



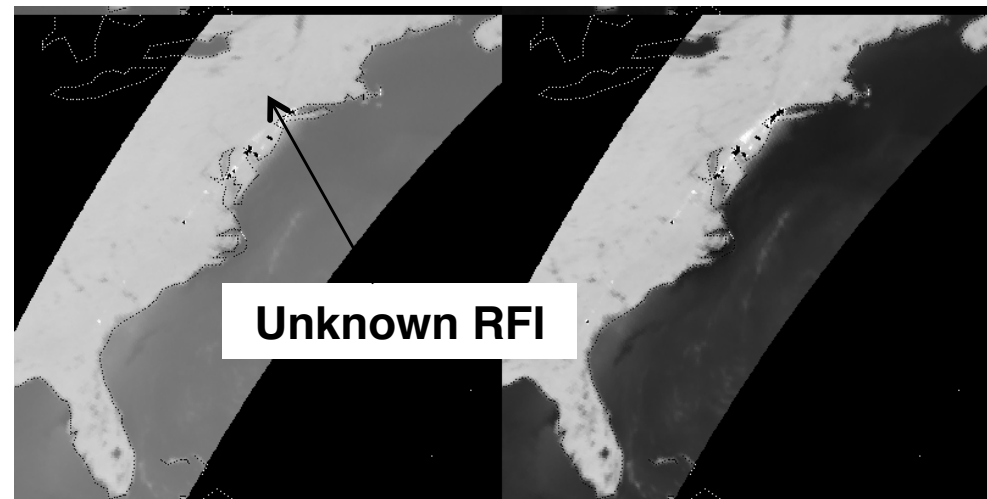
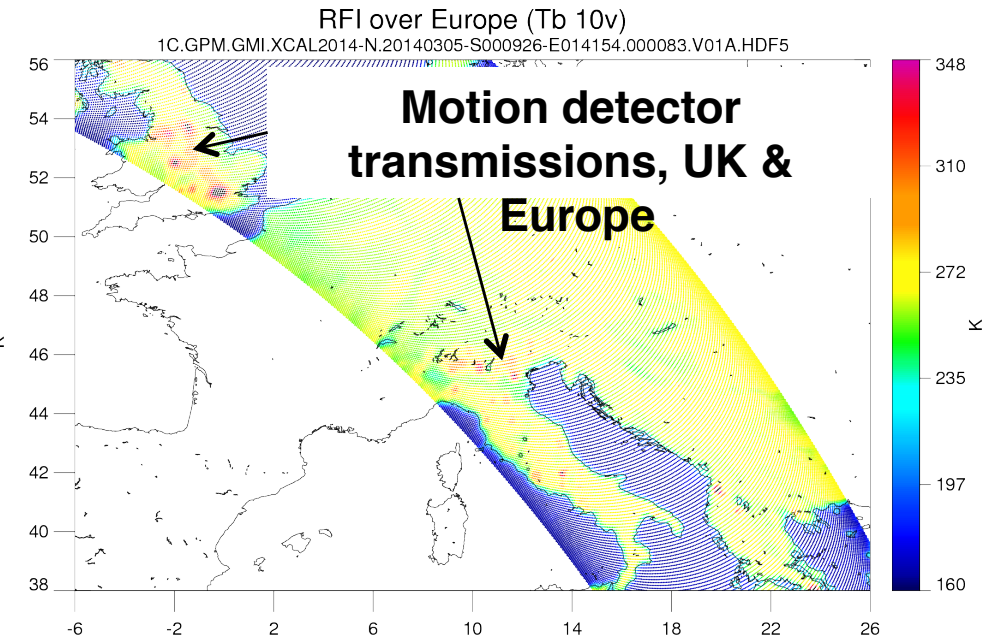
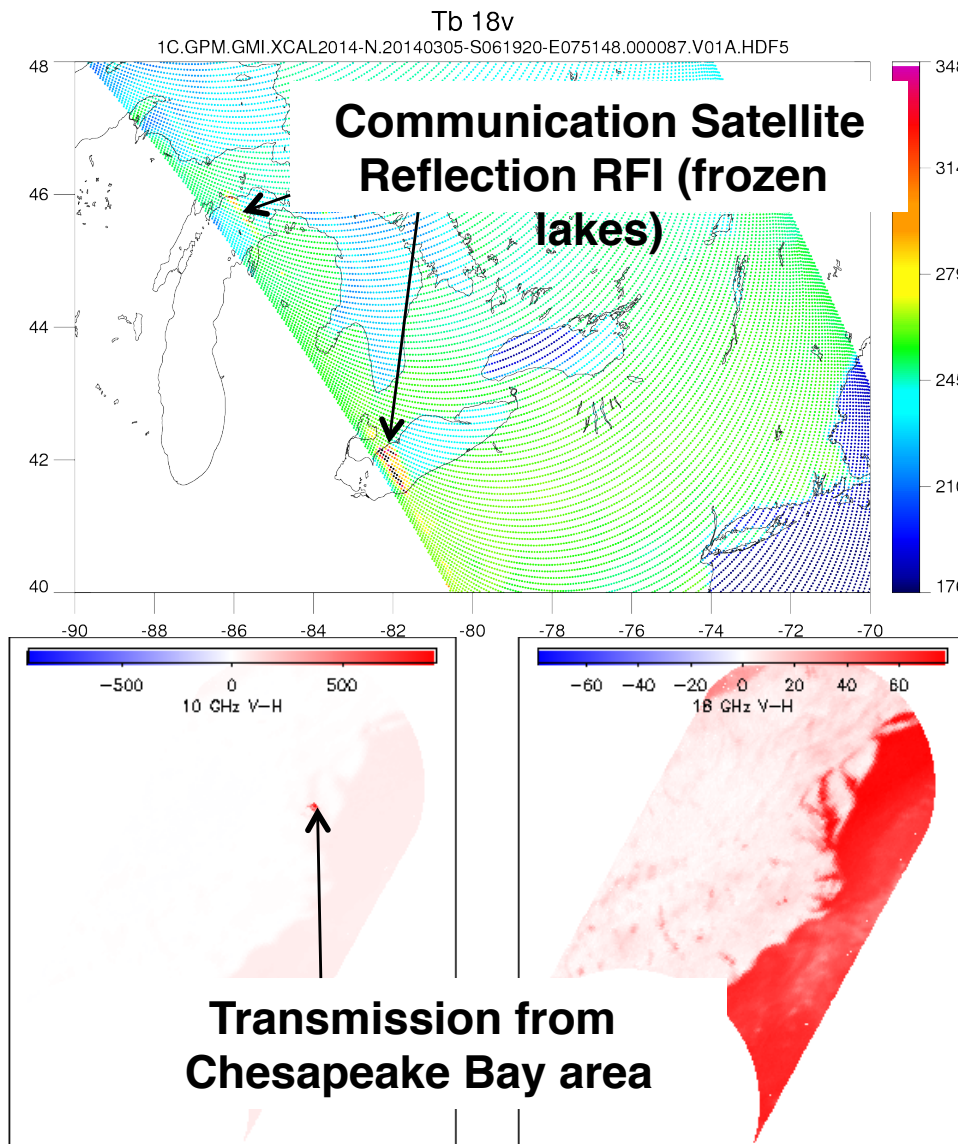
# Frequency Allocations in Remote Sensing (FARS) Technical Committee Annual Meeting

July 14, 2014

Sidharth Misra (Chair)  
Paolo de Matthaeis (Co-chair)



## GPM Microwave Imager RFI Examples



RSS and xcal derived algorithms will identify RFI & mitigate if possible



## Agenda

- Update on membership
- Recent activities
- Update from CORF
- Update from NAS
  - Study on active scientific use of radio spectrum
- Future initiatives
- FARS input requested





## FARS membership

- **Current membership**
  - 86 members
  - Updated members list
  - By employment
    - » Industry: 15
    - » Government: 40
    - » Academia: 31
  - By region
    - » North America: 62
    - » Europe: 17
    - » Asia: 5
    - » Other: 2
- Need to work towards increasing FARS membership from other regions, particularly:
  - India
  - China
  - Australia
  - Latin America
- Membership slightly “decreasing”:
  - By-product of updating membership information





## Recent Activities

- **National Academy of Sciences (NAS) meeting:**
  - At the suggestion of the AdCom, Paolo represented FARS at the NAS meeting on the Active Scientific Use of Radio Spectrum
  - Prof. Al Gasiewski from the study will be presenting at the FARS TC annual meeting
- **IUCAF 4<sup>th</sup> School on Spectrum Management (Chile)**
  - FARS TC member present
- **Committee on Radio Frequencies (CORF) meeting:**
  - Both Paolo and I were invited by the CORF to join in their spectrum management related discussions in D.C.
  - Prof. Jasmeet Judge from CORF will be presenting at the FARS TC annual meeting
- **Space Frequency Coordination Group (SFCG) meeting:**
  - SFCG is an advisory organization with members from Space Agencies and related national and international organizations
  - SFCG is concerned with the effective use and management of radio frequency bands allocated to Space Research, Space Operations, Earth Exploration Satellite, and Meteorological Satellite services
  - FARS might have a greater involvement in the coming years as the role of observers is being expanded
  - FARS member input was requested on a few issues
- **Website updated**
- **FARS article in the June 2014 issue of GRSM**



**FARS Article in the June 2014 Issue  
of the Geoscience and Remote Sensing Magazine**

## TECHNICAL COMMITTEES

**SIDHARTH MISRA**, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA  
**PAOLO DE MATTHAEIS**, Goddard Space Flight Center, National Aeronautics and Space Administration, Greenbelt, MD, USA

## Passive Remote Sensing and Radio Frequency Interference (RFI): An Overview of Spectrum Allocations and RFI Management Algorithms

**Introduction to "Technical Committees"**  
by John Kerekes, Vice President of Technical Activities

Each issue we feature one of our Technical Committees to share with the community their mission, objectives, and activities. Here we present a contribution from the Frequency Allocations in Remote Sensing (FARS) Technical Committee. As explained in the article, FARS represents the interests of our community in regards to use of the radio frequency spectrum. Please contact the Chair or Co-Chair (authors of the article) if you have an interest in participating in this Technical Committee.

A black and white headshot of John Kerekes, a man with glasses, wearing a suit and tie.

**T**he Frequency Allocations in Remote Sensing (FARS) Technical Committee (TC) was formed in 2000 as a means for the IEEE Geoscience and Remote Sensing Society (GRSS) community to discuss spectrum management issues that affect the remote sensing field and to provide a unified interface to the regulatory world. Presently, FARS members include 84 engineers and scientists representing government, academic and industrial entities across 10 countries.

Spectrum management has become an important issue for many members of the GRSS. Increasingly over the past decade, members of GRSS engaged in passive and active microwave remote sensing have been coping with corrupt measurements due to radio frequency interference (RFI) and the changing of the radio frequency (RF) allocation.

To interface between the GRSS membership and the frequency regulatory process, which includes educating the

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membership of current frequencies and influencing regulatory GRSS response. We coordinate stations and responses to regulate current and future use spectrum potential interference issues and RFI detection and mitigation techniques.

As the usable spectrum given the GRSS FARS community approach to deal with interference not only to keep track of frequency allocations but also detect and mitigate unusable data in our spectrum of summarizes frequency allocation observed by passive receiver. Section 3 briefly describes the algorithms developed by the summarizing recent and up to the last section.

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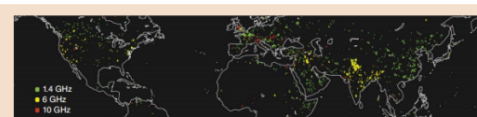
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country is free to modify the ITU table for services within its borders [1].

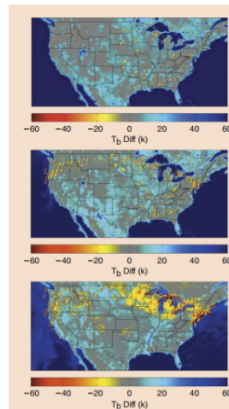
Each allocated service is generally granted either primary or secondary status. Secondary services shall not cause harmful interference to primary services. They also cannot claim protection from harmful interference caused by a primary service; however they can claim protection from harmful interference from sources of the same or other secondary services. Current Radio Regulations have allocated

TABLE 1. REL-THREATENED PASSIVE EESS FREQUENCY ALLOCATIONS

RANGES (GHz)	SCIENTIFIC OBSERVATIONS	SPACEBORNE INSTRUMENTS	RF LEVEL AND SOURCES
1.37–1.40	Soil moisture, sea surface salinity, sea surface wind	SMOS, Aquarius, SMAP	High out of band emissions mostly from man-made transmitters
1.40–1.427			
4.625–7.239*	Soil moisture, sea surface temperature, precipitation	AMSR-2, WindSat	Moderate (especially over the U.S.A.)
10.6–10.7	Precipitation, cloud liquid water, sea surface wind	TM, AMSR-2, WindSat, GPM CMI	Moderate (especially over Europe)
18–18.8	Precipitation, cloud liquid water, snow cover, sea surface wind speed, ice	JASON-2/AMR, AMSR-2, WindSat	Moderate potential from satellite TV service signals
22.27–22.25	Active ocean water vapor	SMAP, JASON-2/AMR, TM, AMSR-2	High, especially vehicle collision radars
23.6–24	Sea surface wind speed, ice	CMI, JASON-2/AMR	



**FIGURE 1.** Map showing RFI detected at three different frequencies: RFI at 1.4 GHz as observed by the Aquarius radiometers during December 2011, RFI at 6 and 10 GHz as observed by AMSR-E during December 2010.



**FIGURE 2.** K-band RFI observed by AMSR-E for July 2005, July 2008 and July 2009. Values shown are the differences between brightness temperatures between 23.8 GHz and 18.7 GHz in V-polarization. RFI appears as negative differences  $< 10$  K (courtesy of McKague et al. [4]).

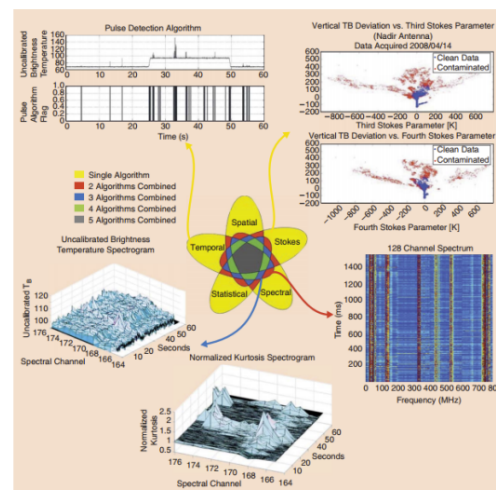
### 3.0 REI MITIGATION ALGORITHMS

RFI detection, mitigation, and in some cases estimation algorithms developed for passive remote sensing can be broadly classified in five categories.

- 1) **Spatial:** This class of algorithms detects the presence of RFI by comparing the pixel under test with its neighboring pixels. This approach is good for high-powered geographically isolated interference sources. The algorithms in this class are designed to extract features that are invariant to the parameters samples in the time domain. They work best for radar-type pulsed signals and are generally optimal when the integration period of the radiometer is much longer than the effective interference signal width [1]. The RFI source needs to be above the noise floor of the measured signal for a successful detection.
- 2) **Spectral:** For Continuous-Wave (CW) narrowband RFI sources a spectral algorithm gives optimal performance. These algorithms are designed to detect signals in neighboring bands for anomalously high signals.
- 3) **Statistical:** These algorithms are based on measuring higher order statistical properties of the signal to gauge if they are different from the noise floor. However, they have the capability to detect low-level interference depending on the type of interfering source.
- 4) **Polarimetric:** These algorithms take advantage of the different nature of the RFI source and the natural source to distinguish it from the natural emission.

Fig. 3 gives an example of the different types of algorithms. As the diagram suggests, various algorithm classes can be combined to deal with different types of interfering sources. Though RFI detection algorithms have been built and developed for many missions over a wide spectrum, missions in the L-band have been the most active in pursuing RFI mitigation strategies. Between the current and upcoming space-borne missions, NASA's Aquarius mission, ESA's SMOS (Soil Moisture Ocean Salinity) mission and NASA's SMAP (Soil Moisture Active Passive) mission have implemented pre-launch and post-processing algorithms to deal with RFI. Even though all these three missions operate in the protected L-band, previous airborne missions have shown that RFI still occurs at this frequency (also see in Fig. 1).

The Aquarius radiometers employ a purely temporal approach also known as "glitch" detector [6-8], closely related to the pulsed RFI detection method. The algorithm integration time was optimized to deal with early-warning radar sources with pulses of similar width [9].



**FIGURE 3** A five dimensional Venn diagram [16] illustrating the different classes of RFI detection and mitigation algorithms and their combinations. Two (red), three (blue), four (green) and five (grey) classes combinations are possible. The algorithms clockwise from top left are: Pulse Detection (Temporal) [8], 3rd/4th Stokes RFI Detection (Polarimetric, courtesy of Skou et al. [10]), Spectrogram for CW signals (Temporal + Spectral), Kurtosis (Temporal + Spectral + Statistical, courtesy of Ruf et al. [17]).

The algorithm is fairly easy to implement, but it is inherently biased and can only detect RFI above the noise floor of the radiometer, potentially missing RFI coming from continuous sources. Fig. 1 shows that it performs satisfactorily by picking up sources around the Europe, China and the Middle East.

The SMOS mission employs a unique interferometric technique for measuring brightness temperatures. This results in an RFI detection approach that is a combination of spatial, temporal (or angular) and polarimetric algorithms. The algorithm proposed by Skou et al. [10] looks

at the third and fourth Stokes parameters of the incoming signal and any deviation away from zero (as seen in Fig. 3 polarimetric). Another algorithm proposed by Misra et al. [11] takes advantage of the smooth geophysical variation of brightness temperature with respect to incidence angles, and detects deviations from a smooth fit. The SMOS mission has been very active in identifying the interference sources at L-band, geo-locating them and turning them off. This has led to more complicated algorithms that not only detect RFI sources but attempt to locate them as well [12].







# **Update from the Committee on Radio Frequencies (CORF) of the National Academy of Science (NAS)**

**presented by Albin J. Gasiewski**





## Upcoming Meetings

- **World Radiocommunication Conference (WRC-15), November 2015**
  - A month-long meeting where international spectrum allocations are decided
  - Most responses are already compiled but there is still room to provide input
- **Space Frequency Coordination Group (SFCG-35), July 2015**
  - Expanded FARS role expected over the next few years
- **Committee on Radio Frequencies (CORF), Fall 2014**
  - Concentrates mostly on radio science with overlapping interests







## Future Strategic Initiatives

- **3% of GRSS reserves and 50% of past years surplus available to the society for strategic initiatives**
  - Approximately 300K USD
  - Ideas are welcome!!
- **Examples:**
  - Sub-committees (depends on volunteers) to prepare comments to ITU Radio Regulations
  - Enable RFI source identification
    - » Reporting tool on FARS website for observed RFI
    - » FARS forwards findings to appropriate agencies
  - Potential partnership with Signal Processing Society
    - » Engage TC in their societies
    - » Invited talks in FARS session





## Requested FARS Input

- Proposed sharing of 5350-5470 MHz band between telecommunication services RLAN (Radio Local Area Networks including Wi-Fi) and active Earth Exploration Satellite Service (EESS) systems
- SAR systems such as ESA's Sentinel-1 and Canada's RadarSat operate at this frequency and would be negatively affected
- An SFCG study shows that a single outdoor RLAN operated within the whole 5350-5470 MHz band is sufficient to exceed the EESS (active) protection criteria and that a RLAN deployment consistent with RLAN industry expectations would create harmful interference exceeding protection criteria
- RLAN supporters contend that mitigation techniques would eliminate the problem (article will be on website)
- FARS TC input is requested



## Definition of Acceptable Interference Level

- Input requested by Thomas VanDeak for changes to Recommendation ITU-R RS.1166-4 "Performance and interference criteria for active spaceborne sensors"
  - document establishes the interference and data availability criteria be applied for instruments used for active sensing of the Earth's land, oceans and atmosphere
  - studies defining protection levels should
    - » reflect state of the art in active sensing
    - » align protection criteria with analysis methods
    - » expand material to include sensor mechanics
  - we will provide material via email



## SFCG Outcomes Relevant to GRSS

### Some Reports, Resolutions and Recommendations Relevant to IEEE GRSS

- **NASA interest in EESS (active) allocations in frequency bands lower than the 432-438 MHz band (particularly 40-50 MHz)**
- **preliminary analysis of potential L-band RFI from Aeronautical Radio Navigation Service (ARNS) and Radiolocation Service (RLS) systems in the 1215-1300 MHz band**
- **Out-of-Band (OoB) Emission Limits for proposed 7235 to 7250 MHz allocation to EESS**
- **analysis of worst case interference from mainlobe-to-mainlobe antenna coupling of EESS active sensor receivers in the 35.5-36.0 GHz band**

