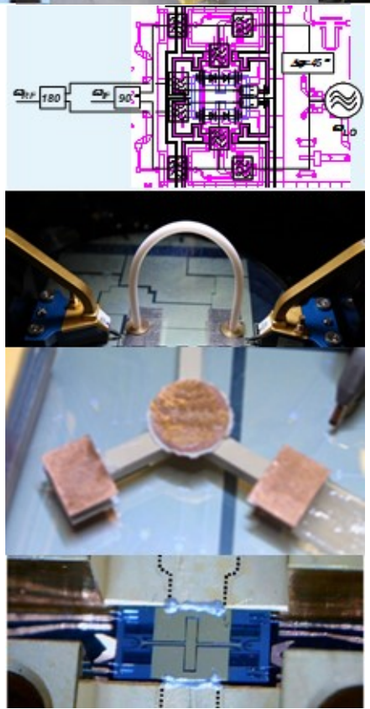
University of Stuttgart

Passive FTTR distribution system using millimeter-wave on polymer fiber

ITU-T Meeting 10 July 2024



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Summary

- Exemplary use case and constraints
- Polymer fiber for 60 GHz microwave signal transmission
- Antenna radiators
- System demonstration examples
- Conclusion

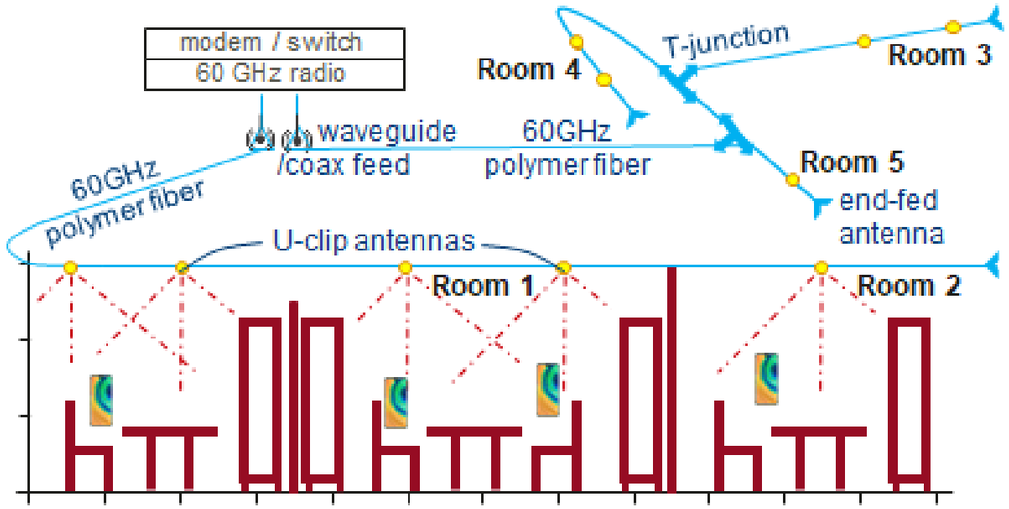
Exemplary use case and constraints

- 60 GHz wireless coverage at short-distance (e.g., indoors) poor since not supported by diffraction & reflection
- Multiple fiber-backed radiators needed for good coverage

- Use of polymer dielectric fiber carrying 60 GHz band signals
- Use of fiber couplers and fiber splitters
- Use of small metal antennas to distribute 60 GHz band signals

Completely passive and reciprocal
(no active circuits, no power supply)

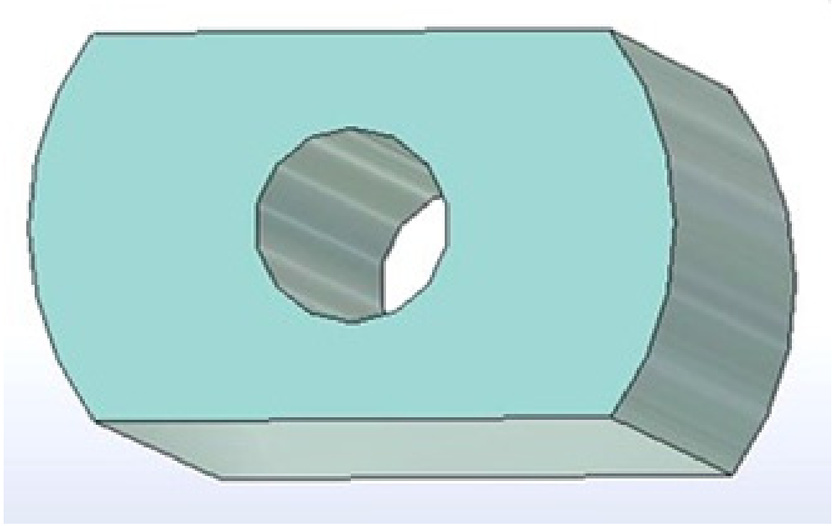
- Example:

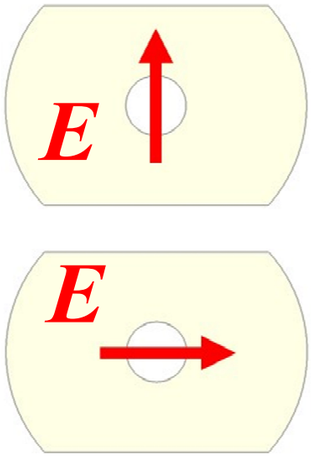


- Dual-polarized (dual-mode) fiber
- Low-loss on-fiber transmission
- Simple fiber-fed antennas

Hardware detail — Mechanically flexible, low-loss, dual-polarized fiber (1/3)

- Extruded PTFE fiber:
  - Non-circular cross section for polarization/mode decoupling
  - Center hole for reduction of (dielectric) transmission loss
- Cross section 2.4 mm x 4 mm / hole diameter 1.2 mm

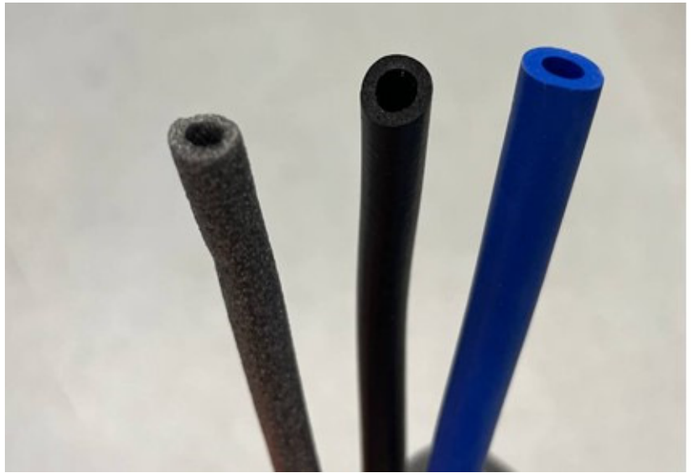


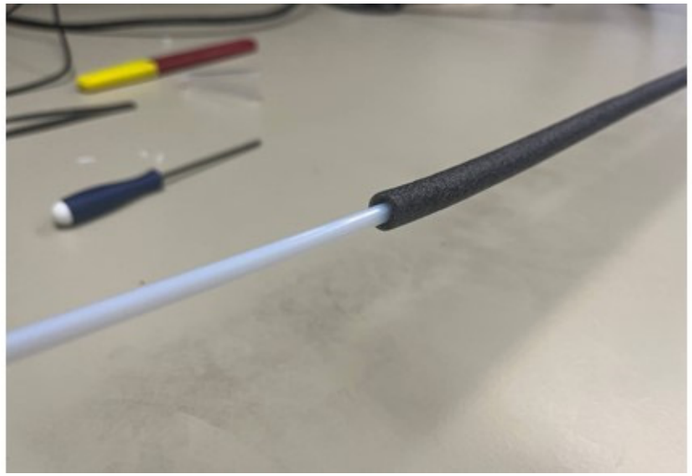


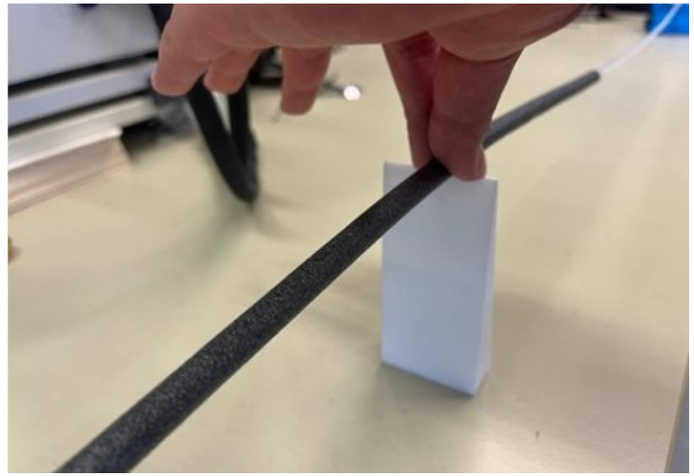
two orthogonal modes/polarizations

Hardware detail — Mechanically flexible, low-loss, dual-polarized fiber (2/3)

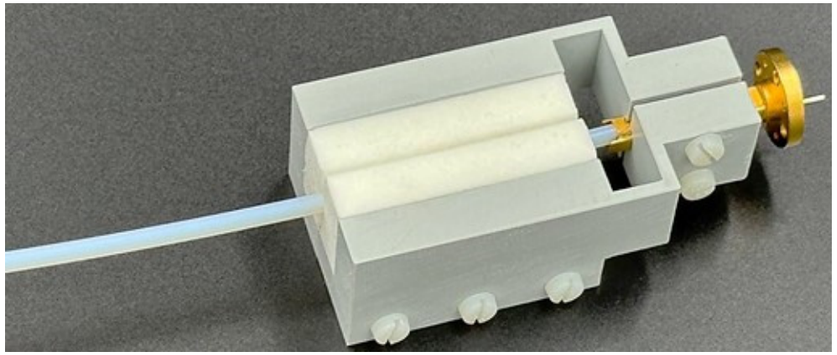
- Foam coating with low-loss polymer foam (negligible added loss) makes the fiber insensitive to touching





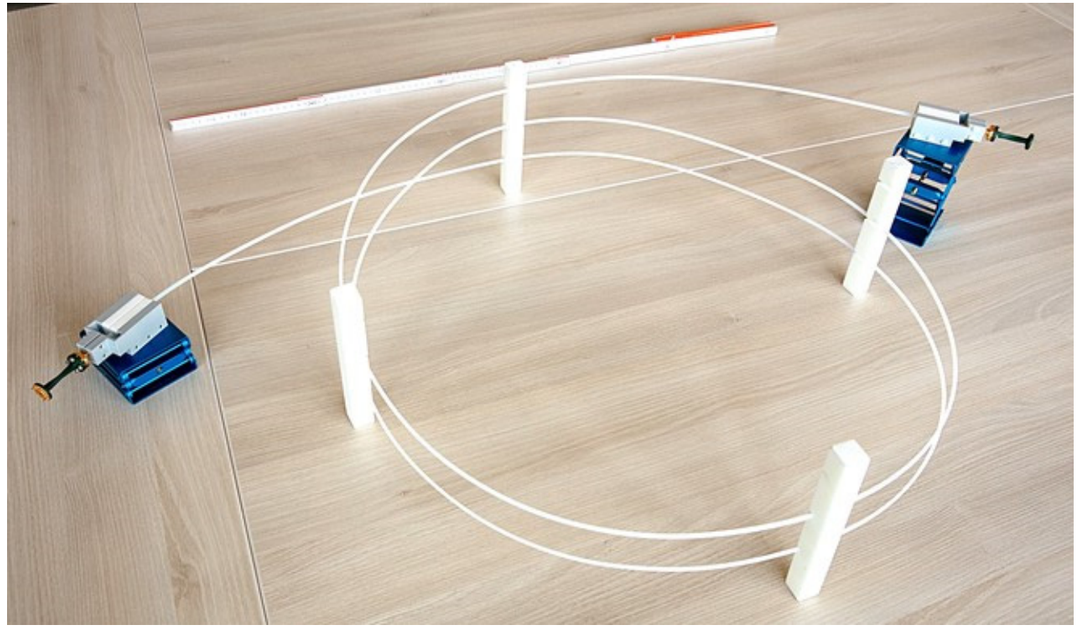


- Transition to rectangular waveguide (WR-15, 50-75 GHz) for measurement purpose (about 1 dB insertion loss)



Hardware detail — Mechanically flexible, low-loss, dual-polarized fiber (3/3)

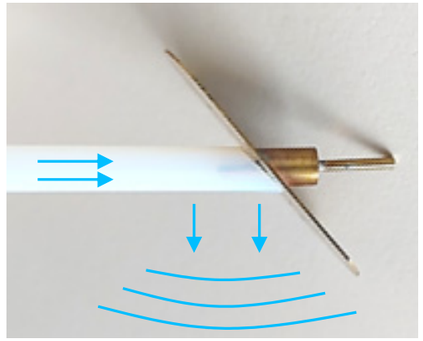
- Measured straight-fiber transmission loss of 1.2 dB/m, 1.6 dB/m (two polarizations/modes, resp.) at 60 GHz
  - Extracted from different lengths, with waveguide adapters de-embedded
- Measured leakage/radiation loss at bend of 0.2 dB for 90° bend with 20 cm radius

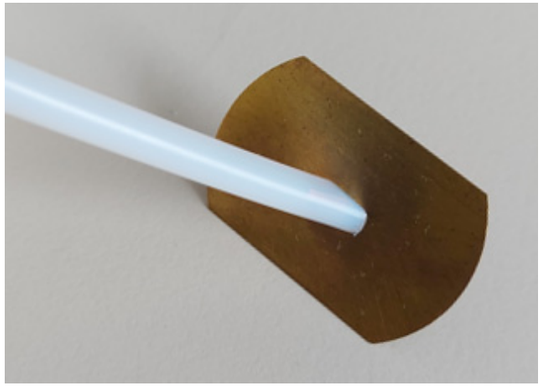


- Trade-off between dielectric loss, bending loss, mechanical flexibility. Also: mode coupling, weight

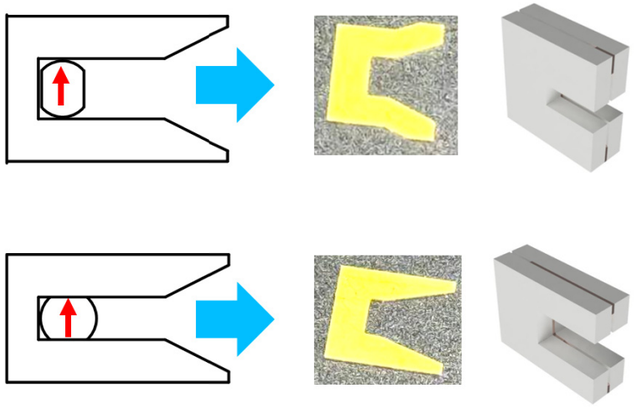
Hardware detail — Passive antenna radiators

- Fiber-end antenna: for both polarizations/modes,
  all radiation is directed sideward/angled

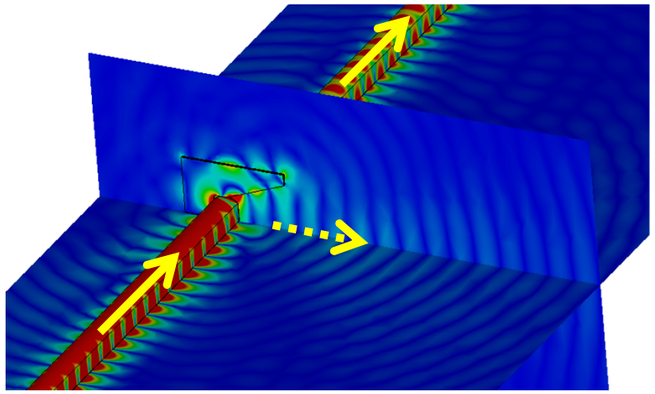




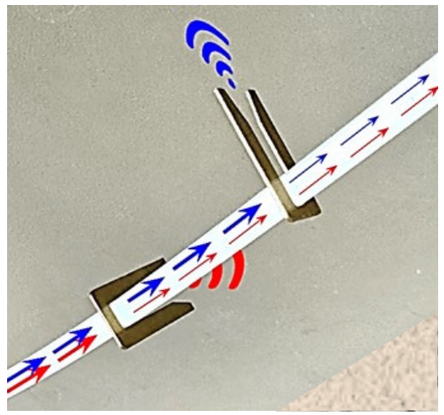
- U-clip antenna: for one selected polarization/mode,
  smaller part of energy is radiated sideward



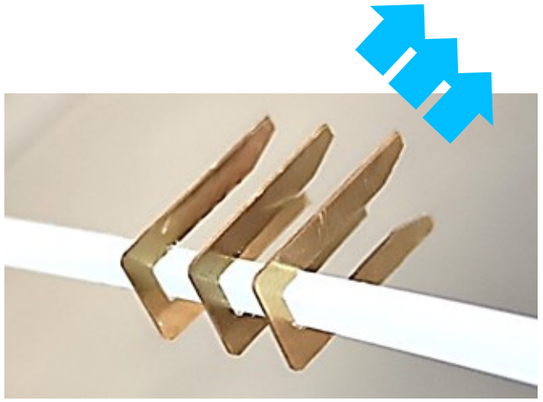
concept / built



operation (E-field mag sim)



2 modes in fiber

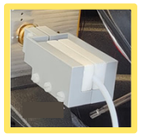


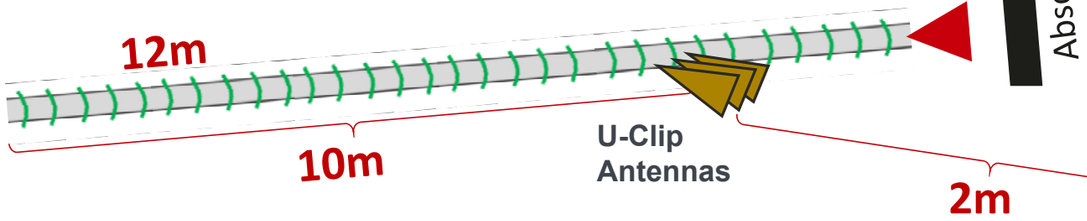
“array” (stronger focus)

System demonstration examples (1/2)

- 60-GHz-lab-demonstration of 802.11ad over 10 m polymer fiber plus 2 m wireless

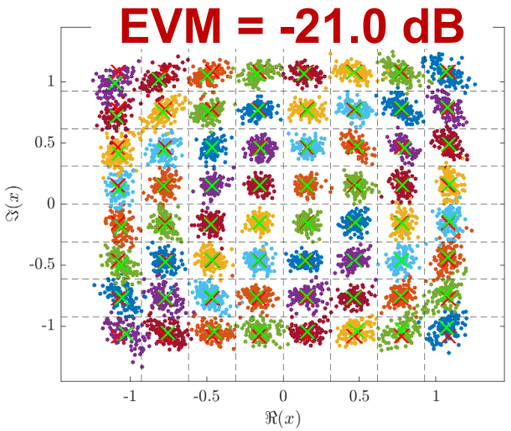
commercial 60-GHz front-end with waveguide access [GotMic]

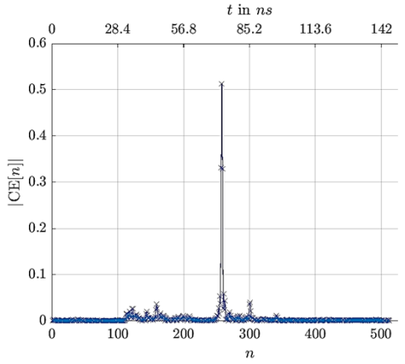




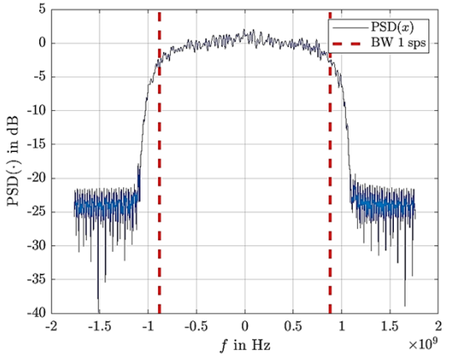
commercial 60-GHz front-end with antenna array [Sivers]

IEEE-Standard	802.11ad (WiGig)
Standardization	2012
Target Carrier	60 GHz
Max. rate / channel	6.7 Gbit/s
Bandwidth /channel	2.16 GHz
FEC	LDPC (1/2…13/16)
Modulation	Single Carrier Max. 64 QAM



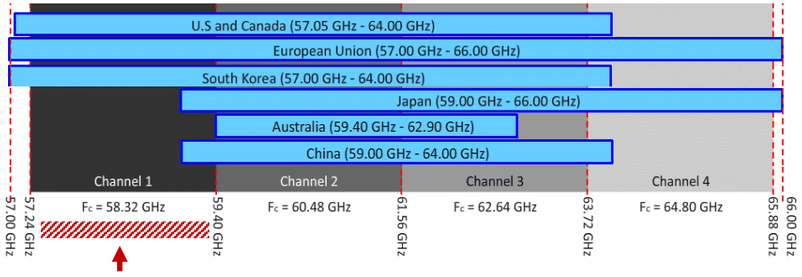


Channel Impulse Response: Time Domain



Channel Impulse Response: Power Spectral Density

60 GHz ISM bands



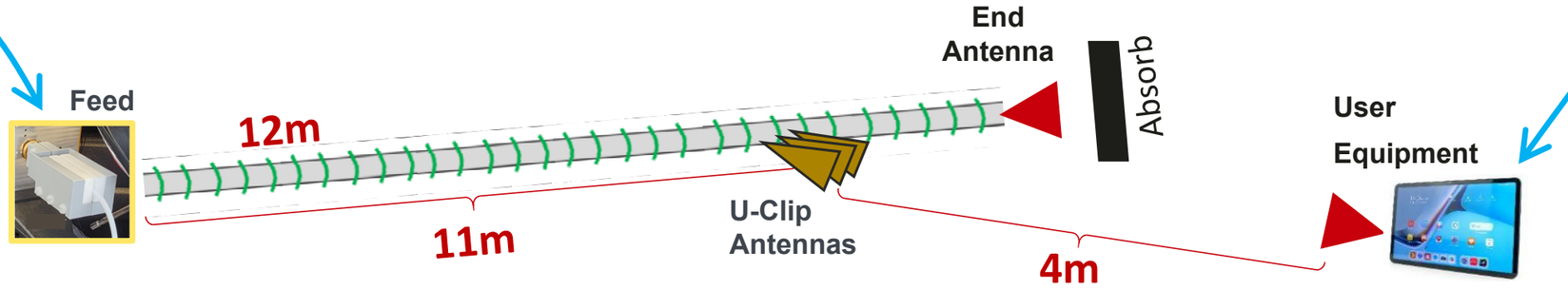
- Error-free 802.11ad with MCS 12.4: Data rate **6.93Gbit/s per channel** (-21.0dB EVM) for 1 of 4 available channels

- Uplink and **downlink** perform close to identically

System demonstration examples (2/2)

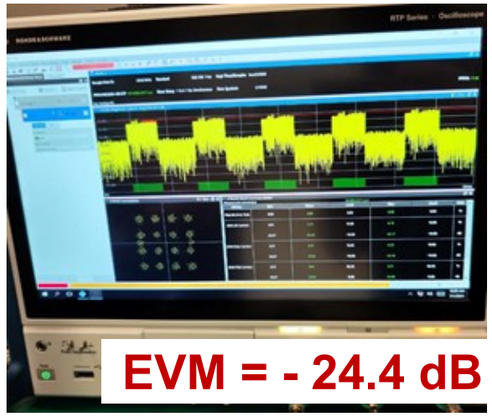
- 60-GHz-lab-demonstration of Wi Fi 6 (802.11ax) over 11 m polymer fiber plus 4 m wireless

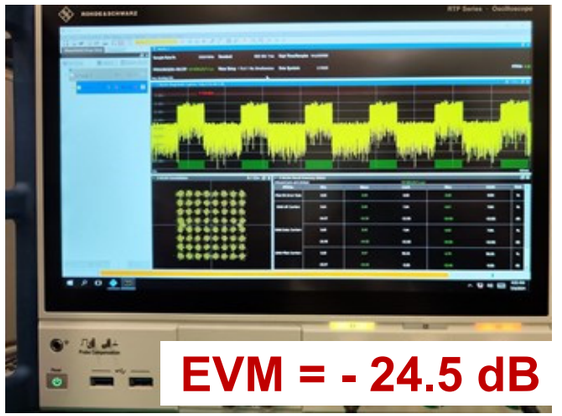
commercial 60-GHz front-end with waveguide access [GotMic]



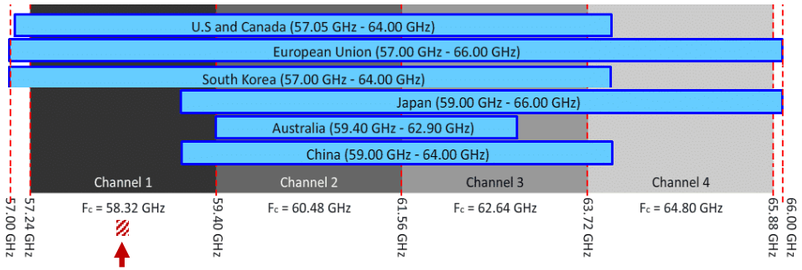
commercial 60-GHz front-end with antenna array [Sivers]

IEEE-Standard	802.11ax (WiFi 6 / WiFi 6E)
Standardization	2021
Target Carrier	2.4, 5, (6) GHz
Max. rate / channel	9.608 Gbit/s
Bandwidth /channel	20/40/80/160 MHz
FEC	LDPC (1/2 … 5/6)
Modulation	OFDM Max.1024 QAM





60 GHz ISM bands



- Error-free 802.11ax with MCS 5: Data rate 576.47Mbit/s (-24.5dB EVM) for **160MHz out of 8640MHz (2%!)** available spectrum

- Uplink and **downlink** perform close to identically

Conclusion

- Signal transmission with GBps demonstrated over several meters of fiber plus several meters of free-space
    - 60 GHz channels: 802.11ad and 802.11ax
- Purely passive system (no electronics & no power supply at antenna location)
- Fiber proven with low transmission loss (<~1.6 dB/m) and low-cost, low-weight, mech.-flexible, touching-ok
- Antennas, splitters, … for dual polarizations/modes shown / to be improved / under development

THANK YOU. ☺