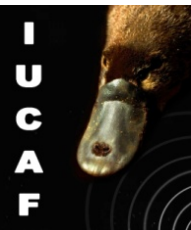


# **ITU-R Recommendations and Reports 2020**

**Masatoshi Ohishi**  
**Spectrum Management Office, NAOJ**



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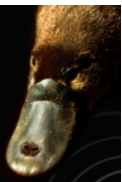


# Recommendations

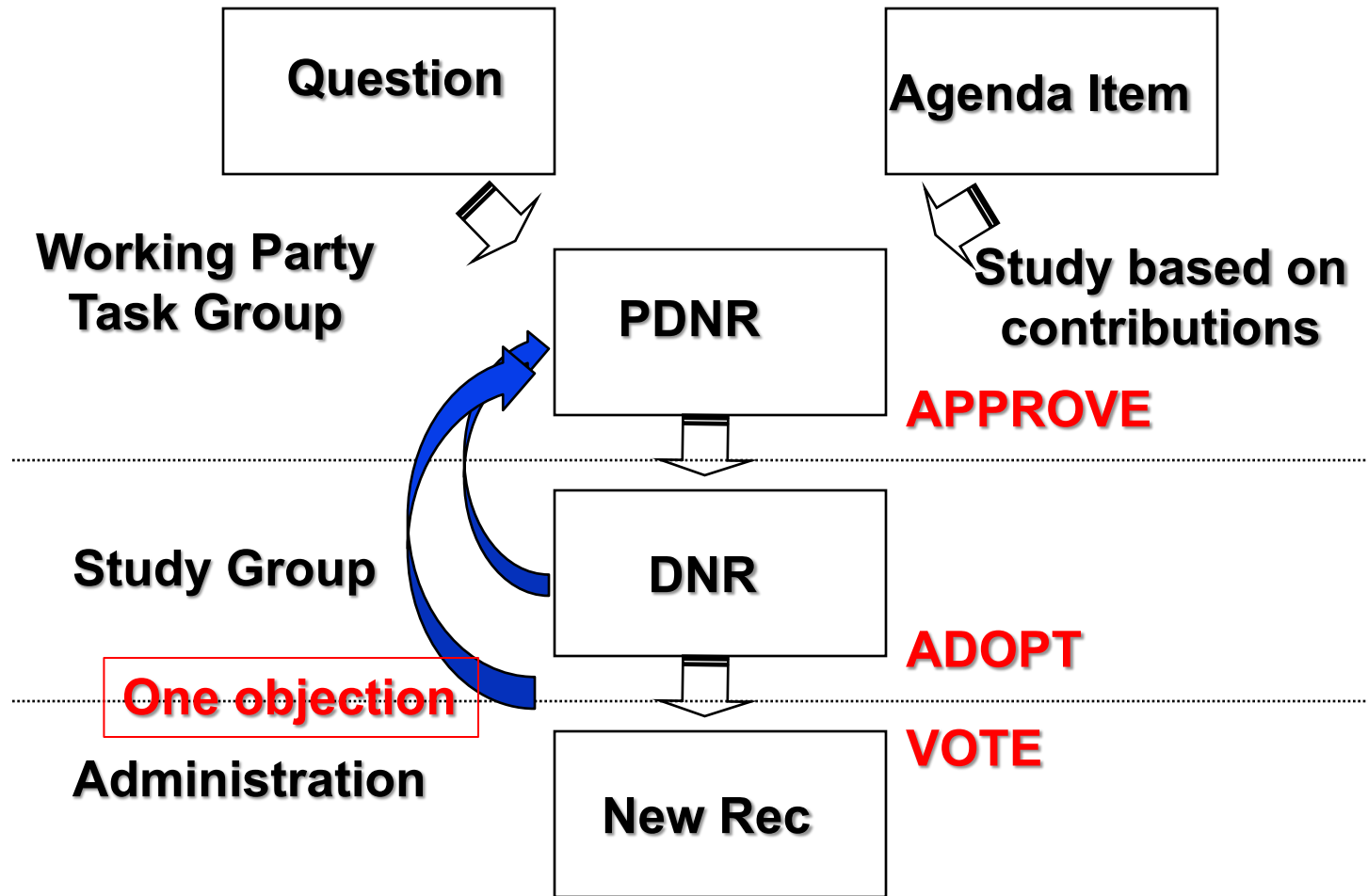
**The ITU-R Recommendations provide a body of technical, operational and regulatory / procedural **information** that has been **agreed upon by the participating administrations**. (Resolution ITU-R 1-5)**

****Not mandatory** regulatory measures !**

**But, Respected by the administrations**



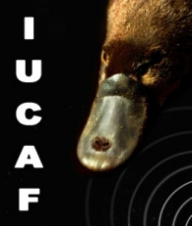
# Production of Recs.





# ITU-R Recommendation Series

<b>BO</b>	<b>Satellite Delivery</b>
<b>BR</b>	<b>Recording for production, archival and play-out; film for television</b>
<b>BS</b>	<b>Broadcasting service (sound)</b>
<b>BT</b>	<b>Broadcasting service (television)</b>
<b>F</b>	<b>Fixed service</b>
<b>M</b>	<b>Mobile, radiodetermination, amateur and related satellite services</b>
<b>P</b>	<b>Radiowave propagation</b>
<b>RA</b>	<b>Radio astronomy</b>
<b>RS</b>	<b>Remote Sensing systems</b>
<b>S</b>	<b>Fixed satellite service</b>
<b>SA</b>	<b>Space applications and meteorology</b>
<b>SF</b>	<b>Frequency sharing and coordination between fixed satellite and fixed service systems</b>
<b>SM</b>	<b>Spectrum management</b>
<b>SNG</b>	<b>Satellite news gathering</b>
<b>TF</b>	<b>Time signals and frequency standards emissions</b>
<b>V</b>	<b>Vocabulary and related subjects</b>



# How to Name Recs

## Recommendation ITU-R RA.769-2

**RA:Radio Astronomy**

**769: sequential number**

**-2 : Revision number**

# ITU-R Recommendations in the Radio Astronomy Series (1)

## Basic Protection Criteria

**RA.314** Preferred frequency bands for radio astronomical measurements

**RA.769** Protection criteria used for radio astronomical measurements

**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 radio astronomy on a primary basis

**RA.1860** Preferred frequency bands for radio astronomical measurements in the range 1-3 THz

## Coordination Zones

**RA.1031** Protection of the radio astronomy service in frequency bands shared with other services

**RA.1272** Protection of radio astronomy measurements above 60 GHz from ground based interference



## ITU-R Recommendations in the Radio Astronomy Series (2)

### **Out-of-Band and Spurious transmissions**

**RA.517 Protection of the radio astronomy services from transmitters operating in adjacent bands**

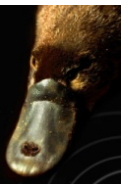
**RA.611 Protection of the radio astronomy service from spurious emissions**

**RA.1237 Protection of the radio astronomy service from unwanted emissions resulting from applications of wideband digital modulation**

### **Protection of regions in Space**

**RA.479 Protection of frequencies for radioastronomical measurements in the shielded zone of the Moon**

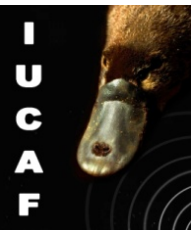
**RA.1417 A radio-quiet zone in the vicinity of the L2 Sun-Earth Lagrange point**



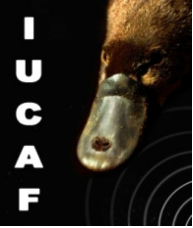
## ITU-R Recommendations in the Radio Astronomy Series (3)

### Miscellaneous

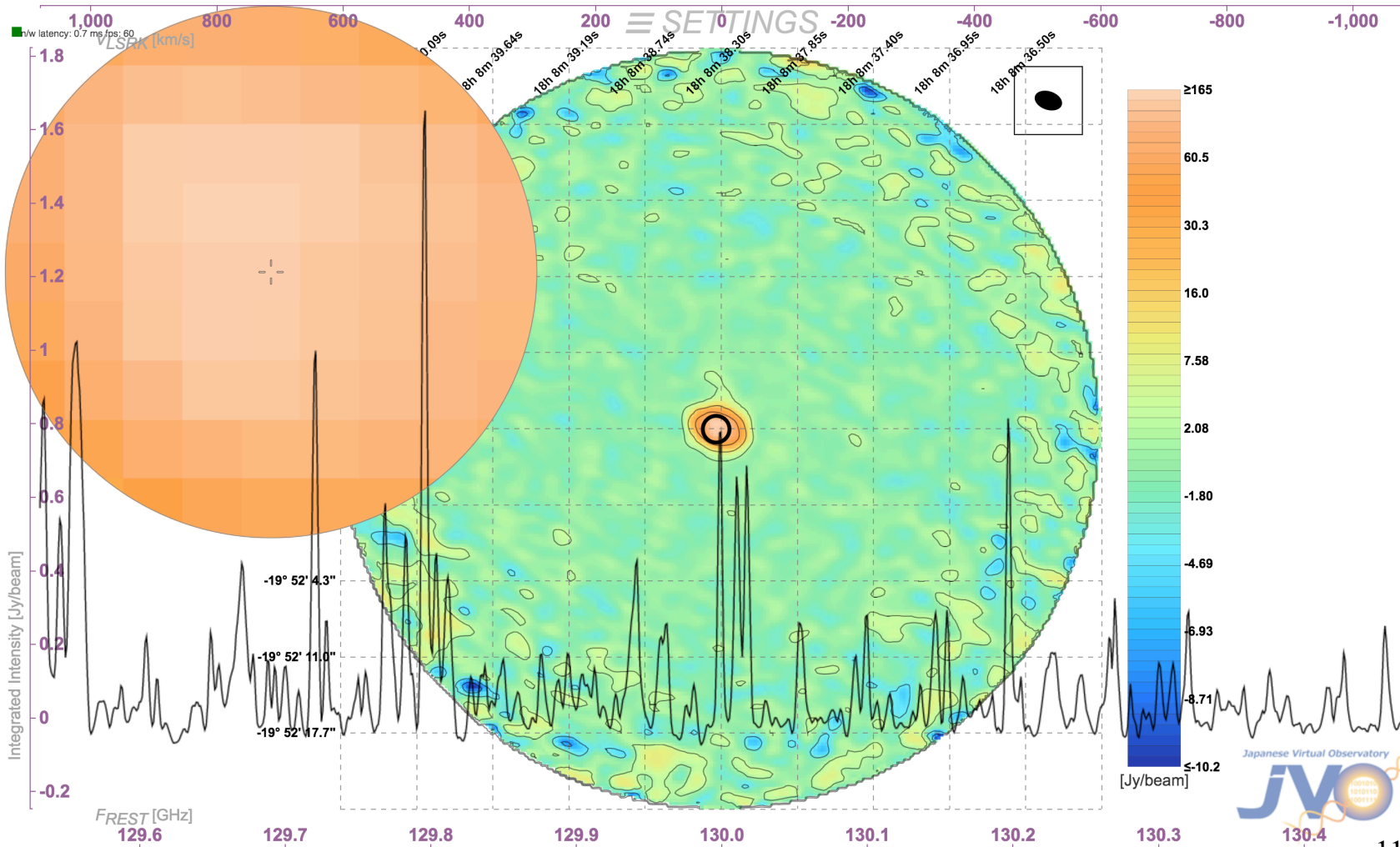
- RA.1630** Technical and operational characteristics of ground-based astronomy systems for use in sharing studies with active services between 10 THz and 1000 THz
- RA.1631** Reference radio astronomy antenna pattern to be used for compatibility analyses between non-GSO systems and radio astronomy service 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



# **Preferred Bands for RAS Rec. 314 ( $<1000$ GHz)**



# An Example of ALMA Data





# IAU Resolution A2 (1991)

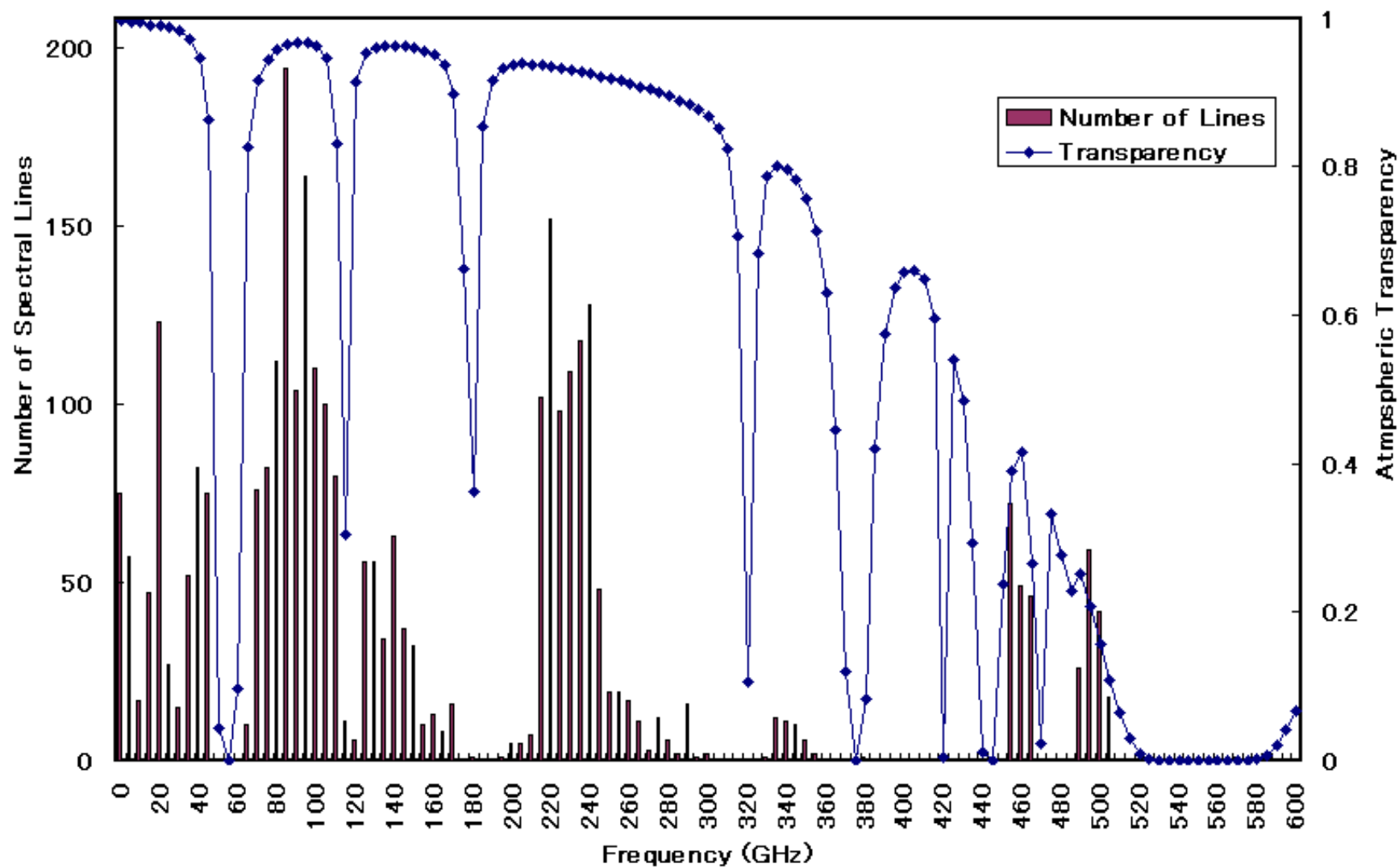
- **List of Important Spectral Lines**
  - > Two tables (0-275 GHz, 275-1000 GHz)
  - > doesn't mean that other lines are not important
  - > **A minimum set to demonstrate to NON-Astronomers**
- **Updated in 2000 @ Manchester to include many lines up to 1000 GHz**  
→ extended to 3000 GHz in 2009
- **Referred to by Recommendations ITU-R RA.314 and RA.1860**

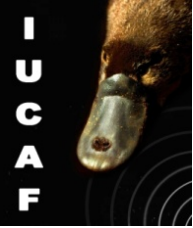




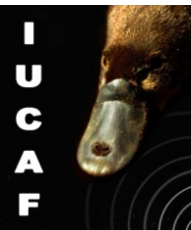
# **Rec. ITU-R RA. 314**

- **List of most important lines among observed 3,000/ possible 10,000 ones**
- **Frequency < 1000 GHz**
- **Frequency bands for Continuum observations**
- **Recommends to protect these bands**
- **Bands not listed in the Rec are also important for RAS**





# **Preferred Bands for RAS Rec. 1860 (1000-3000 GHz)**



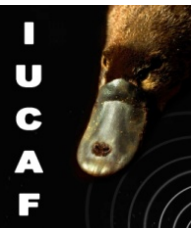
# Line Selection

- **Very abundant species**  
→ commonly used by many observers  
e.g., CO, H<sub>2</sub>O, CS, NH<sub>3</sub>
- **Their isotopologues**  
→ avoid opacity problems  
e.g., <sup>13</sup>CO, C<sup>18</sup>O, HDO
- **Unique in 1-3 THz**  
→ atomic lines, metal hydrides, etc.  
e.g., NII, CH, NH



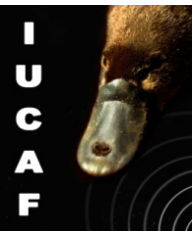
Substance	Rest frequency	Suggested minimum band
Carbon monoxide (CO)	1 036.912	1 035.88 – 1 037.95
Carbon monoxide (CO)	1 267.014	1 265.75 – 1 268.28
Trihydrogen ion (H <sub>2</sub> D <sup>+</sup> )	1 370.085	1 368.71 – 1 371.46
Carbon monoxide (CO)	1 381.995	1 380.61 – 1 383.38
Nitrogen Ion (N <sup>+</sup> )	1 461.132	1 459.814 – 1 462.731
Carbon monoxide (CO)	1 611.793	1 610.18 – 1 613.40
Water (H <sub>2</sub> <sup>18</sup> O)	1 646.398	1 644.75 – 1 648.04
Oxonium hydride (H <sub>3</sub> O <sup>+</sup> )	1 655.834	1 654.18 – 1 657.49
Hydroxyl (OH)	1 834.747	1 832.91 – 1 836.58
Hydroxyl (OH)	1 837.816	1 835.98 – 1 839.65
Carbon monoxide (CO)	1 841.346	1 839.50 – 1 843.19

Substance	Rest frequency	Suggested minimum band
Carbon monoxide (CO)	1 956.018	1 954.06 – 1 957.97
Tricarbon (C <sub>3</sub> )	1 968.595	1 966.63 – 1 970.56
Carbon monoxide (13CO)	1 979.726	1 977.75 – 1 981.71
Carbon monoxide (CO)	2 413.917	2 411.50 – 2 416.33
Hydrofluoric acid (HF)	2 463.428	2 460.96 – 2 465.89
Hydroxyl (OH)	2 509.948	2 507.44 – 2 512.46
Hydroxyl (OH)	2 514.316	2 511.80 – 2 516.83
Carbon monoxide (CO)	2 528.172	2 525.64 – 2 530.70
Oxonium hydride (H <sub>3</sub> O <sup>+</sup> )	2 972.100	2 969.13 – 2 975.07
Oxonium hydride (H <sub>3</sub> O <sup>+</sup> )	2 980.725	2 977.74 – 2 983.71



# Results

- **~360 lines tabulated in 2000 GHz range, with suggested “coverage”s**  
**→ ~ 1 line/ 6GHz**
- **Continuum bands observable from the ground**  
  
**→ Proposed to the ITU**  
**→ Approved as Recommendation ITU-R RA.1860**  
**“Preferred frequency bands for radio astronomical measurements in the range 1-3 THz”**



# **The most important Recommendation For RAS**

## **Rec. 769**



# RA.769

**Defines threshold levels of interference detrimental to RA observations, and recommends to meet these levels**

- **Calculation method**
- **Two modes**
  - > **Continuum mode** (Table 1): total power into an entire RA band
  - > **Spectral line mode** (Table 2): power into a reference band width
- **Threshold values for both modes should be met simultaneously.**





# Calculation of thresholds

$$\frac{\Delta P}{P} = \frac{1}{\sqrt{\Delta f_0 t}}$$

$$\Delta T = \frac{T}{\sqrt{\Delta f_0 t}}$$

$$T = T_A + T_R$$

$$\Delta P_H = 0.1 \Delta P \Delta f$$

$$S_H \Delta f = \Delta P_H + 20 \log f - 158.5$$

P: power spectral density  
at the radiometer input

Integration time:

t=2000 sec

typical value

$\Delta P_H$ : interference  
threshold level in  
power

$S_H$ : spectral power flux  
density for a 0dBi gain  
antenna



TABLE 1

Threshold levels of interference detrimental to radio astronomy continuum observations

Centre frequency <sup>(1)</sup> $f_c$ (MHz)	Assumed bandwidth $\Delta f$ (MHz)	Minimum antenna noise temperature $T_A$ (K)	Receiver noise temperature $T_R$ (K)	System sensitivity <sup>(2)</sup> (noise fluctuations)		Threshold interference levels <sup>(2) (3)</sup>		
				Temperature $\Delta T$ (mK)	Power spectral density $\Delta P$ (dB(W/Hz))	Input power $\Delta P_H$ (dBW)	pfd $S_H \Delta f$ (dB(W/m <sup>2</sup> ))	Spectral pfd $S_H$ (dB(W/(m <sup>2</sup> · Hz)))
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
13.385	0.05	50 000	60	5 000	−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, 1 h, 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 GSO, it is desirable that the levels be adjusted by −15 dB, as explained in § 2.1.



TABLE 2\*

Threshold levels of interference detrimental to radio astronomy spectral-line observations

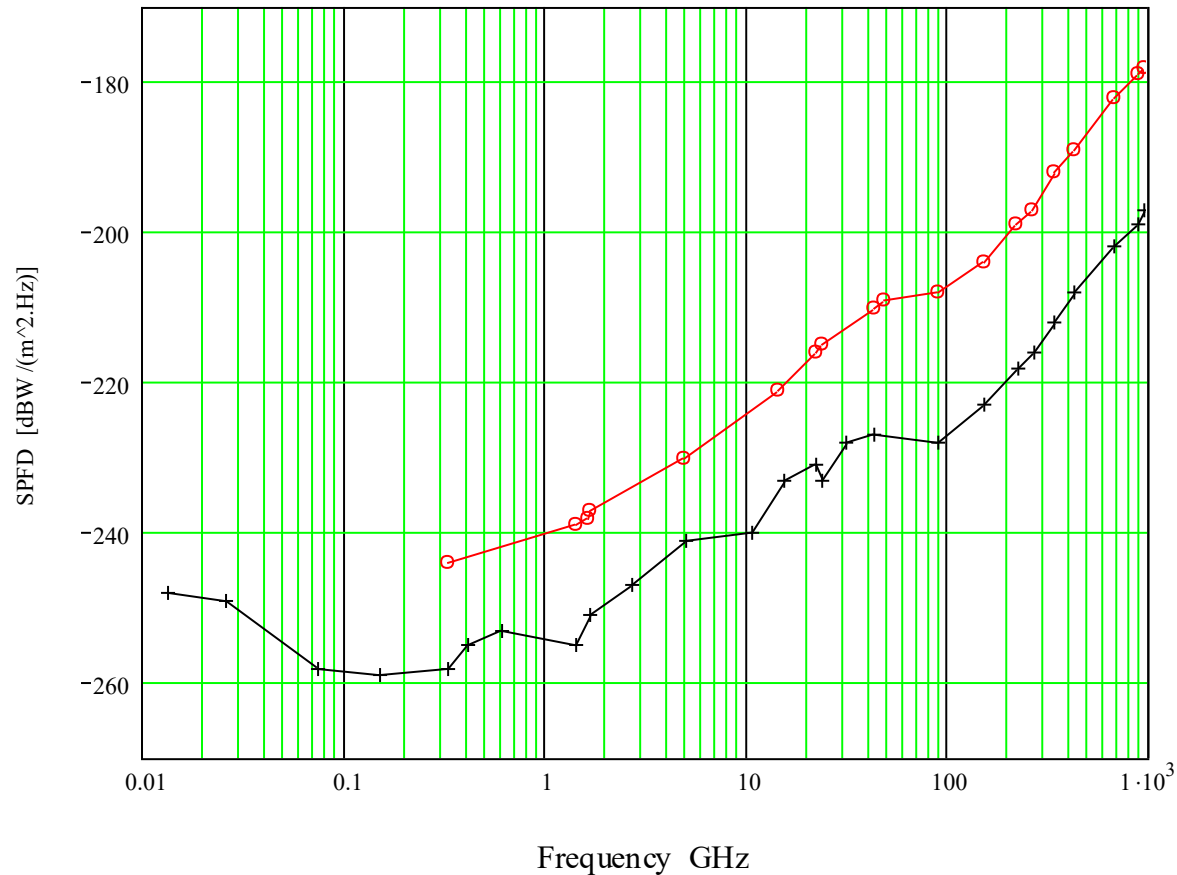
Frequency $f$ (MHz)	Assumed spectral line channel bandwidth $\Delta f$ (kHz)	Minimum antenna noise temperature $T_A$ (K)	Receiver noise temperature $T_R$ (K)	System sensitivity <sup>(2)</sup> (noise fluctuations)		Threshold interference levels <sup>(1) (2)</sup>		
				Temperature $\Delta T$ (mK)	Power spectral density $\Delta P_S$ (dB(W/Hz))	Input power $\Delta P_H$ (dBW)	pfd $S_H \Delta f$ (dB(W/m <sup>2</sup> ))	Spectral pfd $S_H$ (dB(W/(m <sup>2</sup> · Hz)))
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
327	10	40	60	22.3	−245	−215	−204	−244
1 420	20	12	10	3.48	−253	−220	−196	−239
1 612	20	12	10	3.48	−253	−220	−194	−238
1 665	20	12	10	3.48	−253	−220	−194	−237
4 830	50	12	10	2.20	−255	−218	−183	−230
14 488	150	15	15	1.73	−256	−214	−169	−221
22 200	250	35	30	2.91	−254	−210	−162	−216
23 700	250	35	30	2.91	−254	−210	−161	−215
43 000	500	25	65	2.84	−254	−207	−153	−210
48 000	500	30	65	3.00	−254	−207	−152	−209
88 600	1 000	12	30	0.94	−259	−209	−148	−208
150 000	1 000	14	30	0.98	−259	−209	−144	−204
220 000	1 000	20	43	1.41	−257	−207	−139	−199
265 000	1 000	25	50	1.68	−256	−206	−137	−197

\* This Table is not intended to give a complete list of spectral-line bands, but only representative examples throughout the spectrum.

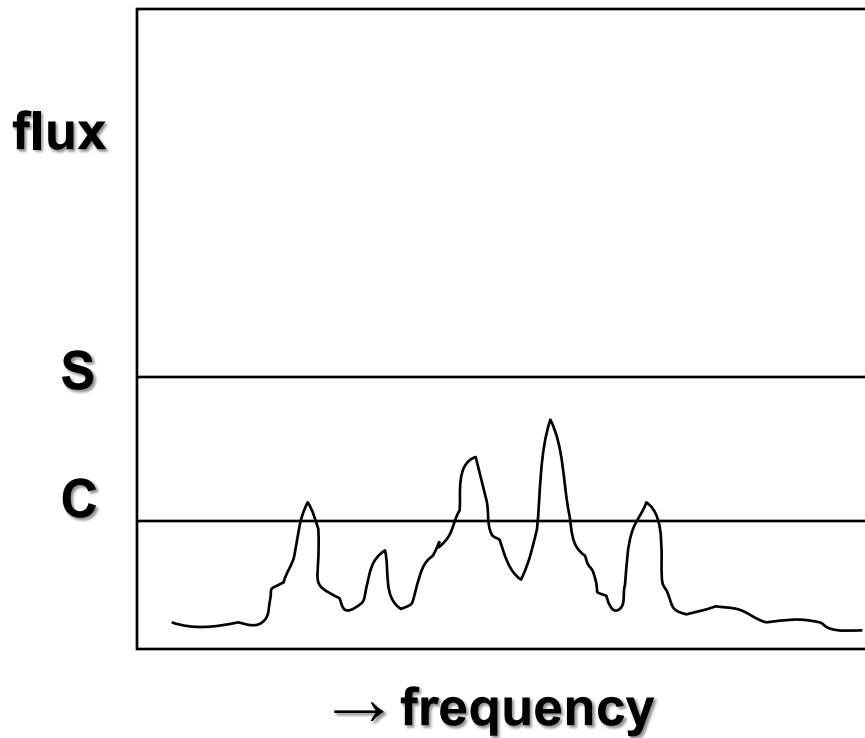
<sup>(1)</sup> An integration time of 2 000 s has been assumed; if integration times of 15 min, 1 h, 2 h, 5 h or 10 h are used, the relevant values in the Table should be adjusted by +1.7, −1.3, −2.8, −4.8 or −6.3 dB respectively.

<sup>(2)</sup> 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 GSO, it is desirable that the levels need to be adjusted by −15 dB, as explained in § 2.1.

# Detrimental thresholds for total power observations

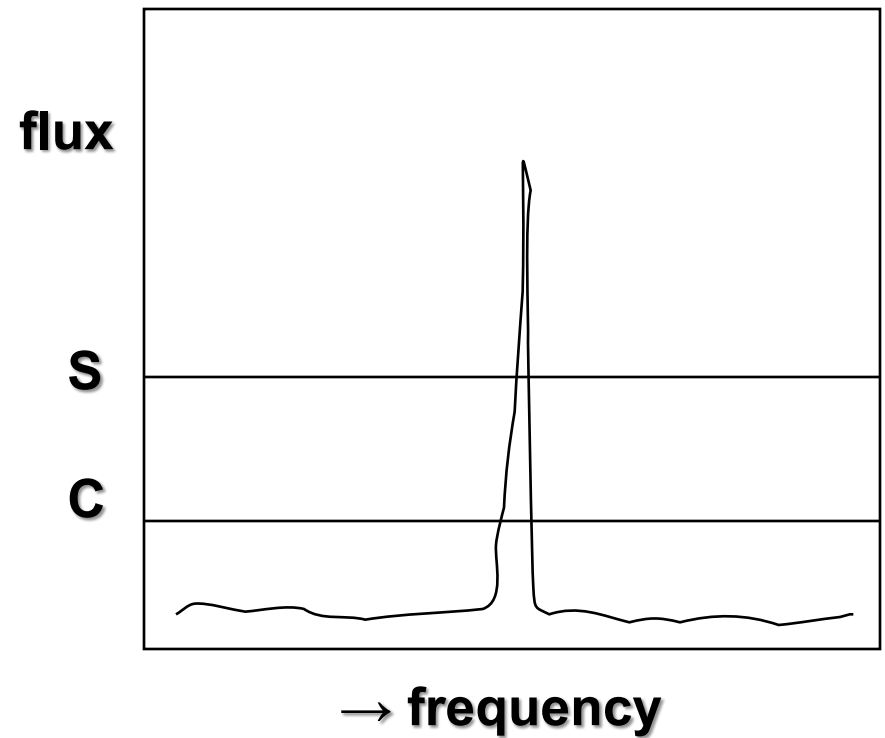


**black, continuum; red, spectral line**



**Total power of interference does not exceed the continuum mode threshold value, **AND** interference power in ANY reference band does not exceed the spectral line mode threshold level**

**→ meets the Rec**



**Total power of interference does not exceed the continuum mode threshold value, **BUT** interference power in at least one reference band exceeds the spectral line mode threshold level**

**→ does not meet the Rec**

# Threshold-level Formula

**Voltage ratio at receiver output:**

$$\frac{\text{Interference}}{\text{rms noise}} = \left[ \frac{S_H (c^2 / 4\pi f^2) \Delta f}{k(T_A + T_R) \Delta f} \right] \sqrt{\Delta f \tau}$$

**For Interference/rms noise = 0.1,**

$$S_H = \frac{0.4 \pi k f^2 (T_A + T_R)}{c^2 \sqrt{\Delta f \tau}}$$

**(see ITU-R RA Handbook Eq. 4.10)**

**Units of  $S_H$  are  $\text{W m}^{-2}\text{Hz}^{-1}$  (spectral power flux density)**

$$F_H = S_H \Delta f = \frac{0.4 \pi k f^2 (T_A + T_R)}{c^2} \sqrt{\frac{\Delta f}{\tau}}$$

**Units of  $F_H$  are  $\text{W m}^{-2}$  (power flux density)**

## Interference threshold for VLBI

In VLBI, the natural fringe frequency is so high that the RFI fringe amplitude can be considered to be reduced to zero at the correlator output. However, the presence of RFI in the receiver can introduce errors into the system calibration. Thus the Interference threshold criterion for VLBI is the level at which the interference power within the receiver (before detection) is **1/100 of the noise power**.

The power ratio *interference/noise* within the receiver is:

$$\left[ \frac{S_H (c^2 / 4\pi f^2)}{k(T_A + T_R)} \right]$$

The RFI threshold for *interference/noise* = 1/100 is:

$$S_H = \frac{0.04k(T_A + T_R)f^2}{c^2}$$



# For VLBI Observations

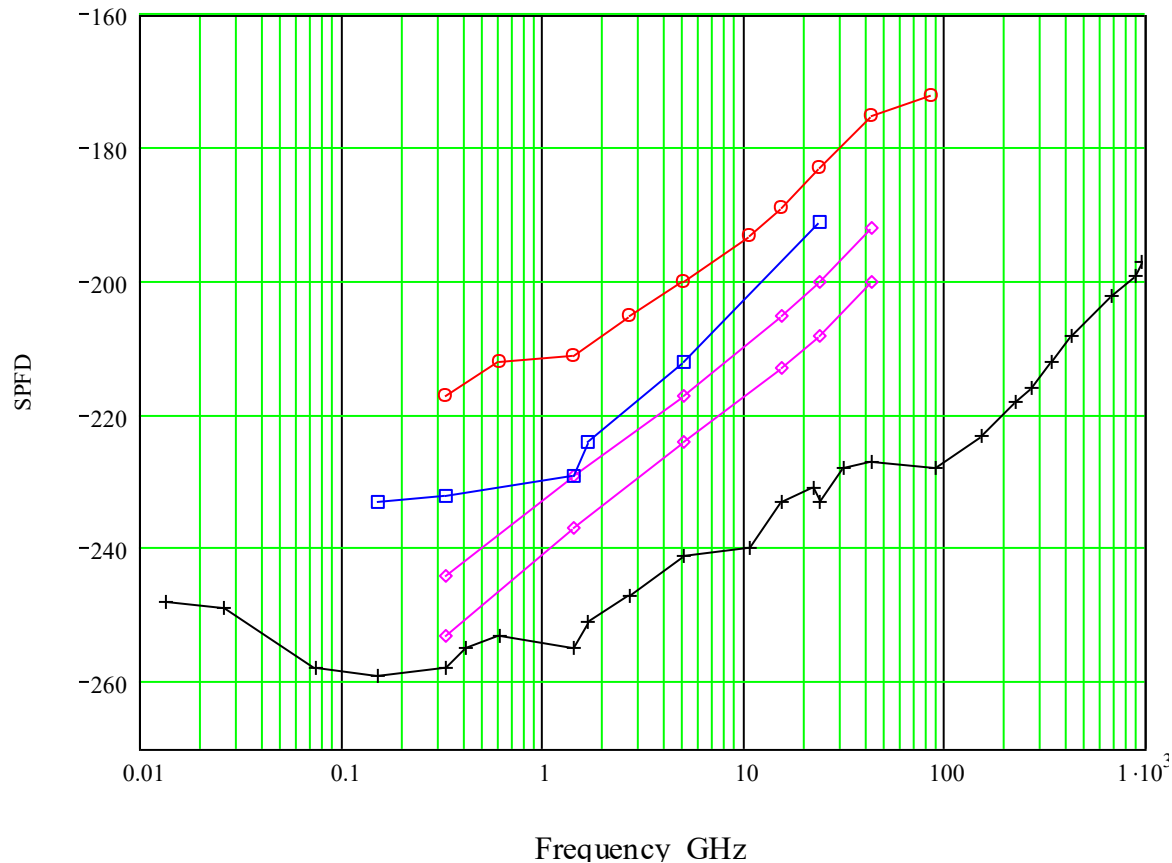
TABLE 3

**Threshold interference levels for VLBI observations**

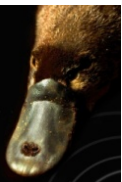
<b>Centre frequency (MHz)</b>	<b>Threshold level (dB(W/m<sup>2</sup> · Hz)))</b>
325.3	-217
611	-212
1 413.5	-211
2 695	-205
4 995	-200
10 650	-193
15 375	-189
23 800	-183
43 000	-175
86 000	-172



# Detrimental thresholds for continuum observations



**black, total power ; magenta, VLA (D and A);  
blue, Merlin; red, VLBI**



## Example of sidelobes

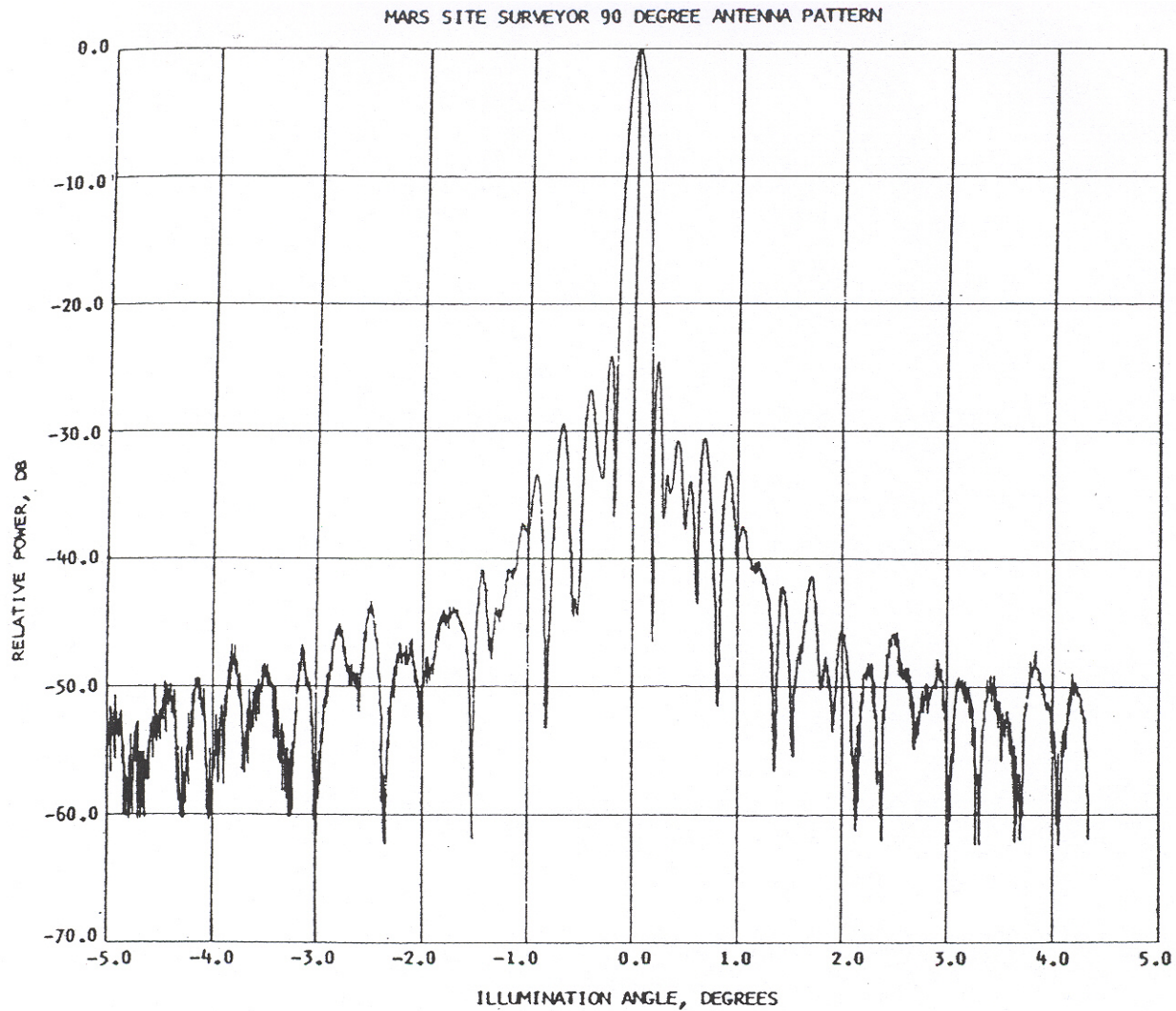
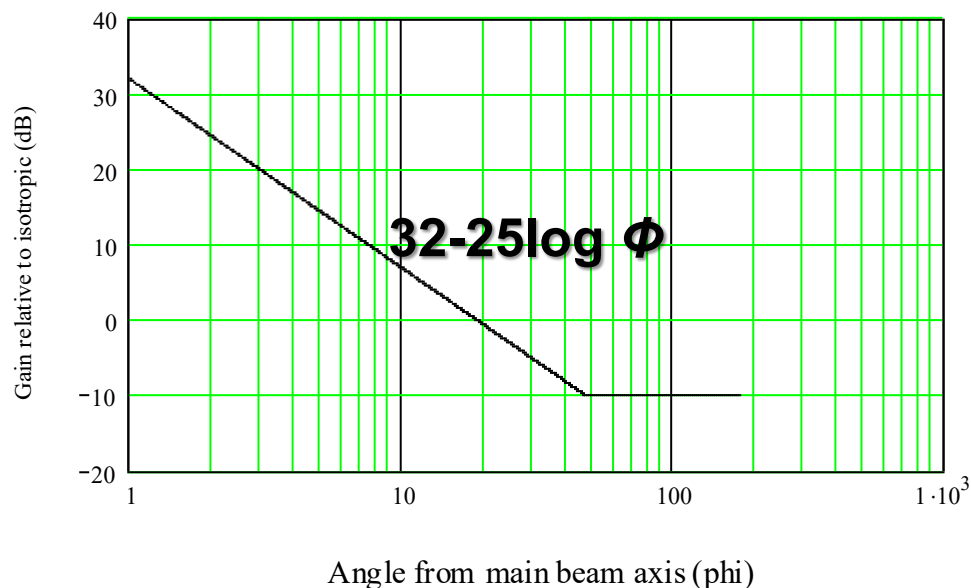


Fig. 5. AAS elevation radiation pattern.

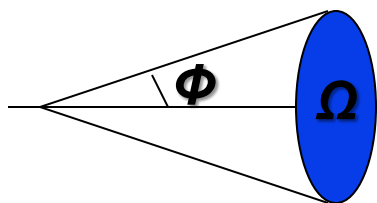
**210-ft antenna at S-band, from Levy, G. S., et al., IEEE Trans. AP-15, 311, 1967.**



## SA.509 Sidelobe Model

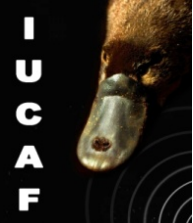


**Empirical sidelobe model for reflector antennas of diameter  $\geq 100$  wavelengths. 90% of sidelobe peaks lie below the curve. Representative of symmetric parabolic-reflector antennas.**



$$\text{Solid angle } \Omega = 2 \pi (1 - \cos \phi)$$

**In RA threshold calculations, **sidelobe gain of 0 dBi** is used in assessing RFIs.**



# Evaluation of RFI in dB

0 dBi

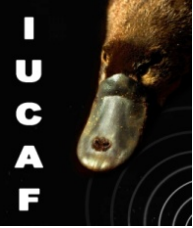
$$P_r = G_r - L_p + G_t + P_t$$

RAS

transmitter

Propagation loss

↑  
Values from Rec. 769

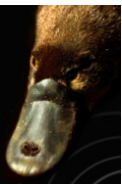


# **RFIs may exceed threshold levels**



## RA.1513

- **Defines tolerable fraction of interference that exceeds the threshold level**
- **Not fraction of time, but fraction of “Data Loss”**
- **RA bands on a primary basis only**
- **Data loss due to any single network**
  - > <2%**
- **Aggregated data loss due to all networks**
  - > <5%; methodology of apportionment between different networks is to be studied**



# Statistical Evaluation of “Data Loss”

- **Recommends 3**
  - > that the percentage of data loss, in frequency bands allocated to the RAS on a primary basis, be determined as the percentage of integration periods of 2 000 s in which the average spectral pfd at the radio telescope exceeds the levels defined (assuming 0 dBi antenna gain) in Recommendation ITU-R RA.769. The effect of interference that is periodic on time scales of the order of seconds or less, such as radar pulses, requires further study;**



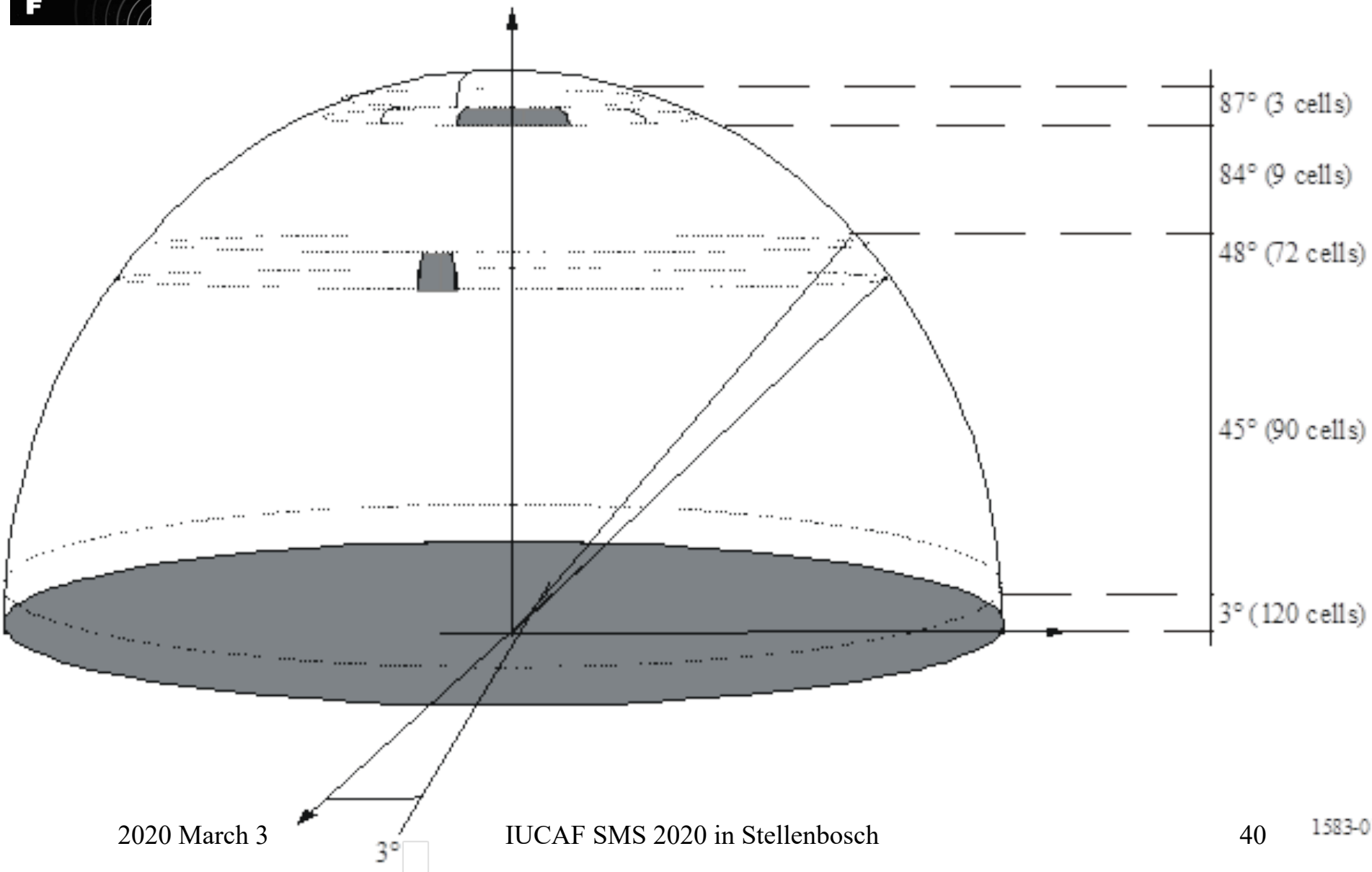
# Cases of non-GSO satellites

- **Recommends 4**
  - > **Use methodology described in Recs S.1586 and M.1583**
  - > **Divide the sky into 2334 cells of approximately 9 square degrees of solid angle each**
  - > **Calculate aggregate interference from visible satellites; randomly point a RAS telescope and statistically evaluate the data loss in each cell**
  - > **In each cell compare the interference level with Rec. 769**
  - > **Evaluate if the fraction of total number of cells that exceed Rec.769 relative to the 2334 cells exceeds 2%**



FIGURE 1

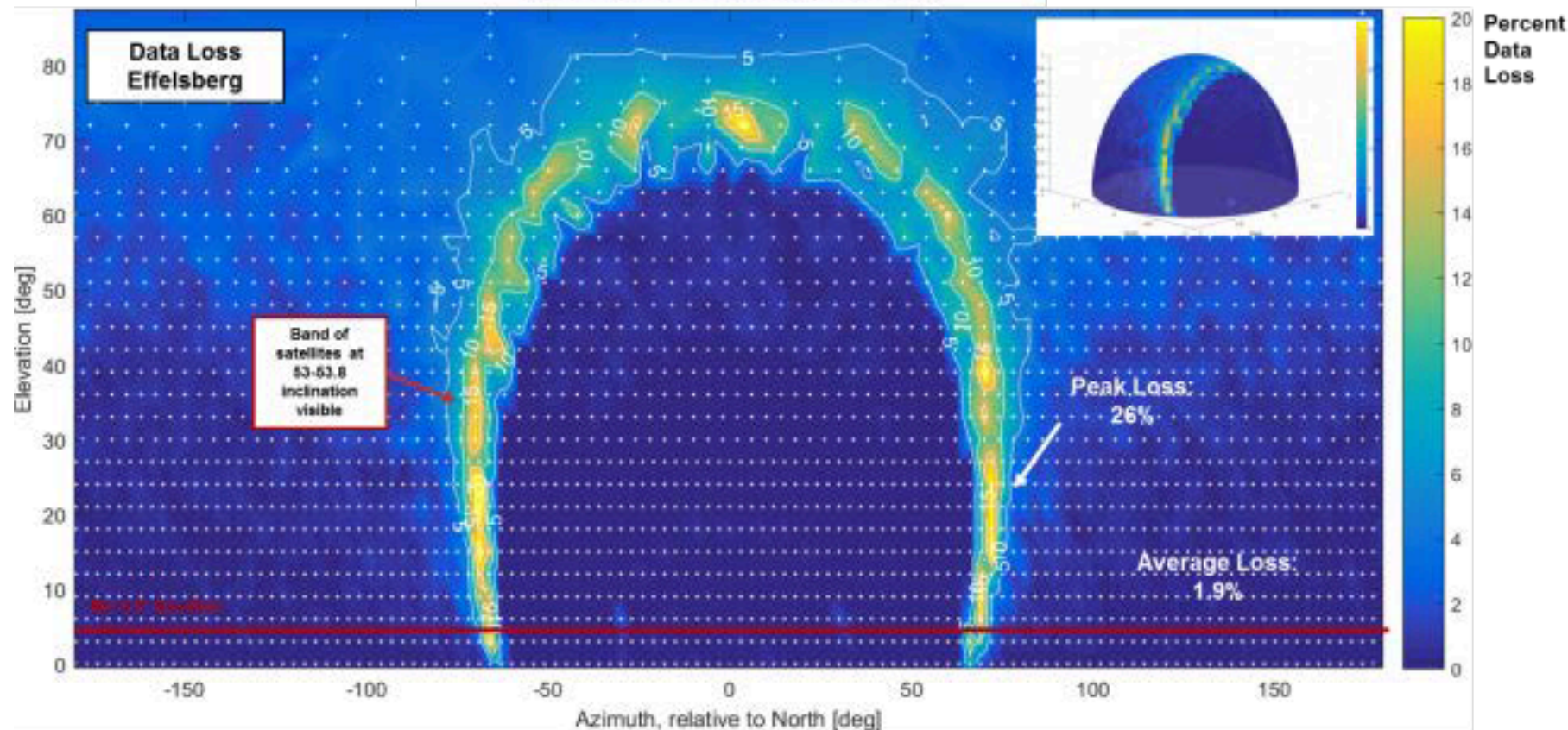
Example of division of the sky in cells of approximately  
9 square degrees of solid angle



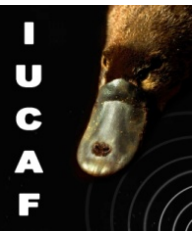


# Starlink

Sky Map of Data Loss [%]  
Effelsberg, Germany (50.5247° N, 6.8836° E)  
Average loss = 1.9%; Peak loss = 26%



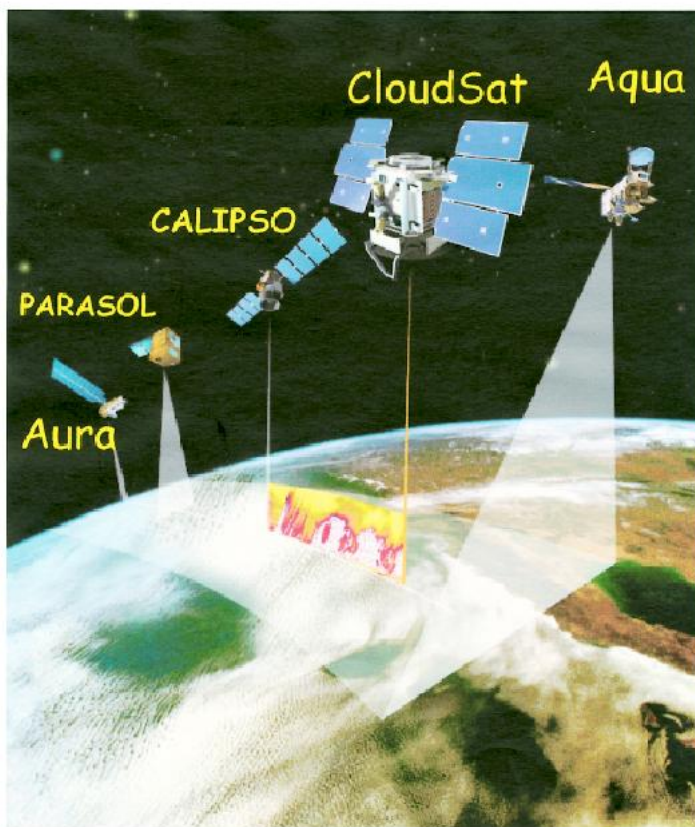
**Effelsberg – Sky Map of Percent Data Loss  
taken from Fig. 64 of ECC Report 271**



# Cloud Sat → Earth Care

# Rec. RA. 1750 also visit at

<http://www.iucaf.org/CloudSat/>



- @94.05 GHz, 100 MHz wide, 1.8 kW  
→ may burn out RA Rx → close “shutter”
- RA.1750 defines the coordination procedure; IUCAF is the gateway
- Liszt’s lecture on Thursday



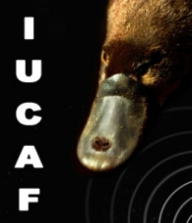
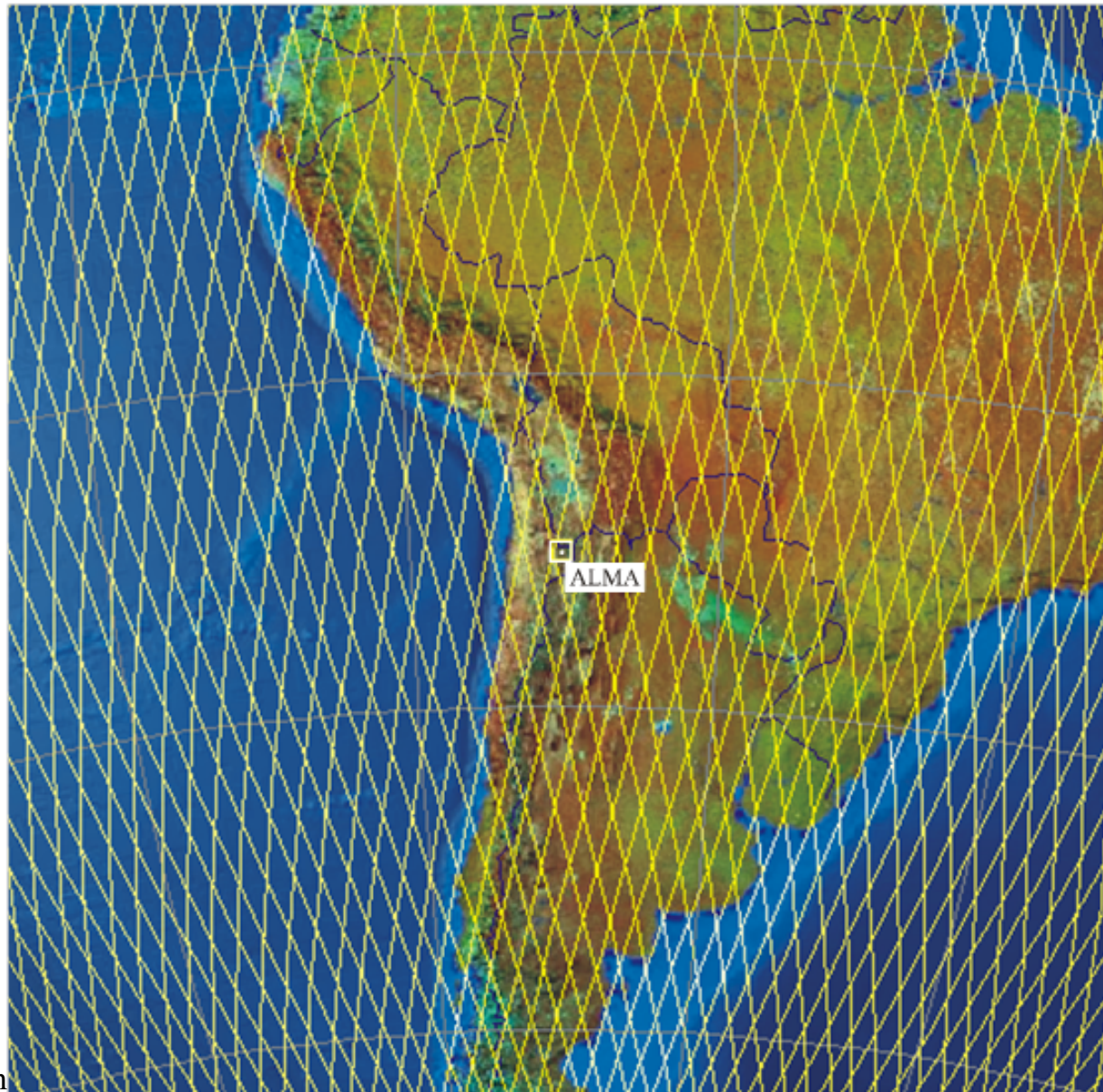


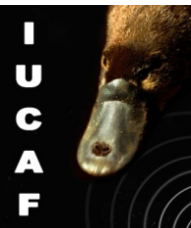
FIGURE 2

Ground tracks of AQUA over a full 16-day period, with the position of ALMA  
marked on a map of South America



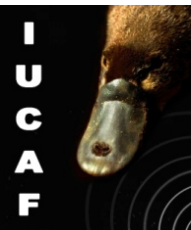
2020 March

1750-02



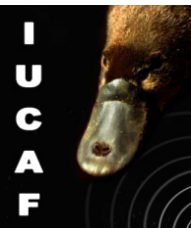
# Other Recs relevant to RAS (1)

- **P-series (Radiowave Propagation)**
  - > 372 : radio noise**
  - > 452 : Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz**
  - > 525 : Calculation of free-space attenuation**
  - > 526 : Propagation by diffraction**
  - > 676 : Attenuation by atmospheric gases and related effects**
  - > 1546 : Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz**



## Other Recs relevant to RAS (2)

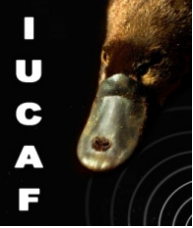
- **RS-series (Remote Sensing Systems)**
  - > **2066 : Protection of the radio astronomy service in the frequency band 10.6-10.7 GHz from unwanted emissions of synthetic aperture radars operating in the Earth exploration-satellite service (active) around 9 600 MHz**



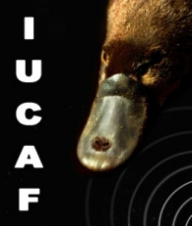
## Other Recs relevant to RAS (3)

- **SM-series**
  - > 329 : Unwanted emissions in the spurious domain
- **M.1316: OH band vs MSS**
- **M.1583 & S.1586: RAS vs non-GSO**
  - ↑ describes Monte Carlo simulation



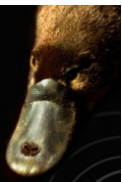


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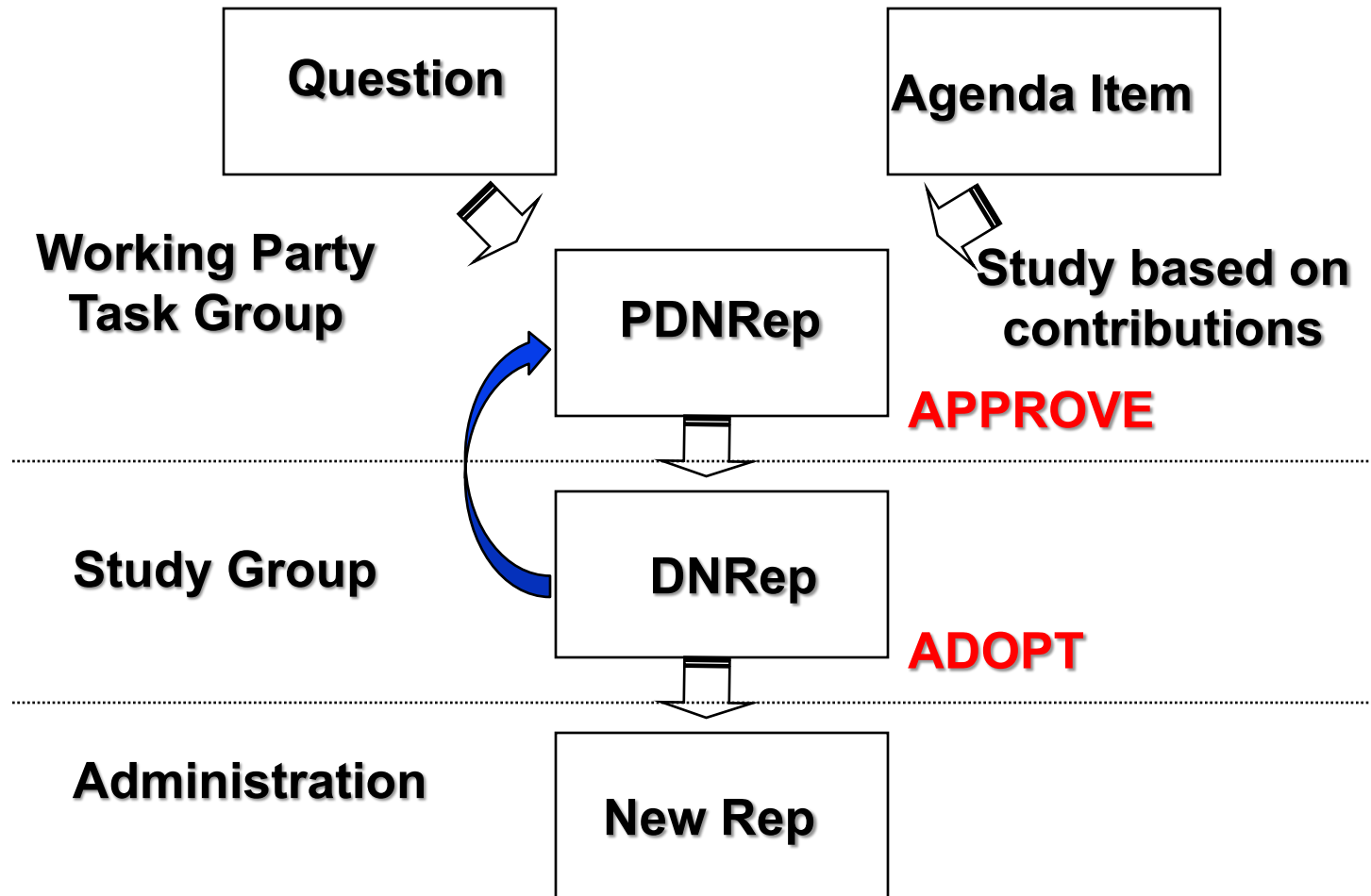


# Reports

**A technical, operational or procedural statement, **prepared by a Study Group** on a given subject related to a current Question or the results of studies referred to in § 3.3 (Resolution ITU-R 1-5)**



# Production of Reps.





# RA series Reports (1)

RA.2099	Radio observations of pulsars for precision timekeeping
RA.2126	Techniques for mitigation of radio frequency interference in radio astronomy
RA.2131	Supplementary information on the detrimental threshold levels of interference to radio astronomy observations in Recommendation ITU-R RA.769
RA.2163	Astronomical use of frequency band 50-350 THz and coexistence with other applications
RA.2188	Power flux-density and e.i.r.p. levels potentially damaging to radio astronomy receivers
RA.2189	Sharing between the radio astronomy service and active services in the frequency range 275-3 000 GHz
RA.2195	The transition to digital television and its impact on the unprotected use by the radio astronomy service of bands used for terrestrial television broadcasting
RA.2259	Characteristics of radio quiet zones



## RA series Reports (2)

RA.2332	Compatibility and sharing studies between the radio astronomy service and IMT systems in the frequency bands 608-614 MHz, 1 330-1 400 MHz, 1 400-1 427 MHz, 1 610.6-1 613.8 MHz, 1 660-1 670 MHz, 2 690-2 700 MHz, 4 800-4 990 MHz and 4 990-5 000 MHz
RA.2403	Threshold interference levels for the protection of space-based radio astronomy observations
RA.2428	Parameters needed for the registration of distributed radio astronomy systems
RA.2457	Coexistence between the radio astronomy service and radiolocation service applications in the frequency band 76-81 GHz



# **Rep. ITU-R RA.2131**

## **Supplementary info for Rec.769**

- **Conversion from spfd/pfd to field strength**  
$$E(\text{dB}(\mu\text{V}/\text{m})) = 145.7633 + \text{TV}(769)$$
- **Comparison between Rec RA.769-1 and 769-2**
  - > **One administration claims that it denies “769-2”, but prefers to “769-1”**
  - > **“769-1” and “769-2” levels are identical for  $f < 50 \text{ GHz}$**
  - > **“769-2” contains threshold levels for the 22GHz band**



# Common Values in Rec 769 (continuum)

Centre frequency (MHz)	Bandwidth (MHz)	pfd (dB(W/m <sup>2</sup> ))	Spectral pfd (dB(W/(m <sup>2</sup> · Hz)))	Electric field (dB(μV/m))
13.385	0.05	−201	−248	−55.2
25.610	0.12	−199	−249	−53.2
73.8	1.6	−196	−258	−50.2
151.525	2.95	−194	−259	−48.2
325.3	6.6	−189	−258	−43.2
408.05	3.9	−189	−255	−43.2
611	6.0	−185	−253	−39.2
1 413.5	27	−180	−255	−34.2
1 665	10	−181	−251	−35.2
2 695	10	−177	−247	−31.2
4 995	10	−171	−241	−25.2
10 650	100	−160	−240	−14.2
15 375	50	−156	−233	−10.2
23 800	400	−147	−233	−1.2
31 550	500	−141	−228	+4.8
43 000	1 000	−137	−227	+8.8



# Different Values in Rec 769 (continuum)

Centre frequency (MHz)	Bandwidth (MHz)	pfd (dB(W/m <sup>2</sup> ))	Spectral pfd (dB(W/(m <sup>2</sup> · Hz)))	Electric field (dB(μV/m))
22 355 (769-2 only)	290	−146	−231	−0.2
89 000	6 000 → 8 000	−125 → −129	−222 → −228	+20.8 → +16.8
110 500 (769-1 only)	11 000	−121	−222	+24.8
150 000 (769-2 only)	8 000	−124	−223	+21.8
166 000 (769-1 only)	4 000	−120	−216	+25.8
224 000	14 000 → 8 000	−114 → −119	−215 → −218	+31.8 → +26.8
270 000	10 000 → 8 000	−113 → −117	−213 → −216	+33.8 → +28.8

\* Arrows have been used to indicate changes in the sense Recommendations ITU-R RA.769-1 → ITU-R RA.769-2.





# Common Values in Rec 769 (spectral line)

Centre frequency (MHz)	Bandwidth (kHz)	pfd (dB(W/m <sup>2</sup> ))	Spectral pfd (dB(W/m <sup>2</sup> · Hz))	Electric field (dB(μV/m))
327	10	−204	−244	−58.2
1 420	20	−196	−239	−50.2
1 612	20	−194	−238	−48.2
1 665	20	−194	−237	−48.2
4 830	50	−183	−230	−37.2
14 488	150	−169	−221	−23.2
22 200	250	−162	−216	−16.2
23 700	250	−161	−215	−15.2
43 000	500	−153	−210	−07.2
48 000	500	−152	−209	−06.2

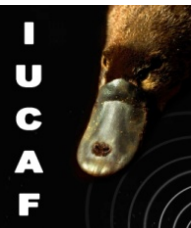
\* Arrows have been used to indicate changes in the sense Recommendations ITU-R RA.769-1 → ITU-R RA.769-2



# Different Values in Rec 769 (spectral line)

Centre frequency (MHz)	Bandwidth (kHz)	pfd (dB(W/m <sup>2</sup> ))	Spectral pfd (dB(W/(m <sup>2</sup> · Hz)))	Electric field (dB(μV/m))
88 600	1 000	-144 → -148	-204 → -208	-58.2 → -62,2
98 000 (769-1 only)	1 000	-143	-203	-57.2
115 000 (769-1 only)	1 000	-141	-201	-55.2
140 000 (769-1 only)	1 500	-139	-200	-54.2
150 000 (769-2 only)	1 000	-144	-204	-58.2
178 000 (769-1 only)	1 500	-136	-198	-52.2
220 000	2 500 → 1 000	-133 → -139	-197 → -199	-51.2 → -53.2
265 000	2 500 → 1 000	-131 → -137	-195 → -197	-49.2 → -51.2

\* Arrows have been used to indicate changes in the sense Recommendations ITU-R  
RA.769-1 → ITU-R RA.769-2.



# Sharing between 275 and 3000 GHz (1)

- **WRC-12 agenda item 1.6**  
updated “identification”s to passive services  
(RAS, EESS(p) and SRS) in footnote No. 5.565  
  
passive services only



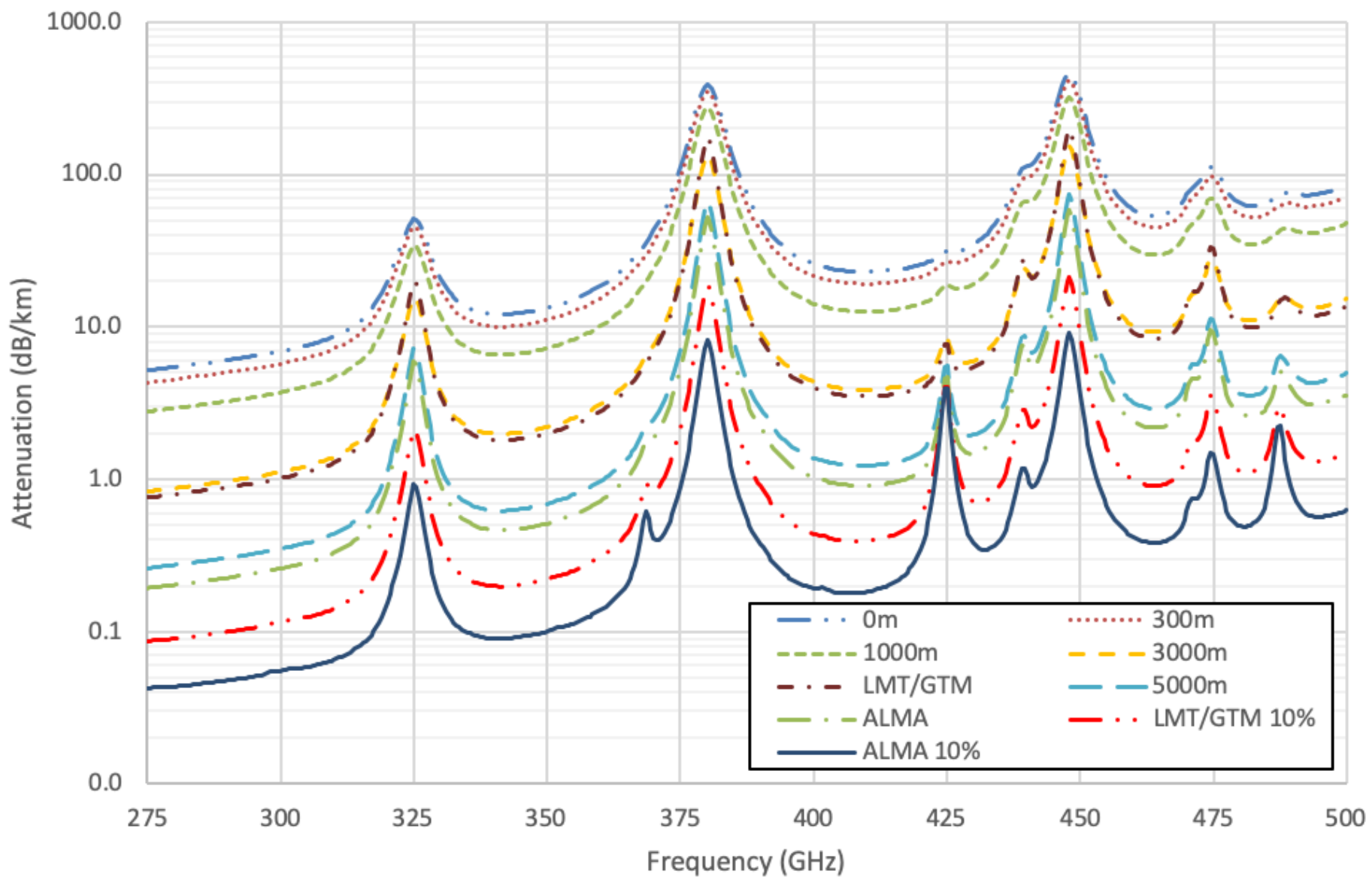
# Concerns by active services

- **“First-in first-served”; new-comers need to demonstrate that they do not interfere with existing services**
- **high frequency region might be exclusively used by passive services**  
**→ no future developments can be made for active services**



# Rep. ITU-R RA.2189

- **Was a fundamental material in demonstrating that the RAS can generally coexist with active services in the frequency region above 275 GHz**
- **Very large atmospheric attenuation/km:  
> between hundreds to hundreds of thousands of dB per km at sea level**
- **Terrestrial radio astronomy can only be conducted at the very highest and driest sites, where THz-frequency emitters are unlikely to be located**



**Horizontal path**



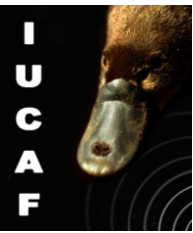
# Upgraded FN 5.565 as of 2012

**5.565** The following frequency bands in the range 275-1 000 GHz are identified for use by administrations for passive service applications:

- radio astronomy service: 275-323 GHz, 327-371 GHz, 388-424 GHz, 426-442 GHz, 453-510 GHz, 623-711 GHz, 795-909 GHz and 926-945 GHz;
- Earth exploration-satellite service (passive) and space research service (passive): 275-286 GHz, 296-306 GHz, 313-356 GHz, 361-365 GHz, 369-392 GHz, 397-399 GHz, 409-411 GHz, 416-434 GHz, 439-467 GHz, 477-502 GHz, 523-527 GHz, 538-581 GHz, 611-630 GHz, 634-654 GHz, 657-692 GHz, 713-718 GHz, 729-733 GHz, 750-754 GHz, 771-776 GHz, 823-846 GHz, 850-854 GHz, 857-862 GHz, 866-882 GHz, 905-928 GHz, 951-956 GHz, 968-973 GHz and 985-990 GHz.

**The use of the range 275-1 000 GHz by the passive services does not preclude use of this range by active services. Administrations wishing to make frequencies in the 275-1 000 GHz range available for active service applications are urged to take all practicable steps to protect these passive services from harmful interference until the date when the Table of Frequency Allocations is established in the above-mentioned 275-1 000 GHz frequency range.**

**All frequencies in the range 1 000-3 000 GHz may be used by both active and passive services. (WRC 12)**



# Sharing between 275 and 3000 GHz (2)

- **WRC-19 agenda item 1.15**  
new “identification”s to fixed service and land mobile service between 275 and 450 GHz





# New footnote 5.X115

**5.X115** For the operation of **fixed and land mobile service** applications in frequency bands in the range 275-450 GHz:

The frequency bands **275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz** are identified for use by administrations for the implementation of land mobile and fixed service applications, where no specific conditions are necessary to protect Earth exploration-satellite service (passive) applications.

The frequency bands 296-306 GHz, 313-318 GHz and 333-356 GHz may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are determined in accordance with Resolution 731 (Rev.WRC-19).

**In those portions of the frequency range 275-450 GHz where radio astronomy applications are used, specific conditions (e.g. minimum separation distances and/or avoidance angles) may be necessary to ensure protection of radio astronomy sites from land mobile and/or fixed service applications, on a case-by-case basis in accordance with Resolution 731 (Rev.WRC-19).**

The use of the above-mentioned frequency bands by land mobile and fixed service applications does not preclude use by, and does not establish priority over, any other applications of radio services in the range of 275-450 GHz. (WRC-19)

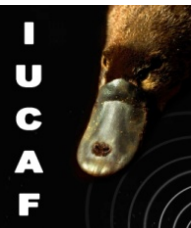


## **RA.2259**

# **Characteristics of Radio Quiet Zones**

- **A summary of existing RQZs**
- **NRQZ (US), ALMA (CL), MRO (AU), AGAA (ZA), FAST (CN),,,,**
- **Details will be given by Di Vruno**

**Some administrations were reluctant to study RQZs, especially international ones.**



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