JOSEF BERNARD

ALMOST EVERY FREQUENCY IN THE RF spectrum, from near DC to billions of cycles per second, is used for some type of communication. Indeed, at times it seems as if there are almost as many communications services as there are frequencies for them to occupy. And at times it seems that the ordering of the different services that make use of the RF spectrum is purely random. Of course it is not. There is usually a good reason for a service being located where it is. In this climb up the "electromagnetic ladder" we'll see some of the varied services that make use of the RF spectrum, and learn why they are in their particular niches.

Meters and hertz

You no doubt have noticed that the location of a signal in the RF spectrum is often specified in hertz, but that sometimes it is specified in *meters*. Meters are a unit of distance, as you might expect. What is being measured is the *wavelength* of the signal. A wavelength is the distance from one point on one cycle to the corresponding point on the next. See Fig. 1. On the other hand, the hertz (abbreviated Hz) is a unit of *frequency*. It indicates how many cycles occur in one second. One hertz is equal to one cycle-per-second.

From DC to Microwave

On this guided tour of the RF spectrum we'll see what types of communications take place where, and why.

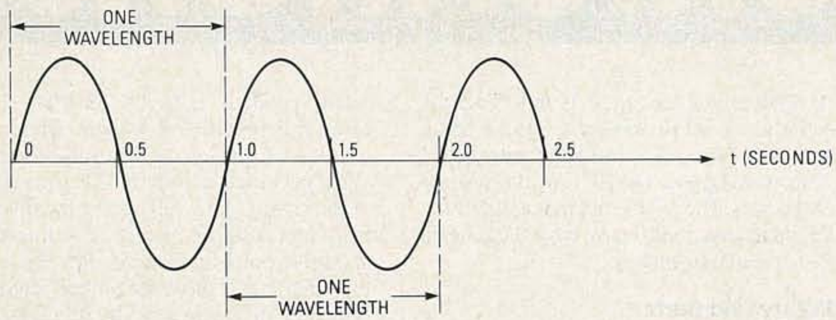


FIG. 1—THE WAVELENGTH AND FREQUENCY of a wave are related through $f = c/\lambda$. Therefore a wave with a frequency of one cycle-per-second (1 hertz) would have a wavelength of 300,000 kilometers.

The relationship between the two measures is simple, and if you know one you can easily determine the other. That's because the wavelength of an electromagnetic wave is inversely proportional to its frequency—that is, the longer the wavelength, the lower the frequency. The relationship between frequency and wavelength is given by $f = c/\lambda$, where f is the frequency in Hz, λ is the wavelength in meters, and c is the speed of light in meters-per-second.

Obviously, either measure can be used to specify the location in the spectrum of an RF (*R*adio *F*requency) signal completely. Why, then, are some signals usually specified in meters while others are specified in hertz?

The main reason is simply tradition. A general rule-of-thumb is that in regions of the spectrum that have been in use the longest—for the most part since before World War II—the common usage is to describe a signal using meters. Thus, the shortwave broadcast bands, and the "high-frequency" bands used by amateur radio operators, are still usually referred to in terms of their wavelengths in meters (25, 31, 40, etc.), and shortwave receivers, which these days frequently are called "communications receivers," have their dials scaled in meters.

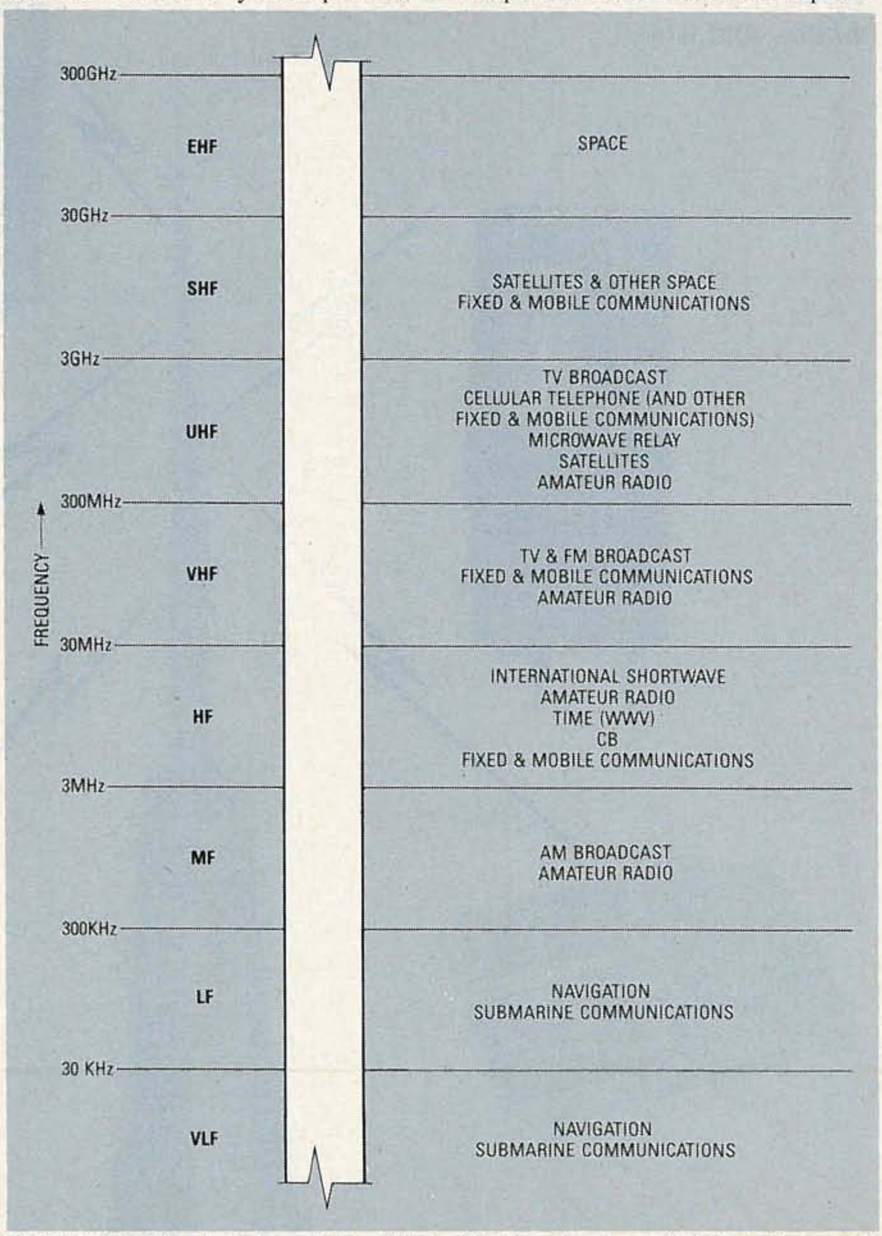
On the other hand, bands in the more-recently exploited part of the spectrum usually are referred to by the frequencies used. An exception to that is in the portion used by radar, and for terrestrial-microwave and satellite communications, where terms such as C-band, Ku-band, K-band, X-band, and the like abound. To confuse matters, those designations have nothing to do with either frequency or wavelength.

Starting at the bottom

The RF spectrum runs from 10,000 Hz (10 kHz) up beyond 300 gigahertz (300×10^9 Hz). The lower limit is within the realm of sound; the upper limit borders on infrared light.

At the very bottom of the RF spectrum are frequencies of tens or hundreds of kilohertz, with corresponding wavelengths of thousands of meters (at 100 kHz an electromagnetic wave has a wavelength of three kilometers, or about 1.8 miles). There, the ground-wave phenomenon predominates; radio waves tend to hug the earth rather than bounce off the ionosphere as they do at higher frequencies. That low-frequency region used to be the domain of the early radio pioneers. The selection of those frequencies was not made freely; the mechanical spark-gap communications sets used by Marconi and others were not capable of generating higher frequencies.

With the spark-gap age long behind us, those lowest frequencies are now used primarily for navigational purposes and for long-range military communications with submarines (although in general water is a poor propagation medium, best results are achieved at lower frequencies). Low and very low frequencies are not used widely for communications because of the problems encountered when attempting to use those frequencies to convey even moderately complex data. Remember, as the frequency of the modulating information increases, so does the bandwidth of the resulting signal. The problem is similar to that encountered when trying to transmit computer data over standard telephone



THE RF SPECTRUM extends from 10 kHz, which is within the realm of sound, to 300 gigahertz, which borders on infrared light.

circuits. Beyond a certain speed of transfer, the bandwidth of the signal exceeds the capability of the telephone lines. At low and very-low frequencies, it doesn't take much modulation to eat up vast stretches of the spectrum. And even low-frequency earth-hugging navigational beacons are being supplanted by newer satellite-based systems.

Medium waves

The MW (*M*edium *W*ave) region stretches from 300 kHz to 3 MHz. The best known part of that region, at least to most of us, is the AM broadcast band. It occupies the frequencies from approximately 540 to 1600 kHz.

At MW frequencies an interesting phenomenon begins to occur. That is, the ground-wave propagation of the low frequencies begins to give way to sky-wave propagation. See Fig. 2. In sky-wave propagation, signals no longer follow the contours of the earth. Instead they travel a line-of-sight path to the horizon, and out into space. Part of the signal may be reflected back to earth by the ionosphere, a region of the atmosphere made up of charged particles. The amount of reflection depends on several factors, but primarily on the frequency of the transmission and the state of the ionosphere itself. The state of the ionosphere changes depending on the time of day (during the daylight hours the sun is bombarding the atmosphere with energy that can cause ionization; at night, the amount of ionization decreases) and the state of solar activity (solar flares and the like can also pour tremendous amounts of energy into the atmosphere). Anyone who has listened to an AM broadcast radio has heard the effects of the changing state of the ionosphere. During the day, reception is limited pretty much to local stations, but after the sun has set stations from hundreds or even thousands of miles away can be heard.

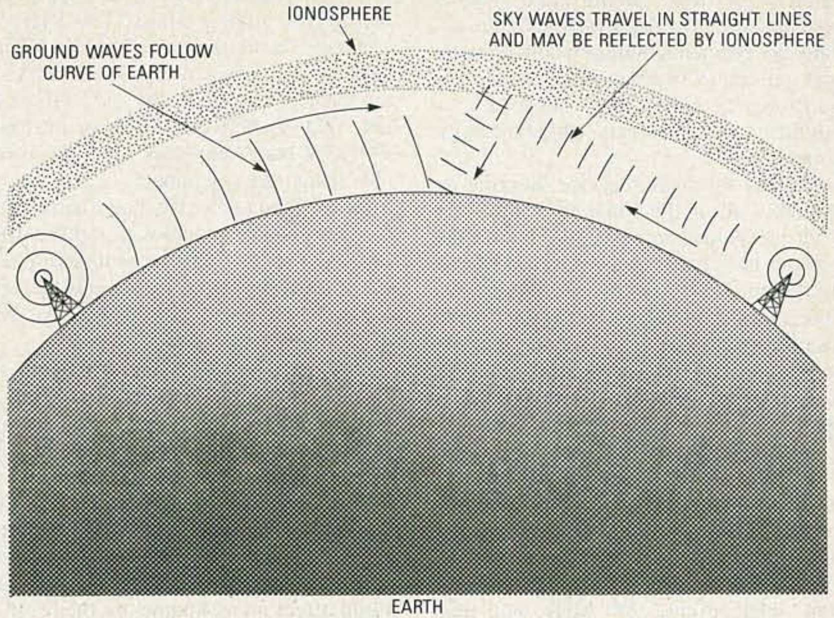


FIG. 2—GROUND WAVES, usually associated with low frequencies, hug the earth. Sky waves resulting from higher-frequency sources travel in straight lines. Depending on their frequency, and on other conditions, the waves may either travel out into space, or be reflected back to earth by the ionosphere.

Short waves

The boundaries between the segments of the RF spectrum are not clearly defined, but somewhere around 200 kHz (150 meters) we find the beginning of the shortwave region of the spectrum. That region extends to beyond 30 MHz (10 meters). The band between 3 and 30 MHz is also known as the HF (*H*igh *F*requency) region. At those frequencies, the reflective properties of the ionosphere are the strongest.

Until the advent of the communications satellite, all long-distance radio communications took place on the shortwave bands, and those bands are still full of activity; not everyone, after all, can afford a satellite earth station.

Note that we are still in the pre-World-War-II part of the spectrum, and thus we most often speak in terms of wavelengths rather than frequencies. Thus SWL's (*S*hort *W*ave *L*isteners) refer to international broadcasts in the 25-, 31-, or 49-meter bands, and amateur radio operators work the 80-, 20-, or 15-meter bands.

The characteristics of the shortwave bands change as they increase in frequency. In the lower reaches of the shortwave portion of the spectrum, propagation is primarily ground wave during the day and sky wave during the evening, much like the AM broadcast band that is located not far below in frequency. Around 30 meters (10 MHz) or so, things begin to turn around and there is good long-distance sky-wave propagation during the day, but the bands shut down at night as there is only short range ground-wave communication.

Propagation on the shortwave bands varies not only with the time of day, but also with the 11-year sunspot cycle. Over a period of 11 years, the degree of sunspot activity rises to a peak, and then falls off considerably. No one is quite sure exactly why that happens, but when sunspot activity is low, as it is now, the higher frequencies become useless for long-distance communications. There simply is no skip. As sunspot activity gradually increases, the ionosphere is restored, and long-distance communications again become possible on the higher shortwave frequencies. The next peak in the sunspot cycle is expected around 1991.

International broadcast services, usually operated by the government of one country or another, abound in the shortwave bands. Sometimes they carry programming for citizens or subjects of those countries to keep them abreast of developments at home. Frequently too, those services are used to disseminate political propaganda—sometimes subtle, and sometimes not so subtle; two such services are Radio Moscow and the Voice of America. Broadcasts from those international services go on 24 hours a day, changing frequencies and transmitter sites to obtain the best propagation conditions to various parts of the world.

Many amateur radio operators, or hams as they are frequently called, make extensive use of shortwave frequencies to talk to other hams around the country and around the world. Frequently, there are contests, with elaborate rules for scoring, in which hams accumulate points for contacting as many stations as they can—the farther away and the harder to find, the better—in a given period.

(An aside in the interest of amateur radio: The primary purpose of that "hobby"—some would call it a way of life—is to engage in two-way communications with other hams. If you just listen—whether it's with a communications receiver or with a VHF or UHF scanner—you're an SWL. When the news services reported last year that "any ham with the proper equipment could have listened in on the president's unscrambled conversations from Air Force One," they should have said, instead, "any listener . . ." Eavesdropping is not the intent of the amateur radio service.)

There's a lot more on the shortwave bands. Although there has been a shift to satellites, with their greater reliability, many commercial services still depend on those bands. Time services, such as WWV, are found at several places on the HF bands, transmitting accurate time and other information around the clock. Much international news and weather information is sent on the shortwave bands by radioteletype (that "jingle-jingle" sound you hear often on the shortwave bands). Many governments maintain contact with their embassies or consulates abroad by shortwave, and the astute observer can spot their "antenna farms" atop buildings in major cities.

Another shortwave service, familiar to just about all, is the *C*itizens' *B*and (CB) service located at around 27 MHz, the old 11-meter ham band. While it's too late to do anything about it at this late date (about 30 years too late), 27 MHz was not a wise place to locate CB. That service was intended for short-range, local use but, as many a CB-er and ham can tell you, when conditions are right there is no better place in shortwave for catching the ionospheric "skip" and talking to stations all over the world, even with just a few watts of output power. (Skip is ham and SWL slang for long-distance sky-wave communications). There is talk of opening up a citizens' band around 900 MHz, and that would make a lot more sense, as well as for shorter antennas! (For another view see "The New World of Communications," which immediately follows this story.)

Very high frequencies

Once above 30 MHz or so, we enter the *V*ery *H*igh *F*requency (VHF) realm. Because that portion of the spectrum, as well as the portions above it, were not exploited until after World War II, signals there are generally specified in terms of frequency rather than wavelength. (Exceptions to that are the six- and two-meter amateur bands.) Except at the very bottom of the VHF region, propagation by skip is rare, and all communications are line-of-sight, or about as far as the horizon, depending on the height of the transmitting and receiving antennas. Maximum ranges of 50 to 60 miles are typical.

Here are found the FM broadcast band, the VHF (naturally) television channels, all sorts of local mobile-communications services (including police and fire departments, mobile telephones, business communications such as taxis and local truckers, airplane-to-airport communications, and many government and military services). Because the communications range is only line-of-sight, those frequencies are ideal for local services and can be reused time and again at fairly short geographic intervals.

The assignment of the frequencies used for television broadcasting is interesting—there are two VHF-TV bands. The lower one starts at 54 MHz for Channel 2; there used to be a Channel 1 but it disappeared a long time ago (For more information see "Whatever Happened to Channel 1" in the March 1982 issue of **Radio-Electronics**). That band continues up to to 88 MHz, the top of Channel 6. There is then a gap of 86 MHz, which is used by the FM broadcast service (between 88 and 108 MHz), among others. The VHF-TV channels begin again at 174 MHz (Channel 7) and continue to 216 MHz, which is the top of Channel 13, the last VHF channel. That gap between the upper and lower VHF-TV bands explains why, if you live in a fringe area, Channel 7 or 8 may be more difficult to receive than Channel 5 or 6. At higher frequencies it is more difficult (and more expensive) to build sensitive receiving equipment, and the efficiency of old antennas and feedlines falls off.

Almost all of us have witnessed the "venetian blind" effect on our TV sets. It is caused by VHF skip, which usually takes place in the spring and fall. The effect is caused by the reception of two TV stations on the same channel. One station is your local one, while the other might be located hundreds of miles away. The horizontal bars that give the venetian-blind effect its nickname are the result of the two signals interfering with one another. If the bars seem to move up or down the screen, it's because the horizontal-sync frequencies of the two stations aren't exactly the same. It takes just a fraction of a percent of difference at 15,734 kHz (the standard horizontal-sync frequency) to be noticeable. That type of interference is analogous to beat notes at audio frequencies or diffraction patterns in light.

Many people have the impression that it is the nature of FM that limits the range of broadcasts made using that type of modulation. That is simply not true! The reason for the limited range of FM broadcasts is that the frequencies assigned to that service are restricted to line-of-sight propagation. Frequency modulation is actually far superior to AM—not only in resistance to atmospheric noise, but in resistance to other types of interference, as well as in resistance to fading. It's just that by the time the usefulness of FM was recognized, the lower frequencies were all occupied. Perhaps that's just as well—the 20-MHz spread of the FM broadcast band allows for plenty of wideband stations transmitting high-quality audio.

Ultra high frequencies

Starting at about 300 MHz and extending to about 3,000 MHz is the UHF (*U*ltra *H*igh *F*requency) band, perhaps best known because of the TV channels found there between 470 and 890 MHz. Until the late 1950's, those frequencies were hardly used at all because the cost of building transmitting and receiving equipment for that part of the spectrum was just too high. In fact, until just a few decades ago, virtually all the frequencies in that band and the ones higher in frequency were part of the FCC's legacy to amateur radio. Amateurs, it was hoped, would learn how to tame those "esoteric" regions of the RF spectrum.

These days, UHF is pretty much an extension of the VHF band. Many of the services found on VHF also now have allocations in the UHF band. Those include the land mobile services (especially cellular telephones and pagers, which have been assigned what was formerly the top of the UHF-TV band), UHF television, and government agencies (police, fire, etc.).

Other than the fact that the VHF frequencies are just about completely occupied, UHF offers a significant advantage to those services where hand-held receivers and/or transmitters are commonplace. That is, UHF communications gear, especially the antenna (remember antenna length is dependent on wavelength), can be made much smaller.

As an aside, handheld transceivers (a transcevier is a combination transmitter/receiver) are commonly called walkie-talkies, but the proper term is "handie-talkie" (because it fits in your hand). A walkie-talkie is actually defined as a transceiver that you can carry around with you—usually strapped to your back or slung over your shoulder on a strap—to leave your hands relatively free. The term "creepie-peepie," for a portable TV-camera/transmitter combination, never caught on (and that's probably a good thing).

Incidentally, you can tell whether a handie-talkie is operating on VHF or UHF by its "rubber duckie" antenna. If it's about as thick as a finger, the unit is for VHF; if it's about the thickness of a wire, it's for UHF.

Once we get to the UHF band, we are dealing with frequencies that begin to approach those of light. Not surprisingly, then, signals here begin to acquire some of the properties of light. One of the most common examples of that is the deterioration of UHF-TV reception during rainy weather. That happens because raindrops tend to block the radio waves, just as they do light, and fewer and fewer get through as the distance between transmitter and receiver increases.

Super high frequencies

While the microwave band "officially" begins at about 250 MHz, the term microwave is now popularly used to describe signals in the *S*uper *H*igh *F*requency (SHF) region, above 3000 MHz. Here it is no longer convenient to refer to frequencies in terms of megahertz; instead we speak in terms of gigahertz, or billions of cycles per second. While wavelengths here are still far longer than those of light, they are also short enough to begin exhibiting many more of the properties of light. At the upper end of the SHF band, 30 GHz, wavelengths are as short as a couple of inches. Like light, microwaves travel in straight lines. They are easily reflected by even small metallic surfaces;

continued on page 53

BENN KOBB*

The New World of Communications

The battle lines have been drawn for the fight over the last frontier in personal communications. In this article we'll learn more about that fight, and the prize that hangs in the balance.

THE 800-MHZ BAND, REGARDED AS THE last feasible band for mobile radio, is the subject of some the most heated controversies in the communications world. In dispute are who should have the right to transmit in that band, and even who should have the right to listen to those transmissions.

This article will describe some of the current and proposed radio services in the 800-MHz band. We'll also see how the battle for control of 800 MHz may affect the future of communications electronics.

Cellular telephone

If you live in one of the more than 100 U.S. cities that have cellular telephone service, you may have noticed that the business pages of your local newspaper have become inundated with advertisements for cellular phones. In an effort to relieve the congestion that had plagued conventional UHF mobile-phone service for years, the FCC in 1983 opened the 825–845 and 870–890-MHz bands to cellular systems. In each market, one 20-MHz band is allocated to a "wireline" carrier affiliated with the telephone company that serves the area, while the other 20 MHz is allocated to an independent "non-wireline" carrier.

Conventional mobile-phone systems typically use a single, high-power transmission site and fewer than 20 channels to cover an area. In contrast, cellular systems operate through a network of many low-power "cell" sites and hundreds of channels. Cell sites can be identified by their towers, which typically sport peculiar, triangular antenna platforms.

As a customer engaged in a cellular call drives from the coverage area of one cell into that of another, changes in signal strength trigger an automatic hand-off of the call from one cell to the next. Ideally, at worst the user hears only a split-second gap in conversation while his mobile unit switches by remote command to the channel required by the next cell.

A typical large-city cellular carrier uses 20 or 30 cell sites, all connected via landline (telephone line) or microwave to a

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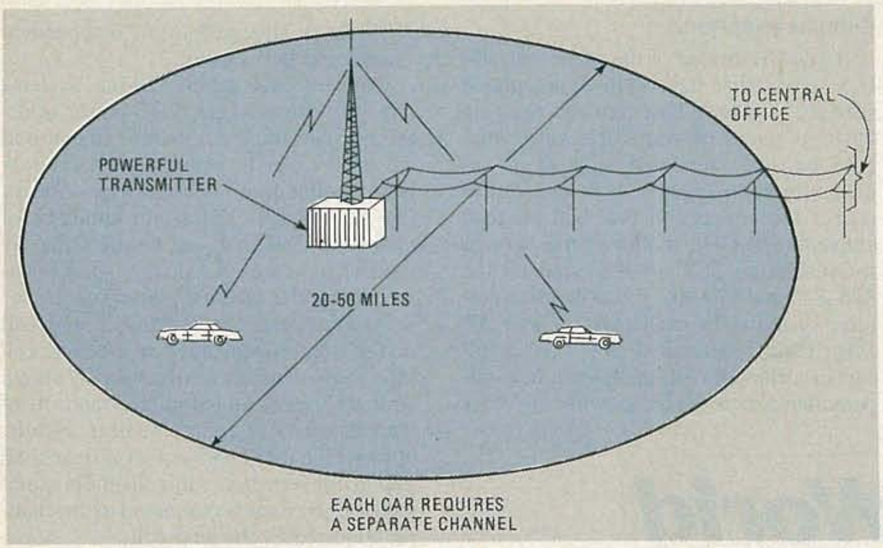
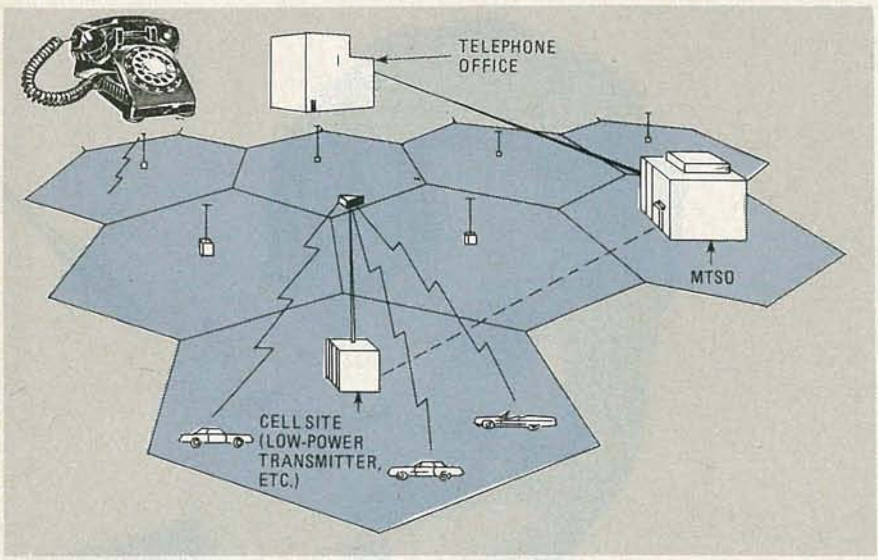


IN A CONVENTIONAL MOBILE TELEPHONE SYSTEM, only a single base station is used to cover the entire service area.



IN THE CELLULAR SYSTEM the service area is divided into smaller "cells." Each cell has its own low-power base station, called a cell site.

central *M*obile *T*elephone *S*witching *O*ffice (MTSO). Essentially a telephone exchange, the MTSO transmits and receives calls between the cellular network and the public telephone-network.

Frequencies can be re-used several times within a cellular system. That feature is what gives cellular its widely-touted spectrum efficiency. Also, the cellular system has a built-in growth mechanism. If the communications traffic in a particular cell becomes too much for it to handle, the cell can be split into smaller cells, freeing additional channels to serve customers without the need to actually expand beyond the already-allocated 20 MHz.

In theory, cell-splitting was designed to help the cellular industry serve larger numbers of customers without the need for more frequencies. In practice, things have not worked out all that well. Major-market cellular carriers have split cells to some extent, but the process is expensive. To split a cell, outlays of hundreds of thousands of dollars are required for site acquisition, engineering, and construction. Further, there have been many instances of local opposition to new tower construction. That opposition has most often been based on aesthetics or the perceived dangers of RF radiation. Because of all of that, carriers have returned to the FCC for more channels after all.

The radio spectrum, however, is a very scarce resource. Only a few megahertz remain unused at 800 MHz, and the FCC has found itself faced with many competing claims for that piece of the spectrum. After considering the claims, the Commission tentatively allocated an additional 12 MHz to the cellular service, even though it appears that the additional spectrum is only needed by a handful of carriers in the nation's largest cities, and that most cellular systems won't even need to use all of their existing 20 MHz.

Other countries that have cellular service are facing a similar dilemma. Should more spectrum be granted to cellular, with its analog FM technology, or should the airwaves be conserved for modulation techniques that could bring consumers exciting new services and better spectrum efficiency? Several European countries that already have FM cellular have decided to conserve parts of the radio spectrum for a futuristic project known as the Pan-European Digital Mobile Telecommunications Network.

That plan promises to bring European consumers a miniature, handheld digital communicator that could eventually replace the mobile telephone and the radio pager, and that could transmit and receive voice and text, as well as images. Tests are already underway in Sweden and Germany of competing time-domain and frequency-domain multiplexed digital-radio systems. Such systems offer greater channel capacity and flexibility than existing systems.

Will digital mobile-radio eventually take the place of analog FM in the United States? The future depends in large part on whether the FCC grants more of the spectrum for FM systems or conserves some of it for more spectrum-efficient technologies. With heavy investments in FM, substantial incentives must emerge for industry in this country to convert to digital. A successful deployment of digital radio in Europe could provide that needed incentive.

Mobile satellite

Cellular telephone is essentially an urban technology. That is, an expensive network of cells and switching centers is necessary to provide cellular service, and only those markets with sufficient population and business activity can profitably support cellular systems. What about the rest of the country? To serve what it viewed as a large, untapped market for mobile communications in the rural U.S., NASA in 1982 announced an ambitious proposal for a *M*obile *S*atellite *S*ervice (MSS) to provide two-way radio, paging, mobile telephone, data, and position-location services to vehicles across the country. A very similar program is underway in Canada, where widely separated remote populations could benefit greatly from a mobile satellite.

A dozen companies agreed with the basic concept and forwarded applications to the FCC for licenses to launch mobile satellites. NASA even agreed to provide a free ride on a Space Shuttle for the winning applicant's satellite, in return for communication services. *(That, of course, was before the Challenger disaster; that incident will considerably delay,* *if not jeopardize, the MSS program, as well as many others.—Editor*) Satellite entrepreneurs projected markets in the millions of units for vehicular, transportable, and, eventually, hand-portable satellite radios. Of course, the cost of implementing MSS will be "astronomical;" one applicant estimated its startup cost to be in the vicinity of $700 million.

The FCC tentatively allocated 821–825 and 866–870 MHz to MSS in November, 1984. No licenses have been granted, however, because that proposed allocation is the target of intense lobbying in Washington by trade associations representing the two-way radio industry and the nation's police, fire, and emergency-medical radio users. Those users insist that their need for additional channels far outweighs any public benefit that might come from MSS. Recent Congressional action requires the FCC to give top priority to public-safety communications in making spectrum decisions. Aspiring mobile-satellite entrepreneurs argue instead that MSS will help to fill the need for public-safety radio, and that metropolitan public-safety agencies could make more use of cellular systems to meet their communication needs.

The MSS debate has escalated beyond the public safety vs. high-tech arena, and has entered the rural vs. urban and even international arenas. Several influential congressmen have lined up firmly behind MSS as the answer to under-served rural-communication needs, while others argue just as strenuously that urban areas, facing severe spectrum shortages, need the 800-MHz band for police and fire radios.

As a way out of the 800-MHz MSS dilemma, many proponents are pushing to kick MSS upstairs to the 1.6-GHz L-band where land-mobile stations do not operate. The L-band technology, they believe, will result in lower costs for satellite radios. In fact, INMARSAT, the *IN*ernational *MAR*itime *SAT*ellite Organization, has just introduced a shoebox-sized L-band mobile satellite-communicator for ships of any size—even the smallest canoe. Expected to cost well under $5000, the unit sends and receives error-free alphanumeric messages through the INMARSAT satellite system anywhere in the world.

Canada, with its substantial commitment to an 800-MHz MSS, is having to reevaluate its frequency selection. If the U.S. moves ahead with an 800-MHz MSS, the two nations' systems will be compatible, each picking-up the other in the event of a malfunction. On the other hand, should the U.S. use the 800-MHz band instead for regular police and fire radios, the Canadian satellite could easily interfere with and receive interference from U.S. users. The FCC has given Canada and international telecommunications authorities official notice that the U.S. desires to use the L-band for MSS.

Radio-determination satellite

A parallel development to MSS is the *R*adio-*D*etermination *S*atellite *S*ervice (RDSS) recently approved by the FCC. Originally proposed by physicist-pilot-science writer Gerard O'Neill as a navigation aid for aircraft, the RDSS service would pinpoint the location of any user in an instant and enable the user to send and receive short alphanumeric messages via satellite from a palm-sized device expected to cost around $500.

Although marine-, aviation-, and land-transportation interests are seen as major customers for RDSS, O'Neill's company, Geostar Corp. of Princeton, NJ, envisioned the system being used also by pedestrians who could signal for help if they witnessed a crime, accident, or other emergency. Geostar weathered lengthy legal and technical battles at the FCC in order to have the RDSS service approved. The Commission concluded that there is a need for RDSS, and allocated spectrum to it in the 1610–1626.5-, 2483–2500-, and 5117–5183-MHz bands. The next step is for Geostar and several other prospective RDSS companies to complete their funding and begin construction and launch of the satellites. How much money will they have to raise? The business plans submitted to the FCC indicate an average required investment of $300 million to start commercial RDSS operation.

Communications privacy

If you're a radio amateur, shortwave listener, or scanner enthusiast, chances are you've heard of the *E*lectronic *C*ommunications *P*rivacy *A*ct (ECPA), a bill pending before the House and the Senate that could have a dramatic impact on hobby radio listening if enacted into law. Where did the ECPA come from and how will it affect radio communications?

Essentially, the ECPA is an attempt by concerned congressmen to bring federal wiretap laws up to date to accommodate new technology, especially electronic mail and mobile-telephone systems. As you may know, existing provisions of the Communications Act of 1934, as amended, prohibit the divulging or misuse of any information you may obtain by monitoring a communication not intended for you. It is that feature of existing law that permits SWL's and scanner listeners to engage in their hobby without fear of criminal prosecution—as long as they don't divulge what they hear or use the information for personal gain or criminal purposes.

The emergence of computer crime, of satellite-TVRO technology, and of cellular-telephone systems have led various trade associations to lobby congressmen to support legislation that would have a broad application to penalize illegal interception of any electronic communication—whether transmitted by wire, fiber optics, cellular, satellite, or a not-yet-invented communications system. Accordingly, two similar bills were introduced providing stiff penalties for unauthorized interception of communications. Those bills are aimed not at amending the Communications Act, but at the wiretap provisions of the Omnibus Crime Control and Safe Streets Act.

The sponsoring trade associations, including the Cellular Telecommunications Industry Association, the Electronic Mail Association, and others, were generally satisfied with the wording of the proposed legislation which would, it appeared, protect their constituencies from invasion of privacy.

Radio-hobby organizations, however, were aghast at the sometimes draconian—and other times just plain confusing—wording of the bills. For example, the ECPA initially would have made it illegal to listen to a signal emitted by a radio in a vehicle but gave the green light to listening to a hand-held radio. Fortunately, that portion was later removed. The status of amateur-radio "autopatch" or telephone interconnection was extremely vague; although the bills "exempted" amateur radio from their privacy protections, they did make it illegal to listen to telephone calls. That issue is still unclear in the current version of the bills, although most observers interpret the language to mean that you won't be criminally liable for listening in on a ham's autopatch call.

UNDER SOME PROVISIONS of the ECPA, if passed, the legal use of scanners and other communications gear would be curtailed.

The bills appeared to make listening to marine, aviation, or governmental stations illegal, too. After lengthy hearings that included testimony from the *A*merican *R*adio *R*elay *L*eague (ARRL) and the *A*ssociation of *N*orth *A*merican *R*adio *C*lubs (ANARC), changes were introduced in the legislation to make it at least somewhat more palatable to radio hobbyists and amateurs.

The current version of the House bill, HR 3378, permits monitoring of most of the radio services you might hear on a scanner or shortwave receiver—as long as those services are not scrambled or encrypted. Unfortunately, the mere reception of a scrambled radio signal—even if

DURING THE CB BOOM of the mid 1970's millions of Americans were installing CB gear, such as the unit shown here, in their cars and homes.

you do not unscramble or demodulate the signal—will carry criminal penalties, at least under the current version. Unauthorized reception of a cellular telephone conversation could result in a fine of up to $500 and up to six months in jail. That provision was adopted even though cellular telephones can be received on 800-MHz scanners, service monitors, spectrum analyzers, and on many TV sets and videocassette recorders when they are tuned above Channel 80. If you recall, in the 1970's the FCC reappropriated the frequencies for the little-used UHF Channels 70 through 83 and reassigned them to mobile-communications services. Part of that allocation went to cellular telephone.

Monitoring of other common-carrier communications, such as microwave radio, paging, or international marine-radiotelephone services, would carry stiffer penalties. However, listening to cordless telephones would be exempt from any criminal sanctions.

How those proposed laws would affect satellite-TVRO owners is anything but clear at this point. Legislators involved in the ECPA have publicly conceded that they don't want the bills to have any effect one way or the other on satellite-TVRO owners, even though monitoring of satellites is specifically prohibited by the legislation unless the material received is intended for use by television broadcast-stations.

The final legislation, if adopted by Congress and signed by the President, could of course end up being more, or less, restrictive than HR 3378. Watch the What's News, Satellite News, and Video News columns in **Radio-Electronics** for any late-breaking information on the ECPA. Hopefully, you won't have to retire your communications receiver and take up butterfly collecting.

Personal radio

The *C*itizens *B*and (CB) radio service operates at 27 MHz. However, the original "Citizens Radio Service" occupied the entire band between 460–470 MHz when it was created in the 1940's. The FCC eventually took most of the UHF band from Citizens Radio and reallocated the frequencies to business and industrial radio-services, turning the old 11-meter ham band over to CB as a sort of compensation for the loss.

A sliver of that 460-MHz band—eight channels—still exists for citizens radio (now called "personal" radio) at UHF, and it is in that band that the "CB of the future" may find a home.

To understand what may happen to the UHF band, and how its fate is tied to the 800-MHz proceedings, it's necessary to backtrack to 1975 when the CB boom was hitting its peak. Millions of Americans were installing CB's in homes and cars, and legitimate users were being crowded out by those "experimenting" with skip and using illegal amplifiers. The FCC was experiencing one of the biggest headaches in its history: A runaway radio service that was impossible to control and license effectively.

The commission at that time received several proposals to initiate a new CB-radio service at 220 MHz in order to take some of the pressure off of the 27-MHz band. The 220-MHz band was the domain of amateur-radio operators, and they strongly objected to that reallocation, predicting that the result would be even more on-the-air chaos.

Hams were successful in keeping 220 MHz. The FCC's eyes turned to establishing the new CB service at 800 MHz, and in 1979 the agency began a large-scale inquiry into how that could be accomplished. Consultants were hired. Thousands of questionnaires were distributed. Comments were received from industry and the public.

In 1983, the General Electric company filed a request with the FCC to expedite the process of authorizing a new service at 800 MHz. It reported the results of its program to develop what it called a *P*ersonal *R*adio *C*ommunications *S*ervice (PRCS), a highly advanced base- and mobile-radio system for the family or small business user. The projected cost for both the base and the mobile unit was under $500. That FM system used selective addressing and microprocessor-controlled channel selection to assure users of a free channel and to reduce interference to the maximum extent possible.

PRCS was a flexible system that would have lent itself well to travelers-assistance and motorist-safety applications. PRCS had, however, one particular capability that represented both its most exciting feature and its downfall. PRCS could be used as a mobile telephone. The user could make telephone calls from a mobile or portable unit, through one's own base station at home, connected to the telephone line in a similar manner as an answering machine. No special charges would apply, unless the user chose to operate through an optional local-repeater system for greater range. Repeater fees were expected to be about $10 a month.

The competition PRCS could have given to the then-infant cellular-telephone industry was considerable. Unlike cellular, PRCS was capable of direct mobile-to-mobile communication and through-the-home mobile-telephone calling at no cost. Attorneys for General Electric's competitors are unwilling to sacrifice any of the precious 800-MHz spectrum to a consumer-oriented personal-radio service. So they filed mountains of documents with the FCC claiming that PRCS would be beset by massive interference and that there was little or no measurable demand for the service anyway, even though GE was attracting interest as a result of PRCS demonstrations.

Faced with competing demands for 800-MHz, and contending that the higher-priced cellular telephone could meet most of the needs projected for the PRCS, the FCC elected not to authorize PRCS and to let the experimental authorizations for the small number of existing PRCS stations expire. A petition for reconsideration of that action, filed by the Personal Radio Steering Group Inc. of Ann Arbor, MI, is still pending.

The FCC did not forget about the promise of personal radio and the possibility of creating some kind of improvement in CB. In January of this year, the Commission returned to those 8 460-MHz channels that belonged to the Citizens Radio of old, now called the *G*eneral *M*obile *R*adio *S*ervice (GMRS), and proposed to establish in those channels a CB Consumer Radio Service based on low-power hand-held radios.

That proposal was greeted with astonishment by a large user of the GMRS channels, REACT, the national association of volunteer emergency-communications teams, and by many non-affiliated personal-radio users and communitywatch groups. Those users have operated GMRS repeater systems for years and did not take kindly to the FCC's recommendation that the Consumer Radio Service be limited to short-range, unlicensed walkie-talkies. GMRS licensees are busy with a campaign to alert their congressional representatives to the take-away that the Consumer Radio Service seems to represent. The FCC maintains that it's keeping an open mind on the subject and won't do anything with the GMRS channels until all of the formal comments are received (the deadline for that was this past June 30) and it has had a chance to analyze them.

THIS MIDLAND *70-526* mobile UHF transceiver is designed for GMRS use.

Flexible radio service

So far, there is still one part of the 800-MHz band that remains unallocated. We've looked at some of the radio services proposed for this band, including one (PRCS) that appears to have been ruled out. The lucky radio service or services that receive an 800-MHz allocation will undoubtedly start a new industry or enhance an existing one, depending on how the allocations are made. Has the FCC given any indication as to what it will do?

Several Commissioners and staff members have indicated that they would like to try a totally different approach to spectrum allocation. Instead of weighing the arguments presented by petitioners and granting the requests they determine are most in the public interest, the FCC is examining the possibility of throwing the remaining portion of the 800-MHz band wide-open for any lawful use by selected licensees.

That would be accomplished by a lottery or auction process to award a limited number of nationwide licenses to parties who in turn would decide for themselves which service—mobile radio, cellular telephone, paging, satellite, video, etc.—would be most profitable. They could then implement their spectrum allocation. That would relieve the commission of the difficult task of deciding which proposed communication services are most beneficial to the public, and would leave the future of the spectrum in the hands of the marketplace.

That proposal, known generally as the Flexible Allocation or Flexible Radio Service, has produced heated debate from within and outside the FCC. The approach could result in the necessity for two-way radio users to buy their channels instead of receiving them "free" with an FCC license.

Such a Flexible Radio Service could, theoretically at least, bring new communications technologies to market faster because detailed FCC approval at every step along the way would not be needed. Proponents of flexible allocation say it is our last chance to try something innovative with the radio spectrum. Opponents of the controversial proposal say it is wrong to conduct economic experiments with precious frequencies needed for public services.

Millions, if not billions of dollars hang in the balance of those critical decisions about how the radio spectrum should best be allocated. The UHF band—particularly 800 MHz—will be the cause of quite a few interesting battles over the future of communications. Who do *you* believe should win the "Spectrum Wars?" **R-E**

FROM DC TO MICROWAVE

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that property is what makes things like radar (which is an acronym for *RA*dio *D*etection *A*nd *R*anging), used for tracking airplanes as well as speeding motorists, possible.

Microwave is used for communications in areas where it is impractical to lay or string cables. Microwave receivers and transmitters located atop high towers in rural areas, or on tall buildings in cities, relay communications over spans of dozens of miles at a time. Much transcontinental voice and data communications, once handled by cable, is now accomplished via microwave links.

The frequencies used by communications satellites are also located in the SHF part of the spectrum. Because, with their relatively short wavelengths, microwaves act like light, they can be treated like light. The familiar satellite dish (see Fig. 3) is actually the radio equivalent of a reflecting telescope. The purpose of the dish in a receiving installation is to collect the microwave signals coming from a satellite transponder and focus them on an antenna (called a probe) located at the dish's focal point (within a feedhorn). Similarly, in a transmitting set-up, the dish is used to concentrate microwave signals into a tight beam. Satellite-TV activity takes place between 3.4 and 4.2 gigahertz (the C-band) and between 11.7 and 12.7 gigahertz (the Ku-band—pronounced "cue-band").

FIG. 3—BECAUSE THEY HAVE PROPERTIES similar to those of light, microwave signals can be collected and focused on an antenna element by a metalic surfaced reflector. That property is the basis of the satellite dish. The satellite dish is the radio equivalent of the optical reflecting telescope.

There is some concern over the effects of microwave radiation on the human body. Just as a microwave oven can induce heating in organic (and metallic) materials by stimulating molecular motion (the faster molecules or atoms move, the hotter they become), any microwave source can do the same. There have been reports that microwave technicians, particularly those working with high power levels, have suffered higher than normal rates of certain disorders such as cataracts. To most of us microwaves pose no health threat but nevertheless, like anything that is potentially dangerous, they should be treated with care and respect.

And beyond

Above the SHF band is the EHF (*E*xtremely *H*igh *F*requency) region. Frequencies there are most conveniently specified in terahertz—thousands of billions of cycles per second. Wavelengths in the EHF region are only in the millimeter range (for reference, a dime is a little less than a millimeter thick). At the top end of the range, the frequencies border on those of infrared light. While little use is made of these frequencies at present, they are beginning to be exploited for communications in space. It is safe to expect that use of those frequencies will grow as our exploration of space continues, and as the frequencies below become occupied. **R-E**