Millimeter Wave Measurement Procedure

KDB

200443 D02 RF Detector Method v01

TCB Workshop
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Rules in Part 15C related to Millimeter Wave

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

**Answer:** Attachment [200443 D01 Millimeter Wave v01](#) provides general guidance for performing compliance measurements on millimeter wave devices operating under 47 CFR Parts 15.253, 15.255 and 15.257.

While section 15.253 does not require using RF detector for measurements, sections 15.255 and 15.257 require that the fundamental emission be measured using RF Detector. Attachment [200443 D02 RF Detector Method v01](#) provides the guidance on how to perform measurements using RF detector applied for 15.255 and 15.257.
Radiated measurement method is preferred over conducted method when
- Transmitter output may not be accessible (e.g. integrated antenna)
- Transmitter output power may be too high for measurement equipments using conducted method

Measurements made in the far-field is preferred as
- Near-field characteristics depend on antenna structure
- No general closed-form solution exists for near-field

Rules 15.255, 15.257 require using RF detector or a down-converter with an RF detector at the output
- RF detector must have detection bandwidth of 57-64 or 92-95 GHz and a video bandwidth (VBW) $\geq$ 10 MHz
- Measurement is performed in time domain using DSO
- DSO must have sampling rate at least twice the video bandwidth of detected signal
- Optional low-pass filter with cut-off frequency $\geq$ 10 MHz can be used to reduce video bandwidth of detected signal
- If low-pass filter is used, DSO sampling rate must be at least twice the cut-off frequency of low-pass filter
RF Detector
Measurement Set-Up

Near-field

Far-field

\[ d_{\text{farfield}} = 2 \cdot \frac{D^2}{\lambda} \]

Digital Storage Oscilloscope (DSO)

Low-pass Filter (optional)

EUT Antenna

Main beam

Far-field distance

Test Antenna

RF Detector
Complication in Far-field Measurement

Although measurement made in far-field is preferred but, in many circumstances, direct measurements at distance specified by the limit (e.g. 3 meters) in far-field are not possible, for example:

- Far-field distance is not practicable for measurements
- Signal is too low to be measured in far-field

Make measurement in near-field, then extrapolate to distance specified by the limit
Background

**Near-field**

- 0.1 of Far-field distance

**Far-field**

- 0.1·\(d_{\text{farfield}}\)
- \(d_{\text{farfield}} = 2 \cdot \frac{D^2}{\lambda}\)

**Attenuation [dB]**

- 0 dB
- 20 dB/decade
- Assumption: No attenuation in this region

**Distance (log scale)**

- Far-field distance
- Near-field distance
- 20 dB/decade
Radiated Measurement Method

- If the measurement is 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 is performed in the near-field but at distance not less than 0.1 of the far-field distance, extrapolate the measured field strength to the calculated far-field distance \( d_{\text{farfield}} \) with a 20 dB/decade extrapolation factor and calculate the EIRP from the extrapolated field strength at the far-field distance.

- If the measurement is 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 \( d_{\text{farfield}} \) at 20 dB/decade.
Example of Distance to the Far-field vs. Wavelength with a 3” (7.6 cm) Antenna

- **Far-field region**: $d > d_{\text{farfield}}$
- **Near-field region**: $d < d_{\text{farfield}}$

**Symbols**:
- $d$: Measurement distance
- $d_{\text{farfield}}$: Distance to the Far-field
- $D$: Largest dimension of EUT antenna
- $\lambda$: Wavelength at the operating frequency
Distance to the Far-field vs. Wavelength and Antenna Sizes

- **Distance to Far-field [m]**
  - 1
  - 3 m
  - 10
  - 30 GHz
  - 37.5 GHz
  - 50 GHz
  - 60 GHz
  - 75 GHz
  - 100 GHz
  - 150 GHz
  - 300 GHz

- **Wavelength [mm]**
  - 1.00
  - 2.00
  - 3.00
  - 4.00
  - 5.00
  - 6.00
  - 8.00
  - 10.00

- **Frequency**
  - 57 - 64 GHz
  - 92 - 95 GHz

- **D** is the largest Dimension of EUT Antenna

- **D** values:
  - D = 2' (5.1 cm)
  - D = 3' (7.6 cm)
  - D = 4' (10.2 cm)
  - D = 5' (12.7 cm)
  - D = 6' (15.2 cm)
  - D = 8' (20.3 cm)

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Equations used in Radiated Measurement Method

- **Distance to far-field**
  \[
  d_{\text{farfield}} = 2 \cdot \frac{D^2}{\lambda}
  \]
  - \(D\): largest dimension of the transmit antenna, in meters
  - \(\lambda\): wavelength, in meters

- **Field strength**
  \[
  E = P + 107 + AF
  \]
  - \(E\): field strength, in dBuV/m
  - \(P\): measured power, in dBm
  - \(AF\): antenna factor of test antenna, in dB
Equations used in Radiated Measurement Method (cont’d)

Extrapolation

\[ E_{\text{SpecLimit}} = E_{\text{Meas}} + 20 \cdot \log \left( \frac{D_{\text{Meas}}}{D_{\text{SpecLimit}}} \right) \]

- \(E_{\text{SpecLimit}}\): field strength of the emission at the distance specified by the limit, in dBuV/m
- \(E_{\text{Meas}}\): field strength of the emission at the measured distance, in dBuV/m
- \(D_{\text{Meas}}\): measurement distance, in meters
- \(D_{\text{SpecLimit}}\): Distance specified by the limit, in meters

IMPORTANT NOTE: This equation is applied only if the characteristics in the near-field are unknown and the measurement of \(E_{\text{Meas}}\) is performed in the near-field but no less than 0.1 of the far-field distance (\(0.1 \cdot d_{\text{farfield}} < D_{\text{meas}} < d_{\text{farfield}}\))
Equations used in Radiated Measurement Method (cont’d)

**EIRP**

\[
EIRP = E_{\text{Meas}} + 20 \cdot \log(D_{\text{Meas}}) - 104.7
\]

- **EIRP**: equivalent isotropic radiated power, in dBm
- **\(E_{\text{Meas}}\)**: field strength of emission at distance \(D_{\text{Meas}}\), in dBUV/m
- **\(D_{\text{Meas}}\)**: measurement distance, in meters

**Field strength in dBUV/m to field strength in V/m**

\[
E_{\text{Linear}} = 10 \left( \frac{E_{\text{Log}} - 120}{20} \right)
\]

- **\(E_{\text{Linear}}\)**: field strength of emission, in V/m
- **\(E_{\text{Log}}\)**: field strength of emission, in dBUV/m
Questions and Answers

Thanks!