Spread Spectrum: Frequency Hopping, Direct Sequence and You

Are you ready for this month's spread-spectrum rule implementation? How do you operate in spread mode? Here's the answer.

By Hal Feinstein, WB3KDU
Member, ARRL Ad Hoc Spread-Spectrum Committee
1410 Rhodes St North
Arlington, VA 22009

As regular readers of *QST* know, after studying the issue since June 1981, the FCC passed a delayed rule allowing radio amateurs to use spread-spectrum frequency-hopping and direct-sequence systems, effective June 1, 1986.[1] However, readers may not know about experimentation that has been ongoing in the spread-spectrum area and how Amateur Radio interoperability will work. This article covers those topics.

This is the station used in the FCC direction-finding test. An ICOM IC-2A was used as a frequency-hopping spread-spectrum beacon. The hop rate was 80 hops/s.

What Is a Spread-Spectrum System?

In the 1986 *ARRL Handbook,* Chapter 21 contains a description of spread-spectrum communications. That section of the *Handbook* should be consulted for an extensive discussion of the subject. The basic explanation is that spread spectrum is a modulation scheme whereby the signal is spread over a very wide bandwidth. This results in a dilution of the signal energy such that the power density present at any point within the spread signal is slight. Beyond a certain distance from the transmitter, the spread signal can be below the noise level yet still be recovered with the proper spread-spectrum receiver. Only the intended receiver (or receivers in a net operation) can recover the signal, as both sender and receivers hold copies of the binary sequence that is used to spread the signal and know when it was started in time. Interference to other users of the same spectrum is slight or nil (unless they are close to the transmitter).

There are two spread-spectrum modes authorized to the radio amateur. Frequency hopping is a mode in which the operating frequency is changed rapidly over the spread bandwidth. Both the transmitter and receiver visit the same frequencies at the same time, and must stay in exact synchronization. Each holds the same list of pseudorandom-ordered frequencies, and the transmitter and receiver start hopping together using the same starting point on the list.

In direct sequence (the other authorized mode), a high-speed pseudorandom binary data stream is used to shift the carrier phase between 0 and 180 degrees. The phase shifting is normally done in a balanced mixer, and the information being transmitted is normally added to the high-speed code sequence.

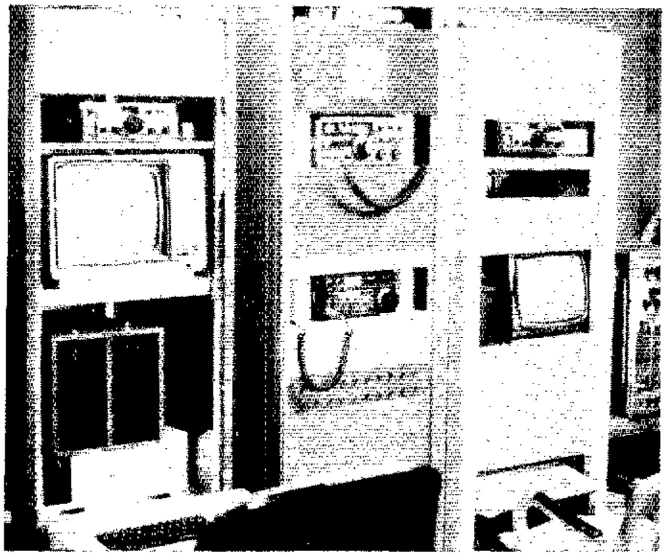
Why Use Spread-Spectrum Systems?

Effective spectrum management allows the greatest use of a band of frequencies by the largest number of possible users. A large number of spread-spectrum systems can occupy the same band and not interfere with each other. Spread spectrum can make use of unused portions of a frequency band—such as between repeater channels. Only by experimentation can radio amateurs learn the true potential of this new mode. The military has been using these systems for years for "antijam" communication, and the radio amateur can benefit from this experience. Computer-assisted power control can be used effectively in this mode to meet the FCC requirement that amateurs run only the minimum power needed for communication. This has not been done to date, but it is a feature for advanced experimenters to work on.

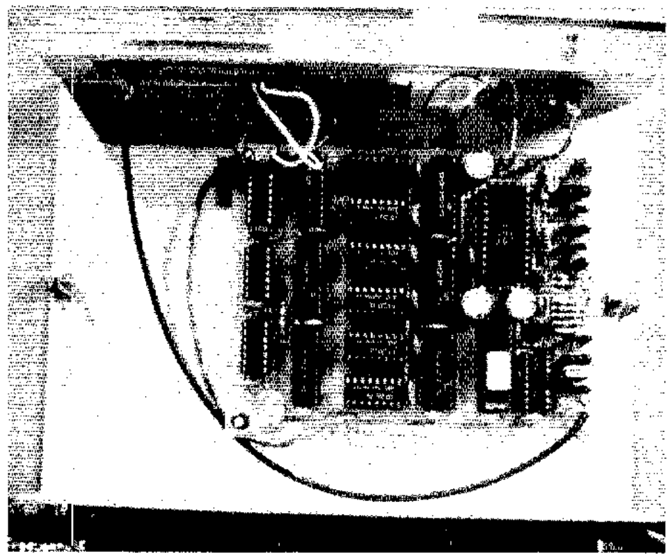
What Has Been Done Up to Now?

The Amateur Radio Research and Development Corporation (AMRAD), a nonprofit club composed of radio and computer amateurs, has been involved with a series of investigative experiments with spread-spectrum systems since September 1980. The investigations fall into five general experiments authorized by a series of FCC Special Temporary Authorities (STAs).

1) Commercial/military frequency-hopping radios were borrowed and used to test on amateur frequencies in the HF bands. The hop rate was slow—only 5 hops



The HF spread-spectrum station at K8MMO. A Xerox 820 computer was used for control. The transmit position is on the right; receive is on the left.



The heart of the HF spread-spectrum station is the frequency synthesizer designed by Fred Williams. This version of "Fred," as the synthesizer is affectionately called by AMRAD members, came from A & A Engineering.[2]

per second (hops/s). The system worked well using voice while hopping in a nonvoice portion of a ham band. Little, if any, interference was noted in a nearby receiver. When the hopper came by, an "aup" or "thu" noise resulted. This experiment was lots of fun. However, the greatest benefit was to get everyone fired up to go build some equipment for the ham bands.

2) Chuck Phillips, N4EZV, constructed hand-held, frequency-hopping FM transceivers. These units hopped at 10-80 hops/s over 3.2 MHz. If the receiver or transmitter lost synchronization, the lost unit would return to a "homing frequency" and "scream" for help. Periodically, the transmitting station would stop and listen on the homing frequency for screams. If one was heard, a new start-up would be initiated. Further details of this system are not available.

3) ICOM IC-2A transceivers were modified to allow a computer (Commodore C64) to set the frequency instead of using the radio's thumbwheels. A beacon was set up to test for interference caused in the 2-meter repeater band. Receiver synchronization schemes were tested. This project was abandoned after spectral analysis of the transmitted signal revealed that the synthesizer was never "locking up." For that reason, fast-hopping operation was not feasible. Modifications of the phase-locked loop filter improved the lockup time, but produced some "strange audio." The FCC located this unit in a direction-finding test in only 25 minutes, proving that the agency is able to regulate this mode of operation using current equipment.

4) Fred Williams of the TRW LSI Products Division designed a direct-synthesis oscillator that is described in February 1985 *QST* and Chapter 29 of the 1986 *ARRL Handbook*. AMRAD has used this synthesizer with the Yaesu FT-7 and FT-101ZD and Xerox 820 computers to frequency hop cleanly on the HF bands. Experiments with these units continued as synchronization software was being perfected. This experiment came to a standstill when the FCC denied AMRAD's latest STA request for permission for further HF experimentation. The net effect of this denial is to force all experiments to 420 MHz and above. Andre Kestleloot, N4ICK, is building a mixer to convert signals from HF to UHF. This mixer will allow these experiments to resume on the air at UHF. Conventional UHF transverters could also be used, but are costly—the AMRAD gang prefers to build their own and save money.

5) Dick Bingham, W7WKR, has produced a single PC board add-on for a 440-MHz hand-held transceiver that allows direct-sequence transmission or reception. It appears that this unit, while allowed under the AMRAD STA, would not be allowed under the new Part 97 rules, because of the method used to add information to the basic spreading sequence. This requires further study.

What Is Interoperability?

The ARRL Board of Directors has authorized, and President Price has appointed, an ad hoc Spread-Spectrum Committee to study interoperability. When the rules go into effect, two radio amateurs who have been working together closely can communicate using spread-spectrum techniques. This is possible because both operators understand how both systems operate and how to begin their spread-spectrum communication and maintain synchronization. But how does an amateur call CQ using spread spectrum, and expect to receive a reply? How does the amateur communicate the spreading sequence in use, starting signal, hopping frequencies, hopping rate and the like to another amateur listening for a spread-spectrum CQ call? How does the amateur identify spread-spectrum transmissions? The rules require conventional identification.

In packet radio, we have a protocol called AX.25 to answer similar questions. It is too early to agree on a protocol for this new mode of communication, but some basics need to be established, such as a home or calling frequency on each band from 420 MHz and above.

The Committee recommends that you use the national FM calling frequency (or another FM simplex frequency if the national frequency is in frequent use in your area) for calling CQ and for announcing spread-spectrum operating parameters. A further recommendation is that you let others in your area know of your experiments through clubs, over repeaters or by any means that seems appropriate. The committee will publish more on these matters as we gain on-the-air experience.

Your suggestions and comments concerning these matters are welcome. Please remember that it is not our goal to stifle experimentation by needless regulation or standardization. Send your comments and suggestions to the committee secretary: Chuck Hutchinson, K8CH, ARRL Headquarters, 225 Main St, Newington, CT 06111.

How Can an Amateur Keep Current on Spread-Spectrum Progress?

Read *QST* and *QEX* to keep current on fast-breaking spread-spectrum news updates. Take advantage of this unique form of Amateur Radio communication. Start by learning the basics that are found in the 1986 *ARRL Handbook*.

Notes

[1] D. Newkirk, "Our new Spread-Spectrum Rules," *QST*, Apr 1986, p. 45.

[2] A & A Engineering, 7970 Orchid Dr, Buena Vista, CA 90620, tel 714-521-4160.