By Paul Wade, W1GHZ

A 222 MHz Transverter for the Yaesu FT-817

Missing the multimode action on 222-MHz? This easy-to-build transverter is the perfect addition to Yaesu's popular mini rig.

Figure 1—A view of the transverter on top of the FT-817.

When the Yaesu FT-817 portable transceiver was introduced last year, it seemed like an ideal IF rig for mountaintopping with portable microwave transverters—a compact radio driving a stack of compact transceive converters. I couldn't resist! After playing with my new toy for a while, I noticed that the only missing feature was 222 MHz coverage. Many new transceivers offer VHF/UHF bands in addition to HF, 6 and 2 meters, and some even add 70 cm, but no current multimode radio operates on the 222-225 MHz band. After the mountains closed for winter, I started thinking about fixing this oversight.

An ideal accessory should have the features and characteristics that make the FT-817 so attractive: good performance in a small, lightweight package requiring only modest power. An ideal location for a transverter would be inside the battery compartment, but the FT-817 uses AA-cells rather than the larger C-cells found in older-generation portable transceivers, so there just isn't enough space. Instead of building a ship in a bottle, I was able to package the 222-MHz transverter shown in Figure 1 in a small aluminum box that sits on top of the transceiver. It provides performance similar to the other covered frequencies and even switches bands automatically in sync with the radio. The transverter will transmit only when the IF band is selected.

Description

One of my previous projects was the "Miniverter"[1]—a bare-bones printed-circuit transverter for 144 MHz. I intended to install several of these inside small 10 meter transceivers to make microwave IF rigs, but the release of the FT-817 shifted my thoughts into new gear. What I learned from the Miniverter became the starting point for the 222-MHz transverter described here.

The transverter design started with the block diagram shown in Figure 2, which outlines the device's basic functions. After I determined the requirements for each functional block in the diagram, I could start on the detailed design of each block. I take the "divide and conquer" approach to engineering. For a large commercial product this is usually a formal process, but for an amateur project, some sketches on scratch paper are sufficient. The block diagram is also helpful in following the circuit descriptions below.

The heart of a transverter is a mixer, also called a "frequency changer," a nonlinear device that combines two signals at different input frequencies to produce new frequencies at the mixer output. These new output frequencies are the sum and difference of the original input frequencies.

In this transverter, the mixer combines input signals with a 198-MHz local oscillator. To transmit, a 24-MHz signal is applied at the IF port from the FT-817; the sum frequency is 222 MHz, which is amplified and sent to the antenna. To receive, 222-MHz signals from the antenna combine with the local oscillator, and the difference frequency, 24-MHz, is sent to the IF port, where the FT-817 is tuned to the desired signal, which has now been converted to the 12-meter band.

The transverter uses filters before and after the mixer—a helical band-pass filter at 222 MHz and a low-pass filter (LPF) in the IF section, which only passes frequencies below about 28 MHz. The mixer used in this transverter is an inexpensive packaged, double-balanced diode mixer commonly used in VHF and UHF transverters. In this case, I

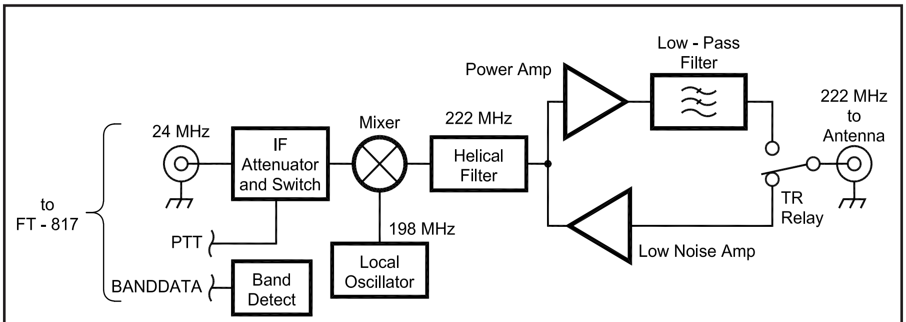


Figure 2—A block diagram of the 222 MHz transverter.

[1]Notes appear on page 38.

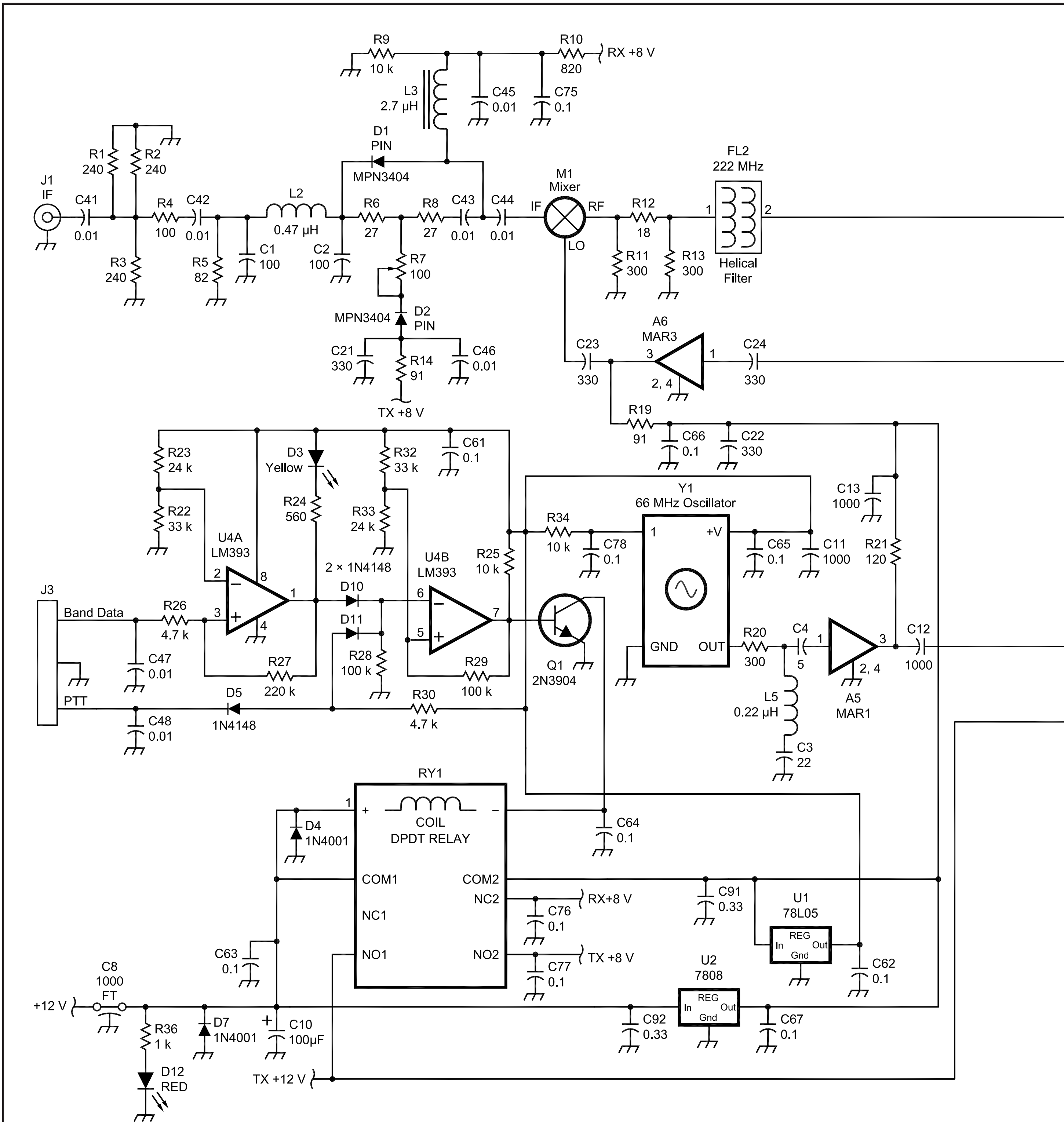
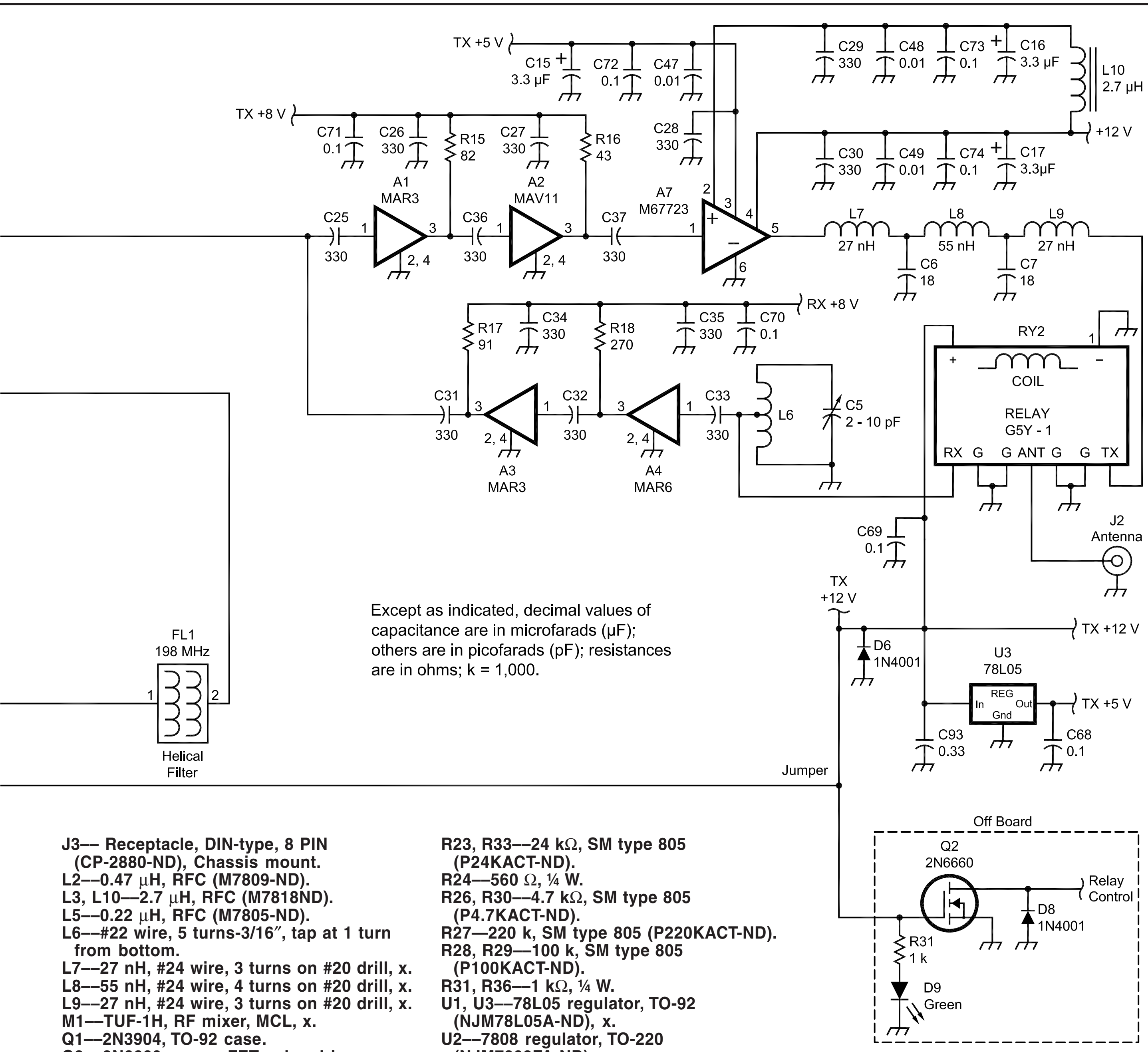


Figure 3—schematic and parts list.

A1, A3, A6—MAR3 MMIC amplifier, MCL, x.
A2—MAV11 MMIC amplifier, MCL, x.
A4—MAR6 MMIC amplifier, MCL, x.
A5—MAR1 MMIC amplifier, MCL, x.
A7—M67723, Mitsubishi 7 W RF amplifier module.
C1, C2—100 pF, SM type 805 (PCC101CGCT-ND).
C3—22 pF, SM type 805 (PCC220CNCT-ND).
C4—5 pF, SM type 805 (PCC050CNCT-ND).
C5—2-10 pF, trimmer (DK SG3002-ND).
C6, C7—18 pF, SM type 805 (PCC180CNCT-ND).
C8—1000 pF, feedthru **.
C10—100 µF, can (P5529-ND).
C11-C13—1000 pF, SM type 805 (PCC102CGCT-ND).
C15-C17—3.3 µF, can (P5565-ND).
C21-C37—330 pF, SM type 805 (PCC331CGCT-ND).
C41-C48—0.01µF, SM type 805 (PCC103BNCT-ND).
C61-C78—0.1µF, SM type 805 (PCC1828CT-ND).
C91-C93—0.33 µF, SM type 805 (PCC1856CT-ND).
D1, D2—PIN diode, MPN3404, **.
D3—LED, yellow.
D5, D10, D11—1N4148.
D4, D6-D8—1N4001.
D9—LED, green.
D12—LED, red.
FL1—198 MHz helical filter, Toko (TK3603-ND), x.
FL2—222 MHz helical filter, Toko (TK3501-ND), x.
J1-J2—BNC RF jack, chassis mount, **.



J3–– Receptacle, DIN-type, 8 PIN (CP-2880-ND), Chassis mount.
L2––0.47 µH, RFC (M7809-ND).
L3, L10––2.7 µH, RFC (M7818ND).
L5––0.22 µH, RFC (M7805-ND).
L6––#22 wire, 5 turns-3/16″, tap at 1 turn from bottom.
L7––27 nH, #24 wire, 3 turns on #20 drill, x.
L8––55 nH, #24 wire, 4 turns on #20 drill, x.
L9––27 nH, #24 wire, 3 turns on #20 drill, x.
M1––TUF-1H, RF mixer, MCL, x.
Q1––2N3904, TO-92 case.
Q2––2N6660, power FET, relay driver.
RY1––DPDT relay, G5V-2-DC12 (Z768-ND).
RY2––RF relay, DIP, G5Y-DC12 (Z724-ND), ** or (255-1087-ND) (alternate).
R1-R3––240 Ω, ¼ W.
R4––100 Ω, ¼ W.
R5––82 Ω, ¼ W.
R6, R8––27 Ω, SM type 805 (P27ACT-ND).
R7––100 Ω, potentiometer (3329H-101-ND).
R9, R25, R34––10 kΩ, SM type 805 (P10KACT-ND).
R10––820 Ω, SM type 805 (P820ACT-ND).
R11, R13, R20––300 Ω, SM type 805 (P300ACT-ND).
R12––18 Ω, SM type 805 (P18ACT-ND).
R14––91 Ω, ¼ W.
R15––82 Ω, SM type 1206 (P82ECT-ND).
R16––43 Ω, ¼ W.
R17, R19––91 Ω, SM type 1206 (P91ECT-ND).
R18––270 Ω, SM type 805 (P270ACT-ND).
R21––120 Ω, SM type 1206 (P120ECT-ND).
R22, R32––33 kΩ, SM type 805 (P33KACT-ND).
R23, R33––24 kΩ, SM type 805 (P24KACT-ND).
R24––560 Ω, ¼ W.
R26, R30––4.7 kΩ, SM type 805 (P4.7KACT-ND).
R27—220 k, SM type 805 (P220KACT-ND).
R28, R29––100 k, SM type 805 (P100KACT-ND).
R31, R36––1 kΩ, ¼ W.
U1, U3––78L05 regulator, TO-92 (NJM78L05A-ND), x.
U2––7808 regulator, TO-220 (NJM7808FA-ND), x.
U4––LM393 comparator, DIP8 (LM393N-ND).
Y1––66 MHz oscillator, ½ DIP (SE1128-ND).

Misc

Box, Hammond 1590BB (HM152-ND).
Ferrite beads (wires leaving board).
Plug, Mini, DIN-type, 8 PIN (CP-2080-ND).
Solder, low residue (KE1407-ND).
PC board––SSB Electronic USA, 124 Cherrywood Dr, Mountaintop, PA 18707; www.ssbusa.com/; tel 570-868-5643.
Parenthetical part numbers are Digi-Key; 701 Brooks Ave South, Thief River Falls, MN 56701; www.digikey.com/; tel 800-344-4539
SM indicates surface mount.
Parts marked x are available as a partial kit from Down East Microwave (see text).
Parts marked ** also available from Down East Microwave; www.downeastmicrowave.com/; tel 908-996-3584.

Why dBm?

RF designers generally characterize signals by their power levels, not their voltages. A signal level of +12 dBm, for example, is 12 decibels greater than a milliwatt, or approximately 13 mW. There are lots of reasons for this apparently arcane choice. The most significant is that if we express everything in decibels (relative to a milliwatt), then we can *add* the gains of adjacent stages. That is, if we pass our +12 dBm signal into a power amplifier with 20 dB of gain, we end up with a signal that is +32 dBm, or a little more than a watt. The system takes a while to become second nature, but once you become comfortable with the terms and the concept you'll wonder how you got along without it!

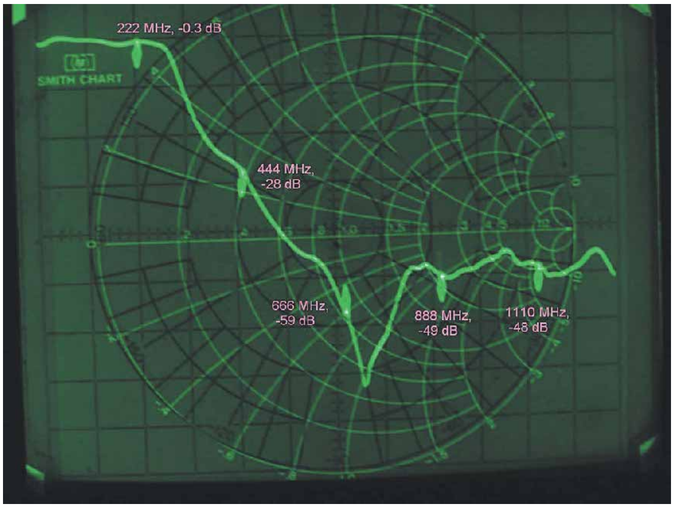


Figure 5—The output low-pass filter response.

used a high-level version for better dynamic range. (Although 222 MHz isn't 20 meters, dynamic range is important for rejecting out-of-band signals from other services, particularly TV signals, which often prevail at the elevated locations we choose for portable operation.)

A good local oscillator is usually the hardest part of any transverter design. It *must* provide a clean signal, because any undesired frequencies generated by the LO can become a source of "birdies" in the receiver. It must also be stable and have low phase noise. Low phase noise is important, as a noisy local oscillator will raise the noise floor of the receiver, particularly in the presence of strong out-of-band signals. Above 50 MHz, the interesting signals are usually the weak ones, so a low noise floor gets them in the log.

A crystal oscillator is the most obvious LO solution. Good crystals have become more expensive and harder to find, except those cut for frequencies used in computer hardware—those are cheap and produced in high volumes. I looked through the Digi-Key catalog (**www.digikey.com**) for DIP-packaged oscillators and found one usable for 222 MHz: 66 MHz times three is a perfect LO for a 12-meter (24-MHz) IF.

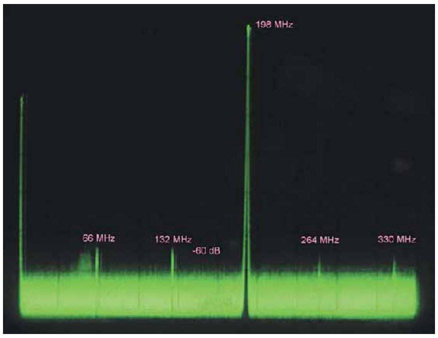


Figure 4—A spectrum display of the local oscillator (LO) output. Note that all spurious signals are at least 60 dB down with reference to the LO.

The next problem is multiplying the oscillator frequency times three. Frequency tripler circuits are usually touchy and inefficient. After some thought, I realized such a circuit is also unnecessary. The packaged oscillators have square-wave outputs, and square waves have plenty of third-harmonic content. Separating the third harmonic and amplifying it with an MMIC (monolithic microwave integrated circuit) probably produces more output than using the same MMIC as a frequency tripler.

Because the frequencies are widely spaced, a simple diplexer is sufficient to separate the 198-MHz third harmonic frequency from the 66-MHz fundamental crystal frequency. I sketched a simple circuit, built a dead-bug-style prototype and fiddled with component values for the best results.

The final circuit is shown in the schematic, Figure 3. Because the packaged oscillator is designed to drive logic circuits with an equivalent load of several hundred ohms, and the MMIC amplifier input is closer to 50 ohms, series resistor R20 is used to provide a better load for the oscillator.

The series-resonant circuit formed by L5 and C3 is a short circuit at 66 MHz, so the fundamental output is dissipated in R20. At the same time, L5 and C3 form an inductive combination at 198 MHz. In combination with C4, the result is an impedance step-down transformer that also forms a high-pass filter.

MMIC amplifier A5 puts out several milliwatts at 198 MHz, with other frequencies at least 10 dB down. After the helical filter, FL1, and another amplifier, A6, an LO level of about +12 dBm (see the sidebar, "Why dBm?") is supplied to the mixer. All other oscillator harmonics are at least 60 dB down, as shown in Figure 4.

Packaged oscillators don't have any provisions for frequency adjustment, but they are inexpensive. I placed two orders for four pieces each, and each group had two oscillators that came within 1 kHz of 198.000 MHz. They do seem to be quite stable, settling down after a short warm-up and staying put, which is what really counts.

The RF Circuit

The 222-MHz output from the mixer passes through a three-resonator helical filter, FL2, to eliminate the other mixing products. The receive path passes through the same filter to eliminate out-of-band signals. A 3-dB pad made up of chip resistors R11-13, inserted between the mixer and the filter, allows each to achieve a reasonable impedance match, which makes both circuits perform more predictably. Mixers are much better behaved when they "look into" a load impedance that is constant over a wide bandwidth. Filters also behave better when their inputs and outputs are terminated by the impedance for which they were designed.

The Transmit Circuit

In transmit, the clean signal coming out of the helical filter is amplified by two MMIC stages, A1 and A2, to boost the output to the +13 dBm required to drive power amplifier module A7. I chose a 5-W Class AB module for linear operation, the Mitsubishi M67723 (**www.rfparts.com**), because it was a good complement to the FT-817. A higher-power module would require much more current and heat-sinking, increasing the size and weight.

Finally, the output passes through a low-pass filter, L7-9 and C6-7, to reduce harmonic content. The design is right out of the tables in the *ARRL Handbook*[2], and works just like the book says it does. The measured response is shown in Figure 5.

The *Handbook* suggests that some amplifiers are less stable with capacitor-input filters, so I took the hint and used the inductor-input design.

The Receive Circuit

I chose to use a MMIC front end, a Minicircuits (**www.minicircuits.com**) MAR-6, for its simplicity, rather than using a GaAsFET in search of the ultimate noise figure. Even so, the noise figure is still better than that found in most transceivers. A tuned circuit, L5 and C6, at the front end is tapped to provide reasonable rejection of out-of-band signals (but not enough for an RF-polluted mountaintop where *serious* filters are required).

The overall receive gain, with two MMIC stages, is just high enough to overcome the losses in the mixer and IF switch. More important is the dynamic range; the second-stage MMIC, a MAR-3, operates at a higher current and has a higher intercept point than the MAR-6 first stage. This device and the high-level mixer were chosen so that the dynamic range is limited by the FT-817 and not the transverter.

The IF Interface

The IF interface is also tailored to match the FT-817, which has two RF-output antenna jacks, selectable by band. I prefer to connect the transverter to the rear jack and use the front jack for other VHF and UHF bands. A band-selection voltage is available on the transceiver's rear accessory jack (called BANDDATA by Yaesu). This voltage is connected to the transverter to make sure it will only transmit when tuned to the IF band, 12 meters. Thus, the transverter can be permanently connected to the rear antenna jack, but will only operate when the FT-817 is tuned to 12 meters.

On the Web, I found a nice band-detect circuit by K6XX (**www.k6xx.com**). Because only 12 meters is needed, I reduced it to a simple comparator, an LM393 dual-comparator IC, U4. The other half of the comparator is used for the PTT line from the accessory jack, with diodes to provide the AND logic so the transverter transmits only when the appropriate band is selected. The comparator also drives a yellow LED to indicate that the transverter is enabled, and a green LED when transmitting. Together with a red power LED, we have a simple traffic-light pattern.

The comparator output logic drives a relay, which is the simplest way to switch voltages between the transmit and receive circuits. The voltages also activate the PIN diode switches for the IF. The FT-817 is operated at its lowest standard power output level, ½ W, but further power reduction is necessary before driving the mixer, which can handle only a few milliwatts.

At the ½ W level, ordinary ¼ W resistors can be used as an input attenuator. In this case, R1 through R5 form a 13 dB attenuator (for transmit and receive). Further power reduction for transmit is provided by a variable attenuator consisting of R6, R7 and R8. R7 adjusts the maximum drive power. On receive, the variable attenuator is bypassed by the PIN diodes, D1 and D2, but the input attenuator remains in the line to protect the mixer in case of switching failure. Between the two attenuators, a simple low-pass pi filter, C1, L2 and C2, keeps LO and RF energy out of the transceiver, passing only frequencies below about 30 MHz.

Voltage Regulators

The FT-817 will operate with rather low battery voltage, so the transverter has internal voltage regulation to maintain stable operation over a wide range of voltages. Most of the circuit is supplied from an 8 V, three-terminal regulator IC, U2. The regulator needs 3 V of headroom, so operation is guaranteed down to 11 V. At 11 V, a "12 V" battery is nearly dead. (Always power your portable gear from a separate battery so the car will start at the end of the day!)

The oscillator is powered from a 5 V, three-terminal regulator, U1, running off the 8 V regulator, so it is doubly-regulated for additional stability. A separate 5 V regulator, U3, provides stable bias for the power amplifier. If it were not separately regulated, the additional current drawn during transmit could change the oscillator frequency slightly.

The Printed-Circuit Board

One of the things I experimented with while building the Miniverter was a "Miniboard" printed-circuit service from ExpressPCB. They provide free PCB layout software (download it from **www.expresspcb.com**) that is quite easy to learn and use. When the PCB layout is complete, the layout is uploaded to their website. The boards are high quality, double-sided boards having plated-through holes for good grounding and are fully tinned for easy soldering. You can't make these in your basement! For those who would rather order completed boards, they are available from SSB Electronic USA (**www. ssbusa.com**).

Looking at the top view of the board in Figure 6, the main helical filter, FL2, is placed as a barrier between the RF side of the board and the IF and LO sections. The isolation helps to reduce "birdies" and other unwanted interactions. The lower-frequency side is crammed fairly tightly to preserve as much space as possible on the higher-frequency side (most of the gain is at 222 MHz). High gain and tight spacing is a recipe for instability. (Instability is the bane of VHF homebrewers and professional RF engineers alike! It often occurs when the output of an amplifier is inadvertently coupled to the amplifier's input, turning the amplifier into an oscillator. We need to pay close attention to layout to avoid these sneaky feedback paths.)

The other key to stable, predictable performance is adequate bypassing. Figure 3 includes plenty of capacitors of different values at different frequencies, with the values chosen for operation just below the self-resonant frequency of each capacitor (see the sidebar, "When Capacitors are Inductors…"). The exact values aren't critical, but shouldn't be changed too much. The power amplifier module, A7, is bypassed for a wide frequency range by using several different capacitor values (bipolar transistor amplifiers are prone to oscillate at low frequencies). The multiple bypass capacitors can be seen in the detail photo in Figure 7. Chip capacitors are small enough to use freely and inexpensive enough, perhaps a nickel each in small quantities, to use by the dozen.

To aid in keeping track of the different bypass capacitors, all the capacitors of the same value have consecutive reference designators (for example, C21 through C37 are all 330 pF) on Figure 3 and the parts list in the caption.

Construction

All essential components are mounted on the printed circuit board. The two that require heat sinking, A7 and U2, attach along one edge so they can be bolted to the box (a dab of heat-sink compound doesn't hurt). Figure 8 shows the completed assembly. The die-cast aluminum box I used had some raised text and mold marks on the bottom, so the surface wasn't flat enough to serve as a heat sink for amplifier module A7. To fix things I flattened the area by scraping off the raised metal with a deburring tool and wrapped some sandpaper around a small flat block so I could sand the area flat. The die-cast metal is soft, so it isn't a big job, but, if you've access to a milling machine, that would make it easier to flatten the bottom surface.

Component placement diagrams from ExpressPCB can be found on the ARRLWeb.[3] There are a lot of chip components—77 resistors and capacitors by my count. Most are the 0805 size (0.08×0.05 inch = 2×1.25 mm), slightly smaller than the 1206 size used by Down

East Microwave in many of its transverters, but large enough for me to assemble without a microscope.

If you aren't comfortable working with chip components and surface-mount soldering, this could be a difficult project. Surface-mount soldering isn't really difficult, however, and can be learned with a bit of practice. A temperature-controlled soldering iron with a fine tip is important (I prefer about 700 ºF), as is thin, "low-residue" solder to eliminate the need for flux removal.

My technique is to put a small amount of solder on one pad, then hold the component in place with tweezers while reheating that pad to attach one end of the component. I then solder the other end of the component to the other pad and touch up the first end if necessary. Where pads and components are close together, a little planning can make it easy to solder the second end of one component while starting the first end of another.

An alternative technique uses soldering tweezers to heat both ends of a component simultaneously. I haven't tried this, but some people like it. I've also heard of folks using two soldering irons the same way.

Because chip components are inexpensive, buy a few spares. If you mess one up or reheat it too many times, simply remove it and throw it away, clean up the pads and try again.

Additional close-up photos of the assembly might help with construction and these can also be found on the ARRL web site.[4] Larger color photos can be downloaded from my Web site, **www.w1ghz.org**.

A parts list is shown in the Figure 3 caption. All parts are readily available from the suppliers listed. There is no complete kit available, but Down East Microwave (**www.downeastmicrowave.com**) has made a partial kit available that includes all of the RF-type parts except the power amplifier. Call them for details. The printed circuit board may be ordered from ExpressPCB by submitting the file **222xvtr.pcb** as a "Miniboard" order for a lot of three boards.

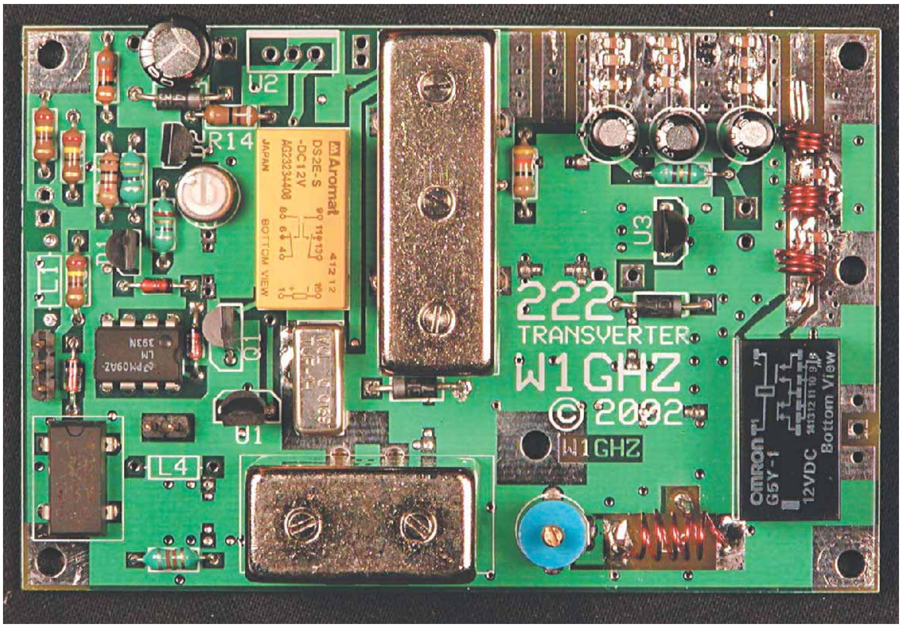


Figure 6—A top view of the transverter board. The main helical filter, FL2, can be seen at the board center, mounted vertically.

When Capacitors are Inductors...

The dirty little secret of passive devices is that at VHF and UHF, things may not be what they seem. Consider an ordinary 1000-pF ceramic disc capacitor, frequently used as a bypass capacitor. With short wire leads sticking out of two parallel metal plates, a 1000-pF ceramic capacitor may actually function as a capacitor at 10 MHz, but at 100 MHz its lead inductance dominates and it's an inductor! The frequency at which the reactance from its lead inductance is exactly equal to the capacitive reactance from its parallel plates is called its *series resonance*—perhaps 40 or 50 MHz for our 1000 pF capacitor. As we approach the series-resonant frequency, the capacitor becomes an RF short-circuit, which is exactly what we want from a bypass capacitor. At higher frequencies, however, it quickly becomes an inductor and it is useless as a bypass capacitor. That's why you won't see many disc capacitors in modern VHF/UHF radios. In fact, surface-mount chip capacitors, with small, low-inductance leads, are much better. Still, their inductance isn't *zero* either and the landing pads on the PC board add additional inductance. So, these tiny parts also exhibit series resonance; it's simply at a higher frequency.

The bypass capacitor values in this transverter were chosen so that the components are operating just below their series-resonant frequencies. Designers also employ several capacitors in parallel when they want to create a broadband RF short. The large capacitors create a path for low-frequency signals and the smaller capacitors (which often have much higher series-resonant frequencies) create a path for higher frequency signals. The bypassing of the power amplifier A7 in Figure 7 illustrates this technique.

The local oscillator should be assembled first and aligned, along with voltage regulators U1 and U2––but not the mixer. Heat sinking of U2 isn't necessary at this time because only the LO is powered. The key LO adjustment is to retune FL1 to 198 MHz, as standard Toko filters are only available for 187 or 192 MHz. A coaxial connector is temporarily attached near the mixer pins to measure the LO output (see the sidebar, "Simple Power Measurement") and the two tuning screws on top of FL1 are adjusted for maximum output. Turning the screws *clockwise* increases the frequency; at least two full revolutions of each screw will be required to reach 198 MHz.

After the LO is aligned, the rest of the board can be assembled. I like to test the board before final assembly, with the FT-817 or appropriate test equipment connected to the IF port and a clip lead to operate the PTT line. The transmit output without the power amplifier should be more than +10 dBm at the A7 input pin connection and should be adjustable with R7. The receive section is tested by applying a signal generator to the antenna connection and peaking C5. R7 should not affect the receive gain. A printed-circuit-mount SMA connector will slip on each of the above-mentioned test points without soldering, or a short piece of coax could be tack-soldered to each test point.

Try to test everything possible before final assembly, while both sides of the board are still accessible. The band detect input should operate and turn on the yellow LED when the input voltage is below about 2.9 V (and not at higher voltages). Grounding the PTT input should only activate the relay when the yellow LED is on. Finally, trim all of the component leads on the bottom side and go over everything one last time, checking for shorts.

The printed circuit board is mounted to the box with six 4-40 screws through the big holes in the board. The board must be spaced high enough from the bottom

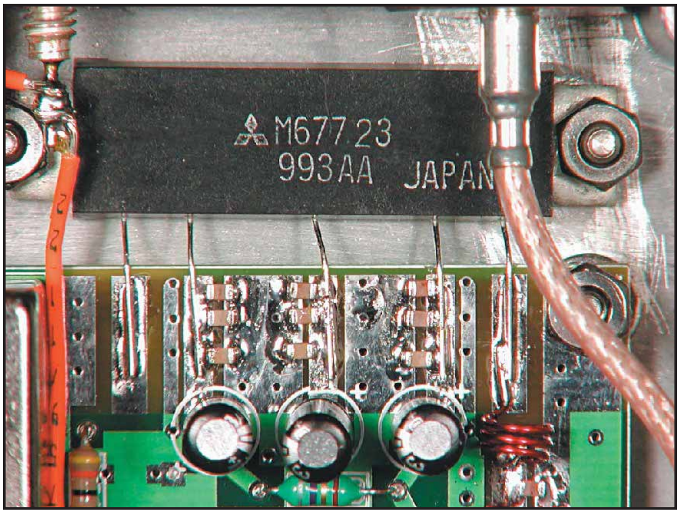


Figure 7—The technique of using multiple RF bypass capacitors to overcome lead reactance. The 9 chip and 3 can capacitors can be seen immediately below the power amplifier module. (See "When Capacitors are Inductors..." sidebar.)

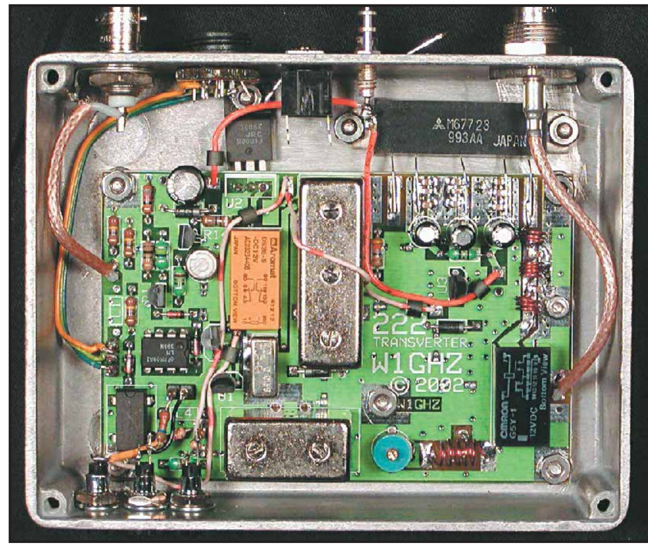


Figure 8—The transverter enclosure with the cover open, showing the completed assembly.

of the box to provide clearance for bottom-side components, but low enough so that the power amplifier leads are short. A flat washer and a hex nut seem to be about the right combination (the washer is against the box). Component leads must be trimmed close to the board. The PCB is held down with more hex nuts, and at least two spots need small-pattern nuts to clear the components.

RF input and output connections from the board terminals to the BNC jacks should be made with thin coaxial cable. The braid must be grounded at both ends with short leads. All other leads leaving the board should be routed away from the RF areas. Placing ferrite beads on the wires will help keep stray RF where it belongs. The photos show how I did the assembly.

Adjustment

After assembly, the transmit attenuator must be adjusted. Hook up the FT-817 and a dummy load and make sure all the switching circuitry works correctly—using the mike button in CW mode will switch to transmit with no output power. Turn R7 fully counterclockwise and set the FT-817 for low power (0.5 W) at 24.9 MHz CW. Key the transverter and adjust R7 for maximum output, which will probably be about 6 or 7 W. If you adjust R7 for 5 W output, the SSB linearity will be good. Now peak FL2 at this frequency so the band-pass filter will cover the whole band. Then readjust R7 for 5 W output. Finally, C5 should be adjusted while receiving a weak signal (or adjusted for best noise figure, if possible).

Performance

The transmitter output is set for 5 W to match the power output of the FT-817 on other bands. The output spectrum is pretty clean, as can be seen in Figure 9. The LO is 45 dB down and other spurs are even lower. The second harmonic is 50 dB down and higher harmonics are more than 70 dB down. At this power output, total current for the radio plus the transverter is about 2 A, which is reasonable for battery operation and close to the current drawn by the FT-817 alone at 5 W output on other bands.

The output spectrum is, however, not quite clean *enough* to put on the air directly. A 5 W transmitter at 222 MHz should have unwanted outputs down to at least –53 dBc (decibels relative to carrier).[5] An external band-pass filter can easily reduce the spurs and harmonics to the required level and help protect the receiver front end from TV transmitters and other interference. Good filters can be found new, such as the DCI-223.5-3H (**www.dci.ca**); surplus, such as the F-199/U (**www.fairradio.com**) or homebrew, such as that recently described in *QEX*.[6]

On receive, the transverter draws about 250 mA. Although I haven't measured the noise figure, weak-signal sensitivity seems very close to a Down East Microwave transverter with a GaAsFET front end. Frequency stability is excellent after warm-up and no frequency adjustment is required. Audio reports on sideband are good.

Of course, if you want this transverter to cover the whole 222-225 MHz band, the FT-817 must be modified to transmit on all frequencies, as no HF ham band is wide enough to provide unmodified coverage. This can be a tricky situation, as modifying your radio for "dc-to-daylight" transmit coverage will violate the warranty. If you want to enable full-band coverage, see **www. mods.dk** for details.

Comparison

The benchmark transverter that I used for comparison is available from Down East Microwave (**www.downeastmicrowave.com**). It's a high-performance unit that was built from a kit for my home station. Some ideas were borrowed from it when I designed this transverter, but I also elected to make some tradeoffs. Here's a quick comparison:

Power Output—The Down East unit puts out 25 W or more and needs a hefty heat sink as a result. I chose to keep the power to 5 W and to use the metal enclosure as a heat sink. The dc input power is also much lower.

Filtering—The Down East unit has an additional helical filter before the power amplifier to further reduce spurs. It's probably more important at the higher power levels. I also reduced the output low-pass filter from four sections to three, losing a bit of harmonic reduction.

Receiver—The Down East unit has a

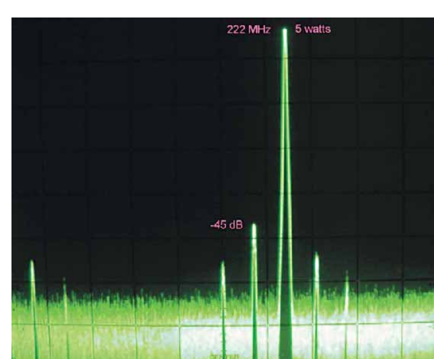


Figure 9—The output spectrum of the 222 MHz transverter, before any filtering. The LO is 45 dB down and the second harmonic is 50 dB down, all referenced to the carrier.

Simple Power Measurement

In writing this article I assumed that you can measure RF power in some reasonably accurate fashion (because I find it an essential capability). How else can you tune a circuit or even tell if something is working? A power meter doesn't have to be a precise instrument. I've used a simple RF detector for years for uncalibrated, relative readings at VHF. The circuit shown in Figure A is simple enough to "dead-bug" on a scrap of PC board or on the back of a coax jack. Simply remember to keep the leads short and you'll be okay. With such a device you can measure RF power in the range of 0 to +20 dBm (1 to 100 mW should yield a corresponding dc voltage from millivolts to several volts).

Because this circuit actually indicates peak RF voltage, it's very sensitive to harmonics and unwanted frequencies, but because both of the test points follow helical filters, the output signal should be clean enough for easy measuring.

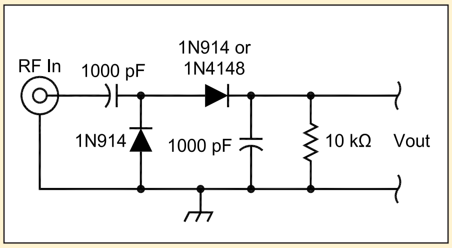


Figure A—Simple RF detector.

GaAsFET front end, so the noise figure is a couple of dB lower. Making a stable, self-biased GaAsFET amplifier can be tricky, so I went with a simple, reliable MAR-6 MMIC design. It's perfect for this low-power station.

IF interface—The Down East unit devotes a lot of board space to a universal IF interface so it can be used with just about any radio ever made. This one is tailored to the FT-817. To use it with another rig (an Elecraft K2, for example) modify the circuit as needed and feel free to change the board design to accommodate those changes.

Local oscillator—The Down East unit uses a relatively expensive crystal with a trimmer to set it right on frequency (until it ages) and a heater to reduce temperature sensitivity. I used a cheap computer oscillator for simplicity and compactness.

Alternatives

Although this transverter is intended for the FT-817, it could certainly be used with other QRP transceivers. For example, it would probably fit inside an Elecraft K2. The choice of IFs is limited only by available oscillator frequencies. Custom oscillators, however, are prohibitively expensive and programmable oscillators have excessive phase noise.

An interesting alternative is to use a 65 MHz oscillator (rather than 66 MHz) to put the IF at 27 to 30 MHz. A CB transceiver could be used for SSB at the low end of the 222 MHz band and a 10 meter transceiver would cover the 223-224.7 MHz segment for FM use. Full-band coverage would still require a modified transceiver.

If more power is required, the use of an external amplifier is fairly straightforward. A solid-state "brick" is fine for FM and CW. Some units are close to being linear and can be used for SSB. Tube amplifiers can provide higher power with better linearity. My transverter easily drives a surplus AM-6155 (**www.fairradio.com**) amplifier to 400 W output—but that amplifier is far from being small and lightweight! The FT-817 transverter was designed for portable and rover operation. For serious high-power operation, a Down East transverter with a full-size transceiver is probably a better choice.

Conclusion

This transverter adds the missing link to the FT-817, giving it 222-MHz capability with performance that is comparable to its other bands. Now backpackers, rovers and other portable operators can have true all-band coverage and still travel light.

Notes

[1]P. Wade, W1GHZ, "2-Meter Miniverter," N.E.W.S. Letter, North East Weak Signal Group, Mar 2001, pp 5-6.

[2]*The 1993 ARRL Handbook for Radio Amateurs*, ARRL, 1992, p 2-40.

[3]**www.arrl.org/files/qst/qst-binaries/wade0103.zip**.

[4]See note 3.

[5]"External-Filter Requirements," *QST*, May 2001, p 33 (sidebar).

[6]Z. Lau, W1VT, "A Low-Cost 222-MHz Helical Band-Pass Filter (RF)," *QEX*, May 2001, p 58.

Paul Wade, W1GHZ, has been licensed since 1962 and has previously held the calls N1BWT and WA2ZZF. Paul has been a microwave experimenter for years; he is President of the North East Weak Signal Group. A former microwave engineer and retired ski instructor, he is currently employed as a computer hardware designer. He was honored by the ARRL with the 2000 Microwave Development Award and, in 2001, with the Thomas Kirby Eastern VHF/UHF Society Award.

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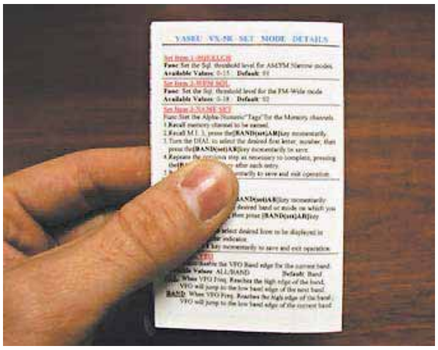

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QST

gree in Electronics and Telecommunications from the University of Brasilia in 1974. Upon graduation, he joined the Brazilian Broadcasting Services Secretariat at the Ministry of Communications, where he worked for more than 20 years at both policy and technical levels. From 1979 to 1994, Mr Blois was Director of the Broadcasting Division of the National Telecommunication Department, Director of the National Telecommunication Department and Director of the Department of Private Telecommunications Services. Mr Blois was the representative of Brazil in the ITU Administrative Council from 1990 to 1993. He was also the representative of Brazil in the Permanent Executive Committee of the Inter-American Telecommunication Commission (COM/CITEL), Organization of American States, from 1991 to 1993. He was the CITEL Executive Secretary from 1994 to 1999. Mr Blois was elected to the post of Deputy Secretary-General of the ITU in February 1999 at the 1998 ITU Plenipotentiary Conference held in Minneapolis.

Election of the ITU Bureau Directors

Each of the three branches of ITU is called a Bureau and is headed by an elected Director. Directors are not permitted to serve more than two terms for a total of eight years. Thus, a new Director was required for the Radiocommunication Bureau, Bob Jones, VE7RWJ/VE3CTM, having reached his limit of eight years.

Mr Houlin Zhao of China and Mr Hamadoun Touré of Mali were elected for second terms as Directors of the Telecommunication Standardization Bureau and Telecommunication Development Bureau, respectively. After two rounds of voting, Mr Valery Victorovich Timofeev, of the Russian Federation, was elected Director of the Radiocommunication Bureau. Mr Timofeev has been the Deputy Minister for Communications and Informatization of the Russian Federation since 1999, and the Deputy Chairman, State Radio-Frequency Commission, of the Russian Federation, since 1992. Other candidates for the position of Director of the Radiocommunication Bureau were Mr Kavous Arasteh (Iran), Mr Fabio Bigi (Italy), and Mr Malcolm Johnson (United Kingdom). Mr Arasteh had withdrawn his candidacy following the first round of balloting.

Unlike past Directors of the Radio Bureau, Mr Timofeev is not a licensed amateur.

ITU's Financial Problems

For decades, the ITU has been running on the concept of "zero real growth (ZRG)," which means holding the line on budgets. The Union's income sources are Member State and Sector Member (industry) dues, publication sales, proceeds from TELECOM trade shows and more recently cost recovery. ZRG had been largely successful until recent years. World Radiocommunication Conferences every 2 or 3 years, new ITU initiatives, translation and interpretation costs, paperwork costs, processing of a backlog of satellite notifications and reduced income from a general slump in the telecommunications industry have combined to force some belt-tightening. A substantial part of ITU costs is payroll. The ITU has cut positions before to save money but has not found it necessary to terminate employees, which is now the case. In addition, meetings are being reduced in length and some are being canceled to keep expenses down.

USTTI Celebrates 20th Anniversary

On October 9, 2002, the United States Telecommunications Training Institute (USTTI) celebrated its 20th anniversary with a reception hosted by Chairman Michael R. Gardner and the US Head of Delegation Ambassador David Gross. More than 150 USTTI alumni attended. The Amateur Radio Administration Course taught each year at ARRL Headquarters is one of the courses offered to government regulators through the USTTI. The ITU formalized training to developing countries by signing an agreement with the USTTI during the conference. As a result, the ITU will now include USTTI courses in its annual operational human capacity-building plan.

Dr Larry E. Price, W4RA, is President of the International Amateur Radio Union. He served as ARRL president from 1984 until 1992. You can reach him at **w4ra@iaru.org**. *Jon Siverling, WB3ERA, is a technical relations specialist on the staff of the ARRL's Technical Relations Office in Washington, DC. You can reach him at* **wb3era@arrl.org**.

FEEDBACK

◊ A news item, "New All-Ham Crew Settles In Onboard International Space Station" [Happenings, Feb 2003, p 81] incorrectly identified one of the Expedition 6 crew members and included an outdated NASA crew photo. The correct lineup is crew commander Ken Bowersox, KD5JBP; cosmonaut Nikolai Budarin, RV3FB, and astronaut Don Pettit, KD5MDT. The accompanying NASA photograph depicted Don Thomas, KC5FVF, who had been slated to be on the Expedition 6 crew but was replaced last summer by Pettit due to an undisclosed medical issue.

◊ The correct telephone number for Datamatrix [New Products, Feb 2003, p 107] is 800-373-6564.

◊ In "The DBJ-1: A VHF-UHF Dual-Band J-Pole" [Feb 2003, p 40], replace "VHF" with "UHF" in the headings of Table 2, columns 1 and 2. Column 3 remains "VHF," as it refers to the use of a 2 meter VHF J-Pole on its third harmonic. Also, the area immediately to the left of the RG-174 stub should not be shaded. The decoupling stub is in series with two separate pieces of twin-lead.

◊ In "A 222 MHz Transverter for the Yaesu FT-817" [Jan 2003, pp 31-38], the sidebar "Why dBm?" contains an error. A signal level of +12 dBm is 16 mW (actually 15.85 mW), not 13 mW, as stated. (Thanks to Dr H. Paul Shuch, N6TX, for calling this to our attention.) Power is nearly doubled every 3 dB, so +3 dBm = 2 mW; +6 dBm = 4 mW; +9 dBm = 8 mW and +12 dBm = 16 mW. Or...dB (power) = 10 log [P_{out} / P_{in}], so 12 dBm = 10 log P_{out}/1, so P_{out}= $\log^{-1}$ (1.2) = 15.85 mW. Note that $\log^{-1}$ (1.2) is *not* the same as [log $(1.2)]^{-1}$. Read this as "The number whose $\log_{10}$ is 1.2 = 15.85" or "10 raised to the 1.2 power = 15.85."

Also, note the following errors in Figure 3, the schematic diagram:

U4A and U4B have the pins swapped (the two sections are interchangeable); the red LED, D12, is connected to +8 V in the photo, near RY1; there are two components labeled C47 on the schematic—the one near J3 becomes C51 (0.01 µF); there are also two components labeled C48—the one near J3 becomes C50 (0.01 µF); C49 is missing from the parts list (0.01 µF), and C79 is missing from schematic (0.1 µF)—in parallel with C17.

The sentence on page 35, under the heading "The Receive Circuit," should read, "A tuned circuit, L6 and C5..."

Q2, the 2N6660, may be hard to find. The IRF510 (Digikey IRF510-ND) is a good, inexpensive substitute. Almost any N-channel power FET will work, however.

J3 clarification—the connections are to the 8-pin ACC jack on the FT-817. BANDDATA and GND go to the same pins, while PTT connects to the TX GND pin.—*tnx K2QO, KA7EXM, W4YN and N9MNP*

The latest corrections and updates can be found on the author's Web site, **www.w1ghz.org/**.

◊ "Amateur Radio and the Rise of SSB" [Jan 2003, p 45], states: "...vestigial sideband (VSB) has been developed for digital television." In fact, television broadcasting has been using VSB to transmit video since way back when TV first came on the air.—*Ed Padgett, KK5WT*