Rainbow Tuner Lives Again

by Joe Everhart, N2CX n2cx@voicenet.com
and George Heron, N2APB n2apb@amsat.org

Back in 1996 the NJQRP Club unleashed the Rainbow Tuner as its first kit in the QRP community. The kits were an instant success with hams all over the world building the project and using it as stand-alone QRP ATU's and built into other equipment and rigs. App notes were written, add-on projects were created and novel circuit adaptations were made. Kitting was stopped in 1998 as we moved on to other club projects, but many newcomers have been asking for the rebirth of the Rainbow Tuner Kit... so here we go again!

This circuit really doesn't tune rainbows, but it does use a rainbow of sorts. It embodies the Spartan design philosophy exemplified by the 40-9er, the Pixie, the Fireball 40, the MRX-40, and other simple QRP "rigs" available today. It combines a very special antenna tuner with a simple-to-use and accurate SWR meter. Intended to fit in the popular Altoids mint tin, it can be built for under $25. The heart of the Rainbow Tuner is a user-friendly SWR indicator that can be used by itself or in other homebrew projects.

The antenna tuning function is performed by L1 and C7, as illustrated in Figure 1. In the configuration shown they are connected as a parallel-tuned resonant circuit with a tapped output. It is intended for use with a half-wave end-fed wire. The high impedance presented by the half-wave wire is transformed to 50 ohms by taps on the toroidal coil. A compression mica trimmer capacitor is used to tune out any reactance presented by the antenna and inductor taps are selectable to give a close match to a 50-Ohm feedline.

A novel SWR bridge was presented in the June 1995 issue of QST by K1KP. It used the familiar toroid type SWR bridge and replaced the meter with LEDs. It had not means of displaying actual SWR but merely a relative indication via brilliance of its LEDs.

The Rainbow SWR indicator uses a bridge circuit more suited to QRP operation and a self-adjusting LED indicator that is only slightly more complex than K1KP's, but providing relative indications for tuning and and exact final SWR reading.

The SWR bridge in Figure 1 consists of resistors R1, R2 and R3. R1 and R2 for a voltage divider with exactly half the input voltage present at their junction. This is rectified by D1 to produce a DC voltage proportional to forward RF power. The other half of the bridge is comprised of R3 and the output load – either an antenna or the tuner circuit, whichever is connected. When the

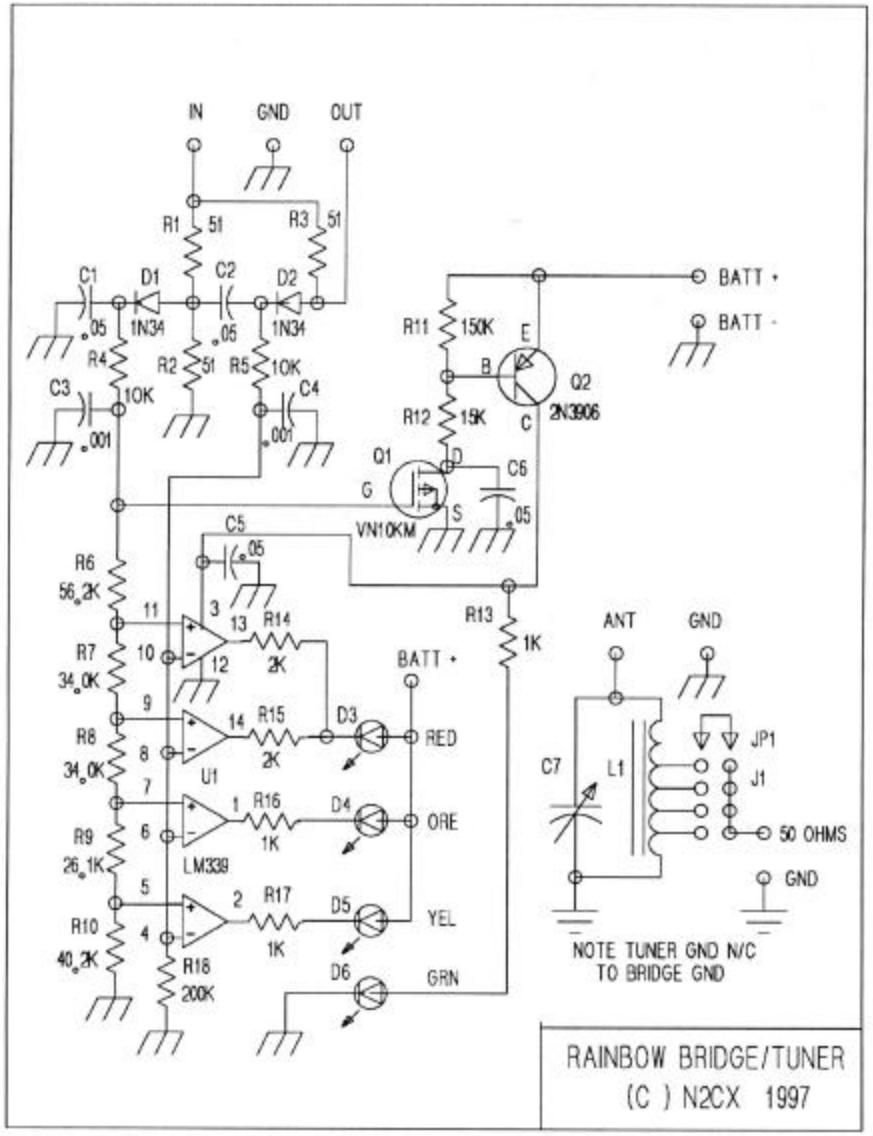

Figure 1: Layout of the Rainbow pcb in the mint tin enclosure

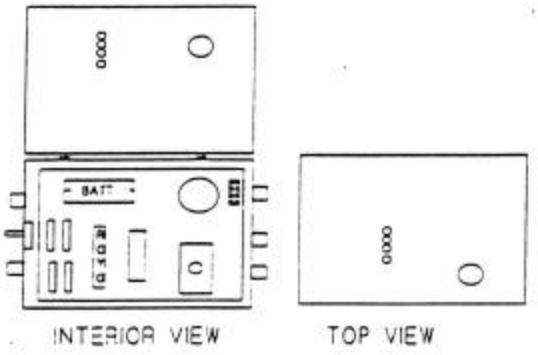

Figure 1: Layout of the Rainbow pcb in the mint tin enclosure

load is 50 ohms, the voltage at the junction of R3 and the load is the same as the R1-R2 junction. This corresponds to a 1:1 SWR and the voltage difference across the bridge arms is zero. When the load is not 50 ohms, the difference voltage is proportional to the SWR. D2 rectifies the difference voltage to provide the reflected voltage.

Using resistors for the SWR bridge provides a real advantage when using the Rainbow Tuner with simple QRP rigs. Most SWR indicators pass their output SWR right on through to the rigs driving them. Transmitters like the one used in the 40-9er and other misbehave with high SWR loads. At best they become unstable and may oscillate, generating off-frequency spurious signals. At worst, a high SWR load may destroy the final transistor. The absorptive bridge in the Rainbow tuner limits the SWR that the transmitter sees to at most 2:1.

Most SWR measurement devices require the operator to adjust for full-scale meter reading on forward power and then switch to a reverse power reading to read the reflected energy. The Rainbow tuner eliminates this complication. It uses the fact that in an SWR bridge the reflected voltage is a fixed fraction of the forward voltage. For example, with a 3:1 SWR, the reflected voltage is always half the forward voltage, no matter what power level is used. As shown in the schematic, the forward sample is connected to a voltage divider RX through RZ. The resistors are chosen to set a fraction of the forward voltage at comparator U1 inputs to correspond to 5:1, 3:1, 2:1 and 1.5:1. The other comparator inputs are fed directly by the reflected voltage. LEDs at the outputs of the comparators indicate SWR by lighting in response to the compared forward and reflected voltages.

The multi-colored LEDs form the rainbow display. As shown in Table 1, only the green LED is on when SWR is less than 1.5:1,

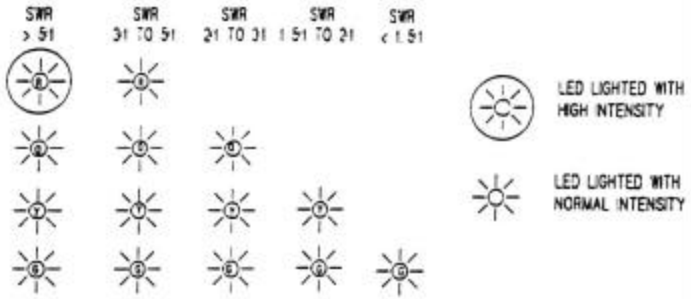

Table 1: Rainbow Display Intensity

both the green and yellow LEDs are on with SWR between 1.5:1 and 2:1, and so on. Two levels of intensity are provided on the red LED for the highest SWR because I ran out of colors for inexpensive LEDs! No voltage regulator is needed by the comparator since it relies only on the resistive divider for accuracy.

The SWR indicator is switched in or out of the circuit by DPDT toggle switch S1. It is not connected at all times for two reasons. First, the tuner has a 6 dB loss, even with a good match to the antenna. Secondly, power is required for illuminating the LEDs when the indicator is being used.

The tuner SWR indicator senses RF and turns itself on with less than 150 mW of RF. Q1 is a special MOSFET with a very low turn-on voltage. I've measured a number of them and all have turned on with less than 1.5 volts.

Recommended battery B1 has a rated capacity of only 33 mAH and the indicators draw from 10 to 50 ma, depending on how many are illuminated. Battery life is prolonged by using the indicator only when needed. Even longer life can be achieved with a 9-volts alkaline battery but it won't fit into the mint tin along with the Rainbow pc board.

The tuner is sized to fit in an Altoids mint tin with room for the SWR bridge selection switch and some small connectors. I used RCA phono jacks because of their small size. The bridge has its own input and output jacks which can be connected to the tuner section with a small coax jumper. This way the tuner and SWR bridge can be used separately, if desired. One could alternatively use a small switch between the bridge and tuner sections to eliminate the extra connector and jumper lead.

The pc board fits into the tin and is insulated from the metal box by a piece of cardboard beneath it. The battery is installed in a holder for a type-N cell. Access to the tuner's variable capacitor is made via a hole punched in the mint tin's lid. Size 6-32 screws and knurled nuts are used for antenna wire and counterpoise connections. Shoulder washers insulate the "hot" antenna wire hardware.

The display LEDs are plugged into a single inline socket strip cut down to 8 pins. The LED leads are bent at right angles so that the socket can be glued inside the mint tin with the LEDs being visible through holes in the tin lid. A short piece of ribbon cable connects the inline socket to the respective pins on the pc board. I prefer to use pins in pc boards to connect external wires – pins like the Vector T-44 types are soldered to the pc board and wires going off-board are soldered to them.

Operation is very simple. To use just the SWR bridge, attach the rig and antenna cables to the proper connectors and set the switch to the "in-line" position. As soon as you transmit, the circuit will turn on and you can read the SWR using the LEDs. When the RF disappears, the tuner shuts off the DC power. When not in use, like during a QSO, set the switch to "bypass".

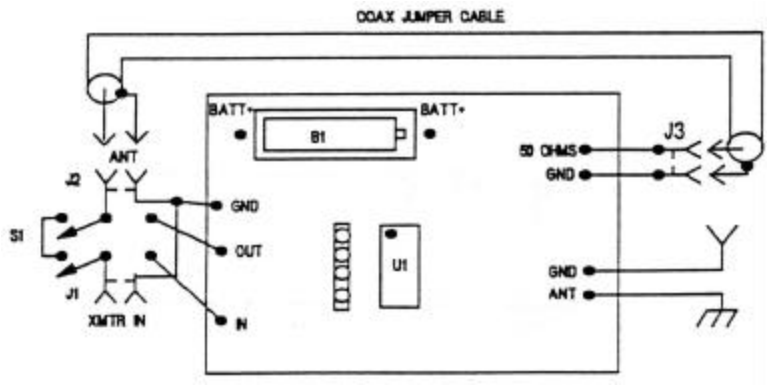

Figure 2: Off-board connections to the Rainbow Tuner pc board

The antenna tuner is intended for a half-wave end-fed wire. An antenna of this type presents an impedance of 1,000 to 10,000 ohms or so. To check out the tuner and learn how it works, connect a non-inductive resistor in that range across the antenna and ground terminals and a coaxial jumper from the tuner phono jack to the SWR bridge ANTENNA jack. Use a 40-meter rig with an output of 150 mW to 1 Watt to feed the RIG jack. Set the tuner tap jumper between the LOW Z taps.

Set the switch to the "in-line" position and key the transmitter while monitoring the LEDs. Adjust the tuner's variable capacitor for the lowest SWR, using a non-metallic tuning tool. If it isn't below 1.5:1, try the next higher tap and repeat the tuning. You should be able to find a tap and tuning setting that illuminates only the green LED.

Tuning with an antenna is done the same way. Use a single ire about 67 feet long and at least one 33-foot wire as a counterpoise. Try to get the antenna wire about 15-20 feet off the ground. Key the transmitter and tune as done with the resistor load. Due to the tuner's limited adjustment range you may find it necessary to trim the antenna slightly to get minimum SWR. It is recommended that once you have found a wire length that tunes up well, always use that wire and counterpoise.

The parts indicated in the schematic were selected for maximum accuracy and performance. Some substitutions can be made, however, with more available components. R1, R2 and R3 directly affect bridge accuracy and the unit's power handling capability. One can use 47-ohm 5% values with only a slight effect on accuracy. Half watt values will be adequate for intermittent use with transmitter power levels up to 2 watts. Smaller wattage resistors will burn up at that power level. One watt values will handle up to 4W input, and 2W resistors theoretically can handle up to 8W input power. Prolonged transmit periods will cause excessive component heating. Precision resistors are shown for R6 through R10 and R18 in the comparator circuit. 5% values can be substituted but will result in degraded SWR accuracy.

NOTES:

1) For further technical detail, refer to the Rainbow Tuner web pages on the NJQRP website, located at http://www.njqrp.org/Rainbow/rb_home.html.

2) A complete Rainbow Tuner Kit may be purchased from the NJQRP Club. All on-board parts, a printed circuit board, an Altoids mint tin, and a comprehensive assembly manual are all included for $28 postpaid (DX orders add $5, please). Write check or M.O. payable to "George Heron, N2APB" and send to 2419 Feather Mae Court, Forest Hill, MD 21050. Orders and payments are also accepted through PayPal by sending funds to n2apb@amsat.org