Lower-Frequency Applications Maintain High Interest

Applications at frequencies below 50 MHz remain a significant part of the electronics business. This report takes a look at those applications, highlighting some that are currently active.

US Frequency Allocations

Table 1 is an abbreviated summary of US frequency allocations from 9 kHz to 50 MHz. Similar services have been lumped together to simplify the list. These services make up the licensed, and some designated unlicensed, radio services approved by the FCC.

Many of these services are familiar, such as radio broadcasting, standard frequency and time, amateur radio and ISM band users. Other applications are less commonly known, especially the many fixed and mobile radio services, which may be used for offshore oil rig communications, remote operations such as survey crews, trans-oceanic air traffic control, or international point-to-point "shortwave" voice and data channels for businesses and government. Some of the active applications in these allocated services include:

Medium-wave broadcasting—"AM radio" is in the process of a conversion to digital transmission. Using in-band, on-channel (IBOC) techniques, the digital signal is

<9 **kHz**	Not allocated
9-190	Various radionavigation, radiolocation, fixed and maritime mobile services, except:
19.95-20.05	Standard frequency & time (20 kHz)
59-61	Standard frequency & time (60 kHz)
190-535	Aeronautical and maritime services, mobile and radionavigation, except:
495-505	(Distress and calling—recently deactivated)
535-1705	Broadcasting (shared with other services from 1605-1705 kHz)
1605-1800	Various radiolocation and mobile services
1800-2000	Amateur radio (shared from 1900-2000 kHz)
1900-2000	Radiolocation
2000-3500	Various fixed and mobile services; maritime and aeronautical, except:
2173.5-2190.5	Mobile distress and calling, and:
2495-2505	Standard frequency & time (2500 kHz)
3500-4000	Amateur radio
4000-4995	Various fixed and mobile services; maritime and aeronautical
4995-5005	Standard frequency & time (5000 kHz)
5005-5450	Various fixed services: maritime, aeronautical and private land mobile
5450-5730	Aeronautical mobile
5730-5950	Fixed and mobile services
5950-6200	Broadcasting
6200-7000	Various fixed and mobile services; maritime and aeronautical
6780 ±15 kHz	Industrial, scientific and medical (ISM)
7000-7300	Amateur radio
7300-9500	Various fixed and mobile services; maritime and aeronautical
9500-9900	Broadcasting
9.995-10.005 **MHz**	Standard frequency & time (10.0 MHz)
10.005-10.100	Aeronautical mobile
10.100-10.150	Amateur radio
10.150-11.650	Various fixed and mobile services; maritime and aeronautical
11.650-12.050	Broadcasting
12.050-13.360	Various fixed and mobile services; maritime and aeronautical
13.360-13.410	Radio astronomy
13.410-13.600	Fixed services
13.56 ±7 kHz	Industrial, scientific and medical (ISM)
13.600-13.800	Broadcasting
13.800-14.000	Fixed and mobile services
14.000-14.350	Amateur radio
14.350-14.990	Fixed and mobile services
14.990-15.010	Standard frequency & time (15.0 MHz)
15.010-15.100	Aeronautical mobile
15.100-15.600	Broadcasting
15.600-17.550	Fixed and mobile services
17.550-17.900	Broadcasting
17.900-18.068	Fixed and mobile services
18.068-18.168	Amateur radio
18.168-19.990	Fixed and mobile services
19.990-20.010	Standard frequency & time (20.0 MHz)
20.010-21.000	Fixed services
21.000-21.450	Amateur radio
21.450-21.850	Broadcasting
21.850-24.890	Fixed and mobile services
24.89024.990	Amateur radio
24.990-25.010	Standard frequency & time (25.0 MHz)
25.010-25.550	Maritime mobile and private land mobile
25.550-25.670	Radio astronomy
25.670-26.100	Broadcasting
26.100-26.960	Maritime mobile and land mobile
26.960-27.410	Personal radio (CB)
27.230-27.540	Private land mobile
27.12 ±163 kHz	Industrial, scientific and medical (ISM)
27.540-28.000	Fixed and mobile services
28.0-29.7	Amateur radio
29.7-37.5	Various fixed, public land mobile and private land mobile services
37.5-38.25	Radio astronomy
40.68 ±20 kHz	Industrial, scientific and medical (ISM)
38.25-50.0	Various fixed, public land mobile and private land mobile services

Table 1 · US frequency allocations up to 50 MHz, as of October 2003. Some services have been combined to simplify the list—see www.ntia.doc.gov/osmhome/allochrt.html for a detailed listing.

transmitted in quadrature with the AM carrier, with data in sidebands. With this system, both existing analog and new digital formats can be transmitted simultaneously. This new service is getting generally favorable reviews, although there are some complaints that IBOC transmission increases the interference level for adjacent channel stations, since sideband energy is only required to be 25 dB below carrier level at 10.2-20 kHz offset

ISM band industrial RF—Heating, plasma and sputtering equipment, with applications mainly at 13.56 MHz, is in high demand. This equipment is used for vaporizing materials for semiconductor fabrication, environmental or decorative coatings. Today, the biggest growth is in flat-panel video display manufacturing. Traditional applications such as curing adhesives or proving heat for thermal bonding remain significant as well.

International "shortwave" broadcasting—In many parts of the world, the ability to broadcast long distances is much more important than it is within the U.S. Although some broadcasters have moved to the Internet for coverage of developed nations, radio service is still significant in less-developed areas. The present ramp-up of Digital Radio Mondial (DRM) technology promises to help maintain this service, since this digital system is more efficient, requiring approximately 7 dB less signal strength than AM for the same reliability.

Government and military HF radio—Although not separately noted on the chart of allocations, various government agencies and the Armed Forces have increased their use of HF communications in recent years, after an earlier near-abandonment in favor of satellite communications. New military objectives of rapid deployment, flexible operations, and highly integrated communications has generated renewed interest in the HF band. The military has identified the limitations of VHF propagation for tactical communications, and much HF work has focused on near-vertical incidence skywave (NVIS) propagation, using the lower HF band (4 to 10 MHz) for communications from short range to a few hundred miles.

Wireline and Part 15 HF Applications

There are numerous applications that use frequencies of operation from kHz to the tens of MHz. Well-known systems include digital subscriber line (DSL/ADSL) data services and CATV backhaul, including "cable modem" digital services. Medical and scientific MRI systems may use frequencies from 10 to 80 MHz. Ultrasonic imaging systems operate with signals up to 8 MHz and higher.

Security systems using field disturbance monitoring techniques operate at various frequencies in the HF band, with low levels as required for compliance with FCC Part 15. Although these systems got lots of attention a a few years ago, it is not a large market segment.

Powerline communications (PLC) and Broadband-over-Powerline (BPL) use electric service wires to guide radio signals without adding new wired infrastructure. PLC has been in use for many years as part of the power distribution monitoring and control system, operating in the 10s to 100s of kHz. BPL is a recent development that operates all across the HF range, also using the powerlines as RF transmission lines, but with the goal of providing high-speed Internet access to paid subscribers. A different in-home system, provided by member companies of the HomePlug® Powerline Alliance, also uses AC power wiring for broadband communications, but—at present—limited to operation inside the customer's home. It is reported that this group is investigating its own version of BPL.

FCC Part 15 and Interference Issues

All unlicensed radio equipment and all electronic equipment capable of creating RF energy (defined as "unintentional radiators" by the FCC), must comply with the radiation limits specified in Part 15 of the FCC Rules, and regardless of radiation level, must not cause harmful interference to licensed radio services. Also, such equipment must accept (is not protected from) interference from properly operating licensed radio services.

Early versions of DSL were known to cause interference, which resulted in more careful selection of carrier frequencies to avoid existing radio services, as well as improvements in the modems that allowed the use of lower signal levels. Now, there are relatively few instances where DSL causes interference.

With a small number of systems in operation, BPL is still attempting to solve issues of interference. Unlike the copper telephone lines used by DSL, powerlines are not balanced and do not have controlled impedance. As such, they are lossy, with radiation as the primary loss mechanism. The losses also require repeaters at regular intervals to restore signal levels, adding to the total system power.

Most BPL interference complaints have been made by amateur radio operators, who are significant users of the HF spectrum. Concerns have also been raised by the aeronautical navigation and international broadcast communities, who fear that widely-deployed BPL will interfere with their operations. As noted earlier, HF spectrum users include government and military communications, and these groups are closely monitoring the development of BPL. As was done with DSL, new BPL technologies are in development that identify and notch out problem frequencies and frequency bands. This type of adaptive approach is intended to confine BPL operations to lesser-used portions of the spectrum.

Another area of interference to note is switching power supplies. While not intended to radiate signals, these circuits operate from the 10s of kHz to 10s of MHz. If poorly constructed, or if a component is defective, a significant amount of energy can be radiated, causing interference to almost any radio service operating at frequencies up to several times the switching frequency.

Summary

Like the first "wireless" systems of more than a century ago, the ability to communicate directly over long distances continues to be the attraction of lower frequency systems. This "oldest" part of the radio spectrum is certainly not being abandoned, and is experiencing changing applications and technologies just like the higher-frequency portions of the spectrum.