A 10M Sideband Transmitter

Add voice to your QRP station.

by Bruce Auld NZ5G

Described in this article is a relatively simple, VFO controlled, double-sideband transmitter with 1 watt output for 10 meters. It's capable of easy and comfortable communications. For example, while this transmitter was still breadboarded, with its innards splayed all across my station operating table, I contacted K7EVL in Wenatchie, Washington, on the first call. He checked my signal, and he, my two-year-old Katie, and I had a merry contact.

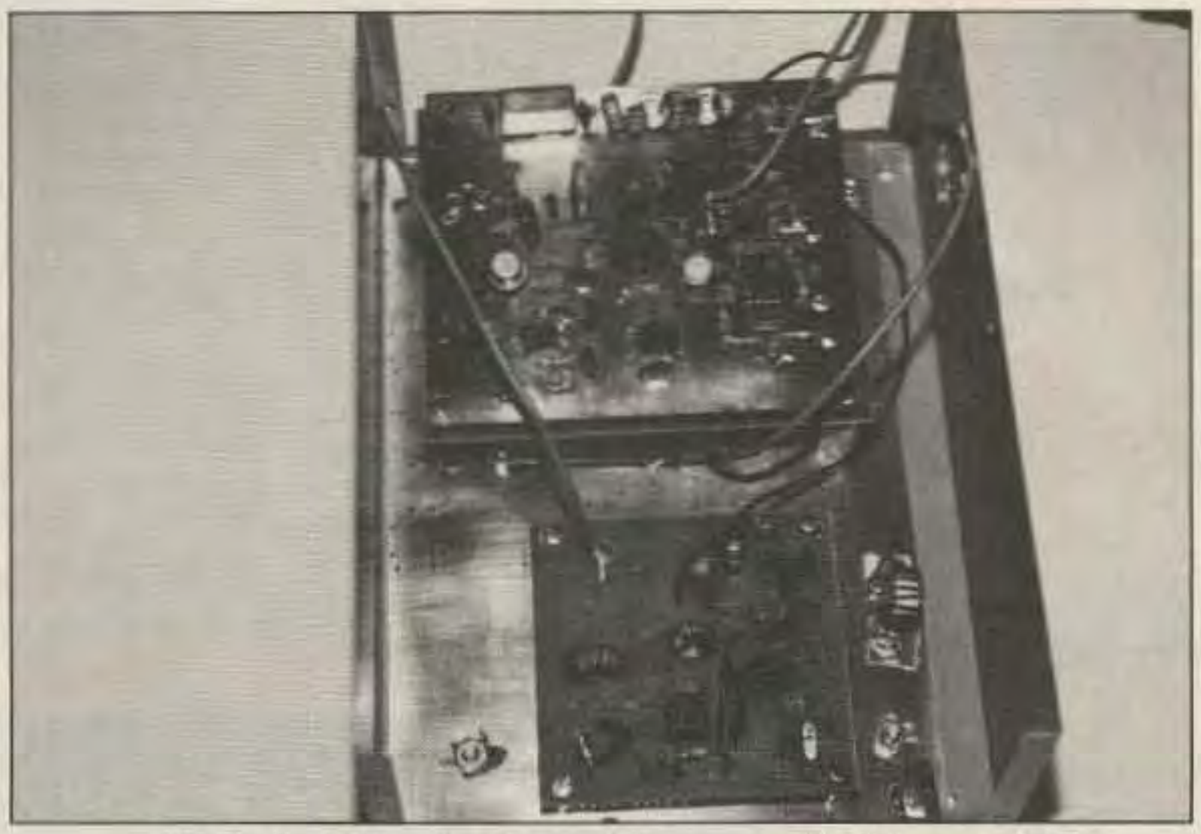

Photo A. A 10 meter transmitter you can build yourself!

The sideband transmitter is designed for hams who are interested in construction. It is also aimed at hams who are neither technicians nor engineers, but who possess some knowledge of RF construction technique. Where possible I've used commonly found parts, commonly used values, and the smallest number of different parts possible. Unless you live in a major city, however, you may have to mail-order some of them.

This project is my distillation of the excellent work of W7ZOI and WA7MLH, whose projects taught me the vagaries of sideband generation. It employs simple, known circuitry with no surprises. It is not single sideband because of the added expense and circuitry to filter the unneeded sideband. However, with plenty of room to spare on 10 meters, this is no problem. The transmitter employs a manual transmit/receive scheme so that inexpensive microphones without PTT mechanisms can be used, and it is intended to be used with the ham's existing station receiver.

The Circuit

Figure 1, the block diagram, shows the flow of the transmitter. The whole of the circuit is designed in modules and interconnected to form a team. Constructed this way, it's easier to understand and troubleshoot.

Referring to Figures 2, 3, and 4, the transmitter is centered around an 11 MHz IF. This frequency was chosen only because I had a bunch of 11 MHz crystals on hand. Any convenient combination of frequencies for the IF/VFO combination can be used to reach the 28 MHz goal. The transmitter employs the simplest form of sideband generation, a single transformer and two diodes. It is fed with audio from the mike and its amplifier, and mixed with the 17.5 MHz VFO signal. In order to place the VFO frequency as low as possible for stability, a mixing scheme was used (hence another 11 MHz crystal). For this purpose, the magical NE602 was used, which is a wonderful device. This chip is a double-balanced mixer boasting an

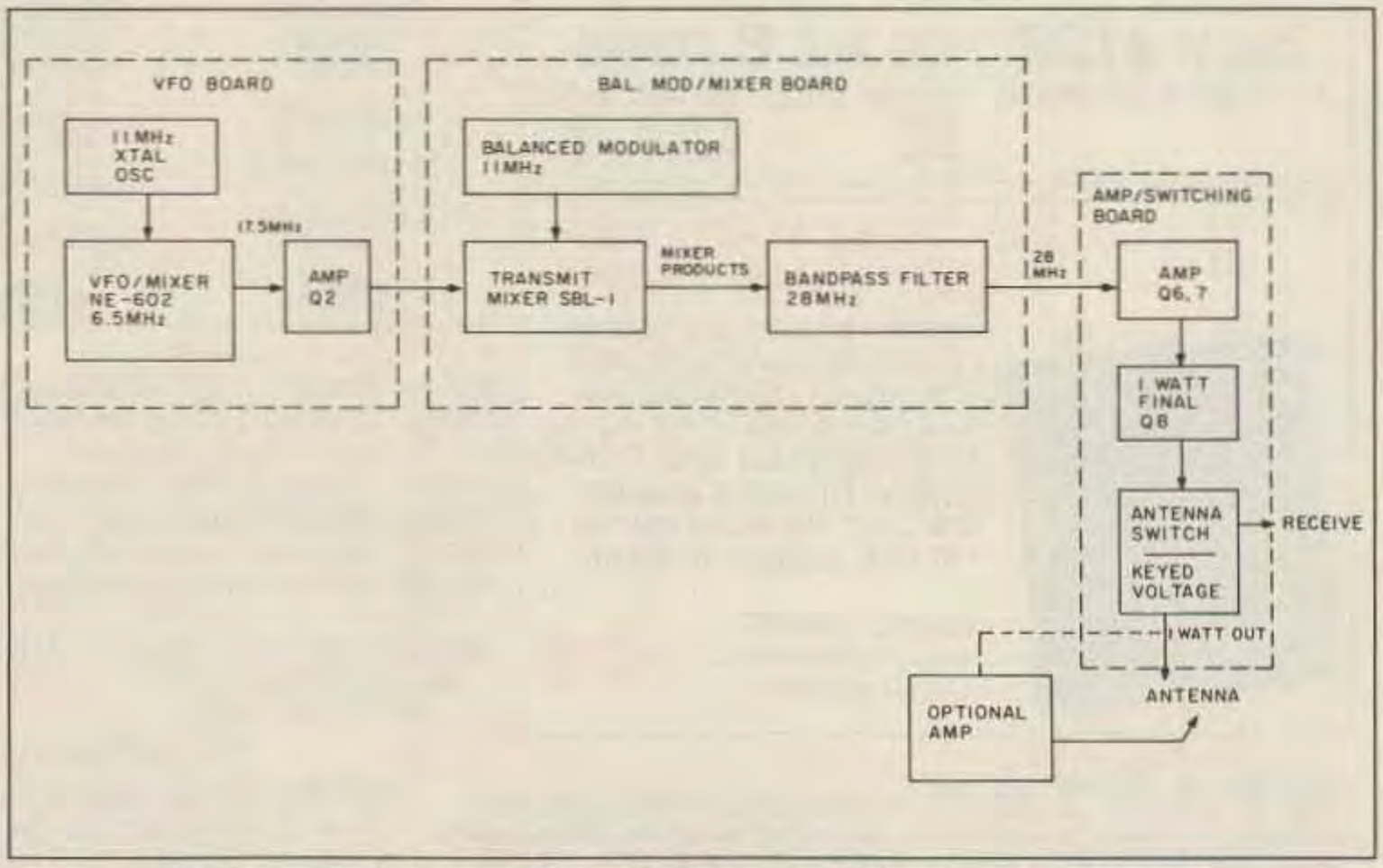

Figure 1. Block diagram of how the 10 meter sideband transmitter works.

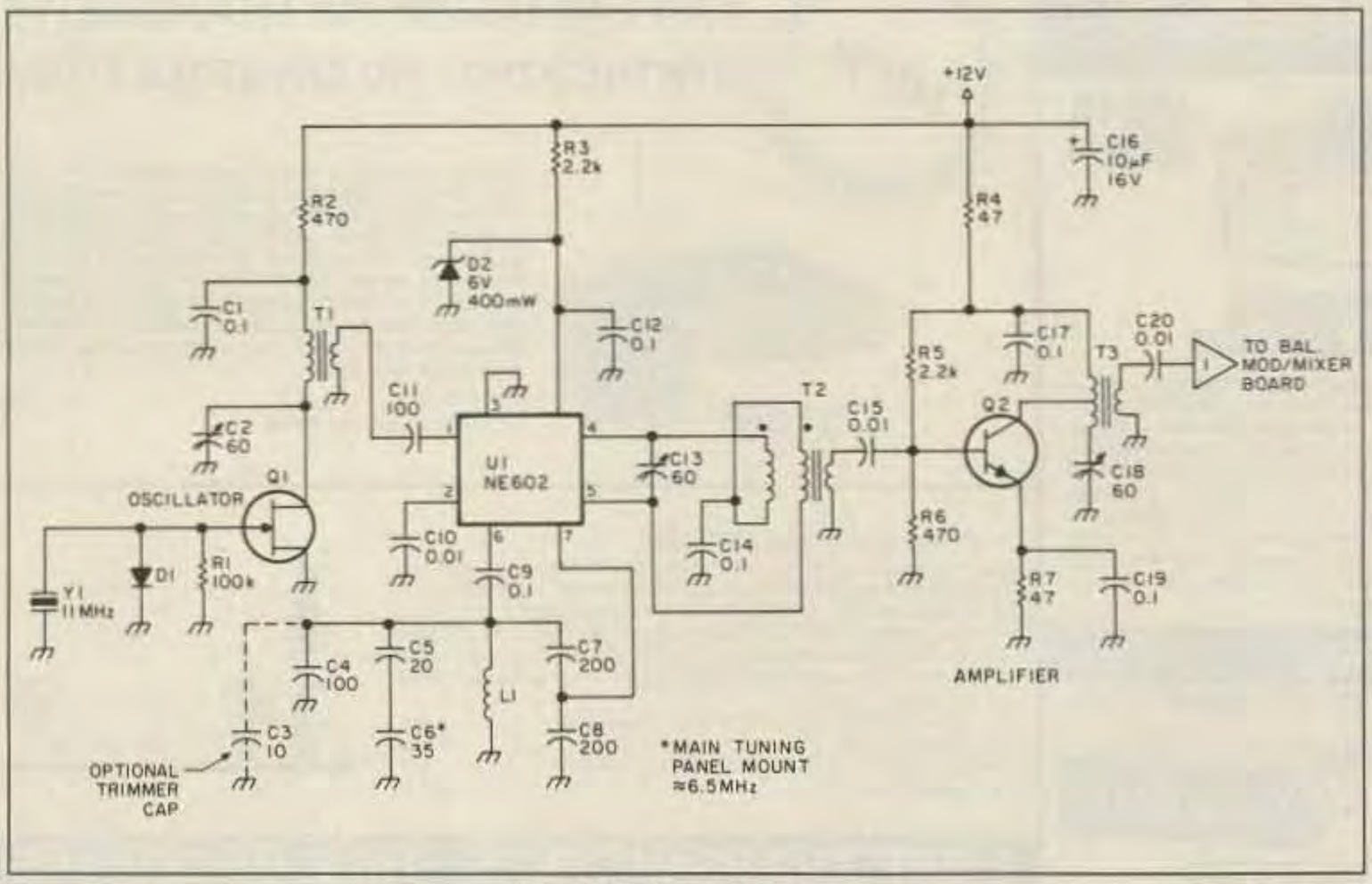

Figure 2. The VFO board.

onboard oscillator. A very respectable signal can be developed with one of these.

The signals from the sideband generator and VFO are amplified and fed into a diode-ring mixer module, U3. The jumble of frequencies that emerge go through a 28 MHz three-pole bandpass filter and a very nice 50 mV 28 MHz signal results. From here it only needs to be amplified. The next two stages are simple class A broadband amplifiers. The final amplifier transistor is the well-known 2N3553. In my unit, however, I use an inexpensive alternative, an RCA 4013 that I purchase from my friendly local parts merchant in single lots for 89 cents each. It performs equally well, and I appreciate the price more each time I destroy one experimenting.

The switching circuitry is designed to change the antenna from receiver to transmitter and to apply voltage to the amplifier chain during transmit periods. The NE602 VFO stage is free running for the sake of stability, but the carrier oscillator in the balanced modulator is normally off. This stage is switched on during transmit periods and for spotting your frequency in the station receiver. This is necessary because you would otherwise hear your carrier (though it has been suppressed) in the receiver all the time. These functions are carried out by a simple DPDT relay and two SPDT toggle switches.

Construction

The transmitter is constructed on three separate circuit boards. Their size was chosen mostly at random, but I have arranged them so that they will fit in a Radio Shack cabinet. The etching pattern and the parts placement guide are provided in Figures 5–7. The parts placement diagrams are viewed from the component side. If you use double-sided PC boards for the balanced modulator or the amplifier, be sure to rout out a space around each hole on the component side. I do this carefully with a ⅛" drill bit. Single-sided material should work just fine for these boards, however.

One may wonder why a single board is not used for this project. Briefly, I have

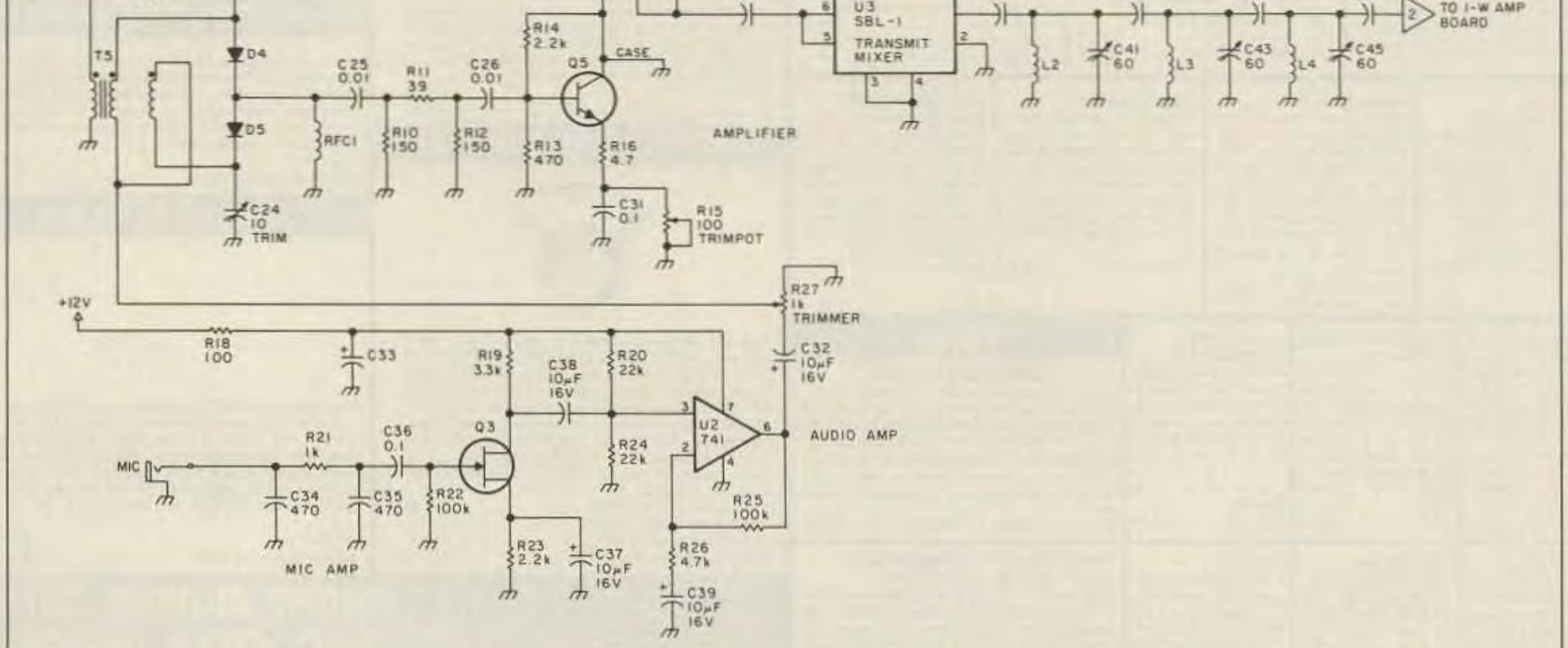

Figure 3. The balanced modulator/mixer board.

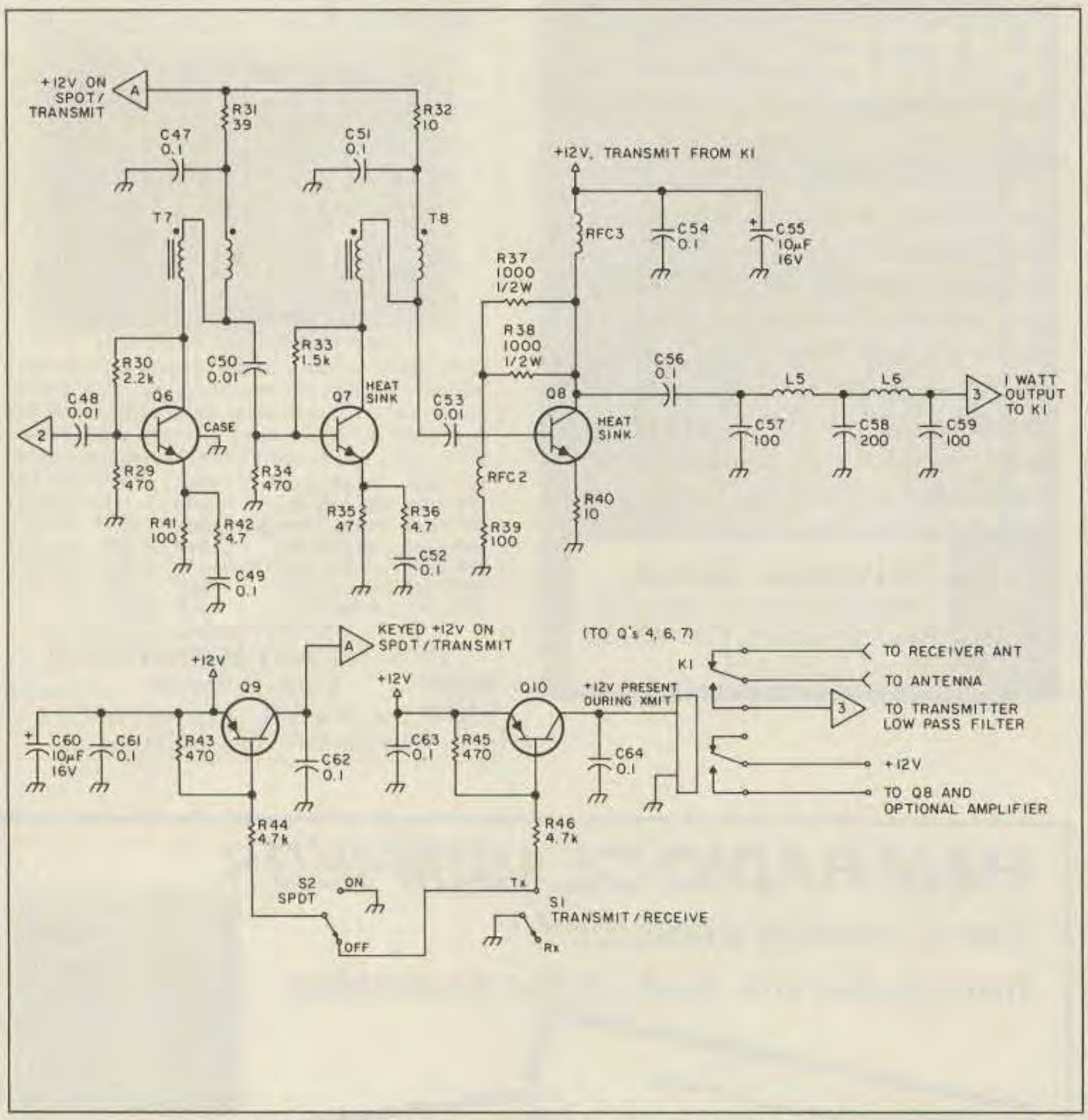

Figure 4. The 1 watt amplifier and switching board.

found that separating these stages greatly increases interstage isolation. Grounding is enhanced and a greater overall stability can be achieved.

I recommend that you build the transmitter in stages and get each stage running properly before you proceed to the next. Some hints for construction of the various modules are as follows:

The VFO

The VFO is the single most important part of the transmitter. If care is not taken to observe basic construction rules, the VFO will drift and you will be very unhappy with the rig. This PC board must be single-sided. Using double-sided board near the frequency determining components of the VFO will introduce unintended capacitance that's unstable with temperature change, causing drift. One frequently overlooked component in this regard is the tuning capacitor. Some home-brewers mounted them on a small square of single-sided board soldered vertically on the VFO board and directly behind the panel-mounted vernier dial. This mount actually forms one wall of the VFO compartment. If you follow this method, make sure the wall is not made of double-sided PC board. Of course, if you use a small aluminum box to house the VFO, this will not be a problem.

L1 lies face down on the board, glued in place after you have determined that the VFO is oscillating in the right place. I have allowed for a small trimmer for adjusting the VFO frequency, but squeezing together or spreading apart the turns of L1 will also work. Make sure that all of the parts coming off of pins 6 and 7 of IC1 are mounted as rigidly as possible.

The Balanced Modulator/Mixer

The balanced modulator/mixer board is the easiest to build and the least critical, except for the bandpass filter. Simply populate the board with parts. The spacing I have used for the pads on the board may not match your junk box parts, but I encourage you to use what you have. Notice, however, that the values for the fixed capacitors in the bandpass filter are rather specific. This stage is the most unforgiving of mistakes, and these values must not be changed casually. If you have no 4.7 pF capacitor, then try a 5 pF. Likewise, a 10 pF might be substituted for the 10.7 pF unit, but beyond that type of substitution, you may significantly affect the performance of the filter.

Note that there is a 6 dB pad (composed of R10, 11, and 12) at the output of the balanced modulator. This helps to achieve a good 50 ohm load for the balanced modulator, and the same input impedance for the following amplifier stage. Originally, I designed the trans-

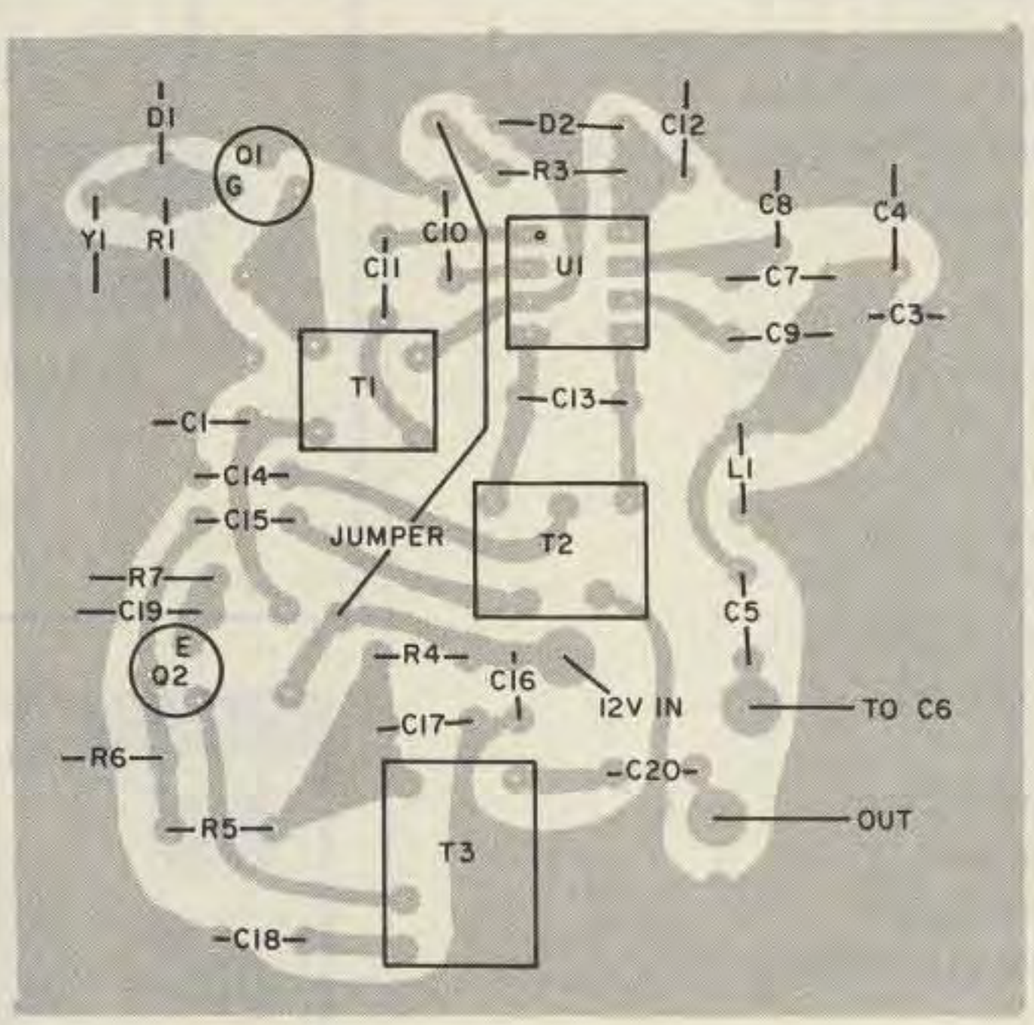

Figure 5 (a) The VFO foil pattern. (b) Parts placment.

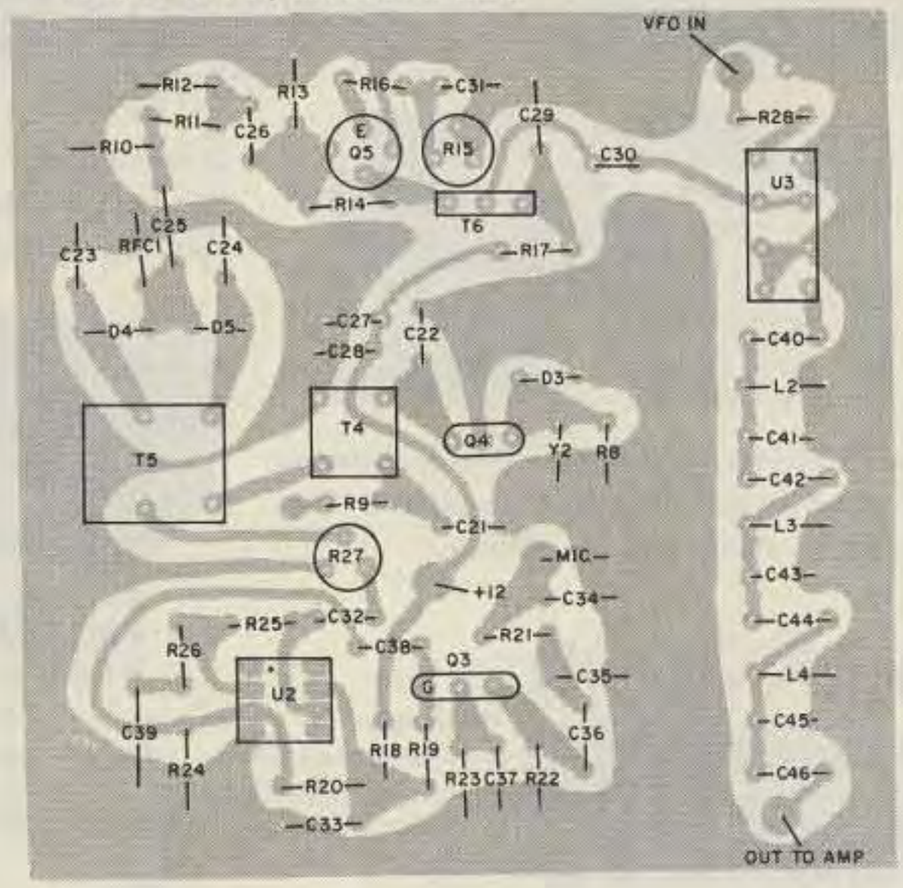

Figure 6 (a) The balanced modulator/mixer foil pattern. (b) Parts placement.

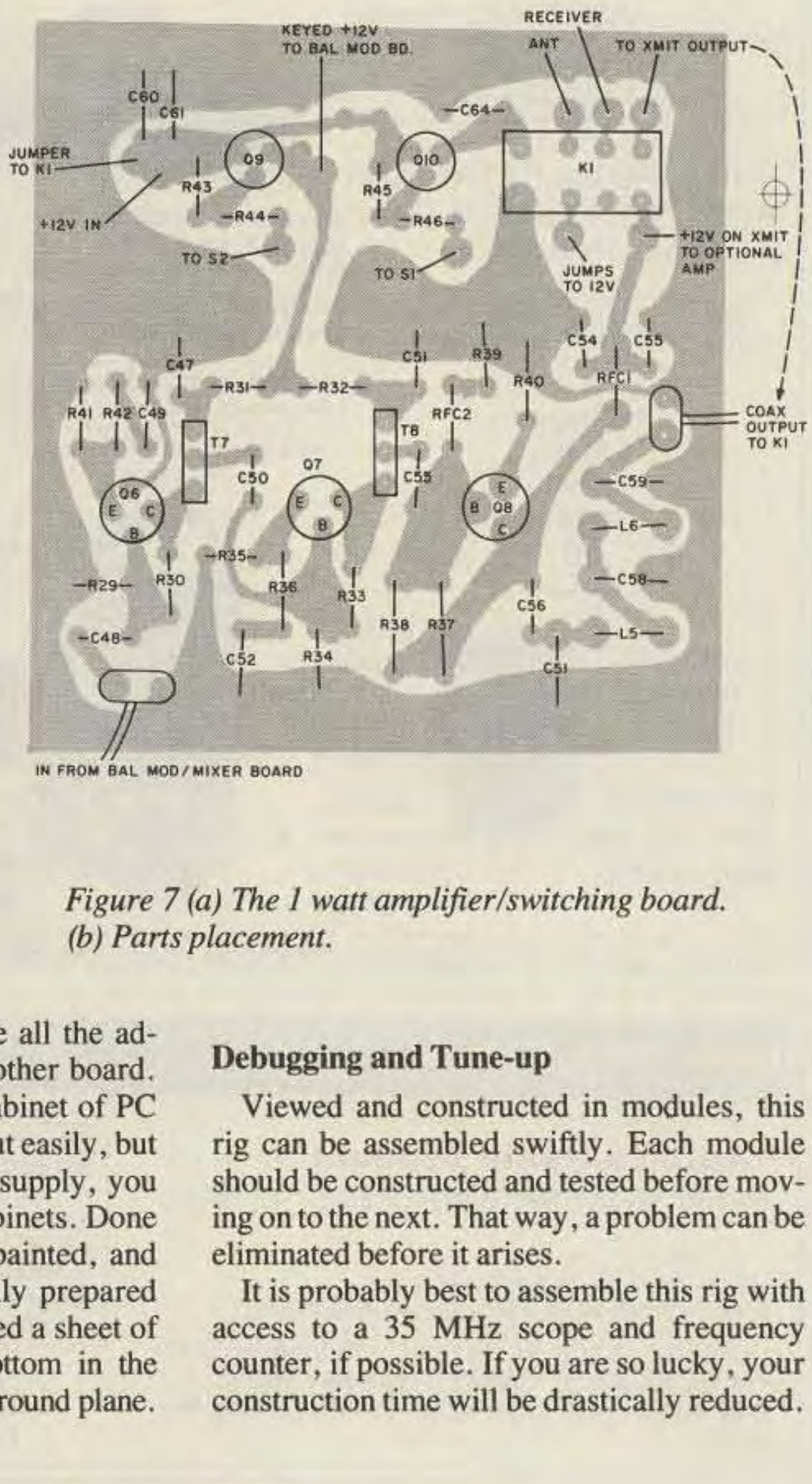

Figure 7 (a) The 1 watt amplifier/switching board. (b) Parts placement.

mitter with such a pad at the end of the bandpass filter, but found that the circuit was stable enough without it. Also, I wanted the 6 dB back! You may find that a pad at the end of the balanced modulator is not needed, and gain the energy otherwise lost heating the resistors.

The boards fit nicely into a Radio Shack cabinet. I double-decked the balanced modulator/mixer and amplifier boards on either side of a 10cm by 10cm PC board. The amplifier board is underneath because all the adjustable components are on the other board. You might consider making a cabinet of PC board material. It is drilled and cut easily, but plenty strong. If you can find a supply, you will save money on expensive cabinets. Done well, they can be lacquered or painted, and rival even the most professionally prepared cabinets in appearance. I also used a sheet of single-sided board as a false bottom in the cabinet. It helps establish a good ground plane.

Debugging and Tune-up

Viewed and constructed in modules, this rig can be assembled swiftly. Each module should be constructed and tested before moving on to the next. That way, a problem can be eliminated before it arises.

It is probably best to assemble this rig with access to a 35 MHz scope and frequency counter, if possible. If you are so lucky, your construction time will be drastically reduced.

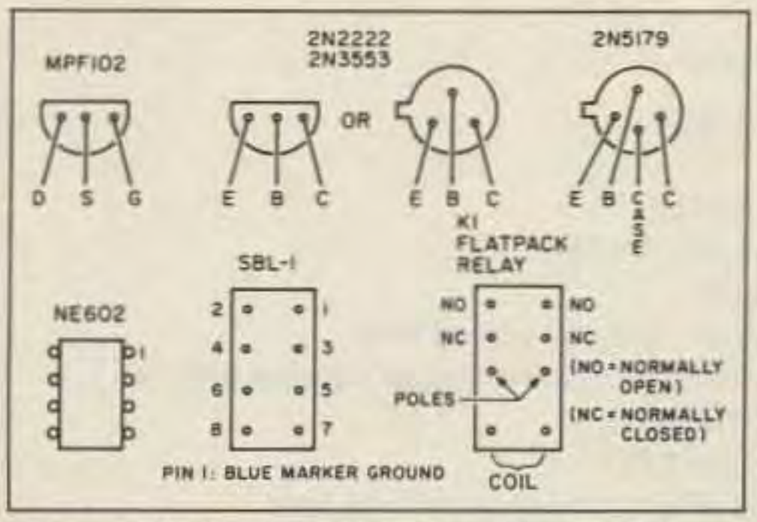

Figure 8. Base diagrams, all bottom view.

Being able to see a signal on the scope and adjust the stage in question is a big help in a sideband project where you are concerned about speech waveform. If you do not have a scope, do not despair. You can probably adjust the transmitter a little at a time with the aid of the station receiver, its S-meter, and a sharp ear. I have adjusted RF stages this way, and while time-consuming, it can be done.

Construct the VFO and confirm that it oscillates at 6.5 MHz or so. Check this by placing the scope probe on pin 7 of IC 1. Confirm that the crystal oscillator, Q1, and its associated components, are running, by placing the probe at pin 1 of IC1. Tweak the output of the crystal oscillator with its trimmer capacitor. Before adding amplifier Q2, check to see that the product of the VFO frequency and the crystal oscillator is at 17.5 MHz or thereabouts. If the counter cannot "sit still" on a frequency, the desired product is not dominant. Tweak the IC's trimmer for maximum output at 17.5 MHz. Adding amplifier Q2 and tweaking its trimmer will further preselect 17 MHz and amplify it to about 3 volts peak-to-peak.

If you have no scope, you will have to find the oscillator's signal in the station receiver. Make sure you have the receiver's antenna lead close to the oscillator for adequate pick up. Adjust the same controls mentioned above for a peak S-meter reading.

C2 sets the VFO's bandspread at about 200 kHz. I chose 28.500 to 28.700 MHz, but adding a turn or two to L1 will lower the VFO frequency to the Novice portion of the band. Eliminating C2 will greatly increase the total bandspread.

Next determine that the balanced modulator carrier oscillator, Q4, will run. It is normally off except during spot and transmit periods, so you will need to temporarily apply voltage to it through its supply line resistor, R9. Peak its output. Plug in a microphone, adjust the audio gain (trimpot R27) for maximum input to T5 (clockwise) and holler. You should hear your best Donald Duck voice at 11 MHz, double-sideband. View the sideband carrier on the scope or listen to your signal n your station receiver and adjust the carrier balance trimmers (C23 and 24) potentiometer for the greatest carrier suppression. Even at maximum suppression, you will still hear a loud carrier in your station receiver. Adjusted properly, though, it will be undetectable by other stations. I have found that the audio gain trimpot is best set at about mid-range for best voice quality. Above that, significant clipping occurs.

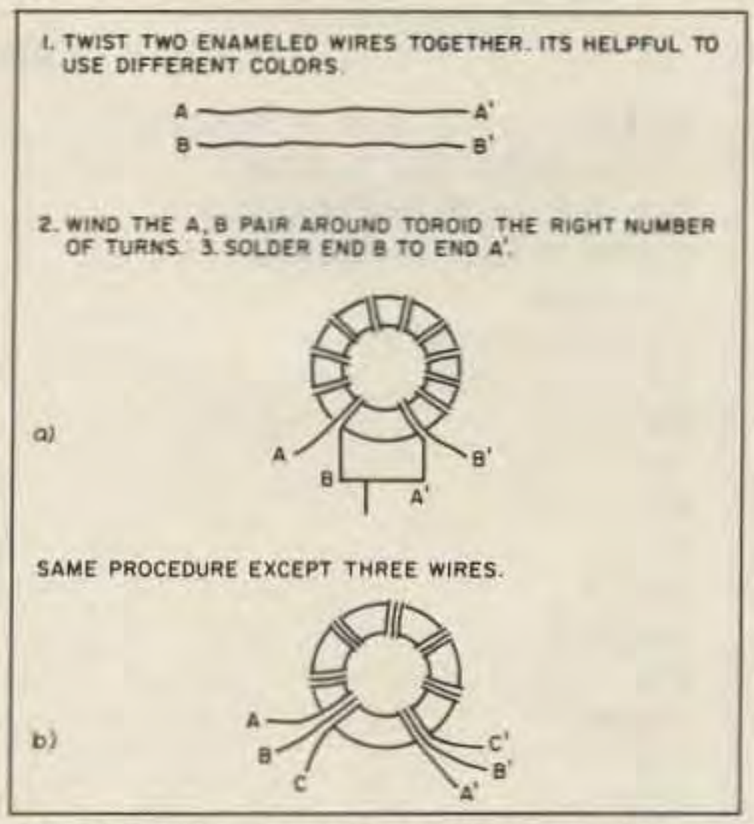

Figure 9. Winding the (a) bifilar transformer, and the (b) trifilar transformer.

The tricky part of the rig is the bandpass filter. The jumble of products from mixing the balanced modulator and VFO frequencies are all present at its input, and you must preselect the 28 MHz energy, pole by pole. Start first at the top of L2 and rotate the trimmer until you find a peak of 28 MHz waveform. Repeat this process at each pole. I have not tried this without a scope, and would expect this to be a rather frustrating part of the assembly if done by ear through the station receiver. Adjust the filter without voltage applied to the amplifier stages.

The rest of the circuit is broadbanded and not adjustble except for the lowpass filter. Final adjustment is made by tweaking every trimmer in the unit for maximum output on a wattmeter and spreading or compressing the turns on the coils in the low pass filter for greatest output. Take care that you do not

Parts List

C1,9,12,14,17,19,28,29,31,36,47, 49,51,52,54,56,61,62,63,64	0.1µF
C10,15,20,21,25,26,30,48,50,53	0.01µF
C16,27,32,33,37,38,39,55,60	10 µF, 16V elec.
C11,57,58	100 pF
C2,13,18,22,41,43,45	60 pF "button" type trimmer
C3	10 pF or similar NPO or air variable trimmer
C4	100 pF NPO
C5	20 pF NPO
C6	35 pF air variable, panel mounted
C7,8	200 pF NPO
C23,24	10 pF trimmer, ceramic OK
C34,35	470 pF
C40	15 pF
C42,44	4.7 pF
C46	10.7 pF
C58	200 pF

R16,42,36	4.7 ohms
R32,40	10 ohms
R11,17,31	39 ohms
R4,7,28,35	47 ohms
R18,41,39	100 ohms
R10,12	150 ohms
R2,6,9,13,29,34,43,45	470 ohms
R21	1000 ohms
R37,38	1000 ohms, 1/2 watt
R33	1500 ohms
R3,5,14,23,30	2200 ohms
R19	3300 ohms
R26,44,46	4700 ohms
R20,24	22k ohms
R1,8,22,25	100k ohms
R27	1k ohm trimpot
R15	100 ohm trimpot

L1	24 turns, T-50-6 toroid
L2,3,4	13 turns, T-37-6
L5,6	8 turns, T-50-6 toriod
T1,4	Primary 33 turns; sec. 3 turns over drain end, T-50-2 toroid
T2	Primary 18 bifilar turns; sec. 3 turns over center of primary, T-37-6 toroid
T3	Primary 20 turns; sec. 3 turns over trimmer end, T-37-6 toroid
T5	10 trifilar turns, FT-37-43 toroid
T6,7,8	10 bifilar turns, FT-37-43 toroid
D1,3	1N914 or other small signal diode
D4,5	Schottky diode preferable, but 1N914 OK
D2	6V, 400 mW zener diode
Y1,2	11 MHz crystal
U1	NE602 balanced mixer/osc. IC
U2	741 single op amp
U3	SBL-1 diode-ring mixer module
Q1,3,4	MPF 102 FET
Q2	2N2222
Q5,6	2N5179 or 2N5109
Q7	2N3866
Q8	2N3553, 2SC2028, RCA 4013, 2SC2075, or equiv. transistors
Q9,10	2N4036 PNP switching transistor
K1	DPDT flatpack relay
S1,2	SPDT toggle switches
RFC1	15 microhenry molded choke
RFC2,3	10 turns, FT-37-43

Parts suppliers: *Tanner Electronics,* 1301 West Beltline Rd., Suite 105, Carrollton TX 75006. Tel. (214) 242–8702. Contact Jim Tanner regarding availability of kits. *Radiokit,* P.O. Box 973, Pelham NH 03076. Tel. (603) 635–2235. *Circuit Specialists,* P.O. Box 3047, Scottsdale AZ 85271-3047. Tel. (800) 528–1417. Blank PC boards are available from FAR Circuits, 18N640 Field Court, Dundee IL 60118. VFO board—$4.50; balanced modulator/mixer—$7; and amplifier board—$7; shipping—$1.50 per order.

detune the bandpass filter such that it is preselecting a different VFO/balanced modulator product. I tried to avoid this possibility by choosing an IF far removed from 28 MHz. While this results in the necessity of a mixing scheme in the VFO circuitry, it made tuning the bandpass filter easy. The first attempt at this circuit employed a 24 MHz IF and 4.5 MHz VFO. This sounded great in theory, but I had practical problems differentiating between 24 and 28 MHz signals.

Beware of self-oscillation. Even these broadband amplifiers will oscillate if overdriven, or if a mismatch occurs between stages. This will result in a waveform that looks like you have a carrier present in the signal. You may look to the balanced modulator for the problem, but you may really have an amplifier oscillating. I have used many different biasing and feedback schemes for Q7 and Q8, and the resistors in these stages should not be changed casually. While it is tempting to change them to obtain more output, you may start an otherwise stable amplifier oscillating madly. Experimenting with some of these components will show what a delicate balance exists in a sideband transmitter.

Adjusted properly, your voice will sound natural in the station receiver, and the wattmeter will bounce merrily with your speech patterns, resting at zero with no speech. If your wattmeter shows a continuous deflection during transmit periods, some imbalance exists. Go through the adjustment procedure again, watching the wattmeter. You should have about a watt peak envelope power. In one version I had more, in another I had less.

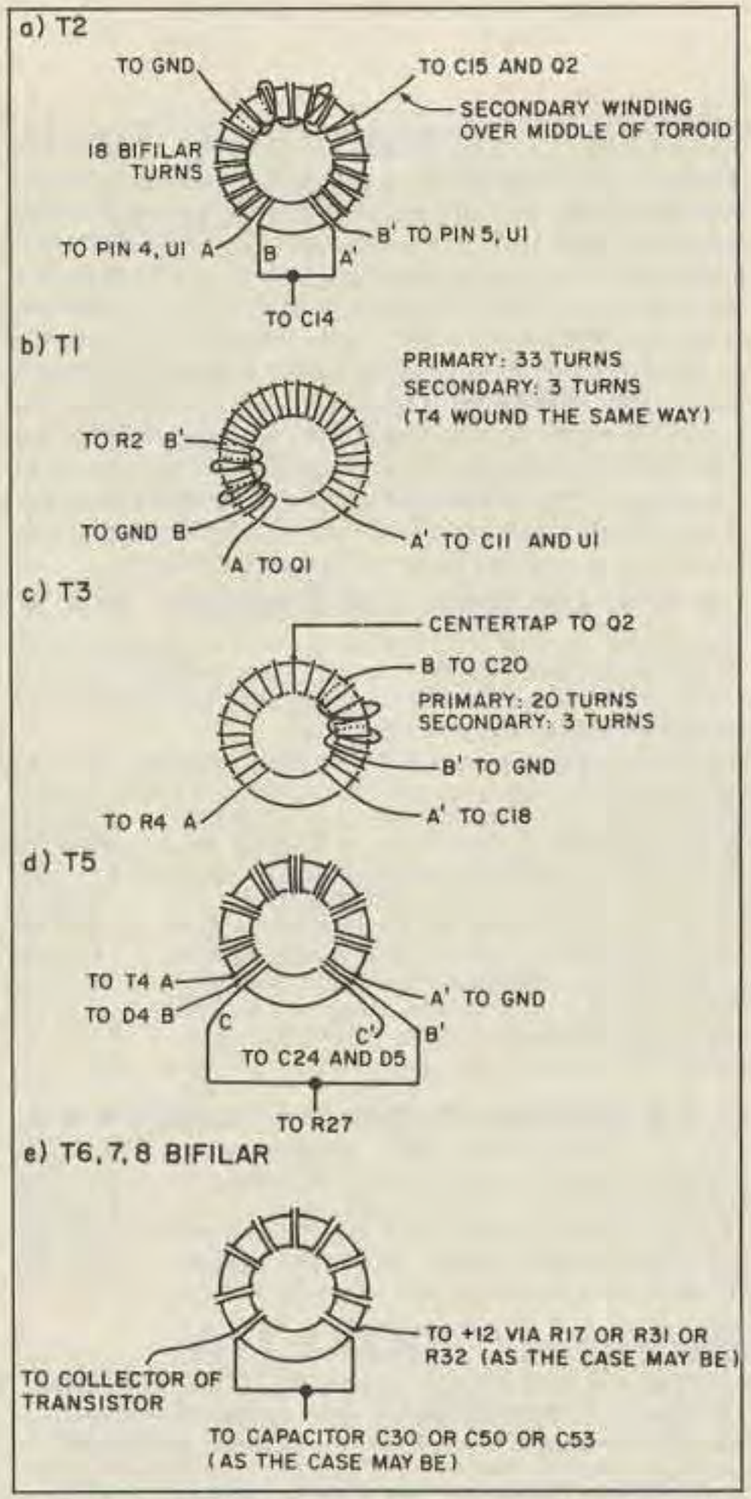

Figure 10. Winding specific toroids: (a) T2, (b) T1, (c) T3, (d) T5, and (e) T6,7,8.

The spot function is enabled by throwing S1. It turns on the carrier oscillator and enables you to tune the transmitter to your receiver's frequency without applying a signal to the antenna. Simply speak into the mike and adjust the frequency until your voice sounds natural.

On The Air!

Ten meters is wide open. After completing the breadboard version of this transmitter, I was immediately rewarded with an enjoyable 1500 mile QSO on the first call. I had the same luck the next day. I have a modest beam antenna at a modest height. You will be pleasantly surprised at what a watt will do on 10 meters. While this rig will not duplicate the performance of the commercial transceivers, it performs admirably. Most importantly, it shows that a non-engineer and non-technician, on a first attempt at a sideband transmitter, can cook up a workable system. If I can do it, so can you! I welcome correspondence regarding this rig or any home-brew topic. Happy home-brewing! 73

You may contact Bruce Auld NZ5G at 1704 Windsor Forest Trail, Roanoke TX 76262. Please enclose an SASE.