# Millimeter Wave Measurement Procedure KDB

## 200443 D02 RF Detector Method v01

TCB Workshop

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Tho Nguyen

# Rules in Part 15C related to Millimeter Wave

| Sections | Operation within the bands |
|---|---|
| 15.253 | 46.7-46.9 GHz and 76.0-77.0 GHz |
| 15.255 | 57-64 GHz |
| 15.257 | 92-95 GHz |

# 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.

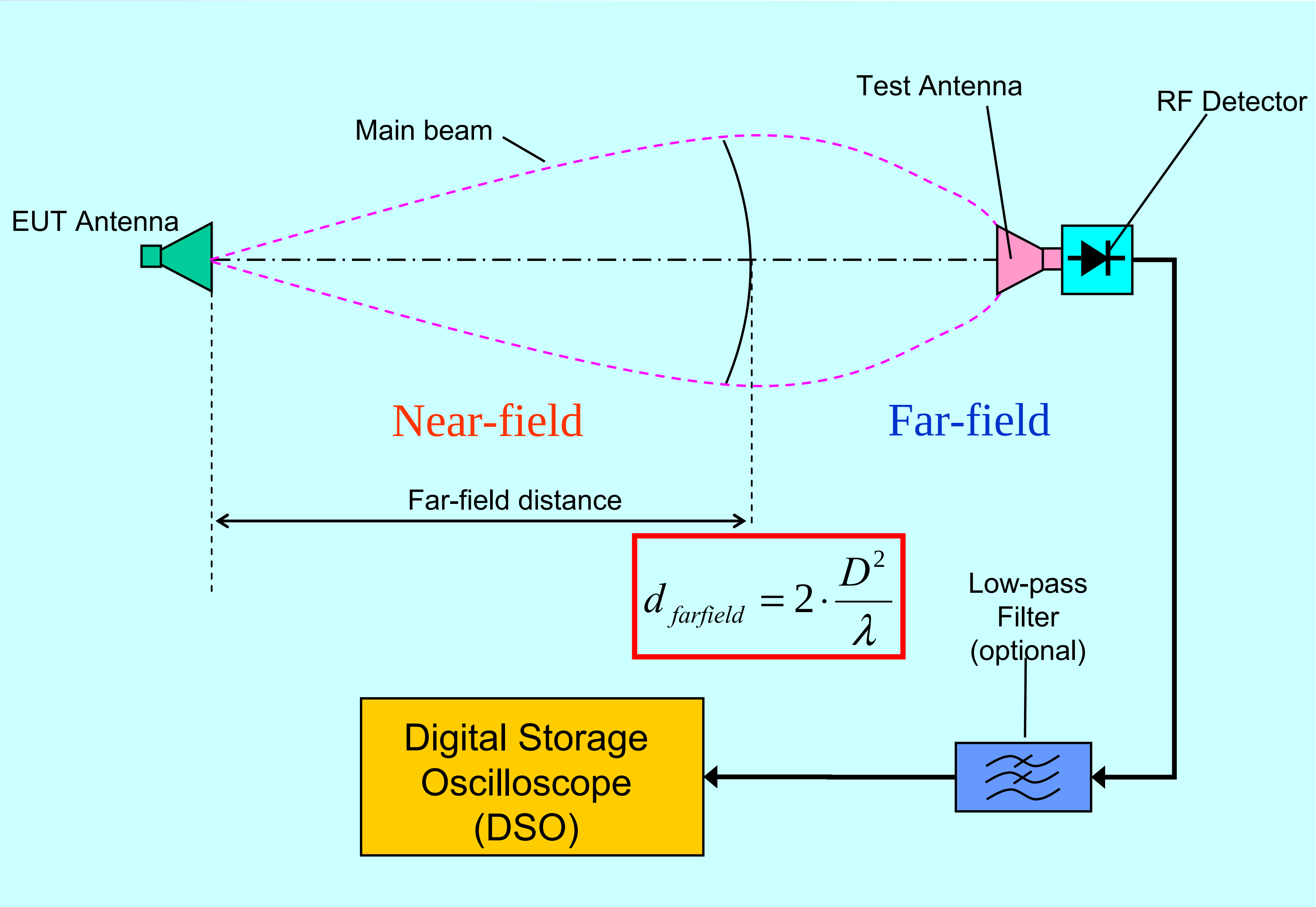
While section 15.253 does not require using RF detector for measurements, sections 15.255 and 15.257 require that the fundamental emission be measured using RF Detector. Attachment 200443 D02 RF Detector Method v01 provides the guidance on how to perform measurements using RF detector applied for 15.255 and 15.257.

# KDB 200443 D02

- 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) ≥ 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 ≥ 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

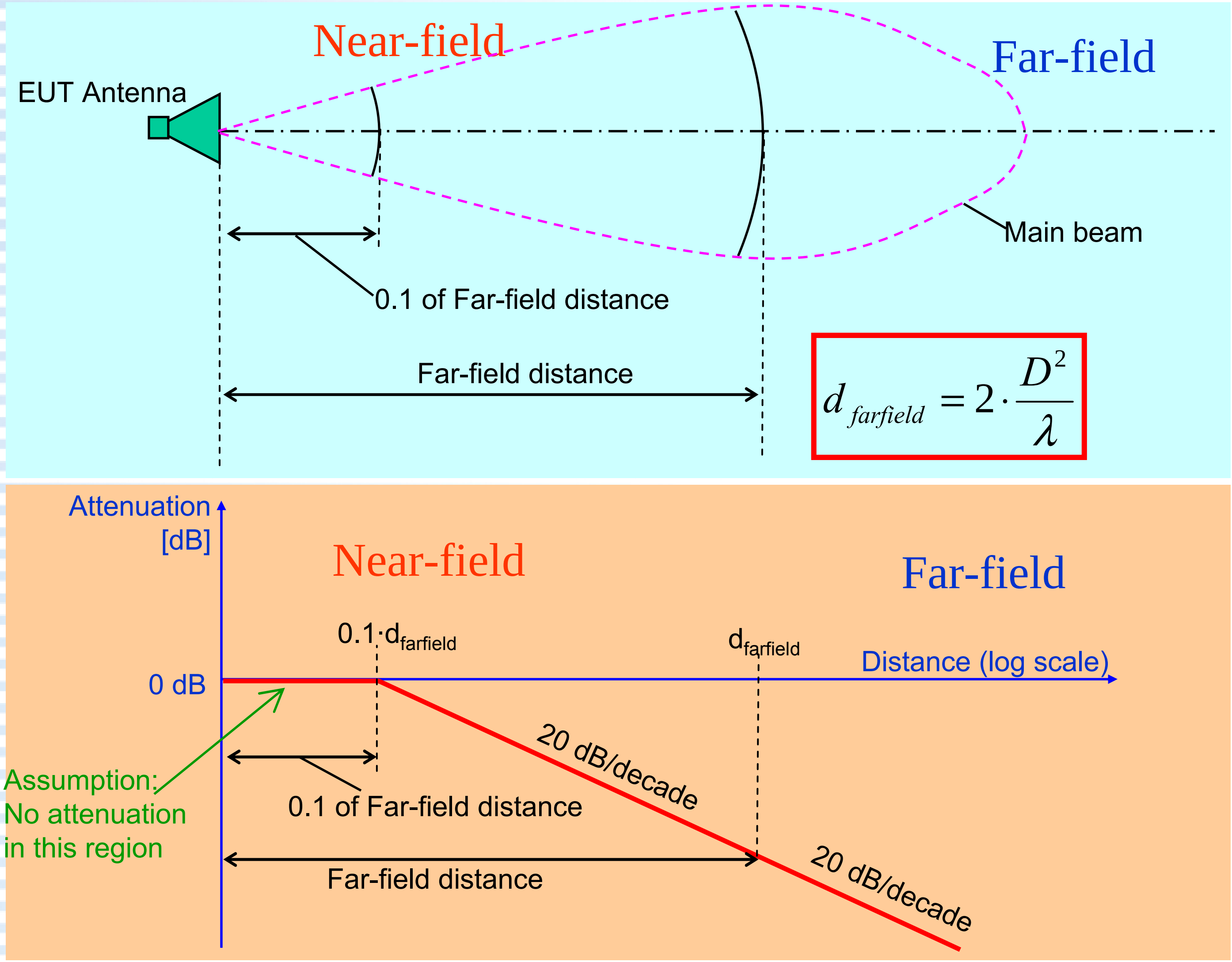
# Measurement Set-Up



# 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) <u>in far-field</u> 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 <u>in near-field</u>, then <u>extrapolate</u> to distance specified by the limit

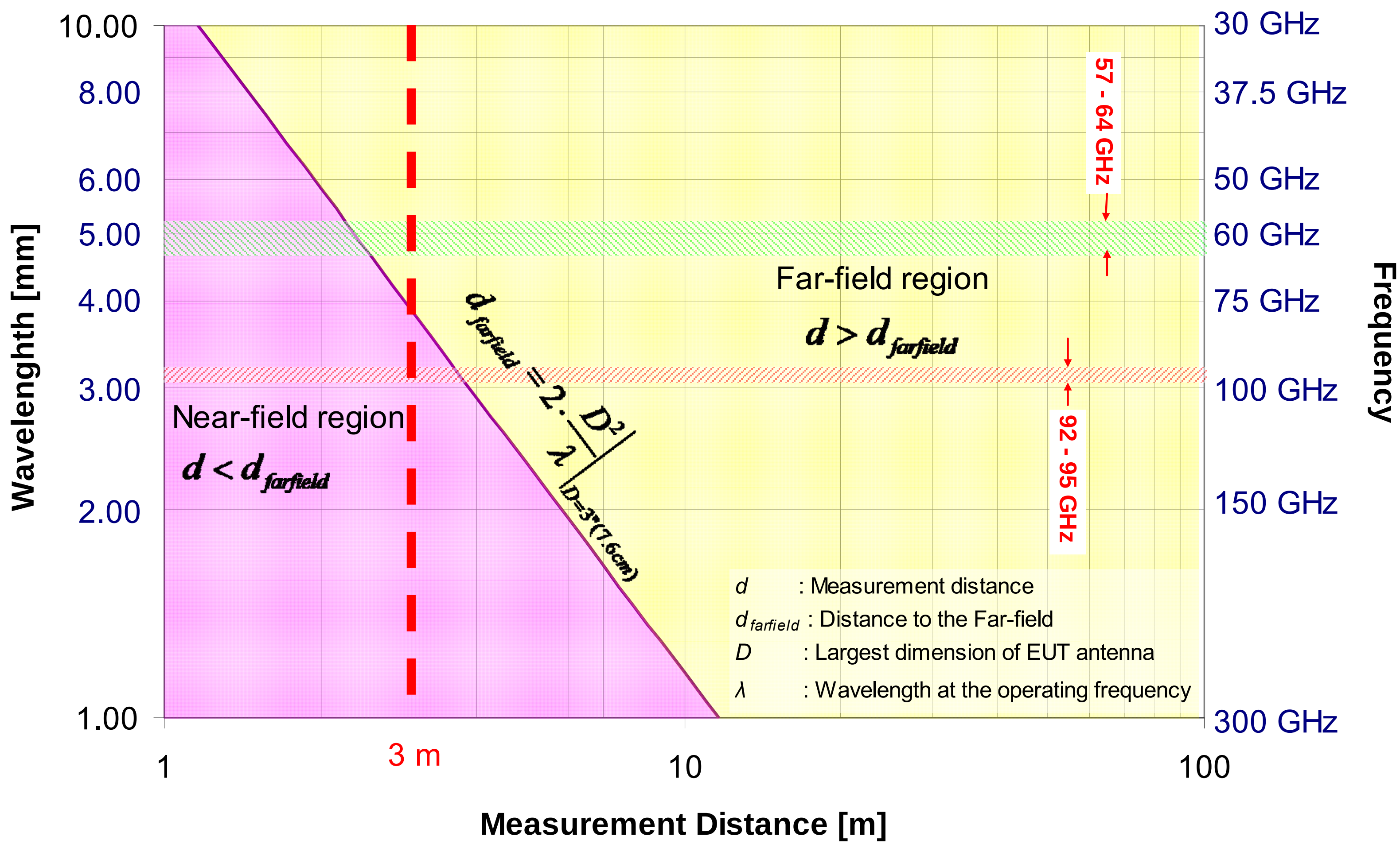
# Background


Near-field
Far-field
EUT Antenna
Main beam
0.1 of Far-field distance
Far-field distance
$d_{farfield} = 2 \cdot \frac{D^2}{\lambda}$
Attenuation [dB]
Near-field
Far-field
0.1·d farfield
d farfield
Distance (log scale)
0 dB
20 dB/decade
Assumption: No attenuation in this region
0.1 of Far-field distance
Far-field distance
20 dB/decade

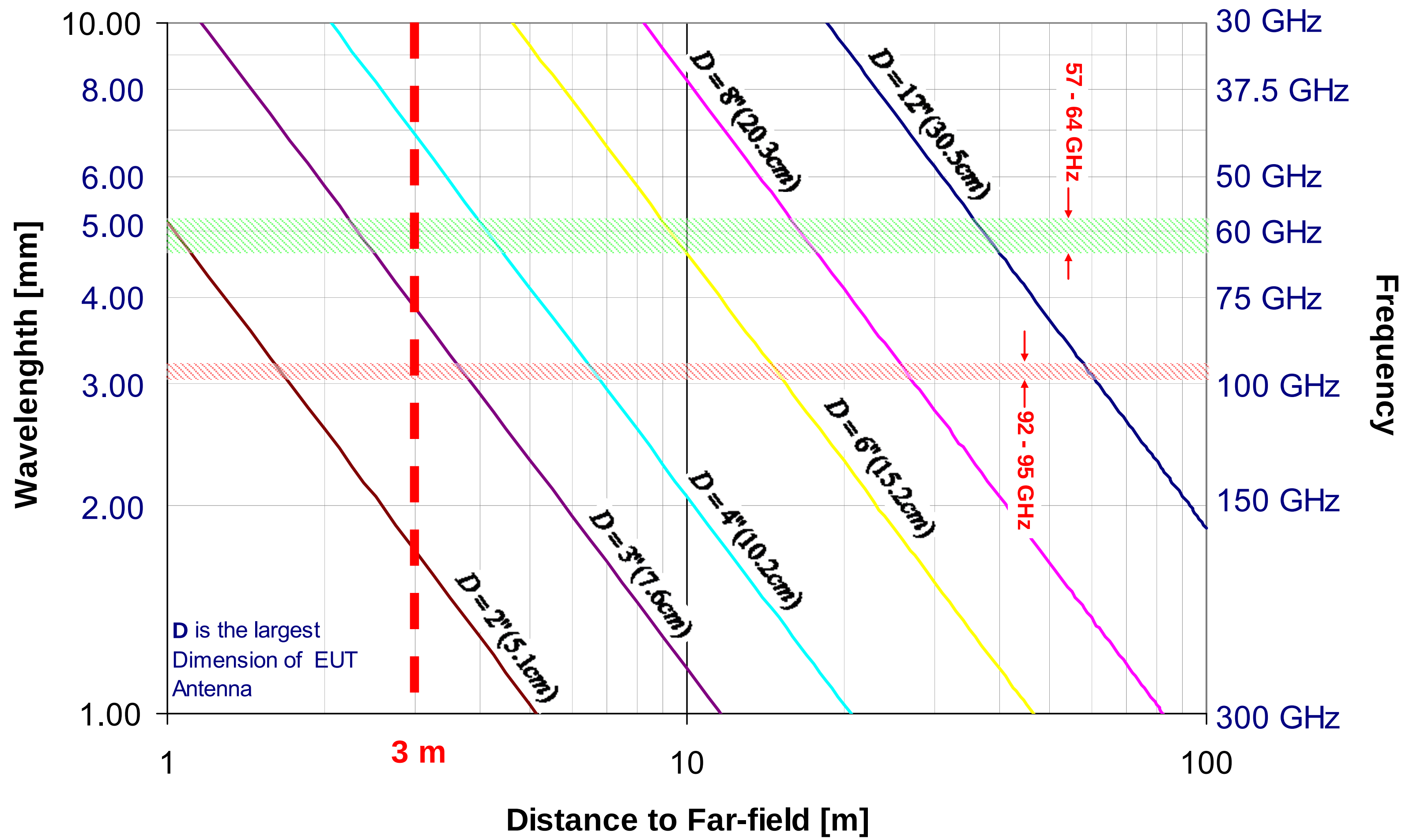
# Radiated Measurement Method

- 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 $d_{farfield}$ 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 $d_{farfield}$ at 20 dB/decade

# Example of Distance to the Far-field vs. Wavelength with a 3” (7.6 cm) Antenna



# Distance to the Far-field vs. Wavelength and Antenna Sizes



# Equations used in Radiated Measurement Method

- Distance to far-field

$$\boxed{d_{farfield} = 2 \cdot \frac{D^2}{\lambda}}$$

*D: largest dimension of the transmit antenna, in meters*

*λ: wavelength, in meters*

- Field strength

*E: field strength, in dBuV/m*

*P: measured power, in dBm*

*AF: antenna factor of test antenna, in dB*

$$\boxed{E = P + 107 + AF}$$

# Equations used in Radiated Measurement Method (cont'd)

- Extrapolation

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

$E_{SpecLimit}$: *field strength of the emission at the distance specified by the limit, in dBuV/m*

$E_{Meas}$: *field strength of the emission at the measured distance, in dBuV/m*

$D_{Meas}$: *measurement distance, in meters*

$D_{SpecLimit}$: *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 $E_{Meas}$ is performed in the near-field but no less than 0.1 of the far-field distance ($0.1 \cdot d_{farfield} < D_{meas} < d_{farfield}$)

# Equations used in Radiated Measurement Method (cont'd)

- EIRP

$$\boxed{EIRP = E_{Meas} + 20 \cdot \log(D_{Meas}) - 104.7}$$

*EIRP: equivalent isotropic radiated power, in dBm*

*$E_{Meas}$: field strength of emission at distance $D_{Meas}$ , in dBuV/m*

*$D_{Meas}$: measurement distance, in meters*

- Field strength in dBuV/m to field strength in V/m

$$\boxed{E_{Linear} = 10^{\left(\frac{E_{Log} - 120}{20}\right)}}$$

*$E_{Linear}$: field strength of emission, in V/m*

*$E_{Log}$: field strength of emission, in dBuV/m*

# Questions and Answers

**Thanks!**