1st RadioNet3 ERATec Forum on Radio Interference in Large Bandwidth Observations, MPIfR, Bonn, 8-12 April, 2013

International Radio Astronomical Spectrum Management Representation

Pietro Bolli
INAF – Astronomical Observatory of Cagliari

SRT SARDINIA RADIO TELESCOPE

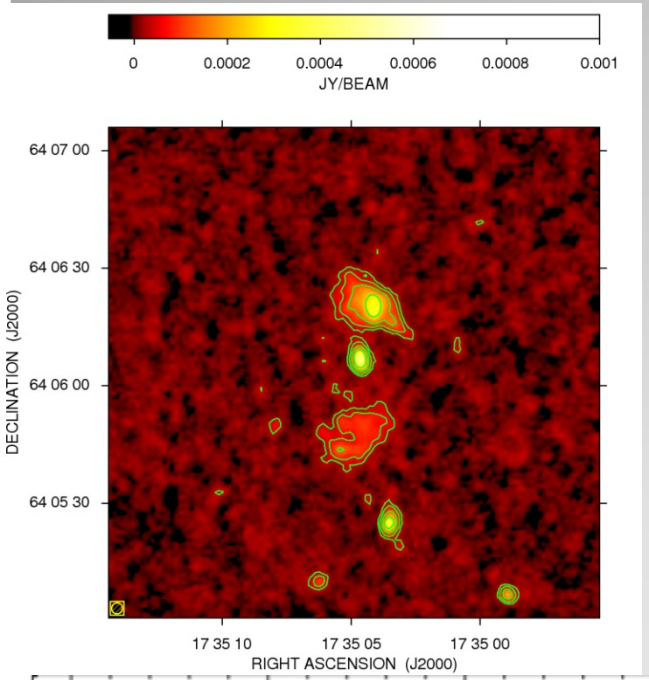
INAF OAC

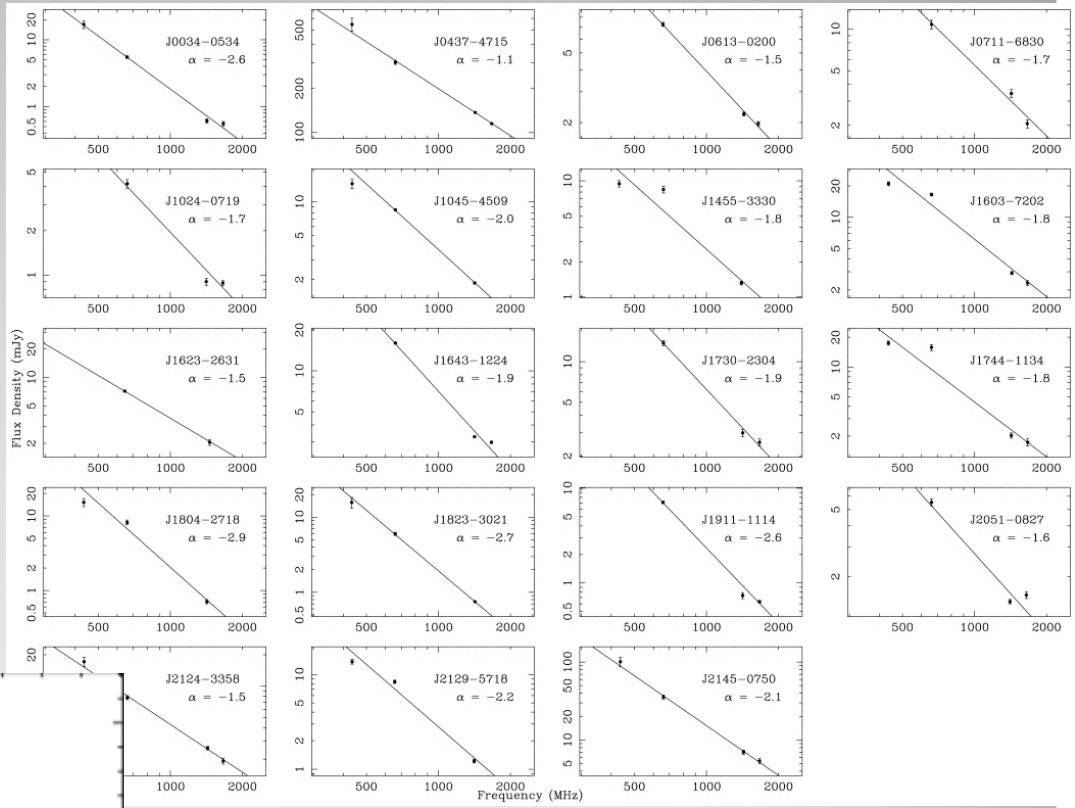
CRAF Committee on Radio Astronomy Frequencies

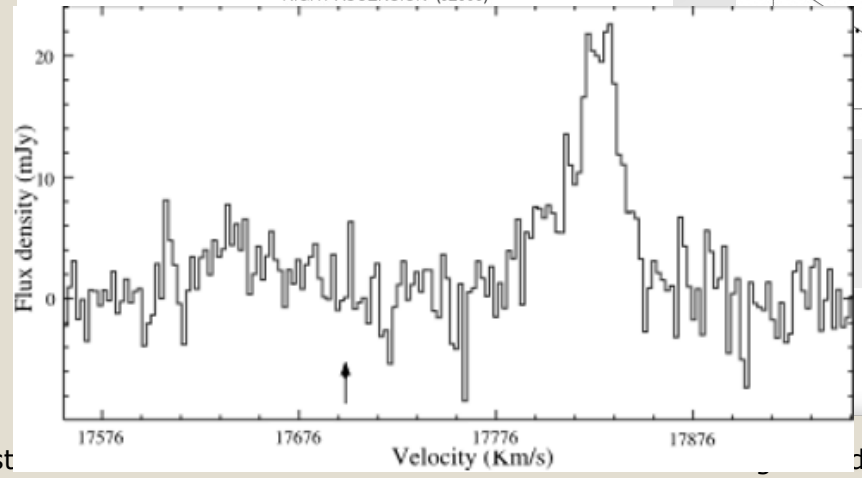
Agenda

- Peculiarities of radio astronomical signals
- Active and passive services
- Frequency bands allocated to RAS
- Committee on Radio Astronomy Frequencies
- Radio spectrum management
- Recent ECC decisions in favour of RAS

Radio astronomical sources

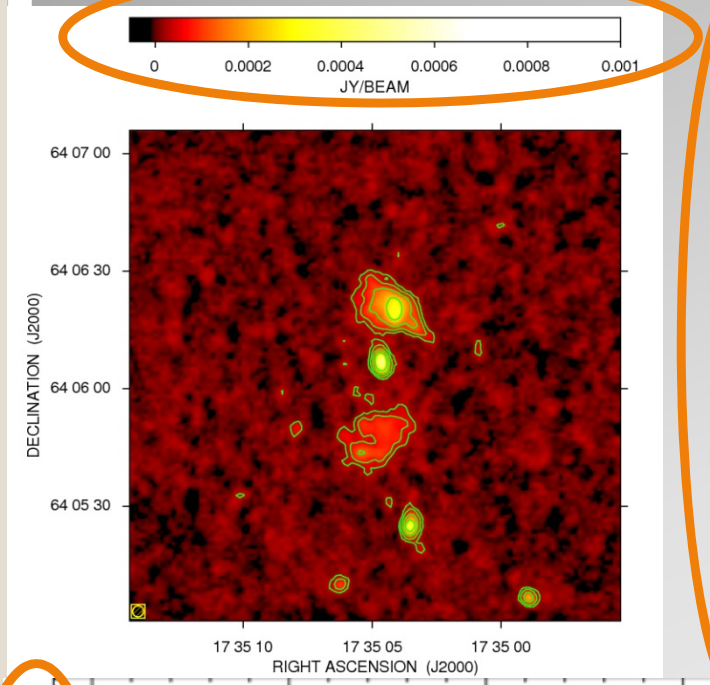


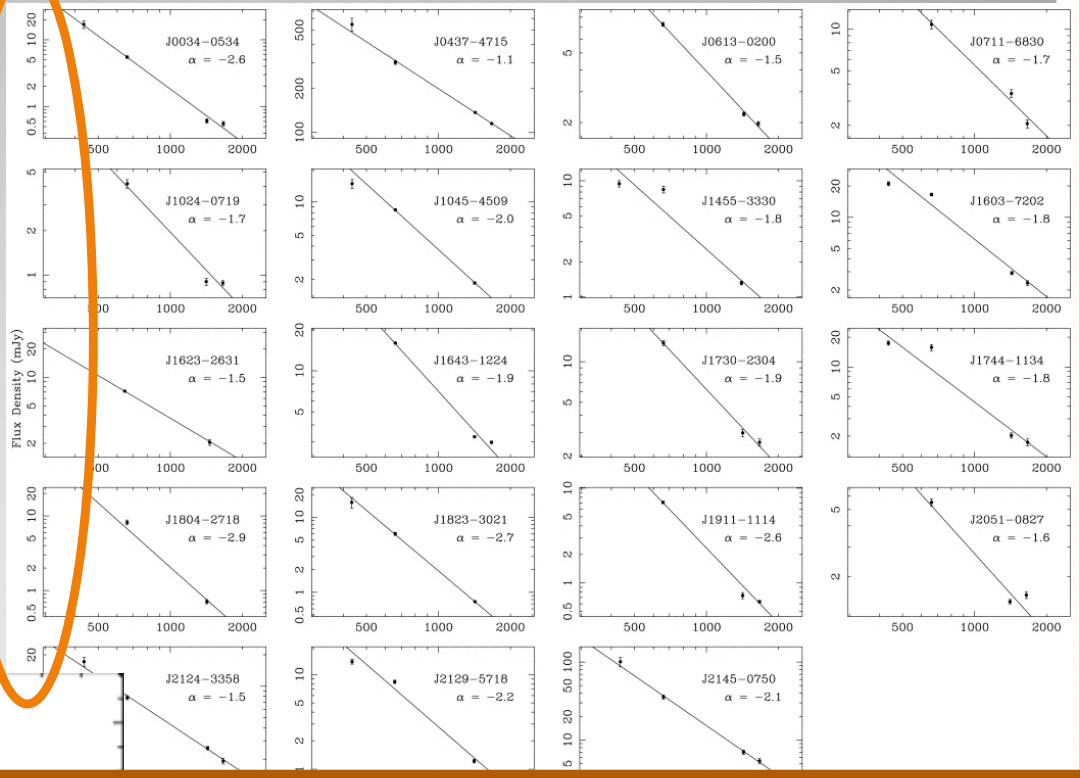


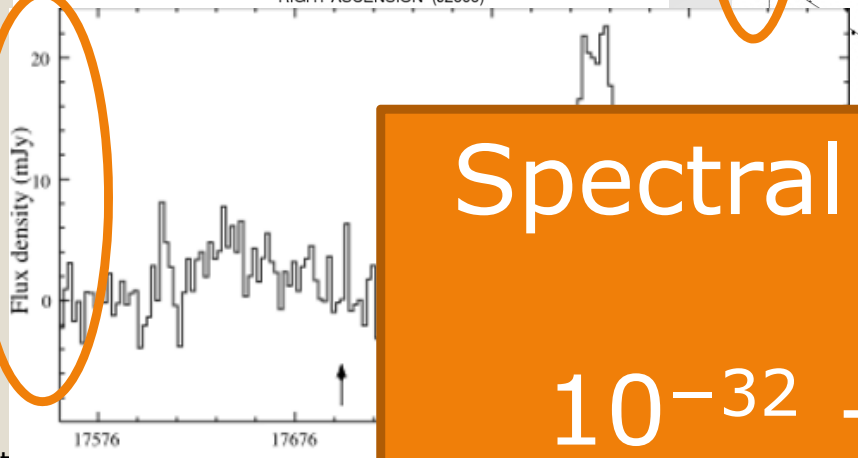


Murgia, et al. 2012, A&A, 548, A75
Tarchi et al. 2003, A&A, 407, L33
Toscano et al. 1998

Radio astronomical sources







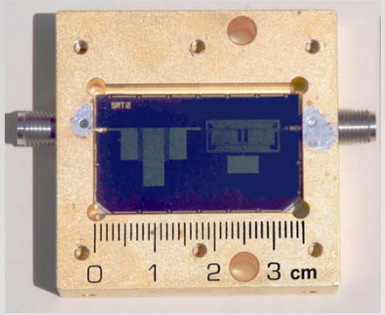
Spectral Power Flux Density

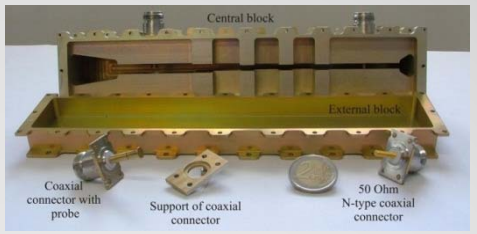
μJy ÷ mJy

10^{-32} ÷ 10^{-29} W/(m²Hz)

How can radio astronomers make it possible … today?

Large collecting areas





Cryo-cooled, low-noise, multi-beam front end

Powerful analog and digital back-end

How can radio astronomers make it possible ... ~~today?~~ and tomorrow?

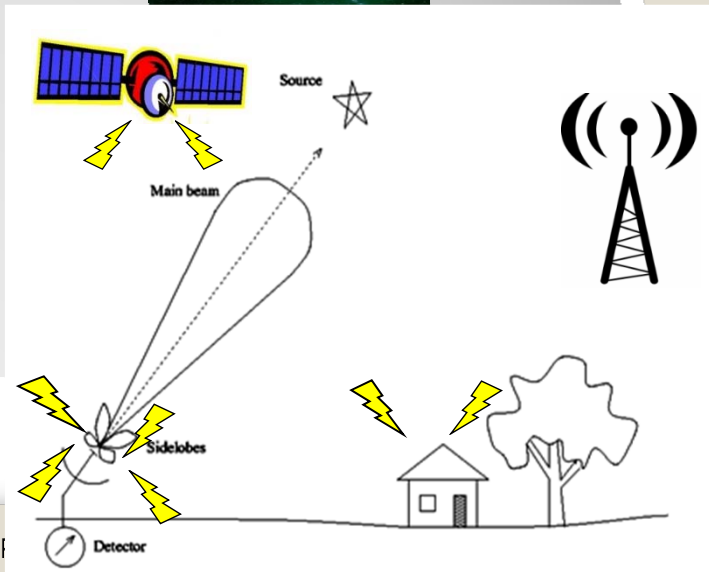
Cryo-cooled

Powerful analog and digital back-end

Radio Frequency Interference

Artificial and natural signals

- **Interference.** Passive service does not cause interference to other users of the radio spectrum.
- **Amplitude.** Radio astronomy observations can achieve microjansky sensitivity equivalent up to 15 orders of magnitude lower than sesnisitivity of active services.
- **Frequency.** Choice of frequencies is constrained by physical laws governing emission process.
- **Location.** Remote transmitter characteristics and location outside our control.



Artificial and natural signals

- **Interfere** Pass
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- **Lo**
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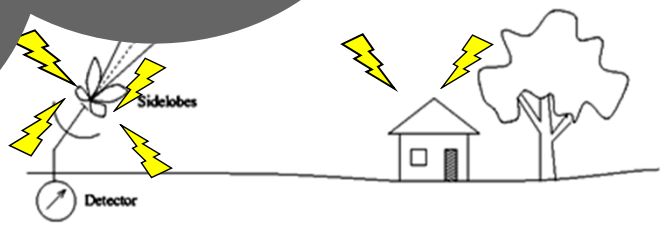
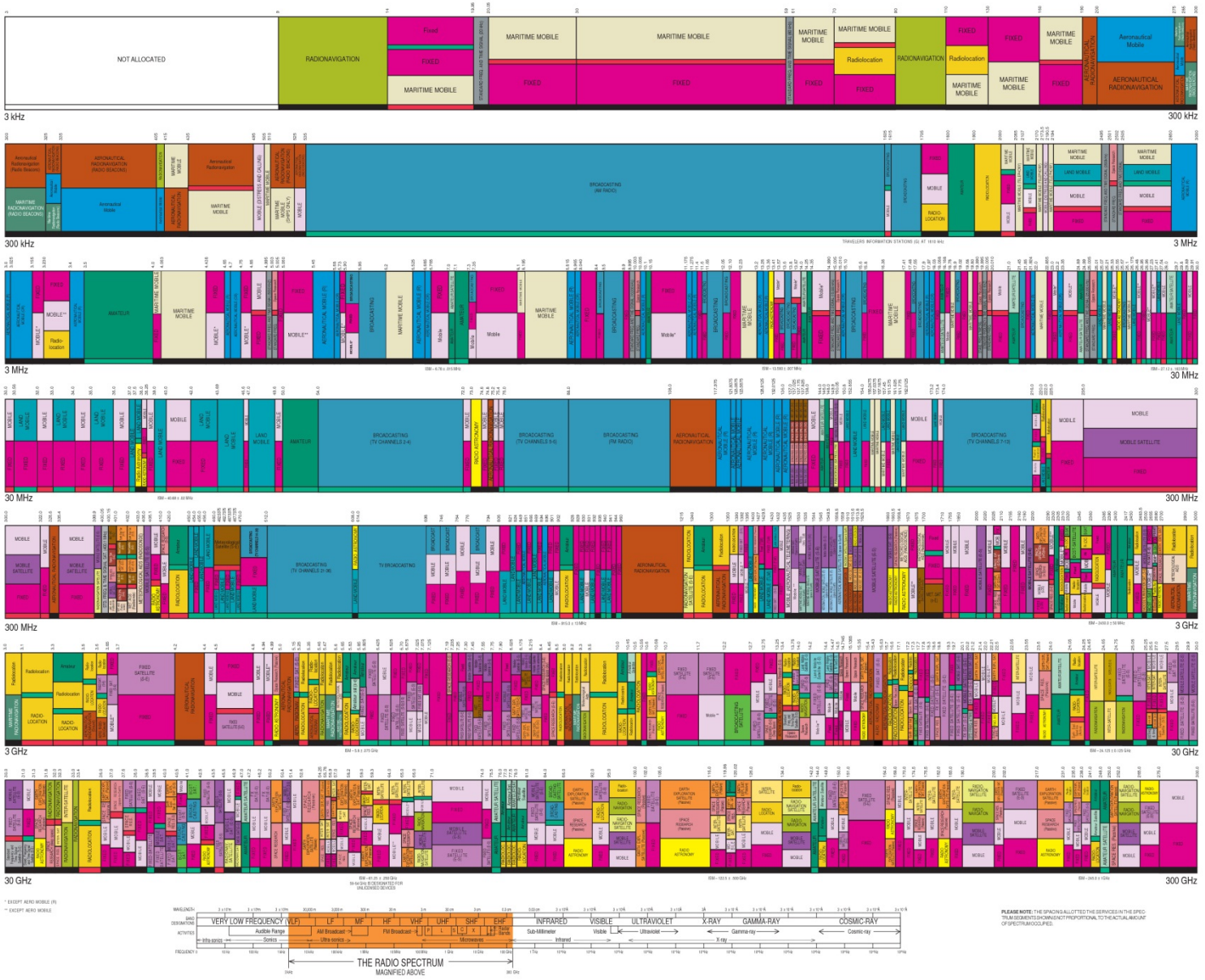
Radio spectrum is now a valuable source of revenue for governments and industry

- 3G auction (2000): £22.47bn
- 4G auction (2012): £2.34bn
- Iridium Next: 2b$
- Automobile SRR: >100M€ (est.)
- License-free UWB: >100M€ (est.)



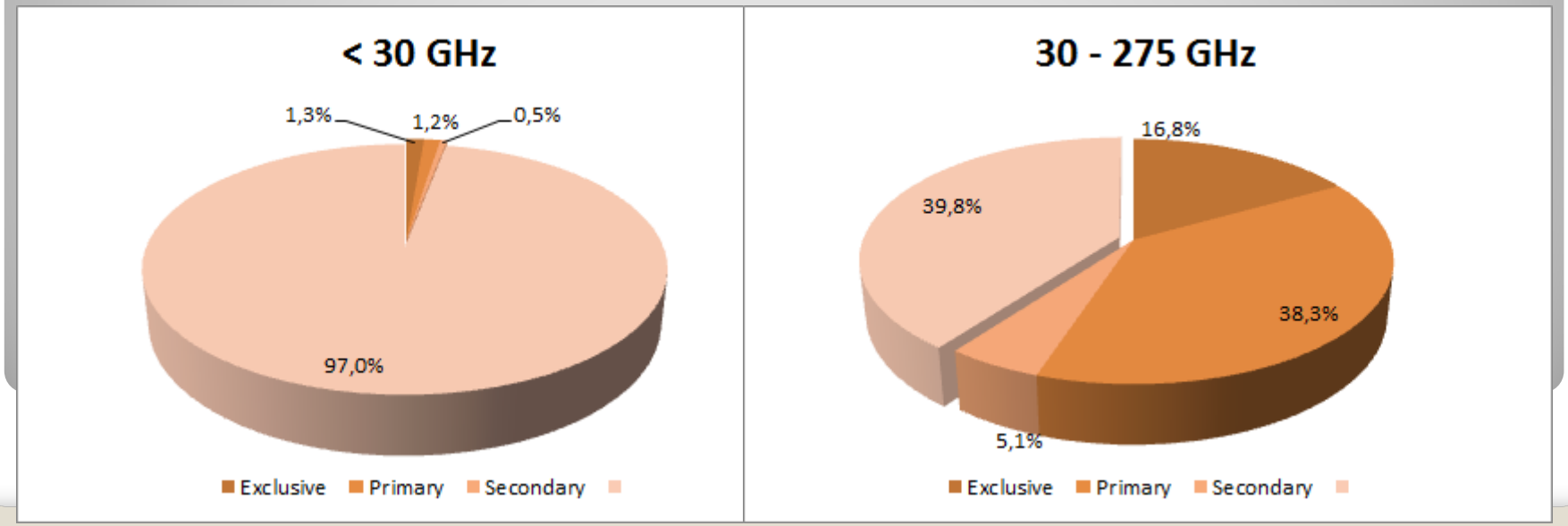
UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

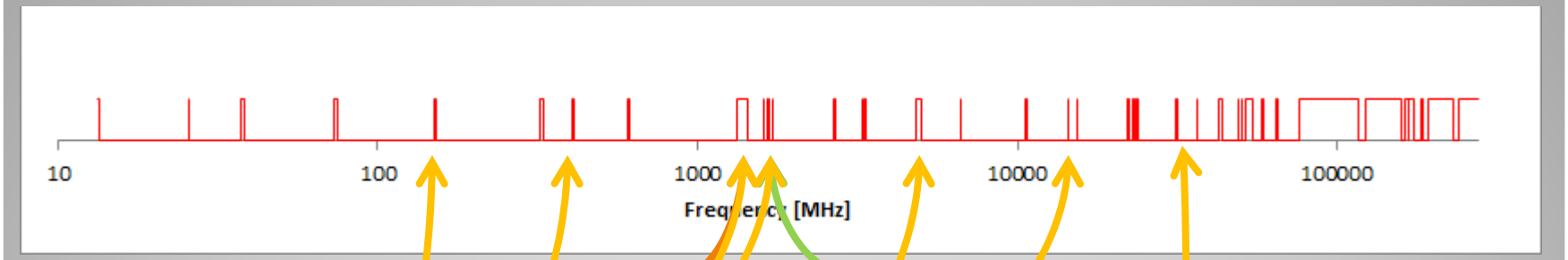


Different allocations status

- **Primary allocations** give legal protection from interference
- **Secondary allocations** do not give protection from primary users in the same band
- Foootnotes draw the attention to the use of a specific band by RAS: **Exclusive passive bands** (n. 5.340 RR) «all emissions are prohibited»



Frequency bands allocated to RAS



1400-1427 MHz
21-cm neutral atomic hydrogen line and for continuum observations.

1610.6 -1613.8
1660 -1670
1718.8 -1722.2 MHz
Astrochemistry with OH line.

322-328.6 / 608-614 / 1400-1427 / 1660-1670 / 4990-5000 / 8400-8500 / 22210-22500 / 42500-43500 MHz.
VLBI

Radio spectrum management

Radio spectrum management is aimed to **coordinate** the vast and growing range of radiocommunication services and to **harmonize** at international level the radio-frequency spectrum.

The allocation of frequency spectrum resources is the **sovereign right** of national governments. But radio waves do not respect national borders ➔ **international regulations** are required!

Radio Regulations are carried on within ITU (agency of the United Nations) and CEPT (administers radio spectrum in Europe).

European Conference of Postal and Telecommunications Administrations

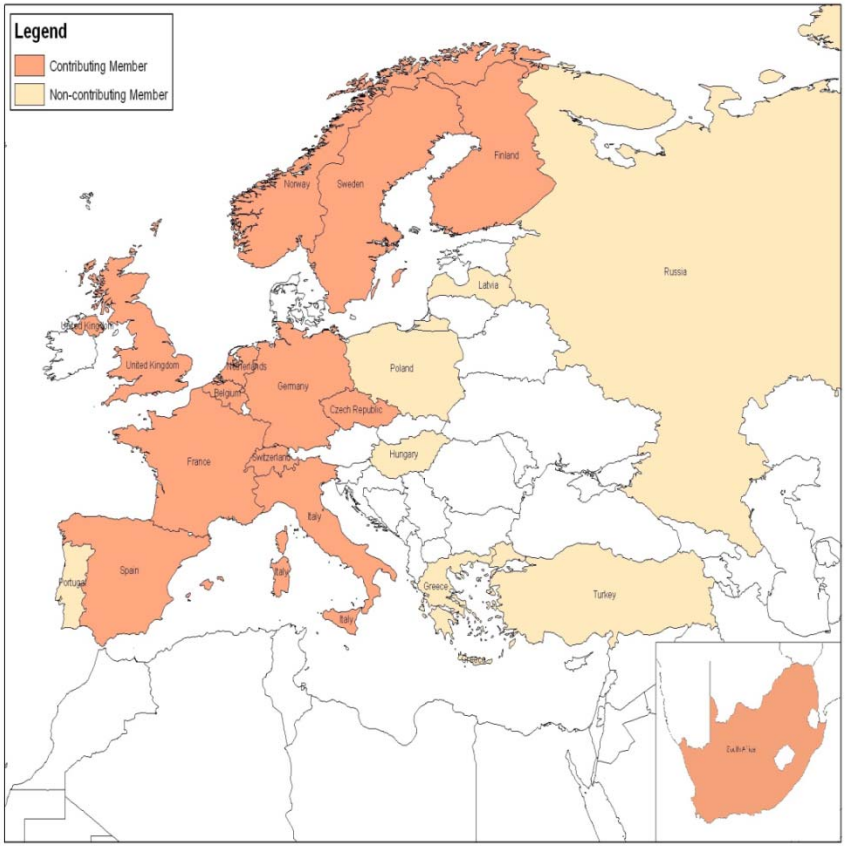
- 48 European countries cooperating to regulate posts, radio spectrum and communications networks

International Telecommunication Union

CRAF represents RAS in ITU Region 1 which includes all CEPT countries
IUCAF
CORF - RAFCAP

CRAF Member Organizations

CRAF was established in 1988 and it acts as an ESF Expert Committee.



20 Member Countries (incl. Russia, Ukraine, Turkey and South Africa) + 4 International organizations: ESA, EISCAT, IRAM and IVS

Funding by MoU: 130 kEuro (+ 10 kEuro from Radionet)

CRAF Chairman: Hans van der Marel

CRAF Frequency Manager: vacant

FP7 Radionet WP7 (RA Spectrum Management) leader: Michael Lindqvist

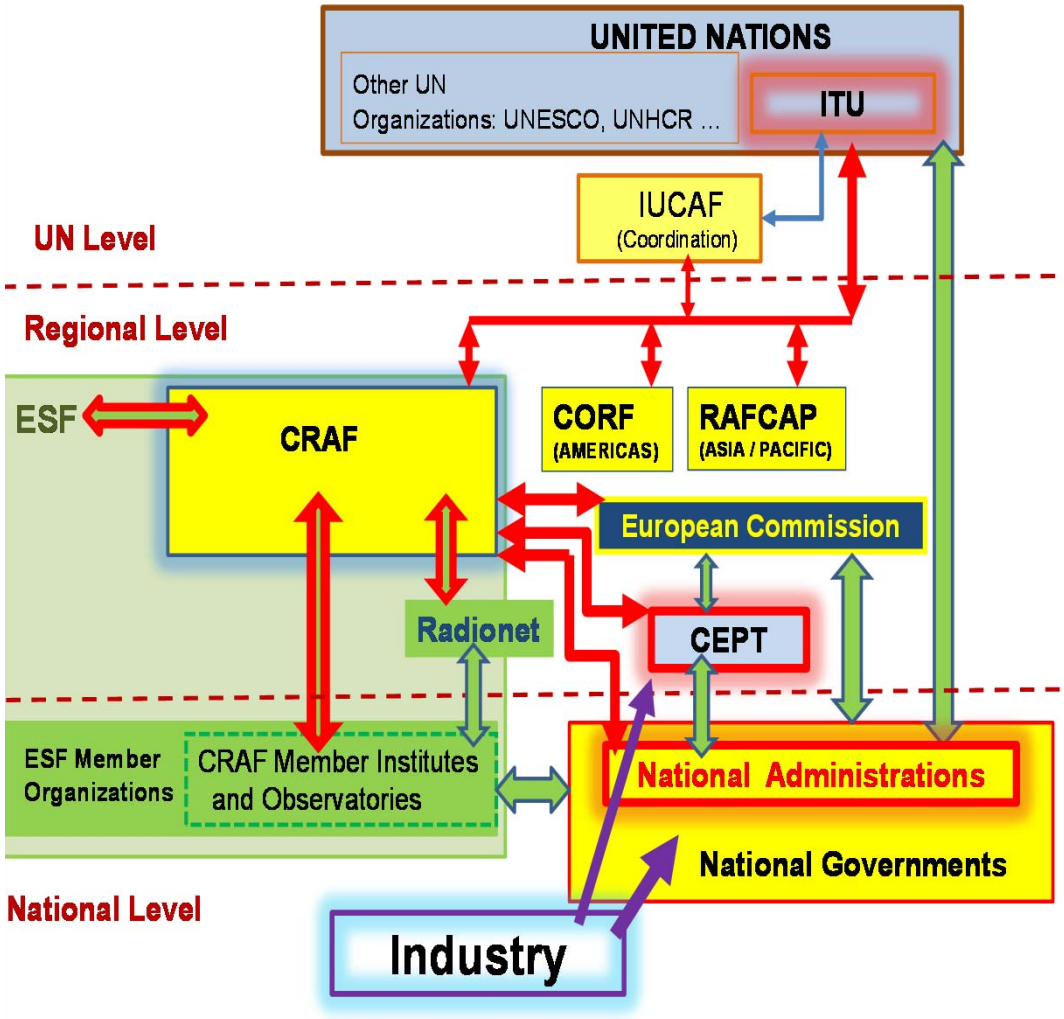
CRAF mission

- to **keep** the frequency bands used for RA observations free from interference;
- to **argue** the scientific needs of the European research community for continued access to and availability of the radio spectrum for RA;
- to **support** related science communities in their needs concerning interference-free radio frequency bands for passive use.

CRAF skills

- Radio astronomy: aims, scope and observational methods
- Radio propagation, radio engineering and technology
- Negotiation, frequency management, administrative procedures and structures

Three Layers of Decision Making



UN: CRAF is a recognized **Sector Member** of the ITU Radiocommunication Sector

EU: CRAF has **observer status** in CEPT (CRAF is recognized by LoU with the CEPT) and participates in ECC meetings

National: CRAF members are consulted by their administrations

World Radio Conference

Geneva on 23 Jan.– 17 Feb. '12 Geneva on 2 - 27 Nov. 2015

13 AIs out of 30 concern RAS. CRAF has prepared a WRC-15 position document which has been accepted by CEPT.

AI 1.17	***to consider possible spectrum requirements and regulatory actions, including appropriate aeronautical allocations, to support wireless avionics intra-communications (WAIC), in accordance with Resolution 423 [COM6/22] (WRC-12);***

Comments

The RAS bands that may potentially be affected are given in the following table.

Frequency Band		RAS Status	FN	RAS Utilization
2655-2690	MHz	sec	5.149	Continuum observations, VLBI
2690 – 2700	**MHz**	**PRI**	**5.340**	Continuum observations, VLBI
4990-5000	MHz	PRI	5.149	Continuum observations, VLBI
5000-5030	MHz	sec		Continuum observations, VLBI
15.35-15.4	**GHz**	**PRI**	**5.340**	Continuum observations, VLBI

Unwanted emissions from WAIC systems may significantly affect RAS use in these bands owing to the acknowledged susceptibility of the RAS to airborne sources of interference. To ensure adequate protection, all RAS bands that might be affected should not be subjected to interference levels from the emissions of WAIC systems that exceed those specified in Recommendation ITU-R RA.769-2.

CRAF Position

CRAF supports the protection of existing radio astronomy allocations. No new allocations for WAIC systems should be made unless acceptable compatibility criteria are established and included in subsequent regulations.

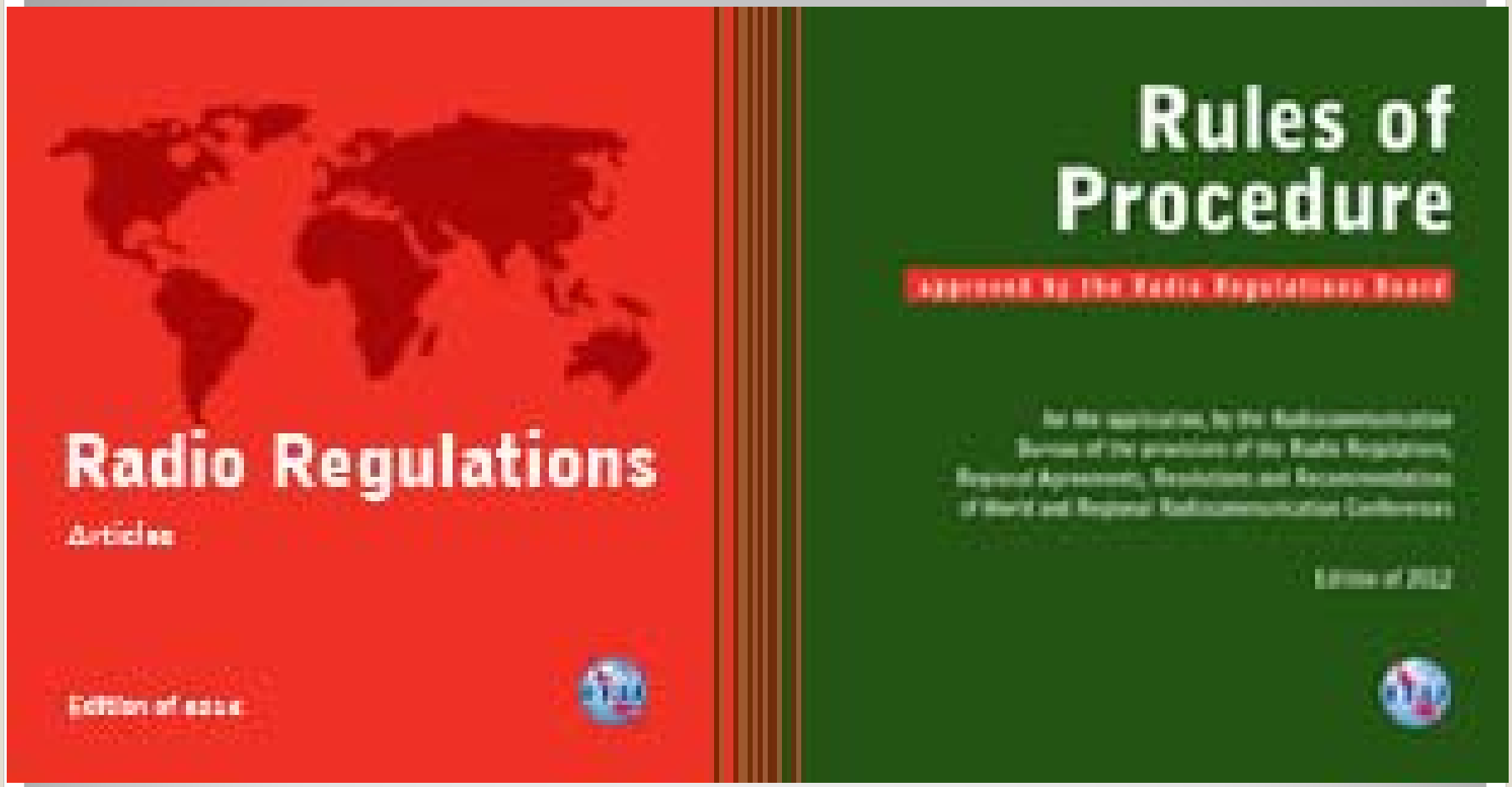
Outcome for CRAF

n. 6 AIs: Satisfactory

n. 2 AIs: Unsatisfactory (AI 1.3 & 1.21)

n. 1 AI: Acceptable

ITU-R Recommendations RA series



ITU-R Recommendations RA series

RA.314 Preferred frequency bands for radio astronomical measurements
RA.479 Protection of frequencies for radioastronomical measurements in the shielded zone of the Moon
RA.517 Protection of the radio astronomy service from transmitters operating in adjacent bands
RA.611 Protection of the radio astronomy service from spurious emissions
RA.769 Protection criteria used for radio astronomical measurements
RA.1031 Protection of the radio astronomy service in frequency bands shared with other services
RA.1237 Protection of the radio astronomy service from unwanted emissions resulting from applications of wideband digital modulation
RA.1272 Protection of radio astronomy measurements above 60 GHz from ground based interference
RA.1417 A radio-quiet zone in the vicinity of the L2 Sun-Earth Lagrange point
RA.1513 Levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the radio astronomy on a primary basis
RA.1630 Technical and operational characteristics of ground-based astronomy systems for use in sharing studies with active services between 10 THz and 1 000 THz
RA.1631 Reference radio astronomy antenna pattern to be used for compatibility analyses between non-GSO systems and radio astronomy service stations based on the epfd concept
RA.1750 Mutual planning between the Earth exploration-satellite service (active) and the radio astronomy service in the 94 GHz and 130 GHz bands
RA.1860 Preferred frequency bands for radio astronomical measurements in the range 1-3 THz

RECOMMENDATION ITU-R RA.769-2

Protection criteria used for radio astronomical measurements

(Question ITU-R 145/7)

(1992-1995-2003)

The ITU Radiocommunication Assembly,

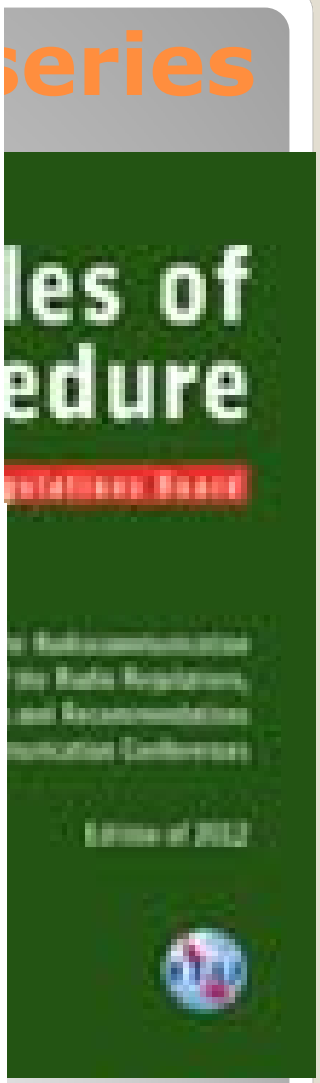
recommends

1 that radio astronomers should be encouraged to choose sites as free as possible from interference;

2 that administrations should afford all practicable protection to the frequencies and sites used by radio astronomers in their own and neighbouring countries and when planning global systems, taking due account of the levels of interference given in Annex 1;

3 that administrations, in seeking to afford protection to particular radio astronomical observations, should take all practical steps to reduce all unwanted emissions falling within the band of the frequencies to be protected for radio astronomy to the absolute minimum. Particularly those emissions from aircraft, high altitude platform stations, spacecraft and balloons;

4 that when proposing frequency allocations, administrations take into account that it is very difficult for the RAS to share frequencies with any other service in which direct line-of-sight paths from the transmitters to the observatories are involved. Above about 40 MHz sharing may be practicable with services in which the transmitters are not in direct line-of-sight of the observatories, but coordination may be necessary, particularly if the transmitters are of high power.



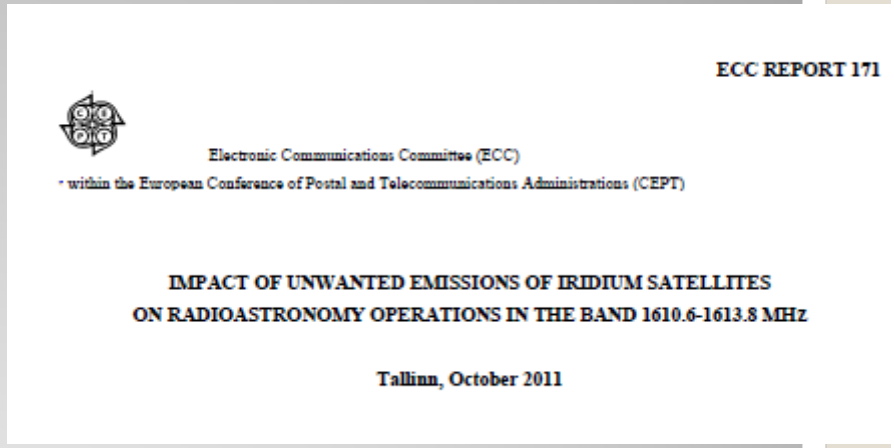
Main CEPT/ITU Groups attended by CRAF and areas of expertise

Group	Topics Covered
CPG-PTA	Science services issues within WRC-15
CPG-PTB	Satellite communications issues within WRC-15
CPG-PTC	Radiolocation issues within WRC-15
CPG-PTD	IMT issues within WRC-15
FM44	Satellite communication systems (Regulatory complement to SE40)
SE7	Compatability & sharing issues for mobile systems below 3 GHz
SE19	Issues relating to the Fixed Service
SE21	Unwanted emissions
SE24	Short range devices
SE40	Satellite communications
SE44	Broadband direct air-to-ground communications (DA2GC)
SRD-MG	SRD maintenance group (Regulatory complement to SE24)
ITU WP7D	Radio astronomy
ITU JTG 4-5-6-7	WRC-15 Agenda Items 1.1 and 1.2

Date	Meeting	Location
08-12/04/13	ITU-R WP7D	Geneva, CH
16-19/04/13	CEPT CPG-PTC	London, UK
16-18/04/13	CEPT PT FM44	Rome, IT
22-23/04/13	CEPT PT SE40	London, UK
22-24/04/13	CEPT PT SE24	Helsinki, FI
24-26/04/13	CEPT SRD-MG	Helsinki, FI
02-03/05/13	CEPT ECC-PT1	Berlin, D
02-10/05/13	ITU-R WP4A	Geneva, CH
06-08/05/13	CEPT CPG-PTD	Berlin, D
13-17/05/13	CEPT WGSE	Lugano, CH
20-24/05/13	CEPT WGFM	Amsterdam, NL

IRIDIUM 1610.6-1613.8 MHz

In 2010, CEPT decided to carry out new measurements using a spectrometer provided by RA community. Analysis of observations at the Leeheim satellite monitoring station shows that **the operation of the satellites in the Iridium network causes interference in the RA band in excess of the limits given in ITU-R RA.769-2**.



ECC REPORT 171

Electronic Communications Committee (ECC)

within the European Conference of Postal and Telecommunications Administrations (CEPT)

IMPACT OF UNWANTED EMISSIONS OF IRIDIUM SATELLITES ON RADIOASTRONOMY OPERATIONS IN THE BAND 1610.6-1613.8 MHz

Tallinn, October 2011

ECC Decision (09)02

1610.6-1613.8 MHz

o carry out new
a spectrometer

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2483.5-2500 MHz (space-to-Earth) are harmonised for use by systems of the mobile-satellite service;

2. that, prior to 1 January 2016, administrations shall consider the interference situation of the Radio Astronomy service operating below 1613.8 MHz before considering granting an authorisation for operation of mobile earth stations operating under the control of MSS systems using downlinks in the frequency band 1613.8-1626.5 MHz (space-to-Earth);

3. that CEPT administrations urge the involved parties (MSS operator and radio-astronomers) to investigate and implement appropriate technical and/or operational short term solutions to alleviate the interference situation;

4. that, after 1 January 2016, in order to protect the Radio Astronomy service in the frequency band 1610.6-1613.8 MHz, administrations shall only authorise operation of mobile earth stations under the control of MSS systems provided the following conditions are met:

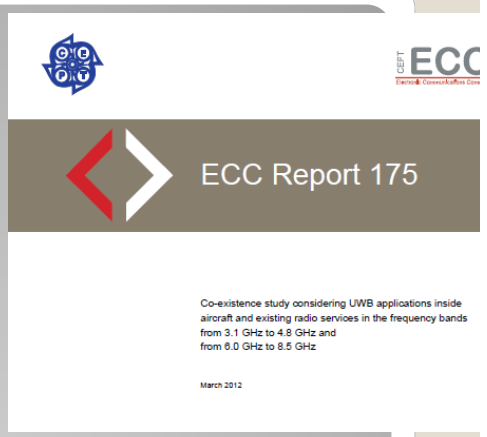
   - that in accordance with Recommendations ITU-R RA.769-2 and ITU-R RA.1513 the spfd-level at radio astronomy stations is limited to -238 dB(W/m²Hz)[2,3] and the data loss resulting from exceeding this limit is ≤ 2% in one or more 20 kHz channels within the frequency band 1610.6-1613.8 MHz at the location of the radio astronomy station from the corresponding MSS system using downlinks in the frequency band 1613.8-1626.5 MHz (space-to-Earth);

   - that the operation of mobile earth stations transmitting in the band 1610-1626.5 MHz is not allowed within a radius calculated on the basis of Figure 1 in the Annex around each radio astronomy station operating in the frequency band 1610.6-1613.8 MHz while taking due account of the shielding effects of the terrain at the relevant radio astronomy site;

5. that the compliance with the conditions for use of radio frequencies by current and future MSS systems in the band 1613.8-1626.5 MHz (space-to-Earth) and the degree of interference in the frequency band 1610.6-1613.8 MHz caused by this usage shall be monitored regularly (e.g. once a year) by a competent body and the results be reported to the ECC;

Methanol line 6.668 GHz

ECC conducted a co-existence study considering **UWB applications onboard aircraft** and existing radio services in the frequency bands from 3.1 GHz to 4.8 GHz and from 6.0 GHz to 8.5 GHz.



considering

n) that the Methanol line at 6.7 GHz discovered in 1991 is becoming a focus of radio-astronomical research;

decides

4) that the technical requirements in the annex apply to devices permitted under this ECC Decision;

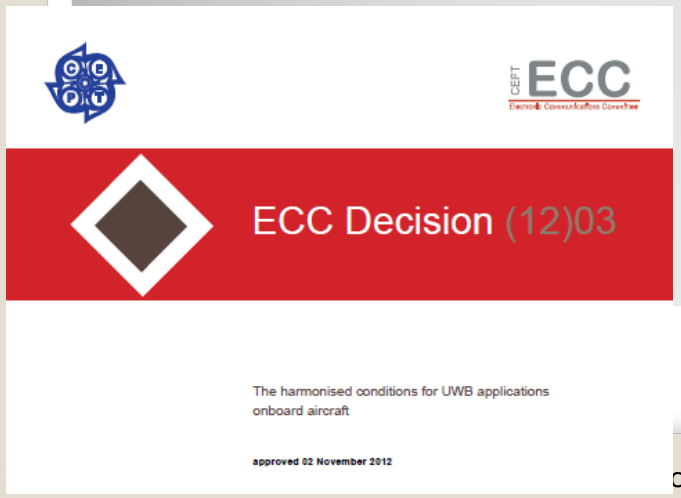


Table 1: Maximum e.i.r.p. limits

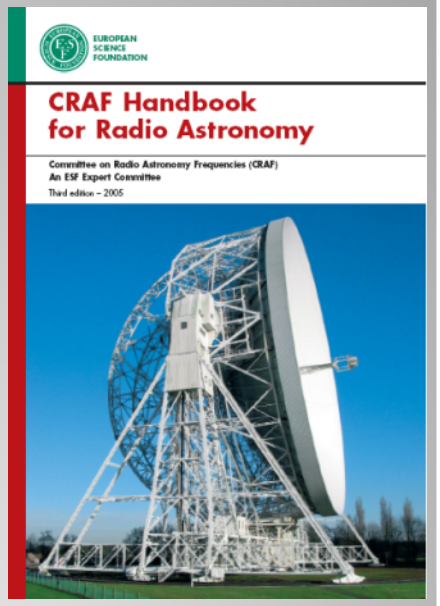
Frequency range	Maximum mean e.i.r.p. spectral density	Maximum peak e.i.r.p. (defined in 50 MHz)	Requirements for mitigation techniques
6.650 -6.6752 GHz	-62.3 dBm/MHz	-21 dBm	notch of 21 dB should be implemented to meet a level -62.3 dBm/MHz [1]
6.6752-8.5 GHz	-41.3 dBm/MHz	0 dBm	7.25-7.75 GHz (FSS and MetSat (7.45-7.55 GHz) protection)[1, 2] 7.75-7.9 GHz (MetSat protection)[1,3]
8.5 to 10.6 GHz	-65 dBm/MHz	-25 dBm	
Above 10.6 GHz	-85 dBm/MHz	-45 dBm	

[1]Alternative mitigation techniques offering equivalent protection such as the use of shielded portholes could be a solution

Summary

- Astronomers want to observe in **much wider frequency bands** than those allocated to RAS.
- **Mitigation techniques** allow to reject specific RFI, even if with some data-losses.
- **Neverthless frequency bands allocated to RAS without detectable interference for many hours of observations are still fundamental.**
- **CRAF is an expert committee** in charge to **safeguard** the continued access to the radio quiet sky; without it, the investment into past and future observatories would be lost.
- CRAF is facing **many changes in the short-term**: Chairman recently appointed, Frequency Manager vacant, new host organization to be identified, new working model under discussion.

More information on CRAF



www.craf.eu

Thanks to Axel Jessner and to Harry Smith for having served CRAF in the last years with competence, professionalism, and highly qualified analysis.

Thanks for your attention.