WHERE DOES THE RADIO SPECTRUM END?

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The focus of this journal is "wireless communications" which is presumed to use radio spectrum. But for the purpose of regulation, what are the upper and lower limits of that spectrum? An International Telecommunications Union publication addresses part of this question as follows

From a technical viewpoint, the radio spectrum is the portion of the electromagnetic spectrum that carries radio waves. The boundaries of the radio spectrum are defined by the frequencies of the transmitted signals, and are usually considered to range from 9 kHz (kilohertz; thousand cycles per second) to 3000 GHz (gigahertz; billion cycles per second). The key characteristics of the spectrum are the propagation features and the amount of information which signals can carry. In general, signals sent using higher frequencies reach shorter distances but have a higher information-carrying capacity. These physical characteristics of the spectrum limit the currently identified range of applications for which any particular frequency band is suitable. [1]

The inclusion of frequencies as low as 9 kHz may seem puzzling to some as acoustic waves at such low frequencies are readily heard. But we are talking about electromagnetic waves here, those with coupled electric and magnetic field as described by Maxwell's Equations, and such waves exists at a much wider range of frequencies. While there are Very Low Frequency/VLF (3–30 kHz) and Ultra Low Frequency/ULF (300 Hz–3 kHz) that have the same numeric frequency as audible acoustic waves, they can not be directly heard since human and animal audible sensors generally [2] react to acoustic pressure, not electromagnetic fields. (However, there may be conductive objects near an observer that transform such VLF or ULF fields into comparable frequency acoustic waves that can be heard.)

At the upper end of the spectrum ITU gives 3000 GHz or 3 THz as the upper limit of its jurisdiction. This is the region of infrared which is normally described by wavelength not the equivalent frequency, so for reference 3 Thz is equivalent to 100 μm. While ITU gives a numeric limit for the upper limit of radio spectrum, there is some disagreement in the infrared/optics community of the lower limit of infrared technology with various sources giving numbers in the range of 1–3 THz.

For many purposes the difference between RF and infrared is the type of technology used and there is a growing convergence as many recognize that there is a transition zone where technology from both disciplines can be used together. Thus RF technology has be classically characterized by components such as mixers and antennas and infrared technology by lenses and diffraction gratings and new innovative systems use components from both traditions.

The ITU allocation table contains frequency allocations up to 275 GHz [3]. In general each frequency above 100 GHz has multiple primary allocations. On the national level, a sample check of several national frequency allocations tables (Canada, U.S., Switzerland, and U.K.) shows that those examined have followed the ITU example and have domestic allocations up to 275 GHz but nothing beyond that. What is harder to tell is what other domestic regulations exists in particular countries to facilitate introduction of new wireless technology in the bands at the upper end of the spectrum. Thus in the U.S. the Federal Communications Commission has allocations up to 275 GHz, but has no specific rules for either timely approval of equipment models or granting licenses or allowing unlicensed use above 95 GHz. Thus anyone seeking to commercialize this upper spectrum in the U.S. would face ambiguous issues of what is needed for regulatory approval and how long it would take.

ITU Radio Regulation 5.565 [4] deals with spectrum in the 275–3000 GHz range. It lists bands that have been "identified for use by administrations for passive service applications" including radio astronomy service, earth exploration-satellite service (passive), and space service (passive). These identified bands are not protected by international allocations as are similar passive bands at lower frequencies. However, it is assumed that national regulators ("administrators" in ITU jargon) will consider the enumerated passive bands and possible impact on them in making determinations about other spectrum use in these bands.

Radio Regulation 5.565 also has the following statement:

"The use of the range 275–1000 GHz by the passive services does not preclude use of this range by active services. Administrations wishing to make frequencies in the 275–1000 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 275–1000 GHz frequency range.

All frequencies in the range 1000–3000 GHz may be used by both active and passive services."

These statements were adopted at 2012 World Radio Conference upon consideration of radio astronomy protection issues discussed in an ITU-R report that found:

"Certain characteristics of the frequency range 275–3000 GHz combine to reduce the likelihood of interference between the radio astronomy service and active services in this range…The conclusions reached in this Report do not apply to frequencies below 275 GHz where significantly greater transmit powers are possible with currently available technology. Atmospheric attenuation is also relatively low at most frequencies below 275 GHz compared to absorption at THz frequencies. Some conclusions may change in the future if substantially more transmit power generation becomes achievable at THz frequencies." [5]

So in summary, ITU and national regulators claim radio spectrum jurisdiction up to 3 THz. Since international and national allocations end at 275 GHz it appears that there has been no "zoning" of frequencies in the 275 GHz to 3 THz range other than an advisory to national regulators to try to protect the passive bands enumerated in RR 5.565. It would thus appear that national regulator approval, or at least a consultation, is need for transmitters in this upper end of RF.

Frequencies below 275 GHz clearly have international and national allocations. These international allocations mean that ITU signatories must protect radio systems of other signatories that are in compliance with the allocation table but need not necessarily limit their uses to the specific allocations. [6] Since propagation at upper microwave frequencies is limited by atmospheric absorption in addition to geometric spreading and the small wavelengths at these frequencies permit very narrow beam antennas, intersystem interference is much less of a concern than at the lower frequencies that were the focus of early radio regulation a century ago. The lack of specific national regulations above 50–100 GHz creates regulatory uncertainty that may adversely impact the capital formation that is necessary to move technology from the pages of journals into commercial products.

REFERENCES

[1] International Telecommunications Union, Radio Spectrum Management, Module 5 of ICT Regulation Toolkit (2007) (www.ictregulationtoolkit.org/en/Document.3729.pdf) The 3000 GHz upper limit is also given in ITU Radio Regulation 2.1, ITU Radio Regulations (2012 Edition) (http://www.itu.int/pub/R-REG-RR/en)

[2] J. C. Lin and Z. Wang , "Hearing of Microwave Pulses by Humans and Animals: Effects, Mechanism, and Thresholds," Health Phys., vol. 92, no. 6, 2007, p. 621–28, http://www.ncbi.nlm.nih.gov/pubmed/17495664, This article describes a special case where certain microwave signals can be "heard" by some individuals.

[3] ITU Radio Regulations op cit.

[4] ibid.

[5] ITU-R, Sharing Between the Radio Astronomy Service and Active Services in the Frequency Range 275–3000 GHz, Report ITU-RA.2189, 2010, http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-RA.2189-2010-PDF-E.pdf.

[6] ITU Radio Regulations, RR 4.4, op cit.

BIOGRAPHY

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