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

Short Title: DTS Meas Guidance

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First Category: Radio Service Rules

Second Category: Measurement Procedures

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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

Note: This document (558074 DTS Meas Guidance DR02 41075) contains a draft of the contents that will eventually be an attachment (558074 D01 DTS Meas Guidance v02) in KDB 558074. The proposed new version of the attachment v02 was first proposed in a draft posted 03/26/2012 (expired on 04/21/2012) in 558074 DTS Meas Guidance DR01. Due to comments on this previous draft in DR01, this new draft (DR02) is posted for additional comments to the proposed attachment (v02).

When the attachment (v02) is finalized it is intended to replace 558074 D01 DTS Meas Guidance v01 currently published. See publication 558074 for current guidance.

6/15/2012

Attachment

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

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), that are not hybrid systems (see KDB 453039), authorized under the same rule part. For measurement guidance relative to non-hybrid FHSS, see 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. 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 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 document 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.[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 resolution bandwidth is not available, then an integrated method utilizing a peak detector is an acceptable alternative.

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[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).

[2] §15.247(b)(3)

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.

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 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. The procedures provided for measuring the maximum conducted (average) 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 in this document 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 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 is then determined by subtracting the EUT transmit antenna gain from the EIRP (assuming logarithmic representation). 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 or gains introduced into the conducted RF path, including cable loss and external attenuation or amplification. These adjustments shall be recorded in the test report.

Radiated measurements shall utilize the guidance and procedures specified in C63.10.

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. This implies that whenever possible, the EUT should be configured to transmit continuously (*i.e.*, 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.

[3] §15.247(a)(2)

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, coding rate, 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.*, channel power and power spectral density, unwanted emission power at the band edge and in all spurious emissions, including those falling within the restricted frequency bands, and for all possible output data streams) 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 video triggering 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.
- 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 (30 dBm) 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 DTS (6 dB) CHANNEL BANDWIDTH MEASUREMENT PROCEDURES

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

7.1 Option 1:

1. Set resolution bandwidth (RBW) = 100 kHz.
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.

7.2 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 = 100 kHz, 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 fundamental emission that may be ≥ 6 dB.

8.0. FUNDAMENTAL EMISSION OUTPUT POWER MEASUREMENT PROCEDURES

8.1 Maximum Peak Conducted Output Power

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

8.1.1 Option 1 (RBW ≥ DTS BW)

This procedure should be used when a spectrum/signal analyzer with a resolution bandwidth that is ≥ the DTS bandwidth can be used to perform the measurement.

1. Set the RBW ≥ DTS bandwidth.
2. Set VBW ≥ 3 x RBW.
3. Set span ≥ RBW.
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.

8.1.2 Option 2 (channel integration method)

This procedure should be used when the maximum available RBW of the spectrum/signal analyzer is less than the DTS bandwidth.

1. Set the RBW = maximum available (at least 1 MHz).
2. Set the VBW = 3 x RBW or maximum available setting (must be ≥ RBW).
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/channel 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 intervals equal to the RBW extending across the DTS channel bandwidth.

8.1.3 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 and shall utilize a fast, average-responding diode type sensor.

8.2 Maximum Conducted Output Power

§15.247(b)(3) permits the maximum (average) 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/signal 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.

The ideal method for measuring the maximum (average) conducted output power is with the EUT is configured to transmit continuously (duty cycle ≥ 98%) at its maximum power control level. However, when this condition cannot be realized, video triggering or signal gating can be used to ensure that the measurements are performed only during periods when the EUT is transmitting at its maximum power control level. An option is also provided that can be used when none of the above requirements can be met with the available measurement instrumentation.

8.2.1 Option 1 (RMS detection with slow sweep speed)

This procedure should be used when an RMS power averaging detector is available in the spectrum/signal analyzer.

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) 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.

8.2.2 Option 2 (spectral trace averaging)

This procedure should be used when an RMS power averaging detector is not available in the spectrum/signal analyzer.

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 = 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.

8.2.3 Option 3 (average power meter method)

This procedure provides an alternative for determining the RMS output power using a broadband RF average power meter with a thermocouple detector if the EUT can be configured to transmit continuously or if 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.

8.2.4 Alternative 1 (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 one of the procedures above 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.
3. Note that when a power meter is used to perform this measurement then the integration period must exceed the repetition period of the transmitted signal by at least a factor of five.

9.0 MAXIMUM POWER SPECTRAL DENSITY MEASUREMENT PROCEDURES

A conducted power spectral density (PSD) limit of 8 dBm in any 3 kHz band segment within the DTS bandwidth is specified during any time interval of continuous transmission.[4] 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 the peak PSD procedure shall be used and if maximum conducted output power was measured then the average PSD procedure shall be used).

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 DTS PSD as applicable.

[4] §15.247(e)

9.1 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 channel center frequency.
2. Set the span to 5-30 % greater than the DTS channel bandwidth.
3. Set the RBW ≥ 3 kHz.
4. Set the VBW ≥ 3 x RBW.
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 within the RBW.
10. If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat.

9.2 Option 2 (RMS 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 channel center frequency.
2. Set the analyzer span to 5-30% greater than the DTS channel bandwidth.
3. Set the RBW ≥ 3 kHz.
4. Set the VBW ≥ 3 x RBW.
5. Detector = power average (RMS).
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 in the RBW.
10. If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat.

9.3 Option 3 (Trace Average PSD)

This procedure can be used when the maximum conducted output power was used to demonstrate compliance, the analyzer does not have an RMS power averaging detector, 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 channel center frequency.
2. Set span to encompass entire DTS channel bandwidth.
3. Set RBW ≥ 3 kHz.
4. Set VBW ≥3 x RBW.
5. Detector = sample.
6. Ensure that the number of measurement points in the sweep ≥ 2 x span/RBW.
7. Sweep time = auto couple.
8. Employ trace averaging (RMS) mode over a minimum of 100 traces.

9. Use the peak marker function to determine the maximum amplitude level in the RBW.
10. If measured value exceeds limit, reduce RBW (no less than 3 kHz) and repeat.

10.0 MAXIMUM UNWANTED EMISSION LEVEL MEASUREMENT PROCEDURES

10.1 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, based on either RF conducted or radiated measurements, 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 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 (average) 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 should be used to demonstrate compliance to these limits. Note that these procedures can be used in either an RF conducted or radiated test set-up. Radiated tests must be performed on a test site that conforms to C63.4 requirements and must utilize the procedures specified in C63.10 to maximize the measured emission levels.

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 channel bandwidth (the channel with the maximum PSD level can be used to establish the reference level):

10.1.1 Reference Level Measurement

1. Set analyzer frequency to DTS channel 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.

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

10.1.2 Unwanted Emissions Level Measurement

1. Set start frequency to DTS channel edge frequency.

2. Set stop frequency so as to encompass the spectrum to be examined.
3. Set RBW = 100 kHz.
4. Set VBW ≥ 300 kHz.
5. Detector = peak.
6. Trace Mode = max hold.
7. Sweep = auto couple.
8. Allow the trace to stabilize (this may take some time, depending on the extent of the span).
9. Use peak marker function to determine maximum amplitude in 100 kHz.

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 10.1.

10.2 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)**.

10.2.1 Radiated Emissions 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. Radiated measurements remain the primary method for demonstrating compliance to the specified limits provided that the procedures defined in C63.10 are followed.

10.2.2 Antenna-Port Conducted Emissions Measurements

Antenna-port conducted measurements are acceptable as an alternative to radiated measurements for demonstrating compliance to the limits 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 also be required.

10.2.2.1 EIRP Limits for Antenna-Port Conducted Emissions Measurements

§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.

This relationship can be used to determine correspondent EIRP limits from the field strength limits at the associated measurement distances specified in **§15.209(a)**.

Additionally, when a conducted test is performed in lieu of a radiated test, an additional factor must be added to the measured amplitude level to account for ground reflections. For emissions at frequencies less than or equal to 30 MHz , a maximum ground reflection factor of 6 dB is assumed and for emissions at frequencies greater than 30 MHz but less than or equal to 1000 MHz, a maximum ground reflection factor of 4.7 dB is assumed. For emissions on frequencies greater than 1000 MHz, no ground reflection factor is applied.

Table 1 below provides the applicable EIRP limits determined from the application of the above equation, including the appropriate ground reflection factors.

Table 1: EIRP Limits for Conducted Measurements in Restricted Frequency Bands

Frequency (F) (MHz)	EIRP Limit (dBm)
0.009-1.705	6.3 – 20log F (kHz)
1.705-30.0	-51.7
30-88	-60.0
88-216	-56.4
216-960	-54.0
960-1000	-46.0
≥ 1000	-41.3

10.2.2.2 Antenna Gain Assumptions

The EIRP limits listed in Table 1 can be used to facilitate conducted measurements of unwanted emissions on frequencies that fall into the restricted frequency bands. A conducted measurement will determine the maximum output power associated with an emission; however, in order to determine the associated EIRP level, the gain of the transmitting antenna must also be considered (added to the measured output power when working in logarithmic terms).

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.[5] 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 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.

[5] 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.

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 (*e.g.*, MIMO or beamforming antennas), see KDB Publication 662911.

10.2.2.3 Radiated Spurious Emissions Measurement

An additional 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 C63.10). All detected emissions must comply with the applicable limits.

10.2.3 Measurement Detectors

§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 specifications are also assumed to apply to conducted emissions measurements.

In all cases, compliance can be demonstrated solely on the basis of measurements performed with a peak detector utilizing the minimum resolution bandwidths specified below.

10.2.4 Minimum Resolution Bandwidths

The appropriate resolution bandwidth for use when performing conducted measurements of the emissions levels within the restricted frequency bands is provided in Table 2 as a function of frequency range.

Table 2. Minimum Resolution Bandwidth as a Function of Frequency.

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

10.2.5 Peak and Quasi-Peak Measurement Procedures

10.2.5.1 Peak Power Procedure

1. Start and Stop Frequency = adequate to encompass frequency range of interest.
2. RBW = (see Table 2 above).
3. VBW ≥ 3 x RBW.

4. Detector = Peak.
5. Trace Mode = max hold.
6. Sweep = auto coupled.
7. Allow trace to stabilize.

10.2.5.2 Quasi Peak Power Procedure

1. Center Frequency = center of unwanted emission of interest.
2. Detector = CISPR quasi peak.
3. RBW = auto couple.
4. Sweep time = auto coupled.

10.2.6 Average Power Measurement Procedures

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

When these average measurement procedures are used, 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.

10.2.6.1 RMS Power Averaging

This procedure should be used when a power averaging (RMS) detector is available in the spectrum analyzer.

1. Set the analyzer start/stop frequencies to encompass the entire unwanted emission bandwidth or frequency range of interest (may be limited by the available number of measurement points).
2. Set the RBW = (see Table 2 above).
3. Set the VBW ≥ 3 x RBW.
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 the appropriate resolution bandwidth.

10.2.6.2 Trace Averaging

This procedure should be used when a power averaging (RMS) detector is not available in the spectrum analyzer.

1. Set the analyzer start/stop frequencies to encompass the entire unwanted emission bandwidth or frequency range of interest (may be limited by the available number of measurement points).
2. Set the RBW = (see Table 2 above).
3. Set the VBW ≥ 3 x RBW.
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 the resolution bandwidth.

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