1.1.1 CNU Transmitter Output Requirements

The CNU shall output an RF Modulated signal with characteristics delineated in Table Error**! No text of specified style in document.**-1.

Table** Error! No text of specified style in document.**-1 - CNU transmitter output signal characteristics

Parameter	Value
FDD Frequency Bands	FDD Mode: 5 MHz – 234 MHz
TDD Frequency Bands	CNU shall support the following frequency bands, either separately or together: 5 MHz – 277 MHz (low band) 750 MHz – 1800 MHz (high band)
Signal Type	OFDMA
Maximum OFDMA Channel Bandwidth	192 MHz
Minimum Occupied Bandwidth	6.4 MHz for 25 kHz subcarrier spacing 10 MHz for 50 kHz subcarrier spacing
Number of Independently configurable OFDMA channels	Minimum of TBD channels
Subcarrier Channel Spacing	25 kHz, 50 kHz
FFT Size	50 kHz: 4096 (4K FFT) 25 kHz: 8192 (8K FFT)
Sampling Rate	204.8 MHz (192 MHz Block Size)
FFT Time Duration	40 µsec (25 kHz subcarriers) 20 µsec (50 kHz subcarriers)
Modulation Type	QPSK, 8-QAM, 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM, 512-QAM, and 1024-QAM
Bit Loading	Variable per RB Constant for subcarriers of the same type in the RB Support zero valued subcarriers (subcarrier nulling) per profile and RB
Level	Shall be capable of transmitting a total average output power of 65 dBmV May be capable of transmitting a total average output power greater than 65 dBmV
Output Impedance	75 ohms
Output Return Loss	> 6 dB 5-f_{max} MHz (42/65/85/117/204 MHz) > 6 dB f_{max} – 1218 MHz > 6 dB f_{max} – 1.794 GHz for CNUs that can transit up to 1.794 GHz

Commented [sr1]: Need motion on this

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1.1.2 Upstream Transmit Fidelity Requirements

A CNU is required to generate up to TBD channel-blocks of OFDMA

A CNU's Transmit Channel Set (TCS) is the set of OFDMA channels being transmitted by the CNU.

With BW_{OFDMA} being the combined occupied bandwidth of the OFDMA channel(s) in its TCS, the CNU is said to have N_{eq} = ceil(BW_{OFDMA} (MHz)/1.6 MHz) "equivalent channels" in its TCS.

"Equivalent channel power" of a channel refers to the power in 1.6 MHz of spectrum assuming the channel has occupied bandwidth of 6.4 MHz (5.12 MHz modulation rate).

The "equivalent channel power" of an OFDMA channel is the average power of the OFDMA subcarriers of the channel normalized to 1.6 MHz bandwidth. This equivalent channel power of an OFDMA channel is denoted as $PSD_{1.6}$. The TCS has one, or TBD OFDMA channels, but also is described as having N_{eq} number of equivalent channels.

Each channel in the TCS is described by its reported power, which is the power of the channel when it is fully granted. Each channel is also characterized by its "equivalent channel power," which is the channel power normalized to 1.6 MHz (Power Spectral Density of the average power of the channel multiplied by 1.6 MHz).

1.1.2.1 Transmit Power Requirements

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The transmit power requirements are a function of the number and occupied bandwidth of the OFDMA channels in the TCS. The minimum highest value of the total power output of the CNU is 65 dBmV, although higher values are allowed. The total maximum power is distributed among the OFDMA channels in the TCS, based on equal power spectral density when the OFDMA channels are fully granted to the CNU. This ensures that each OFDMA channel can be set to a power range within the dynamic range window (DRW) between its maximum power, P_{hi}, and minimum power, P_{low}, and that any possible transmit grant combination can be accommodated without exceeding the transmit power capability of the CNU.

Maximum equivalent channel power ($PSD_{1.6Max}$) is calculated as $PSD_{1.6Max} = 65$ dBmV – $10\log_{10}(N_{eq})$.

Commented [sr4]: Do we want to maintain the 1.6MHz normalizations

The CLT shall limit the commanded $PSD_{1.6Max}$ to 53.2 dBmV if N_{eq} is ≤ 15. This enforces a maximum power spectral density of 65 dBmV per 24 MHz.

The minimum value allowed is $PSD_{1.6Min} = 17$ dBmV.

The CNU shall not transmit on any channel in the TCS at a value higher than P_{hi} or lower than P_{low}. The values for P_{hi} and P_{low} are functions of $PSD_{1.6Max}$, $PSD_{1.6Min}$, and N_{eq}.

The CNU sends transmit power level commands and pre-equalizer coefficients to the CNU to compensate for upstream plant conditions. The top edge of the DRW is set to a level, $P_{load\_min\_set}$, close to the highest $PSD_{1.6}$ transmit channel to optimally load the DAC. In extreme tilt conditions, some of the channels will be sent commands to transmit at lower $PSD_{1.6}$ values that use up a significant portion of the DRW. Additionally, the pre-equalizer coefficients of the OFDMA channels will also compensate for plant tilts. The CLT enforces a DRW of 12 dB, which is sufficient to accommodate plant tilts of up to 10 dB from lower to upper edge of the upstream band. Since the fidelity requirements are specified in flat frequency conditions from the top of the DRW, it is desirable to maintain CNU transmission power levels as close to the top of the DRW as possible.

1.1.2.2 OFDMA Fidelity Requirements

The following requirements assume that any pre-equalization is disabled, unless otherwise noted.

When channels in the TCS are commanded to the same equivalent powers, the reference signal power in the "dBc" definition is to be interpreted as the measured total grant power. When channels in the TCS are commanded to different equivalent channel powers, the commanded total power of the transmission is computed, and a difference is derived compared to the commanded total power which would occur if all channels had the same $PSD_{1.6}$ as the highest equivalent channel power in the TCS, whether or not the channel with the largest equivalent channel power is included in the grant. Then this difference is added to the measured total transmit power to form the reference signal power for the "dBc" spurious emissions requirements.

1.1.2.2.1 Spurious Emissions

The noise and spurious power generated by the CNU shall not exceed the levels given in Table 2, Table 3, and Table 4. Up to five discrete spurs can be excluded from the emissions requirements listed in Table 2, Table 3 and Table 4 and have to be less than -42 dBc relative to a single subcarrier power level.

SpurFloor is defined as:

SpurFloor = max{ -57 + 10*log10(100% Grant Spectrum/192 MHZ), -60} dBc

Under-grant Hold Number of Users is defined as:

Under-grant Hold Number of Users = Floor{ 0.2 + 10^((-44 - SpurFloor)/10) }

Under-grant Hold Bandwidth is defined as:

Under-grant Hold Bandwidth = (100% Grant Spectrum)/(Under-grant Hold Number of Users)

These spurious performance requirements only apply when the CNU is operating within certain ranges of values for P_{load_n}, for n = 1 to the number of upstream channels in the TCS, and for granted bandwidth of Under-grant Hold Bandwidth or larger; where P_{load_1} the highest loaded channel in this specification (i.e., its power is the one closest to P_{hi}).

When a CNU is transmitting over a bandwidth of less than Under-grant Hold Bandwidth, the spurious emissions requirement limit is the power value (in dBmV), corresponding to the specifications for the power level associated with a grant of bandwidth equal to Under-grant Hold Bandwidth.

When there are two or more channels in the TCS, the CNU's spurious performance requirements shall be met only when the equivalent 1.6 MHz CEA channel powers ($PSD_{1.6}$) are within 6 dB of $P_{load\_min\_set}$ ($P_{load\_min\_set}$ +6>=P_{load_n}>= $P_{load\_min\_set}$).

Commented [sr5]: The term channel is used a lot in this section… makes we wonder if the intent is equivalent ch or ofdm channel block

Further, the CNU's spurious emissions requirements shall be met with two or more channels in the TCS only when $P_{load\_1} = P_{load\_min\_set}$. When $P_{load\_1} < P_{load\_min\_set}$, the spurious emissions requirements in absolute terms are relaxed by $P_{load\_1} - P_{load\_min\_set}$.

When a CNU is transmitting with any equivalent channel power with loading $P_{load\_min\_set}$ + 16 dB or lower ($P_{load>}$ $P_{load\_min\_set}$+ 16 dB), the spurious emissions requirement limits are not enforced.

The spurious performance requirements do not apply to any upstream channel from the time the output power on any active upstream channel has varied by more than ±3 dB since the last global reconfiguration time through the end of the next global reconfiguration time changes, excluding transmit power changes due to PLC commands in P_{hi}.

Commented [sr6]: Need to add GTR

In Table 2, inband spurious emissions include noise, carrier leakage, clock lines, synthesizer spurious products, and other undesired transmitter products. It does not include ISI. The signal reference power for OFDMA inband spurious emissions is the total transmit power measured and adjusted (if applicable) as described in Section 1.1.2.2, and then apportioned to a single data subcarrier.

The measurement bandwidth is 160 kHz for the Between Bursts (none of the channels in the TCS is bursting) specs of Table 2, except where called out as 4 MHz or 250 kHz. The signal reference power for Between Bursts transmissions is the total transmit power measured and adjusted (if applicable) as described in Section 1.1.2.2.

The Transmitting Burst specs apply during the resource blocks granted to the CNU (when the CMI uses all or a portion of the grant), and for 20 µs before and after the granted resource block for OFDMA. The Between Bursts specs apply except during a used grant of resource blocks on any active channel for the CNU, and 20 us before and after the used grant for OFDMA. The signal reference power for Transmitting Burst transmissions, other than inband, is the total transmit power measured and adjusted (if applicable) as described in Section 1.1.2.2.

For the purpose of spurious emissions definitions, a granted burst refers to a burst of resource blocks to be transmitted at the same time from the same CM; these resource blocks are not necessarily contiguous in frequency.

Table 2 - Spurious Emissions

Parameter	Transmitting Burst	Between Bursts[3]
Inband	-60 dBc OFDMA [NOTE: also see MER requirement]	-72 dBc
Adjacent Band	See Table 4	-72 dBc
Within the upstream operating range 5-234 MHz (excluding assigned channel, adjacent channels)	See Table 3	-72 dBc
For the case where the upstream operating range is 5-42 MHz: CNU Integrated Spurious Emissions Limits (all in 4 MHz, includes discretes)[1] 42 to 54 MHz 54 to 60 MHz 60 to 88 MHz 88 to 1218 MHz	 -40 dBc -35 dBmV -40 dBmV -45 dBmV	 -26 dBmV -40 dBmV -40 dBmV max(-45 dBmV, -40 dB ref downstream)[2]

Commented [JS7]: Should we keep these cases of using smaller upstream bands? Will need for the TDD high band cases.

Parameter	Transmitting Burst	Between Bursts[3]
For the case where the upstream operating range is 5-42 MHz: CNU Discrete Spurious Emissions Limits[1] 42 to 54 MHz 54 to 88 MHz 88 to 1218 MHz	 -50 dBc -50 dBmV -50 dBmV	 -36 dBmV -50 dBmV -50 dBmV
For the case where the upstream operating range is 5-85 MHz: CNU Integrated Spurious Emissions Limits (all in 4 MHz, includes discrete spurs)[1] 85 to 108 MHz 85 to 108 MHz (Should) 108 to 136 MHz 136 to 1218 MHz	 -45 dBc -50 dBc -40 dBmV -45 dBmV	 -31 dBmV -36 dBmV -40 dBmV max(-45 dBmV, -40 dB ref downstream)[2]
For the case where the upstream operating range is 5-85 MHz: CNU Discrete Spurious Emissions Limits[1] 85 to 108 MHz 108 to 1218	 -50 dBc -50 dBmV	 -36 dBmV -50 dBmV
For the case where the upstream operating range is 5-204 MHz: CNU Integrated Spurious Emissions Limits (all in 4 MHz, includes discrete spurs)[1] 204 to 258 MHz 204 to 258 MHz (Should) 258 to 1218 MHz	 -50 dBc -60 dBc -45 dBmV	 -72 dBc -72 dBc max(-45 dBmV, -40 dB ref downstream)[2]
For the case where the upstream operating range is 5-204 MHz: CNU Discrete Spurious Emissions Limits[1] 204 to 258 MHz 258 to 1218 MHz	 -50 dBc -50 dBmV	 -36 dBmV -50 dBmV

Table Notes:

Note 1 These spec limits exclude a single discrete spur related to the tuned received channel; this single discrete spur must be no greater than -40 dBmV.

Note 2 "dB ref downstream" is relative to the received downstream signal level. Some spurious outputs are proportional to the receive signal level.

Note 3 Relative to the previous transmission

1.1.2.2.1.1 Spurious Emissions in the Upstream Frequency Range

Table 3 lists the required spurious level in a measurement interval. The initial measurement interval at which to start measuring the spurious emissions (from the transmitted burst's modulation edge) is 400 kHz from the edge of the transmission's modulation spectrum. Measurements should start at the initial distance and be repeated at increasing distance from the carrier until the upstream band edge or spectrum adjacent to other modulated spectrum is reached.

For OFDMA transmissions with non-zero transmit windowing, the CNU shall meet the required performance measured within the 2.0 MHz adjacent to the modulated spectrum using slicer values from a CLT burst receiver or equivalent, synchronized to the downstream transmission provided to the CNU.

In the rest of the spectrum, the CNU shall meet the required performance measured with a bandpass filter (e.g., an unsynchronized measurement).

For OFDMA transmissions with zero transmit windowing, CNU shall meet the required performance using synchronized measurements across the complete upstream spectrum.

Spurious emissions allocation for far out spurious emissions =

Round{ SpurFloor + 10*log10(Measurement bandwidth/Under-grant hold Bandwidth),0.1}.

For transmission bursts with modulation spectrum less than the Under-grant Hold Bandwidth, the spurious power requirement is calculated as above, but increased by $10*\log_{10}$ (Under-grant Hold Bandwidth/Grant Bandwidth).

Table 3 - Spurious Emissions Requirements in the Upstream Frequency Range for Grants of Under-grant Hold Bandwidth and Larger[1]

100% Grant Spectrum (MHz)	SpurFloor (dBc)	Under-grant Hold #Users	Under-grant Hold Bandwidth (MHz)	Measurement Bandwidth (MHz)	Specification in the Interval (dBc)
Up to 64	-60.0	40	100% Grant Spectrum/40	1.6	Round{ SpurFloor + $10*\log_{10}$(Measurement Bandwidth/Under-grant Hold Bandwidth),0.1}
[Ex: 22 MHz]			[0.55 MHz]		[-55.4]
[Ex: 46 MHz]			[1.15 MHz]		[-58.6]
Greater than 64, up to 96	-60.0	40	100% Grant Spectrum/40	3.2	Round{ SpurFloor + $10*\log_{10}$(Measurement Bandwidth/Under-grant Hold Bandwidth),0.1
[Ex 94 MHz]			[2.35 MHz]		[-58.7]
Greater than 96, up to 192	max{ -57 + $10*\log_{10}$(100% Grant Spectrum/192 MHZ), -60}	Floor{ 0.2 + 10^((-44 - SpurFloor)/10) }	100% Grant Spectrum)/(Under-grant Hold Number of Users)	9.6	Round{ SpurFloor + $10*\log_{10}$(Measurement Bandwidth/Under-grant Hold Bandwidth),0.1}
[Ex: 142 MHz]	[-58.3]	[27]	[5.3]		[-55.7]
[Ex: 190 MHz]	[-57.0]	[20]	[9.5		[-57.0]
Greater than 192	max{ -57 + $10*\log_{10}$(100% Grant Spectrum/192 MHZ), -60}	Floor{ 0.2 + 10^((-44 - SpurFloor)/10) }	100% Grant Spectrum)/(Under-grant Hold Number of Users)	12.8	Round{ SpurFloor + $10*\log_{10}$ (Measurement Bandwidth/Under-grant Hold Bandwidth),0.1}
[Ex: 204 MHz]	[-56.8]	[19]	[10.5]		[-55.9]
Note 1 Spurious Emissions Requirements in the Upstream Frequency Range Relative to the Per Channel Transmitted Burst Power Level for Each Channel for Grants of Under-grant Hold Bandwidth and Larger					

Within the measurement bandwidth of Table 3, spurious emissions measured for individual subcarriers shall contain no more than +3 dB power larger than the required average power of the spurious emissions in the full measurement bandwidth.

Optionally for OFDMA transmissions, bandpass measurements rather than synchronous measurements may be applied.

As an example illustrating the smaller measurement bandwidth requirements, consider 94 MHz 100% grant spectrum, with -58.7 dBc spurious emissions allowed in 3.2 MHz measurement bandwidth, with the measurement bandwidth starting as close as 400 kHz from the modulation edge of the transmitted burst. If the subcarrier spacing is 25 kHz, there are 128 subcarriers in the 3.2 MHz measurement bandwidth. Each subcarrier has, on average, a requirement of -58.7 dBc – 21.1 dB = -79.8 dBc, but the requirement is relaxed to -79.8 dBc + 3 dB = -76.8 dBc (noting that -21.07 dB corresponds to $1/128^{th}$). The under-grant hold bandwidth is 2.35 MHz for this example. When a 100% grant has 65 dBmV transmit power, a grant of 2.4 MHz has 49.1 dBmV power. With a single OFDMA channel and its 100% grant power at 65 dBmV, the spurious emissions requirement with a grant of 2.4 MHz, measured in 25 kHz is 49.1 dBmV – 76.8 dBc = -27.7 dBmV. -76.8 dBc corresponds to -57.1 dBr for this example (since 2.35 MHz/25 kHz is a factor of 94, or 19.7 dB).

Commented [sr8]: May need to rework example with 192Mhz ch width

1.1.2.2.1.2 Adjacent Channel Spurious Emissions

Spurious emissions from a transmitted burst may occur in adjacent spectrum, which could be occupied by OFDMA subcarriers.

Table 4 lists the required adjacent channel spurious emission levels when there is a transmitted burst with bandwidth at the Under-grant Hold Bandwidth. The measurement is performed in an adjacent channel interval of 400 kHz adjacent to the transmitted burst modulation spectrum. For OFDMA transmissions, the measurement is performed starting on an adjacent subcarrier of the transmitted spectrum (both above and below), using the slicer values from a CLT burst receiver or equivalent synchronized to the downstream transmission provided to the CNU.

It should be noted that the measurement bandwidth for Table 4 is less than the measurement bandwidths in Table 3. Thus, comparing the two tables in terms of the specification "dBc" values requires appropriate scaling. In addition, Table 4 provides specification "dBc" only for grants of a specific amount for each row, while Table 3 provides "dBc" specification for grants of all sizes from the Under-grant Hold Bandwidth to 100%.

For transmission bursts with modulation spectrum less than the Under-grant Hold Bandwidth, the spurious power requirement is calculated as above, but increased by $10*\log_{10}$(Under-grant Hold Bandwidth/Grant Bandwidth).

For transmission bursts with modulation spectrum greater than the Under-grant Hold Bandwidth, the spurious power requirement in the adjacent 400 kHz is calculated by converting the requirement to absolute power "dBmV" for a grant of precisely Under-grant Hold Bandwidth from Table 4, and similarly computing the absolute power "dBmV" from Table 3 for a grant equal to:

The Given Grant - The Under-grant Hold Bandwidth.

Then, the absolute power calculated from Table 3 is scaled back in exact proportion of 400 kHz compared to the measurement bandwidth in Table 3. Then the power from Table 4 is added to the scaled apportioned power from Table 3 to produce the requirement for the adjacent 400 kHz measurement with a larger grant than the Under-grant Hold Bandwidth. The requirement for adjacent spurious power in adjacent 400 kHz is:

P1(Grant Bandwidth – Under-grant Hold Bandwidth) = absolute power derived from Table 3 (dBmV)

P2(Under-grant Hold Bandwidth) = absolute power derived from Table 4 (dBmV)

$P1_{scaled}$ = P1 * (0.4 MHz)/(Measurement Bandwidth (MHz) used in Table 3) (dBmV)

$P_{spec\_limit} = P1_{scaled} + P2$ (dBmV)

Within the measurement bandwidth of Table 4, spurious emissions measured for individual subcarriers shall contain no more than +3 dB power larger than the required average power of the spurious emissions in the full measurement bandwidth. Optionally for OFDMA transmissions, bandpass measurements rather than synchronous measurements may be applied.

Table 4 - Adjacent Channel Spurious Emissions Requirements Relative to the Per Channel Transmitted Burst Power Level for Each Channel

100% Grant Spectrum (MHz)	SpurFloor (dBc)	Under-grant Hold #Users	Under-grant Hold Bandwidth (MHz)	Measurement Bandwidth (MHz)	Specification in Adjacent 400 kHz With Grant of Under-grant Hold Bandwidth (dBc)
Up to 64	-60.0	40	100% Grant Spectrum/40	0.4 MHz	Round{10*log10(((10^(SpurFloor/10)) + (10^(-57/10))) x(0.4 MHz/Under-grant Hold Bandwidth)),0.1}
[Ex: 22 MHz]			[0.55 MHz]		[-56.6]
[Ex: 46 MHz]			[1.15 MHz]		[-59.8]
Greater than 64, up to 96	-60.0	40	100% Grant Spectrum/40	0.4 MHz	Round{10*log10(((10^(SpurFloor/10)) + (10^(-57/10))) x(0.4 MHz/Under-grant Hold Bandwidth)),0.1}
[Ex 94 MHz]			[2.35 MHz]		[-62.9]
Greater than 96	max{ -57 + 10*log10(100% Grant Spectrum/192 MHZ), -60} Round nearest 0.1 dB	Floor{ 0.2 + 10^((-44 - SpurFloor)/10) }	100% Grant Spectrum)/Under-grant Hold Number of Users	0.4 MHz	Round{10*log10(((10^(SpurFloor/10)) + (10^(-57/10))) x(0.4 MHz/Under-grant Hold Bandwidth)),0.1}
[Ex: 142 MHz]	[-58.3]	[27]	[5.3]		[-65.8]
[Ex: 190 MHz]	[-57.0]	[20]	[9.5]		[-67.7]
[Ex: 204 MHz]	[-56.8]	[19]	[10.5]		[-68.1]

1.1.2.2.2 Spurious Emissions During Burst On/Off Transients

The CNU shall control spurious emissions, prior to and during ramp-up, during and following ramp-down, and before and after a burst.

The CNU's on/off spurious emissions, such as the change in voltage at the upstream transmitter output, due to enabling or disabling transmission, shall be no more than 50 mV.

The CNU's voltage step shall be dissipated no faster than 4 µs of constant slewing. This requirement applies when the CNU is transmitting at +55 dBmV or more per channel on any channel.

At backed-off transmit levels, the CNU's maximum change in voltage shall decrease by a factor of 2 for each 6 dB decrease of power level in the highest power active channel, from +55 dBmV per channel, down to a maximum change of 3.5 mV at 31 dBmV per channel and below. This requirement does not apply to CNU power-on and power-off transients.

1.1.2.2.3 MER Requirements

Transmit modulation error ratio (TxMER or just MER) measures the cluster variance caused by the CNU during upstream transmission due to transmitter imperfections. The terms "equalized MER" and "unequalized MER" refer to a measurement with linear distortions equalized or not equalized, respectively, by the CLT receive equalizer. The requirements in this section refer only to unequalized MER, as described for each requirement. MER is measured on each modulated data subcarrier and non-boosted pilot (MER is computed based on the unboosted pilot power) in a resource block of a granted burst and averaged for all the subcarriers in each resource block. MER includes the effects of Inter-Carrier Interference (ICI), spurious emissions, phase noise, noise, distortion, and all other undesired transmitter degradations with an exception for a select number of discrete spurs impacting a select number of subcarriers. MER requirements are measured with a calibrated test instrument that synchronizes to the OFDMA signal, applies a receive equalizer in the test instrument that removes MER contributions from nominal channel imperfections related to the measurement equipment, and calculates the value. The equalizer in the test instrument is calculated, applied and frozen for the CNU testing. Receiver equalization of CLT linear distortion is not provided; hence this is considered to be a measurement of unequalized MER, even though the test equipment contains a fixed equalizer setting.

1.1.2.2.3.1 Definitions

MER is defined as follows for OFDMA. The transmitted RF waveform at the F connector of the CNU (after appropriate down conversion) is filtered, converted to baseband, sampled, and processed using standard OFDMA receiver methods, with the exception that receiver equalization is not provided. The processed values are used in the following formula. No external noise (AWGN) is added to the signal.

The carrier frequency offset, carrier amplitude, carrier phase offset, and timing will be adjusted during each burst to maximize MER as follows:

- One carrier amplitude adjustment common for all subcarriers and OFDMA symbols in burst.
- One carrier frequency offset common for all subcarriers resulting in phase offset ramping across OFDMA symbols in bursts.
- One timing adjustment resulting in phase ramp across subcarriers.
- One carrier phase offset common to all subcarriers per OFDMA symbol in addition to the phase ramp.

MER_i is computed as an average of all the subcarriers in a mini-slot for the i^{th} resource block in the OFDMA grant:

$$\mathrm{MER}_i\,(\mathrm{dB}) = 10 \cdot \log_{10}\left(\frac{E_{avg}}{\frac{1}{N}\sum_{j=1}^{N}\left(\frac{1}{M}\sum_{k=1}^{M}\left|e_{j,k}\right|^2\right)}\right)$$

where:

E_{avg} is the average constellation energy for equally likely symbols,

M is the number of symbols averaged,

N is the number of subcarriers in a mini-slot,

$e_{j,k}$ is the error vector from the jth subcarrier in the resource block and kth received symbol to the ideal transmitted QAM symbol of the appropriate modulation order.

A sufficient number of OFDMA symbols shall be included in the time average so that the measurement uncertainty from the number of symbols is less than other limitations of the test equipment.

MER with a 100% grant is defined as the condition when all OFDMA resource blocks in the transmit channel set are granted to the CNU.

MER with a 5% grant is defined as the condition when less than or equal to 5% of the available OFDMA resource blocks have been granted to the CNU.

1.1.2.2.3.2 Upstream MER Requirements

Unless otherwise stated, the CNU shall meet or exceed the following MER limits over the full transmit power range, all modulation orders, all grant configurations and over the full upstream frequency range.

The following flat channel measurements with no tilt (Table 5) are made after the pre-equalizer coefficients have been set to their optimum values. The receiver uses best effort synchronization to optimize the MER measurement.

Table 5 - Upstream MER Requirements (with pre-equalization)

Parameter	Value
MER (100% grant)	Each resource block MER ≥ 44 dB (Notes 1,2)
MER (5% grant)	Each resource block MER ≥ 50 dB (Notes 1,2)
Pre-equalizer constraints	Coefficients set to their optimum values

Table Notes:

1. Up to 5 subcarriers within the entire upstream bandwidth with discrete spurs may be excluded from the MER calculation if they fall within transmitted resource blocks. These 5 spurs are the same spurs that may be excluded for spurious emissions and not an additional or different set.
2. This value is to be met when $P_{load} = P_{load\_min\_set}$.

The following flat channel measurements (Table 6) are made with the pre-equalizer coefficients set to unity and no tilt and the receiver implementing best effort synchronization. For this measurement, the receiver may also apply partial equalization. The partial equalizer must not correct for the portion of the CNU's time-domain impulse response greater than 200 ns or frequency-domain amplitude response greater than +1 dB or less than -3dB from the average amplitude.

Table 6 - Upstream MER Requirements (no pre-equalization)

Parameter	Value
MER (100% grant)	Each resource block MER ≥ 40 dB (Notes 1,2)
MER (5% grant)	Each resource block MER ≥ 40 dB (Notes 1,2)
Pre-equalizer constraints	Pre-equalization not used

Table Notes:

1. Up to 5 subcarriers within the entire upstream bandwidth with discrete spurs may be excluded from the MER calculation if they fall within transmitted resource blocks. These 5 spurs are the same spurs that may be excluded for spurious emissions and not an additional or different set.
2. This value is to be met when $P_{load} = P_{load\_min\_set}$.

1.1.3 Upstream Pre-Equalization

A CNU shall implement a linear pre-equalizer with a single complex coefficient per subcarrier.

The CLT shall direct a CNU to pre-equalize its upstream transmission using CLT-assigned pre-equalization coefficients as a step in the ranging process.

The CLT uses the CNU's probe signal for pre-equalizer coefficient updates. The probes are described in Section TBD.

The CLT may specify the subcarriers (i.e., frequency range) over which coefficient updates is to be performed.

The CLT shall compensate for phase offset and phase slope in the coefficients if the probes are used for timing offset measurements when calculating the pre-equalizer coefficient. Phase offset is compensated by averaging phase over all subcarriers and subtracting it. The phase slope is compensated by subtracting the phase linear trend over all subcarriers, after unwrapping 2*pi jumps.

The CLT shall have the ability to scale the transmission power per subcarrier when configuring the probe transmission using the range response message.

Commented [JS9]: This exists for epoc but the message name has not been fully agreed to

The CNU shall scale its transmission power per channel when transmitting the probe as required by the CLT in the range response message. The range of the scaling values is: 0 to [10log(skip+1)] dB. Skip is defined in Section **Error! Reference source not found.**.

The CNU shall use a default value of 1+j0 for all pre-equalizer coefficients. The PLC message carries the pre-equalization information, and may instruct the CNU to either multiply the equalizer coefficients with the existing coefficients (as described below), or to load them directly.

The CNU shall multiply the coefficients sent by the CLT in the range response message with the existing coefficients, to get the new coefficients, when instructed by the CLT, as follows:

Ck(i+1)=Ck(i) * Ak(i)

where: Ck(i) is the pre-equalizer coefficient of the k-th subcarrier, as used in the last probe transmission, Ck(i+1) is the updated pre-equalizer coefficient of the k-th subcarrier and Ak(i) is the update coefficient information received from the CLT as a response to the corresponding probe transmission. "*" indicates a complex multiplication.

The CNU shall normalize the new calculated coefficients as follows:

mean (abs (Ck)^2) = 1 (summation is over all k)

The CNU shall implement per subcarrier pre-equalization that will enable it to meet the performance requirements specified in Section 1.1.1.

The CNU shall apply pre-equalization for all its data transmissions.

The CNU shall be able to transmit a probe signal with or without pre-equalization (all coefficients are 1+j*0) when measuring upstream frequency response.

1.1.4 CLT Receiver Input Power Requirements

The CLT Upstream Demodulator shall operate with an average input signal level, including ingress and noise to the upstream demodulator, up to 31 dBmV.

The CLT shall be settable according to Table 7 for intended received power normalized to 6.4 MHz of bandwidth.

The CLT Upstream demodulator shall operate within its defined performance specifications with received bursts within the ranges defined in Table 7 of the set power.

Commented [sr10]: Where is the PER performance requirement for the CLT

Table 7 - Upstream Channel Demodulator Input Power Characteristics

Modulation	Minimum Set Point	Maximum Set Point	Range
QPSK	-4 dBmV	10 dBmV	-9 / +3
8-QAM	-4 dBmV	10 dBmV	-9 / +3
16-QAM	-4 dBmV	10 dBmV	-9 / +3
32-QAM	-4 dBmV	10 dBmV	-9 / +3
64-QAM	-4 dBmV	10 dBmV	-9 / +3
128-QAM	0 dBmV	10 dBmV	-9 / +3
256-QAM	0 dBmV	10 dBmV	-9 / +3
512-QAM	0 dBmV	10 dBmV	-3 / +3
1024-QAM	0 dBmV	10 dBmV	-3 / +3
2048-QAM	7 dBmV	10 dBmV	-3 / +3
4096-QAM	10 dBmV	10 dBmV	-3 / +3