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Interface Practices Subcommittee

AMERICAN NATIONAL STANDARD

ANSI/SCTE 279 2022

1.8 GHz Broadband Radio Frequency Hardline Amplifiers for Cable Systems

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Document Type: Specification

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☐ Test or Measurement	☐ Checklist	☐ Facility
☐ Architecture or Framework	☐ Metric	☒ Access Network
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1. Introduction

1.1. Executive Summary

The purpose of this document is to identify common characteristics of hardline amplifiers to be used in 1.8 GHz broadband hybrid fiber coax (HFC) networks.

1.2. Scope

This document recommends mechanical, environmental, and electrical standards for broadband radio frequency (RF) amplifiers that support DOCSIS® 4.0 frequency division duplex (FDD) capabilities, with downstream operation at frequencies up to 1794 MHz and upstream operation at frequencies up to 684 MHz.

Products covered by this document include the high gain single and multiport amplifiers required to support drop-in upgrades at legacy amplifier locations, as well as the lower gain booster amplifiers that may be required between amplifier locations with very long spacings. The devices are intended for an outdoor rated environment.

This document does not cover amplifiers with echo cancellation (required to support full duplex (FDX)), amplifiers used in nodes (commonly referred to as launch amplifiers), or other variations of low gain amplifiers that may be required for a full distributed gain amplifier (DGA) architecture.

1.3. Benefits

Broadband RF amplifiers are an integral part of an HFC network and enable signals to be carried greater distances along coax with minimal degradation in signal integrity. Identifying key characteristics of the amplifiers required to support DOCSIS 4.0 FDD will assist manufacturers by defining their requirements, which will benefit the industry by increasing the capacity and extending the useful life of the HFC network.

1.4. Intended Audience

Cable, fiber and telecommunications designers, operators, and engineers.

1.5. Areas for Further Investigation or to be Added in Future Versions

Consideration may be given to adding launch amplifiers used in nodes and additional varieties of lower gain amplifiers required for full DGA architectures that may support downstream frequencies up to 3 GHz.

2. Normative References

The following documents contain provisions which, through reference in this text, constitute provisions of this document. The editions indicated were valid at the time of subcommittee approval. All documents are subject to revision and, while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

[SCTE 43]	ANSI/SCTE 43 2015 (R2021), Digital Video Systems Characteristics Standard for Cable Television
[SCTE 45]	ANSI/SCTE 45 2017, Test Method for Group Delay
[SCTE 46]	ANSI/SCTE 46 2014 (R2021), Test Method for AC to DC Outdoor Power Supplies
[SCTE 48-1]	ANSI/SCTE 48-1 2021, Test Method for Measuring Shielding Effectiveness of Passive and Active Devices Using a GTEM Cell
[SCTE 62]	ANSI/SCTE 62 2018, Measurement Procedure for Noise Figure
[SCTE 81]	ANSI/SCTE 81 2018, Surge Withstand Test Procedure
[SCTE 91]	ANSI/SCTE 91 2015, Specification for 5/8-24 RF & AC Equipment Port, Female
[SCTE 143]	ANSI/SCTE 143 2018, Test Method for Salt Spray
[SCTE 144]	ANSI/SCTE 144 2017, Test Procedure for Measuring Transmission and Reflection
[SCTE 186]	ANSI/SCTE 186 2021, Product Physical, Environmental, Electrical, Sustainability, and Quality Requirements for Cable Telecommunications

2.2. Standards from Other Organizations

[ASTM]	ASTM G 154, Standard Practice For Operating Fluorescent Light Apparatus For UV Exposure Of Nonmetallic Materials
[GR-2873]	GR-2873, July 1995, Generic Requirements for Coaxial Drop Passive Elements
[IEC 60529]	IEC 60529, 2001; Degrees Of Protection Provided By Enclosures (IP Code)
[IEC 61000]	IEC/EN 61000-4-2 ESD, Lightning Testing and Surge Immunity Testing
[IEEE C62.41]	IEEE C62.41, IEEE Recommended Practice For Surge Voltages In Low-Voltage AC Power Circuits
[MIL 889]	MIL-STD-889, July 21, 2021, Galvanic Compatibility Of Electrically Conductive Materials
[NADCA]	NADCA G-6-6-15, NADCA Product Specification Standards for Die Casting

2.3. Other Published Materials

No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

[SCTE 17] ANSI/SCTE 17 2018, Test Procedure for Carrier to Noise (C/N, CCN, CIN, CTN)

3.2. Standards from Other Organizations

No informative references are applicable.

3.3. Other Published Materials

No informative references are applicable.

4. Compliance Notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
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Deprecated	Use is permissible for legacy purposes only. Deprecated features *may* be removed from future versions of this document. Implementations *should* avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

AC	alternating current
AGC	automatic gain control
ALSC	automatic level/slope control
CATV	community antenna television
CCN	carrier to composite noise
CIN	carrier to intermodulation noise
CTN	carrier to thermal noise
CW	continuous wave
dB	decibel
dBmV	decibels relative to 1 millivolt
DC	direct current
DGA	distributed gain amplifier
DOCSIS	Data Over Cable Service Interface Specification
ES	extended spectrum

ESD	electrostatic discharge
FDD	frequency division duplex
F_{DS-LBE}	frequency, downstream lower band edge
F_{US-LBE}	frequency, upstream lower band edge
F_{US-UBE}	frequency, upstream upper band edge
FDX	full duplex
FTEC	fast-transfer electronic-crowbar surge protector
GHz	gigahertz
HALT	highly accelerated life testing
HFC	hybrid fiber coax
MHz	megahertz
ns	nanosecond
OFDM	orthogonal frequency-division multiplexing
psi	pounds per square inch
RF	radio frequency
RMS	root mean square
RoHS	restriction of hazardous substances
SC-QAM	single-carrier quadrature amplitude modulation
SCTE	Society of Cable Telecommunications Engineers
TCP	total composite power
UHS	ultra-high split
UI	user interface
UVB	ultraviolet B
USB	universal serial bus

5.2. Definitions

Definitions of terms used in this document are provided in this section. Defined terms that have specific meanings are capitalized. When the capitalized term is used in this document, the term has the specific meaning as defined in this section.

downstream	The direction of signal transmission from the headend, hub site, or optical node to the subscriber. Also called forward.
upstream	The direction of signal transmission from the subscriber to the headend, hub site, or node. Also called return or reverse.
frequency division duplex (FDD)	This describes a bi-directional broadband RF communications system where the downstream and upstream each have their own dedicated, non-overlapping frequency spectrums.

6. Amplifier Types

The amplifier types listed below are the types that apply for this document.

6.1. Multiport Amplifier

A multiport amplifier (also known as system amplifier, bridger, or trunk/bridger) is a high gain amplifier that has at least two RF output ports driven by independent power amplifiers. The housing is intended for outdoor use and can be strand or pedestal mounted. The amplifier is normally alternating current (AC) line powered.

6.2. Line Extender Amplifier

A line extender is a high gain amplifier that has one or two RF output ports driven by a single power amplifier. The housing is intended for outdoor use and can be strand or pedestal mounted. The amplifier is normally AC line powered.

6.3. Booster Amplifier

A booster amplifier is a single RF output amplifier, smaller in size than a line extender with lower power consumption and lower gain. The booster amplifier is intended to boost the signal between legacy high gain amplifier locations for scenarios where it is needed due to very long amplifier spacings. The housing is intended for outdoor use and can be strand, pedestal, or cabinet mounted. The amplifier is normally AC line powered.

6.4. Compact Amplifier

A compact amplifier has one, two, or three RF output ports in a ports-down configuration with high gain. The ports-down housing type is intended for outdoor use and can be cabinet mounted. The amplifier is normally AC line powered and/or mains powered. The compact amplifier form factor can include bridger, trunk/bridger or line extender configurations.

7. Electrical – for High Gain Amplifiers

7.1. Upstream / Downstream Frequency Splits & Diplexers

This section pertains to the upstream / downstream frequency split options and associated diplex filters and other low-pass/high-pass filters.

7.1.1. Upstream / Downstream Frequency Split Options

The upstream / downstream frequency split options and their associated requirements are listed in Table 1. The available frequency split options ***shall*** be listed in published specifications.

Table 1 – Upstream / Downstream Frequency Split Options

Split Name	Requirement as an Option for the Amplifier	Upstream Upper Band Edge Frequency ($F_{US\text{-}UBE}$)	Downstream Lower Band Edge Frequency ($F_{DS\text{-}LBE}$)	Notes
Sub-split	*should* be supported	42 MHz	54 MHz	Note 1, 2
Euro-split	*should* be supported	65 MHz	85 MHz	Note 1, 2
Mid-split	***shall*** be supported	85 MHz	108 MHz	Note 1
High-split	***shall*** be supported	204 MHz	258 MHz	Note 1
UHS-300	*may* be supported	300 MHz	372 MHz	Note 1
UHS-396	***shall*** be supported	396 MHz	492 MHz	Note 1
UHS-492	***shall*** be supported	492 MHz	606 MHz	Note 1
UHS-684	*should* be supported	684 MHz	834 MHz	Note 1

Notes:

1. Downstream *may* start lower in frequency
2. This frequency split is required to support a transition from these existing legacy splits to the higher frequency splits that *may* be activated later (after initial installation).

7.1.2. Diplex Filters

This section pertains to the diplex filters and associated low-pass/high-pass filters required to keep the downstream and upstream RF paths isolated in in a high gain FDD amplifier.

Diplex filters and any associated low-pass/high-pass filters ***shall*** be modular plug-in type assemblies.

Diplex filters and any associated low-pass/high-pass filters ***shall*** be field upgradeable, meaning that the plug-in filters can be changed out in the field without the need for any retuning or verification testing on a bench.

Diplex filters and any associated low-pass/high-pass filters *may* be remotely switchable. For switchable filters, at least a pair of filter sets (each associated with a different upstream/downstream frequency split) would be able to be plugged into the amplifier for all applicable input/output RF ports. One frequency split would be selected as the starting split, and the alternate split with increased upstream spectrum could be remotely switched into operation in the future.

7.2. Downstream RF Parameters

This section pertains to the downstream (forward path) RF parameters associated with the various high gain amplifier types. Unless otherwise noted, all of the following downstream RF parameters ***shall*** apply for the full downstream passband.

7.2.1. Passband

Downstream passband ***shall*** be 108 to 1794 MHz and *should* be 54 or 85 to 1794 MHz to support the upstream/downstream frequency splits in section 7.1.1.

Downstream passband ***shall*** be specified in published specifications.

7.2.2. Operational Gain

Downstream operational gain is the station gain at highest rated frequency from downstream input to downstream output, with all other ports terminated. Where applicable, it includes a sufficient back-off from full gain to accommodate the gain reserves required to accommodate AGC level control.

The amount of downstream operational gain is not specified (left to manufacturer discretion). However, at the time of publication it was anticipated that the operational gain at 1794 MHz for the highest gain amplifiers might need to be in the 48 to 50 dB range to meet industry drop-in architecture requirements while minimizing amplifier re-spacing and the need for booster amplifiers.

The minimum operational gain at room temperature at the highest rated downstream frequency for each operating mode supported ***shall*** be specified in published specifications.

The specification ***shall*** note that the operational gain is for the station and is specified with 0 dB input equalization and 0 dB input attenuation settings.

Operational gain ***shall*** be measured in accordance with [SCTE 144].

7.2.3. Internal Slope

Downstream internal slope refers to the dB difference in amplifier gain at the highest and lowest frequencies in the passband, with 0 dB input equalization. Internal slope is typically established via interstage equalization. In amplifiers this has normally been a “cable” type of equalization (having opposite frequency dependent loss characteristics than coaxial cable), as opposed to a straight-line slope due to “linear” equalization.

The range of downstream internal slope adjustment is not specified (left to manufacturer discretion).

The downstream internal slope ***shall*** be adjustable in no greater than 0.5 dB increments.

The range of internal slope adjustment and the type of equalization used to establish it ***shall*** be specified in published specifications.

Internal slope ***shall*** be measured in accordance with [SCTE 144].

7.2.4. Frequency Response

The downstream frequency response (also referred to as flatness) measured from the input port to any output port ***shall not*** exceed ±0.5 dB from downstream lower band edge to 1218 MHz relative to the internal slope (tilt) of the amplifier.

The downstream frequency response (also referred to as flatness) measured from the input port to any output port ***shall not*** exceed ±0.75 dB from downstream lower band edge to 1794 MHz relative to the internal slope (tilt) of the amplifier.

Additionally, the downstream frequency response from $F_{DS\text{-}LBE}$ to $F_{DS\text{-}LBE}$ plus 50 MHz, and from 1744 MHz to 1794 MHz ***shall not*** exceed ±0.3 dB.

Downstream frequency response at room temperature ***shall*** be specified in published specifications.

Frequency response ***shall*** be measured in accordance with [SCTE 144].

7.2.5. Noise Figure

A maximum downstream noise figure value is not specified (left to manufacturer discretion) with the understanding that lower noise figures are beneficial.

Typical noise figure at room, hot, and cold temperature ***shall*** be specified in published specifications.

The specification ***shall*** note that the noise figure is for the station (inclusive of input losses, including diplex filters) and is specified with 0 dB input equalization and 0 dB input attenuation settings.

Noise figure ***shall*** be measured in accordance with [SCTE 62].

7.2.6. Group Delay Variation

Group delay variation is the difference between the maximum and minimum group delay measured between two different frequencies.

The downstream group delay variation is not specified (left to manufacturer discretion).

Typical group delay variation at room temperature across each 6 MHz and/or 8 MHz frequency range listed below ***shall*** be specified in published specifications for each upstream/downstream frequency split option.

- $F_{DS\text{-}LBE}$ to $F_{DS\text{-}LBE}$ +6 MHz
- $F_{DS\text{-}LBE}$ +6 MHz to $F_{DS\text{-}LBE}$ +12 MHz
- $F_{DS\text{-}LBE}$ +12 MHz to $F_{DS\text{-}LBE}$ +18 MHz

- $F_{DS\text{-}LBE}$ to $F_{DS\text{-}LBE}$ +8 MHz
- $F_{DS\text{-}LBE}$ +8 MHz to $F_{DS\text{-}LBE}$ +16 MHz
- $F_{DS\text{-}LBE}$ +16 MHz to $F_{DS\text{-}LBE}$ +24 MHz

Group delay ***shall*** be measured in accordance with [SCTE 45].

7.2.7. RF Test Points

Each downstream RF output port ***shall*** have a directional RF test point.

The downstream RF input port ***shall*** have an RF test point which *may* be directional.

All downstream RF test points ***shall*** be -20 dB relative to the associated input/output port.

The downstream RF output test points *should* be accurate across the downstream passband to -20 dB +/- 0.5 dB and ***shall*** be accurate to -20 dB +/- 1.0 dB.

All downstream RF output port test points ***shall*** be on the common path of the diplex filter associated with the port to allow the test point to also be used for upstream injection. The upstream injection functionality allows this test point to be used with test equipment requiring two-way communications.

The RF test point type, loss relative to associated input/output port, and accuracy at room temperature ***shall*** be specified in published specifications.

The measurements ***shall*** be in accordance with [SCTE 144].

7.2.8. Noise and Distortion Performance

7.2.8.1. Carrier to Noise and Intermodulation Noise

The high gain FDD amplifiers defined in this document will amplify wide-band downstream RF signals and generate intermodulation distortion due to non-linearities at higher RF output power levels. A common approach to specifying the intermodulation distortion performance is needed to allow direct performance comparisons.

At select frequencies the ratio of RF output power to the following types of noise and noise-like intermodulation products ***shall*** be specified in published specifications. Refer to [SCTE 17] for related definitions and calculations.

- CTN: Carrier to Thermal Noise – this can be measured or can be calculated based on measured amplifier RF input power, measured noise figure, and the thermal noise in 75 ohms for a given bandwidth (-57.4 dBmV for 6 MHz) at room temperature.

- CCN: Carrier to Composite Noise – this has to be measured. The “composite noise” component is the summation of thermal noise and the intermodulation noise (i.e. noise-like intermodulation distortion products) produced by the amplifier.
- CIN: Carrier to Intermodulation Noise – this has to be calculated (using 10LOG power subtraction of CCN minus CTN).

The ratios ***shall*** be based on the *actual* RF signal output power, with the assumption that the RF signals used are digital in nature. The fact that the ratios are associated with actual RF signal power (as opposed to historically used “analog” or “analog equivalent” carrier levels) ***shall*** be noted.

The ratios ***shall*** be based on average carrier power and noise power measurements, both made with (or corrected to) common bandwidths of 6 MHz.

The specified performance ***shall*** be associated with typical performance at room temperature, with a notation explaining the improvement or reduction relative to room temperature performance that is expected at hot and cold temperature extremes (if any).

The typical room temperature performance ***shall*** be depicted in graphs associated with each RF output profile in Table 2, across a 9 dB range of total composite output power, in 1 dB increments, with the highest output power value being associated with a CCN not greater than 30 dB.

In the graphs, the typical performance may be depicted for each test frequency, or it may be depicted for the worst-case frequency in the legacy spectrum and the worst-case frequency in the extended spectrum. The test frequency ranges within the legacy spectrum and the extended spectrum are defined in Table 3. See Figure 1 for a graph example.

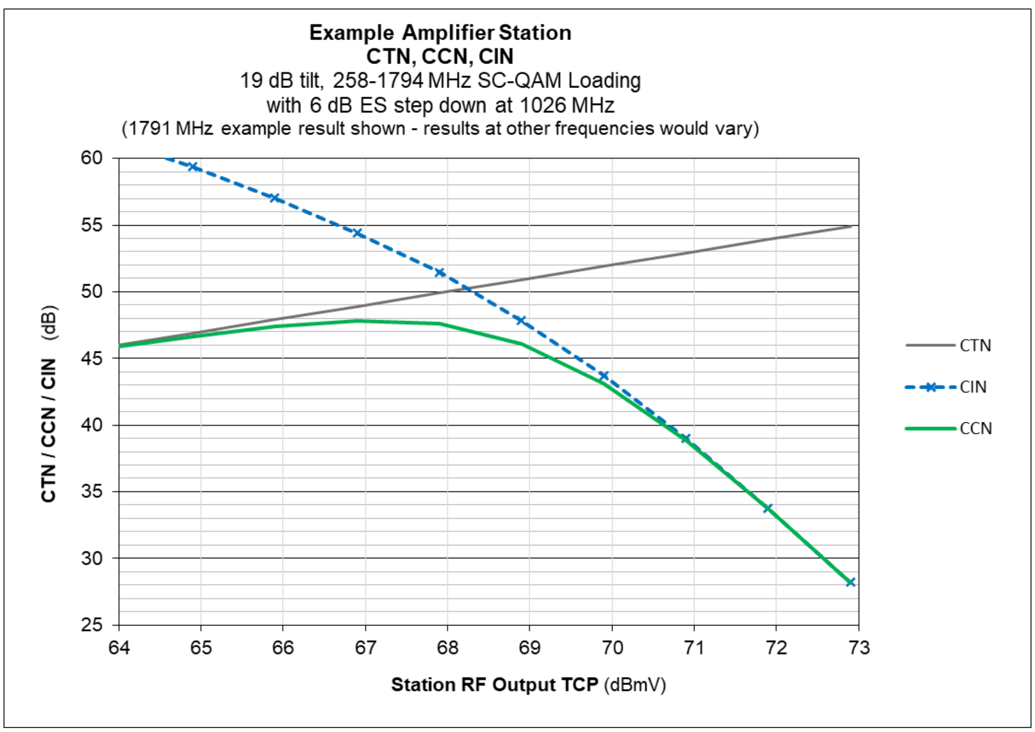

Figure 1 – Example CTN / CCN / CIN Performance Graph

Information associated with each RF output profile used for such characterization – including the occupied spectrum, the amount and start frequency of the extended spectrum step-down (if used), and the total output tilt (disregarding step-down), ***shall*** be provided.

For each RF output profile used the RF output power levels in a 6 MHz bandwidth for each test frequency ***shall*** be provided for at least one of the output TCP values shown in the associated graph, allowing users to calculate the RF output power levels associated with any of the other TCP values via simple addition or subtraction.

7.2.8.2. Bit Error Ratio

The high gain FDD amplifiers defined in this document will amplify wide-band downstream RF signals and *may* introduce SC-QAM$_{256}$ bit errors due to non-linearities at higher RF output power levels. A common approach to specifying the BER performance is needed to allow direct performance comparisons.

The SC-QAM$_{256}$ pre-FEC BER ***shall*** also be characterized for each RF output profile and output TCP increment, using the same test frequencies at or below 1 GHz that are used for the published CTN/CCN/CIN performance graphs defined in section 7.2.8.1.

The SC-QAM$_{256}$ pre-FEC BER performance ***shall*** be associated with typical performance at room temperature, with a notation explaining the improvement or reduction relative to room temperature performance that is expected at hot and cold temperature extremes (if any)

The BER performance ***shall*** be depicted in graphs, preferably on the same graphs that shows the associated CTN/CCN/CIN, but with the BER referenced to a secondary y axis. In the graphs, the typical performance may be depicted for each test frequency in the legacy spectrum, or it may be depicted for the worst-case frequency in the legacy spectrum. The test frequency ranges within the legacy spectrum are defined in Table 3.

The y axis for the BER performance graph ***shall*** span from 1E-10 to 1E-2.

7.2.8.3. Common RF Output Profiles for Intermodulation Distortion and BER Characterization

Two common RF output profiles ***shall*** be used for the published performance requirements outlined in sections 7.2.8.1 and 7.2.8.2. Information associated with each of the RF output profiles is listed in Table 2.

Table 2 – Common RF Output Profiles for Characterization

<table>
<tr><th rowspan="3">RF Profile</th><th colspan="3">Legacy Spectrum</th><th colspan="4">Extended Spectrum (ES)</th><th rowspan="3">Total RF Output Tilt (linear)</th></tr>
<tr><th rowspan="2">Signal Type</th><th colspan="2">Frequency (MHz)</th><th rowspan="2">Signal Type</th><th colspan="2">Frequency (MHz)</th><th rowspan="2">ES Step Down</th></tr>
<tr><th>Start</th><th>Stop</th><th>Start</th><th>Stop</th></tr>
<tr><td>1</td><td>SC-QAM$_{256}$</td><td>258</td><td>1026</td><td>SC-QAM$_{256}$</td><td>1026</td><td>1794</td><td>0 dB</td><td>19 dB</td></tr>
<tr><td>2</td><td>SC-QAM$_{256}$</td><td>258</td><td>1026</td><td>SC-QAM$_{256}$</td><td>1026</td><td>1794</td><td>6 dB</td><td>19 dB</td></tr>
</table>

Table 2 Notes:

The legacy and extended spectrum frequency bands shown in the table are expected to be filled contiguously between the start and stop frequencies with the signal types shown.

While in practice the extended spectrum will be filled with wideband OFDM RF signals, SC-QAM RF signals can replicate the OFDM signals from an RF power loading perspective for amplifier performance testing.

The total RF output tilt is across the band from 258 to 1794 MHz and equates to a linear reference tilt line which the ES step down in dB is referenced to. It might be considered the "virtual" output tilt.

7.2.8.4. Common RF Test Frequencies for Intermodulation Distortion and BER Characterization

Common RF test frequency ranges ***shall*** be used for the published performance requirements outlined in sections 7.2.8.1 and 7.2.8.2.

Table 3 – Common RF Test Frequency Ranges

Test Frequency Range	Width of Range	Range Description
261 to 279 MHz	18 MHz	Low frequency – legacy band
603 to 627 MHz	24 MHz	Mid frequency – legacy band
1029 to 1047 MHz	18 MHz	Low frequency – extended spectrum band
1389 to 1413 MHz	24 MHz	Mid frequency – extended spectrum band
1773 to 1791 MHz	18 MHz	High frequency – extended spectrum band

For each range description in Table 3, a test channel with center frequency falling within the associated test frequency range ***shall*** be used for determining the published performance specifications.

7.3. Upstream RF Parameters

This section pertains to the upstream (return path) RF parameters associated with the various amplifier types. Unless otherwise noted all the following upstream RF parameters ***shall*** apply for the full upstream passband.

7.3.1. Passband

Upstream passband *should* be 5 to 684 MHz and ***shall*** be at least 10 to 492 MHz and ***shall*** support the frequency splits as called out in section 7.1.1. If the manufacturer specifies an upstream low frequency band edge of 10 MHz, upon request they ***shall*** provide performance information in the 5 to 10 MHz region.

Upstream passband ***shall*** be specified in published specifications.

7.3.2. Operational Gain

Upstream operational gain is the station gain at highest rated frequency from upstream input to upstream output, with all other ports terminated. Where applicable, it ***shall*** include a sufficient back-off from full gain to accommodate the gain reserves required to accommodate quasi-AGC and/or thermal level control.

The amount of upstream operational gain is not specified (left to manufacturer discretion). However, at the time of publication it was anticipated that the operational gain at 684 MHz for the high gain amplifiers *may* need to be in the 30-32 dB range to meet industry drop-in architecture requirements while maintaining sufficient dynamic range performance.

The minimum operational gain at room temperature at the highest rated upstream frequency for each frequency split and operational mode ***shall*** be specified in published specifications.

The specification ***shall*** note that the operational gain is for the station (inclusive of input losses) and is specified with 0 dB input and 0 dB output attenuation settings.

Operational gain ***shall*** be measured in accordance with [SCTE 144].

7.3.3. Internal Slope

Upstream internal slope refers to the dB difference in amplifier gain at the highest and lowest frequencies in the passband. While historically the upstream path in amplifiers has not made use of deliberate internal slope, in the much wider upstream spectrums used for DOCSIS 4.0 FDD it *may* provide performance benefits. If implemented for upstream it is anticipated that the internal slope would be established via interstage equalization using “cable” type equalization.

The range of upstream internal slope adjustment is not specified (left to manufacturer discretion).

The upstream internal slope, if adjustable, ***shall*** be adjustable in no greater than 0.5 dB increments.

The range of internal slope adjustment (if adjustable), and the type of equalization used to establish it ***shall*** be specified in published specifications.

Internal slope ***shall*** be measured in accordance with [SCTE 144].

7.3.4. Frequency Response

The upstream frequency response (also referred to as flatness) measured from the input port to any output port ***shall not*** exceed ±1.0 dB relative to the internal slope of the amplifier.

Upstream frequency response at room temperature ***shall*** be specified in published specifications.

Frequency response ***shall*** be measured in accordance with [SCTE 144].

7.3.5. Noise Figure

A maximum upstream noise figure value is not specified (left to manufacturer discretion) with the understanding that lower noise figures are beneficial.

The typical noise figure at room, hot, and cold temperature ***shall*** be specified in published specifications.

The specification ***shall*** note that the noise figure is for the station (inclusive of input losses) and is specified with 0 dB upstream input attenuation.

Noise figure ***shall*** be measured in accordance with [SCTE 62].

7.3.6. Group Delay Variation

Group delay variation is the difference between the maximum and minimum group delay measured between two different frequencies.

The upstream group delay variation is not specified (left to manufacturer discretion).

Typical group delay variation at room temperature across each frequency range listed below ***shall*** be specified in published specifications for each upstream/downstream frequency split option.

- F_{US-LBE} to F_{US-LBE} +3.2 MHz
- F_{US-LBE} +3.2 MHz to F_{US-LBE} +6.4 MHz
- F_{US-LBE} +6.4 MHz to F_{US-LBE} +9.6 MHz
- F_{US-LBE} +9.6 MHz to F_{US-LBE} +12.8 MHz

- F_{US-UBE} to F_{US-UBE} -6.4 MHz
- F_{US-UBE} -6.4 MHz to F_{US-UBE} -12.8 MHz

Group delay ***shall*** be measured in accordance with [SCTE 45].

7.3.7. RF Test Points

Each upstream RF input port ***shall*** have a directional RF input test point.

The upstream RF output port ***shall*** have an upstream RF output test point which *may* be directional.

Each upstream input port ***shall*** also have an upstream RF injection test point on the common path of the diplex filter associated with the port. This upstream injection test point also serves as the downstream RF output test point allowing it to be used with test equipment requiring two-way communications.

All upstream RF test points ***shall*** be -20 dB relative to the reference point.

All upstream RF test points ***shall*** be accurate to -20 dB +/- 1 dB.

The RF test point type, loss relative to associated input/output port, and accuracy at room temperature ***shall*** be specified in published specifications.

The test point related measurements ***shall*** be measured in accordance with [SCTE 144].

7.3.8. Noise and Distortion Performance

The high gain FDD amplifiers defined in this document will amplify wide-band upstream RF signals and generate intermodulation distortion due to non-linearities at higher RF output power levels. A common approach to specifying the intermodulation distortion performance is needed to allow direct performance comparisons.

At select frequencies the ratio of RF output power to the following types of noise and noise-like intermodulation products ***shall*** be specified in published specifications. Refer to [SCTE 17] for related definitions and calculations.

- CTN: Carrier to Thermal Noise – this can be measured or can be calculated based on measured amplifier RF input power, measured noise figure, and the thermal noise in 75 ohms for a given bandwidth (-57.4 dBmV for 6 MHz) at room temperature.
- CCN: Carrier to Composite Noise – this has to be measured. The "composite noise" component is the summation of thermal noise and the intermodulation noise (i.e. noise-like intermodulation distortion products) produced by the amplifier.
- CIN: Carrier to Intermodulation Noise – this has to be calculated (using 10LOG power subtraction of CCN minus CTN).

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The ratios ***shall*** be based on average carrier power and noise power measurements, both made with (or corrected to) common bandwidths of 6 MHz.

The specified performance ***shall*** be associated with typical performance at room temperature, with a notation explaining the improvement or reduction relative to room temperature performance that is expected at hot and cold temperature extremes (if any).

The typical room temperature performance ***shall*** be depicted in a dynamic range graph for each upstream bandwidth associated with a supported frequency split, with the X axis representing the station upstream input power in dBmV/6 MHz.

The characterization testing for the graphed performance ***shall*** be conducted:

- with flat upstream RF inputs to the amplifier station (no tilt).
- with a fully loaded US spectrum (from 10 MHz to US upper band edge), consisting of either 6 MHz SC-QAM signals or band-pass filtered white noise (such as that commonly used for NPR testing).
- with RF input power increased in 2 dB increments across the range of input powers associated with a minimum CCN of 35 dB at both high and low RF input powers.

The graphed performance values specified ***shall*** be associated with the worst-case CCN performance in the upstream spectrum, as measured in the applicable test frequency ranges shown in Table 4.

Table 4 – Common Upstream Amplifier Test Frequency Ranges for High Gain Amplifier

Test Frequency Ranges
39 to 57 MHz
261 to 279 MHz
483 to 501 MHz

7.4. Downstream Set-up and Control

This section describes functions and features associated with the initial downstream set-up/configuration of the amplifier or with the downstream control of the amplifier during operation.

7.4.1. Electronically Controlled Attenuation/Equalization/Cable Simulation

The amplifier ***shall*** use electronically controlled attenuation, equalization, and cable simulation, for downstream RF alignment, conversely, the amplifier ***shall not*** use plug-in attenuators, equalizers, or cable simulators. The electronically controlled attenuation, equalization, and cable simulation ***shall*** be adjustable in no greater than 0.5 dB increments.

7.4.2. Universal Plug-In

The amplifier ***shall*** provide an interstage plug-in location that could be used for as needed future plug-ins, such as frequency response correction/shaping boards. For factory shipped amplifiers the universal plug-in location ***shall*** have a removable jumper installed to allow RF continuity.

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7.4.3. Auto-Alignment

Auto-alignment means the amplifier can align itself during initial set-up (self-adjustment of attenuation and equalization). Downstream auto-alignment would be expected to make use of the downstream configuration settings and to be based on logic meant to optimize RF performance.

Auto-alignment for downstream *may* be provided either in the base product offering or as an option.

7.4.4. AGC (ALSC)

Automatic gain control (AGC) or automatic level/slope control (ALSC) is used to maintain stable RF output levels of the amplifier as RF input levels vary due to temperature induced changes to coaxial and passive losses. Such control has typically been accomplished by monitoring RF output power levels at specific frequencies (called pilot frequencies) and driving an associated attenuation/equalization circuit as needed to maintain stable RF output levels over temperature.

AGC for downstream ***shall*** be provided.

The AGC ***shall*** be designed to compensate for internal amplifier loss variations over temperature and for coaxial cable loss variations over temperature, where the 1.8 GHz coaxial loss preceding the amplifier is equal to the operational gain of the amplifier.

7.4.4.1. Multi Frequency AGC (ALSC)

Multi frequency AGC (or ALSC) makes use of at least two pilot frequencies, one in the lower and one in the upper portion of the downstream frequency spectrum. The AGC ***shall*** be designed to function properly with SC-QAM or OFDM RF signals (or equivalent) in the pilot frequency spectrum. The AGC is not required to function properly with CW or analog video modulated carriers in the pilot frequency spectrum. This method provides closed loop feedback control of both level and tilt." Multi frequency AGC ***shall*** be used in any downstream RF AGC.

7.4.4.2. Agile AGC (ALSC)

Agile AGC means all frequencies used as pilots in the multi frequency AGC can be configured by the user.

The multi frequency AGC (ALSC) ***shall*** be agile. This allows shifting of the pilot frequencies if an operator shifts the frequency allocation of downstream spectrum to accommodate increases in upstream spectrum.

7.4.4.3. AGC (ALSC) Pilot Loss Protection

AGC pilot loss protection is meant to prevent a loss of RF signal at a pilot frequency from causing an AGC to rail the amplifier to a full gain condition. The AGC pilot loss protection method is not specifically defined but might include reverting to an alternate pilot frequency, reverting to a thermistor based (thermal) type of gain control, locking the interstage attenuation/equalization settings to the states in use prior to the loss of pilot signal, or other methods that achieve the desired functionality.

The downstream AGC ***shall*** make use of a pilot loss protection mechanism.

7.5. Upstream Set-up and Control

This section describes functions and features associated with the initial upstream set-up/configuration of the amplifier or with the upstream control of the amplifier during operation.

7.5.1. Electronically controlled Attenuation/Equalization

The amplifier ***shall*** use electronically controlled attenuation and equalization for upstream RF alignment, conversely, the amplifier ***shall not*** use plug-in attenuators or equalizers.

7.5.2. Auto-Alignment

Auto-alignment means the amplifier is capable of aligning itself during initial set-up (self-adjustment of attenuation and equalization). Upstream auto-alignment would be expected to make use of the upstream configuration settings and to be based on logic meant to optimize RF performance.

Auto-Alignment for upstream *may* be provided either in the base product offering or as an option.

7.5.3. RF Level Control

A means of controlling upstream RF level variation over temperature ***shall*** be provided. This *may* be accomplished via quasi-AGC or thermal level control (as defined in section 7.5.3.2), or by other means. The means of upstream RF level control, the expected performance over temperature, and the associated test conditions ***shall*** be specified in published specifications.

7.5.3.1. Quasi-AGC

While traditional AGC circuits based upon monitoring RF power levels are not generally considered feasible in the upstream due to the bursty nature of upstream RF transmissions, a form of quasi-AGC *may* be feasible. This might make use of some form of monitoring of the downstream AGC/RF status and use of logic that would drive an associated upstream attenuation/equalization circuit accordingly to improve the stability of the upstream RF output levels over temperature.

7.5.3.2. Thermal Level Control

Thermal level control is another method used to improve the stability of RF output levels of the amplifier as RF input levels vary due to temperature induced changes to coaxial and passive losses. Such control has typically been accomplished by referencing a thermistor-based circuit and driving an associated attenuation/equalization circuit as needed to improve the stability of the upstream RF output levels over temperature.

7.5.3.2.1. Thermal Level Control – Selectable Range

If thermal level control is offered, selectable range means the user can select from more than one compensation range. Programmable or selectable compensation might include “x dB of aerial cable compensation” or “x dB of underground cable compensation” where x is a fixed value, or where x is a user selectable value within a given range.

Range selection for thermal level control *may* be provided in conjunction with any thermal level control offering.

7.5.4. Upstream Ingress Switch

An upstream ingress switch is typically a three-state switch on each upstream input port that is user selectable to assist in ingress localization efforts. The three states for the upstream RF path are “On” (no extra attenuation added), “Off” (a very high amount of attenuation added), or “-x dB” (where either a fixed or a user selected amount of additional attenuation is added).

An upstream ingress switch *should* be provided, either in the base product offering or as an option.

8. Configuration/Control and Monitoring – for High Gain Amplifiers

8.1. Local via Console/Wireless

The amplifier ***shall*** have a local management interface for configuration and monitoring. This interface ***shall*** be usable with a (Windows) PC and with a handheld tablet/smartphone (Android /iOS/ Windows). The manufacturer ***shall*** publish the minimum operating system requirements for this application.

The local management interface ***shall*** be usable with a cable connection and *may* be usable with wireless connection to PC/handheld. The wired connection *should* be based on standard connectors and cables, such as USB. The wireless transceiver ***shall not*** be built into the amplifier, since this is not desired due to increased complexity, cost, security, and EMC issues. Thus, a wireless transceiver that *may* be plugged into a USB port is recommended if the wireless option is provided. The wireless connection ***shall*** be based on Bluetooth or Wi-Fi so that no extra hardware is needed for the PC/handheld.

The user interface (UI) ***shall*** be based on a separate app running in the PC/handheld to get optimal user experience on different screens and form factors.

The local management interface ***shall*** have built-in security so that connection can only be established by authorized persons. Lid/tamper switch and connection detection ***shall*** be used for automatic logout.

8.2. Remote

The amplifier ***shall*** have an option available for remote management for configuration and monitoring, implemented as a plug-in module.

A two-way transponder based on a DOCSIS 3.0 (or higher) modem ***shall*** be offered as an option.

The same UI app used for local management interface *should* be usable also with remote management interface, with identical layout, parameters, and user experience.

8.3. Associated Parameters and Functions

Table 5 lists the parameters and functions that *may* be required to be controlled/configured (write commands) or monitored/reported (read commands). Applicability for a given type of amplifier is dependent on its particular configuration and the requirements outlined in the associated document section for the given parameter/function.

Any parameter/function that is required to be supported via local management ***shall*** also be supported via the remote management option.

Table 5 – Parameters and Functions for Local/Remote Monitoring

Parameter/Function	Section	Associated Control/Configure (write) Functions	Associated Monitor/Status Reporting (read) Functions
Amplifier Type	6		report amp type
Pluggable Diplex Filters	7.1.2		report current frequency split
Switchable Diplex Filters	7.1.2	select active frequency split	report current frequency split
DS Electronically Controlled Attenuation	7.4.1	select amount of attenuation	report amount of attenuation
DS Electronically Controlled Equalization	7.4.1	select amount of equalization	report amount of equalization
DS Electronically Controlled Cable Simulator (Inverse Equalization)	7.4.1	select amount of cable simulation (inverse equalization)	report amount of cable simulation (inverse equalization)
DS Auto-Alignment	7.4.3	select mode	report mode
DS Agile AGC	7.4.4.2	select AGC frequencies	report current AGC frequencies
DS AGC Pilot Loss Protection	7.4.4.3	select mode	report current mode (AGC or loss protected)
US Electronically Controlled Attenuation	7.5.1	select amount of attenuation	report amount of attenuation
US Electronically Controlled Equalization	7.5.1	select amount of equalization	report amount of equalization
US Auto-Alignment	7.5.2	select mode	report mode
	7.5.2	configure auto-align parameters	report configured settings report status
US Quasi-AGC	7.5.3.1	select mode	report mode
	7.5.3.1	configure mode	report configured settings report status
US Thermal Level Control	7.5.3.2	select mode	report mode
US Thermal Control, Selectable Range	7.5.3.2.1	select range	report range
US Ingress Switch	7.5.4	select state (On, Off, -x dB)	report state
Power Supply Input Voltage	14.2		report voltage
Power Supply Output Voltage	14		report voltage(s)

9. Mechanical – for High Gain Amplifiers

This section applies only for NEW housings used for high gain amplifiers.

9.1. Amplifier Housing Requirements

The amplifier housing is typically a clam-shell type comprised of both a base and a lid.

9.1.1. Dimensions

The external dimensions of the housing ***should not*** exceed the dimensions listed below when oriented in a horizontal (strand mount) position with hinge side down. This includes cooling fins, hinge, and other protrusions. Length is measured from the external face of the entry port insert on one side of the housing to the external face of the corresponding entry port insert on the other side of the housing. Height is measured from the top to the bottom of the housing. Depth is measured from the front to the back of the housing.

- Multi-port housings ***should not*** exceed 18" L x 10" H x 10 D".
- Line extender housings ***should not*** exceed 12" L x 10" H x 10 D".

9.1.2. Attachment Method to Strand and Pedestal

For all amplifier types identified as supporting strand mounting in section 6, the housing ***shall*** have two 5/16"-18 threaded inserts on the top surface of the housing base. These inserts are intended for horizontal strand mounting or mounting inside a pedestal.

The strand mount clamp ***shall*** also be able to serve as the bond/ground wire attachment.

Bolts used for housing mounting ***shall*** use 5/16"-18 threads and ½" hex head.

For strand mount amplifier types, the housing ***shall*** have two 5/16"-18 threaded inserts in the housing base. These threaded inserts are intended to allow the housing to be hung vertically or horizontally on a flat surface with separate bracket.

9.1.3. Entry Ports

The housing external entry ports ***shall*** be compliant with [SCTE 91].

9.1.4. Test Ports

For all high gain strand mount amplifiers, RF test ports ***shall*** make use of a male G-connector that is meant to mate with an external female F type connector or probe.

For all high gain cabinet mount amplifiers (i.e. compact amps), RF test ports ***shall*** make use of a female F-connector.

Optional external test ports ***shall*** be compliant with [SCTE 91], but *may*:

- omit the heat shrink sleeve ridge
- have a port length less than the minimum port length (dimension H).

9.1.5. Hinges

All housings ***shall*** include a hinged connection between the base and the lid that incorporates a retention mechanism to prevent the lid from being dropped accidentally. If the hinge incorporates hinge pins, they ***shall*** be stainless steel, removable, and make use of a retention mechanism to prevent accidental loss during a housing lid exchange.

9.1.6. Closure Bolts

For strand mount amplifier types:

- Housing closure bolt locations ***shall*** use stainless steel thread inserts.
- Housing closure bolts ***shall*** be ½” hex head with 5/16”-18 threads, captive to the lid, spring-loaded, and constructed of stainless steel.
- Torque number sequence for the housing closure bolts ***shall*** be cast on the outside of the housing.

9.1.7. Hardline Connector Trim Guide

For multiport and line extender amplifiers, a hardline connector center pin trim guide ***shall*** be cast on the outside of the housing.

For compact amplifiers, if space allows a hardline connector center pin trim guide ***shall*** be cast on the outside of the housing. If space is limited a permanent label conforming to the requirement in section 15.5.1 ***shall*** be used.

9.1.8. Material

The housing ***shall*** be manufactured from an A360 die cast aluminum or similar material to meet or exceed environmental and galvanic compatibility requirements defined in this specification.

9.1.9. Finish

The housing finish ***shall*** meet Class 1, and *may* meet Class 2, Functional Grade per NADCA G-6-6-15 [NADCA].

9.2. Module Retention Bolts

All internal module retention bolts ***shall*** be hex, Torx, or Phillips head and a torque specification ***shall*** be provided. This applies to all type of modules that are tightened down to the housing using bolts, including RF amplifier modules and power supply modules, for example.

9.3. Seizure Screws

Any seizure screws used to seize the center pin of a coaxial connector ***shall*** be hex, Torx, or Phillips head, and a torque specification ***shall*** be provided.

10. Electrical – for Booster Amplifier

10.1. Upstream / Downstream Frequency Splits & Diplexers

This section pertains to the upstream / downstream frequency split options and the associated diplex filters (if used) and other low-pass/high-pass filters (if used).

10.1.1. Upstream / Downstream Frequency Split Options

The upstream / downstream frequency split options and their associated requirements are listed in Table 6. The available frequency split options ***shall*** be listed in published specifications.

Table 6 – Upstream / Downstream Frequency Split Options

Split Name	Requirement as an Option for the Amplifier	Upstream Upper Band Edge Frequency ($F_{US\text{-}UBE}$)	Downstream Lower Band Edge Frequency ($F_{DS\text{-}LBE}$)	Notes
Sub-split	should be supported	42 MHz	54 MHz	Note 1, 2
Euro-split	should be supported	65 MHz	85 MHz	Note 1, 2
Mid-split	***shall*** be supported	85 MHz	108 MHz	Note 1
High-split	***shall*** be supported	204 MHz	258 MHz	Note 1
UHS-300	*may* be supported	300 MHz	372 MHz	Note 1
UHS-396	***shall*** be supported	396 MHz	492 MHz	Note 1
UHS-492	***shall*** be supported	492 MHz	606 MHz	Note 1
UHS-684	should be supported	684 MHz	834 MHz	Note 1

Notes:

1. Downstream *may* start lower in frequency.
2. This frequency split is required to support a transition from these existing legacy splits to the higher frequency splits that *may* be activated later (after initial installation).

10.1.2. Diplex Filters

This section pertains to the diplex filters and associated low-pass/high-pass filters that *may* be required to keep the downstream and upstream RF paths isolated in in a low gain booster amplifier.

If used, diplex filters and any associated low-pass/high-pass filters ***shall*** be either modular plug-in type assemblies or fixed on-board circuits in modular amplifier assemblies that can be swapped out without re-splicing the back housing.

If used, the plug-in diplex filters and any associated low-pass/high-pass filters, or the modular amplifier assemblies ***shall*** be field upgradeable, meaning that the plug-in filters or modular amplifier assemblies can be changed out in the field without the need for any retuning or verification testing on a bench.

10.2. Downstream RF Parameters

This section pertains to the downstream (forward path) RF parameters associated with the booster amplifier type. Unless otherwise noted, all of the following downstream RF parameters ***shall*** apply for the full downstream passband.

10.2.1. Passband

Downstream passband ***shall*** be 108 to 1794 MHz and *should* be 54 or 85 to 1794 MHz to support the upstream/downstream frequency splits in section 10.1.1.

Downstream passband ***shall*** be specified in published specifications.

10.2.2. Operational Gain

Downstream operational gain is the station gain at highest rated frequency from downstream input to downstream output, with all other ports terminated.

The amount of downstream operational gain is not specified (left to manufacturer discretion). However, at the time of publication it was anticipated that the operational gain at 1794 MHz for the booster amplifiers might need to be in the 10 to 13 dB range (with 0 dB input attenuation) to meet industry drop-in architecture requirements while minimizing amplifier re-spacing.

The minimum operational gain (with 0 dB input attenuation) at room temperature at the highest rated downstream frequency ***shall*** be specified in published specifications.

Operational gain ***shall*** be measured in accordance with [SCTE 144].

10.2.3. Internal Slope

Downstream internal slope refers to the dB difference in amplifier gain at the highest and lowest frequencies in the passband, with 0 dB input equalization. Internal slope (if implemented) is typically established via internal equalization. In amplifiers this has normally been a "cable" type of equalization (having opposite frequency dependent loss characteristics than coaxial cable), as opposed to a straight-line slope due to "linear" equalization.

If the booster amplifier has internal slope, it ***shall*** be fixed (non-adjustable). The amount of internal slope and the type of internal equalization used to establish it ***shall*** be specified in published specifications.

Internal slope ***shall*** be measured in accordance with [SCTE 144].

10.2.4. Frequency Response

The downstream frequency response (also referred to as flatness) measured from the input port to any output port ***should not*** exceed ±0.5 dB from downstream lower band edge to 1794 MHz relative to the internal slope (tilt) of the amplifier.

The downstream frequency response (also referred to as flatness) measured from the input port to any output port ***shall not*** exceed ±0.75 dB from downstream lower band edge to 1794 MHz relative to the internal slope (tilt) of the amplifier.

Downstream frequency response at room temperature ***shall*** be specified in published specifications.

Frequency response ***shall*** be measured in accordance with [SCTE 144].

10.2.5. Noise Figure

A maximum downstream noise figure value is not specified (left to manufacturer discretion) with the understanding that lower noise figures are beneficial.

Typical noise figure at low and high frequencies and at room, hot, and cold temperatures ***shall*** be specified in published specifications.

The specification ***shall*** note that the noise figure is for the station (inclusive of input losses, including diplex filters if used).

Noise figure ***shall*** be measured in accordance with [SCTE 62].

10.2.6. Group Delay Variation

Group delay variation is the difference between the maximum and minimum group delay measured between two different frequencies.

The downstream group delay variation is not specified (left to manufacturer discretion).

Typical group delay variation at room temperature across each 6 MHz and/or 8 MHz frequency range listed below ***shall*** be specified in published specifications for each upstream/downstream frequency split option.

- $F_{DS\text{-}LBE}$ to $F_{DS\text{-}LBE}$ +6 MHz
- $F_{DS\text{-}LBE}$ +6 MHz to $F_{DS\text{-}LBE}$ +12 MHz
- $F_{DS\text{-}LBE}$ +12 MHz to $F_{DS\text{-}LBE}$ +18 MHz

- $F_{DS\text{-}LBE}$ to $F_{DS\text{-}LBE}$ +8 MHz
- $F_{DS\text{-}LBE}$ +8 MHz to $F_{DS\text{-}LBE}$ +16 MHz
- $F_{DS\text{-}LBE}$ +16 MHz to $F_{DS\text{-}LBE}$ +24 MHz

Group delay ***shall*** be measured in accordance with [SCTE 45].

10.2.7. RF Test Points

The downstream RF output port ***shall*** have a test point which *may* be directional or non-directional.

The downstream RF input port *may* have an RF test point which *may* be directional or non-directional.

All downstream RF test points ***shall*** be -20 dB relative to the associated input/output port.

The downstream RF test points ***shall*** be accurate to -20 dB +/- 1.5 dB.

The downstream RF output port test points ***shall*** be on the common path of the diplex filter (if used) to allow the test point to also be used for upstream injection. The upstream injection functionality allows this test point to be used with test equipment requiring two-way communications.

The RF test point type, loss relative to associated input/output port, and accuracy at room temperature ***shall*** be specified in published specifications.

The measurements ***shall*** be in accordance with [SCTE 144].

10.2.8. Noise and Distortion Performance

The FDD booster amplifiers defined in this document will amplify wide-band downstream RF signals and generate intermodulation distortion due to non-linearities at higher RF output power levels. A common approach to specifying the intermodulation distortion performance is needed to allow direct performance comparisons. Refer to section 7.2.8.1 (Carrier to Noise and Intermodulation Noise) for related information on the terms used in this section.

The following ***shall*** be specified in published specifications:

- For RF output profile 1 in Table 7, the maximum amplifier RF output TCP value (in dBmV) associated with CCN ≥ 55 dB in the legacy spectrum and in the extended spectrum.
- For RF output profile 2 in Table 7, the maximum amplifier RF output TCP value (in dBmV) associated with CCN ≥ 55 dB in the legacy spectrum and with CCN ≥ 49 dB in the extended spectrum.

The maximum TCP values specified ***shall*** be associated with the worst CCN performance in the legacy spectrum and in the extended spectrum, as measured in the test frequency ranges shown in Table 8.

The specified performance ***shall*** be associated with performance at room, hot, and cold temperature.

Note that SC-QAM pre-FEC BER measurements and associated specifications are not a requirement for the booster amplifier as it is not anticipated that there will be bit errors associated with excessive distortion when the CCN performance is greater than or equal to the values shown above.

Table 7 – Common RF Output Profiles for Characterization

RF Profile	Legacy Spectrum			Extended Spectrum (ES)				Total RF Output Tilt
	Signal Type	Frequency (MHz)		Signal Type	Frequency (MHz)		ES Step Down	
		Start	Stop		Start	Stop		
1	SC-QAM_{256}	258	1026	SC-QAM_{256}	1026	1794	0 dB	15 dB
2	SC-QAM_{256}	258	1026	SC-QAM_{256}	1026	1794	6 dB	15 dB

Table 8 – Common RF Test Frequency Ranges

Test Frequency Range	Width of Range	Range Description
261 to 279 MHz	18 MHz	Low frequency – legacy band
603 to 627 MHz	24 MHz	Mid frequency – legacy band
1029 to 1047 MHz	18 MHz	Low frequency – extended spectrum band
1389 to 1413 MHz	24 MHz	Mid frequency – extended spectrum band
1773 to 1791 MHz	18 MHz	High frequency – extended spectrum band

For each range description in Table 8, a test channel with center frequency falling within the associated test frequency range ***shall*** be used for the characterization testing associated with the published performance specifications.

10.3. Upstream RF Parameters

This section pertains to the upstream (return path) RF parameters associated with the various amplifier types. Unless otherwise noted all the following upstream RF parameters ***shall*** apply for the full upstream passband.

10.3.1. Passband

Upstream passband *should* be 5 to 684 MHz and ***shall*** be at least 10 to 492 MHz and ***shall*** support the frequency splits as called out in section 10.1.1. If the manufacturer specifies an upstream low frequency band edge of 10 MHz, upon request they ***shall*** provide performance information in the 5 to 10 MHz region.

Upstream passband ***shall*** be specified in published specifications.

10.3.2. Operational Gain

Upstream operational gain is the station gain at highest rated frequency from upstream input to upstream output, with all other ports terminated.

The amount of upstream operational gain is not specified (left to manufacturer discretion). However, at the time of publication it was anticipated that the operational gain at 684 MHz for the booster amplifiers *may* need to be in the 4 to 7 dB range to meet industry drop-in architecture requirements while maintaining sufficient dynamic range performance.

The minimum operational gain at room temperature at the highest rated upstream frequency for each frequency split ***shall*** be specified in published specifications.

Operational gain ***shall*** be measured in accordance with [SCTE 144].

10.3.3. Internal Slope

Upstream internal slope (also referred to as internal tilt) refers to the dB difference in amplifier gain at the highest and lowest frequencies in the passband. While historically the upstream path in amplifiers has not made use of deliberate internal slope, in the much wider upstream spectrums used for DOCSIS 4.0 FDD it *may* provide performance benefits. If implemented for upstream it is anticipated that the internal slope would be established using “cable” type equalization.

The amount of internal slope and the type of equalization used to establish it ***shall*** be specified in published specifications.

Internal slope ***shall*** be measured in accordance with [SCTE 144].

10.3.4. Frequency Response

The upstream frequency response (also referred to as flatness) measured from the input port to any output port ***shall not*** exceed ±1.0 dB relative to the internal slope of the amplifier.

Upstream frequency response at room temperature ***shall*** be specified in published specifications.

Frequency response ***shall*** be measured in accordance with [SCTE 144].

10.3.5. Noise Figure

A maximum upstream noise figure value is not specified (left to manufacturer discretion) with the understanding that lower noise figures are beneficial.

Typical noise figure at low and high frequencies and at room, hot, and cold temperatures ***shall*** be specified in published specifications.

The specification ***shall*** note that the noise figure is for the station (inclusive of input losses).

Noise figure ***shall*** be measured in accordance with [SCTE 62].

10.3.6. Group Delay Variation

Group delay variation is the difference between the maximum and minimum group delay measured between two different frequencies.

The upstream group delay variation is not specified (left to manufacturer discretion).

Typical group delay variation at room temperature across each frequency range listed below ***shall*** be specified in published specifications for each upstream/downstream frequency split option.

- $F_{US\text{-}LBE}$ to $F_{US\text{-}LBE}$ +3.2 MHz
- $F_{US\text{-}LBE}$ +3.2 MHz to $F_{US\text{-}LBE}$ +6.4 MHz
- $F_{US\text{-}LBE}$ +6.4 MHz to $F_{US\text{-}LBE}$ +9.6 MHz
- $F_{US\text{-}LBE}$ +9.6 MHz to $F_{US\text{-}LBE}$ +12.8 MHz

- $F_{US\text{-}UBE}$ to $F_{US\text{-}UBE}$ -6.4 MHz
- $F_{US\text{-}UBE}$ -6.4 MHz to $F_{US\text{-}UBE}$ -12.8 MHz

Group delay ***shall*** be measured in accordance with [SCTE 45].

10.3.7. RF Test Points

The upstream RF input port ***shall*** have a test point which *may* be directional or non-directional.

The upstream RF output port *may* have an RF test point which *may* be directional or non-directional.

All upstream RF test points ***shall*** be -20 dB relative to the associated input/output port and be accurate to +/- 1.5 dB.

The upstream input port shall also have an upstream RF injection test point on the common path of the diplex filter associated with the port. This upstream injection test point also serves as the downstream RF output test point allowing it to be used with test equipment requiring two-way communications.

The RF test point type, loss relative to associated input/output port, and accuracy at room temperature ***shall*** be specified in published specifications.

The test point related measurements ***shall*** be measured in accordance with [SCTE 144].

10.3.8. Noise and Distortion Performance

The FDD booster amplifiers defined in this document will amplify wide-band upstream RF signals and generate intermodulation distortion due to non-linearities at higher RF output power levels. A common approach to specifying the intermodulation distortion performance is needed to allow direct performance comparisons. Refer to section 7.2.8.1 (Carrier to Noise and Intermodulation Noise) for related information on the terms used in this section.

The following ***shall*** be specified in published specifications:

- The maximum amplifier RF output TCP value (in dBmV) associated with CCN ≥ 50 dB, for all frequency splits supported.

The characterization testing associated with the published specification(s) ***shall*** be conducted:

- With the equivalent of 15 dB RF output tilt from 10 to 684 MHz, with output tilt reduced accordingly for reduced upstream bandwidths associated with other frequency splits supported.
- With a fully loaded US spectrum (from 10 MHz to US upper band edge), consisting of either 6 MHz SC-QAM RF signals or band-pass filtered white noise (such as that commonly used for NPR testing).

The specified performance ***shall*** be associated with performance at room, hot, and cold temperature.

The maximum TCP values specified ***shall*** be associated with the worst CCN performance in the upstream spectrum, as measured in the test frequency ranges shown in Table 9.

Table 9 – Common Upstream Amplifier Test Frequency Ranges for Booster Amplifier

Test Frequency Range
39 to 57 MHz
261 to 279 MHz
483 to 501 MHz

10.4. Downstream Set-up and Control

This section describes functions and features associated with the initial downstream set-up/configuration of the amplifier or with the downstream control of the amplifier during operation.

10.4.1. Attenuation and Equalization

The booster amplifier ***shall not*** have adjustable downstream equalization, or cable simulation.

The booster amplifier *should* have a user adjustable 4-state control mechanism that allows selection of downstream input attenuation values of 0, 2, 4, and 6 dB to reduce station gain and increase the range of locations that the amplifier can be inserted in the network.

10.5. Upstream Set-up and Control

This section describes functions and features associated with the initial upstream set-up/configuration of the amplifier or with the upstream control of the amplifier during operation.

10.5.1. Attenuation and Equalization

The booster amplifier ***shall not*** have adjustable upstream gain or slope.

11. Configuration/Control and Monitoring – for Booster Amplifier

The booster amplifier ***shall not*** have local or remote management interfaces for configuration and monitoring.

12. Mechanical – for Booster Amplifier

This section applies only for new booster amplifier housings.

12.1. Amplifier Housing Requirements

The amplifier housing *may* be similar to those used for hardline passives or *may* be a clam-shell type comprised of both a base and a lid. The small size suggested is to allow the potential for adding a booster amplifier in-line in an existing tap or passive pedestal.

12.1.1. Dimensions

The external dimensions of the housing ***should not*** exceed 8” L x 8” H x 6” D.

12.1.2. Attachment Method to Strand and Pedestal

A mounting clamp ***shall*** be incorporated to allow mounting the amplifier to the strand or in a pedestal. The mounting clamp *may* be located at the manufacturers preferred location provided that they meet the housing requirements herein. An ergonomic method for fastening the device to the strand or pedestal mounting system *may* be incorporated as long as it does not compromise the strand lashing wire or block access to ports or bond wire attachment. The strand mount clamp *may* also serve as the bond wire attachment.

12.1.3. Entry Ports

The housing external entry ports ***shall*** be compliant with [SCTE 91].

12.1.4. Test Ports

All RF test ports ***shall*** make use of either:

- a male G-connector that is meant to mate with an external female F type connector or probe

or

- a female F-connector.

Optional external test ports ***shall*** be compliant with [SCTE 91], but *may*:

- omit the heat shrink sleeve ridge
- have a port length less than the minimum port length (dimension H).

12.1.5. Hinges

Any clam-shell type housings ***shall*** include a hinged connection between the base and the lid that incorporates a retention mechanism to prevent the lid from being dropped accidentally. If the hinge incorporates hinge pins, they ***shall*** be stainless steel, removable, and make use of a retention mechanism to prevent accidental loss during a housing lid exchange.

12.1.6. Closure Bolts

Housing closure bolts ***shall*** be 5/16”, 3/8”, or 7/16” hex head, captive to the lid, and constructed of stainless steel.

12.1.7. Hardline Connector Trim Guide

A hardline connector center pin trim guide ***shall*** be cast on the outside of the housing.

12.1.8. Material

The housing ***shall*** be manufactured from an A360 die cast aluminum or similar material to meet or exceed environmental and galvanic compatibility requirements defined in this specification.

12.1.9. Finish

The housing finish ***shall*** meet Class 1, and *may* meet Class 2, Functional Grade per NADCA G-6-6-15 [NADCA].

12.2. Module Retention Bolts

All internal module retention bolts, if required, ***shall*** be hex, Torx, or Phillips head and a torque specification ***shall*** be provided. This applies to all type of modules that are tightened down to the housing using bolts, including RF amplifier modules and power supply modules, for example.

12.3. Seizure Screws

Any seizure screws used to seize the center pin of a coaxial connector ***shall*** be hex, Torx, or Phillips head, and a torque specification ***shall*** be provided.

13. General Parameters – for All Amplifiers

13.1. Return Loss

The return loss is the measured one port reflection with all other RF ports terminated into 75 ohms.

The return loss for all amplifier RF ports ***shall*** meet or exceed the requirements in Table 10.

Table 10 – RF Port Return Loss

Frequency (MHz)	Station – As Tuned at Factory	Station – After Field Diplexer Change
5 to 10	≥13	≥13
10 to 40	≥18	≥18
40 to 80	≥17	≥16.5
80 to 160	≥16	≥15
160 to 320	≥15	≥13.5
320 to 640	≥14	≥12
640 to 1280	≥13	≥12
1280 to 1794	≥12	≥12

Note that for a given upstream/downstream frequency split, the cross over region (between upstream upper band edge and downstream lower band edge) is excluded from the requirements in Table 10. The minimum return loss at room temperature for factory tuned stations ***shall*** be specified in published specifications.

Return loss ***shall*** be measured in accordance with [SCTE 144].

13.2. RF Shielding Effectiveness

The amplifier station ***shall*** provide the minimum RF shielding effectiveness listed in Table 11 with the housing closed and the closure bolts tightened in accordance with the manufacturer's recommended torque and sequence.

Table 11 – Shielding Effectiveness

Frequency (MHz)	Shielding Effectiveness (dB)
5 to 1002	≥ 120
1002 to 1218	≥ 110

Frequency (MHz)	Shielding Effectiveness (dB)
1218 to 1794	≥ 100

Shielding Effectiveness at room temperature ***shall*** be specified in published specifications.

Shielding Effectiveness ***shall*** be measured in accordance with [SCTE 48-1].

13.3. Surge Withstand

The surge withstand of the amplifier ***shall*** be at minimum compliant with [IEEE C62.41] Category B3, Combination Wave 6kV/3 kA (2 ohm) at all KS ports.

The amplifier ***shall not*** suffer any physical or functional damage after exposure to surge testing.

Surge withstand ***shall*** be specified in published specifications.

Surge withstand ***shall*** be measured in accordance with [SCTE 81].

The manufacturer ***shall*** specify any configuration (such as fuse or shunt placement) required for surge testing.

13.4. Surge Protection

The amplifier's AC path ***should*** include a fast-transfer electronic-crowbar surge protector (FTEC). These typically fire at high input voltages and present a short circuit to the line during periods of high AC voltage or over voltage. After the AC input voltage returns to normal, the FTEC resumes its open state. Gas discharge tubes ***shall not*** be used as the primary form of surge protection.

13.5. Electro-Static Discharge Withstand

Amplifiers ***shall*** survive without damage or reduced performance and ***shall not*** reset after being subjected to an IEC/EN61000-4-2 ESD test procedure; Level IV with the Human Body Model (8 kV direct contact, 15 kV air discharge) [IEC 61000].

14. Power Related – for All Amplifiers

14.1. AC Input Voltage Frequency Range

Line powered amplifiers ***shall*** operate within an AC frequency range of 47 to 63 Hz.

14.2. AC Input Voltage Range

Line powered amplifiers ***shall*** operate within the manufacturers specified input voltage range (to match the low voltage cut-off).

14.3. Low Voltage Cut-Off / Turn On

Low voltage cut-off is meant to prevent amplifiers from continuing to draw increasing current if input voltage goes very low due to temporary disturbances.

High gain amplifiers ***shall*** have a low voltage cut-off that engages to turn off the amplifier/power supply when the input voltage drops to a manufacturer-specified voltage range.

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High gain amplifiers ***shall*** have a low voltage turn on that engages to turn the amplifier/power supply back on when the input voltage increases to a manufacturer-specified voltage range.

There ***shall*** be at least a 3 volt hysteresis between the low voltage cut-off and the low voltage turn on.

Booster amplifiers *may* have a low voltage cut-off and turn-on feature.

14.4. Maximum AC Through Current (Amps)

Amplifiers specified maximum through AC current (steady state) ***shall*** be at least 15 amps.

Amplifiers ***shall*** operate with a maximum AC peak current of 20 amps for 2 hours with no electrical performance or physical degradation including no melting of solder in the AC power passing circuitry, and no melting of plastic components. The test *should* occur at the high temperature extreme.

14.5. AC Current Draw (Amps)

AC current draw (in amps) ***shall*** be based on measurements made with a typical CATV-type ferroresonant AC power supply (quasi-square wave).

Published specifications ***shall*** include a table showing RMS AC current draw across the AC input voltage range, in 5 volt increments.

The typical current draw at room temperature ***shall*** be specified for the configuration with maximum current draw, and with other common configurations. For example: with AGC RF level control, and with/without transponder.

14.6. Power Consumption (Watts)

AC power consumption (in watts) ***shall*** be based on measurements made with a typical CATV-type ferroresonant AC power supply (quasi-square wave).

Published specifications ***shall*** include a table showing power consumption across the AC input voltage range, in 5 volt increments.

The typical power consumption at room temperature ***shall*** be specified for the configuration with maximum power consumption, and with other common configurations. For example: with AGC RF level control, and with/without transponder.

14.7. Power Saving Features

Amplifiers *may* incorporate features to reduce power consumption. For example, they *may* include reducing gain block bias under reduced loading conditions, and/or turning off gain blocks associated with unused ports.

14.8. AC Power Routing

Amplifiers ***shall*** be supplied with automotive plug-in blade type shunts or fuses for internal amplifier power routing.

14.9. Power Supply Specs – General

14.9.1. Power Supply Type

The power supply ***shall*** be a switch mode power supply. A switch mode power supply incorporates a switching regulator to convert electrical power efficiently.

The power supply ***shall*** provide AC in-rush current limiting.

14.9.2. Power Factor Correcting Power Supply

Power factor is the ratio of the real power to the apparent power required to operate a device, where apparent power is the product of the RMS input voltage times the RMS input current and real power is the instantaneous product of the time varying voltage and time varying current. Refer to [SCTE 46] for more detailed definitions and associated formulas.

The power supply for the high gain amplifiers *should* be a power factor correcting power supply with a power factor greater than 0.95.

14.9.3. Output Short Circuit Protection

The power supply ***shall not*** be damaged by a short circuit on any DC output.

15. Environmental – for All Amplifiers

15.1. Operating Temperature

Amplifiers ***shall*** operate from -40 C to +60 C ambient temperature across the rated input voltage range in a still-air environment. This is the temperature of the ambient air external to the amplifier housing. This is the temperature range over which the amplifier is specified to operate and meet the stated performance.

Amplifiers ***shall*** meet all requirements without the need for any special cooling methods.

15.2. Altitude

Amplifiers ***shall*** operate without impairment at an altitude range of -60 m (-200 ft) to 2000 m (6,500 feet) above mean sea level from 0 to 60 C.

15.3. Salt Spray

The device ***shall*** meet all performance requirements after a minimum of 1000 hours of salt spray when tested in accordance with [SCTE 143].

The device ***shall*** exhibit corrosion penetration of less than 50% metal thickness and show no evidence of internal damage.

All unused ports (F/KS) ***shall*** be appropriately sealed during testing to prevent saltwater compound entry via the ports.

15.4. Galvanic Compatibility

All external ports ***shall*** use metal inserts which are galvanically compatible with the housing.

All external ports ***shall*** use metal port caps which are galvanically compatible with the housing.

Galvanic compatibility is defined as the differential in anodic index voltage between various metals at the junction. [MIL 889] shows the Anodic Index (V) of various common metal platings. For galvanic compatibility, the anodic voltage differential *should* fall within the recommended limits in Table 12.

Table 12 – Recommended Anodic Voltage Differential Limits

Environment	Anodic Index
Salt Spray, Outdoor, High Humidity	± 0.15V
Normal Environment: Indoor non-temperature and non-humidity controlled	± 0.25V
Controlled Environments	± 0.50V

15.5. Label Durability

15.5.1. External Labels

Any external amplifier labels ***shall*** be legible and without significant degradation after ultraviolet B (UVB) exposure per [GR-2873] and [ASTM].

Labels ***shall*** remain legible after exposure to common cleaning chemicals, insecticides and pesticides, and over the operating temperature range, for the duration of the products expected lifetime.

15.5.2. Internal Labels

Any internal amplifier labels ***shall*** remain legible after exposure to common cleaning chemicals, insecticides, and pesticides and over the operating temperature range, for the duration of the products expected lifetime.

15.6. Pressure Testing

Amplifier housings with no additional sealant materials, such as tape, silicone, epoxy, etc. ***shall not*** produce air bubbles when submerged under 1 meter of water for 10 minutes and pressurized to 10 pounds per square inch (psi).

15.7. IP Rating

The strand mount amplifier housings ***shall*** have a minimum rating of ingress protection (IP) 67 and the cabinet mount compact amplifier housings ***shall*** have a minimum rating of IP 54, per [IEC 60529].

15.8. Highly Accelerated Life Testing (HALT)

The amplifier ***shall*** be subjected to highly accelerated life testing (HALT) and published test results ***shall*** be provided to customers upon request.

15.9. Restriction of Hazardous Substances (RoHS)

The amplifier ***shall*** comply with the Restriction of Hazardous Substances (RoHS) directive. The manufacturer ***shall*** comply with the most current version at the time of manufacturing release.

15.10. Unpackaged Equipment Free Fall Drop Test

The amplifier ***shall*** operate normally and meet vendors specifications after exposure to a free fall drop onto a concrete surface per section 7.2.2 of [SCTE 186].

15.11. Transportation/Operational Mechanical Vibration

The amplifier ***shall*** operate normally and meet vendors specifications after exposure to Transportation Mechanical Vibration per section 7.2.3 and Operational Vibration per section 7.2.6 of [SCTE 186].

16. Regulatory/Compliance

Amplifier hardware, software, equipment, materials and components comprising all subsystems ***shall*** meet or exceed all applicable regulatory, safety and industry standard compliance requirements.