

Build an APRS Encoder Tracker

Could your club or public-service group benefit from an affordable, real-time tracking system that can monitor the location of dozens of fixed or mobile items (people, assets, vehicles, locations, etc) on a high-resolution computer map? Of course! Using the ever-improving automatic position reporting system (APRS), you can now assemble an economical mobile tracking system using off-the-shelf and readily available parts.

The state of the Amateur art is often amazing, and the present-day sophistication and usefulness of the automatic position reporting system, APRS, developed by packet radio guru Bob Bruninga, WB4APR, is a shining example. Using APRS software, a simple encoder and *Streets on a Disk*, a professional-grade computer mapping program, you can create a sophisticated mobile tracking and status system that encodes real-time GPS data for transmission by an FM transmitter. This article describes how to construct this system using an FM transceiver or an inexpensive MFJ data radio operating at 144.390 MHz, the 2-meter APRS operating frequency in the US and Canada.

The system permits listeners (workers or volunteers at emergency response centers or other served agencies, for example) to track the location and status of multiple fixed and mobile vehicles (or other assets) using the detailed *Streets on a Disk* mapping program. Using this new system, a simple encoder (microphone- or fixed-mounted) changes the color of a vehicle's icon as displayed on the map to visually alert those monitoring of any changes in status.

During the Southern California 1993 firestorms, I recognized the need for accurate information regarding the location of volunteer amateur operators. I discovered that standard APRS software identifies a volunteer's general location when that volunteer has a GPS receiver connected to a TNC and interfaced to an FM transceiver—but the maps that accompa-

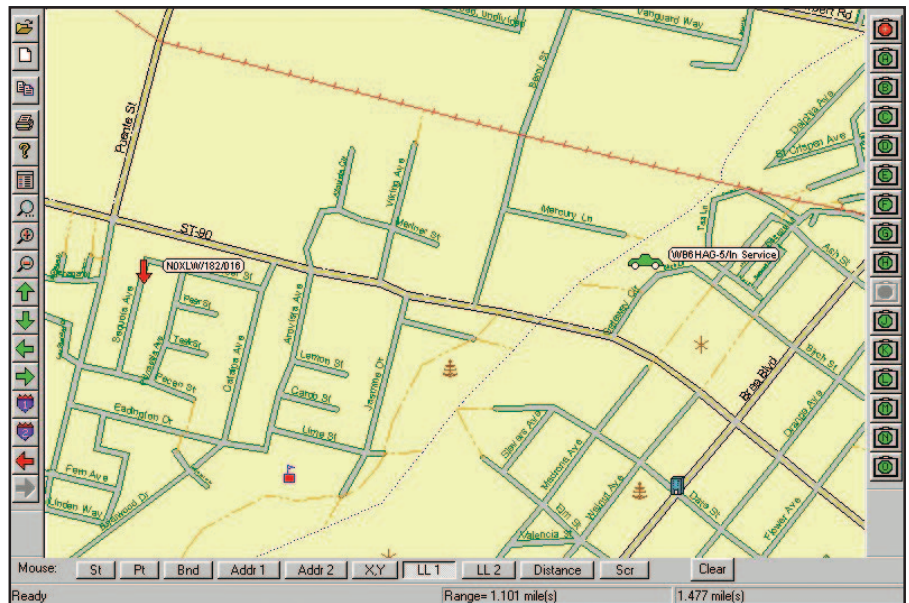


Figure 1—This *Streets on a Disk* map displays two methods of indicating a mobile station's location: with a red arrow (to indicate direction) or with a vehicle icon, in this case, a car. Call signs accompany each indication, and speed and course information accompany arrows, while status information accompanies vehicle icons.

nied the DOS version of APRS at that earlier date (*APRS-DOS*) didn't provide the street-level accuracy I required. To remedy this, I found a mapping program (*Streets on a Disk*, which I'll simply refer to as *Streets*) that solved this problem. I contacted Bob Bruninga, WB4APR, the author of *APRS-DOS*, and asked for help in interfacing his program with the new software.

Bob modified *APRS-DOS* to interface

with *Streets*. Scott Klynas, of Klynas Engineering (www.klynas.com), designed *Streets* to accept latitude and longitude data and other information from an external interface and integrate that information into its mapping system. Thus, the software displays moving vehicle icons with station call signs and other pertinent information defined by the user and *APRS-DOS*. (You can download a demo copy of *Streets* from www.klynas.com/

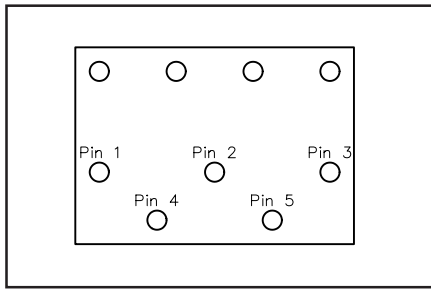


Figure 2—Pin locations of the previously installed DIN connector on the MFJ data radio PCBA.

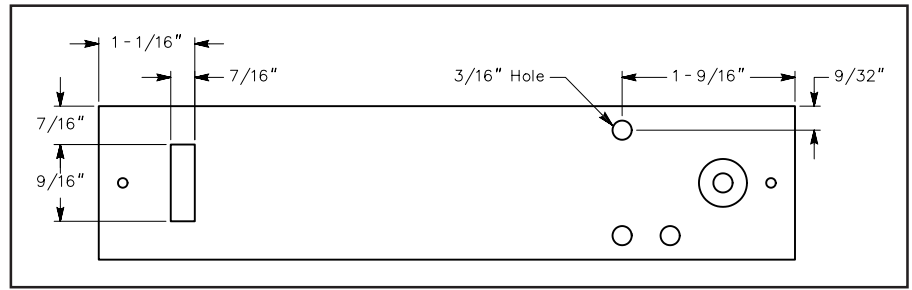


Figure 3—Dimensions for mounting the thumbwheel switch and LED to the front panel of the MFJ data radio.

free.html.)

WB4APR further enhanced his *APRS-to-Streets* interface by removing the DOS maps and adding advanced features. (This updated version, *APRS-STTS*, is available as a shareware from <ftp://tapr.org/aprssig/dosstuff/APRSdos/aprs-sts.zip>.) *APRS-STTS* takes advantage of the status messages generated by inexpensive encoders available from APRS Engineering (Mic-E and MIM modules) and Byonics (TinyTrak), as well as the encoders built into Kenwood TM-D700 and TH-D7 transceivers. *APRS-STTS* overlays the encoder status messages onto *Streets* maps.

Thanks to these new capabilities, the vehicle icons displayed on the maps now change color according to decoded status messages. For example, when a vehicle's status is "in-service," the vehicle icon is green; when the status changes to "returning," the icon turns white. Much like the sophisticated systems used by law-enforcement agencies, this feature allows receiving stations to quickly assess a vehicle's operating status. *Streets* shows the eight possible status messages as text, color or both, and displays the "emergency" status in a uniform manner for all vehicle types. That is, instead of displaying a vehicle symbol (car, truck, jeep, etc), a red rectangle with the station's identification and the word "Emergency!" is shown.

To accommodate a greater variety of indicators, *Streets*' icon table was expanded from 64 to 320 fields. Using *Streets* with an optional *GPS.STA* file translates the standard APRS symbol codes from *APRS-STTS* and displays them on *Streets* maps (*GPS.STA* is available free with complete instructions from <ftp://www.klynas.com/APRSSTS.ZIP>). APRS symbols include red arrows and vehicle icons that change color according to received status messages. The arrows identify a moving vehicle's direction and speed. (*APRS-STTS* translates GPS course and speed information and uses a red arrow to display that information on the *Streets* map.) The red arrow is user-configurable and may be disabled to display the correct APRS vehicle icon.

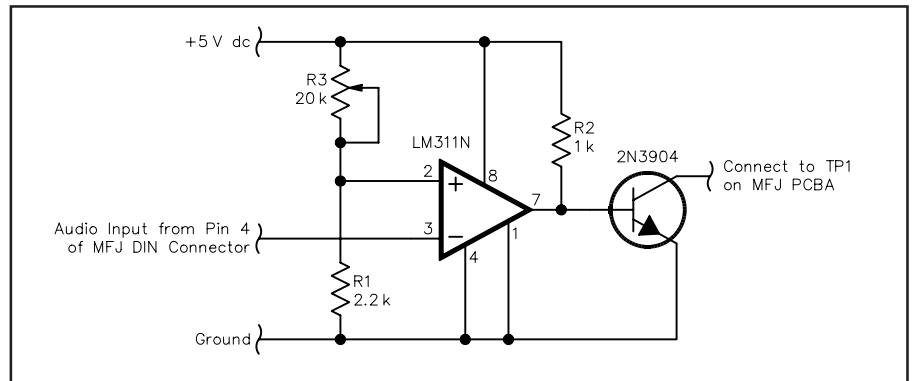


Figure 4—Squelch circuit for the MFJ data radio.

Parts List

Byonics

TinyTrak I with Mic-E Option

Digi-Key

2- $\frac{1}{2}$ -inch male/female threaded hexagonal standoffs, part no. 8401-ND

20-k Ω potentiometer, part no. K4A24-ND

End caps, part nos. CH194-ND and CH195-ND

LM311N-ND IC

Thumbwheel switch, part no. CH185-ND

Garmin

GPS30 magnetic mounting kit (optional)

GPS35-HVS GPS receiver

MFJ

8621-X2 data radio

RadioShack

0.1- μ F capacitor, part no. 272-0109 (optional)

1-k Ω , $\frac{1}{4}$ -W resistor

1N4148 diodes

2.2-k Ω , $\frac{1}{4}$ -W resistor

2N3904 transistor

8-pin IC socket (optional)

DIP shunt shorting jumpers, part no. 276-1512

Vector board, part no. 276-0148

APRS-STTS also translates APRS vehicle symbols to a car or van icon whenever it decodes an encoder status message. This information is transferred to the *Streets* maps and is displayed as various car or van colors with a reference to the status message. Users can disable this option, which causes *Streets* to display the correct vehicle type (rather than a car or van) with its corresponding status color.

Generating the correct status information requires an encoder that's compatible with the Mic-E standard. The APRS Engineering Mic-E/MIM encoder is compatible, but if you use a Byonics TinyTrak encoder you must order the Mic-E option (an additional \$5 at press time). The encoders built into Kenwood TM-D700 and TH-D7 transceivers work great, but you may find that the steps required to select status messages to be a bit complex in the field (you have to wade through several menus to make the switch). With a Mic-E/MIM or TinyTrak, you simply flip or rotate a switch to change status messages.

Building the Tracker

Adding a GPS receiver to Kenwood TH-D7 or TM-D700 transceivers and using their built-in Mic-E encoder circuitry is the simplest way of assembling a mobile tracker. Using the transceiver's somewhat cumbersome menu structures

to change status information may be more complex than using a Mic-E/MIM or TinyTrak. So, this article describes how to assemble the simpler system using the encoder with an MFJ 8621-X2 data radio or another 2-meter FM transceiver.

If you choose to use the MFJ VHF Data Radio, Model No. 8621-X2, tuned to 144.390 MHz, you'll need a GPS receiver, an analog-to-BCD converter (a simple BCD thumbwheel switch), a squelch circuit and a Mic-E-compatible encoder assembly. Using your own VHF FM transceiver, you need the same devices minus the squelch circuit.

MFJ 8621-X2 Modifications

Before you tear into your MFJ 8621-X2 data radio to fit the encoder and associated parts, be aware that any modifications—including these—technically void the factory warranty. That said, I used the Byonics TinyTrak encoder for this modification (the APRS Engineering Mic-E/MIM encoder works, too), along with a Garmin GPS35 TracPak 12-channel receiver.

Getting Started

Remove the printed circuit board assembly (PCBA) from the MFJ chassis.

Remove the five-pin DIN data connector and dc power receptacle from the PCBA.

Prepare four insulated #26 wires of different colors, one cut to six inches and the others cut to four inches in length.

In the location where the DIN connector was previously installed, solder separate wires to pin numbers one and three, and two wires (one 6-inch and one 4-inch) to pin number four on the PCBA (see Fig-

ure 1 for the pin locations). Identify which colored wire is connected to each pin number. I chose white for pin one (AFSK In), yellow for pin three (PTT), and two blue wires for pin four.

Strip the unconnected end of each wire and twist them all together with the exception of the six-inch wire on pin four. The ends will be soldered later to the squelch circuit and the TinyTrak.

Prepare the following: four #26 wires (two red and two black) cut to six inches in length, and an #18 red and black power-lead pigtail, 12 inches in length.

Connect the red wires to the positive side of the dc power circuit and the black wires to the negative side. Be careful not to short any adjacent circuits while soldering these wires in place and do not install a power connector on the other end of the power cable pigtail until you have reinstalled the PCBA into its metal chassis.

MFJ Metal Chassis Modifications

The MFJ front panel requires a square hole for mounting the BCD thumbwheel switch and a round hole for mounting a yellow LED that indicates when the GPS receiver is locked onto the satellites.

The size of the square hole depends on the size of the BCD thumbwheel switch you use. I used the 10-position BCD cherry thumbwheel switch from Digi-Key (part no. CH185-ND) and its associated end caps (part nos. CH194-ND and CH195-ND). Using this switch assembly requires cutting the square hole at the location with the dimensions shown in Figure 2. Make sure your switch hardware is positioned so it will not interfere with the MFJ PCBA.

Drill a $\frac{3}{16}$ -inch hole for the yellow

LED at the location shown in Figure 2. Drill the MFJ front cover plate first and use it as a drilling template for the aluminum chassis.

The large hole on the back of the MFJ chassis must be enlarged to $\frac{3}{4}$ inch to permit an electrical clamp to be screwed into the chassis. This clamp is used to protect and secure the GPS receiver wires that will be installed later. You may choose another fastener, if desired.

Squelch Circuit Assembly

The MFJ data radio needs a squelch circuit for the encoder to function properly. I found the circuit shown in Figure 4 at various Web sites and made some modifications. It can be built on a vector board from Radio Shack.

This circuit is simple to construct and fits nicely inside the MFJ data radio housing. Its required 5-V dc power is provided by the TinyTrak PCBA, as described in the next section. You can replace potentiometer R3 with a fixed resistor once you determine the value required to set the squelch level, as described in the Testing section below.

Connect the blue wire at pin four of the MFJ DIN connector to pin three of the LM311 IC to provide audio input to the squelch circuit.

Connect the collector of the 2N3904 transistor to TP1, located on the MFJ PCBA near the data DIN connector.

TinyTrak Assembly

Assemble the TinyTrak PCBA according to the instructions provided with the following exceptions: Do *not* install LEDs D3 and D4 and resistors R12 and R13 (see Figure 5). I installed the green LED for D1 and the yellow LED for D2, but attached a six-inch wire pigtail to the yellow LED leads and connected the other end of the pigtail to the TinyTrak PCBA at location D2. Later you will mount this LED into the $\frac{3}{16}$ -inch hole drilled into the MFJ radio's front panel and secure it with silicone adhesive. This LED shows when the GPS receiver is locked and providing accurate data.

Only one 1N4148 diode is provided in the kit. You need to purchase or scrounge two more from Radio Shack or elsewhere. When installing D5, install it on end into the PCBA with the band facing toward you and bend its opposite lead into a loop or hook near the body of the diode. Duplicate this process with the remaining two diodes and place their respective ends into mountings holes located near pins 12 and 13 of the IC. The TinyTrak PCBA has a silk-screened "number 1" next to the hole for IC pin 12 and a "number 2" next to the hole for IC pin 13. Once completed, you will have

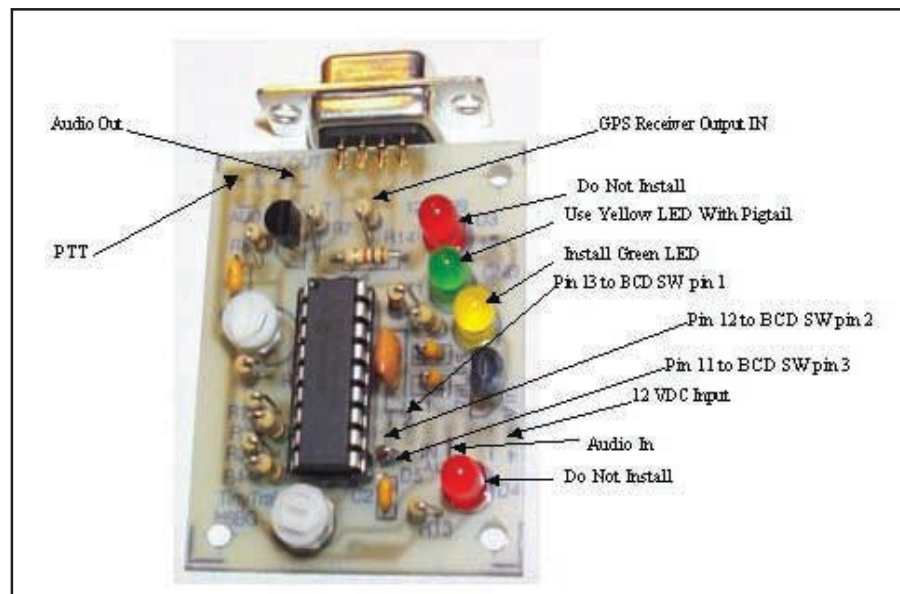


Figure 5—Modified TinyTrak circuit-board assembly.

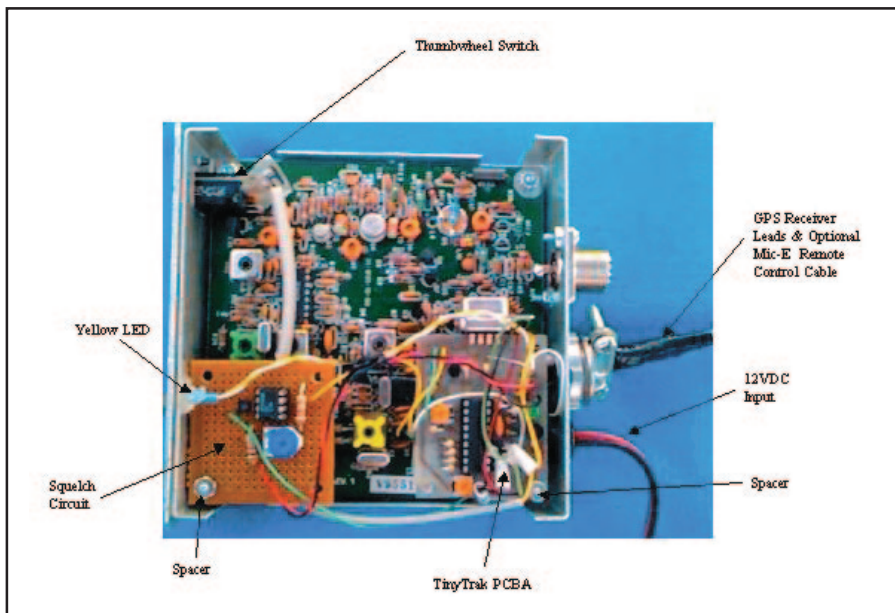


Figure 6—Modified MFJ data radio.

three diodes standing on end near IC pins 11, 12 and 13.

Connect a five-inch length of red #26 wire from the output of the Q2 5-V regulator and a five-inch length of black #26 wire to the ground pad near the Q2 regulator, then twist these wires together. This pigtail will power the squelch circuit. Connect the other ends of the pigtail to the squelch circuit PCBA power input, red wire to 5 V dc and the black wire to ground.

Attach the free ends of the red and black wires from the MFJ PCBA power connection to the 12-V dc input holes on the TinyTrak PCBA.

At this time, program the TinyTrak with your call sign and vehicle token type according to the encoder's instructions.

Sub-Assemblies

Install the MFJ PCB assembly back into its chassis.

Insert the main MFJ PCBA power lead pigtail through the small hole where the power connector was previously located. I used a strain relief purchased from Radio Shack to secure the pigtail in the hole and soldered a two-pin connector to the wire ends.

Solder the antenna bus wire to the SO-239 center connector.

Do not install the two #4-40 nuts on the screws located on the right side of the MFJ PCBA. Instead, use a hexagonal 1/2-inch male/female threaded standoff (Digi-Key part no. 8401-ND) and mount one nut on each screw end. These are used for mounting the squelch circuit and TinyTrak PCBA (see Figure 6). When

mounting it (later), make sure you place a piece of insulating material (double-sided tape, cardboard, etc.) between the TinyTrak PCBA and the top of the MFJ's metal coil enclosure that sits below the TinyTrak assembly. Otherwise, you will short its circuitry.

I used a Garmin GPS GPS35-HVS receiver for this project because the receiver is actually embedded into the antenna housing—it's essentially a "plug and play" assembly. I inserted the GPS receiver/antenna cable through the wire clamp mounted on the backside of the MFJ chassis and soldered the black and red power leads to the MFJ PCBA 12-V dc connection point mentioned previously. The white lead from this cable is connected to the GPS input on the TinyTrak PCBA. The remaining GPS cable leads are not used.

The remaining wires connected at the MFJ data DIN connector will now be attached to the TinyTrak PCBA. The wire located at pin one (white) is soldered to the "audio out" point, DIN pin three (yellow) is soldered to the PTT point, and pin four (blue) is soldered to the "audio in" point. Mount the TinyTrak PCBA on the standoff nearest the back MFJ housing by using the #4-40 nut that once held the MFJ PCBA in place at that location. The TinyTrak PCBA will rest on an MFJ coil enclosure. Make sure you placed insulating material between the two.

Pre-wire the thumbwheel switch using three #26 wires of different colors (red, green and yellow). Cut them to 12 inches in length and twist them together. Cut a black #26 wire to four inches and solder

Sources

APRS software and Mic-E Encoder: APRS Engineering LLC, 115 Old Farm Ct, Glen Burnie, MD 21060; www.toad.net/~wcllement/bruninga/mic-lite.html; <ftp://tapr.org/aprssiig/dosstuff/APRSdos/aprs-sts.zip>

TinyTrak: Byonics, Byron Garrabrant, 8378 Granite Mountain Ln, Las Vegas, NV 89129; www.byonics.com

Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677; tel 800-344-4539, fax 218-681-3380; www.digi-key.com

Garmin, 1200 E 151st St, Olathe, KS 66062; tel 913-397-8200, fax 913-397-8282; www.garmin.com

Streets on a Disk: Klynas Engineering, PO Box 1818, Santa Maria, CA 93456-1818; tel 805-938-9988, fax 805-938-0988; www.klynas.com

MFJ 8621-X2 data radio: MFJ Enterprises, PO Box 494, Mississippi State, MS 39762; tel 800-647-1800, fax 662-323-6551; www.mfjenterprises.com

APRS-STX: Jim Carter, WB6HAG, 2029 W Hall Ave, Santa Ana, CA 92704; <ftp://www.klynas.com/APRSSTX.ZIP>

one end to the switch terminal "C" pad. Solder the red wire to pad two, green to pad four, and yellow to pad eight of the thumbwheel PCBA pads. Pass all the wires through the front of the MFJ panel at the pre-cut switch opening. Solder the black wire coming from terminal "C" to the MFJ's PCBA ground plane. Install the thumbwheel switch into the front side of the MFJ panel opening. Solder the opposite ends of the remaining switch wires to the diodes at Pins 11 (red), 12 (green) and 13 (yellow) on the TinyTrak PCBA. You might want to place shrink tubing onto each wire lead before soldering the wires to the diodes. This will help to eliminate any potential shorts.

The yellow LED, mounted on the six-inch pigtail on the TinyTrak PCBA, is mounted into the MFJ front-panel hole and secured with silicone adhesive.

Use a short piece of wire to connect the squelch circuit input to TP1 on the MFJ PCBA assembly. I used DIP shunt shorting jumpers from Radio Shack (part no. 276-1512) and connected the wire from the squelch circuit input connection to one side and connector TP1 to the other side, located near the DIN connector area. This eliminates any soldering in that area

since the shunt slides nicely over TP1.

Connect pin four of the MFJ DIN connector (blue wire) to pin three of IC, LM311, located on the squelch assembly board. The second wire (blue), located on pin four of the DIN connector, is connected to the TinyTrak audio input pad, and the MFJ DIN connector pin one (white wire) is connected to the TinyTrak audio output pad. This completes the assembly process.

Mount the squelch assembly onto the front standoff in the MFJ housing by using the #4-40 nut that once held the MFJ PCBA in place. Do not install the cover until testing is complete. It's advisable to add an insulator to the top inside cover above the area where the TinyTrak PCBA is located (I used plastic tape). This eliminates any possible shorting between the TinyTrak resistor leads and the top cover.

Testing

Double-check your wiring before applying power, then set the thumbwheel switch to position 0. Attach an antenna to the antenna connector on the MFJ data radio, place the GPS antenna in a location that can "see" the sky as clearly as possible and apply 12 V dc to the MFJ radio's power lead.

Depress the power switch on the MFJ radio. The MFJ power LED will glow and the green LED located on the TinyTrak will flash several times to indicate the firmware is working properly. The yellow LED (mounted on the MFJ front panel) will blink once every second until a GPS signal is locked, then it will glow steadily.

If you used a fixed resistor at R3, you

simply have to adjust R9 until the green LED goes off when there is no signal.

If you didn't use a fixed resistor to replace potentiometer R3, adjust R3 until the green LED lights on the TinyTrak PCBA. Next, adjust R9 on the TinyTrak until the green LED goes out. Then, slowly turn R3 in the opposite direction until the green LED comes on again. Use another VHF receiver to monitor 144.390 MHz and adjust R3 so the green light just goes out when no APRS signals is heard on the other receiver. When adjusted correctly, the green LED turns on when a signal is received.

The MFJ data radio should now be transmitting at the prescribed time you programmed into the TinyTrak. If the TinyTrak remains keyed after the transmitter is unkeyed, install 0.1- μ F capacitors across the base and emitter of the 2N2222 transistor to ground.

Adjust R6 on the TinyTrak PCBA for proper modulation by using a deviation meter or by listening to your VHF receiver on the other VHF receiver used earlier. If the modulation level is set too high you will hear the tones change pitch, which indicates that the transmitter is clipping the audio. As a result, other stations will not be able to decode your packets.

Once everything is working properly, select a thumbwheel switch setting to indicate your mobile status. The status positions are as follows:

- 0 = off duty or out of service
- 1 = en-route
- 2 = in service
- 3 = returning
- 4 = committed

- 5 = special
- 6 = priority
- 7 = emergency
- 8 = not used
- 9 = not used

The MFJ radio will now transmit your status based upon the setting of the thumbwheel switch and cause the color of your vehicle icon to change on the *Streets* map to represent your vehicle status.

Install the top cover of the MFJ radio, making sure no circuit assemblies short out to the top cover. Installing insulating material to the underside of the cover prevents this from occurring.

Conclusion

If you experience any problems with *APRS-STS*, *Streets on a Disk*, or TinyTrak products, please contact the respective developers for assistance.

I hope you find this system helpful in your daily activities or during emergency operations at EOC, RACES or ARES events. If you have questions regarding this system, please email me at the address below.



Jim Carter, WB6HAG, is the Product Compliance and Regulatory Manager for Yamaha Corporation of America, where he is responsible for FCC, UL and environmental compliance matters. He received his amateur license in 1963 and holds an Amateur Extra class license, as well as the General Radiotelephone license. An ARRL member, he's active in the Orange County RACES. You can contact the author at 2029 W Hall Ave, Santa Ana, CA 92704; jecarter@ix.netcom.com.