1

The Radio Frequency Spectrum and Wireless Communications

1.1 Historical Overview

Between 1864 and 1873, James Clerk Maxwell (1831–1894), a Scottish theoretical physicist, demonstrated that four relatively simple equations could fully describe electric and magnetic fields and their interaction. He described how charges and currents can produce an electromagnetic radio wave. In 1887, in the research laboratory of a young German physicist, Heinrich Hertz, the first radio transmitter began working briefly over a range of just a few meters. Alexander Popov (1859–1906) demonstrated his instrument for the detection and recording of electrical oscillations on May 7, 1895. In the spring of the same year, Guglielmo Marconi (1874–1937) took his wireless experiments outdoors and soon discovered that an intervening hill was no barrier to the reception of electromagnetic waves. According to the ITU Statistics (ITU 2015), in December 2014, there are more than 7 Billion mobile-cellular telephone subscriptions in the 228 ITU Member States; this is equivalent to 100% of the world's population.

The Radio Frequency (RF) spectrum is a natural resource; however, it is commonly agreed that wireless telecommunications need regulation at national, regional and global levels. The first sentence of the International Telecommunication Union (ITU) Constitution (ITU 2011) fully recognizes "the sovereign right of each State to regulate its telecommunication." The sovereign right of states to act independently within their territory is enshrined in general international law. RF is a national limited resource, much like water, land, gas, and minerals. Like these, it is scarce; however, the RF is renewable and not nearing exhaustion. It requires optimal use; if we do not use the RF spectrum in real time, this is an economic waste of a national resource. The RF is an ethereal medium, carrying wireless e-communications: a networked service of general economic interest (similar to transport, gas, and electricity). RF regulation is nationally important in theory, policy, and practice. Technological advances, innovation, penetration of new technologies, economic and military power are all directly connected to wireless regulation. The radio frequencies serve as a lever to raise the economic and social conditions of society.

Radio Spectrum Management: Policies, Regulations and Techniques, First Edition. Haim Mazar.

The RF ether is not related to any cultural factor *per se*: history, tradition, language, religion, or legal origin. RF is perceived as a technical rather than a cultural factor, in contrast to currency, legislation, taxes or left-hand driving issues. In RF allocation, the common denominator among countries may be the dominant factor. For this reason the RF standards can be harmonized more easily (unlike, e.g., foreign affairs), and the national RF allocation chart can be copied without alteration, from country to country (if these countries are located in the same ITU region). Lessons, ideas, and technologies cross the ocean easily, as RF is the same worldwide, it exists everywhere, it serves all nations, and it deserves to be used rationally, for worthwhile applications, such as saving lives, emergencies, navigation, smart sustainable cities, multicultural broadcasting, health, education, agriculture, science, research, meteorology, astronomy, the environment, urban and rural planning, and basic human welfare.

The RF spectrum is located in the public domain of a nation, so the State authority must manage it efficiently, for the greatest benefit of the entire population. RF spectrum management takes place within a regulatory framework comprised of engineering, and the main departments in the government regulating the economy and legislation. Authorized spectrum users enjoy the benefits of the RF license and its associated obligations to access the spectrum.

1.2 A General Communication Channel

The definition of telecommunication given in the ITU Constitution is: "any transmission, emission or reception of signs, signals, writings, images and sounds or intelligence of any nature by wire, radio, optical or other electromagnetic systems." Figure 1.1 schematically depicts a general communication channel (Shannon, 1949, p. 2). There are two kinds of media: wired (the transmitter is linked to the receiver via a cable) or wireless (the transmitter is linked to the receiver via electromagnetic waves). This book discusses the wireless medium. Most vital industry and military sectors are based on access to radio frequencies: mobile communications, audio and television broadcasting, satellites, radiolocation, transportation, and the Internet of Things (IoT).

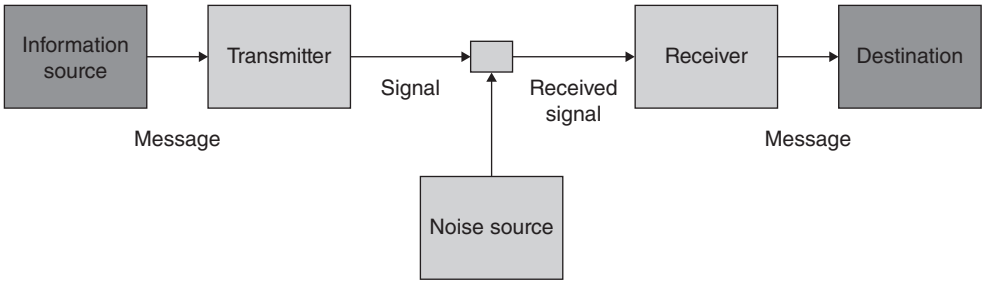

Figure 1.1 Shannon's schematic diagram of a general communication

1.3 Radio Frequency Bands

Based on ITU Radio Regulations (ITU 2012), No. 2.1 (Article 2, provision 1), Table 1.1 specifies the symbols of the radio frequency bands.

Table 1.1 RF spectrum frequency bands

Band number	Symbols	Frequency range	Metric subdivision
4	VLF	3–30 kHz	Myriametric waves
5	LF	30–300 kHz	Kilometric waves
6	MF	300–3,000 kHz	Hectometric waves
7	HF	3–30 MHz	Decametric waves
8	VHF	30–300 MHz	Metric waves
9	UHF	300–3,000 MHz	Decimetric waves
10	SHF	3–30 GHz	Centimetric waves
11	EHF	30–300 GHz	Millimetric waves
12		300–3,000 GHz	Decimillimetric waves

1.4 Scarcity of the RF Spectrum

Provision 0.3, in the principles of the ITU Radio Regulations, states: "[R]adio frequencies and the geostationary satellite orbit are limited natural resources and … they must be used rationally, efficiently and economically." The institutional, legal and economic challenges are mainly due to the scarcity of radio resources. Figure 1.2 depicts how the RF enters a higher RF, due to the scarcity of radio resources and the need for higher bandwidths. The relatively lower frequencies, such as the VHF and UHF bands, are the scarcest, due to their quality, with extended range and reliable wireless communications, without line-of-sight between the transmitter and the receiver. Scarcity is the direct result of the spread of cellular equipment and the growing demand for wireless data; the RF is the narrow bottleneck that prevents higher capacities.

Figure 1.2 Scarcity of RF increases in time. Source: ITU-D Resolution 9 report ITU-D 2014 Market mechanisms used for frequency assignment; Resolution 9: participation of countries, particularly developing countries, in spectrum management. Reproduced with permission

As the RF spectrum is limited, the regulators and all the wireless players will have to accommodate more services in less spectrum, within budgetary limits. The challenges in frequency management are no longer simply technical and administrative, but also economic and financial.

Market strategies are steadily imposing themselves on all the players in the radio communications sector, especially regulators and operators. The World Trade Organization's (WTO) Telecommunications Services Reference Paper of April 24, 1996 (paragraph 6) promotes new methods to allocate and use scarce resources:

> Any procedures for the allocation and use of scarce resources, including frequencies, numbers and rights of way, will be carried out in an objective, timely, transparent and non-discriminatory manner. The current state of allocated frequency bands will be made publicly available, but detailed identification of frequencies allocated for specific government uses is not required.

Around the world, the most restricted licensed RFs are the FM radio 88–108 MHz, the cellular frequency bands, and the satellite Ku Band 12–18 GHz. However, despite RF scarcity, it is important to note that at any place in the world, most of the available frequencies are unused, see Chapter 8.

References

Note: * the author contributed to this reference.

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