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Draft Laboratory Division Publications Report

Title: Signal Boosters – Basic Definitions and Concepts For Equipment Authorization Applications

Short Title: Signal Booster Definitions

Reason: Revision and supersede of the definitions portions of the existing 2007 policy and procedure document, due to FCC-13-21 new rules. This draft request comments for attachment 935210 D01 Booster Definitions

Publication: 935210

Keyword/Subject: 20.21; 90.219; 22; 24; 27; 90; signal booster; amplifier

First Category: Radio Service Rules

Second Category: Measurement Procedures

Third Category:

Question: What device type definitions should be used for determining applicable rules for signal booster, amplifier, and repeater devices?

Answer: The attachments below:

935210 D01 Booster Definitions v01, provides guidance for classifying types of devices and applicable rules for performing compliance measurements on signal boosters operating under 47 CFR §§ 20.21, 90.219, and Parts 22, 24, 27, 90; interim considerations for some provisions and devices under other rules is also given, e.g., parts 2, 25, 97, 101.

935210 D02 Certification Requirements v01, provides certification requirements for signal boosters that operate under Parts 20, 22, 24, 27 and 90 of the FCC rules.

Attachment List:

935210 D01 Booster Definitions v01[1]
935210 D02 Certification Requirements v01[2]

[1] This draft is for attachment 935210 D01 Booster Definitions v01 which will be published by May 20, 2013.
[2] Attachment 935210 D02 Certification Requirements v01 is also available for review (until May 15th 2013), posted as a separate draft publications: 935210 D02 Signal Boosters Certification v01 DR02-41372. Comments to D02 must be filed under that separate draft posting and not under this draft posting.

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Signal Boosters – Basic Definitions and Concepts For Equipment Authorization Applications

1 Introduction

The Commission recently adopted and released a Report and Order (FCC 13-21, WTB Docket 10-4) that includes technical, operational and registration requirements for signal boosters used with devices and wireless networks that operate under Parts 22, 24, 27 and 90 of the rules.[3] The new rules create two classes of signal boosters, Consumer and Industrial, for Commercial Mobile Radio Services (CMRS) and further clarified booster requirements for Private Land Mobile Radio Services (PLMRS). This document provides additional guidance about basic definitions and various known types of signal booster devices, to facilitate equipment authorization application filings for such devices under part 2 subpart J of the Commision's rules. Annex A provides supplemental information to assist classifying device based on two basic system block diagrams. In cases where the following guidance is not clearly applicable, an applicant or agent or test lab should submit a KDB inquiry providing details. Annex B is an attachment that further clarifies some of the terms by repeating the "Signal Boosters Terminology and Concepts" appendix from the Order. Annex C covers some additional terms commonly used for products which may be classified as boosters or repeaters. Finally, Annex D is an attachment for reference containing the text of the preceding version of OET Lab. Div. publication KDB 935210 definitions and application filing guidelines for boosters and related devices.

[3] This document covers primarily terms and defintions for signal boosters devices subject to the rules and requirements described in the Report and Order FCC 13-21, WTB Docket 10-4; booster, amplifier, and repeater devices operating under other rule parts and/or sections may continue to use existing FCC and OET rules, policies, and procedures for equipment authorization.

2 Booster Device Terms and Definitions

This section summarizes basic device-related terms and definitions established by the Order, as well as lists a few existing terms and definitions from other FCC rules and documents.

2.1 Signal Boosters In Subscriber Based Services

The term "signal booster" as used in the Order and the associated rule sections includes all manner of amplifiers, repeaters, boosters, distributed antenna systems, and in-building radiation systems that serve to amplify signals ***between a device and a wireless network***. [Order, ¶ 3, fn 1]

2.1.1 Consumer Signal Booster (Part 20)

A **Consumer Signal Booster (Part 20)** is a device that automatically receives, amplifies, and retransmits *on a bi-directional basis* the signals received from base, fixed, mobile, or portable stations, with no change in frequency or authorized bandwidth, and that is marketed and sold to the general public for use without modification. [§ 20.3].

Consumer Signal Boosters allow an individual to improve wireless coverage within a limited area such as a home, car, boat or RV. Consumer Signal Boosters are designed to be installed without third-party professional assistance and used "out-of-the-box" without fine tuning or other technical adjustments. [FCC-13-21, ¶ 13]

Consumer Signal Boosters can be operated only with approved antennas, cables, and/or coupling devices as specified by the manufacturer of the Consumer Signal Booster. [§ 20.21(a)(3)]

Consumer boosters are further distinguished in terms of the intended operating frequency ranges relative to wireless services providers' frequency bands, as follows.

a) Provider-Specific (Frequency Selective) Consumer Signal Booster: A Provider-Specific Consumer Signal Booster may only operate on the frequencies and in the market areas of the specified licensee(s). A Provider-Specific Consumer Signal Booster may only be certificated and operated with the consent of the licensee(s) whose frequencies are being amplified by the device. [§ 20.3]

b) Wideband Consumer Signal Booster: A Wideband Consumer Signal Booster may operate on the frequencies and in the market areas of multiple licensees. [§ 20.3]

Besides delineation by congruence of device and service provider frequency ranges [2.1.1 a). b)], all **Consumer Boosters** are also distinguished by station equipment type and RF exposure device type, as follows.

c) Fixed Consumer Signal Booster: A Consumer Signal Booster designed to be operated in a fixed location in a building (i.e. indoors). [§ 20.3]

d) Mobile Consumer Signal Booster: A Consumer Signal Booster designed to operate in a moving vehicle where both uplink and downlink transmitting antennas are at least 20 cm from the user or any other person. [§ 20.3]

2.1.2 Industrial Signal Booster (Part 20)

An **Industrial Signal Booster (Part 20)** is any signal booster that is not a Consumer Signal Booster (Part 20) [i.e., CMRS parts 22, 24, 27, 90 (ESMR)].[4] [§ 20.3]

Industrial Signal Boosters may be fixed-station equipment or mobile-station equipment, and are designed for installation by licensees or qualified installers. Unlike Consumer Signal Boosters, industrial signal boosters used in the CMRS bands are not distinguished as wideband or provider-specific. Part 90 Signal Boosters, other than Consumer Signal Boosters, are a type of Industrial Signal Booster—see other specific terms and definitions below. [Order, ¶ 15]

2.2 Signal Boosters for PSRS and PLMRS Operations Under Part 90 (§ 90.219)

The following specific terms and definitions apply only for devices subject to § 90.219.

2.2.1 Signal Booster (§ 90.219)

A **Signal Booster (§ 90.219)** is a device or system that automatically receives, amplifies, and retransmits signals from wireless stations into and out of building interiors, tunnels, shielded outdoor areas and other locations where these signals would otherwise be too weak for reliable communications. Signal booster systems may contain both Class A and Class B signal boosters as components. [§ 90.219(a)]

All **§ 90.219 boosters** are a type of Industrial Signal Booster, and are classified as either **Class A boosters** (narrowband) or **Class B boosters** (wideband).[5] [Order, ¶ 15]

Note also that Consumer Signal Boosters are not defined for PLMRS or PSRS because licensees are considered to operate private services. Part 90 PLMR licensees typically obtain authorizations for individual narrowband channels or groups of channels to satisfy their own communication needs. Moreover, many Part 90 channels are interleaved and a

[4] Industrial Signal Boosters include large, high powered devices intended for professional or enterprise use. These devices tend to have more expansive functionality than Consumer Signal Boosters. For example, unlike Consumer Signal Boosters, many Industrial Signal Boosters incorporate remote monitoring capability to allow the operator to use a graphical user interface to control the device's functions, including remote power control, turn-on, and turn-off. The output power and gain for Industrial Signal Boosters are typically multiple times the power and gain of Consumer Signal Boosters. These devices are designed to serve multiple users simultaneously and cover larger areas such as stadiums, shopping malls, office buildings, tunnels, and campuses. An Industrial Signal Booster installation may support a single wireless provider or multiple wireless providers. In addition, such an installation may utilize a greater number of antennas, amplifiers, and other components, compared to Consumer Signal Boosters. [FCC-13-21, ¶ 16]

[5] FCC Signal Boosters, Part 90 Signal Boosters (http://wireless.fcc.gov/signal-boosters/part-90-boosters/index.html)

licensee's channels may not be adjacent to one another, which presents unique considerations for signal boosters used with Part 90 PLMR services. [Order, ¶ 144]

a) Class A signal booster: A signal booster designed to retransmit signals on one or more specific channels. A signal booster is deemed to be a Class A signal booster if none of its passbands exceed 75 kHz. [§ 90.219(a)]

b) Class B signal booster: A signal booster designed to retransmit any signals within a wide frequency band. A signal booster is deemed to be a Class B signal booster if it has a passband that exceeds 75 kHz. [§ 90.219(a)]

Class B signal boosters may be deployed only at fixed locations; mobile operation of Class B signal boosters is prohibited (after November 1, 2014). [§ 90.219(d)(4)]

Except for signal boosters incorporating distributed antenna systems (DAS) and installed in buildings, the passband of a Class B booster shall not encompass both commercial services (such as ESMR and Cellular Radiotelephone) and Part 90 Land Mobile and Public Safety Services. [§ 90.219(d)(7)]

2.2.2 Distributed Antenna System (DAS) (§ 90.219)

A **Distributed Antenna System (DAS) (§ 90.219)** is a network of spatially separated antenna nodes connected to a common source via a transport medium that provides wireless service within a geographic area or structure. [§ 90.219(a)]

A distributed antenna system (DAS) is a system of spatially separated antennas connected via cables (i.e., coaxial or fiber optic cable) to a signal source, such as a base station or an external antenna capable of communicating with a base station wirelessly. DAS are used to distribute wireless signals through large structures such as skyscrapers, hospitals, hotels, arenas and tunnels where the signal coverage may be lacking or to increase the capacity of the wireless system by achieving channel reuse on a smaller scale. Some DAS configurations may be considered signal boosters when the network of internal antennas achieves communication through the use of an amplifier that is connected to an external antenna that communicates with a base station wirelessly. [Order, APPENDIX B, ¶ 3]

2.3 Booster, Amplifier, Repeater Devices Under Other Licensed Rules

2.3.1 Signal amplifier (Part 90): A device that amplifies radio frequency signals and is connected to a mobile radio transceiver, portable or handset, typically to the antenna connector. Note that a signal amplifier is not the same thing as a signal booster. [§ 90.7]

2.3.2 External radio frequency (RF) power amplifier (Part 97): A device capable of increasing power output when used in conjunction with, but not an integral part of, a transmitter. [97.3; see also 2.815] *Syn.:* ERFPA. {*This paragraph is for background info only, and is not part of FCC-13-21 provisions.*}

2.3.2 In-building radiation systems (Part 22): Supplementary systems comprising low power transmitters, receivers, indoor antennas and/or leaky coaxial cable radiators,

designed to improve service reliability inside buildings or structures located within the service areas of stations in the Public Mobile Services. [§ 22.99] {*This paragraph is for background info only, and is not part of FCC-13-21 provisions.*}

2.3.3 Repeater: A device that retransmits the signals of other stations. Repeaters are different from boosters in that they can include frequency translation and can extend coverage beyond the design of the original base station. A repeater is typically single channel, but can also be multiple channels. [KDB pub. 935210 (Apr. 2007)] {*This paragraph is for background info only, and is not part of FCC-13-21 provisions.*}

2.6.3 Mobile repeater station (Part 90 PLMRS): A mobile station authorized to retransmit automatically on a mobile service frequency, communications to or from hand-carried transmitters; used to extend the communications range of hand-carried units. [§ 90.7, § 90.247]

3 Equipment Authorization System (EAS) Form-731 equipment class designators

Equipment classes to be used for signal booster device applications are shown in the following table.[6] An applicant or agent or test lab should submit a KDB inquiry providing details in case equipment class and/or allowed composite-application conditions are unclear for any specific device.

Table 1 – New and Existing Form-731 Equipment Classes for Licensed-Service Signal Booster and Related Equipment Types

B2W	Part 20 Wideband Consumer Booster (CMRS 22/24/27/90-S)
B2P	Part 20 Provider-Specific Consumer Booster (CMRS 22/24/27/90-S)
B2I	Part 20 Industrial Booster (CMRS 22/24/27/90-S)
B9A	Part 90 Class A Industrial Booster (non-SMR)
B9B	Part 90 Class B Industrial Booster (non-SMR)
BOS	All other signal boosters (other than §§ 20.21, 90.219)
AMP	Amplifier (devices not under Bxx equipment classes)*
PCB	PCS Licensed Transmitter (booster devices not under Bxx equipment classes)*
TNB	Licensed Non-Broadcast Station Transmitter (booster devices not under Bxx equipment classes)*
* Existing equipment classes PCB, TNB may be used for booster devices not subject to rules and polices adopted pursuant to §§ 20.21, 90.219, and FCC 13-21. NOTE 1–Since the early 2000s, FCC OET policy indicated that the equipment class AMP is used for basic unidirectional-path signal amplifier devices, and equipment classes PCB or TNB for all other signal booster and related device types. NOTE 2–In the above, 90-S refers to part 90 subpart S, i.e., ESMR per §§ 90.209(b)(7), 90.614(b),(c).	

Devices with multiple equipment classes – composite applications: FCC OET application filing procedures require more than one Form-731 per FCC ID whenever a device has operations subject to multiple rule parts or rule sections each with different equipment classes; such a multiple-Form-731 FCC ID is known as a composite-system application [§ 2.1033(e)]. For signal booster devices, composite applications with more than one of the equipment classes listed in Table 1 (e.g., B2W and B2P) are not permitted. For booster system devices using a wireless link for system-internal operations (see discussion in Annex A), composite applications are permitted; e.g., 802.11 under part 15, equiment class DTS and/or NII, along with B2P.

[6] The Form-731 equipment class is a three character code which is used by FCC to define a type of equipment and the radio service in which it is used; (https://apps.fcc.gov/oetcf/eas/reports/EquipmentRulesList.cfm). In many cases the rule part and type of operation (i.e. portable, mobile, base station, handheld, etc) can be determined from the equipment class. The equipment class also generally determines the required exhibit types in a Form-731 application [§ 2.1033(c), § 2.911(b)] (https://apps.fcc.gov/oetcf/eas/misc/EasFaq.cfm).

4 Frequency bands for signal boosters under §§ 20.21 and 90.219

Consumer Signal Boosters must be designed and manufactured such that they operate only on the frequencies and rule parts used for the provision of subscriber-based services [§ 20.21(e)(3)], i.e., as listed in the following table.

Table 2 – Frequency Bands (in MHz) for Consumer Signal Booster Equipment Grants

22 (Cellular)	824-849 UL 869-894 DL
24 (Broadband PCS)	1850-1915 UL 1930-1995 DL
27-L (AWS-1)	1710-1755 UL 2110-2155 DL
27 (Lower A-E Blocks)	A 698-704 / 728-734 B 704-710 / 734-740 C 710-716 / 740-746 D 716-722 E 722-728
27 (700 MHz Upper C Block)	746-757 UL 776-787 DL
90 (Specialized Mobile Radio) [a] [90.614(b),(c)]	813.5/817-824 UL 858.5/862-869 DL
[a] Consumer Signal Boosters for operation on Part 90 (Specialized Mobile Radio) frequencies will not be certificated until the FCC releases a Public Notice announcing the date that Consumer Signal Boosters may be used in the band [20.21(e)(3)].	

Form-731 extended frequency listings per the provisions of KDB pub. 634817 are not permitted for Consumer Signal Booster equipment grants.

Industrial Signal Boosters that are to be professionally installed and operated in close coordination with affected licensees will not be limited to specific spectrum bands. [Order, ¶ 36]

Table 3 lists the basic Part 90 PLMRS bands, for reference.[7]

[7] FCC WTB Wireless Services – Industrial/Business (http://wireless.fcc.gov/services/index.htm?job=service_bandplan&id=industrial_business).

Table 3 – Summary of various Part 90 PLMRS band allocations and service types (for info only – refer to rules for details)

F_L (MHz)		F_L (MHz)	Rule(s)
25	–	50	90 (select bands)
72	–	76	90 (select bands)
136	–	150	Not available under 90 subparts B, C land mobile service
150	–	150.05	Federal (non-FCC)
150.05	–	150.8	90.265
150.8	–	162.0125	90
162.0125	–	173.2	90.265
173.2	–	173.4	90
173.4	–	174	Federal (non-FCC)
406.1	–	420	90.265
420	–	421	ULS shows no licensees for 420-420.9 MHz presently
421	–	430	90
430	–	450	Not available under 90 subparts B, C land mobile service
450	–	470	90 (select bands)
470	–	512	90
758	–	768	90-R, Public Safety (PS) Broadband (FirstNet)
768	–	769	PS Guardband
769	–	775	PS Narrowband
788	–	798	90-R, Public Safety (PS) Broadband (FirstNet)
798	–	799	PS Guardband
799	–	805	PS Narrowband
806	–	817	90 NPSPAC, PS, B/ILT, SMR, 90.614(c)
817	–	824	90 ESMR [90.614(b),(c)]
851	–	862	90 NPSPAC, PS, B/ILT, SMR, 90.614(c)
862	–	869	90 ESMR [90.614(b),(c)]

ANNEX A

Booster, Amplifier, and Repeater Device Types and Configurations

A.1 General

This annex gives additional discussion and background information for the terms and definitions used in equipment authorization application processing of licensed-service signal boosters and similar devices.

A.2 Basic device types and configurations

A.2.1 Signal amplifier devices

Figure 1 a) shows a simplified schematic of (single-enclosure) amplifier device. FCC OET policy for equipment application processing has conventionally reserved use of the Form-731 equipment class AMP only for an ERFPA, i.e., a device inserted between a transmitter (i.e., equipment class TNB/PCB; see Section 3 of this document) and an antenna.[8,9] An ERFPA is defined as having only one (i.e., uni-directional) antenna transmit port.

A.2.2 Single-enclosure booster devices

Figure 1 b) shows a simplified schematic of an example single-enclosure consumer booster (Form-731 equipment class B2W or B2P), connecting to a device using either contact/proximity coupling or connection via an RF port/connector. Figure 2 shows a simplified diagram of a basic single-enclosure booster system and the associated basic parameters.

A.2.3 Two-enclosure booster systems

Figure 3 shows a simplified diagram of a basic two-enclosure booster system and associated basic parameters. Example device types include indoor-DAS and outdoor-DAS (see also **2.5** in this document). Another example is a donor/server Consumer Booster system with two non-identical component enclosures, using 802.11 for the system-internal transport link between the donor unit placed near a window and the server unit placed elsewhere in a building for coverage enhancment.

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[8] "There are cases when the unit is not a transmitter or an amplifier. These cases include categories defined as Boosters, Repeaters, Translators and Extenders. We define them as follows: Booster: With antenna input – receives and amplifies on the same frequency – in one direction. Repeater: With antenna input – receives, amplifies and retransmits on a different frequency. (Does not demodulate the signal and retransmit. This would be classified as a transmitter.) Extender: A bi-directional Booster or Repeater. These terms or any other unique equipment description should be entered in the Notes portion of the 731 Form." FCC-TCB conference notes, *TCB OVERVIEW FOR LICENSED DEVICES*, FCC OET Lab (F. Coperich), Dec. 1999.

[9] See footnote 3.

Where donor-side and server-side components (components B, C of Figure 3) are not electrically identical, each component generally is subject to separate / individual equipment authorization. For example, where a donor-side device never connects to an antenna for transmitting over-the-air, then only part 15 subpart B digital device aurthorization might apply. Donor-side and server-side components generally need to tested together as a system, and equipment applications need to describe and address compliance for supported signal and modulation types for each path. The Form-731 "part of a system that operates with, or is marketed with, another device that requires an equipment authorization" needs to be completed as applicable, e.g., when transport link uses proprietary signaling such that each donor or server component operates only with specific associated devices.

One example conventional device type has been a fiber-optic distribution system that receives RF signals from an antenna, distributes the signal over fiber-optic cable, and then retransmits at another location, for example within a building or tunnel. Most fiber-optic systems are signal boosters; however, some may be repeaters (frequency translation). These systems generally have two enclosures typically called host (or local or donor unit) and remote. Some systems may also have an optional expander box for fan-out to multiple remotes. The system transmits downlink signals from the remote unit to handsets, portables, or clients, and transmits uplink signals via the host unit. Usually but not always the uplink goes through an intermediate amplifier to a "donor" antenna. Therefore both uplink and downlink paths must be tested, unless an application filing effectively documents how connection of the uplink to a donor antenna with or without an intermediate amplifier will be prevented; for example always use only a cabled direct connection to a base station. Systems are typically comprised of two or more of the following components: host unit (might be digital device only); remote unit; expansion unit; passive interface unit; active interface unit. [KDB pub. 935210 (Apr. 2007)]

A.3 Figures for Annex A

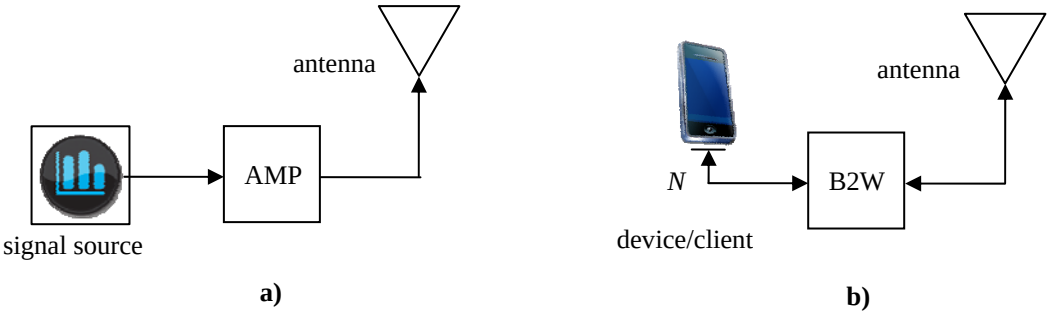
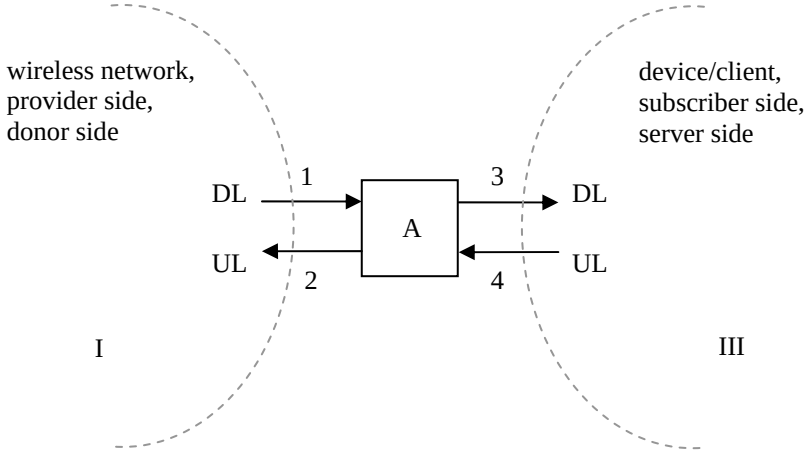


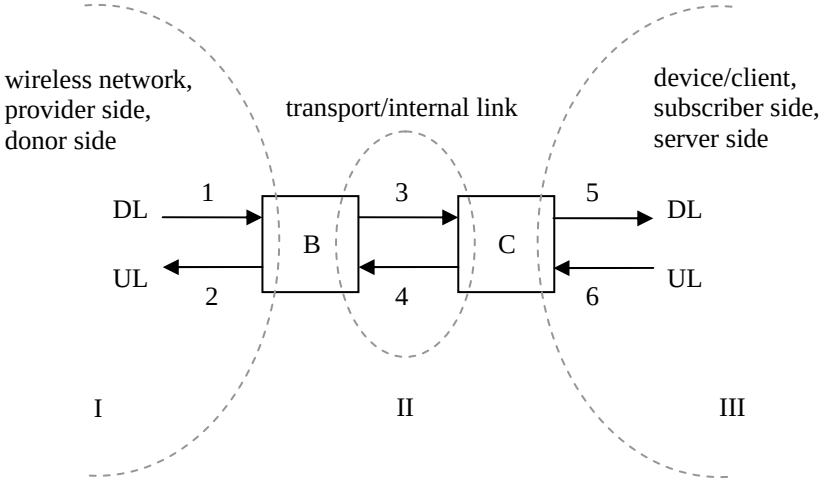
Figure 1–Simplified schematics of: a) single-enclosure amplifier device – Form-731 equipment class AMP; b) single-enclosure consumer booster – Form-731 equipment class B2W or B2P, connecting to a device at node *N* using either contact/proximity coupling or RF-port connection.



KEY:

- A: Single enclosure booster device, with donor-side and server-side ports.
- UL, DL: Uplink (subscriber / mobile station to provider / base station); downlink (provider / base station to subscriber / mobile station).
- 1…4: Signal paths 1,2,3,4 typically are parts 22, 24, 27, 90 paired-band frequencies; each of donor-side and server-side may or may not connect to over-the-air antenna(s).
- I, III: Region I: provider / base-station coverage; Region II: booster internal operations; Region III: subscriber / mobile-station coverage, e.g., indoors, dead spot (§ 22.99).

Figure 2–Simplified schematic of single-enclosure booster device, and signal path and coverage/operations regions geometries



KEY:

- B, C: Donor-side and server-side system components. For this basic configuration, components B,C may or may not be electrically identical. B,C typically are tested together as a system, however generally each may be subject to separate / individual equipment authorization (e.g., separate FCC IDs).
- UL, DL: Uplink (subscriber / mobile station to provider / base station); downlink (provider / base station to subscriber / mobile station).
- Signal paths 1,2,5,6 typically are parts 22, 24, 27, 90 paired-band frequencies; each of donor-side and server-side may or may not connect to over-the-air antenna(s). Signal paths 3,4 are system internal "transport" paths, typically RF-on-fiber-optic or coax cable or over-the-air locally; for the latter two, either on-channel or frequency-shifted.
- I, II, III: Region I: provider / base-station coverage; Region II: booster internal operations; Region III: subscriber / mobile-station coverage, e.g., indoors, dead spot (§ 22.99).

Figure 3–Simplified schematic of two-enclosure booster system, and signal path and coverage/operations regions geometries

ANNEX B

Signal Boosters Terminology and Concepts

NOTE–Appendix B from FCC-13-21 is repeated here for background and convenience.

1. *Signal Booster Basics.* Signal boosters are signal amplifiers that can be deployed in many different configurations to improve the wireless connection between a mobile device and the wireless network. Signal boosters are often used to amplify and distribute wireless signals to areas with poor signal coverage and can expand the area of reliable service to unserved or weak signal areas, including garages, underground transportation systems, and large buildings. Two key variables affect the quality of a wireless connection. The first variable is distance to the nearest cell site or base station. In general, the farther away a cell phone is moved from a cell site, the weaker the signal. The second variable is any physical obstacle between the cell phone and the base station. Natural and man-made obstacles, including terrain and buildings, can block the radio frequency waves, which form the communications link between a cell phone and a base station. In addition, metal, glass, and foliage, while not entirely blocking a signal, can attenuate or reduce the signal.[10] Poor quality signals can lead to dropped calls, slower data speeds, and depleted battery life.

2. *Fixed Signal Boosters.* Signal boosters can be used in a variety of applications, both fixed and mobile. Fixed signal boosters facilitate the use of mobile devices inside homes, buildings, and other structures, such as sports arenas, by amplifying or distributing signals within the structure that would otherwise be too weak to achieve communications. A basic fixed signal booster can serve a single room in a house, while an enhanced booster can serve a multistory building. A typical fixed signal booster configuration includes an outside antenna installed on a roof or side of a building.[11] The outside antenna is connected via coaxial cable to an interior amplifier, which either has a built-in antenna or is connected to one or more interior panel antennas that permit communication with mobile devices in the structure.

3. A distributed antenna system (DAS) is a system of spatially separated antennas connected via cables (*i.e.*, coaxial or fiber optic cable) to a signal source, such as a base station or an external antenna capable of communicating with a base station wirelessly. DAS are used to distribute wireless signals through large structures such as skyscrapers, hospitals, hotels, arenas and tunnels where the signal coverage may be lacking or to increase the capacity of the wireless system by achieving channel reuse on a smaller scale. Some DAS configurations may be considered signal boosters when the network of internal antennas achieves communication through the use of an

[10] *Ex Parte* Letter from Russell D. Lukas to Marlene H. Dortch, Secretary, Federal Communications Commission (May 12, 2010), Attachment *In-Car Cellular Signal Boosters, White Paper Prepared for: Wilson Electronics* at 2.
[11] In consumer applications, the "outside" antenna is often mounted inside a window.

amplifier that is connected to an external antenna that communicates with a base station wirelessly.

4. *Mobile Signal Boosters.* Typically, mobile signal boosters transmit and receive wireless signals to and from a cell phone operated inside a vehicle (*e.g.*, car, boat or RV).[12] A typical mobile signal booster installation consists of an outside antenna attached to the roof of a vehicle, which is connected using coaxial cable to an amplifier and an inside antenna. Depending on the manufacturer and model, a cell phone can connect to the mobile signal booster using an antenna adapter that connects directly to the wireless device, a docking "cradle," or wirelessly.

5. *Problems Encountered with Signal Boosters*. Poorly designed, improperly installed or malfunctioning signal boosters can cause interference to both commercial and public safety wireless networks. Signal boosters can produce "noise,"[13] which has the potential to interfere with wireless networks. This "noise" can take the form of adjacent channel interference, oscillation, or base station receiver overload, which are explained below.

6. *Adjacent Channel Noise (The "Near-Far" Problem).* One "noise" problem that can be created by signal boosters occurs when a subscriber is far from the provider's base station that provides its service, but near a different wireless provider's base station that is using an adjacent frequency block. Many signal boosters are wideband and will amplify any signal within the frequency range or "passband"[14] of the signal booster filter, which could include all of the licensees providing service in that area. Therefore, while the wideband booster would benefit the subscriber installing it, because it will amplify the subscriber's weak signal to a level necessary to achieve communication, it could also harm an adjacent licensee because the booster is amplifying signals or creating noise on the adjacent spectrum block where it is not needed or desired. This scenario is more problematic for wideband mobile signal boosters because a signal booster could be operating with maximum amplification to assist provider "A's" subscriber with a weak signal while driving by provider "B's" base station, generating sufficient noise for provider B's base station to drop communications with its subscribers that may be operating at the fringes of provider B's base station's coverage area.[15] Higher power signal booster operation can thus create the potential for adjacent-channel interference to other wireless providers' base stations that may be nearby if the device is not properly installed or not operating with appropriate safeguards.

[12] We recognize that some consumers may choose to use a mobile booster indoors such as in a home or office.
[13] In radio communications, "noise" refers to any unwanted electromagnetic energy or signal that degrades or obstructs the desired signals.
[14] The passband is the frequency range which the signal booster is designed to amplify.
[15] Digital modulation techniques, especially Code Division Multiple Access (CDMA) rely upon power control of the subscriber units for efficient use. The network will monitor the received power of the subscriber units and send command signals to increase or lower transmitter power to ensure that all subscriber signals arrive at the base stations with similar power levels. If one subscriber's signal is too strong, it reduces the capacity of the system and may result in the base station dropping calls from subscribers that are further away from the base station; this is called cell shrinkage.

7. *Oscillation*. Another type of "noise" signal boosters can create is oscillation (feedback). Oscillation occurs when the signal from the internal antenna of a signal booster reaches the external antenna of the device and generates uncontrollable high level signals.[16] Oscillation can interfere with both the signal from the base station to the wireless device as well as the signal from the wireless device to the base station. As a result, the licensee as well as others operating within the passband frequencies of the signal booster may experience interference. To avoid oscillation, antennas require attenuation (isolation), *i.e.*, vertical and horizontal spacing between the antennas.[17]

8. *Base Station Receiver Overload*. Most wireless networks employ dynamic power control to maximize network capacity. Power control operates by precisely adjusting the power of the base stations and handsets within the network to achieve the optimal signal level for reliable communications. Power control minimizes interference, maximizes handset battery life, and increases the life span of base transceiver station power amplifiers.[18] Typically, signal boosters are not dynamically controlled by the network and thus may continue to amplify a handset's signal even when it is not needed, which may overload the base station. This can apply both to mobile signal boosters that can travel close to a different provider's base stations, as well as fixed signal boosters that are not coordinated with the providers that the booster is capable of affecting. In addition, signal boosters create unique issues for code division multiple access (CDMA) networks. In a CDMA system, to maximize network capacity, wireless providers use power control to ensure that the received power of all subscribers at the base station is at the minimum level needed for reliable communications. The presence of a signal booster within the power control loop of a CDMA system can increase the received power of a subscriber at the base station, which would affect the power control operation of all wireless devices being served by that base station. As a result, the base station receiver may not be able to operate as efficiently as designed, could drop some calls, or could be overloaded,[19] adversely affecting the coverage and capacity of the serving base station as a whole.

[16] This is similar to the noise created when a microphone is placed too close to a speaker.

[17] AT&T explains that its Global System for Mobile Communications (GSM) network interprets an oscillating signal booster signal as external noise and as a result, the network electronically instructs all cell phones being served by that sector to increase power in an effort to overcome the perceived noise. AT&T further explains that this action effectively constricts the coverage of the affected cell site section, which causes cell phones to drop calls and lose coverage. In addition, AT&T notes that this action reduces battery life of the signal booster user's own phone as well as the cell phones of other subscribers whose phones automatically increase power to overcome the interference caused by the signal booster. AT&T PN Comments at 26-27.

[18] A base transceiver station power amplifier amplifies signals at the base station before they are transmitted through the antenna.

[19] Overload occurs when a receiver is unable to reject excessive energy outside its intended frequency band of operation.

ANNEX C

Booster, Amplifier, and Repeater Various Terms and Definitions From Other Sources

NOTE–This annex is for information and background purposes only; these terms and definitions generally are not applicable for FCC equipment authorization application filing purposes. Source citations do not constitute endorsement or adoption by FCC of a document or its contents.

C1. Donor coupling loss: is the coupling loss between the repeater and the donor base station [3GPP TS 36.106]

C.2 Downlink: Signal path where base station transmits and mobile receives. [3GPP TS 36.106]

C.3 Repeater: (A) A device that receives, amplifies and transmits the radiated or conducted RF carrier both in the downlink direction (from the base station to the mobile area) and in the uplink direction (from the mobile to the base station) [3GPP TS 36.106] **(B)** device with two RF ports, both of which are intended to be connected to antennas, which is capable of receiving, amplifying and transmitting simultaneously in one direction a signal in a BSS transmit band and in the other direction a signal in the corresponding BSS receive band [ETSI EN 301 489-50] **(C)** an equipment, essentially including one or more amplifiers and/or regenerators and associated devices, inserted at a point in a transmission medium; Note – A repeater may operate in one or both directions of transmission. [IEV 704-05-01] **(D)** equipment, part of a radio station, which retransmits received signals after amplification and any specified processing, usually with frequency translation [IEV 713-08-05]

C.4 Uplink: Signal path where mobile transmits and base station receives. [3GPP TS 36.106]

C.5 Zone enhancers (aka "booster amplifiers"): are used to improve the quality of a signal in shadowed locations. They are typically installed at locations where the signal strength of the main station, or the ability of the subscriber/mobile radio to communicate with the main station, is significantly impaired due to topography or building losses. Such locations include valleys, parking garages, larger buildings that have been constructed with materials that tend to inhibit radio frequency penetration, and communities located near fringe coverage areas. They can be deployed as part of cellular/personal communication service (PCS), paging or other land mobile systems; however, they are not intelligent devices, as they do not perform signal hand-offs. [CPC-2-1-05]

C.6 Cellular/PCS Mobile Enhancers: Mobile enhancers, also known as in-vehicle cellular amplifiers/repeaters, provide enhanced cellular/PCS signal levels within the confines of a vehicle with no physical connection to the cellular telephone(s) itself. These types of devices utilize two antennas, one external to the vehicle and one internal. The cellular/PCS signal is received by the external antenna, amplified, and then repeated from the internal antenna. Conversely, when the

cellular/PCS telephone(s) transmits, the signal is received by the internal antenna, amplified, and then repeated to the cell site via the external antenna. [CPC-2-1-05]

C.7 radio equipment: equipment which contains Radio digital unit and Radio unit

C.8 radio digital unit: equipment which contains base band and functionality for controlling Radio unit

C.9 radio unit: equipment which contains transmitter and receiver

C.10 distributed base station (DBS): (A) Conventional basestations are located adjacent to the antenna in a small hut at the base of the antenna tower. Finding suitable sites can be a challenge because of the footprint required for the hut, the need for structural reinforcement of rooftops, and the availability of both primary and backup power sources. CPRI (Common Public Radio Interface) allows the use of a distributed architecture where basestations, containing the radio equipment control (REC), are connected to remote radio heads via lossless fibre links that carry the CPRI data. This architecture reduces costs for service providers because only the remote radio heads containing the radio equipment (RE) need to be situated in environmentally challenging locations. The basestations can be centrally located in less challenging locations where footprint, climate, and availability of power are more easily managed. [CPRI Specification V5.0] **(B)** In general mobile radio base stations consist of a BaseBandUnit (BBU) and a Radio Frequency Unit (RFU), which usually is a RemoteRadioHead (RRH) in a distributed base station architecture. [ETSI GS ORI 001]

C.11 signal booster: A stationary device that automatically reradiates signals from base transmitters without channel translation, for the purpose of improving the reliability of existing service by increasing the signal strength in dead spots. [22.99]

C.12 dead spots: Small areas within a service area where the field strength is lower than the minimum level for reliable service. Service within dead spots is presumed. [22.99]

C.13 fill-in transmitters: Transmitters added to a station, in the same area and transmitting on the same channel or channel block as previously authorized transmitters, that do not expand the existing service area, but are established for the purpose of improving reception in dead spots. [22.99]

SOURCES:

3GPP TS 36.106 V10.4.0 (2012-06), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); *FDD Repeater radio transmission and reception (Release 10)*; *ALSO* 3GPP TS 36.143 V10.3.0 (2012-03), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); *FDD repeater conformance testing (Release 10).*

Industry Canada, CPC-2-1-05, *Zone Enhancers*, Spectrum Management and Telecommunications, Client Procedures Circular, Issue 1, April 2008.

ETSI EN 301 489-50 V1.2.1 (2013-03), Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; *Part 50: Specific conditions for Cellular Communication Base Station (BS), repeater and ancillary equipment.*

IEV Online, Electropedia: The World's Online Electrotechnical Vocabulary, (http://www.electropedia.org/).

CPRI Specification V5.0 (2011-09-21), *Common Public Radio Interface (CPRI); Interface Specification*; (http://www.cpri.info/spec.html), also e.g., (http://www.altera.com/technology/high_speed/protocols/cpri/pro-cpri.html).

ETSI GS ORI 001 V1.1.1 (2011-10), Open Radio equipment Interface (ORI); *Requirements for Open Radio equipment Interface (ORI) (Release 1)*.

ANNEX D
FOR INFO ONLY, TO BE OMITTED FROM FINAL KDB PUB.

AMPLIFIER, BOOSTER, AND REPEATER - BASIC ITEMS (KDB Apr. 2007)

This EAB reminder sheet is intended to institute uniform procedures for equipment authorizations of amplifier, booster, and repeater devices. This includes typical in-building radiation systems consisting at a minimum of one host unit and one or more remote units, used to improve service reliability inside buildings or other structures located within particular licensed service areas.

I) EXCERPTS AND DEFINITIONS FROM FCC RULES

Part 2 section 815 External radio frequency power amplifiers.
"(a) As used in this part, an external radio frequency power amplifier is any device which, (1) when used in conjunction with a radio transmitter as a signal source is capable of amplification of that signal, and (2) is not an integral part of a radio transmitter as manufactured."

Part 22
22.377(e) "Transmitters used with in-building radiation systems must be installed such that, to the extent possible, they are readily accessible only to persons authorized by the licensee to access them."

22.383 "Licensees may install and operate in-building radiation systems …"

22.527 "Licensees may install and operate signal boosters …"

22.99 "*Repeater.* A fixed transmitter that retransmits the signals of other stations."

22.99 "*Cellular repeater.* In the Cellular Radiotelephone Service, a stationary transmitter or device that automatically re-radiates the transmissions of base transmitters at a particular cell site and mobile stations communicating with those base transmitters, with or without channel translation."

22.99 "*Signal booster.* A stationary device that automatically reradiates signals from base transmitters without channel translation, for the purpose of improving the reliability of existing service by increasing the signal strength in dead spots."

22.99 "*In-building radiation systems.* Supplementary systems comprising low power transmitters, receivers, indoor antennas and/or leaky coaxial cable radiators, designed to improve service reliability inside buildings or structures located within the service areas of stations in the Public Mobile Services."

Part 90
90.219 – "Licensees authorized to operate radio systems in the frequency bands above 150 MHz may employ signal boosters at fixed locations …"

90.7 "*Mobile repeater station.* A mobile station authorized to retransmit automatically on a mobile service frequency, communications to or from hand-carried transmitters."

90.7 "*Signal booster.* A device at a fixed location which automatically receives, amplifies, and retransmits on a one-way or two-way basis, the signals received from base, fixed, mobile, and portable stations, with no change in frequency or authorized bandwidth. A signal booster may be either narrowband (Class A), in which case the booster amplifies only those discrete frequencies intended to be retransmitted, or broadband (Class B), in which case all signals within the pass-band of the signal booster filter are amplified."

Part 24
No special definitions given – use Part 22 concepts.

II) FIBER-OPTIC AND OTHER SIMILAR RF DISTRIBUTION SYSTEMS

Fiber-optic distribution systems are a type of in-building radiation system that receives RF signals from an antenna, distributes the signal over fiber-optic cable, and then retransmits at another location for example within a building or tunnel. Most fiber-optic systems are signal boosters; however, some may be repeaters. These systems generally have two enclosures typically called host (or local or donor unit) and remote. Some systems may also have an optional expander box for fan-out to multiple remotes. The system transmits downlink signals from the remote unit to handsets, portables, or clients, and transmits uplink signals via from the host unit. Usually but not always the uplink goes through an intermediate amplifier to a "donor" antenna. Therefore both uplink and downlink must be tested, unless filing effectively documents how connection of uplink to donor antenna with or without an intermediate amplifier will be prevented, such as for always only a cabled connection to a base station. Fiber-optic systems are not amplifiers (AMP equipment class) – they are equipment class TNB or PCB. The same approval procedures also apply for multiple-enclosure systems connected by coax cable.

Synonyms and related terms: in-building radiation system, coverage enhancer, distributed antenna system, fiber-optic distribution system, converter, donor antenna

Typical in-building or distributed antenna systems can consist of five different components (enclosures), not counting antennas:

1) host unit
- a) transmits uplink to base station via antenna thru coax, ***passive interface unit*** , or ***active interface unit*** (amplifier)
- b) sends base-station downlink via fiber-optic or coax to ***remote***
- c) receives handset uplink via fiber-optic or coax from ***remote***
- d) optional connection to ***expansion unit*** via fiber-optic
- e) separate FCC ID from ***remote***, unless electrically identical
- f) ***non-transmitting host unit***
  - i) connects directly to a base station via coax cable but does not connect to antenna or amplifier
  - ii) Part 15 digital device subject to Verification, no FCC ID

2) remote unit
- a) receives base-station downlink via fiber-optic or coax from ***host***, transmits via antenna to handsets
- b) returns handset uplink via fiber-optic or coax to ***host***
- c) separate FCC ID from ***remote***, unless electrically identical

3) expansion unit
- a) fiber-optic or coax from ***host***
- b) fiber-optic or coax fan-out to ***remote(s)***
- c) Part 15 digital device subject to Verification, no FCC ID

4) *passive interface unit*
- a) contains attenuators, splitters, combiners
- b) coax cable connection between ***host*** and base-station
- c) passive device, no FCC ID

5) *active interface unit*
- a) amplifies uplink signal from ***host unit*** for transmit by donor antenna
- b) attenuates downlink from donor antenna
- c) coax cable connection between ***host*** and ***active interface unit***
- d) usually has separate FCC ID; in some cases could be combined/included with ***host*** as one enclosure

AMPLIFIER, BOOSTER, AND REPEATER REMINDER SHEET

III) GENERAL DEFINITIONS FOR CERTIFICATION PURPOSES

The following three general definitions follow from those stated in the Part 22, 24, and 90 rule sections as listed above. Two of the definitions replace previous EAB internal definitions given for booster, repeater and extender. The general term "extender" is the same as booster, but booster should be used rather than extender. The general term "translator" is the same as repeater, but repeater should be used rather than translator.

External radio frequency power amplifier (ERFPA) - any device which, (1) when used in conjunction with a radio transmitter signal source, is capable of amplification of that signal, and (2) is not an integral part of a radio transmitter as manufactured. The EAS equipment class AMP is used only for an ERFPA device inserted between a transmitter (TNB/PCB) and an antenna (has only one antenna port)

Booster is a device that automatically reradiates signals from base transmitters without channel translation, for the purpose of improving the reliability of existing service by increasing the signal strength in dead spots. An "in-building radiation system" is a signal booster. These devices are not intended to extend the size of coverage from the originating base station. A booster can be either single or multiple channels***.***

Repeater is a device that retransmits the signals of other stations. Repeaters are different from boosters in that they can include frequency translation and can extend coverage beyond the design of the original base station. A repeater is typically single channel but can also be multiple channels.

ERFPA (AMP) and boosters/repeaters (TNB/PCB) can generally be authorized for all rule parts except 15 and 18.

Tests should be done with each typical signal. e.g., for F3E emissions use 2500 Hz with 2.5 or 5 kHz deviation. Use of CW signal for some tests is acceptable in lieu of actual emission, in some cases when CW signal gives worst case.

IV) REMINDER SHEET ITEMS

[ ] Form 731 entries –

- For ERFPA as defined above
  - In one enclosure
    - Equipment Class – AMP
    - List AMP in frequency tolerance field of Form 731
    - List emission designators without necessary bandwidth (e.g., F3E, F1D)
  - In two enclosures
    - Does not exist (if it does, use same entries as for one enclosure)
- For Booster as defined above
  - In one enclosure
    - Equipment Class – TNB or PCB
    - List AMP in frequency tolerance field of Form 731
    - List emission designators without necessary bandwidth (e.g., F3E, F1D)
    - List in comments field the word “booster”
  - In two enclosures (host/remote)
    - Two separate FCC IDs/applications
    - Equipment Class – TNB or PCB
    - List AMP in frequency tolerance field of Form 731
    - List emission designators without necessary bandwidth (e.g., F3E, F1D)
    - List in comments field the words “Part of booster system used with FCC ID: xxxyyy.” (Where xxxyyy is FCC ID of other TNB or PCB in system).
- For Repeater as defined above
  - In one enclosure
    - Equipment Class – TNB or PCB
    - List AMP in frequency tolerance field of Form 731 if device contains no frequency translation; otherwise, measure frequency tolerance and list.
    - List in comments field the word “repeater”
  - In two enclosures (host/remote)
    - Two separate FCC IDs/applications
    - Equipment Class – TNB or PCB
    - List AMP in frequency tolerance field of Form 731 if device contains no frequency translation; otherwise, measure frequency tolerance and list.
    - List in comments field the words “Part of repeater system used with FCC ID: xxxyyy.” (Where xxxyyy is FCC ID of other TNB or PCB in system).

[ ] Applicable rule part(s) –

- Specific rule part(s) the device will be used with. Verify applicable emission masks etc and if booster rules apply.
- Check to see if frequency and device is licensable in applicable rule part.

[ ] Booster rules – Include exhibit or correspondence showing applicant was informed that boosters must meet all criteria stated in Sections 90.219 and 22.383 for related booster/in-building operations.

[ ] Single or multiple FCC IDs – One FCC ID per transmitter enclosure or rack, not per system.
[ ] Form 731 line items – All transmitters in the device (uplink/downlink) should be listed and tested.
[ ] System operation – When transmitter requires other devices in a system, select Form 731 “Part of system…” checkbox. List FCC IDs of other components. Test with system components if needed. Usually applies for fiber-optic systems. Control of power level is one implication.
[ ] Radiated spurs (enclosure) – Use of CW signal (low, mid. and high freq.) is acceptable rather than all modulations
[ ] Conducted spurs – Test all modulation types [TDMA, CDMA, and FM (covers GSM and F1D)] at low, mid. and high frequency
[ ] Intermodulation –Test all modulation types [TDMA, CDMA, and FM (covers GSM and F1D)]
- CW signal rather than typical signal is acceptable (for FM).
- At maximum drive level, for each modulation: one test with three tones, or two tests (high-, low-band edge) with two tones
- Limit usually is -13dBm conducted.
- Not needed for Single Channel systems.
- Combination of modulation types not needed.

[ ] Occupied bandwidth – Use RBW 300 Hz or 1% RBW. The spectral shape of the output should look similar to input for all modulations.
[ ] Output power –
- Power on Form 731 should be clearly understood as either composite of multi-channels or per carrier. If power is composite include in comments field: "Power output listed is composite for multi-channel operation."
- Check that the input drive level is at maximum input rating and maximum gain settings for all tests. Check both uplink and downlink input levels. See manual or brochures/technical description for maximum rating. May need to check FCC identifier of transmitter used for tests.
- Confirm device cannot operate in saturation. Are there means to control maximum power and to assure linear operation (use in system configuration may be necessary)? How is saturation or over-modulation prevented for pulsed signal inputs?
- Meets power limits of 90.219 for Part 90 booster operations.

[ ] Out of Band Rejection – Test for rejection of out of band signals. Filter freq. response plots are acceptable.

2-11-04/EAB/RF