



**Federal Communications Commission
Office of Engineering and Technology
Laboratory Division**

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**Guidance for Performing Compliance Measurements on
Digital Transmission Systems (DTS) Operating Under §15.247**

1.0 General

The measurement procedures provided herein are applicable only to digital transmission system (DTS) devices operating in the 902 MHz to 928 MHz, 2400 MHz to 2483.5 MHz, and/or 5725 MHz to 5850 MHz bands under §15.247 of the FCC rules¹. This procedure is not applicable to frequency-hopping spread spectrum systems (FHSS) that are not hybrid systems, authorized under the same rule part. For measurements of non-hybrid FHSS devices, see DA 00-705, released on March 30th, 2000. It should be noted that whenever a device utilizes combined technologies (*e.g.*, DTS and U-NII), each component must be shown to be in compliance with the applicable rule requirements.

2.0 Power limits, definitions and device configuration

The maximum output power limit for DTS devices is specified as 1 watt and is expressed in terms of either maximum peak conducted output power or maximum conducted output power.²

The maximum peak conducted output power is defined as the maximum power level measured with a peak detector using a filter with width and shape of which is sufficient to accept the signal bandwidth. However, when a filter with adequate width is not available, an integrated method utilizing a peak detector is acceptable.

The maximum conducted output power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level.

The minimum 6 dB bandwidth of a DTS transmission shall be at least 500 kHz.³ Within this document, this bandwidth is referred to as the *DTS bandwidth*. The procedures provided herein for measuring the maximum peak conducted output power assume the use of the *DTS bandwidth*.

The procedures provided herein for measuring the maximum conducted (average) output power assume the use of the occupied bandwidth (OBW) as the reference for power integration. See ANSI C63.10⁴ for guidance pertaining to measuring the OBW.

¹ Starting June 2, 2015, devices operating in the 5725-5850 MHz band will no longer be certified under the §15.247 rules and will instead be subject to the §15.407 rules and requirements. For further information on permissive changes and marketing restrictions see KDB Publications 789033 and 926956.

² See 47 CFR 15.247(b)(3)

³ §15.247(a)(2)

3.0 Acceptable measurement configurations

The measurement procedures described herein are based on the use of an antenna-port conducted test configuration. However, if antenna-port conducted tests cannot be performed on an EUT (*e.g.*, portable or handheld devices with integral antenna), then radiated tests are acceptable for demonstrating compliance to the conducted emission requirements. The guidance provided herein is applicable to either antenna-port conducted or radiated compliance measurements.

If a radiated test configuration is used, then the measured power or field strength levels shall be converted to equivalent conducted power levels for comparison to the applicable output power limit. This may be accomplished by first measuring the radiated field strength or power levels using a methodology for maximum peak conducted power or maximum conducted (average) power as applicable and peak or average power spectral density as applicable. The radiated field strength or power level can then be converted to EIRP (see ANSI C63.10 for guidance). The equivalent conducted output power or power spectral density is then determined by subtracting the EUT transmit antenna gain (guidance applicable to devices utilizing multiple antenna technologies is provided in KDB 662911) from the EIRP (assuming logarithmic representation). All calculations and parameter assumptions shall be provided in the test report.

Antenna-port conducted measurements shall be performed using test equipment that matches the nominal impedance of the antenna assembly to be used with the EUT. Additional attenuation may be required in the conducted RF path to prevent overloading of the measurement instrument. The measured power levels shall be adjusted to account for all losses or gains introduced into the conducted RF path, including cable loss, external attenuation or amplification. These adjustments shall be recorded in the test report.

Radiated measurements shall utilize the procedures specified in ANSI C63.10, as applicable.

Averaging over the symbol alphabet is permitted when measuring the maximum conducted (average) output power; however, time intervals when the transmitter is off or transmitting at reduced power levels are not to be considered. Thus, whenever possible the EUT shall be configured to transmit continuously (*i.e.*, with a duty cycle of greater than or equal to 98 %) at the maximum power control level over a random symbol set. Alternatively, sweep triggering/signal gating may be employed within the measurement instrumentation so that all measurements are performed while the EUT is transmitting at its maximum power control level.

The DTS emission limits apply to the total of the emissions from all outputs of the transmitter. Thus, emissions from the transmitter outputs must be summed before comparing the measured emissions to the emission limit. See KDB 662911 for additional guidance.

4.0 Test suite considerations

Depending on the operational frequency range utilized by a particular DTS EUT, compliance measurements can be required on multiple frequencies or channels. §15.31(m) specifies the number of frequencies/channels that shall be tested as a function of the frequency range over which the EUT operates.

Many DTS EUTs utilize wireless protocols that provide for operation in multiple transmission modes, where the data rate, bandwidth, modulation, coding rate, and number of data streams are often variable.

⁴ ANSI C63.10, *American National Standard for Testing Unlicensed Wireless Devices*, Institute for Electrical and Electronic Engineers (IEEE).

When such multiple modes of operation are possible, then compliance to the applicable technical requirements shall be confirmed for any and all realizable operational modes.

In some cases, it might be possible to identify one or more specific operational modes that produce the “worst-case” test results with respect to all of the required technical limits (*e.g.*, output power, power spectral density, unwanted emission power at the band edge and in all spurious emissions, and for each possible output data stream), and then reduce the testing to just these modes on each of the frequencies/channels required per §15.31(m). Whenever this type of test reduction is utilized, a complete and detailed technical justification shall be provided in the test report, to include measurement data where applicable.

5.0 Reference level/attenuation/headroom

5.1 General considerations

For measurements where the bandwidth of the emission is greater than the resolution bandwidth of the measuring instrument care must be taken to ensure that the input mixer of the instrument is operating in its linear region, and is not saturating or clipping the signal.

For measurements where the bandwidth of the emission is less than or equal to the resolution bandwidth of the measuring instrument it is generally sufficient that the peak of the displayed signal be less than the reference level, as long as the instrument attenuation is set to AUTO.

5.2 Setting the proper reference level and input attenuation

Set attenuation to auto. If finer control of attenuation is required to achieve a sufficiently low noise floor for out-of-band measurements, manual setting of attenuation is permitted provided that the power level corresponding to the reference level setting specified below falls within the mixer level range recommended by the instrument manufacturer.

Set the reference level based on power measurements of the signal or by ensuring that the "head room" between the maximum spectrum level and the reference level is at least $10 \log(99\% \text{ occupied bandwidth/RBW})$. The nominal channel bandwidth or the Emission Bandwidth may be substituted for 99% occupied bandwidth in this formula if a measurement of occupied bandwidth is not available.

Additional headroom (*i.e.*, higher reference level) equal to $10 \log(1/\text{duty cycle})$ will be needed if the headroom calculation is based on power or spectrum measurements that are averaged across the on/off cycle of the transmission. For example, the reference level should be set 3 dB higher if the settings are based on power or spectrum measurements that are averaged across the on/off cycles of a 50 percent duty cycle transmission.

For in-band measurements the reference level is based on in-band power or maximum in-band spectrum level.

The same reference level is also used for out-of-band measurements unless a preselector attenuates the in-band signal sufficiently to justify a lower reference level.

6.0 Duty cycle, transmission duration and maximum power control level

Preferably, all measurements of maximum conducted (average) output power will be performed with the EUT transmitting continuously (*i.e.*, with a duty cycle of greater than or equal to 98%). When continuous operation cannot be realized, then the use of sweep triggering/signal gating techniques can be utilized to ensure that measurements are made only during transmissions at the maximum power control level. Such sweep triggering/signal gating techniques will require knowledge of the minimum transmission duration (T) over which the transmitter is on and is transmitting at its maximum power control level for the tested mode of operation. Sweep triggering/signal gating techniques can then be used if the measurement/sweep time of the analyzer can be set such that it does not exceed T at any time that data is being acquired (*i.e.*, no transmitter off-time is to be considered).

When continuous transmission cannot be achieved and sweep triggering/signal gating cannot be implemented, alternate procedures are provided that can be used to measure the average power; however, they will require an additional measurement of the transmitter duty cycle. Within this guidance document, the duty cycle refers to the fraction of time over which the transmitter is on and is transmitting at its maximum power control level. The duty cycle is considered to be constant if variations are less than ± 2 percent, otherwise the duty cycle is considered to be non-constant.

The term “maximum power control level” is intended to distinguish between operating power levels of the EUT and differences in power levels of individual symbols that occur with some modulation types such as quadrature amplitude modulation (QAM). During testing, the EUT is not required to transmit continuously at its highest possible symbol power level. Rather, it should transmit all of the symbols and should do so at the highest power control level (*i.e.*, highest operating power level) of the EUT.

Measurements of duty cycle and transmission duration shall be performed using one of the following techniques:

- a) A diode detector and an oscilloscope that together have sufficiently short response time to permit accurate measurements of the on and off times of the transmitted signal.
- b) The zero-span mode on a spectrum analyzer or EMI receiver if the response time and spacing between bins on the sweep are sufficient to permit accurate measurements of the on and off times of the transmitted signal. Set the center frequency of the instrument to the center frequency of the transmission. Set $RBW \geq OBW$ if possible; otherwise, set RBW to the largest available value. Set $VBW \geq RBW$. Set detector = peak or average. The zero-span measurement method shall not be used unless both RBW and VBW are $> 50/T$ and the number of sweep points across duration T exceeds 100. (For example, if VBW and/or RBW are limited to 3 MHz, then the zero-span method of measuring duty cycle shall not be used if $T \leq 16.7$ microseconds.)

7.0 Transmit antenna performance considerations

The conducted output power limits for DTS EUTs are based on the use of transmit antennas with directional gains that do not exceed 6 dBi. If transmit antennas with an effective directional gain greater than 6 dBi are used, then the conducted output power from the EUT shall be reduced, as specified in the applicable requirements for DTS.⁵

⁵ See 47 CFR 15.247(b) and 15.247(c).

For those cases where the rule specifies that the conducted output power be reduced by the amount in dB that the directional gain of the transmitting antenna exceeds 6 dBi, the applicable output power limit shall be calculated as follows:

$$P_{\text{Out}} = P_{\text{Limit}} - (G_{\text{Tx}} - 6) \quad (1)$$

where:

P_{Out} is the maximum conducted output power in dBm,
 P_{Limit} is the output power limit in dBm,
 G_{Tx} is the maximum transmitting antenna directional gain in dBi.

For those cases where the rule specifies that the conducted output power be reduced by 1 dB for every 3 dB that the directional gain of the transmitting antenna exceeds 6 dBi, the applicable output power limit shall be calculated as follows:

$$P_{\text{Out}} = P_{\text{Limit}} - \text{Floor}[(G_{\text{Tx}} - 6)/3] \quad (2)$$

where:

P_{Out} is the maximum conducted output power in dBm,
 P_{Limit} is the output power limit in dBm,
 $\text{Floor}[x]$ is the largest integer not greater than x (*i.e.*, drop all fractional portions of the real number retaining only the least integer value of the operation),
 G_{Tx} is the maximum transmitting antenna directional gain in dBi.

Additional guidance for determining the effective antenna gain of EUTs that utilize multiple transmit antennas simultaneously or sequentially is provided in KDB 662911.

8.0 DTS bandwidth

One of the following procedures may be used to determine the modulated *DTS bandwidth*.

8.1 Option 1:

- a) Set RBW = 100 kHz.
- b) Set the video bandwidth (VBW) $\geq 3 \times \text{RBW}$.
- c) Detector = Peak.
- d) Trace mode = max hold.
- e) Sweep = auto couple.
- f) Allow the trace to stabilize.
- g) Measure the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points (upper and lower frequencies) that are attenuated by 6 dB relative to the maximum level measured in the fundamental emission.

8.2 Option 2:

The automatic bandwidth measurement capability of an instrument may be employed using the X dB bandwidth mode with X set to 6 dB, if the functionality described above (*i.e.*, RBW = 100 kHz, VBW $\geq 3 \times \text{RBW}$, peak detector with maximum hold) is implemented by the instrumentation function. When

using this capability, care shall be taken so that the bandwidth measurement is not influenced by any intermediate power nulls in the fundamental emission that might be ≥ 6 dB.

9.0 Fundamental emission output power

9.1 Maximum peak conducted output power

One of the following procedures may be used to determine the maximum peak conducted output power of a DTS EUT.

9.1.1 $RBW \geq DTS$ bandwidth

This procedure shall be used when the measurement instrument has available a resolution bandwidth that is greater than the *DTS bandwidth*.

- a) Set the $RBW \geq DTS$ bandwidth.
- b) Set $VBW \geq 3 \times RBW$.
- c) Set span $\geq 3 \times RBW$
- d) Sweep time = auto couple.
- e) Detector = peak.
- f) Trace mode = max hold.
- g) Allow trace to fully stabilize.
- h) Use peak marker function to determine the peak amplitude level.

9.1.2 PKPM1 Peak power meter method

The maximum peak conducted output power may be measured using a broadband peak RF power meter. The power meter shall have a video bandwidth that is greater than or equal to the *DTS bandwidth* and shall utilize a fast-responding diode detector.

9.2 Maximum conducted (average) output power

9.2.1 General

§15.247 permits the maximum conducted (average) output power to be measured as an alternative to the maximum peak conducted output power for demonstrating compliance to the limit. When this option is exercised, the measured power is to be referenced to the OBW rather than the *DTS bandwidth* (see ANSI C63.10 for measurement guidance).

When using a spectrum analyzer or EMI receiver to perform these measurements, it shall be capable of utilizing a number of measurement points in each sweep that is greater than or equal to twice the span/RBW to set a bin-to-bin spacing of $\leq RBW/2$ so that narrowband signals are not lost between frequency bins.

If possible, configure or modify the operation of the EUT so that it transmits continuously at its maximum power control level. The intent is to test at 100 % duty cycle; however a small reduction in duty cycle (to no lower than 98 %) is permitted, if required by the EUT for amplitude control purposes. Manufacturers are expected to provide software to the test lab to permit such continuous operation.

If continuous transmission (or at least 98 % duty cycle) cannot be achieved due to hardware limitations (e.g., overheating), the EUT shall be operated at its maximum power control level, with the transmit duration as long as possible, and the duty cycle as high as possible during which sweep triggering/signal gating techniques may be used to perform the measurement over the transmission duration.

9.2.2 Measurement using a spectrum analyzer (SA)

9.2.2.1 Selection of test method

- a) **Method AVGSA-1 or AVGSA-1 Alternative** (averaging with the EUT transmitting at full power throughout each sweep) shall be applied if either of the following conditions can be satisfied.
 - 1) The EUT transmits continuously (or with a duty cycle $\geq 98\%$).
 - 2) Sweep triggering can be implemented in such a way that the device transmits at the maximum power control level throughout the duration of each of the instrument sweeps to be averaged. This condition can generally be achieved by triggering the instrument's sweep if the duration of the sweep (with the instrument configured as in Method AVGSA-1) is equal to or shorter than the duration T of each transmission from the EUT, and if those transmissions exhibit full power throughout their durations.
- b) **Method AVGSA-2 or AVGSA-2 Alternative** -- averaging across on and off times of the EUT transmissions, followed by duty cycle correction shall be applied if the conditions of the preceding item a) cannot be achieved, and the transmissions exhibit a constant duty cycle during the measurement duration. Duty cycle will be considered to be constant if variations are less than ± 2 percent.
- c) **Method AVGSA-3 (RMS detection across on and off times of the EUT with max hold) or AVGSA-3 Alternative** (reduced VBW averaging across on and off times of the EUT with max hold) shall be applied if the conditions of the preceding paragraphs a) and b) cannot be achieved.

9.2.2.2 Method AVGSA-1 (trace averaging with the EUT transmitting at full power throughout each sweep)

- a) Set span to at least 1.5 times the OBW.
- b) Set RBW = 1-5% of the OBW, not to exceed 1 MHz.
- c) Set VBW $\geq 3 \times$ RBW.
- d) Number of points in sweep $\geq 2 \times$ span / RBW. (This gives bin-to-bin spacing \leq RBW/2, so that narrowband signals are not lost between frequency bins.)
- e) Sweep time = auto.
- f) Detector = RMS (i.e., power averaging), if available. Otherwise, use sample detector mode.
- g) If transmit duty cycle $< 98\%$, use a sweep trigger with the level set to enable triggering only on full power pulses. The transmitter shall operate at maximum power control level for the entire duration of every sweep. If the EUT transmits continuously (i.e., with no off intervals) or at duty cycle $\geq 98\%$, and if each transmission is entirely at the maximum power control level, then the trigger shall be set to "free run".
- h) Trace average at least 100 traces in power averaging (i.e., RMS) mode.
- i) Compute power by integrating the spectrum across the OBW of the signal using the instrument's band power measurement function, with band limits set equal to the OBW band edges. If the instrument does not have a band power function, sum the spectrum levels (in power units) at intervals equal to the RBW extending across the entire OBW of the spectrum.

9.2.2.3 Method AVGSA-1 Alternative (RMS detection with slow sweep and EUT transmitting continuously at full power)

- a) Set span to at least 1.5 times the OBW.
- b) Set RBW = 1-5% of the OBW, not to exceed 1 MHz.
- c) Set VBW $\geq 3 \times$ RBW.
- d) Number of points in sweep $\geq 2 \times \text{span} / \text{RBW}$. (This gives bin-to-bin spacing $\leq \text{RBW}/2$, so that narrowband signals are not lost between frequency bins.)
- e) Manually set sweep time $\geq 10 \times (\text{number of points in sweep}) \times (\text{transmission symbol period})$, but not less than the automatic default sweep time.

NOTE— The transmission symbol period (in seconds) is the reciprocal of the symbol rate (in baud or symbols per second). Note that each symbol can represent one or several data bits and thus the symbol rate should not be confused with the gross bit rate (expressed in bits/second). In no case should the sweep time be set less than the auto sweep time.

- f) Set detector = RMS.
- g) The EUT shall be operated at $\geq 98\%$ duty cycle or sweep triggering/signal gating shall be employed such that the sweep time is less than or equal to the transmission duration T.
- h) Perform a single sweep.
- i) Compute power by integrating the spectrum across the OBW of the signal using the instrument's band power measurement function, with band limits set equal to the OBW band edges. If the instrument does not have a band power function, sum the spectrum levels (in power units) at intervals equal to the RBW extending across the entire OBW of the spectrum.

9.2.2.4 Method AVGSA-2 (trace averaging across on and off times of the EUT transmissions, followed by duty cycle correction)

- a) Measure the duty cycle, x, of the transmitter output signal as described in 6.0.
- b) Set span to at least 1.5 times the OBW.
- c) Set RBW = 1-5% of the OBW, not to exceed 1 MHz.
- d) Set VBW $\geq 3 \times$ RBW.
- e) Number of points in sweep $\geq 2 \times \text{span} / \text{RBW}$. (This gives bin-to-bin spacing $\leq \text{RBW}/2$, so that narrowband signals are not lost between frequency bins.)
- f) Sweep time = auto.
- g) Detector = RMS (*i.e.*, power averaging), if available. Otherwise, use sample detector mode.
- h) Do not use sweep triggering. Allow the sweep to “free run”.
- i) Trace average at least 100 traces in power averaging (*i.e.*, RMS) mode; however, the number of traces to be averaged shall be increased above 100 as needed such that the average accurately represents the true average over the on and off periods of the transmitter.
- j) Compute power by integrating the spectrum across the OBW of the signal using the instrument's band power measurement function with band limits set equal to the OBW band edges. If the instrument does not have a band power function, sum the spectrum levels (in power units) at intervals equal to the RBW extending across the entire OBW of the spectrum.
- k) Add $10 \log (1/x)$, where x is the duty cycle, to the measured power in order to compute the average power during the actual transmission times (because the measurement represents an average over both the on and off times of the transmission). For example, add $10 \log (1/0.25) = 6$ dB if the duty cycle is 25 %.

9.2.2.5 Method AVGSA-2 Alternative (RMS detection with slow sweep with spectrum bin averaging across on and off times of the EUT transmissions, followed by duty cycle correction)

- a) Measure the duty cycle, x , of the transmitter output signal as described in 6.0.
- b) Set span to at least 1.5 times the OBW.
- c) Set RBW = 1-5% of the OBW, not to exceed 1 MHz.
- d) Set VBW $\geq 3 \times$ RBW.
- e) Number of points in sweep $\geq 2 \times \text{span} / \text{RBW}$. (This gives bin-to-bin spacing $\leq \text{RBW}/2$, so that narrowband signals are not lost between frequency bins.)
- f) Manually set sweep time $\geq 10 \times (\text{number of points in sweep}) \times (\text{total on/off period of the transmitted signal})$.
- g) Set detector = RMS.
- h) Perform a single sweep.
- i) Compute power by integrating the spectrum across the OBW of the signal using the instrument's band power measurement function with band limits set equal to the OBW band edges. If the instrument does not have a band power function, sum the spectrum levels (in power units) at intervals equal to the RBW extending across the entire OBW.
- j) Add $10 \log (1/x)$, where x is the duty cycle, to the measured power in order to compute the average power during the actual transmission times.

9.2.2.6 Method AVGSA-3 (RMS detection across on and off times of the EUT with max hold)

- a) Set span to at least 1.5 times the OBW.
- b) Set sweep trigger to "free run".
- c) Set RBW = 1-5% of the OBW, not to exceed 1 MHz.
- d) Set VBW $\geq 3 \times$ RBW
- e) Number of points in sweep $\geq 2 \times \text{span} / \text{RBW}$. (This gives bin-to-bin spacing $\leq \text{RBW}/2$, so that narrowband signals are not lost between frequency bins.)
- f) Sweep time $\leq (\text{number of points in sweep}) \times T$, where T is defined in Section 6.0. If this gives a sweep time less than the auto sweep time of the instrument, Method AVGSA-3 shall not be used (use AVGSA-3 Alternative). The purpose of this step is so that averaging time in each bin is less than or equal to the minimum time of a transmission.
- g) Detector = RMS.
- h) Trace mode = max hold.
- i) Allow max hold to run for at least 60 s, or longer as needed to allow the trace to stabilize.
- j) Compute power by integrating the spectrum across the OBW of the signal using the instrument's band power measurement function with band limits set equal to the OBW band edges. If the instrument does not have a band power function, sum the spectrum levels (in power units) at intervals equal to the RBW extending across the entire OBW.

9.2.2.7 Method AVGSA-3 alternative (reduced VBW averaging across on and off times of the EUT with max hold)

- a) Set span to at least 1.5 times the OBW.

- b) Set sweep trigger to “free run”.
- c) Set RBW = 1-5% of the OBW, not to exceed 1 MHz.
- d) Set VBW $\geq 1/T$, where T is defined in 6.0).
- e) Number of points in sweep $\geq 2 \times \text{span} / \text{RBW}$. (This gives bin-to-bin spacing $\leq \text{RBW}/2$, so that narrowband signals are not lost between frequency bins.)
- f) Sweep time = auto.
- g) Detector = peak.
- h) Video filtering shall be applied to a voltage-squared or power signal (*i.e.*, RMS mode), if possible. Otherwise, it shall be set to operate on a linear voltage signal (which can require use of linear display mode). Log mode shall not be used.
 - 1) The preferred voltage-squared (*i.e.*, power or RMS) mode is selected on some instruments by setting the “Average-VBW Type” to power or RMS.
 - 2) If RMS mode is not available, linear voltage mode is selected on some instruments by setting the display mode to linear. Other instruments have a setting for “Average-VBW Type” that can be set to “Voltage” regardless of the display mode.
- i) Trace mode = max hold.
- j) Allow max hold to run for at least 60 s, or longer as needed to allow the trace to stabilize.
- k) Compute power by integrating the spectrum across the 26 dB OBW of the signal using the instrument’s band power measurement function with band limits set equal to the OBW band edges. If the instrument does not have a band power function, sum the spectrum levels (in power units) at intervals equal to the RBW extending across the entire OBW.
- l) If linear mode was used in step h) above, add 1 dB to the final result to compensate for the difference between linear averaging and power averaging.

9.2.3 Measurement using a power meter (PM)

9.2.3.1 Method AVGPM (Measurement using an RF average power meter)

- a) As an alternative to spectrum analyzer or EMI receiver measurements, measurements may be performed using a wideband RF power meter with a thermocouple detector or equivalent if all of the conditions listed below are satisfied.
 - 1) The EUT is configured to transmit continuously, or to transmit with a constant duty factor.
 - 2) At all times when the EUT is transmitting, it shall be transmitting at its maximum power control level.
 - 3) The integration period of the power meter exceeds the repetition period of the transmitted signal by at least a factor of five.
- b) If the transmitter does not transmit continuously, measure the duty cycle (x) of the transmitter output signal as described in Section 6.0.
- c) Measure the average power of the transmitter. This measurement is an average over both the on and off periods of the transmitter.
- d) Adjust the measurement in dBm by adding $10\log(1/x)$, where x is the duty cycle to the measurement result.

9.2.3.2 Method AVGPM-G (Measurement using a gated RF average power meter)

Alternatively, measurements may be performed using a wideband gated RF power meter provided that the gate parameters are adjusted such that the power is measured only when the EUT is transmitting at its

maximum power control level. Since this measurement is made only during the ON time of the transmitter, no duty cycle correction is required.

10.0 Maximum power spectral density level in the fundamental emission

10.1 Selection of applicable test method

The DTS rules specify a conducted PSD limit within the *DTS bandwidth* during any time interval of continuous transmission.⁶ Such specifications require that the same method as used to determine the conducted output power shall also be used to determine the power spectral density. Therefore, if maximum peak conducted output power was measured to demonstrate compliance to the output power limit, then the peak PSD procedure below (Method PKPSD) shall be used. If maximum conducted output power was measured to demonstrate compliance to the output power limit, then one of the average PSD procedures shall be used, as applicable based on the following criteria (the peak PSD procedure is also an acceptable option):

- a) **Method AVGPSD-1 or AVGPSD-1 Alternative** (averaging with the EUT transmitting at full power throughout each sweep) shall be applied if either of the following conditions can be satisfied.
 - 1) The EUT transmits continuously (or with a duty cycle $\geq 98\%$).
 - 2) Sweep triggering can be implemented in such a way that the device transmits at the maximum power control level throughout the duration of each of the instrument sweeps to be averaged. This condition can generally be achieved by triggering the instrument's sweep if the duration of the sweep is equal to or shorter than the duration *T* of each transmission from the EUT, and if those transmissions exhibit full power throughout these durations.
- b) **Method AVGPSD-2 or AVGPSD-2 Alternative** (averaging across on and off times of the EUT transmissions, followed by duty cycle correction) shall be applied if the conditions of the preceding item a) cannot be achieved, and the transmissions exhibit a constant duty cycle during the measurement duration. Duty cycle will be considered to be constant if variations are less than ± 2 percent.
- c) **Method AVGPSD-3 (RMS detection across on and off times of the EUT with max hold) or AVGPSD-3 Alternative** (reduced VBW averaging across on and off times of the EUT with max hold) shall be applied if the conditions of the preceding paragraphs a) and b) cannot be achieved.

If the average PSD is measured with a power averaging (RMS) detector or a sample detector, then the instrument shall be capable of utilizing a number of measurement points in each sweep that is greater than or equal to twice the span/RBW to set a bin-to-bin spacing of $\leq \text{RBW}/2$, so that narrowband signals are not lost between frequency bins.

Where the measured total power (peak conducted output power or maximum conducted output power) complies with the PSD limit, then the actual measurement of PSD is not required, provided that the PSD level is reported as being equal to the measured total output power.

10.2 Method PKPSD (peak PSD)

This procedure shall be used if maximum peak conducted output power was used to demonstrate compliance, and is optional if the maximum conducted (average) output power was used to demonstrate compliance.

⁶ See 47 CFR 15.247(e).

- a) Set analyzer center frequency to DTS channel center frequency.
- b) Set the span to 1.5 times the *DTS bandwidth*.
- c) Set the RBW to: $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$.
- d) Set the VBW $\geq 3 \times \text{RBW}$.
- e) Detector = peak.
- f) Sweep time = auto couple.
- g) Trace mode = max hold.
- h) Allow trace to fully stabilize.
- i) Use the peak marker function to determine the maximum amplitude level within the RBW.
- j) If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat.

10.3 Method AVGPST-1 (trace averaging with EUT transmitting at full power throughout each sweep)

This procedure may be used when the maximum (average) conducted output power was used to demonstrate compliance to the output power limit. This is the baseline method for determining the maximum (average) conducted PSD level. If the instrument has an RMS power averaging detector, it must be used; otherwise, use the sample detector. The EUT must be configured to transmit continuously (duty cycle $\geq 98\%$); otherwise sweep triggering/signal gating must be implemented to ensure that measurements are made only when the EUT is transmitting at its maximum power control level (no transmitter off time is to be considered).

- a) Set instrument center frequency to DTS channel center frequency.
- b) Set span to at least 1.5 times the OBW.
- c) Set RBW to: $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$.
- d) Set VBW $\geq 3 \times \text{RBW}$.
- e) Detector = power averaging (RMS) or sample detector (when RMS not available).
- f) Ensure that the number of measurement points in the sweep $\geq 2 \times \text{span/RBW}$.
- g) Sweep time = auto couple.
- h) Employ trace averaging (RMS) mode over a minimum of 100 traces.
- i) Use the peak marker function to determine the maximum amplitude level.
- j) If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat (note that this may require zooming in on the emission of interest and reducing the span in order to meet the minimum measurement point requirement as the RBW is reduced).

10.4 Method AVGPST-1 Alternative (RMS detection with slow sweep speed and EUT transmitting continuously at full power)

This procedure may be used as an alternative to 10.3 when the maximum (average) conducted output power was used to demonstrate compliance to the fundamental output power limit and the EUT can be configured to transmit continuously (duty cycle $\geq 98\%$), or when sweep triggering/ signal gating can be implemented to ensure that measurements are made only when the EUT is transmitting at its maximum power control level (no transmitter off time to be considered).

- a) Set instrument center frequency to DTS channel center frequency.
- b) Set the instrument span to 1.5 times the OBW.

- c) Set the RBW to: $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$.
- d) Set the VBW $\geq 3 \times \text{RBW}$.
- e) Detector = power average (RMS).
- f) Ensure that the number of measurement points in the sweep $\geq 2 \times \text{span/RBW}$.
- g) Manually set the sweep time to: $\geq 10 \times (\text{number of measurement points in sweep}) \times (\text{transmission symbol period})$ but no less than the auto sweep time.
 NOTE—the transmission symbol period (in seconds) is the reciprocal of the symbol rate (in baud or symbols per second). Note that each symbol can represent one or several data bits and thus the symbol rate should not be confused with the gross bit rate (expressed in bits/second). In no case should the sweep time be set less than the auto sweep time.
- h) Perform the measurement over a single sweep.
- i) Use the peak marker function to determine the maximum amplitude level.
- j) If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat (note that this may require zooming in on the emission of interest and reducing the span in order to meet the minimum measurement point requirement as the RBW is reduced).

10.5 Method AVGPST-2 (trace averaging across on and off times of the EUT transmissions, followed by duty cycle correction)

This procedure is applicable when the EUT cannot be configured to transmit continuously (*i.e.*, duty cycle < 98%), and when sweep triggering/signal gating cannot be used to measure only when the EUT is transmitting at its maximum power control level, and when the transmission duty cycle is constant (*i.e.*, duty cycle variations are less than ± 2 percent):

- a) Measure the duty cycle (x) of the transmitter output signal as described in 6.0.
- b) Set instrument center frequency to DTS channel center frequency.
- c) Set span to at least 1.5 times the OBW.
- d) Set RBW to: $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$.
- e) Set VBW $\geq 3 \times \text{RBW}$.
- f) Detector = power averaging (RMS) or sample detector (when RMS not available).
- g) Ensure that the number of measurement points in the sweep $\geq 2 \times \text{span/RBW}$.
- h) Sweep time = auto couple.
- i) Do not use sweep triggering. Allow sweep to “free run”.
- j) Employ trace averaging (RMS) mode over a minimum of 100 traces.
- k) Use the peak marker function to determine the maximum amplitude level.
- l) Add $10 \log (1/x)$, where x is the duty cycle measured in step (a), to the measured PSD to compute the average PSD during the actual transmission time.
- m) If resultant value exceeds the limit, then reduce RBW (no less than 3 kHz) and repeat (note that this may require zooming in on the emission of interest and reducing the span in order to meet the minimum measurement point requirement as the RBW is reduced).

10.6 Method AVGPSD-2 Alternative (RMS detection with slow sweep speed with spectrum bin averaging across on and off times of the EUT transmissions, followed by duty cycle correction)

This procedure is applicable as an alternative to 10.5 when the EUT cannot be configured to transmit continuously (*i.e.*, duty cycle < 98%), and when sweep triggering/signal gating cannot be used to measure only when the EUT is transmitting at its maximum power control level, and when the transmission duty cycle is constant (*i.e.*, duty cycle variations are less than ± 2 percent):

- a) Measure the duty cycle (x) of the transmitter output signal as described in 6.0.
- b) Set instrument center frequency to DTS channel center frequency.
- c) Set the instrument span to 1.5 times the OBW.
- d) Set the RBW to: $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$.
- e) Set the VBW $\geq 3 \times \text{RBW}$.
- f) Detector = power average (RMS) or sample detector (when RMS not available).
- g) Ensure that the number of measurement points in the sweep $\geq 2 \times \text{span/RBW}$.
- h) Manually set the sweep time to: $\geq 10 \times (\text{number of measurement points in sweep}) \times (\text{total on/off period of the transmitted signal})$.
- i) Do not use sweep triggering. Allow sweep to “free run”.
- j) Perform the measurement over a single sweep.
- k) Use the peak marker function to determine the maximum amplitude level.
- l) Add $10 \log (1/x)$, where x is the duty cycle measured in step (a), to the measured PSD to compute the average PSD during the actual transmission time.
- m) If the resultant value exceeds limit, reduce RBW (to no less than 3 kHz) and repeat (note that this may require zooming in on the emission of interest and reducing the span in order to meet the minimum measurement point requirement as the RBW is reduced).

10.7 Method AVGPSD-2 (RMS detection across on and off times of the EUT with max hold)

This procedure is applicable when the EUT cannot be configured to transmit continuously (*i.e.*, duty cycle < 98%), and when sweep triggering/signal gating cannot be used to measure only when the EUT is transmitting at its maximum power control level and when the transmission duty cycle is not constant (*i.e.*, duty cycle variations exceed ± 2 percent):

- a) Set the instrument span to a minimum of 1.5 times the OBW.
- b) Set sweep trigger to “free run”.
- c) Set RBW to: $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$.
- d) Set VBW $\geq 3 \times \text{RBW}$
- e) Number of points in sweep $\geq 2 \times \text{Span} / \text{RBW}$. (This ensures that bin-to-bin spacing is $\leq \text{RBW}/2$, so that narrowband signals are not lost between frequency bins.)
- f) Sweep time $\leq (\text{number of points in sweep}) \times T$, where T is defined in 6.0.
NOTE—if this results in a sweep time less than the auto sweep time of the instrument, then this method shall not be used (use AVGPSD-2 Alternative instead). The purpose of this step is to ensure that averaging time in each bin is less than or equal to the minimum time of a transmission.
- g) Detector = RMS.

- h) Trace mode = max hold.
- i) Allow max hold to run for at least 60 seconds, or longer as needed to allow the trace to stabilize.
- j) Use the peak marker function to determine the maximum PSD level.
- k) If the measured value exceeds limit, reduce RBW (to no less than 3 kHz) and repeat (note that this may require zooming in on the emission of interest and reducing the span in order to meet the minimum measurement point requirement as the RBW is reduced).

10.8 Method AVGPS-3 Alternative (reduced VBW averaging across on and off times of the EUT with max hold)

This procedure is applicable as an alternative to 10.7 when the EUT cannot be configured to transmit continuously (*i.e.*, duty cycle < 98%), and when sweep triggering/signal gating cannot be used to measure only when the EUT is transmitting at its maximum power control level and when the transmission duty cycle is not constant (*i.e.*, duty cycle variations exceed ± 2 percent):

- a) Set the instrument span to a minimum of 1.5 times the OBW.
- b) Set sweep trigger to “free run”.
- c) Set RBW to: $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$.
- d) Set VBW $\geq 1/T$, where T is defined in 6.0.
- e) Number of points in sweep $\geq 2 \text{ Span} / \text{RBW}$. (This ensures that bin-to-bin spacing is $\leq \text{RBW}/2$, so that narrowband signals are not lost between frequency bins.)
- f) Sweep time = auto.
- g) Detector = peak.
- h) Video filtering shall be applied to a voltage-squared or power signal (*i.e.*, RMS mode), if possible. Otherwise, it shall be set to operate on a linear voltage signal (which can require use of linear display mode). Log mode shall not be used.
 - 1) The preferred voltage-squared (*i.e.*, power or RMS) mode is selected on some instruments by setting the “Average-VBW Type” to power or RMS.
 - 2) If RMS mode is not available, linear voltage mode is selected on some analyzers by setting the display mode to linear. Other instruments have a setting for “Average-VBW Type” that can be set to “Voltage” regardless of the display mode.
- i) Trace mode = max hold.
- j) Allow max hold to run for at least 60 seconds, or longer as needed to allow the trace to stabilize.
- k) Use the peak marker function to determine the maximum PSD level.
- l) If linear mode was used in step h), add 1 dB to the final result to compensate for the difference between linear averaging and power averaging.
- m) If the measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat (note that this may require zooming in on the emission of interest and reducing the span in order to meet the minimum measurement point requirement as the RBW is reduced).

11.0 Emissions in non-restricted frequency bands

11.1 General

The DTS rules specify that in any 100 kHz bandwidth outside of the authorized frequency band, the power shall be attenuated according to the following conditions:⁷

- a) If the maximum peak conducted output power procedure was used to demonstrate compliance as described in 9.1, then the peak output power measured in any 100 kHz bandwidth outside of the authorized frequency band shall be attenuated by at least 20 dB relative to the maximum in-band peak PSD level in 100 kHz (*i.e.*, 20 dBc).
- b) If maximum conducted (average) output power was used to demonstrate compliance as described in 9.2, then the peak power in any 100 kHz bandwidth outside of the authorized frequency band shall be attenuated by at least 30 dB relative to the maximum in-band peak PSD level in 100 kHz (*i.e.*, 30 dBc).
- c) In either case, attenuation to levels below the 15.209 general radiated emissions limits is not required.⁸

The following procedures shall be used to demonstrate compliance to these limits. Note that these procedures can be used in either an antenna-port conducted or radiated test set-up. Radiated tests must conform to the test site requirements and utilize maximization procedures defined herein.

11.2 Reference level measurement

Establish a reference level by using the following procedure:

- a) Set instrument center frequency to DTS channel center frequency.
- b) Set the span to ≥ 1.5 times the *DTS bandwidth*.
- c) Set the RBW = 100 kHz.
- d) Set the VBW $\geq 3 \times$ RBW.
- e) Detector = peak.
- f) Sweep time = auto couple.
- g) Trace mode = max hold.
- h) Allow trace to fully stabilize.
- i) Use the peak marker function to determine the maximum PSD level.

Note that the channel found to contain the maximum PSD level can be used to establish the reference level.

11.3 Emission level measurement

- a) Set the center frequency and span to encompass frequency range to be measured.
- b) Set the RBW = 100 kHz.
- c) Set the VBW $\geq 3 \times$ RBW.
- d) Detector = peak.

⁷ See 15.247(d).

⁸ See 15.209(a).

- e) Sweep time = auto couple.
- f) Trace mode = max hold.
- g) Allow trace to fully stabilize.
- h) Use the peak marker function to determine the maximum amplitude level.

Ensure that the amplitude of all unwanted emissions outside of the authorized frequency band (excluding restricted frequency bands) are attenuated by at least the minimum requirements specified in 11.1 a) or 11.1 b). Report the three highest emissions relative to the limit.

12.0 Emissions in restricted frequency bands

The DTS rules specify that emissions which fall into restricted frequency bands shall comply with the general radiated emission limits.⁹

12.1 Radiated emission measurements

Since the emission limits are specified in terms of radiated field strength levels, measurements performed to demonstrate compliance have traditionally relied on a radiated test configuration.¹⁰ Radiated measurements remain the principal method for demonstrating compliance to the specified limits; however antenna-port conducted measurements are also now acceptable to demonstrate compliance (see below for details). When radiated measurements are utilized, test site requirements and procedures for maximizing and measuring radiated emissions that are described in ANSI C63.10 shall be followed.

12.2 Antenna-port conducted measurements

12.2.1 General

Antenna-port conducted measurements may also be used as an alternative to radiated measurements for demonstrating compliance in the restricted frequency bands. If conducted measurements are performed, then proper impedance matching must be ensured and an additional radiated test for cabinet/case spurious emissions is required.

12.2.2 General Procedure for conducted measurements in restricted bands

- a) Measure the conducted output power (in dBm) using the detector specified (see 12.2.2, 12.2.3, and 12.2.4 for guidance regarding measurement procedures for determining quasi-peak, peak, and average conducted output power, respectively).
- b) Add the maximum transmit antenna gain (in dBi) to the measured output power level to determine the EIRP level (see 12.2.5 for guidance on determining the applicable antenna gain)
- c) Add the appropriate maximum ground reflection factor to the EIRP level (6 dB for frequencies \leq 30 MHz, 4.7 dB for frequencies between 30 MHz and 1000 MHz, inclusive and 0 dB for frequencies $>$ 1000 MHz).
- d) For devices with multiple antenna-ports, measure the power of each individual chain and sum the EIRP of all chains in linear terms (*e.g.*, Watts, mW).

⁹ See 15.247(d).

¹⁰ See 15.209(a)

- e) Convert the resultant EIRP level to an equivalent electric field strength using the following relationship:

$$E = \text{EIRP} - 20 \log D + 104.8$$

where:

E = electric field strength in dB μ V/m,

EIRP = equivalent isotropic radiated power in dBm

D = specified measurement distance in meters.

- f) Compare the resultant electric field strength level to the applicable limit.
g) Perform radiated spurious emission test

12.2.3 Quasi-Peak measurement procedure

The specifications for measurements using the CISPR quasi-peak detector can be found in Publication 16 of the International Special Committee on Radio Frequency Interference (CISPR) of the International Electrotechnical Commission.

As an alternative to CISPR quasi-peak measurement, compliance can be demonstrated to the applicable emission limits using a peak detector.

12.2.4 Peak power measurement procedure

Peak emission levels are measured by setting the instrument as follows:

- a) RBW = as specified in Table 1.
b) VBW $\geq 3 \times$ RBW.
c) Detector = Peak.
d) Sweep time = auto.
e) Trace mode = max hold.
f) Allow sweeps to continue until the trace stabilizes. (Note that the required measurement time may be longer for low duty cycle applications).

Table 1—RBW as a function of frequency

| Frequency | RBW |
|-------------|-------------|
| 9-150 kHz | 200-300 Hz |
| 0.15-30 MHz | 9-10 kHz |
| 30-1000 MHz | 100-120 kHz |
| > 1000 MHz | 1 MHz |

If the peak-detected amplitude can be shown to comply with the average limit, then it is not necessary to perform a separate average measurement.

12.2.5 Average power measurement procedures

Three conditional procedures are provided for performing conducted average power measurements. Use the appropriate procedure for which the EUT qualifies.

12.2.5.1 Trace averaging with continuous EUT transmission at full power

If the EUT can be configured or modified to transmit continuously (duty cycle ≥ 98 percent) then the average emission levels shall be measured using the following method (with EUT transmitting continuously).

- a) RBW = 1 MHz (unless otherwise specified).
- b) VBW $\geq 3 \times$ RBW.
- c) Detector = RMS, if $\text{span}/(\# \text{ of points in sweep}) \leq (\text{RBW}/2)$. Satisfying this condition may require increasing the number of points in the sweep or reducing the span. If this condition cannot be satisfied, then the detector mode shall be set to peak.
- d) Averaging type = power (*i.e.*, RMS).
 - 1) As an alternative, the detector and averaging type may be set for linear voltage averaging.
 - 2) Some instruments require linear display mode in order to use linear voltage averaging. Log or dB averaging shall not be used.
- e) Sweep time = auto.
- f) Perform a trace average of at least 100 traces.

12.2.5.2 Trace averaging across on and off times of the EUT transmissions followed by duty cycle correction

If continuous transmission of the EUT (*i.e.*, duty cycle ≥ 98 percent) cannot be achieved and the duty cycle is constant (*i.e.*, duty cycle variations are less than ± 2 percent), then the following procedure shall be used:

- a) The EUT shall be configured to operate at the maximum achievable duty cycle.
- b) Measure the duty cycle, x , of the transmitter output signal as described in section 6.0.
- c) RBW = 1 MHz (unless otherwise specified).
- d) VBW $\geq 3 \times$ RBW.
- e) Detector = RMS, if $\text{span}/(\# \text{ of points in sweep}) \leq (\text{RBW}/2)$. Satisfying this condition may require increasing the number of points in the sweep or reducing the span. If this condition cannot be satisfied, then the detector mode shall be set to peak.
- f) Averaging type = power (*i.e.*, RMS).
 - 1) As an alternative, the detector and averaging type may be set for linear voltage averaging.
 - 2) Some instruments require linear display mode in order to use linear voltage averaging. Log or dB averaging shall not be used.
- g) Sweep time = auto.
- h) Perform a trace average of at least 100 traces.
- i) A correction factor shall be added to the measurement results prior to comparing to the emission limit in order to compute the emission level that would have been measured had the test been performed at 100 percent duty cycle. The correction factor is computed as follows:
 - 1) If power averaging (RMS) mode was used in step f), then the applicable correction factor is $10 \log(1/x)$, where x is the duty cycle.
 - 2) If linear voltage averaging mode was used in step f), then the applicable correction factor is $20 \log(1/x)$, where x is the duty cycle.

- 3) If a specific emission is demonstrated to be continuous (≥ 98 percent duty cycle) rather than turning on and off with the transmit cycle, then no duty cycle correction is required for that emission.

NOTE: Reduction of the measured emission amplitude levels to account for operational duty factor is **not** permitted. Compliance is based on emission levels occurring during transmission - **not** on an average across on and off times of the transmitter.

12.2.5.3 Reduced VBW averaging across on and off times of the EUT transmissions with max hold

If continuous transmission of the EUT (*i.e.*, duty cycle ≥ 98 percent) cannot be achieved and the duty cycle is not constant (*i.e.*, duty cycle variations exceed ± 2 percent), then the following procedure shall be used:

- a) Set RBW = 1 MHz.
- b) Set VBW $\geq 1/T$.
- c) Video bandwidth mode or display mode
 - 1) The instrument shall be set to ensure that video filtering is applied in the power domain. Typically, this requires setting the detector mode to RMS and setting the Average-VBW Type to Power (RMS).
 - 2) As an alternative, the instrument may be set to linear detector mode. Ensure that video filtering is applied in linear voltage domain (rather than in a log or dB domain). Some instruments require linear display mode in order to accomplish this. Others have a setting for Average-VBW Type, which can be set to "Voltage" regardless of the display mode.
- d) Detector = Peak.
- e) Sweep time = auto.
- f) Trace mode = max hold.
- g) Allow max hold to run for at least 50 times (1/duty cycle) traces.

12.2.6 Determining the applicable transmit antenna gain

A conducted power measurement will determine the maximum output power associated with a restricted band emission; however, in order to determine the associated EIRP level, the gain of the transmitting antenna (in dBi) must be added to the measured output power (in dBm).

Since the out-of-band characteristics of the EUT transmit antenna will often be unknown, the use of a conservative antenna gain value is necessary. Thus, when determining the EIRP based on the measured conducted power, the upper bound on antenna gain for a device with a single RF output shall be selected as the maximum in-band gain of the antenna across all operating bands, or 2 dBi, whichever is greater. However, for devices that operate in multiple frequency bands while using the same transmit antenna, the highest gain of the antenna within the operating band nearest in frequency to the restricted band emission being measured may be used in lieu of the overall highest gain when the emission is at a frequency that is within 20 percent of the nearest band edge frequency, but in no case shall a value less than 2 dBi be used.

See KDB 662911 for guidance on calculating the additional array gain term when determining the effective antenna gain for a EUT with multiple outputs occupying the same or overlapping frequency ranges in the same band.

12.2.7 Radiated spurious emission test

An additional consideration when performing conducted measurements of restricted band emissions is that unwanted emissions radiating from the EUT cabinet, control circuits, power leads, or intermediate circuit elements will likely go undetected in a conducted measurement configuration. To address this concern, a radiated test shall be performed to ensure that emissions emanating from the EUT cabinet (rather than the antenna port) also comply with the applicable limits.

For these cabinet radiated spurious emission measurements the EUT transmit antenna may be replaced with a termination matching the nominal impedance of the antenna. Procedures for performing radiated measurements are specified in ANSI C63.10. All detected emissions shall comply with the applicable limits.

13.0 Band-edge measurements

13.1 General

When performing peak or average radiated measurements, emissions within 2 MHz of the authorized band edge may be measured using the marker-delta method described below. The integration method described below can be used when performing conducted or radiated average measurements.

13.2 Marker-delta method

The marker-delta method, as described in ANSI C63.10, can be used to perform measurements of the radiated unwanted emissions level at the band-edges provided that the 99% OBW of the fundamental emission is within 2 MHz of the authorized band edge.

13.3 Integration method

The following procedures may be used to determine the average power or power density of any unwanted emission. Use the procedure described in 13.3.1 when the EUT can be configured to transmit continuously (i.e., duty cycle $\geq 98\%$). Use the procedure described in 13.3.2 when the EUT cannot be configured to transmit continuously but the duty cycle is constant (i.e., duty cycle variations are less than ± 2 percent). Use the procedure described in 13.3.3 when the EUT cannot be configured to transmit continuously and the duty cycle is not constant (duty cycle variations equal or exceed 2 percent).

13.3.1 Trace averaging with continuous EUT transmission at full power

If the EUT can be configured or modified to transmit continuously (i.e., duty cycle ≥ 98 percent) then the average emission levels within 2 MHz of the authorized band edge may be measured using the following method (with EUT transmitting continuously).

- a) Set instrument center frequency to the frequency of the emission to be measured (must be within 2 MHz of the authorized band edge).
- b) Set span to 2 MHz
- c) RBW = 100 kHz.
- d) VBW $\geq 3 \times$ RBW.
- e) Detector = RMS, if span/(# of points in sweep) \leq (RBW/2).
- f) Averaging type = power (i.e., RMS).
 - 1) As an alternative, the detector and averaging type may be set for linear voltage averaging.

- 2) Some instruments require linear display mode in order to use linear voltage averaging. Log or dB averaging shall not be used.
- g) Sweep time = auto.
- h) Perform a trace average of at least 100 traces.
- i) Compute the power by integrating the spectrum over 1 MHz using the analyzer's band power measurement function with band limits set equal to the emission frequency ($f_{\text{emission}} \pm 0.5$ MHz). If the instrument does not have a band power function, then sum the amplitude levels (in power units) at 100 kHz intervals extending across the 1 MHz spectrum defined by $f_{\text{emission}} \pm 0.5$ MHz.

13.3.2 Trace averaging across on and off times of the EUT transmissions followed by duty cycle correction

If continuous transmission of the EUT (*i.e.*, duty cycle ≥ 98 percent) cannot be achieved and the duty cycle is constant (*i.e.*, duty cycle variations are less ± 2 percent), then the following procedure may be used to measure the average power of unwanted emissions within 2 MHz of the authorized band edge:

- a) The EUT shall be configured to operate at the maximum achievable duty cycle.
- b) Measure the duty cycle, x , of the transmitter output signal as described in section 6.0.
- c) Set instrument center frequency to the frequency of the emission to be measured.
- d) Set span to 2 MHz
- e) RBW = 100 kHz.
- f) $VBW \geq 3 \times RBW$.
- g) Detector = RMS, if $\text{span}/(\# \text{ of points in sweep}) \leq (RBW/2)$. Satisfying this condition may require increasing the number of points in the sweep or reducing the span. If this condition cannot be satisfied, then the detector mode shall be set to peak.
- h) Averaging type = power (*i.e.*, RMS).
 - 1) As an alternative, the detector and averaging type may be set for linear voltage averaging.
 - 2) Some instruments require linear display mode in order to use linear voltage averaging. Log or dB averaging shall not be used.
- i) Sweep time = auto.
- j) Perform a trace average of at least 100 traces.
- k) Compute the power by integrating the spectrum over 1 MHz using the instrument's band power measurement function with band limits set equal to the emission frequency ($f_{\text{emission}} \pm 0.5$ MHz). If the spectrum analyzer does not have a band power function, then sum the amplitude levels (in power units) at 100 kHz intervals extending across the 1 MHz spectrum defined by $f_{\text{emission}} \pm 0.5$ MHz.
- l) A correction factor shall be added to the measurement results prior to comparing to the emission limit in order to compute the emission level that would have been measured had the test been performed at 100 percent duty cycle. The correction factor is computed as follows:
 - 1) If power averaging (RMS) mode was used in step f), then the applicable correction factor is $10 \log(1/x)$, where x is the duty cycle.
 - 2) If linear voltage averaging mode was used in step f), then the applicable correction factor is $20 \log(1/x)$, where x is the duty cycle.
 - 3) If a specific emission is demonstrated to be continuous (≥ 98 percent duty cycle) rather than turning on and off with the transmit cycle, then no duty cycle correction is required for that emission.

NOTE: Reduction of the measured emission amplitude levels to account for operational duty factor is **not** permitted. Compliance is based on emission levels occurring during transmission - **not** on an average across on and off times of the transmitter.

13.3.3 Reduced VBW averaging across on and off times of the EUT transmissions with max hold

If continuous transmission of the EUT (*i.e.*, duty cycle ≥ 98 percent) cannot be achieved and the duty cycle is not constant (*i.e.*, duty cycle variations equal or exceed ± 2 percent), then the following procedure may be used to measure unwanted emissions within 2 MHz of the authorized band edge:

- a) Set analyzer center frequency to the frequency of the emission to be measured.
- b) Set span to 2 MHz
- c) RBW = 100 kHz.
- d) VBW $\geq 1/T$.
- e) Video bandwidth mode or display mode
 - 1) The analyzer shall be set to ensure that video filtering is applied in the power domain. Typically, this requires setting the detector mode to RMS and setting the Average-VBW Type to Power (RMS).
 - 2) As an alternative, the analyzer may be set to linear detector mode. Ensure that video filtering is applied in linear voltage domain (rather than in a log or dB domain). Some analyzers require linear display mode in order to accomplish this. Others have a setting for Average-VBW Type, which can be set to "Voltage" regardless of the display mode.
- f) Detector = Peak.
- g) Sweep time = auto.
- h) Trace mode = max hold.
- i) Allow max hold to run for at least 50 times (1/duty cycle) traces.
- j) Compute the power by integrating the spectrum over 1 MHz using the analyzer's band power measurement function with band limits set equal to the emission frequency ($f_{\text{emission}} \pm 0.5$ MHz). If the spectrum analyzer does not have a band power function, then sum the amplitude levels (in power units) at 100 kHz intervals extending across the 1 MHz spectrum defined by $f_{\text{emission}} \pm 0.5$ MHz.

Change Notice

04/09/2013: 558074 D01 DTS Meas Guidance v02 changed to 558074 DTS Meas Guidance v03 as follows:

The primary changes in this version of the KDB relative to the previous are:

1. The required RBW to be used for measuring the DTS bandwidth is changed from 1% of DTS BW to an absolute value of 100 kHz.
2. Procedures have been added to accommodate average measurements on an EUT with a non-constant duty cycle that cannot be placed into a continuous transmission mode and sweep triggering/signal gating techniques cannot be used.

3. The procedures for performing band-edge measurements have been expanded to permit the conditional use of a narrower RBW to perform measurements.
4. The formatting has been revised to be more consistent with the UNII measurement guidance.

04/09/2013: 558074 D01 DTS Meas Guidance v03 changed to 558074 DTS Meas Guidance v03r01 to correct typographical errors and reference links.

06/06/2014: 558074 D01 DTS Meas Guidance v03r01 changed to 558074 D01 DTS Meas Guidance v03r02 to effect the following changes:

1. Added a footnote to indicate that equipment operating in the 5725-5850 MHz band will no longer be certified under the §15.247 rules after July 2, 2015 but instead must apply under the revised §15.407 (U-NII) rules
2. Removed the unnecessary requirement that the number of measurement points \geq span/RBW from 11.3.
3. Removed the procedures for performing integrated peak power measurements (9.1.2 and 13.3.1) because they do not produce accurate and repeatable results when applied to a random variable such as the peak power of a noise-like (i.e., digitally-modulated) signal.
4. Clarified the “Band Edge” measurement guidance provided in 13.0 to reflect that only the marker-delta method is subject to the limitation that it can only be applied to emissions that are within 2MHz of the authorized band edge (i.e., the integration method is not subject to the same limitation).