Developing an IEEE Standard to Assess Interference on Remote Sensing Frequency Bands

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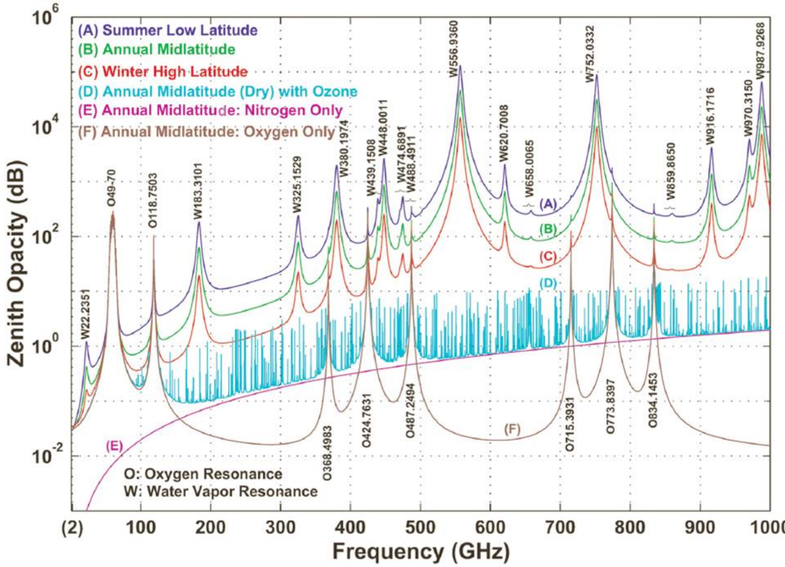
Introduction

Introduction

Spaceborne microwave remote sensing instruments are critical for Weather and Climate monitoring.

These sensors acquire measurements at specific frequencies:

- determined by the **geophysical characteristics** of the Earth surface and atmosphere
- specified in 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.

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

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**

Active Remote Sensing Allocations

Frequency allocations to EESS (active) services

432 - 438 MHz*	13.25 - 13.75 GHz
1215 - 1300 MHz	17.2 - 17.3 GHz
3100 - 3300 MHz*	24.05 - 24.25 GHz*
5250 - 5570 MHz	35.5 – 36 GHz
8550 – 8650 MHz	78 - 79 GHz
9.5 – 9.8 GHz	94 - 94.1 GHz
9.8 – 9.9 GHz*	133.5 - 134 GHz
9.9 - 10.64 GHz	237.9 – 238 GHz

* Secondary Allocations

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

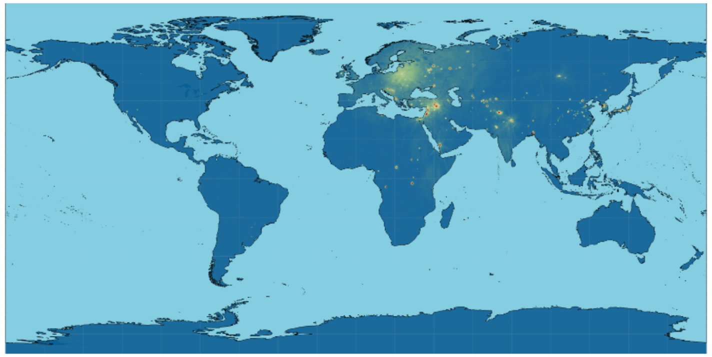
RFI in satellite measurements leads to:

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

RFI in Remote Sensing

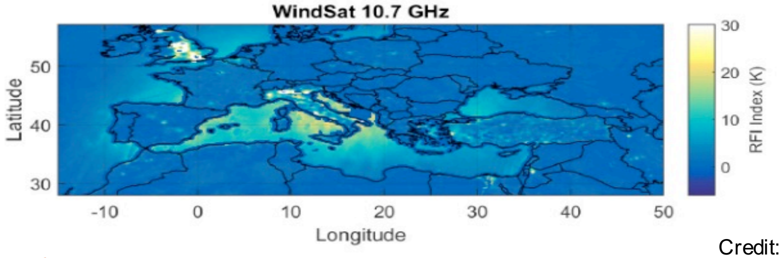
Presence of RFI in several instruments is documented in the scientific literature or mission related websites. However, interference information from Earth Observation satellite missions is scarce, sparsely disseminated and not following consistent methodologies.

1.41 GHz (SMOS, passive)



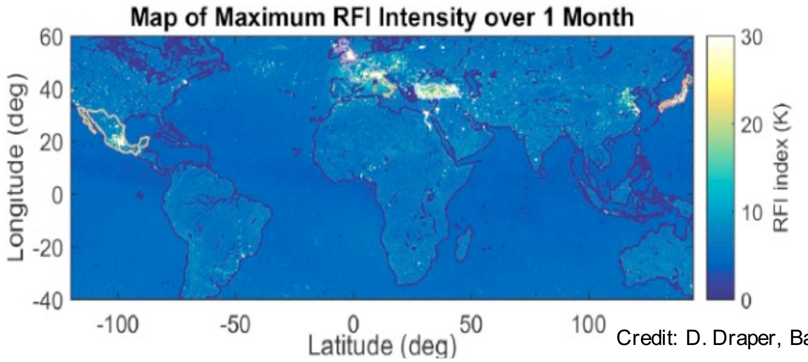
Credit: SMOS RFI team, ESAC

10.7 GHz (WindSat, passive)



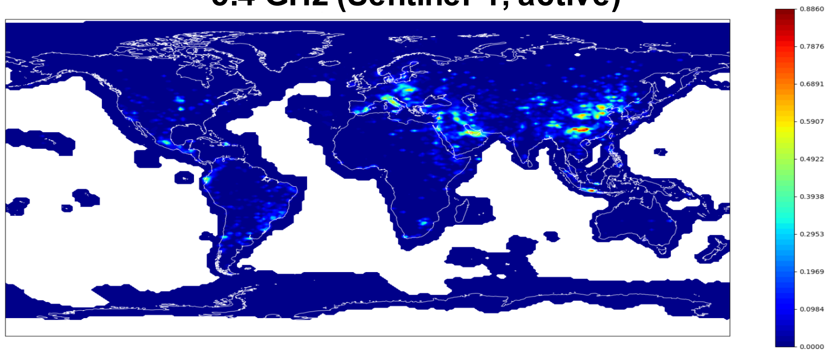
Credit: D. Draper, Ball Aerospace

10.65 GHz (AMSR2, passive)



Credit: D. Draper, Ball Aerospace

5.4 GHz (Sentinel 1, active)



Credit: Franceschi et al. ARESYS

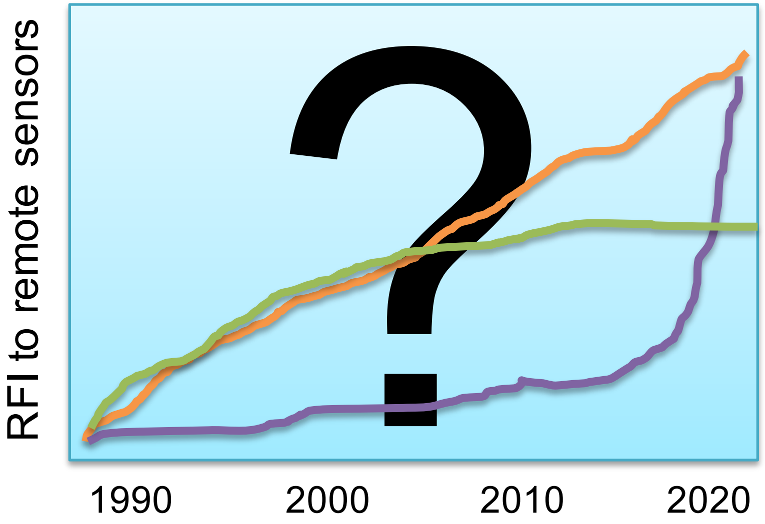
Purpose of the Standard Development

Purpose of the Standard

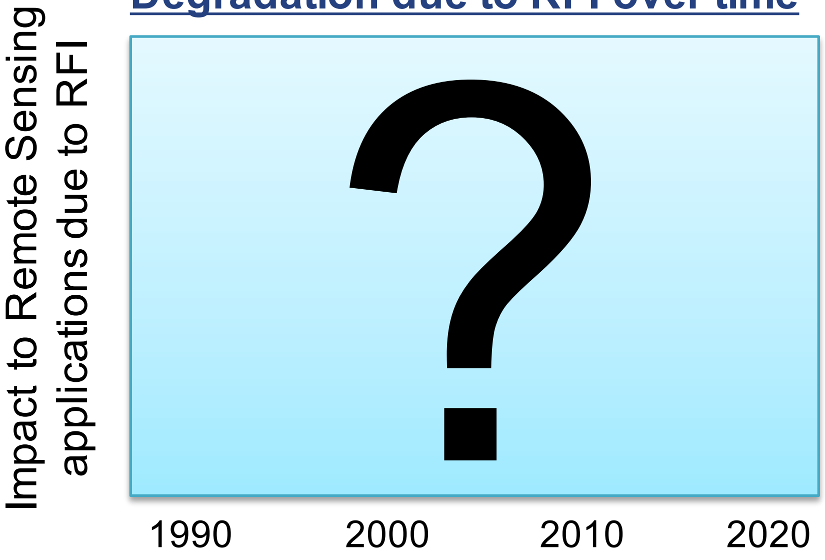
Engineering Principle

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



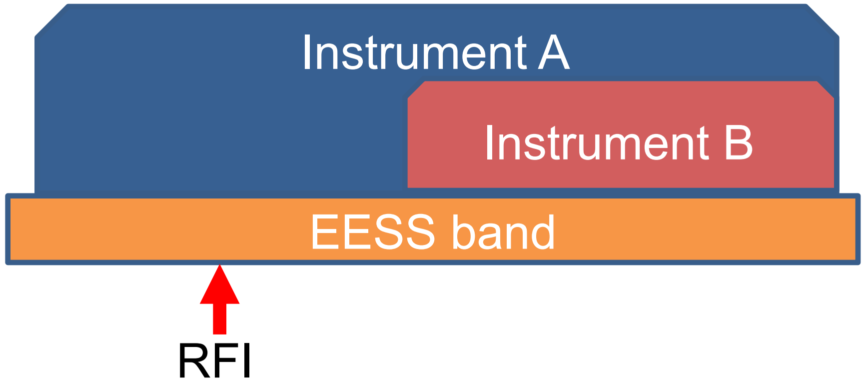
Purpose

- Main goal is **to develop standards for methodologies to consistently evaluate the quality of frequency bands (both active and passive) with respect to RFI**
- These standards will provide criteria to assess RFI impact on remote sensing in the frequency bands and also guidelines for remote sensing missions to document man-made RFI.
- A further goal is to ensure a continuing and consistent measure of the impinging RFI and its impact in each of the considered remote sensing frequency bands over a long timeframe.
- This recorded information is to be used to inform policy decision makers and the public regarding the impact of man-made RFI in any given remote sensing frequency band on remote sensing operations and products.

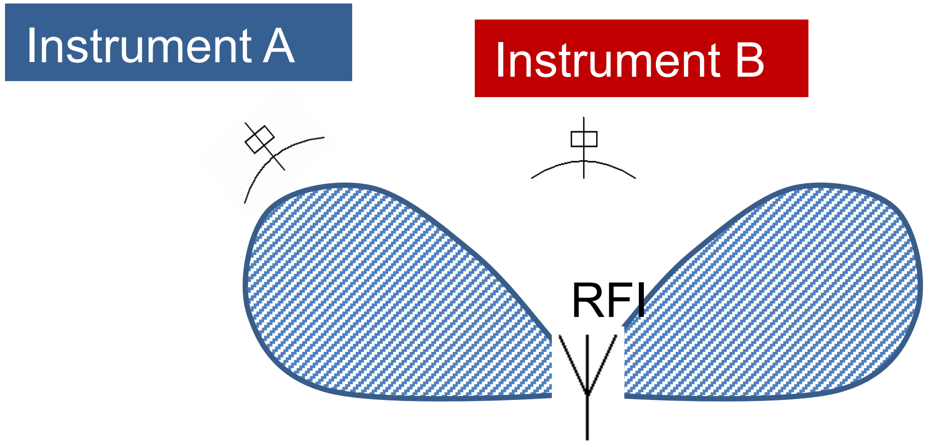
Currently Identified Points of Discussion

- Quantification of the band vs quantification of the sensor:

Example 1: Difference in operating band



Example 2: Difference in observation angle

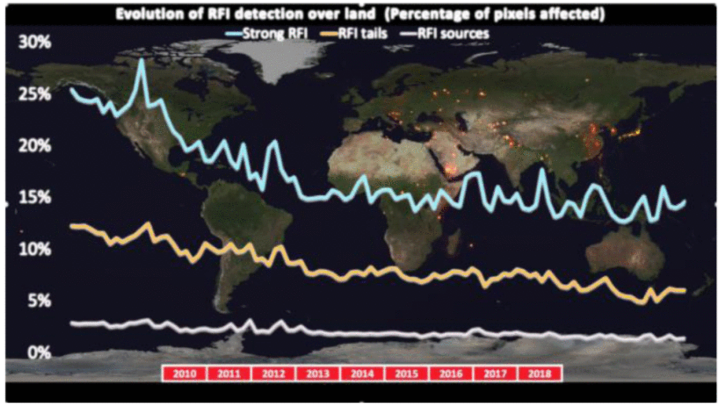


- Option 1: If RFI is detected by one instrument, then consider all band contaminated
- Option 2: Weight RFI by contamination score or certainty

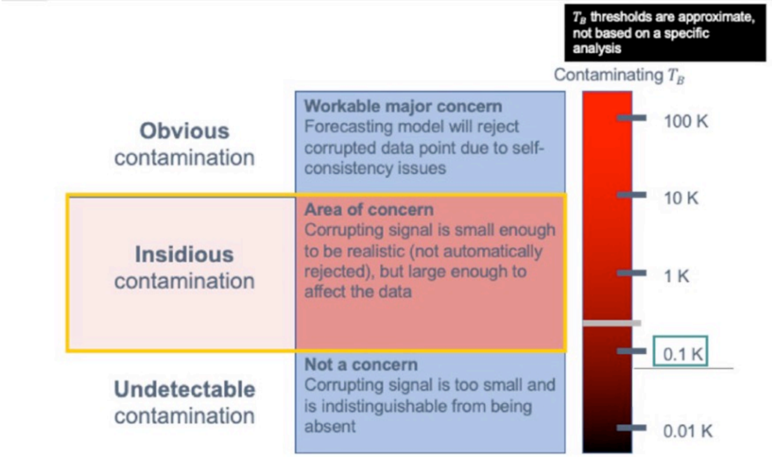
Currently Identified Points of Discussion

Several Dimensions on RFI:

- Dynamic:
  - Changes along time (weeks/months/years)
  - Changes within 1 observation (scanning radars, sub-sampling)
- Geography:
  - Regional vs Global RFIs
  - 1 sources vs extended/multiple sources within 1 footprint
- Detectability: Ability of sensor to detect RFI:
  - clear RFI cases vs insidious RFI



Credit: Llorente et al. RFI 2019



Credit: David Lubar. Testimony to U.S. House of Representatives

Initial step 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. 5G services
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

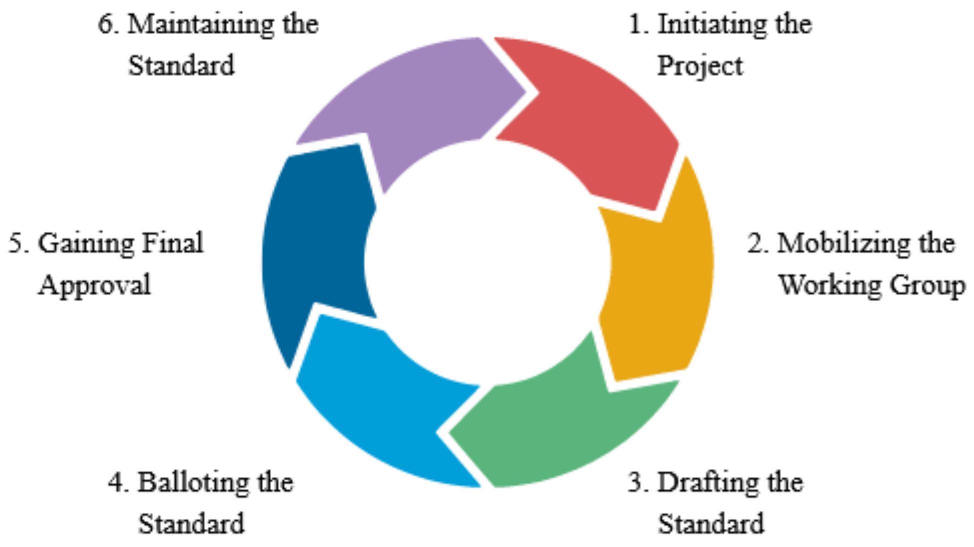
Adapted from S. Misra and P. de Matthaeis, "Passive remote sensing and radio frequency interference (RFI): An overview of spectrum allocations and RFI management algorithms", *IEEE Geoscience and Remote Sensing Magazine*, vol. 2, no. 2, pp. 68-73, June 2014.

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	

Process for Standard development

Cycle for IEEE Standards Development



Developing a Standard:

The first steps in developing an IEEE Standards are:

1. Submitting a Project Authorization Request (PAR) to IEEE SA that
    - states the reason for the project and what the WG intends to do
    - defines the type of Standard to be followed

Standards	Recommended practices	Guides
Documents with mandatory requirements	Documents in which procedures and positions preferred by the IEEE are presented	Documents in which alternate approaches to good practice are suggested but no clear-cut recommendations are made

Developing a Standard

The first steps in developing an IEEE Standards are:

2. Establishing a Working Group
   - Call for Participation to form the WG
   - The WG will then develop the Standard with inputs and feedback from the stakeholders
   - Officially, a standard needs to be developed within 4 years after IEEE SA acceptance of the PAR

IEEE SA
STANDARDS ASSOCIATION

CALL FOR PARTICIPATION

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

Status

Timeline (past)

2019

- 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

2020

- 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)

2021

- 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: 4^{th} WG meeting: **Approval of the Outline of the Standard document**

Timeline (current & future)

2022

- 2022: Drafting of the Standard
- Dec'22: Draft 1.0. Initial draft approved by group

2023

- Sep'23: Draft 2.0: Review and modification of content

2024

- 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

2025

- May'25: Publication

Thanks for your attention.

Join the RFI in Remote Sensing Working Group

for the development of this standard!

Contact me at:

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Any questions?