International Telecommunication Union

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G.9700

Amendment 1

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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Access networks – Metallic access networks

Fast access to subscriber terminals (G.fast) – Power spectral density specification

Amendment 1

Recommendation ITU-T G.9700 (2014) – Amendment 1

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Recommendation ITU-T G.9700

Fast access to subscriber terminals (G.fast) – Power spectral density specification

Amendment 1

Summary

Recommendation ITU-T G.9700 specifies power spectral density (PSD) mask requirements for fast access to subscriber terminals (G.fast), 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. It complements the physical layer (PHY) specification in Recommendation ITU-T G.9701.

Amendment 1 provides support for a new 106 MHz profile with +8 dBm maximum aggregate transmit power.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.9700	2014-04-04	15	11.1002/1000/12010
1.1	ITU-T G.9700 (2014) Amd. 1	2016-09-30	15	11.1002/1000/12842

* 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.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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Fast access to subscriber terminals (G.fast) – Power spectral density specification

Amendment 1

Editorial note: This is a complete-text publication. Modifications introduced by this amendment are shown in revision marks relative to Recommendation ITU-T G.9700 (2014).

1 Scope

This Recommendation complements the physical layer (PHY) 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 digital subscriber line (DSL) technologies;
- applicable electromagnetic compatibility (EMC) regulations or standards; and
- local EMC issues.

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 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 (G.fast) – Physical layer specification*.

3 Definitions

This Recommendation defines the following terms:

3.1 **ceiling(*x*)**: The smallest integer which is not less than *x*.

3.2 **floor(*x*)**: The largest integer which is not greater than *x*.

3.3 f_{SC}: A parameter representing the frequency of subcarrier spacing.

3.4 subcarrier: A fundamental element of a discrete multitone (DMT) modulator. The modulator partitions the channel bandwidth into a set of parallel subchannels. The centre frequency of each subchannel is a subcarrier 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 Multitone

DP Distribution Point

DSL Digital Subscriber Line

EMC Electromagnetic Compatibility

FAST (G.fast) Fast Access to Subscriber Terminals

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 Subcarrier Mask

TDD Time-Division Duplexing

TxPSDM Transmit PSD Mask

5 Conventions

None.

6 Transmit PSD mask

6.1 Overview

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

− limit PSD mask (LPM);

− subcarrier mask (SM);

− PSD shaping mask (PSM);

− notching mask (NM); and

− low-frequency edge stop-band mask (LESM).

The TxPSDM applied to the FAST transceiver unit (FTU) at the optical network unit (FTU-O) or at the FTU remote site (i.e., subscriber end of the loop) (FTU-R) may be different.

For an FTU, the PSD of the transmit signal at any frequency shall never exceed the TxPSDM.

The LPM (see clause 7.2.1) specifies the absolute maximum limit of the TxPSDM. The subcarrier mask (SM), PSD shaping mask (PSM), notching mask (NM) and low-frequency edge stop-band mask (LESM) provide reduction and shaping of the TxPSDM using four mechanisms:

− subcarrier masking;

− notching of specific frequency bands;

− PSD shaping; and

− low-frequency edge stop-band masking.

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

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

NOTE 1 – When determining the correct PSD to use in a particular jurisdiction, operators should use tools provided to ensure compliance with national and regional electromagnetic compatibility (EMC) regulations giving special consideration to protecting receivers for the safety of life services which may not be immediately adjacent to the drop wires carrying ITU-T G.9701 signals. Examples include various VHF aeronautical radio navigation channels in the band 108-117.975 MHz, and aeronautical emergency communications channels (e.g., 121.5 MHz) and maritime emergency communications channels in the HF and VHF bands.

NOTE 2 – 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 two mechanisms: a mechanism of discontinuous operation that allows the FTU 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 quality of service (QoS) targets.

NOTE 3 – TXPSDM is defined in various averaging bandwidths according to frequency as defined in Table 8-1, except in sub-bands at the low frequency band edge and in the region of MIB defined notches, where TXPSDM_W (1 MHz wideband) and TXPSDM_N (10 kHz narrowband) masks apply as described in clauses 6.5 and 6.6.

6.2 Limit PSD mask (LPM)

The limit PSD mask (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.

6.3 Subcarrier masking

Subcarrier masking shall be used to eliminate transmission on one or more subcarriers. The subcarrier mask (SM) is configured in the distribution point management information base (DP-MIB) by use of the ITU-T G.997.1 parameter CARMASK. The transmit power of subcarriers specified in the SM shall be set to zero (linear scale). The SM shall override all other instructions related to the transmit power of the subcarrier.

The SM is defined as a number of masked frequency bands. Each band is specified by a start subcarrier index (x_L) and a stop subcarrier index (x_H), as {x_L, x_H}. An SM including *S* bands can be represented in the following format:

$$SM(S) = [\{x_{L1}, x_{H1}\}, \{x_{L2}, x_{H2}\}, \ldots \{x_{LS}, x_{HS}\}]$$

All subcarriers 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 both masked subcarriers that are defined by an annex defining regional requirements so as to comply with local regulations and masked subcarriers 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 subcarrier masking; it is addressed by notching (see clause 6.5).

6.4 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. The PSD shaping mask (PSM) is configured in the DP-MIB by use of the ITU-T G.997.1 parameter PSDMASK.

The PSM is defined on the frequency range between the lowest subcarrier x_1 (with x_1=ceiling(f_{tr1}/f_{SC})) and the highest subcarrier x_H (with x_H=floor(f_{tr2}/ f_{SC})), 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 the PSM is specified by a subcarrier index x_n and a value of PSD_n at that subcarrier expressed in dBm/Hz, $\{x_n, PSD_n\}$. PSD_1 shall also apply to subcarriers below x_1, and PSD_H shall also apply to subcarriers above x_H. A PSM including S segments can be represented by (S+1) breakpoints in the following format:

$$\text{PSM}(S) = [\{x_1, PSD_1\}, \{x_2, PSD_2\} \dots \{x_S, PSD_S\}, \{x_H, PSD_H\}]$$

An FTU 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 PSD_n of PSM breakpoints shall be set above –90 dBm/Hz.

6.5 Notching of specific frequency bands

The FTU 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 notching mask (NM) shall be defined in terms of subcarrier indices SC_{start} and SC_{stop}.

The valid range of notch start tone index, SC_{start}, is all valid tone indices that are less than or equal to the minimum frequency of the protected radio band minus $f_{SC}/2$. The valid range of notch stop tone index, SC_{stop}, is all valid tone indices that are higher than or equal to the maximum frequency of the protected radio band plus $f_{SC}/2$.

Within the notch, all subcarriers shall be turned off and the notching mask (NM) shall be equal to LPM −20 dB.

NOTE 1 – Subcarriers at either side of the masked subcarriers may also need to be turned off in order to meet the requirement on TxPSDM notch depth.

An FTU shall support at least 16 arbitrary notches simultaneously.

For a notch, two PSD masks are defined:

− Narrowband transmit PSD mask (TXPSDM_N)

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

  The TXPSDM_N is defined as the maximum of the NM and a lower limit of −100 dBm/Hz:

$$\text{TxPSDM\_N} = \max[\text{NM}, -100 \text{ dBm/Hz}].$$

– 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 centred on the frequency in question:

$$PSD\_W(f) = 10 \times \log 10\left(\left(\frac{1}{100}\right) \times \sum_{i=(-49)}^{50} 10^{\left(\frac{PSD\_N(f+i\times 10kHz)}{10}\right)}\right)$$

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 6-1 frequency in question:

TxPSDM_W(*f*) = max[NM(*f*), lower limit(*f*)].

Table 6-1 – 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 notches 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 ($SC_{start}\times f_{SC}$ + ½×MBW) < *f* < ($SC_{stop}\times f_{SC}$ − ½×MBW).

For notches that are 1 MHz or wider:

– the transmit PSD is required to satisfy the narrowband transmit PSD mask TxPSDM_N for frequencies ($SC_{start}\times f_{SC}$ + ½×MBW) < *f* < ($SC_{stop}\times f_{SC}$ − 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×f_{SC} + ½×MBW + 0.5MHz) < *f* < ($SC_{stop}\times f_{SC}$ − 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 details the frequencies for the international amateur radio bands. FTUs should be capable of being configured to notch amateur radio bands individually based on the needed protection.

Appendix II details the frequencies for the broadcast radio services (frequency modulation (FM) and digital audio broadcasting (DAB)).

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

NOTE 2 – NM may be used to notch individual broadcast stations depending on spectrum utilization.

6.6 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 centred on the frequency in question.

The TXPSDM_N is defined as shown in Figure 6-1, where PSD_{tr3} is the value of the in-band LPM at frequency f_{tr3}. 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 < (f_{tr3} − ½×MBW), where $f_{tr1} \le f_{tr3} \le$ 30 MHz. The PSD values above the transition frequency f_{tr3} are considered as in-band and defined in clause 7.2.1.1.

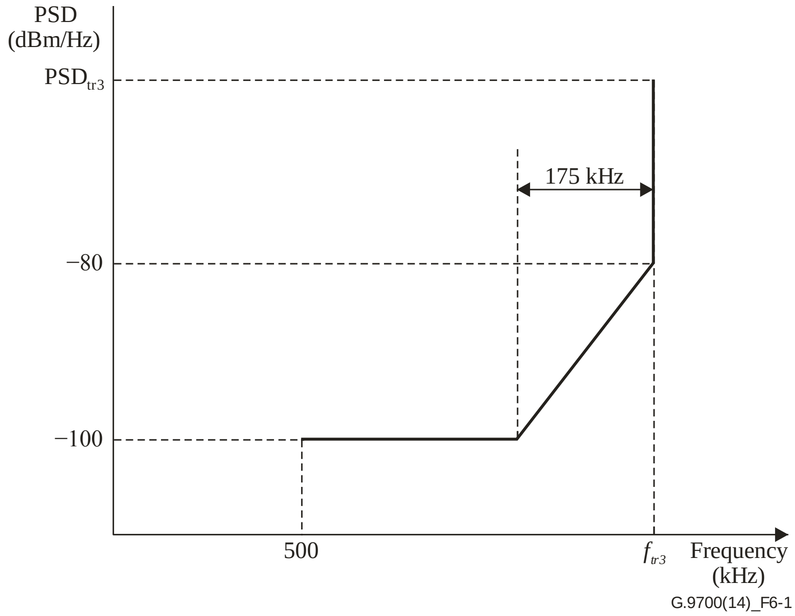

Figure 6-1 – Low-frequency edge stop-band mask

– 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 6.5.

The TXPSDM_W(f) is defined in Table 6-2 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 < (f_{tr3} − 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 6-2 – 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

7 Specification of spectral content

7.1 Profile control parameters

Each profile specifies normative values for the following parameters:

– the number of subcarriers (N);
– the subcarrier spacing (f_{SC});
– the cyclic extension parameters L_{CP} and β; and
– the maximum aggregate transmit power (applies to both downstream and upstream directions).

Table 7-1 shows the valid control parameters for each profile. The parameters are defined in [ITU-T G.9701].

Table 7-1 – Profile control parameters

Parameter	Profile (Note 1)		
	106 MHz (106a)	**106 MHz (106b)**	**212 MHz**
N	2048 (Note 2)	2048 (Note 2)	For further study
f_{SC}	51.75 kHz	51.75 kHz	51.75 kHz
L_{CP}	N/64 × m for m = 4, 8, 10, 12, 14, 16, 20, 24, 30 and 33 samples @ 2×N×f_{SC} samples/s	N/64 × m for m = 4, 8, 10, 12, 14, 16, 20, 24, 30 and 33 samples @ 2×N×f_{SC} samples/s	For further study
β	64 and 128 samples @ 2×N×f_{SC} samples/s	64 and 128 samples @ 2×N×f_{SC} samples/s	For further study
Maximum aggregate transmit power	+4 dBm (See clauses 7.3 and 7.4)	+8 dBm (See clauses 7.3 and 7.4)	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 subcarrier indices corresponds to frequencies between 2 and 106 MHz.			

7.2 PSD mask specifications

7.2.1 Limit PSD mask (LPM)

The limit PSD mask (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 7.2.1.1. The out-of-band LPMs are defined in clause 7.2.1.2.

7.2.1.1 In-band LPM

The in-band LPMs for the 106 MHz profile and the 212 MHz profile are shown in Figures 7-1 and 7-2, respectively. The parameters for these LPMs are presented in Tables 7-2 and 7-3, respectively.

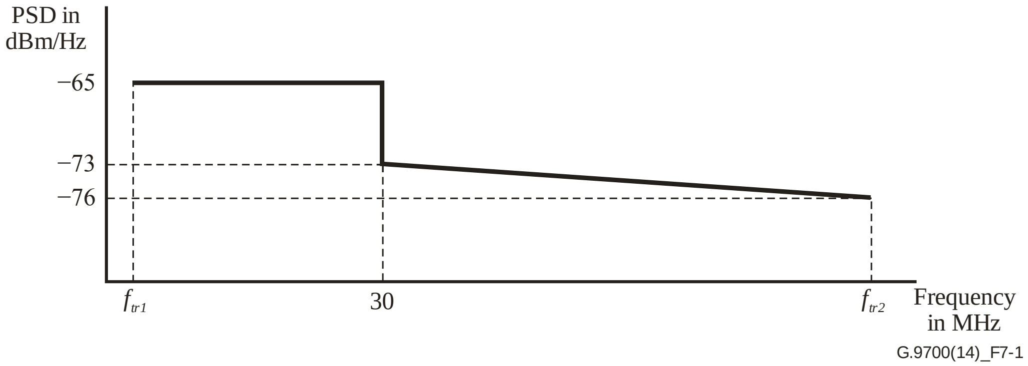

Figure 7-1 – In-band limit PSD mask for 106 MHz profile

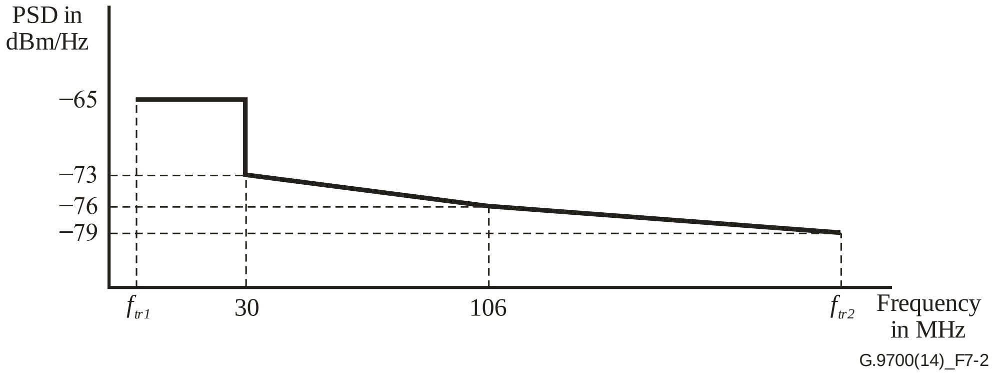

Figure 7-2 – In-band limit PSD mask for 212 MHz profile

Table 7-2 – Parameters of in-band LPM for 106 MHz profile

Parameter	Frequency (MHz)	PSD (dBm/Hz)	Description
f_{tr1}	2	–65	The LPM below f_{tr1} is defined in clause 7.2.1.2.
	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 f_{tr2} is defined in clause 7.2.1.2
f_{tr2}	106	–76	

Table 7-3 – Parameters of in-band LPM for 212 MHz profile

Parameter	Frequency (MHz)	PSD (dBm/Hz)	Description
f_{tr1}	2	–65	The LPM below f_{tr1} is defined in clause 7.2.1.2.
	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 f_{tr2} is defined in clause 7.2.1.2
	106	–76	
f_{tr2}	212	–79	

NOTE – When additional spectrum shaping is used as described in clause 6 (for example, to provide spectrum compatibility or to comply with wideband power limit), various parts of the TxPSDM could be reduced by switching subcarriers off or reducing their transmit power. Additional frequency notches may also be applied if required.

7.2.1.2 Out-of-band LPM

The out-of-band LPM shall be as shown in Figure 7-3 for the low-frequency edge, and in Figure 7-4 for the high-frequency edge, where PSD_{tr1} is the value of the in-band LPM at frequency f_{tr1} and PSD_{tr2} is the value of the in-band LPM at frequency f_{tr2}. The parameters for these LPMs are presented in Tables 7-4 and 7-5, respectively.

The out-of-band LPM applies for frequencies below the low-edge transition frequency f_{tr1} and for frequencies above the high-edge transition frequency f_{tr2}. The PSD values between the transition frequencies f_{tr1} and f_{tr2} are considered as in-band and defined in clause 7.2.1.1.

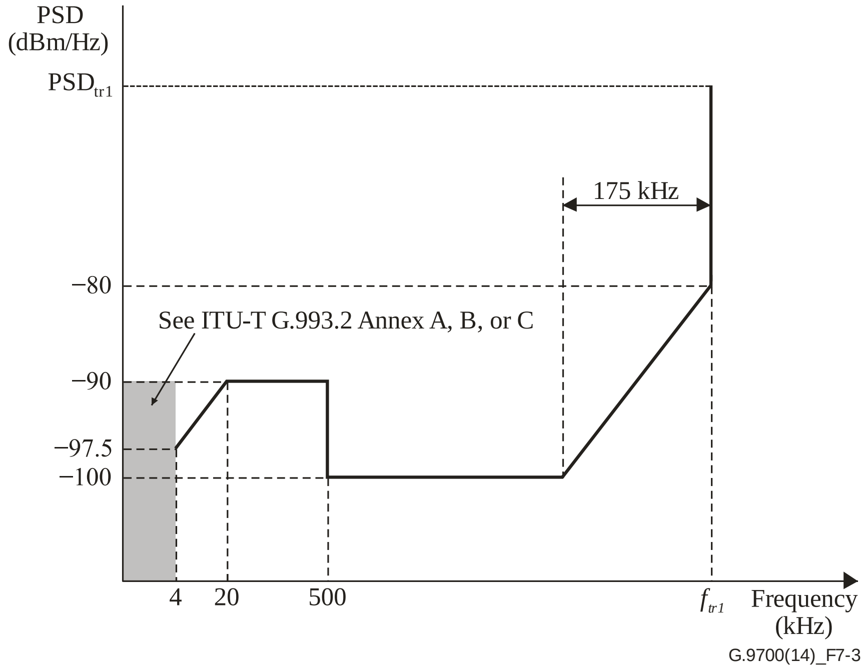

Figure 7-3 – Low-frequency edge out-of-band LPM

Requirements for frequencies below 4 kHz are specified in Annexes A, B and C of [ITU-T G.993.2] for the regions of North America, Europe and Japan, respectively.

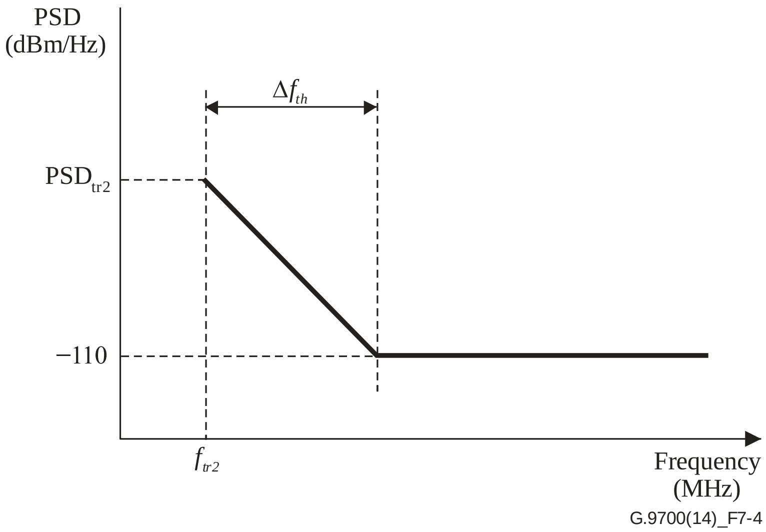

Figure 7-4 – High-frequency edge out-of-band LPM

Table 7-4 – Parameters of low-frequency edge out-of-band LPM

f_{tr1} (MHz)	PSD_{tr1} (dBm/Hz)	Description
2	–65	The PSD limit at transition frequency f_{tr1} drops from PSD_{tr1} 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. Subcarriers below f_{tr1} shall not be used for transmission (neither data nor any auxiliary information).

Table 7-5 – Parameters of high-frequency edge out-of-band LPM

f_{tr2} (MHz)	PSD_{tr2} (dBm/Hz)	Transition band, Δf_{th} (MHz)	Description
106	–76	20	The PSD limit in the transition band (Δf_{th}) shall be obtained by linear interpolation in dB over linear frequency scale. Subcarriers above f_{tr2} shall not be used for transmission (neither data nor any auxiliary information).
212	–79	40	

7.2.2 Permanently masked subcarriers

For both the 106 MHz profile and the 212 MHz profile, subcarriers with indices from 0 to 39 (inclusive) shall be permanently masked. They shall not be used for transmission (neither for data nor for any auxiliary information).

7.3 Termination impedance

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

7.4 Maximum aggregate transmit power

The values of the maximum aggregate transmit power are defined in this Recommendation under an assumption that the transmissions 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 maximum aggregate transmit power of both the FTU-O (in the downstream direction) and the FTU-R (in the upstream direction) shall not exceed the level specified in Table 7-1 for any given profile when measured using the termination impedance defined in clause 7.3.

Further limitations are the subject for annexes defining different regional requirements (for further study).

8 Transmit PSD verification

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

The measurement bandwidth (MBW) for evaluation of the PSD shall be as defined in Table 8-1. The measurement bandwidth shall be centred 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) are 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 7.3.

Table 8-1 – Measurement bandwidth settings for transmit PSD verification

Frequency band	Measurement bandwidth (MBW)
4 kHz < f < 20 kHz	1 kHz
20 kHz < f < f_{tr1}	10 kHz
(f_{tr1} + ½×MBW) to (30 MHz – ½×MBW)	1 MHz
(30 MHz + ½×MBW) to (f_{tr2} – ½×MBW)	1 MHz
> f_{tr2} to 300 MHz	100 kHz
Any notched frequency band	10 kHz

Appendix I

International amateur radio bands

(This appendix does not form 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
70 000	70 500
144 000	148 000

Appendix II

Broadcast radio bands

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

This appendix includes bands related to receivers likely to be in close proximity to the installation, omitting allocations for obsolete technologies such as analogue TV. Generally the services concerned are radio broadcasts.

Table II.1 – Broadcast radio bands in the frequency range up to 212 MHz

Band start (kHz)	Band stop (kHz)	Service
87 500	108 000	FM
174 000	216 000	Digital terrestrial television (Region 2)
174 000	230 000	Digital terrestrial television/Digital audio broadcasting (Regions 1 and 3)

Appendix III

Definition of transmitter PSD (TXPSD) for non-continuous transmissions

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

This appendix provides a formal definition for transmitter power spectral density (TXPSD) for signals comprising a stream of symbols including quiet periods, such as those produced by time division duplexed DMT systems.

This appendix defines TXPSD that is applicable to a stream of transmitted symbols, a punctured stream of symbols, or a continuous stream of symbols. Transmitted symbols are all symbols transmitted in the transmission period for the transmission direction. The quiet symbol positions in the transmission period are excluded. It does not define a measurement technique.

This appendix defines TXPSD in terms of an intermediate variable, "Transmitter Symbol PSD" (TXSPSD). TXSPSD is defined in relation to the Expectation of the energy spectral density (ESD) of symbols transmitted in a particular direction.

The ESD of a symbol voltage waveform $V_S(t)$ is derived into a reference impedance of 100 Ω.

$$ESD(V_s, f) = \frac{1}{R_0}\left|\int_{-\infty}^{\infty} V_s(t).e^{-i2\pi ft}dt\right|^2 (in\ unit\ of\ Joule/Hz)$$

$$R_0 = 100\ \Omega$$

TXSPSD is derived from the Expectation of the ESD over a set of transmitted symbols.

$$TXSPSD(f) = f_{DMT}.\mathrm{E}[ESD(V(t), f);\ V \in S] \text{ (in unit of W/Hz)}$$

$$S = \{S_0, S_1 \ldots S_N\}$$

$S_0, S_1 \ldots S_N$ is a valid sequence of transmitted symbols

$E[x]$ is the statistical expectation of x.

This normalization by the period of the symbol ensures that in the limit an infinite sequence of symbols has TXSPSD that converges to the classical PSD derived from the Fourier transform of the autocorrelation function.

The verifiable TXPSD is defined in a particular bandwidth *bw* as follows:

$$TXPSD(bw, f) = 30 + 10 \times log_{10}\left(\frac{1}{bw}\int_{f-\frac{bw}{2}}^{f+\frac{bw}{2}} TXSPSD(f_b)df_b\right) \text{ (in unit of dBm/Hz)}$$

TXPSDM(*f*) is the maximum permitted level for *TXPSD*(*bw*,*f*) of a long symbol sequence.

Methods for compliance verification are out of the scope of this Recommendation.

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