Radio spectrum

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The **radio spectrum** is the part of the electromagnetic spectrum from 3 Hz to 3000 GHz (3 THz). Electromagnetic waves in this frequency range, called radio waves, are extremely widely used in modern technology, particularly in telecommunication. To prevent interference between different users, the generation and transmission of radio waves is strictly regulated by national laws, coordinated by an international body, the International Telecommunication Union (ITU).[1]

Different parts of the radio spectrum are appointed by the ITU for different radio transmission technologies and applications; some 40 radiocommunication services are defined in the ITU's Radio Regulations (RR).[2] In some cases, parts of the radio spectrum are sold or licensed to operators of private radio transmission services (for example, cellular telephone operators or broadcast television stations). Ranges of allocated frequencies are often referred to by their provisioned use (for example, cellular spectrum or television spectrum).[3]

Contents

By frequency

A **band** is a small section of the spectrum of radio communication frequencies, in which channels are usually used or set aside for the same purpose.

Above 300 GHz, the absorption of electromagnetic radiation by Earth's atmosphere is so great that the atmosphere is effectively opaque, until it becomes transparent again in the near-infrared and optical window frequency ranges.

To prevent interference and allow for efficient use of the radio spectrum, similar services are allocated in bands. For example, broadcasting, mobile radio, or navigation devices, will be allocated in non-overlapping ranges of frequencies.

Each of these bands has a basic bandplan which dictates how it is to be used and shared, to avoid interference and to set protocol for the compatibility of transmitters and receivers. See detail of bands:http://www.ntia.doc.gov/files/ntia/Spectrum_Use_Summary_Master-06212010.pdf

As a matter of convention, the ITU divides the radio spectrum into 12 bands, each beginning at a wavelength which is a power of ten (10^n) metres, with corresponding frequency of $3\times10^{8-n}$ hertz, and each covering a decade of frequency or wavelength. Each of these bands has a traditional name. For example, the term *high frequency* (HF) designates the wavelength range from 100 to 10 metres, corresponding to a frequency range of 3 MHz to 30 MHz. This is just a naming convention and is not related to allocation; the ITU further divides each band into subbands allocated to different uses.

Band name	Abbreviation	ITU band	Frequency and wavelength in air	Example uses
Extremely low frequency	ELF	1	3–30 Hz 100,000 km – 10,000 km	Communication with submarines
Super low frequency	SLF	2	30–300 Hz 10,000 km – 1000 km	Communication with submarines
Ultra low frequency	ULF	3	300–3000 Hz 1000 km – 100 km	Submarine communication, communication within mines
Very low frequency	VLF	4	3–30 kHz 100 km – 10 km	Navigation, time signals, submarine communication, wireless heart rate monitors, geophysics
Low frequency	LF	5	30–300 kHz 10 km – 1 km	Navigation, clock time signals, AM longwave broadcasting (Europe and parts of Asia), RFID, amateur radio
Medium frequency	MF	6	300–3000 kHz 1 km – 100 m	AM (medium-wave) broadcasts, amateur radio, avalanche beacons
High frequency	HF	7	3–30 MHz 100 m – 10 m	Shortwave broadcasts, citizens' band radio, amateur radio and over-the-horizon aviation communications, RFID, over-the-horizon radar, automatic link establishment (ALE) / near-vertical incidence skywave (NVIS) radio communications, marine and mobile radio telephony
Very high frequency	VHF	8	30–300 MHz 10 m – 1 m	FM, television broadcasts and line-of-sight ground-to-aircraft and aircraft-to-aircraft communications, land mobile and maritime mobile communications, amateur radio, weather radio
Ultra high frequency	UHF	9	300–3000 MHz 1 m – 100 mm	Television broadcasts, microwave oven, microwave devices/communications, radio astronomy, mobile phones, wireless LAN, Bluetooth, ZigBee, GPS and two-way radios such as land mobile, FRS and GMRS radios, amateur radio, satellite radio
Super high frequency	SHF	10	3–30 GHz 100 mm – 10 mm	Radio astronomy, microwave devices/communications, wireless LAN, most modern radars, communications satellites, cable and satellite television broadcasting, DBS, amateur radio, satellite radio

Extremely high frequency	EHF	11	30–300 GHz 10 mm – 1 mm	Radio astronomy, high-frequency microwave radio relay, microwave remote sensing, amateur radio, directed-energy weapon, millimeter wave scanner
Terahertz or Tremendously high frequency	THz or THF	12	300–3000 GHz 1 mm – 100 μm	Experimental medical imaging to replace X-rays, ultrafast molecular dynamics, condensed-matter physics, terahertz time-domain spectroscopy, terahertz computing/communications, remote sensing, amateur radio

ITU

The **ITU radio bands** are designations defined in the ITU Radio Regulations. Article 2, provision No. 2.1 states that "the radio spectrum shall be subdivided into nine frequency bands, which shall be designated by progressive whole numbers in accordance with the following table[4]".

The table originated with a recommendation of the IVth CCIR meeting, held in Bucharest in 1937, and was approved by the International Radio Conference held at Atlantic City in 1947. The idea to give each band a number, in which the number is the logarithm of the approximate geometric mean of the upper and lower band limits in Hz, originated with B.C. Fleming-Williams, who suggested it in a letter to the editor of *Wireless Engineer* in 1942. (For example, the approximate geometric mean of Band 7 is 10 MHz, or 10^7 Hz.)[5]

Table of ITU Radio Bands

Band Number	Symbols	Frequency Range	Wavelength Range†
4	VLF	3 to 30 kHz	10 to 100 km
5	LF	30 to 300 kHz	1 to 10 km
6	MF	300 to 3000 kHz	100 to 1000 m
7	HF	3 to 30 MHz	10 to 100 m
8	VHF	30 to 300 MHz	1 to 10 m
9	UHF	300 to 3000 MHz	10 to 100 cm
10	SHF	3 to 30 GHz	1 to 10 cm
11	EHF	30 to 300 GHz	1 to 10 mm
12	THF	300 to 3000 GHz	0.1 to 1 mm

† This column does not form part of the table in Provision No. 2.1 of the Radio Regulations

IEEE

Radar-frequency bands according to IEEE standard[6]

Band designation	Frequency range	
HF	0.003 to 0.03 GHz	High Frequency[7]
VHF	0.03 to 0.3 GHz	Very High Frequency[7]
UHF	0.3 to 1 GHz	Ultra High Frequency[7]
L	1 to 2 GHz	Long wave
S	2 to 4 GHz	Short wave
C	4 to 8 GHz	Compromise between S and X
X	8 to 12 GHz	Used in WW II for fire control, X for cross (as in crosshair). Exotic.[8]
K_u	12 to 18 GHz	Kurz-under
K	18 to 27 GHz	German Kurz (short)
K_a	27 to 40 GHz	Kurz-above
V	40 to 75 GHz	
W	75 to 110 GHz	W follows V in the alphabet
mm or G	110 to 300 GHz [note 1]	Millimeter[6]

1. The designation mm is also used to refer to the range from 30 to 300 GHz.[6]

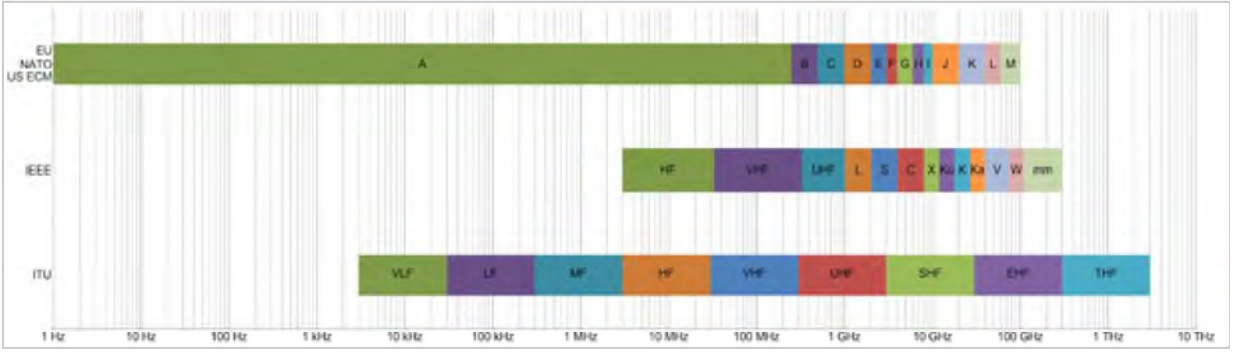
EU, NATO, US ECM frequency designations

NATO LETTER BAND DESIGNATION[9][8][10]				BROADCASTING BAND DESIGNATION
NEW NOMENCLATURE		OLD NOMENCLATURE		
BAND	FREQUENCY (MHz)	BAND	FREQUENY (MHz)	
A	0 – 250	**I**	100 – 150	Band I 47 – 68 MHz (TV)
				Band II 87.5 – 108 MHz (FM)
		G	150 – 225	Band III 174 – 230 MHz (TV)
B	250 – 500	**P**	225 – 390	
C	500 – 1 000	**L**	390 – 1 550	Band IV 470 – 582 MHz (TV)
				Band V 582 – 862 MHz (TV)
D	1 000 – 2 000	**S**	1 550 – 3 900	
E	2 000 – 3 000			
F	3 000 – 4 000			
G	4 000 – 6 000	**C**	3 900 – 6 200	
H	6 000 – 8 000	**X**	6 200 – 10 900	
I	8 000 – 10 000			
J	10 000 – 20 000	**Ku**	10 900 – 20 000	
K	20 000 – 40 000	**Ka**	20 000 – 36 000	
L	40 000 – 60 000	**Q**	36 000 – 46 000	
		V	46 000 – 56 000	
M	60 000 – 100 000	**W**	56 000 – 100 000	
US- MILITARY / SACLANT				
N	100 000 – 200 000			
O	100 000 – 200 000			

Waveguide frequency bands

Band	Frequency range [11]
R band	1.70 to 2.60 GHz
D band	2.20 to 3.30 GHz
S band	2.60 to 3.95 GHz
E band	3.30 to 4.90 GHz
G band	3.95 to 5.85 GHz
F band	4.90 to 7.05 GHz
C band	5.85 to 8.20 GHz
H band	7.05 to 10.10 GHz
X band	8.2 to 12.4 GHz
K_u band	12.4 to 18.0 GHz
K band	15.0 to 26.5 GHz
K_a band	26.5 to 40.0 GHz
Q band	33 to 50 GHz
U band	40 to 60 GHz
V band	40 to 75 GHz
E band	60 to 90 GHz
W band	75 to 110 GHz
F band	90 to 140 GHz
D band	110 to 170 GHz
Y band	325 to 500 GHz

Comparison of radio band designation standards



Comparison of frequency band designations

Frequency	IEEE[6]	EU, NATO, US ECM	ITU	
			no.	abbr.
3 Hz		A		
30 Hz			1	ELF
300 Hz			2	SLF
3 kHz			3	ULF
30 kHz			4	VLF
300 kHz			5	LF
3 MHz			6	MF
30 MHz	HF		7	HF
250 MHz	VHF		8	VHF
300 MHz		B	9	UHF
500 MHz	UHF			
1 GHz		C		
2 GHz	L	D		
3 GHz	S	E		
4 GHz		F	10	SHF
6 GHz	C	G		
8 GHz		H		
10 GHz	X	I		
12 GHz		J		
18 GHz	K_u			
20 GHz	K			
27 GHz		K		
30 GHz	K_a			
40 GHz		L	11	EHF
60 GHz	V			
75 GHz		M		
100 GHz	W			
110 GHz				
300 GHz	mm			
3 THz			12	THF

By application

Broadcasting

Broadcast frequencies:

- Longwave AM Radio = 148.5 kHz – 283.5 kHz (LF)
- Mediumwave AM Radio = 530 kHz – 1710 kHz (MF)
- Shortwave AM Radio = 3 MHz – 30 MHz (HF)

Designations for television and FM radio broadcast frequencies vary between countries, see Television channel frequencies and FM broadcast band. Since VHF and UHF frequencies are desirable for many uses in urban areas, in North America some parts of the former television broadcasting band have been reassigned to cellular phone and various land mobile communications systems. Even within the allocation still dedicated to television, TV-band devices use channels without local broadcasters.

The Apex band in the United States was a pre-WWII allocation for VHF audio broadcasting; it was made obsolete after the introduction of FM broadcasting.

Air band

Airband refers to VHF frequencies 118 to 137 MHz, used for navigation and voice communication with aircraft. Trans-oceanic aircraft also carry HF radio and satellite transceivers.

Marine band

The greatest incentive for development of radio was the need to communicate with ships out of visual range of shore. From the very early days of radio, large oceangoing vessels carried powerful long-wave and medium-wave transmitters. High-frequency allocations are still designated for ships, although satellite systems have taken over some of the safety applications previously served by 500 kHz and other frequencies. 2182 kHz is a medium-wave frequency still used for marine emergency communication.

Marine VHF radio is used in coastal waters and relatively short-range communication between vessels and to shore stations. Radios are channelized, with different channels used for different purposes; marine Channel 16 is used for calling and emergencies.

Amateur radio frequencies

Amateur radio frequency allocations vary around the world. Several bands are common for amateurs worldwide, usually in the HF part of the spectrum. Other bands are national or regional allocations only due to differing allocations for other services, especially in the VHF and UHF parts of the radio spectrum.

Citizens' band and personal radio services

Citizens' band radio is allocated in many countries, using channelized radios in the upper HF part of the spectrum (around 27 MHz). It is used for personal, small business and hobby purposes. Other frequency allocations are used for similar services in different jurisdictions, for example UHF CB is allocated in Australia. A wide range of personal radio services exist around the world, usually emphasizing short-range communication between individuals or for small businesses, simplified or no license requirements, and usually FM transceivers using around 1 watt or less.

Industrial, scientific, medical

The ISM bands were initially reserved for non-communications uses of RF energy, such as microwave ovens, radio-frequency heating, and similar purposes. However, in recent years the largest use of these bands has been by short-range low-power communications systems, since users do not have to hold a radio operator's license. Cordless telephones, wireless computer networks, Bluetooth devices, and garage door openers all use the ISM bands. ISM devices do not have regulatory protection against interference from other users of the band.

Land mobile bands

Bands of frequencies, especially in the VHF and UHF parts of the spectrum, are allocated for communication between fixed base stations and land mobile vehicle-mounted or portable transceivers. In the United States these services are informally known as business band radio. See also Professional mobile radio.

Police radio and other public safety services such as fire departments and ambulances are generally found in the VHF and UHF parts of the spectrum. Trunking systems are often used to make most efficient use of the limited number of frequencies available.

The demand for mobile telephone service has led to large blocks of radio spectrum allocated to cellular frequencies.

Radio control

Reliable radio control uses bands dedicated to the purpose. Radio-controlled toys may use portions of unlicensed spectrum in the 27 MHz or 49 MHz bands, but more costly aircraft, boat, or land vehicle models use dedicated radio control frequencies near 72 MHz to avoid interference by unlicensed uses. The 21st century has seen a move to 2.4 gigahertz spread spectrum RC control systems.

Licensed amateur radio operators use portions of the 6-meter band in North America. Industrial remote control of cranes or railway locomotives use assigned frequencies that vary by area.

Radar

Radar applications use relatively high power pulse transmitters and sensitive receivers, so radar is operated on bands not used for other purposes. Most radar bands are in the microwave part of the spectrum, although certain important applications for meteorology make use of powerful transmitters in the UHF band. Radio waves are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light. Radio waves have frequencies as high as 300 GHz

to as low as 3 kHz, though some definitions describe waves above 1 or 3 GHz as microwaves, or include waves of any lower frequency. At 300 GHz, the corresponding wavelength is 1 mm (0.039 in), and at 3 kHz is 100 km (62 mi). Like all other electromagnetic waves, they travel at the speed of light. Naturally occurring radio waves are generated by lightning, or by astronomical objects.

Artificially generated radio waves are used for fixed and mobile radio communication, broadcasting, radar and other navigation systems, communications satellites, computer networks and innumerable other applications. Radio waves are generated by radio transmitters and received by radio receivers. Different frequencies of radio waves have different propagation characteristics in the Earth's atmosphere; long waves can diffract around obstacles like mountains and follow the contour of the earth (ground waves), shorter waves can reflect off the ionosphere and return to earth beyond the horizon (skywaves), while much shorter wavelengths bend or diffract very little and travel on a line of sight, so their propagation distances are limited to the visual horizon.

To prevent interference between different users, the artificial generation and use of radio waves is strictly regulated by law, coordinated by an international body called the International Telecommunications Union (ITU), which defines radio waves as "electromagnetic waves of frequencies arbitrarily lower than 3 000 GHz, propagated in space without artificial guide".[1] The radio spectrum is divided into a number of radio bands on the basis of frequency, allocated to different uses

See also

- Bandplan
- Bandstacked
- Cellular frequencies
- DXing
- Frequency allocation
- Geneva Frequency Plan of 1975
- North American Regional Broadcasting Agreement
- Open spectrum
- Radio astronomy
- Radio § Communication system
- Scanner (radio)
- Two-way radio
- U-NII
- Ultra-wideband
- WARC bands

Notes

1. ITU Radio Regulations – Article 1, Definitions of Radio Services, Article 1.2 Administration: Any governmental department or service responsible for discharging the obligations undertaken in the Constitution of the International Telecommunication Union, in the Convention of the International Telecommunication Union and in the Administrative Regulations (CS 1002)
2. International Telecommunication Union´s Radio Regulations, Edition of 2012.
3. Colin Robinson (2003). *Competition and regulation in utility markets*. Edward Elgar Publishing. p. 175. ISBN 978-1-84376-230-0.

4. ITU Radio Regulations, Volume 1, Article 2; Edition of 2008. Available online at [1] (http://life.itu.int/radioclub/rr/art02.htm)
5. Booth, C.F. (1949). "Nomenclature of Frequencies". *The Post Office Electrical Engineers' Journal*. **42** (1): 47–48.
6. IEEE Std 521-2002 *Standard Letter Designations for Radar-Frequency Bands* (http://standards.ieee.org/findstds/standard/521-2002.html).
7. Table 2 in [6]
8. Norman Friedman (2006). *The Naval Institute Guide to World Naval Weapon Systems*. Naval Institute Press. pp. xiii. ISBN 978-1-55750-262-9.
9. Leonid A. Belov; Sergey M. Smolskiy; Victor N. Kochemasov (2012). *Handbook of RF, Microwave, and Millimeter-Wave Components*. Artech House. pp. 27–28. ISBN 978-1-60807-209-5.
10. NATO Allied Radio Frequency Agency (ARFA) HANDBOOK – VOLUME I; PART IV – APPENDICES, … G-2, … NOMENCLATURE OF THE FREQUENCZ AND WAVELENTH BANDS USED IN RADIOCOMMUNCATION.
11. www.microwaves101.com "Waveguide frequency bands and interior dimensions" (http://www.microwaves101.com/encyclopedia/waveguidedimensions.cfm)

References

- ITU-R Recommendation V.431: Nomenclature of the frequency and wavelength bands used in telecommunications (http://www.itu.int/rec/R-REC-V.431/en). International Telecommunication Union, Geneva.
- IEEE Standard 521-2002: Standard Letter Designations for Radar-Frequency Bands
- AFR 55-44/AR 105-86/OPNAVINST 3430.9A/MCO 3430.1, 27 October 1964 superseded by AFR 55-44/AR 105-86/OPNAVINST 3430.1A/MCO 3430.1A, 6 December 1978: Performing Electronic Countermeasures in the United States and Canada, Attachment 1,ECM Frequency Authorizations.

External links

- UnwantedEmissions.com (http://www.unwantedemissions.com) A reference to radio spectrum allocations.
- "Radio spectrum: a vital resource in a wireless world" (http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/index_en.htm) European Commission policy.