04/08/2013

Federal Communications Commission
Office of Engineering and Technology
Laboratory Division Public Draft Review

Draft Laboratory Division Publications Report

Title: Guidelines for compliance testing of millimeter wave devices

Short Title: Millimeter wave testing

Reason: Revision to provide futher guidance with a new attachment: **200443 D02 RF Detector Method v01**

Publication: 200443

Keyword/Subject: 15.253; 15.255; 15.257; millimeter wave

First Category: Radio Service Rules

Second Category: Measurement Procedures

Third Category:

Question: What measurement procedures should be used for determining compliance of millimeter wave devices?

Answer: The attachment Millimeter Wave provides general guidance for performing compliance measurements on millimeter wave devices operating under 47 CFR Parts 15.253, 15.255 and 15.257.

Sections 15.255 and 15.257 require that the fundamental emission be measured using a RF Detector.

Attachment 200443 D02 RF Detector Method v01[1] provides further guidance for Sections 15.255 and 15.257 on how to perform measurements using an RF detector that has a detection bandwidth of 57-64 or 92-95 GHz and a video bandwidth of at least 10 MHz.

Attachment List:

Millimeter Wave[2]

200443 D02 RF Detector Method v01[1]

[1] This draft will be published by May 20, 2013. Prior to publication applicants can use this draft guidance (200443 D02 RF Detector Method v01) during the interim period for compliance testing.

[2] Attachment Millimeter Wave currently in KDB 200443 and is not under draft review.

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Guidelines for Compliance Testing of
Millimeter Wave Devices subject to the RF Detector Measurement in
Sections 15.255 & 15.257

1. Introduction

This publication provides a measurement procedure for devices subject to the requirements of Sections 15.255 and 15.257, where the fundamental emission is required to be measured with an RF detector that has a detection bandwidth of 57-64 or 92-95 GHz and a video bandwidth of at least 10 MHz.

2. General considerations

The following measurements shall be performed during transmit intervals. Normally radiated emission measurements are expected to be performed, though in some cases it may possible to perform conducted fundamental emission measurements if there is access to the transmitter output. Care must be taken to assure that peak emission levels do not exceed the safe input levels or cause amplitude compression for the measurement instruments such as spectrum analyzers, harmonic mixers, oscilloscopes, RF diode detectors and frequency downconverters. Attenuators may be required when making conducted measurements while low noise amplifiers may be required for radiated emission measurements. Be aware that when using harmonic mixers in conjunction with a spectrum analyzer, image interference with the fundamental emission will occur when the bandwidth of the fundamental is greater than twice the I.F. frequency of the spectrum analyzer.

The fundamental emission measurements are performed using a digital storage oscilloscope (DSO) and with a minimum RF Detector bandwidth of 10 MHz. The video bandwidth of the RF Detector is dependent on the load which is the input impedance of the DSO. In order to achieve the required video bandwidth it is necessary to connect the RF Detector to the 50 ohm input of the DSO.[3]

When the output of the RF detector is applied to the 50 ohm input of the DSO (which has the same 12 pf input capacitance) with a 50 ohm coax cable, the video bandwidth can be as high as several hundred megahertz but the amplitude will be reduced depending on the characteristics of the RF detector. If desired, a 10 MHz or greater low pass filter could then be introduced to reduce the bandwidth of the

[3] The reason that the 1 megohm input of a DSO should not be used is that it typically has a capacitance of about 12 pf which reduces the video bandwidth of the RF detector to significantly less than the 10 MHz minimum required by the rules. The video bandwidth will be further reduced by the introduction of a coax cable to connect the DSO to the RF detector (which is necessary to permit the manipulation of the test antenna/detector to measure the radiated emissions).

detected signal applied to the input of the DSO. A DSO typically has functions that calculate and display the desired average and peak values of the signal.

When a low pass filter is not used in the measurement, the sampling rate must be at least twice the bandwidth of the detected signal. If a low pass filter, with a cutoff frequency greater than 10 MHz, is used, the sampling rate must be at least twice the cutoff frequency of the low pass filter.

Spurious emission measurements are performed with a spectrum analyzer to determine compliance with the field strength limits. All emissions below 1000 MHz are based on measurements employing a CISPR quasi-peak detector. All spurious emissions above 1000 MHz are to be measured with an average detector utilizing a 1 MHz resolution bandwidth with a one millisecond dwell time over each 1 MHz segment. The frequency span of the analyzer should equal the number of sampling bins times 1 MHz and the sweep rate of the analyzer should equal the number of sampling bins times one millisecond. The video bandwidth of the measurement instrument shall not be less than the resolution bandwidth and trace averaging shall not be employed. The emission measurement is to be repeated over multiple sweeps with the analyzer set for maximum hold until the amplitude stabilizes.

3. Fundamental emission bandwidth

Section 15.255 specifies that when the emission bandwidth is less than 100 MHz, there is a limit on the peak conducted output power which is the product of 500 mW times the emission bandwidth divided by 100 MHz. For the purpose of determining compliance with this requirement, the emission bandwidth is defined as the 6 dB bandwidth when measured with a 100 kHz RBW. For other purposes in Sections 15.255 and 15.257, the emission bandwidth is defined as the 26 dB bandwidth when measured with a RBW no less than 1 MHz.

a) Using a receive test antenna and amplifier, if necessary, for the 57-64 GHz frequency range, display the signal on a spectrum analyzer with sufficient amplitude to permit measurement of the bandwidth. A harmonic mixer or downconverter may be necessary if the frequency range of the spectrum analyzer is insufficient to display the signal directly.

b) Determine the 6 dB bandwidth of the signal. If the bandwidth is less than 100 MHz, calculate the peak power limit from equation (1).

$$P_{Limit} = \left(\frac{BW}{100}\right) * 500mW \quad (1)$$

c) Determine the 26 dB emission bandwidth.

4. Fundamental emission power measurement

a) Place the EUT in a continuous transmission mode.

b) For radiated emission measurements, attach a test horn antenna for the fundamental frequency band to the RF input of an RF detector or a downconverter with an RF detector at the output. If necessary, insert a low noise amplifier between the output of the test antenna and the RF input. For conducted transmitter output power measurements, connect the RF detector or the downconverter with appropriate attenuation to the output port of the EUT, if available.

c) Connect the video output of the detector to the 50 ohm input of the DSO through a 10 MHz or greater low pass filter.

d) For radiated emission measurements, place the test horn in the main beam of the EUT at a distance which will provide a signal within the operating range of the RF detector or downconverter.

e) Set the sampling rate of the DSO to the required value. Adjust the memory depth, the triggering and the sweep speed to obtain a display which is representative of the signal considering the type of modulation. If the signal is non-continuous, identify the segment of the signal which has the highest amplitude and adjust the triggering and the sweep speed to capture that segment.

f) For radiated emission measurements, calculate the distance to the far field of the fundamental emission using equation (2).

$$d_{farfield} = \frac{2D^2}{\lambda} \qquad (2)$$

where:

D = largest dimension of the transmit antenna

λ = wavelength

g) For radiated emission measurements, maximize the received signal from the EUT in the far field. If it is impractical to make measurements in the far field because of the distance or low signal levels, measurements may be performed in the near field but a low noise amplifier and/or a higher gain test antenna should be used to make measurements at the greatest distance from the EUT which provides an adequate signal to noise ratio to permit accurate amplitude measurements.

h) Record the average and peak from the DSO and, for radiated emissions, the measurement distance.

i) Measurement system calibration. To determine the power level from the signal display on the DSO, the measurement system must be calibrated. This can be accomplished by applying a signal from a source of known amplitude to the input of the RF detector or downconverter and adjusting the amplitude of the source so the level on the DSO display equals the recorded measured amplitude.

j) For radiated emissions, calculate the field strength (F.S) in dBμV/meter using equation (3).

$$F.S. = P + 107 + AF \qquad (3)$$

where:

F.S. is field strength in dBμV/meter

P is power in dBm

AF is antenna factor of test antenna

k) For radiated emissions, calculate the EIRP (dBm). If the measurement was performed in the far field, calculate the EIRP using equation (4).

$$EIRP = F.S. - 104.8 + 20Log(d) \qquad (4)$$

where:

d = measurement distance

If the measurement was performed in the near field and the antenna characteristics in the near field are known, determine the value of the field strength in the far field and calculate the EIRP. If the characteristics in the near field are not known and the measurement was performed in the near field but no less than 0.1 of the far field distance, extrapolate the measured field strength to the calculated far field distance $d_{farfield}$ with a 20 dB/decade extrapolation factor and calculate the EIRP from the extrapolated field strength at the far field distance. If the measurement was performed at a distance less than 0.1 of the far field distance, assume that the measurement was performed at 0.1 of the far field distance and extrapolate to the far field distance $d_{farfield}$ at 20 dB/decade.

l) For radiated emission measurements, calculate conducted transmitter output power P_{Cond} (dBm) using equation (5).

$$P_{Cond} = EIRP - G_{dBi} \tag{5}$$

where:

G_{dBi} is gain of EUT antenna.

m) For conducted emission measurements, calculate the EIRP using equation (6).

$$EIRP = P_{Cond} + G_{dBi} \tag{6}$$

5. Spurious emissions

Spurious radiated emissions below 40 GHz must comply with the general field strength limits of Section 15.209. Below 1000 MHz, measurements are made with a CISPR quasi-peak detector and above 1000 MHz measurements are made with an average detector with a 1 MHz RBW at 3 meters. From 40 GHz to 200 GHz the emissions must not exceed 90 pW/cm^2 (18,000 µV/m) at 3 meters. Measurements are to be performed at the specified limit distance. If signal levels are insufficient to permit measurements at the limit distance, measurements should be performed at the greatest distance possible and extrapolated to the limit distance as specified in Section 15.31.

6. Frequency stability

The fundamental emission must be contained within the frequency band over the temperature range -20 to +50 degrees Celsius with an input voltage variation of 85% to 115% of rated input voltage. Frequency stability is to be measured according to Section 2.1055 to determine where the equipment may be operated within the frequency band without the fundamental emission extending beyond the band of operation.