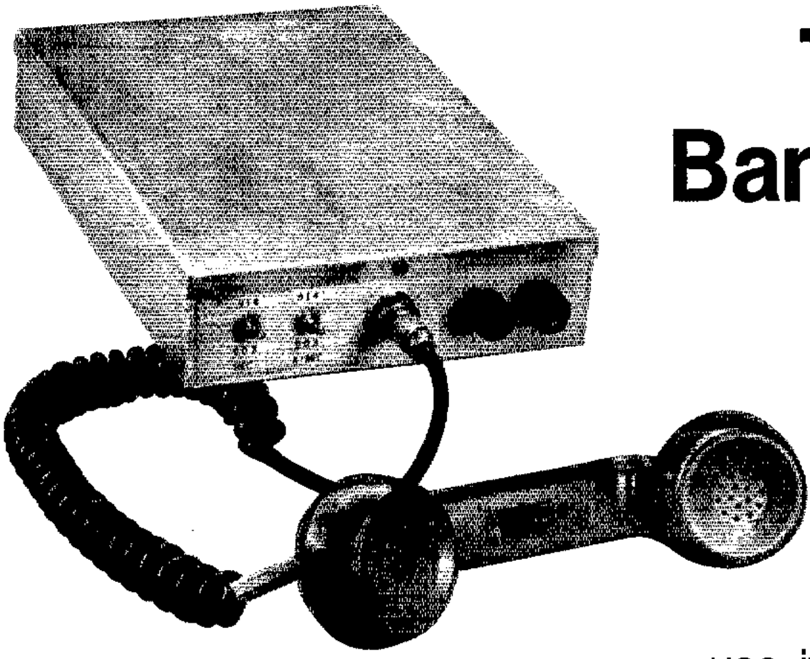

The 900-MHz Band — What's in Store for Amateurs?

Here's an overview of what you may find on the band and ways to use it, and a look at the ARRL's interim band plan.

By Albert D. Helfrick,* K2BLA

The 902-928 MHz band will soon be available for amateur use. (See Dec. 1984 Happenings, p. 61). The FCC has proposed, in PR Docket 84-960, to allow powers of up to 1500-W PEP output with emission types AØ, A1, A2, A3, A4, A5, FØ, F1, F2, F3, F4, F5 and pulse (P), subject to some conditions (see Table 1, note 1). When the band becomes available, we'll share it with several other services, including government, auto-vehicle monitoring and the industrial, scientific and medical (ISM) services. There are some other radio services using this band. Those stations currently operating in the 902-928 MHz band will have to endure probable interference from the ISM services or relocate to another frequency.

It is true that amateurs already have a band in the 1-GHz region that has been available for some time. What is unique about the slightly lower frequency that will make it attractive to radio amateurs? First, the frequency is adjacent to the new mobile cellular-telephone band (discussed later). This means the enormous strides in cellular technology can be adopted for the Amateur Service. In the future, surplus equipment that can be modified for use in the amateur segment will appear. Also, the upper UHF TV channels that are used primarily for translators in remote areas are close to the cellular mobile-telephone band. Since the upper limit of the UHF TV band is 890 MHz, the most likely items to carry over from UHF TV are antennas. Many UHF TV antennas may be made to work at 900 MHz with only slight modifications.

Cellular Mobile Service

The core of the cellular mobile-telephone service is a base station that provides communication within a "cell" (hence the name of the service) having a radius of eight miles (about 13 km). Each base station is linked to other base stations. A set of channel frequencies is available, and frequency-agile mobile units search for an unused frequency. Relatively low power (typically less than 10 W) is used at the mobile end, and is controllable from the base station. Therefore, only as much power as is necessary to establish reliable communications is used, permitting the frequency to be reused in a nearby cell. This is a totally new concept in mobile-to-base station communications.

When a base station realizes that use of the maximum power available does not provide reliable communications, the base station will determine which adjacent cell has a better signal from the mobile transmitter. The mobile is then handed off to that cell. As long as the mobile unit is within the service area of a cell, the service is continuous.

The transmit and receive frequency difference is 45 MHz. Mobile transceivers typically have a 45-MHz first IF and use a common synthesizer for the transmitter and receiver. Of course, being a commercial telephone service, the cellular transceivers operate full duplex — another reason for the different transmit and receive frequencies.

What's Up There?

The nature of the radio services currently occupying this frequency range should be understood in order to appreciate some of the potential problems of using the band. The ISM services are essentially assigned one frequency, 915 MHz, and are restricted to the 902-928 MHz range. This results in a 13-MHz tolerance for the carrier for narrowband sources and a tolerance-plus-bandwidth for broadband sources. Some applications of the 900-MHz frequencies are industrial heating, motion and position detection for assembly lines, burglar or intrusion alarms, and electronic door openers. There has been some discussion of operating microwave ovens at this frequency.

Most of the industrial applications of the frequency involve the transmission of a 915-MHz carrier. For example, the automatic door opener and the intrusion alarm transmit a 915-MHz carrier and receive reflections from nearby objects. The sensor unit transmits and receives simultaneously using the transmitter oscillator as a conversion signal for what amounts to a zero IF superheterodyne. Normally, the reflection frequency is precisely the same as the transmitter oscillator frequency, and when the received signal is heterodyned with the transmitter oscillator, the result is dc. When the received reflections are from moving ob-

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Table 1
ARRL Interim 900-MHz Band Plan[1]

Frequency (MHz)	*Type of Use*
902-904	Narrow-bandwidth, weak-signal work
902-902.8	SSTV, FAX, ACSB, Experimental
902.8-903	Reserved for EME, CW expansion
903-903.05	EME, exclusively
903.07-903.08	CW beacons
903.1	CW, SSB calling frequency
903.4-903.6	Crossband linear translator input
903.6-903.8	Crossband linear translator output
903.8-904	Experimental beacons, exclusively
904-906	Digital communications[2,8]
906-907	Narrow-bandwidth FM simplex services, 25-kHz channels[6]
906.5	National FM simplex calling frequency
907-910	FM repeater inputs, paired with 919-922 MHz outputs: 119 pairs, every 25 kHz (e.g., 907.025, 907.050 MHz); uncoordinated test pair 908-920 MHz[2,4]
910-916	ATV[2,3]
916-918	Digital communications[2,8]
918-919	Narrow-bandwidth FM control links and remote bases
919-922	FM repeater outputs, paired with 907-910 MHz inputs[2,4]
922-928	Wide-bandwidth experimental, simplex ATV, spread spectrum[5,7]

[1]Extracts of *FCC Rules and Regulations,* Paragraph 2.106, Table of Frequency Allocations, as modified by General Docket 80-739, December 8, 1983:

US267: "In the band 902-928 MHz, Amateur Radio stations shall not operate within the States of Colorado and Wyoming, bounded by the area of: latitude 39° N to 42° N and longitude 103° W to 108° W."

US275: "The band 902-928 MHz is allocated on a secondary basis to the amateur service subject to not causing harmful interference to the operations of Government stations authorized in this band or to Automatic Vehicle Monitoring (AVM) systems. Stations in the amateur service must tolerate any interference from the operations of industrial, scientific, and medical (ISM) devices, AVM systems and the operations Government stations authorized in this band." (Note: Since the secondary allocation of 902 to 928 MHz to amateurs is confined to ITU Region 2, this band will not be available to amateurs in American Samoa, Baker Island, The Commonwealth of Northern Mariana, Guam, Howland, Jarvis, Palmyra and Wake Islands.)

[2]Coordinated assignments required.

[3]ATV assignments should be made according to modulation type (for example, VSB ATV, SSB ATV or combinations thereof). Coordination of multiple users of a single channel in a local area can be achieved through isolation by means of cross polarization and directional antennas.

[4]Coordinate assignments at 100 kHz until allocations are filled, then assign 50-kHz channels until allocations are filled before assigning 25-kHz channels.

[5]Simplex services only; permanent users shall not be coordinated in this segment. High-altitude repeaters or other unattended fixed operations are not permitted.

[6]Voice and nonvoice operations.

[7]Spread-spectrum operation requires FCC authorization.

[8]Consult FCC Rules and Regulations, Paragraph 97.69, for allowable data rates and bandwidths.

jects, a Doppler shift of the received-signal frequency occurs. For small velocities, such as those experienced by a person walking, the Doppler shift is only a few hertz, but this can be separated easily from the dc component gathered from fixed objects and used to trigger a burglar alarm or open a door. These motion and position sensors are used in various configurations for production line and process monitoring.

Power Levels

There is no limit to the amount of power that may be radiated by any one of the 900-MHz devices. The FCC rules and regulations that control ISM devices (Sec. 18.14) states, "the energy radiated shall be reduced to the greatest extent practicable." This implies that if a great amount of radiated energy is needed for the task at hand, it is legal to radiate the necessary amount, but not more. At first, it might seem that such lack of restrictions would doom the 900-MHz band before it is ever implemented. There are some important considerations, however. Although the FCC does not limit the emission levels, other regulatory agencies do. This is because high levels of RF energy at 900 MHz are dangerous. Industrial heating devices must be well shielded to prevent harmful radiation.

In the case of motion and position detectors, it is desirable to have a narrow beam and to use low power so that the detector is sensitive to nearby motion but not to distant activity. Using high power would interfere with other sensors used in the vicinity, since all motion sensors are licensed for the same 915-MHz frequency. Protecting large areas with motion-sensing equipment has been only marginally successful because the 915-MHz signal can easily penetrate walls and be falsely triggered from motion *outside* the protected building!

Although it is not good practice to radiate megawatts at 915 MHz, there will be signals in the band that have to be overcome. Most of the systems in the band use unstabilized oscillators operating at the output frequency. This explains the ±13 MHz frequency tolerance for ISM equipment. We must assume that after time, although the ISM equipment is adjusted initially for a frequency of 915 MHz, the units will have drifted and will be distributed about 915 MHz. We must further assume that no units have violated the law by drifting beyond the 13-MHz limit and, therefore, the distribution of frequencies is such that very few units are operating within a few megahertz of the 902-928 MHz limits. (Assuming that all units are legal may be a bit optimistic. If we assume that a small percentage are illegal, the analysis is still valid.)

Life at 900 MHz

Amateur coexistence with other 900-MHz signal sources can be improved in several ways. One of them could be FCC restriction of broadband emissions. If the signal bandwidth is limited to, for example, 50 kHz, there will be less interference to voice communications from TV and pulse transmissions. Many applications and experimental emissions can operate with bandwidths of less than 50 kHz.

One method of avoiding interference is to use spread-spectrum techniques. With this system, the operating frequency within the band is selected rapidly in a random fashion. The existence of interfering signals on the chosen frequency adds to the receiver noise level rather than creating a debilitating situation, which would occur if the interfering signal happened to be exactly on the operating frequency.

Yet another possibility is to use a switchable carrier frequency that changes only when an interfering signal appears close enough to the operating frequency to cause harmful interference. ISM devices, because of their free-running oscillators, tend to drift with temperature and supply voltage variations. If a repeater or transceiver is frequency agile, the operating frequency can be changed to avoid interference.

Equipment

Already there are several cost-effective items developed for the cellular telephone service that are usable in the 900-MHz amateur band: transistors for various power levels, hybrid power amplifiers and even affordable GaAsFET transistors made specifically for use on the cellular telephone frequencies. As mentioned earlier, surplus cellular-telephone equipment, such as antennas, duplexers and other suitable hardware, is also available, as well as the UHF TV antennas.

Amateurs who are only occasional VHF operators and seldom venture into UHF construction may find the techniques used at 900 MHz to be a bit odd. The higher-frequency circuits use a construction technique called "microstripline." These striplines appear to be nothing more than copper PC-board traces to the unknowing eye, but are, in fact, transmission-line sections that act as capacitors, inductors, transformers and directional couplers. Some components, such as leadless chip capacitors and transistors with broad, flat leads and flat packages (rather than "cans" with wire leads), are made specifically for microstripline construction.

Some Experiments

To gain a bit of insight into 900-MHz operation, I obtained an experimental license from the FCC, built several pieces of 900-MHz equipment and performed some tests. A single-channel and a synthesized multichannel transceiver were

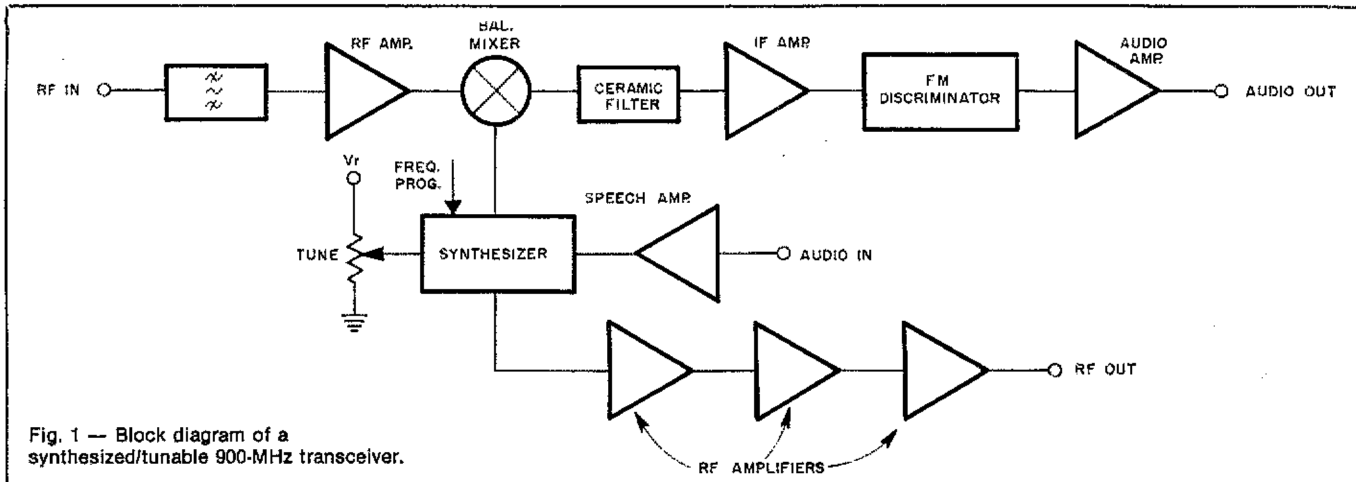


Fig. 1 — Block diagram of a synthesized/tunable 900-MHz transceiver.

assembled. Fig. 1 is a block diagram of the multichannel transceiver. The homemade equipment is shown in Figs. 2 and 3. The synthesizer provides only one output frequency, which serves as the transmit frequency and the receiver LO. Therefore, the transmit and receive frequencies differ by the IF — in this case, 10.7 MHz. A switch disables the synthesizer and permits the VCO (voltage-controlled oscillator) control voltage to be varied by means of a potentiometer. Doing so makes the receiver tunable over the range of 850 to 1050 MHz.

Receiving

I first listened to the 902-928 MHz band to assess the amount of interference from ISM equipment. At my home, which is at the very bottom of a river valley, no interference was ever heard. Although checks with a calibrated signal generator showed the receiver sensitivity to be 2 µV, *nothing* was ever heard in the tuning range of the receiver. (No matter what the generator shows, it is encouraging to actually hear *something*!)

The receiver was transported to a nearby hill. This hill is only 900 feet (275 meters) above sea level, but it is line-of-sight to New York City (35 miles, or 56 km, distant) and most of the metropolitan area. Tuning across the band (850-1050 MHz) now revealed hundreds of signals! A large number of mobile radio units, repeaters, digital data and paging services were heard as well as several STLs (studio-transmitter links) for New York radio stations. The STLs originate in downtown Manhattan and produced full-quieting signals in my receiver (about 10 µV or more) with a simple corner-reflector antenna. Most important, tuning through the 902-928 MHz portion still uncovered no signals.

The initial tests were conducted during the weekend, but it was necessary to repeat the tests during the week when industrial plants were operating. The results of several weekday tests showed increased operation of the land-mobile services. This was expected since these services are used primarily by industry. But no activity in the 902-928 MHz region was noticed. This came as a complete surprise and is very encouraging.

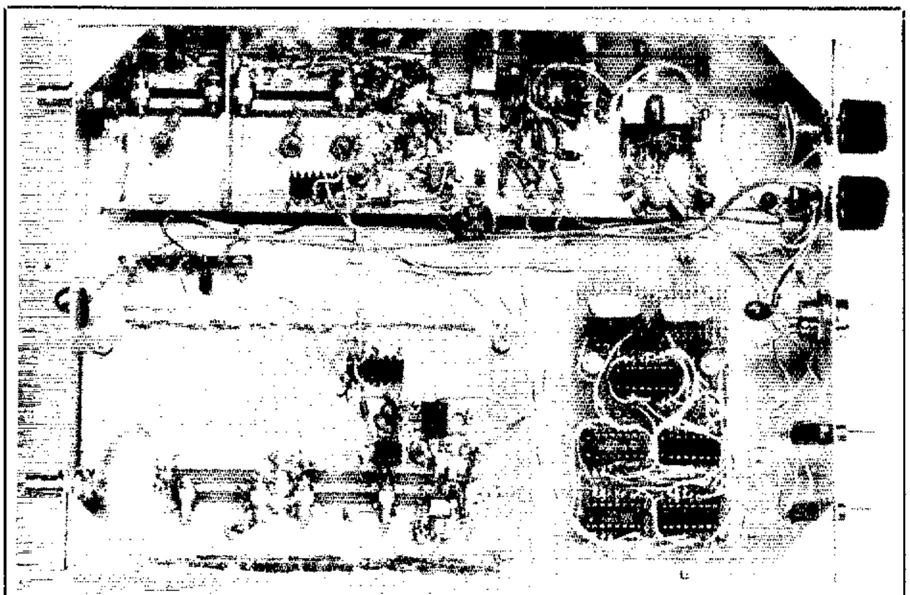
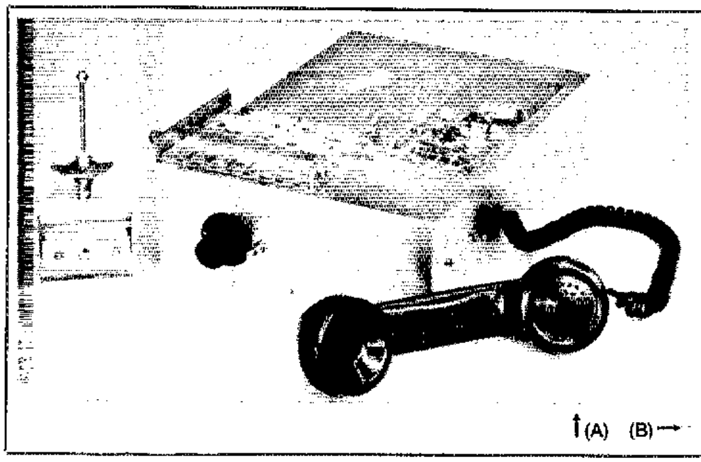


Fig. 2 — An inside view of one piece of the author's homemade 900-MHz gear. The transmitter and receiver sections can be used individually or integrated into a transceiver (as they are here) for simplex or duplex operation, or for use as a repeater. For the LO, a free-running oscillator is employed. Its frequency is divided by means of a high-speed ECL frequency divider and is phase-locked to a crystal oscillator. A single 8-pin IC is required for frequency division in lieu of several stages of frequency multiplication, associated tuned circuits and accompanying spurious signals.

Transmitting

I then tried some basic two-way transmissions using two transceivers and simple antenna systems. Each transceiver uses FM with a peak deviation of 15 kHz and a receiver with a 1-µV sensitivity. The transmitters have a power output of about 500 mW. A corner reflector was used for the fixed-station antenna, and a quarter-wave vertical for the mobile installation. Operation was conducted on two frequencies: 903.3 and 914 MHz. Both transceivers could transmit or receive on either frequency, simplex or full duplex. The transmit/receive frequency split (10.7 MHz) placed one frequency in the center of the band, where the interference was expected to be the worst, and the other frequency at the band edge, where interference was expected to be minimal.

Separate transmit and receive antennas were employed. Although a large physical separation is not required, it is necessary to place the antennas so the transmitter/receiver isolation is on the order of 32 dB. This is because transmitter energy, being phase coherent with the LO, can combine with the LO energy in the mixer.



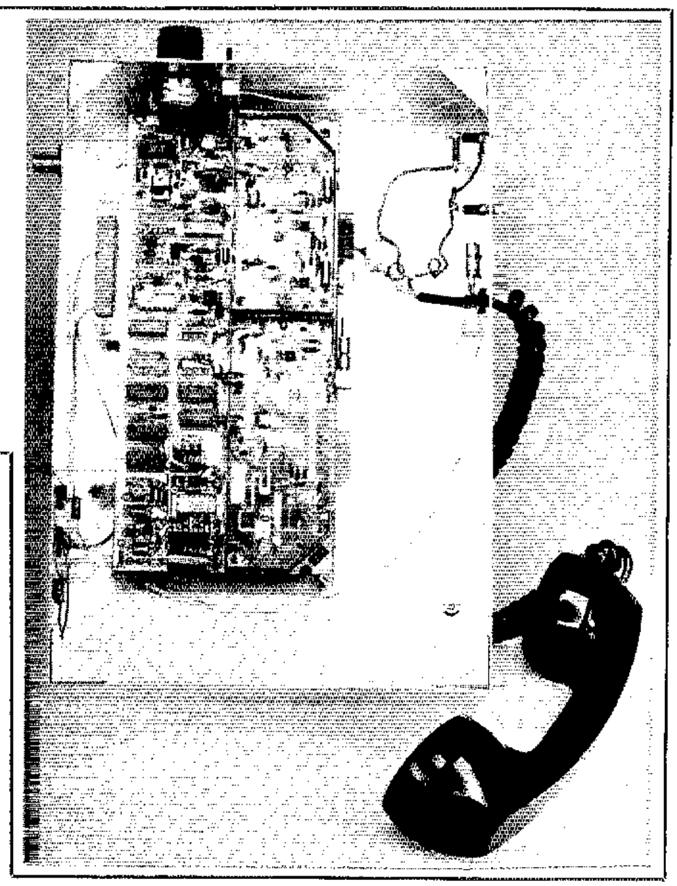


Fig. 3 — External and internal views of another homemade 900-MHz transceiver. This particular unit uses surplus avionics boards.

This energy will add or subtract from the LO power, and possibly degrade mixer performance. A typical situation would include an LO power of +13 dBm (1 V), and a transmitter power of +27 dBm (500 mW). The receiver RF amplifier has an overall gain, including the RF filter losses, of about 8 dB. This increases the amount of transmitter power reaching the receiver mixer by a like amount. Unless high-Q filters (such as cavity resonators) are used ahead of the receiver RF amplifier, it will provide very little transmitted-signal rejection. In the mixer, it's desirable to maintain at least a 10-dB ratio between the LO power and the transmitter power arriving from the antenna. This requires a +3 dBm maximum mixer gain and, because of the 8-dB gain ahead of the mixer, a −5 dBm input to the receiver. For a transmitter-power level of 500 mW, this equates to a 32-dB antenna isolation. This measure of isolation is not difficult to obtain, and is accomplished easily with corner reflectors and many other directional antennas.

Results

The first lesson I learned from the transmission tests is that 900-MHz FM propagation is definitely line-of-sight: If you can't see it, you can't hear it! During one test, approximately one mile from the transmitter, the signal went from full quieting to nothing within a few hundred feet as the vehicle passed behind a small hill. In a similar situation, I recaptured a faded signal by using the corner-reflector antenna and pointing it at a nearby hill to receive a signal reflection. Those of us who are familiar with 2-meter mobile fading will find 900 MHz unique, as the fading rate is much more rapid.

Another important fact is that at 900 MHz, losses are everywhere. The lowest-loss RF cable must be used, along with the shortest length required. Also, *calculated* dimensions for antennas are not close enough; the antenna must be trimmed using a network analyzer or an SWR indicator. In general, anything done in a shoddy manner will result in a system that will not work.

Summary

In the final analysis, is there any hope for amateur use of 900 MHz? Decidedly, yes. Its line-of-sight nature limits mobile communications, and the band is more suited to point-to-point links. The band is ideal for remote base and repeater control. If full duplex operation is authorized, the 900-MHz band will be ideal for linking Field Day sites, emergency communications sites, command centers, and so on.

Although difficulties will be encountered with mobile communications, they are not impossible to overcome. For reliable communications, a repeater or base station with a good antenna location is a must. Whereas a few hundred milliwatts and a gain antenna are suitable for a remote link, more power is required for reliable mobile operation. This is because the mobile unit cannot use a high-gain antenna and, when the mobile unit is shadowed, a reflected signal is required; there is signal power loss associated with reflected signals. A particular coverage area should be defined, and a gain antenna with the narrowest possible beam width (the highest possible gain) should be used to cover the area by the base station or repeater. Mobile and base station receiver sensitivity should be better than 1 μV, and the transmitter power should be on the order of 10 W or more.

Perhaps one of the more promising challenges — and a solution to the rather limited range of the 900-MHz band — is the establishment of an amateur cellular network. This network could operate on the 900- and 1200-MHz bands using linked, low-power, local repeaters. An ambitious undertaking, certainly, but it wouldn't be the first time the amateur community met a challenge.

An amateur cellular network would be somewhat different from the commercial network since considerably fewer users would be involved. Amateurs are used to waiting their turn and sharing a frequency, whereas commercial telephone users wouldn't appreciate someone constantly using their telephone! Another significant difference between the commercial and amateur networks is that amateur operation is from radio to radio, whereas the commercial operation is from radio to land line. Telephone companies use land lines to link cellular systems. Amateurs, on the other hand, have several radio bands available for the task of linking cellular repeaters. It is not the intent of this article to propose cellular standards, and the cellular concept is left to future development. The 900-MHz band affords new challenges to the radio amateur, and will be gladly welcomed.

VUCC on 902

The popular VHF/UHF Century Club award (VUCC), instituted in January 1983, anticipated future occupancy of the 902-MHz band by amateurs. Thus, the minimum qualifying level for working different grid-square locators on that band was set at 25. It will be quite a challenge to be the first to make 902-MHz VUCC!