

W and D-Band for 5G Backhaul/Fronthaul

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Contents

- What's happening in Europe above 90 GHz
- Radio Regulation (RR) – region 1-2-3
- General assumptions and basic considerations
- Why such an aggregation into W and D-Band
- W-Band: Proposal for Frequency arrangement
- D-Band: Proposal for Frequency arrangement
- Spectrum evolution for backhaul
- W-Band vs D-Band - 1Gbps and 10 Gbps solution
- Recommendations

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.

CURRENT REGULATIONS

RADIO REGULATION (RR) – REGION 1-2-3

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)*”

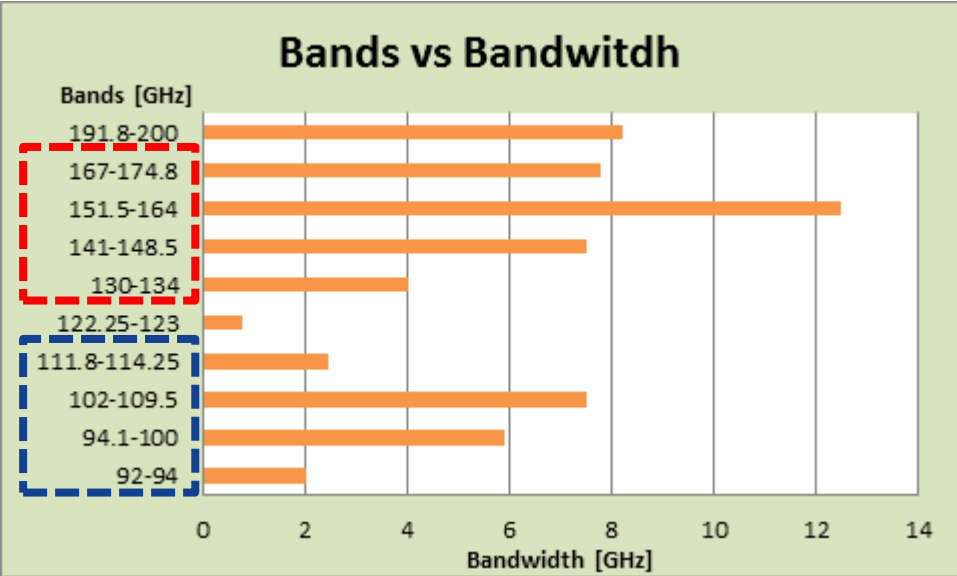
General assumptions and basic considerations

- 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 $n \times 250\text{MHz}$ 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 Gbps 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%



Slices of spectrum allocated to FS

| Designation | $f_{min} - f_{max}$ [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 → 92 - 114.25 GHz

• D band → 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.

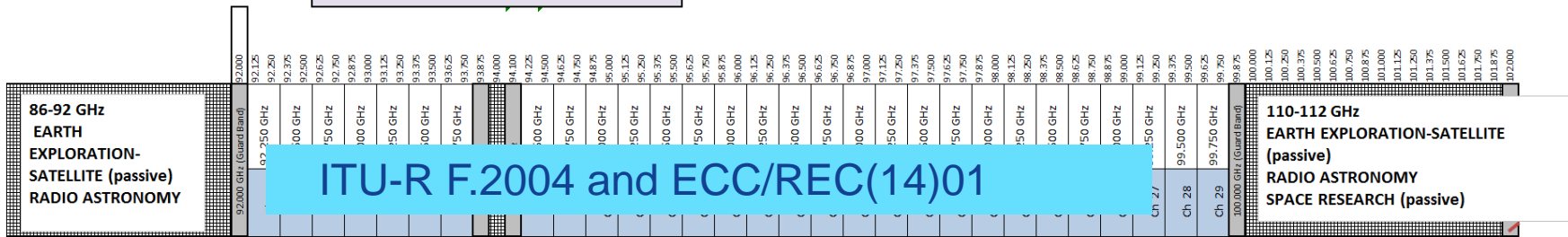
Bands 1 and 2 are already regulated by recommendations ITU-R F.2004 and ECC/REC(14)01 and their different use would imply changes in those recommendations.

Total: 17.85GHz

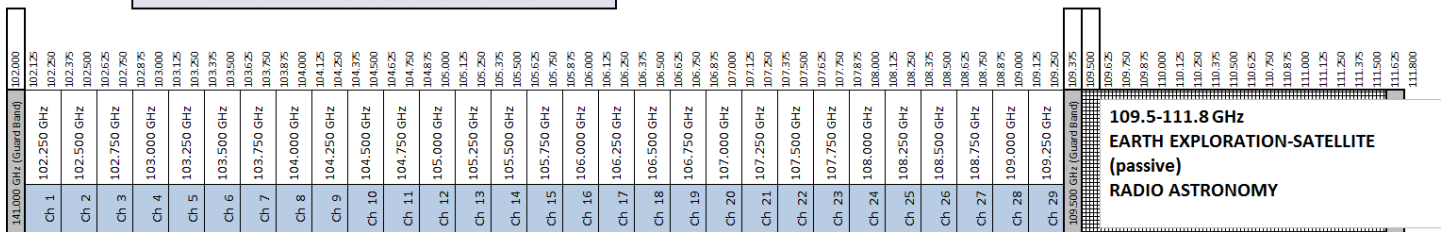
Next slide the current ETSI proposal.

W-Band - 92 - 114.250 GHz range: Fixed Service allocated sub-bands. Proposal 250 MHz

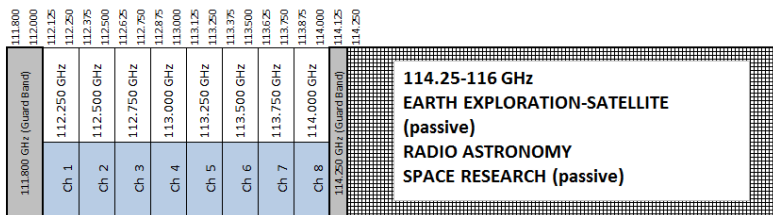
Sub-band "A": 29 x 250 MHz



Sub-band "B": 29 x 250 MHz



Sub-band "C": 8 x 250 MHz



Total= 66 x 250MHz



D- Band

THE RANGE 130-174.7 GHZ

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

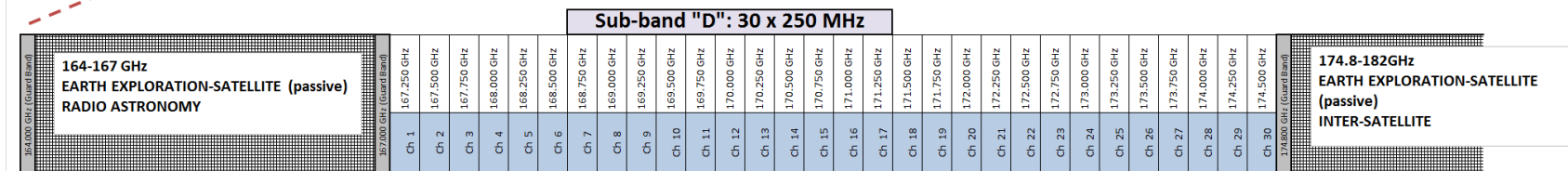
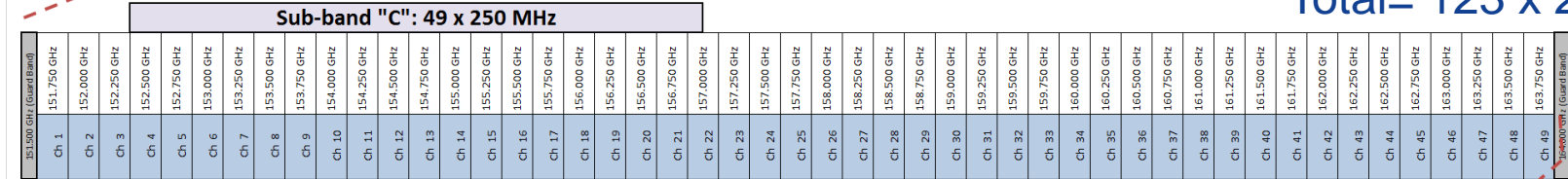
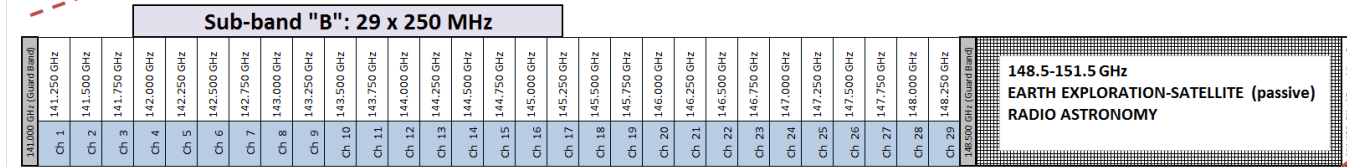
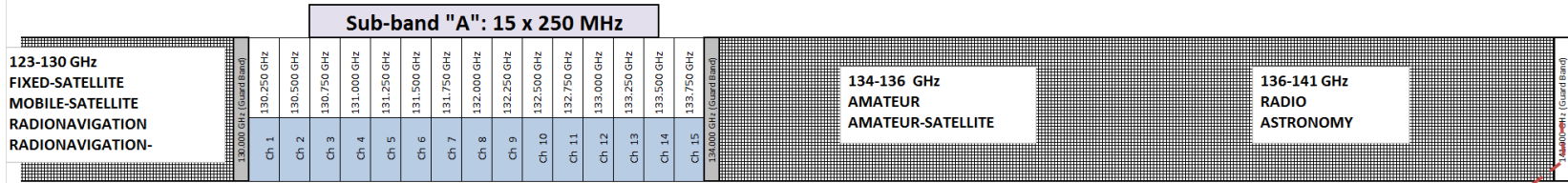
1. 130-134 GHz (total 4000 MHz)
2. 141-148.5 GHz (total 7500 MHz)
3. 151.5-155.5 GHz (total 4000 MHz)
4. 155.5-158.5 GHz (total 3000 MHz)
5. 158.5-164 GHz (total 5500 MHz)
6. 167 - 174.7 GHz (total 7700 MHz)

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



Total= 123 x 250MHz

Spectrum evolution for backhaul



Huge bandwidth available



92-114 GHz

130-175 GHz

Propagation conditions not dramatically worse than E-band (FSL 130 dB/km)



FSL 132 dB/km

FSL 136 dB/km

Rain impact not so dramatic.



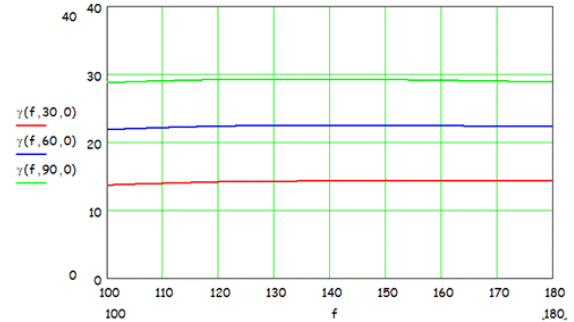
High integration level



Component miniaturization
Antenna mainly

Specific attenuation [dB/Km] due to rain vs Frequency

Consistent with evolution towards 5G and Ultra-Dense Networks



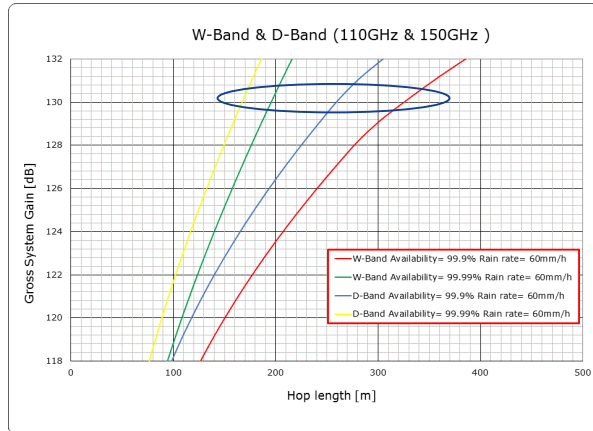
W-Band vs D-Band - What is enabling



Capacity

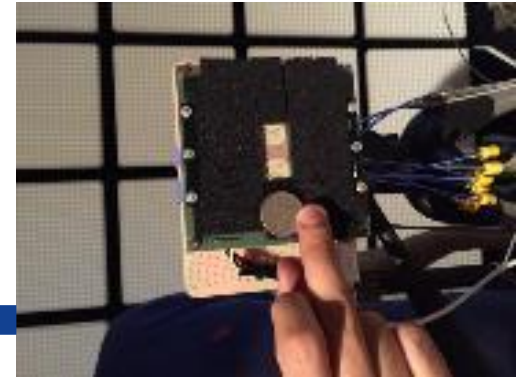
Innovative arrangements

Multiple small antennas



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

Very high throughput up to 40 Gbps

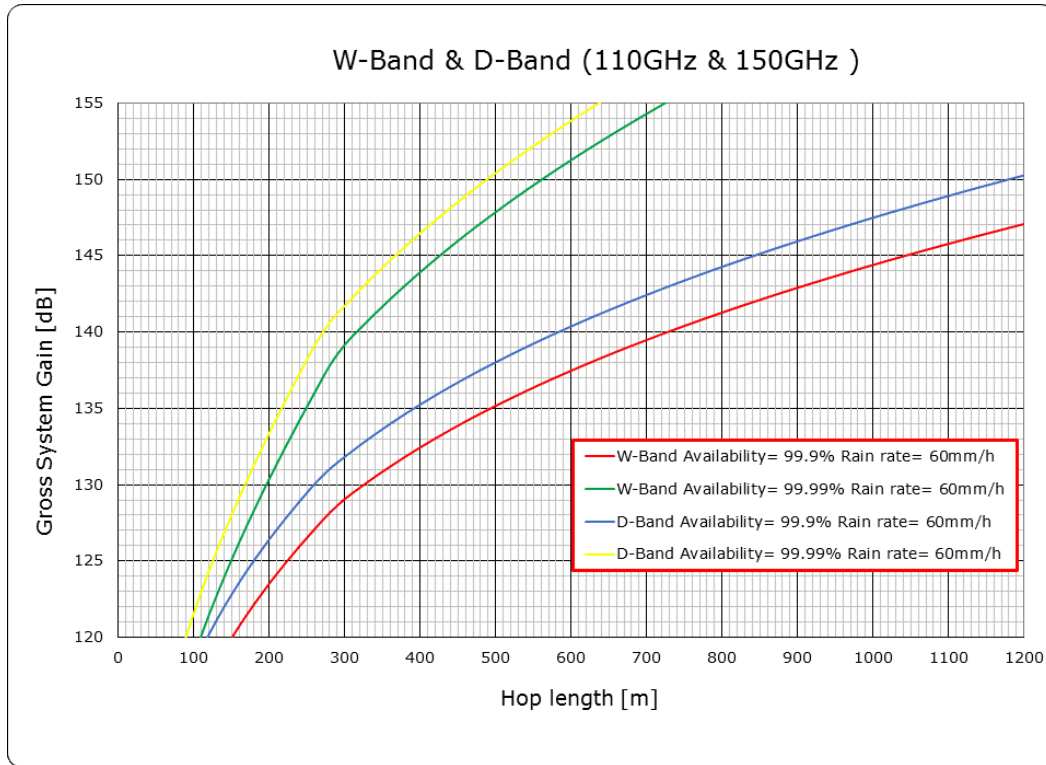


E.g. : W-Band beam-steering prototype (Bell-Labs)



W-Band vs D-Band

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



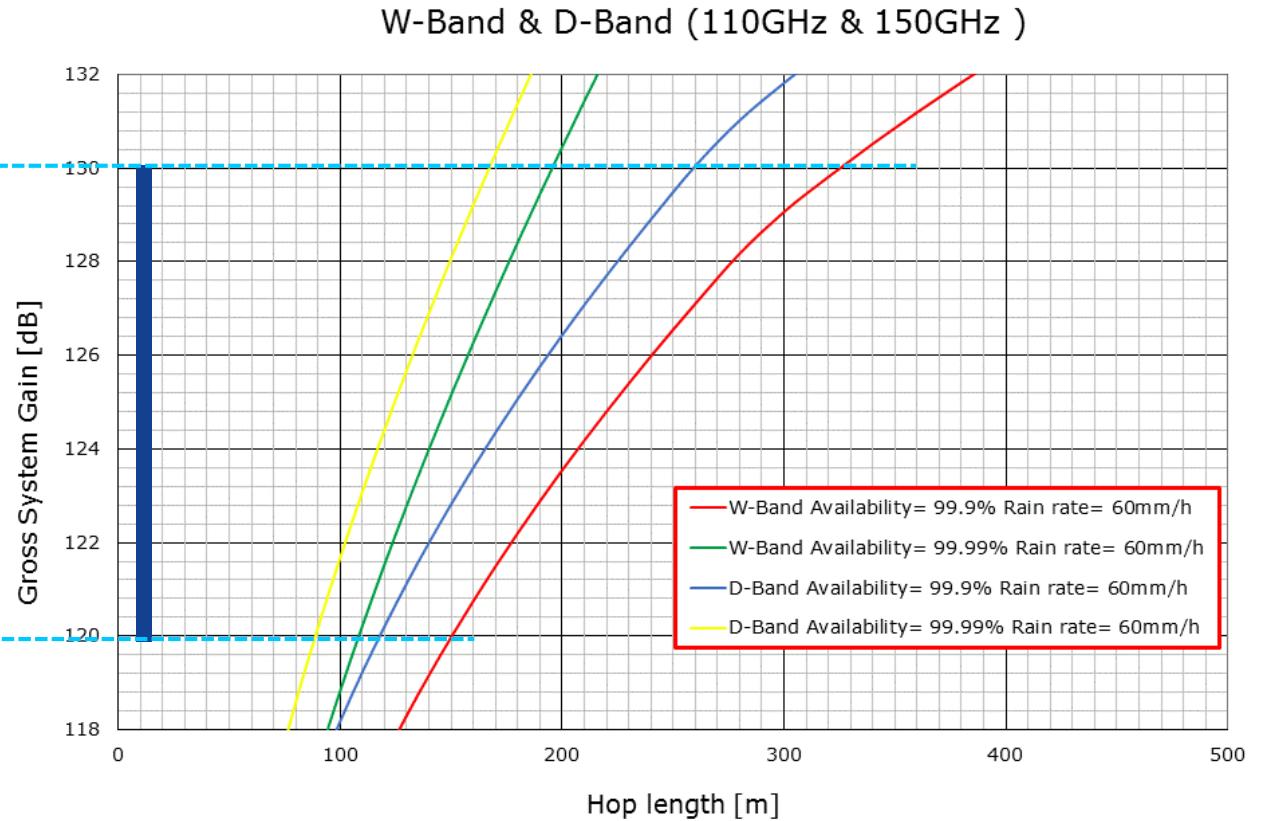
Calculation's conditions:

- 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

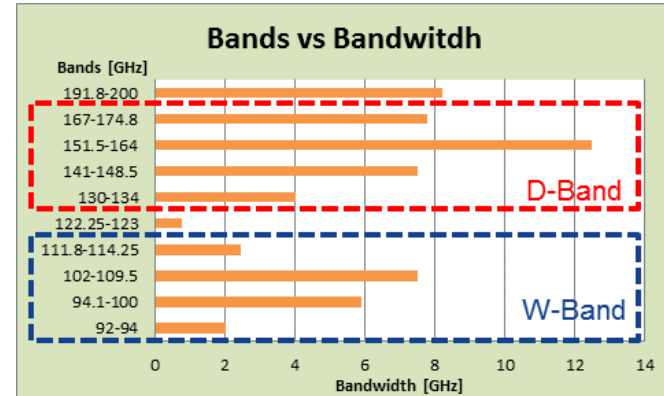
Antennas Gain – 35 dBi



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.



NOKIA