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AEA PKT-1

Heathkit HD-4040 TNC Kit

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TAPR, Heathkit® and AEA Terminal-Node Controllers

Every so often, Amateur Radio discovers and embraces a new communications mode. In the late '40s there was the introduction of SSB, in the 70s 2-meter-repeater operation came into vogue and now in the mid '80s there is the rapid growth of amateur packet radio. We will explain the use of the terminal-node controller (TNC) as we review the the Heathkit HD-4040 and the AEA PKT-1 TNCs. Both are based on the original kit designed and marketed by the Tucson Amateur Packet Radio Corporation (TAPR), but they represent different approaches: The Heathkit unit is available only in kit form, while the AEA PKT-1 is available only assembled and tested. TAPR has produced two different TNCs. The original TAPR-1 is used as the baseline for the TNCs reviewed here. The TAPR-1 is no longer in production, but the two designs considered here follow the TAPR-1 kit so closely, we will use the term "TAPR" to describe any features that are common to all of the designs (for example, the TAPR software . . .). Differences among the three units will be described as well. The TAPR-2 is currently available. It reflects a complete change in design and configuration, as it uses Z80® technology and is considerably smaller.

While it is outside the scope of this review to provide a complete introduction to packet radio, we must explain what a TNC does. Briefly, a TNC receives data from a computer or terminal, divides that data into small "packets" of information, and sends the packets to a transmitter. In the other direction, the TNC accepts packets from a receiver, converts them into data, and sends the data to a computer or terminal. The transmission and reception of packets, the detection and correction of errors in packets, and the exact format of each packet is managed by a *protocol.* The protocol can be thought of as a program that runs on a microprocessor in the TNC.

While there are many diverse applications of packet radio, they can be roughly divided into two categories: *conversational operation,* in which the operator types at a terminal as though in a standard RTTY QSO; and *block-oriented operation,* in which large blocks of data (computer programs, messages, pictures, and so on) are exchanged. Each of these modes of operation makes different demands on a packet radio system, and these demands must be kept in mind when selecting a TNC. More information on the ins and outs of packet radio may be found in the July and August 1985 issues of *QST.*[1]

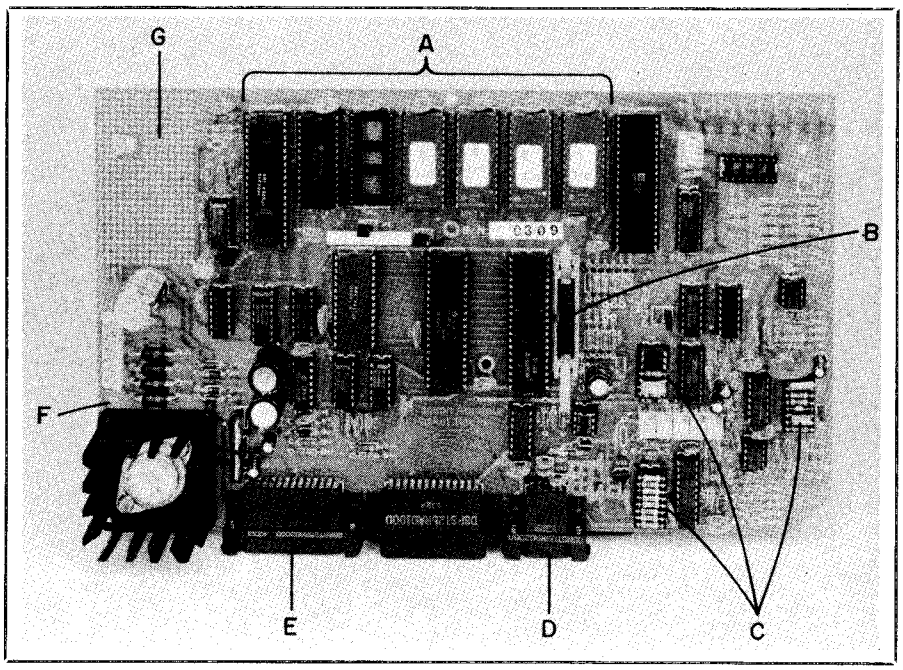

Fig. 1—The TAPR TNC board. The HD-4040 PC board, Fig. 3, is essentially the same. A marks the CPU and memory ICs. The modem disconnect header at B is used to connect an external modem. Component headers, C, make it easy to change the tones and frequency shift of the internal modem. The radio connects at D, and the terminal or computer connects at E. Power-supply components are shown at F. The wire-wrap field at G allows small circuits to be added to the TNC.

The Heathkit HD-4040 TNC Kit

The HD-4040 kit includes a good-quality PC board, identical to the TAPR original, complete with silk-screened component locations and solder mask; bags of parts; a painted and labeled cabinet; a couple of hundred pages of documentation, including an assembly manual, a user's manual and loads of pictorial diagrams; and software in programmable-read-only memory (PROM). The only significant departure from the TAPR kit is that the RESET, BANK SELECT, SOFT/HARD RESET and RAM/ROM switches are not brought out to the front panel in the Heath version. The '4040 was assembled in a couple of evenings by Mark Wilson, AA2Z. Total construction time, including the initial calibration and test procedures, was just under 10 hours. Almost all of the components mount on the PC board, and anyone who can solder and follow directions should be able to complete this kit with no trouble.

Assembly Instructions

Although our kit was one of the first TNCs produced by Heath, the 72-page assembly instruction book is clearly written, thoroughly illustrated, logically structured and—perhaps most important—free of major errors. We found a few minor typographical errors, but only one error in the Operational Checks section that could lead a builder astray. More on that later. Heath had an advantage in that they could draw extensively on the outstanding documentation prepared for the original TAPR kit.

The instructions provide not only a parts list, but also hints on how to identify uncommon parts or parts with ambiguous numbers (for example, some of the ICs used can be identified by more than one part number, depending on the manufacturer). Most components come grouped in labeled envelopes, and static-sensitive ICs come in antistatic pouches. Many of the diodes, resistors and capacitors are taped together on a reel in the order that they are to be placed on the board. This thoughtful idea saves much time that might be spent locating the right part in a pile of loose components, and it eliminates any questions about which part is which. In our kit, all parts were present and accounted for.

As is usual with Heathkit, the manual devotes several pages to assembly hints and gives a short course on soldering. If you are unfamiliar with proper soldering techniques, take a few minutes to read this section carefully, and practice on junk-box parts. Many of the problems that inexperienced builders encounter are the result of poor soldering practices.

After finishing the kit, we feel that Heath has done an excellent job with their version of the TAPR kit. The one disappointment is the way the front-panel LEDs are mounted: First you solder the LEDs to the PC board, and then you must very carefully bend them so that each red lens fits through the appropriate hole in the front panel. This operation is a bit scary because of the fragile nature

[1]H. Price, "What's All This Racket About Packet?" *QST,* July 1985, pp. 14-17, and "A Closer Look at Packet Radio," *QST,* Aug. 1985, pp. 17-20.

Fig. 2—The AEA PKT-1 comes completely assembled and tested. All that is required is connection to a radio and terminal, and it's ready to go.

of the components. A better approach might be to preform the leads before soldering them in place.

Checkout and Troubleshooting

Initial checkout of the TNC is straightforward, but there is one error that can leave you scratching your head. Under Step 2 of the Operational Checks, Heath tells you that when you switch the power on, the CW ID LED (D2) will light and then go out after one to two seconds. In fact, the opposite is true! After one to two seconds, D2 will light up and stay on.

Chances are good that your TNC will "come up running" if you follow directions and solder carefully. If not, refer to the troubleshooting section in the assembly manual. If you still have a problem, Heath has a technical assistance number you can call for help.

Calibration

The TNC includes a modem based on the popular EXAR 2206 and 2211 ICs. This modem must be calibrated before the TNC can be used on the air. Normally, you would need a frequency counter or oscilloscope to calibrate the modem. The TNC contains a computer and an accurate clock, however, so the TNC can be used to calibrate the modem. A CALibrate command is sent from the terminal to the TNC, and the TNC software provides calibration instructions and feedback on the terminal screen. Modem tones are adjusted using trimmer potentiometers on the PC board. LEDs on the board indicate which way the controls should be turned. Modem calibration, using the TNC computer and built-in software, is a 10-minute procedure.

The Terminal Interface

To communicate, a TNC must be connected to a terminal or a computer. The information on interfacing that appears in this section, and the section that follows, applies to the AEA TNC as well as the Heathkit. The TAPR design uses the RS-232-C interface standard for this TNC-to-computer connection. The RS-232-C interfaces are available for most home computers, and stand-alone terminals usually employ the RS-232-C standard.

The TAPR terminal interface software accommodates terminals running between 50 bauds and 19.2 kbauds. When a terminal is first connected to the TNC, an "autobaud" program determines how fast the terminal is transmitting. Terminals can use either 7- or 8-bit ASCII, with one or two stop bits.

Radio Interfacing

The TNC sends packets through the modulator to the radio transmitter and receives packets from the receiver through the demodulator. The TNC must be connected to the transmitter microphone input and the PTT line, and to the receiver output. For most radios, this is as easy as hooking up a microphone and a speaker. Several exceptions to this rule are listed in the TNC manuals, and hookup procedures for the exceptions are provided. We have used the TAPR TNCs with several different radios, from small hand-held radios to computerized HF rigs, and have never had any trouble getting the TNC to transmit and receive properly. The modem circuit is well designed and does not rely on critical receiver and transmitter adjustments.

The AEA PKT-1

One reason TAPR designed the TNC was to make packet radio popular. To induce commercial manufacturers to enter packet radio, TAPR sold, for a nominal fee, nonexclusive commercial rights to the TNC design. The PKT-1 resulted from the purchase by AEA of TAPR's "OEM package." This TNC runs the same software as the TAPR TNC and employs almost the same hardware. It comes assembled, tested and warranted. If you want a factory-supported TNC, or do not have the time, inclination or ability to build a kit, the PKT-1 is a way to get the TAPR TNC.

The differences between the TAPR/Heath TNC and the PKT-1 are:

1) The PKT-1 is powered from an outboard 12-V dc supply (not included with the unit), while the TAPR and Heath versions contain an ac-operated supply.

2) Some components on the TAPR and Heath TNCs are mounted on DIP headers and, being easily removable, allow the modem to be quickly reconfigured. These same components are soldered to the board in the PKT-1 (although a header could be installed).

3) The TAPR and Heath TNCs provide a "modem disconnect" header that can be used to connect an external modem. The PKT-1 does not have this header, but room exists on the PC board to install one.

4) The software for all three TNCs supports a parallel input/output (PIO) chip. This chip is supplied with the TAPR and Heath TNCs, but not with the PKT-1. The PIO is not used in normal operation.

5) AEA fixed a problem with the original TAPR design. On occasion, the contents of the nonvolatile RAM (NOVRAM) would be garbled when the unit was turned off. AEA corrected this problem.

None of the above differences is critical, except the lack of DIP headers on the PKT-1. The 12-V dc supply for the PKT-1 is, in fact, useful for portable and emergency operation. You can, if you wish, add the missing headers, connectors and chip to the PKT-1.

Operation

In discussing operation, we will use the term "TNC" to refer to all three versions of the TAPR design. The question, "How does the TNC operate?" is best answered in several parts, bearing in mind how the TNC is used. On one hand, it is connected to another TNC via radio. On the other hand, it is connected through the RS-232-C interface to a computer or terminal.

The TNC Computer

The heart of the TNC is a Motorola 6809 microprocessor with its associated memory. The TNC comes with 32 kbytes of read-only memory (ROM) and 8 kbytes of random-access memory (RAM). The ROM holds the TNC operating programs. The RAM is used to hold data before it is transmitted and after it is received. The 8 kbytes of RAM have been sufficient for all packet-radio operation that we have done, including the remote operation of a computer over packet radio. There is an extra memory socket on the PC board that can be used to expand either ROM or RAM.

The Modem

The modem is the "mouth and ears" of the TNC, and the TAPR designers paid special attention to this important subsystem. During design and layout, great care was taken to make the EXAR chips perform well. A filter is included ahead of the demodulator to accommodate the audio characteristics of most FM receivers. This filter, and an extensive redesign of the demodulator during TAPR's initial testing, have produced a demodulator that is both stable and sensitive. Although the EXAR demodulator was not designed to work in a noisy radio environment, the TAPR design performs well. In the TAPR and Heath units, the components that set the modem shift and center frequency, and determine the characteristics of the pre-demodulator filter, are located on DIP headers, and can be quickly changed. Thus, these units can be used both on VHF, where the shift is 1000 Hz, and on HF, where the usual shift is 200 Hz. If you want to use an external modem, you simply plug it into the modem disconnect header.

Other Hardware

The TNC uses a WD1933 high-level data-

link controller (HDLC) to process packets. The controller checks incoming packets to make sure that they conform to the protocol and that they are error free. It then passes bytes of data and control information to the TNC computer. When transmitting packets, the HDLC chip takes addresses and data from the TNC computer and formats a packet for transmission. The HDLC chip calculates the critical *frame check sequence* (FCS), that helps to detect errors in packets, for each packet sent and received. You can build a TNC without an HDLC chip, but using one allows the computer to process input/output on a byte-by-byte basis, rather than on a bit-by-bit basis. This results in approximately an eight-fold reduction in the number of microprocessor instructions needed to simply send or receive a packet.

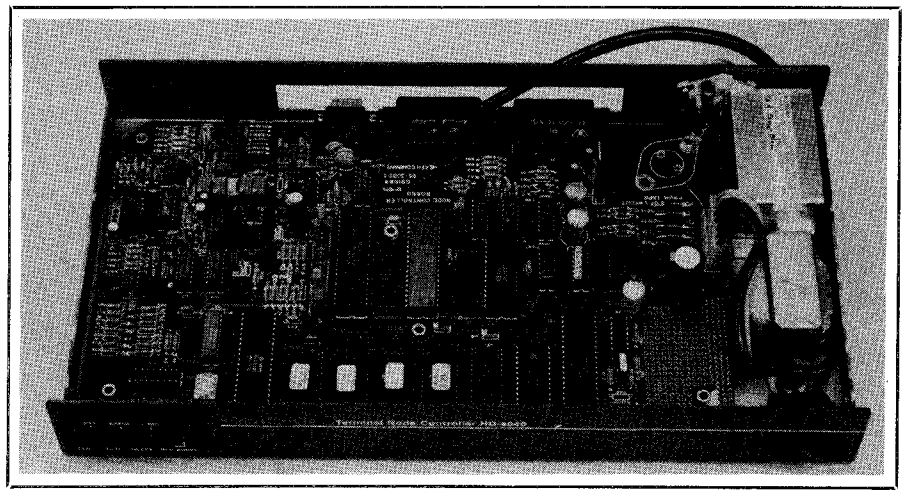

Fig. 3—The Heathkit HD-4040 is supplied in kit form, with cabinet and power supply, and can be assembled in about 10 hours. The power-supply regulator mounts to the rear cabinet panel, eliminating the heat sink.

Protocol Software

The TNC software that controls the packet radio 'connection' must adhere strictly to a protocol that specifies how packets should be addressed, how errors are to be handled, and how to "establish connection" to and "disconnect" from another TNC. These three TNCs implement both the old VADCG protocol and the ARRL standard AX.25[SM Pending] protocol. We have had experience only with the AX.25 software. Implementation of this protocol seems to be correct and bug-free, making the TNC compatible with all other AX.25 TNCs. The full AX.25 protocol is implemented, including the ability to operate through as many as eight digital repeaters ("digipeaters") and to act as a digipeater for other stations.

The AX.25 standard is mature and in widespread use. Although it is unlikely to change, replacement of four inexpensive PROMs in the TNC will allow it to change with the standard. Whenever new software becomes necessary or desirable, TAPR, Heath and AEA say they will make new PROMs available.

Command Software

In addition to protocol software, a TNC must have software to allow the user to configure the TNC and to send packets to and receive them from the protocol program. The TNC software allows many commands, is easy to use, and is free from bugs.

A list of the commands available to the TNC user takes many pages in the user's manual. Everything from packet protocol timing to the size of the terminal screen display can by changed by the user. The commands are logical and easy to remember. For instance, to connect to station KE3Z, simply type CONNECT KE3Z. To connect to KE3Z through the W1AW digipeater, type CONNECT KE3Z VIA W1AW. Simple, isn't it? Like most Amateur Radio equipment, the TNC has a few commands and controls you will use regularly, and dozens more you will seldom use.

Although we do not think that a complete list of commands is necessary here, we will discuss how the available commands facilitate the two modes of packet-radio operation mentioned earlier: conversational operation and block-oriented operation.

Conversational Operation

When most operators first get on the air with packet radio, they want to "talk" to someone; they want to sit at the keyboard and type messages to other operators on the network and have them type back. We call this "conversational operation." TAPR calls this mode the "converse mode." You can enter the converse mode by typing CONV and leave it by typing CONTROL-C.

Although conversational operation may sound simple, there are several operating parameters that you may want to customize. The TNC provides commands to change these parameters. For instance, in packet radio, it is not desirable to transmit each character as it is typed. Characters are saved and sent in groups. This means, among other things, that the "hunt-and-peck" typist doesn't have to transmit while looking for the next key, and that one frequency can accommodate several simultaneous QSOs.

If characters are not transmitted as they are typed, when are they sent? You can tell the TNC to send data several ways. Packets can be sent when the operator types a special character, after a certain number of characters have been typed, or after a fixed period of time. A combination of these methods is usually used. For instance, you might configure your TNC to send a packet after you type a CR or after you type 80 characters, whichever comes first. This will assure that packets do not become too long and that the receiving station gets each line as soon as it is complete. Adding a timer to send packets every 30 seconds assures that the receiving operator gets a steady flow of data.

We must also consider how received packets are presented to the computer or terminal connected to the TNC. We have already pointed out that the TNC can send and receive ASCII data at several speeds. In the converse mode, the operator also specifies how many characters can fit on a single screen line, whether a line-feed character should be sent after a carriage-return character, and whether the terminal will display lower-case characters. Several other parameters can be changed, but by now you should get the picture.

Much packet operation is conversational. The TAPR command set allows adjustment of operating parameters to compensate for such variables as terminal type, network congestion and typing speed. The TNC converse mode was designed and executed with both the novice and expert in mind.

Block-Oriented Operation

In view of the flexibility of the converse mode, you may wonder why any other modes are required. The need for other modes of operation stems from the desire to use packet radio for true computerized communications. A few such applications that come to mind are: program transfers, computer "time sharing," bulletin board operation and computer-graphics communications. For operations in these applications, you want the data sent by one computer to be received by another computer *unchanged*. You do not want an accidental CONTROL-C to put you back in command mode. This mode of operation is called "data transparent," and is identified as "transparent mode" in the TNC.

You put the TNC in transparent mode by typing TRANS. After this, data sent to the TNC is transmitted when a specified number of characters has been collected, or when a timer runs out. The number of characters and the length of time can be varied. To exit the transparent mode, a specially timed character sequence must be sent to the TNC. The timing and the special character sequence can be changed to suit specific applications and make it unlikely that the data being sent to the TNC by your computer will result in the TNC accidentally exiting the transparent mode.

The transparent mode is essential for many sophisticated packet-radio applications. In these TNCs the transparent mode is easy to use, and need only be used when necessary. Novice packet-radio operators ("packeteers") may never use the transparent mode, but it is available if needed. No operator is likely to outgrow the TNC.

Reading the Mail

Conversational and block-mode operation both entail transmission of data. Most amateurs do not spend as much time transmitting as they do "reading the mail." The TNC provides several commands that make it easy to monitor a network. These commands take advantage of the addresses that are sent with each packet, and allow the operator to choose

which station's packets he wishes to see. By typing MTO, followed by a list of stations, you tell the TNC to show you only packets addressed *to* those stations. MFROM does the same thing for packets *from* certain stations. If you want to read all the mail on a channel, simply type MALL ON. These commands allow you to watch only traffic that interests you, rather than forcing you to see everything that is sent.

Other Commands

We have described a few of the TNC's commands. The designers of the TAPR software were very careful: There are commands to vary all of the important parameters of the TNC, but you need only memorize two or three commands to use the TNC. This careful design makes the TNC a joy to operate and ensures that the TNC will not limit the operator.

Conclusion

We are enthusiastic about these TNCs. They represent the beginning of a new realm of communications for radio amateurs. The original TAPR TNC was designed, implemented, debugged and marketed by a group of amateurs, and that makes it more exciting. That Heath and AEA have embraced this new mode and jumped at the chance to make TNCs available in quantity to the amateur community bodes well for the future of packet radio. If you want to join the packet revolution, take a look at these TNCs.

The HD-4040 is manufactured by Heath Company, Benton Harbor, MI 49022, tel. 616-982-3411; price class, $300. The PKT-1 is manufactured by Advanced Electronic Applications, Inc., P.O. Box C-2160, Lynnwood, WA 98036, tel. 206-775-7373; price class, $500.—*Jeff Ward, K8KA, and Mark Wilson, AA2Z*

SOLICITATION FOR PRODUCT REVIEW EQUIPMENT BIDS

[In order to present the most objective reviews, ARRL purchases equipment "off-the-shelf" from Amateur Radio dealers. ARRL receives no remuneration for items presented in the Product Review or New Products columns.—Ed.]

The following ARRL-purchased Product Review equipment is for sale to the highest bidder. Prices quoted are minimum acceptable bids, and reflect a discount from the purchase price.

Sealed bids must be submitted by mail and be postmarked on or before November 27. Bids postmarked after the closing date will not be considered. Bids will be opened seven days after the closing postmark date. In the case of a tie, the highest bid bearing the earliest postmark will be declared the successful bidder.

Please clearly identify the item you wish to bid on, using the manufacturer's name, model number or other identification number, if specified. Each item requires a separate bid and envelope. Shipping charges will be paid by the successful bidder, FOB Newington. The successful bidder will be advised by mail of the successful bid. No other notifications will be made, and no information will be given by telephone to anyone regarding final price or identity of the successful bidder.

Please send your bids to Kathy McGrath, Product Bids, ARRL, 225 Main St., Newington, CT 06111.

Info-Tech M107 RTTY modem. Min. bid $130.

Info-Tech M44 AMTOR converter. Min. bid $207.

Trio-Kenwood TH-21AT 2-meter FM handheld transceiver, s/n 5042641, AJ-3 antenna adapter, SC-8T soft case, PB-21 battery pack and SMC-30 external speaker/microphone (as a package only—see April 1985 *QST*). Min. bid $172.

ICOM IC-471A 70-cm transceiver, s/n 01051, IC-SM-6 microphone (as a package only—see Aug. 1985 *QST*). Min. bid $533.

Amateur Radio Software

AEA-Soft AMTORTEXT-64, s/n 12. Min. bid $47.

New Products

CENTURION ACQUIRES EAR COM LINE

☐ Centurion International, Inc. has acquired the Ear Com product line. Ear Com is a miniature earpiece transducer that permits the user to send and receive voice communications through a radio set or intercom in high ambient-noise environments. The unit permits hands-free operation by the user, and can be used with protective gear and clothing such as a hard hat, gas mask, respirator or hearing protector.

The Ear Com functions as a remote microphone/speaker through the earpiece that picks up voice sounds through the user's otolaryngeal system. The control module amplifies, filters and conditions the voice signals, which are then passed on to the associated transceivers for transmission. Incoming audio signals are passed from the transceiver through the control unit to the earpiece. The system is compatible with AM, FM or SSB, and can be worn on a belt or installed in an automobile, motorcycle or aircraft.

For a free color brochure on the Ear Com system, contact Sales Department, Centurion International, Inc., P.O. Box 82846, Lincoln, NE 68501, tel. 402-467-4491 or 1-800-228-4563 (outside Nebraska).—*Bruce O. Williams, WA6IVC*

RADIO AMATEUR *CALLBOOK* PUBLICATIONS

☐ Three new publications—*The North American Callbook,* the *International Callbook* and the *Callbook Supplement*—have been announced for 1986 by Radio Amateur Callbook, Inc. The *North American Callbook* lists the licensed amateurs in all countries in North America plus those in Hawaii and U.S. possessions. This information is carefully screened and checked to ensure utmost accuracy. This volume contains international postal information, worldwide QSL bureaus, radio amateur census information, and much more.

The *International Callbook* lists calls, names and addresses for licensed amateurs in all countries outside North America. Coverage includes Europe, Asia, Africa, South America and the Pacific area (exclusive of Hawaii and U.S. possessions).

The *Callbook Supplement* is a new concept in Callbook updates. To be published on June 1, the new supplement will list the combined activity in both the *North American* and the *International* editions for the preceding six months. One supplement will bring you thousands of new licenses, address changes and "then and now" call changes from countries around the world.

For information or literature, contact the publisher, Radio Amateur Callbook, Inc., 925 Sherwood Dr., Box 247, Lake Bluff, IL 60044, tel. 312-234-6600—*Bruce O. Williams, WA6IVC*