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Title: Procedures for Compliance Measurement of the Fundamental Emission Power of Licensed Wideband (> 1 MHz) Digital Transmission Systems

Short Title: Power Meas License Digital Systems

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Keyword/Subject: Guide for power measurement of fundamental for licensed devices with bandwidths greater than 1 MHz

First Category: Administrative Requirements

Second Category: Measurement Procedures

Third Category:

Question: What are the procedures for compliance measurement for the fundamental emission power for licensed wideband (> 1 MHz) digital transmission systems?

Answer: The attachment below 971168 D01 Power Meas License Digital Systems v01 provides a methodology for fully characterizing the fundamental power of wideband (> 1 MHz) digitally modulated RF signals acceptable to the FCC for demonstrating compliance for licensed transmitters.

Attachment List:

971168 D01 Power Meas License Digital Systems v01

Attachment

Procedures for Compliance Measurement of the Fundamental Emission Power of Licensed Wideband (> 1 MHz) Digital Transmission Systems

1.0 Introduction

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

The procedures presented herein are intended to provide a methodology for fully characterizing the fundamental power of wideband (> 1 MHz) digitally modulated RF signals acceptable to the FCC for demonstrating compliance to the applicable output power limits, as specified in the individual rule sections for licensed transmitters. These procedures are deemed applicable for use with contemporary spectrum analyzers and/or vector signal analyzers and can be used in either conducted or radiated test configurations.

2.0 Test Requirements

2.1 The measurements specified herein must be performed over a period of time when the equipment under test (EUT) is transmitting continuously at its maximum output power over the measurement duration (*i.e.*, no averaging permitted over transmitter quiescent periods). For TDMA and/or other burst transmissions, this may require the use of specialized test software or time gated spectrum analysis techniques. If required, consult the spectrum/signal analyzer manufacturer literature for details on how to configure the analyzer to perform time-gated measurements.

2.2 Many of the measurements specified herein require the use of a modern spectrum/signal analyzer with digital signal processing capabilities for performing statistical averaging and computing power statistics.

2.3 For devices that are capable of utilizing multiple channel bandwidths and/or modulation schemes, compliance measurements must be performed on all possible combinations to ensure that the "worst case" emission levels are captured.

2.4 The procedures defined herein can be used in either a conducted or radiated measurement set-up.

3.0 Measurement of the Signal Bandwidth

A contemporary digitally-modulated signal is typically spread over a relatively wide signal bandwidth. As such, the measurement of an individual RF carrier cannot be easily performed as was typical with analog signals. Rather, the power of a digital signal with no visible or prominent carriers must be expressed over a specified bandwidth, not at the peak of a specific carrier in the channel. Therefore, it becomes necessary to measure the signal bandwidth prior to performing a measurement of the signal power with a spectrum or signal analyzer.

For licensed digital wideband transmitters, the signal bandwidth of interest is the occupied bandwidth (OBW). [1] Section 2.202(a) of the FCC rules defines the occupied bandwidth (OBW) as the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean power is equal to 0.5% of the total mean power radiated by a given emission.

The following is an acceptable procedure for measuring the OBW with a contemporary spectrum or signal analyzer.

First, acquire the DUT Signal:

Set frequency = nominal signal center frequency;

Set span = at least twice the anticipated signal bandwidth;

Set RBW ≈ 1% of span;

Set VBW = 3 x RBW;

Use auto-couple sweep time.

Then activate the occupied bandwidth measurement function:

Ensure that OBW span is wide enough to capture all modulation products including emission skirts (~ 2 x signal bandwidth);

Set % Power = 99.0%;

Select the average power (RMS) detector;

Optimize the reference level;

Record the displayed OBW value.

4.0 Measurement of the Average Power over the Fundamental Signal Bandwidth

To ensure repeatability, an average power measurement procedure must be capable of producing consistent results no matter how complex the modulation/coding scheme utilized. This necessitates a methodology that is independent of signal-specific waveform characteristics.

[1] Although many rule parts specify an emission bandwidth, defined as the bandwidth between points on the emission skirts that are 26 dB down from the fundamental power level, the occupied bandwidth is a more accurate and straightforward measurement and is acceptable to the FCC in lieu of the signal's emission bandwidth.

The RMS function as implemented in contemporary spectrum analyzers takes the measured waveform values collected over a specific time period (integration time), squares each linear value, sums them and then divides out the time units and performs a square root of the result to bring the value back into scale with the original units. The effect of this function is to homogenize the waveform variations to an average or mean value.

Digital data transmissions require a specific bandwidth to transmit information. Therefore, the average output power must be expressed over the signal bandwidth.

Integrated Band Power Measurement Procedure with Spectrum/Signal Analyzer

Set frequency = nominal signal center frequency;

Set span = 2 x occupied bandwidth;

Set resolution bandwidth ≈ 1-5 % of the span, not to exceed 1 MHz;

Set VBW ≥ 3 x resolution/measurement BW [2];

Select average power (RMS) detector;

Set sweep time and number of measurement points to achieve a minimum of 1 millisecond/pt integration time [3] (*e.g.*, set sweep time to 1 sec for 1001 measurement points);

Activate trace averaging routine over a minimum of 10 sweeps;

Activate marker/span pair and set span = signal or channel bandwidth;

Activate the band/interval power marker function;

Record the band power level;

Make necessary adjustments to the measured power level to account for any test peripherals (cable loss, external attenuation, pre-amplifier gain, etc.);

Record adjusted value as the average signal power level.

5.0 Measurement of Average Power Spectral Density

This method is used to measure the average power over a specified reference bandwidth when the limit is expressed as an average power spectral density (PSD).

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[2] If a VBW of 3 x RBW is not realizable, set VBW to maximum value.
[3] Sweep time (millisec) = 1 millisec x (trace points -1).

Set frequency = nominal signal center frequency;

Set span = 2 x occupied bandwidth;

Set resolution bandwidth = the specified reference bandwidth (*e.g.,* 1 MHz);

Set VBW ≥ 3 x resolution BW [4];

Select average power (RMS) detector;

Set sweep time and number of measurement points to achieve a 1millisecond/pt integration time [5] (*e.g.*, set sweep time to 1 sec for 1001pts);

Activate trace averaging routine over a minimum of 10 sweeps;

Use marker peak search function to find maximum power spectral density in the reference bandwidth;

Record the maximum PSD measured level;

Make necessary adjustments to the measured PSD level to account for any test peripherals (cable loss, external attenuation, pre-amplifier gain, etc.);

Record adjusted value as the average PSD in the reference bandwidth.

6.0 Measurement of the Peak-to-Average Power Ratio (PAPR)

The inherent randomness of the power peaks in a noise-like signal 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 digitally-modulated signal is predictable only on a statistical basis. Thus, for these types of signals, a statistical measurement of the peak power is necessary.

Power Complimentary Cumulative Distribution Function (CCDF) curves 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 instrument's resolution bandwidth can be set wide enough to accommodate the entire input signal bandwidth. The following guidelines are offered for performing a CCDF measurement.

[4] If a VBW of 3 x RBW is not realizable, set VBW to maximum value.
[5] Sweep time (msec) = 1 msec x (trace points -1).

Refer to instrument's analyzer instruction manual for details on how to use the power statistics/CCDF function;

Set resolution/measurement bandwidth ≥ signal's occupied bandwidth;

Set the number of counts to a value that stabilizes the measured CCDF curve;

Set the measurement interval to 1 ms;

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

7.0 Determination of the Peak Power from Measured Parameters

For those rule parts where the maximum permissible output power of a digital transmitter is specified in terms of peak power, levels can be calculated from the measured average power and the measured peak-to-average power ratio as follows:

$$P_{Pk} = P_{Avg} - PAPR$$

where:

P_{Pk} = peak power level with a probability equivalent to the measured PAPR value, in same units as average power level (*e.g.*, dBm or dBW);
P_{Avg} = measured average power level over the occupied bandwidth, in dBm or dBW;
PAPR = measured peak-to-average power ratio with associated probability, in dB.