Product Review Column from *QST* Magazine

October 1995

QST Compares: GPS-Compatible TNCs
(AEA PK-12; Kantronics KPC-3; PacComm TINY-2 MK-2)

QST Compares: Antenna-Modeling Software

QST Compares: GPS-Compatible TNCs

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Imagine staring at a map on your computer monitor. It's a map of your state. Blue lines indicate rivers and other bodies of water. Green lines trace major highways. You press a key and zoom into a particular area of your state. Along one stretch of highway you see clusters of symbols with Amateur Radio call signs. As you watch, your packet-radio TNC receives a transmission...and one of the symbols *moves!* Welcome to the Automatic Packet Reporting System, otherwise known as *APRS*.

The Automatic Packet Reporting System (APRS) is the brainchild of Bob Bruninga, WB4APR. APRS exploits the ability of TNCs to transmit *beacon* packets that carry short strings of alphabetical characters and/or numbers. A beacon is an *unconnected* packet. You can think of unconnected packets as "broadcasts." The information is sent to no one in particular and can be received by anyone. An unconnected packet can be relayed through a node or digipeater if you "tell" your TNC to do so. (See July 1993 *QST*, page 92, and February 1994 *QEX*, page 9, for more information.)

The ability to send beacons has been a feature of TNCs since the earliest days of packet, but two developments in the '90s finally made APRS feasible. The first was the introduction of small TNCs that could operate on batteries. These little boxes could go anywhere without relying on ac power. The second was the debut of compact, affordable *Global Positioning System* (GPS) receivers. GPS receivers rely on signals from military satellites to determine position coordinates with an accuracy of about 200 feet or better. Most of these receivers have ports that allow their data output to be transferred to other devices...such as TNCs.

It didn't take long for Bob to realize that he was on to something big. If you could take the position information from a GPS receiver and incorporate it into beacon packets transmitted by a TNC, you could tell everyone on a packet network *exactly where that GPS receiver was located.* And if the receiving TNCs could pass this information to computers, and if the computers could display the position as map symbols... bingo! You could do more than tell the other packeteers where the GPS receiver was located, you could *show* them—along with the call sign of the transmitting station.

With the proper APRS gear, you can track just about anything that moves, and note the locations of things that don't. You can put an TNC and a GPS receiver into a payload package beneath a helium-filled weather balloon and track its path as it cruises over the Earth. You can even install an APRS system in your automobile, allowing your buddies to follow your adventures around the town, state or wherever. More "settled" hams can simply beacon the locations of their stations for all to see. The choice is yours.

Finding APRS Software

APRS software is distributed as shareware and may be copied for any amateur application. The software includes maps for most areas of the US. You can also edit and add more detail to the maps. Registered copies for IBM PCs are available for $19 from Bob Bruninga, WB4APR, 115 Old Farm Ct, Glen Burnie, MD 21060. A Macintosh version of APRS, *MacAPRS*, was developed by Keith Sproul, WU2Z, and Mark Sproul, KB2ICI.

If you're a denizen of cyberspace, you'll find various versions of APRS software on CompuServe's *HamNet* forum, on the ARRL *Hiram* BBS (203-594-0306), on the APRS BBS (410-280-2503), at the TAPR World Wide Web page at ftp://ftp.tapr.org/tapr/SIG/aprssig/upload/ (assuming your Web browser has ftp capability) and many other Internet sites.

APRS is especially suitable for public-service applications. For example, some hams have established networks of packet stations that relay weather telemetry along with their position information. Anyone with the proper hardware and software can monitor rapidly changing weather conditions over a wide area. For example, you could watch barometric pressure readings fall and wind speeds increase as a severe thunderstorm moved through a particular location.

How Do You Get Started?

The good news is that you *don't* need to buy a GPS receiver or a special TNC to enjoy APRS—at least in a limited sense. To get your feet wet you need only the APRS software (see the sidebar "Finding APRS Software") and your normal packet TNC. Just determine your latitude and longitude as best you can. Look it up in an atlas or borrow a friend's GPS receiver. After you feed the information to the APRS software, your TNC will regularly announce your position to anyone who is monitoring. Your station location and call sign appear on APRS-generated maps (see Figure 1). You can even use APRS software to exchange bulletins and enjoy other network functions.

Most APRS activity is on 2 meters, with 145.79 MHz being the popular frequency. There is also APRS activity on the HF packet frequencies.

A "static" APRS station is fine until you get the urge to start moving. That's when you'll need your own GPS receiver. Fortunately, GPS receiver prices are plummet-

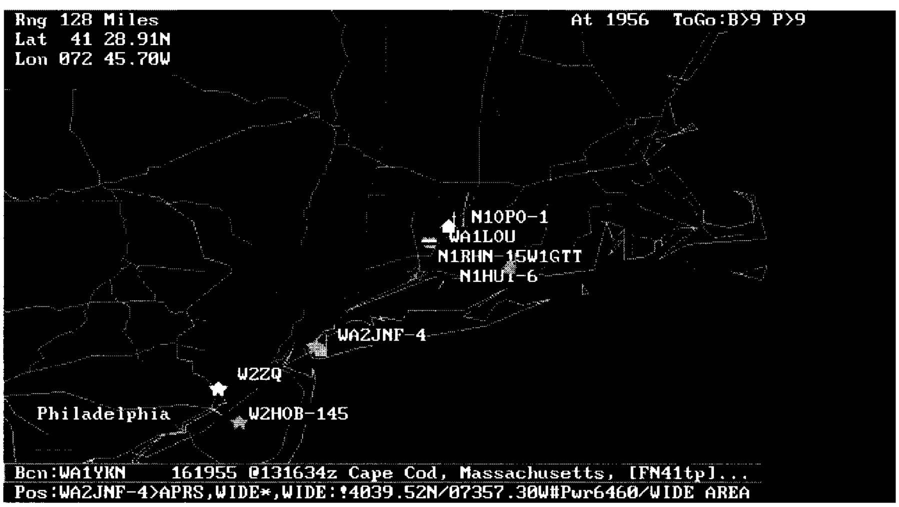


Figure 1—APRS software in action. Packet TNCs beacon latitude and longitude data. The receiving stations process the information and display the results on computer-generated maps.

ing. When this review was written, some models were selling at less than $300. You don't need anything fancy, but your receiver *must* include an *NEMA* data input/output port.

The NEMA standard specifies that GPS data signals conform to RS-232. But many GPS receivers simply use what could be described as *pseudo*-TTL: voltage levels switching between ±5 V with RS-232 polarity. Other GPS units use "true" TTL and require a converter for RS-232 compatibility.

And what about that TNC? You need a TNC that can process the data from the GPS receiver and create APRS-compatible beacon packets. You don't need a special TNC *per se*, but you *do* need a TNC that's equipped with the proper GPS *firmware*.

All the major TNC manufacturers have produced units with GPS firmware. One manufacturer has even created TNCs with *built-in* GPS receivers. For this review we evaluated the AEA PK-12, Kantronics KPC-3 and the PacComm TINY-2 MK-2. The MFJ 1278B (with GPS firmware) and the new PacComm *PicoPacket* have been announced, but both were unavailable prior to the review deadline.

AEA PK-12 (with version 7.1 firmware)

The PK-12 is AEA's entry in the compact-TNC competition. This 1200-baud TNC includes full-featured mail handling (with automatic mail forwarding) along with 32 kbytes of mailbox capacity (expandable to 128 k). In addition to its GPS firmware, the PK-12 supports the KISS and HOST modes, as well as a node function.

Its compact styling (approximately 6×5×1.5 inches) makes the PK-12 well-suited for mobile use. Because it draws less than 80 mA (considerably less in some configurations), the PK-12 is ideal for battery-operated stations.

From the standpoint of the average packet user, the PK-12 package has a lot to offer. The manual itself is a comprehensive packet tutorial. It's written in a friendly, informal style. In the appendix you find page after page of audio input/output wiring diagrams for various radios. This section alone will save time and headaches!

As you review the PK-12's functions and command structure, you find neat little gems such as WHYNOT. If you turn the WHYNOT function on, the PK-12 will generate messages to let you know why certain received packets were not displayed. For example, the message "MBX Sequence" means that a frame was received out of sequence, probably a retry. If something has gone awry during your connection to a friend, BBS, etc, at least WHYNOT can offer some clues.

For those who enjoy tinkering with their TNC functions on a frequent basis, there is the REINIT command. By invoking REINIT, you'll set all PK-12 parameters to their factory defaults *without* erasing messages stored in the mailbox. This gets you out of trouble without burning your bridges in the process!

Advanced packeteers will welcome the PK-12's protocol for meteor-scatter work. (It's activated by turning **UBIT 18** *on*.) It allows a Master/Slave connection to be established. Once such a connection is made, the Master station (the station that initiated the connection) sends information frames or polling frames and waits for an acknowledgment from the Slave station. The Slave doesn't transmit until the Master "tells" it to do so via the polling frame. This avoids collisions and makes the most efficient use of the available time. In the case of meteor scatter, this time is measured in seconds!

The Master/Slave connection is also available in the form of *DAMA—D*emand *A*ssigned *M*ultiple *A*ccess. When operating in the DAMA mode, a packet node or BBS can dynamically assign channel priority to individual stations. The Master station (the node or BBS) polls each connected Slave station in turn, "asking" if the station has information to transmit. If the TNC has data to send, it can do so. If not, it does nothing and the Master station "remembers" this fact. The next time it polls the Slaves, it will skip the quiet station. The inactive station will have an opportunity to change its status (by sending a packet) at a later time.

DAMA reduces packet collisions on crowded channels. This would be a major improvement for packet networks, although DAMA is used only in Europe at the present time.

Every PK-12 includes free software—including a recent version of APRS and a basic terminal program.

The PK-12 and GPS

With the PK-12 (and now the PK-96 and PK-232) you can enjoy one of three GPS/APRS configurations:

1. Dual GPS/TNC simultaneous operation: With AEA's APRS adapter cable (optional) you can connect a GPS receiver and the PK-12 to the same computer COM port. The APRS software uses the adapter to switch between the PK-12 and the GPS unit as necessary.

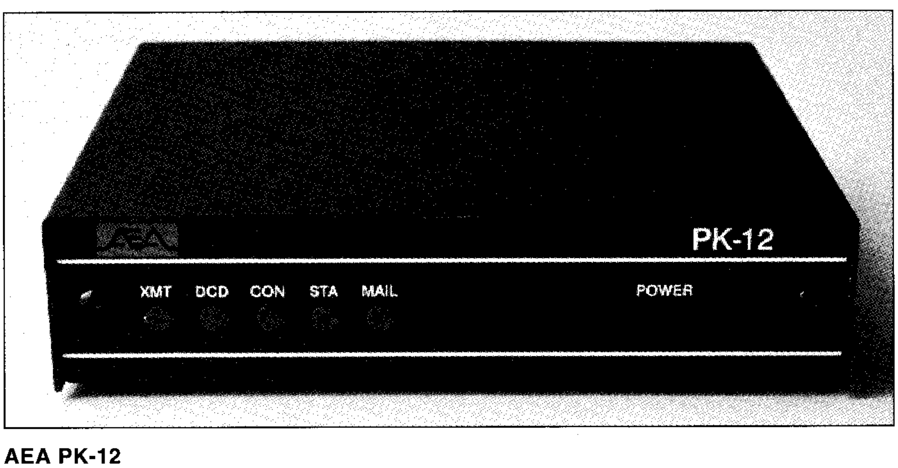
2. APRS without a GPS receiver: Just connect the PK-12 to your computer and monitor the APRS activity in your area. (This is the static APRS station described earlier.)

3. Stand-Alone Tracking: Connect the PK-12 to a GPS receiver and take it on the road. No computer is necessary. The PK-12 automatically detects the presence of the GPS receiver and incorporates its data output into the TNC beacon packets.

For this review I operated the PK-12 in the dual-simultaneous configuration (although I opted to use an extra COM port rather than sharing a single port) as well as the tracking mode. It performed very well in both applications.

The PK-12's GPS features include remote polling. This means that the PK-12 will respond with its location whenever it receives a UI packet directed to the programmed **GPOLL** call sign. I set the GPOLL of my PK-12 to WB8IMY-7 and asked a friend to send an unconnected packet to that call sign. Sure enough, the PK-12 instantly transmitted its location according to the data it was receiving from the GPS receiver. (We were using a Sony GPS receiver at the time.)

Some GPS receivers need an initialization string from the TNC when you power-up the unit. The PK-12 complies with the ability to send a programmable string. (Our GPS receiver didn't need initialization, but it's nice to know that the PK-12 can pull it off!) The PK-12 also allows you to remotely program your GPS receiver via radio. The trick, however, is knowing what your GPS receiver needs to "see" from the TNC and keeping the RS-232 levels in line.
Manufacturer: Advanced Electronic Applications, PO Box C2160, 2006 196th St SW, Lynnwood, WA 98036, tel 206-774-5554. *Suggested retail price:* $129.



AEA PK-12

Kantronics KPC-3 (with version 6.0 firmware)

We first reviewed the KPC-3 two years ago (December 1993 *QST*, page 81). This slim, lightweight TNC was praised for its many convenient features, including a flexible mailbox system (expandable to 512 kbytes of storage capacity) and remote access. The KPC-3 even includes the capability to monitor HF WEFAX transmissions, although it only receives and processes monochrome images (weather maps, etc).

The KPC-3 can be easily powered by a 9-V battery. In its stingiest power-conservation mode, the KPC-3 draws a maximum of 15 mA. This fact, combined with its tiny size, makes it an ideal candidate for APRS applications.

The GPS-Capable KPC-3

You activate the KPC-3's GPS firmware through the **INTFACE** command. **INTFACE GPS** places the TNC in the GPS mode and sends an initialization string (if required) to the GPS receiver. So, if you're about to hit the road with your TNC and GPS receiver, all you need do is connect the KPC-3 to your computer just long enough to place it in the GPS mode. (By the way, sending three **CONTROL-C** characters kicks the KPC-3 back to the Terminal mode for normal operation.)

The KPC-3 incorporates some clever features in its GPS firmware. For example, you can set up your KPC-3 to begin beaconing its position at, say, 6:01 PM and every 30 minutes thereafter. This is a handy option when you have many APRS stations operating together. If they were all equipped with KPC-3s, your group could set up a "slotted" beacon system. One station could start beaconing at 6:01, the next station at 6:02, the next station at 6:03 and so on. If you set the beacon interval at every 30 minutes, the first station would beacon at 6:01, 6:31, 7:01 and onward through the night. The second station, however, would beacon at 6:02, 6:32, 7:02, etc. By staggering the beacon times, you neatly avoid interference.

Now let's say that you want to automatically generate location information at various times, but you *don't* want the KPC-3 to transmit beacons. No problem. You can command the KPC-3 to *store* the information that would otherwise be sent. The KPC-3 holds the data in its *tracking buffers* for you to examine at a later time.

With most GPS-capable TNCs, you can't access the standard commands when the TNC is in the GPS mode. This is true of the KPC-3...with one exception. Through the use of the password-protected remote SysOp function, you can connect to your KPC-3 from another packet station and change any parameters you desire—including the GPS parameters. This would be very convenient for controlling remote installations such as APRS weather stations.

Like the PK-12, the KPC-3 can simultaneously share a computer port with your GPS receiver. A switching adapter is still necessary to allow the APRS software to automatically select the GPS receiver or the KPC-3. When this review went to press, Kantronics had announced the availability of a switching adapter that utilizes *hardware* flow control. This is important for those times when you need to jump from the APRS software to, say, *PacTerm* or another software package that requires hardware flow control to communicate with the TNC. With the Kantronics adapter there's no need to switch cables. Just boot up your program and go.

During my tests with the KPC-3, I used it as a stand-alone tracker. I simply connected my Sony GPS receiver to the KPC-3's rear-panel serial port and used an H-T as my tracking transceiver. From my home station, I watched as my friend cruised through central Connecticut in his minivan. The KPC-3 parsed the data from the GPS receiver and created beacon packets that I received at 1-minute intervals. I was even able to watch, with more than a little amusement, as he became lost in downtown Meriden, Connecticut. (The tracking lines on the APRS display turned into a tangled mess as he repeatedly retraced his route!)

Software

The KPC-3 comes with a 3.5-inch diskette that's full of useful information on Kantronics products—from specifications to user tips. The disk also includes a copy of *PacTerm* to get you up and running right away, as well as an update for their popular *HostMaster* software. They even throw in *GMON*, which is used to monitor G-TOR transmissions. (It's possible to monitor G-TOR conversations with the KPC-3 in the WEFAX mode.) A convenient menu program helps you navigate through the software and documents on the disk. All you have to do is enter **TNC** and you're on your way. *Manufacturer:* Kantronics, 1202 East 23rd St, Lawrence, KS 66046, tel 913-842-7745, fax 913-842-2021. *Suggested retail price:* $119.95.

PacComm TINY-2 MK-2

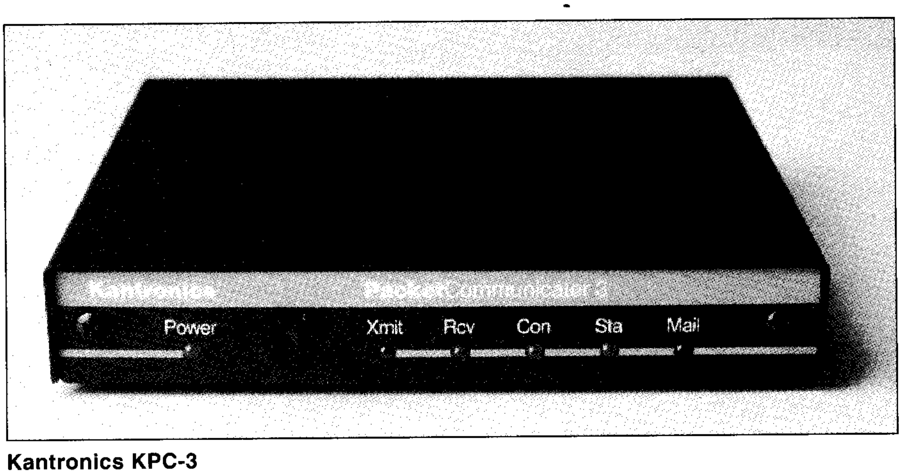
Of the three TNCs I tested, only the PacComm TINY-2 MK-2 had the distinction of including its own *internal* GPS receiver. PacComm's *PicoPacket* also includes an internal GPS receiver but, as I mentioned earlier, the *PicoPacket* was unavailable when I was conducting this review.

The TINY-2 was also featured in our December 1993 TNC roundup (page 84). At the time we noted its enhanced mailbox capability, and the fact that it was TAPR-2 compatible with a modem-disconnect header. This allows you to substitute another modem of your choice, such as a PSK modem for working the 1200-baud PACSATs.

Even then the TINY-2 boasted a GPS mode that was NEMA compatible. APRS was just gathering steam in 1993 and PacComm was already on the bandwagon. With the latest version of the TINY-2, PacComm has taken the next logical step by building the packet TNC and the GPS receiver into the same box.

The internal Trimble Navigation GPS receiver connects to a $2^3/_8$-inch-diameter patch antenna mounted on a magnetic base. The entire assembly is about the size, thickness and color of a large chocolate cookie; inconspicuous by anyone's standards. Approximately 15 feet of thin feed line connects the antenna to the receiver via a small jack on the back panel of the TINY-2. Setting up a mobile APRS station is as easy as popping the "microwave mag-mount" antenna onto the roof of your car.

Unlike other GPS-compatible TNCs, you don't need to hook up your computer to switch the TINY-2 to the GPS mode. A push-button switch on the rear panel selects either the GPS mode or normal TNC func-



Kantronics KPC-3

tions. While you still need to connect your PC to program the various parameters, this switching arrangement makes APRS remarkably quick and easy. If you ever feel the need to track someone's movements on the fly, you simply throw the TINY-2 into the vehicle, connect a power source, connect your radio, press the **GPS** button, and turn everything on. A well-prepared ham could begin sending GPS information in less than a minute.

Despite this convenience, there is a catch. You *cannot* use the TINY-2 and its GPS receiver simultaneously as separate units. That is, your APRS software cannot poll the GPS receiver for position information, then communicate with and control the TNC. You can use the TINY-2 as a normal TNC for monitoring APRS transmissions, or as the heart of a GPS-equipped tracker, but not both. According to PacComm, their *PicoPacket* works around this problem by having two serial ports. The GPS receiver feeds into one, and the TNC siphons off the data for transmitting. The computer can have full-time access to the other port and can get the current GPS information by querying the TNC.

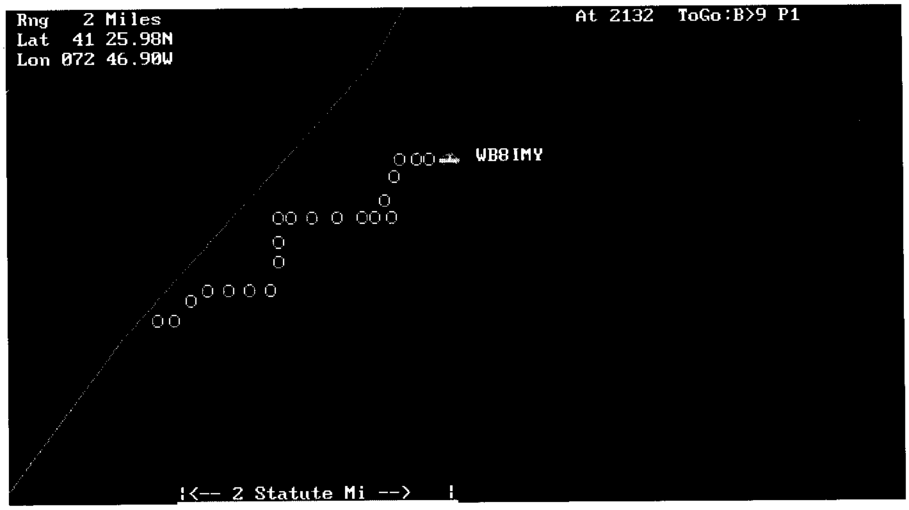


Figure 2—I was about half-way through my Sunday drive with the TINY-2 when this APRS "snapshot" was taken. The map view has been "zoomed in" to pick up maximum detail. The diagonal line to the left of my meandering track is Interstate 91.

On the Road with the TINY-2

The sheer convenience of the TINY-2 was obvious during my first mobile test. I slapped the antenna onto the roof of my car and I was under way in no time. I had configured the TINY-2 to beacon my location once every 10 seconds as I cruised through the countryside. There was nothing for me to do but drive. The GPS receiver acquired the satellites, cranked out my changing locations and the TNC sent the information back to my home station. When I returned, my APRS software displayed the result (Figure 2).

A Brickbat and a Bouquet

In the 1993 review I was critical of the TINY-2's manual. Unfortunately, this aspect of the TNC hasn't changed. GPS and APRS information is especially sparse. It is assumed that you're already familiar with the subjects. (According to PacComm they are now including more detailed GPS information with the TINY-2). If you're new to packet radio, get help from an experienced ham before tackling the TINY-2.

On the other hand, I was pleasantly surprised to see that PacComm still includes a power-supply module with the TINY-2. It may seem like a trivial item, but if your present dc power supply is bogged down with other current-hungry goodies, it's nice to know that you won't have to connect yet more wires to run your TINY-2. Just plug in the module and connect the power cord. *Manufacturer:* PacComm, 4413 N Hersperides St, Tampa, FL 33614-7618, tel 813-874-2980, fax 813-872-8696. *Suggested retail price:* $629.

For More Information About APRS and the Global Positioning System...

Articles and Publications

Stan Horzepa, WA1LOU, "Track-It Radio," Packet Perspective, *QST*, Jul 1993, p 92.

Timothy Knauer, NY9F, "You Are Here," *73*, Jul 1990, p 18.

Bradford Parkinson, "History and Operation of NAVSTAR, the Global Positioning System," *IEEE Transactions on Aerospace and Electronic Systems*, Volume 30, No. 4, Oct 1994, p 1145.

Richard Doherty, "Mobile Finder Banishes that Lost Feeling," *Electronic Engineering Times*, Sep 19, 1988.

Internet World Wide Web

The following URLs are valid as of September 1, 1995.

For APRS information:

http://www-ns.rutgers.edu/~ksproul/MacAPRS.html

http://www.mindspring.com/~rwf/aprs.html

For GPS information:

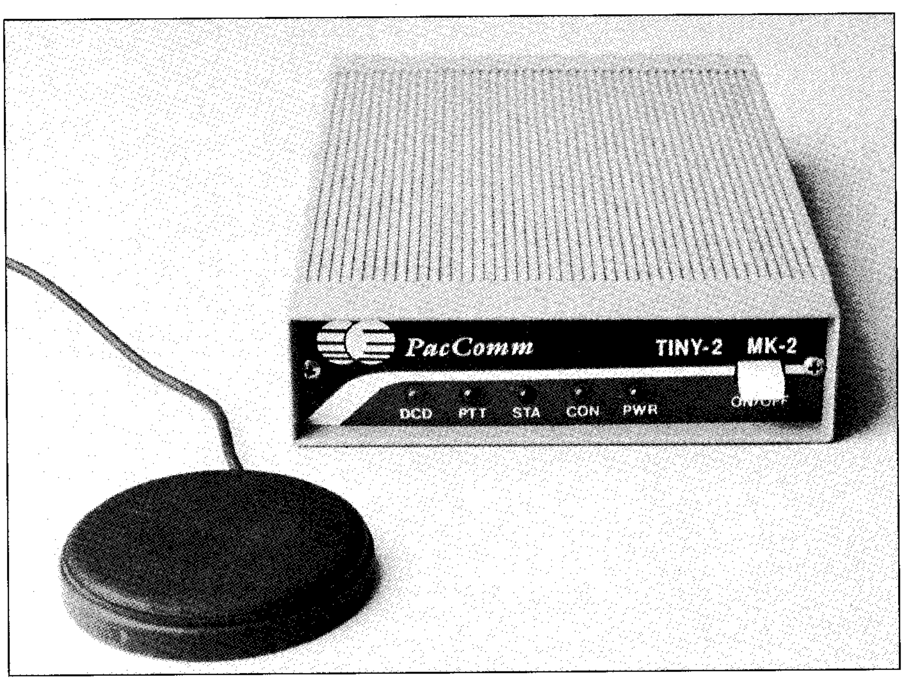
http://www.zilker.net/~hal/geoscience/gps.html

http://wwwhost.cc.utexas.edu/ftp/pub/grg/main.html

http://sirius.chinalake.navy.mil/

http://galaxy.einet.net/editors/john-beadles/introgps.htm

http://www.navcen.uscg.mil/



PacComm Tiny-2 MK-2

QST Compares: Antenna-Modeling Software

Reviewed by R. Dean Straw, N6BV
Senior Assistant Technical Editor

For years, *QST* Product Reviews covered hardware: transmitters, receivers, keyers, audio filters and so on. Today, we are constantly reminded that we live in the "Information Age," where computers control almost everything—our toasters, vacuum cleaners, cars and, of course, our ham rigs. It's software that makes the hardware sing and dance.

Both Brian Beezley, K6STI, and Roy Lewallen, W7EL, have achieved solid commercial success with their antenna modeling programs, developing many loyal partisans over the years. In the last five years many, if not most, antenna articles in the amateur literature have sported detailed azimuth and elevation plots created by *ELNEC* or *NEC/Wires*, *MN*, *AO*, or *YO*. This Product Review is about the latest in commercial antenna-modeling software, based on *NEC* (the Numerical Electromagnetics Code, originally developed by the US government) from these two software authors.

Why *NEC*?

If you already have *MININEC* or one of its variations, such as *ELNEC* or *MN*, you may be wondering whether you really need to buy a new *NEC*-based modeling program, such as *EZNEC*, *NEC/Wires* or *NEC/Yagis*. *MININEC* is fine for many antenna-modeling problems but it has serious limitations when analyzing a number of real, practical antennas. If a horizontally polarized antenna is located less than about 0.2 wavelengths above the ground, *MININEC*-derived programs will report that the gain is higher, sometimes substantially higher, than it should be.

Users have reported that *MININEC* has built-in frequency offsets, most often noted on multielement VHF Yagis. It also has difficulties with certain wire geometries, such as that of a quad antenna. There are workarounds for some of these problems, but these can cause the programs to run more slowly, often substantially. *NEC*-based programs do not suffer from these problems and they often run significantly faster. In addition, *NEC*-based programs can directly model lossless transmission lines, an important factor in phased arrays and log-periodic antennas.

So, take it from a veteran modeling enthusiast—if accuracy, speed and enhanced modeling capability are important to you, then you should definitely consider upgrading from *MININEC* to a *NEC*-based program such as those covered here.

EZNEC, by Roy Lewallen, W7EL

If you are already an *ELNEC* user, you will be very comfortable with *EZNEC*, introduced in July 1995 *QST*. For those new to the world of antenna modeling, *EZNEC* lives up to the reputation for "reasonably friendly" operation established by its little brother. I must warn you, however, about antenna modeling: it is not all that easy, no matter what program you use. The user must be able to visualize antennas as objects in three-dimensional space, something not all people are really comfortable doing.

Antenna modeling programs require the user to look at an antenna as a set of straight-line "wires," with x, y and z coordinates for the end of each wire. W7EL's on-disk EZNEC.DOC documentation is clear and well written, guiding the neophyte user through the intricacies of modeling. You should read it several times, even if you are an experienced modeler. There are also sample files on disk, with a detailed description of the subtleties in each design.

EZNEC's main menu is laid out in a logical, if somewhat busy, fashion. See Figure 1. The operator uses two-letter abbreviations to enter any submenu. For example, keying in "GT" will take you instantly to the "Ground Type" submenu, where you may define the type of ground over which an antenna is situated. More complicated functions take you to other full-size screens to enter data. For example, keying in "LO" will take you to the LOad screen, where you may specify the placement and types of various loads, such as parallel-tuned traps, series inductors, capacitors, resistors, etc.

One of the very nice, intuitive features of *EZNEC* is that you may specify a "load" or "source" generator in terms of the percentage from one end of a particular wire. For example, to put a source in the center of wire number five, you would specify **50% from End 1 of Wire 5**. *EZNEC* figures out the best segment placement automatically.

Since the process of specifying wires is often a complex, tedious and error-prone task, you should draw a picture, on paper, of the desired antenna before starting on the computer. Then, you can use *EZNEC*'s "View Antenna" function to see a detailed geometric picture of the antenna you are entering, wire by wire. You may rotate, scale, zoom in or zoom out the picture to inspect minute details.

A particularly endearing feature, unique to W7EL's software, is the "Highlight" function in View Antenna. You use the arrow keys to highlight each wire on-screen, one by one. The numeric values (x, y, z, diameter, and length) for that wire are shown in detail. With Highlight, you can sort out a complicated model made up of many wires. See Figure 2, showing a two-element quad, with segment 2 highlighted

```
                  EZNEC  ver. 1.0
             (c) 1995  by Roy Lewallen, W7EL

TI  TITLE:                   Dipole w/arms rotated down
FR  FREQUENCY:               14 MHz. (wavelength = 70.25509 ft.)

WI  WIRES:                   3 Wires              WL  WIRE LOSS: Copper
SO  SOURCES:                 1 Source             UN  UNITS:     Feet
LO  LOADS:                   0 Loads
TL  TRANSMISSION LINES:      0 Lines
GT  GROUND TYPE:             Real/Hi Accuracy Anal    LAST FILE SVD/RCLD:
GD  GND DESCRIPTION:         1 Medium                 LAST.EZ

PT  PLOT TYPE:               Azimuth              RF  REFERENCE: 0 dBi
PA  ELEVATION ANGLE:         20 Deg.              SZ  SWR Z0:    50 ohms
PR  PLOT/TABLE RANGE:        0 - 360 Deg. (full)  FI  PLOT FLDS: Tot fld only
SS  STEP SIZE:               1 Deg.
OR  OUTER RING OF PLOT:      Automatic scaling

(BR)owse file  (DE)lete, (RE)call, (SA)ve desc  (Freq S)wp  <RET> = Plot
(AN)alyze  (CU)rrents  (Guideline C)k  (Load D)ata  (OP)tions  (Print D)esc
(Src D)ata  (TA)ble  (View A)nt  (EX)it pgm without saving desc  (QU)it
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Figure 1—Main menu for *EZNEC*. A simple inverted-V dipole is being analyzed, over real high-accuracy (Sommerfeld/Norton) ground.

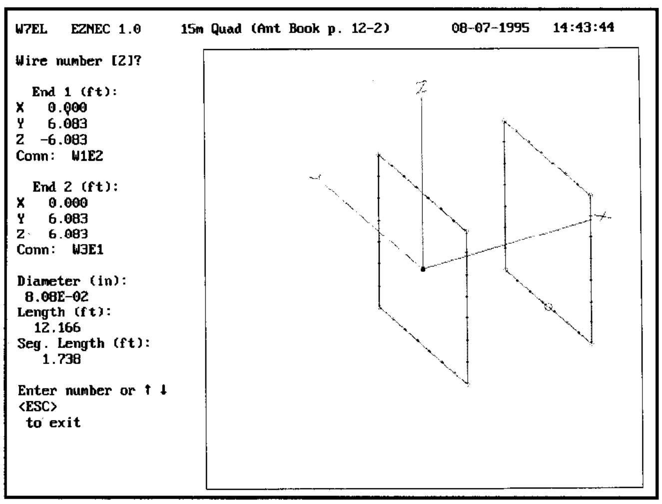

Figure 2—*EZNEC*'s "View Antenna" function, with wire number 2 "highlighted" to show the x, y, z coordinates for each end of the wire. This function allows even very complicated model geometry to be checked for mistakes.

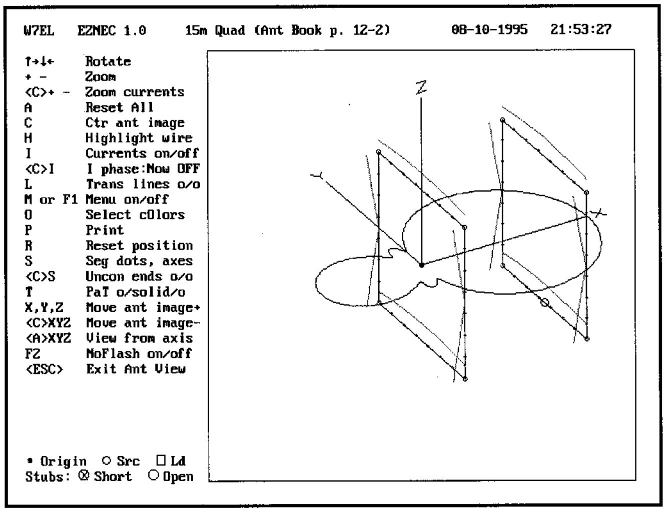

Figure 3—The "View Antenna" function, with overlay of the azimuth plot for 2-element 15-meter quad. Note currents on the antenna wires.

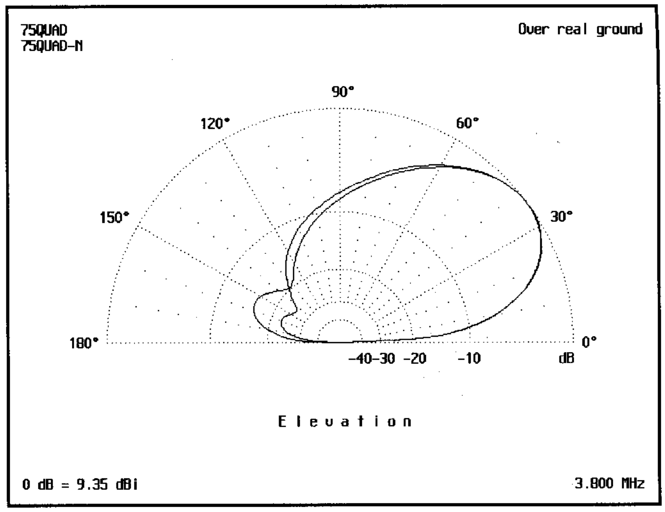

Figure 4—Overlay of two elevation plots of N6BV 75-m quad. The plot with more than 20 dB F/B is by *NEC/Wires*, while the other is by *AO*. This illustrates the frequency shift inherent in *MININEC*-derived programs for critically tuned models—the *AO* model peaked 15 kHz higher in frequency.

on the View Antenna screen.

Once you have specified, inspected and then saved your model to disk, you next press the **ENTER** key. The program computes for a while and then displays either an azimuth or elevation plot, your choice, showing how your antenna performs. *EZNEC* must recalculate when changing between an azimuth or an elevation plot. I find this annoying compared to the way K6STI's programs work, where both elevation and azimuth plots are computed at the same time and are alternately displayed by hitting the **ENTER** key.

However, I do like *EZNEC*'s unique ability to "Recall" and overlay multiple "Traces," W7EL's terminology for an elevation or azimuth plot pattern saved to disk. (Beezley's programs allow for only two patterns to be displayed on one plot.) In *EZNEC*, you may overlay as many as five Trace patterns on one plot, each with different color legends. Actually, you can overlay even more, if you don't mind the confusion trying to figure out which Trace is which!

Where such a multiple-trace capability becomes really useful is if you do a detailed frequency sweep. For example, I ran a sweep from 21.0 to 21.5 MHz, in steps of 50 kHz, for a 2-element quad. The resulting 11 Traces on one plot could easily be distinguished despite the limitation of only five different on-screen colors, since the trend of how the patterns changed with frequency was smooth and obvious to the eye. I recommend that you model any antenna over a range of frequencies, not just at a single spot frequency, where you might miss the progress of a trend entirely. Remember the story of the three blind men trying to describe an elephant?

Another *really* neat feature of *EZNEC* (and *ELNEC)* is that once either an elevation or an azimuth pattern has been generated, it may be overlaid on the View Antenna plot. This reveals the relationship between the wire geometry, the currents on each wire, and the resulting pattern. See Figure 3 for an example of this.

EZNEC produces user-customizable tables stored to disk for later use, including antenna currents. By contrast, K6STI's *NEC/Wires* saves only a limited set of parameters to disk for later examination. This doesn't include antenna currents, which are often excellent diagnostic indicators of whether the modeling is being done right—that is, sudden jumps in current can indicate that insufficient segments are being allocated to a wire. *EZNEC* can also write impedance files to disk for later analysis by the popular *ARRL MicroSmith* program.

Nice touches like these lead me to state that many of *EZNEC* features are more refined than similar ones in *NEC/Wires*, which predated *EZNEC* by several years. In other words, Lewallen has taken the time to really hide the mainframe-based, FORTRAN-like character of the core *NEC2* program behind the pretty face of *EZNEC*. *Manufacturer:* Roy Lewallen, W7EL, PO Box 6658, Beaverton, OR 97007. *Suggested retail price:* $89 postpaid (add $3 outside US/Canada).

AO 6.5, *NEC/Wires 2.0* and *TA 1.0*, by Brian Beezley, K6STI

In July 1995 *QST*, Brian Beezley introduced the *TA 1.0* program, repositioning his other products at the same time by dropping all copy protection and by lowering prices, especially for bundles of his programs. For this review, I chose a $120 package of three programs, making up what I considered a general-purpose modeling suite. With this lineup, you can model, perhaps even optimize, anything from a simple dipole to multiple phased verticals, Beverages, stacked Yagis—even stacked rhombics.

The first program in this review suite is *AO 6.5*, the Antenna Optimizer. *AO* has carved a unique niche for itself in the modeling world; nobody else does anything quite like it. The operator chooses the degree to which various parameters are to be optimized: gain, front-to-back ratio, or SWR, and the frequency range over which the chosen optimization is to be done. Then the particular variables to be juggled by the program are chosen. For example, you might want to optimize front-to-back ratio and SWR bandwidth by varying the lengths of the first director and driven element in a quad. Once instructed, *AO* does its thing, unattended and overnight if need be.

For really critical designs, *AO* results sometimes should be viewed with a jaundiced eye, because of the small inaccuracies inherent in its *MININEC*-derived core algorithm. While Beezley has calibrated *AO* to be close to the results from *NEC*, really critical optimizations still require full *NEC* accuracy. By design, both *AO* and *NEC/Wires* use the same input files. Many modelers first do a "coarse-tune" optimization with *AO* and then manually "fine-tune" with the big brother program, *NEC/Wires*.

I followed this procedure when I designed my 75/80-meter quad (which I'll describe someday in print). When this antenna was built and tested, *NEC/Wires* results were accurate within 2 kHz on 3.8 MHz; while *AO* results were within about 15 kHz for this critical, narrow-band design. See Figure 4 for an elevation plot from *AO* for this quad, overlaid with the pattern generated by *NEC/Wires*.

AO is faster than other *MININEC*-type

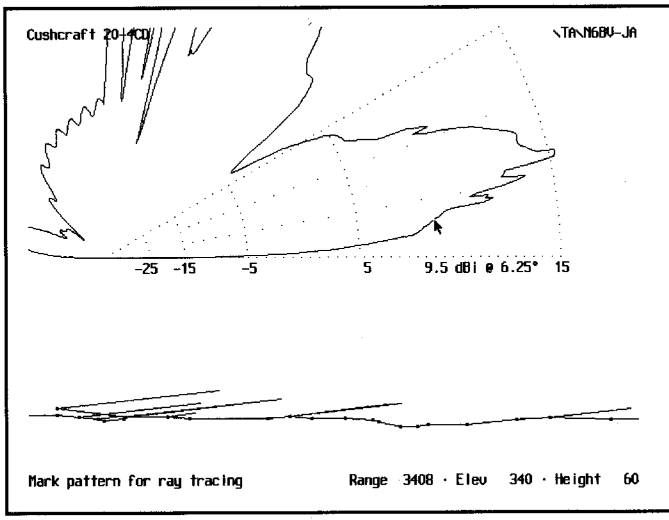

Figure 5—Output screen from *TA* program, showing elevation pattern and terrain at N6BV QTH towards Japan, with a 60-foot high 4-element Yagi on 14.0 MHz. At 6.25° the response is 9.5 dBi, with numerous components of reflection, diffraction and reflection-diffraction shown interacting with the terrain at this elevation angle.

programs, since many routines were written in speedy assembly language. (I should also mention that *YO*, Beezley's Yagi Optimizer, is blazingly fast, since it is streamlined for modeling only Yagis and also uses custom assembly-language routines.)

For *NEC/Wires* and *NEC/Yagis*, Beezley tweaked his FORTRAN compiler's math libraries for speed, using assembly-language routines. The result is a noticeably faster program compared with other implementations of *NEC2*, including the original. For example, a two-element 15-meter quad (with 154 total segments) took about 17% less time to complete using *NEC/Wires* (79 seconds total) than did *EZNEC* (95 seconds total) on my '486DX/33 computer.

An input file for either *AO* or *NEC/Wires* is created using an ASCII text processor, outside of the programs. At first glance, this seems like a disadvantage, compared to *EZNEC* with its smooth, integrated environment. However, the advantage of the Beezley strategy is that the user can define data as *symbolic variables*, rather than as fixed numbers. In fact, antennas may even be defined incorporating trigonometric functions and arithmetic expressions, simplifying complex models by letting the programs do the math work. Symbolic variables are extremely powerful tools.

TA, Terrain Analyzer 1.0

Both *AO* and *NEC/Wires* and *NEC/Yagis* have been on the market for several years and many excellent antenna designs have resulted from their use. However, what's really new and exciting is K6STI's *TA* software, introduced in July 1995. *TA* evaluates the effect of real-world terrain on the elevation pattern of real antennas, perhaps ones designed using *AO* and/or *NEC/Wires*.

TA is a *ray-tracing* program. In effect, it shoots a series of "rays" from an antenna towards the ground terrain in a particular azimuthal direction—rather like shooting a bunch of bullets. The rays interact with the ground in many complicated ways: by bouncing off it in classical reflections, by diffracting off peaks and valleys in the terrain, or by compound combinations of reflections and diffractions. At the end of their travels, each ray is vector-summed with all the others to create an overall far-field elevation pattern for the antenna/terrain combination. The reader might also want to read my article on this ray-tracing technique with diffraction and reflection in the July 1995 issue of *QEX*.

Things get *very* complicated, very fast, when a large number of rays are computed over even a moderately complex terrain. An analysis like *TA*'s has become practical only with the widespread availability of powerful desktop PCs in today's hamshack. In fact, *EZNEC* and all the Beezley programs require a minimum of '386DX + '387 coprocessor and VGA to run.

Rather wistfully, Brian related to me recently that he used to spend endless hours tweaking an antenna design, gaining perhaps 0.1 dB of extra gain, or maybe a 2 dB better front-to-back ratio. With *TA* he found that his super-tweaked antenna's performance at various elevation angles could easily be down 10 dB or more from what he expected. This was due solely to the effect of real terrain, as compared to ideal flat ground. He also mentioned that *TA* was one of the most difficult, painstaking programming tasks he had ever undertaken. Both he and I firmly believe that diffraction-modeling programs like *TA* herald in a new age of understanding about why certain antenna configurations at certain QTHs work the way they do (or don't).

To use *TA*, you first generate a terrain file by carefully taking multiple range/elevation data points off a USGS topographic ("topo") chart for your QTH. This is a painstaking task and you must do it for each azimuth direction of interest (towards Europe, Japan, South America, etc.), for more than a mile out from your tower base. You will also need a data file for the antenna you want to evaluate over your terrain. Beezley has included with *TA* more than 40 sample *.PF plot files. Each contains the free-space elevation amplitude and phase data for one antenna, ranging from a simple dipole to a monster 13-element 20-meter Yagi on a 320-foot boom. He also includes the terrain profiles for a number of prominent US contest stations, for fun and comparison. (Want to see how your QTH compares to that of KM1H or K5ZD?)

Figure 5 shows the *TA* output for the N6BV QTH towards Japan, using a single 60-foot high four-element Yagi at 14.0 MHz. The elevation response of the antenna is shown at the top, with a picture of the terrain at the bottom. *TA* is mouse-oriented. In Figure 5, I clicked on the elevation response at 6.25° to show the various reflection and diffraction components associated with this exit angle as they interacted with the terrain.

With *TA* you can even identify which terrain points affect the elevation pattern. You do this by "grabbing" a terrain point with the mouse and moving it up, down or sideways. When you release the mouse button, the elevation response is computed and displayed. I have dubbed this the "bulldozer" analysis mode—wouldn't it be great if our neighbors actually did allow us to sculpt their landscapes with a bulldozer to optimize our antenna patterns? *Manufacturer:* Brian Beezley, K6STI, 3532 Linda Vista, San Marcos, CA 92069, tel 619-599-4962. *Suggested retail prices*: *AO 6.5*, *NEC/Wires 2.0*, *YO 6.5*, *NEC/Yagis 2.5*, *TA 1.0*. Any one program: $60; three bundled together: $120; five bundled together: $200. Prices are postpaid, add $5 for international shipping.

Conclusion

In recent years computer modeling of antennas has become commonplace in the ham world, thanks in large measure to the programming efforts of W7EL and K6STI. A better understanding of existing antenna types—and even some brand-new forms of antennas—has resulted from intelligent application of modern modeling programs, especially *NEC2*-based modeling programs such as *EZNEC* and *NEC/Wires*.

Now, modeling the effects of terrain on the launch of HF signals opens up new possibilities for the systematic, scientific design of HF radio stations. And by the way, just how do you know what elevation angles you *should* be designing for and analyzing with a program like *TA*? Hint: Get the latest *ARRL Antenna Book*. The diskette bundled with the 17th edition contains a wealth of statistical data concerning the incoming elevation angles needed for all portions of the 11-year solar cycle. This data covers the entire US to important DX areas around the world. QST