ISM Radio Bands: Will the Concept Work In the Future?

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We sometimes tend to forget that RF and microwave devices are now everywhere. High Frequency technology no longer consists of expensive, sometimes unreliable, "magic" hardware only available for defense applications and a few serious hobbyists.

In order to regulate anticipated usage by various low power devices, the Industrial, Scientific and Medical (ISM) portions of the electromagnetic spectrum were established by the International Telecommunication Union Radio Sector (ITU-R) in 5.138, 5.150, and 5.280 Radio Regulations and first adopted in May 1985 by the US Federal Communications Commission (FCC). In addition to the venerable microwave oven operating at approximately 2.45 MHz, in recent years many other modern applications have been authorized in these and other bands.

Many modern communications devices are in general use in the ISM bands (governed by FCC Rules Part 18) under the "umbrella" of FCC Part 15. These include cordless phones, wireless Local Area Networks (LANs) at 915 MHz, 2.45, and 5.8 GHz and Sensor Networks at 915 MHz and 2.45 GHz. Medical diathermy equipment also uses the 915 and 2.45 GHz bands. Few activities are licensed in the ISM bands, and since ISM devices generally consist of emitters, not receivers, Part 15-compliant receivers must tolerate interference from ISM devices. Typical attached notices state: *This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference. And (2) this device must accept any interference received, including interference that may cause undesired operation.*

FCC and Part 15

The FCC regulates both intentional radiation of transmitters and unintentional radiation of noise and interference from electrical equipment. A new website, www.fcc.gov, provides a wealth of information including detailed information on Part 15, including:

FCC 15.107 Conducted Emissions including AC Line

FCC 15.109 Unintentional Radiation from ITE

FCC 15.205 Restricted bands of operation

FCC 15.207 Conducted emissions from intentional radiators

FCC 15.209 Radiated emission Limits, general requirements

FCC 15.247 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz (includes frequency hopping rules)

ISM Device Proliferation

Recently there has been a proliferation of ISM RFID devices such as smart cards and biometric passports. Wireless Local Area Network (LAN) devices such as Bluetooth, HIPERLAN and IEEE 802.11/WiFi use the 2.45 and/or 5.8 GHz bands. IEEE Standard 802.15.4 ZigBee personal area networks, smart energy controllers, safety/security and tracking devices are becoming commonplace. Trivia notes: the name ZigBee refers to the waggle dance of honey bees after they return to the beehive. Bluetooth is an anglicized version of the Scandinavian name, Blåtand/Blåtann, the epithet of the tenth-century King Harald I of Denmark and parts of Norway who united inharmonious Danish tribes into a single kingdom. The device name implies that Bluetooth does the same with communications protocols, uniting them into one universal standard.

Besides WiFi in households, there are mobile displays, remote printers, security systems, home theater controls, electronic fridge pads -- the list keeps growing. Worldwide Digital Cordless Telecommunications (WDCT) uses the 2.4 GHz ISM band. Radio control equipment for toys and hobbyists also uses the 2.4 GHz band. Note that some low-power personal communications are actually outside the ISM bands.

Hedy Lamarr and Early ISM

The early beginnings of Spread Spectrum communications found in ISM bands is often attributed to the cousin of my late beloved uncle, William L. Antheil Jr. Bill's older cousin, George Antheil (1900-1959) was a somewhat renowned concert pianist and composer known for introducing rather unconventional machine-like and airplane sound effects into some of his music.

Working in Hollywood during World War II, George collaborated with actress Hedy Lamarr to develop a torpedo guidance technique for the US Navy (Patent No. 2,292,387). At defense meetings in Europe during the 1930s Lamarr and former husband Friedrich Mandl learned that radio-guided missiles could easily be jammed. Mandl was chairman of Hirtenberger Patronen-Fabrik, a leading armaments firm founded by his father.

Because Antheil's piano had 88 keys, Lamarr and Antheil's frequency-hopping scheme employed 88 frequencies, and was intended to make Allied radio-guided torpedoes more difficult for Axis enemies to detect or jam. George mentions this activity in his 1945 autobiography, *Bad Boy of Music*. Initially the patent work was dismissed as impractical, with at least one officer suggesting that Lamarr and Antheil proposed to install a player piano inside a torpedo. Antheil countered it could instead be the size of a wrist watch. This was long before the advent of integrated circuits or even the transistor.

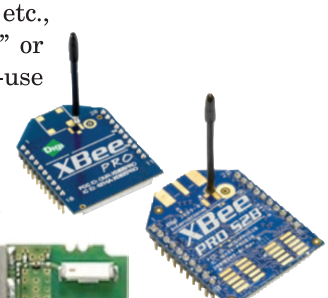
Their technique was finally used in secure military devices in the late 1950s and early 1960s, after the patent expired. Considerable notoriety came in recent years when spread spectrum was became widely used in cellular telephones and other communications devices using techniques like Code Division Multiple Access (CDMA) and Coded Orthogonal Frequency Division Multiplexing (COFDM). This work is not the only frequency-hopping effort dating back seven or eight decades. For example, in the USSR, the first work describing CDMA was published in 1935 by Professor D.V. Aggeev.

The take-away here may be that today's exponential growth of wireless technology is made possible by not only inexpensive, high-volume field effect transistors, microprocessors, and displays, but also by good ideas -- some of which, like Maxwell's Equations, were conceived long before they could be practically implemented.

Interference and Buffers

Airwaves problems are emerging in densely populated areas of the globe. Our finite amount of spectrum and even smaller band assignments for ISM makes for large challenges in the near future. There are examples of phone calls being picked up by baby monitors, digital TV signals interfering with wireless heart monitors, radar detectors interfering with tag devices, etc. Of more serious concern, some bands used for defense such as tracking, guidance, electronic warfare etc., may have little or no "buffer" or "guard" bands between high-use commercial channels.

Spread spectrum and digital transmission are helping in many areas along with



mesh networking, in which each device that receives a signal retransmits it, allowing for lower power. Also software-controlled cognitive radios can hop around the spectrum to find bands without much traffic or sense changing propagation characteristics. For example, Bluetooth devices eventually may be able to sense nearby Wi-Fi signals and avoid them. Companies that manufacture new generations of smart devices are lobbying hard to get parts of spectrum near UHF television channels.

The challenge is no longer simply to build better radios with spectral purity and low noise figures, but to implement support hardware and software to make them "smart" and also provide "seamless," highly reliable performance. Fortunately, the newest technology is growing immensely and can provide significant enhancements. The older technology will still be around, however, and may be subject to sudden unintended interference surprises as frequency bands become more congested. If, for example, someone's garage door suddenly opens unexpectedly, the average consumer will have little tolerance or understanding. Regulatory agencies such as the FCC and National Telecommunications and Information Administration (NTIA) will need to be increasingly aware, vigilant and sometimes accommodating of disruptive technology as the use of the airwaves continues to grow at an exponential rate within a finite spectrum, which now can be fully exploited from HF to terahertz frequencies.