A Single-Board, No-Tune 902-MHz Transverter

Using printed band-pass filters, monolithic microwave integrated circuits and an on-board local oscillator, this inexpensive transverter brings new ease to 33-centimeter operation.

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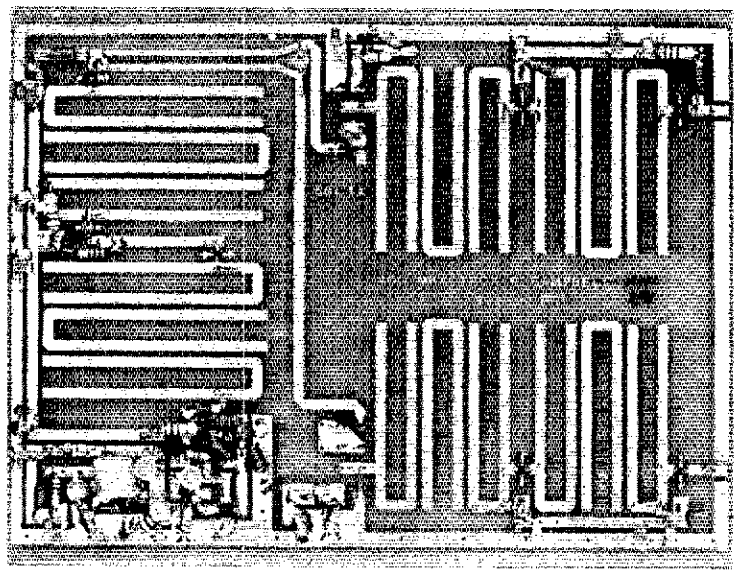
The sole obstacle many amateurs face to getting on the UHF and microwave bands is a lack of equipment. It's not that the equipment and antennas for these bands are expensive or unobtainable; it's more that many would-be microwavers feel intimidated by the prospect of building their own gear for these bands. If you have a 2-meter multimode transceiver, you're already well along in getting on the 902-MHz and higher bands. The complete 902-MHz transverter I'll describe here is printed on a single 5- × 7-inch G10 circuit board and costs less than $150 to build. You'll soon



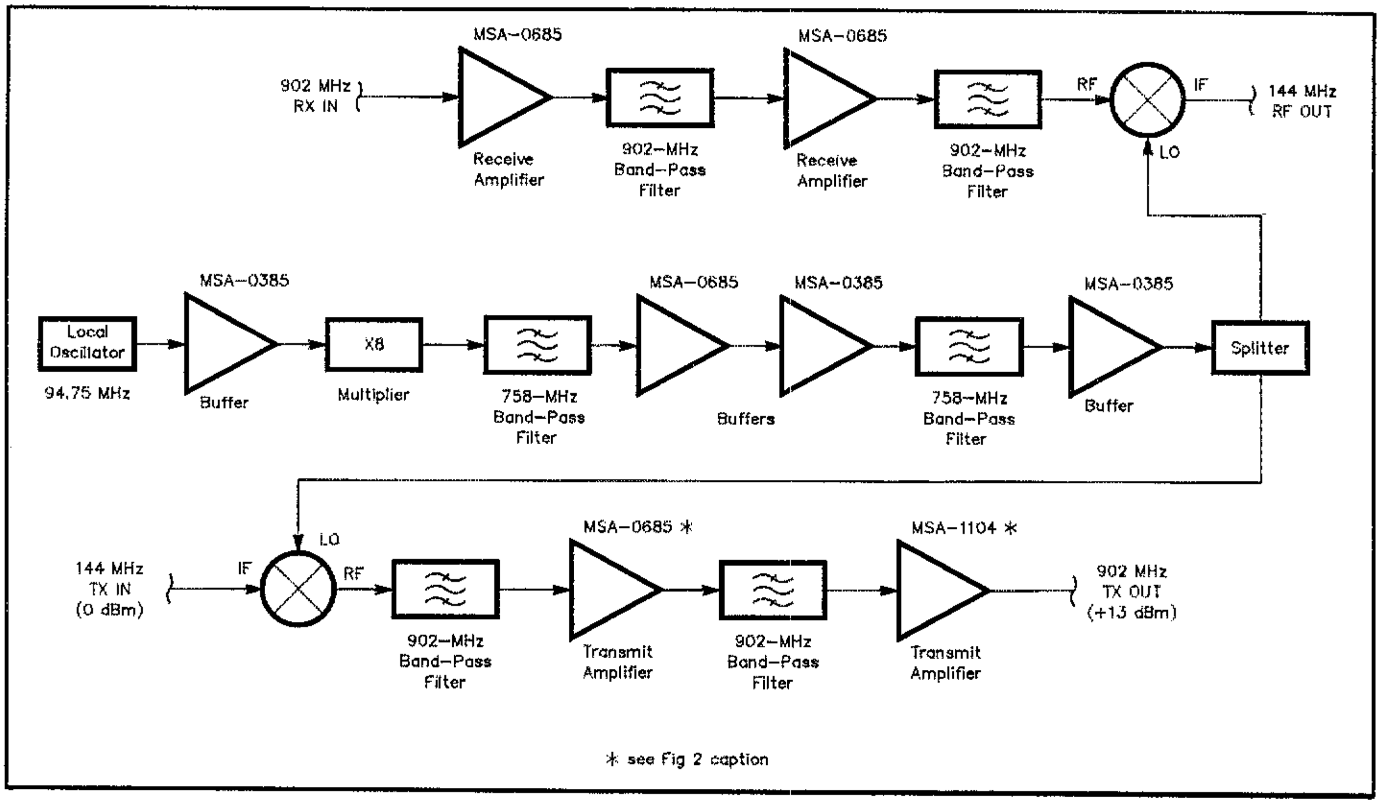
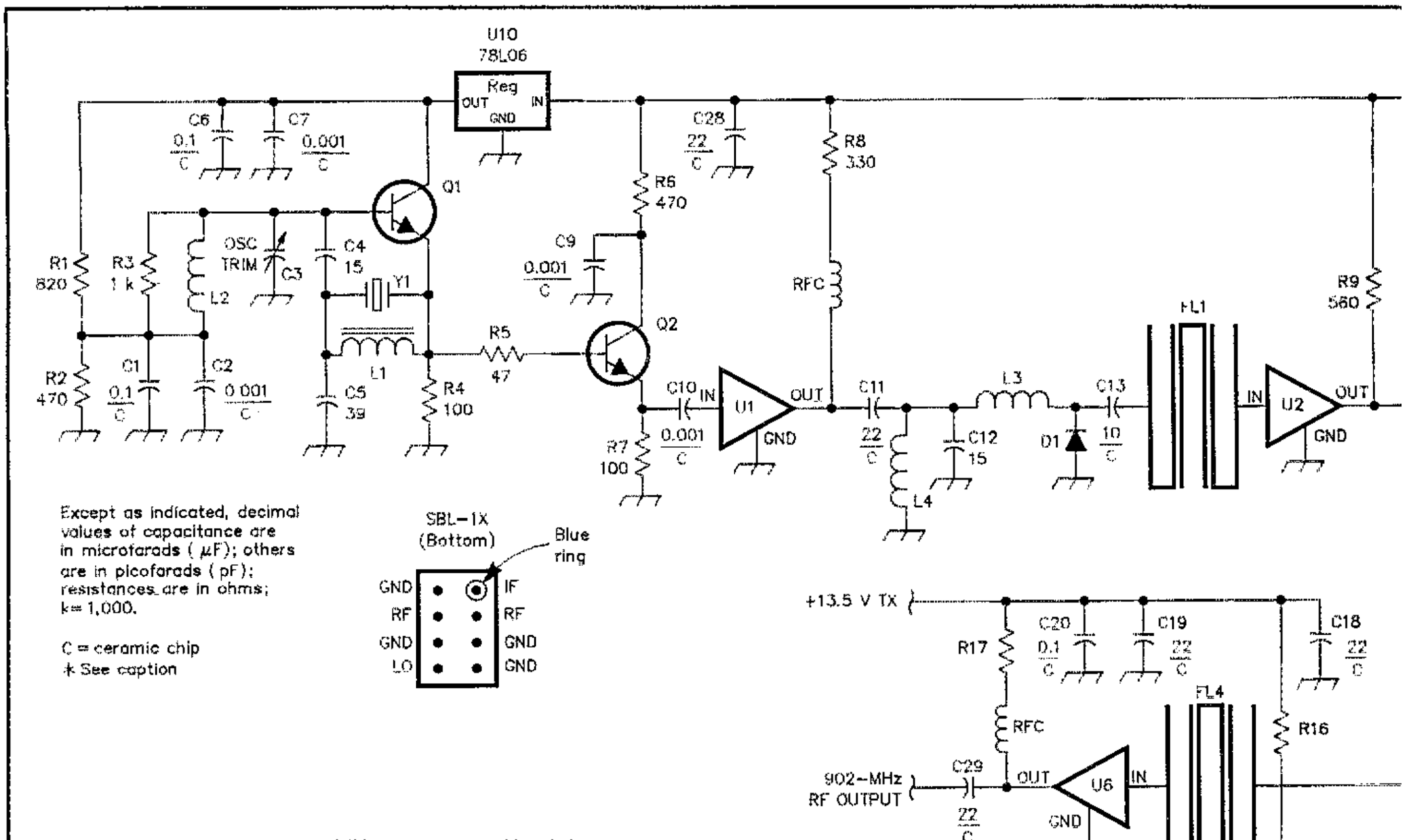


Fig 1—Block diagram of the single-board 902-MHz transverter. Unlike similar designs for the higher bands, this unit has an on-board local oscillator and discrete mixers. The only external connections are for the IF transceiver, antenna and power supply.



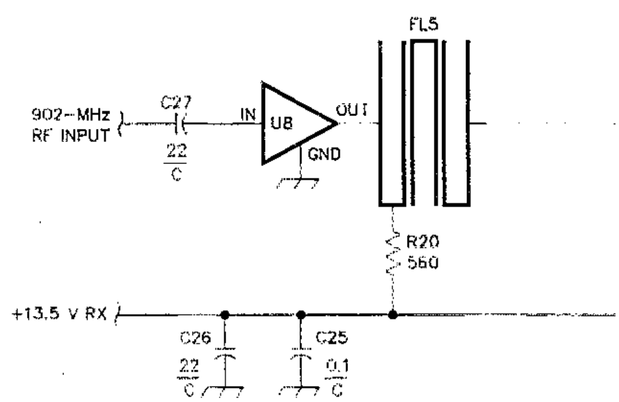


Fig 2—Schematic of the 902-MHz transverter. Heed the manufacturer's specifications for MMIC connections. The boxed part of the circuit isn't on the PC board, but may be needed to drive your 144-MHz IF receiver. A pi-network attenuator can be used here, if appropriate (see text and Fig 3). Filters FL1-FL6 are etched band-pass units. All resistors are ¼-W carbon-composition units unless specified otherwise. See the parts list for differences between 0-dBm-output and 13-dBm-output versions.

C3—3- to 10-pF ceramic or piston trimmer.
C4, C12—15 pF, miniature ceramic, NPO.
C5—39 pF, miniature ceramic, NPO.
C11, C14-19, C21, C24, C26-29—22 pF, ceramic chip, NPO.
C13—10 pF, ceramic chip, NPO.
D1—Multiplier diode; HP2800, HP2835 or 1N5711.
L1—10 turns no. 28 enam wire on T-25-6 toroid core.
L2—7 turns no. 24 enam wire, 0.1 inch diam, closewound.
L3, L4—8 turns no. 24 enam wire, 0.1 inch diam, closewound.
Q1, Q2—AT42085, NE021, BFX89 or equiv.
RFC—8 turns no. 24 enam wire, 0.1-in. diam, closewound.
R13, R14—150 Ω, ¼ W.
R15—33 Ω, ¼ W.
R16—360 Ω for low-power version; 560 Ω for high-power version.
R17—½ W; 330 Ω for low-power version; 130 Ω for high-power version.
U1—Avantek MSA-0385 or Mini-Circuits MAR-3.
U2, U7, U8—Avantek MSA-0685 or Mini-Circuits MAR-6.
U3, U4—Avantek MSA-0385 or Mini-Circuits MAR-3.
U5—Avantek MSA-0685 or Mini-Circuits MAR-6 for high-power version; MSA-0285 or MAR-2 for low-power version.
U6—Avantek MSA-0385 or Mini-Circuits MAR-3 for low-power version; MSA-1104 for high-power version.
Y1—94.75-MHz crystal. See text.

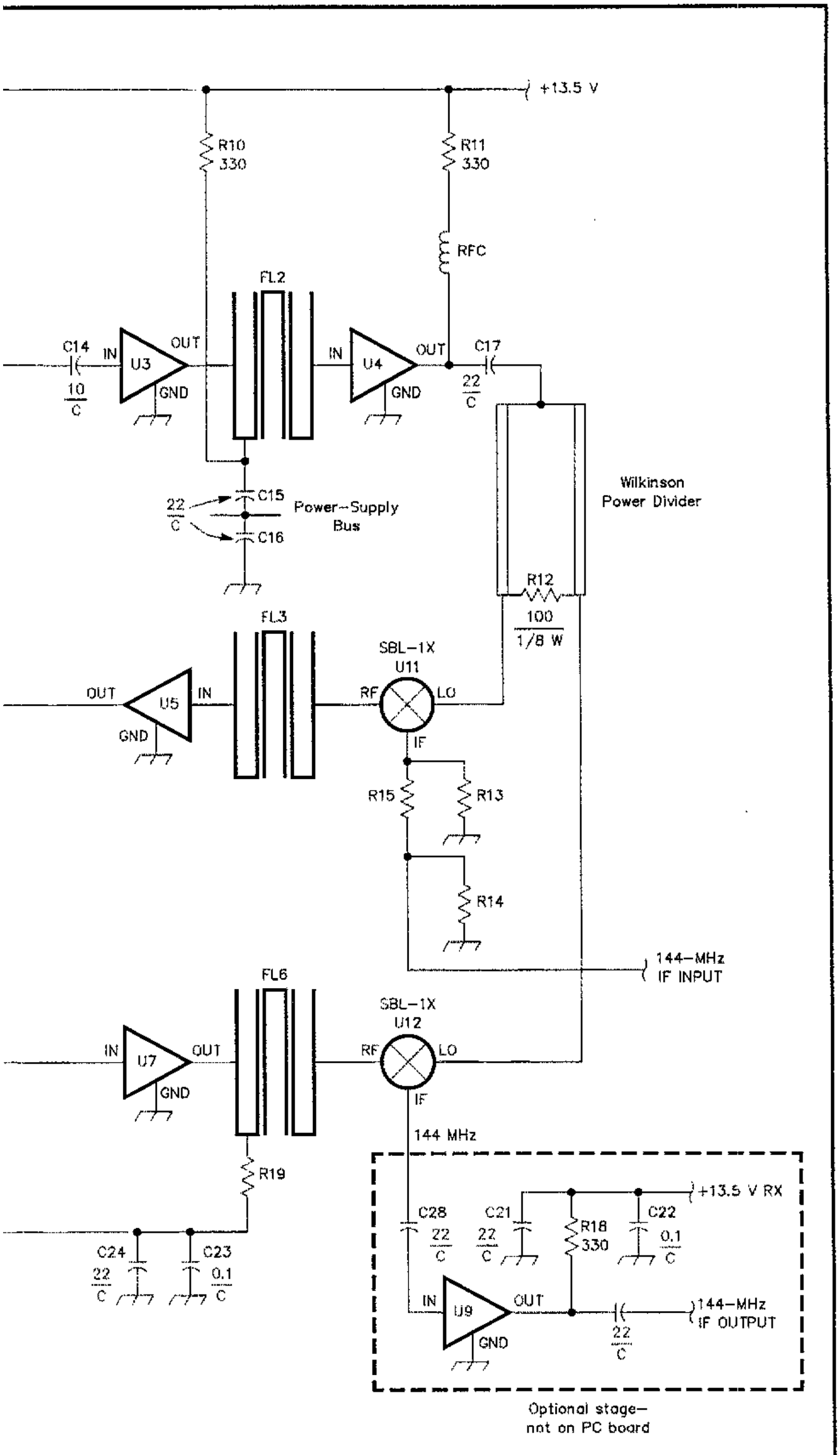
see that you don't need lots of money or much building skill to put a 33-cm station on the air!

This transverter, unlike similar designs for higher-frequency bands,[1-4] has its local oscillator (LO) on the main PC board; only a 12-V supply, 144- and 902-MHz signals enter and exit the board. All the gain stages employ low-cost plastic MMIC (monolithic microwave integrated circuit) amplifiers. All the band-pass filters, traditionally the trickiest part of UHF-equipment design, are hairpin, third-order Chebyshev types printed on the PC board. The filters require *no adjustments*, like those of the higher-frequency transverters. Kits of parts and assembled transverters are available from Down East Microwave.[5]

Introduction

This transverter, shown in block-diagram form in Fig 1, was a natural development

[1]Notes appear on p 29.



following my 1.3-GHz transverter[6] and 576-MHz local-oscillator (LO) board.[7] The signal filters were scaled to pass 900-940 MHz and the LO filters were scaled to pass 740-780 MHz. The LO is a Butler type operating in the 100-MHz range, followed by a broad-tuned Schottky-diode multiplier and printed bandpass filter to reject all but the desired 758-MHz harmonic.

The 1.3-GHz transverter uses etched quadrature hybrid mixers. Scaled for the 758-MHz LO needed to convert a 144-MHz IF signal to 902 MHz, these mixers are too large to fit on a reasonably small PC board. A number of reasonably priced, discrete double-balanced mixers (DBMs) are available for frequencies below 1 GHz, so a pair of such mixers are used in this transverter. Prepackaged discrete DBMs need far less board space than etched mixers.

The transverter prototypes were built using Mini-Circuits SRA-11H and SRA-2CM mixers. The second-generation design shown here uses less-expensive Mini-Circuits SBL-1X mixers. Fig 2 shows the schematic diagram.

The Local Oscillator

Using prepackaged mixers freed up enough circuit-board space for an on-board local oscillator. The LO circuit is nearly identical to the 540- to 580-MHz version described in July 1989 *QST*.[8] For 758-MHz output, the Butler oscillator's frequency can be 94.75 MHz (×8), 108.286 MHz (×7) or 126.333 MHz (×6). As it turns out, 94.75 MHz is the best choice, as the oscillator is easiest to adjust and the undesired oscillator harmonics at 853 and 948 MHz are farther (and therefore easier to filter) from the RF-amplifier and transmit-amplifier passbands.

The prototypes used 126.333-MHz seventh-overtone crystals. The first prototype built at KK7B uses SRA-11H mixers, which are specified for +17 dBm LO injection. A few decibels more output from the harmonic generator is obtained by biasing the diode as described in "A Clean Microwave Local Oscillator."[9] An 820-Ω bias resistor was used for this.

With an MSA-1104 LO amplifier and careful tweaking of the inductors in the harmonic generator, +18.5 dBm was available before the Wilkinson power divider that splits the LO for the receive and transmit mixers. This is sufficient for good performance with SRA-11H mixers. For the low-level SRA-2CM and SBL-1X mixers, +10 dBm output from the LO is optimum, which is easily obtained with the parts indicated in Fig 2.

All spurious LO outputs below 1.3 GHz are more than 40 dB below the desired output, but the LO filters have some spurious responses in the 1.4-GHz range. The spurs in this range may be stronger, depending on drive level to the MMICs in the LO chain. The worst-case spurs in any of the prototype LOs were 20 dB below the desired output. Adding a low-pass filter after the LO would reduce the high-frequency LO spurs; I didn't do this, because these low-level, high-frequency spurs aren't visible in the RF-output spectrum and don't degrade receiver performance.

RF Amplifiers

The transmit and receive amplifiers are similar to those in the 1.3-GHz transverter, except that the filters are somewhat closer to being ideal at 902 MHz, so only two MMICs per chain are needed to obtain the required gain. MSA-0685s are used for both receive stages, providing a noise figure (NF) under 4 dB, more than 20 dB of conversion

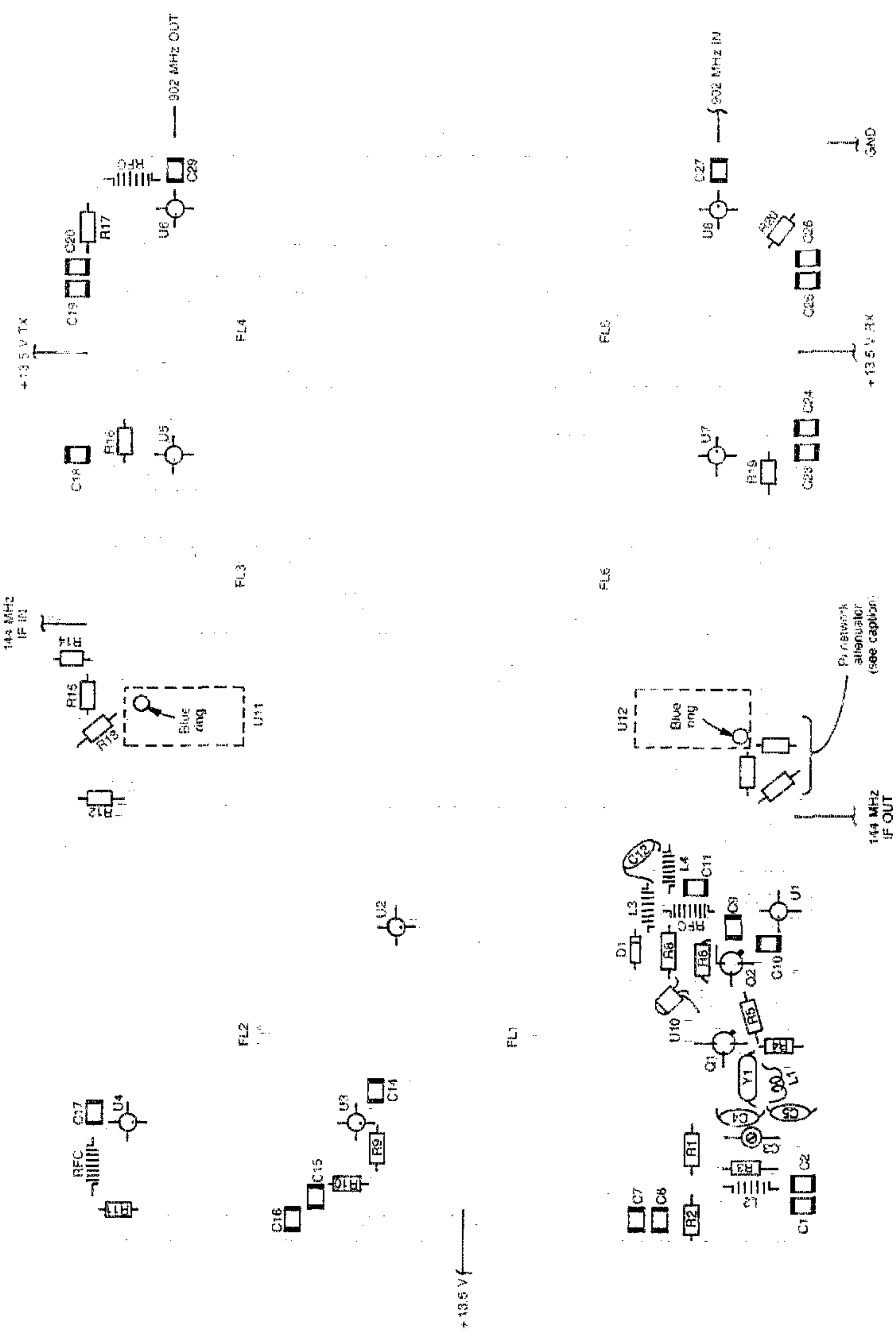


Fig 3—Part-placement diagram for the transverter. Although either MCL or Avantek MMICs are acceptable for use in this project, the MMICs shown here are marked like MCL parts (the colored dot signifies the input lead).

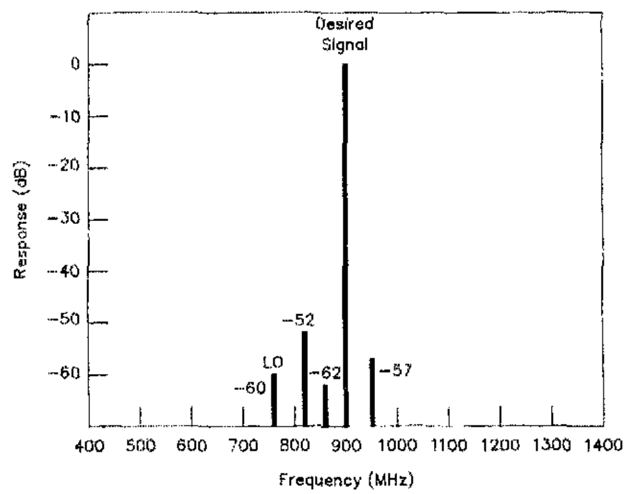


Fig 4—The transverter's spectral output. Vertical divisions are 10 dB; horizontal divisions are 100 MHz. All spurious outputs are at least 50 dB down from the carrier (−50 dBc). This plot shows that it doesn't take expensive or complex circuitry to generate clean signals—even above 900 MHz.

gain (including filter and mixer loss), and a stable 50-Ω termination for an external GaAsFET preamplifier.

The first prototypes used an MSA-0685 IF amplifier after the receiver mixer, but total gain was excessive. The SBL-1X version uses a 3-dB resistive pad at the receiver IF port to keep the receive-converter output to an appropriate level.

The transmit amplifier provides 13 dBm (20 mW) output at the 1-dB compression point. This is appropriate for driving a discrete amplifier chain, or for direct connection to the antenna for local, line-of-sight or hilltop operation. Most hybrid linear-amplifier modules suitable for 33-cm use, such as the MC5874 and M67769,[10] require a lower drive level. Fig 2 and the parts list specify components for versions with 13 dBm (20 mW) output and with 0 dBm (1 mW) output to best suit your requirements.

Construction, Tuning and Operation

Because of the tight dimensional tolerances required for etched microwave filters that require no adjustments, and because there are many variables in the *QST* printing process, a PC-board etching pattern is not included with this article. If you want to make a board for your own use, send an SASE to the ARRL Technical Department Secretary for a dimensioned copy of the artwork.[11] PC boards, parts and kits are available, however, as mentioned earlier.[12] Follow the construction guidelines discussed in Jim Davey's 1989 article,[13] and use only high-quality, microwave-rated porcelain chip capacitors in building the circuit.

Avantek and Mini-Circuits (MCL) make MMICs suitable for use in this project. See the parts list in the Fig 2 caption for equivalent parts. There is some variation in the packaging of MMICs. Some use a colored dot at the bevel-cut input lead; others use a raised dot at the output lead. Be sure to install the MMICs in the correct orientation.

Fig 3 shows placement of parts on the transverter PC board. The 144-MHz IF output comes off the board via a pad adjacent to U12. If necessary, you can use the traces in that area for a pi-network attenuator, or as a take-off point for the receiver signal or for a subsequent amplifier stage, such as the boxed section in the lower right corner of Fig 2.

Once the PC board is populated, the only adjustment this transverter requires is tweaking of its LO trimmer (C3) to ensure reliable oscillator starting. To do this, apply 13.5 V to the LO. If you can, observe the LO signal at 758 MHz and adjust the trimmer until the oscillator restarts every time power is removed and reapplied. If you like, you can also use either the 902-MHz transmit or receive section to verify this. The 94.75-MHz LO is also audible on standard FM-broadcast receivers. In operation, apply 13.5 V to the LO and the transmit or receive section, depending on which is in use. (It's good practice to remove power from the unused stage.)

Performance

When driven with 1 mW of 144-MHz RF, this transverter provides a clean, low-power 902-MHz signal. All spurious outputs are more than 50 dB below the desired output, as shown in Fig 4. The transmit-converter output is suitable for direct connection to a linear amplifier without additional filtering.

On receive, the transverter's under-4-dB noise figure and unconditionally stable 50-Ω input termination are hard to beat. Image rejection is more than 70 dB. No input filtering is done before the first amplifier stage, so the input stage is susceptible to overload in high-RF environments. For use in such environments, there are several options:

- Replace the receive amplifiers with MSA-1104s. This increases the noise figure by about 1 dB and increases dynamic range by about 10 dB. This is usually not enough of an improvement to cure overload, though.
- Omit the first amplifier stage. This increases the noise figure to 7 or 8 dB, but will probably cure the problem.
- The best alternative: Use an external, low-loss filter. If this or any other transverter is to be used around other transmitters, it is good practice to use a low-loss cavity filter before the first receive-amplifier stage.

Conclusions

When used with a suitable outboard linear amplifier and a GaAsFET preamp, this transverter easily outperforms older designs—at a fraction of the cost. The performance advantages gained by the use of printed band-pass filters, combined with the elimination of all microwave adjustments and the need for a spectrum analyzer, are significant advances in the state of the art that are common to this family of microwave transverters.

When this transverter is coupled with the right antenna system, you can work tremendous DX on the 902-MHz band. Dave (WA3JUF) Mascaro's *QST* article, "A High-Performance UHF and Microwave System Primer," which begins on page 30 of May 1991 *QST*, has antenna ideas and lots of other useful information on how to get the most out of your UHF station.

Acknowledgment

Thanks to Don Hilliard, WØPW, for building and testing a prototype, and for preparing the schematic.

Notes

[1]R. Campbell, "A Single Board No-Tuning 23 cm Transverter," *Proceedings of the 23rd Conference of the Central States VHF Society* (Newington: ARRL, 1989), pp 44-52. This book is available from ARRL for $12 (plus $2.50 postage and handling, or $3.50 for UPS or insured parcel post), or from your local dealer.
[2]J. Davey, "No-Tune Transverter for 2304 MHz," *Proceedings of Microwave Update '89* (Newington: ARRL, 1989), pp 30-34. See note 1 for ordering information.
[3]J. Davey, "A No-Tune Transverter for 3456 MHz," *QST*, Jun 1989, pp 21-26. Also see Feedback, Oct 1990 *QST*, p 31.
[4]R. Campbell, "A Single-Board Bilateral 5760-MHz Transverter," *QST*, Oct 1990, pp 27-31. This article lists, in its end notes, sources for lots of information on microwave antennas and other subjects of general interest.
[5]Etched PC boards, crystals, kits of parts, assembled boards and complete transverters are available for this rig and the projects referenced in notes 1-4 and 7, from Down East Microwave, RR 1 Box 2310, Troy, ME 04987, tel 207-948-3741, fax 207-948-5157. Catalog available.
[6]See note 1.
[7]R. Campbell, "A Clean, Low Cost Microwave Local Oscillator," *QST*, Jul 1989, pp 18-23.
[8]See note 7.
[9]R. Campbell, "A Clean Microwave Local Oscillator," *Proceedings of the 1296 and 2304 Conference*, reprinted in *Proceedings of the 21st Conference of the Central States VHF Society* (Newington: ARRL, 1987), pp 51-57. See note 1 for ordering information.
[10]Down East Microwave (see note 5) carries these hybrid amplifier modules.
[11]Send a no. 10 SAE with one unit of First-Class postage to the ARRL Technical Department Secretary; request the July 1991 *QST* 902-MHz transverter template package. The PC-board artwork is copyrighted by Down East Microwave. Feel free to use it to make boards for your personal, noncommercial use, but not for commercial purposes.
[12]See note 5.
[13]See note 3.