An Introduction to the Bilateral Transverter

VHF DXing with 100-mW ssb interest you? Get into the act with a "BT" for great fun with "whisper" power!

By Fred Brown,* W6HPH

If your shack is typical, it is equipped with an "all band" (80- through 10-meter) ssb/cw transceiver. Vhf bands, and even 160 meters, can be added to these ubiquitous boxes by means of a *transverter* (Fig. 1A). The transverter up-converts the transceiver rf output to the desired vhf band and also down-converts the received vhf signal to the hf band. Since a common local oscillator is used for the heterodyne process, the receive and transmit frequencies are translated an identical amount, and the transceiver operates just as it would on hf.

Reduced to its barest essentials, the transverter simplifies to nothing more than an oscillator-mixer combination, as in Fig. 1B. If the mixer is of a *bilateral* type, it will handle both the up and down frequency conversions, no antenna switching or changeover relays will be needed.

The principal advantage of such a bilateral transverter (BT) is simplicity, as should be apparent from comparing Figs. 1A and 1B. Of course, a price must be paid for this simplicity: Power output will be very limited, and the receiver noise figure will not be the ultimate. The BT, by itself, will not meet the needs of the demanding vhf DXer. Nevertheless, it is adequate for working the locals and for getting started on a new band. Furthermore, the BT can be upgraded later by adding a power amplifier and/or a receive preamplifier.

Work DX with four diodes? Here's proof of the pudding. These cards confirm contacts with W6HPH, who was using nothing more than an attic dipole in conjunction with the 50-MHz BT described here.

System Principles

Theoretically, there is no efficiency or power limitation to the frequency-conversion process. In principle, we could convert as much as 100 watts of hf ssb into nearly 100 watts of vhf ssb with nothing more than a passive mixer. To do this with presently available devices, and with a reasonable local oscillator power level, is not within the current state of the art.

Probably the most practical form of bilateral mixer is the four-diode, ring-modulator type of doubly balanced mixer originally developed for telephone communication. As with any mixer, sum and difference frequencies in addition to harmonics of the local oscillator are produced. These unwanted mixer products must be removed by a good band-pass filter.

The diode mixers used in the transverters described here operate at an rf output level of 100-mW PEP. To some, this might seem like a QRP level where communication would be impossible, but the author has made solid 3000-mile (km = mi × 1.6) contacts with the 6-meter BT. Usually, range is limited more by the antenna and location than power. Remember, if you are 40 dB over S-9 with a kilowatt, you will still be S-9 with 100 mW. Realistically, 100 mW is a power level suitable for the vhf beginner who is interested mainly in exploring a new band and working the locals or other easy-to-work stations.

As a receiver, the BT will never win any noise-figure contests. The best you will be able to do is about 8 dB worse than the NF of your hf transceiver. Even so, signals as weak as 0.5 microvolt are easily readable. With only 100 mW on transmit, you will always be able to hear more than you can work. Furthermore, one point in favor of the BT as a receiver is its excellent cross-modulation performance. In this department it will surpass any vhf converter.

The 6-Meter BT

Twenty meters was chosen as the i-f for the 6-meter BT because both the 21- and 28-MHz bands would have been too close in frequency to one half of 50 MHz. As can be seen from Fig. 2, four transistors are used to provide 36-MHz injection for the doubly balanced mixer. About 1 watt of rf is developed; any crystal-controlled 36-MHz source that provides this level of power could be ap-

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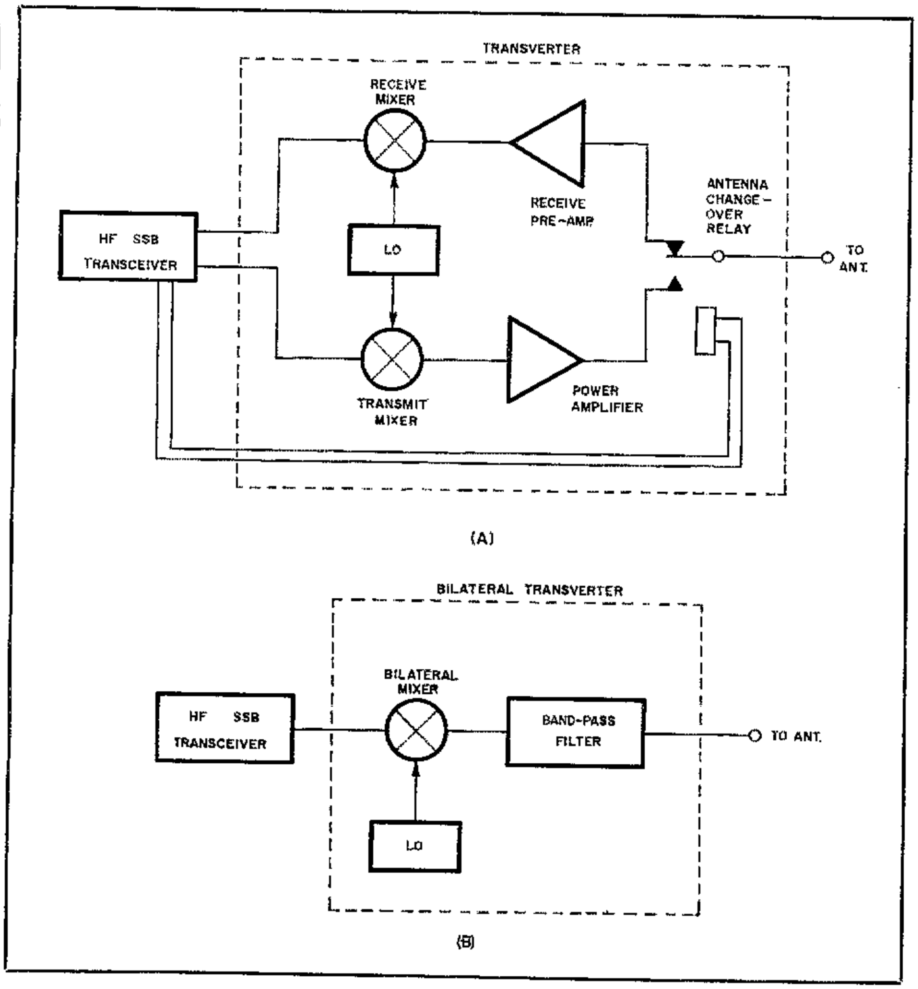
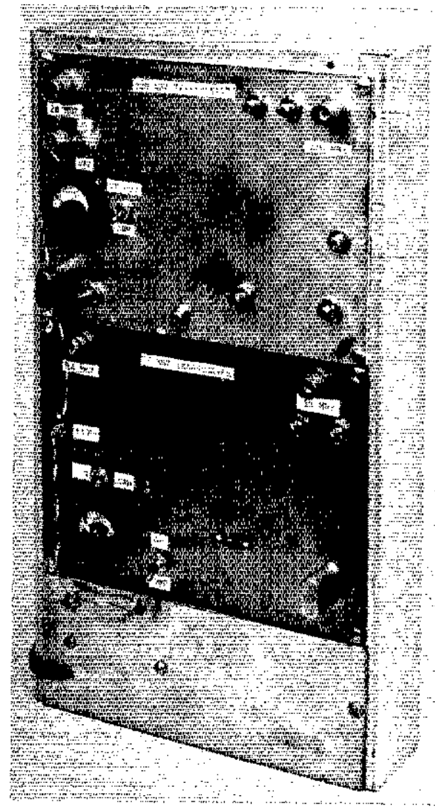


Fig. 1 — The conventional transverter shown at A requires two rf connections to the hf transceiver, plus a push-to-talk control voltage for the antenna changeover relay. The much simpler bilateral transverter at B requires only one connection to the hf transceiver.



The two transverters are shown here "rack" mounted in a 7- × 13- × 2-in. aluminum chassis. Behind the bottom panel is a regulated 12-V power supply. Total shielding is recommended to avoid i-f leakthrough problems. If a nonmetallic box is used, it should be lined with metal foil.

plied. For instance, a reworked CB rig could be substituted for the LO rather than the circuit shown.

The doubly balanced mixer (DBM) is followed by a two-pole filter (L6-C6 and L7-C7), which prevents the unwanted image and harmonic products from reaching the antenna. To some degree, this filter also acts as an antenna coupler, since C6 and C7 can be adjusted to match any impedance that does not depart radically from 50 ohms (resistive).

Any of a large number of transistors could have been chosen for Q1 through Q4. The 2N2222As were used because they are inexpensive and readily available. Q1 is a conventional overtone crystal oscillator. Q2, a buffer/amplifier, drives the parallel combination of Q3 and Q4. The latter two transistors are fitted with small heat sinks. An L-pi network[1] is used between the collectors of Q3/Q4 and the DBM to provide optimum coupling along with good harmonic suppression. A stabilizing network (C4, L5 and R1) performs as a parasitic suppressor for Q3 and Q4. The low L-C ratio tank circuit (C4 and L5) is parallel resonant at 36 MHz and prevents power loss in R1 at this frequency. At all other frequencies, R1 loads Q3 and Q4, thereby preventing parasitics. L5 may be adjusted by squeezing or spreading turns to resonate with C4 at exactly 36 MHz. Resonance should be determined with a dip meter, which in turn has been checked against a frequency counter or calibrated receiver to indicate the precise frequency.

A 0-100 microammeter can be switched to monitor either DBM dc current or rf output voltage. The former is used in tuning up the LO chain, and the latter is used for tuning the DBM and two-pole filter for maximum rf output.

The ring modulator is unusual in that the four diodes are self-biased by the bypassed resistor, R2. As a result, the diodes act as varactors throughout most of the rf cycle, which means the balanced mixer functions partly as a parametric up-converter. This permits a much higher saturated power output than could be attained with a conventional ring modulator.

Unfortunately, like most parametric converters, it is also subject to parasitics. These parametric parasitics can be extinquished by reducing the value of R2, but at the expense of lower saturated output. The value of R2 should be the maximum that will permit completely stable operation.

Construction

Both the 50-MHz and the 220-MHz BTs are constructed on 5- × 6-1/2 inch (mm = in. × 25.4) double-sided circuit boards, the correct size for a standard 5-× 6-1/2- × 1-1/2-inch meter box. Suggested component layouts are shown in Figs. 3 and 5.

Terminal-strip construction was chosen in preference to the more popular printed-circuit technique. There are several reasons, the main one being that all components are maintained close to a conducting ground plane. This is important in vhf work because it avoids the radiation and ground-loop problems of pc boards. In addition, if the board is used as the cover of a conducting box, a completely shielded rig results. Furthermore, terminal-strip or stand-off construction makes circuit alterations easier than would be the case with pc board construction.

Tune-Up

Collector current of Q2 can be observed

[1] *VHF-UHF Manual*, 1969 edition, RSGB, p. 6.12.

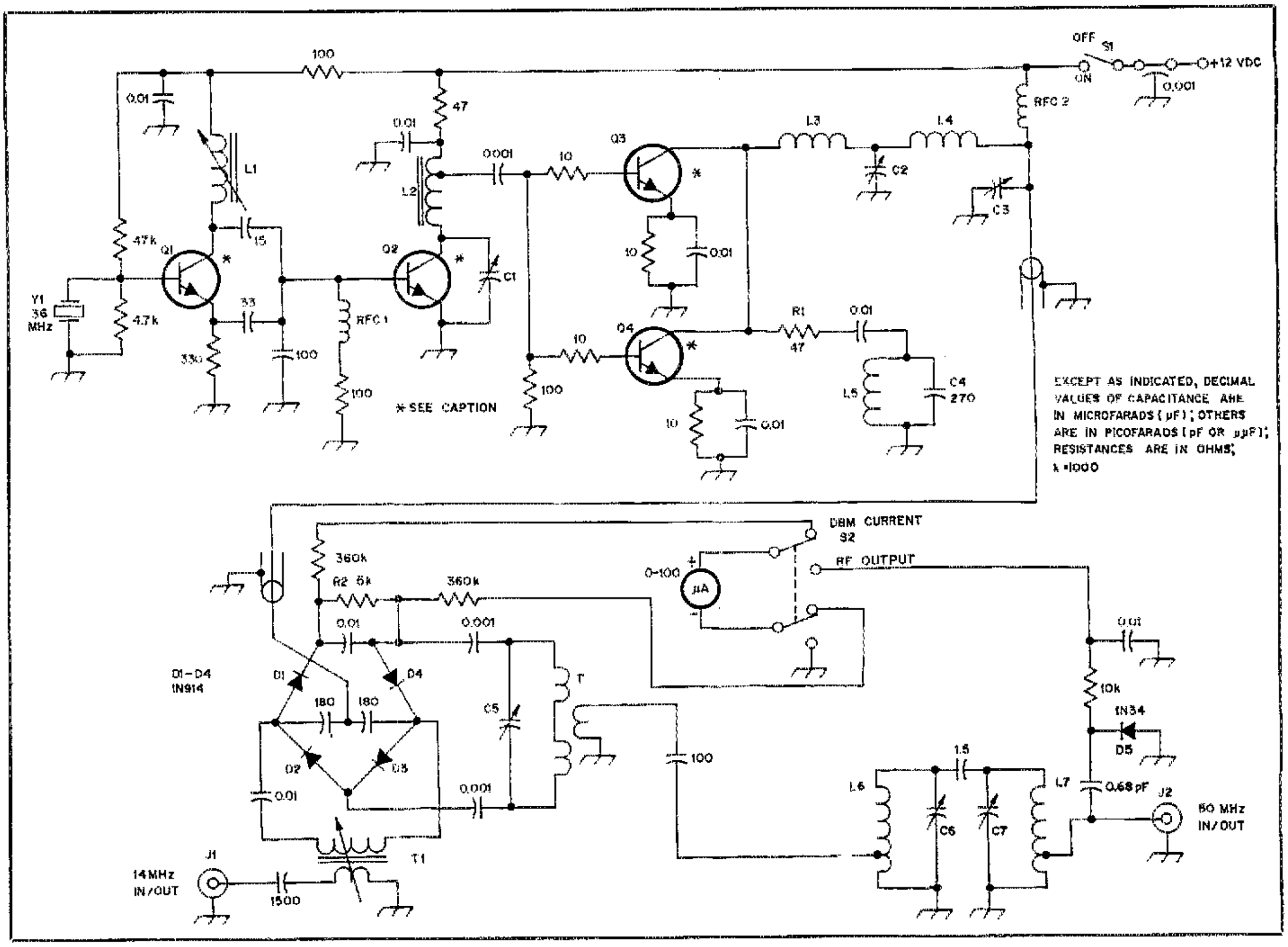


Fig. 2 — Inexpensive 2N2222A transistors may be used in the 6-meter BT. The doubly balanced mixer consists of diodes D1 through D4 coupled to the antenna through a 2-pole filter.

C1 — 2.5-11 pF ceramic trimmer.
C2 — 100-pF APC trimmer or Arco 463.
C3, C5 — 9-180 pF mica trimmer, Arco 463.
C6, C7 — 3-32 pF, E. F. Johnson 160-130.
D1-D4, incl. — Switching diode, 1N914
D5 — Germanium diode, 1N34.
L1 — 11 turns no. 22 enam. copper wire, close wound on 1/4-in. slug-tuned form.
L2 — 9 turns no. 24 enam. copper wire on Amidon T37-2 toroid form, tapped at 3 turns.
L3 — 1.1 µH, 23 turns no. 24 enam. copper wire close wound on 3/16-in. dia form.
L4 — 0.95 µH, 8 turns no. 18 enam. copper wire, 3/8-in. ID, close spaced, air wound.
L5 — 3 turns, no. 14 enam. copper wire, airwound, 3/8 in. ID, 1/2 in. long.
L6, L7 — 11 turns, no. 14, copper wire, 5/8-in. ID, 1-3/8 in. long, air wound. Tap two turns from ground end.
RFC1, RFC2 — 22 µH, J. W. Miller no. 70F225A1 or equiv.
S1 — Spst.
S2 — Dpdt.
T1 — Primary: 5 turns no. 24 hookup wire wound over secondary tape. Secondary: 1.5 µH. 16 turns no. 26 enam. copper wire, close wound on 1/4-in. slug-tuned form and covered with a single layer of vinyl tape.
T — 2-1/2 turns each side of center, no. 18 enam. copper wire on 1/2-in. dia form with 3-turn no. 24 enam. copper wire link. See Fig. 3.

by connecting a voltmeter across the 47-ohm resistor in series with L2. There will be no Q2 collector current unless Q1 is oscillating. L1 should be adjusted to maximize this current. In like manner, the emitter currents of Q3 and Q4 can be checked by measuring the dc voltages across the two 10-ohm emitter resistors. These voltages should be around 0.6 V and should be roughly equal. If unequal, they can be balanced by reducing the value of the 10-ohm base resistor of whichever transistor is drawing the smaller current. C2 and C3 can then be adjusted for maximum DBM diode current as indicated on the microammeter. It should be possible to exceed 60 µA.

With the LO chain functioning properly, the next step is to connect the 14-MHz port to a receiver and to run a moderately strong 50-MHz signal into the antenna

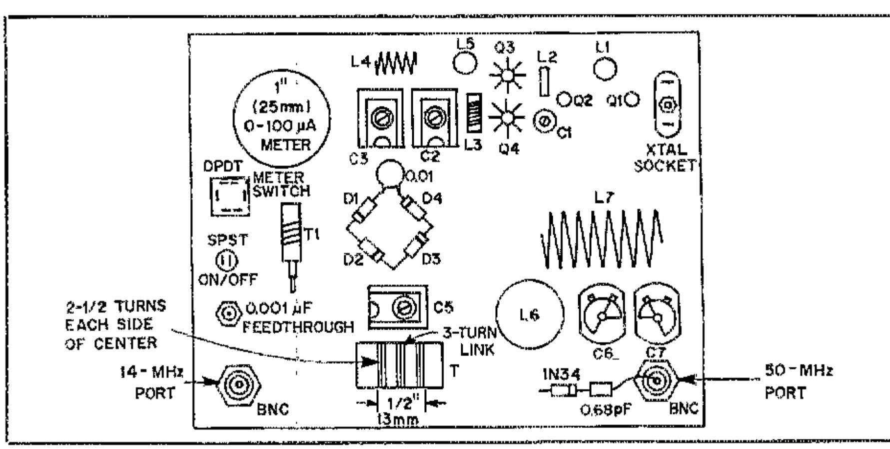


Fig. 3 — Suggested component placement for the 50-MHz BT. The copper-clad board measures 5 × 6-1/2 inches. Only the larger components are shown. Coils are generally oriented to minimize inductive coupling between them. Winding details of L5 are shown. Transistors Q3 and Q4 are fitted with small heat sinks. A short length of miniature coaxial cable can be used to connect C3 to the ring modulator. All other rf leads should be reasonably short and direct.

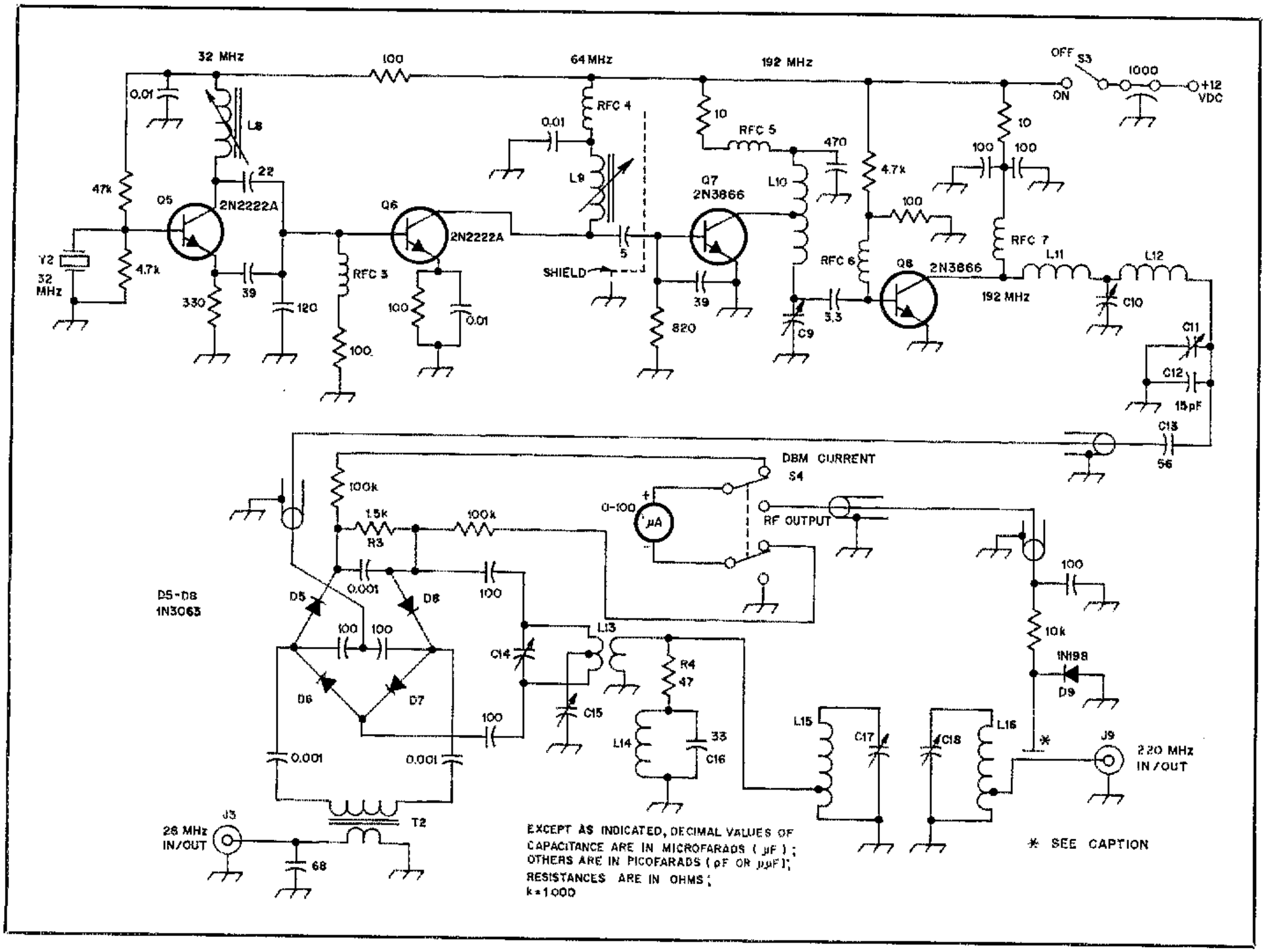


Fig. 4 — The 220-MHz BT is similar to the 50-MHz model but uses a 28-MHz i-f. Input and output impedances are 50 to 75 ohms. The rf pickup (*) for the meter is a short length of insulated wire brought near the center conductor of the coaxial fitting. It is adjusted for half-scale meter deflection when you are running full output into a matched load.

C9, C10, C11 — 2-9 pF, E. F. Johnson 160-104.
C12 — 15 pF disc ceramic.
C13 — 56 pF disc ceramic.
C14, C15 — 4-40 pF, Arco 422.
C17, C18 — 1.5-5 pF, E. F. Johnson 160-102.
D5-D8, incl. — Silicon switching diode, 1N3063.
D9 — Germanium diode, 1N198.
L8 — 10 turns no. 28 enam. copper wire, close wound on 1/4-in. slug-tuned coil form.
L9 — 9 turns no. 28 enameled copper wire, close wound on 0.215-in. dia slug-tuned form.
L10 — 4 turns no. 16, 1/4-in. dia, 5/16 in. long, air wound, center tapped.
L11 — 8 turns, no. 16 copper wire, 3/8-in. ID, 9/16 in. long, air wound.
L12 — 8 turns, no. 16 copper wire, 1/4-in. ID, 9/16 in. long, air wound.
L13 — One turn no. 14 copper wire, 5/8-in. ID, center tapped with a 1-turn, close-coupled link. See Fig. 5.
L14 — One turn no. 18 copper wire, 1/4-in. dia. Resonates with C16 at exactly 221 MHz.
L15, L16 — 5 turns, no. 16 copper wire, 3/8-in. ID, 1/2 in. long, tapped one turn from low end.
RFC3 — 22 μH, J. W. Miller no. 70F225A1 or equiv.
RFC4-RFC7, incl. — 1.5 μH, J. W. Miller no. 4604 or equiv.
S3 — Spst.
S4 — Dpdt.
T2 — Secondary is 5 turns no. 28 enameled copper wire close wound on 0.3-in. dia. by 0.6 in. long powdered-iron slug. Inductance is 0.5 μH. Cover secondary with one layer of vinyl electrical tape, and wind three-turn primary with no. 24 hookup wire over tape.

port. C5, C6, C7 and T1 can then be tuned for maximum S-meter reading.

The equipment is now ready to be connected to an antenna or dummy load and tuned up. First, be sure that the transceiver drive has been reduced to a very low level so that the output is well below 1 watt. Switch the transceiver to cw, and press the key. The DBM current should not rise more than 20%. If it does, the drive should be reduced further. Typically, the required drive will be +27 dBm. Switch the microammeter to the rf-output position, and again close the key. Tune C5, C6 and C7 for maximum meter readings, repeating the process a few times, since there is some interaction among these adjustments.

Your BT is now ready to go on the air. Normally, the DBM current will kick up 10% or so on voice peaks, but if it goes much higher, that indicates the DBM is overdriven. This will result in flat topping.

The 220-MHz BT

The 220-MHz model has an intermediate frequency of 28 MHz. Many transceivers cover 28 to 30 MHz fully, a range that permits coverage of 220 to 222 MHz if the LO is at 192 MHz. Again, any crystal controlled source that develops 0.25 watt or more at this frequency, such as a reworked Sonobuoy transmitter, could take over as the LO.

The oscillator-multiplier chain, shown in Fig. 4, uses commonplace and inexpensive transistors. Q5 is an overtone crystal oscillator at 32 MHz, and Q6 doubles to 64 MHz. If a 64-MHz crystal is available, one transistor could be eliminated. Q7 is a tripler to 192 MHz. Its output is amplified by Q8, which develops about 0.25 watt of drive for the DBM. An L-Pi network matches the collector impedance of Q8 to 50 ohms, and the rf energy is delivered to the DBM through a short length of miniature 50-ohm coaxial cable.

Details of the DBM layout are shown in Fig. 5. Because of their switching speed, 1N3063 diodes were chosen. Like the 6-meter version, the DBM proved susceptible to parasitics. Rather than sacrifice output by reducing the value of R3, a parasitic suppressor was used on the out-

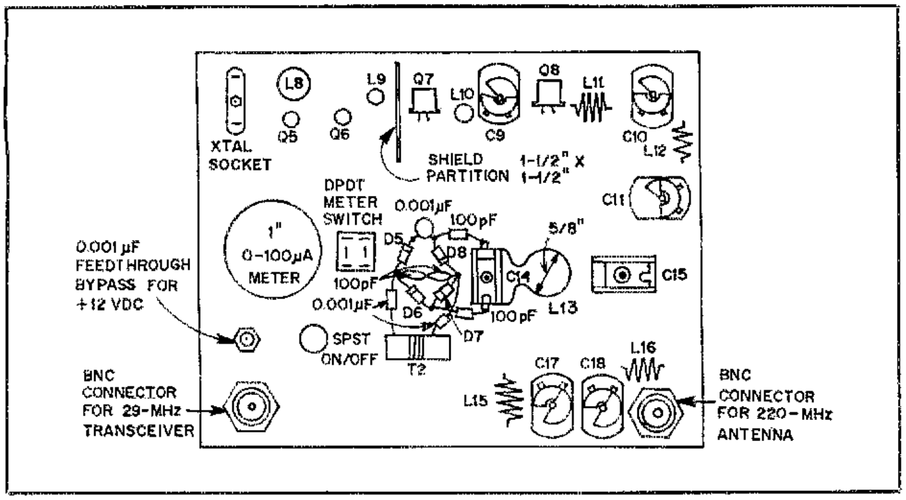


Fig. 5 — Suggested parts placement for the 220-MHz BT. Short lengths of miniature coaxial cable are used for connecting C11 to the DBM and for connecting the link of L13 to the tap on L15. L13 is spaced 1/2 inch above the board. The one-turn link is directly below it and tightly coupled. All rf leads must be short, especially the emitter leads.

Table 1

Measured Collector Currents

Q1 — 4.3 mA	Q5 — 6.7 mA
Q2 — 39 mA	Q6 — 4.2 mA
Q3 — 60 mA	Q7 — 27 mA
Q4 — 60 mA	Q8 — 61 mA

put link. This network consists of R4, C16 and L14. The combination of C16 and L14 forms a low L-C ratio tuned circuit, which must be resonated to precisely 221 MHz. This tuned circuit prevents the desired output from being lost in R4.

The two-pole filter (L15-C17 and L16-C18) ensures that only 220-MHz rf reaches the antenna. In Fig. 4 there is apparently no coupling between these two tank circuits. Each coil is oriented to minimize inductive coupling, but since the two capacitors are mounted adjacent to each other, there is sufficient stray capacitance between the two stators to provide "top coupling." As in the 6-meter transverter, some antenna impedance matching can be accommodated by careful adjustment of C17 and C18.

Tuning

Tune-up procedure is similar to the 50-MHz BT method. There are sampling resistors in series with the collectors of Q5, Q7 and Q8, which permit measurement of collector current if a voltmeter is connected temporarily across the appropriate resistor. Emitter current of Q6 can be checked in the same manner. It will be zero unless Q5 is oscillating. L9 should be adjusted to maximize this current. C8 should be adjusted for maximum collector current of Q7, and C9 for maximum Q8 collector current.

Collector currents should be approximately as shown in Table 1, with everything properly adjusted. C10, C11 and C15 should be adjusted for maximum DBM current as indicated by the microammeter. It should exceed 65 µA.

Rough adjustments of C14, C17 and C18 can be made by feeding a strong 221-MHz signal into the antenna port and tuning for maximum S-meter reading on a 29-MHz receiver.

Switch the transceiver to the cw mode, and begin the tune-up with the drive control turned all the way down, gradually advancing it to a point where the DBM current increases about 10%. Then switch the meter to indicate rf-output voltage. Next, alternately adjust C14, C17 and C18 for maximum meter reading. Repeat the adjustments a few times, since there is some interaction. Approximately +23 dBm of drive power is required. This completes the tune-up.

Results

With the help of the November 1980 6-meter band opening, the author has worked all eight northeastern states and three Canadian provinces. The antenna was nothing more than an attic dipole, 13 feet above ground. Amateur operators at several stations were incredulous that such a good signal could come from four diodes. On 220 MHz, the F2 layer does not provide transcontinental DX; but with a small Yagi, several Los Angeles stations, 75 miles away, have been worked with good reports. QST

[Editor's Note: Both bilateral transverters described in this article meet FCC requirements for spectral purity. Laboratory tests show the most significant spurious emissions for the 50-MHz transverter were 50 dB below the power of the fundamental. For the 220-MHz transverter, the most significant spurious emission was 43 dB down. Spectral analysis of the two-tone tests on these units disclosed that the third-order products for the 50-MHz and 220-MHz transverters were both 30 dB below PEP.]

Strays

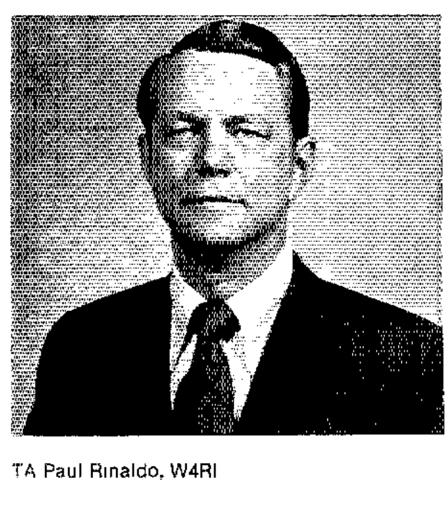
TA PROFILES

☐ We are indeed grateful to have ARRL Technical Advisor Paul L. Rinaldo, W4RI, on our TA team. He is our specialist for computer communications, spread spectrum and technical aids to the handicapped.

Licensed in 1949 as W9IZA Paul received his Extra Class license in 1954, and he also holds a First Class Radiotelephone license, a Second Class Radiotelegraph license and a Ship Radar Endorsement. W4RI has been an active computer enthusiast since 1975.

Paul is a Life Member of the ARRL, an author of technical articles published in *QST* and editor of *QEX: The Experimenter's Exchange* (see August 1981 *QST*, p. 48). He has organized five ARRL Technical Symposia and has managed two personal computing shows. A Life Member of AMSAT, a member of AFCEA and IEEE, W4RI is active in vehicular technology and computer societies. He is president and director of the Amateur Radio Research and Development Corporation (AMRAD). Under AMRAD, he is program manager for a two-year grant from the U.S. Department of Education for research in applying personal computers to telecommunications for the deaf.

Residing in McLean, Virginia, Paul is president and founder of Communications Resources, Inc., and has provided consultant services in communications, communications security, electronic countermeasures and business computers. He previously served in various positions with the Federal government as a technical advisor working with foreign countries, as a technical manager and as a communications officer. His experience includes planning, systems development, operations, training, installation and technical writing. — *Marian Anderson, WB1FSB*



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