International Spectrum Management

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NRAO, Tucson

Spectrum Management

Radio Frequency Management Is Done by Experts Who Meld Years of Experience With a Curious Blend of Regulation, Electronics, Politics and Not a Little Bit of Larceny. They Justify Requirements, Horse-trade, Coerce, Bluff and Gamble With an Intuition That Cannot Be Taught Other Than by Long Experience

Vice Admiral Jon L. Boyes
U.S. Navy

Why does Radio Astronomy need Protection?

Radio Astronomy deals with such extremely weak signals.

• Received terrestrial communications signals are typically 10^6 to 10^{12} (i.e. 60 dB to 120 dB) stronger than the flux from cosmic sources

•Communications engineers like received signals to be 60 dB *above* the noise

• Radio astronomers typically work with signals that are 60 dB *below* the noise

• "A garage door opener on the moon would appear on the earth as the brightest radio source in the sky"

• Radio observatories are usually put in remote locations to avoid man-made interference – but this alone isn't enough protection.

• Satellite interference is the worst of all – no terrain shielding, line-of-sight propagation, can cover nearly a hemisphere of the earth, moving & multiple sources of interference, permitted levels of unwanted emission are very high.

Spectrum management is important both to Single Dishes and to Interferometers

- BUT it's more **more important to the Single Dish telescope**, because
  - Interferometers have an inherent interference suppression (fringe rate, correlation between spaced telescopes) that is denied to the Single Dish
  - There are probably fewer options for RFI mitigation strategies with a Single Dish

What protection does Radio Astronomy have?

- Inside protected RA bands, ITU recommendations and regulations apply
- Outside the protected RA bands, there is in general **no** protection. In special cases, a national administration **may** choose to give some additional protection close to a specific observatory, but this is rare – the FCC and the Green Bank ***National Radio Quiet Zone*** is the best example. Arecibo also enjoys some special treatment. However, this gives no protection from satellites …
- Outside the protected RA bands, at a given observatory the options are:
  - Attempts at coordination with potential interferers
  - Interference Mitigation techniques. (Mitigation techniques often need to be applied INSIDE protected bands too, unfortunately.)

International Protection: the ITU

The International Telecommunications Union (ITU) was originally created to standardize and regulate telegraphic communication between nations. Still concerned with standards, but (thanks in part to the Titanic disaster in 1912) also international frequency allocations and regulations: ITU-R.

- The ITU is part of the United Nations. Regulations made within the ITU have the force of an International Treaty
- The International Telecommunications Union (ITU-R) officially recognized Radio Astronomy in 1959, as a "radiocommunication service."

How the ITU works

- Part of the United Nations. Regulations have the status of an International Treaty
- 3-year cycle: WRC-2000 in Instanbul, WRC-2003 in Geneva
- Between WRCs, countries (administrations) make proposals for changes & additions to the regulations. So does IUCAF.
  - Several meetings per year, usually in Geneva.
  - Proposals that survive go to the "CPM" and then to the WRC for further discussion.
  - Specialist working groups: E.g.
    - "7" = science services
      - WP7D = Radio Astronomy
    - "4" = Fixed satellite service.
      - WP4A = "Efficient Orbit Utilization"

A short glossary of jargon:

- CORF: Committee on Radio Frequencies. Sponsored by National Academy of Sciences. Makes representations to FCC on US licensing & regulatory issues, for US scientific spectrum users.
- ITU: International Telecommunication Union. Responsible for all internationally-agreed regulations of the radio spectrum.
- IUCAF: Scientific Committee on Allocation of Frequencies for Radio Astronomy and Space Science. Represents passive services at the ITU. IUCAF is sponsored by the IAU, URSI and COSPAR.   International.

Radio Astronomy participation in the ITU process

- There are 2 routes by which radio astronomers participate:
  - As members of the ITU delegations of your national administration
  - **IUCAF**: *almost a nation*

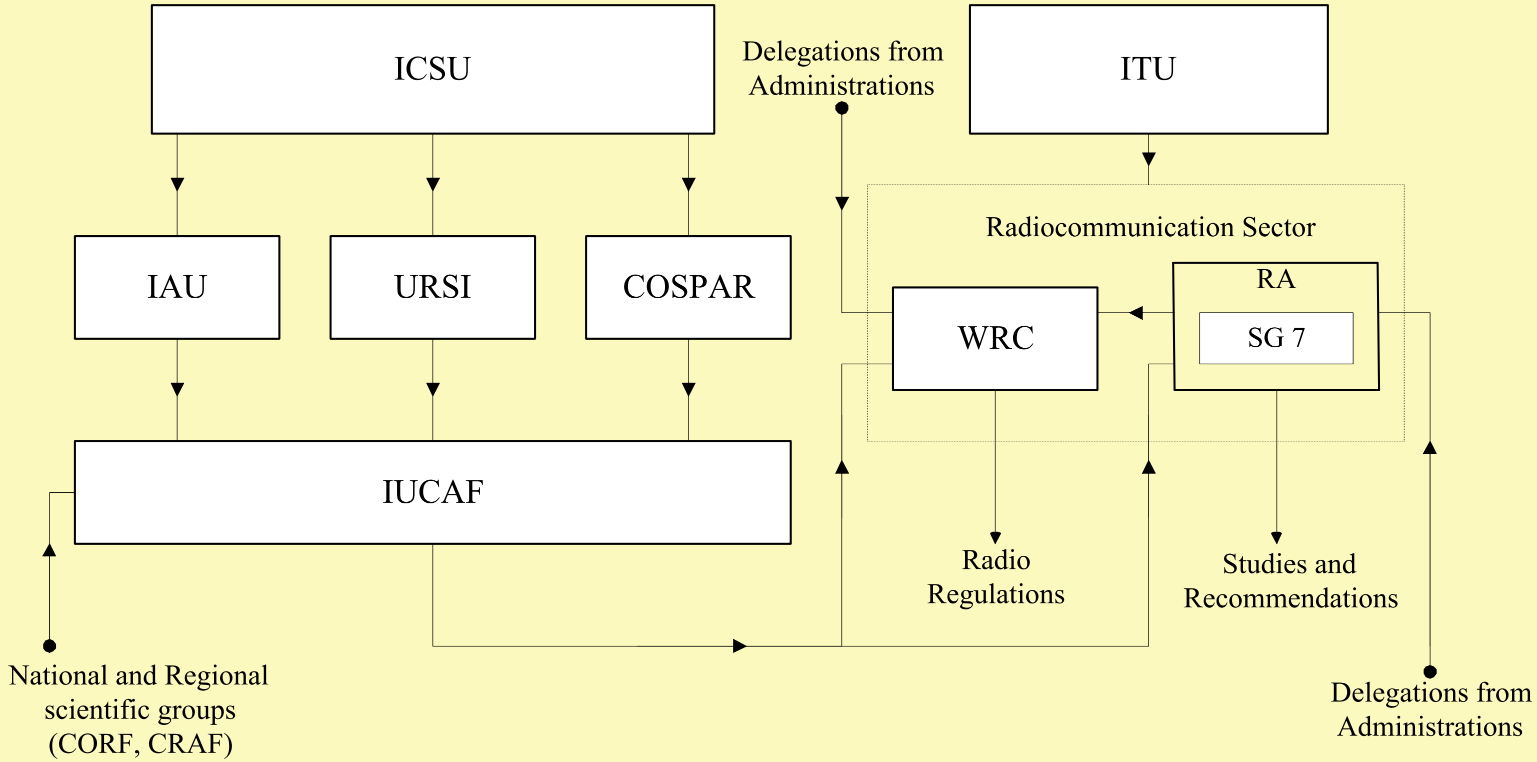
HISTORY:

In 1960 ICSU set up the Inter-Union Commission "IUCAF" to work towards keeping parts of the radio spectrum clear for passive, scientific use.

- Represents URSI, the IAU and COSPAR at the International Telecommunications Union (ITU).
- Formation was partly prompted by the potential threat from Project WEST FORD. (Needles in orbit).
- In 1961 CORF was established "to serve as the United States counterpart to IUCAF."

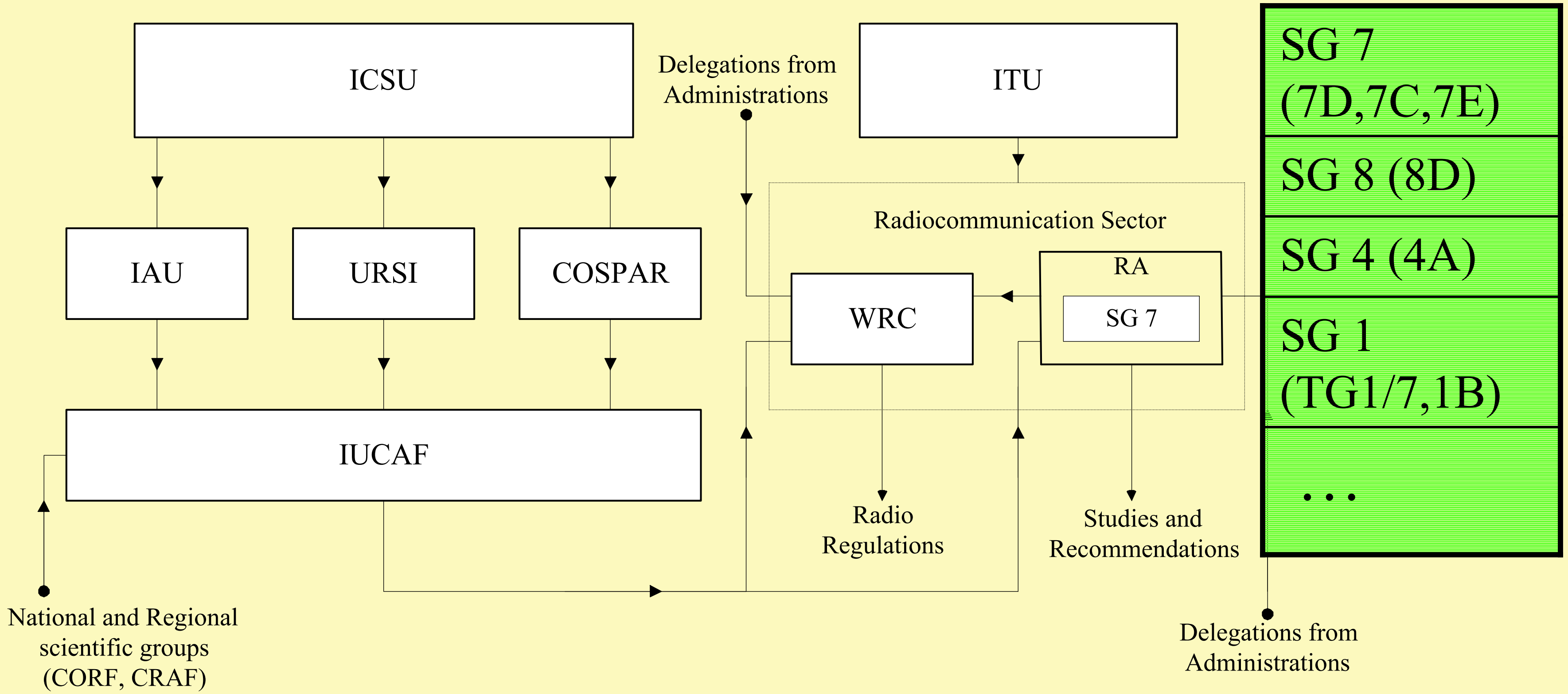
ITU working parties & task groups most relevant to Radio Astronomy:

- WP7D (Radio Astronomy)
- WP7C (Earth Exploration satellites)
- WP7E (Inter-service sharing)
- WP1B (Spectrum management methodologies)
- WP4A (Efficient orbit/spectrum utilization)
- WP8D (Mobile satellites & radiodetermination satellites)
- TG1/7 (Protection of passive services from unwanted emissions)



where (in alphabetical order):

CORF Committee on Radio Frequencies
COSPAR Committee on Space Research
CRAF Committee on Radio Astronomical Frequencies
IAU International Astronomical Union
ICSU International Council of Scientific Unions
ITU International Telecommunication Union
IUCAF Inter-Union Commission for the Allocation of Frequencies for Radio Astronomy and Space Science
RA Radiocommunication Assembly
SG 7 Radiocommunication Study Group7
URSI International Union of Radio Science
WRC World Radiocommunication Conference



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RA Radiocommunication Assembly
SG 7 Radiocommunication Study Group7
URSI International Union of Radio Science
WRC World Radiocommunication Conference

Federal Communications Commission
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FCC CHAIRMAN MICHAEL K. POWELL OUTLINES CRITICAL ELEMENTS OF FUTURE SPECTRUM POLICY

Washington, DC – FCC Chairman Michael Powell today outlined four critical elements for future spectrum policy initiatives. Powell made his remarks at the opening of the final day of four public workshops the FCC Spectrum Policy Task Force has convened to seek broad industry, government and public input on spectrum policy issues.

1. <u>More efficient use of spectrum.</u> Powell called for more efficient use of existing spectrum, not just allocation of more spectrum.

Powell said the problem increasingly is that demand for spectrum far outstrips the amount of available spectrum. "The real challenge is how to get more use out of spectrum that 80 percent of the time lies fallow." Powell suggested the answer relies on the empowerment of technology that will allow for more innovative uses of existing technologies like software defined radio and spectrum sharing. He also cited the need for continued use of unlicensed bands which he called "a source of innovation for showing us the vision of alternative ways spectrum can be used that are outside the traditional 'command and control' model."

"The time has come to realize that there's not a whole lot of spectrum in the closet we have back here at the FCC that hasn't been put out yet," Powell said. "If there was, I assure you we'd roll it out and get it out of here."

2. <u>Shift from a "command and control" model of regulation to market based mechanisms</u> Powell said, "There is no question that we need to be able to deal with unpredictable and dynamic changes fast enough to be meaningful in the market and meaningful to consumers." He said that the "laborious process" of government command and control "has served the country well to this point, but is futilely too slow to rapidly move things to new and better innovative uses."

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Allocations and Service Rules for the 71-76 GHz, 81-86 GHz and 92-95 GHz Bands	)	WT Docket No. 02-146
	)	
Loea Communications Corporation Petition for Rulemaking	)	RM-10288

NOTICE OF PROPOSED RULE MAKING

Adopted: June 13, 2002 **Released: June 28, 2002**

Comment Date: 90 days after publication in the Federal Register
Reply Comment Date: 135 days after publication in the Federal Register

By the Commission: Commissioners Abernathy, Copps and Martin issuing separate statements.

TABLE OF CONTENTS

Paragraph #

5. RAS Protection in the 81-86 GHz, 92-94 GHz, and 94.1-95 GHz Bands

43. In order to avoid interference to 18 RAS observatories that currently receive in the 81-86 GHz, 92-94 GHz, and 94.1-95 GHz bands, National Science Foundation (NSF) requests that we require licensees of all other allocated services in these bands to coordinate with these RAS sites.[54] NSF states that coordination radii on the order of 150 kilometers (93 miles) around the 8 single dish observatories and 25 kilometers (15.5 miles) around the 10 Very Long Baseline Array (VLBA) stations appear to be sufficient to ensure protection of these RAS facilities.

44. In paragraphs 30 and 40, above, we propose to allocate the 81-86 GHz, 92-94 GHz, and 94.1-95 GHz bands to the RAS on a primary basis. These RAS allocations were made at WRC-2000 as result of U.S. proposals and NTIA has requested their implementation.[55] We recognize that radio astronomers must observe radio waves of cosmic origin at frequencies over which they have no control.[56] We note, however, that the 86-92 GHz band is already allocated to the RAS on a primary basis. In light of this adjacent 6 gigahertz primary allocation, we request comment on whether the 81-86 GHz, 92-94 GHz, and 94.1-95 GHz bands should also be allocated to the RAS on a primary basis. Is this quantity of spectrum necessary for RAS purposes and would such a large allocation hinder effective use of spectrum needed for other applications? If not all of this spectrum is needed by the RAS, which portions are most essential or, alternatively, should certain portions be on a secondary or unprotected basis?

45. The customary means of protecting RAS reception is through coordination around RAS observatories. We tentatively propose to adopt a new United States footnote (footnote USzzz) that would specify the maximum coordination distances requested by NSF at the 18 indicated observatories with regard to RAS reception in the 81-86 GHz, 92-94 GHz, and 94.1-95 GHz bands.[57] However, we request comment on means to minimize any coordination burden on relevant parties. For example, are the

UNITED

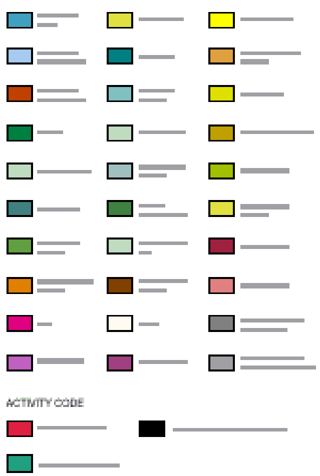
STATES

FREQUENCY

ALLOCATIONS

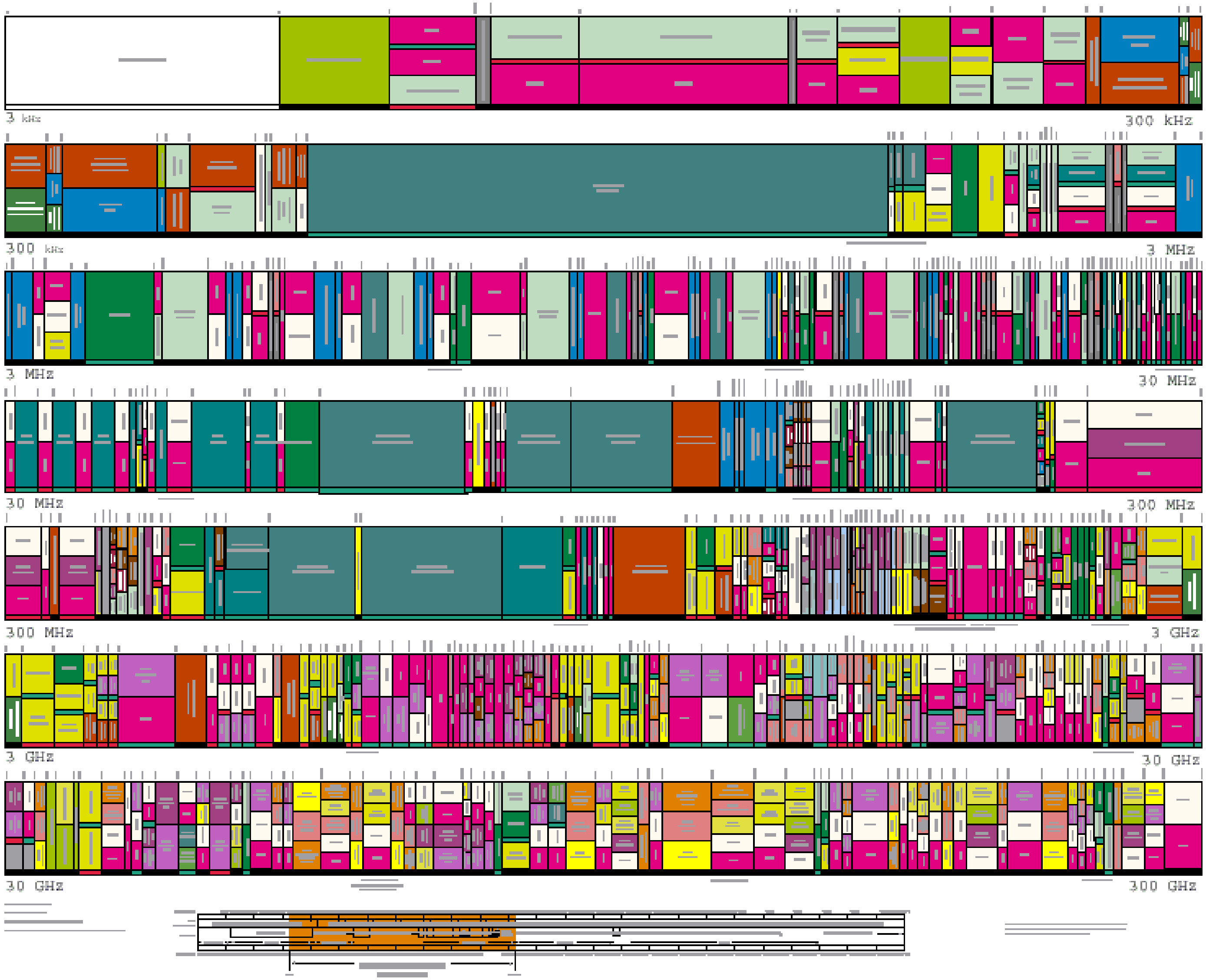
THE RADIO SPECTRUM

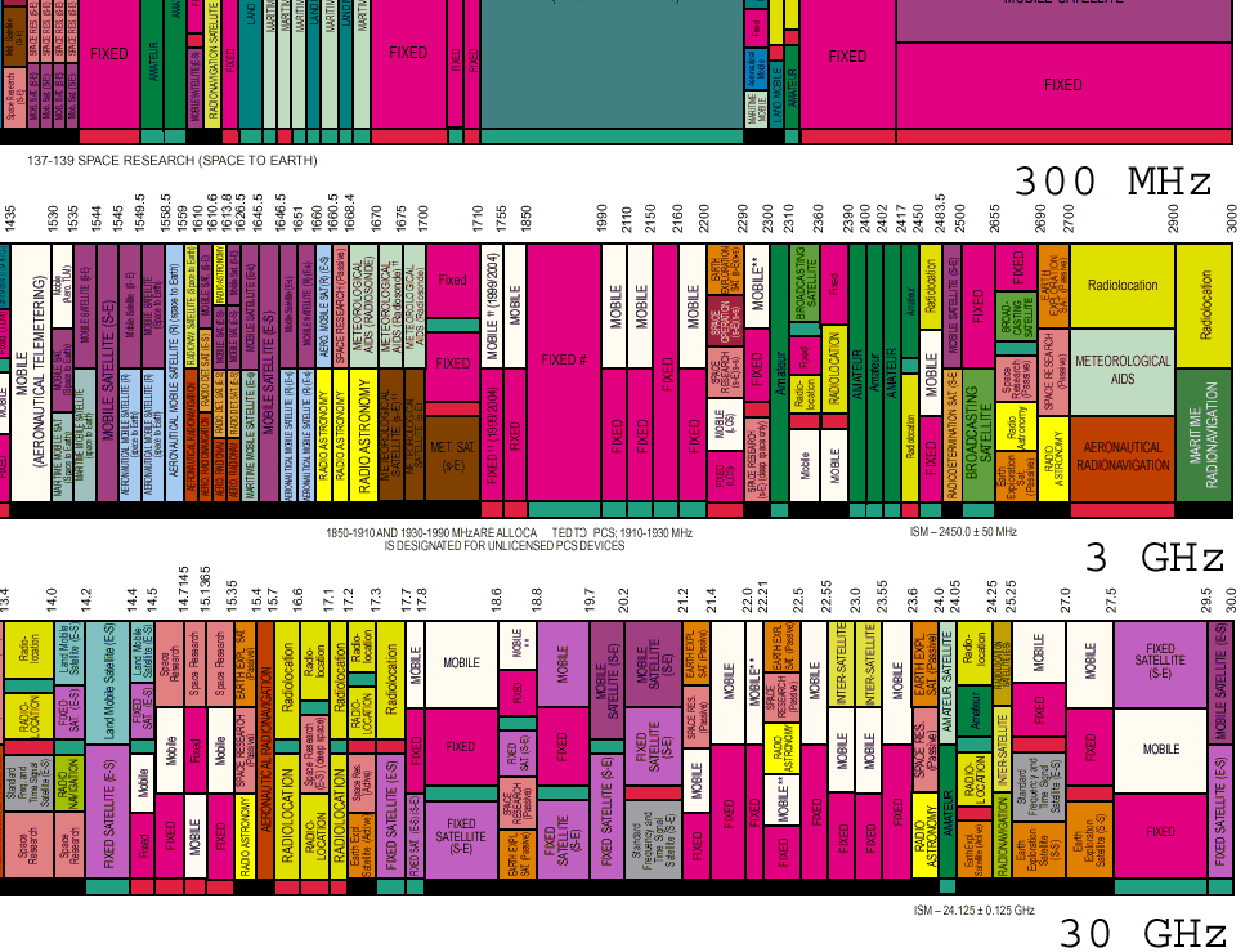
RADIO SERVICES COLOR LEGEND



ACTIVITY CODE

ALLOCATION USAGE DESIGNATION




137-139 SPACE RESEARCH (SPACE TO EARTH)
300 MHz
1435
1530
1535
1544
1545
1549.5
1558.5
1559
1610
1610.6
1613.8
1626.5
1645.5
1646.5
1651
1660
1660.5
1668.4
1670
1675
1700
1710
1755
1850
1990
2110
2150
2160
2200
2290
2300
2310
2360
2390
2400
2402
2417
2450
2483.5
2500
2655
2690
2700
2900
3000
MOBILE (AERONAUTICAL TELEMETERING)
MOBILE SATELLITE (S-E)
AERONAUTICAL MOBILE SATELLITE (R) (space to Earth)
MOBILE SATELLITE (E-S)
RADIO ASTRONOMY
SPACE RESEARCH (Passive)
METEOROLOGICAL AIDS (RADIOSONDE)
FIXED
MET. SAT. (s-E)
MOBILE ** (1999/2004)
FIXED ** (1999/2004)
MOBILE
FIXED #
Fixed
MOBILE**
Amateur
AMATEUR
BROADCASTING SATELLITE
RADIOLOCATION
Radiolocation
MOBILE SATELLITE (S-E)
RADIODETERMINATION SAT. (S-E)
BROADCASTING SATELLITE
METEOROLOGICAL AIDS
AERONAUTICAL RADIONAVIGATION
MARITIME RADIONAVIGATION
1850-1910 AND 1930-1990 MHz ARE ALLOCATED TO PCS; 1910-1930 MHz IS DESIGNATED FOR UNLICENSED PCS DEVICES
ISM – 2450.0 ± 50 MHz
3 GHz
13.4
14.0
14.2
14.4
14.5
14.7145
15.1365
15.35
15.4
15.7
16.6
17.1
17.2
17.3
17.7
17.8
18.6
18.8
19.7
20.2
21.2
21.4
22.0
22.21
22.5
22.55
23.0
23.55
23.6
24.0
24.05
24.25
25.25
27.0
27.5
29.5
30.0
Radiolocation
Land Mobile Satellite (E-S)
FIXED SATELLITE (E-S)
Space Research
AERONAUTICAL RADIONAVIGATION
RADIOLOCATION
RADIO ASTRONOMY
MOBILE
FIXED
FIXED SATELLITE (S-E)
MOBILE SATELLITE (S-E)
INTER-SATELLITE
AMATEUR SATELLITE
Amateur
MOBILE SATELLITE (E-S)
ISM – 24.125 ± 0.125 GHz
30 GHz

Recommendation ITU-R RA.769

TABLE 1

Threshold levels of interference detrimental to radio astronomy continuum observations

Centre frequency[(1)] f_c (MHz)	Assumed bandwidth Δf (MHz)	Minimum antenna noise temperature T_A (K)	Receiver noise temperature T_R (K)	System sensitivity[(2)] (noise fluctuations): Temperature ΔT (mK)	System sensitivity[(2)] (noise fluctuations): Power spectral density ΔP (dB(W/Hz))	Threshold interference levels[(2) (3)]: Input power ΔP_H (dBW)	Threshold interference levels[(2) (3)]: Power flux-density $S_H \Delta f$ (dB(W/m^2))	Threshold interference levels[(2) (3)]: Spectral power flux-density S_H (dB(W/(m^2·Hz)))
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
13.385	0.05	50 000	60	5000	–222	–185	–201	–248
25.610	0.12	15 000	60	972	–229	–188	–199	–249
73.8	1.6	750	60	14.3	–247	–195	–196	–258
151.525	2.95	150	60	2.73	–254	–199	–194	–259
325.3	6.6	40	60	0.87	–259	–201	–189	–258
408.05	3.9	25	60	0.96	–259	–203	–189	–255
611	6.0	20	60	0.73	–260	–202	–185	–253
1 413.5	27	12	10	0.095	–269	–205	–180	–255
1 665	10	12	10	0.16	–267	–207	–181	–251
2 695	10	12	10	0.16	–267	–207	–177	–247
4 995	10	12	10	0.16	–267	–207	–171	–241
10 650	100	12	10	0.049	–272	–202	–160	–240
15 375	50	15	15	0.095	–269	–202	–156	–233
22 355	290	35	30	0.085	–269	–195	–146	–231
23 800	400	15	30	0.050	–271	–195	–147	–233
31 550	500	18	65	0.083	–269	–192	–141	–228
43 000	1 000	25	65	0.064	–271	–191	–137	–227
89 000	8 000	12	30	0.011	–278	–189	–129	–228
150 000	8 000	14	30	0.011	–278	–189	–124	–223
224 000	8 000	20	43	0.016	–277	–188	–119	–218
270 000	8 000	25	50	0.019	–276	–187	–117	–216

(1) Calculation of interference levels is based on the centre frequency shown in this column although not all regions have the same allocations.

(2) An integration time of 2 000 s has been assumed; if integration times of 15 min, 1h, 2 h, 5 h or 10 h are used, the relevant values in the table should be adjusted by +1.7, –1.3, –2.8, –4.8 or –6.3 dB respectively.

(3) The interference levels given are those which apply for measurements of the total power received by a single antenna. Less stringent levels may be appropriate for other types of measurements, as discussed in § 2.2. For transmitters in the geostationary orbit, it is desirable that the levels be adjusted by –15 dB, as explained in § 2.1.

What protection does RA have?
ITU-R RA.769 ("rec 769")

Example Frequency	**RA.769 limit**	
325 MHz	1.6 Jy	
1420 MHz	3.2 Jy	
10.65 MHz	100 Jy	
43 GHz	2000 Jy	

… for 98% (or 95% aggregate) of the time.

What protection does RA have? ITU-R RA.769 (“rec 769”)

Example Frequency	RA.769 limit	“Practical limits of unwanted emission”
325 MHz	1.6 Jy	630000 Jy
1420 MHz	3.2 Jy	630000 Jy
10.65 MHz	100 Jy	630000 Jy
43 GHz	2000 Jy	4000000 Jy

… for 98% (or 95% aggregate) of the time.

Many successes over the years:

- At WARC 1979 India had proposed that 322-328.6 MHz be allocated to radio astronomy (Deuterium).
- The **NATO** countries and the USA supported this allocation (this was still in the "cold war" period).
- The Soviet Union had an extensive radar network around the Middle East at 327 MHz.
- In May 1960, it had tracked the Gary Powers U2 spy plane over Soviet territory.
- A radio astronomy allocation at 327 MHz would effectively shut down the radar network!

Current Issues

- Satellites: potentially very high level of unwanted emissions into adjacent RA bands. Politically powerful adversaries.
- Coordination: protection of "the band" everywhere on the globe is no longer assured. In some cases, only the immediate location of listed RA observatories is now protected, even in exclusive RA bands.

Transmitting from Space

The Global Transmission Services Experiment

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Email: jens.schiemann@esa.int

Introduction

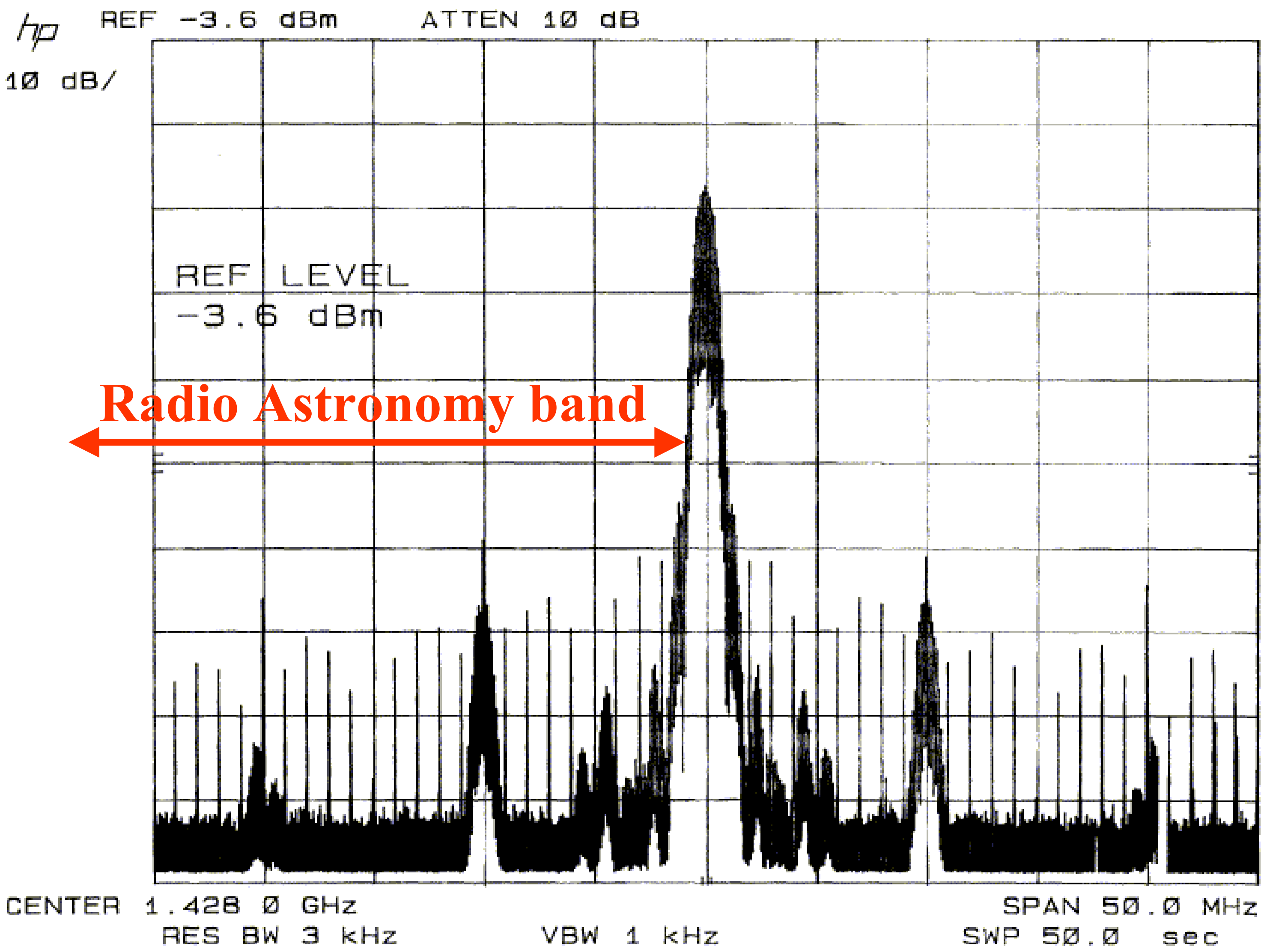
In 1996, following the successful Euromir-95 mission, ESA negotiated with RSC-Energia the Euromir Extension mission. Euromir-E should have taken place towards the end of 1997, and reused much of ESA's equipment already onboard Mir. However, the Progress collision in June 1997 destroyed these plans – the vast majority of ESA's equipment became inaccessible inside the damaged Spektr module.

The Global Transmission Services project will be Western Europe's first major experiment aboard the Space Station....

The Objectives and Concept of GTS

Time-signal stations on Earth usually transmit their information at long wavelengths. Watches synchronise themselves with these signals by activating their receivers typically once per day or after turn-on. In Germany, the signal is broadcast by the Physikalisch-Technische Bundesanstalt (PTB), in Braunschweig, using a simple encoding scheme to transfer both time information and synchronisation impulses on a 77 kHz carrier. Although this scheme is quite efficient and simple, it has several

Spectrum of the International Space Station GTS transmitter



(Part of a response from ESA, Sep 3 2002.)

…

· The NASA ISS Frequency Baseline shows that the GTS frequencies were agreed at ISS coordination level and that the GTS was correctly classified as a Russian/German experiment (not ESA).

Consequently ESA cannot take any responsibility for interference caused to the Radioastronomy community as result of the frequency choice in non-compliance with the ITU Radio Regulations by the Russian authorities. It is suggested that official regulatory complaints, in accordance with Article 4.4 and Article 15, be addressed to the Russian Administration rather than to ESA or ESA administrations."

http://www.iucaf.org

IUCAF

International Council for Science

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- CORF
- COSPAR
- CRAF
- IAU
- ICSU
- URSI

SCIENTIFIC COMMITTEE ON FREQUENCY ALLOCATIONS FOR

RADIO ASTRONOMY AND SPACE SCIENCE

IUCAF operates under the auspices of **ICSU**, the **International Council for Science**, which is part of **UNESCO**. **IUCAF** is sponsored by the

IAU(the International Astronomical Union),
URSI(the International Union of Radio Science), and
COSPAR(the Committee on Space Research)

IUCAF meeting place in Geneva, where strategy is planned

"IUCAF members had to evolve from being starry-eyed astronomers as they encountered a world of politics, lobbying, entertainment, threats, espionage and bribery. On one occasion, an offer (in Geneva) of two million dollars in cash "*to shut up*" proved no match for dedication to the joys and excitement of twentieth-century astrophysics."

*Brian Robinson, "**Frequency Allocation: The First Forty Years**."*
Ann Rev. Astron. Astrophys. 1999, 37:65-96