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Laboratory Division**

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**MEASUREMENTS GUIDANCE FOR INDUSTRIAL AND NON-CONSUMER SIGNAL
BOOSTER, REPEATER, AND AMPLIFIER DEVICES**

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1.0 INTRODUCTION

In Report and Order FCC 13-21 (WT Docket No. 10-4, referred to as “the *Order*”) [R1], the Commission outlines equipment authorization and operational requirements for signal boosters that operate under Parts 20, 22, 24, 27 and 90 of the FCC rules. The *Order* created two classes of signal boosters, Consumer and Industrial, with specific regulatory requirements for each class. Part 90 PLMR signal boosters, a special type of Industrial Boosters, have additional unique requirements as specified in Section 90.219. This document provides a summary of the equipment authorization requirements for industrial and non-consumer amplifiers, boosters, and repeaters as well as acceptable procedures for performing the necessary compliance measurements.

This guidance must be used in conjunction with the most recent version of KDB Publication 935210 D02 [R7], which describes basic administrative and other application content requirements and guidance for these devices (e.g., reporting and labeling requirements). Due to some significant changes relative to the preceding rules and procedures, for devices where the policies and test procedures may not be applicable, manufacturers, test labs, and TCBs are encouraged to submit KDB inquiries to request clarification and guidance before initiating compliance testing or before submitting an application for equipment authorization.

Procedures for compliance measurements on industrial signal boosters operating under Sections 20.21 and 90.219 are also provided in Clause 7 of ANSI C63.26-2015 [R12]. As part of the rule changes adopted by the *First Report and Order* FCC 17-93 (docket no. 15-170) [R13], Sections 2.910(c) and 2.1041 were amended to include ANSI C63.26-2015 as an acceptable measurement procedures standard for equipment that operates in authorized radio services covered by its scope, where compliance measurements are required per Sections 2.1046, 2.1047, 2.1049, 2.1051, 2.1053, 2.1055, 2.1057, also 2.911(c).¹ KDB Publications 935210 D05 served as a basis for and was developed concurrently with the

¹ ANSI C63.26-2015 was developed by ANSI-Accredited Standards Committee (ASC) C63® to provide equipment authorization applicants, manufacturers, and test laboratories with uniform, reliable, and consistent measurement

ANSI C63.26 measurement procedures, and as such each provides pertinent guidance for performing compliance measurements for signal boosters operating under Sections 20.21 and 90.219.² As a companion document for use along with ANSI C63.26-2015, KDB Publication 935210 D05 provides rule section numbers and other information about FCC rules, policies, and procedures that is otherwise generally not part of the normative text in documents developed by the Accredited Standards Committee (ASC) C63[®]—Electromagnetic Compatibility (EMC).

2.0 MEASUREMENT EQUIPMENT REQUIREMENTS FOR AMPLIFIER/BOOSTER TESTING

Basic guidance for measurement instrumentation and accessories is given in the following paragraphs. Instrumentation recommendations are also available, for example, in KDB Publication 971168 [R8], TIA-102.CAAA-D [R9], and TIA-603-D [R11].

2.1 Spectrum analyzer, signal analyzer, or EMI receiver

Most of the measurement procedures provided in this document presume the use of a spectrum/signal analyzer or an EMI receiver with similar capabilities. Such measurement instrumentation must provide the following minimum capabilities:

- a) a tuning range that will permit measurements over the frequency ranges to be investigated (including unwanted emissions),
- b) a power averaging (rms) detector,
- c) a positive peak power detector,
- d) a trace averaging mode (i.e., capability to average over multiple measurement traces),
- e) a maximum hold (max hold) mode,
- f) an integrated power function (e.g., band or channel power),
- g) a burst power measurement capability.

2.2 Signal generator

Several of the technical requirements are expressed such that one or more input signals are required when collecting the data necessary to demonstrate compliance (e.g., intermodulation tests). Thus, the capability to generate a minimum of two separate signal paths may be required (two independent signal generators or one signal generator with separately-controlled dual outputs). The signal generator(s) must have the following minimum capabilities:

- a) Tuning range that completely encompasses the operational frequency ranges of the amplifier/booster (e.g., 100 kHz to 3 GHz),
- b) Nominal output power range of -103 dBm to +20 dBm,
- c) Ability to replicate CMRS signal types GSM, CDMA, W-CDMA (LTE is optional) with a pseudo-random symbol pattern,
- d) Ability to replicate PLMRS signal types (e.g., P25 Phase 1, P25 Phase 2, TETRA),
- e) Ability to generate CW tones and band-limited AWGN.

procedures necessary to demonstrate that transmitters used in licensed radio services comply with FCC's technical requirements. ASC C63[®] is a standards development organization that includes participants from the wireless industry, test laboratories, and regulators. At present ASC C63[®] has an open project for developing various updates of ANSI C63.26; information is available at: (http://www.c63.org/documents/misc/matrix/c63_standards.htm).

² Applicants, test labs, and TCBS are requested to submit a KDB inquiry requesting guidance in case unclear or inconsistent provisions are found between ANSI C63.26-2015 and KDB Publication 935210.

2.3 RF network analyzer

Used to characterize the relative gains, losses, and/or VSWR associated with passive networks, active devices, and signal propagation paths. Must have a frequency range suitable for the network, device or system being characterized. Must have the same characteristic impedance (typically 50 Ω) as the network, device, or system being characterized.

2.4 RF step attenuators

Some tests will require that the requisite input signal power be stepped over a specified range of values. This is typically accomplished by utilizing external RF step attenuators inserted into the input signal path. The resolution of the measurement steps may require the use of a combination of linear step attenuators to provide at least 0 dB to 70 dB of attenuation in 10 dB steps, 0 dB to 10 dB of attenuation in 1 dB steps, and 0 dB to 1 dB in 0.1 dB steps.

2.5 RF combiner and directional coupler

Several of the measurement procedures presented herein will require that input signals be combined (e.g., intermodulation test) or that output signals be differentiated at a common port (e.g., noise and variable gain tests). The RF combiners and directional couplers necessary to accomplish this shall be rated to cover the frequency band under test and rated for coupled and output power levels from the EUT. RF directional couplers must provide a minimum of 10 dB of coupling loss.

2.6 RF filters

Some of the measurement procedures may require that RF filtering (band pass and/or band notch) be applied to enable measuring a desired signal level in the presence of an introduced undesired signal. Tunable filters are recommended and the specific tuning ranges should be commensurate with the operational frequency range capabilities of the signal booster under test. All RF filters shall be rated for at least 1 W of input power.

2.7 RF cables and adapters

All RF cables and adapters used in the measurements described herein shall be rated for the appropriate frequency and power ranges and must be impedance-matched (VSWR \leq 1.5:1) with respect to the booster under test.

3.0 TEST METHODS FOR CMRS NON-CONSUMER REPEATER/AMPLIFIER AND INDUSTRIAL BOOSTER DEVICES

3.1 General

Commercial Mobile Radio Services (CMRS) non-consumer RF repeaters, amplifiers, and industrial boosters shall be tested for compliance with the applicable regulatory technical requirements. Input and output power and emissions measurements must be performed using test signals that are intended to bound the typical signal space encountered within the CMRS bands. Broadband amplifiers/boosters shall be tested using a representative band-limited AWGN signal. The AWGN test signal must have a 4.1 MHz 99 % occupied bandwidth (OBW) (representative of a 5 MHz LTE channel). Narrowband test signals shall use a representative MSK modulated signal, with a Gaussian Filter of 0.3 and a data rate of 270 kbps (representative of a GSM-TDMA signal).

3.2 Measuring AGC threshold level

The AGC threshold is to be determined as follows.³

In the case of fiber-optic distribution systems, the RF input port of the equipment under test (EUT) refers to the RF input of the supporting equipment RF to optical convertor; see also descriptions and diagrams for typical DAS booster systems in KDB Publication 935210 D02 [R7].

Devices intended to be directly connected to an RF source (donor port) only need to be evaluated for any over-the-air transmit paths.

- a) Connect a signal generator to the input of the EUT.
- b) Connect a spectrum analyzer or power meter to the output of the EUT using appropriate attenuation as necessary.
- c) The signal generator should initially be configured to produce either of the required test signals (i.e., broadband or narrowband).
- d) Set the signal generator frequency to the center frequency of the EUT operating band.
- e) While monitoring the output power of the EUT, measured using the methods of 3.5.3 or 3.5.4, increase the input level until a 1 dB increase in the input signal power no longer causes a 1 dB increase in the output signal power.
- f) Record this level as the AGC threshold level.
- g) Repeat the procedure with the remaining test signal.

3.3 Out-of-band rejection

A signal booster shall reject amplification of other signals outside of its passband. Adjust the internal gain control of the EUT (if so equipped) to the maximum gain for which equipment certification is sought.

- a) Connect a signal generator to the input of the EUT.
- b) Configure a swept CW signal with the following parameters:
 - 1) Frequency range = ± 250 % of the passband, for each applicable CMRS band (see also KDB Publication 935210 D02 [R7] and KDB Publication 634817 [R5] about selection of frequencies for testing and for grant listings).
 - 2) Level = a sufficient level to affirm that the out-of-band rejection is > 20 dB above the noise floor and will not engage the AGC during the entire sweep.
 - 3) Dwell time = approximately 10 ms.
 - 4) Number of points = $\text{SPAN}/(\text{RBW}/2)$.
- c) Connect a spectrum analyzer to the output of the EUT using appropriate attenuation.
- d) Set the span of the spectrum analyzer to the same as the frequency range of the signal generator.
- e) Set the resolution bandwidth (RBW) of the spectrum analyzer to be 1 % to 5 % of the EUT passband, and the video bandwidth (VBW) shall be set to $\geq 3 \times \text{RBW}$.
- f) Set the detector to Peak Max-Hold and wait for the spectrum analyzer's spectral display to fill.
- g) Place a marker to the peak of the frequency response and record this frequency as f_0 .

³ Consistent with for example TIA-156 [R10], for compliance testing purposes the terms automatic gain control (AGC), automatic level control (ALC), and output level control (OLC) are generally taken to be synonyms, which refer to a means by which gain or output power is electronically adjusted as a function of voltage or some other specified parameter(s).

- h) Place two markers, one at the lowest and the other at the highest frequency of the envelope of the spectral display, such that each marker is at or slightly below the -20 dB down amplitude, to determine the 20 dB bandwidth.
- i) Capture the frequency response of the EUT.
- j) Repeat for all frequency bands applicable for use by the EUT.

3.4 Input-versus-output signal comparison

A 26 dB bandwidth measurement shall be performed on the input signal and the output signal; alternatively, the 99% OBW can be measured and used. See KDB Publication 971168 [R8] for more information on measuring OBW.

- a) Connect a signal generator to the input of the EUT.
- b) Configure the signal generator to transmit the AWGN signal.
- c) Configure the signal amplitude to be just below the AGC threshold level (see 3.2), but not more than 0.5 dB below.
- d) Connect a spectrum analyzer to the output of the EUT using appropriate attenuation.
- e) Set the spectrum analyzer center frequency to the center frequency of the operational band under test. The span range of the spectrum analyzer shall be between $2 \times$ to $5 \times$ the emission bandwidth (EBW) or alternatively, the OBW.
- f) The nominal RBW shall be in the range of 1 % to 5 % of the anticipated OBW, and the VBW shall be $\geq 3 \times$ RBW.
- g) Set the reference level of the instrument as required to preclude the signal from exceeding the maximum spectrum analyzer input mixer level for linear operation. In general, the peak of the spectral envelope must be more than $[10 \log (\text{OBW} / \text{RBW})]$ below the reference level. Steps f) and g) may require iteration to enable adjustments within the specified tolerances.
- h) The noise floor of the spectrum analyzer at the selected RBW shall be at least 36 dB below the reference level.
- i) Set spectrum analyzer detection function to positive peak.
- j) Set the trace mode to max hold.
- k) Determine the reference value: Allow the trace to stabilize. Set the spectrum analyzer marker to the highest amplitude level of the displayed trace (this is the reference value) and record the associated frequency.
- l) Place two markers, one at the lowest and the other at the highest frequency of the envelope of the spectral display, such that each marker is at or slightly below the -26 dB down amplitude. The 26 dB EBW (alternatively OBW) is the positive frequency difference between the two markers. If the spectral envelope crosses the -26 dB down amplitude at multiple points, the lowest or highest frequency shall be selected as the frequencies that are the furthest removed from the center frequency at which the spectral envelope crosses the -26 dB down amplitude point.
- m) Repeat steps e) to l) with the input signal connected directly to the spectrum analyzer (i.e., input signal measurement).
- n) Compare the spectral plot of the input signal (determined from step m) to the output signal (determined from step l) to affirm that they are similar (in passband and rolloff characteristic features and relative spectral locations), and include plot(s) and descriptions in test report.
- o) Repeat the procedure [steps e) to n)] with the input signal amplitude set to 3 dB above the AGC threshold.
- p) Repeat steps e) to o) with the signal generator set to the narrowband signal.
- q) Repeat steps e) to p) for all frequency bands authorized for use by the EUT.

3.5 Mean output power and amplifier/booster gain

3.5.1 General

The guidance in the following subclauses is provided for performing the measurement of mean input and output power of a CMRS non-consumer amplifier, repeater, or industrial booster, to compute the gain of the device.

- a) Adjust the internal gain control of the EUT to the maximum gain for which the equipment certification is being sought. Any EUT attenuation settings shall be set to their minimum value.
- b) Input power levels (uplink and downlink) should be set to maximum input ratings while confirming that the device is not capable of operating in saturation (non-linear mode) at the rated input levels, including during the performance of the input/output power measurements.

3.5.2 Measuring the EUT mean input and output power

- a) Connect a signal generator to the input of the EUT.
- b) Configure to generate the AWGN (broadband) test signal.
- c) The frequency of the signal generator shall be set to the frequency f_0 as determined from 3.3.
- d) Connect a spectrum analyzer or power meter to the output of the EUT using appropriate attenuation as necessary.
- e) Set the signal generator output power to a level that produces an EUT output level that is just below the AGC threshold (see 3.2), but not more than 0.5 dB below.
- f) Measure and record the output power of the EUT; use 3.5.3 or 3.5.4 for power measurement.
- g) Remove the EUT from the measurement setup. Using the same signal generator settings, repeat the power measurement at the signal generator port, which was used as the input signal to the EUT, and record as the input power. EUT gain may be calculated as described in 3.5.5.
- h) Repeat steps f) and g) with input signal amplitude set to 3 dB above the AGC threshold level.
- i) Repeat steps e) to h) with the narrowband test signal.
- j) Repeat steps e) to i) for all frequency bands authorized for use by the EUT.

3.5.3 Power measurement Method 1: using a spectrum or signal analyzer

Guidance for performing input/output power measurements using a spectrum or signal analyzer is provided in KDB Publication 971168 [R8].

3.5.4 Power measurement Method 2: using a power meter

As an alternative to measuring input and output power levels with a spectrum or signal analyzer, a broadband RF power meter may be used with appropriate detector, as specified in KDB Publication 971168 [R8].

3.5.5 Calculating the mean gain of the CMRS non-consumer amplifier, repeater, or industrial booster

NOTE—Sections 20.21 and 2.1033(c) do not require gain test data; inclusion of industrial booster gain test data in test reports submitted for FCC equipment authorization is optional.

After the mean input and output power levels have been measured as described in the preceding subclauses, the mean gain of the EUT can be determined from:

Gain (dB) = output power (dBm) – input power (dBm).

Report the mean gain for each authorized operating frequency band and each test signal stimulus.

3.6 Measuring out-of-band/out-of-block (including intermodulation) emissions and spurious emissions

3.6.1 General

Refer to the applicable rule part(s) for specified limits on unwanted (out-of-band/out-of-block and spurious) emissions.

Spurious emissions shall be measured using a single test signal sequentially tuned to the low, middle, and high channels or frequencies within each authorized frequency band of operation.

Out-of-band/out-of-block emissions (including intermodulation products) shall be measured under each of the following two stimulus conditions:

- a) two adjacent test signals sequentially tuned to the lower and upper frequency band/block edges;
- b) a single test signal, sequentially tuned to the lowest and highest frequencies or channels within the frequency band/block under examination.

NOTE—Single-channel boosters that cannot accommodate two simultaneous signals within the passband may be excluded from the test stipulated in step a).

3.6.2 Out-of-band/out-of-block emissions conducted measurements

- a) Connect a signal generator to the input of the EUT.
If the signal generator is not capable of generating two modulated carriers simultaneously, then two discrete signal generators can be connected with an appropriate combining network to support this two-signal test.
- b) Set the signal generator to produce two AWGN signals as previously described (e.g., 4.1 MHz OBW). Set the signal generator amplitudes so that the power from each into the EUT is equivalent.
- c) Set the center frequencies such that the AWGN signals occupy adjacent channels, as defined by industry standards such as 3GPP or 3GPP2, at the upper edge of the frequency band or block under test.
- d) Set the composite power levels such that the input signal is just below the AGC threshold (see 3.2), but not more than 0.5 dB below. The composite power can be measured using the procedures provided in KDB Publication 971168 [R8], but it will be necessary to expand the power integration bandwidth so as to include both of the transmit channels. Alternatively, the composite power can be measured using an average power meter as described in KDB Publication 971168 [R8].
- e) Connect a spectrum analyzer to the output of the EUT using appropriate attenuation as necessary.
- f) Set the RBW = reference bandwidth in the applicable rule section for the supported frequency band (typically 1 % of the EBW or 100 kHz or 1 MHz)
- g) Set the VBW = 3 × RBW.
- h) Set the detector to power averaging (rms) detector.
- i) Set the Sweep time = auto-couple.
- j) Set the spectrum analyzer start frequency to the upper block edge frequency, and the stop frequency to the upper block edge frequency plus 300 kHz or 3 MHz, for frequencies below and above 1 GHz, respectively.
- k) Trace average at least 100 traces in power averaging (rms) mode.
- l) Use the marker function to find the maximum power level.

- m) Capture the spectrum analyzer trace of the power level for inclusion in the test report.
- n) Repeat steps k) to m) with the composite input power level set to 3 dB above the AGC threshold.
- o) Reset the frequencies of the input signals to the lower edge of the frequency block or band under test.
- p) Reset the spectrum analyzer start frequency to the lower block edge frequency minus 300 kHz or 3 MHz, for frequencies below and above 1 GHz, respectively, and the stop frequency to the lower band or block edge frequency.
- q) Repeat steps k) to n).
- r) Repeat steps a) to q) with the signal generator configured for a single test signal tuned as close as possible to the block edges.
- s) Repeat steps a) to r) with the narrowband test signal.
- t) Repeat steps a) to s) for all authorized frequency bands or blocks used by the EUT.

3.6.3 Spurious emissions conducted measurements

- a) Connect a signal generator to the input of the EUT.
- b) Set the signal generator to produce the broadband test signal as previously described (i.e., 4.1 MHz OBW AWGN).
- c) Set the center frequency of the test signal to the lowest available channel within the frequency band or block.
- d) Set the EUT input power to a level that is just below the AGC threshold (see 3.2), but not more than 0.5 dB below.
- e) Connect a spectrum analyzer to the output of the EUT using appropriate attenuation as necessary.
- f) Set the RBW = reference bandwidth in the applicable rule section for the supported frequency band of operation (e.g., reference bandwidth is typically 100 kHz or 1 MHz).
- g) Set the VBW $\geq 3 \times$ RBW.
- h) Set the Sweep time = auto-couple.
- i) Set the spectrum analyzer start frequency to the lowest RF signal generated in the equipment, without going below 9 kHz, and the stop frequency to the lower band/block edge frequency minus 100 kHz or 1 MHz, as specified in the applicable rule part.
The number of measurement points in each sweep must be $\geq (2 \times \text{span}/\text{RBW})$, which may require that the measurement range defined by the start and stop frequencies be subdivided, depending on the available number of measurement points provided by the spectrum analyzer.⁴
- j) Select the power averaging (rms) detector function.
- k) Trace average at least 10 traces in power averaging (rms) mode.
- l) Use the peak marker function to identify the highest amplitude level over each measured frequency range. Record the frequency and amplitude and capture a plot for inclusion in the test report.
- m) Reset the spectrum analyzer start frequency to the upper band/block edge frequency plus 100 kHz or 1 MHz, as specified in the applicable rule part, and the spectrum analyzer stop frequency to $10 \times$ the highest frequency of the fundamental emission (see Section 2.1057). The number of measurement points in each sweep must be $\geq (2 \times \text{span}/\text{RBW})$, which may require that the measurement range

⁴ A general rule-of-thumb is that when an power averaging (rms) detector is specified, it is optional to use a positive peak detector under the premise that peak-detected power measurements will always result in levels that are greater than or equal to those obtained with an average detector (i.e., the results will be conservative). The tradeoff for the simplicity of using a peak detector is that the results can demonstrate up to 10 dB or more of margin relative to the average measurement for noise-like signals, which sometimes can make a difference between passing or failing a test. It can be more efficient to perform a first measurement with a peak detector, and then for any emissions identified as non-compliant, repeat the measurement with a power averaging (rms) detector over a smaller frequency span for which the number of measurement points will satisfy the requirement. Other information is given in KDB Publication 971168.

defined by the start and stop frequencies be subdivided, depending on the available number of measurement points provided by the spectrum analyzer.

- n) Trace average at least 10 traces in power averaging (rms) mode.
- o) Use the peak marker function to identify the highest amplitude level over each of the measured frequency ranges. Record the frequency and amplitude and capture a plot for inclusion in the test report; also provide tabular data, if required.
- p) Repeat steps i) to o) with the input test signals firstly tuned to a middle band/block frequency/channel, and then tuned to a high band/block frequency/channel.
- q) Repeat steps c) to p) with the narrowband test signal.
- r) Repeat steps b) to q) for all authorized frequency bands/blocks used by the EUT.

3.7 Frequency stability measurements

Frequency stability measurements are required by Section 2.1055 of the FCC rules. However, this requirement presumes that the EUT processes an input signal in a manner that can influence the output signal frequency/frequencies (i.e., most signal boosters do not incorporate an oscillator). If this is not the case (i.e., the amplifier, booster, or repeater does not alter the input signal in any way), then a frequency stability test may not be required.

When performing frequency stability measurements on these types of devices, the instability associated with the EUT must be isolated from any frequency instability associated with the measurement instrumentation. One method for realizing this isolation is to connect the reference clock input of the signal generator to the reference output of the frequency counter to confirm that any frequency instability is associated with the EUT, but is not due to differences between the reference oscillators internal to the measurement instrumentation.

3.8 Spurious emissions radiated measurements

This measurement is intended to produce test data necessary to demonstrate compliance to the radiated spurious emission requirements specified in Section 2.1053 of the FCC rules. This test is intended to capture any emissions that radiate directly from the case, cabinet, control circuits, etc., instead of via the antenna output port, and thus would not be captured in conducted spurious emission measurements. See KDB Publication 971168 [R8] for measurement procedure guidance.

4.0 TEST METHODS FOR PLMRS/PSRS REPEATER/AMPLIFIER AND INDUSTRIAL BOOSTER DEVICES

4.1 General

The procedures in this clause are specific to EUTs intended for operating in the Private Land Mobile Radio Services (PLMRS) and Public Safety Radio Services (PSRS)⁵, which are governed under the provisions and requirements of the Part 90 rules (i.e., Section 90.219 applies).

Table 1 depicts signal types associated with PLMRS operations, which are to be considered as test signals to be used in performing compliance testing on PLMRS amplifiers, repeaters, and industrial boosters. Not all of the procedures in this clause will require using each of the signals listed in Table 1, because for

⁵ As explained in § 90.16, Public Safety Radio Services is part of the Public Safety Radio Pool, also known as the Public Safety Pool.

many EUTs a CW tone can adequately model the narrowband signals typically encountered within these services. For EUTs supporting digitally modulated signals, the intended operating signal types should be tested (e.g., P25 Phase 1, P25 Phase 2, TETRA, etc.), especially for PSRS devices. Devices intended for use in 700 MHz Public Safety Broadband spectrum shall be tested using a representative band-limited AWGN signal (99 % OBW of 4.1 MHz) or the applicable signal type (e.g., LTE).

Table 1—Test signals for PLMRS devices

Emission Designator	Modulation	Occupied Bandwidth	Channel Bandwidth	Audio Frequency
16K0F3E	FM	16 kHz	25 kHz	1 kHz
11K3F3E	FM	11.3 kHz	12.5 kHz	1 kHz
4K00F1E	FM	4 kHz	6.25 kHz	1 kHz
N/A	CW	N/A	N/A	N/A

4.2 Measuring AGC threshold

Testing at and above the AGC threshold will be required.⁶ The AGC threshold shall be determined by applying the procedure of 3.2, but with the signal generator configured to produce a test signal defined in Table 1, a CW input signal, or a digitally modulated signal, consistent with the discussion about signal types in 4.1.

4.3 Out-of-band rejection

A signal booster shall reject amplification of other signals outside of its passband. Adjust the internal gain control of the EUT to the maximum gain for which equipment certification is sought.

- a) Connect a signal generator to the input of the EUT.
- b) Configure a swept CW signal with the following parameters:
 - 1) Frequency range = ± 250 % of the manufacturer's specified pass band.
 - 2) The CW amplitude shall be 3 dB below the AGC threshold (see 4.2), and shall not activate the AGC threshold throughout the test.
 - 3) Dwell time = approximately 10 ms.
 - 4) Frequency step = 50 kHz.
- c) Connect a spectrum analyzer to the output of the EUT using appropriate attenuation.
- d) Set the RBW of the spectrum analyzer to between 1 % and 5 % of the manufacturer's rated passband, and VBW = $3 \times$ RBW.
- e) Set the detector to Peak and the trace to Max-Hold.
- f) After the trace is completely filled, place a marker at the peak amplitude, which is designated as f_0 , and with two additional markers (use the marker-delta method) at the 20 dB bandwidth (i.e., at the points where the level has fallen by 20 dB).
- g) Capture the frequency response plot for inclusion in the test report.

4.4 Input-versus-output signal comparison

Compliance with the emission mask of the EUT output shall be measured for the public safety service signal types as specified in 4.1.

⁶ See footnote 1 about the terms and concepts AGC, ALC, OLC.

Refer to the applicable regulatory requirements (e.g., Section 90.210) for emission mask specifications.

- a) Connect a signal generator to the input of the EUT.
- b) Configure the signal generator to transmit the appropriate test signal associated with the public safety emission designation (see Table 1).
- c) Configure the signal level to be just below the AGC threshold (see results from 4.2).
- d) Connect a spectrum analyzer to the output of the EUT using appropriate attenuation as necessary.
- e) Set the spectrum analyzer center frequency to the nominal EUT channel center frequency. The span range for the spectrum analyzer shall be between $2 \times$ to $5 \times$ the EBW (or OBW).
- f) The nominal RBW shall be 300 Hz for 16K0F3E, and 100 Hz for all other emissions types.
- g) Set the reference level of the spectrum analyzer to accommodate the maximum input amplitude level, i.e., the level at f_0 per 4.3.
- h) Set spectrum analyzer detection mode to peak, and trace mode to max hold.
- i) Allow the trace to fully stabilize.
- j) Confirm that the signal is contained within the appropriate emissions mask.
- k) Use the marker function to determine the maximum emission level and record the associated frequency.
- l) Capture the emissions mask plot for inclusion in the test report (output signal spectra).
- m) Measure the EUT input signal power (signal generator output signal) directly from the signal generator using power measurement guidance provided in KDB Publication 971168 [R8] (input signal spectra).
- n) Compare the spectral plot of the output signal (determined in step k), to the input signal (determined in step l) to affirm they are similar (in passband and rolloff characteristic features and relative spectral locations).
- o) Repeat steps d) to n) with the input signal amplitude set 3 dB above the AGC threshold.
- p) Repeat steps b) to o) for all authorized operational bands and emissions types (see applicable regulatory specifications, e.g., Section 90.210).
- q) Include all accumulated spectral plots depicting EUT input signal and EUT output signal in the test report, and note any observed dissimilarities.

4.5 Input/output power and amplifier/booster gain

4.5.1 General

The following guidance is provided for performing measurements of mean input power and output power of a PLMRS and/or PSRS amplifier repeater, or industrial booster, to facilitate computing the gain of the device.

Adjust the internal gain control of the EUT to the maximum gain for which the equipment certification is being sought. Any EUT attenuation settings shall be set to their minimum value.

Input power levels (uplink and downlink) should be set to maximum input ratings, while confirming that the device is not capable of operating in saturation (non-linear mode) at the rated input levels, including during the performance of the input/output power measurements.

4.5.2 Measuring input and output power levels for determining amplifier/booster gain

Apply the same guidance as in 3.5.2 to measure the maximum input and output power levels necessary for computing the mean EUT gain, but with the following modifications:

- a) Configure the signal generator for CW operation, instead of AWGN,
- b) Select the spectrum analyzer positive peak detector, instead of the power averaging (rms) detector,
- c) Activate the max hold function, instead of the trace averaging function,
- d) Use in conjunction with the guidance in 4.5.3.

4.5.3 Power measurement Method 1: using a spectrum or signal analyzer

- a) Set the frequency span to at least 1 MHz.
- b) Set RBW = 100 kHz.
- c) Set VBW $\geq 3 \times$ RBW.
- d) Set the detector to PEAK, and trace mode to MAX HOLD.
- e) Place a marker on the peak of the signal, and record the value as the maximum power.
- f) Repeat step e) but with the EUT in place.
- g) EUT gain may be calculated as described in 4.5.5.

4.5.4 Power measurement Method 2: using a power meter

As an alternative to measuring the input and output power levels with a spectrum or signal analyzer, a broadband RF power meter may be used with an appropriate detector. EUT gain may be calculated as described in 4.5.5.

4.5.5 Calculating amplifier, repeater, or industrial booster gain

NOTE—Sections 90.219 and 2.1033(c) do not require gain test data; inclusion of industrial booster gain test data in test reports submitted for FCC equipment authorization is optional.

After the input and output power levels have been measured as described in the preceding subclauses, the gain of the EUT can be determined from:

$$\text{Gain (dB)} = \text{output power (dBm)} - \text{input power (dBm)}.$$

Report the gain for each authorized operating frequency band, and each test signal stimulus.

4.6 Noise figure measurements

Section 90.219(e)(2) limits the noise figure of a signal booster to ≤ 9 dB in either direction. The following discussion provides guidance for demonstrating compliance with this requirement.

Several widely recognized methods for performing noise figure measurements are available. Some require the use of specialized equipment, such as a noise figure analyzer and/or an excess noise ratio (ENR) calibrated noise source, while others involve the use of conventional measurement instrumentation such as a spectrum analyzer. Methods that require use of a noise figure analyzer are generally accepted as producing the most accurate results, and are considered to be the reference method within this document, while others are considered to be acceptable alternative methods. Consult the relevant instrumentation application notes for detailed guidance regarding the selection and application of an appropriate methodology for performing noise figure measurements. Note also that noise figure measurements require that any AGC circuitry be disabled over the duration of the measurement.

4.7 Measuring out-of-band/out-of-block (including intermodulation) and spurious emissions

4.7.1 General

Refer to the applicable rule part(s) for specified limits on unwanted (out-of-band/out-of-block and spurious) emissions (e.g., Section 90.210).

Spurious emissions shall be measured using a single test signal sequentially tuned to the low, middle, and high channels or frequencies within each authorized frequency band of operation.

Intermodulation products shall be measured using two CW signals with all available channel spacings (e.g., 12.5 kHz and 6.25 kHz) with the center between these channels being equal to the center frequency f_0 as determined from 4.3.

NOTE—Intermodulation-product spurious emission measurements are not required for single-channel boosters that cannot accommodate two simultaneous signals within the passband.

4.7.2 Out-of-band/out-of-block emissions conducted measurements

- a) Connect a signal generator to the input of the EUT.
If the signal generator is not capable of producing two independent modulated carriers simultaneously, then two discrete signal generators can be connected, with an appropriate combining network to support the two-signal test.
- b) Configure the two signal generators to produce CW on frequencies spaced consistent with 4.7.1, with amplitude levels set to just below the AGC threshold (see 4.2). Set the signal generator amplitudes so that the power from each into the EUT is equivalent.
- c) Connect a spectrum analyzer to the EUT output.
- d) Set the span to 100 kHz.
- e) Set $RBW = 300 \text{ Hz}$ with $VBW \geq 3 \times RBW$.
- f) Set the detector to power averaging (rms).
- g) Place a marker on highest intermodulation product amplitude.
- h) Capture the plot for inclusion in the test report.
- i) Repeat steps c) to h) with the composite input power level set to 3 dB above the AGC threshold.
- j) Repeat steps b) to i) for all operational bands.

4.7.3 EUT spurious emissions conducted measurements

- a) Connect a signal generator to the input of the EUT.
- b) Configure the signal generator to produce a CW signal.
- c) Set the frequency of the CW signal to the center channel of the EUT passband.
- d) Set the output power level so that the resultant signal is just below the AGC threshold (see 4.2).
- e) Connect a spectrum analyzer to the output of the EUT, using appropriate attenuation as necessary.
- f) Set the $RBW = 100 \text{ kHz}$. (i.e., for 30 MHz to 1 GHz PLMRS and/or PSRS booster devices)
- g) Set the $VBW = 3 \times RBW$.
- h) Set the Sweep time = auto-couple.
- i) Set the detector to PEAK.
- j) Set the spectrum analyzer start frequency to 30 MHz (or the lowest radio frequency signal generated in the EUT, without going below 9 kHz if the EUT has additional internal clock frequencies), and the stop frequency to $10 \times$ the highest allowable frequency of the EUT passband.
- k) Select MAX HOLD, and use the marker peak function to find the highest emission(s) outside the passband. (This could be either at a frequency lesser or greater than the passband frequencies.)
- l) Capture a plot for inclusion in the test report.

m) Repeat steps c) to l) for each authorized frequency band/block of operation.

4.8 Frequency stability measurements

Section 90.219(e)(4)(i) requires that a signal being retransmitted by an amplifier, repeater, or industrial booster meets the frequency stability requirements of Section 90.213. However, this requirement presumes that the EUT processes an input signal in ways that can influence the output signal frequency/frequencies; however, most signal boosters do not incorporate an oscillator). If the amplifier, booster, or repeater does not alter the input signal in any way, then a frequency stability test may not be required.

When performing frequency stability measurements on these types of devices, the instability associated with the EUT must be isolated from any frequency instability associated with the measurement instrumentation. One method for realizing such isolation is to connect the reference clock input of the signal generator to the reference output of the frequency counter, to confirm that any frequency instability is associated with the EUT, and is not due to differences between the reference oscillators internal to the measurement instrumentation.

4.9 Spurious emissions radiated measurements

This measurement is intended to produce test data necessary to demonstrate compliance to the radiated spurious emission requirements specified in Section 2.1053 of the FCC rules. This test is intended to capture any emissions that radiate directly from the case, cabinet, control circuits, etc., instead of via the antenna output port, and thus would not be captured in conducted spurious emission measurements. See KDB Publication 971168 [R8] for measurement procedure guidance.

5.0 SELECTED FCC DOCUMENTS AND REFERENCES FOR OTHER BACKGROUND

For KDB publications listed, the most recent version as published at the time of application submission should be used; see (<https://apps.fcc.gov/oetcf/kdb/reports/GuidedPublicationList.cfm>).

- [R1] FCC 13-21; Amendment of Parts 1, 2, 22, 24, 27, 90 and 95 of the Commission's Rules to Improve Wireless Coverage Through the Use of Signal Boosters; WT Docket No. 10-4; Report and Order; Adopted: February 20, 2013; Released: February 20, 2013.
- [R2] FCC DA 14-15; Wireless Telecommunications Bureau Announces Availability of Part 90 Class B Signal Booster Registration Tool; January 7, 2014; (<https://signalboosters.fcc.gov/signal-boosters/>).
- [R3] FCC PS Docket No. 13-209; FCC 16-48; Emission Mask Requirements for Digital Technologies on 800 MHz NPSPAC Channels; Analog FM Capability on Mutual Aid and Interoperability Channels; Final rule; 81 FR 30198-30202; May 16, 2016.
- [R4] KDB Publication 388624 D01 Permit But Ask Procedure; KDB Publication 388624 D02 Permit But Ask List.
- [R5] KDB Publication 634817 D01 Frequency Range Listings for Certification Grants; KDB Publication 634817 D02 Frequency Range Listings Background.
- [R6] KDB Publication 662911 D01 Emissions Testing of Transmitters with Multiple Outputs in the Same Band.
- [R7] KDB Publication 935210 D02, Signal Boosters Basic Certification Requirements.

- [R8] KDB Publication 971168 D01 Measurement Guidance For Certification Of Licensed Digital Transmitters; KDB Publication 971168 D02 Example Emission Measurements Guidance For Specific Service Rules.
- [R9] TIA-102.CAAA-D 2013, Project 25 Digital C4FM/CQPSK Transceiver Measurement Methods.
- [R10] TIA-156 2006, Land Mobile Radio Antenna Systems Minimum Standards for RF Signal Boosters.
- [R11] TIA-603-D 2010, Land Mobile FM or PM Communications Equipment Measurement and Performance Standards.
- [R12] ANSI C63.26-2015, *American National Standard for Compliance Testing of Transmitters*.
- [R13] FCC 17-93; Amendment of Parts 0, 1, 2, 15 and 18 of the Commission's Rules regarding Authorization of Radiofrequency Equipment; ET Docket No. 15-170; First Report and Order; Adopted: July 13, 2017; Released: July 14, 2017.

Change Notice

2/12/2016: 935210 D05 Indus Booster Basic Meas v01 is replaced by 935210 D05 Indus Booster Basic Meas v01r01. Updates summary is as follows, primarily for consistency where appropriate with the most recent version of test procedures from the ASC C63® Wireless Working Group (September 2015).

- Clause 2 added into paragraph, along with citations of KDB 971168 and TIA-603-D, TIA-102.CAAA-D.
- 2.3 added about network analyzer.
- At 3.2 added footnote 1 about terms AGC, ALC, etc.
- At 3.3 b) clarified bands and frequencies.
- At 3.3 inserted j) for other bands.
- At 3.4 omitted mention of 90.219.
- At 3.4 l) corrected from 2 dB to 26 dB.
- At 3.4 near end clarified repeat procedures steps.
- At 3.5.2 near end clarified repeat procedures steps.
- At 3.6.3 i) added footnote 2 about average and peak and number of points.
- 4.1 updated to consider digitally modulated signals and e.g. LTE.
- 4.4 emission types omitted and replaced by cross-reference to 4.1
- 4.7.1 updated to consider other channel spacings.
- Clause 5 added with document citations.

10/27/2017: 935210 D05 Indus Booster Basic Meas v01r01 is replaced by 935210 D05 Indus Booster Basic Meas v01r02. Summary of updates is as follows.

- Citations added for FCC 17-93 and ANSI C63.26.
- Miscellaneous format/style editorial changes (change from “§” to “Section,” etc.).
- Note added in 4.7.1.
- Reference updated for docket no. 13-209.

04/12/2019: 935210 D05 Indus Booster Basic Meas v01r02 is replaced by 935210 D05 Indus Booster Basic Meas v01r03. Summary of updates is as follows.

- Correct designations and cross-references for applicable f_0 in 3.4, 4.4, and 4.7.1 (for consistency with 7.2.2.3, 7.2.3.3, and 7.2.3.6, respectively, of ANSI C63.26-2015).
- Reference 4.5.5 not 3.5.5 in 4.5.4.

04/03/2020: 935210 D05 Indus Booster Basic Meas v01r03 is replaced by 935210 D05 Indus Booster Basic Meas v01r04. Summary of updates is as follows.

- Clarification on frequencies of operation added in 3.3 and 4.3 introductory paragraphs.
- Added amplitude requirement in 3.6.2 b) and 4.7.2 b) (per ASC C63® SC-4 Wireless WG input).
- Cross-reference error corrected in 3.6.3 q).