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

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Narrowband orthogonal frequency division multiplexing power line communication transceivers – Power spectral density specification

Recommendation ITU-T G.9901

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Recommendation ITU-T G.9901

Narrowband orthogonal frequency division multiplexing power line communication transceivers – Power spectral density specification

Summary

Recommendation ITU-T G.9901 specifies the transmitted output voltage in the band 9–535 kHz, the control parameters that determine spectral content, power spectral density (PSD) mask requirements, a set of tools to support the reduction of the transmit PSD, the means to measure this PSD for transmission over power line wiring, as well as the allowable total transmit power into a specified termination impedance.

Recommendation ITU-T G.9901 also complements the system architecture, physical layer (PHY) and data link layer (DLL) specifications in Recommendations ITU-T G.9902 (G.hnem), ITU-T G.9903 (G3-PLC), and ITU-T G.9904 (PRIME).

This edition contains the following modifications.

– The output voltage limits set for the ITU-T G.9902 FCC-2 bandplan have been extended to ITU-T G.9903 technology and thus placed in the main body. Care has been taken to reference existing standards as far as possible.

– The clarification of the tone masking feature in Annex B.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.9901	2012-11-20	15	11.1002/1000/11827
1.1	ITU-T G.9901 (2012) Amd. 1	2013-07-12	15	11.1002/1000/11895
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Keywords

Narrowband power line communications, power spectral density, conducted emission limits, G3-PLC, PRIME

* 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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Recommendation ITU-T G.9901

Narrowband orthogonal frequency division multiplexing power line communication transceivers – Power spectral density specification

1 Scope

This Recommendation specifies the control parameters that determine spectral content, power spectral density (PSD) mask requirements, a set of tools to support the reduction of the transmit PSD, the means to measure this PSD for the transmission over power line wiring, as well as the allowable total transmit power into a specified termination impedance. It complements the system architecture, physical layer (PHY), and data link layer (DLL) specifications in [ITU-T G.9902] (G.hnem), [ITU-T G.9903] (G3-PLC) and [ITU-T G.9904] (PRIME).

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.9902] Recommendation ITU-T G.9902 (2012), *Narrowband orthogonal frequency division multiplexing power line communication transceivers for ITU-T G.hnem networks*.

[ITU-T G.9903] Recommendation ITU-T G.9903 (2014), *Narrowband orthogonal frequency division multiplexing power line communication transceivers for G3-PLC networks*.

[ITU-T G.9904] Recommendation ITU-T G.9904 (2012), *Narrowband orthogonal frequency division multiplexing power line communication transceivers for PRIME networks*.

[IEC 61334-5-1] IEC 61334-5-1:2001, *Distribution automation using distribution line carrier systems – Part 5-1: Lower layer profiles – The spread frequency shift keying (S-FSK) profile*.

[CISPR 16-1-2] CISPR 16-1-2:2014, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Coupling devices for conducted disturbance measurements*.

[EN 50065-1] EN 50065-1:2011, *Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148, 5 kHz – Part 1: General requirements, frequency bands and electromagnetic disturbances*.

[ARIB STD-T84] ARIB STD-T84 (2002), *Power line communication equipment (10 kHz-450 kHz)*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 bandplan [ITU-T G.9902]: This is a specific range of the frequency spectrum that is defined by a lower frequency and upper frequency.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AMN	Artificial Mains Network
CES	Circuit Emulation Service
DLL	Data Link Layer
FCH	Frame Control Header
FFT	Fast Fourier Transform
LV	Low Voltage
NB-PLC	Narrowband-Power Line Communication
OFDM	Orthogonal Frequency Division Multiplexing
PFH	PHY-Frame Header
PHY	Physical layer
PLC	Power Line Communication
PMSC	Permanently Masked Subcarrier
PSD	Power Spectral Density
S-FSK	Spread Frequency Shift Keying

5 Conventions

None.

6 Transmitted output voltage specifications relating to the 3 kHz–148.5 kHz band

For Europe, [EN 50065-1] shall apply.

7 Transmitted output voltage specifications relating to the 148.5 kHz–535 kHz band

The following limits shall be met.

1) The output signal voltage measured using a peak detector with a 200 Hz bandwidth in no part of the frequency band shall exceed 120 dB (µV) when loaded on an artificial mains network (AMN).

2) The output signal voltage measured using a peak detector over the entire band when loaded on an AMN shall not exceed 137 dB (µV).

3) The output signal voltage outside the band 148.5 kHz–535 kHz shall comply with [EN 50065-1].

7.1 Artificial mains network

The AMN shall comply with clause 4.4 of [CISPR16-1-2].

The test setup shall comply with Figure 4 of [EN50065-1] for single-phase PLC systems and with Figure 6 of [EN 50065-1] for three-phase PLC systems.

Annex A

Power spectral density specifications for G.hnem transceivers

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

NOTE – This annex includes the PSD specifications relating to [ITU-T G.9902].

A.1 Frequency band specifications

For compliance with this Recommendation, it is mandatory to support at least one of the CENELEC bandplans or at least one of the FCC bandplans.

A.1.1 CENELEC band

When operating in the CENELEC band (3 kHz–148.5 kHz), a node shall use the control parameters specified in Table A.1 (see clause 8.4.7 of [ITU-T G.9902]).

Table A.1 – Orthogonal frequency division multiplexing modulator control parameters for the CENELEC band

Notation	Value
N	128
f_{SC}	1.562 5 kHz
N_{GI-PL}	12 – 1, 2 bit mapping 24 – 3, 4 bit mapping
N_{GI-HD}	0
N_{GI-CES}	0
B	8
f_{US}	$64 \times f_{SC}$

The CENELEC band is divided into sub-bands, forming bandplans A, B and CD described in clauses A.1.1.1 to A.1.1.3.

A.1.1.1 CENELEC-A bandplan

Parameters for the CENELEC-A bandplan are defined in Table A.2.

Table A.2 – Parameters for CENELEC-A bandplan

Notation	Value	Note
f_{START}	35.937 5 kHz	Lowest frequency of CENELEC-A bandplan (subcarrier number 23)
f_{END}	90.625 kHz	Highest frequency of CENELEC-A bandplan (subcarrier number 58)
Permanently masked subcarrier indices	0 to 22, 59 to 127	Clause 8.4.2.1 of [ITU-T G.9902]

A.1.1.2 CENELEC-B bandplan

Parameters for the CENELEC-B bandplan are defined in Table A.3.

Table A.3 – Parameters for CENELEC-B bandplan

Notation	Value	Note
f_{START}	98.437 5 kHz	Lowest frequency of CENELEC-B bandplan (subcarrier number 63)
f_{END}	120.312 5 kHz	Highest frequency of CENELEC-B bandplan (subcarrier number 77)
Permanently masked subcarrier indices	0 to 62, 78 to 127	Clause 8.4.2.1 of [ITU-T G.9902]

A.1.1.3 CENELEC-CD bandplan

Parameters for the CENELEC-CD bandplan are defined in Table A.4.

Table A.4 – Parameters for CENELEC-CD bandplan

Notation	Value	Note
f_{START}	125 kHz	Lowest frequency of CENELEC-CD bandplan (subcarrier number 80)
f_{END}	143.75 kHz	Highest frequency of CENELEC-CD bandplan (subcarrier number 92)
Permanently masked subcarrier indices	0 to 79, 93 to 127	Clause 8.4.2.1 of [ITU-T G.9902]

A.1.2 FCC bandplans

When operating in the FCC band (9 kHz–490 kHz), a node shall use the control parameters specified in Table A.5 (see clause 8.4.7 of [ITU-T G.9902]).

Table A.5 – Orthogonal frequency division multiplexing modulator control parameters for the FCC band

Notation	Value
N	256
f_{SC}	3.125 kHz
N_{GI}	24 – 1, 2 bit mapping 48 – 3, 4 bit mapping
$N_{GI\text{-}HD}$	0
$N_{GI\text{-}CES}$	0
β	16
f_{US}	$128 \times f_{SC}$

Bandplans FCC, FCC-1 and FCC-2 defined over the FCC band are described in clauses A.1.2.1 to A.1.2.3. Additional bandplans over the FCC band are for further study.

A.1.2.1 FCC bandplan

Parameters for the FCC bandplan are defined in Table A.6.

Table A.6 – Parameters for FCC bandplan

Notation	Value	Note
f_{START}	34.375 kHz	Lowest frequency of FCC bandplan (subcarrier number 11)
f_{END}	478.125 kHz	Highest frequency of FCC bandplan (subcarrier number 153)
Permanently masked subcarrier indices	0 to 10, 154 to 255	Clause 8.4.2.1 of [ITU-T G.9902]

A.1.2.2 FCC-1 bandplan

Parameters for FCC-1 bandplan are defined in Table A.7.

Table A.7 – Parameters for FCC-1 bandplan

Notation	Value	Note
f_{START}	34.375 kHz	Lowest frequency of FCC bandplan (subcarrier number 11)
f_{END}	137.5 kHz	Highest frequency of FCC bandplan (subcarrier number 44)
Permanently masked subcarrier indices	0 to 10, 45 to 255	Clause 8.4.2.1 of [ITU-T G.9902]

A.1.2.3 FCC-2 bandplan

Parameters for FCC-2 bandplan are defined in Table A.8.

Table A.8 – Parameters for FCC-2 bandplan

Notation	Value	Note
f_{START}	150 kHz	Lowest frequency of FCC bandplan (subcarrier number 48)
f_{END}	478.125 kHz	Highest frequency of FCC bandplan (subcarrier number 153)
Permanently masked subcarrier indices	0 to 47, 154 to 255	Clause 8.4.2.1 of [ITU-T G.9902]

A.1.3 ARIB bandplan

The ARIB bandplan shall follow the requirements set out in section 3.4 of [ARIB STD-T84].

When operating in the ARIB bandplan, a node shall use the parameters specified in clause A.1.2 with the following modification: tones 134–153 are defined as permanently masked subcarrier (PMSC; see clause 8.4.2.1 of [ITU-T G.9902] for the definition of PMSC tones).

A.2 Transmit power spectral density mask

A.2.1 Frequency notching

[ITU-T G.9902] supports frequency notching for regulatory and coexistence purposes. Notching shall apply to all components of a PHY frame [preamble, PHY-frame header (PFH), circuit emulation service (CES), and payload] and to all PHY frames transmitted in the domain.

If frequency notching is implemented by masking subcarriers, they shall be determined using the following rules.

– A frequency region between any two consecutive subcarriers ($f$sc) is divided into 4 equally-spaced sections that are further grouped into two equal regions: R1, which is around each subcarrier, and R2, which is in the middle of two subcarriers, as shown in Figure A.1.

– If the notched frequency falls in the R1 region of a subcarrier, this subcarrier and two adjacent subcarriers shall be masked [i.e., a total of three subcarriers whose indices are (n − 1), n and (n + 1) shall be masked if the notched frequency falls in the R1 region that contains subcarrier n].

– If the notched frequency falls in the R2 region, the two nearest subcarriers on both sides shall be masked [i.e., a total of four subcarriers whose indices are (n − 1), n, (n + 1) and (n + 2) shall be masked if the notched frequency falls in the R2 region between subcarriers n and (n + 1)].

NOTE – Depending on the relative position of the frequency that is required to be notched with respect to subcarriers, the number of masked subcarriers can vary, but the notched frequency is at least ($7 \times f_{SC}/4$) kHz away from the nearest subcarrier that is not masked.

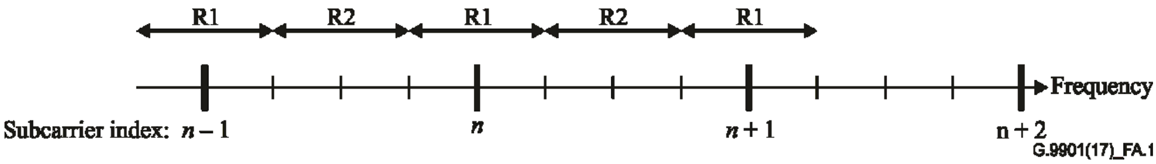

Figure A.1 – Frequency notching

Annex B

Power spectral density specifications for G3-PLC transceivers

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

NOTE – This annex includes the PSD specifications relating to [ITU-T G.9903].

B.1 Frequency band specifications

B.1.1 CENELEC band

When operating in the CENELEC bands (3-148.5 kHz), a node shall use the control parameters specified in Table B.1.

Table B.1 – Orthogonal frequency division multiplexing modulator control parameters for the CENELEC bands

Number of fast Fourier transform (FFT) points	$N = 256$
Number of overlapped samples	$N_O = 8$
Number of cyclic prefix samples	$N_{CP} = 30$
Number of frame control header (FCH) symbols	$N_{FCH} = 13$
Sampling frequency	$f_s = 0.4$ MHz
Number of symbols in preamble	$N_{pre} = 9.5$

B.1.1.1 CENELEC-A bandplan

When operating in the CENELEC-A bandplan, a node shall use the parameters specified in Table B.2.

Table B.2 – Parameters for CENELEC-A bandplan

	Number of subcarriers	**First subcarrier** (kHz)	**Last subcarrier** (kHz)
CENELEC-A	36	35.937 5	90.625

B.1.1.2 CENELEC-B bandplan

When operating in the CENELEC-B bandplan, a node shall use the parameters specified in Table B.3.

Table B.3 – Parameters for CENELEC-B bandplan

	Number of subcarriers	**First subcarrier** (kHz)	**Last subcarrier** (kHz)
CENELEC-B	16	98.437 5	121.875

B.1.2 FCC band

When operating in the FCC band (9 kHz–490 kHz), a node shall use the control parameters specified in Table B.4.

Table B.4 – Orthogonal frequency division multiplexing modulator control parameters for FCC band

Number of FFT points	$N = 256$
Number of overlapped samples	$N_O = 8$
Number of cyclic prefix samples	$N_{CP} = 30$
Number of FCH symbols	$N_{FCH} = 12$
Sampling frequency	$f_s = 1.2$ MHz
Number of symbols in preamble	$N_{pre} = 9.5$

When operating in the FCC bandplan, a node shall use the parameters specified in Table B.5.

Table B.5 – Parameters for the FCC bandplan

Bandplan	Number of subcarriers	First subcarrier (kHz)	Last subcarrier (kHz)
FCC	72	154.687 5	487.5

B.3 Transmit power spectral density mask

The [ITU-T G.9903] PHY is provisioned to allow tone masking features to:

1) provide flexibility in complying with regional regulations, e.g., facilitating coexistence with radio services;
2) allow coexistence with other power line communication technologies operating in the same band, e.g., spread frequency shift keying (S-FSK) systems in compliance with [IEC 61334-5-1];
3) allow flexibility in separating [ITU-T G.9903] domains by frequency division, e.g., by assigning non-overlapping bands to different [ITU-T G.9903] domains.

The transmitter shall use an appropriate scheme to insert deep notches into the spectrum. In particular, two frequencies referred to in [IEC 61334-5-1] as mark and space frequencies f_M and f_S, shall be notched in order to cohabitate with S-FSK systems.

Depending on the relative position of the required notch frequency with respect to subcarriers, a few subcarriers are masked. No data is sent over the masked subcarriers. According to Figure B.1, if the notch frequency is in the R1 region, SC(n − 1), SC(n) and SC(n + 1) are masked (a total of three subcarriers). If the notch frequency is in the R2 region the two nearest subcarriers on either side [i.e., SC(n − 1), SC(n), SC(n + 1) and SC(n + 2)] are masked (a total of four subcarriers).

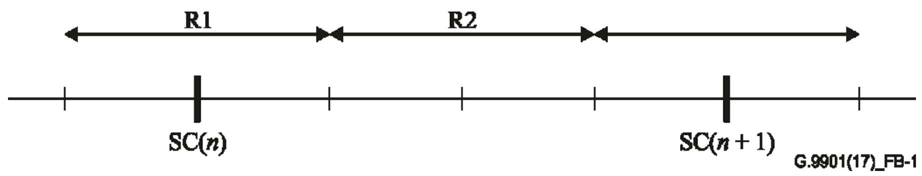

Figure B.1 – Frequency notching

A notching map should be a global parameter that is set in the initialization step of the devices. As described above, to provide sufficiently deep notches for a particular frequency band, it is required to zero one (or sometimes two) extra subcarriers before and after that band, depending on the position of the notch with respect to the subcarriers. The following pseudo code can be used for the decision between one/two extra subcarriers.

if NotchFreq/SamplingFreq × FFTSize is in R1

Sc(*n*-1) = Sc(*n*) = Sc(*n*+1) = 0

if NotchFreq / SamplingFreq × FFTSize is in R2

Sc(*n*-1) = Sc(*n*) = Sc(*n*+1) = Sc(*n*+2) = 0

SamplingFreq and FFTSize are 400 kHz and 256 respectively.

Sc is an array that determines which subcarriers are used to transmit data [if Sc(*i*) is zero, no data is sent using that subcarrier].

Frequency notching reduces the number of active tones that are used for transmitting information. Since notching is done for all the transmit signals, including FCH, the number of symbols in the FC depends on the number of active tones.

The following piece of code can determine the number of orthogonal frequency division multiplexing (OFDM) symbols that are used for transmitting the 33 bit FC:

fcSize = 33; // Size of FC

rxFCSymNum = *ceil*(((fcSize + 6) × 2 × 6) / freqNum);

where freqNum is the number of available subcarriers after frequency notching and *ceil* is the ceiling function.

For instance, in the case of coexistence with [IEC 61334-5-1], in order to minimize its effect on S-FSK signal, the OFDM modem shall not transmit any signal in-between S-FSK frequencies, i.e., in the 63 kHz–74 kHz band. The notched subcarriers in this mode are shown in Table B.6.

Table B.6 – Notched subcarriers in cohabitation mode

Subcarrier number	Frequency of the subcarrier
39	60.937 5
40	62.500 0
41	64.062 5
42	65.625 0
43	67.187 5
44	68.750 0
45	70.312 5
46	71.875 0
47	73.437 5
48	75.000 0
49	76.562 5

Therefore 11 subcarriers cannot transmit data. Considering the fact that there are a total of 36 subcarriers available, 25 subcarriers remain for data transmission, resulting in an FC with 19 OFDM symbols because *ceil*[(33 + 6) × 2 × 6/25] = 19.

All stations shall use tone masking on the subcarriers specified in each substation in order to be compliant with the transmit spectrum mask. The transmitted PSD of a notched frequency shall be 25 dB below the limits specified for the rest of the subcarriers – see for example Figure B.2.

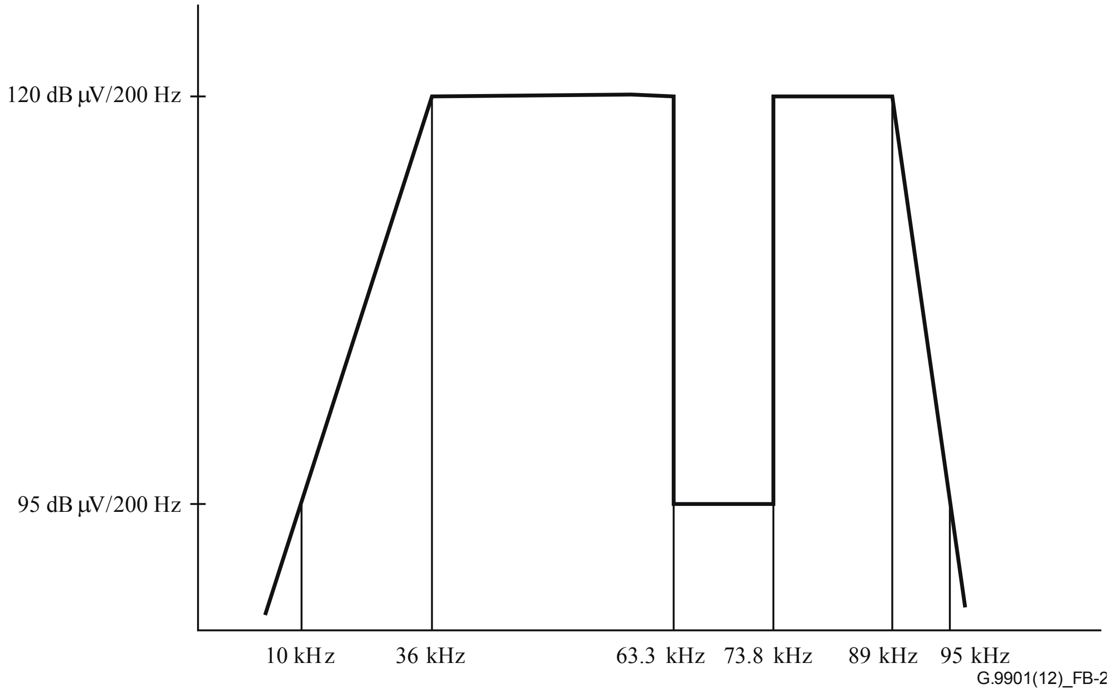

Figure B.2 – Spectrum with two notches inserted to cohabitate with spread frequency shift keying power line communication modem

Measurements are made using a spectrum analyser with a resolution bandwidth of 200 Hz and a quasi-peak detector. The transmitter shall be configured to repeatedly transmit maximum length rolling data pattern packets.

B.3.1 Spurious transmission

It is the obligation of the manufacturer to ensure that spurious transmissions conform to regulations in effect for the country in which this station is used.

Annex C

Power spectral density specifications for PRIME transceivers

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

NOTE – This annex includes the PSD specifications relating to [ITU-T G.9904].

C.1 Introduction

This annex specifies the PSD relating to [ITU-T G.9904]. [ITU-T G.9904] is an OFDM-based PLC communications scheme in the CENELEC-A band as defined in the main body of this Recommendation. The PHY entity uses frequencies in the 3 kHz–95 kHz band and is restricted to applications for monitoring or controlling the low voltage distribution network, including energy usage of connected equipment and premises. However, it is well known that frequencies below 40 kHz show several problems in typical low-voltage (LV) power lines. For example:

– load impedance modulus seen by transmitters is sometimes below 1 Ω, especially for base nodes located at transformers;

– coloured background noise, which is always present in power lines and caused by the summation of numerous noise sources with relatively low power, exponentially increases its amplitude towards lower frequencies;

– meter rooms pose an additional problem, as consumer behaviour is known to have a deeper impact on channel properties at low frequencies, i.e., operation of all kinds of household appliance leads to significant and unpredictable time variance of both the transfer function characteristics and the noise scenario.

Consequently, the OFDM signal will use a frequency bandwidth of 47.363 kHz located in the high frequencies of the CENELEC-A band.

The OFDM signal itself will use 97 (96 data plus one pilot) equally spaced subcarriers with a short cyclic prefix.

C.2 PHY parameters

Table C.1 lists OFDM control and timing parameters.

Table C.1 – Frequency and timing parameters of the PRIME PHY

Baseband clock (Hz)	250 000	
Subcarrier spacing (Hz)	488.281 25	
Number of data subcarriers	84 (header)	96 (payload)
Number of pilot subcarriers	13 (header)	1 (payload)
FFT interval (samples)	512	
FFT interval (µs)	2 048	
Cyclic prefix (samples)	48	
Cyclic prefix (µs)	192	
Symbol interval (samples)	560	
Symbol interval (µs)	2 240	
Preamble period (µs)	2 048	

C.3 CENELEC bandplan

Start and end frequencies are f_s = 41 992 Hz and f_f = 88 867 Hz, respectively.

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