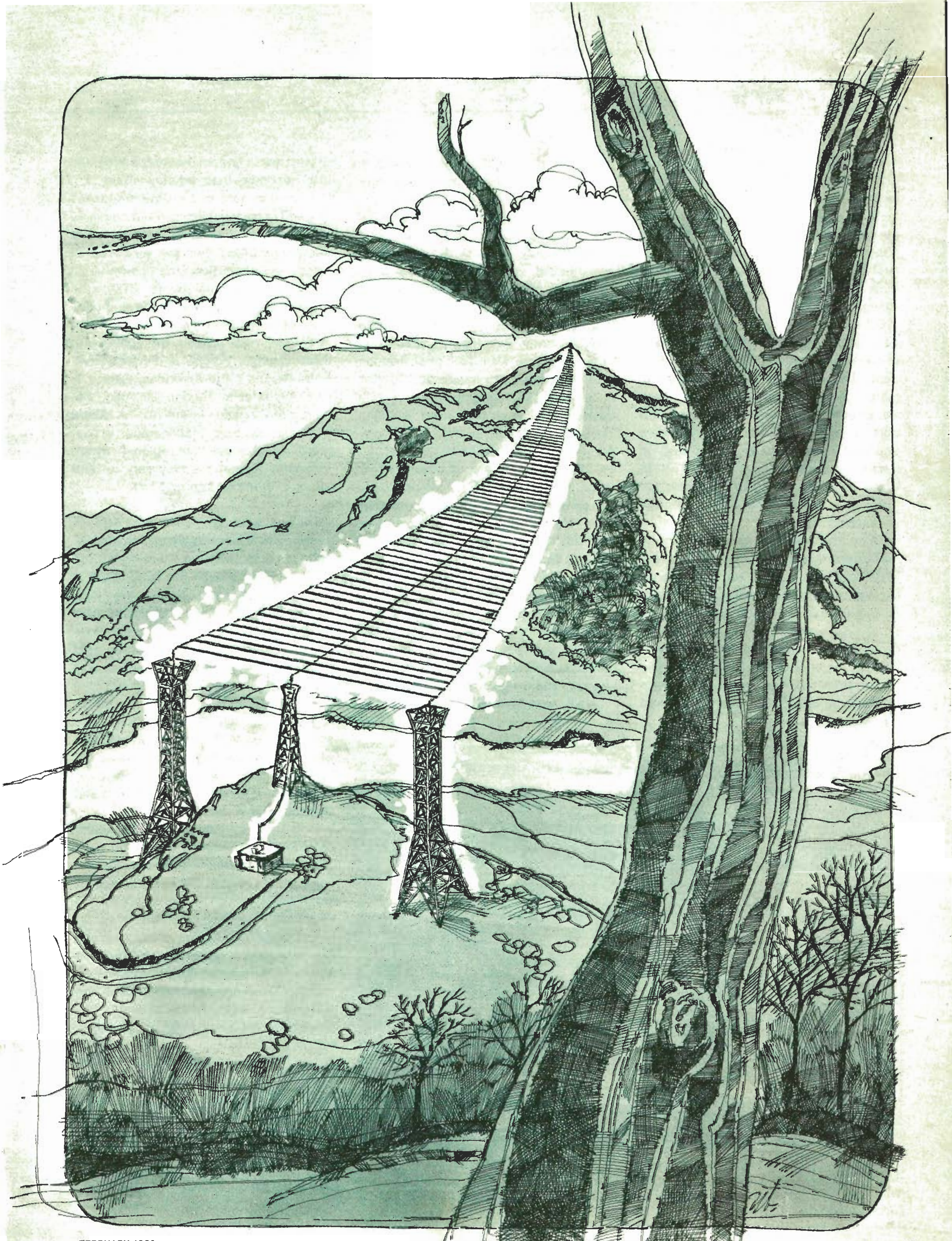


energy at such wavelengths than at higher frequencies and shorter wavelengths.

The spark gap was the principal means of generating r-f. Designed at the peak of spark-gap technology, the original *NAA* was the world's first high-power longwave radio station. It was erected in Arlington, Virginia by the U.S. Navy as a 1913 experiment to determine the feasibility of long-distance wireless communications. This station employed a Fessenden synchronous rotary spark transmitter. In the following decade, many government and commercial radio stations were constructed, some on ships and some on shore. They operated on frequencies ranging from several tens of kilohertz to a few hundred kilohertz. At the time, these frequencies were hardly considered *low*!

Such stations were characterized by high-power spark-gap transmitters, very large and costly antennas, and operating wavelengths that measured not feet or meters but miles or kilometers. In those days, most stations communicated on wavelengths of 1000 meters or longer. "Rock-crusher" *NAA* transmitted on the then relatively short wavelength of 2500 meters. French station *YN* was heard by many old-timers listening on this side of the Atlantic on the respectably long wavelength of 15,000 meters—20 kHz! Later, the American Telephone and Telegraph Company scored a longwave first by establishing a reliable transatlantic voice circuit as early as 1923. The company employed an operating frequency of 55 kHz.

The long waves remained in vogue until the early Twenties, at which time radio amateurs went to higher frequencies to escape the murderous interference from the high-power commercial point-to-point and broadcast stations. These hams made an amazing discovery—the higher the operating frequency, the greater the communications range. When word got out, almost everyone joined the exodus to higher frequencies. The long waves went into a decline that only began to be reversed after the Second World War. Their renaissance in recent years is due in large part to important propagation characteristics that make them superior to the higher frequencies for a number of applications such as radiolocation, certain types of communications, and very precise timekeeping and frequency measurements.

We'll next examine what types of signals you'll find on the long waves and the services that employ them. It's important to note that a given frequency or band of frequencies is not necessarily allocated to the same service on a worldwide basis. For the purposes of frequency allocation, the International Telecommunications Union (ITU), the organization charged with the responsibility of overseeing the use of the radio spectrum, has divided the globe into three regions. Europe and Africa comprise Region I; the Americas, Region II; and Australasia, Region III. Also, because propagation in the tropics differs considerably from that in other areas, there are tropical "subregions" where frequency allocations may vary to take these differences into account.

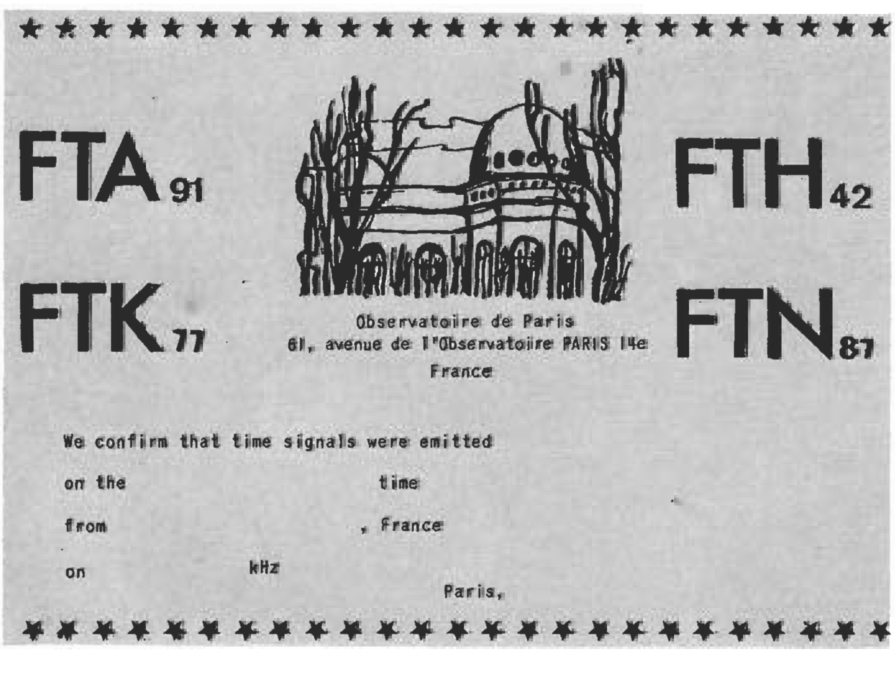



*Fig. 1. This QSL card was received from the French time station FTA91, which transmits Coordinated Universal Time (UTC) in Morse code on 91.15 kHz.*

**Beacons and Weather Stations.** In years past, the mainstay of aeronavigation was a longwave system called the *radio range*. Although the radio range is somewhat obsolete today, the 200-to-400-kHz radio-range band is still used for aircraft direction-finding. Small, low-power transmitters located at or near airports form a network of electronic range patterns enabling aircraft to home in on them. These stations are being replaced by elements of the more sophisticated *VOR* and *TACAN* systems which operate on vhf and uhf. They are still important navigation aids, however, in remote areas of the United States and Canada, and in other parts of the world. In fact, there are still over 3000 beacons of various kinds around the globe!

A list of selected beacons appears in Table I. You should be able to hear at least one or two beacons if you live anywhere in the United States or southern Canada. Note that these stations use "identifiers" rather than regular call letters to help tie in the ID with station location. Most operate between 190 and 400 kHz at relatively low power. They make for some interesting and challenging DX "catches".

Some stations also transmit continuous aviation and marine weather broadcasts using amplitude modulation. These transmitters can be heard out to approximately 100 miles during the day and 1000 miles or more at night. You'll also find that the frequencies around 500 kHz are active with marine radio traffic. Exactly 500 kHz is an international calling and distress frequency.

**Time and Frequency Standards.** Over the past few years, the long waves have become a popular source of channels for accurate time and frequency standards. Approximately twelve stations around the world now broadcast highly accurate marker signals 24 hours a day; mostly on frequencies below 100 kHz. Why are the long waves especially well suited for this application? They are to a large extent free of the small but, to some users, important errors that result from the variations in signal propagation which affect reception of regular ("shortwave") transmissions of time and frequency stations. The hf signals from such familiar stations as *WWV, WWVH* and the Canadian *CHU* are affected by fading, multiple-path reception, and propagation which either make them difficult to receive or unsuitable for use when high accuracy is demanded.

Because the long waves are much less affected by propagation irregularities and thus make steady, reliable reception possible, many of the agencies that provide such services have set up longwave installations. Much of this interest is new-found, but not all. One of the first broadcast time services, provided by British station GBR, was instituted in 1926. At the time it first went on the air, it was reported to be the world's most powerful radio station. Even today, its 16-kHz signal is widely received in the United States. The station boasts a frequency accuracy of better than 5 parts in $10^{10}$, or 5 parts in 10,000,000,000! Table II lists the world's major low-band standard time and frequency stations, including WWVR, the National Bureau of Standards station transmitting on 60 kHz.

Shown in Fig. I is a QSL card from French Station FTA91, which is operated by the Paris Observatory. Its frequency is 91.15 kHz and transmitter power is 45 kilowatts. This station is heard all over Europe broadcasting Coordinated Universal Time (UTC, the successor to Greenwich Mean Time or GMT) in Morse Code.

**Radio location.** The stability of propagation phenomena on the long waves, coupled with the fact that such signals tend to cover vast areas by following the curvature of the earth, has made these frequencies very useful to radiolocation services such as *LORAN* and *OMEGA*. The *LORAN-C* system is used primarily by both ships and planes to accurately determine position anywhere in the coverage area, which now encompasses more than 16 million square miles. *LORAN-C* can tell you where you are, with $\frac{1}{4}$-mile accuracy, and let you return to within 50 to 300 feet of that same spot, time after time. It operates continuously, no matter what the weather, and is accurate, dependable and cost-efficient. *LORAN-C* is an advanced version of *LORAN-A*, an almost obsolete service that shares the 160-meter band with radio amateurs.

*LORAN-C* is used by the merchant marine, commercial fishermen, tugboats, charter boats, and pleasure boaters. This year, coverage will be available in all coastal waters of the U.S. mainland except those off the northern coast of Alaska, and the system will have replaced the older, less accurate *LORAN-A*. A two-year overlap is being provided before the *LORAN-A* transmitters are turned off.

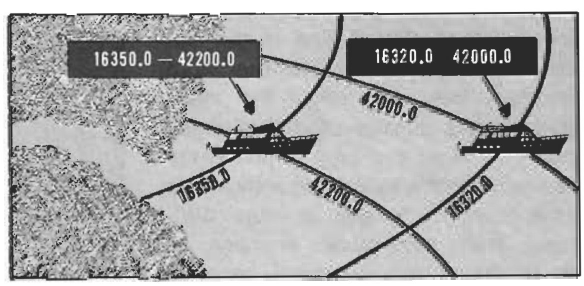



*Fig. 2. Radiolocation by LORAN-C signals and charts. A special receiver directs the user to two curved "lines of position." The intersection of these lines pinpoints receiver location.*

*LORAN-C* transmitters operate in chains, sending out pulsed 100-kHz signals. A special *LORAN-C* receiver at the position to be determined measures the slight difference in time between the arrivals of signals from a pair of transmitters spaced hundreds of miles apart. This time difference, measured in microseconds, is read off a display in the receiver and correlated with a curved "line of position" on a *LORAN-C* chart. The receiver is then turned to a different pair of transmitters and a second time difference determined. This is correlated with a second curved line of position on the *LORAN-C* chart. The intersection of the two "lines of position" allows the user to identify his specific location. A sample *LORAN-C* chart, shown in Fig. 2, illustrates how vessels can plot their positions using this system.

For best results, a fully automatic *LORAN-C* receiver should be used. If ultimate accuracy is not required, a semiautomatic, manual or combination *LORAN-A/LORAN-C* receiver is acceptible. Those who merely want to tune in a *LORAN-C* transmitter and hear what one sounds like can use any standard communications receiver that tunes down to 100 kHz. *LORAN-C* transmitters operate on that frequency and can be readily identified by their characteristic pulsating sound.

On even longer wavelengths than *LORAN-C* is the *OMEGA* navigation system, which began operation in the late 1960's. It works somewhat like *LORAN*, but in the region of from 10 to 14 kHz, which is more stable from a propagation standpoint than the somewhat higher frequencies used by *LORAN-C*. Its range, more than 8000 miles, is greater than that of *LORAN*. A network of only eight stations is enough to cover the entire world, day and night. The longer wavelengths *OMEGA* employs are, to some extent, able to penetrate water, making it possible for submerged submarines to determine their positions.

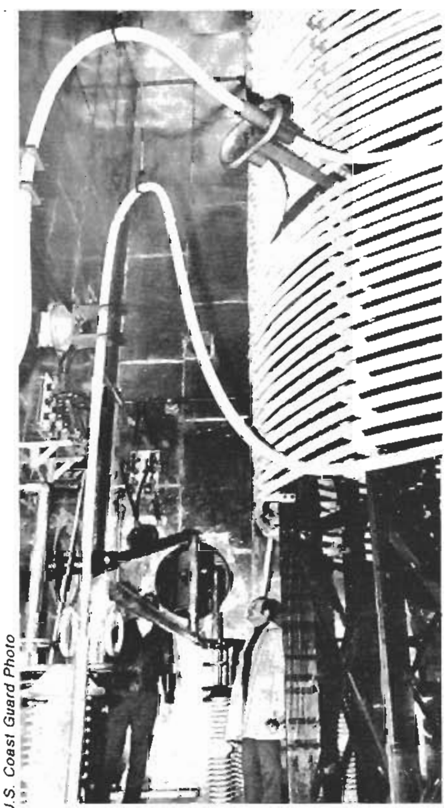
You can hardly miss the strange-sounding *OMEGA* transmissions, and you might even hear signals from *ALPHA*, the somewhat similar Russian longwave radiolocation system. Another, slightly older system you might also hear is *DECCA*. Look for its carriers around 71, 85, and 113 kHz. None of the transmitters associated with these systems broadcasts a recognizable identification, but you can hardly miss hearing their signals. You're a bit too late, though, to hear an unusual type of longwave transmission called *CONSOLAN* which has been rendered obsolete by *LORAN-C* and *OMEGA*. For years, navigators charted their way across the Atlantic aided by such *CONSOLAN* stations as the 194-kHz *TUK* located at Nantucket, Massachusetts. A *CONSOLAN* station broadcast a special sequence of dits and dahs which enabled a navigator to determine an approximate bearing with respect to that station. He did this by counting the number of dits and dahs he heard and then plotting the information on a special chart. He could then cross-reference this bearing with two other bearings (such as from *LORAN* or other *CONSOLAN* stations, a celestial "sun-shot" or a radio bearing) to get a fairly accurate fix on his position. The 2000-watt Nantucket station is still on the air, but when *CONSOLAN* was phased out a few years ago, it became an ordinary radio beacon.

**Broadcasters.** The 150-to-285-kHz band is a popular broadcast band in Europe, Africa, and some parts of Asia. Range is usually much greater than that on the domestic AM broadcast band. A number of Americans were first exposed to long-wave broadcasting during service in World War II and in the occupation following it. While they were overseas, they discovered the many good musical programs that Europeans could tune in on the long waves. There are few longwave broadcast enthusiasts in this country, however, and most SWL clubs don't pay much attention to LW/BC DXing. This is primarily because relatively few receivers cover it, and it's also tough to pull the broadcasters through the heavy interference from the many beacon and weather stations in the Western Hemisphere.

Broadcasters, like many long wave users, tend to employ super-high-power transmitters and very large antennas to make received signals as strong as possible. What do transmitting tubes that can handle large amounts of power look like? Shown in Fig. 3 is an Eimac X-2159 water-cooled power tetrode rated at a plate dissipation of 1250 kilowatts (1.25 megawatts) and a typical class-C r-f output power of 2.158 megawatts! It is designed for use in megawatt-range medium- and longwave transmitters. This giant tube weighs 175 lb (80 kg), is more than 25 inches (64 cm) high, and has a diameter of 17 inches (43 cm). The tetrode's two-section *filament* requires 700 amperes at 18.5 volts per section!

Table III is a list of some of the broadcast stations using the long waves, many of which can be received in the continental U.S. All run power levels of *one megawatt* or more. Besides these super-power stations, there are low-power broadcasters in, among other countries, the United Kingdom, Denmark, Iceland, Finland, Norway, Sweden, Algeria, and Morocco. Note that most longwave broadcasters do not use call signs.

**The Military.** Longwave signals follow the curvature of the earth over vast distances, and can even penetrate to short depths beneath the ocean's surface. These and other characteristics make the long waves well suited for the ultrareliable world-wide communications that the Armed Forces require. The Navy, in particular, is interested in the long waves because they offer the ability to communicate reliably with submerged submarines—something that's just not possible on the higher frequencies. Accordingly, it operates very high-power stations in such far-flung locations as San Francisco; Cutler, Maine; and the Canal Zone on frequencies between 15 and 30 kHz. They enable the Navy to maintain dependable, world-wide communications almost unaffected by propagation conditions and solar activity. Tuning around the long waves you'll hear such Naval calls as *NPG, NBA, NPM,* and *NSS* on both CW and RTTY. Many of these stations operate continuously, and reception is usually very steady. The beginner who would like to improve his proficiency in Morse Code will find some excellent practice material free for the asking.



U.S. Coast Guard Photo

*Two workers are dwarfed by the 40-foot tapped inductor helix at OMEGA station at Aldra, Norway.*

**Other Longwave Users.** There are a number of stations operating below 600 meters, including those operated by such news services as the Associated Press. So they, too, can be put to good use for code practice. Many use radioteletype, which makes it possible to adjust and calibrate RTTY receiving equipment using their very stable transmissions. As we'll see later, there's a sort of ham band down there, too—the so-called "1750-meter experimenters band," where low-power transmissions are allowed by the FCC without a license of any kind.

Below approximately 3 kHz is a *strange* world where wavelengths are measured in hundreds or thousands of *kilometers or miles. Not much is really* known about this portion of the radio spectrum where frequencies overlap on what we know as "audio." There have been experiments on frequencies lower than 100 Hz, most of them employing digital techniques and very narrow bandwidths. The military is especially interested in the communications potential of these lowest of frequencies.

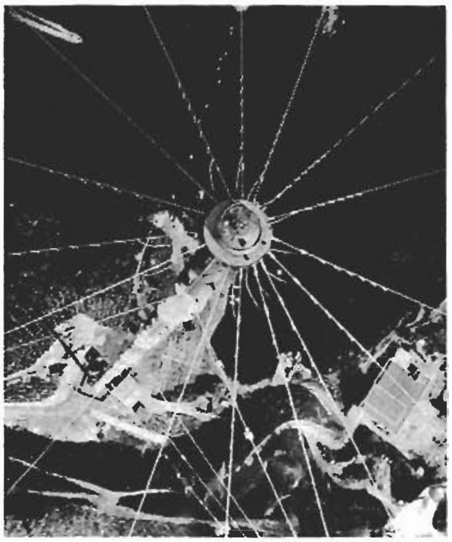
The long waves have many other applications besides wireless communications. For example, many "wireless" intercoms operate between 130 and 200 kHz. These low frequencies are used to prevent interference with standard AM broadcast reception and excessive radiation from the house wiring that carries the signals. Digital watches also make use of low-frequency oscillations for timekeeping. They contain miniature oscillators whose operating frequencies, usually 32.768 kHz, are derived from quartz crystals. You might be able to see or hear the output of a digital watch if you have a sensitive oscilloscope, a frequency counter with a high-gain preamplifying probe, or a sensitive longwave receiver. Ultrasonic cleaners, such as those used by industrial firms and jewelers, make use of the fact that ultrasonic sound waves generated by a transducer in a liquid-filled tank can do wonders in cleaning the inaccessible nooks and crannies of delicate jewelry and watches. A typical ultrasonic cleaner employs a powerful oscillator operating at between 25 and 50 kHz whose output is used to drive a piezoelectric transducer. My own 100-watt, 41-kHz Heathkit cleaner puts out a healthy dose of longwave radio-frequency energy that hopefully won't set any DX records!

**Whistlers.** One source of signals found in the longwave portion of the spectrum isn't human at all—it's a natural phenomenon known as "whistlers," one of radio's oldest mysteries. Whistlers are believed to emanate from lightning discharges in the earth's atmosphere. According to the prevalent theory, the lightning discharges disturb the earth's magnetic field, resulting in the generation of electromagnetic "signals". Whistlers can sometimes be heard on longwave receivers and even on long, high-gain audio lines. (The lines act as antennas of sorts.) Whistlers have been variously described as rushing noises, strange hisses, whistles descending in pitch, and even as a "dawn chorus" heard at sunrise, akin to the sound of birds at dawn.

**Propagation.** How do signals propagate at these low frequencies? There's no blanket answer to this question because much depends on just *how low* the frequencies are. At the high-frequency end of the long waves, around 500 kHz, propagation isn't much different from that of the AM broadcast band or the 160-meter amateur band. Daytime propagation is limited to ground wave

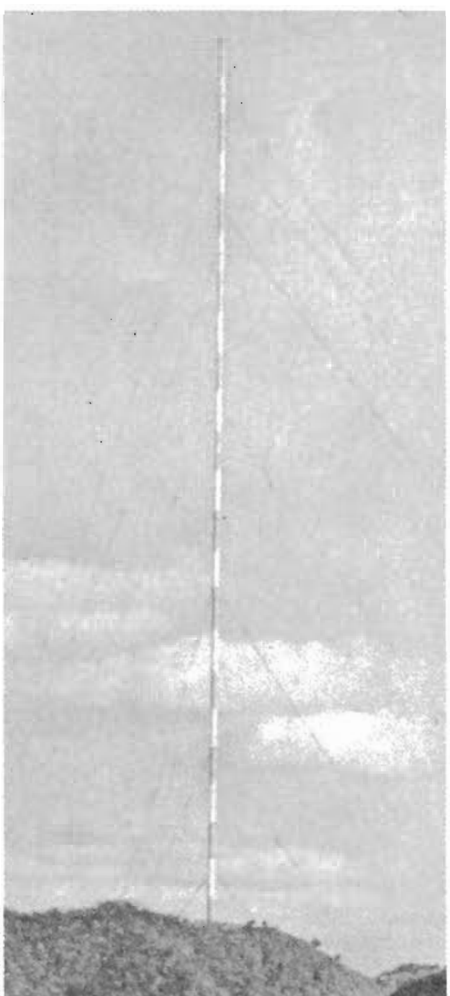
Courtesy of EIMAC, Div. of Varian Corp.

*Fig. 3. Giant power vacuum tube typically found in longwave transmitters. This water-cooled tetrode weights 175 lb (80 kg) and has a rated plate dissipation of 1.25 megawatts!*



U.S. Coast Guard Photo

*Two views of the 1500-foot antenna tower at OMEGA Station H in Tsu-Shima, Japan. Surrounding islands were used to anchor guy wires. Ten feet wide, the structure is tallest in Orient.*



U.S. Coast Guard Photo

(one hundred miles or so), and nightfall extends reception out to several thousand miles. As the frequency of interest decreases, however, say to 100 kHz or less, signals tend to propagate in "duct-like" or waveguide fashion. The groundwave travels over greatly extended distances because it hugs the earth and follows its curvature. The very low frequencies can easily travel halfway around the world, and even penetrate a short distance beneath the surface of the ocean!

There are several reasons why long waves propagate as they do. The ionosphere, that highly charged or "ionized" region of the earth's atmosphere that extends from 30 to 250 miles above the surface, tends to act like a duct or "rubber waveguide" for signals with very long wavelengths. This is at least partially explained by the fact that the altitude of the ionosphere is comparable to the wavelengths of radio signals at these frequencies. Also, although medium- and high-frequency signals tend to be absorbed by the lower layers of the ionosphere and by the earth itself, the long waves are usually absorbed to a much lesser extent. Furthermore, the *reflectivity* of the ionosphere with respect to longwave signals tends to remain fairly constant, making long-distance communications on the long waves much more stable than those on higher frequencies on hourly, daily, and seasonal basis. This is one reason why longwave broadcasting is so popular in many parts of the world—stations operating on these low frequencies can be heard coming through "loud and clear" morning, noon or night, every day of the year.

During the daytime, longwave propagation is almost exclusively by ground waves traveling close to the surface of the earth. Over land paths, maximum distances are reduced by absorption caused by ohmic resistance of the ground. This is much less of a problem, however, than it is at medium or high frequencies. For a given level of transmitter power, *ground-wave* range is much greater on the longer wavelengths than on short waves. At the lowest frequencies, it can become global in scope. To benefit from the DX possibilities of the long waves, however, transmitter power must be high and antennas large. At the lowest frequencies, antennas may be found strung between mountains or even *buried* in the earth! There is *some* sky-wave propagation of the long waves. As frequencies increase and approach the medium waves (around 300 kHz or so), sky-wave propagation becomes more common, especially at night. Actually, if there were *no* sky-wave propagation, there would be no fading or any change at all in received signal strength at great distances from the transmitting site. There often is some fading, particularly at the higher long-wave frequencies, attesting to the existence of sky waves. During the daytime, the lower frequencies tend to be slightly reflected from the *D* or lowest layer of the ionosphere. At night, the *D* and *E* layers mostly disappear and absorption of radio signals decreases dramatically. Signals can then be reflected back to earth from the highest ionospheric *F* layers as sky-wave or skip signals. Because of phase differences, the sky wave tends to destruc-

**TABLE I**
**SELECTED BEACONS AND WEATHER STATIONS**

| Call | Location | Frequency (kHz) |
|---|---|---|
| SFI | Petaluma CA | 192 |
| SOG | Norwood, MA | 201 |
| EZ | Elizabeth, NJ | 208 |
| ZFP | Freeport, Bahamas | 209 |
| UKT | Quakertown, PA | 210 |
| UCF | Cienfuegos, Cuba | 212 |
| BH | Birmingham, AL | 224 |
| LG | Long Beach, CA | 233 |
| GNI | Grand Isle, LA | 236 |
| YZE | Gore Bay, Ontario, Canada | 245 |
| YWG | Winnipeg, Manitoba, Canada | 248 |
| HZ | Halifax, Nova Scotia, Canada | 248 |
| MFR | Medford, OR | 263 |
| VKN | Montpelier, VT | 268 |
| AUH | Aurora, NE | 278 |
| IA | Houston, TX | 326 |
| ZIY | Grand Cayman, BWI | 344 |
| AAA | Lincoln, IL | 329 |
| ICL | Clarinda, IA | 350 |
| AK | Akron, OH | 362 |
| LEO | Leon, Mexico | 365 |
| ZP | Sandspit, British Columbia, Canada | 368 |
| 5E | Ringes Island, N.W.T., Canada | 380 |
| PCZ | Waupaca, WI | 382 |
| DDP | San Juan, Puerto Rico | 391 |
| ZBB | Bimini, Bahamas | 397 |
| EWP | Newport, AR | 400 |

tively interfere with the ground-wave if both are incident upon the receiving antenna. This causes fading and "jitter" in reception. At the lower frequencies, sky-wave propagation and the attendent phasing effect become less and less pronounced. Their absence makes for superb, rock-steady signal reception—most uncommon in hf communications.

**Noise.** Of course, there is an important limiting factor in longwave communications. It is atmospheric noise or QRN. High noise levels plague the long waves, with the tropical regions being the worst. Thunderstorm static can be horrendous, as longwave listeners (LWLs) will readily attest. Severe thunderstorms in the vicinity of your longwave receiver can easily increase your noise level *90 dB or more*! To overcome the high noise levels and improve the signal-to-noise ratio at the receiver, transmitting power must be very high. This is really the only way to get a jump on the QRN because in most cases it's not practical to build Yagi beams or other high-gain directional antennas for these wavelengths. Can you imagine how big a 5-element, rotatable beam cut for 10 kHz would be? About the only partial remedy in the way of antennas is to use a slightly directive, noise-cancelling antenna such as a loop or "wave" antenna at the receiver.

The high atmospheric noise level is a major impediment to experimental communications on the so-called "1750-meter band" which we'll cover in the second part of this article. Transmitter power is limited on that band to only one watt! Line-noise RFI is a big problem, too. It is much more bothersome than on the higher frequencies. Electric light dimmers, motors, heating pads, household appliances, and "leaky" power lines are major sources of electrical noise that interferes with experimenter communications.

Owing to high noise levels at most big-city and suburban locations, many of the more serious LWLs (much like amateur astronomers) pack their gear and go to the mountains or seashore to escape man-made interference. Portable loop antennas and battery-powered transmitters, receivers, and receiving converters make this a fairly practical enterprise.

This concludes Part One of this article. In Part Two, we'll take a look at equipment that can be used for longwave listening and give details about the 160-to-190-kHz, license-free experimenters band. ◇

U.S. Coast Guard Photo

*LORAN-C transmitter at St. Paul Is., Alaska, has a 625-foot antenna.*

**TABLE II
LONGWAVE TIME AND FREQUENCY STATIONS AROUND THE WORLD**

| Call | Location | Frequency (kHz) |
|---|---|---|
| GBR | Rugby, England | 16 |
| NBA | Canal Zone (Panama) | 24 |
| JG2AS | Chiba, Japan | 40 |
| RTZ | Irkutsk, USSR | 50 |
| OMA | Prague, Czechoslovakia | 50 |
| MSF | Rugby, England | 60 |
| WWVB | Fort Collins, Colorado | 60 |
| HBG | Prangins, Switzerland | 75 |
| DCF77 | Mainflingen, Germany | 77.5 |
| FTA91 | Paris, France | 91.15 |
| DGI | Oranienburg, Germany | 185 |

**TABLE III
SELECTED LONGWAVE BROADCASTING STATIONS**

| Location | Frequency (kHz) |
|---|---|
| Brasov, Romania | 155 |
| Khabarovsk, USSR | 155 |
| Allouis, France | 164 |
| Minsk, USSR | 164 |
| Moscow, USSR | 173 |
| Saarlouis, Germany | 180 |
| Ankara, Turkey | 182 |
| Konigswusterhausen, Germany | 185 |
| Birobidjan, USSR | 191 |
| Blagoveshensk, USSR | 191 |
| Monte Carlo, Monaco | 218 |
| Konstantynow, Poland | 227 |
| Jinglinster, Luxembourg | 236 |
| Leningrad, USSR | 236 |
| Vladivostok, USSR | 245 |
| Tipasa, Algeria | 251 |
| Irkutsk, USSR | 263 |
| Moscow, USSR | 263 |
| Uherske, Czechoslovakia | 272 |

**FOR MORE INFORMATION**

*The Long Wave Club of America*, Box 33188, Granada Hills, CA 91344, publishes the bimonthly *Lowdown* and other items of interest to the LWL. Membership dues of $6 annually includes a subscription to the *Lowdown*. For more information, send a *large*, self-addressed envelope with two units of first-class postage attached.

*The National Radio Club Publications Center*, Box 401, Gales Ferry, CT 06335, offers reprints of various articles dealing with the long waves.

*The U.S. Government Printing Office*, Washington, DC 20402, offers a number of publications dealing with longwave beacons and broadcasters, such as *Airman's Information Manual, Location Identifiers*, and *Broadcasting Stations of the World*.

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