Development of a Standard to quantify RFI contamination in the remote sensing frequency bands

R. Oliva,
P. de Matthaeis,
R. Natsuaki,
R. Diez-Garcia
B. Backus

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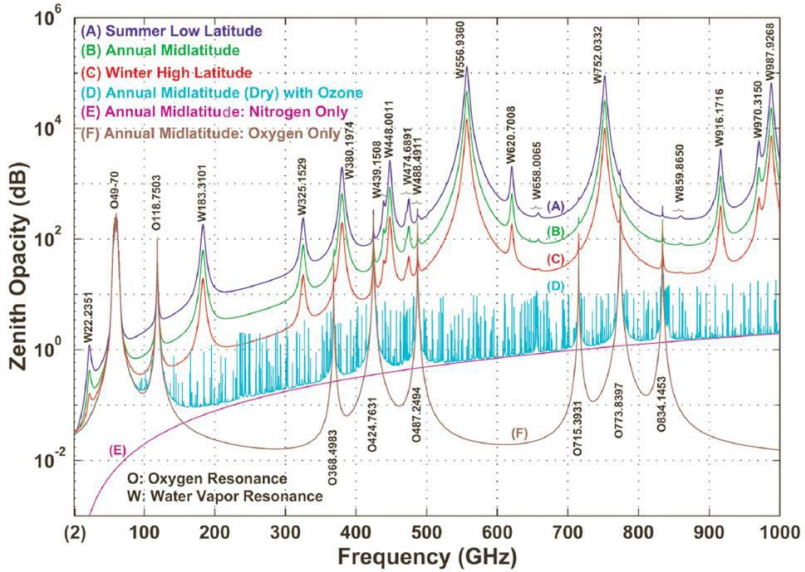
Introduction

Introduction

Space borne microwave remote sensing instruments are critical for Weather and Climate monitoring. They can be active (radar) or passive (radiometers).

- Active instruments receive the signal they emit after scattering back on Earth.
- Passive instruments capture the radiation emitted naturally by the Earth.

These instruments measure at specific frequencies determined by the **geophysical characteristics** of the Earth surface and atmosphere and the international **Radio Regulations**.



National Academies of Sciences, Engineering, and Medicine. 2015. *Handbook of Frequency Allocations and Spectrum Protection for Scientific Uses: Second Edition*. Washington, DC: The National Academies Press. https://doi.org/10.17226/21774

Radio Regulations

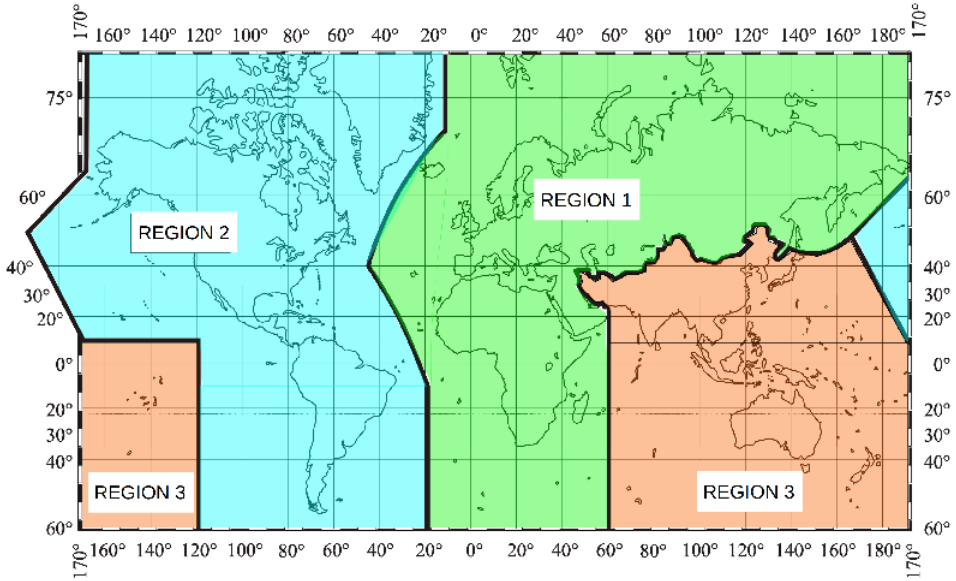
Frequency allocation is the international designation of spectrum portions to specific services, in order to avoid unregulated usage and to minimize mutual interference.

This process is controlled by various governmental and international organizations, particularly the **International Telecommunication Union** at the highest level.

Radio Regulations

The **Radio Regulations (RR)** are a basic ITU document that establishes the rules governing radiocommunication services and utilization of the radio frequency spectrum at international level

There are 3 ITU regions:



Passive Remote Sensing Allocations

Primary frequency allocations to EESS (passive) not shared with any other services except RAS (radio astronomy)

1400 - 1427 MHz	50.2 - 50.4 GHz	164 - 167 GHz
2690 - 2700 MHz	52.6 - 54.25 GHz	182 - 185 GHz
10.68 - 10.7 GHz	86 - 92 GHz	190 - 191.8 GHz
15.35 - 15.4 GHz	100 - 102 GHz	200 - 209 GHz
23.6 - 24 GHz	109.5 - 111.8 GHz	226 - 231.5 GHz
31.3 - 31.5 GHz	114.25 - 116 GHz	250 - 252 GHz
31.5 - 31.8 GHz*	148.5 - 151.5 GHz	

* in Region 2 only

Passive Remote Sensing Allocations

Frequency allocations to EESS (passive) shared with other services

10.6 - 10.68 GHz	54.25 - 59.3 GHz
18.6 -18.8 GHz	116 - 122.25 GHz
21.2 - 21.4 GHz	155.5 - 158.5 GHz
22.21 - 22.5 GHz	174.8 - 182 GHz
31.5 - 31.8 GHz*	185 - 190 GHz
36 - 37 GHz	235 - 238 GHz

* in Regions 1 and 3 only

Passive Remote Sensing Allocations

Bands allocated to EESS (passive) on a secondary basis or not allocated

1370 - 1400 MHz
2640 - 2690 MHz
4200 - 4400 MHz
4950 - 4990 MHz
6425 - 7250 MHz*
15.2 - 15.35 GHz

* this band is not allocated to the EESS (passive) but it is used subject to RR No. **5.458**

Radio Frequency Interference

Spaceborne microwave remote sensing instruments are experiencing more and more Radio Frequency Interference (RFI).

Radio Frequency Interference can be:

- **In-band:** Intentional emissions within the bandwidth used by our instrument.
- **Out-of-band emissions (OOBE)**: non-intentional emissions immediately outside the bandwidth where the remote sensing operates which results from the modulation process, but excluding spurious emissions
- **Spurious emissions**: non-intentional emissions outside the necessary BW and whose level may be reduced without affecting transmission, including harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products

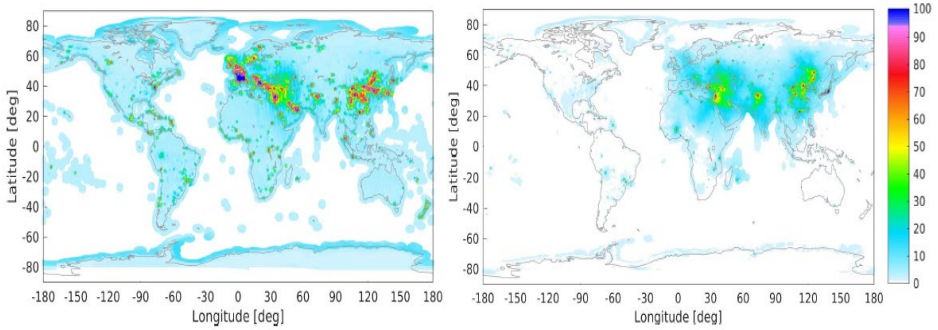
RFI in satellite measurements leads to:

- data loss
- increased radiometric noise
- wrong retrievals of the geophysical parameters.

RFI in Remote Sensing

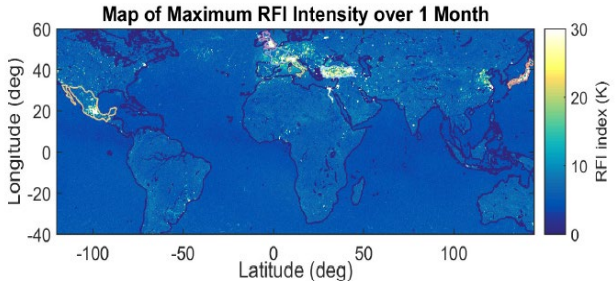
Presence of RFI in several instruments is found in the scientific literature. However, the interference information from Earth Observation satellite missions is scarce, sparsely disseminated and following different methodologies.

1.41 GHz



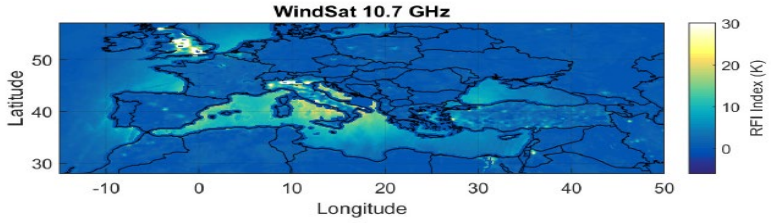
Credit: P de Matthaeis and Y. Soldo, NASA

AMSR2 10.65 GHz



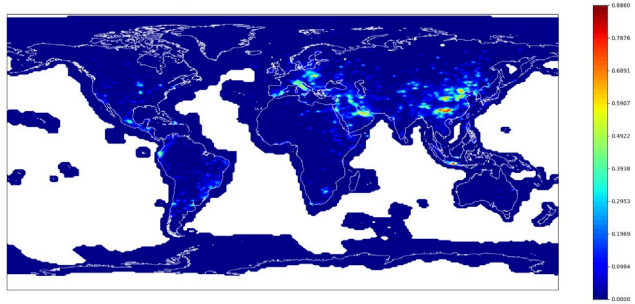
Credit: D. Draper, Ball Aerospace

10.7 GHz



Credit: D. Draper, Ball Aerospace

Sentinel 1 5.4 GHz



Credit: Franceschi et al. ARESYS

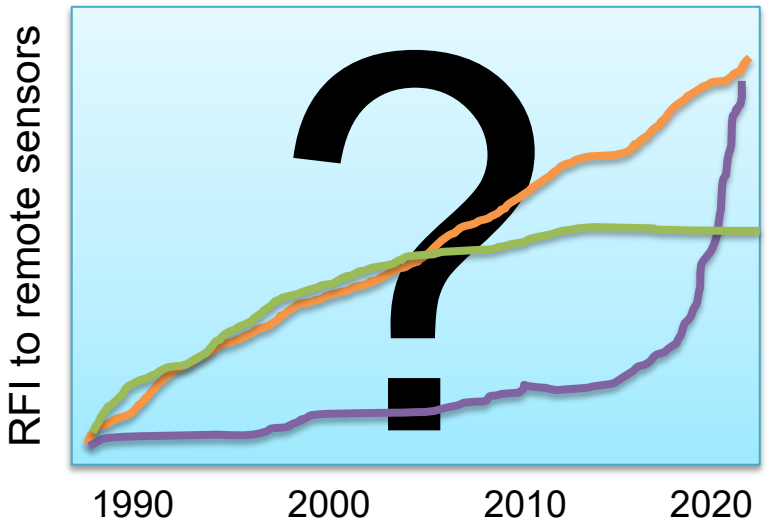
Purpose of the Standard Development

Purpose of the Standard

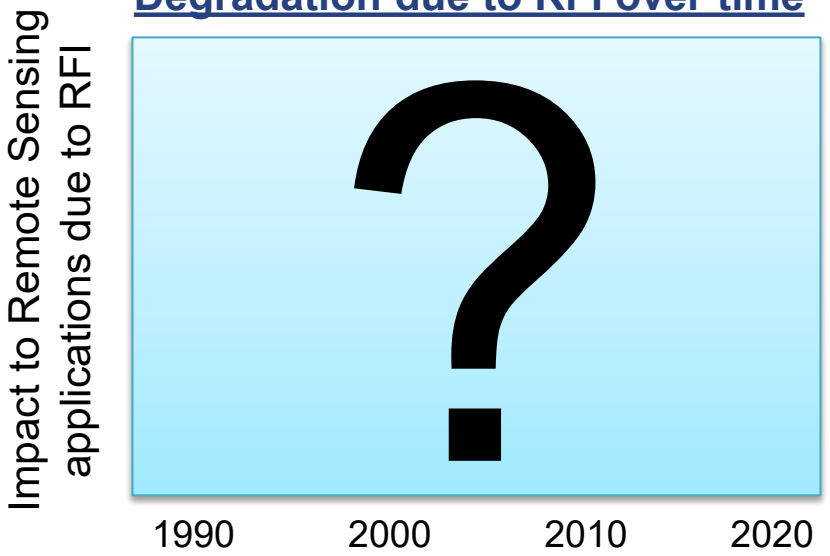
Engineering Principle

The first step to controlling any malleable parameter is to acquire the capacity to measure that parameter accurately.

RFI by RS band over time



Degradation due to RFI over time



Scope of the Standard

- **New IEEE standard to define a methodology to quantitatively evaluate the amount of man-made Radio Frequency Interference (RFI) in any given frequency band allocated to space-based remote sensing.**

- Useful in understanding the situation of all the bands allocated to remote sensing, follow their trends and in defining priorities for our spectrum managers.

Objective is to update this table

IEEE Band	Frequency Range	Passive Sensors	RFI
L	1.400-1427 MHz	Soil moisture, sea surface salinity, sea surface wind, vegetation index	High; out of band emissions mostly from air surveillance radars
C	6425-7.250 MHz	Soil moisture, sea surface salinity, precipitation	Moderate (especially over the U.S.A.)
X	10.6-10.7 GHz	Precipitation, cloud liquid water, sea surface wind speed, sea surface temperature	Moderate (especially over Europe)
Ku	18.6-18.8 GHz	Precipitation, cloud liquid water, snow cover, sea surface wind speed, sea ice	Moderate; potentially from satellite TV service signals.
K	22.21–22.5 GHz	Atmospheric water vapor, Sea surface wind speed, sea ice, precipitation, snow cover	Moderate; vehicle anti-collision radars
K	23.6–24 GHz	Atmospheric water vapor, Sea surface wind speed, sea ice, precipitation, snow cover	Moderate; vehicle anti-collision radars
Ka	31.3–31.8 GHz	Precipitation, cloud liquid water, snow cover, sea surface wind speed, sea ice	Low; new sources observed off oil platforms near the Indian subcontinent
Ka	36-37 GHz	Precipitation, cloud liquid water, snow cover, sea surface wind speed, sea ice	Low; new sources observed off oil platforms near the Indian subcontinent
V	50.2–50.4 GHz	Atmospheric temperature profiling	Moderate: potential for RFI due to spectrum sharing rules at 55–57
V	51.4–59.3 GHz	Atmospheric temperature profiling	Moderate: potential for RFI due to spectrum sharing rules at 55–57

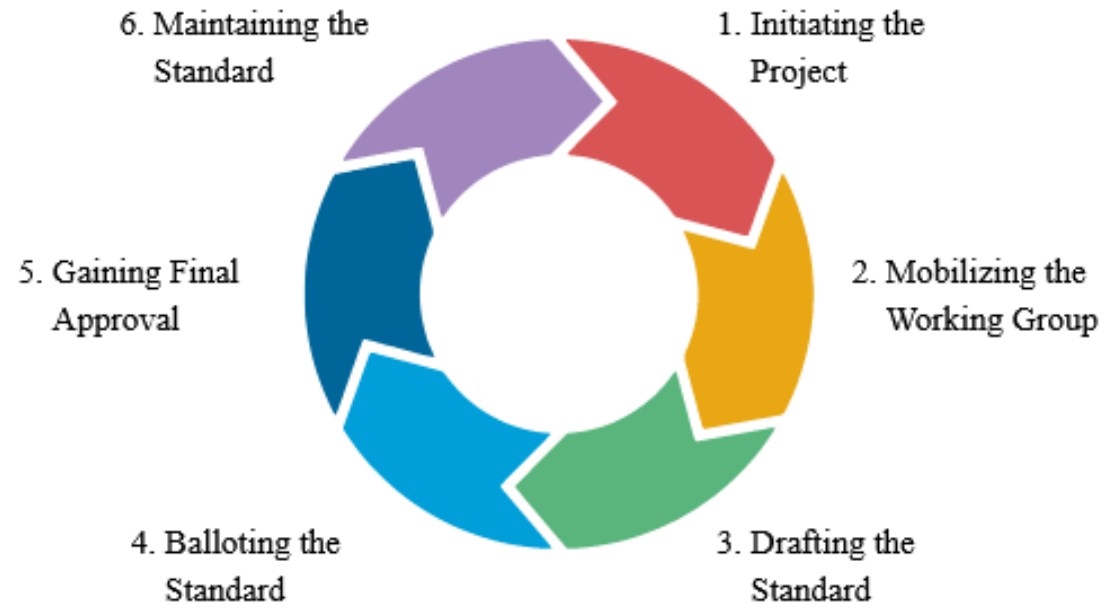
Adapted from S. Misra and P. de Matthaeis, "Passive remote sensing and radio frequency interference (RFI): An overview of spectrum allocations and RFI management algorithms", *IEEE Geoscience and Remote Sensing Magazine*, vol. 2, no. 2, pp. 68-73, June 2014.

and to fill this table

IEEE Band	Frequency Range	Active Sensors	RFI
P	432-438 MHz	Imaging radar	
L	1215-1300 MHz	Imaging radar, scatterometer	
S	3100-3300 MHz	Imaging radar, scatterometer, altimeter	
C	5250-5570 MHz	Imaging radar, altimeter	
X	8550-8650 MHz	Imaging radar, scatterometer, altimeter	
	9300-9900 MHz	Imaging radar, scatterometer, altimeter	
Ku	13.25-13.75 GHz	Scatterometer, altimeter, precipitation radar	
	17.20-17.30 GHz	Scatterometer, precipitation radar	
K	24.05-24.25 GHz	Precipitation radar	
Ka	35.5-36 GHz	Scatterometer, altimeter, precipitation radar	
W	78-79 GHz	Cloud profiling radar	
	94-94.1 GHz	Cloud profiling radar	
mm	133.5-134 GHz	Cloud profiling radar	
	237.9-238 GHz	Cloud profiling radar	

Status

Process of IEEE Standard development



IEEE SA
STANDARDS ASSOCIATION

CALL FOR PARTICIPATION

First WG meeting took place on **14 June 2021**

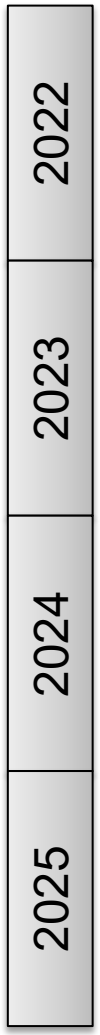
Timeline (past)

- Jul'19: **Initial Idea** of using Standards to support RFI discussed at FARS-TC annual Meeting during IGARSS'19.
- Oct'19: A study group among FARS-TC members is created to propose goal

- Jul'20: Discussion of the goal for the Standard postponed due to Covid.
- Oct'20: FARS-TC Annual Meeting present initial proposal at virtual Annual Meeting.
- Nov'20: FARS-TC present initial proposal at virtual Microrad conference. Decision to move forward with the Project Authorisation Request (PAR)

- Feb'21: Submission of PAR 4006 to Standards Association
- Mar'21: NESCOM approves PAR 4006. The activity becomes IEEE-SA
- Jun'21: **First WG meeting takes place**
- Dec'21: 4th WG meeting: **Approval of the Outline of the Standard document**

Timeline (present & future)



- 2022: Drafting of the Standard
- Dec'22: Draft 1.0. Initial draft approved by group
- Sep'23: Draft 2.0: Review and modification of content
- Mar'24: Draft 3.0. Ballot ready draft
- Jun'24: Formation of a Standards Association Ballot Group
- Jul'24: Initiate SA Ballot
- Dec'24: Submit to RevCom
- May'25: Publication

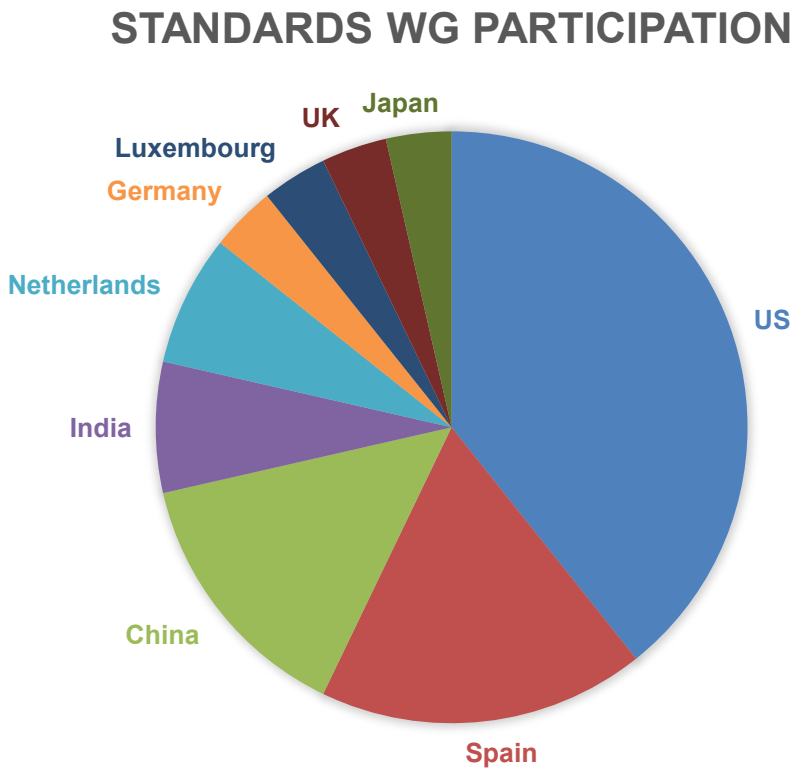
The RFI in Remote Sensing Working Group,

28 Participants from different countries

20 Voting Members

We've hold 6 Working Group Meetings,

and many sub-group meetings



Quantifying Band Contamination: Initial draft Flowchart

Step 1 - RFI Detection
Acquisition-Reference-Frame

Step 2 – RFI Maps (per Sensor)
Sensor-Reference-Frame

Step 3 – RFI Maps
Global-Reference-Frame

Step 4 – Output products
RFI characterization

Quantifying Band Contamination: Initial draft Flowchart

Step 1 - RFI Detection
Acquisition-Reference-Frame

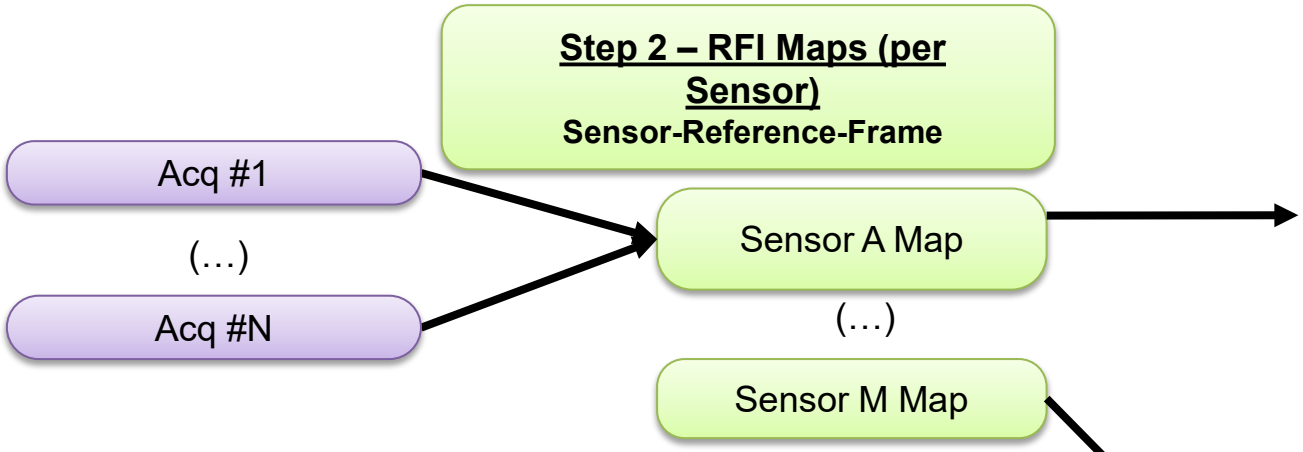
- Acq #1
- Acq #2
- (…)
- Acq #N

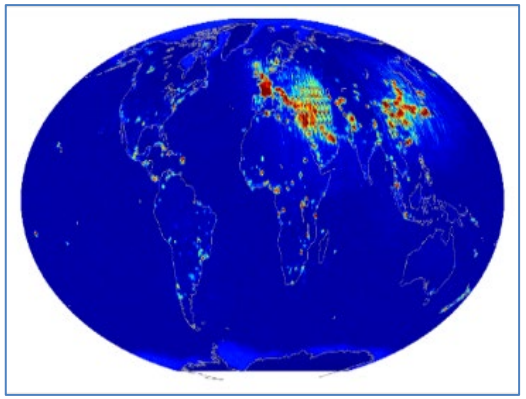
Eg. For a single acq, sensor, in a given band…

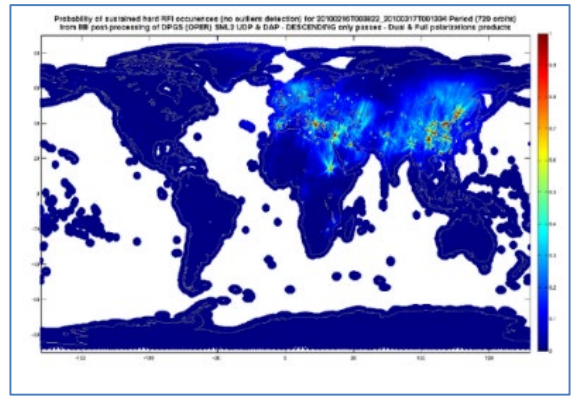
Standard may provide:

- false alarm rate requirement (quality control)
- variety of sensor-dependent detection techniques and detailed implementation procedures
- procedure for usage of custom RFI detection
- List / format of information to be reported

Quantifying Band Contamination: Initial draft Flowchart





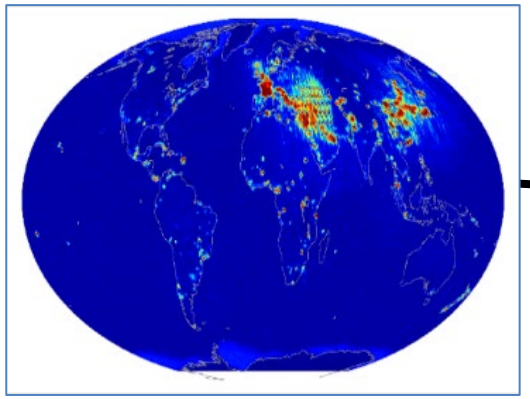


Eg. For a given sensor, in a given band…

Standard may provide:

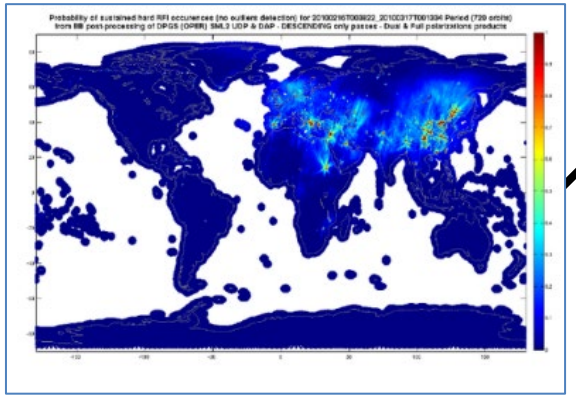
- How and how often to collate acquisitions
- How to geolocate acquisitions: (RFI contamination / RFI sources)

Quantifying Band Contamination: Initial draft Flowchart



Step 3 – RFI Maps
Global-Reference-Frame

RFI Map for Band



Eg. For a given band…

Standard may provide:

- Transformations to achieve
  - sensor-to-global-conversion
  - global-to-sensor-conversion (e.g., for assessing impact on future missions based on collected standard data)

Quantifying Band Contamination: Initial draft Flowchart

RFI Map for Band → **Step 4 – Output products**
RFI characterization →

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Standard may provide:

- Transformations to quantify/grade bands globally
  - per country/continent
- Method to plot along time

Join the RFI in Remote Sensing Working Group:

To join the WG on Standards, you have to register interest in our WG (GRSS/SC/RFIRSWG RFI in Remote Sensing Working Group), by following the link:

https://development.standards.ieee.org/myproject-web/app#interests

Thanks for your attention! Any question?

roliva@ieee.org