributions are expected from Japan and potentially Korea and China to address concerns about the inclusion of testing and compatibility information in this document rather than in Reports SM.2449 (mobile and portable devices) and SM.2451 (EVs) where similar information already exists. Additional contributions to Reports SM.2449 and SM.2451 from other administrations may also result in further needed editorial and organizational changes to SM.2303.*]

## 7.4 Frequency range 300-405 kHz for WPT for mobile and portable devices

Further studies pursuant to Recommendation ITU-R [SM.2129](https://www.itu.int/rec/R-REC-SM/recommendation.asp?lang=en&parent=R-REC-SM.2129) ‘Guidance on frequency ranges for operation of non-beam wireless power transmission systems for mobile and portable devices’ can be found in Report ITU-R SM.2449.

## 7.5 Frequency range [1610]/1700-1800 kHz for WPT for mobile and portable devices

Further studies pursuant to Recommendation ITU-R [SM.2129](https://www.itu.int/rec/R-REC-SM/recommendation.asp?lang=en&parent=R-REC-SM.2129) ‘Guidance on frequency ranges for operation of non-beam wireless power transmission systems for mobile and portable devices’ can be found in Report ITU-R SM.2449.

## 7.6 [Frequency range 2000-2170 kHz for WPT for mobile and portable devices]

[Further studies pursuant to Recommendation ITU-R [SM.2129](https://www.itu.int/rec/R-REC-SM/recommendation.asp?lang=en&parent=R-REC-SM.2129) ‘Guidance on frequency ranges for operation of non-beam wireless power transmission systems for mobile and portable devices’ can be found in Report ITU-R SM.2449.]

## 7.7 Frequency range 6 765-6 795 kHz for WPT

There have been concerns expressed by other working parties about the possibility of unwanted RF energy that is harmonically-related to WPT systems operating in this and other bands. Working Parties 7D and 6A in particular have expressed concern about the second harmonic of WPT energy in this ISM band (6 765-6 795 kHz × 2 = 13 530-13 590 kHz) which overlaps with the HF broadcasting band 13 570-13 870 kHz and falls close to the band 13 360-13 410 kHz, which is allocated to the radio astronomy service on a primary basis.

According to experts involved in studying WPT issues, the energy in this band would generally be line spectra (and therefore would have narrow bandwidths). However, there is some possibility of unwanted energy sidebands on both sides of the primary emission. The level of these sidebands should be much lower, but may depend on a number of factors, including: the design of the WPT equipment, characteristics of the load being supplied, filtering/shielding of the source and load, the degree of coupling to the load and possibly other factors.

Considering that the 6 765-6 795 kHz band is one that is designated for ISM use under RR No. **5.138** (subject to Administration approval), and also noting the interference protections provided to radiocommunications services under RR No. **15.13**, more study is needed to ensure that unwanted RF energy (including harmonic energy) from WPT operations is at a level that does not cause harmful interference to a radiocommunication service operating in other spectrum bands.

## 7.8 Impact to the standard frequency and time signal services

Working Party 7A provided information for consideration on frequency ranges that over the years World Radiocommunication Conferences allocated the frequency bands 19.95-20.05 kHz, 2 495‑2 505 kHz (2 498-2 502 kHz in Region 1), 4 995-5 005 kHz, 9 995‑10 005 kHz, 14 990‑15 010 kHz, 19 990-20 010 kHz and 24 990-25 010 kHz, to the standard‑frequency and time-signal service. In addition, the following frequency bands for use by the standard-frequency and time‑signal satellite service were allocated:

400.05-400.15 MHz,

4 200-4 204 MHz (space-to-Earth),

6 425-6 429 MHz (Earth-to-space),

13.4-14 GHz (Earth-to-space),

20.2-21.2 GHz (space-to-Earth),

25.25-27 GHz (Earth-to-space),

30-31.3 GHz (space-to-Earth).

Additional standard frequencies and time signals are emitted in other frequency bands, e.g. 14‑19.95 kHz and 20.05-70 kHz and in Region 1 also in the bands 72-84 kHz and 86-90 kHz, which have been designated by other conferences (see No. **5.56** of the Radio Regulations).

The ERC [Recommendation 70-03](https://docdb.cept.org/download/25c41779-cd6e/Rec7003e.pdf) [3] on the use in Europe specifies frequency ranges, their maximum field strength, and locations as shown in Table 21:

TABLE 21

Standard frequency and time signals to be protected within 9-90 kHz and   
119-135 kHz (ERC Recommendation 70-03) [3]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Stations | Frequency | Protection bandwidth | Maximum field strength at 10 m | Location |
| MSF | 60 kHz | +/–250 Hz | 42 dBuA/m | United Kingdom |
| RBU | 66.6 kHz | +/–750 Hz | 42 dBµA/m | Russian Federation |
| HBG | 75 kHz | +/–250 Hz | 42 dBµA/m | Switzerland |
| DCF77 | 77.5 kHz | +/–250 Hz | 42 dBµA/m | Germany |
| DCF49 | 129.1 kHz | +/–500 Hz | 42 dBµA/m | Germany |
| NOTE 1 – The limit is reduced to 42 dBµA/m at 10 m. | | | | |

Section 7.1 and Table 18 in this Report provide practical case studies in Japan on the impact to the standard frequency and time signal services.

## 7.9 CEPT experiences to protect services from the emissions of inductive SRDs

This Section details the CEPT experiences till now with the protection of services from the emissions of inductive SRD applications. In 2009 the inductive SRD limits were discussed to accommodate higher power SRD applications and WPT applications. A study was performed, and the results published in ECC Report 135 “Inductive limits in the frequency range 9 kHz to 148.5 kHz”.

It was found that a protection was needed for the time signal transmitters operating in the CEPT countries. Notches with a maximum emitted power level of 42 dBuA/m at 10 m were specified to protect these transmitters. It needs to be noted that the frequency range studied does not include frequencies above 148.5 kHz, it also does not discuss harmonics far outside the range 9-148.5 kHz.

This means that for example 350 kHz DGPS beacons and 198 kHz broadcasting and time signal transmitters are not studied, it is likely that these need more stringent protection limits due to the higher frequency.

These limits and notches were later included in the EC commission decision on SRD’s and later reflected in ETSI standard EN 300 330.

In 2014 European industry requested wider spectrum masks and higher power for 13.6 MHz inductive devises such as RFID and contactless smartcards. A study was performed, and the results published in ECC Report 208 “Impact of RFID devices on radio services in the band 13.56 MHz”.

The services considered were the broadcasting and radio astronomy service.

It was concluded that a solution could be found in two different spectrum masks accommodating both high power narrowband and low power wideband emissions. An emission level of ‑3.5 dBuA/m at 10 m was found to be an absolute maximum for the mentioned services.

It needs to be noted that only interference to the broadcasting service was actually tested. Other services such as the radio amateur service are not adequately protected but based on the relatively low deployment of devices, this was considered acceptable at that time.

For the higher deployment of WPT and its associated spurious emissions these limits need to be seriously reconsidered.

Supporting CEPT documents for further studies are:

ERC Report 69: “Propagation model and interference range calculation for inductive systems 10 kHz – 30 MHz”.

ERC Report 74: “Compatibility between radio frequency identification devices (RFID) and the radioastronomy service at 13 MHz”

ECC Reports 67: “Compatibility study for generic limits for the emission levels of inductive SRD’s below 30 MHz”

The inductive approach of actively notching out sensitive frequencies could be used as a spectrum management solution to accommodate WPT devices in regions or area’s where specific services are active while the 13 MHz approach of setting a maximum OOB limit in combination with a stringent spectrum mask provides a generic out of band limit for the global protection of radiocommunication services.

1. This chapter may be reviewed in the future within the context of ongoing revisions to reports ITU-R SM.2449 and SM.2451. [↑](#footnote-ref-1)
2. Work carried out by the BBC in about 2007 revealed that the rms modulation depth on AM transmissions varied from around 20% for speech to around 40% for heavily compressed ‘pop’ music. AM radio is used primarily for speech and so this must be considered as the ‘worst case’. [↑](#footnote-ref-2)