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23–27 May
2022

**TAKING THE PULSE
OF OUR PLANET FROM SPACE**



Radio Frequency Interference Issues in Earth Observation and the Activities of the IEEE GRSS Frequency Allocations in Remote Sensing (FARS) Technical Committee to Address Them

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IEEE Geoscience and Remote sensing Society

26 May 2022

The Frequency Allocations in Remote Sensing Technical Committee (FARS TC)

- was established in the year 2000 by the IEEE Geoscience and Remote Sensing Society (GRSS);
- its mission is to interface between GRSS membership and frequency regulatory process by
 - educating the remote sensing community on spectrum management issues and processes
 - providing spectrum managers and regulators with technical input and perspective from remote sensing scientists and engineers
 - promoting the development of radio frequency interference detection and mitigation technology
 - fostering the exchange of information between researchers in different fields with the common goal of minimizing harmful interference between systems



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Roger Oliva

European Space Agency - ESAC
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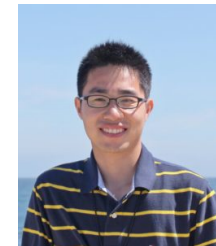
German Aerospace Center (DLR)
Oberpfaffenhofen, Germany



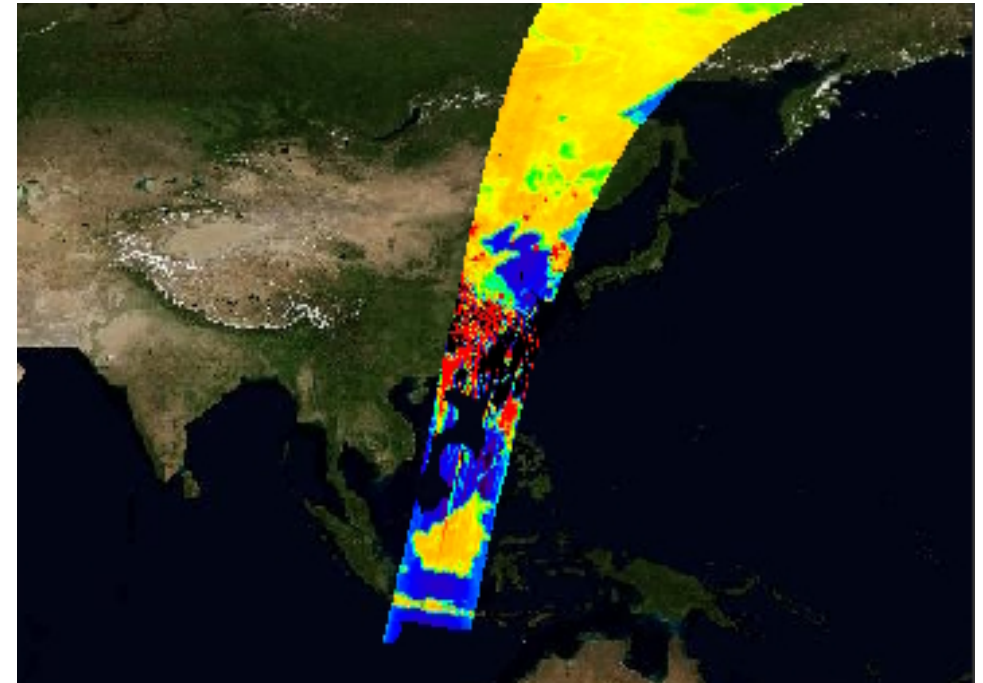
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- Simultaneous use of the same or contiguous portions of the radio spectrum by different radio services can lead to Radio Frequency Interference (RFI) between systems
- RFI can affect remote sensing operations in different ways:
 - if strong, can lead to complete loss of measurements;
 - if medium, can produce degradation of the data;
 - if weak, can remain undetected and produce an error that propagates all the way to the final geophysical products.



- To avoid interference between systems, the radio spectrum is divided into separate bands, each assigned or “allocated” for use by one or more radio services.
- RFI can be caused by:
 - out of band emissions
 - illegal in-band signals
- interference can be of different types :
 - Narrow-band RFI, for example from commercial land-mobile radio and amateur radio
 - Pulsed RFI, for example from radiolocation radar systems
 - Broadband RFI, for example from broadband communications systems
- Passive sensors often operate in protected bands where all transmissions are prohibited*
- Active sensors usually share a band with other services

BANDS [GHz]	RFI SOURCES
1.40 - 1.427	out of band emissions mostly from air surveillance radars
6.425 - 7.25	fixed and mobile satellite services
10.6 - 10.7	air surveillance radars, fixed and mobile satellite services
18.6 - 18.8	satellite TV service signals
22.21 - 22.5	vehicle anti-collision radars
31.3 - 31.8	no significant interference observed
36 - 37	
51.4 - 59.3	potential for RFI due to spectrum-sharing rules at 55-57 GHz
86 - 92	no significant interference observed

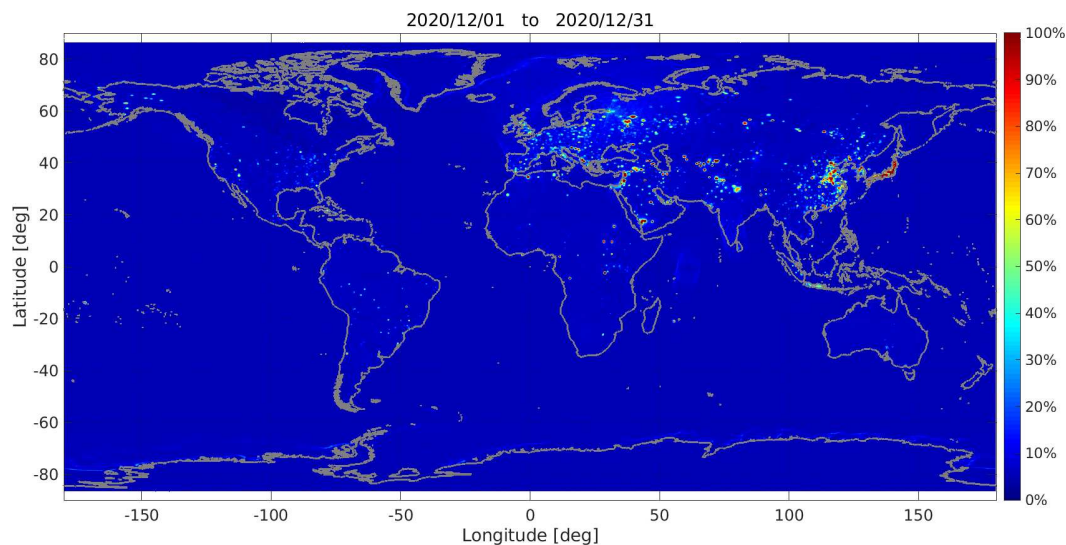
BANDS [GHz]	RFI SOURCES
1.215 - 1.30	air surveillance radars, Radio Navigation Satellite System (RNSS), amateur radio
5.25 - 5.57	air surveillance radars, RNSS, RLAN
9.03 - 9.90	air surveillance radars
13.25 - 13.75	air surveillance radars, RNSS
35.5 - 36.0	air surveillance radars, fixed and mobile satellite services
90 - 94	air surveillance radars

1400 - 1427 MHz

SMAP radiometer

radiolocation radar systems

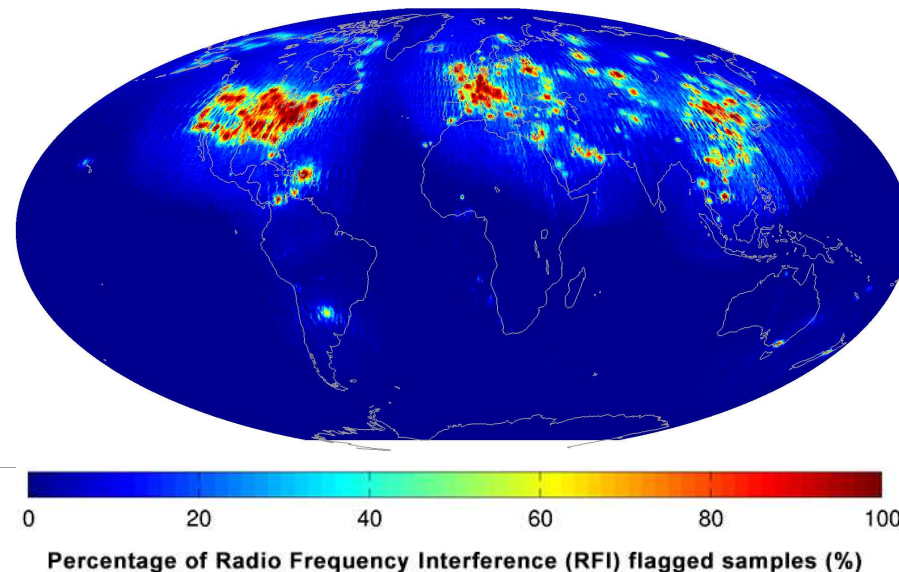
ground IF equipment for satellite TV



1215 - 1300 MHz

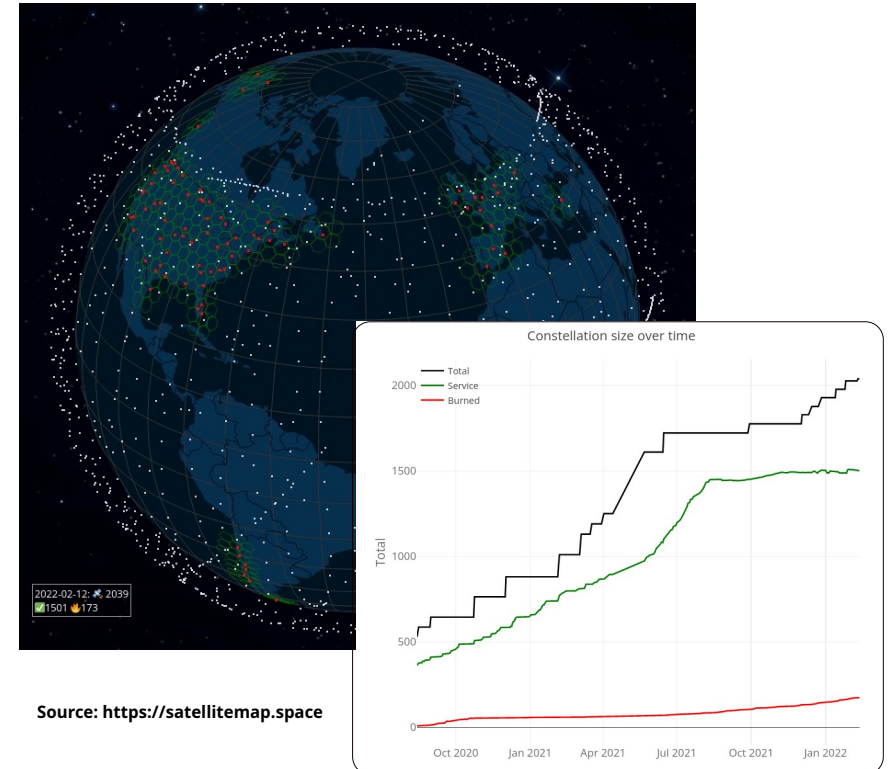
Aquarius scatterometer

radiolocation radar systems



- Constellations of telecommunications satellites are being planned as an answer to the need to expand broadband Internet access to remote areas or to airplanes, ships, etc.
 - use of non geo-stationary orbits (non GSO) at low altitude (300 to 2,000 km) eliminates the problem of latency due to the long distance (35,000 km) between satellite and Earth station in geo-stationary orbits (GSO)
 - however, a very large number of satellites is needed to achieve global coverage
- Higher frequencies and technology advances allows to greatly reduce the size of the satellites that can be launched into orbit in batches of tens at a time
- Satellites are grouped on separate inclined/polar orbital planes

Starlink on 12 February 2022



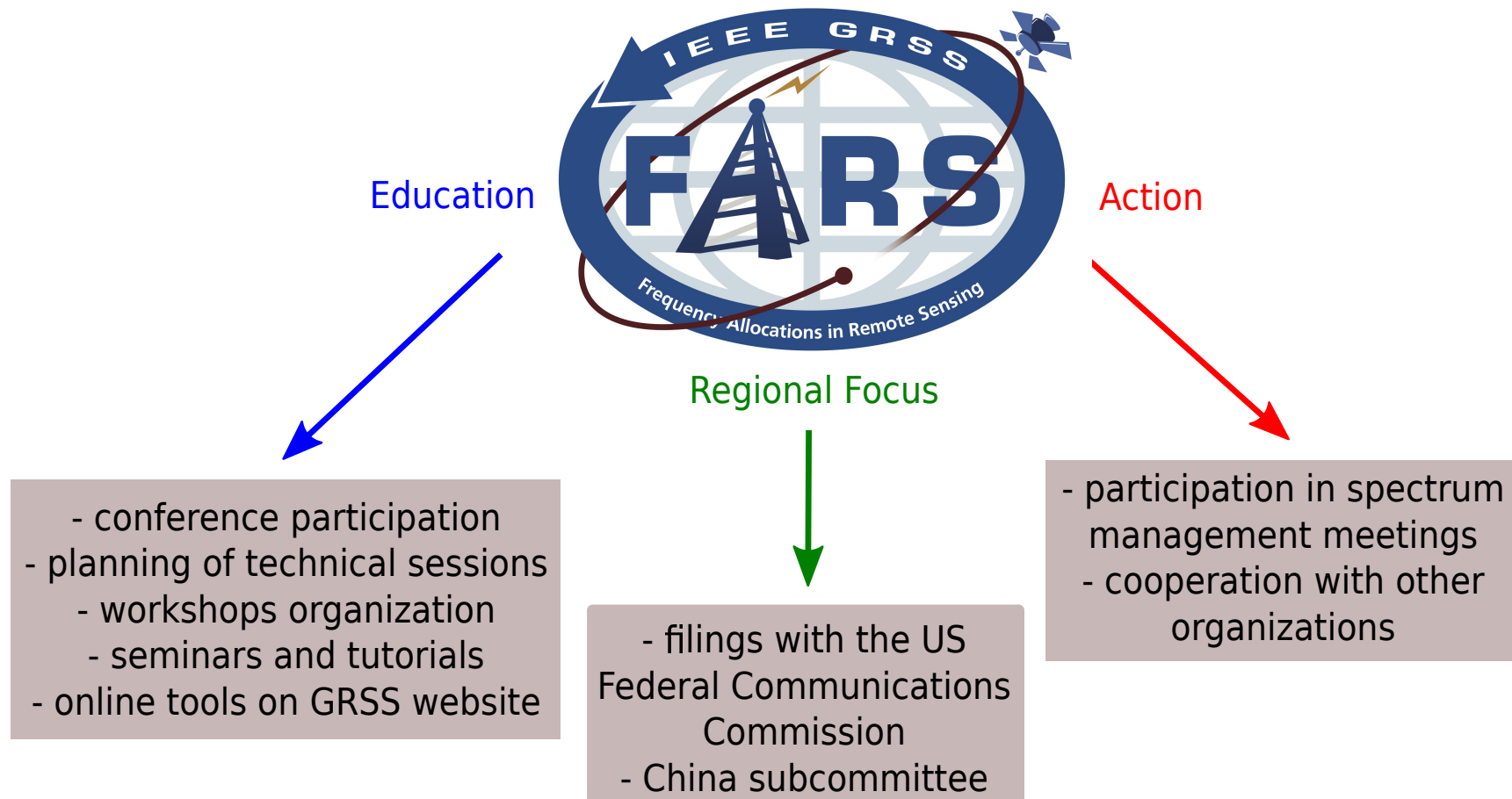
Source: <https://satellitemap.space>

Constellation Name	Owner	Altitude [km]	Frequency Bands	Number of Satellites	
				Current	Planned
Starlink	Space-X	340, 550 and 1,150	Ku, Ka and V	~ 2,000	30,000
OneWeb	UK+Bharti	~1,200	Ku, Ka and V	~400	648
Kuiper	Amazon	590 to 630	Ka	-	3,236
Lightspeed	Telesat	1,015 and 1,325	Ku and V	15	298

Sources:

- National Science Foundation Report no. JSR-20-2H:
The Impacts of Large Constellations of Satellites, January 21, 2021.
- <https://www.space.com>, <https://oneweb.net/>, <https://www.aboutamazon.com> and <https://www.telesat.com/resources/lightspeed-specifications-sheet/>

Band	Frequency [GHz]		Relevant EESS Band [GHz]	Notes
	Downlink	Uplink		
Ku	10.7-12.2	14.0-14.8	10.6-10.7	
Ka	17.7–19.7		18.6-18.8	GSO only
		27.5–30	31.3-31.8	
V	37.5-39.5		36-37	
		42.5-43.5	50.2-50.4	
		49.2-50.2		
		50.4-51.4		

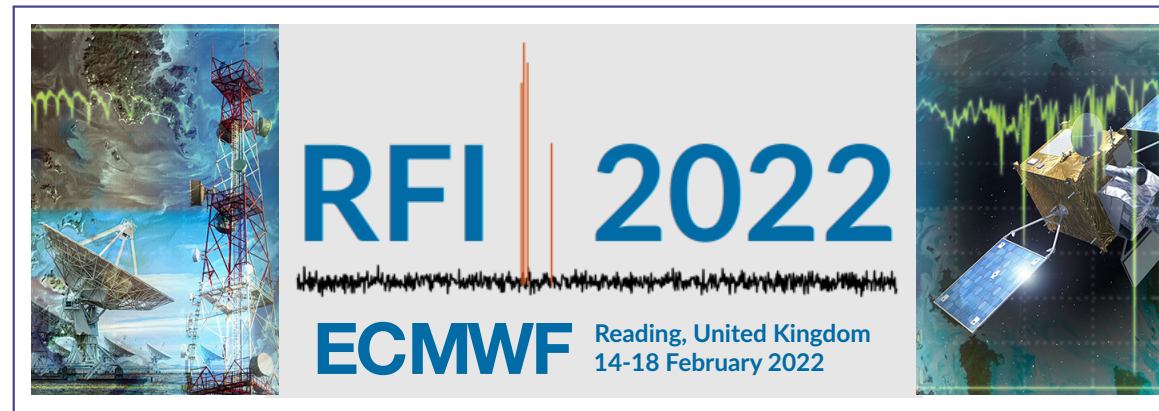


- The International Geoscience and Remote Sensing Symposium (IGARSS) is the main annual GRSS conference.
- At every IGARSS, FARS TC organizes one or more invited sessions on interference detection and mitigation techniques for passive/active remote sensing, status of missions dealing with RFI, and spectrum management issues.
- IGARSS 2022 will take place on July 17-22, 2022 in Kuala Lumpur, Malaysia



<https://www.igarss2022.org>

- Cooperation between radio astronomy and remote sensing communities, but also other fields, such as GNSS, meteorology and space link communications.
- Hosted virtually by the European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading, UK on February 14-18, 2022.



<https://www.rfi2022.org>

- Participation and contributions to international spectrum management meetings such as
 - Study Groups of the International Telecommunication Union - Radiocommunication Sector (ITU-R)
 - Space Frequency Coordination Group (SFCG)
- Cooperations with space agencies and other committees (e.g., the Committee on Radio Frequencies - CORF - of the US National Academies)
- Filing of comments to the US Federal Communications Commission (FCC) on relevant matters such as the application of WRC-19 OOB limits into 23.6-24 GHz

● Working Party 7C (Remote Sensing Systems)

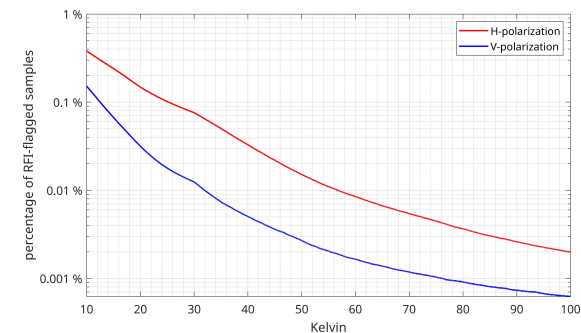
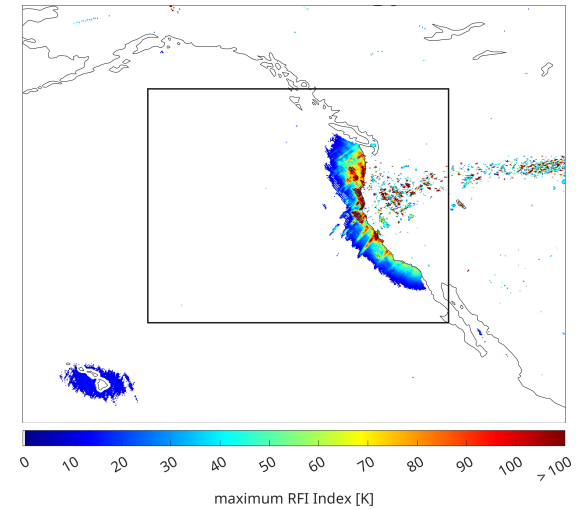
- continuing involvement in the ITU-R draft Report on Analysis of interference received by EESS (passive) sensors in the 18.6-18.8 GHz band
- also following WRC-23 AI 1.12 on new secondary allocation to EESS (active) around 45 MHz and other topics

● Working Party 3J (Radiowave Propagation Fundamentals)

- defining input format and other issues (wind velocity model) related to the scattering model for ocean surface
- draft new ITU-R Recommendation on Earth surface bistatic scattering coefficient prediction has been split into two parts, sea surface and land
- aiming to send sea surface scattering recommendation to Study Group 3 for approval at the upcoming 2022 WP 3J meeting

● Both documents very important for WRC-23 AI 1.16 and AI 1.17 sharing studies

- Recommendation ITU-R RS.2017 requires a data availability of 99.9% for the 18.6-18.8 GHz band over a measurement area of 10,000,000 km².
- Analysis of the fraction of measurements affected by interference was performed on an area centered on the Pacific Ocean at 40.5° N 122.5° E.
- Results shows RFI at 10 K present in more than 0.1% of measurements acquired over the study area.



- Review of international regulatory issues affecting remote sensing, with the goal of
 - detailing World Radiocommunication Conference agenda items that could have a potential impact on remote sensing operations (excluding aspects related to satellite-ground communications)
 - including other ITU-R topics that could also affect remote sensing operations
 - informing IEEE GRSS members of these concerns so that they may engage their administrations to consider the IEEE GRSS views in their decision-making process
- It will be an official IEEE GRSS document
- Draft under development
- Expected to be in final form by end of 2022

- Initiative between FARS-TC and IEEE Standards Association (SA) to develop a standard on the quality assessment of EESS bands with respect to presence of RFI:
- Goal is to define:
 - how to quantitatively assess RFI in EESS frequency bands
 - best practices to consistently document RFI affecting remote sensing missions



- It acts as a liaison between the main FARS TC leadership and the Chinese technical/scientific community;
- inaugurated in August 2019 with a one-day seminar in Xi'an with lectures on various RFI and spectrum management issues and particular attention to the local national situation;
- activities currently focus on:
 - using local expertise on SAR systems to detect and localize RFI in ALOS-2 data;
 - analysis of RFI at 10.65 and 18.7 GHz in HY-2B and FY-3D measurements.



● Motivation:

- to raise awareness about the increasingly difficult regulations for remote sensing band operations resulting from higher allowable interference levels, along with documenting the actual interference observed in those bands
- to pinpoint regulation enforcement for different regions and countries and allow a free exchange of information between remote sensing scientists and engineers regarding potential interference hazards
- to be used by a community broader than IEEE GRSS
- to aid local authorities in mitigation of non-primary interfering sources globally

● The online interface still under development includes two distinct tools:

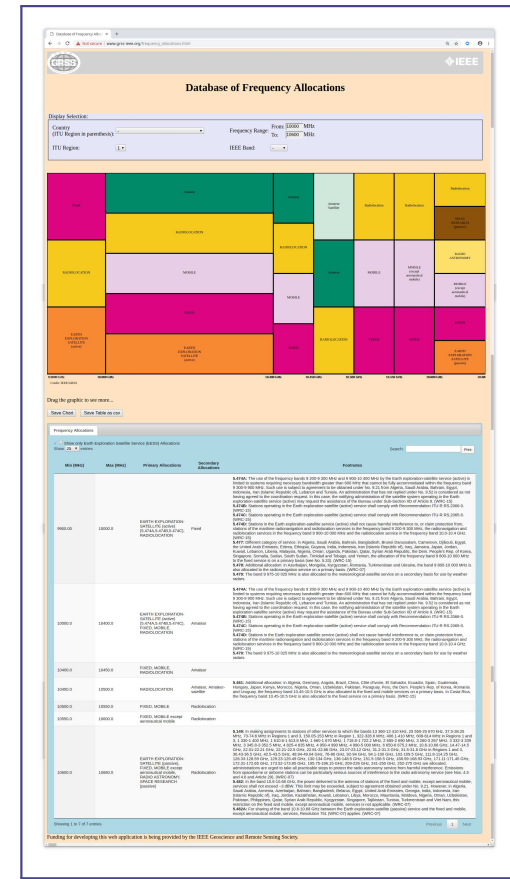
- a searchable database of interference observed by some remote sensing instruments
- a display system for frequency allocations, with particular focus on remote sensing bands

- RFI data can be selected by observing sensor, country or ITU region, frequency and time range
- RFI locations are shown on a map and listed in a table
- currently contains data for:
 - Soil Moisture Ocean Salinity (SMOS) radiometer
 - Soil Moisture Active Passive (SMAP) radiometer
 - 10 and 18 GHz channels of the GPM Microwave Imager (GMI)
- under development:
 - Aquarius (historical)
 - AMSR-2

http://www.classic.grss-ieee.org/rfi_observations.html

Country Code	Country	Start Frequency (MHz)	End Frequency (MHz)	Latitude (deg)	Longitude (deg)	Start Date	End Date	Observing Instrument
AE	United Arab Emirates	1400	1427	24.44	54.53	2021-10-01	2022-03-31	SMOS
AE	United Arab Emirates	1412.3	1414.7	24.44	54.52	2021-12-19	2022-04-10	SMAP
AF	Alghanistan	18500	18700	34.56	69.22	2022-02-28	2022-03-30	GMI
AL	Albania	1400	1427	41.32	19.79	2010-01-01	2022-03-31	SMOS
AL	Albania	1400	1427	40.61	20.78	2019-06-01	2022-03-31	SMOS

- displays and lists frequency allocations from the Radio Regulations
- selection is possible by:
 - ITU region
 - frequency range
- footnotes are also included
- option to see only EESS band with adjacent allocations
- available on the GRSS website at http://www.classic.grss-ieee.org/frequency_allocations.html



- Thank you for your attention!
- For more information on the FARS Technical Committee visit <https://tinyurl.com/fars-tc>
- No GRSS membership required to join
- For any questions, please write to fars_chairs@grss-ieee.org.

