International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R RA.314-10

(06/2003)

Preferred frequency bands for radio astronomical measurements

RA Series

Radio astronomy

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Recommendations

(Also available online at http://www.itu.int/publ/R-REC/en)

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

Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2010

RECOMMENDATION ITU-R RA.314-10

Preferred frequency bands for radio astronomical measurements

(Question ITU-R 145/7)

(1953-1956-1959-1966-1970-1974-1978-1982-1986-1990-1992-2002-2003)

The ITU Radiocommunication Assembly,

considering

a) that the development of radio astronomy has led to major technological advances, particularly in receiving techniques and to improved knowledge of fundamental radio-noise limitations of great importance to radiocommunication, and promises further important results;

b) that the advancement of radio astronomy requires the protection of certain frequency bands from interference;

c) that the International Astronomical Union (IAU) is maintaining and updating the list of spectral lines of the greatest importance to radio astronomy;

d) that radio astronomers study spectral lines both in bands allocated to the radio astronomy service and, as far as spectrum usage by other services allows, outside the allocated bands, and that this has resulted in the detection of more than 3 000 spectral lines as illustrated in Fig. 1 of Annex 1;

e) that account should be taken of the Doppler shifts of the lines, due to the relative motion of source and observer;

f) that certain frequency bands have been allocated for continuum observations, and that the exact positions of these bands in the spectrum are not of critical importance, but that their centre frequencies should be in the ratio not more than two to one, taking the width of relevant atmospheric windows into account;

g) that radio astronomers have made useful astronomical observations from the Earth's surface in all available atmospheric windows ranging from 2 MHz to 1 000 GHz and above;

h) that the technique of space radio astronomy, which involves the use of radio telescopes on space platforms, provides access to the entire radio spectrum above about 10 kHz, including parts of the spectrum not accessible from the Earth due to absorption in the atmosphere;

j) that some types of high-resolution interferometric observations require simultaneous reception, at the same radio frequency, by receiving systems located in different countries, on different continents, or on space platforms;

k) that world administrative radio conferences and world radiocommunication conferences have made improved frequency allocations for radio astronomy, but that protection in many bands, particularly those shared with other services, may still need careful planning,

recommends

1 that administrations should afford all practicable protection to the frequencies used by radio astronomers in their own and neighbouring countries;

2 that particular attention should be given to securing or maintaining adequate protection for the frequency bands listed in Tables 1 and 2, which contain rest frequencies and Doppler-shifted frequencies of the astrophysically most important spectral lines identified by the General Assembly of the IAU, and in Table 3, which contains the frequency bands allocated to the radio astronomy service that are preferred for continuum observations;

3 that administrations be asked to provide assistance in the coordination of observations of spectral lines in bands not allocated to radio astronomy.

TABLE 1

Radio-frequency lines of the greatest importance to radio astronomy at frequencies below 275 GHz

Substance	Rest frequency	Suggested minimum band	Notes[1]
Deuterium (DI)	327.384 MHz	327.0-327.7 MHz	
Hydrogen (HI)	1 420.406 MHz	1 370.0-1 427.0 MHz	(2), (3)
Hydroxyl radical (OH)	1 612.231 MHz	1 606.8-1 613.8 MHz	(4)
Hydroxyl radical (OH)	1 665.402 MHz	1 659.8-1 667.1 MHz	(4)
Hydroxyl radical (OH)	1 667.359 MHz	1 661.8-1 669.0 MHz	(4)
Hydroxyl radical (OH)	1 720.530 MHz	1 714.8-1 722.2 MHz	(3), (4)
Methyladyne (CH)	3 263.794 MHz	3 252.9-3 267.1 MHz	(3), (4)
Methyladyne (CH)	3 335.481 MHz	3 324.4-3 338.8 MHz	(3), (4)
Methyladyne (CH)	3 349.193 MHz	3 338.0-3 352.5 MHz	(3), (4)
Formaldehyde (H_2CO)	4 829.660 MHz	4 813.6-4 834.5 MHz	(3), (4)
Methanol (CH_3OH)	6 668.518 MHz	6 661.8-6 675.2 MHz	(3)
Helium ($^3He^+$)	8 665.650 MHz	8 657.0-8 674.3 MHz	(3), (6)
Methanol (CH_3OH)	12.178 GHz	12.17-12.19 GHz	(3), (6)
Formaldehyde (H_2CO)	14.488 GHz	14.44-14.50 GHz	(3), (4)
Cyclopropenylidene (C_3H_2)	18.343 GHz	18.28-18.36 GHz	(3), (4), (6)
Water vapour (H_2O)	22.235 GHz	22.16-22.26 GHz	(3), (4)
Ammonia (NH_3)	23.694 GHz	23.61-23.71 GHz	(4)
Ammonia (NH_3)	23.723 GHz	23.64-23.74 GHz	(4)
Ammonia (NH_3)	23.870 GHz	23.79-23.89 GHz	(4)
Sulphur monoxide (SO)	30.002 GHz	29.97-30.03 GHz	(6)
Methanol (CH_3OH)	36.169 GHz	36.13-36.21 GHz	(6)
Silicon monoxide (SiO)	42.519 GHz	42.47-42.57 GHz	(6), (8)
Silicon monoxide (SiO)	42.821 GHz	42.77-42.86 GHz	
Silicon monoxide (SiO)	43.122 GHz	43.07-43.17 GHz	
Silicon monoxide (SiO)	43.424 GHz	43.37-43.47 GHz	
Dicarbon monosulphide (CCS)	45.379 GHz	45.33-45.44 GHz	(6)

TABLE 1 (*end*)

Substance	Rest frequency	Suggested minimum band	Notes[1]
Carbon monosulphide (CS)	48.991 GHz	48.94-49.04 GHz	
Oxygen (O_2)	61.1 GHz	56.31-63.06 GHz	(5), (6), (7)
Deuterated water (HDO)	80.578 GHz	80.50-80.66 GHz	
Cyclopropenylidene (C_3H_2)	85.339 GHz	85.05-85.42 GHz	
Silicon monoxide (SiO)	86.243 GHz	86.16-86.33 GHz	
Formylium ($H^{13}CO^+$)	86.754 GHz	86.66-86.84 GHz	
Silicon monoxide (SiO)	86.847 GHz	86.76-86.93 GHz	
Ethynyl radical (C_2H)	87.3 GHz	87.21-87.39 GHz	(5)
Hydrogen cyanide (HCN)	88.632 GHz	88.34-88.72 GHz	(4)
Formylium (HCO^+)	89.189 GHz	88.89-89.28 GHz	(4)
Hydrogen isocyanide (HNC)	90.664 GHz	90.57-90.76 GHz	
Diazenylium (N_2H^+)	93.174 GHz	93.07-93.27 GHz	
Carbon monosulphide (CS)	97.981 GHz	97.65-98.08 GHz	(4)
Sulphur monoxide (SO)	99.300 GHz	99.98-100.18 GHz	
Methyl acetylene (CH_3C_2H)	102.5 GHz	102.39-102.60 GHz	(5)
Methanol (CH_3OH)	107.014 GHz	106.91-107.12 GHz	
Carbon monoxide ($C^{18}O$)	109.782 GHz	109.67-109.89 GHz	
Carbon monoxide (^{13}CO)	110.201 GHz	109.83-110.31 GHz	(4)
Carbon monoxide ($C^{17}O$)	112.359 GHz	112.25-112.47 GHz	(6)
Cyano radical (CN)	113.5 GHz	113.39-113.61 GHz	(5)
Carbon monoxide (CO)	115.271 GHz	114.88-115.39 GHz	(4)
Oxygen (O_2)	118.750 GHz	118.63-118.87 GHz	(7)
Formaldehyde ($H_2{}^{13}CO$)	137.450 GHz	137.31-137.59 GHz	(6)
Formaldehyde (H_2CO)	140.840 GHz	140.69-140.98 GHz	
Carbon monosulphide (CS)	146.969 GHz	146.82-147.12 GHz	
Nitric oxide (NO)	150.4 GHz	149.95-150.85 GHz	(5)
Methanol (CH_3OH)	156.602 GHz	156.45-156.76 GHz	
Water vapour (H_2O)	183.310 GHz	183.12-183.50 GHz	
Carbon monoxide ($C^{18}O$)	219.560 GHz	219.34-219.78 GHz	
Carbon monoxide (^{13}CO)	220.399 GHz	219.67-220.62 GHz	(4)
Cyano radical (CN)	226.6 GHz	226.37-226.83 GHz	(5)
Cyano radical (CN)	226.8 GHz	226.57-227.03 GHz	(5)
Carbon monoxide (CO)	230.538 GHz	229.77-230.77 GHz	(4)
Carbon monosulphide (CS)	244.953 GHz	244.72-245.20 GHz	(6)
Nitric oxide (NO)	250.6 GHz	250.35-250.85 GHz	(5)
Ethynyl radical (C_2H)	262.0 GHz	261.74-262.26 GHz	(5)
Hydrogen cyanide (HCN)	265.886 GHz	265.62-266.15 GHz	
Formylium (HCO^+)	267.557 GHz	267.29-267.83 GHz	
Hydrogen isocyanide (HNC)	271.981 GHz	271.71-272.25 GHz	

Notes relating to Table 1:

(1) If Notes (2) or (4) are not listed, the band limits are the Doppler-shifted frequencies corresponding to radial velocities of ± 300 km/s (consistent with line radiation occurring in our galaxy).

(2) An extension to lower frequency of the allocation of 1 400-1 427 MHz is required to allow for the higher Doppler shifts for HI observed in distant galaxies.

(3) The current international allocation is not primary and/or does not meet bandwidth requirements. See the Radio Regulations (RR) for more detailed information.

(4) Because these line frequencies are also being used for observing other galaxies, the listed bandwidths include Doppler shifts corresponding to radial velocities of up to 1 000 km/s. It should be noted that HI has been observed at frequencies redshifted to 500 MHz, while some lines of the most abundant molecules have been detected in galaxies with velocities up to 50 000 km/s, corresponding to a frequency reduction of up to 17%.

(5) There are several closely spaced lines associated with these molecules. The listed bands are wide enough to permit observations of all lines.

(6) This line frequency is not mentioned in RR Article 5.

(7) These lines are observable only outside the atmosphere.

(8) A portion of the "suggested minimum band" for this line extends outside the band allocated to the radio astronomy service. Protection for observations conducted in this portion of the band may not be practicable.

NOTE 1 – A more extended list of astrophysically important and often observed line frequencies, the "Recommended Rest Frequencies for Observed Interstellar Molecular Microwave Transitions", is maintained by a group at the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, United States of America, (http://physics.nist.gov/PhysRefData/).

TABLE 2

Radio-frequency lines of the greatest importance to radio astronomy at frequencies between 275 and 1 000 GHz (not allocated in the RR)

Substance	Rest frequency (GHz)	Suggested minimum band (GHz)	Notes(1)
Diazenylium (N_2H^+)	279.511	279.23-279.79	
Carbon monosulphide (CS)	293.912	292.93-294.21	
Hydronium (H_3O^+)	307.192	306.88-307.50	
Deuterated water (HDO)	313.750	313.44-314.06	
Carbon monoxide ($C^{18}O$)	329.330	329.00-329.66	
Carbon monoxide (^{13}CO)	330.587	330.25-330.92	
Carbon monosulphide (CS)	342.883	342.54-343.23	
Carbon monoxide (CO)	345.796	345.45-346.14	
Hydrogen cyanide (HCN)	354.484	354.13-354.84	

TABLE 2 (*continued*)

Substance	Rest frequency (GHz)	Suggested minimum band (GHz)	Notes[1]
Formylium (HCO^+)	356.734	356.37-357.09	
Oxygen (O_2)	368.498	368.13-368.87	
Diazenylium (N_2H^+)	372.672	372.30-373.05	(2)
Water vapour (H_2O)	380.197	379.81-380.58	(2)
Hydronium (H_3O^+)	388.459	388.07-388.85	
Carbon monosulphide (CS)	391.847	390.54-392.24	
Oxygen (O_2)	424.763	424.34-425.19	
Carbon monoxide ($C^{18}O$)	439.088	438.64-439.53	
Carbon monoxide (^{13}CO)	440.765	440.32-441.21	
Carbon monoxide (CO)	461.041	460.57-461.51	
Deuterated water (HDO)	464.925	464.46-465.39	
Carbon (C)	492.162	491.66-492.66	
Deuterated water (HDO)	509.292	508.78-509.80	
Hydrogen cyanide (HCN)	531.716	529.94-532.25	(2)
Carbon monosulphide (CS)	538.689	536.89-539.23	(2)
Water vapour ($H_2{}^{18}O$)	547.676	547.13-548.22	(2)
Carbon monoxide (^{13}CO)	550.926	549.09-551.48	(2)
Water vapour (H_2O)	556.936	556.37-557.50	(2)
Ammonia ($^{15}NH_3$)	572.113	571.54-572.69	(2)
Ammonia (NH_3)	572.498	571.92-573.07	(2)
Carbon monoxide (CO)	576.268	574.35-576.84	(2)
Carbon monosulphide (CS)	587.616	587.03-588.20	(2)
Deuterated water (HDO)	599.927	599.33-600.53	(2)
Water vapour (H_2O)	620.700	620.08-621.32	(2)
Hydrogen chloride (HCI)	625.040	624.27-625.67	
Hydrogen chloride (HCI)	625.980	625.35-626.61	
Carbon monosulphide (CS)	636.532	634.41-637.17	
Carbon monoxide (^{13}CO)	661.067	658.86-661.73	
Carbon monoxide (CO)	691.473	690.78-692.17	
Oxygen (O_2)	715.393	714.68-716.11	(2)
Carbon monosulphide (CS)	734.324	733.59-735.06	(2)
Water vapour (H_2O)	752.033	751.28-752.79	(2)
Oxygen (O_2)	773.840	773.07-784.61	(2)
Hydrogen cyanide (HCN)	797.433	796.64-798.23	
Formylium (HCO^+)	802.653	801.85-803.85	
Carbon monoxide (CO)	806.652	805.85-807.46	
Carbon (C)	809.350	808.54-810.16	
Carbon monosulphide (CS)	832.057	829.28-832.89	
Oxygen (O_2)	834.146	833.31-834.98	

TABLE 2 (*end*)

Substance	Rest frequency (GHz)	Suggested minimum band (GHz)	Notes[1]
Carbon monosulphide (CS)	880.899	877.96-881.78	
Water vapour (H_2O)	916.172	915.26-917.09	(2)
Carbon monoxide (CO)	921.800	918.72-922.72	(2)
Carbon monosulphide (CS)	929.723	926.62-930.65	
Water vapour (H_2O)	970.315	969.34-971.29	(2)
Carbon monosulphide (CS)	978.529	977.55-979.51	(2)
Water vapour (H_2O)	987.927	986.94-988.92	(2)

(1) The band limits are the Doppler-shifted frequencies corresponding to radial velocities of ± 300 km/s (consistent with line radiation occurring in our galaxy).

(2) These lines are observable only outside the atmosphere.

TABLE 3

Frequency bands allocated to the radio astronomy service that are preferred for continuum observations

Frequency band (MHz)	Frequency band (GHz)
13.360-13.410	10.6-10.7
25.550-25.670	15.35-15.4
37.5-38.25(1)	22.21-22.50
73-74.6(2)	23.6-24.0
150.05-153(3)	31.3-31.8
322-328.6	42.5-43.5
406.1-410	76-116(1)
608-614(4)	
1 400-1 427	123-158.5(1)
1 660-1 670	164-167
2 655-2 700(1)	200-231.5
4 800-5 000(1)	241-275(1)

(1) These bands include secondary allocations.

(2) Allocation (primary) in Region 2, protection recommended in Regions 1 and 3.

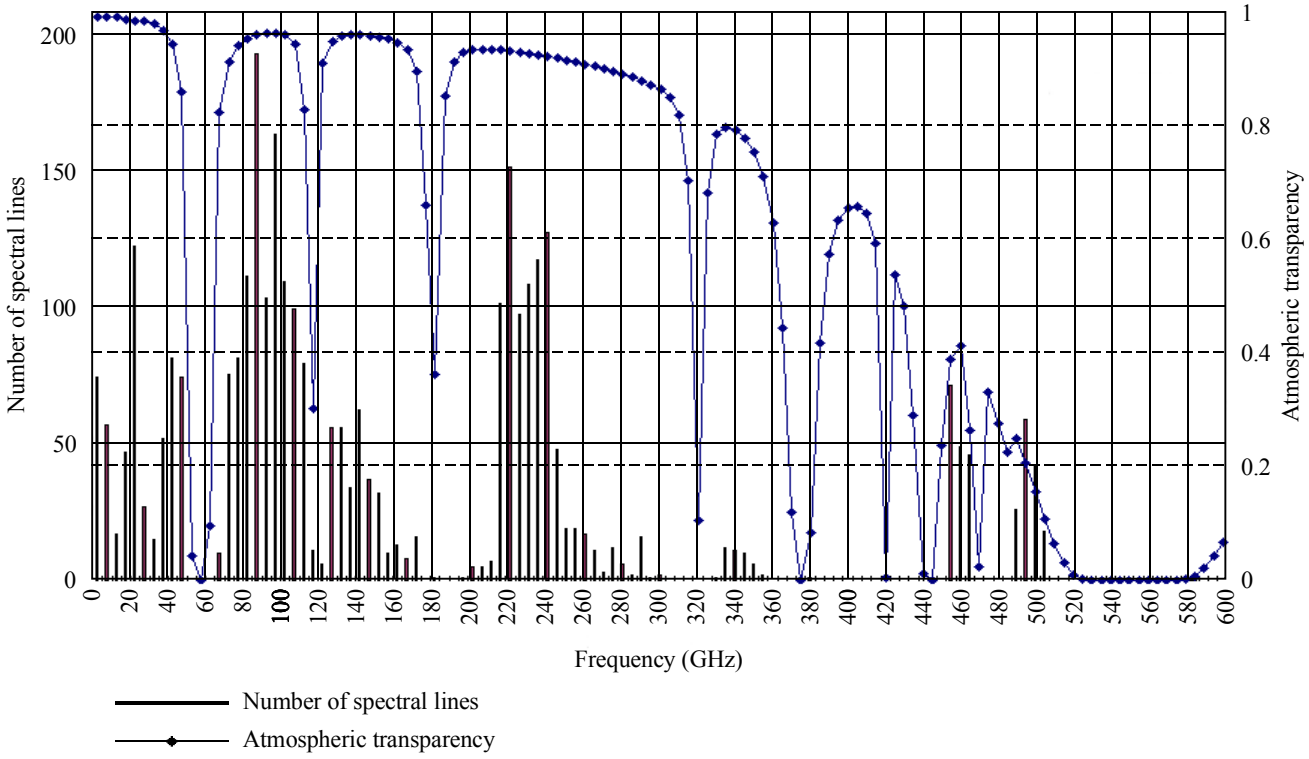
(3) Allocation (primary) in Region 1, Australia and India.

(4) Allocation (primary) in Region 2, the African Broadcasting Area (606-614 MHz), China (606-614 MHz) and India. In Region 1 (except the African Broadcasting Area) and in Region 3 this band is allocated on a secondary basis.

Annex 1

FIGURE 1

Frequency distribution of spectral lines detected by radio astronomical observations and atmospheric transparency below 600 GHz



Note – Histogram shows the number of currently detected spectral lines, in 5 GHz bins. Several lines have been detected above 600-625.9 GHz (HCI), 691.5 GHz (CO), 806.9 GHz (CO) and 809.3 GHz (C). The US standard atmosphere model was used for the calculation of atmospheric transparency. The transparency was calculated in every 5 GHz bin for: altitude = 4.2 km, H_2O pressure = 1 mm precipitation, and pressure = 640 hPa. Atmospheric transparency is the fraction of energy from outside of the atmosphere, that reaches the surface of the Earth. It can be related with the atmospheric attenuation by attenuation (dB) = –10 log (transparency).

0314-01