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# Electromagnetic environment of body-worn equipment in the 2.4 GHz and 13.56 MHz industrial, scientific and medical band

Recommendation ITU-T K.133

ITU-T

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## Electromagnetic environment of body-worn equipment in the 2.4 GHz and 13.56 MHz industrial, scientific and medical band


### Summary

Recommendation ITU-T K.133 specifies electromagnetic characterization of the radiation and conduction environment for body-worn electronic devices.


### History

| Edition | Recommendation | Approval | Study Group | Unique ID* |
|---|---|---|---|---|
| 1.0 | ITU-T K.133 | 2018-01-13 | 5 | 11.1002/1000/13456 |


### Keywords

Body-worn equipment, electromagnetic environment, EM environment, body-worn device.


* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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## Introduction

In recent years, many body-worn communication devices, such as those for medical use, smart watches and smart bracelets, have been produced and are widely used by the public. Most of them have a wireless fidelity (Wi-Fi) or Bluetooth module that uses the 2.4 GHz industrial, scientific and medical (ISM) band for communication or implement near field communication technology in the 13.56 MHz ISM band. This Recommendation is applicable to the environment in which body-worn equipment operates.

# Recommendation ITU-T K.133

## Electromagnetic environment of body-worn equipment in the 2.4 GHz and 13.56 MHz industrial, scientific and medical band

## 1 Scope

This Recommendation specifies electromagnetic characterization of the radiation and conduction environment for body-worn electronic devices. Body-worn equipment includes that for electronic glasses, electronic bracelets, smartphone-supported watches and health supervision.

This Recommendation aims to provide an effective and exercisable method to improve understanding of the electromagnetic (EM) environment of body-worn devices.

## 2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.34] Recommendation ITU-T K.34 (2003), *Classification of electromagnetic environmental conditions for telecommunication equipment – Basic EMC Recommendation*.

[ITU-T K.79] Recommendation ITU-T K.79 (2015), *Electromagnetic characterization of the radiated environment in the 2.4 GHz ISM band*.

[IEC TR 61000-2-5] IEC TR 61000-2-5:2017, *Electromagnetic compatibility (EMC) – Part 2-5: Environment – Description and classification of electromagnetic environments*.

[ISO/IEC 18000-3] ISO/IEC 18000-3:2010, *Information technology – Radio frequency identification for item management – Part 3: Parameters for air interface communications at 13.56 MHz*.

[ISO/IEC 18000-4] ISO/IEC 18000-4:2015, *Information technology – Radio frequency identification for item management – Part 4: Parameters for air interface communications at 2.45 GHz*.

## 3 Definitions

### 3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

**3.1.1 body-worn device** [b-ITU-T K.91]: A portable device containing a wireless transmitter or transceiver which may be located close to a person's torso except the head during its intended use or operation of its radio functions (e.g., on a belt clip, holster, pouch, or on a lanyard when worn as necklace).

### 3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

**3.2.1 electronic glasses equipment**: A type of body-worn device that is similar to glasses in shape and that has an information record module, as well as a signal-processing unit, incorporated within it.

**3.2.2 electronic bracelet equipment**: A type of body-worn device that is similar to a bracelet in shape and that has an information record module, as well as a signal-processing unit, incorporated within it.

**3.2.3 smart watch**: A type of body-worn device that is similar in shape to a watch and that has an information record module, as well as a signal-processing unit, incorporated within it.

**3.2.4 wireless body area communication (WBAN)**: A short-range communication technique within, on and in the immediate proximity of a human body.

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

| | |
|---|---|
| AC | Alternating Current |
| AM | Amplitude Modulation |
| DC | Direct Current |
| EM | Electromagnetic |
| EMC | Electromagnetic Compatibility |
| ERP | Effective Radiated Power |
| ESD | Electrostatic Discharge |
| HIPERLAN | High Performance Radio Local Area Network |
| ISM | Industrial, Scientific and Medical |
| LAN | Local Area Network |
| PLT | Power Line Telecommunication |
| RF | Radio Frequency |
| RFID | Radio Frequency Identification |
| r.m.s. | root mean square |
| WBAN | Wireless Body Area Communication |
| Wi-Fi | Wireless Fidelity |

## 5 Conventions

None.

## 6 Description of the body-worn device environment

### 6.1 Typical configuration of the body-worn device environment

Many people use body-worn devices to monitor human health and exercise. The wireless network around the human body connects to the Internet and other networks to exchange information with other nodes or the remote centre.

If several body-worn devices are located in a person's body area, a high deployment density of wireless equipment results and produces a complex radiated EM environment.

Figure 1 shows a typical layout scenario consisting of body-worn devices and the surrounding body area environment. In Figure 1, affected objects can be classified by wearable centre node or body-worn device according to coupling mechanism.

The body-worn device environment usually has the following features.

1) Typical dimensions of the body-worn device environment is usually defined as 2 m × 2 m × 2 m.

2) The number of body-worn devices on one person is typically in the range 1-10.

3) Most person have at least one mobile phone and possibly several body-worn devices.

4) There is typically one ISM band body-worn device in each body-worn device node.

5) Depending on the number of body-worn device nodes, there may be two or three ISM band devices for everybody.

6) It is common to find two personal node clusters within a 3 m separation distance in a crowded area.

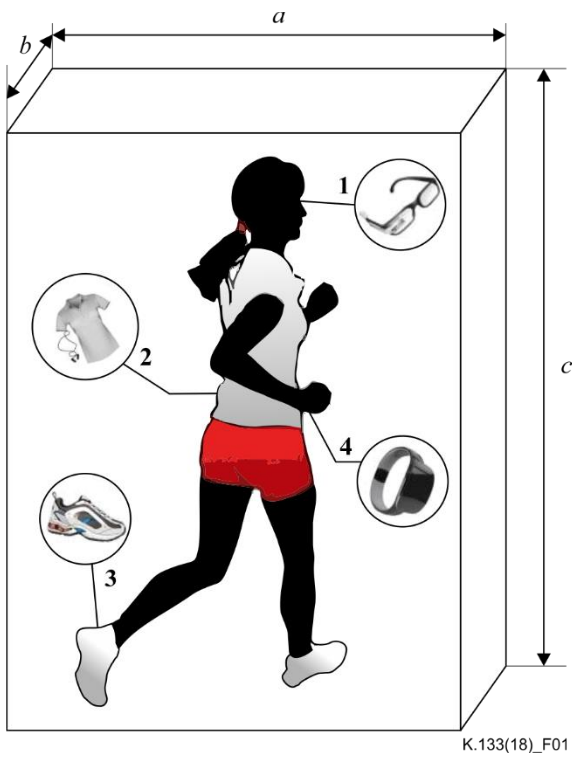


**Figure 1 – Typical body-worn device environment [b-elecfans.com]**

The body-worn devices layout is shown in Figure 1. The volume, *abc*, is 2 m × 2 m × 2 m [one wearable centre node (labelled 2), such as a handset with an ISM band communication module, is installed at waist height of about 1 m]. Three body-worn devices (labelled 1, 4 and 3) are located at heights of about 1.7 m, 1,0 m and 0.0 m around the head, the wrist and the foot as glasses, watch and shoe, respectively. Other body-worn devices can be used, such as an intelligent waistband or intelligent walking stick.

## 6.2 Powering and ports

There are at least two kinds of powering mechanism for body-worn devices:

1) powered by battery only – this kind of device has an enclosure port only;

2) powered by battery, and can be powered or charged through a direct current (DC) power input port (barrel port or USB port etc.) or alternating current (AC) power input port.

### 6.3 Mobility

With movement, body-worn devices can work in several typical EM environments – commercial, residential, industrial and so on. This Recommendation takes this feature into account. However, consideration of the speed of mobility to the EM environment is under study.

### 6.4 Possibility of interference

Interference can occur because the operating frequency of the devices is in the 2.4 GHz, 13.56 MHz or other frequency band.

Considering that telecommunication equipment density is very high in some areas and that a metal frame of a cabin reflects electromagnetic waves, the problem of electromagnetic compatibility (EMC) can be severe. The transmission rate of a wireless local area network (LAN) system can be greatly affected in this situation.

Refer to [ITU-T K.79] to analyse the possibility of interference in the 2.4 GHz ISM band.

When body-worn devices operate on commercial or industrial premises, such as a hospital or factory, interference from ISM devices can affect body-worn devices.

## 7 Typical phenomena in the electromagnetic environment of body-worn equipment

In the 2.4 GHz and 13.56 MHz bands, typical phenomena in the EM environment of body-worn equipment are as follows.

a) Conducted high-frequency phenomena:
   - direct-conducted continuous wave;
   - transients.

b) Radiated high frequency phenomena:
   - radiated (continuous wave) oscillatory disturbances;
   - radiated (modulated) signal disturbances;
   - radiated (transient) pulsed disturbances.

c) Electrostatic discharge (ESD) phenomena in the 13.56 MHz or 2.4 GHz band.

The details of these phenomena are described in the basic EMC Recommendation [ITU-T K.34] and in [IEC TR 61000-2-5]. In the context of this Recommendation and in accordance with the IEC EMC approach, the term "high frequency" applies to frequencies above 9 kHz.

## 8 Disturbance characteristics and levels in the 2.4GHz and 13.56MHz bands

### 8.1 Attributes of environment

Enclosure:

– radiated signal from ISM services in the 13.56 MHz band;
– radiated signal from portable communication devices in the 2.4 GHz band [e.g., wireless phones, Bluetooth and wireless fidelity (Wi-Fi)];
– high concentration of multimedia and household equipment (e.g., microwave oven);
– amateur radio in the 2.4 GHz band.

Alternating current power:

– high concentration of switched mode power supplies;
– existence of power line telecommunication (PLT) equipment.

## 8.2 Specification of disturbance characteristics and levels

According to [ITU-T K.34] and [IEC TR 61000-2-5], the disturbance characteristics and levels in the 13.553-13.567 MHz and 2.400 0-2.483 5 GHz bands are as listed in Tables 1 to 6.

**Table 1 – Disturbance degrees, levels (in volts per metre, r.m.s.) and distance to source – Radiated continuous oscillatory disturbances**

| **Disturbance degree and corresponding field strength** | Phenomena (sources) |
|---|---|
| | ISM Group 2 equipment |
| | Transmitter frequencies [MHz] |
| | 13.553 to 13.567<br>2 400 to 2 500 |
| | Distance to source [m] |
| A (Controlled) | Case-by-case according to the equipment requirements |
| 1 0.3 V/m | *d* (Note) |
| 2 1 V/m | *d* (Note) |
| 3 3 V/m | *d* (Note) |
| 4 10 V/m | *d* (Note) |
| 5 30 V/m | *d* (Note) |
| X (harsh) | Case-by-case according to the situation |
| NOTE – ISM group 2 equipment (according to [b-CISPR 11]) is not limited in the power used for operation and therefore there are no limits to be observed for radiated disturbances with regard to EMC. Hence it is not possible to generally calculate distance, *d*. | |

(Source: Table 16 of [IEC TR 61000-2-5].)

**Table 2 – Disturbance degrees, levels (in volts per metre, r.m.s.) and distance to source – Analogue communication services below 30 MHz**

| **Disturbance degree and corresponding field strength** | Phenomena (sources) |
|---|---|
| | Amplitude modulation (AM) broadcasting<br>$P$ = 500 kW |
| | Transmitter frequencies [MHz] |
| | 0.150 – 30 |
| | Distance to source [m] |
| A (Controlled) | Case-by-case according to the equipment requirements |
| 1 0.3 V/m | 16 500 |
| 2 1 V/m | 4 959 |
| 3 3 V/m | 1 650 |
| 4 10 V/m | 430 |
| 5 30 V/m | 378.5 |
| X (harsh) | Case-by-case according to the situation |
| NOTE 1 – No AM broadcasting transmitter is expected in the ISM bands, but spurious emissions of radio frequency (RF) sources may be present in ISM bands if RF filters are not properly implemented.<br>NOTE 2 – The distances are derived assuming an antenna gain of 2.15 dBi of a half-wavelength dipole antenna and at the lowest frequency. This table provides data for the frequency range 0.150 MHz to 30 MHz for a 500 kW transmitter. Other power levels (50 kW to 2 500 kW) and antenna types (and resulting antenna gains) are also possible. | |

(Source: Table 19 of [IEC TR 61000-2-5].)

**Table 3 – Disturbance degrees, levels (in volts per metre, r.m.s.) and distance to source – Amateur radio bands in the 2.4 GHz band**

| Disturbance degree and corresponding field strength | Amateur radio station<br>$P$ = 1 500 W<br>$P_{EIRP}$ ≈ 2 500 W<br>Transmitter frequencies 2 300-2 450 MHz |
|---|---|
| | Distance to source [m] |
| A (Controlled) | Case-by-case according to the equipment requirements |
| 1   0.3 V/m | 905 |
| 2   1 V/m | 271 |
| 3   3 V/m | 90.5 |
| 4   10 V/m | 27.1 |
| 5   30 V/m | 9.05 |
| X (harsh) | Case-by-case according to the situation |

NOTE 1 – The distances are derived assuming a power of 1 500 W and an antenna gain of 2.15 dBi of a half-wavelength dipole antenna. Practical limitations restrict antenna gain for lower frequency bands and amplifier power for higher frequency bands.

NOTE 2 – The above-mentioned power and frequency bands are a summary of all three ITU Regions. The power $P$ is (if not otherwise mentioned) the maximum allowed output power of the amplifier. The power arriving at the antenna and radiated by it is $P_{ANT}$ and is $P$ reduced by the losses of the feeding cable. For easy calculation of $E$ and $d$, the effective isotropic power $P_{EIRP}$ is useful. Most antennas have a direction with maximum radiation, i.e., in that direction they have a significant antenna gain $G_{ISO}$ compared to an isotropic radiator. $E$ and $d$ of this maximum radiation can be easily calculated by means of $P_{EIRP}$, which is obtained by multiplying $P_{ANT}$ by the isotropic antenna gain $G_{ISO}$. $d$ Is the spatial distance from the antenna. A power $P$ = 1 500 W fed into a dipole results in an isotropic effective radiated power of $P_{EIRP}$ ≈ 2 500 W.

In the case of an amateur radio station operating at VHF, UHF, SHF and EHF, many antenna types are possible. Typical resulting antenna gains $G_{ISO}$ are between about 10 dBi and >30 dBi. These (mostly rotatable) antennas are normally mounted on antenna towers 10 m to 30 m above ground or on a roof. In this case, full field strength will occur only in the direction of the main beam of the antenna. Even for slight deviations from the direction of maximum beam strength, significant reductions of antenna gain are observed.

The same values for $P_{EIRP}$ and therefore for $E$ and $d$ in the beam direction for the amateur station in this example could also be obtained with $P$ = 100 W, a feeding cable attenuation of 2 dB and a directional antenna with an isotropic antenna gain $G_{ISO}$ of 16 dBi. However, with the same $P_{EIRP}$, the probability of disturbance of such an antenna is much lower than that of an omnidirectional antenna, because the beam width is limited in the horizontal and vertical plane.

(Source: Table 31 of [IEC TR 61000-2-5].)

**Table 4 – Disturbance degrees, levels (in volts per metre, r.m.s.) and distance to source – Other RF items in 2.4 GHz band**

| **Disturbance degree and corresponding field strength** | **Wideband data transmission systems and high performance radio local area network (HIPERLAN; Note 1)**<br>***P* = 0.1 WERP**<br>**Transmitter frequencies**<br>**2.400 0-2.483 5 GHz** | **Wideband data transmission systems and HIPERLAN terminal (Note 2)**<br>***P* = 0.1 WERP**<br>**Transmitter frequencies**<br>**2.400 0-2.483 5 GHz** |
|---|---|---|
| | Distance to source [m] | |
| A (Controlled) | Case-by-case according to the equipment requirements | |
| 1 0.3 V/m | 58 | 7.4 |
| 2 1 V/m | 17 | 2.2 |
| 3 3 V/m | 5.8 | 0.74 |
| 4 10 V/m | 1.7 | 0.22 |
| 5 30 V/m | 0.58 | 0.074 |
| X (harsh) | Case-by-case according to the situation | |
| NOTE 1 – The absolute gain of wideband data transmission systems/HIPERLAN is assumed to be 20 dBi maximum (for fixed wireless access service).<br>NOTE 2 – The absolute gain of wideband data transmission systems/HIPERLAN is assumed to be 2.14 dBi (for terminals).<br>NOTE 3 – ERP: effective radiated power. | | |

(Source: Table 33 and Table 34 of [IEC TR 61000-2-5].)

**Table 5 – Disturbance degrees, levels (in volts per metre, r.m.s.) and distance to source – Radio frequency identification systems**

| **Disturbance degree and corresponding field strength (Note 1)** | **Radio frequency identification (RFID) (Note 2)**<br>***P* = 4 W**<br>**Transmitter frequencies**<br>**13.56MHz** | **RFID ( Note 3)**<br>***P* = 4WEIRP**<br>**Transmitter frequencies**<br>**2450 MHz** |
|---|---|---|
| | Distance to source [m] | |
| A (Controlled) | Case-by-case according to the equipment requirements | |
| 1 0.3 V/m | 3.3 | 36.55 |
| 2 1 V/m | 1.6 | 11 |
| 3 3 V/m | 0.9 | 3.7 |
| 4 10 V/m | 0.49 | 1.1 |
| 5 30 V/m | 0.28 | 0.37 |
| X (harsh) | Case-by-case according to the situation | |
| NOTE 1 – The fields are calculated from Formula B.6 for 13.56 MHz RFID and Formula B.4 for 2 450 MHz RFID in Annex B of [IEC TR 61000-2-5].<br>NOTE 2 – See [ISO/IEC 18000-3].<br>NOTE 3 – See [ISO/IEC 18000-4], the power level is specified by EIRP, an antenna gain of 0 dBi is assumed. | | |

(Source: Table 39 of [IEC TR 61000-2-5].)

**Table 6 – Disturbance degrees, levels (in microamperes per metre, r.m.s.) and distance to source – Radio frequency identification systems**

| Disturbance degree and corresponding field strength | RFID (Note 2)<br>***P* = 4 W**<br>**Transmitter frequencies**<br>**13.56 MHz** |
|---|---|
| | Distance to source [m] |
| A (Controlled) | Case-by-case according to the equipment requirements |
| 1 3 μA/m | 600 |
| 2 10 μA/m | 180 |
| 3 30 μA/m | 60 |
| 4 100 μA/m | 17 |
| 5 300 μA/m | 5.2 |
| 6 1000 μA/m | 2.7 |
| X (harsh) | Case-by-case according to the situation |
| NOTE 1 – The fields are calculated from Formula B.7 in Annex B of [IEC TR 61000-2-5].<br>NOTE 2 – See [ISO/IEC 18000-3]. | |

(Source: Table 40 of [IEC TR 61000-2-5].)

## 9 Interference management

No significant interference source has yet been identified. This is under study.

If interference occurs on body-worn equipment, Table 7 may be used by the wearer, the manufacturer or other interested stakeholder to collect information about the case. Information about cases of interference sent to ITU-T SG5 for further study is welcome. See Table 7.

**Table 7 – Template for submission of information about cases of interference**

<table>
<tr><td colspan="2">Title</td><td colspan="4"></td></tr>
<tr><td colspan="2" rowspan="2">Nature of trouble</td><td colspan="4">malfunction, disturbance, other (                    )</td></tr>
<tr><td colspan="4">More detail:</td></tr>
<tr><td colspan="2">Environment</td><td colspan="4">1. Residence 2. Office 3. Outdoor<br>4. Industrial area 5.Telecom centre<br>6. Others (                    )</td></tr>
<tr><td colspan="6">Situation, configuration, measured data, etc. (Please add figures, if necessary.)</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="2">Source of EM interference</td><td colspan="4"></td></tr>
<tr><td colspan="2" rowspan="2">Type of interference</td><td colspan="4">Characteristics of the interferences</td></tr>
<tr><td>Type</td><td>Frequency (band)</td><td>Level</td><td>Others</td></tr>
<tr><td rowspan="2">Conducted</td><td rowspan="2">Voltage or current</td><td>Continuous</td><td>Hz</td><td>[    ]</td><td></td></tr>
<tr><td>Transient</td><td>Hz</td><td>[    ]</td><td></td></tr>
<tr><td rowspan="2">Radiated</td><td rowspan="2">Electromagnetic wave (field)</td><td>Continuous</td><td>Hz</td><td>[    ]</td><td></td></tr>
<tr><td>Transient</td><td>Hz</td><td>[    ]</td><td></td></tr>
</table>

# Appendix I

## Study roadmap of the electromagnetic environment and electromagnetic compatibility issues of body-worn devices and Bluetooth v4

(This appendix does not form an integral part of this Recommendation.)

The number of body-worn devices sold annually exceeded 100 million in 2016. There are more developers working on applications for body-worn devices [b-WTST]. The EMC of body-worn devices needs study. Furthermore, the EM environment and EMC failure cases and problems require collection and study.

### I.1 Bluetooth v4 and the body-worn device electromagnetic environment

Most body-worn devices use Bluetooth v4 for data exchange, as it features very low power consumption and high data rates. The EM environment when using Bluetooth v4 in the 2.4 GHz band needs study; to optimize power consumption, devices could switch between sleep and working mode. The EM environment characteristics of wake-up and sleep modes require collection and study.

### I.2 Cases of electromagnetic compatibility failure in body-worn devices

A few EMC failure cases have been reported. Big EMC problems are not found now with body-worn devices. However, body-worn device applications increase year on year; there are some healthcare and medical body-worn devices that may be interfaced with other normal use body-worn devices. Any EMC interference cases need continuous collection and study.

### I.3 Proposed procedure for the study of electromagnetic compatibility of body-worn devices

The following steps are proposed:

1) collection of EMC failure cases of body-worn devices;
2) study of EMC failure cases;
3) collection of EMC test data and results of body-worn devices;
4) comparison and study of test data and results;
5) drafting of EMC requirements and test conditions.

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