Frequency Management challenges for existing and future EO missions

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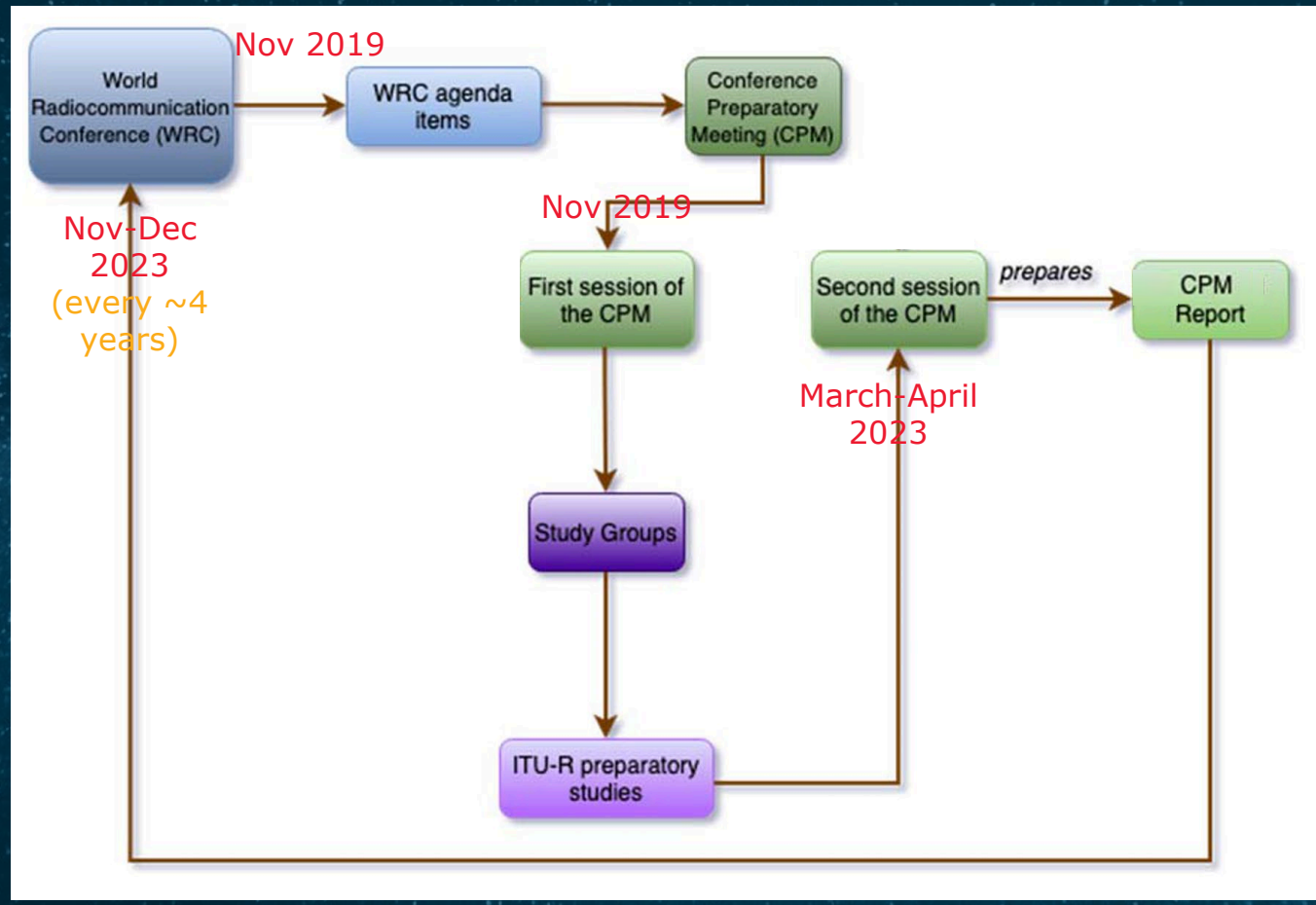
LPS 22

Topics

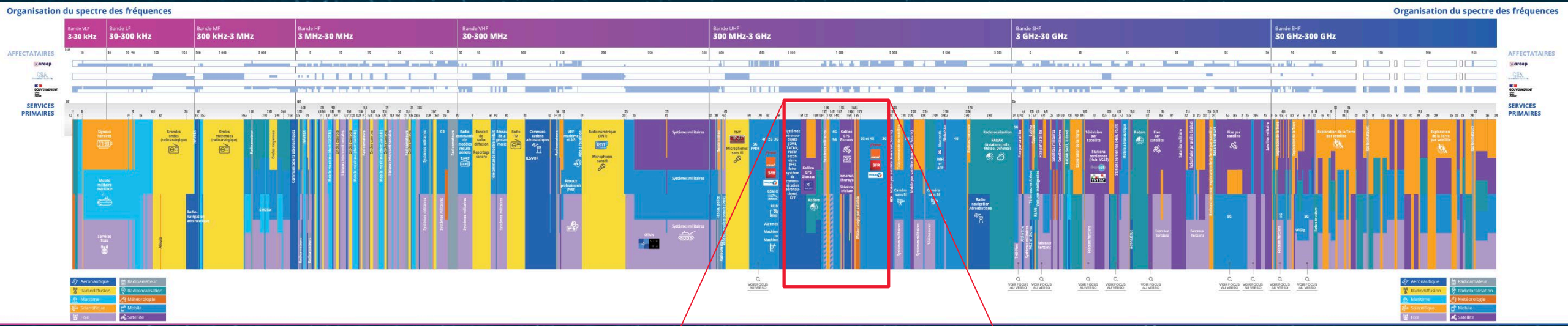
- Oveview of frequency allocation process & RFI issues
- Potential topics:
  1. Coexistence between active and passive
  2. Gap between scientists and frequency managers
  3. Role of AI
  4. Reporting of RFI
  5. RFI processing: on-board vs on-ground
  6. Lessons learnt and future missions
  7. Future frequency needs of science missions

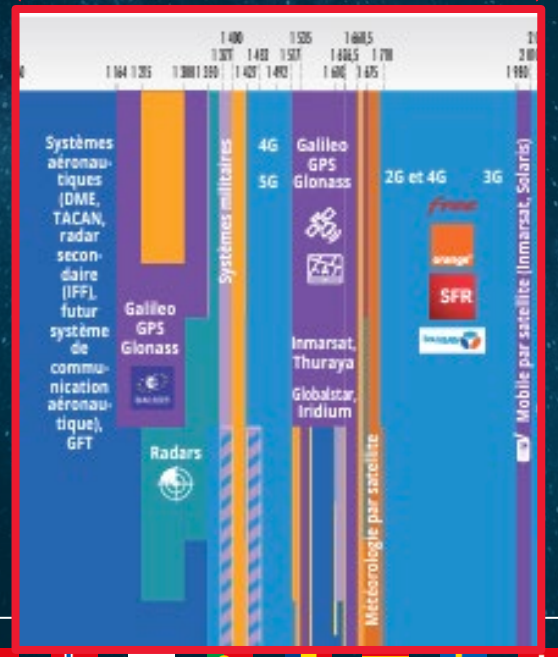
Frequency allocations process

Spectrum is allocated to “services” by the WRC (World Radiocommunications Conference).



Frequency allocation table





Frequency usage of ESA EO missions

Freq. band [GHz]	0.432 0.438	1.215 1.300	1.400 1.427*	5.25 5.57	6.425 7.250	10.6 10.7	13.25 13.75	18.6 18.8	23.6 24.0*	31.3 31.8*	33.65 34.35	35.5 36.0	36 37	50.2 50.4*
AWS														Radiom
Biomass	SAR													
CIMR			Radiom		Radiom	Radiom		Radiom					Radiom	
CRISTAL							Altim	Radiom	Radiom		Radiom	Altim		
CryoSat-2							Altim							
EarthCARE														
Harmony				SAR										
MetOp				Scatt					Radiom	Radiom				Radiom
MetOp-SG-A									Radiom	Radiom				Radiom
MetOp-SG-B				Scatt				Radiom	Radiom	Radiom				Radiom
ROSE-L		SAR												
Sentinel-1				SAR										
Sentinel-1 NG				SAR										
Sentinel-3				Altim			Altim		Radiom				Radiom	
Sentinel-6				Altim			Altim	Radiom	Radiom		Radiom			
SMOS			Radiom											
Main issues	Exclu-sion zones	RFI + avoid inter-fering	Terres-trial RFI	Space-borne & Terres-trial RFI	No alloca-tion	RFI + Space-borne OOBE		Space-borne & Terres-trial RFI	RFI + 5G (WRC-19)		Powerful military radars (e.g. KREMS)		Military radars & other RFI	
Missions	Biomass	ALOS2, SMAP	SMOS, SMAP	S1, RCM	AMSR-E, -2	AMSR-E, -2		GMI	Jason-1 and -2		CRISTAL, S6		S3	

Frequency usage of ESA EO missions

Freq. band [GHz]	52.6 59.3	86 92*	94.0 94.1	114.25 122.25	127.5 132.5	155.6 158.4	164 167*	165.5 170.5	174.8 191.8	226.0 231.5*	239.2 247.2	313 356	439 467	657 692
AWS	Radiom	Radiom					Radiom		Radiom			Radiom		
Biomass														
CIMR														
CRISTAL		Radiom			Radiom			Radiom						
CryoSat-2														
EarthCARE			CPR											
Harmony														
MetOp	Radiom	Radiom				Radiom			Radiom					
MetOp-SG-A	Radiom	Radiom					Radiom		Radiom	Radiom				
MetOp-SG-B	Radiom	Radiom		Radiom			Radiom		Radiom		Radiom	Radiom	Radiom	Radiom
ROSE-L														
Sentinel-1														
Sentinel-1 NG														
Sentinel-3														
Sentinel-6		Radiom			Radiom			Radiom						
SMOS														
Main issues		FOD + RSTT	FOD + RSTT + Protect RAS	6G + short range devices in Europe + no allocation (for some)							6G + WRC23 AI 1.14			
Missions		AWS, MetOp	Earth-CARE	AWS, CRISTAL, MetOp, S6							MetOp-SG			

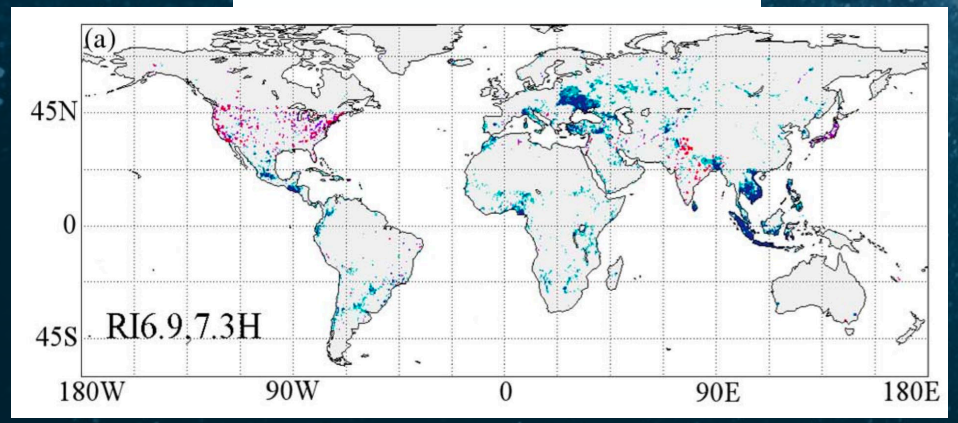
Coexistence between passive and active services

Increasing push from active services towards coexistence, including in purely passive bands!

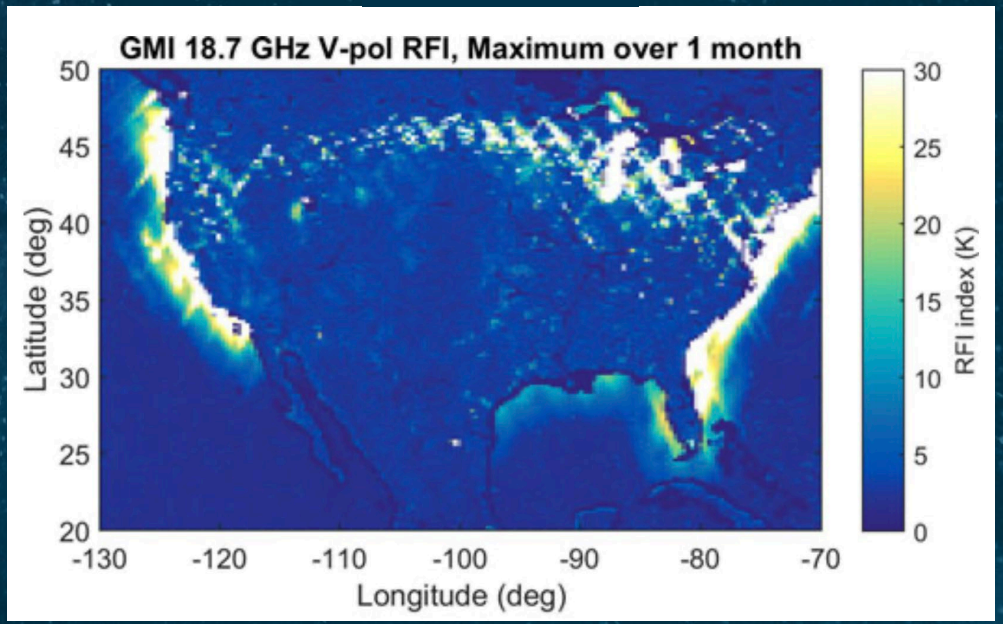
Some radiometers operate in bands also used by active services, e.g. AMSR-2 near 7 GHz; GMI in 18.7 GHz.

- Is coexistence between passive and active services feasible under certain conditions?
- What is the role of the science community in protecting the purely passive bands?

Red scale: RFI near 6.9 GHz
Blue scale: RFI near 7.3 GHz
[de Nijs et al., 2015]



[Draper, 2018]



Gap between scientists and frequency managers

Both scientists and (some) frequency managers have the same goal: no RFI in science measurements.

But the two communities are somewhat disconnected.

	Science	Freq mgmt
What is RFI?	Measurements are degraded → RFI	Is the received power above the acceptable threshold? Is this received power persistent enough? If yes to both → harmful RFI
Units of RFI	E.g. 500 K	E.g. -140 dBW/Hz
Is there RFI?	Look at scientific articles; look at actual measurements	If none is reported via SIRRS and there are no ITU docs on it, then no → successful coexistence

How can we narrow the gap and improve collaboration?

AI's role in dealing with RFI

Artificial Intelligence has already been used in some RFI detection/localization algorithms, however:

- Could AI be used more extensively in RFI algorithms?
- What can we get from AI that we can't get in other ways?
- What are the potential drawbacks on relying more on AI?
- Some AI applications need training datasets. How to build them?

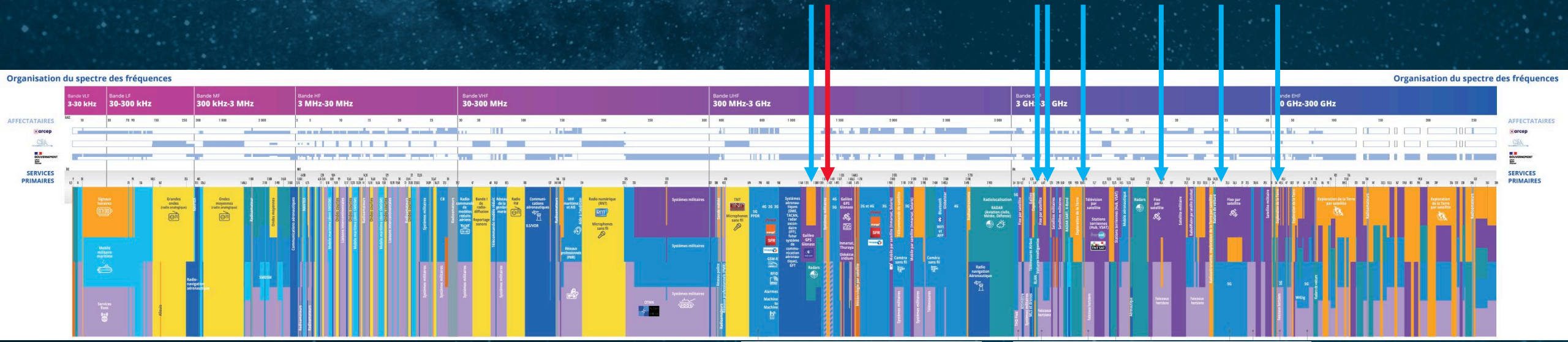
RFI Reporting

Reporting of RFI affecting EO sensors has occurred in only one band so far: 1400-1427 MHz (SMOS, SMAP).

ITU documents have some examples of RFI in other bands, e.g. 1.26 GHz and 18.7 GHz.

But RFI is affecting many more frequency bands!

How do we increase the reporting of RFI sources?



RFI Reported

RFI not reported

RFI processing: where to include it?

Routine RFI processing has clearly become a need for science missions.

It can be done in multiple ways:

1. On-board RFI processing
2. On-ground RFI processing
    a. By individual missions
    b. By a dedicated center, used by multiple missions

Some future missions, e.g. CIMR, will have on-board processing, but on-ground processing will also be possible, to some extent.

What are the pros and cons of each approach?

Lessons learnt & future missions

SMOS, SMAP and other missions have dedicated significant resources to RFI.

Based on the lessons learnt from those missions, what are some hardware or software solutions that you would recommend to future missions?

And what are the lessons learnt regarding RFI in missions already launched?

Any technology that has not been fully investigated yet, and that may help with RFI?

Future frequency needs of EO sensors

Some future sensors plan to operate in bands not used before, e.g.:

- 45 MHz radar sounders
- 243 GHz ice cloud imagers
- Wide-band radiometers in the 0.4 – 2 GHz range

Other sensors operate traditionally outside EO allocations:

- 6.9 GHz radiometers

Ideally, what should be done to align the frequency allocation table with future science needs?

0.04
0.05

0.4-2

Freq. band [GHz]	0.432 0.438	1.215 1.300	1.400 1.427*	5.25 5.57
Biomass	SAR			
CIMR			Radiom	
Harmony				SAR
MetOp				Scatt
MetOp-SG-A				
MetOp-SG-B				Scatt
ROSE-L		SAR		
Sentinel-1				SAR
Sentinel-1 NG				SAR
Sentinel-3				Altim
Sentinel-6				Altim
Main issues	Excl. zones	RFI + avoid inter-fering	Terres-trial RFI	S/C & Terres-trial RFI
Missions	Biomass	ALOS2, SMAP	SMOS, SMAP	S1, RCM