Linear Transverters for 144 and 220 Mhz

By Paul Drexler, WB3JYO

The CW and SSB portions of the 144-and 220-MHz bands have swelled with activity during the past few years. Although there is plenty of commercially made CW and SSB gear for 144 MHz, there is little available for 220. Paul Drexler, WB3JYO, designed and built the linear transverters described here and shown in Figs. 40 through 62. These projects enable the use of a standard 28-MHz transceiver as a tunable IF for 144- or 220-MHz operation. Construction is less complicated than building a complete transceiver, and all of the good features of the HF rig (such as a clean SSB source, stable VFO and good crystal filters) are incorporated. Chapters 11 and 12 contain additional information on transverter theory. Although these transverters may be tuned for any segment of operation, they were designed mainly to cover the lower portion of each band (144 to 145 MHz and 220 to 221 MHz). A 12-V power supply and an antenna are the only other equipment necessary to complete the VHF station. The complete transverter design includes a minimum of hard-to-find components and should be easily reproducible. Although the text and illustrations center around the 220-MHz transverter, component values are given for the 144-MHz unit as well. Except for the local oscillator (LO), all circuits are common to both designs. The receive converter has a 0.6-dB noise figure and an overall conversion gain of 28 dB. These figures were verified on an

HP8970A noise-figure meter with an HP346A noise source. Transmit-converter power output is a conservative 1 W under linear operation. The companion amplifier produces 8 to 10 W of linear output power. Much care was taken to make the transmit chain as clean as possible, and the receive converter incorporates techniques to maximize sensitivity and dynamic range.

CIRCUIT DESCRIPTION

Fig. 41 shows the transverter block diagram. The main difference between the 144- and 220-MHz versions is the LO. Although transceive operation is depicted, the experimenter may choose to limit construction to either transmit only or receive only. LO energy is injected into a high-level (+ 17 dBm) doubly balanced mixer during receive. Received signals are amplified by a GaAsFET preamplifier and then filtered before entering the mixer. The 28-MHz



Fig. 40 — The 144- or 220-MHz transverter is built using a modular circuit approach. Each circuit is boxed and mounted on a chassis with interconnections of short lengths of 50-ohm coaxial cable.



Fig. 41 — Block diagram of the 144- and 220-MHz transverters. All blocks but the local oscillator are common to both bands.



Fig. 42 — Schematic diagram of the 192-MHz local oscillator. All resistors are Vt-VJ carbon-composition types unless otherwise noted. Capacitors are silver-mica or miniature monolithic ceramic types unless otherwise noted. Capacitors marked with polarity are electrolytic.

C1 — 25-pF (max.) miniature ceramic trimmer. C2, C3, C4 — 9-pF (max.) miniature ceramic

trimmer. C5, C7 — 10-pF (max.) ceramic piston trimmer or miniature ceramic trimmer. C6 — 0.5-pF ceramic chip or gimmick capacitor. See text.

J1, J2 — Chassis-mount female BNC connector. L1 — 10t no. 24 enam., 0.100-inch ID, close wound.

L2 — 15t no. 28 enam. on T25-6 toroid core. L3, L4 — 5t no. 24 enam., 0.125-inch ID, close wound.

L5 — 4t no. 24 enam., 0.125-inch ID, close wound.

L6, L7 — 5t no. 18 tinned, 0.250-inch ID, spaced one wire dia. Tap at 1t from ground.

Q2 — RCA CA3049 transistor array. CA3054 or Motorola MC3346 are acceptable substitutes.

RFC1-RFC4 — 2.2-/*H molded miniature RF choke.

T1 — 7t no. 30 enam., trifilar wound on T25-12 core or Mini-Circuits T4-1 transformer. See text.

U1 — Three-terminal voltage regulator, 8 V, 100 mA (LM78L08 or equiv.).

Y1 — Fifth-overtone, 96-MHz series-resonant crystal, HC-18/U holder.

signal at the output port of the mixer is sent to a post amplifier and band-pass filter, and then to the 28-MHz IF receiver.

On transmit, LO energy and a low-level RF signal from the 28-MHz IF transceiver are fed to a standard-level (+7

dBm) doubly balanced mixer. The mixer output is filtered to eliminate the image and other unwanted responses, and then the desired signal is amplified by five stages to reach the 1-W level. The output of the 1-W transmit converter is further filtered to meet FCC rules and regulations. An optional 8-to 10-W amplifier is described for those desiring greater power output.

This transverter is built in a modular fashion. All of the major circuit blocks are built into separate enclosures and interconnected by 50-ohm coaxial cable. Modular construction lends itself to on-the-air experimentation and development, as well as simple troubleshooting. Any stage may be removed from the circuit for modification, or a new stage may be substituted. Although commercially available diecast boxes (BUD CU-123 and CU-124 or Hammond 1590A and 1590B) are used here, double-sided PC-board enclosures or Miniboxes may be used. Mounting all circuits in individual boxes is highly recommended for versatility and shielding. All component connections are made using direct, point-to-point construction techniques.

Local Oscillator

A schematic diagram of the local oscillator for the 220-MHz transverter is shown in Fig. 42. A frequency of 96 MHz has been chosen so that only one stage of multiplication is necessary to obtain the needed 192-MHz LO frequency. The crystal, Yl, is a series-resonant, fifth-overtone type in an HC-18/U package. The oscillator used is a common-base circuit derived from an article by Joe Reisert, W1JR.1 Most crystal oscillators tend to oscillate at a frequency slightly higher than the crystal's fundamental mode of operation. In this circuit, L2 cancels the Co crystal capacitance, thus bringing the oscillator down to the desired frequency.

The author chose to use a 95.95-MHz crystal (for a 191.9-MHz LO); an IF frequency of 28.1 MHz corresponds to an operating frequency of 220.0 MHz. Strong signals from stations operating on 10 meters may be picked up by the transverter interconnecting cables, interfering with signals being received from 220 MHz. Also, when more than one transverter with a 28-MHz IF is operated in the same room (at a multioperator VHF contest station, for example), it is not uncommon to hear signals from the other IF transceivers.

Oscillator output is fed into an active doubler constructed with a CA3049 transistor array. This circuit is based on a suggestion by Bill Strunk, K3ZMA. The doubler features as much as 7-dB gain and excellent harmonic suppression because of its balanced input circuit. A CA3054 or MC3346 transistor array may be used in place of the CA3049. Output energy from the doubler is further amplified by Q3 and Q4 to bring the LO to the required mixer input level. Filtering is accomplished at the LO output by a lightly coupled double-tuned filter. All spurious and harmonic energy is better than 55 dB below the desired signal. A clean LO is necessary to avoid interference problems caused by undesired mixing products during receive and transmit.

After the filter, a resistive power divider is used to drive the transmit and receive mixers. Resistive pads attenuate the LO signal to the proper level while providing a 50-fi impedance for the mixer input.

Although a similar lineup could be employed for 144 MHz, a three-stage 116-MHz oscillator is shown schematically in Fig. 43. The 144-MHz transverter uses a 116-MHz series-resonant crystal (Yl) to avoid frequency multipliers. Oscillator output is amplified by Q2 and Q3 until it reaches the level necessary to drive both the transmit and receive mixers. LO output is filtered by a double-tuned band-pass filter. After the filter, a resistive power divider is used to drive the transmit and receive mixers; again, pads attenuate the signal to the proper level. With the filters properly adjusted, all spurious outputs from the LO are about 58 dB below the fundamental. Fig. 44 shows the spectral output from the LO receive port.

Receive Converter

The 144- and 220-MHz receive converters are identical, except for the tuned circuits in the front end. In each case, the converter consists of a GaAsFET preamplifier, a mixer/diplexer circuit and an optional 28-MHz post amplifier. The mixer/ diplexer and post amplifier circuits are the same, regardless of band. Each of the three receive converter blocks is built into a separate module. This was done to facilitate experimentation and development of each stage. Of course, it is possible to build all three circuits in one box. This subject will be addressed in the construction portion of this article.

Mixer

The heart of the receive converter is a Mini-Circuits SRA-1H high-level, doubly balanced mixer (DBM). See Fig. 45. This mixer requires an LO injection level of + 17 dBm, compared with the + 7 dBm injection level required for standard mixers. The high-level mixer offers superior strong-signal handling characteristics while maintaining the port-to-port isolation, image suppression and simplicity inherent in a DBM. The SRA-1H is modestly priced and available in small quantities directly from the manufacturer.

Reactive terminations can ruin the excellent IMD characteristics of a DBM.2>3 The IF port, in particular, is most sensitive to a nonresistive 50-ohm termination. Anything short of a 20-dB resistive pad at the IF port will result in increased IMD products and a lower third-order-intercept point. Feeding the output of a DBM directly into a narrowband amplifier will decrease the mixer's third-order intercept point as compared to a purely resistive termination. The diplexer circuit shown in Fig. 45 represents one solution to the problem of proper mixer termination. The di-plexer's low-pass response presents a 20-dB return loss at 28 MHz and terminates higher frequencies into 50 ohms.

RF Preamplifier

A low-noise, high-dynamic-range GaAsFET preamplifier is used in front of the mixer to overcome mixer conversion loss. The GaAsFET device offers exceptional performance, compared with most bipolars and MOSFETs, and designs abound.4'5 The circuit in Fig. 46 has proven reliable during many hours of on-the-air

operation. This simple design offers a noise figure of 0.4 dB, as measured on an HP8970A noise-figure meter with the HP346A noise source. This noise figure is much lower than the feed line loss preceding the preamplifier; performance is exceptional for all applications short of intensive EME receiving. A 30-mA bias current achieves optimum signal-handling capability. The third-order-intercept point is +25 dBm. Gain is 24 dB.

The double-tuned filter between the preamp and mixer provides a reasonable degree of filtering. A trap (L2) is used to attenuate the 164-MHz (188 MHz for the 2-meter version) image. Fig. 47A shows the swept frequency response of the 220-MHz version. A comb line or helical filter might be used if greater selectivity is required.

1 Reisert, Joe, "VHF/UHF Receivers," Ham Radio, March 1984, pp. 42-46.

2 Will, Peter, "Reactive Loads — The Big Mixer Menace," Microwaves, April 1971, pp. 38-42.

3 Cheadle, Dan, "Selecting Mixers for Best Inter-mod Performance," Microwaves, Nov. and Dec. 1973.

4 Kraus, Geoff, "VHF and UHF Low Noise Preamplifiers," QEX, Dec. 1981, p. 3.

s Reisert, Joe, "Low Noise GaAsFET Technology," Ham Radio, Dec. 1984, pp. 99-112.

28-MHz Post Amplifier

For most amateur applications, a 28-MHz post amplifier is not necessary. It serves to amplify the 28-MHz IF signal to increase S-meter readings. The author lives among several of the "big gun" VHF stations in southeastern Pennsylvania, so high dynamic range is essential to avoid overload problems. The receive converter operates nicely without any post amplification, thereby preserving the IF receiver's dynamic range.

The 28-MHz post amplifier shown in Fig. 48 has been included here for those operators fortunate enough to live away from strong in-band signals. The 2N5109 is readily available and provides good performance at low cost. In this circuit, the device is biased to provide 13-dB gain with a third-order-intercept point of + 26 dBm. The design features a tuned input circuit and a broadband output transformer. A double-tuned band-pass filter at the output assures a clean signal for the IF receiver. Fig. 47B shows the swept frequency response of the post amplifier. If you live in an area with loud local signals, yet want to use a post amplifier, a pad may be used between the post amplifier and the IF receiver to reduce the converter gain to a level that the IF receiver can handle. The value of attenuation will depend on the IF receiver's ability to handle large signals. When you first connect the receive converter to the IF receiver, you will probably notice that the S-meter on the receiver moves up to S3 or higher (a lot depends on the nature of your specific receiver), even with no signals present. To determine the right pad value for your application, place a variable step attenuator in the line between post amp and IF receiver and increase the attenuation until the IF receiver S-meter is just above zero. If you want to leave the step attenuator in the line, fine. If not, you can build a pad with the correct value from the attenuator tables given in Chapter 25 of this Handbook. Transmit Converter

A schematic diagram for the 1-W transmit converter is shown in Fig. 49. The 192-MHz LO (116-MHz LO for the 144-MHz version) and 28-MHz signals are mixed in a Mini-Circuits SRA-1 standard-level DBM. A pad is necessary to limit the 28-MHz input to a maximum level of -10 dBm, ensuring good linearity and spectral purity. No parts values are shown for the IF pad; the exact resistor values will depend on the amount of 28-MHz drive available from the transverter output of your IF transceiver. For example, if your IF rig delivers 20 mW (+13 dBm) at the transverter output, you would need to build a 23-dB pad. See Chapter 25 for tables listing resistor values for different levels of attenuation.



Fig. 43 — Schematic diagram of the 116-MHz local oscillator for the 2-meter transverter. All resistors are Vi-W, carbon-composition types unless otherwise noted. Capacitors are silver-mica or miniature monolithic ceramic types unless otherwise noted. Capacitors marked with polarity are electrolytic.

C1 — 25-pF (max.) miniature ceramic trimmer.

C2, C3 — 15-pF (max.) miniature ceramic trimmer.

C4, C5 — 10-pF (max.) ceramic piston trimmer or miniature ceramic trimmer.

C6 — 0.5-pF ceramic chip or gimmick capacitor. See text.

J1, J2 — Chassis-mount female BNC connector.

L.1 — 8t no. 24 enam., 0.100-inch ID, close wound.

L2 — 13t no. 28 enam. on T25-6 toroid core.

L3, L4 — 7t no. 24 enam., 0.125-inch ID, close wound.

L5, L6 — 8t no. 18 tinned, 0.250-inch ID, spaced one wire dia. Tap at 1t from ground.

RFC1-RFC3 — 2.7-uH molded miniature RF choke.

U1 — Three-terminal voltage regulator, 8 V, 100 mA (LM78L08 or equiv.).

Y1 — Fifth-overtone, 116-MHz series-resonant crystal, HC-18/U holder.

Mixer output is fed through a resistive pad for proper termination, and then filtered by a double-tuned band-pass filter to reduce the image and other undesired mixing products. Two 2N2857 amplifier stages follow the filter, followed by two 2N4427 stages. The final amplifier stage is a 2N5946. All stages are biased for linear operation. The 2N5946 may be substituted with a lower-power 2N5945 or 2N5944 device; if you substitute, you may have to alter the input and output matching, as well as the bias circuit. A 7-element Chebyshev low-pass filter (Fig. 50) follows the 2N5946. Swept filter response is shown in Fig. 51B. The output is exceptionally clean; a spectral plot is shown in Fig. 51 A.

Although some designers may question the use of five stages to achieve 1-watt output, there are several good reasons for doing so. This transmit converter is rated for conservative operation at a healthy, filtered 1-W output. It is not "almost" a watt, like some four-stage designs. AH stages are run below their maximum possible output level, ensuring clean, linear composition types unless otherwise noted. Capacitors are silver-mica or miniature monolithic ceramic types unless otherwise noted. Capacitors marked with polarity are electrolytic.



Fig. 45 — Schematic diagram of the receive mixer and diplexer filter. Capacitors are silver-mica. Resistors are Vi-W carbon-composition types.

J1-J3 — Chassis-mount female BNC

connector. L1 - 0.35 /iH; 6t no. 24 enam. on T50-6

toroid core. L2 - 0.205 /tH; 5t no. 24 enam. on T50-6

toroid core. L3 — 0.18 /tH; 5t no. 24 enam. on T37-6 toroid core. U1 — Mini-Circuits SRA-1H high-level, doubly balanced mixer. Available directly from the manufacturer. See text.



Fig. 47 — Swept response of the 220-MHz Preamplifier (A) and the 28-MHz post amplifier (B). The image filter at the output of the 220-MHz preamplifier produces a deep null at 164 MHz.



Fig. 46 — Schematic diagram of the 144- or 220-MHz GaAsFET preamplifier. All resistors are 1/4-W carbon composition types unless otherwise noted. Capacitors are silver-mica or miniature monolithic ceramic types unless otherwise noted. Capacitors marked with polarity are electrolytic.

C1, C2, C5, C7 — 10-pF (max.) ceramic piston trimmer or miniature ceramic trimmer.

C3, C4 — 500-pF ceramic chip capacitor.

C6 — 0.3 to 3 pF ceramic piston trimmer.

J1, J2 — Chassis-mount female BNC connector.

L1 - 220 MHz: 3t no. 18 enam., 0.250-inch ID, close wound. 144 MHz: 5t. L2 - 220 MHz: 13t no. 24 enam. on

T44-10 toroid core; 144 MHz: 27t no. 26 enam. On T37-10 toroid core.

L3, L4 — 220 MHz: 5t no. 18 tinned wire, 0.250-inch ID, spaced one wire dia. Tap at 1t from ground. 144 MHz: same as 220 MHz, except coil is 7t.

Q1 — Single-gate GaAsFET, MGF1402.

RFC1 — 68 uH molded miniature RF choke.

T1 — 4t no. 28 enam. bifilar wound on T25-12 toroid core.

U1 — Three-terminal voltage regulator, 5 V, 100 mA (LM78L05 or equiv.).



Fig. 48 — Schematic diagram of the 28-MHz post amplifier. All resistors are Vi-W carbon-composition types unless otherwise noted. Capacitors are silver-mica or miniature monolithic ceramic types unless otherwise noted. Capacitors marked with polarity are electrolytic.

C1, C2, C3 — 15-pF (max.) miniature ceramic trimmer.

J1, J2 — Chassis-mount female BNC connector.

L1 — 12t no. 26 enam. on T37-6 toroid core.

L2, L3 — 15t no. 26 enam. on T37-6 toroid core. Tap at 4t from ground. RFC1 — 10-fiH miniature molded RF choke.

T1 — 20t no. 30 enam. bifilar wound on T37-10 toroid core.



Fig. 49 — Schematic diagram of the 144- and 220-MHz transmit converter. All resistors are 1/t-W carbon-C1, C3, C5, C6, C7 — Miniature ceramic trimmer, 220 MHz: 8 pF (max.); 144 MHz: 25 pF (max.).

C2 — Silver-mica capacitor, 220 MHz: 2 pF; 144 MHz: 3 pF.

C4 — Silver-mica capacitor, 220 MHz: 3 pF; 144 MHz: 5 pF.

C8 — Miniature ceramic trimmer, 220 MHz:

15 pF (max.); 144 MHz: 25 pF (max.). C9, C10 – 25-pF (max.) miniature ceramic trimmer (same for both bands).

C11, C12 — Ceramic piston trimmer or miniature ceramic trimmer, 220 MHz: 10 pF (max); 144 MHz: 25 pF(max). J1-J3 — Chassis-mount female BNC connector.

L1, L2 — 220 MHz: 4t no. 20 tinned, 0.250-inch ID, spaced one wire dia. Tap at 1t from ground. 144 MHz: Same as 220 MHz except coil is 6t.

L3, L4, L5 - 220 MHz: 3t no. 20 tinned, 0.250-inch ID, spaced one wire dia. 144 MHz: Same as 220 MHz except coil is 5t.

L6 — 220 MHz: 1t no. 20 tinned, 0.250-inch ID. 144 MHz: 2t no. 20 tinned, 0.250-inch ID, spaced one wire dia. L7 - 220 MHz: 1t no. 20 tinned, 0.250-inch ID. 144 MHz: 3t no. 20 tinned, 0.250-inch ID, spaced one wire dia. L8 —

220 MHz; 6t no. 20 enam., 0.250-inch ID, close wound, 144 MHz; Same as 220 Mhz except coil is 8t, L9, L10 — 15 t no. 22 enam. on T44-10 toroid core (same for both bands). R1 — Start with 68-ohm, 2-W resistor; vary for proper bias. See text. RFC1-RFC4 — 220 MHz: 1.8-uH miniature molded RF choke; 144 MHz: 2.2-uH miniature molded RFC. U1 — Mini-Circuits SRA-1 standard level, doubly balanced mixer. Available directly from the manufacturer. See text.



operation. The gain from the extra stage also allows the use of the filters after the mixer and at the output. The author lives in an area where the VHF bands are congested, so clean, linear operation is a must for sound relations with other amateurs sharing the band.

Power Amplifier

An optional 8- to 10-W linear power amplifier is shown schematically in Fig. 52. This amplifier uses another 2N5946 transistor. The design is relatively simple. Input matching is accomplished by Cl, C2 and LI, L2, C3 and C4 match the output. The only differences between the 220-MHz and 144-MHz versions are the values of LI and L2. The bias circuit, suggested by Dave Mascaro, WA3JUF, uses an LM317 adjustable regulator to provide a stiff bias supply. The LM317 circuit is capable of providing 30- to 40-mA of stable bias current.

Switching

Fig. 53 is a schematic diagram of the transverter switching circuitry. Kl is used to switch power to the transverter modules in transmit and receive. When the transverter is powered on, 12.5-V dc is applied directly to the LO and through Kl to the VHF preamplifier and 28-MHz post amplifier. When J2 is closed, Kl removes power from the preamplifier and post amplifier and applies 12.5-V dc to the transmit converter and power amplifier. The LO, used for transmit and receive, is always on.

When J2 is closed, K2 is also energized. K2, an RF relay, switches the antenna between the VHF preamplifier input and the power amplifier output. Relays of this type are generally available at flea markets at modest prices. Since most HF transceivers have separate transverter input and output connections, no relay switching for the IF rig is included. The transmit converter IF input is connected directly to the transverter output on the HF transceiver, while the Post amplifier output is connected directly to the transverter input on the HF transceiver.

Relays with 26-V dc coils were used here since most surplus coaxial relays require this voltage. While relays with any coil voltage could be used, it is a good idea to run relays and electronics from separate power supplies to avoid possible problems caused by voltage transients that occur when the relay coils are switched. The diode and capacitor connected across the relay coil power line help to alleviate transients.

CONSTRUCTION TECHNIOUES

Although this project is not intended for a first-time effort, anyone having a reasonable amount of VHF construction experience should encounter no difficulty. As with all VHF circuits, a certain amount of construction care is required.

Proper grounding techniques, RF bypassing and shielding will ensure stable operation. Feedthrough grounding is used • to provide a low-inductance ground return to both sides of the PC board. Basically, this means drilling a hole through the PC board at key points where components must have a good RF ground and installing a rivet or piece of no. 20 tinned wire soldered to both sides of the board. See Fig. 54. Check the schematic diagrams for each circuit and install ground feed-throughs accordingly.

High-quality, low-inductance capacitors ensure a good RF bypass. Ceramic chip capacitors work best. These can be expensive, however, so they are used only where absolutely necessary. Epoxy encapsulated, miniature, monolithic ceramic capacitors work quite well as bypass capacitors.

Tight shielding between the input and output of each stage of the transmit converter eliminates the likelihood of feedback. Shielding was only found necessary on the transmit converter.

The variable capacitors used in each stage are miniature ceramic or piston trimmers. The value of these capacitors is not critical as long as you use capacitors with maximum values close to those specified in the schematic diagram. For example, there are many capacitors available with a range from 2 to 8 pF or 2 to 12 pF. Any of these will work fine in circuits that call for 9- or 10-pF-maximum variables. Ceramic piston trimmers are most convenient for building the double-tuned band-pass filters. Johanson, Trimtronics or Voltronics all manufacture 8- to 10-pF maximum piston trimmers suitable for these filters.

"Dead bug" layout is best suited for VHF/UHF construction. As shown in the accompanying photographs, components are supported by their leads above the ground plane. In most cases, component leads are soldered directly to the leads of other components, keeping the length of each interconnection to a minimum. A lowinductance RF ground is achieved since the component leads are soldered directly to the ground plane. This construction method eliminates the need for designing an etched PC board, a task not easily accomplished at VHF and above.

Each circuit, or "module," is built on a piece of double-sided circuit board stock and mounted in a separate metal enclosure. In the transverter shown in the photographs, each module is built into a small Hammond 1590 series diecast box. In each case, the box cover has been discarded. The circuit board holding the components has been shaped to fit the box tightly in place of the cover. Each module has BNC connectors for RF input and output. Voltage is supplied through a feedthrough capacitor. The result is an RF-tight enclosure for each part of the circuit. Since the 1-W transmit converter board is large, and a suitable diecast box is expensive, the transmit converter is mounted under the chassis that supports the rest of the modules.



Fig. 51 — The plot at A shows the spectral output of the 1-W, 220-MHz transmit converter after filtering. All harmonics and spurious emissions are at least 60 dB below the fundamental output. This transmit converter meets current FCC spectral-purity specifications. The plot at B is the swept frequency response of the low-pass filter shown in Fig. 50.



Fig. 52 — Schematic diagram of the 8- to 10-W power amplifier. Capacitors are monolithic ceramic types unless otherwise noted. Capacitors marked with polarity are electrolytic. C1, C4 — 10-100 pF mica trimmer (Arco 406 or equiv.).

C2, C3 — 5-75 pF mica trimmer (Arco 405 or equiv.).

C5 — 51 pF metal-clad book-mica capacitor. See text.

C6, C7 — 1000 pF metal-clad book-mica capacitor. See text.

J1, J2 — Chassis-mount female BNC connector.

L1 — 220 MHz: Vat no. 20 tinned, 0.250-inch ID ("hairpin loop"); 144 MHz: 1t no. 20 tinned, 0.250-inch ID.

L2 — 220 MHz: 1t no. 20 tinned, 0.250-inch ID; 144 MHz: 2t no. 20 tinned, 0.250-inch ID,

spaced one wire dia.

L3 — VK-200 wideband RF choke. L4 — 8t no. 20 enam., 0.250-inch ID, close wound.

Q1 — 2N5946 or Thompson-CSF SD1160 RF power transistor.



Fig. 53 — Schematic diagram of the transverter switching arrangement.

J1, J2 — Chassis-mount female Cinch-Jones power plug.

J3 — Chassis-mount phono jack. K1 — DPDT power relay, 3-A contacts, 26-V dc coil.

K2 — SPDT coaxial antenna changeover relay, BNC connectors, 26-V dc coil.

S1 — SPDT switch, 5-A contacts.



Fig. 54 — Detail of the feedthrough grounding used to achieve a good RF ground. See text for details. *FInding Parts*

These days, it is becoming increasingly difficult to find parts. This transverter makes use of parts available from a number of sources. The parts suppliers table in Chapter 35 lists many possible sources, and still others advertise in QST and other amateur magazines. Some parts sources are listed below. You can find addresses and other information in Chapter 35 for companies that are listed by name only here. This list is by no means complete; these are sources that the author knows of that will sell to individuals in small quantities.

•Advanced Receiver Research, Box 1242, Burlington, CT 06013 (MGF1402 GaAsFETs)

•Amidon Associates (toroid cores, ferrite beads, VK-200 chokes)

•Applied Invention (piston trimmers, chip caps)

•MHz Electronics, 3802 N. 27th Ave., Phoenix, AZ 85017 (transistors, book-mica capacitors)

•Microwave Components of Michigan (trimmers, piston trimmers, GaAsFETs, chip caps, feedthrough caps, diecast boxes)

•Mini-Circuits, P.O. Box 166, Brooklyn, NY 11235 (mixers, Tl in 192-MHz LO)

•Mouser Electronics (resistors, capacitors, ceramic trimmers, molded RF chokes, diecast boxes)

•Radiokit (toroid cores, ferrite beads, Arco variables, diecast boxes)

•R.F. Gain, Ltd. (transistors)

Local Oscillator

Build the local oscillator first; you'll need LO energy to test most of the other stages. Before soldering anything, gather all of the necessary components and lay them out on the board in order to plan adequate room before

constructing. Follow the schematic diagram and refer to Fig. 55 for an idea of how to lay out the board. Although the 192-MHz LO for the 220-MHz transverter is shown, layout is similar for the 116-MHz version.

Once the general layout scheme has been achieved, the components may be soldered together, beginning with Ql. Keep component leads short, but leave enough room so that you can change components if necessary. Make sure that the leads of Yl are as short as possible and that the crystal will not touch the box that the LO will be installed in. A dab of silicone sealant will hold the crystal in place.

Ql, Q2 and Q3 are mounted "belly up" with their leads sticking into the air. Note that Ql and Q3 have a lead that is connected to the case. Solder this lead to ground. The collector of Q4 is tied to the case, so it is mounted with the leads facing the ground plane. Make sure that the case of Q4 does not touch the ground plane or other components. Dc power for the LO enters the case through a feedthrough capacitor. Miniature molded RF chokes and bypass capacitors decouple the power line at each stage. In Fig. 55, these RFCs and capacitors are arranged in a horizontal line that traverses the top of the board. Ql is powered through an 8-V, three-terminal regulator IC. Mount the associated bypass capacitors as close to the IC body as possible.

Q2 has several unused sections. Cut off all unused leads before soldering it into the circuit. Tl is a trifilar-wound transformer on a T25-12 toroid core. See Fig. 56 for details. Although the transformer used here was wound by hand, a Mini-Circuits model T4-1 may also be used.

The output filter uses two ceramic piston trimmer capacitors mounted through the circuit board. These piston trimmers make it convenient to mount L6 and L7; common ceramic trimmers like those used in the rest of the circuit will also work here. A shield made from a piece of double-sided circuit-board material separates L6 and L7, eliminating overcoupling and ensuring a "clean" filter response. Although a 0.5-pF ceramic chip capacitor was used to couple the two filter sections, a IA-inch-long gimmick capacitor made from two pieces of no. 28 enameled wire twisted tightly together will work here.

One of the advantages of dead bug construction — one that you should take advantage of — is that each stage can be tested individually. After you build the basic oscillator (Ql and associated components), you can test for 96 (or 116) MHz



Fig. 55 — The 192-MHz local oscillator is laid out in the order it is drawn on the schematic diagram. Q1 is at the far left; Q4 is near the center of the board. The band-pass filter is at the right, next to J1 and J2. The resistors used for the power divider and pad are soldered into the circuit with virtually no lead length.



Fig. 56 — Winding details for T1 in the 192-MHz LO. Label one end of three 5-inch pieces of enameled wire as shown. Holding all three wires flat, in parallel, begin threading the toroid starting with the unlabeled end of the three wires. Carefully wind the toroid by feeding the entire group of wires in parallel. Once seven turns have been wound, use an ohmmeter to trace the unlabeled ends. Label the end of wire A by A', and so on.-After the windings have

been properly labeled, connect T1 as shown.



Fig. 57 — Closeup of the VHF RF preamplifier. The input components at the left of the board are mounted with as little lead length as possible, to minimize losses.

output by capacitively coupling into a receiver or spectrum analyzer from the 50-ohm pad at the output of the stage. When you are sure Ql is working, build the next stage and test it. Proceed alternately building and testing each stage until you reach the final output stage.

When all of the LO stages are complete, check the operating frequency with a counter or spectrum analyzer. Tune each stage for maximum output. Tuning is somewhat interactive, so recheck each stage after you have done the initial tuneup. Each variable capacitor should have a definite peak. If you have a method of checking low power levels, check the output at the receive and transmit ports. Power output should be as indicated on the drawings. All other stages are constructed in a like manner. Lay the board out in advance: start at the input and work toward the output. Test each stage after you build it, and fix any problems before continuing to the next stage.

Preamplifier

The GaAsFET transistor requires special handling care because it is especially sensitive to static electricity. Solder the transistor into the circuit last; use a grounded-tip, low-temperature soldering iron. If a static-free work station is unavailable, ground yourself before removing the MGF1402 from its protective package to prevent static buildup from destroying the device.

Although an MGF1402 is specified, you can use other devices if you change the biasing resistors accordingly. Consult the references listed at the end of this project writeup before attempting a substitution. The MGF1402 is a fairly common transistor and is available from several of the suppliers listed in Chapter 35.

The general layout is shown in Fig. 57. Although BNC connectors were used here, Type-N or SMA connectors may be employed. A number of ground feedthroughs are used at points indicated on the schematic diagram. These feedthroughs are necessary for stable operation and optimum performance; they must be used. See Fig. 54. Ceramic chip capacitors are mandatory for the source bypass on the MGF1402. Do not attempt to substitute lowgrade capacitors here! Chip capacitors provide a low-impedance source ground; this is of particular importance for stable operation with high-gain devices such as the microwave GaAsFET used here. The MGF1402 is mounted directly to the source bypass capacitors by its source leads. First, solder one end of each chip capacitor to the ground plane. Then solder one source lead to each chip capacitor. See the preamplifier projects that appear earlier in this chapter for complete details of this mounting scheme.

The output filter is similar to the one described in the local-oscillator section. In this case, however, the coupling capacitor is a 0.3- to 3-pF trimmer. A toroidal coil is added for the 164-MHz image trap.



Fig. 58 — Closeup of the 28-MHz post amplifier. Q1 uses a push-on finned heat sink. The transistor case is tied to the collector, so the heat sink must be positioned away from the case and nearby components.



Fig. 59 — Closeup of the receive mixer and diplexer filter. RG-174 cable is used between the nixer and input connectors.



28-MHz Post Amplifier

The 2N5109 post amplifier shown in Fig. 58 requires little special care. Note, however, the use of a push-on, finned heat sink. Keep the heat sink away from the circuit board and other components since the 2N5109 case is tied to the transistor collector.

Receive Mixer

The receive mixer and diplexer filter may be housed in one enclosure, as shown in Fig. 59. The SRA-1H is best mounted on top of the circuit board with the pins protruding through to the component side. Carefully mark and drill eight holes using

a no. 59 drill bit. All holes on top of the board are deburred with a 1/8-inch drill bit; turn the bit by hand to remove the copper from around the hole. This allows for ample clearance where leads are close to touching the board. Deburr the holes for pins 1, 3, 4 and 8 on the component side of the board. The other pins are grounded and should be soldered directly to the ground plane.

Transmit Converter

Construction of the transmit converter requires a little extra planning for component layout because of the number of stages involved. Position the SRA-1 and the five transistors to allow sufficient room for the remaining components. It is better to allow extra room than to be cramped for space. Refer to Fig. 60 for ideas on board layout.

Fig. 60 — The transmit converter incorporates extensive bypassing and shielding. J1 and J2 are at the bottom left. Q1, Q2 and Q3 are arranged along the lower edge of the board, below the horizontal shield. Q4 and Q5 are above that shield; Q4 is to the right. The two emitter leads of Q5 are soldered directly to the ground plane near the center of the board. The low-pass filter is between Q5 and the output connector.

Drill any mounting holes as you go along. Start by mounting the SRA-1 using the same technique described above. Then mount J1 and J2. Build the mixer bandpass filter first, and then work stage-by-stage toward the output. Ql, Q2 and Q3 should be shielded by placing a small piece of sheet metal or double-sided circuit-board material over each transistor. Cut a U-shaped notch in the shield to clear the transistor case. Each shield may be soldered directly to the ground plane. Ql and Q2 are mounted "belly up," while Q3 and Q4 are mounted "right side up." Cut the Q3 and Q4 emitter lead to lA inch before soldering the transistor in place. Note that Ql and Q2 have four leads; one is tied directly to the transistor case and must be soldered to the ground plane. The case of Q3, however, is connected to the collector, so be sure to leave adequate clearance between the case and the shield. Q4 must have a push-on, finned heat sink. The heat sink should not touch any other components. Again, keep all leads as short as possible.

Q5 is a stud-mounted power transistor. Drill a hole just large enough to pass the threaded stud and transistor base through the circuit board. The emitter leads should lay almost flat on the component side of the board. Cut the collector and base leads to half of the original length, while leaving the emitter leads full length. The heat sink for Q5 is made from a U-shaped piece of brass sheet (the same material used for the circuit-board shields). Mount DI on top of the heat sink for good thermal contact; solder the ground end of DI directly to the heat sink.



Fig. 61 — Space is a bit tight, but the 10-W amplifier will fit inside a small diecast box. Q1 is mounted at the center of the board. Input circuitry is to the left, output to the right. U1 and associated bias circuitry are behind the shield adjacent to J1.

The value of Rl must be determined experimentally. Start with a 68-ohm, 2-W resistor. Measure the quiescent current of Q5 by inserting a milliammeter in the circuit at the cold end of L8. The quiescent current should be between 20 and 40 mA; adjust the value of Rl until proper bias is achieved.

The transmit converter is tuned by applying 12.5-V dc, LO energy and a 28-MHz signal attenuated to provide - 10 dBm at the mixer input. Peak the double-tuned filter for maximum 220-MHz (or 144-MHz) output. If a spectrum analyzer is available, tune for a balance between maximum 220-MHz (or 144-MHz) energy and minimum spurious output. Next, peak Cl through C3. Alternately peak C5 and C6 for maximum output. C7, C8, C9 and C10 are adjusted in the same manner. Although a wattmeter may be used for tuning purposes, a spectrum analyzer tells the full story. Tune each stage for a compromise between output power and spectral purity.

Harmonics are 60-dB down after filtering. After you're through adjusting the transmit converter, power output should be 1 watt.

Power Amplifier

The 10-W amplifier shown in Fig. 61 is mounted in its own diecast box. Ground feedthroughs are used beneath the 2N5946 emitter leads and at all variable capacitor grounds. The LM317 regulator IC must be attached to a heat sink. Bias should be adjusted for a quiescent current of 40 to 60 mA.

C5, C6 and C7 are Unelco metal-clad book-mica capacitors. These capacitors provide an excellent low-impedance RF ground and are designed to work at high-current points. For stable operation, it is important that you use book-mica capacitors at these points.

The heat sink is fashioned from two U-shaped pieces of aluminum sheet. Be careful when mounting the heat sink; lateral pressure on the 2N5946 stud may break the transistor.

Summary

The transverter modules are arranged on a chassis as shown in Figs. 40 and 62. Short runs of 50-ohm coaxial cable interconnect the units. Most of the dc power wiring is done underneath the chassis.

The 144/220-MHz transverter represents a low-cost, modern approach to getting on the VHF bands. Circuit

construction is straightforward, and the design makes use of commercially available parts. The modular construction approach offers flexibility for easy troubleshooting and experimentation.



Fig. 62 — The transmit converter is mounted in a cutout portion of the chassis, component side down. Dc for the transmit and receive chains is brought in to K1 and from there to a barrier strip. Wires are routed from the barrier strip to each module.

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