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Title: Measurement Guidance for Certification of Licensed Digital Transmitters

Short Title: Power Meas License Digital Systems

Reason: Update of the document taking into account procedures in ANSI C63.26-2015.

Publication: 971168

Keyword/Subject: Power and emission measurements of licensed devices with bandwidths > 1 MHz

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Question:

What are the procedures for compliance measurements for licensed wideband (> 1 MHz) digital transmission systems?

Answer:

Attachment 971168 D01 Power Meas License Digital Systems v03 provides procedures for measuring power and unwanted emissions of wideband (> 1 MHz) digitally modulated RF signals that are acceptable to the FCC for demonstrating compliance for licensed transmitters.

Attachment 971168 D02 Misc OOBE License Digital Systems v01 provides emission measurement guidance for specific service rules.

Attachment 971168 D03 IM Emission Repeater Amp v01 provides basic guidance for intermodulation product spurious emission testing of frequency translating repeater system equipment and similar devices.

Attachment List:

971168 D01 Power Meas License Digital Systems v03
971168 D02 Misc OOBE License Digital Systems v01
971168 D03 IM Emission Repeater Amp v01

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MEASUREMENT GUIDANCE FOR CERTIFICATION OF LICENSED DIGITAL TRANSMITTERS

1 INTRODUCTION AND APPLICABILITY

Modern radio frequency (RF) signals use complex digital modulation/coding schemes that produce waveforms similar to Gaussian noise (except having different amplitude statistics) within the transmit channel. Hence, digitally modulated RF signals are often referred to as "noise-like." Traditional measurement techniques used for analog signals often are inadequate for characterizing the output power of these noise-like RF signals.

Procedures for compliance measurements on digitally-modulated licensed devices are included in Clause 5 of ANSI C63.26-2015, American National Standard for Compliance Testing of Transmitters. KDB Publication 971168 D01 served as a basis in the development of the ANSI C63.26 measurement procedures, and as such it provides pertinent guidance for performing compliance measurements for devices operating under several FCC licensed-service rule parts.

KDB Publication 971168 D01 provides general measurement guidance applicable to digital transmitters, operating with wideband (> 1 MHz) digitally modulated RF signals applying for certification under the various licensed rule parts (e.g., Sections 22, 24, 25 (ATC), 27, 90, 95, 101). Guidance is provided relative to the minimum certification requirements specified in Section 2.1033(c)(14) along with Sections 2.1046 through 2.1057. Further to Section 2.911(c), the specific limits and any additional requirements are given in the applicable individual radio service rule parts.

The associated document KDB Publication 971168 D02 describes other details about out-of-band emissions measurements for digital transmitters, for two example radio service operations under parts 27 and 101, and further information for mobile station equipment operating under part 27 BRS/EBS service rules. As another basic procedure for licensed devices, KDB Publication 971168 D03 provides basic guidance for intermodulation product spurious emission testing of frequency-translating repeater system equipment and similar devices.

The measurement guidance and procedures provided herein supersedes that provided in previous versions of KDB Publication 971168.

2 GENERAL MEASUREMENT CONSIDERATIONS

2.1 Transmitters employed in network communications

Many of the digital transmitters operating under the licensed rule parts operate in server-client relationships or other networking configurations in which the client transmitting characteristics are determined based on communications with a controlling server or base station. When testing such devices, it will be necessary to either use special test software provided by the manufacturer, or a base station simulator capable of establishing a communication link with the equipment-under-test (EUT), to facilitate the measurements described herein.

2.2 Measurement instrumentation considerations

Many of the measurement procedures provided herein require the use of a spectrum/signal analyzer or EMI receiver. When using such measurement instrumentation, consideration must be given to avoiding amplitude overload and when setting parameters such as the amplitude reference level and appropriate attenuation.[1]

When performing measurements where the occupied bandwidth (OBW) of the emission being measured is less than or equal to the resolution bandwidth (RBW) of the measurement instrument, it is generally sufficient that the peak amplitude of the signal under measurement be less than the reference level with the instruments attenuation level set to auto-couple. However, when performing measurements where the OBW of the emission being measured is greater than the RBW, care must be taken to ensure that the input mixer of the instrument is operating within its linear region (i.e., is not being saturated by and/or clipping the input signal).

Typically, the auto-attenuation function of the instrument is adequate to prevent measurement overload; however, when measuring high-power devices (e.g., base station transmitters), it can be necessary use additional external attenuation in the signal path. When manually adjusting the attenuation level (e.g., when measuring unwanted emission levels), care must be taken to ensure that the reference level falls within the acceptable mixer level range specified by the instrument manufacturer.

The reference level should be set based on the anticipated power level of the signal under measurement. When performing in-band power measurements, the reference level should be set based on the anticipated maximum total signal power or spectral envelope power. This same reference level must be maintained when performing unwanted emission measurements unless a preselector is used to attenuate the in-band signal power sufficiently to justify the use of a lower reference level.

Adequate headroom can typically be ensured by maintaining a minimum separation between the maximum anticipated signal amplitude and the reference level of at least 10 log (OBW / RBW) dB. When measuring across the on/off cycles of a burst transmission, additional headroom may be required between the signal amplitude and the reference level, equivalent to 10 log (1 / duty cycle) dB.

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[1] Where it has been determined that a wireless communications test set (aka base-station simulator or call box) implements the peak and average power measurements in a manner consistent with a spectrum analyzer/EMI receiver/power meter (e.g., supports power averaging (rms) measurements, and peak envelope detection with maximum hold for peak measurements), and where the instrument settings specified in Clause 5 can be realized, then they can be considered to be an acceptable alternative measurement instrument. Parties using alternative instrumentation should establish reasonable assurances for themselves that the resulting technical data are consistent with the results obtained per the described procedures. In sampling testing of certified devices, the FCC may utilize the methods described in Clause 5 of this document, which will serve as the reference in the case of dispute.

3 MODULATION CHARACTERISTICS

The applicant shall provide a detailed description of all modulation formats to be used, including the response characteristics (frequency, phase and amplitude) of any filters provided, and a description of the modulating wavetrain, shall be submitted for the maximum rated conditions under which the equipment will be operated. [Section 2.1033(c)(13)]

The applicant shall provide a curve or other equivalent data which shows that the equipment will meet the modulation requirements of the rules under which the equipment is to be licensed. [Section 2.1047(d)]

These requirements can be satisfied by listing the digital modulation schemes employed along with a brief explanation of the bit/symbol representation.

4 OCCUPIED BANDWIDTH MEASUREMENTS

4.1 General

The occupied bandwidth (OBW), that is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 % of the total mean power radiated by a given emission, shall be measured when modulated by an input signal such that its amplitude and symbol rate represent the maximum rated conditions under which the equipment will be operated. The signal shall be applied through any filter networks, pseudo-random generators or other devices required in normal service. Additionally, the occupied bandwidth shall be shown for operation with any devices used for modifying the spectrum when such devices are optional at the discretion of the user. [Section 2.1049(h)]

Many of the individual rule parts specify a relative OBW in lieu of the 99 % OBW. In such cases, the OBW is defined as the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, outside of which all emissions are attenuated by at least X dB below the transmitter power, where the value of X is typically specified as 26.

The relative OBW must be measured and reported when it is specified in the applicable rule part; otherwise, the 99 % OBW shall be measured and reported. The test report shall specify which OBW is reported.

A spectrum/signal analyzer or other instrument providing a spectral display is recommended for these measurements and the video bandwidth shall be set to a value at least three times greater than the IF/resolution bandwidth to avoid any amplitude smoothing. Video filtering shall not be used during occupied bandwidth tests.

The OBW shall be measured for all operating conditions that will affect the bandwidth results (e.g., variable modulations, coding, or channel bandwidth settings).

4.2 Occupied bandwidth – relative measurement procedure

The reference value is the highest level of the spectral envelope of the modulated signal.

a) The spectrum analyzer center frequency is set to the nominal EUT channel center frequency. The span range for the spectrum analyzer shall be between 2 × to 5 × the anticipated OBW.
b) The nominal resolution bandwidth (RBW) shall be in the range of 1 % to 5 % of the anticipated OBW, and the VBW shall be at least 3 × RBW.
c) Set the reference level of the instrument as required to prevent the signal from exceeding the maximum input mixer level for linear operation. In general, the peak of the spectral envelope must be at least 10 log (OBW / RBW) below the reference level.
NOTE—Steps a) through c) may require iteration to adjust within the specified tolerances.
d) The dynamic range of the spectrum analyzer at the selected RBW shall be at least 10 dB below the target "−X dB" requirement; i.e., if the requirement calls for measuring the –26 dB OBW, the spectrum analyzer noise floor at the selected RBW shall be at least 36 dB below the reference value.
e) Set the detection mode to peak, and the trace mode to max hold.
f) Determine the reference value: Set the EUT to transmit a modulated signal. Allow the trace to stabilize. Set the spectrum analyzer marker to the highest level of the displayed trace (this is the reference value).
g) Determine the "−X dB amplitude" as equal to (Reference Value – X). Alternatively, this calculation can be performed by the analyzer by using the marker-delta function.
h) Place two markers, one at the lowest and the other at the highest frequency of the envelope of the spectral display such that each marker is at or slightly below the "–X dB amplitude" determined in step g). If a marker is below this "−X dB amplitude" value it shall be placed as close as possible to this value. The OBW is the positive frequency difference between the two markers.
The spectral envelope might cross the "−X dB amplitude" at multiple points. The lowest or highest frequency shall be selected as the frequencies which are the farthest away from the center frequency at which the spectral envelope crosses the "−X dB amplitude."
i) The occupied bandwidth shall be reported by providing plot(s) of the measuring instrument display, with including markers depicting the relevant frequency and amplitude information (e.g., marker table). The frequency and amplitude axes and scale shall be clearly labeled. Tabular data may be reported in addition to the plot(s).

4.3 Occupied bandwidth – power bandwidth (99 %) measurement procedure

The following procedure shall be used for measuring (99 %) power bandwidth

a) The spectrum analyzer center frequency is set to the nominal EUT channel center frequency. The frequency span for the spectrum analyzer shall be set wide enough to capture all modulation products including the emission skirts (i.e., 2 × OBW to 5 × OBW).
b) The nominal IF filter bandwidth (3 dB RBW) shall be in the range of 1 % to 5 % of the anticipated OBW, and the VBW shall be at least 3 × RBW.
c) Set the reference level of the instrument as required to keep the signal from exceeding the maximum input mixer level for linear operation. In general, the peak of the spectral envelope must be at least 10 log (OBW / RBW) below the reference level.
NOTE—Steps a) through c) may require iteration to adjust within the specified tolerances.
d) Set the detection mode to peak, and the trace mode to max hold.
e) Use the 99 % power bandwidth function of the spectrum analyzer (if available) and report the measured bandwidth.
f) If the instrument does not have a 99 % power bandwidth function, the trace data points are to be recovered (extracted from the instrument) and directly summed in linear power terms. The recovered

amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5 % of the total is reached; that frequency is recorded as the lower frequency. The process is repeated until 99.5 % of the total is reached; that frequency is recorded as the upper frequency. The 99 % power bandwidth is the difference between these two frequencies.

g) The OBW shall be reported by providing plot(s) of the measuring instrument display, with including markers depicting the relevant frequency and amplitude information (e.g., marker table). The frequency and amplitude axes and scale shall be clearly labeled. Tabular data may be reported in addition to the plot(s).

5 RF OUTPUT POWER

5.1 Peak power measurements

5.1.1 General

Sections 2.1046 (a) and (c) call for conducted power measurements at the RF output terminal(s) of a device.[2] Some radio service rule parts specify RF output power limits in terms of, for example, total peak output power or total peak ERP or EIRP. The total peak power is often implied when the limits specify peak power or peak ERP or EIRP, without additional specification of a reference bandwidth. Also, when the output power limits are specified in terms of total average power or total average ERP or EIRP, it is acceptable to demonstrate compliance using total peak power measurements under the assumption that the measured peak power will always be greater than or equal to the measured average power. The peak output power, which can subsequently be used to determine the peak ERP or EIRP, can be measured with a spectrum/signal analyzer, an EMI receiver, or a peak-reading power meter. Guidance is provided below for measurements performed with these instruments.

5.1.2 Peak power measurements with a spectrum/signal analyzer or EMI receiver

The instrument must have an available measurement/resolution bandwidth that is equal to or exceeds the OBW. If this capability is available, then the following procedure can be used to determine the total peak output power.

a) Set the RBW ≥ OBW.
b) Set VBW ≥ 3 × RBW.
c) Set span ≥ 2 × RBW
d) Sweep time = auto couple.
e) Detector = peak.
f) Ensure that the number of measurement points ≥ span / RBW.
f) Trace mode = max hold.
g) Allow trace to fully stabilize.
h) Use the peak marker function to determine the peak amplitude level.

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[2] Various SAR evaluation and test exclusion provisions in KDB Publication 447498 D01 (RF EXPOSURE PROCEDURES AND EQUIPMENT AUTHORIZATION POLICIES FOR MOBILE AND PORTABLE DEVICES) (and references therein) also require conducted power data measured at the RF output port(s).

5.1.3 Peak power measurements with a peak-reading power meter

The total peak output power may 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 emission bandwidth and utilize a fast-responding diode detector. Consult the instrument operator's manual for specific operating details for the particular power meter to be used.

5.2 Average power measurements

5.2.1 General

Some radio service rule parts specify the RF output power limits in terms of total average power or total average ERP or EIRP. Total average power is often implied when the limit is stated as average but no reference bandwidth is specified. When average power measurements are permitted, there may also be a limit imposed on the peak-to-average power ratio (PAPR) of the signal.

When average limits are specified, the averaging is to be performed only over durations of active transmissions at maximum output power level (i.e., averaging over the symbol transitions particular to the applied modulation scheme). For licensed digital transmitters, average measurements do not include averaging over periods when the transmitter is quiescent or when operating at reduced power levels. Thus, for burst transmissions, the EUT must either be configured to transmit continuously at full power while the compliance measurement is performed, or the measurement instrumentation must be configured to acquire data only over durations when the EUT is actively transmitting at full power. A spectrum/signal analyzer, an EMI receiver or an average-reading power meter can be used to perform this measurement as long as the above condition can be realized.

Additionally, when using a spectrum/signal analyzer to perform an average power measurement, the number of measurement points in each sweep must be set greater than or equal to twice the span divided by the RBW (# measurement points ≥ 2 × span / RBW). This will ensure a bin-to-bin spacing that is less than or equal to the RBW / 2, so that narrowband signals are not lost between frequency bins.

5.2.2 Procedure for use with a spectrum/signal analyzer when EUT can be configured to transmit continuously or when sweep triggering/signal gating can be properly implemented

The EUT is considered to transmit continuously if it can be configured to transmit at a burst duty cycle of greater than or equal to 98 % throughout the duration of the measurement. If this condition can be achieved, then the following procedure can be used to measure the average output power of the EUT.

This procedure can also be used when the EUT cannot be configured to transmit continuously, provided that the measurement instrument can be configured to trigger a sweep at the beginning of each full-power transmission burst, and the sweep time is less than or equal to the minimum transmission time during each burst (i.e., no burst off-time is to be included in the measurement).

a) Set span to 2 × OBW to 3 × OBW
b) Set RBW = 1 % to 5 % of the OBW, not to exceed 1 MHz.
c) Set VBW ≥ 3 × RBW.
d) Set number of measurement points in sweep ≥ 2 × span / RBW.
e) Sweep time:
    1) set = auto-couple, or

2) set ≥ [10 × (number of points in sweep) × (transmission symbol period)] for single sweep (automation-compatible) measurement.

f) Detector = power averaging (rms).

g) If the EUT can be configured to transmit continuously (i.e., burst duty cycle ≥ 98 %), then set the trigger to free run.

h) If the EUT cannot be configured to transmit continuously (i.e., burst duty cycle < 98 %), then use a sweep trigger with the level set to enable triggering only on full power bursts and configure the EUT to transmit at full power for the entire duration of each sweep. Verify that the sweep time is less than or equal to the transmission burst duration. Time gating can also be used under similar constraints (i.e., configured such that measurement data is collected only during active full-power transmissions).

i) Trace average at least 100 traces in power averaging (rms) mode, if sweep is set to auto-couple. To accurately determine the average power over multiple symbols, it can be necessary to increase the number of traces to be averaged above 100 or, if using a manually configured sweep time, increase the sweep time.

j) Compute the power by integrating the spectrum across the OBW of the signal using the band-power or channel-power measurement function of the instrument, with the band/channel limits set equal to the OBW band edges. If the instrument does not have a band-power or channel-power function, then sum the spectrum levels (in linear power units) at intervals equal to the RBW extending across the entire OBW of the spectrum.

5.2.3 Procedures for use with a spectrum/signal analyzer when EUT cannot be configured to transmit continuously and sweep triggering/signal gating cannot be properly implemented

5.2.3.1 General

If the EUT cannot be configured to transmit continuously (burst duty cycle < 98 %) and sweep triggering/signal gating techniques cannot be properly implemented, then one of the following procedures can be used. The selection of the applicable procedure will depend on the characteristics of the measured burst duty cycle.

An oscilloscope with a diode detector that combined have sufficiently short response time to permit accurate measurements of the on and off times. A fundamental condition for all average power compliance measurements are that they be performed with the EUT transmitting continuously (duty cycle ≥ 98 %) at maximum output power level. However, in those cases where this condition cannot be realized, then one of the alternate procedures must be selected based on whether the EUT transmitter exhibits a constant or a non-constant duty cycle. The measurement of transmitter duty cycle shall be performed using one of the following techniques:

a) Off times of the transmitted signal.

b) The zero-span mode on a spectrum analyzer 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.[3]

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[3] Burst duty cycle measurements require that the spectrum/signal analyzer has properly configured synchronization and gated inputs. The spectrum/signal analyzer provides better accuracy when the synchronization and gated pulses have rise times and fall times that are faster than the rise times and fall times of the signal under measurement.

5.2.3.2 Constant burst duty cycle

If the measured burst duty cycle is constant (i.e., duty cycle variations are less than ± 2 %), then:

a) Set span to 2 × OBW to 3 × OBW
b) Set RBW = 1 % to 5 % of the OBW, not to exceed 1 MHz.
c) Set VBW ≥ 3 × RBW.
d) Number of points in sweep ≥ 2 × span / RBW. (This gives bin-to-bin spacing ≤ RBW / 2, so that narrowband signals are not lost between frequency bins.)
e) Sweep time:
    1) set = auto-couple, or
    2) set ≥ [10 × (number of points in sweep) × (transmission symbol period)] for single sweep (automation-compatible) measurement.
f) Detector = power averaging (rms).
g) Set sweep trigger to "free run."
h) Trace average at least 100 traces in power averaging (rms) mode if sweep is set to auto-couple. To accurately determine the average power over the on and off time of the transmitter, it can be necessary to increase the number of traces to be averaged above 100, or if using a manually configured sweep time, increase the sweep time.
i) Compute power by integrating the spectrum across the OBW of the signal using the band-power or channel-power measurement function of the instrument with band/channel limits set equal to the OBW band edges. If the instrument does not have a band-power or channel-power function, sum the spectrum levels (in linear power units) at intervals equal to the RBW extending across the entire OBW of the spectrum.
j) Add 10 log (1 / duty cycle) to the measured power to compute the average power during continuous transmission. For example, add 10 log (1 / 0.25) = 6 dB if the duty cycle is a constant 25 %.

5.2.3.3 Non-constant burst duty cycle

If the measured burst duty cycle is not constant (i.e., duty cycle variations are greater than or equal to ± 2 %), then:

a) Set the span to 2 × OBW to 3 × OBW
b) Set RBW = 1 % to 5 % of the OBW, not to exceed 1 MHz.
c) Set VBW ≥ 3 × RBW.
d) Set the number of measurement points in sweep ≥ 2 × span / RBW.
e) Configure a sweep time such that each display point is averaged over a period less than the transmit burst time (i.e., transmission duration > sweep time / number of measurement points in sweep) but allows for averaging over multiple symbols (e.g., by setting the sweep time >> number of measurement points in sweep × the symbol period). The sweep time should be configured toward the upper end of the range defined by: (number of points × symbol period < sweep time < transmission duration × number of measurement points). Where possible (i.e., where dwell time per point is still >> symbol period, and sweep time is greater than the auto-coupled sweep time), setting the dwell time per point to one-half of the transmission duration may result in a more repeatable measurement (i.e., sweep time = transmission duration / 2 × number of measurement points).
f) Detector = power averaging (rms).
g) Set sweep trigger to "free run."

h) Trace mode = max hold.
i) Allow trace to fully stabilize.
j) Compute the power by integrating the spectrum across the OBW of the signal using the band-power or channel-power measurement function of the instrument with band/channel limits set equal to the OBW band edges. If the instrument does not have a band-power or channel-power function, then sum the spectrum levels (in linear power units) at intervals equal to the RBW extending across the entire OBW of the spectrum.

5.2.4 Average power measurement with average-reading power meter

As an alternative to the use of a spectrum/signal analyzer or EMI receiver to perform a measurement of the total in-band average output power, a wideband RF average-reading power meter with a thermocouple detector or equivalent can be used under certain conditions.

If the EUT can be configured to transmit continuously (i.e., the burst duty cycle ≥ 98 %) and at all times the EUT is transmitting at is maximum output power level, then a conventional wide-band RF power meter can be used.

If the EUT cannot be configured to transmit continuously (i.e., the burst duty cycle < 98 %), then there are two options for the use of an average-reading power meter.

a) First, a gated average-reading power meter can be used to perform the measurement if the gating parameters can be adjusted such that the power is measured only over active transmission bursts at maximum output power levels.

b) A conventional average-reading power meter can also be used if the measured burst duty cycle is constant (i.e., duty cycle variations are less than ± 2 %) by performing the measurement over the on/off burst cycles and then correcting (increasing) the measured level by a factor equal to 10 log (1 / duty cycle).

5.3 Peak power spectral density measurements with a spectrum/signal analyzer or EMI receiver

Some licensed rule parts specify the RF output power limits in terms of peak power spectral density (PSD) or peak ERP or EIRP spectral density (i.e., the power or ERP or EIRP limits are defined over a specified reference bandwidth, often 1 MHz). In addition, measured peak-PSD levels can be used to demonstrate compliance to average-PSD limits under the assumption that the peak-PSD will always be greater than or equal to the average-PSD.

The following procedure can be used with a spectrum/signal analyzer or EMI receiver to determine peak-PSD.

a) Set the analyzer center frequency to the OBW center frequency.
b) Set the span to 2 × OBW to 3 × OBW.
c) Set the RBW to the specified reference bandwidth (typically 1 MHz for f > 1 GHz).
d) Set the VBW ≥ 3 × RBW.
e) Detector = peak.
f) Sweep time = ≥ 10 × (number of points in sweep) × (transmission symbol period).
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 specified reference bandwidth, i.e., the peak-PSD.

5.4 Average power spectral density measurements with a spectrum/signal analyzer or EMI receiver

Some licensed rule parts specify the RF output power limits in terms of maximum- or average-PSD, or average ERP or EIRP spectral density (i.e., the power or ERP or EIRP limits are defined over a specified reference bandwidth, often 1 MHz).

When average-PSD limits are specified, the averaging is to be performed only over durations of active transmissions at maximum output power level (i.e., averaging over durations of active transmissions at maximum output power level). Thus, for burst transmissions, the EUT must either be configured to transmit continuously at full power while the compliance measurement is performed, or the measurement instrumentation must be configured to acquire data only over durations when the EUT is actively transmitting at full power. A spectrum/signal analyzer or an EMI receiver can be used to perform this measurement as long as the above condition can be realized.

Additionally, when using a spectrum/signal analyzer to perform an average power measurement, the number of measurement points in each sweep must be set greater than or equal to twice the span divided by the RBW (# measurement points $\geq 2 \times$ span / RBW). This will ensure a bin-to-bin spacing that is less than or equal to the RBW / 2, so that narrowband signals are not lost between frequency bins.

The average-PSD is measured following the same procedures described in 5.2.2 for measuring the total average power, but with the RBW set to the reference bandwidth specified by the applicable regulatory requirement, and by using the marker function to identify the maximum-PSD instead of summing the power across the OBW. If the measurement condition of 5.2.2 cannot be realized, then one of the alternative procedures in 5.2.3.2 or 5.2.3.3 should be selected, based on whether the transmitter duty cycle is constant (variations $\leq \pm 2$ %) or non-constant (variations $> \pm 2$ %), respectively.

5.5 Power adjustments for devices with multiple output ports

The procedures above provide guidance for measuring the conducted RF output power referenced to a single transmitter port. Many contemporary digital transmission devices utilize multiple output ports to accommodate multiple-input and multiple-output (MIMO) technologies. In these cases it becomes necessary to measure the RF power at each output power and then sum the measured power levels (in linear terms) to determine the effective RF output power. The procedures for MIMO and similar devices given in KDB Publication 662911 should be used where applicable.

5.6 Determining ERP and EIRP from conducted RF output power measurement results

In many cases, the RF output power limits for licensed digital transmission devices are specified in terms of effective radiated power (ERP) or equivalent isotropically radiated power (EIRP). Typically, ERP is specified when the operating frequency is less than or equal to 1 GHz, and EIRP is specified when the operating frequency is greater than 1 GHz. Both are determined by adding the transmit antenna gain to the conducted RF output power, with the primary difference between the two being that when determining the ERP, the transmit antenna gain is referenced to a dipole antenna (i.e., dBd) whereas when determining the EIRP, the transmit antenna gain is referenced to an isotropic antenna (dBi).

The relevant equation for determining the ERP or EIRP from the conducted RF output power measured using the guidance provided above is:

ERP or EIRP = $P_{Meas} + G_T - L_C$

where:

ERP or EIRP = effective radiated power or equivalent isotropically radiated power, respectively (expressed in the same units as P_{Meas}, typically dBW or dBm);
P_{Meas} = measured transmitter output power or PSD, in dBm or dBW;
G_T = gain of the transmitting antenna, in dBd (ERP) or dBi (EIRP);
L_C = signal attenuation in the connecting cable between the transmitter and antenna, in dB.[4]

For devices utilizing multiple antennas, KDB Publication 662911 provides guidance for determining the effective array transmit antenna gain term to be used in the above equation.

5.7 Peak-to-average power ratio

5.7.1 General

Many rule parts that permit the measurement of average power levels for comparison to the applicable RF output power limit also specify a limit on the peak-to-average power ratio (PAPR). If peak power or power density is used to demonstrate compliance, a PAPR measurement is not required. The following two procedures offer guidance for measuring the PAPR.

5.7.2 Peak power in a broadband noise-like signal from CCDF measurements

The inherent randomness of the power peaks in a noise-like signal and the wide bandwidths associated with modern technologies makes it difficult to quantify the peak power using traditional measurement techniques for determining the peak power of an analog signal. The peak power of a noise-like (e.g., digitally-modulated) signal is predictable only on a statistical basis, a statistical measurement of the peak power is necessary.

Graphs of the power complementary cumulative distribution function (CCDF) provide a means for characterizing the power peaks of a digitally modulated signal on a statistical basis. A CCDF curve depicts the probability of the peak signal amplitude exceeding the average power level. Most contemporary measurement instrumentation include the capability to produce CCDF curves for an input signal, provided that the resolution bandwidth of the instrument can be set wide enough to accommodate the entire input signal bandwidth. Guidelines for performing a CCDF measurement are as follows.

a) Refer to the instruction manual of the instrument for details on how to use the power statistics/CCDF function;
b) Set resolution/measurement bandwidth ≥ OBW of the signal, or ≥ specified reference bandwidth;
c) Set the number of counts to a value that stabilizes the measured CCDF curve;
d) Set the measurement interval as follows:

[4] For personal/portable radios utilizing an integral antenna, this factor is typically negligible. However, in a fixed station transmit system that utilizes a long cable run between the transmitter and the transmitting antenna, this factor can be significant. The minimum cable loss should be used in this equation.

1) For continuous transmissions, set to [10 × (number of points in sweep) × (transmission symbol period)] or 1 ms.
2) For burst transmissions, employ an external trigger that is synchronized with the EUT burst timing sequence, or use the internal burst trigger with a trigger level that allows the burst to stabilize. Set the measurement interval to a time that is less than or equal to the burst duration.
3) If there are multiple carriers (i.e., multiple emission signals with specific associated necessary bandwidths) in a single antenna port, the peak power for that port shall be determined for each individual carrier by disabling the other carriers while measuring the required carrier, then the total peak power is calculated from the sum of the individual carrier peak powers.

e) Record the maximum PAPR level associated with a probability of 0.1 %.

5.7.3 Alternative procedure for PAPR

Use one of the procedures presented in 5.1 to measure the total peak power and record as P_{Pk}. Use one of the applicable procedures presented in 5.2 to measure the total average power and record as P_{Avg}. Both the peak and average power levels must be expressed in the same logarithmic units (e.g., dBm). Determine the PAPR from:

$$\text{PAPR (dB)} = P_{Pk}\text{ (dBm)} - P_{Avg}\text{ (dBm)}.$$

5.8 Radiated measurement considerations for RF output power

5.8.1 General

The guidance provided in the preceding subclauses assumes that the measurements are performed on a conducted-signal basis (i.e., power referenced to the antenna terminals) via a coaxial cable connection between the EUT transmit antenna port and the measurement instrumentation. In addition to Section 2.1046 conducted power test data, further to Section 2.911(c) radiated power measurements may be needed for some devices when an applicable radio service rule specifies ERP or EIRP limits. However, for some EUTs, for example portable or handheld devices having one or more transmitting integral antennas, measurements cannot be performed in a conducted signal configuration. In such cases, it becomes necessary to perform compliance measurements in a radiated test arrangement.[5] Although the basic guidance for instrumentation and settings given above is equally applicable in a radiated test arrangement, the following guidance pertains specifically to performing radiated measurements when used along with the procedures in the preceding subclauses.

5.8.2 Test site requirements

Radiated measurements are typically performed on an open-area test site (OATS) or within a semi-anechoic or fully-anechoic chamber. KDB Publication 414788 provides general guidance for radiated emission test site requirements.[6] Current FCC Laboratory policy [2.1041, 2.947(a)(3)] requires that final

[5] Further to Sections 2.1041 and 2.947(a)(3), radiated measurements may be acceptable for some integral-antenna devices for Sections 2.1046 and 2.1051 compliance purposes.

[6] KDB Publication 414788 D01, Test Sites for Radiated Emission Measurements.

radiated measurements shall use substitution methods as described in TIA-603-E[7] (see also KDB Publication 442401).[8]

5.8.3 EUT placement, measurement distance and amplitude maximization

The EUT shall be arranged for measurement as described in TIA-603-E or ANSI C63.4.[9]

The distance between the EUT and the test antenna shall be adequate to ensure that the measurements are performed in the radiated far-field. The maximum amplitude of the radiated output power must be found by employing a volume search comprising both the horizontal (azimuth) and vertical (elevation) planes. The polarization of the measurement antenna must also be matched with the EUT to determine the maximum amplitude. The procedures given in ANSI C63.4 for ensuring that the radiated amplitude is maximized shall be used.

5.8.4 Measurement quantity conversions

It is often more convenient to measure the field strength in a radiated measurement and then mathematically convert the measured level to an equivalent power level for comparison to the applicable limit. The following relationships can be used to facilitate using radiated measurement data to demonstrate compliance to the relevant conducted output power limits (assuming that all radiated data was collected in the far-field region of both transmit and receive antennas):

a) E (dBμV/m) = Measured amplitude level (dBμV) + Cable Loss (dB) + Antenna Factor (dB/m).
b) E (dBμV/m) = Measured amplitude level (dBm) + 107 + Cable Loss (dB) + Antenna Factor (dB/m).
c) E (dBμV/m) = EIRP (dBm) – 20 log D + 104.8; where D is the measurement distance in meters.
d) EIRP (dBm) = E (dBμV/m) + 20 log D − 104.8; where D is the measurement distance in meters.
e) ERP = EIRP – 2.15 (dB); where ERP and EIRP are expressed in consistent units.
f) EIRP = ERP + 2.15 (dB); ERP and EIRP are expressed in consistent units.

Note that the antenna factor is typically only provided for standard measurement distances (e.g., 1 m and/or 3 m), and thus may be a deciding factor in choosing what measurement distance to use.

6 SPURIOUS EMISSIONS AT ANTENNA TERMINALS

6.1 General

The spurious (unwanted) emission limits specified in the individual FCC rule parts applicable to licensed digital transmitters (typically under the heading "emission limits") normally apply to any and all emissions that are present outside of the authorized frequency band/block and apply to emissions in both the out-of-band and spurious domains. In some rule parts, the unwanted emission limits are specified by

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[7] ANSI/TIA-603-E-2015, *Land Mobile FM or PM Communications Equipment Measurement and Performance Standards*, Telecommunications Industry Association.

[8] KDB Publication 442401, Subject: Radiated emission measurements for licensed radio equipment.

[9] ANSI C63.4-2014, *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*, Institute of Electrical and Electronic Engineers.

an emission mask that defines the applicable limit as a function of the frequency range relative to the authorized frequency block.

Typically, unwanted emissions are required by the licensed rule parts to be attenuated below the transmitter power by a factor of at least X + 10 log P dB, where P represents the transmitter power expressed in watts and X is a specified scalar value (e.g., 43). This specification can be interpreted in one of two equivalent ways. First, the required attenuation can be construed to be relative to the mean carrier power, with the resultant of the equation X + 10 log P being expressed in dBc (dB relative to the maximum carrier power). Alternatively, the specification can be interpreted as an absolute limit when the specified attenuation is actually subtracted from the maximum permissible transmitter power [i.e., 10 log P – {X + 10 log P}], resulting in an absolute level of −X dBW [or (−X + 30) dBm].

Normally, the applicable rule part specifies the reference bandwidth for measuring unwanted emission levels (typically, 100 kHz if the authorized frequency band/block is at or below 1 GHz and 1 MHz if the authorized frequency band/block is above 1 GHz), effectively depicting the unwanted emission limit in terms of a power spectral density. In those cases where no reference bandwidth is explicitly specified, the values in the parenthetical above should be assumed.

A relaxation of the reference bandwidth is often provided for measurements within a specified frequency range at the edge of the authorized frequency block/band (e.g., within the first Y MHz outside of the authorized frequency band/block, where the value of Y is specified in the relevant rule part). This is often implemented by permitting the use of a narrower RBW (typically limited to a minimum RBW of 1 % of the OBW) for measuring the out-of-band emissions without a requirement to integrate the result over the full reference bandwidth. Beyond the specified frequency range in which this relaxation is permitted, it is also typically acceptable to use a narrower RBW (again limited to a minimum of 1 % of OBW) to increase accuracy, but the measurement result must subsequently be integrated over the full reference bandwidth.

Some rule parts specify that the unwanted emission limits are expressed in terms of peak or average power or PSD, while other rule parts do not. When no explicit specification is made, then it should be assumed that the unwanted emissions are to be measured in a manner consistent with how the power or PSD in the fundamental emission is measured (e.g., if peak power or PSD measurements were performed to demonstrate compliance to the fundamental power limit, then the peak power or PSD of the unwanted emissions shall be measured for comparison to the applicable emission limits).

The procedures provided in Clause 5 (in particular, 5.3 and 5.4) are also applicable to the measurement of unwanted emissions, with some minor modifications. In addition, the requirements associated with the procedures are also applicable when used to measure unwanted emission levels (e.g., the requirement to perform average measurements only during active bursts and the minimum required number of measurement points). Modifications to the procedures include the following.

Instead of setting a center frequency, set the start and stop frequency to accommodate the frequency range over which the unwanted emissions measurement is to be performed. At the frequency block/band edge, it is acceptable to employ a start frequency or stop frequency such that the 3 dB point of the RBW coincides with the block/band edge frequency (e.g., start/stop frequency can be set equal to the block edge frequency ± RBW / 2). The span of the measurement can be set to encompass the frequency range under examination, subject to the minimum measurement point requirement (minimum of one measurement point per RBW for peak-PSD measurements and two measurement points per RBW for average-PSD measurements).

In licensed rule parts in general, the unwanted emission limit is expressed in terms of "average" power. The use of "Max Hold" will not result in a true average power measurement. Instead, the proper trace mode for performing an average measurement is the "trace average" mode. Alternatively, a single sweep measurement can be used with the sweep speed set such that a relatively long dwell is realized in each trace bucket (typically at least 1 ms per trace point).

Consult the applicable rule part to determine the specific details applicable to the measurement of unwanted emission levels.

6.2 Radiated measurement considerations for spurious emissions at antenna terminals

See 5.8 for details.

7 FIELD STRENGTH OF SPURIOUS RADIATION

When antenna-port conducted measurements are performed to demonstrate compliance to the applicable unwanted emission limits (Section 2.1051), a separate radiated measurement is required to detect spurious emissions that may be radiated directly from the cabinet, control circuits, power leads, or intermediate circuit elements under normal conditions of installation and operation (Section 2.1053). Note that when radiated measurements are performed to demonstrate compliance to the unwanted emission limits (e.g., for an EUT with integral transmit antenna), this measurement is not required.

These measurements are performed with the transmit antenna port(s) terminated. Unless otherwise specified in the applicable rule section, the same limits applicable to spurious (unwanted) emissions at the antenna terminals also apply to radiated spurious emissions.

The considerations and requirements specified in 5.8 apply.

8 FREQUENCY SPECTRUM TO BE INVESTIGATED

The frequency spectrum that must be examined for evaluating unwanted emission levels for compliance to the applicable limits is specified in Section 2.1057. In all cases, the spectrum shall be investigated from the lowest radio frequency generated by the EUT without going below 9 kHz up to the following:

a) If the EUT operates below 10 GHz: to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.
b) If the EUT operates at or above 10 GHz and below 30 GHz: to the fifth harmonic of the highest fundamental frequency or to 100 GHz, whichever is lower.
c) If the EUT operates at or above 30 GHz: to the fifth harmonic of the highest fundamental frequency or to 200 GHz, whichever is lower.

The amplitudes of unwanted emissions that are attenuated more than 20 dB below the applicable limit are not required to be reported.

9 FREQUENCY STABILITY

The frequency stability of the transmitter shall be measured while varying the ambient temperatures and supply voltages over the ranges specified in Section 2.1055. The specific frequency stability limits are provided in the relevant rules section(s).

CHANGE NOTICE

6/04/2013: 971168 D01 Licensed DTS Guidance v01 is replaced by 971168 D01 Licensed DTS Guidance v02. Sublcause 5.3(e) modified relax measurement point requirement for preliminary measurements and 5.8.1 modified to reflect current laboratory policy with respect to substitution requirements.

6/07/2013: 971168 D01 Licensed DTS Guidance v02 is replaced by 971168 D01 Power Meas License Digital Systems v02r01. The previous guidance 971168 D01 Licensed DTS Guidance v02 should have been identified as 971168 D01 Power Meas License Digital Systems v02.

- 971168 D01 Power Meas License Digital Systems v02r01 and 971168 D01 Licensed DTS Guidance v02 are the same documents and the only difference is to correct the document name and Change notice of 06/07/2013. A revesion (r01) was added to identify this document name change and change notice.
- 971168 D01 Power Meas License Digital Systems v02r01 updates the previous publication 971168 D01 Power Meas License Digital Systems v01.
- 971168 D01 Power Meas License Digital Systems v02r01 was updated after receiving comments on draft publication 971168 D01 Power Meas License Digital Systems v02 DR02-41372.

10/17/2014: 971168 D01 Licensed DTS Guidance v02r01 is replaced by 971168 D01 Licensed DTS Guidance v02r02.

- Cross-references added to new 971168 D02 Misc OOBE License Digital Systems v01.
- Footnote added at Cl. 5 about using base-station simulator for power measurements.
- Numbering corrected at subclauses in 5.2.2 and 5.4.2.
- Cross-reference to MIMO etc. KDB Pub. 662911 added at 5.5.
- Basic far-field condition stated at 5.8.3.
- Basic guidance about trace-average setting added in Cl. 6.

04/TBD/2017*: 971168 D01 Power Meas License Digital Systems v02r02 is replaced by 971168 D01 Power Meas License Digital Systems v03. Substantive modifications are as follows. * Changes reflected in this draft that are planned to be published.

- Updated standards references in footnotes.
- Inserted subheadings “General” in several subclauses, for resolving hanging paragraphs.
- Updated steps in procedures per any differences with ANSI C63.26-2015, where procedures overlap across the documents.
- Added line and footnote in 5.1 about conducted power.
- Added references to KDB Publications 414788, 442401.
- Omitted “upper band/block edge” from Clause 8.
- The former 5.4.1 and 5.4.2 are omitted, being replaced (as redundant) by the fourth paragraph of 5.4 in this version (similar as with 5.2.4.5 of ANSI C63.26-2015).
- Added appendix listing correspondences between 971168 D01 and ANSI C63.26-2015 subclauses.

APPENDIX A
GENERAL CORRESPONDENCE BETWEEN SELECTED SUBCLAUSES OF KDB PUBLICATION 971168 D01 WITH ANSI C63.26-2015 SUBCLAUSES

KDB Publication 971168 D01 v03	ANSI C63.26-2015
2.1 Transmitters employed in network communications	5.2.1 RF power measurement instrumentation considerations
2.2 Measurement instrumentation considerations	4.2.3 Spectrum analyzer
2.2 Measurement instrumentation considerations	5.2.2 RF signal type considerations
3 MODULATION CHARACTERISTICS (general compared to ANSI C63.26-2015)	5.3 Modulation characteristics
4 OCCUPIED BANDWIDTH MEASUREMENTS	5.4.2 Typical modulation configurations (5.4 Occupied bandwidth)
4.1 Occupied bandwidth – relative measurement procedure	5.4.3 Occupied bandwidth—Relative measurement procedure
4.2 Occupied bandwidth – power bandwidth (99%) measurement procedure	5.4.4 Occupied bandwidth—Power bandwidth (99%) measurement procedure
5.1 Peak power measurements, 5.1.1 General	5.2.3.1 General
5.1.2 Peak power measurements with a spectrum/signal analyzer or EMI receiver	5.2.3.3 Measurement of peak power in a narrowband signal with a spectrum/signal analyzer or EMI receiver
5.1.3 Peak power measurements with a peak-reading power meter	5.2.3.2 Measurement of peak power with a peak power meter
5.2 Average power measurements, 5.2.1 General	5.2.4.1 General (includes “decision process” for method, narrowband vs. broadband)
5.2.2 Procedure for use with a spectrum/signal analyzer when EUT can be configured to transmit continuously or when sweep triggering/signal gating can be properly implemented	5.2.4.4.1 General
Procedures for use with a spectrum/signal analyzer when EUT cannot be configured to transmit continuously and sweep triggering/signal gating cannot be properly implemented, 5.2.3.1 General	5.2.4.3.4 Measurement of the transmitter (EUT) duty cycle
5.2.3.2 Constant burst duty cycle	5.2.4.4.2 Alternative procedure for measuring average power of a broadband signal with a constant duty cycle using a spectrum/signal analyzer or EMI receiver
5.2.3.3 Non-constant burst duty cycle	5.2.4.4.3 Alternative procedure for measuring average power of a broadband signal with a non-constant duty cycle using a spectrum/signal analyzer or EMI receiver
5.2.4 Average power measurement with average-reading power meter	5.2.4.2 General procedure for measuring average power with an average power meter
5.3 Peak power spectral density measurements with a spectrum/signal analyzer or EMI receiver	5.2.3.5 Measurement of peak power spectral density with a spectrum/signal analyzer or EMI receiver
5.4 Average power spectral density measurements with a spectrum/signal analyzer or EMI receiver	5.2.4.5 Procedures for measuring the average power spectral density with a spectrum/signal analyzer or EMI receiver
5.5 Power adjustments for devices with multiple output ports	5.2.5.3 Power adjustments for EUTs with multiple transmit antenna output ports
5.6 Determining ERP and EIRP from conducted RF output power measurements	5.2.5.5 Determining ERP and/or EIRP from conducted RF output power measurements
5.7 Peak-to-average power ratio	5.2.6 Peak-to-average power ratio
5.7.2 Peak power in a broadband noise-like signal from CCDF measurements	5.2.3.4 Measurement of peak power in a broadband noise-like signal using CCDF
5.8 Radiated measurement considerations for RF output power	5.2.7 Radiated power measurements
6 SPURIOUS EMISSIONS AT ANTENNA TERMINALS	5.7.1 General
6 SPURIOUS EMISSIONS AT ANTENNA TERMINALS { X+10logP }	6.4.4.2 Relative emission limits; 6.4.5.4 Directional gain calculations for conducted out-of-band and spurious measurements; see also 5.7 of ANSI C63.26-2015
7 FIELD STRENGTH OF SPURIOUS RADIATION	5.5 Radiated emissions testing
8 FREQUENCY SPECTRUM TO BE INVESTIGATED	5.1.1 Frequency spectrum to be investigated
9 FREQUENCY STABILITY	5.6 Frequency stability testing