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

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Question: What are the in band, out-of band and restricted band radio frequency measurement requirements for a Digital Transmission System (DTS)?

Answer: The attachment below, 558074 D01 DTS Meas Guidance v02, provides Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under CFR Title 47 15.247.

Attachment List:

558074 D01 DTS Meas Guidance v02

Attachment

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

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1.0 SCOPE

The measurement guidance provided herein is applicable only to Digital Transmission System (DTS) devices operating in the 902-928 MHz, 2400-2483.5 MHz and/or 5725-5850 MHz bands under **§15.247** of the FCC rules (Title 47 of the Code of Federal Regulations).

This guidance document is not applicable to frequency-hopping spread spectrum systems (FHSS) authorized under the same rule part. For measurement guidance relative to FHSS, see FCC Public Notice DA 00-705 and/or C63.10[1] .

The measurement guidance provided in this document supersedes prior FCC guidance for performing DTS compliance measurements but does not invalidate the previous measurement guidance provided in C63.10. All of the legacy procedures provided in C63.10 are retained herein; however, in some cases they have been relegated to alternative status. The intent of this guidance is to provide clarification to existing procedures and to expand available measurement options in an effort to accommodate the digital modulation schemes associated with contemporary DTS applications. The primary changes relative to the previous FCC guidance relative to DTS compliance measurements are:

- An expansion to the available suite of spectrum analyzer-based methodologies for measuring DTS output power.
- A clarification to the required adjustments to output power relative to transmit antenna gain in excess of 6 dBi.
- A modification of the acceptable procedures for measuring power spectral density.
- Specific procedures for measuring unwanted (out-of-band) emissions.
- A new provision to permit antenna port conducted measurement of unwanted emissions in the restricted frequency bands.

It should be noted that whenever a device utilizes combined technologies (*e.g.*, DTS and UNII), each component must be shown to be in compliance with the applicable rule requirements. For example, for a device that combines both DTS and UNII transmitters, the DTS component must be shown to be in compliance with **§15.247** requirements and the UNII component must demonstrate compliance to the requirements specified in **§15.407**. Additional measurement guidance for demonstrating compliance to **§15.407** (UNII) requirements can be found in KDB Publication 789033. In those frequency bands where multiple rule parts apply (*e.g.*, 5725-5850 MHz), the applicant must specify the rule part that they are applying under and demonstrate compliance accordingly.

2.0 POWER LIMITS, DEFINITIONS, AND DEVICE CONFIGURATION

The output power limit for DTS devices considered in this guidance is specified by rule as 1 watt (30 dBm) when expressed in terms of either maximum peak conducted output power or maximum conducted output power.

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.

[1] ANSI C63.10-2009, *American National Standard for Testing Unlicensed Wireless Devices*, Accredited Standards Committee C63® —Electromagnetic Compatibility, IEEE, 10 September, 2009 (hereinafter C63.10).

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 term "maximum power control level" is intended to distinguish between the operational power levels of the equipment under test (EUT) and those power levels associated with individual symbols.

§15.247(a)(2) specifies that the minimum 6 dB bandwidth shall be at least 500 kHz. 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 emission bandwidth (EBW), as used in this document, is defined as the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, that are 26 dB down relative to the maximum level of the modulated carrier.[2] The procedures provided herein for measuring the maximum conducted output power assume the use of the EBW.

3.0 ACCEPTABLE MEASUREMENT CONFIGURATIONS

The measurement procedures described herein are based on the use of an antenna-port conducted test configuration. However, in those cases where antenna-port conducted tests cannot be performed, then the use of a radiated measurement configuration is acceptable to demonstrate compliance to the technical requirements specified in **§15.247**. The guidance provided herein is applicable to either antenna-port conducted or radiated measurements.

If a radiated test configuration is used, then the measured power or field strength levels must be converted to equivalent conducted power levels for comparison to the applicable output power limit. This can be accomplished by first converting the measured radiated field strength or power levels to equivalent isotropic radiated power (EIRP) (see KDB Publication 412172 for guidance). The equivalent maximum conducted output power can then be determined by subtracting the EUT transmit antenna gain from the EIRP. All calculations and parameter assumptions must be provided.

Antenna-port conducted measurements must 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 must be adjusted to account for all losses in the conducted RF path, including cable loss and external attenuation, and shall be recorded in the test report.

Radiated measurements shall utilize the guidance and procedures specified in C63.4[3] and/or C63.10, as applicable.

Averaging over the symbol alphabet is permitted when measuring the maximum conducted output power; however, time intervals when the transmitter is off or transmitting at reduced power levels are not to be considered. This implies that whenever possible, the EUT should be configured to transmit continuously *(i.e.*,

[2] §15.403(i).

[3] ANSI C63.4-2009, *American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz*, Accredited Standards Committee C63® —Electromagnetic Compatibility, IEEE, 15 September, 2009 (hereinafter C63.4).

with a duty cycle of greater than or equal to 98%) over a random symbol set at the maximum power control level. Alternatively, video triggering or signal gating can be employed to ensure that all measurements are performed with the EUT transmitting at its maximum power control level.

The maximum conducted output power must include the total transmit power delivered to all antennas and antenna elements (see KDB Publication 662911 for additional guidance).

4.0 TEST SUITE CONSIDERATIONS

Depending on the operational frequency range utilized by a particular DTS EUT, compliance measurements may be required on multiple frequencies or channels. **§15.31(m)** specifies the number of frequencies/channels that must 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 scheme and number of data streams are often variable. When such multiple modes of operation are possible, then compliance to the applicable technical requirements must be ensured for any and all realizable operational modes.

In some cases, it may 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 and power spectral density associated with the fundamental emission, unwanted emission power at the band edge and in all spurious emissions, including those falling within the restricted frequency bands, 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 must be provided, to include measurement data where applicable.

5.0 DUTY CYCLE AND TRANSMISSION DURATION DETERMINATION

While it is preferred that the maximum conducted output power be measured with the EUT configured to transmit continuously (*i.e.*, with a duty cycle of ≥ 98%), or to employ video triggering or signal gating to ensure that measurements are made when the EUT is transmitting at its maximum power control level, in those cases where such configurations cannot be realized, either through normal operation or specialized test modes, it will become necessary to determine the duty cycle for the mode of operation under test. In this context, 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 maximum-power transmission duration (T), refers to the time duration over which the EUT is transmitting at its maximum power control level for the mode of operation under test. When using averaging techniques to determine the maximum conducted output power level with a spectrum analyzer, the sweep time must be $\leq T$ in order to ensure that transmitter off-time is not included in the measurement.

The measurement of the duty cycle and minimum transmission duration shall be performed with one of the following techniques:

a) Using a diode detector and oscilloscope that together have sufficiently short response time to permit accurate measurement of the on and off times of the transmitted signal.
b) Using the zero-span mode of a spectrum analyzer, if the response time and spacing between measurement bins are sufficient to permit accurate measurement of the on and off times of the transmitted signal.

- Set the analyzer center frequency to the transmitted signal center frequency.
- Set the RBW ≥ bandwidth of the transmitted signal, if possible. Otherwise set the RBW to the maximum available value.
- Set the VBW ≥ RBW.
- Select the peak detector.
- Ensure that both the RBW and VBW are greater than 50/*T* and the number of sweep points over the transmission duration (*T*) exceeds 100.

6.0 TRANSMIT ANTENNA PERFORMANCE CONSIDERATIONS

The conducted output power limits specified in **§15.247(b)** are based on the use of transmit antennae with directional gains that do not exceed 6 dBi. If transmit antennae 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 **§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:

$$P_{Out} = 30 - (G_{Tx} - 6)$$

where:

P_{Out} = maximum conducted output power in dBm,
G_{Tx} = 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:

$$P_{Out} = 30 - \text{Floor}[(G_{Tx} - 6)/3]$$

where:

P_{Out} = maximum conducted output power in dBm,
Floor[x] = 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} = the maximum transmitting antenna directional gain in dBi.

Additional guidance for determining the effective antenna gain of EUTs that utilize multiple transmit antennae simultaneously or sequentially (*e.g.*, MIMO or beamforming technologies) is provided in KDB Publication 662911.

7.0 REQUIRED COMPLIANCE MEASUREMENTS

7.1 DTS (6 dB) Bandwidth

One of the following procedures can be used to determine the modulated DTS signal bandwidth:

7.1.1 Option 1:

1. Set resolution bandwidth (RBW) = 1-5 % of the anticipated DTS bandwidth.
2. Set the video bandwidth (VBW) ≥ 3 x RBW.
3. Detector = Peak.
4. Trace mode = max hold.

5. Sweep = auto couple.
6. Allow the trace to stabilize.
7. Measure the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points (upper and lower) that are attenuated by 6 dB relative to the maximum level measured in the fundamental emission. Use the resultant bandwidth to readjust the RBW, if necessary, to achieve a RBW to DTS bandwidth ratio of 1-5 % and repeat.

7.1.2 Option 2:

The automatic bandwidth measurement capability of a spectrum analyzer may be employed using the X dB bandwidth mode with X set to 6 dB, if it implements the functionality described above (*e.g.*, RBW = 1-5% of BW, VBW ≥ 3 x RBW, peak detector with maximum hold). When using this capability, care should be taken to ensure that the bandwidth measurement is not influenced by any intermediate power nulls in the signal that may be ≥ 6 dB.

7.2. Fundamental Emission Output Power

7.2.1 Maximum Peak Conducted Output Power

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

7.2.1.1 Option 1 (zero span method)

This procedure requires availability of a spectrum analyzer with a resolution bandwidth that is ≥ the DTS bandwidth.

1. Set the RBW ≥ DTS bandwidth.
2. Set VBW ≥ 3 x RBW.
3. Set display to zero-span mode.
4. Sweep time = auto couple.
5. Detector = peak.
6. Trace mode = max hold.
7. Allow trace to fully stabilize.
8. Use peak marker function to determine the peak amplitude level.

7.2.1.2 Option 2 (integrated band power method)

This procedure provides an integrated measurement alternative for use with a spectrum analyzer where the maximum available RBW < the DTS bandwidth.

1. Set the RBW = 1 MHz.
2. Set the VBW = 3 MHz.
3. Set the span to fully encompass the DTS bandwidth.
4. Detector = peak.
5. Sweep time = auto couple.
6. Trace mode = max hold.
7. Allow trace to fully stabilize.
8. Use the spectrum analyzer's band power measurement function with the band limits set equal to the DTS bandwidth edges (for some analyzers, this may require a manual override to ensure use of peak detector). If the spectrum analyzer does not have a band power function, sum the spectrum levels (in linear power units) at 1 MHz intervals extending across the DTS bandwidth.

7.2.1.3 Option 3 (peak power meter method)

The maximum peak conducted output power can be measured using a broadband peak RF power meter. The power meter must have a video bandwidth that is greater than or equal to the DTS bandwidth.

7.2.1.4 Alternative 1 (bandwidth correction method):

This procedure is a legacy procedure for use with a spectrum analyzer where the maximum available RBW < DTS bandwidth (*i.e.*, alternative to Option 1).

1. Set the RBW and VBW to the maximum available widths.
2. Set the span to fully encompass the DTS bandwidth.
3. Detector = peak.
4. Sweep time = auto couple.
5. Trace mode = max hold.
6. Set the analyzer display = linear mode.
7. Allow trace to fully stabilize.
8. Use peak marker to find the maximum amplitude within the RBW.
9. Correct the displayed amplitude by adding a bandwidth correction factor (BWCF) determined from: BWCF = 10log (DTS bandwidth)/RBW).

7.2.2 Maximum Conducted Output Power

§15.247(b)(3) permits the maximum conducted output power to be measured as an alternative to the maximum peak conducted output power for demonstrating compliance to the limit. When these procedures are utilized, the power is referenced to the emission bandwidth (EBW) rather than the DTS bandwidth (see Section 2.0 for definitions).

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

One of the following procedures can be used to determine the maximum conducted average output power when the EUT is configured to transmit continuously (duty cycle ≥ 98%), or when sweep triggering or signal gating is implemented so that the measurements are performed when the EUT is transmitting at its maximum power control level (*i.e.*, sweep time ≤ *T*).

7.2.2.1 Option 1 (RMS detection with slow sweep speed)

1. Set the analyzer span to encompass the entire EBW.
2. Set the RBW = 1 MHz.
3. Set the VBW ≥ 3 MHz.
4. Detector = power average (RMS) or sample detector.
5. Ensure that the number of measurement points in the sweep ≥ 2 x (span/RBW).
6. Manually set the sweep time to: ≥10 x (number of measurement points in sweep) x (transmission symbol period).
7. Perform the measurement over a single sweep.
8. Use the spectrum analyzer's band power measurement function with band limits set equal to the EBW band edges.

Note: If the analyzer does not have a band power function, sum the spectral levels (in linear power units) at 1 MHz intervals extending across the entire EBW.

7.2.2.2 Option 2 (spectral trace averaging)

1. Set the analyzer span to encompass the entire EBW.
2. Set the RBW = 1 MHz.
3. Set the VBW ≥ 3 MHz.
4. Ensure that the number of measurement points in the sweep ≥ 2 x (span/RBW).
5. Sweep time = auto couple.
6. Detector = power averaging (RMS) or sample detector.
7. Employ trace averaging in power averaging (RMS) mode over a minimum of 100 traces.
8. Use the spectrum analyzer's band power measurement function with band limits set equal to the EBW band edges.

Note: If the analyzer does not have a band power function, sum the spectral levels (in linear power units) at 1 MHz intervals extending across the entire EBW.

7.2.2.3 Option 3 (average power meter method)

As an alternative to spectrum analyzer measurements, the maximum conducted average output power can be measured with a broadband RF average power meter with a thermocouple detector or equivalent if all of the following conditions are satisfied:

1. The EUT is configured to transmit continuously or the power meter can be triggered or gated such that the power is measured only when the EUT is transmitting at its maximum power control level.
2. The integration period of the power meter must exceed the repetition period of the transmitted signal by at least a factor of five.
3. If the EUT cannot be configured to transmit continuously and the power meter cannot be triggered or gated to compensate, the power over the on/off periods can be measured and then up-scaled by adding 10log (1/duty cycle) to the logarithmic representation of the measured power (see section 5.0 for guidance on determining the applicable duty cycle).

7.2.2.4 Alternative 1 (Reduced VBW with max hold)

The following procedure can be used with spectrum analyzers that do not have power averaging capability.

1. Set span to encompass the entire EBW.
2. Set sweep trigger to "free run".
3. Set RBW = 1 MHz.
4. Set VBW ≥ 1/*T*, but not less than 10 Hz.
5. Detector = RMS or sample if the number of measurement points in the sweep ≥ 2 x (span/RBW), otherwise use the peak detector.
6. Sweep time = auto couple.
7. Video filtering shall be applied to the voltage-squared or RMS detected power. Otherwise, it shall be applied to a linear voltage signal (may require use of linear display mode). Log mode shall not be used.
   (a) The preferred voltage-squared (*i.e.*, power or RMS) mode is selected on some analyzers by setting the "Average-VBW Type" to power or RMS.
   (b) If RMS mode is not available, linear voltage mode is selected on some analyzers by setting the display mode to linear. Other analyzers have a setting for "Average-VBW Type" that can be set to "Voltage" regardless of the display mode.
9. Trace mode = max hold.
10. Allow trace level to accumulate for at least 60 seconds, or longer as needed until trace stabilizes.

11. Compute power by integrating the spectrum across the EBW using the analyzers band power function with band limits set equal to the EBW band edges. If the spectrum analyzer does not have a band power function then sum the spectrum levels (in power units) at 1 MHz intervals extending across the EBW.
12. If linear mode was used in step 8 then add 1 dB to the final result to compensate for the difference between linear averaging and power averaging.

7.2.2.5 Alternative 2 (zero-span mode with trace averaging):
This procedure can be used when the sweep time is > *T* and a RBW ≥ EBW is available.
1. Set analyzer center frequency to the EBW center frequency.
2. Set display to zero-span mode.
3. Set RBW ≥ EBW.
4. Set VBW ≥ 3 x RBW (or to highest VBW setting – must be ≥ RBW)
5. Set sweep time = *T*.
6. Detector = power averaging (RMS) or sample detector.
7. If EUT cannot be configured to transmit continuously, then use a video trigger set to enable triggering only on full power transmission durations (gated sweeping may also be used to ensure measurement sweeps occur only while the EUT is transmitting).
8. Employ trace averaging in power averaging (RMS) mode over a minimum of 100 traces.
9. Use the peak marker function to determine the maximum power amplitude.

7.2.2.6 Alternative 3 (average over on/off periods with duty cycle correction)
When the EUT cannot be configured to transmit continuously (*i.e.*, duty cycle < 98%), and video triggering or signal gating cannot be used to measure only when the EUT is transmitting at its maximum power control level, then use either the Option 1 or 2 procedure in free run mode to determine the average power inclusive of the on/off periods of the transmitter and then correct by the duty cycle as follows:
1. Measure the duty cycle per the guidance provided in Section 5.0.
2. Add 10log (1/duty cycle) to the logarithmic representation of the maximum measured power level.

7.3 Maximum Power Spectral Density Level in the Fundamental Emission

§15.247(e) specifies a conducted power spectral density (PSD) limit of 8 dBm in any 3 kHz band segment within the DTS bandwidth during any time interval of continuous transmission. By rule, the same method as used to determine the conducted output power shall be used to determine the power spectral density (*i.e.,* if maximum peak conducted output power was measured then use the peak PSD procedure and if maximum conducted output power was measured then use the average PSD procedure).

However, since the power spectral density limit is based on the maximum permissible output power spread over a 500 kHz bandwidth, whenever the actual bandwidth of a DTS signal exceeds 500 kHz (typical among contemporary DTS transmissions), then the PSD limit effectively becomes inconsequential (*i.e.*, the more the actual DTS bandwidth exceeds 500 kHz, the greater the margin between the actual PSD and the PSD limit). In addition, the use of a peak PSD procedure will always result in a "worst-case" measured level for comparison to the limit. Therefore, whenever the DTS bandwidth exceeds 500 kHz, it is acceptable to utilize the peak PSD procedure to demonstrate compliance to the PSD limit, regardless of how the fundamental output power was measured.

If the average PSD is measured with a power averaging (RMS) detector or a sample detector, then the spectrum analyzer must be capable of utilizing a number of measurement points in each sweep that is greater than or equal to twice the span/RBW in order to ensure bin-to-bin spacing of ≤ RBW/2 so that narrowband signals are not lost between frequency bins.

One of the following procedures can be used to determine the power spectral density of a DTS EUT.

7.3.1 Option 1 (Peak PSD)

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

1. Set analyzer center frequency to DTS signal center frequency.
2. Set the span to 5-30 % greater than the DTS bandwidth.
3. Set the RBW = 100 kHz.
4. Set the VBW ≥ 300 kHz.
5. Detector = peak.
6. Sweep time = auto couple.
7. Trace mode = max hold.
8. Allow trace to fully stabilize.
9. Use the peak marker function to determine the maximum amplitude level.
10. Scale the observed power level to an equivalent value in 3 kHz by adjusting (reducing) the measured amplitude by a bandwidth correction factor (BWCF) where BWCF = 10log (3 kHz/100 kHz = -15.2 dB).

7.3.2 Option 2 (Average PSD)

This procedure can be used when the maximum conducted output power was used to demonstrate compliance and the EUT can be configured to transmit continuously (duty cycle ≥ 98%), or video triggering or signal gating can be implemented to ensure that measurements are made when the EUT is transmitting at its maximum power control level.

1. Set analyzer center frequency to DTS signal center frequency.
2. Set the analyzer span to 5-30% greater than the DTS bandwidth.
3. Set the RBW = 100 kHz.
4. Set the VBW ≥ 300 kHz.
5. Detector = power average (RMS) or sample detector.
6. Ensure that the number of measurement points in the sweep ≥ 2 x span/RBW.
7. Manually set the sweep time to: ≥ 10 x (number of measurement points in sweep) x (transmission symbol period).
8. Perform the measurement over a single sweep.
9. Use the peak marker function to determine the maximum amplitude level.
10. Scale the observed power level to an equivalent level in 3 kHz by adjusting (reducing) the measured amplitude by a bandwidth correction factor (BWCF) where: BWCF = 10log (3 kHz/100 kHz = -15.2 dB).

7.3.3 Alternative 1 (Peak PSD alternative)

1. Set analyzer center frequency to DTS signal center frequency.
2. Set span to encompass entire DTS bandwidth.
3. Set RBW = 3 kHz.
4. Set VBW = 10 kHz.
5. Detector = peak.

6. Trace mode = maximum hold.
7. Allow trace to fully stabilize.
8. Reset trace mode = view
9. Use peak marker to find maximum amplitude.
10. Adjust spectrum analyzer center frequency to the marker frequency.
11. Reset span to 300 kHz.
12. Set sweep time to 100 seconds.
13. Trace mode = maximum hold.
14. Use peak marker to find maximum PSD level.

7.3.4 Alternative 2 (Average PSD alternative)

This procedure can only be used if the EUT can be configured to transmit continuously (duty cycle ≥ 98%) or if video triggering or signal gating can be employed to ensure that measurement occurs only when the EUT is transmitting at its maximum power control level.

1. Set analyzer center frequency to DTS signal center frequency.
2. Set span to encompass entire DTS bandwidth.
3. Set RBW = 3 kHz.
4. Set VBW = 9 kHz.
5. Detector = RMS or sample, if the number of measurement points in the sweep ≥ 2 x (span/RBW), otherwise use the peak detector.
6. Set sweep time = auto couple.
7. Employ trace averaging in power averaging (RMS) mode over a minimum of 100 traces
   Note: some analyzers may require manual selection of peak detector to ensure its use in this mode.
8. Use peak marker to find maximum PSD level.

7.4 Maximum Unwanted Emission Levels

7.4.1 Unwanted Emissions into Non-Restricted Frequency Bands

§15.247(d) specifies that in any 100 kHz bandwidth outside of the authorized frequency band, the power shall be attenuated according to the following conditions:

If the maximum peak conducted output power procedure was used to demonstrate compliance to **15.247(b)(3)** requirements, then the peak conducted 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.

If maximum conducted output power was used to demonstrate compliance to **15.247(b)(3)** requirements, 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 average PSD level in 100 kHz.

In either case, attenuation to levels below the general emission limits specified in **§15.209(a)** is not required.

The following procedures shall be used to demonstrate compliance to these limits.

First, establish a reference level by using the following procedure to measure the maximum peak PSD level in any 100 kHz bandwidth over the DTS bandwidth:

7.4.1.1 Reference Level Measurement

1. Set the RBW = 100 kHz.
2. Set the VBW ≥ 300 kHz.
3. Set the span to 5-30 % greater than the DTS bandwidth.
4. Detector = peak.
5. Sweep time = auto couple.
6. Trace mode = max hold.
7. Allow trace to fully stabilize.
8. Use the peak marker function to determine the maximum amplitude.

Next, determine the peak PSD in any 100 kHz bandwidth in those emissions outside of the authorized frequency band using the following measurement:

7.4.1.2 Unwanted Emissions Level Measurement

1. Set RBW = 100 kHz.
2. Set VBW ≥ 300 kHz.
3. Set span to encompass the spectrum to be examined.
4. Detector = peak.
5. Trace Mode = max hold.
6. Sweep = auto couple.
7. Allow the trace to stabilize (this may take some time, depending on the extent of the span).

Ensure that the amplitude of all unwanted emissions outside of the authorized frequency band (excluding restricted frequency bands) is attenuated by at least the minimum requirements specified in 7.4.1.

7.4.2 Unwanted Emissions into Restricted Frequency Bands

§15.247(d) specifies that emissions which fall in the restricted bands, as defined in **§15.205(a)**, must comply with the radiated emission limits specified in **§15.209(a)**.

7.4.2.1 Radiated versus Conducted Measurements

Since the emission limits provided in **§15.209(a)** are specified in terms of radiated field strength levels, measurements performed to demonstrate compliance have traditionally relied on a radiated test configuration. Traditional radiated measurements are still acceptable for demonstrating compliance provided that the procedures defined in C63.10 and/or C63.4, as applicable, are followed.

Given that all other emission limits applicable to DTS transmitters are specified in terms of conducted power levels, antenna-port conducted measurements will also be permitted as an alternative to radiated measurements 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 emissions will be required.

§15.209(a) specifies radiated emissions limits for unwanted emissions in the restricted bands in terms of the maximum permissible electric field strength at a specified measurement distance. A correspondent EIRP level can be determined from the following relationship:

$$eirp = (e \times d)^2/30$$

where:

eirp = the equivalent isotropic radiated power in watts,
e = electric field strength in V/m,
d = measurement distance in meters.

Converting the above equation to the logarithmic equivalent yields:

$$EIRP = E + 20\log(d) - 104.8$$

where:

EIRP = the equivalent isotropic radiated power in dBm,
E = electric field strength in dBμV/m,
d = measurement distance in meters.

By utilizing this relationship, equivalent EIRP limits can be determined from the field strength limits and the associated measurement distances as specified in **§15.209(a)**.

§15.35(a) specifies that on frequencies less than and below 1000 MHz, the radiated emissions limits assume the use of a CISPR quasi-peak detector function and related measurement bandwidths. **§15.35(b)** specifies that on frequencies above 1000 MHz, the radiated emissions limits assume the use of an average detector and a minimum resolution bandwidth of 1 MHz.

These relationships provide a convenient means for demonstrating compliance to the radiated emissions limits applicable to the restricted bands through the use of antenna-port conducted measurements; however, some additional considerations also apply.

The first consideration when performing antenna-conducted measurements is that a value representative of the maximum transmitter antenna gain must be added to the measured conducted power level to determine the EIRP. Since the out-of-band characteristics of the EUT transmit antenna will often be unknown, the use of a conservative antenna gain value is required. 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.[4] However, for devices that operate in multiple bands while using the same transmit antenna, the highest gain of the antenna within the operating band nearest in frequency to the unwanted 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 Publication 662911 for guidance on calculating the additional array gain term when determining the effective antenna gain for an EUT with multiple outputs occupying the same or overlapping frequency ranges in the same band (*e.g.*, MIMO or beamforming antennas).

[4] If an EUT uses an "electrically short antenna" (*i.e.*, an antenna shorter than its resonant length of 1/4th or 1/2 wavelength), the in-band antenna gain may be low—perhaps even less than 0 dBi—but the gain may be higher at an out-of-band frequency where the antenna is resonant. In such a case, the gain is not expected to exceed that of a resonant ½-wavelength dipole, which is 2.15 dBi—rounded, here, to 2 dBi.

A second consideration is that unwanted emissions radiating from the EUT cabinet, control circuits, power leads, or intermediate circuit elements can 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 radiated emission measurements the EUT transmit antenna may be replaced with a termination matching the nominal impedance of the antenna. Established procedures for performing radiated measurements shall be used (see C63.4 and/or C63.10).

7.4.2.2 Procedures for Antenna-Port Conducted Measurements of Unwanted Emissions in the Restricted Bands

7.4.2.2.1 Unwanted Emissions in Restricted Bands on Frequencies ≤ 1000 MHz

1. Measure the antenna conducted output power (dBm) using the procedures presented below.

Although the limits for unwanted emissions in the restricted frequency bands below 1000 MHz are based on the use of a CISPR quasi-peak detector, it is suggested that the initial measurement be made using a peak detector to maximize time efficiency. If all measured unwanted emissions are shown to comply with the applicable limits then no further measurements are required. Any unwanted emissions that are found to be out of compliance when a peak detector is used can subsequently be isolated and measured using the CISPR quasi-peak detector.

7.4.2.2.1.1 Peak Power Procedure

Span = adequate to encompass frequency range of interest.
RBW = (see Table 1 below).
VBW ≥ 3 x RBW.
Detector = Peak.
Trace Mode = max hold.
Sweep = auto coupled.
Allow trace to stabilize.

Table 1. Resolution Bandwidth Settings as a Function of Frequency Range

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

2. Determine EIRP (see KDB Publication 412172)

3. Add appropriate factor to model worst-case ground reflections
For emissions ≤ 30 MHz, add a factor of 6.0 dB;
For emissions > 30 MHz and ≤ 1000 MHz, add a factor of 4.7 dB.

4. Convert EIRP to an equivalent electric field strength level using the following equation:

$$E = EIRP - 20\log(d) + 104.8$$

where:

E = electric field strength, in dBμV/m,
EIRP = equivalent isotropic radiated power, in dBm,
d = specified measurement distance, in meters (see Table 2).

5. Compare to applicable limit.

Table 2. Measurement Distance as a Function of Frequency.

Frequency	Distance (meters)
9- 490 kHz	300
0.490-30 MHz	30
30-1000 MHz	3

For those emissions that exceed the limit with peak detection, repeat measurement using the following quasi-peak detection procedure.

7.4.2.2.1.2 Quasi Peak Power Procedure

Span = adequate to encompass the emission of interest.
Detector = CISPR quasi peak.
RBW = auto couple.
Sweep time = auto coupled.

7.4.2.2.2 Unwanted Emissions in Restricted Bands on Frequencies > 1000 MHz

The average emission levels shall be measured with the EUT transmitting continuously (≥ 98% duty cycle) at its maximum power control level. Video triggering or signal gating can also be used to ensure that measurements are performed only when the EUT is transmitting at its maximum power control level.

The spectrum analyzer must be capable of utilizing a number of measurement points in each sweep that is greater than or equal to twice the span/RBW in order to ensure bin-to-bin spacing of ≤ RBW/2 so that narrowband signals are not lost between frequency bins.

One of the following procedures shall be used to measure the average emission levels within the restricted frequency bands above 1 GHz.

7.4.2.2.2.1 Option 1 (Power Averaging)

This procedure can be used with the EUT transmitting continuously at its maximum power control level or when video triggering or signal gating is used with a sweep time ≤ T.

1. Set the analyzer span to encompass the entire unwanted emission bandwidth.
2. Set the RBW = 1 MHz.
3. Set the VBW ≥ 3 MHz.
4. Detector = power average (RMS).
5. Ensure that the number of measurement points in the sweep to ≥ 2 x (span/RBW).
6. Manually set the sweep time to: ≥ 10 x (number of measurement points in sweep) x (transmission symbol period).
7. Perform the measurement over a single sweep.
8. Use the peak marker function to determine the maximum average power level in any 1 MHz of the unwanted emission.

7.4.2.2.2.2 Option 2 (Trace Averaging)

This procedure can be used with the EUT transmitting continuously at its maximum power control level or when video triggering or signal gating is used with a sweep time ≤ T.

1. Set the analyzer span to encompass the entire unwanted emission bandwidth above the measurement system noise level.
2. Set the RBW = 1 MHz.
3. Set the VBW ≥ 3 MHz.
4. Ensure that the number of measurement points in the sweep ≥ 2 x (span/RBW).
5. Set sweep time = auto couple.
6. Detector = sample.
7. Employ trace averaging over a minimum of 100 traces.
8. Use the peak marker function to determine the maximum average power level in any 1 MHz of the unwanted emission.

7.4.2.2.2.3 Option 3 (Reduced VBW)

This procedure can be used with the EUT transmitting continuously at its maximum power control level or when video triggering or signal gating is used with a sweep time ≤ T using a spectrum analyzer that does not incorporate power averaging capabilities.

1. Set span to encompass the entire unwanted emission bandwidth.
2. Set sweep trigger to “free run”.
3. Set RBW = 1 MHz.
4. Set VBW ≥ $1/T$ but not less than 10 Hz, where T is defined in Section 5.0.
5. Ensure that the number of measurement points in the sweep ≥ 2 x (span/RBW).
6. Sweep time = auto couple.
7. Detector = peak.
8. Video filtering shall be applied to voltage-squared or RMS detected power. Otherwise, it shall be applied to a linear voltage signal (may require use of linear display mode). Log mode shall not be used.
   (a) The preferred voltage-squared (*i.e.*, power or RMS) mode is selected on some analyzers by setting the “Average-VBW Type” to power or RMS.

(b) If RMS mode is not available, linear voltage mode is selected on some analyzers by setting the display mode to linear. Other analyzers have a setting for "Average-VBW Type" that can be set to "Voltage" regardless of the display mode.

9. Trace mode = max hold.
10. Allow trace level to accumulate for at least 60 seconds, or longer as needed until trace stabilizes.
11. Compute power by integrating the spectrum across the OBW/EBW of the signal using the analyzers band power function with band limits set equal to the OBW/EBW band edges. If the spectrum analyzer does not have a band power function then sum the spectrum levels (in power units) at 1 MHz intervals extending across the OBW/EBW.
12. If linear mode was used in step 8 then add 1 dB to the final result to compensate for the difference between linear averaging and power averaging.

7.4.2.2.3 Applicability of §15.35(b) and §15.35(c) in Restricted Frequency Bands

§15.35(b) specifies a peak limit of 20 dB above the maximum permitted average emission limit on any frequency or frequencies above 1000 MHz. When performing antenna-port conducted measurements, this requirement translates to an absolute peak EIRP limit of -21.2 dBm. For radiated measurements, this translates to a peak field strength limit of 74 dBμV/m at 3 meters.

The following procedure can be used to demonstrate compliance to this peak limit.

1. Set the analyzer span to encompass the entire unwanted emission bandwidth.
2. Set the RBW = span.
3. Set the VBW ≥ RBW.
4. Set sweep time = auto couple.
5. Detector = peak.
6. Allow the trace to stabilize.
7. Use the peak marker function to determine the maximum amplitude.

§15.35(c) permits a duty cycle reduction to the measured field strength (or equivalent EIRP) when pulsed operation is employed. For unwanted emissions that fall into Restricted Bands and can be shown to have timing characteristics (*i.e.*, carrier on/off time) that are the same as exhibited by the fundamental emission (*e.g.*, harmonically related emissions), it is permissible to reduce the measured steady state power or field strength level by a duty cycle factor determined over a 100 millisecond period that encompasses the maximum cumulative transmitter on-time for any realizable mode of operation. [5]

7.4.2.2.4 Band-Edge Measurements

The measurement of unwanted emissions at the edge of the authorized frequency bands can be complicated by the capture of RF energy from the fundamental emission within the RBW passband. Thus, for measurements at the band edges, a narrower resolution bandwidth (no

[5] The mode of operation used to demonstrate compliance must be representative of the "worst-case" condition (*i.e.*, the maximum realizable duty cycle).

less than 10 kHz) can be used within the first 1 MHz beyond the fundamental emission, provided that that measured energy is subsequently integrated over the appropriate reference bandwidth (*i.e.*, 100 kHz or 1 MHz). This integration can be performed using the band power function of the spectrum analyzer or by summing the spectral levels (in linear power units) over the appropriate reference bandwidth.

Alternatively, the marker-delta method, as described in KDB 913591 and in C63.10, can be used to perform band-edge measurements.

Change Notice:
03/22/2012 558074 D01 DTS Meas Guidance v01 has changed to 558074 D01 DTS Meas Guidance v02. The following modifications have been made:

1. Provisions have been added to permit the use of power meters for measuring the maximum peak conducted output power and the maximum conducted output power.
2. An alternative procedure for measuring maximum peak conducted output power has been added.
3. Alternative procedures for measuring maximum conducted output power have been added to harmonize with existing C63.10 guidance.
4. A distinction is made between the DTS bandwidth (relative to the 6 dB points) and the emission bandwidth (relative to the 26 dB points).
5. Procedures have been added to accommodate the measurement of maximum conducted output power of DTS devices that cannot be configured to transmit continuously (*i.e.*, with duty cycle ≥ 98%).
6. Compliance test suite requirements have been clarified.
7. The PSD measurement requirements have been revised and alternative procedures have been added to harmonize with existing C63.10 guidance.
8. The applicability of 15.35(c) has been clarified.
9. The marker-delta method for band-edge measurements has been included.