

The 18th International TOVS Study Conference

# Radio Frequency Interference (RFI) for Earth Exploration Satellite (passive) bands: **overview of SMOS satellite RFI operating at 1.4 GHz**

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# WHAT IS INTERFERENCE ?

According to the ITU Radio Regulations:

- 1.166 **interference**: The effect of unwanted energy due to one or a combination of **emissions, radiations, or inductions** upon reception in a **radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.**
- 1.169 **harmful interference**: **Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations .**
- 4.7 For the purpose of resolving cases of harmful interference, the space research (passive) service and the earth exploration-satellite (passive) service shall be afforded protection from different services in other bands only to the extent that these different services are protected from each other.
- 15.10 The out-of-band emissions of transmitting stations should not cause harmful interference to services which operate in adjacent bands in accordance with these regulations.
- 15.21 If an administration has information of an infringement of the Constitution, the Convention or the Radio Regulations (in particular Article 45 of the Constitution and No. 15.1 - **All stations are forbidden to carry out unnecessary transmissions, or the transmission of superfluous signals, or the transmission of false or misleading signals -of the Radio Regulations**) committed by a station under its jurisdiction, the administration shall ascertain the facts and take the necessary actions.

## Earth Exploration Satellite Service(passive)

Radio frequencies represent scarce and key resources: ruled by the International Telecommunication Union (ITU) – R (Radio) sector

**Earth Exploration Satellite Service (passive) is an essential radio service for Earth Observation.**

**Radio Regulation (RR) 1.51: Passive remote sensing of characteristics of the Earth and its natural phenomena using space based assets**

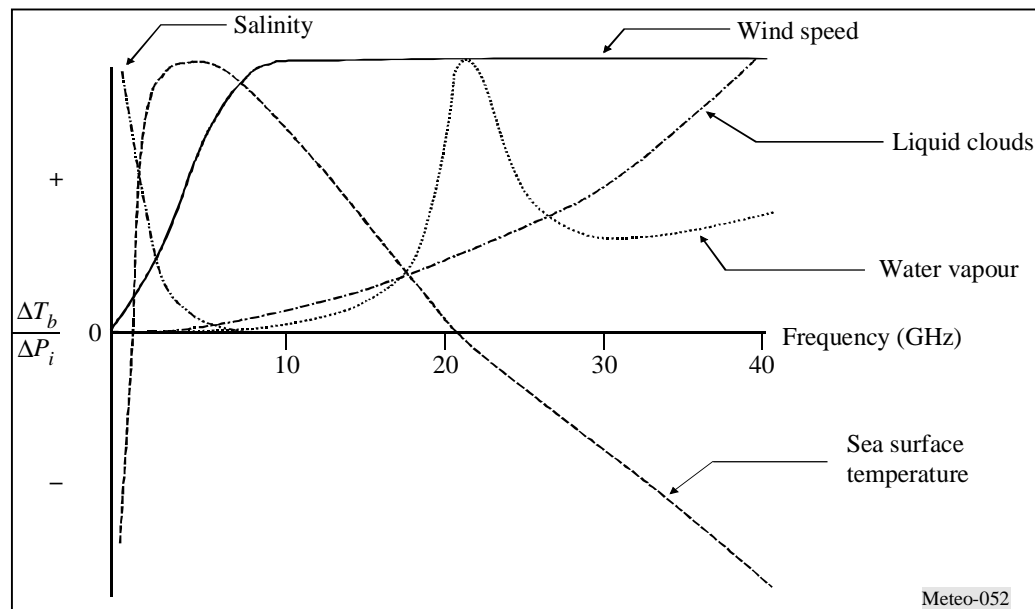
**5.340 All emissions are prohibited in the following bands : (Extracts ./..)**

### 1 400-1 427 MHz,

10.68-10.7 GHz  
 23.6-24 GHz,  
 31.3-31.5 GHz,  
 31.5-31.8 GHz, in Region 2,  
 50.2-50.4 GHz,  
 52.6-54.25 GHz,  
 86-92 GHz,

**Shared passive bands  
 with other Radio services :**

10.6-10.68 GHz  
**18.6-18.8 GHz,**  
 36-37 GHz,



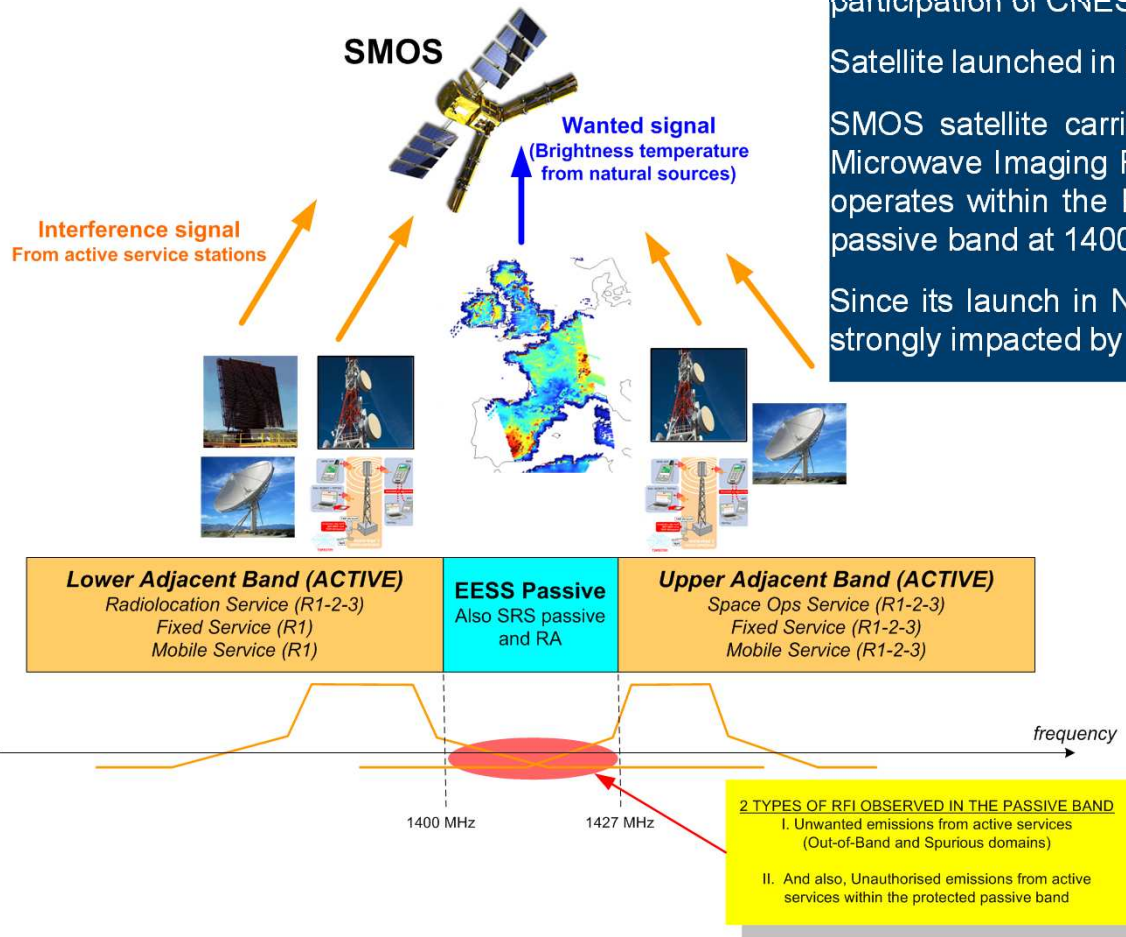
# SMOS RFI in the 1400-1427MHz band

The SMOS mission is a joint program led by ESA with participation of CNES in France and CDTI in Spain.

Satellite launched in November 2009

SMOS satellite carries a single payload on board, MIRAS, a Microwave Imaging Radiometer with Aperture Synthesis, which operates within the Earth Exploration Satellite Service (EESS) passive band at 1400-1427 MHz.

Since its launch in November 2009, SMOS images have been strongly impacted by Radio Frequency Interference (RFI).

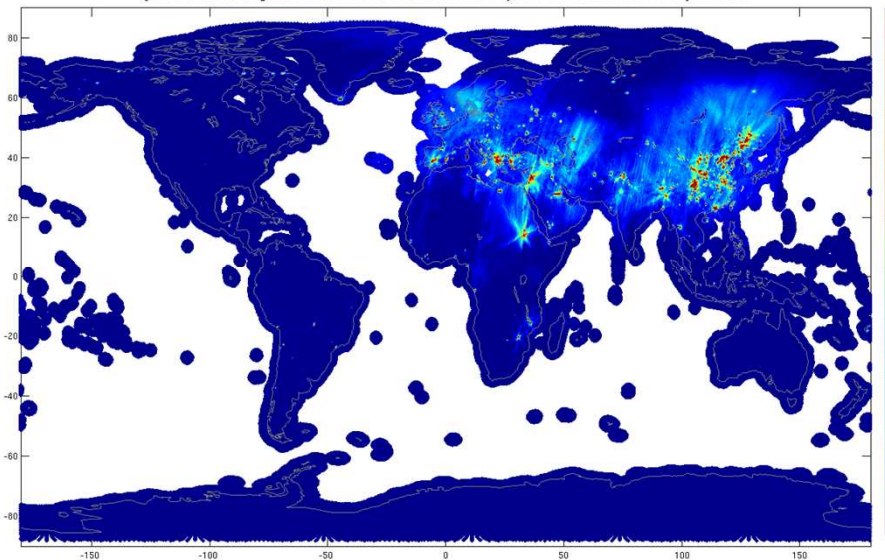




# SMOS RFI contamination probability map

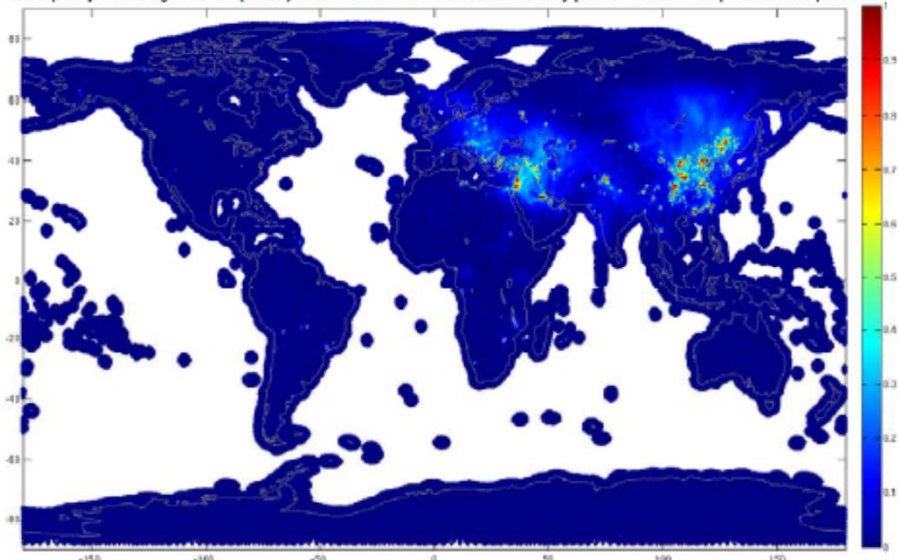
- Big efforts have been necessary to improve the identification, geo-location and characterisation of the RFI sources (currently RFI emitters can be detected and located with accuracy as good as 5km)
- As a result of world-wide action, and thanks to the involvement and cooperation of the National Administrations involved, SMOS RFI scenario has improved considerably over the last two years
- However, there are still over 300 RFIs observed in the 1400-1427 MHz passive band worldwide

Probability of RFI occurrences at the beginning of the mission (mid February 2010 until mid March 2010) for DESCENDING passes



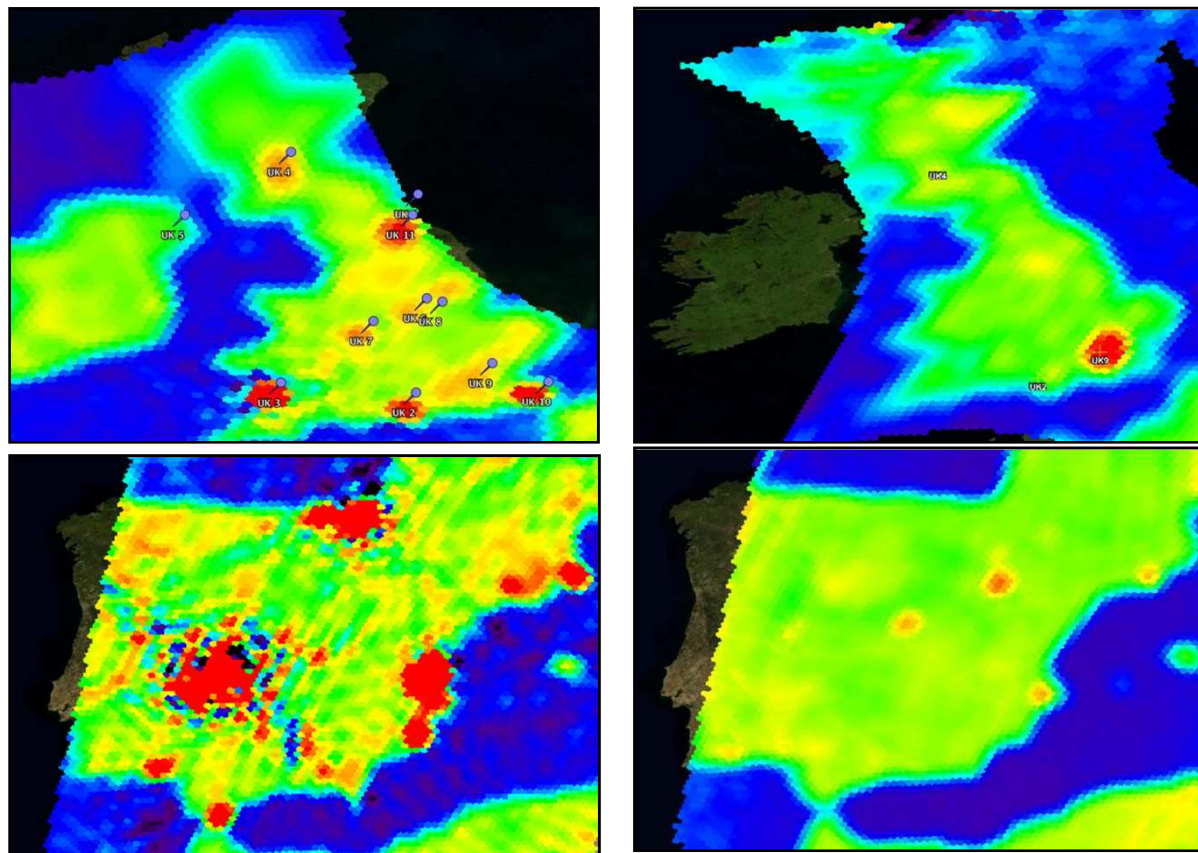
**After Launch (early 2010)**

Probability of sustained hard RFI occurrences (no outliers detection) for 20110801T001817\_20110831T150530 Period (881 half orbits) from BB post-processing of DPGS (OPER) SML2 UDP & DAP - DESCENDING only passes - Dual & Full polarizations products



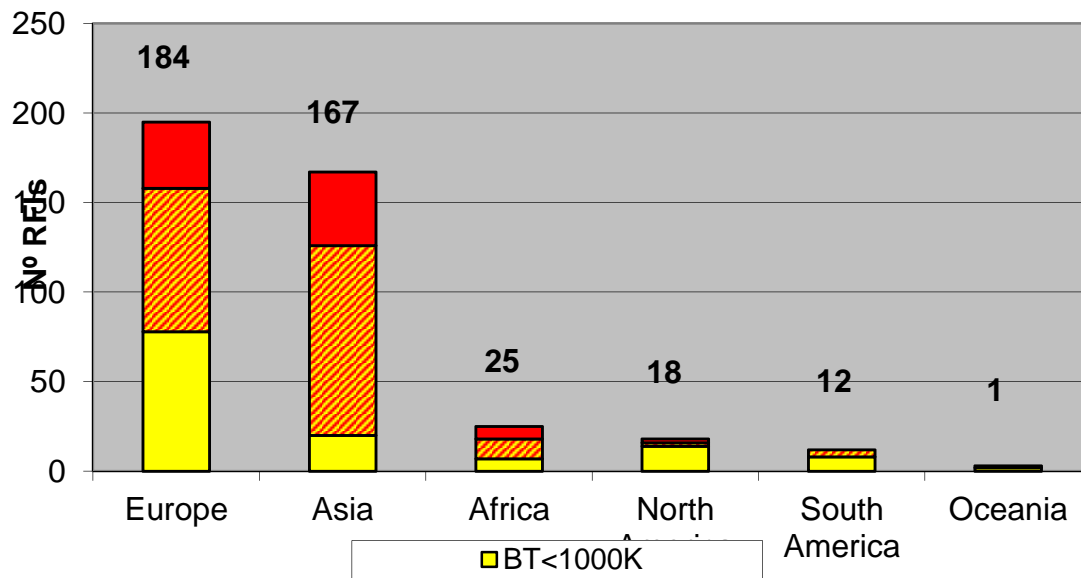
**August 2011**

# Some examples of RFI SMOS removal

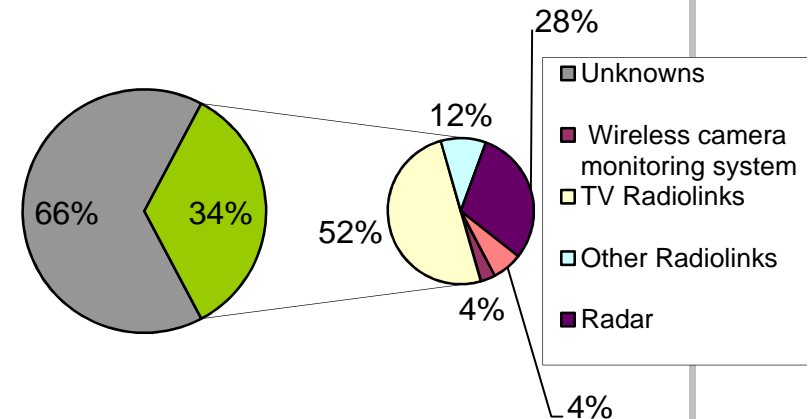


# Distribution and characteristics of RFI in the World

**SMOS RFI in the world by November 2011:  
Distribution of detected sources per continent,**

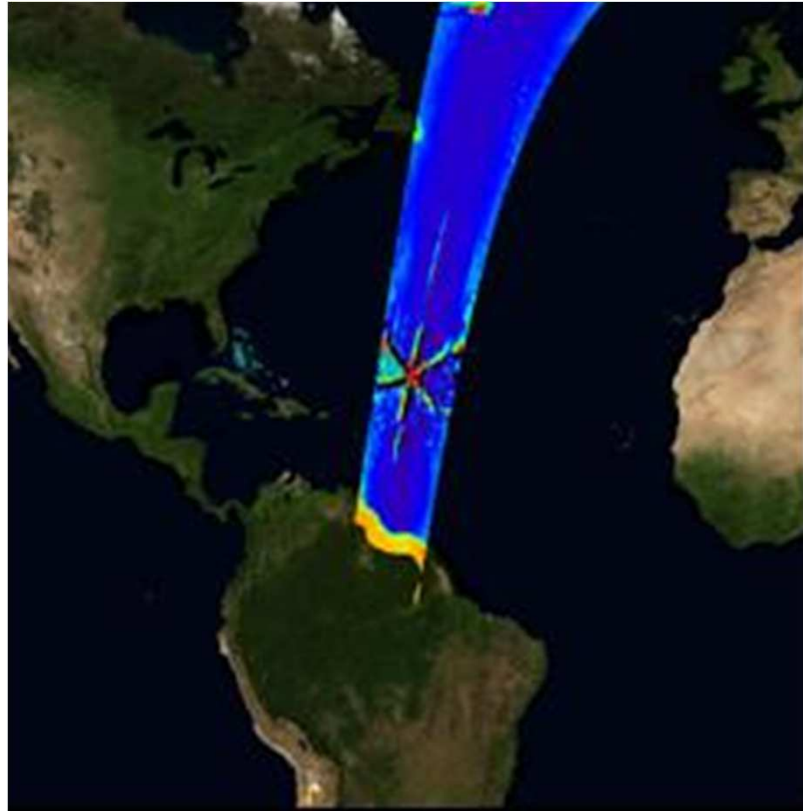


**SMOS RFI Sources Type  
(switched OFF) in Nov. 2011**



**The RFI's number in Europe is the largest in this plot, because new RFI's are discovered once one strong source is switched Off.**

# Continental regions are not the only ones affected by RFI



## Effect of RFI over Oceans:

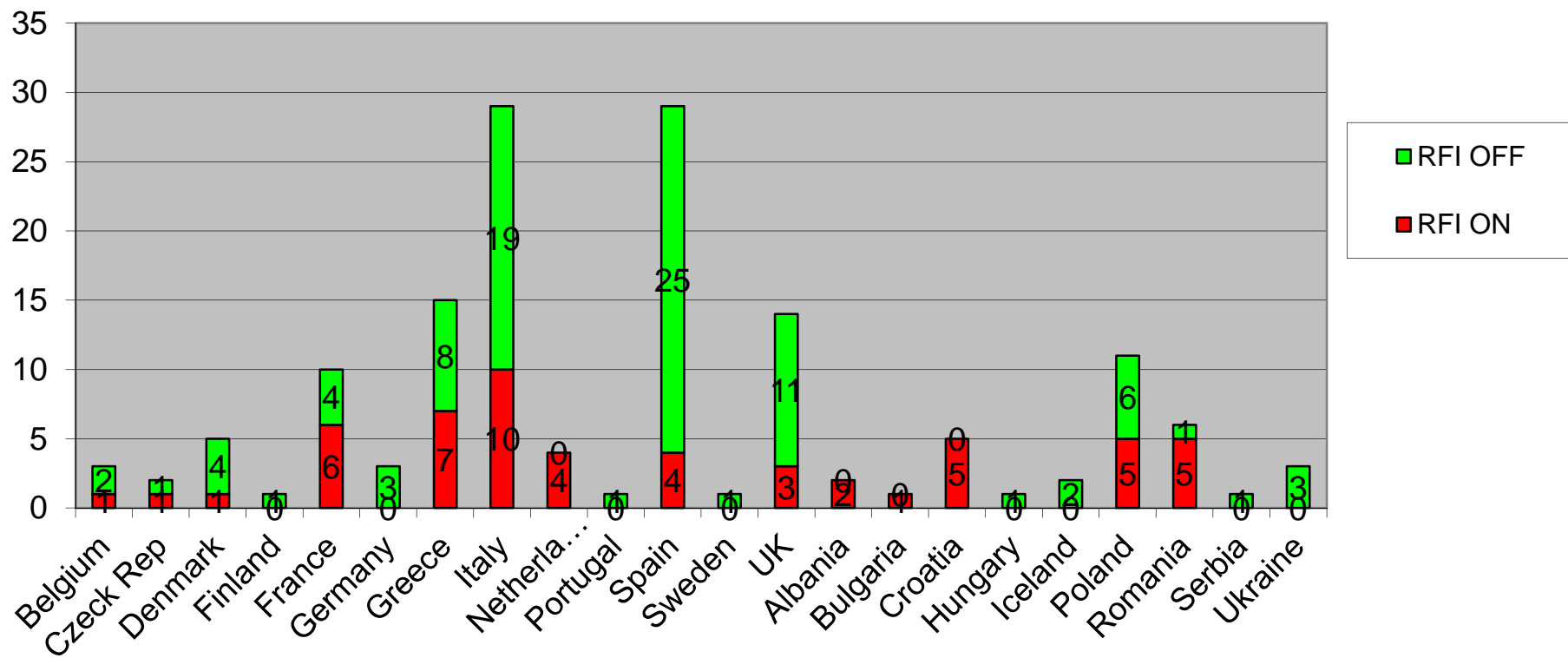
- Due to terrestrial RFIs that can affect larger areas, including of course neighbouring oceans

## And also

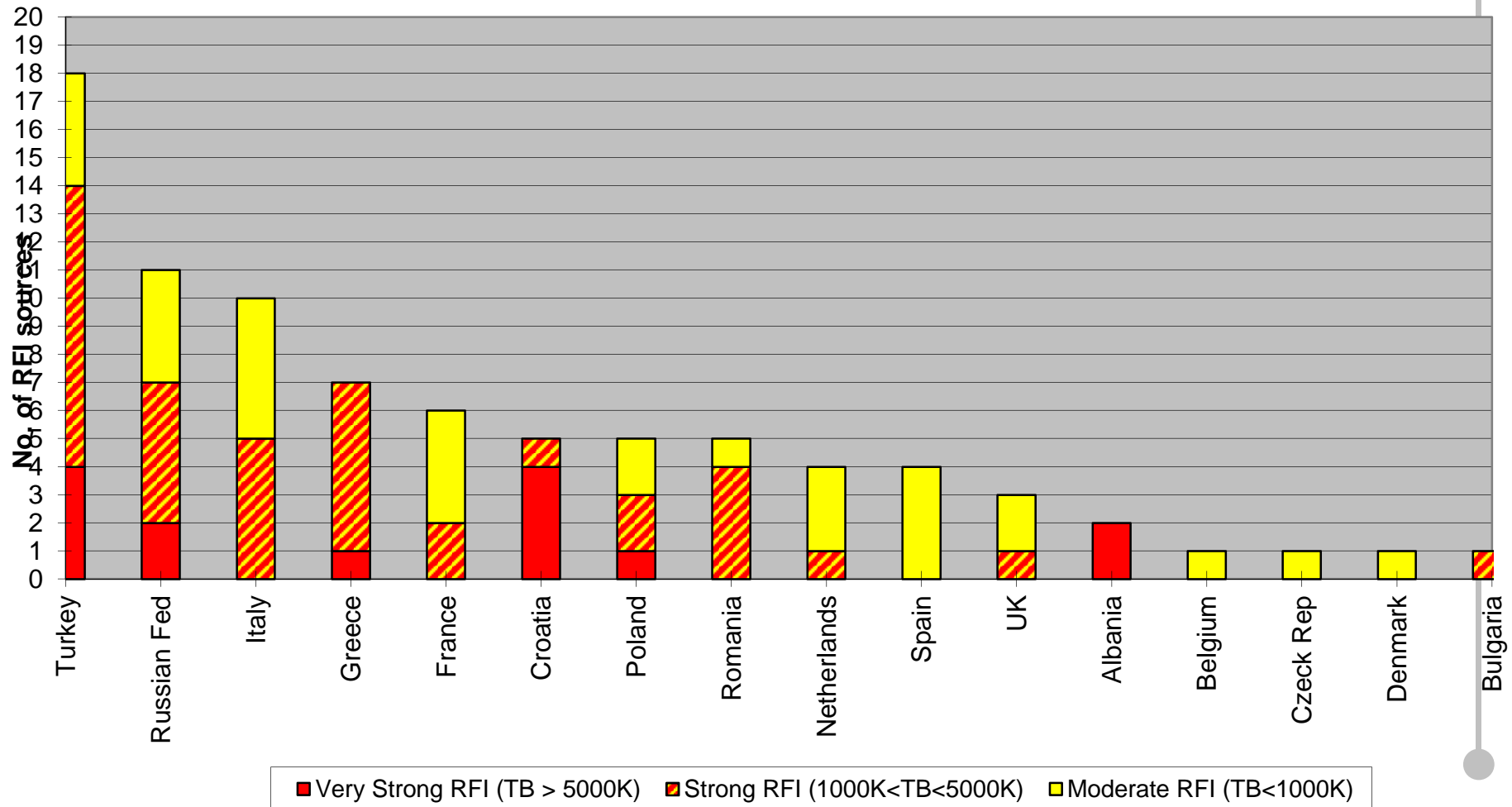
- Due to **RFI emitters on board certain ships have been observed to emit in the protected band.**



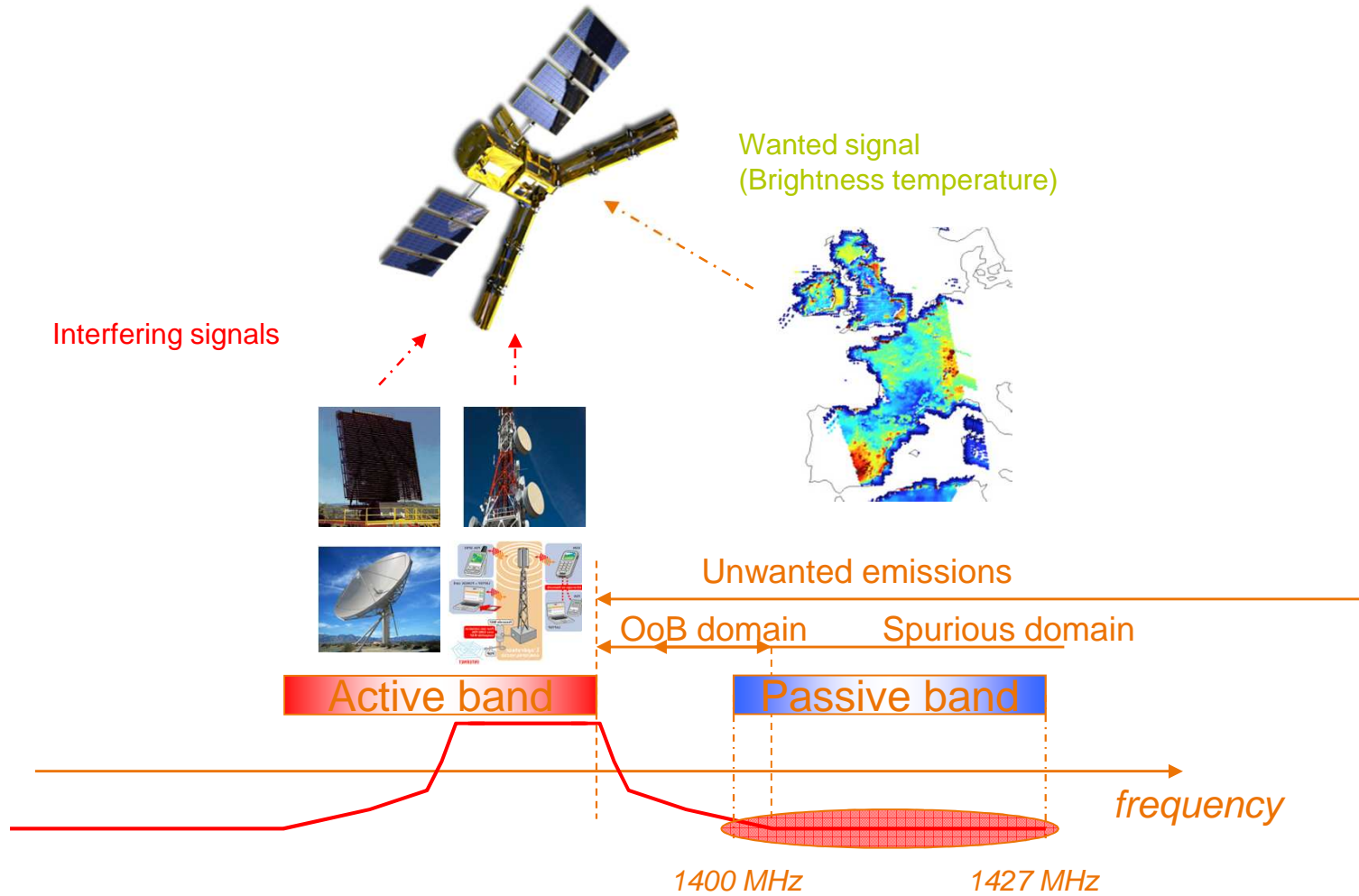
# RFI situation in Europe (Nov. 2011)



### SMOS RFI in Europe by Nov. 2011: Distribution of sources per country, with indication of the interference strength



# INTERNATIONAL REGULATION ISSUE



# ITU-R and CEPT REGULATIONS

## 1. ITU-R

**RESOLUTION 750 (WRC 2007)** Compatibility between the Earth exploration-satellite service (passive) and relevant active services ..../..

2 to urge administrations to take all reasonable steps to ensure that unwanted emissions of active service stations in the bands and services listed in Table 1-2 below do not exceed the recommended maximum levels contained in that table, noting that EESS (passive) sensors provide worldwide measurements that benefit all countries, even if these sensors are not operated by their country

Band 1400-1427 MHz : adoption of recommended limits for : Radiolocation, Fixed, Mobile, Space Operation

## 2. European level (CEPT)

There is no mechanism for adopting any compulsory limit or regulation. However, ECC adopted decision ECC(11)01 deciding ..../..

***2 that the unwanted emissions limits detailed in the Annex shall apply to stations in the active services operating in CEPT countries in the 1350-1400 MHz and 1427-1452 MHz bands brought into use after the date mentioned in Decides 4;***

Although this initiative is unlikely to have an immediate effect on the currently flying satellite SMOS, the expected provisions will be beneficial on the long term.



The **RFI sources observed by SMOS** satellite can be grouped in two main categories :  
illegal in-band emissions inside the protected band  
excessive unwanted emissions from systems operating in the adjacent bands

REPORT ITU-R RS.2165 : **Identification of degradation due to interference and characterization of possible interference mitigation techniques for passive sensors operating in the Earth exploration-satellite service (passive)**

**Three categories of RFI** received by a passive sensor

**High levels of RFI** that are **obviously inconsistent with natural radiation**. As such, these can be detected, but the corresponding measurements are lost.

**Very low levels of RFI below protection criteria**: cannot be detected by on-board passive sensors, and hence do not have impact on the output products.

**Low levels of RFI that cannot be discriminated from natural radiations**: represent very serious problem since degraded data would be seen as valid.

**Mitigation techniques** ( i.e. digital techniques like RFI cancellation, ways of extending dynamic range, statistical analysis and other high performance filtering) **are not operationally implemented**: are not a substitute for exclusive or shared allocated passive spectrum for development and enforcement of regulations.

Even if it were possible to detect and mitigate RFI, it would result in a degradation of the corresponding output products.

**18.6-18.8 GHz: EESS(passive) shared with FIXED and FIXED SATELLITE.** Footnotes in the Radio Regulations limit the emitted powers of these radio services.

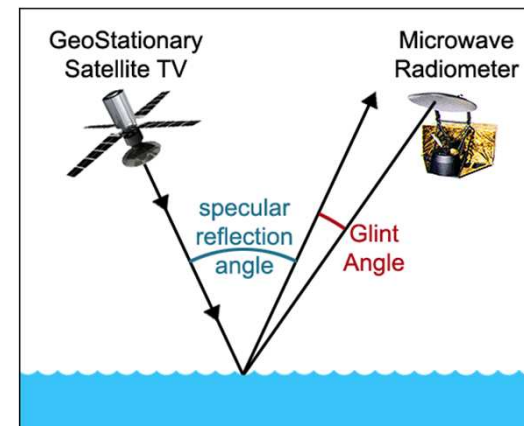
18.6-18.8 GHz: critical resource for EESS that supports many operational environmental products, such as snow cover, sea surface wind speed, and soil moisture measurements.

Evidence of RFI has been found in many 18 GHz passive space-base observations (AMSR-E, Windsat, ..) (AMSR2, GCOM to follow).

RFIs are identified as one of the fastest growing source of errors in measurements of microwave Sea Surface Temperature (SST) and wind speeds. The RFI impact on water vapour, cloud liquid water and rain rate is less, but still growing. The RFI errors are caused by two main sources:

**1. Media broadcasting activities (including television and radio) from commercial satellites in geostationary orbits.**

**2. Ground-based instrumentation in the microwave range**



## EESS and RR 5.340

### RESOLUTION 673 (Rev WRC-12): **The importance of Earth observation radiocommunication application:**

to recognize that the use of spectrum by Earth observation applications has a considerable societal and economic value

to urge administrations to take into account Earth observation radio-frequency requirements and in particular protection of the Earth observation systems in the related frequency bands

**REPORT ITU-R RS.2178: The essential role and global importance of radio spectrum use for Earth observations and for related applications.**

**RADIO SPECTRUM POLICY GROUP REPORT AND OPINION ON a Coordinated EU spectrum Approach for Scientific Use of Radio Spectrum (*RSPG Report and Opinion # 6, October 2006, European Union*).**

**The RSPG considers that these (exclusive passive allocations) represent essential natural resources and urges Member States to respect their obligations under No. 5.340 of the Radio Regulations, which prohibits all emissions in the corresponding frequency bands. The RSPG recommends the EC, when preparing appropriate measures on spectrum, to support the needs of the scientific services in these particular bands.**

Earth observation activities are based on the **increased and essential importance of passive microwave sensing**. Satellite operations in passive bands without degradation due to radio-frequency interference (RFI) is essential. The **passive frequency bands, which have been chosen on purpose**, are well defined in the Radio regulations.

**Removal of interference is one of the priorities of ITU-R (constitution).**

**SMOS: very good example of the impact of active services on passive passives (*not to be done*): illegal in band emissions, unwanted emissions.**

**RSPG (EU) report: the respect of 5.340 bands should be highlighted.**

**Importance of having feedback of the ITWG community to know whether RFI are growing in some bands in order to get regulatory adequate action: ITU-R, CEPT.**