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Unintended electromagnetic radiation of large satellite constellations and its impact on radio astronomy

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UNITED NATIONS
Office for Outer Space Affairs



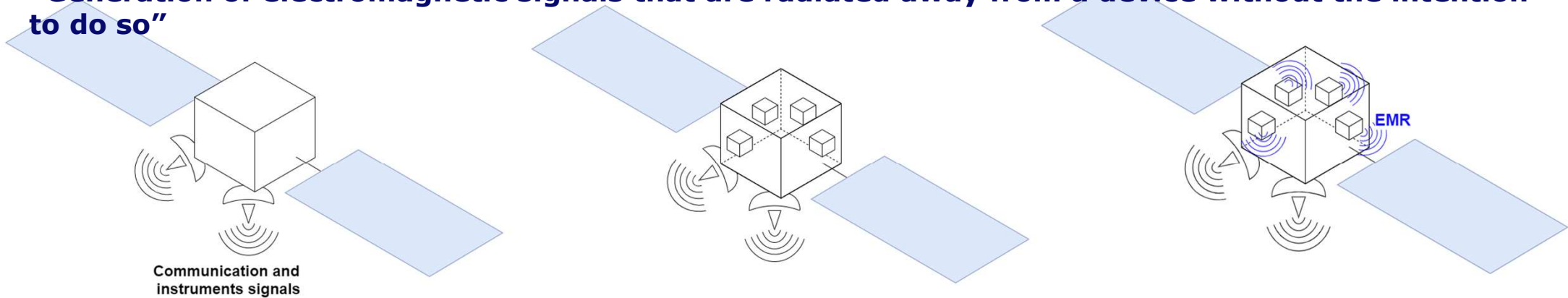
Agenda

- Unintended electromagnetic radiation (EMR)
- Satellite system EMR
- Study of EMR at 150 MHz
- Proposed way forward



Unintended electromagnetic radiation (EMR) I

“Generation of electromagnetic signals that are radiated away from a device without the intention to do so”



Intentional emissions

- Communication
- Instruments
- Associated to signal generation process

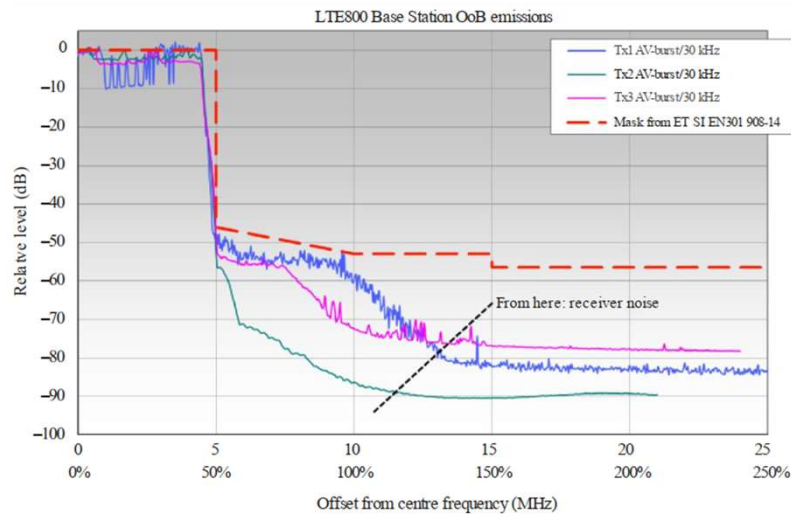
Unintentional radiation

- By-product of the operation of an electrical device
- Switching signals, clocks, high speed comms, etc

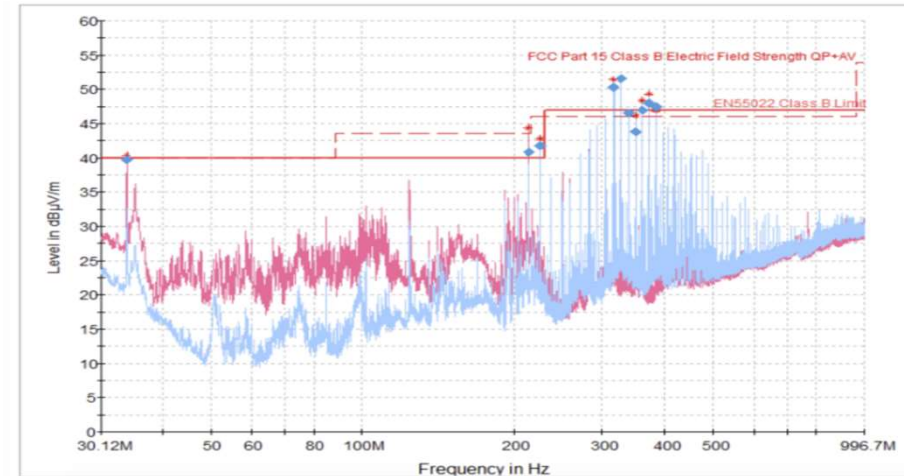


Unintended electromagnetic radiation (EMR) II

FIGURE 8
OoB emissions from LTE800 base stations



Report SM.2421-08



Generic example of a radiated emissions test

Intentional emissions

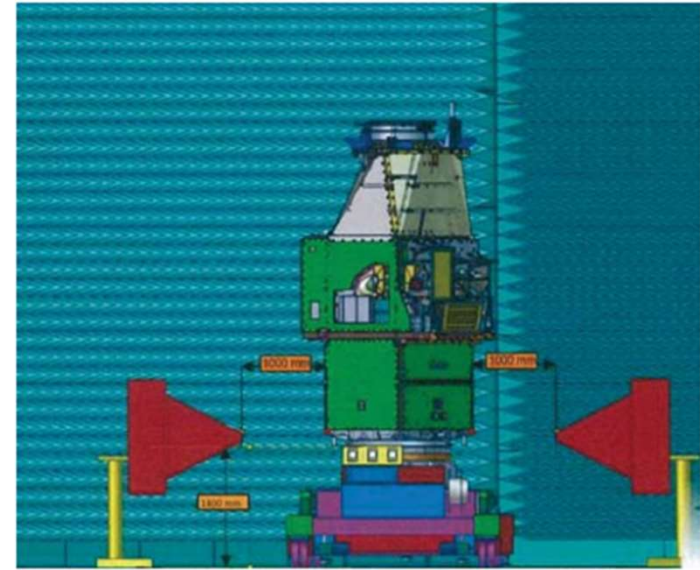
- Regulated by ITU-R and each country
- In band, Out of Band and spurious emissions

Unintentional radiation

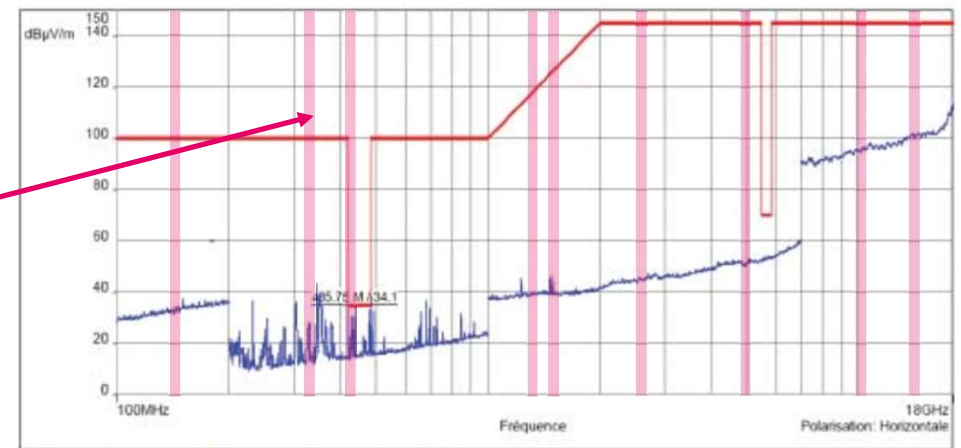
- IEC standards, adopted nationally
- Broadband, no defined carrier
- <1 GHz, but can be higher
- Repeatable in series production

Satellite system EMR

- EMR is rarely made public
- Standards at component level: MIL-STD, ECSS, NASA (tailored to a specific mission)
- Tests are limited to Self-compatibility, and Launcher compatibility
- Radiation levels in RAS bands?



Typical system level radiated emissions test



Typical Radiated Emissions masks and results for system level testing. Red: mask, Blue: measurement

Source: G. Yavaş and S. Akgül, "GÖKTÜRK-1 Satellite System Level Radiated Emission and Radiated Susceptibility Tests,"



What if a large satellite constellation has EMR in a radio astronomy band?

Study case: 150.05 – 153 MHz



Study of Equivalent Power Flux Density (epfd) of some satellite constellations

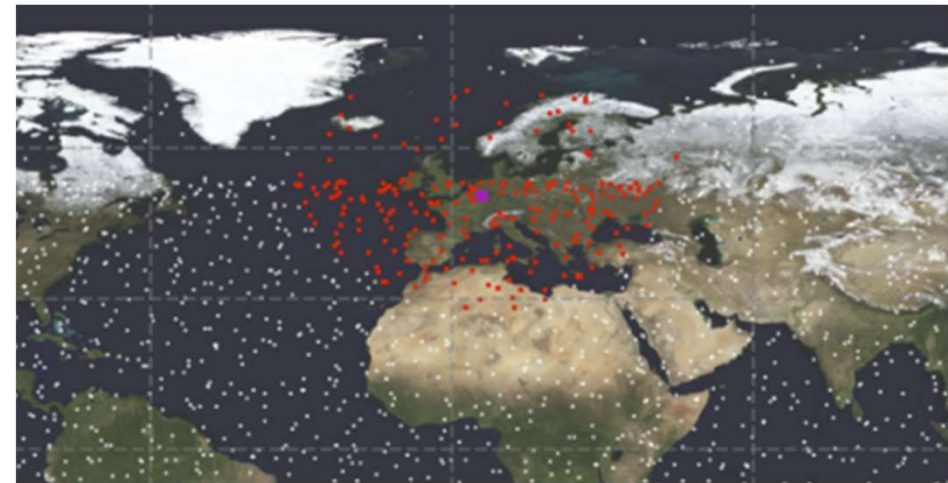
- Position of all satellites each second
- All possible pointings of a radio telescope
- Many iterations of 2000s (statistical method)
- Average received power mapped in local sky
- **Calculated maximum allowed EMR for RA769 level and 2 % data loss**

Constellation	Hiber	Swarm	Starlink ph1	OneWeb ph1
Altitudes [km]	600	500	550	1200
Number of satellites	72	150	4400	720
Frequency [MHz]	150	150	150	150
Emission level [dBuV/m] @ 10m , 120 kHz RBW	30	30	30	30

Constellation parameters used for the study

Telescope	Large dish	Medium dish
Lon,lat [deg]	(0, 50)	(0, 50)
Altitude [km]	0	0
Antenna diameter [m]	70	25
Frequency [MHz]	150	150
Protection level [dBW/m2]	-194	-194

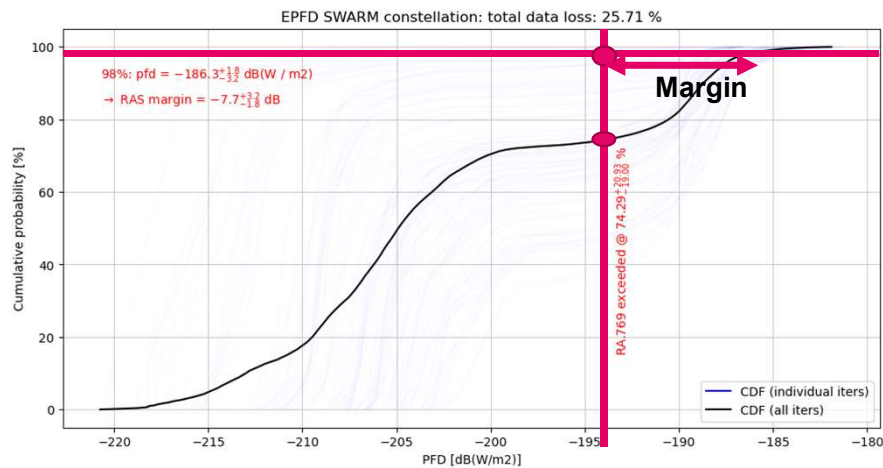
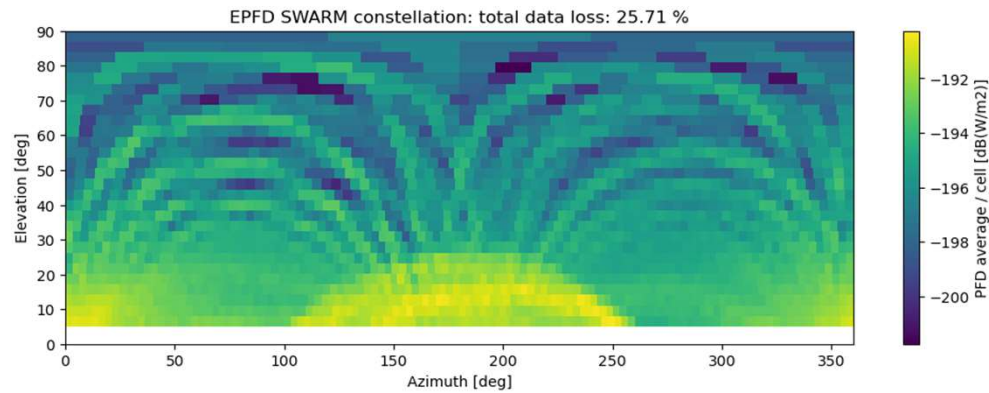
Single radio telescope parameters used for the study



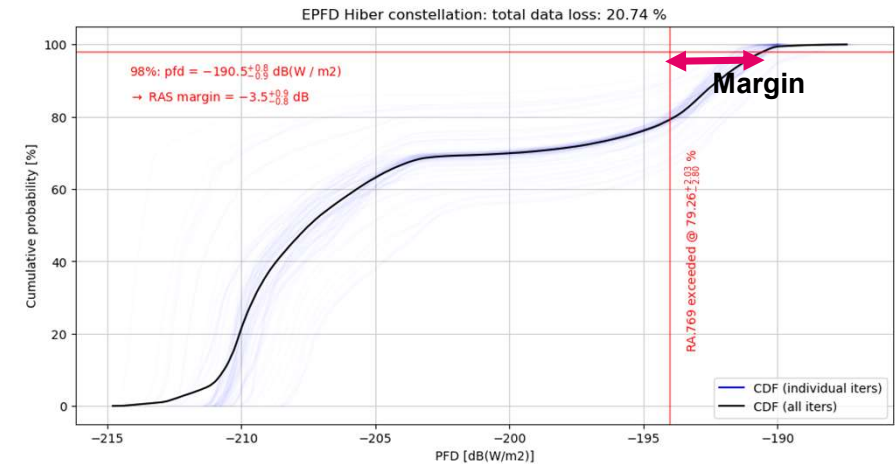
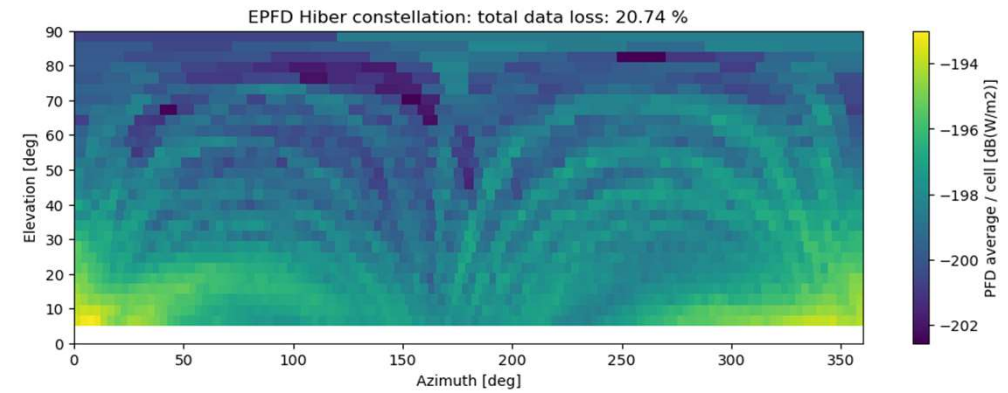
Snapshot of Starlink ph1 constellation (4400 satellites), in red all satellites above the horizon at the Effelsberg radio telescope.



Epfd results for 25m antenna (Swarm - Hiber)



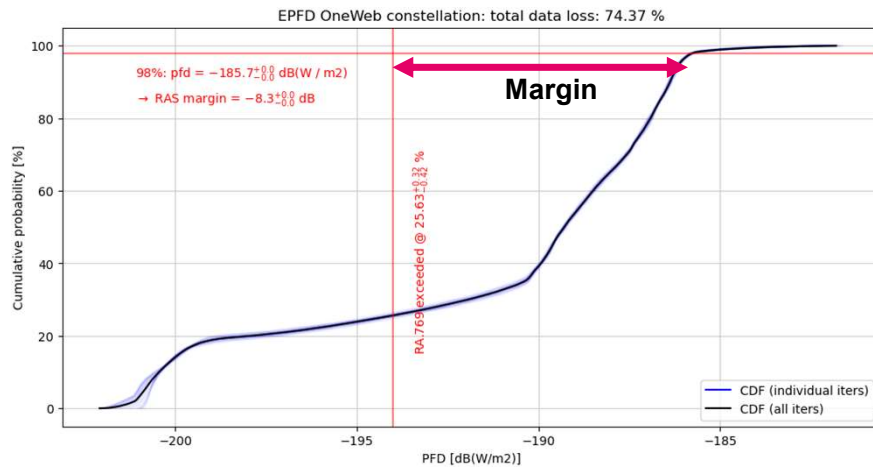
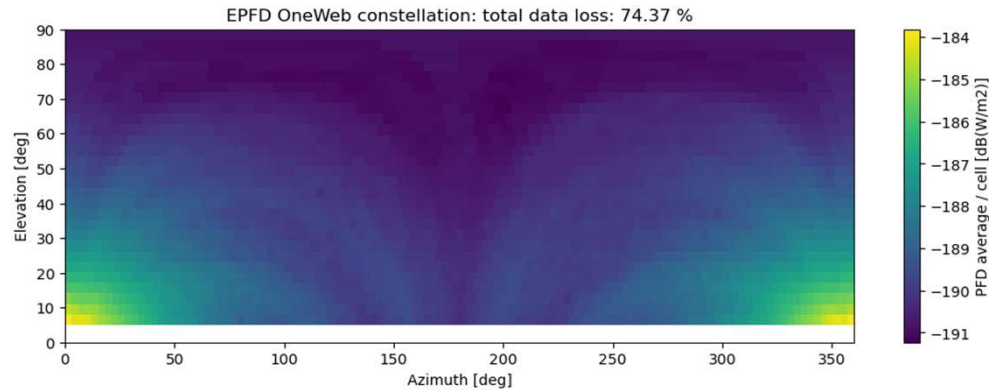
**Margin (with assumed EMR level)
 - 7.7 dB**



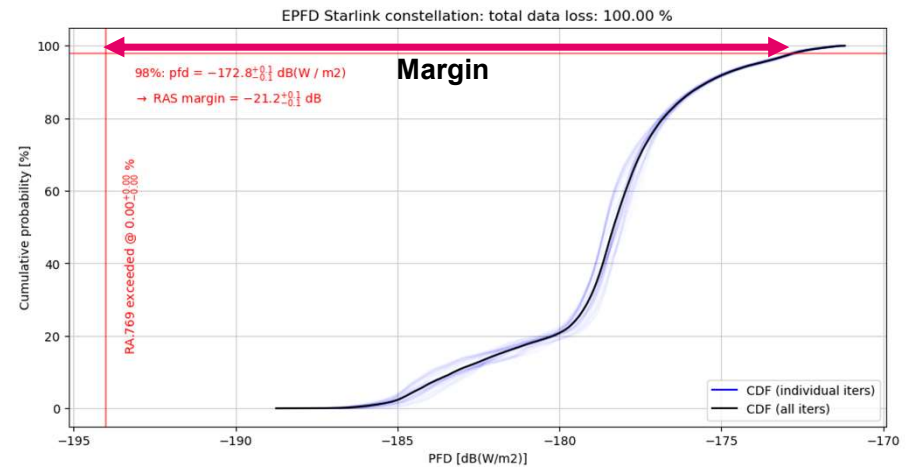
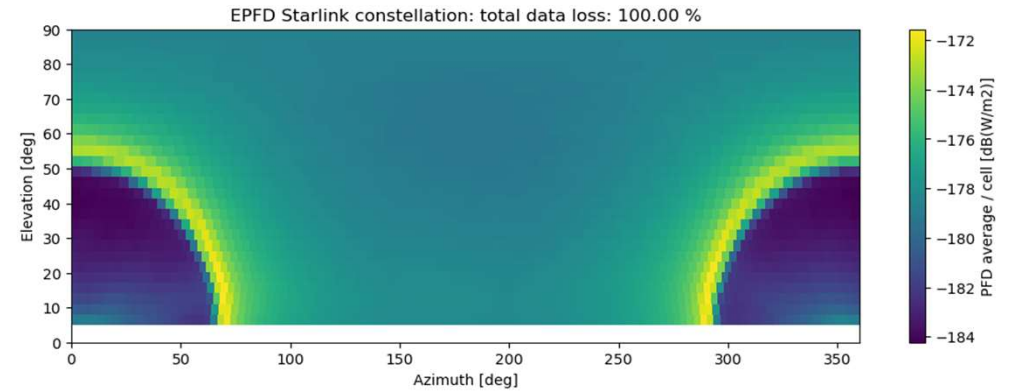
**Margin (with assumed EMR level)
 - 3.3 dB**



Epfd results for 25m antenna (OneWeb - Starlink)



Margin (with assumed EMR level)
- 8.3 dB

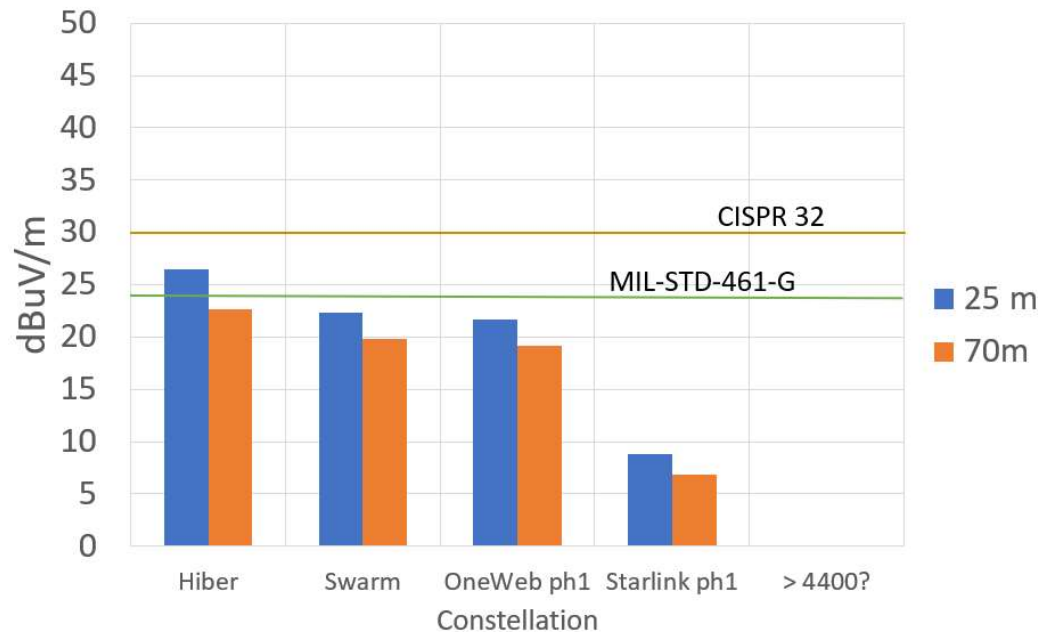


Margin (with assumed EMR level)
- 21.2 dB



Maximum EMR permitted

Maximum EMR @ 150 MHz

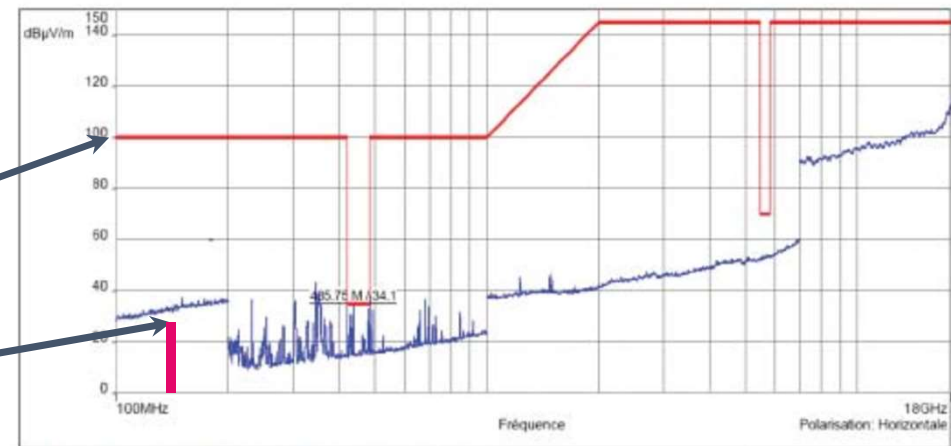


- EMR as a satellite level parameter
- Depends on:
 - Constellation parameters
 - Only small changes with RAS antenna diameter
 - Observer location

Note: EMR spectrum used as example, not related to any large constellation's EMR

100 dBuV/m

25 dBuV/m



Proposed way forward

1. Acknowledge the risk from satellite constellation EMR to radio astronomy (realization of it can deny access to a protected radio band and it escalates with satellite numbers)
2. How to establish a maximum EMR level for a satellite constellation in the RAS bands? Epfd, worst case, others?
3. Can the RAS bands be included as critical bands in satellite level EMR tests?
4. Could these limits be incorporated into regulations? And where? ITU-R? ITU-T?
5. Could this be enforced?



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Thank you very much for your
attention



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