MOBILE TEST SUMMIT 2025
Virtual conference connecting the World

RF and Certification Challenges in mmWave Wi-Fi

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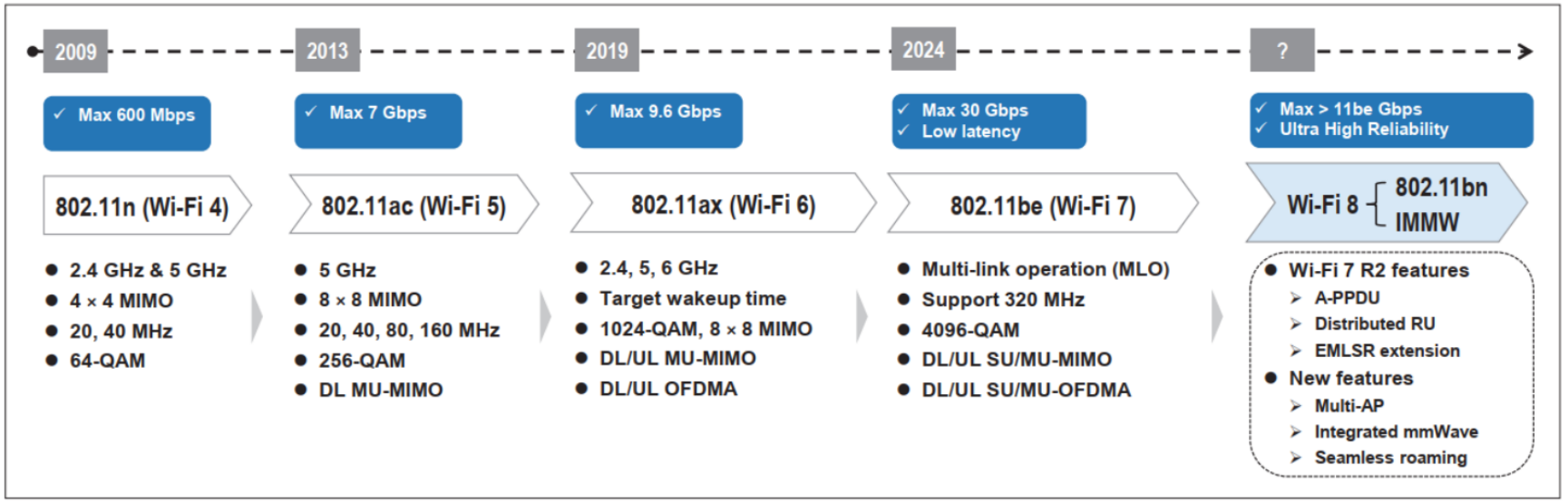
Outlines

- Wi-Fi technology Evolution
- Key Aspects of IMMW Wi-Fi
- RF and Antennas challenges in mmW Wi-Fi
- Certification and test systems challenges
  - OTA and EMC
  - RF Exposure
- Conclusion

Wi-FI technology Evolution



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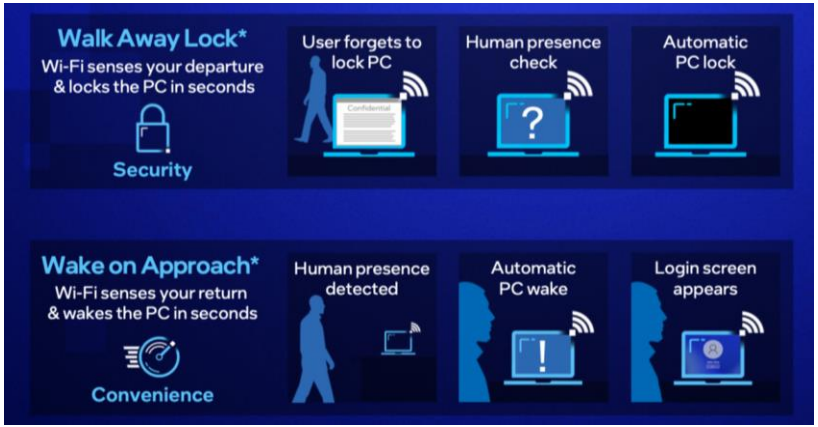
Key Aspects of IMMW Wi-Fi

- High Throughput and low latency
- Good QoS in dense environment
- New sensing applications e.g. detection, ranging, gesture recognition
- Adress the lack of 6GHz band of Wi-Fi in some countries

Example of sensing applications



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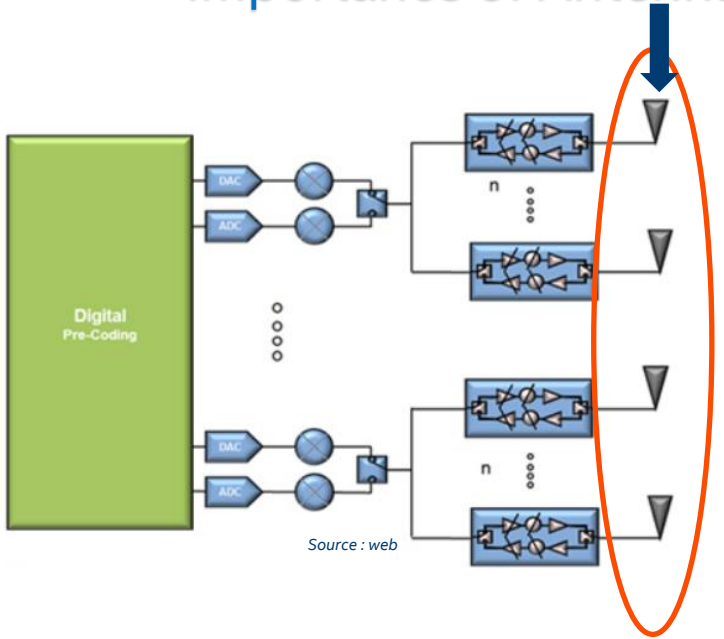
RF AND ANTENNAS CHALLENGES

mmW RF Front-End Challenges

- Number of radio technologies increasing with smaller device form factor
- The diversity of user applications (e.g., communication, sensing, gaming, localization, etc.) requires more and more complex RF architectures
- Known challenges of mmW : Beamforming to compensate high free space losses
- The multiplication of radio front ends has a direct impact on the complexity, cost, and integration aspects.

Importance of Antenna



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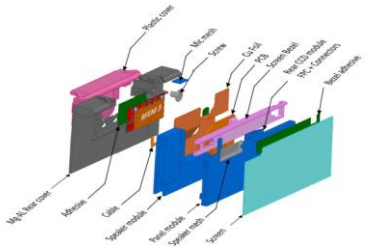
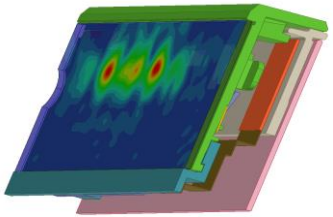
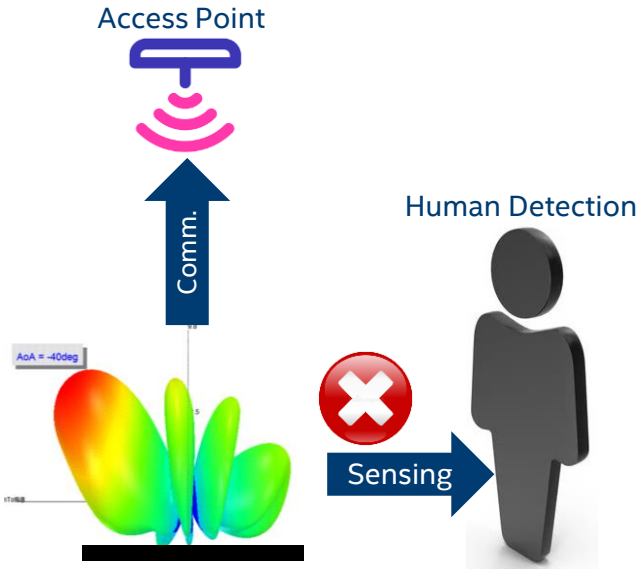
IMMW Antenna Challenges

- Same challenges related to beamforming aspects
- Typical current mmW antenna arrays are broadside

  - Trade-off is needed between communication and sensing → Different designs topologies may be required
- Integration Aspects







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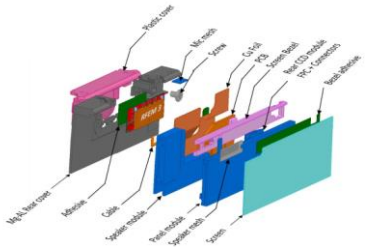
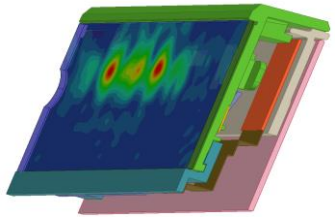
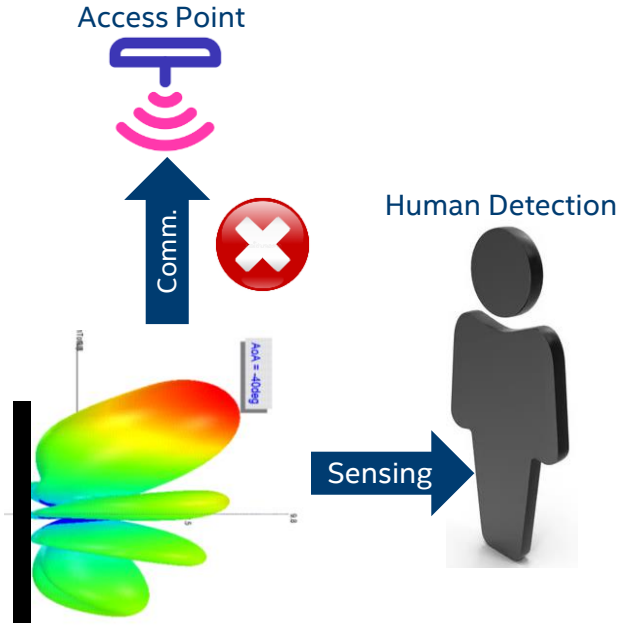
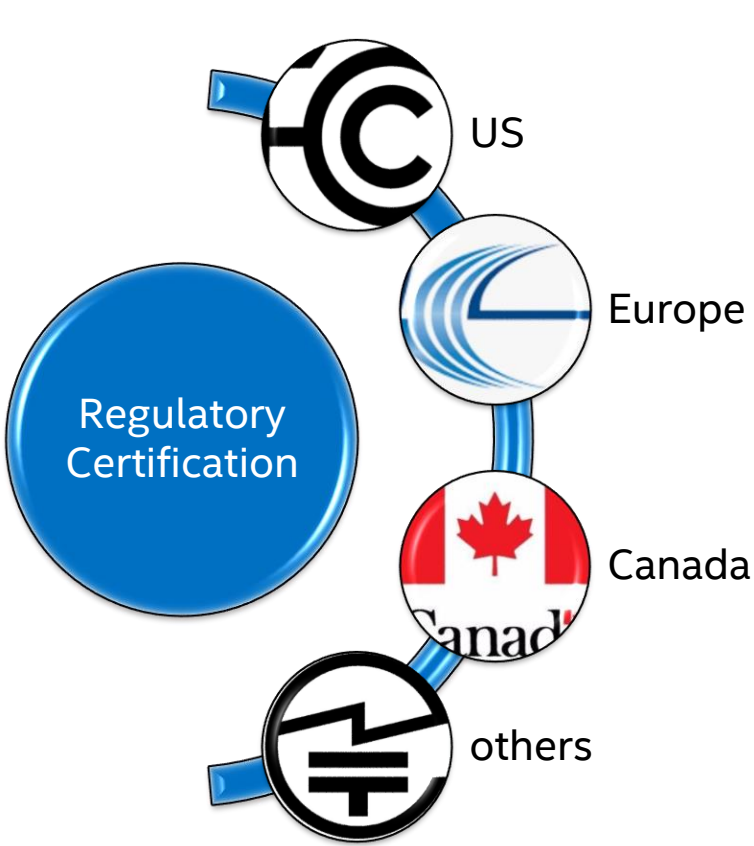


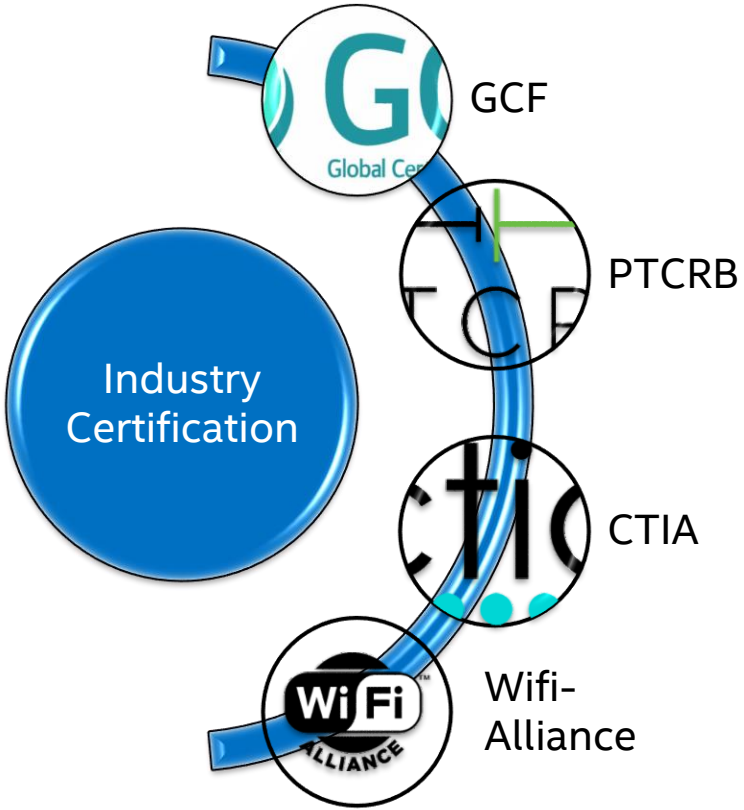




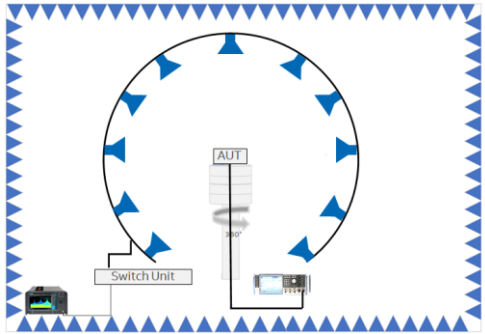
CERTIFICATION AND TEST SYSTEMS CHALLENGES

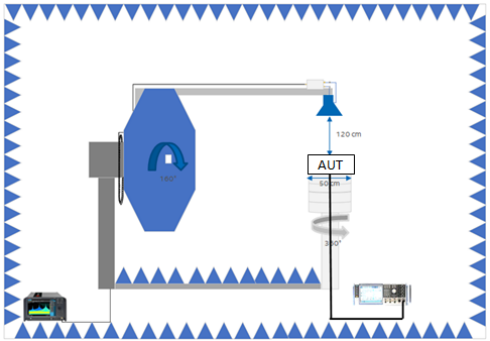
Certification Types

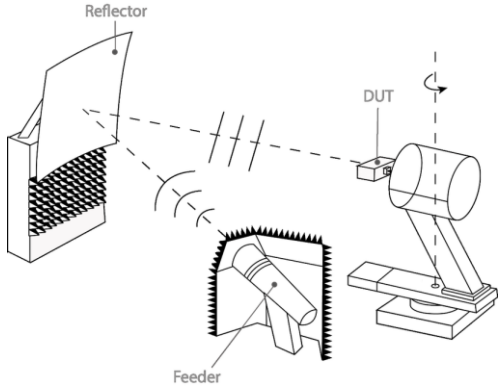




1- EMC, OTA mmW : Radiated only Test System



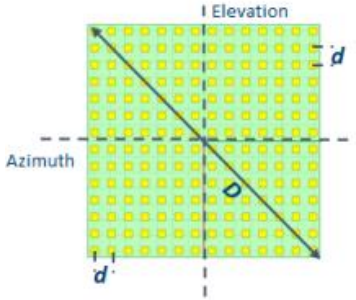




- 3D positioning system
- Direct vs. Indirect Far field
- Near Field vs. Far Field
- Test time and accuracy

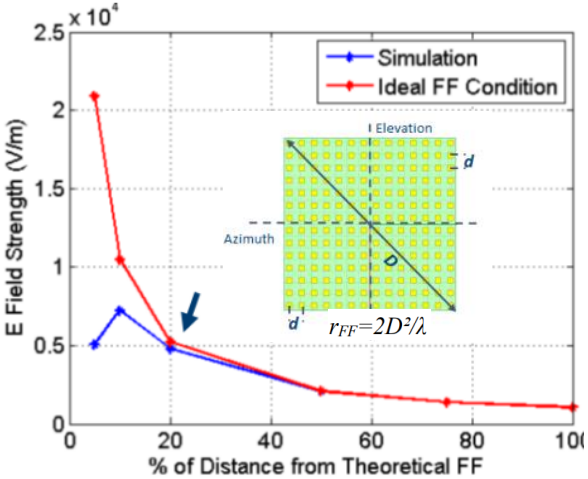
1a- Measurement Distance Challenges

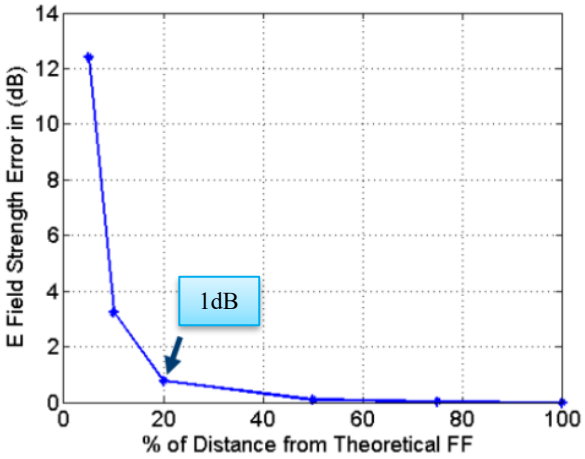
- Antenna arrays with beamforming features are used for mmW.
- Due to the small wavelengths vs. antenna size ratio the classical Far Field distance leads to unpractical measurement distances e.g. *@39 GHz and 30 cm antenna size the FF distance is 23m.*
- Parameters to be considered to define measurement distance for mmW devices:
  - ✓ Applicable Test Cases
  - ✓ Antenna /Device Electrical Size:
  - ✓ Test Environment (Black Box vs. White Box)

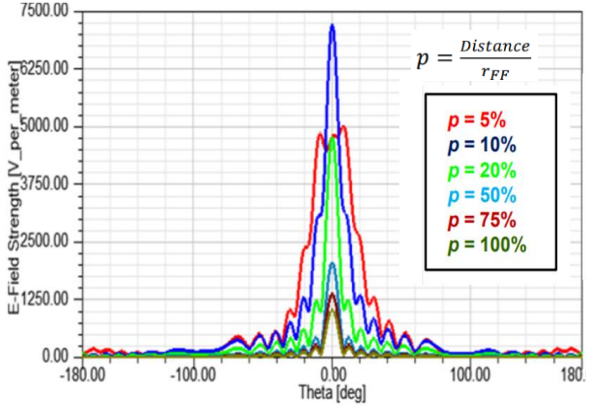


1a-FF Distance Definition based Field Amplitude [2,3]

Example :Array : 14 x 14

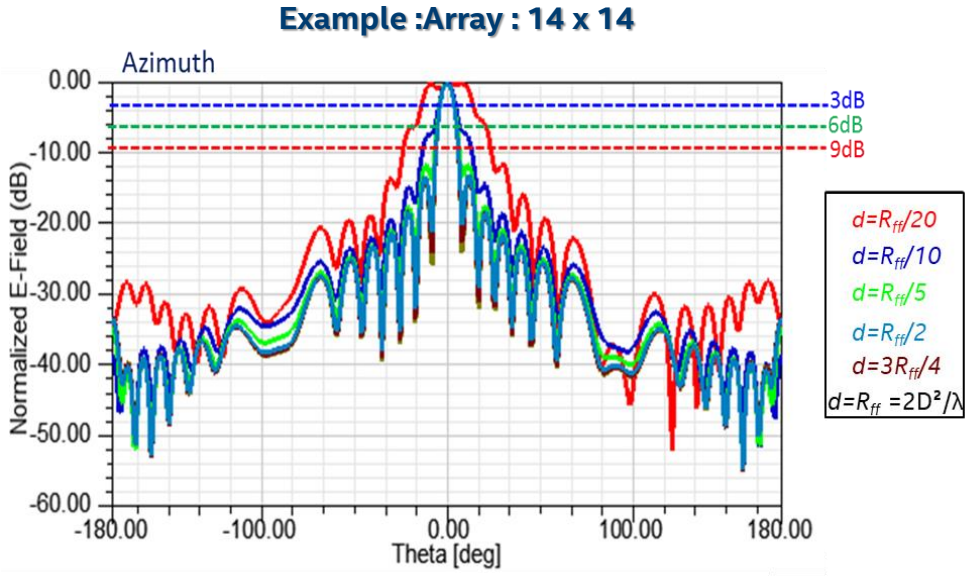


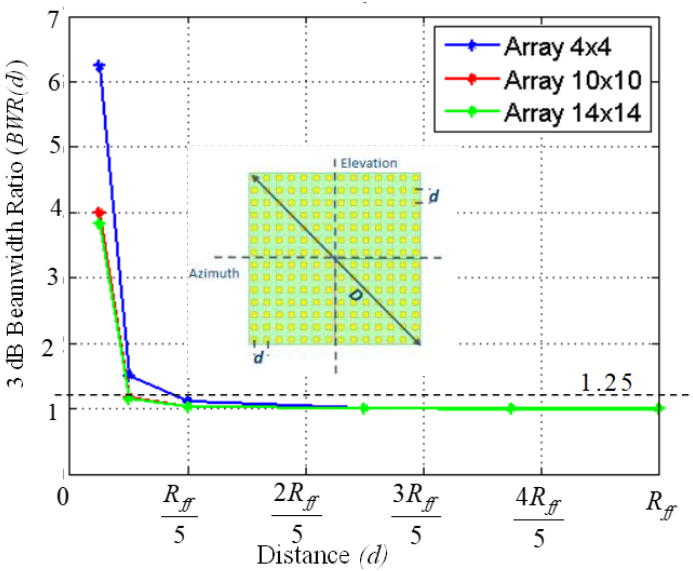




1. Determine the distance where the E-field linear behavior is respected with a specific deviation from ideal conditions
2. The error in dB to be added to the MU

1a- FF Distance Definition based on Beamwidth [2,3]





1. Beamwidth deviation ratio is defined as criteria for FF distance determination
2. The *BWR* ratio at a distance *d* is defined as the ratio between the NF beamwidth $BW_{NF}(d)$ at that distance and the ideal FF beamwidth BW_{FF}

$$BWR(d) = \frac{BW_{NF}(d)}{BW_{FF}} \leq 1.25$$

Maximum power difference of 1dB

It works for shifted beam

2-RF Exposure Regulatory Compliance

- ✓ Human Body > 20cm to any radiator: MPE (Max Permissible Exposure) calculation
- ✓ Human Body < 20cm to radiator up to 6GHz* : SAR (Specific Absorption rate)
- ✓ Human Body to radiator > 6GHz : PD (Power Density)

$$SAR = \frac{\sigma |E|^2}{2\rho}$$

$$S_{av} = \frac{1}{AT} \int \int (\mathcal{E} \times \mathcal{H}) \cdot \hat{\mathbf{n}} dA dT .$$

Standard	Frequency (GHz)	Exposure Limit	Spatial Avg.
ICNIRP 2020 IEEE C95.1™-2019	≤ 6	SAR: 2 W/kg	10 g
	6 - 300	APD: 20 W/m^2 IPD: 55/$f_G^{0.177}$	4 cm^2
	30 - 300	APD: 40 W/m^2 IPD: 110/$f_G^{0.177}$	1cm^2
ISED (Canada)	≤ 6	1.6W/kg	1g
	6 -300	APD: 20 W/m^2 IPD: 55/$f_G^{0.177}$	4 cm^2
	30 – 300	APD: 40 W/m^2 IPD: 110/$f_G^{0.177}$	Peak
FCC	≤ 6	SAR: 1.6 W/kg	1 g
	6 – 100	IPD: 10 W/m^2	4 cm^2

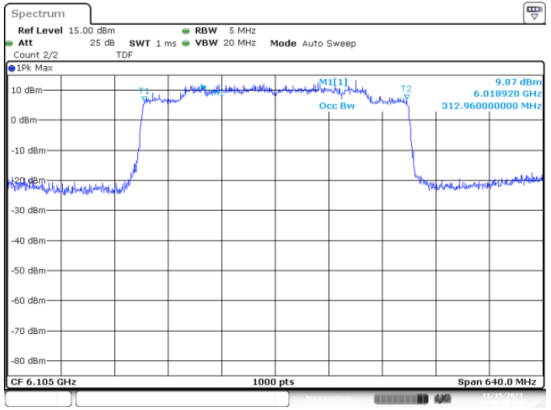
Basic Restrictions(In Body)
1. SAR = Specific Absorption Rate
2. APD = Absorbed Power Density
3. EPD = Epithelial Power Density

Note: APD=EPD

Reference Level (Free Space)
1. IPD = Incident Power Density

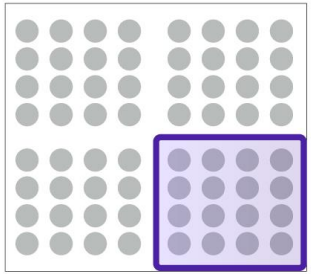
2a- RF Exposure : high number of test configurations

- ❑ Higher frequencies e.g. 30-300 GHz
- ❑ Larger Bandwidth e.g. 2560 MHz
- ❑ Complex Waveforms and Modulations
- ❑ Different transmission modes

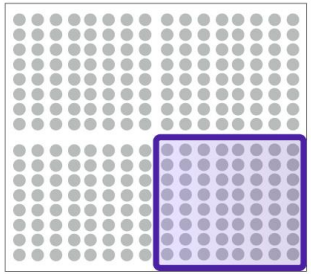


UNII6 SISO A 802.11be320 ch31 6105MHz 99%

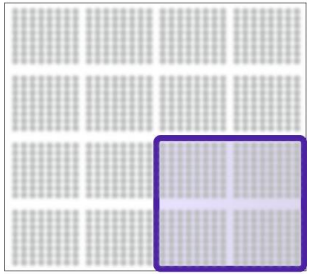
64 QAM - WiFi 4 (802.11n)



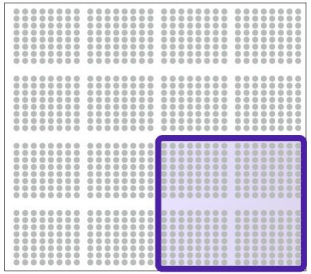
256 QAM - WiFi 5 (802.11ac)



1024 QAM - WiFi 6 (802.11ax)



4096 QAM - WiFi 7 (802.11be)



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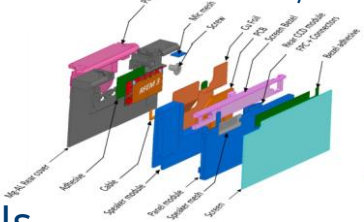
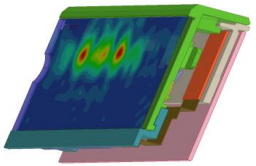
2b-Power Density test procedure

1 - Near-field simulation of antenna + Industrial Design:

- Complex simulation method: spatial resolution boundaries, truncation effects, etc.
- Definition of:
  - Evaluation planes
  - Dielectric coefficients of materials





- Calculation of worst exposure cases and corresponding PD by post-processing all antenna array configurations

2 - Validation of simulated PD @ worst exposure plane

- E-field measurement using near-field probe, H-field reconstruction and power density calculation
- Correlation between near-field measurement and simulation at exposure plane

Conclusion

- mmW Wi-Fi allows better user experience and provide opportunity for new applications e.g. sensing, detection, ranging, etc.
- Additional challenges at RF and Antenna needs to be considered
- Regulatory certification aspects have also some challenges related to test system and number of test configurations

References

[1] X. Liu et al., "Wi-Fi 8: Embracing the Millimeter-Wave Era," in IEEE Communications Magazine, vol. 63, no. 3, pp. 69-75, March 2025, doi: 10.1109/MCOM.002.2400059.

[2] W. El Hajj et al. “Practical and Empirical Measurement Distance Definition for 5G Devices at mm-Waves,” Special Session at 2021 IEEE CAMA.

[3] W. El Hajj, T. Andriamiharivolamena, J. A. Del Real and N. Asrih, "Definition of Far Field Measurement Distance for 5G mmW Antenna Arrays: Application on N × M Patch Arrays," 2022 16th ion (EuCAP), Madrid, Spain, 2022,