mmWave Coalition

Approaches to Sharing Spectrum Above 95 GHz

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mmWave Coalition

(https://mmwavecoalition.org/)

- mmWC is a group of innovative companies and universities united in the objective of removing regulatory barriers to technologies using frequencies ranging from 95 GHz to 275 GHz:
  - American Certification Body, Inc.
  - Azbil North America Research and Development, Inc.
  - GlobalFoundries U.S. Inc.
  - Keysight Technologies, Inc.
  - Nokia
  - NSI-MI
  - Nuvotronics, Inc.
  - NYU WIRELESS
  - Qorvo, Inc.
  - Virginia Diodes, Inc.

Basic Goal: NIB Spectrum Sharing >95 GHz Based on Mutual Cooperation in the Public Interest & Objective Transparent Criteria

DAS cellular/Wi-Fi in National Radio Quiet Zone ski resort

https://www.npr.org/sections/alltechconsidered/2013/10/08/218976699/enter-the-quiet-zone-where-cell-service-wi-fi-are-banned

Basic Issues

- Scientific uses of passive spectrum provide key benefits to the public, to the economy, and to the nation – **they must be protected from harmful interference**
- Concepts developed when use was primarily at lower bands *may* overprotect such use and should be revalidated now that there is interest in active uses >95 GHz
  – When originally implemented decades ago there was no opportunity cost of blocking access to this spectrum
  – Assumptions made for lower frequencies may not be all valid for higher ones and did not consider sharing options now available
  – Marketplace approaches to regulation deeper seated now than in past

Why mmW/THz differs from classic spectrum policy assumptions?

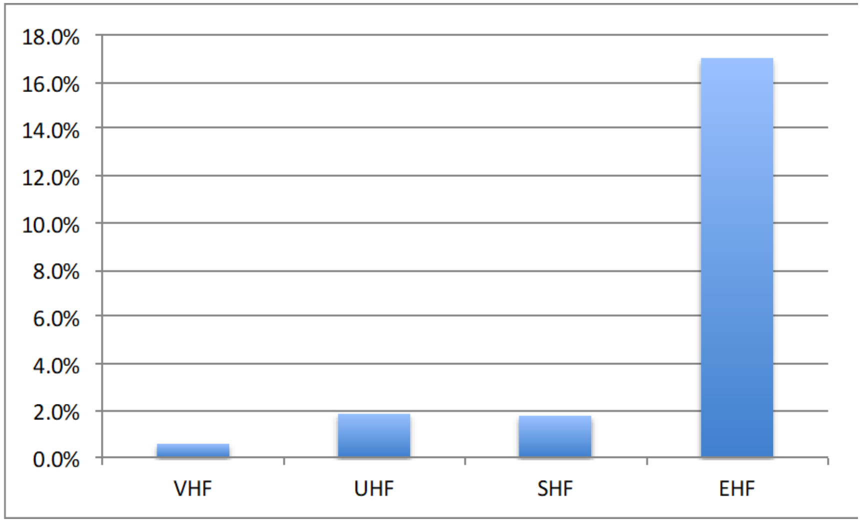
- Due to high density of molecular resonances mmW/THz has many passive allocations and special protections of ITU RR 5.340:

  5.340 All emissions are prohibited in the following bands:
  …, 100-102 GHz, 109.5-111.8 GHz, 114.25-116 GHz, 148.5-151.5 GHz, 164-167 GHz, 182-185 GHz, 190-191.8 GHz, 200-209 GHz, 226-231.5 GHz, 250-252 GHz. (Allocations <100 GHz omitted)

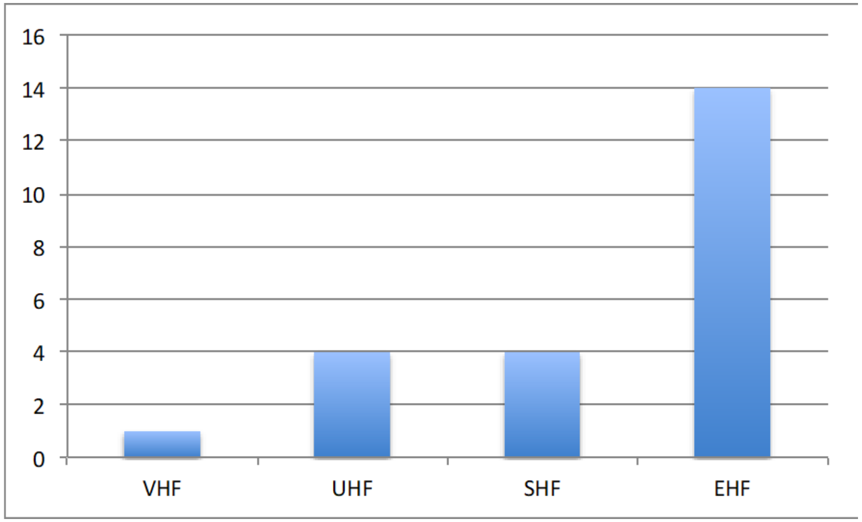
  - There are additional passive primary & coprimary allocations above 100 GHz not included in 5.340 *e.g.* 235-238 GHz
  - Main sharing issue is passive satellites/EESS NOT radio astronomy/RAS
  - RR 4.4 gives US *option* of permitting NIB emissions in such bands

Impact of “Forbidden Bands” on mmW/THz use

Size of forbidden bands



Number of forbidden bands



There are other EESS primary/coprimary allocations w/o US246 protection
Maximum bandwidth between EESS allocations – 26 GHz

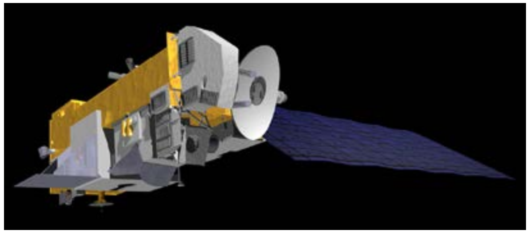
There are no ITU allocations above 275 GHz at present although WRC-19 AI 1.15 will consider a nonbinding band plan

Passive Spectrum Uses

- Oldest is radio astronomy
  - Focus is frequencies with molecular resonances to detect molecules in distant places
  - Observatories for 95+ GHz generally in high arid places
- Environment sensing from satellites (EESS)
  - Also focuses on molecular resonances
  - Worldwide coverage from downward looking satellite sensors necessary
    - Sharing is complicated by necessary downward looking antennas

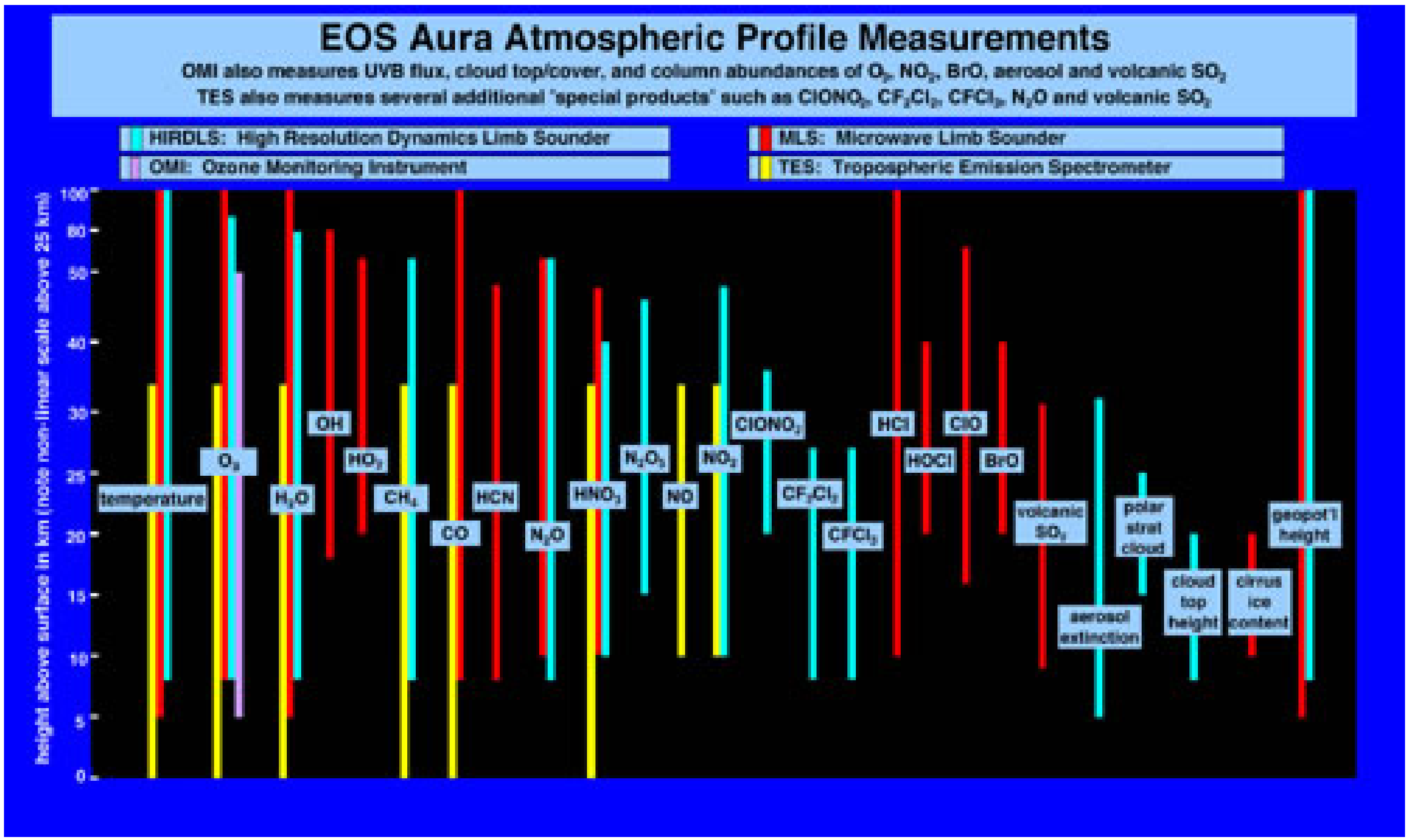
mmW/THz Radio Telescopes

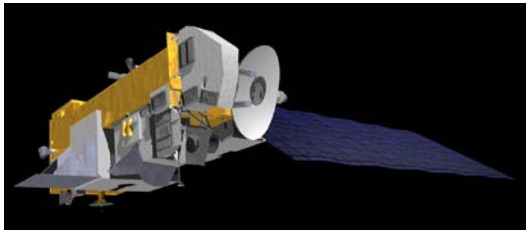
- Few >100 GHz east of Mississippi River
  - Hawaii, California & Arizona
  - Protection straightforward & noncontroversial
- Chile's Atacama Desert is a "hot spot" for RAS due to high dry climate near equator
- RAS/terrestrial frequency coordination of terrestrial has long history



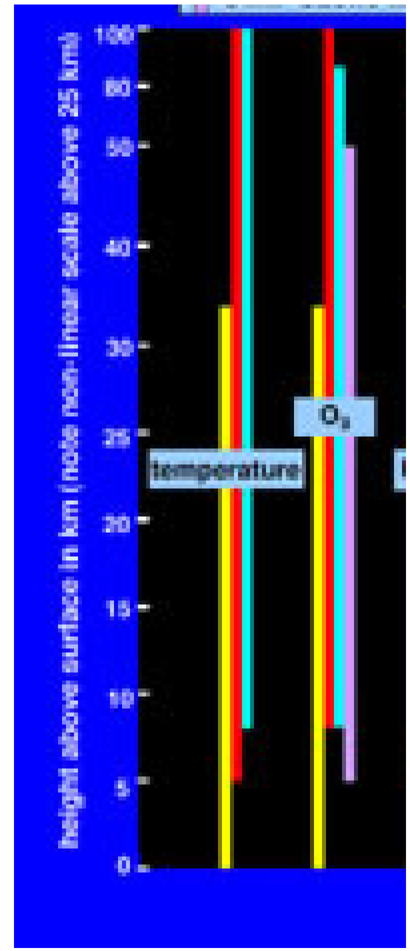
EESS

https://aura.gsfc.nasa.gov/scinst.html





EESS



- EESS bands and sensors have overlapping capabilities
  - If band use has:
    - low marginal costs,
    - no impact from opportunity cost of other uses
    - Nearly unquestioned access to multiple spectrum blocks due to NTIA/IRAC processes

→ system designers may use bands whose capabilities are redundant

Why mmW/THz differ from classic spectrum policy assumptions?

- Small **λ** permits practical use of antennas designs not practical at lower bands
- Intermittent anomalous propagation, *e.g.* ducting, not documented
- High magnitude frequency dependent atmospheric absorption at low altitudes and for low elevation angles paths
  - Somewhat dependent on humidity
  - <u>But</u> paths at high elevation angles have little impact from absorption

237 GHz Issue
Europe Example

http://spectrum.ieee.org/telecom/wireless/a-new-record-for-terahertz-transmission

A New Record for Terahertz Transmission

Engineers achieve amazing data rates in a once-inaccessible band

By Lily Hay Newman
Posted 28 Nov 2013 | 20:30 GMT

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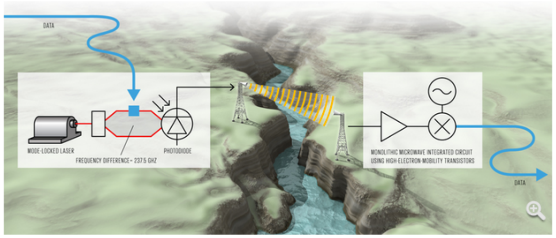


Illustration: Emily Cooper

Bridging a Gap: Two components from the beam of a mode-locked laser shine on a photodiode to produce near-terahertz radiation. A monolithic microwave IC receives the signal and extracts the data.

The problem with the radio spectrum between 3 and 3000 megahertz is that it's crowded. Television, radio, mobile phones, Bluetooth, GPS, two-way communication devices, and Wi-Fi all operate in this high- to ultrahigh-frequency range. So with nowhere to go but up, researchers have been working for decades to utilize the 3- to 3000-gigahertz span. In October, a team reported a hopeful sign—a record 100-gigabit-per-second wireless data transmission.

Scientists in Germany, at the Karlsruhe Institute of Technology (KIT), the Fraunhofer Institute for Applied Solid State Physics, and the University of Stuttgart, created a wireless connection between a transmitter and a receiver that were 20 meters apart at a frequency of 237.5 GHz. This frequency is in

- Why was this done in Germany not USA?
- Would NTIA/IRAC concur on such an experiment?
  - Not likely based on recent precedent!
- Isn't what's good for the GDP, good for scientific research *if* win/win sharing solutions are found?

235-238
EARTH EXPLORATION-SATELLITE (passive) FIXED-SATELLITE (space-to-Earth) SPACE RESEARCH (passive)
5.563A 5.563B

mmW/THz Communications Possibilities

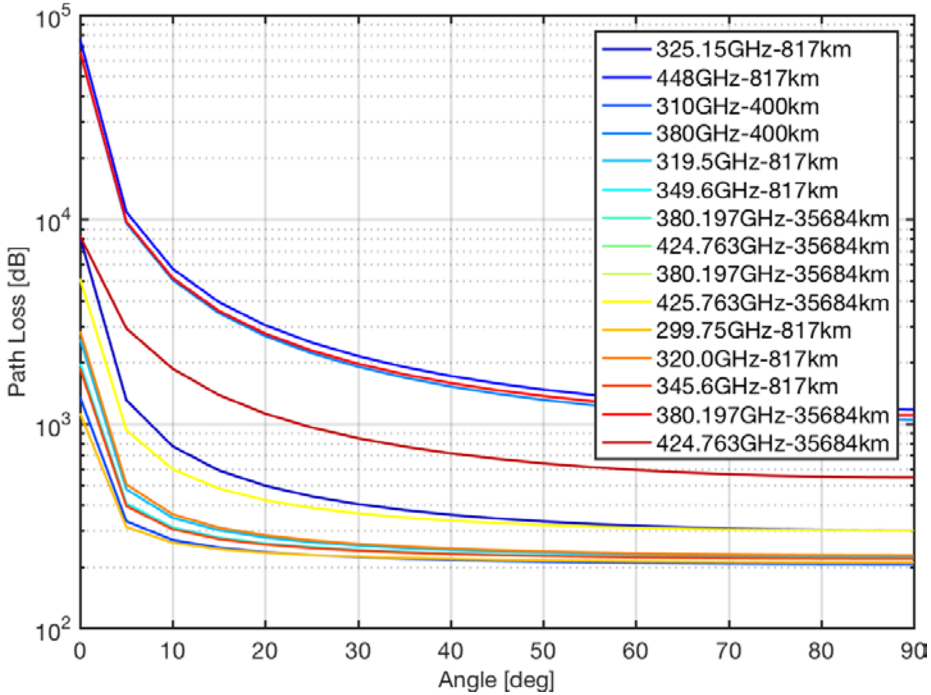
- Cellular backhaul – in certain cases
  - High capacity cell sites will need a lot of backhaul
  - Fiber is cheapest ***if*** fiber is in the ground already
  - BUT in some places fiber installation is slow and <u>very</u> expensive
- Temporary restoration of fiber links in disasters
- Temporary fixed communications for special events & disaster recovery

Noncommunications mmW/THz Uses

- THz spectroscopy
  - Reflections give spectroscopic information about nature of object
  - Wide bandwidth systems can measure structure very precisely
    - Plywood thickness on factory production lines
    - Coatings of medicine pills
    - Verify “special” coatings on aircraft & submarines
  - Used in NASA Space Shuttle program to verify safety critical heat tile adhesion to spacecraft
    - One manufacturer of this equipment commercialized it after NASA-funded R&D for Space Shuttle safety enhancements

Sharing Issues

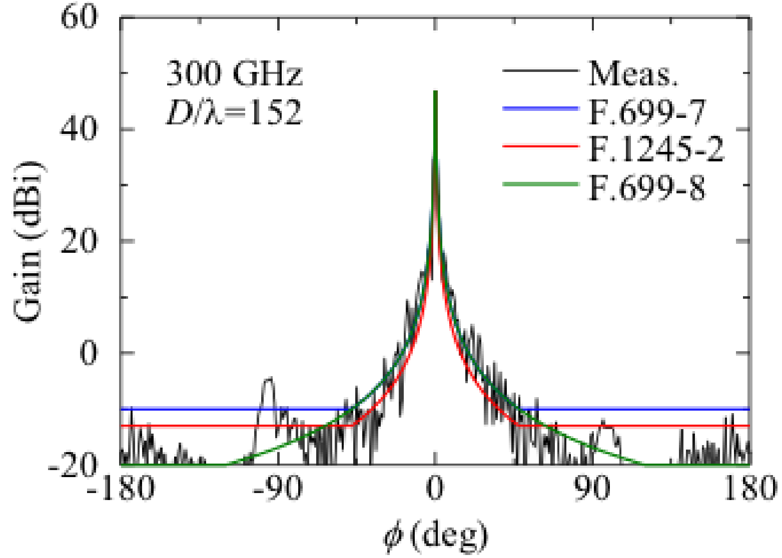
- Most telecom signals have low elevation angles
  - Low elevation angle paths have HUGE path losses though atmosphere
  - High elevation angles have more traditional losses ~200 dB
  - High elevation angle sidelobes are key interference potential



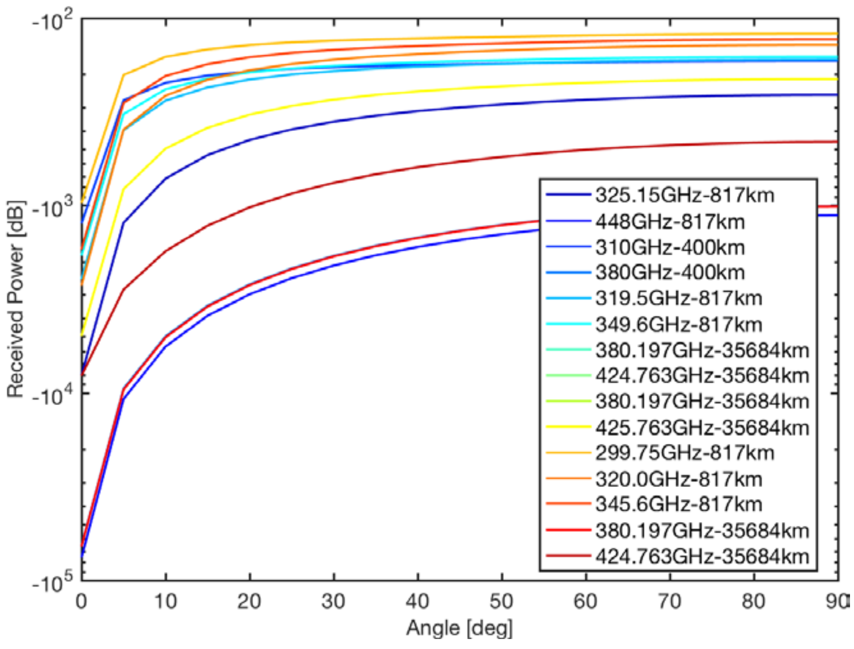
Sharing Issues

- Traditional sharing analysis assume traditional antennas such as dishes and horns which have sidelobe levels of -10 to -20 dBi
- Power reaching satellite from such sidelobes levels is a problem as satellite passes overhead since path loss drops significantly and antenna gain much less

ITU-R models for FS sidelobes



Impact of conventional sidelobe levels on passive satellites



- No problem as satellite rises in the sky due to high path loss at low elevation angles even though telecom antenna gain is high
- At high angles gain drops by 50-70 dB **but** path loss drops by 1000s of dB!

Passive Sharing Issue: Dialogue Needed!

- Both sides have legitimate needs and interests to protect
  - Tendency to assume a zero sum game as is often case in lower spectrum
- Both sides need to try new creative approaches in bands where passive/telecom sharing is of interest

Some possible sharing approaches

- Quasioptical antenna design with possible absorbers to suppress heavily high elevation angle gain
  - Gain at low and negative elevation angles not an issue
- Variant of MIMO technology that uses closed loop to optimize telecom T->R path while using open loop to minimize gain towards known (Az,El) of passive satellites in view
  - Open loop needs analysis for sensitivity to physical pointing errors and manufacturing variability
  - Can it be calibrated by looking at RF sources in sky or other satellites?
- Coherent laser-like sources
  - Not yet feasible <2 THz

Some possible sharing approaches

- Should future passive satellite planning include coordination with terrestrial designers in the design phase on possible joint design approaches for interference free spectrum sharing with minimal cross coupling?

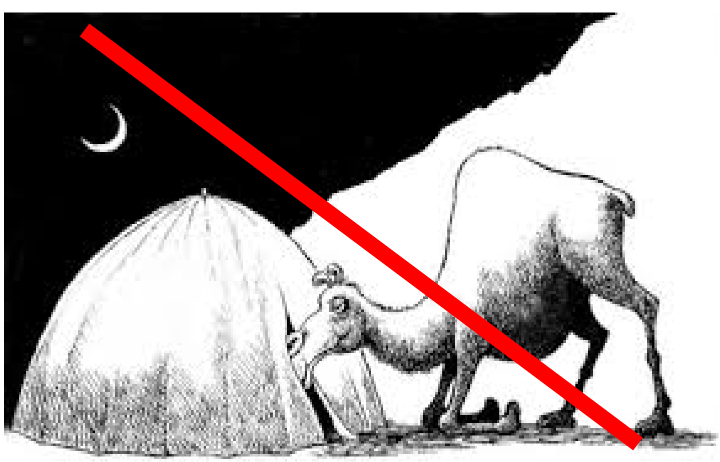
- mmWC has suggested to NTIA that CORF should explicitly consider EESS sharing issues and balancing concerns of entire NAS/NAE membership

Regulatory Issues

- Should US246 “No station shall be authorized to transmit” provision be modified to limit skyward emissions to levels stipulated in ITU-R recommendations for EESS protection?
  - Specific proposal in mmWC’s NTIA filing
- While all bands in US246 have resonances of possible interest, in view of past experiences with collected data are some of these bands redundant for present and expected environmental sensing requirements?
  - Opportunity costs were <u>not</u> considered at time of these allocations

Regulatory Issues

- Traditional experimental licenses of limited area and time duration should be coordinated on based on interference potential of the actual experiment in space/time/frequency and not on “slippery slope”/“camel’s nose” issues
  - Any conditions should be solely interference based



New FCC Rules

https://docs.fcc.gov/public/attachments/FCC-19-19A1.pdf

- *Nominally* permits 10 year "experiments", including equipment sale, on any frequency between 95 GHz and 3 THz
- Subject to:

§ 5.702 Licensing requirement – necessary showing.

Each application must include a narrative statement describing in detail how its experiment could lead to the development of innovative devices and/or services on frequencies above 95 GHz and describe, as applicable, its plans for marketing such devices. This statement must sufficiently explain the proposed new technology/potential new service and incorporate an interference analysis that explains how the proposed experiment would not cause harmful interference to other services. The statement should include technical details, including the requested frequency band(s), maximum power, emission designators, area(s) of operation, and type(s) of device(s) to be used.

- Timely access to EESS technical parameters will be needed and understanding of mutually agreeable methodology for analysis

Conclusions

- Wideband communications and THz spectroscopy uses above 95 GHz offer new opportunities not available in lower bands
- Sharing R&D inhibited by absolute prohibition in decades old US246 text that even blocks experiments
  - Recent US mmWave Coalition filings at FCC give more specific alternatives

https://ecfsapi.fcc.gov/file/113010791160/Ex%20Parte%20Supplement%20of%20mmWave%20Coalition%20FINAL.pdf

https://ecfsapi.fcc.gov/file/10130024051912/mmW%20Coalition_NTIA%201%2019%20RFC%20comm%20final.pdf

Thank you for your time

Questions?

DAS cellular/Wi-Fi in National Radio Quiet Zone ski resort