ETSI World Class Standards

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Spectrum Choices For The Future

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QUALCOMM®

Designing 5G for evolving and future use cases

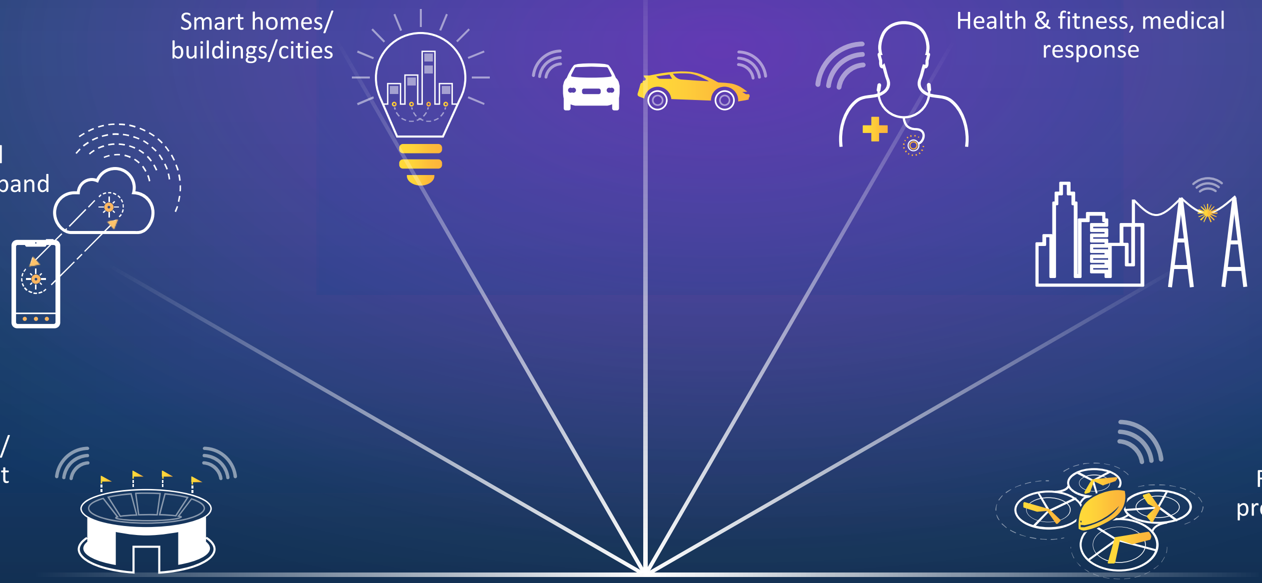
Adaptability for new services not yet known

Wide Area IOE

Connecting everything

Mobile broadband

nhancing the foundation

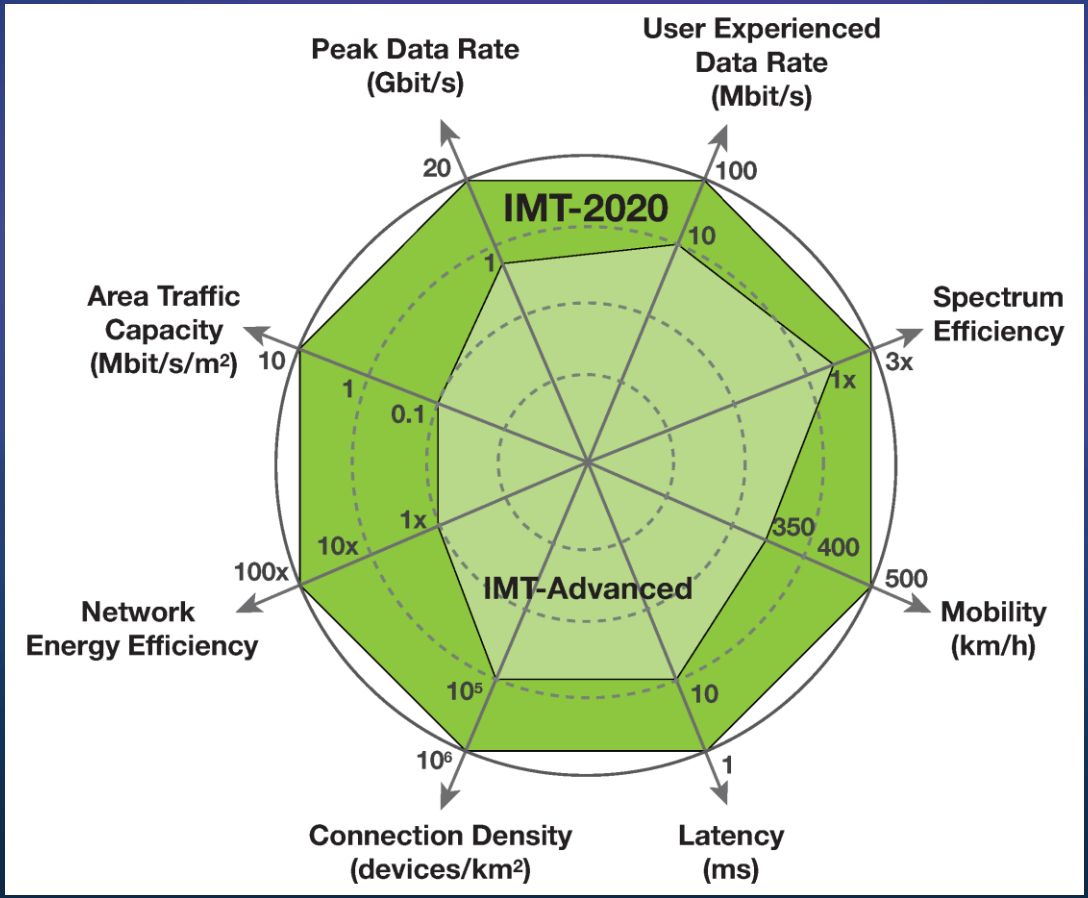


More reliable services

Improved reliability & security

ITU-R KPIs for IMT2020/5G

- Very ambitious requirements compared to IMT-Advanced:
  - 10x more “User Experienced Data Rate”, 20x more “Peak Data Rates”, 100x more “Area Traffic Capacity”, 10x more “Connection Density”, 3x more Spectrum efficiency



IMT-2020/5G requires enormous additional spectrum

- Improved spectral efficiency can't by far cater for meeting 5G requirements on User Experienced Data Rate, Peak Data Rates and Area Traffic Capacity.
- The key measures to meet 5G requirements are network densification/small cells and allocation of additional spectrum
  - In particular, enormous new spectrum is needed for delivering new capabilities that require access to much wider channel bandwidths than those of existing systems
- An approach only based on clearing spectrum below 6 GHz for exclusive use isn't sufficient
  - Spectrum for shared access: both Licensed Shared Access (LSA) and Unlicensed Shared Access
  - Spectrum for exclusive access: bands above 6GHz[1] are essential for supporting wide channel bandwidths
- Spectrum below 6GHz is still essential for an economical delivery of 5G (as well as 4G) mobile services

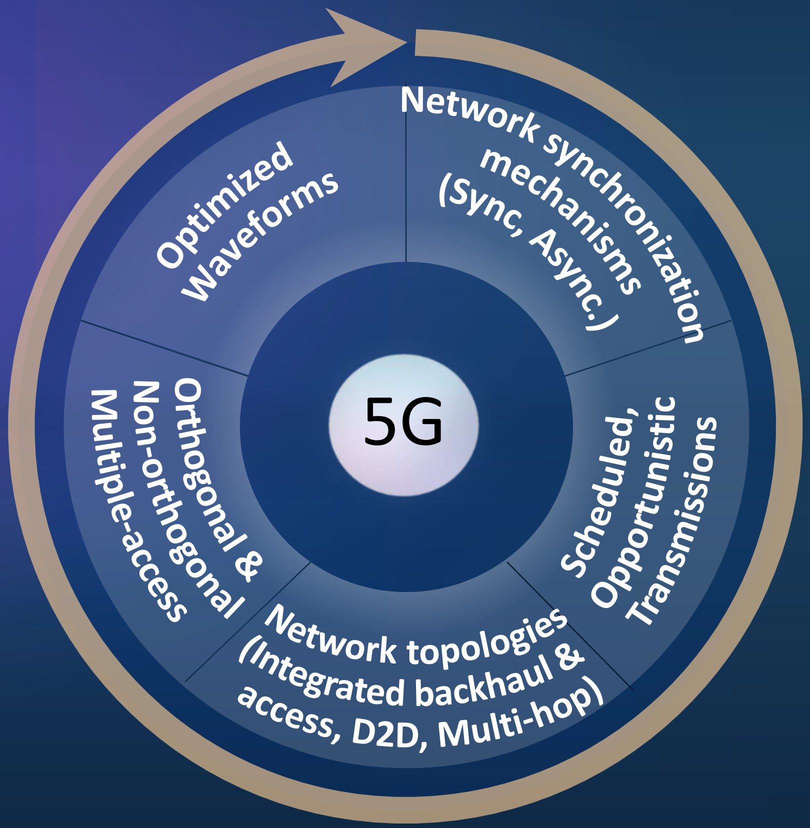
[1] In the following, this is referred to as mmW although the range above 6GHz includes cm-Wave, too

Unified 5G design across spectrum types and bands

From narrowband to wideband, licensed & unlicensed, TDD & FDD

Band		Single component carrier channel Bandwidth examples	Target Characteristics
FDD/TDD	<3 GHz	1, 5, 10, 20MHz	Deep coverage, mobility, high spectral efficiency, High reliability, wide area IoE
TDD	≥3GHz (e.g. 3.8-4.2, 4.4-4.9)	80, 160MHz	Outdoor & indoor, mesh, Peak rates up to 10gbps
TDD	5GHz	160, 320MHz	Unlicensed
TDD	mmWave	250, 500 MHz, 1, 2 GHz	Indoor & outdoor small cell, access & backhaul

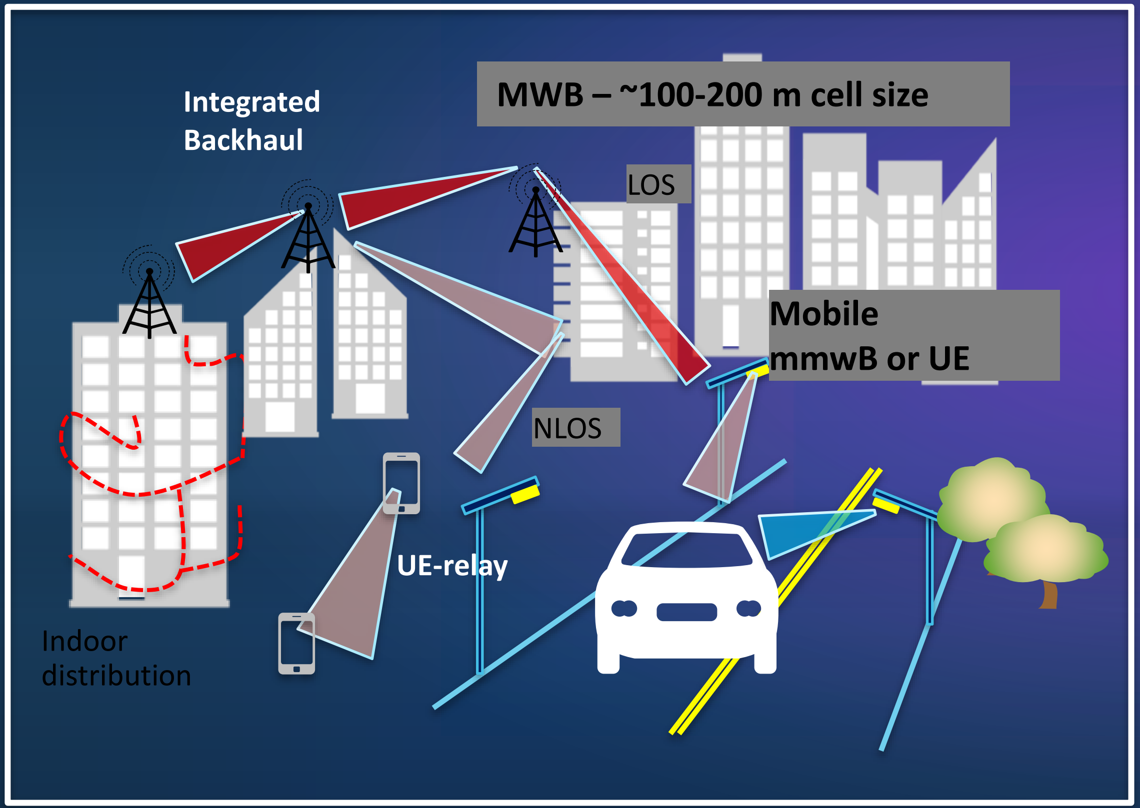
Range of application requirements
Diverse spectrum types



Millimeter Wave: Opportunities and Challenges

Massive bandwidths and spatial reuse counter-balanced by robustness and device aspects

Example: Outdoor Deployment



Opportunities

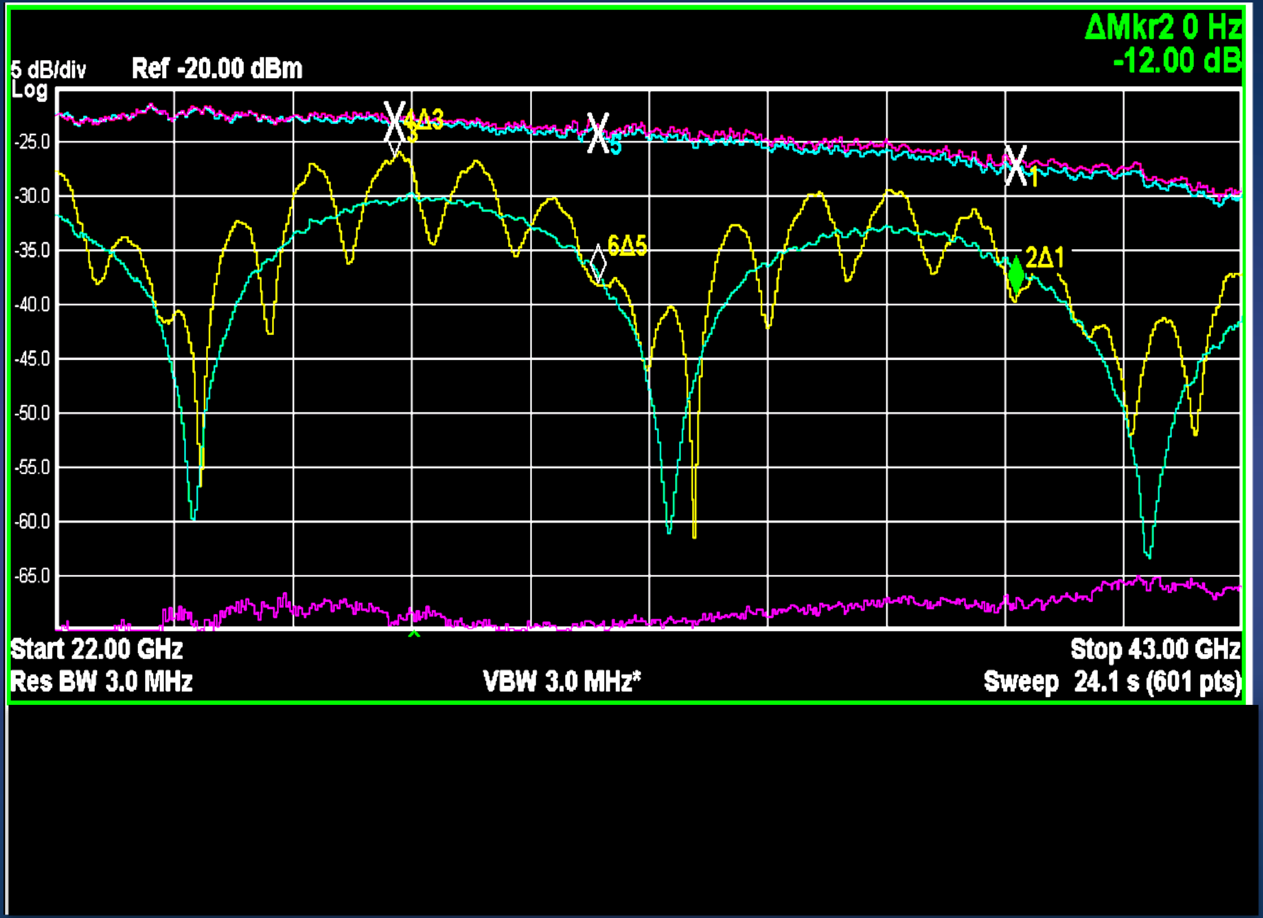
- Availability of tremendous amount of spectrum enabling wide bandwidths
- Reduced size of antenna system enables dense spatial reuse
- Narrower beams resulting in beamforming advantage
- Coverage through reflections and LoS

Key Challenges

- Robust beam search & tracking
- Device and RF challenges at mmW
- Disadvantageous propagation characteristic
- System design with directional transmissions

Millimeter Wave: A Brief Look

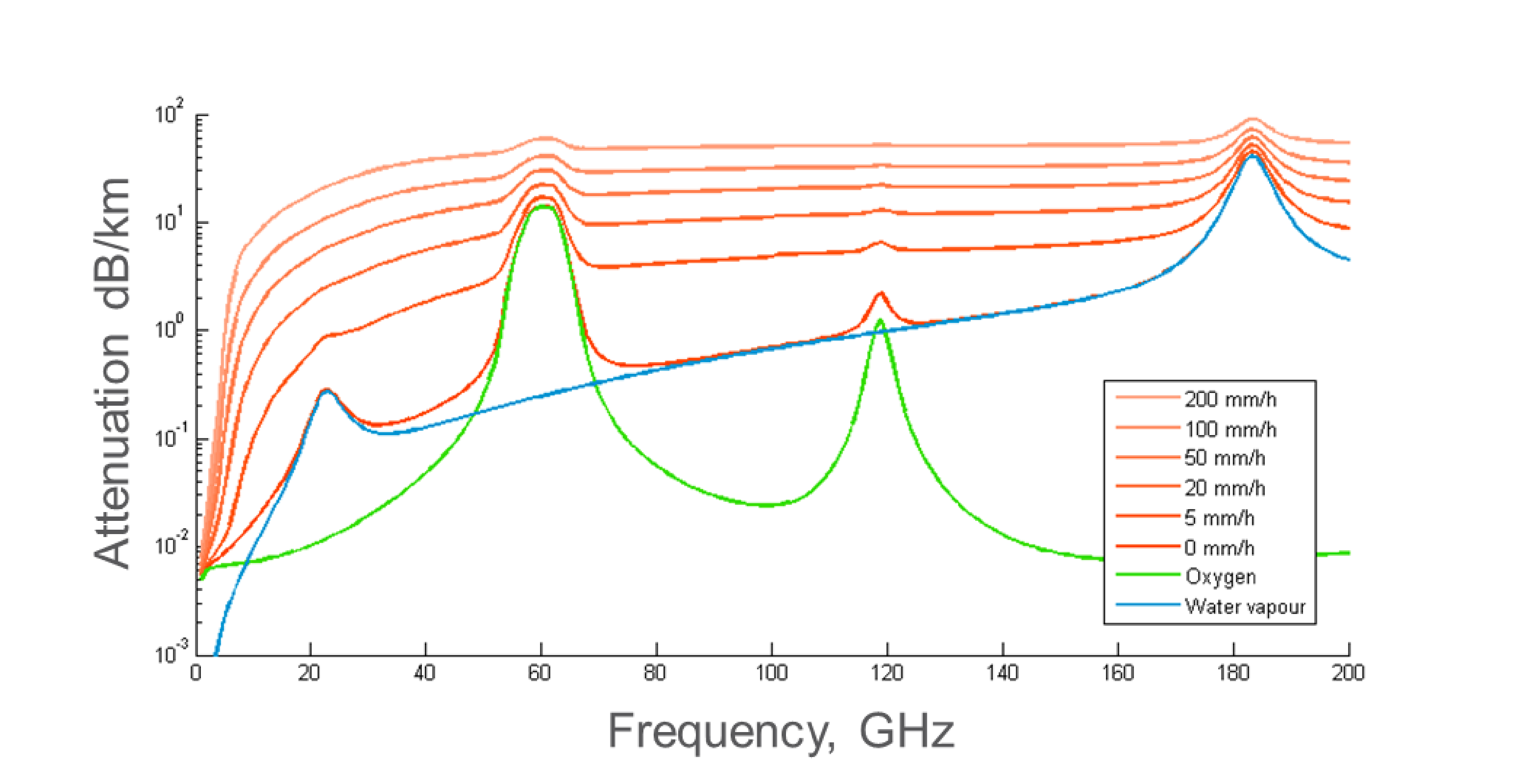
Material Response: An Example



Sample: Two layered dry wall, separated by air gap

- Structure construction can create deep notches, so just as important to consider as pure reflectivity
- Wide bandwidth frequency notches can occur and require path diversity to overcome

(Predicted) Attenuation due to environmental effects

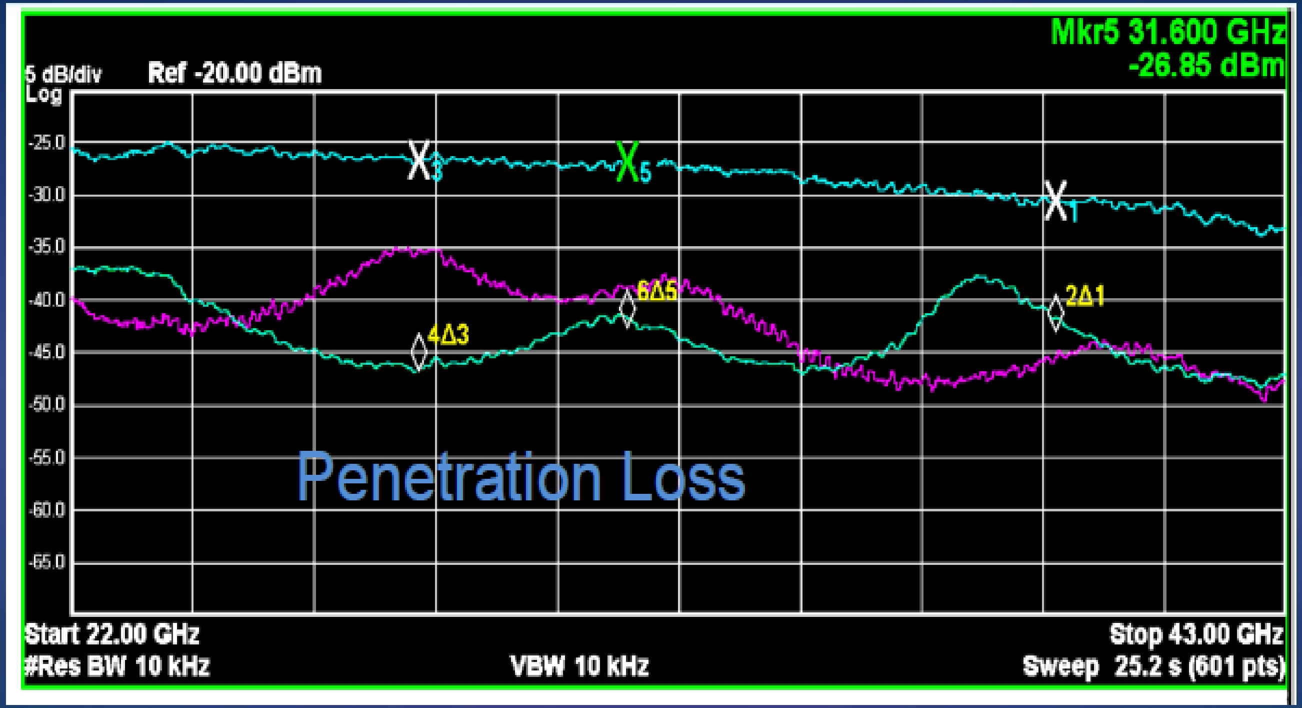


Taken from ETSI ISG mWT White Paper No. 10

- Very high Oxygen attenuation around 60 GHz, low attenuation for other frequency ranges
- Attenuation due to H_2O vapors is of little concern
- Predicted attenuation due to rain depends on the rainfall intensity, e.g. 10-20 dB attenuation at 100 mm/h

Penetration Loss: An Example

Out-to-in penetration loss for a tinted external window

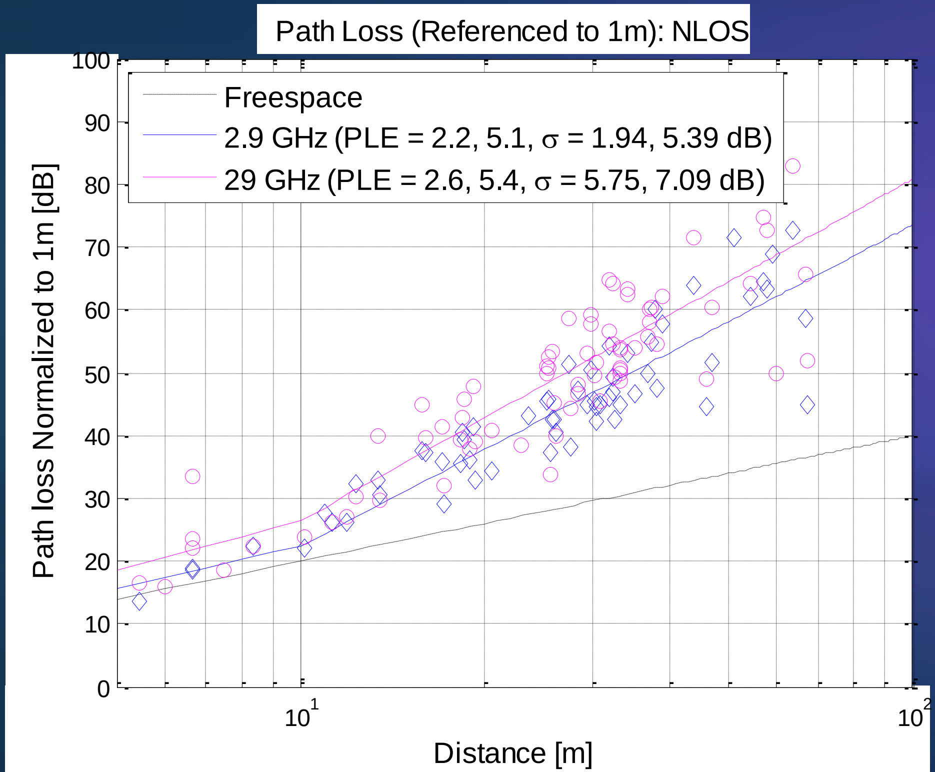


- Out-to-in penetration loss can be challenging in case of indoor coverage from outdoor deployment
  - Suburban areas impacted heavily by foliage
  - Windows with metallic tint tend to reflect rather than allow signal to pass through
  - Insulation wrapped in metal foil can also cause reflections and reduce penetrability
- Could be advantageous for insulating interference between indoor deployment and outdoor deployment

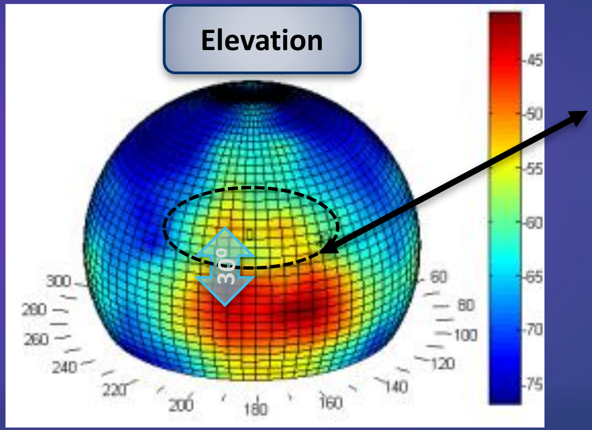
Indoor Office Propagation Measurements

Path loss characteristics between 2.9 and 29 GHz (after referencing to 1m)

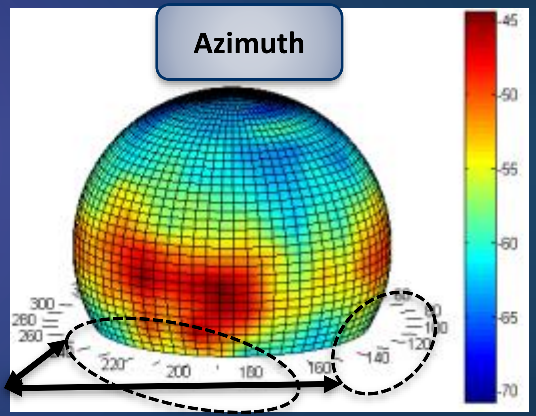
NLOS: Omni



NLOS: Spherical Scan with Horn Antenna



Resolvable paths in elevation
→ *Suggests a 3-D channel model*



Path diversity in azimuth
→ *Potential to withstand blockage events*

Propagation characteristics of mmW: a summary

Propagation characteristics of mmW vs those of the bands used in existing mobile systems

- Much higher free space path loss (FSPL)
  - Compared to 2.9GHz, the 29GHz band has 20dB more FSPL, 60 GHz even 26dB more FSPL
- Higher diffraction losses, particularly in outdoor environment
  - Based on UTD[1] propagation model, diffraction loss of 28GHz is about 10dB more than that of 2GHz
  - Indoor channels are highly reflective which could help to compensate for lossy diffraction
  - The challenge would be processing the dominant reflected and scattered multipath components alongside the direct component
- Higher blockage and outdoor to-indoor penetration losses make indoor coverage from outdoor deployment a big challenge
- Also, blockage due to foliage (trees), body, buildings, moving vehicles and other obstacles is a big challenge for mmW system design
- Attenuation due to environmental effects could be challenging, in particular for intense rainfalls
- Indoor small cell the main deployment given sufficient path diversity in indoor channels
  - Outdoor small cell feasible, however requires more dense deployment

[1]Uniform Theory of Diffraction

Thank You