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Above 275 GHz

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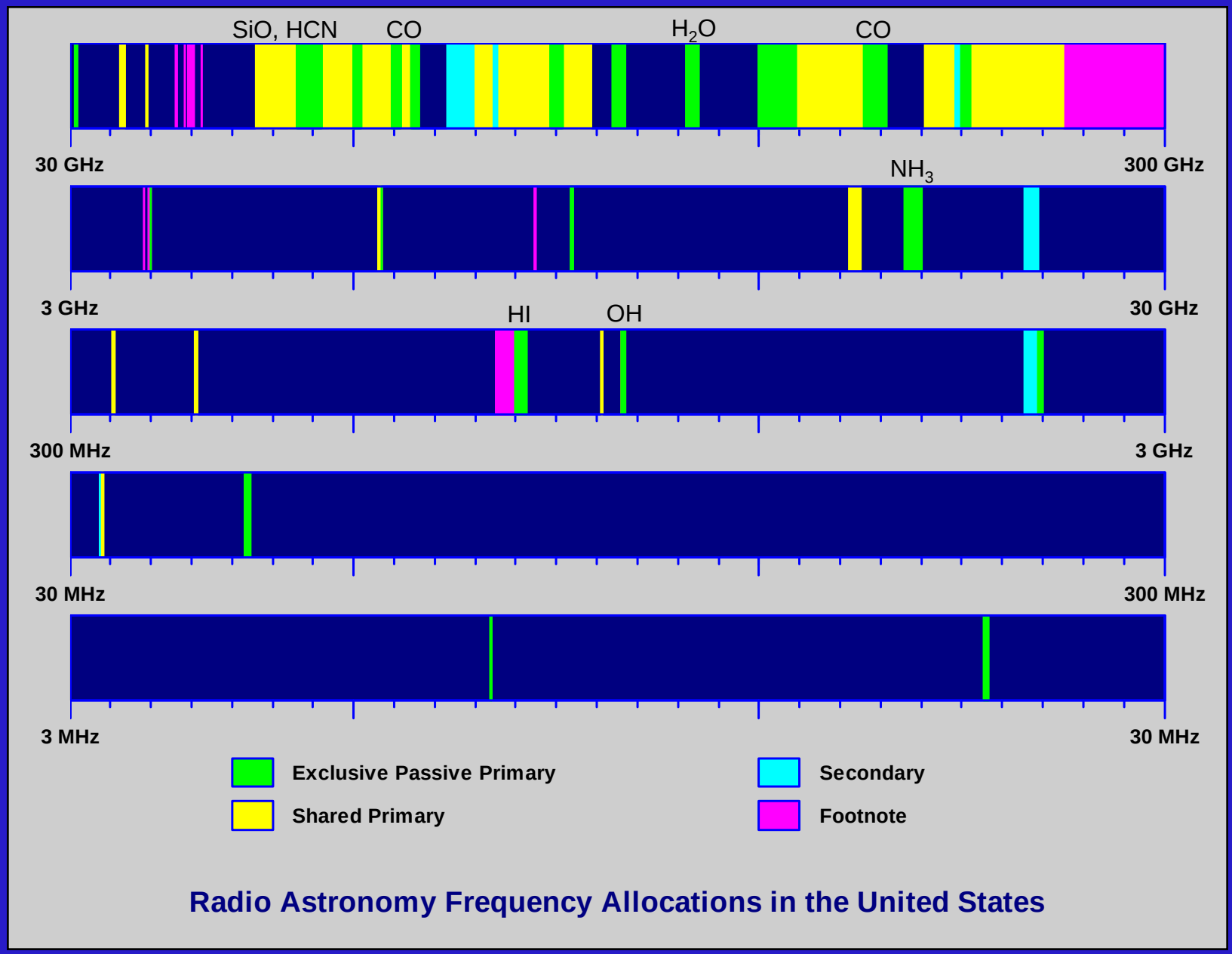

Radio Astronomy Frequency Allocations in the United States

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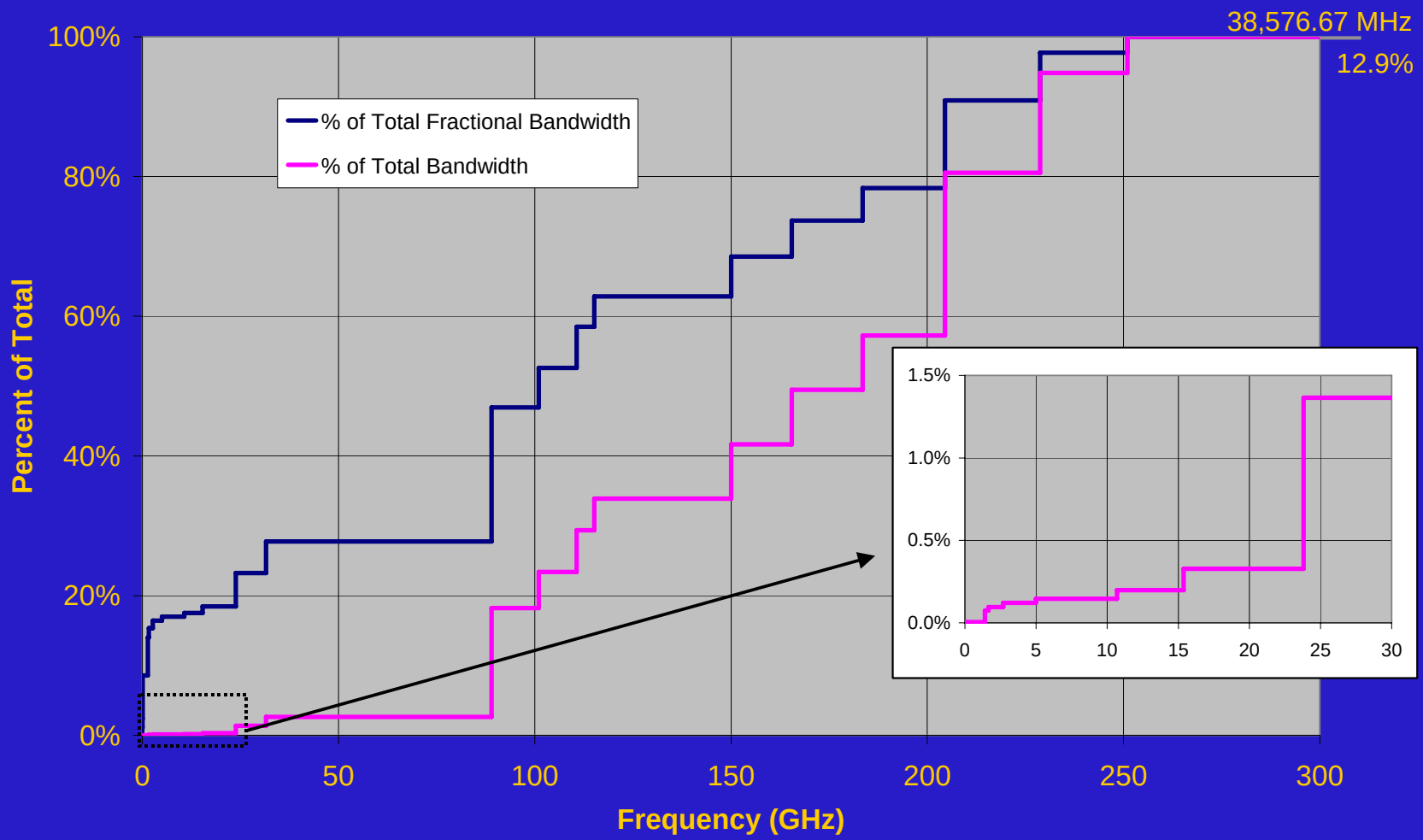
Cumulative Distribution of Exclusive Passive Spectrum Allocations



Less than 1.5% of our cleanest bandwidth is below 30 GHz

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Above 275 GHz

- The International Table of Frequency Allocations presently extends to an upper limit of 275 GHz
- The U.S. Table of Frequency Allocations extends to an upper limit of 300 GHz, and also contains a reference to 5.565
- Both the ITU and the FCC adopt the following definition of “radio waves”:
  - Electromagnetic waves of frequencies arbitrarily lower than 3,000 GHz, propagated in space without artificial guide.
- Although not allocated, bands between 275 – 3000 GHz are the purview of the ITU and FCC
- Footnote 5.565 to the Table (ITU and FCC) notes the interest of the radio astronomy and EESS services in frequencies between 275 and 1 000 GHz

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Footnote 5.565

"The frequency band 275-1000 GHz may be used by administrations for experimentation with, and development of, various active and passive services. In this band a need has been identified for the following spectral line measurements for passive services:

> **"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): 275-277 GHz, 294-306 GHz, 316-334 GHz, 342-349 GHz, 363-365 GHz, 371-389 GHz, 416-434 GHz, 442-444 GHz, 496-506 GHz, 546-568 GHz, 624-629 GHz, 634-654 GHz, 659-661 GHz, 684-692 GHz, 730-732 GHz, 851-853 GHz and 951-956 GHz.**

"Future research in this largely unexplored spectral region may yield additional spectral lines and continuum bands of interest to the passive services. Administrations are urged to take all practicable steps to protect these passive services from harmful interference until the date when the allocation Table is established in the above-mentioned frequency band."

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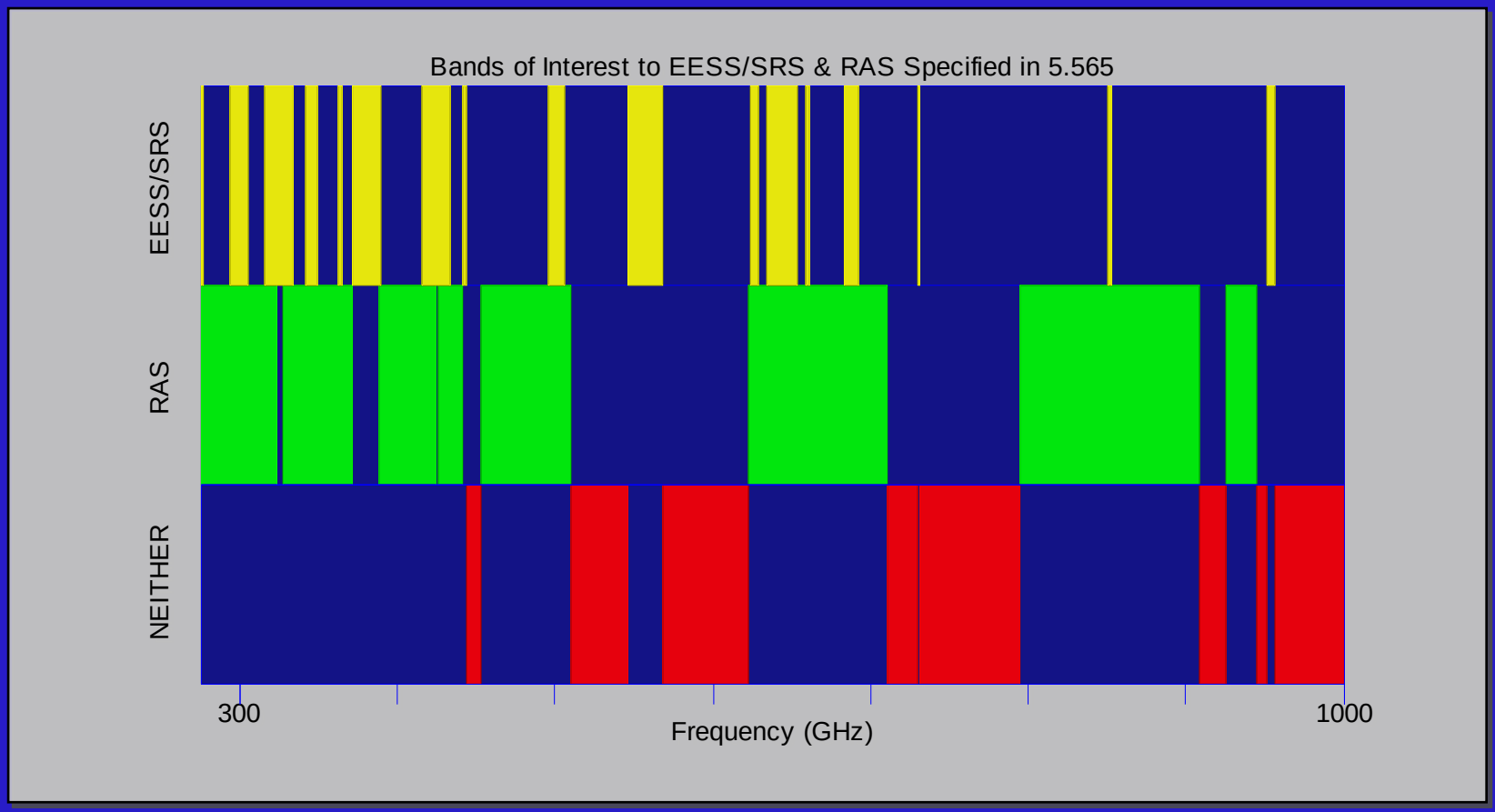
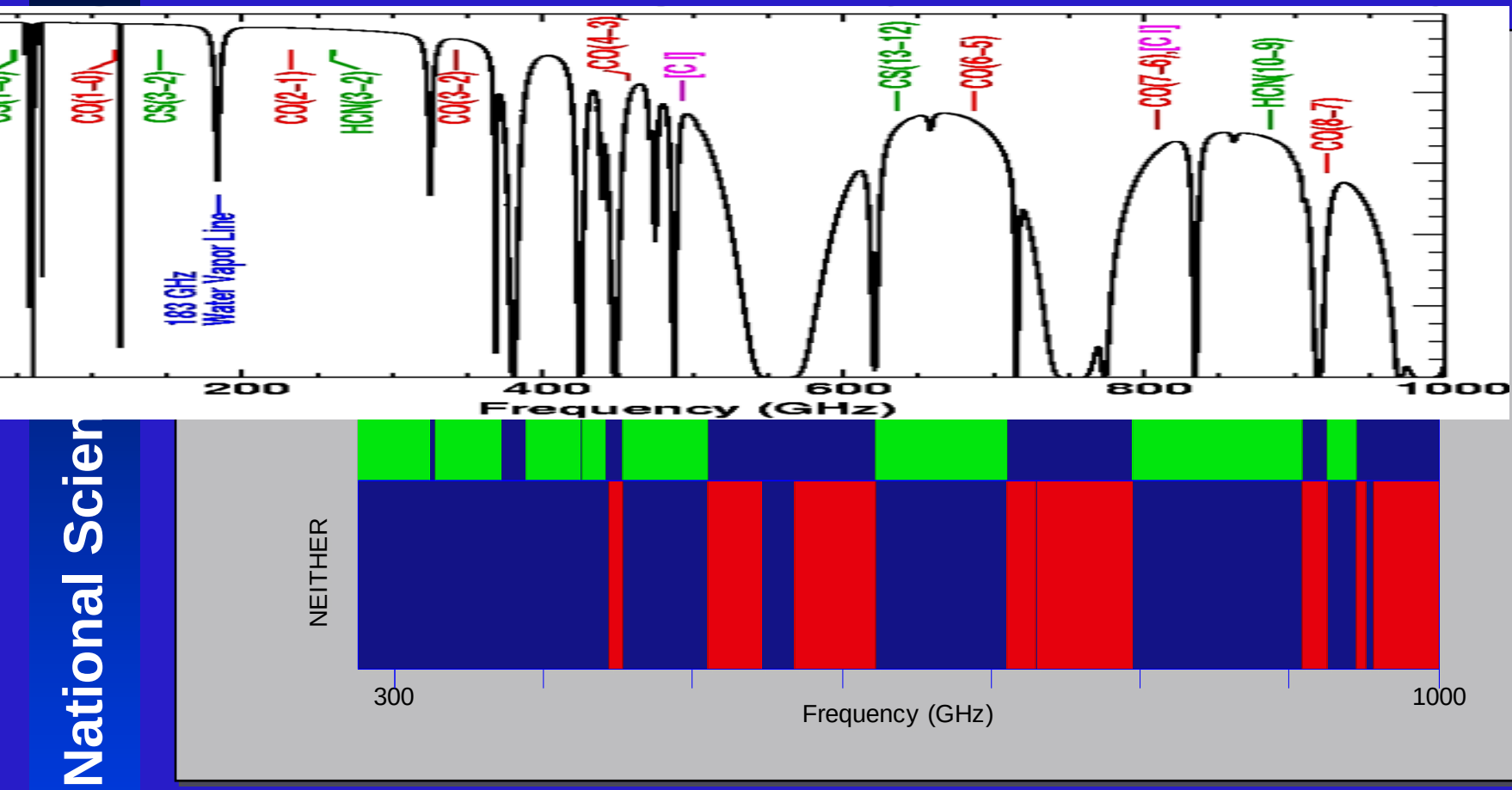


275 – 1000 GHz covered by 5.565:

- EESS: 155 GHz (21%)
- RAS: 422 GHz (58%)
- COMBINED: 476 GHz (66%)
- NEITHER: 249 GHz (34%)

Bands not Covered (GHz):

444 – 453	732 – 795
510 – 546	909 – 926
568 – 623	945 – 951
711 – 730	956 – 1000



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Above 275 GHz

- Resolution 950 (WRC-03) considers the use of the frequencies between 275 and 3 000 GHz, and invites the ITU-R:
  - to conduct the necessary studies in time for consideration by WRC-10 with a view to the modification of No. 5.565 or the possible extension of the Table of Frequency Allocations above 275 GHz, including advice on the applications suitable for such bands.
- Resolution 803 (WRC-03) establishes the consideration of frequency allocations between 275 GHz and 3 000 GHz as item 2.2 of the preliminary agenda for WRC-10.
- Through Working Party 7D (Radio Astronomy) of the ITU, we are presently attempting to establish specific bands of interest to Radio Astronomy in the range 275 – 3 000 GHz, in anticipation of possible future WRC activity

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Above 275 GHz

- Bands of interest below 1000 GHz are based upon a list of spectral lines of astrophysical interest established in ITU-R Recommendation RA.314-10
- Spectral lines of interest above 1000 GHz have, to date, been based upon line data from NIST.
  - IAU Division X Working Group on Astrophysically Important Spectral Lines (with considerable cross-membership with ITU WP 7D) meeting in Prague (August 2006) established a provisional list of astrophysically important spectral lines which was the NIST list as originally submitted to WP 7D by U.S.
  - The list is missing important lines
  - Specific consideration for continuum bands is also needed
- The involvement of astronomers actively involved in submm observational research is needed to refine the list of bands of astrophysical importance between 275 and 3000 GHz.

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ITU Recommendation ITU-R RA.314-10

Radio-frequency lines of the greatest importance to radio astronomy between 275 and 1,000 GHz

Substance	Chemical Notation	Frequency (GHz)		Doppler (km/s)		Covered by 5.565
		Rest	Suggested Minimum Band	Toward	Away	
Diazenylium	N_2H^+	279.511	279.23 – 279.79	299	302	Yes
Carbon monosulphide	CS	293.912	292.93 – 294.21	304	1005	Yes
Hydronium	H_3O^+	307.192	306.88 – 307.50	301	305	Yes
Deuterated water	HDO	313.750	313.44 – 314.06	296	297	Yes
Carbon monoxide	$C^{18}O$	329.330	329.00 – 329.66	300	301	Yes
Carbon monoxide	^{13}CO	330.587	330.25 – 330.92	302	306	Yes
Carbon monosulfide	CS	342.883	342.54 – 343.23	303	300	Yes
Carbon monoxide	CO	345.796	345.45 – 346.14	298	300	Yes
Hydrogen cyanide	HCN	354.484	354.13 – 354.84	301	300	Yes
Formylium	HCO^+	356.734	356.37 – 357.09	299	306	Yes
Oxygen	O_2	368.498	368.13 – 368.87	303	300	Yes
Diazenylium	N_2H^+	372.672	372.30 – 373.05	304	300	No
Water vapor	H_2O	380.197	379.81 – 380.58	302	305	No
Hydronium	H_3O^+	388.459	388.07 – 388.85	302	301	Yes
Carbon monosulfide	CS	391.847	390.54 – 392.24	301	1003	Yes
Oxygen	O_2	424.763	424.34 – 425.19	301	299	No
Carbon monoxide	$C^{18}O$	439.088	438.64 – 439.53	302	306	Yes
Carbon monoxide	^{13}CO	440.765	440.32 – 441.21	303	303	Yes
Carbon monoxide	CO	461.041	460.57 – 461.51	305	307	Yes
Deuterated water	HDO	464.925	464.46 – 465.39	300	300	Yes
Carbon	C	492.162	491.66 – 492.66	303	306	Yes
Deuterated water	HDO	509.292	508.78 – 509.80	299	302	Yes
Hydrogen cyanide	HCN	531.716	529.94 – 532.25	301	1005	No
Carbon monosulfide	CS	538.689	536.89 – 539.23	301	1005	No
Water vapor	$H_2{}^{18}O$	547.676	547.13 – 548.22	298	299	No
Carbon monoxide	^{13}CO	550.926	549.09 – 551.48	301	1002	No
Water vapor	H_2O	556.936	556.37 – 557.50	304	305	No
Ammonia	$^{15}NH_3$	572.113	571.54 – 572.69	302	301	No

Substance	Chemical Notation	Frequency (GHz)		Doppler (km/s)		Covered by 5.565
		Rest	Suggested Minimum Band	Toward	Away	
Ammonia	NH_3	572.498	571.92 – 573.07	300	303	No
Carbon monoxide	CO	576.268	574.35 – 576.84	298	1001	No
Carbon monosulfide	CS	587.616	587.03 – 588.20	298	299	No
Deuterated water	HDO	599.927	599.33 – 600.53	301	299	No
Water vapor	H_2O	620.700	620.08 – 621.32	299	300	No
Hydrogen chloride	HCl	625.040	624.27 – 625.67	302	370	Yes
Hydrogen chloride	HCl	625.980	625.35 – 626.61	302	302	Yes
Carbon monosulfide	CS	636.532	634.41 – 637.17	300	1003	Yes
Carbon monoxide	^{13}CO	661.067	658.86 – 661.73	301	1004	Yes
Carbon monoxide	CO	691.473	690.78 – 692.17	302	301	Yes
Oxygen	O_2	715.393	714.68 – 716.11	300	299	No
Carbon monosulfide	CS	734.324	733.59 – 735.06	300	300	No
Water vapor	H_2O	752.033	751.28 – 752.79	302	300	No
Oxygen	O_2	773.840	773.07 – 784.61	4172	299	No
Hydrogen cyanide	HCN	797.433	796.64 – 798.23	300	298	Yes
Formylium	HCO^+	802.653	801.85 – 803.85	447	300	Yes
Carbon monoxide	CO	806.652	805.85 – 807.46	300	298	Yes
Carbon	C	809.350	808.54 – 810.16	300	300	Yes
Carbon monosulfide	CS	832.057	829.28 – 832.89	300	1004	Yes
Oxygen	O_2	834.160	833.31 – 834.98	295	306	Yes
Carbon monosulfide	CS	880.899	877.96 – 881.78	300	1004	Yes
Water vapor	H_2O	916.172	915.26 – 917.09	300	299	No
Carbon monoxide	CO	921.800	918.72 – 922.72	299	1005	No
Carbon monosulfide	CS	929.723	926.62 – 930.65	299	1004	Yes
Water vapor	H_2O	970.315	969.34 – 971.29	301	302	No
Carbon monosulfide	CS	978.529	977.55 – 979.51	301	300	No
Water vapor	H_2O	987.927	986.94 – 988.92	301	300	No

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Working List of Spectral Lines of Astrophysical Interest Between 1,000 – 3,000 GHz

Approved by IAU Div X WG on Astrophysically Important Spectral Lines, August 2006

Substance	Chemical Notation	Frequency (GHz)		Doppler (km/s)	
		Rest	Suggested Minimum Band	Toward	Away
Carbon monoxide	CO	1036.912	1035.88 – 1037.95	300	299
Carbon monoxide	CO	1267.014	1265.75 – 1268.28	300	299
Trihydrogen ion	H_2D^+	1370.085	1368.71 – 1371.46	301	301
Carbon monoxide	CO	1381.995	1380.61 – 1383.38	300	301
Nitrogen ion	N^+	1461.132	1459.67 – 1462.59	299	300
Carbon monoxide	CO	1611.793	1610.18 – 1613.40	299	300
Water	$H_2{}^{18}O$	1646.398	1644.75 – 1648.04	299	300
Oxonium hydride	H_3O^+	1655.834	1654.18 – 1657.49	300	300
Hydroxyl	OH	1834.747	1832.91 – 1836.58	300	300
Hydroxyl	OH	1837.816	1835.98 – 1839.65	299	300
Carbon monoxide	CO	1841.346	1839.50 – 1843.19	300	301
Carbon monoxide	CO	1956.018	1954.06 – 1957.97	299	300
Tricarbon	C_3	1968.595	1966.63 – 1970.56	299	300
Carbon monoxide	^{13}CO	1979.726	1977.75 – 1981.71	300	300
Carbon monoxide	CO	2413.917	2411.50 – 2416.33	300	300
Hydrofluoric acid	HF	2463.428	2460.96 – 2465.89	300	301
Hydroxyl	OH	2509.948	2507.44 – 2512.46	300	300
Hydroxyl	OH	2514.316	2511.80 – 2516.83	300	300
Carbon monoxide	CO	2528.172	2525.64 – 2530.70	300	301
Oxonium hydride	H_3O^+	2972.100	2969.13 – 2975.07	300	300
Oxonium hydride	H_3O^+	2980.725	2977.74 – 2983.71	300	301

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Recommendation

- A review of the scientific uses of the radio spectrum should include bands above 275 GHz, to help establish a favorable position internationally and domestically when allocations in this frequency range are addressed.