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| **Radio communication Study Groups** |  |
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| Source: COM 15 – LS 065-E  Subject: Question ITU-T 4/15 | **Document 5B/323-E Document 5C/187-E Document 5D/442-E Document 1A/108-E Document 5A/328-E Document 6A/284-E** |
| **25 July 2013** |
| **English only** |
| ITU-T Study Group 15 | |
| Liaison Statement on Determination of the  ITU-T G.fast PSD specification | |

The members of Q4/15 have considered your liaisons regarding ITU-T G.fast at the 1-12 July  
 ITU-T SG 15 meeting. As suggested in the liaisons, Q4/15 has split the draft ITU-T G.fast into two parts: the ITU-T G.fast PSD specification (containing functionality identified as having regulatory impact) and the ITU-T G.fast Physical Layer specification (containing the other transceiver functionality). The ITU-T G.fast PSD specification will follow the Traditional Approval Process (TAP) and has been determined at this ITU-T SG 15 meeting. The ITU-T G.fast Physical Layer specification will follow the Alternative Approval Process (AAP) with the goal of consent at the 6 December 2013 ITU-T WP 1/SG 15 meeting. We hope that the steps that we have taken address your concerns.

ITU-T Q4/15 has noted your concerns about spectral use up to 400 MHz. We want to point out that the highest frequency ever considered for this technology is 212 MHz, with the determined version of the ITU-T G.fast PSD specification being limited to frequencies up to 106 MHz. ITU-T Q4/15 fully recognizes the competence of ITU-R on spectral usage. We hope this clarification somewhat eases your concerns.

The ITU-T G.fast PSD specification sets the absolute limit on the transmitted PSD on the wireline and provides the necessary tools that ITU-T G.fast equipment shall support (such as PSD shaping and notching – e.g., to notch the FM and HAM bands) to allow the equipment operator to configure a transmit PSD limitation that complies with any nationally and regionally applicable EMC requirements.

The newly determined ITU-T G.fast PSD specification is attached for your review and comments. This Recommendation may be considered for approval at the March/April 2014 ITU‑T SG 15 meeting at the earliest.

Q4/15 looks forward to receiving your comments and working in close cooperation in finalizing this Recommendation.

We will forward the ITU-T G.fast physical layer specification to you once it has reached consent.

Attachment: Draft new Recommendation ITU-T G.9700 (fast-psd) (TD067/PLEN Rev.1).

|  |  |
| --- | --- |
| **For action to:** | ITU-R WP 1A, WP 6A, and WPs 5A, 5B, 5C, 5D |
| **For comment to:** | - |
| **For information to:** | - |
| **Approval:** | ITU-T SG 15 meeting (12 July 2013) |
| **Deadline:** | 1 March 2014 |
|  |  |
| **Contact:**  Frank Van der Putten Alcatel-Lucent Belgium | **Email:** [frank.van\_der\_putten@alcatel-lucent.com](mailto:frank.van_der_putten@alcatel-lucent.com) |

ATTACHMENT

Draft new Recommendation ITU-T G.9700 (fast-psd)   
(for Determination, July 2013)

Source: ITU-T TD 067 Rev.1 (PLEN/15)

Attached is draft Recommendation G.9700 for determination under TAP.

|  |  |  |
| --- | --- | --- |
| **Contact:** | Les Brown  Huawei  China | Tel: 1 (905) 826-4248  Cell: 1 (647) 290-1900  Email: [lesbrown@sympatico.ca](mailto:lesbrown@sympatico.ca) |

Draft Recommendation ITU-T G.9700 (ex. G.fast-psd)

Fast access to subscriber terminals (FAST) – Power spectral   
density specification

Summary

Recommendation ITU-T G.9700 specifies power spectral density (PSD) mask requirements, a set of tools to support reduction of the transmit PSD mask, profile control parameters that determine spectral content including the allowable maximum aggregate transmit power into a specified termination impedance, and methodology for transmit PSD verification. It complements the physical layer (PHY) specification in [ITU-T G.9701].

Keywords

<Optional>

Introduction

<Optional - This clause should appear only if it contains information different from Scope and Summary>

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Draft Recommendation ITU-T G.9700 (ex. G.fast-psd)

Fast access to subscriber terminals (FAST) – Power spectral density specification

# 1 Scope

This Recommendation complements the physical layer specification in [ITU-T G.9701].

It specifies:

* Power spectral density (PSD) limit mask requirements;
* A set of tools to support reduction of the transmit PSD mask;
* Profile control parameters that determine spectral content including the allowable maximum aggregate transmit power into a specified termination impedance; and
* A methodology for transmit PSD verification.

This ensures that the technology can address:

* Regional requirements;
* Operator deployment requirements, for example compatibility with other DSL technologies;
* Applicable EMC regulations or standards; and
* Local EMC issues.

# 2 References

The following ITU-T Recommendations and other references contain provisions that, 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 G.993.2] Recommendation ITU-T G.993.2 (2011), *Very high speed digital subscriber line transceivers 2 (VDSL2)*

[ITU-T G.9701] Recommendation ITU-T G.9701 (2014), *Fast access to subscriber terminals (FAST) – Physical layer specification*

# 3 Definitions

This Recommendation defines the following terms:

**3.1 Sub-carrier:** A fundamental element of a discrete multi-tone (DMT) modulator. The modulator partitions the channel bandwidth into a set of parallel sub-channels. The centre frequency of each sub-channel is a sub-carrier, onto which bits may be modulated for transmission over a channel.

# 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DAB Digital Audio Broadcasting

DMT Discrete Multi‑Tone

DP Distribution Point

DSL Digital Subscriber Line

FM Frequency Modulation

FTU FAST Transceiver Unit

FTU-O FTU at the Optical Network Unit

FTU-R FTU at the Remote site (i.e., subscriber end of the loop)

LESM Low-frequency Edge Stop-band Mask

LPM Limit PSD Mask

MBW Measurement Bandwidth

MIB Management Information Base

NM Notching Mask

PSD Power Spectral Density

PSM PSD Shaping Mask

QoS Quality of Service

SM Sub-carrier Mask

TDD Time Division Duplexing

TxPSDM Transmit PSD Mask

# 5 Transmit PSD mask

## 5.1 Overview

The transmit PSD mask (TxPSDM) is constructed from the combination of the following masks:

* Limit PSD mask (LPM),
* Sub-carrier mask (SM),
* PSD shaping mask (PSM),
* Notching masks (NM), and
* Low-frequency edge stop-band mask (LESM).

The TxPSDM applied to FTU-O and FTU-R may be different.

For a G.9701 transceiver, the PSD of the transmit signal at any frequency shall never exceed the TxPSDM.

The LPM (see clauses 6.1.2) specifies the absolute maximum limit of the TxPSDM. The SM, PSM, NM and LESM provide reduction and shaping of the TxPSDM using four mechanisms:

* sub-carrier masking,
* notching of specific frequency bands;
* PSD shaping; and
* Low-frequency edge stop-band masking.

Support of these four mechanisms is mandatory in both FTU-O and FTU-R.

The TxPSDM shall comply with applicable national and regional regulatory requirements.

NOTE – In addition to the masks defined in this Recommendation that provide absolute limits to the TxPSDM (both in-band and out-of-band), [ITU-T G.9701] defines a mechanism of discontinuous operation that allows the transceiver to dynamically switch off the transmit power in each particular connection when no data is present for transmission and a mechanism of low power mode (L2). Both mechanisms allow the system to further reduce the transmit power to a value that is sufficient to achieve the given bit rate and QoS targets.

## 5.2 Limit PSD mask (LPM)

The LPM defines the absolute maximum PSD limit of the TxPSDM that shall never be exceeded. All the other mask definitions and mechanisms used to construct the TxPSDM can only result in a reduction of the mask from the limits established by the LPM.

## 5.3 Sub-carrier masking

Sub-carrier masking shall be used to eliminate transmission on one or more sub-carriers. Sub-carrier masking is defined in the DP-MIB by a sub-carrier mask (SM). The transmit power of sub-carriers specified in SM shall be set to zero (linear scale). The SM shall override all other instructions related to the transmit power of the sub-carrier.

The SM is defined as a number of masked frequency bands. Each band is specified by a start sub‑carrier index (*x*L) and a stop sub-carrier index (*x*H), as {*x*L, *x*H}. An SM including *S* bands can be represented in the following format:

SM(S) = [{x*L*1, x*H*1}, {x*L*2, x*H*2}, … {x*L*S, x*H*S}]

All sub-carriers within the band, i.e., with indices higher than or equal to *x*L and lower than or equal to *x*H, shall be switched off (transmitted with zero power).

NOTE – The SM is intended to incorporate masked sub-carriers that are defined by a regional annex to comply with local regulations, and masked sub-carriers that are defined by the user or service provider to facilitate local deployment practices. Protection of radio services is not intended to be addressed by sub-carrier masking. It is addressed by notching (see clause 5.5).

## 5.4 Power spectral density shaping

Power spectral density (PSD) shaping allows reduction of the TxPSDM in some parts of the spectrum, mainly for spectrum compatibility and coexistence with other access and home network technologies. PSD shaping is specified in the DP-MIB by a PSD shaping mask (PSM).

PSM is defined on the frequency range between the lowest sub-carrier *x*1 and the highest sub-carrier *x*H, and consists of one or more frequency segments. The boundaries of the segments are defined by set breakpoints. Within each segment, the PSM may either be constant or form a linear slope between the given breakpoints (in dBm/Hz) with the frequency expressed in a linear scale.

Each breakpoint of PSM is specified by a sub-carrier index *xn* and a value of *PSDn* at that sub‑carrier expressed in dBm/Hz, {*xn*, *PSDn*}. P*SD*1 shall also apply to sub-carriers below *x*1 and P*SDH* shall also apply to sub-carriers above *xH*. A PSM including *S* segments can be represented by (*S*+1) breakpoints in the following format:

PSM(*S*) = [{*x*1, *PSD*1}, {*x*2, *PSD*2} … {*x*S, *PSD*S}, {*xH*, *PSDH*}]

A transceiver shall support configuration of at least 32 PSM breakpoints.

If one or more PSM breakpoints are set above the LPM, the transmit PSD mask shall be set to: TxPSDM = min(PSM, LPM). All values of *PSDn* of PSM breakpoints shall be set above – 90 dBm/Hz.

## 5.5 Notching of specific frequency bands

The transceiver (either FTU-O or FTU-R) shall be capable of being configured to notch one or more specific frequency bands in order to protect radio services, for example, amateur radio bands or broadcast radio bands.

Each notch in the NM shall be defined in terms of sub-carrier indices SCstart and SCend.

The valid range of start tone index, SCstart, is all valid tone indices that are less than or equal to the minimum frequency of the notched band – *FSC*/2. The valid range of stop tone index, SCstop,is all valid tone indices that are higher than or equal to the maximum frequency of the notched band + *FSC*/2.

Within the notched band, all sub-carriers shall be turned off and the transceiver shall be capable to be configured with a notching mask (NM) up to at least 20 dB below the LPM.

NOTE – Sub-carriers either side of the masked sub-carriers may also need to be turned off in order to meet the requirement on TxPSDM notch depth.

For a notched band, two PSD masks are defined:

* Narrowband Transmit PSD Mask (TXPSDM\_N)

This mask is defined to verify the PSD using a MBW=10 kHz centered on the frequency in question.

The TXPSDM\_N is defined as the maximum of the configured Notch Mask (NM) and a lower limit of −100 dBm/Hz:

TxPSDM\_N = max[NM, −100 dBm/Hz]

* Wideband Transmit PSD Mask (TXPSDM\_W)

This mask is defined to verify a mathematically calculated wideband average PSD (PSD\_W), obtained by averaging the narrowband measurements (PSD\_N) (measured in an MBW=10 kHz) over a 1 MHz window centered on the frequency in question:



with

PSD\_N(*f*) the narrowband measurement at frequency *f*, expressed in dBm/Hz

PSD\_W(*f*) the mathematically calculated wideband average PSD at frequency *f*, expressed in dBm/Hz

The TXPSDM\_W is defined as the maximum of the Notch Mask (NM) and a lower limit as defined in Table 5.1 frequency in question:

TxPSDM\_W(*f*) = max[NM(*f*), lower limit(*f*)]

Table 5-1 – TXPSDM\_W lower limit requirements

|  |  |
| --- | --- |
| **Frequency MHz** | TXPSDM\_W  lower limit [dBm/Hz] |
| 2.0 - 4.0 | -100 |
| 4.0 ‑ 5.0 | -110 |
| > 5.0 | -112 |

For notched bands that are narrower than 1 MHz:

* the transmit PSD is only required to satisfy the narrowband transmit PSD mask TxPSDM\_N, and this for frequencies (SCstart×*FSC* + ½×MBW) < *f* < ( SCend×*FSC*  − ½×MBW).

For notched bands that are 1 MHz or wider:

* the transmit PSD is required to satisfy the narrowband transmit PSD mask TxPSDM\_N, for frequencies (SCstart×*FSC* + ½×MBW) < *f* < ( SCend×*FSC*  − ½×MBW), and
* the wideband average transmit PSD (PSD\_W(f)) is required to satisfy the wideband transmit PSD mask TxPSDM\_W for frequencies (SCstart×FSC + ½×MBW + 0.5MHz) < *f* < (SCend×FSC − ½×MBW − 0.5MHz). The mask value to be compared against shall be the maximum value the mask takes within the 1 MHz window [*f* – 0.5 MHz, *f* + 0.5 MHz].

Appendix I of this Recommendation details the frequencies for the international amateur radio bands. Transceivers should be capable of being configured to notch amateur radio bands individually based on the needed protection.

Appendix II of this Recommendation details the frequencies for the broadcast radio services (FM and DAB).

FM, DAB and other radio services will require different notch configurations depending on the characteristics of the specific radio service.

Note: NM may be used to notch individual broadcast stations depending on spectrum utilization.

## 5.6 Low frequency edge stop-band masking

For the low frequency edge stop-band mask (LESM), two PSD masks are defined:

* Narrowband Transmit PSD Mask (TXPSDM\_N)

This mask is defined to verify the PSD using an MBW=10 kHz centered on the frequency in question.

The TXPSDM\_N is defined as shown in Figure 5-1, where PSDtr3 is the value of the in-band LPM at frequency *ftr3*. The mask values in the transition band are obtained using linear interpolation in dB over a linear frequency scale.

The transmit PSD is required to satisfy the narrowband Transmit PSD Mask TxPSDM\_N, for frequencies (0.5 MHz + ½×MBW) < *f* < ( *ftr*3 − ½×MBW), where *ftr*1 ≤ *ftr*3 ≤ 30 MHz. The PSD values above the transition frequency *ftr1* are considered as in-band and defined in clause 6.2.1.1.



Figure 5-1 – Low-frequency edge stop-band mask

* Wideband Transmit PSD Mask (TXPSDM\_W)

This mask is defined to verify a mathematically calculated wideband average PSD over a 1 MHz window (PSD\_W(*f*)) as defined in clause 5.5.

The TXPSDM\_W(*f*) is defined in Table 5.2 for the frequency in question.

The wideband average transmit PSD (PSD\_W(*f*)) is required to satisfy the wideband transmit PSD mask TxPSDM\_W for frequencies (2.0 MHz + ½×MBW + 0.5MHz) < *f* < (*ftr*3 − 175kHz − ½×MBW − 0.5MHz). The mask value to be compared against shall be the maximum value the mask takes within the 1 MHz window [ *f* – 0.5 MHz, *f* + 0.5 MHz].

Table 5-2 – LESM TXPSDM\_W requirements

|  |  |
| --- | --- |
| **Frequency (MHz)** | LESM  TXPSDM\_W  (dBm/Hz) |
| 2.0 to 4.0 | − 100 |
| 4.0 to 5.0 | − 110 |
| > 5.0 | − 112 |

# 6 Specification of spectral content

## 6.1 Profile control parameters

Each profile specifies normative values for the following parameters:

* The number of sub-carriers;
* The sub-carrier spacing;
* The cyclic extension parameters *LCP* and β; and
* The maximum aggregate transmit power (applies to both downstream and upstream directions);

Table 6-1 shows the valid control parameters for each profile. The parameters are defined in [ITU-T G.9701].

| Table 6-1 – Profile control parameters | | |
| --- | --- | --- |
| Parameter | Profile (Note 1) | |
| 106 MHz | 212 MHz |
| *N* | 2048 (Note 2) | For further study |
| *FSC* | 51.75 kHz | 51.75 kHz |
| *LCP* | *N*/64 × *m* for *m* = 4, 8, 10, 12, 14, 16, 20, 24, 30 and 33 samples @ 2\**N*\**FSC* samples/s | For further study |
| β | 64 and 128 samples @ 2\**N*\**FSC* samples/s | For further study |
| Maximum aggregate transmit power | + 4 dBm (See clauses 6.3 and 6.4) | For further study |
| NOTE 1 – Future profiles may be defined with higher maximum aggregate transmit powers provided that they are within the bounds of the limit PSD mask specified in this Recommendation.  NOTE 2 – The range of valid sub-carrier indices corresponds to frequencies between 2 and 106 MHz. | | |

## 6.2 PSD mask specifications

### 6.2.1 Limit PSD mask (LPM)

The LPM represents the absolute maximum that the TxPSDM shall never exceed. The in-band LPMs for 106 MHz profile and 212 MHz profile are presented in clause 6.2.1.1. The out-of-band LPMs are defined in clause 6.2.1.2.

#### 6.2.1.1 In-band LPM

The in-band LPMs for the 106 MHz profile and the 212 MHz profile are shown in Figure 6-1 and Figure 6-2, respectively. The parameters for these LPMs are presented in Table 6-2 and Table 6-3, respectively.



Figure 6-1 – In-band limit PSD mask for 106 MHz profile



Figure 6-2 – In-band limit PSD mask for 212 MHz profile

Table 6-2 – Parameters of in-band LPM for 106 MHz profile

| Parameter | Frequency (MHz) | PSD (dBm/Hz) | Description |
| --- | --- | --- | --- |
| *ftr1* | 2 | – 65 | The LPM below *ftr1* is defined in clause 6.2.1.2. |
|  | 30 | – 65 |
|  | 30 | – 73 | The PSD limit values between the points listed shall be obtained by linear interpolation in dB over linear frequency scale. The LPM above *ftr2* is defined in clause 6.2.1.2 |
| *ftr2* | 106 | – 76 |

Table 6-3 – Parameters of in-band LPM for 212 MHz profile

| Parameter | Frequency (MHz) | PSD (dBm/Hz) | Description |
| --- | --- | --- | --- |
| *ftr1* | 2 | – 65 | The LPM below *ftr1* is defined in clause 6.2.1.2. |
|  | 30 | – 65 |
|  | 30 | – 73 | The PSD limit values between the points listed shall be obtained by linear interpolation in dB over linear frequency scale. The LPM above *ftr2* is defined in clause 6.2.1.2 |
|  | 106 | – 76 |
| *ftr2* | 212 | – 79 |

NOTE 1 – When additional spectrum shaping is used as described in clause 5 (e.g., to provide spectrum compatibility or to comply with wide-band power limit), various parts of the TxPSDM could be reduced by switching sub-carriers off or reducing their transmit power. Additional frequency notches may also be applied if required.

#### 6.2.1.2 Out-of-band LPM

The out-of-band LPM shall be as shown in Figure 6-3 for the low-frequency edge, and as shown in Figure 6-4 for the high-frequency edge, where PSDtr1 is the value of the in-band LPM at frequency *ftr1* and PSDtr2 is the value of the in-band LPM at frequency *ftr2*. The parameters for these LPMs are presented in Table 6-4 and Table 6-5, respectively.

The out-of-band LPM applies for frequencies below the low-edge transition frequency *ftr*1 and for frequencies above the high-edge transition frequency *ftr*2. The PSD values between the transition frequencies *ftr1* and *ftr2*are considered as in-band and defined in clause 6.2.1.1.



Figure 6-3 – Low-frequency edge out-of-band limit PSD mask

Requirements for frequencies below 4 kHz are specified in G.993.2 Regional Annexes A, B or C.



Figure 6-4 – High-frequency edge out-of-band limit PSD mask

Table 6-4 – Parameters of low-frequency edge out-of-band LPM

|  |  |  |
| --- | --- | --- |
| ***ftr1***  **(MHz)** | PSDtr1  (dBm/Hz) | Description |
| 2 | – 65 | The PSD limit at transition frequency *ftr1* drops from PSDtr1 to – 80 dBm/Hz.  The PSD limit in the transition band shall be obtained by linear interpolation in dB over linear frequency scale.  The PSD limit between 4 and 20 kHz shall be obtained by linear interpolation in dB over a log(*f*) scale.  Sub-carriers below *ftr1* shall not be used for transmission (neither data nor any auxiliary information). |

Table 6-5 – Parameters of high-frequency edge out-of-band LPM

|  |  |  |  |
| --- | --- | --- | --- |
| ***ftr2***  **(MHz)** | PSDtr2  **(dBm/Hz)** | Transition band, Δ*fth*  **(MHz)** | Description |
| 106 | – 76 | 20 | The PSD limit in the transition band (Δ*fth*) shall be obtained by linear interpolation in dB over linear frequency scale.  Sub-carriers above *ftr2* shall not be used for transmission (neither data nor any auxiliary information). |
| 212 | –79 | 40 |

### 6.2.2 Permanently masked sub-carriers

For both the 106 MHz profile and the 212 MHz profile, sub-carriers with indices from 0 to 40 (inclusive) shall be permanently masked. They shall not be used for transmission (neither for data nor for any auxiliary information).

## 6.3 Termination impedance

A termination impedance of RV = 100 Ohm, purely resistive, at the U interface, shall be used for both FTUs. In particular, RV = 100 Ohm shall be used as a termination for the transmit PSD and aggregate transmit power definition and verification.

## 6.4 Maximum aggregate transmit power

The maximum aggregate transmit power of both the FTU-O (in the downstream direction) and FTU-R (in the upstream direction) shall not exceed the level specified in Table 6-1 for any given profile when measured using the termination impedance defined in clause 6.3.

Further limitations are the subject for regional Annexes (for further study).

# 7 Transmit PSD verification

The values of the transmit PSD mask are defined in this Recommendation under an assumption that the transmission were continuous. In systems using time division duplexing (TDD), such as [ITU-T G.9701], transmission in a particular direction is not continuous, but occurs only during designated time periods. This shall be taken in account by the applied measurement procedure.

The measurement bandwidth (MBW) for evaluation of the PSD shall be as defined in Table 7-1. The measurement bandwidth shall be centered on the frequency in question.

The mask value to be compared against shall be the maximum value the mask takes within a window [*f* − ½×MBW, *f* + ½×MBW].

NOTE: If in a certain frequency range both a narrowband transmit PSD mask (TXPSDM\_N) and a wideband transmit PSD mask (TXPSDM\_W) is defined, the MBW values defined in this clause relate to the narrowband PSD measurements PSD\_N.

PSD masks are specified with respect to a reference termination impedance, as defined in clause 6.3.

Table 7-1 – Measurement bandwidth settings for transmit PSD verification

|  |  |
| --- | --- |
| Frequency band | Measurement Bandwidth  (MBW) |
| 4 kHz < *f* < 20 kHz | 1 kHz |
| 20 kHz < *f* < *ftr1* | 10 kHz |
| (*ftr1+* ½×MBW)to (30 MHz*–* ½×MBW) | 1 MHz |
| (30 MHz*+* ½×MBW) to (*ftr2 –* ½×MBW) | 1 MHz |
| *>ftr2* to 300 MHz | 100 kHz |
| Any notched frequency band | 10 kHz |

Appendix I  
  
International amateur radio bands

(This annex forms an integral part of this Recommendation.)

Table I.1 – International amateur radio bands in the frequency range 0-212 MHz

|  |  |
| --- | --- |
| Band start (kHz) | Band stop (kHz) |
| 1 800 | 2 000 |
| 3 500 | 4 000 |
| 7 000 | 7 300 |
| 10 100 | 10 150 |
| 14 000 | 14 350 |
| 18 068 | 18 168 |
| 21 000 | 21 450 |
| 24 890 | 24 990 |
| 28 000 | 29 700 |
| 50 000 | 54 000 |
| 144 000 | 148 000 |

Appendix II  
  
Broadcast radio bands

(This annex forms an integral part of this Recommendation.)

Table II.1 – Broadcast radio bands in the frequency range 0-212 MHz

|  |  |  |
| --- | --- | --- |
| Band start (kHz) | Band stop (kHz) | Service |
| 88 000 | 108 000 | FM |
| 174 000 | 230 000 | DAB |

\_\_\_\_\_\_\_\_\_\_\_\_\_