# iPosi Loss Measurements applied to 6 GHz Fixed Microwave (and more) protection from LTE/5G

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# Today’s Briefing and Update

- iPosi previously briefed the Commission and OET in other proceedings or settings on its Loss Profile Measurements (LPM) for Shared Spectrum
- iPosi’s A-GNSS employs measurements of GPS/GNSS signal attenuation as a measure of in-to-outdoor loss.
- It employs extreme sensitivity, deeply-assisted GNSS thus is useful for indoor measurements vital to many 5G shared spectrum situations.
- This is directly applicable to 6 GHz Fixed Microwave protection as well as other legacy services, including other bands adopting AFC or CBRS systems.
- Today, this briefing focuses on 6 GHz and AFC-based automated coordination
- Also applicable to sharing FSS (3.7 to 4.2 GHz) as a potential option to other spectrum disposition alternatives
- Also relevant but outside today’s limited time briefing…
  - We note the same LPM method has been successfully applied by another Federal agency to their coordinated sharing among outdoor entities. This will be a subject for a future briefing.


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# NPRM from 18-295 (Paragraph 71)

*NPRM, Paragraph 71:* Are there other methods or equipment form-factors that would discourage outdoor usage of low-power access point unlicensed devices that we should consider? For example, noting that GPS signals generally do not penetrate very far into buildings, would it be feasible and cost effective to require low-power access points to monitor GPS satellite signals and to cease transmissions if a GPS signal is detected? **Would it be better to set a GPS signal threshold rather than a detection threshold above which a low-power access point would be required to shut off to differentiate between clear-sky (outdoor) GPS satellite view and indoor detection?**

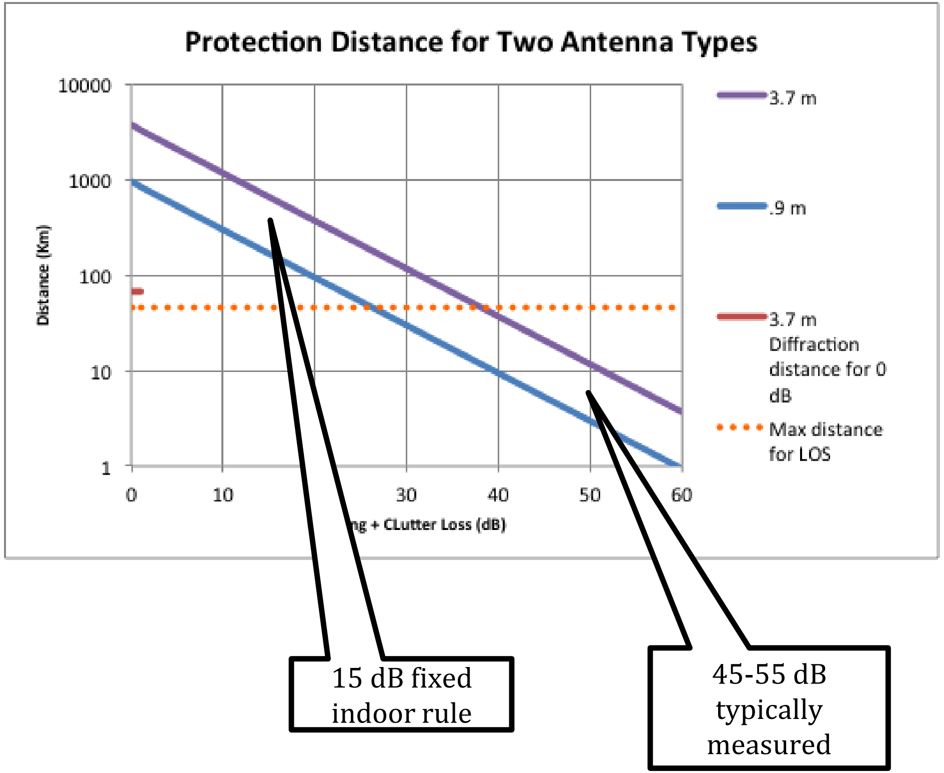
- We brief and update the Commission today with answers to these questions
- We applaud the Commission's and OET's recognition of GPS
- We take GPS-enabling much further – creating ubiquitous, reliable, automated, high availability, legacy-protective shared spectrum services for dense 5G
- We provide a comprehensive locate/sync/share solution to not only synchronize and locate cells or terminals, but apply GPS measurements so cells may operate intelligently based on surrounding attenuation from *in-situ* building materials that, like a Faraday cage, limit signal range, thus eliminate interference across prevailing 5G shared-band scenarios

# Methodology and parameters for LTE to 6 GHz FS

- Co-channel analysis, minimum distances to isolate FS from a single LTE transmitter
- Fixed Microwave (FS) parameters
  - Adopted Fletcher, Heald and Hildreth ex parte, March 13, 2018 ref[5] and ITU RR
  - FS noise floor: -96dBm/20 MHz, ref[5]
    - Allowed 0.5 dB noise rise/fade margin reduction
    - Tolerable interference threshold: -105 dBm/20 MHz
- Select two representative FS antennas and their patterns: 3.7 m and 0.9 m dish, both COT
  - Set all antenna heights to 30 m (one exception for LOS with h1= 3m and h2 = 45m)
    - Elevation angle set at worst case, 0 degrees elevation
  - Model UHX12-59; 3.7 m dish, Gmax=45 dB [1,2]
  - Model VHLP3-6W: 0.9m dish, Gmax=33 dB [3,4]
- Indoor LTE/AP up to EIRP 30 dBm over 20 MHz
  - Note: Indoor EIRP 30 dBm; FCC proposes 24 dBm, thus 6 dB margin in this analysis
- Free Space Path Loss
  - Includes curved earth diffraction beyond horizon
- Results: Present zones, maximum exclusion range to isolation threshold protecting FS

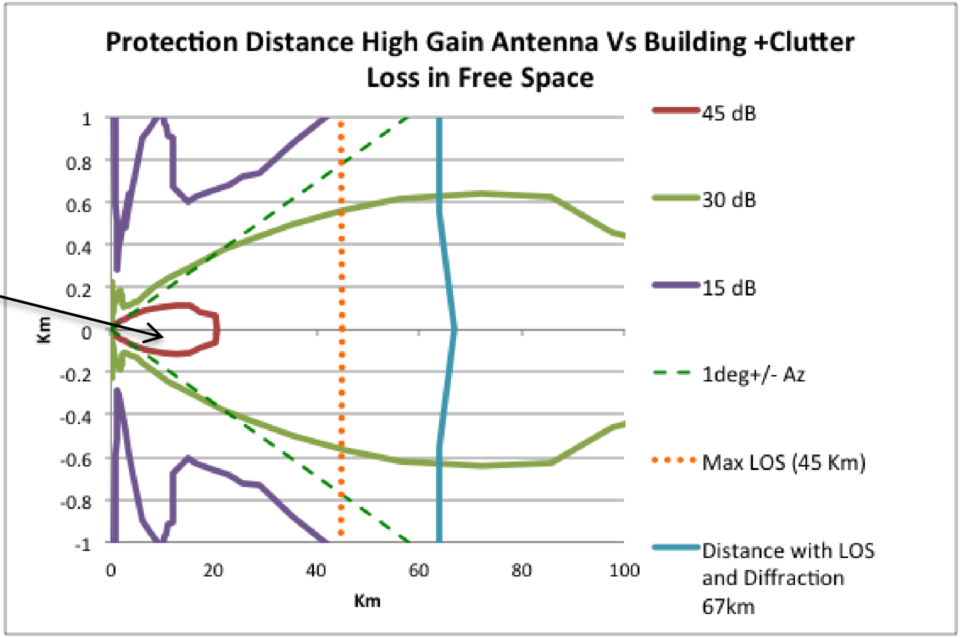
# Protection Distances – On Boresight Cases

- Longest stand-off distance is if there is line of sight (LOS) between building and FS site
  - Range past horizon applicable due to diffraction, in this model over plane earth
- Isolation path distances for radial paths away from boresight shrink.  Analyze that next.
- GPS loss measurements may beneficially include complex cluttered, *complex* signal paths (i.e., sum of indirect scatter, reflection, diffraction paths).
  - Intermediate structures create *apparent* non-LOS path.
  - However, complex diffraction, scattering reflection (or a composite of those) paths may exist that lessen the *apparent* isolation that generalized statistical models  miss
- **Exclusion area and distance reduces substantially applying known, measured building loss factors – *accurately measured at the point of 6 GHz shared band transmissions.***



# Exclusion Zones for 15, 30, and 45 dB Building + Clutter Loss Cases

Typical 45 dB building loss (toward FS site) results in 3.5 square km exclusion zone



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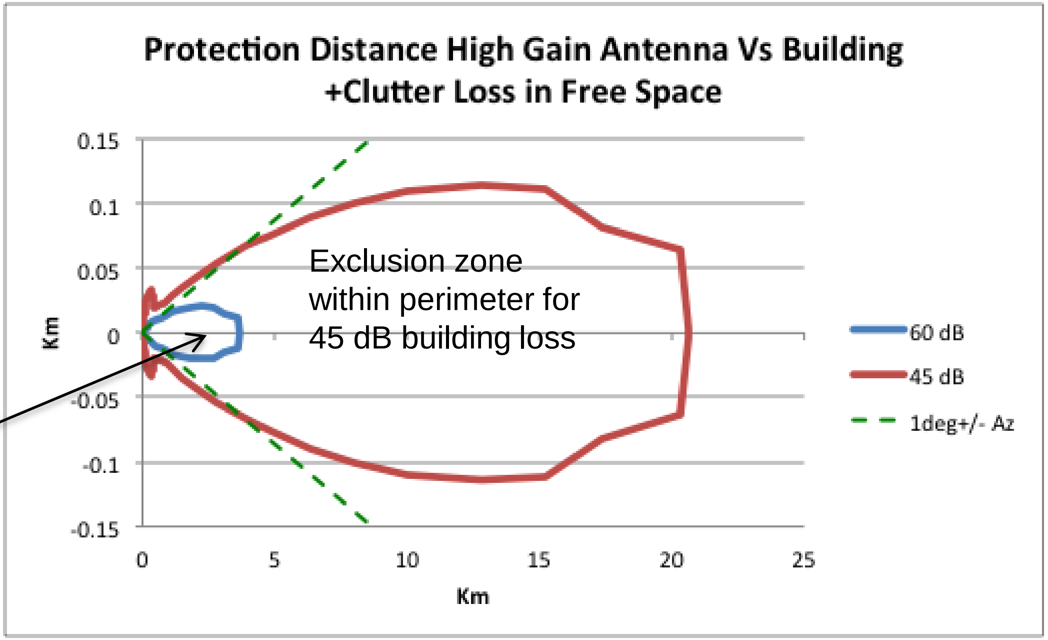
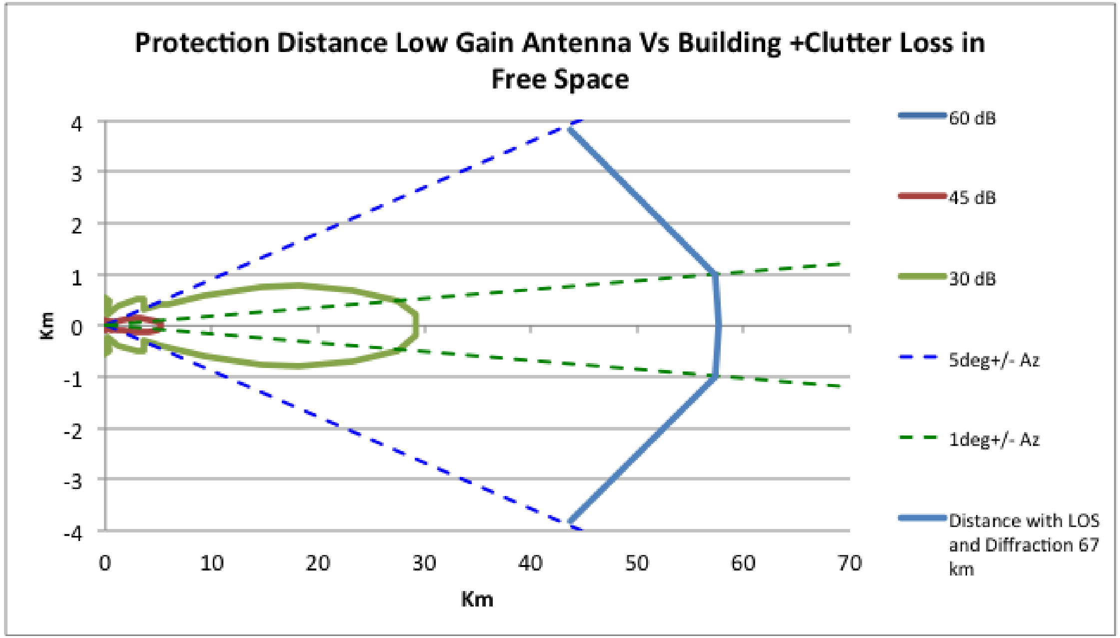
# Exclusion Zones for 45, 60 dB Building Loss + FSPL



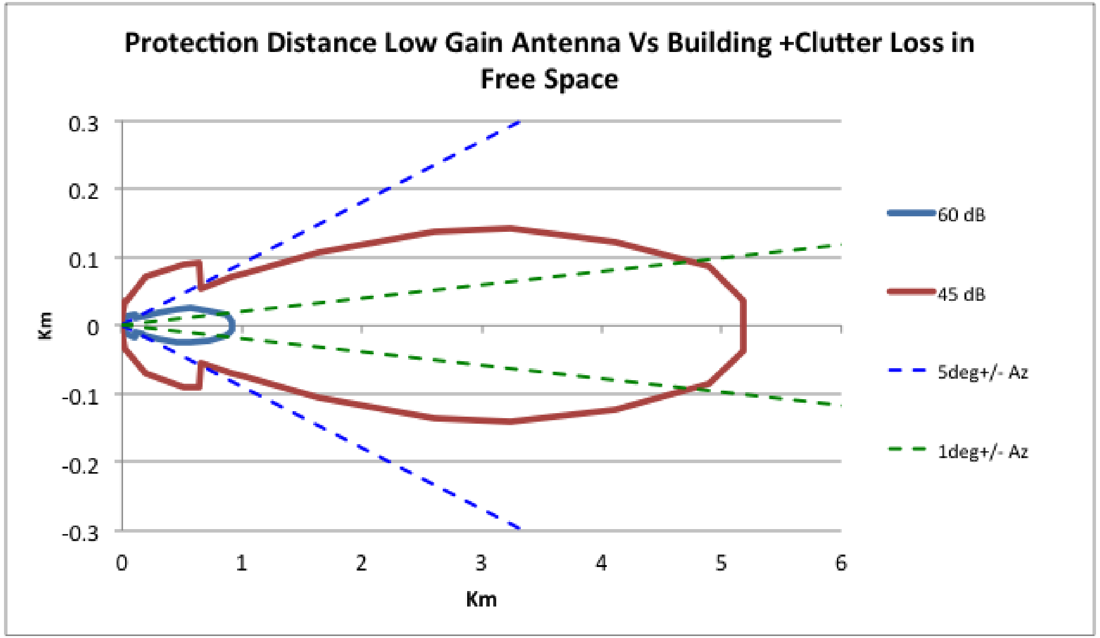

Exclusion zone within perimeter for 60 dB loss

# Exclusion Zones for Lower Gain FS Antenna
# 30, 45, 60 dB Building + FSPL



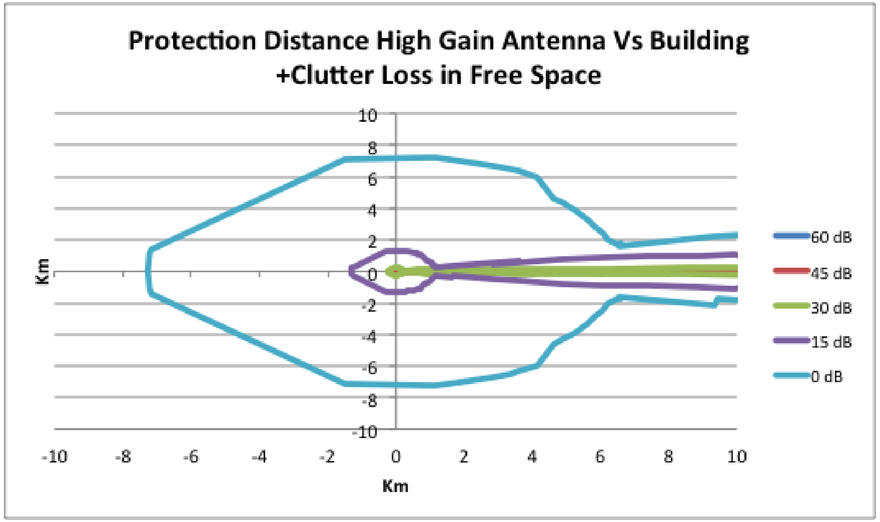

- Co-Channel exclusion zone for 30 dB measured building loss is 34.5 sq Km

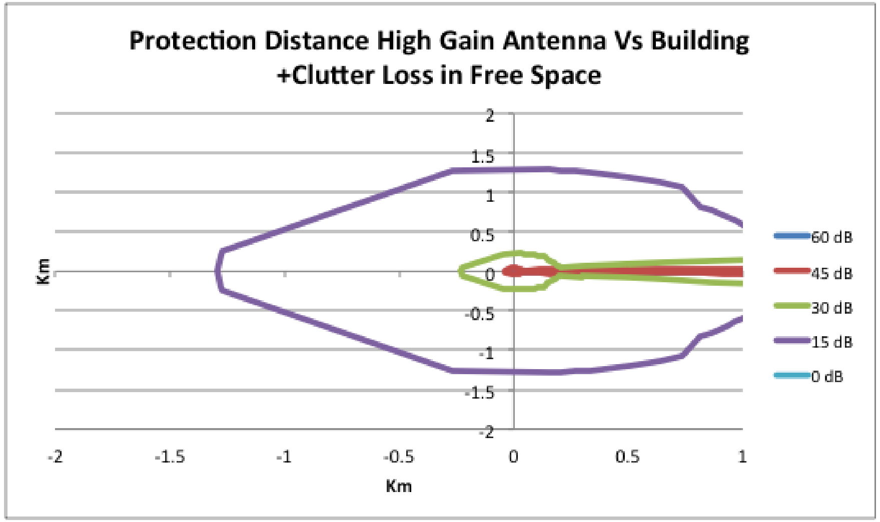
# Exclusion Zones, Lower Gain FS Antenna Pattern with 45, 60 dB Building Loss + FSPL




- 45, 60 dB building loss measurements
- Exclusion zones are 3.45 (45 dB) and 0.11 sq Km (60 dB)

# Antenna Back Lobe Exclusion Zone Impacts




- Back Lobe and field retro-reflection are also considered
- Building Losses presented with back lobe simulations: Measured loss 15-60 dB
- Analysis uses ITU recommendation (Ref 8) for back lobe antenna gain factors to derive path isolation area, distance



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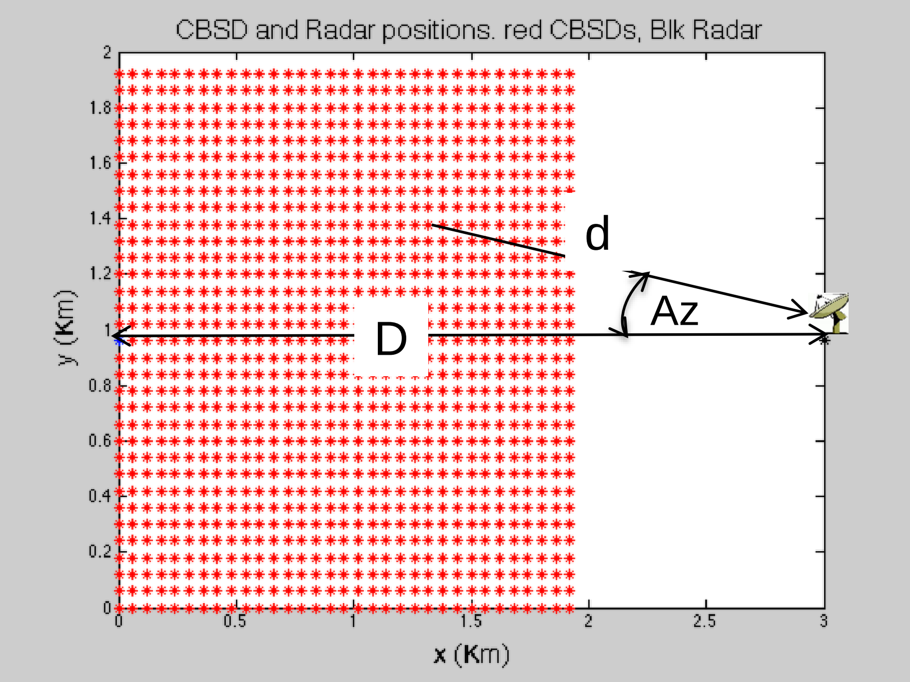
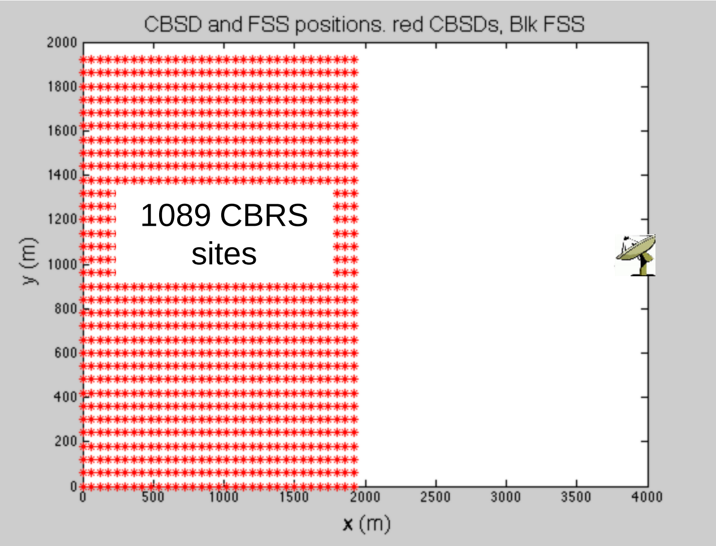
# Dense Co-Channel Simulation for CBRS & High Availability FSS

- Co-channel sharing parameters
  - Noise Power =-105 dBm/30 MHz*
  - FSS Interference threshold: **I/N <= -12 dB**
- CBRS density: 1089 indoor cells within 2x2 km urban area
- CBRS Bandwidth: 3 x 10 MHz contiguous channels (matching FSS receiver maximum channel bandwidth)
- CBRS EIRP: All at full power, 30 dBm
- Buildings: 60m center to center
- CBSD's placed above local clutter, at 30m elevation (HAAT), with FSS is 10m elevation
- Outdoor path loss (first pass): Ehata model. Suburban "suburban homogeneous" (later run: FSPL in lieu of)
- FSS antenna pattern: FCC gain pattern with 20 degrees elevation and FCC azimuthal gain pattern
- Calculate isolation/interference
  - with 15 dB building loss, and subsequently
  - with mix of buildings with random loss variable between 15 to 55 dB
- D is distance taken from farther edge of the CBRS urban cluster, and extends to the FSS site (right side)

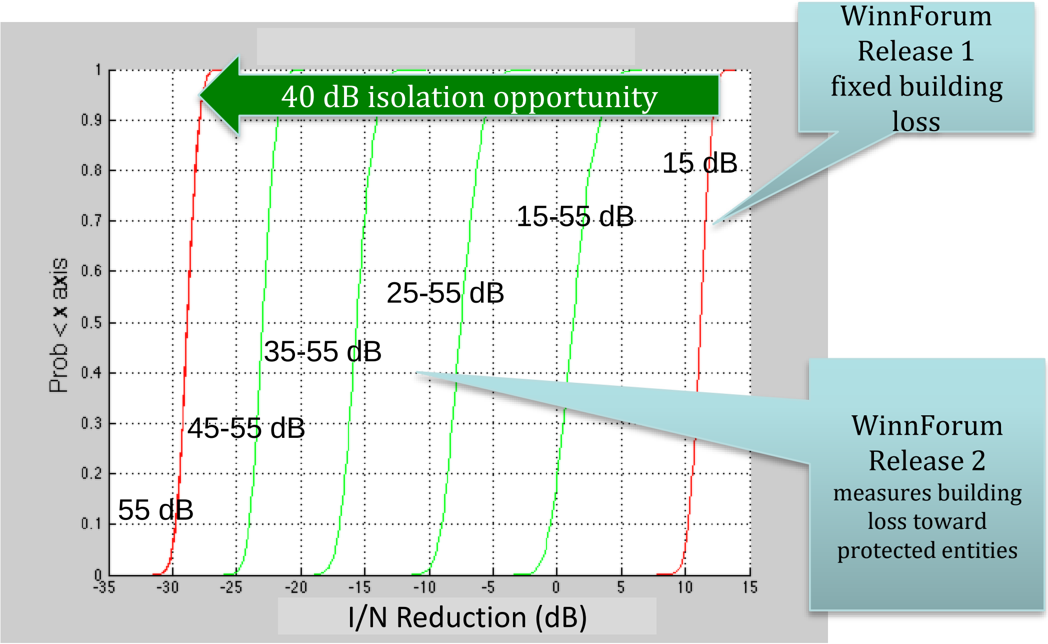



* From Intelsat ex parte filing: "C-Band / 5G Coexistence FCC Debrief Presented by Intelsat & SES " 4/19/2018

# Urban FSS Earth Station Site Near CBRS Dense Co-Channel Sharing Sites




Dish boresight at 20 deg elevation, aimed toward the CBSD 1089 site 30dBm, 30 MHz cluster




- Building loss measurements often provide losses of 40 dB or greater. “Blind” fixed 15 dB rule, adopted from models lose sharing efficiency, yet can be measured, determined, used to protect legacy services.
- **Simulation’s mid-point: Yields 100x increase in spectrum re-use and overall bandwidth capacity while fully protecting legacy FSS site from a 1089-site cluster in/near FSS boresight.**

# Conclusions

- iPosi deeply-assisted GNSS (A-GNSS) provides method to enable sharing via deterministic measurements for site-specific building loss in AFC based 6 GHz
  - Also captures surrounding clutter losses up to the measurement range of the A-GNSS receiver (50-60dB)
- Scales to other mid-frequency candidate sharing bands and service interference thresholds
- Provides deterministic measurements reduce isolation loss variation and uncertainty.
- Ready for 6 GHz, AFC and CBRS bands, sharing systems,
- Deterministic techniques should be used due to large uncertainty in statistical models that require lots of margin
- Building loss must be measured to provide the greatest sharing
- Winnforum WG1 approved
- Encourage the Commission allow deterministic building loss measurements in the rules

# GNSS/GPS Building Loss Profile
# Additional Details
# & References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# GNSS/GPS Entry/Exit Losses
# For Measurements at Other Mid-Band Frequencies

- Dynamic range increases adding newer L5 to L1 signal measurements
  - L5 is 400 MHz below L1, thus provides greater building penetration
  - 3 dB more ambient power than L5
- Same entry/exit measurements span across sharing at 1.7, 3.1, 3.7, and 6 to 8.5 GHz

| Factor (dB) | 3.5 GHz | 6 GHz |
|---|---|---|
| L1 C/A Dynamic range | 46.5 | 46.5 |
| L5 Sensivity increase | 3 | 3 |
| L5 power incr | 4 | 4 |
| L5 to freq (rms) from NIST | 4 | 8 |
| Dynamic range | 57.5 | 61.5 |

- Dynamic range for 6 GHz AFC measurements exceeds 60 dB
  - NIST study, ref[7]

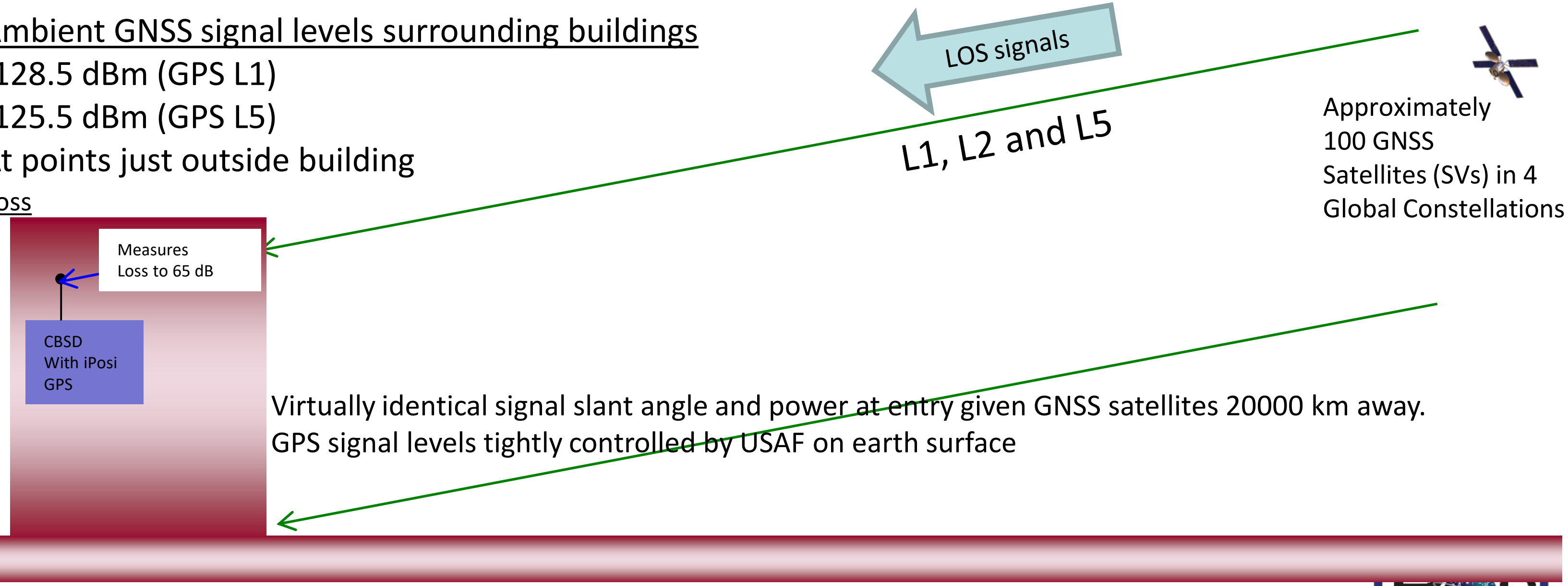
# Measuring Building Loss- Azimuth and Elevation Entry Angle Tolerances

- Elevation tolerance: Up to 70 degree entry angle signals within 1-2 dB of horizontal entry
- Azimuth tolerance: Up to 45 degree entry angle tolerance (various references)

<u>Ambient GNSS signal levels surrounding buildings</u>
-128.5 dBm (GPS L1)
-125.5 dBm (GPS L5)
At points just outside building

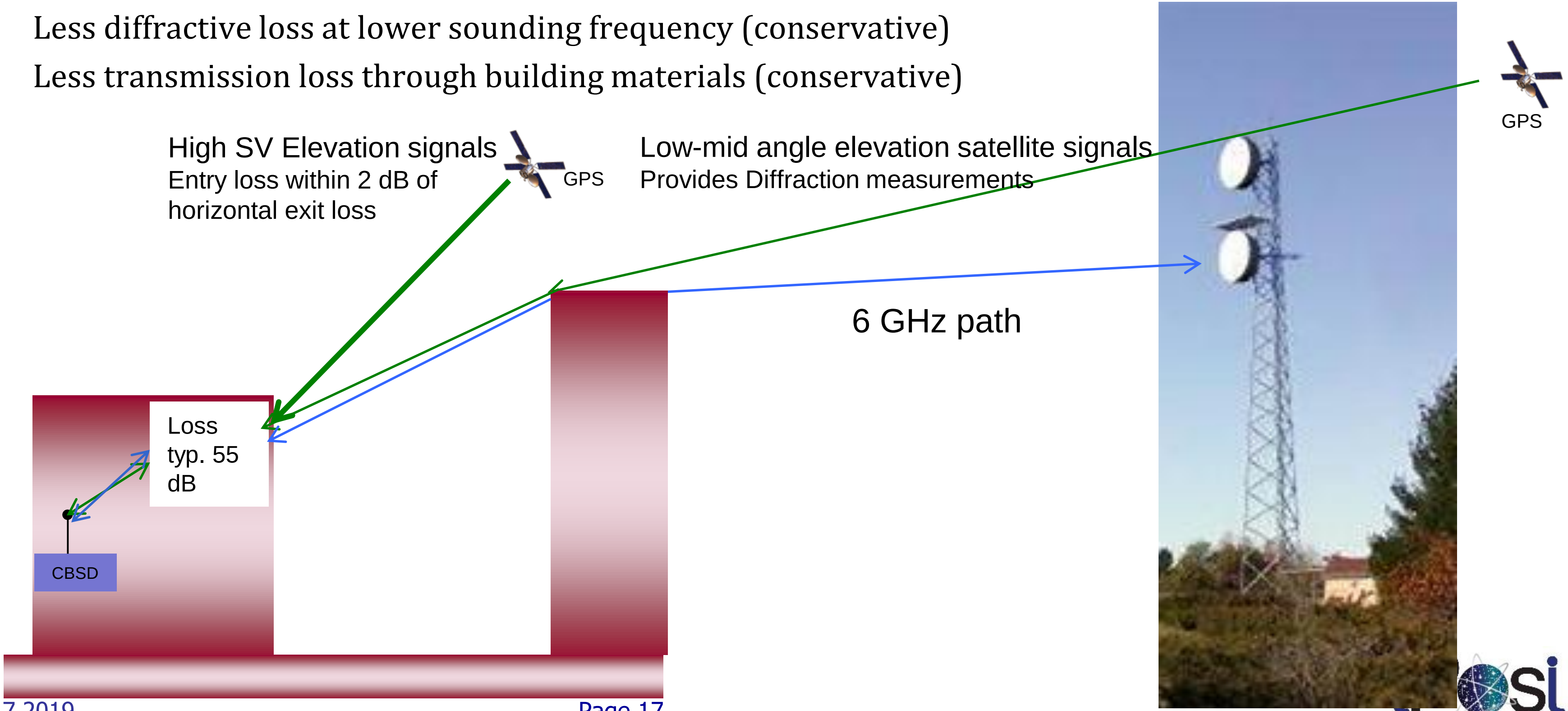
<u>Building entry/exit loss</u>
"X" dBm measured at CBSD GPS Antenna

**Building entry/exit Loss = Ambient – X dB**



# Outdoor Measurements Benefits:
## Captures Complex Diffraction, Scattering and Reflection Composite Paths That Models Miss

- Lower frequency sounding signals incur less loss than 3.5 or 6 GHz carriers
  - Less diffractive loss at lower sounding frequency (conservative)
  - Less transmission loss through building materials (conservative)

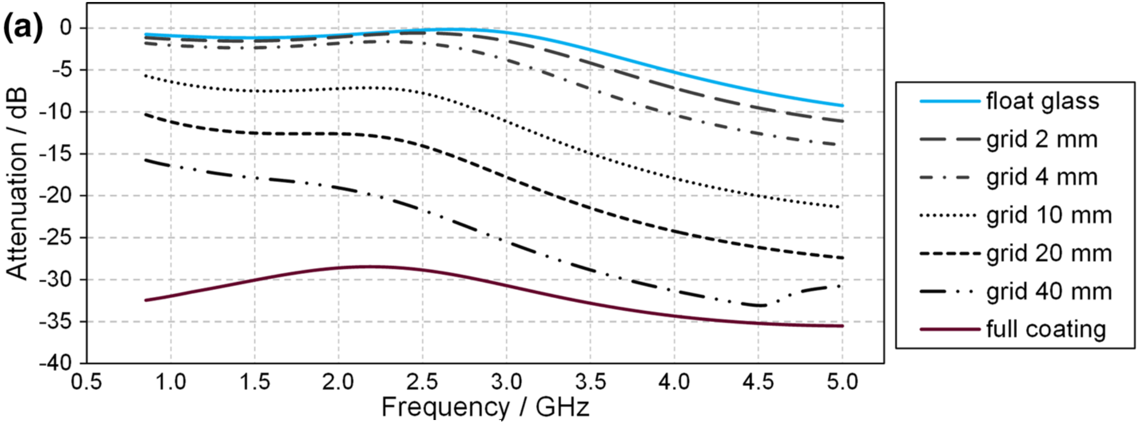


# Building Material RF Transmission Losses - 1.5 (GPS) versus 6 GHz (NIST)

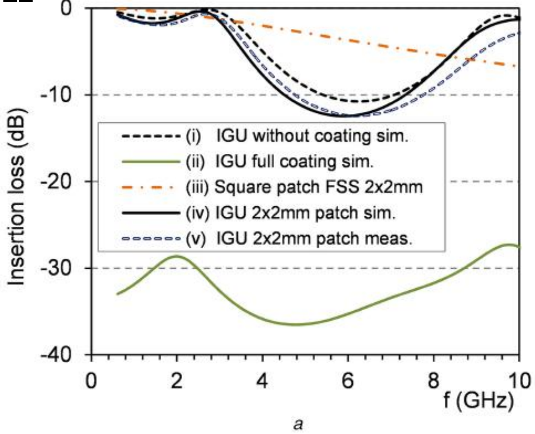

| | |
|---|---|
| Min difference | 5 dB |
| **95%-tile** | **7 dB** |
| 90%-tile | 8 dB |
| 50%-tile | 21 dB |

# Low Emissivity Architectural Glass: Mid-Band RF Transmission Losses

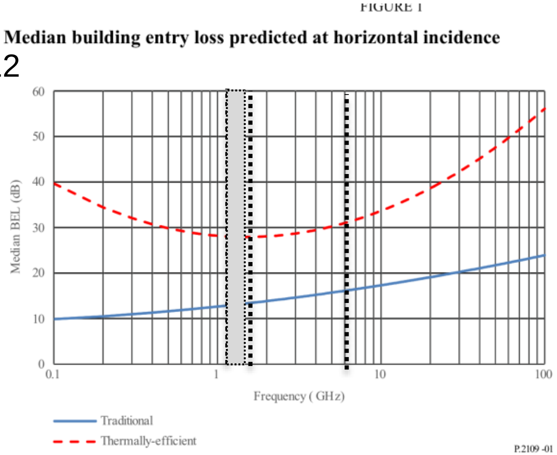
Ref 10




Ref 11




Ref 12




- Ref 10: Uniformly coated glass presents virtually same loss between 1 to 3 GHz. 6 GHz presents 5 dB more loss than 1.5 GHz at 30 dB
- Ref 11 transmission loss at 6 GHz is ~35 dB, or 5 dB more than 1.5 GHz
- Ref 12 transmission loss at 6 GHz reaches 30 dB while loss at 1.5 GHz just below 30 dB in thermally insulated buildings.

# Building Loss Measurement Summary

- Building entry and exit losses at 6 GHz are well represented by sounding signal measurements taken inside buildings where signals penetrate outer wall structures using globally available GPS/GNSS 1.1-1.5 GHz signals
- Building materials create a 7 dB (>95% percent) minimum loss difference between GPS sounding and 6 GHz carrier frequencies. This assures sounding signal losses are conservative, and can be optionally and simply compensated (i.e., add 7 dB to measurements to derive 6 GHz loss values)
- With respect to low emissivity (Low E) glass, commonly used in modern buildings, loss values vary considerably. Building composition (concrete and glass) vary considerably, thus affect each building's loss.
- Tinted and other Low-E glass categories present 5-20 dB microwave transmission loss values. Multi-layer coated glasses present the highest mid-band loss values, per Reference [10], summarized in the table below.

| Carrier Frequency | Uniform Coating Penetration Loss |
|---|---|
| 1.176 GHz (GPS L5) | 30 dB |
| 1.575 GHz (GPS C/A) | 30 dB |
| 3.5 GHz | 33 dB |
| 6 GHz | 35 dB (Extrapolated) |

# References

1 https://www.commscope.com/catalog/antennas/product_details.aspx?id=31002

2 https://www.commscope.com/catalog/antennas/pdf/part/26210/UHX12-59.pdf

3 https://www.commscope.com/catalog/antennas/product_details.aspx?id=52761

4 https://www.commscope.com/catalog/antennas/pdf/part/52763/VHLP3-6W-6WH_A.pdf

5 FCC GN Docket No. 17-183, Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz, Ex Parte Communication, Fletcher, Heald & Hisdreth, March 13, 2018

6 Propagation data and prediction methods required for the design of terrestrial line-of-sight systems,Recommendation ITU-R P.530-17

7 Stone, W. et al. Electromagnetic Signal Attenuation in Construction Materials, NISTIR 6055,Oct 1997

8 Antenna Models For Electromagnetic Compatibility Analyses, NTIA TM-13-489,Oct 2012

9 FCC RR Title 47 101.115, https://www.ecfr.gov/cgi-bin/text-idx?SID=a1260bc8e4fe9748e2a366a940017676&mc=true&node=se47.5.101_1115&rgn=div8

10 Bouvard ,O et al , Structured transparent low emissivity coatings with high microwave transmission, Appl. Phys. A (2017) 123:66DOI 10.1007/s00339-016-0701-8

11 Burnier ,L. et al, Energy saving glazing with a wide band-pass FSS allowing mobile communication: upscaling and characterisation , IET Microwaves ,Antennas & Propagation, ISSN 1751-8725

12 Prediction of building entry loss, ITU-R P.2109 (6/2017)