W and D-Band for 5G Backhaul/Fronthaul

Mario G. Frecassetti
X-Haul BL - Nokia
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WHAT’S HAPPENING IN EUROPE ABOVE 90 GHZ

○ First promoted by ETSI ISG mWT (+) for 5G Backhaul /Fronthaul network
  ○ Nokia (X-Haul BL) is among the founder member of mWT.

○ CEPT ECC (^) approved two new Work Items to develop Fixed Service (FS) above 92 GHz
  ○ Scope are to develop ECC Recommendation and ECC Report containing guidelines on deployment of fixed services operating in the allocated bands.
  ○ Deadline mid 2018

(+) ETSI ISG mWT – Industry Specification Group - millimetre Wave Transmission
(^) CEPT - European Conference of Postal and Telecommunications Administrations is the organization where policy makers and regulators from 48 countries across Europe collaborate to harmonise telecommunication, radio spectrum, and postal regulations to improve efficiency and co-ordination.
Within 92 GHz – 200 GHz, the following frequency bands are allocated to FS:

1. 92-94 GHz (total 2000 MHz)
2. 94.1-95 GHz (total 900 MHz)
3. 95-100 GHz (total 5000 MHz)
4. 102-109.5 GHz (total 7500 MHz)
5. 111.8-114.25 GHz (total 2450 MHz)
6. 130-134 GHz (total 4000 MHz)
7. 141-148.5 GHz (total 7500 MHz)
8. 151.5-155.5 GHz (total 4000 MHz)
9. 155.5-158.5 GHz (total 3000 MHz) (*)
10. 158.5-164 GHz (total 5500 MHz)
11. 167 - 174.7 GHz (total 7700 MHz)
12. 191.8 -200 GHz (total 8200 MHz)

Within 92 GHz - 200GHz, the following frequency bands are covered by RR No 5.340 stating that “All emissions are prohibited”.

• 100-102 GHz
• 109.5-111.8 GHz
• 114.25-116 GHz
• 148.5-151.5 GHz
• 164-167 GHz

Furthermore, studies would consider relevant unwanted emissions from FS into this bands

(*) according to RR NO 5.562G – “The date of entry into force of the allocation to the fixed and mobile services in the band 155.5-158.5 GHz shall be 1 January 2018. (WRC-2000)”
General assumptions and basic considerations

- Transport of capacities in the order of 1 to more than 10 Gbps. 40 Gbps with parallel streams
- Efficient use of spectrum should be pursued.
- 1Gbit/s can be obtained using a 250 MHz channel and 128 QAM modulation.
- More capacity aggregating n x 250MHz channels up to a 2GHz.

- Minimum channel size of 250 MHz is considered the best approach for both FDD/TDD because:
  - Capacity up to 1 Gbps can be easily delivered
  - Capacity can be easily scaled up to 10 Gpbs aggregating more channels.
  - Parts of E-Band design can be reused and ready for improvements.
- Whether specified (not recommended), a large duplex separation is needed, for allowing duplexing filters (>15GHz in D Band)
Why such an aggregation into **W-Band** and **D-Band**

- Different portions of spectrum, allocated to FS, with size ranging from 1 GHz to 12.5 GHz.
- Better avoid to have plenty of different bands when the behaviour is the same.
- Each band to be covered with an homogeneous approach.
  - Single type of Waveguide
  - Single amplifier- Relative Bandwidth within 30%

### Designation $f_{\text{min}} - f_{\text{max}}$ [GHz] | Cut-off Frequencies [GHz] | Band
---|---|---
WR8 | RG138 (silver) | 90.00-140.0 | 73.8 | W-band
WR7 | RG136 (silver) | 110.0-170.0 | 90.8 | D-band

Identified two bands:

- **W band $\rightarrow$ 92 - 114.25 GHz**
- **D band $\rightarrow$ 130 -174.5 GHz**

Left orphan 122.25-123 GHz
- Too small and far from the others.
- Too far and unfeasible to cover it with a single approach
  - 191.8-200 GHz
W Band

THE RANGE 92-114.5 GHZ

According to RR table, in this range five formally separate bands are available to FS:

1. 92-94 GHz (total 2000 MHz)
2. 94.1-95 GHz (total 900 MHz)
3. 95-100 GHz (total 5000 MHz)
4. 102-109.5 GHz (total 7500 MHz)
5. 111.8-114.25 GHz (total 2450 MHz)

Even if formally separated in RR (i.e. different services allocation) bands 2 and 3 can be considered the same (94.1-100 GHz) for FS point of view. Bands 1 and 2 are already regulated by recommendations ITU-R F.2004 and ECC/REC(14)01 and their different use would imply changes in those recommendations.

Total: 17.85GHz

Next slide the current ETSI proposal.
W-Band - 92 - 114.250 GHz range: Fixed Service allocated sub-bands. Proposal 250 MHz

Sub-band "A": 29 x 250 MHz

Sub-band "B": 29 x 250 MHz

Sub-band "C": 8 x 250 MHz

Total = 66 x 250 MHz
D- Band

THE RANGE 130-174.7 GHZ

According to RR Tables, in this range six formally separate bands are available to FS:

1. 130-134 GHz (total 4000 MHz)
2. 141-148.5 GHz (total 7500 MHz)
3. 151.5-155.5 GHz (total 4000 MHz)
4. 155.5-158.5 GHz (total 3000 MHz)
5. 158.5-164 GHz (total 5500 MHz)
6. 167-174.7 GHz (total 7700 MHz)

Even if formally separated in RR (i.e. different services allocation) bands 3, 4 and 5 can be considered the same (151.5-164 GHz with a total 12500 MHz width) for FS point of view.

Total: 31.7GHz

Next slide the current ETSI proposal.
D-Band - 130 - 174.8 GHz range: Fixed Service allocated sub-bands. Proposal 250 MHz slots

Sub-band "A": 15 x 250 MHz

132-130 GHz
FIXED-SATELLITE
MOBILE-SATELLITE
RADIONAVIGATION

134-136 GHz
AMATEUR
AMATEUR-SATELLITE

136-141 GHz
RADIO ASTROLOGY

Sub-band "B": 29 x 250 MHz

141-148 GHz
EARTH EXPLORATION-SATELLITE (passive)
RADIO ASTROLOGY

Sub-band "C": 49 x 250 MHz

Sub-band "D": 30 x 250 MHz

164-167 GHz
EARTH EXPLORATION-SATELLITE (passive)
RADIO ASTROLOGY

Total = 123 x 250MHz
Spectrum evolution for backhaul

<table>
<thead>
<tr>
<th>uWave</th>
<th>V-band</th>
<th>E-band</th>
<th>W-band</th>
<th>D-band</th>
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</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Huge bandwidth available</td>
<td>92-114 GHz</td>
<td>130-175 GHz</td>
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<tr>
<td>Propagation conditions not dramatically worst than E-band (FSL 130 dB/km)</td>
<td>FSL 132 dB/km</td>
<td>FSL 136 dB/km</td>
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<tr>
<td>High integration level</td>
<td>Rain impact not so dramatic.</td>
<td>Component miniaturization Antenna mainly</td>
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</table>

Consistent with evolution towards 5G and Ultra-Dense Networks

Specific attenuation [dB/Km] due to rain vs Frequency
W-Band vs D-Band - What is enabling

uWave | V-band | E-band | W-band | D-band

Capacity

Innovative arrangements

Multiple small antennas

Single device with multiple carriers to be considered as single emission.

Very high throughput up to 40 Gbps

E.g. : W-Band beam-steering prototype (Bell-Labs)

10 Gbps@ 99.9% up to 300m

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W-Band vs D-Band

Maximum hop length vs Gross System Gain: Rain rate 60mm/h – Availability 99.9% & 99.99%

Calculation’s conditions:

- ITU-R P.530-16 - up to 100GHz
- ITU-R P.838-3 - Specific attenuation model for rain for use in prediction methods – up to 1000GHz
- ITU-R P.676-11 - Attenuation by Atmospheric Gases – up to 1000GHz
Solution for 10Gbps 2GHz channel
→ Hops length up to 300m

Antennas Gain – 40 dBi

Antennas Gain – 35 dBi

W-Band & D-Band (110GHz & 150GHz)
Recommendations

We recommend:

• To consider the spectrum from 92 to 175 GHz for future Fixed service application.

• In order to facilitate the industrial stakeholders in this matter:
  - Aggregation of spectrum slices into two bands (W and D-Band), as here proposed
  - Channel raster should be 250MHz based and multiple channels aggregation possible
  - Consider multiple carriers in parallel as single emission, facilitating frequency coordination.
  - Duplexer spacing should be left unexpressed

• D-Band, alias 130-174.5GHz, should be considered first, helping the overall ecosystem to better focalise investments and research.