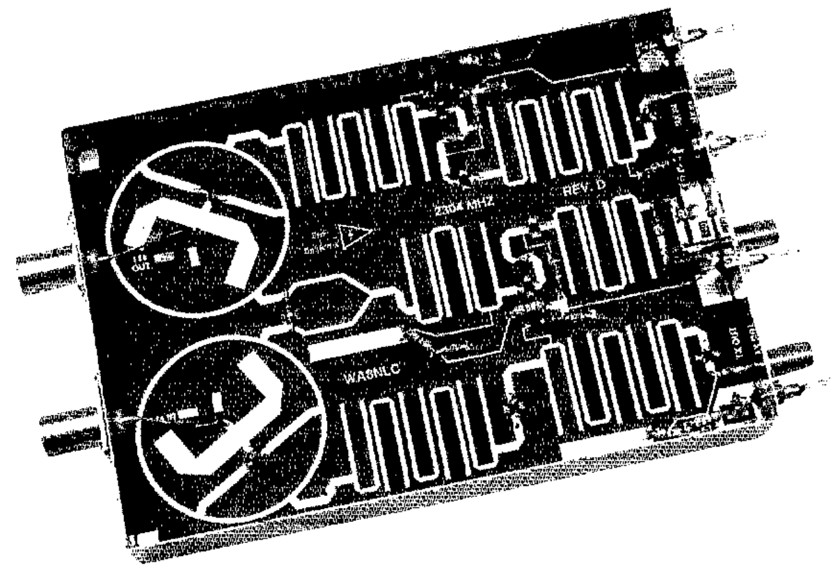
A No-Tune Transverter for the 2304-MHz Band

The latest in the family of simple, high-performance microwave transverters, this version, like its 903, 1296, 3456 and 5760-MHz cousins, uses etched band-pass filters and monolithic amplifiers for simplicity and reliability.

By Jim Davey, WA8NLC
4664 Jefferson Township Pl
Marietta, GA 30066



Amateur microwave activity is exploding! In just the past few years, there has been a tremendous resurgence in interest, activity and experimentation on the bands above 1 GHz. Articles abound in *QST* and elsewhere describing easy to build equipment and antennas for all the amateur bands through at least 5760 MHz.[1-5] In 1985, the now annual Microwave Update conference was started to exchange ideas and operating experience. The response was fantastic! Since that first conference, a renaissance has truly occurred

[1]Notes appear on page 39.

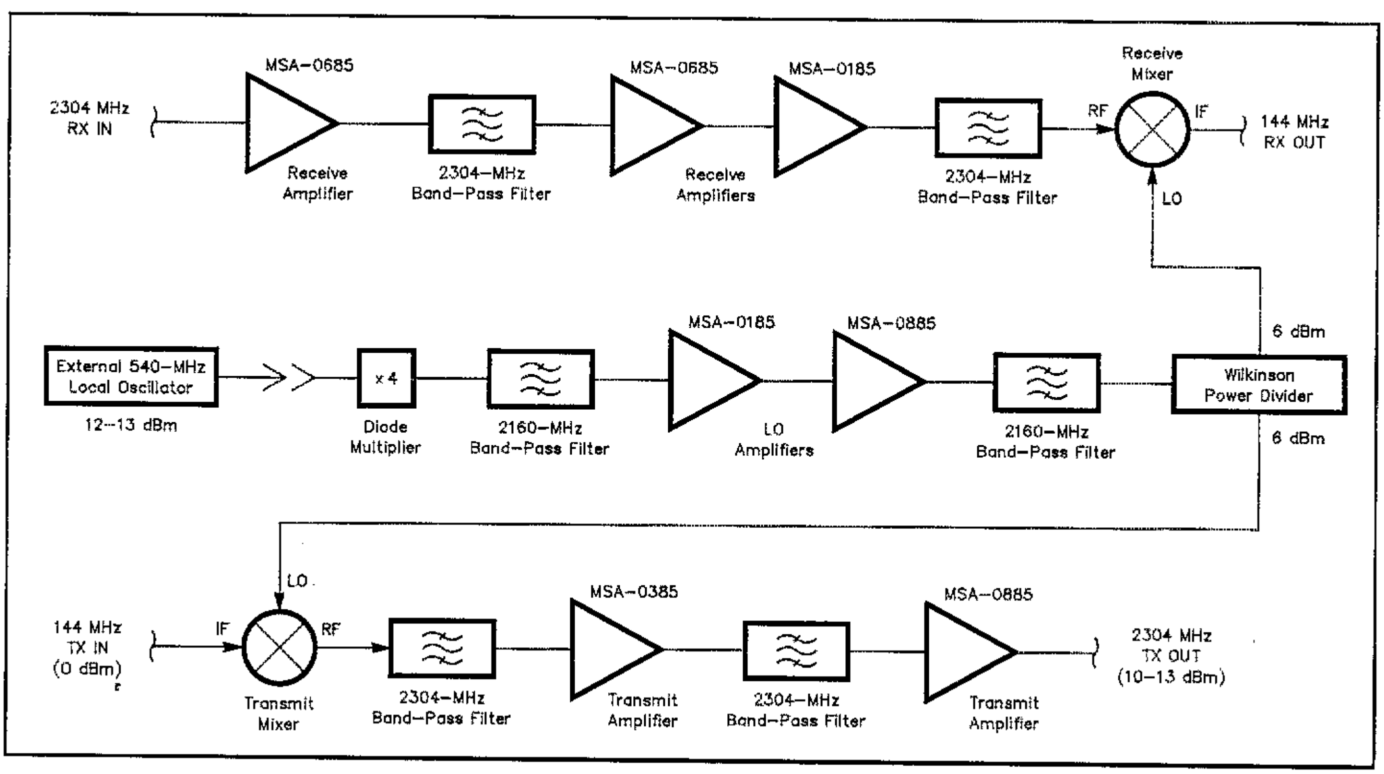
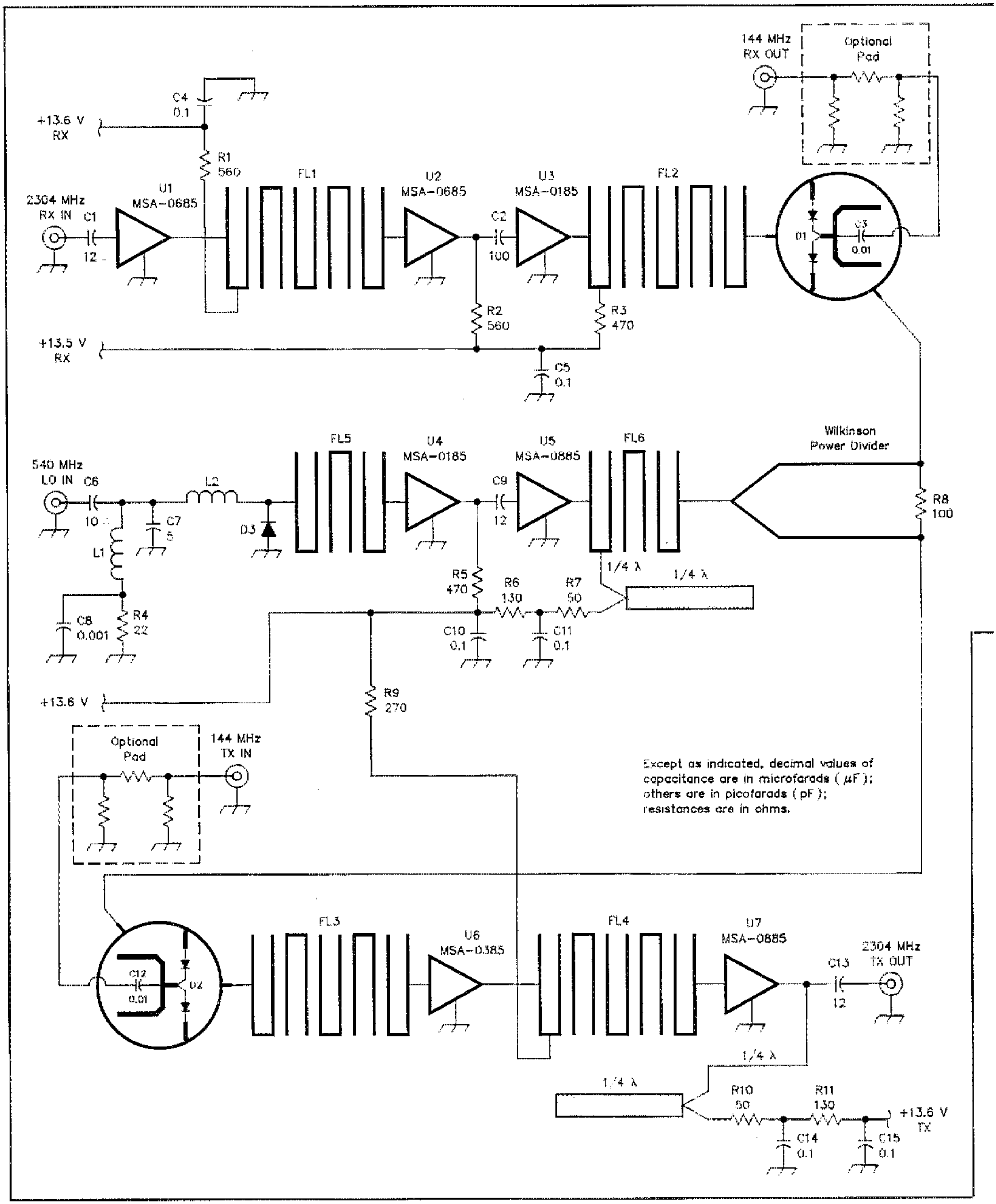


Fig 1—Block diagram of the 2304-MHz transverter. The filters, mixers and power divider are etched on the Teflon PC board. All the amplifier stages use 50-Ω gain blocks (monolithic microwave integrated circuits—MMICs). This design is nearly identical to the 3456-MHz version in layout and operation.



in the amateur microwave world. Now, VHF-contest operation nearly always includes a serious effort on several microwave bands. Often, a lot of preparation also goes into the construction of rover stations that can provide valuable contest multipliers from many different grid squares. Increased activity has led to most distance records being repeatedly broken. The list goes on and on.

Small, portable solid-state equipment has replaced the rack full of equipment so often associated with microwave stations of old. Hilltopping using simple low-power equipment has become a subculture of the hobby in itself. This article describes a small, lightweight transverter module for the 2304-MHz band that is ideally suited for low-power

Fig 2—Schematic of the 2304-MHz transverter. See the text and notes for parts sources. When building this transverter, follow good microwave construction practices, as detailed in the 3456-MHz transverter article (see text and notes). The Avantek MSA-0185 is equivalent to the Mini-Circuits MAR-1; the MSA-0685 is equivalent to the MAR-6, etc. (Lead labeling varies, however; follow the manufacturer's instructions.) Bias-resistor values given are for 13.6-V operation. All capacitors in the 2304-MHz signal path are 50- or 100-mil ceramic chips, except for the 0.01-µF coupling capacitors at the IF input and output. Here, use ceramic discs, encapsulated chips or other low-loss capacitors. Use ¼ -W carbon composition or film resistors.

D1, D2—Hewlett-Packard HSMS-2822 surface-mount diode pair.
D3—Hewlett-Packard 5082-2835 Schottky diode.
FL1-FL6—Etched band-pass filter.
L1—4 turns #28 enameled wire, 0.075 inch ID, closewound.
L2—5 turns #28 enameled wire, 0.075 inch ID, closewound.
U1, U2—Avantek MSA-0685 or Mini-Circuits MAR-6.
U3, U4—Avantek MSA-0185 or Mini-Circuits MAR-1.
U5, U7—Avantek MSA-0885 or Mini-Circuits MAR-8.
U6—Avantek MSA-0385 or Mini-Circuits MAR-3.

Etched Band-Pass Filters

Just how much filtering is needed in a 2304-MHz transverter? Well, since there are no FCC regulations for purity of emissions at this frequency, that depends entirely on your design objectives. In this transverter, simplicity of design and construction was a primary goal, consistent with reasonably clean performance in both the transmitter and receiver.

In the receiver, the purpose of filtering is to remove the 2016-MHz image to maintain optimum system sensitivity. Without it, noise or signals at the image frequency (and it's almost always noise at this frequency!) is converted to the IF frequency and degrades system sensitivity by up to 3 dB. Filtering also helps protect the receiver from the myriad out-of-band signals that the MMIC receiver chain will dutifully amplify, causing IMD or desense in later stages.

The image is relatively easy to eliminate; it has to be attenuated by only about 20 dB to assure that it won't affect receiver performance. For out-of-band signals, ideally you should limit the window that the receiver sees to just that necessary for your operating needs—perhaps a few megahertz. This degree of selectivity is very difficult to achieve at this frequency without paying the price in increased insertion loss, large physical size and stringent construction tolerances. Microstrip resonators cannot achieve this level of performance, so I took a more realistic approach.

In the 2304-MHz transverter, the receiver passband is 240 MHz wide, which is a reasonable compromise between performance and construction tolerance. However, since the first MMIC is located ahead of the on-board filters, an external filter may be required in some circumstances, as described in the text. Using the transverter on a hilltop covered with microwave, cellular, paging, television and FM broadcast transmitters may be impossible without an external filter. If an outboard GaAsFET preamp is used, a highly selective filter may be needed ahead of it, too, as most preamp circuits do not exhibit much selectivity.

In the transmitter, four mixing products are most troublesome. The mixing image (LO – IF) at 2016 MHz is present in the mixer output. Also present are the LO + 2(IF) product at 2448 MHz and the LO + 3 (IF) product at 2592 MHz. A large amount of the 2160-MHz LO signal also appears there because of the single-balanced mixer's finite LO- to RF-port isolation.

To drop these spurs to acceptable levels, I reduced the transmitter's filter bandwidths to 180 MHz in the latest version of the transverter. Additional filter insertion loss is the price for this bandwidth decrease, but the transmitter chain has enough gain to overcome the loss and still drive the MSA-0885 output stage to 10 mW.

Filtering in the LO multiplier is comparatively easy because the closest unwanted products of the diode multiplier are over 500 MHz from the desired signal. A pair of three-pole, 270-MHz-bandwidth filters does the job nicely here. —*WA8NLC*

hilltop work or as the heart of a more sophisticated home station. It follows the design philosophy of its 3456-MHz predecessor,[6] using etched single-balanced mixers and etched band-pass filtering. No tuning adjustments are necessary (nor are they recommended!) for proper operation. Broadband monolithic microwave integrated circuits (MMICs) serve as stable gain blocks. External power amplifiers and receive preamplifiers can be added later to enhance the station's capabilities, but the basic transverter is capable of surprisingly distant communications.

Introduction

The 2304-MHz transverter, shown in block diagram form in Fig 1, was a natural outgrowth of the 3456-MHz transverter. Like its higher-frequency cousin, it uses a 2-meter IF. Separate transmit and receive paths are provided to simplify the addition of external power amplifiers, preamplifiers and IF-conditioning circuits. All the amplifiers in the transverter operate linearly, so you can use it on any mode. The transverter requires a separate 540-MHz local oscillator (LO). In July 1989 *QST*, Rick Campbell, KK7B, described a no-tune LO module that is ideal for use with this transverter.[7] The transverter uses common, inexpensive parts. Boards, parts and kits are available, as are assembled and tested transverters.[8]

Design

The transverter, shown schematically in Fig 2, is built on 0.032-inch woven Teflon board material with a dielectric constant of 2.5 and half-ounce copper foil. The key to the circuit's simplicity lies in the printed microstrip third- and fifth-order Chebyshev band-pass filters. (See the sidebar, "Etched Band-Pass Filters.")[9,10] These filters have excellent stopband rejection and low insertion loss. Fig 3 is a network-analyzer plot of one of the five-pole receiver filters, showing attenuation and return loss in the passband. Midband insertion loss is just 2.1 dB, thanks to the low-loss Teflon PC-board substrate.

The center frequency and bandwidth of the receive filters were chosen to also allow receive-only operation on the OSCAR Mode S downlink at 2401 MHz using a 564.25-MHz LO. The transmitter-filter bandwidth is narrower, to help suppress unwanted mixing products. The transverter shouldn't be used for transmitting above 2325 MHz without an external cavity or interdigital filter that attenuates the LO signal by at least 10 dB.

Transmit Converter

Transmitter power output is 10 to 20 mW (10 to 13 dBm) and varies slightly with component variations in the Avantek MSA-0885 MMIC output stage. Although more power would help balance the transverter's capability with that of most home stations, power-amplifier stages are best implemented as external accessories. It's good design practice to limit the amount of gain in a single box to 30 dB or so, unless special efforts are taken to prevent feedback. (See the sidebar, "Packaging the Transverter.")

External amplifiers based on 100-mW GaAsFETs, such as the $33 Avantek ATF-21170, are about as easy to build as a receive preamp. Linear bipolar devices, also available at reasonable prices, are also good candidates for use in the next transmit-amplifier stage.[11]

Receive Converter

The transverter's receive-converter noise figure (NF) is approximately 4.5 dB. This may seem high by today's standards, but it can be easily dropped to 1 dB or less by any modern GaAsFET preamplifier with a gain of 14 dB or more. Al Ward, WB5LUA, described an excellent preamplifier for this purpose in May 1989 *QST*.[12]

The transverter's first receive stage, an Avantek MSA-0685 MMIC, provides a 50-Ω input impedance to properly terminate

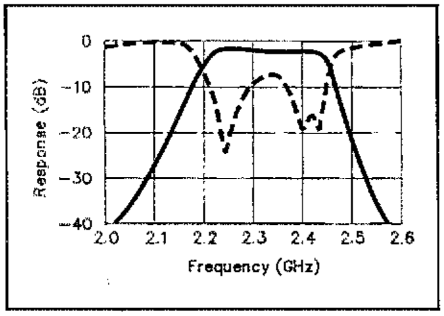


Fig 3—This network-analyzer plot shows the response of the etched band-pass filters used in the 2304-MHz transverter. The solid line shows the filter response. The passband is approximately 240 MHz wide. The broken line shows filter input return loss, 8.6 dB at 2305 MHz, which equates to an input SWR of about 2.2:1.

an outboard preamp. The preamp can be mast-mounted or connected directly to the transverter input, as explained later.

The receiver chain is designed to accommodate a variety of device configurations depending on your needs. The schematic and block diagram show the standard configuration using an MSA-0685 driving another MSA-0685 and an MSA-0185. These MMICs are inexpensive and available from a number of sources. For a lower receiver NF (about 3.2 dB), you can use a newer but slightly more expensive MMIC, the Avantek INA-03184, in the spot occupied by the first '0685. The NF of this MMIC is about

Packaging the Transverter

The box you use to house your microwave transverter is an important part of the circuit. At 2 meters, the enclosure choice is usually made with convenience, cost and/or eye appeal in mind. At microwave frequencies, typical enclosures often have dimensions (with respect to the wavelength) that affect the circuit in ways that cannot be ignored.

Why is the enclosure size in relation to wavelength important? Over a range of frequencies, the enclosure can act as rectangular waveguide (a very low-loss transmission line) and can conduct radiated energy from one part of the circuit to another where it undesirably affects circuit operation.* This can have subtle effects, such as increasing unwanted transmitter products, or more noticeable problems, like oscillating amplifier stages.

Below the operating range of a waveguide, the attenuation rises very rapidly. This is called the waveguide's *lower cutoff frequency*. Ideally, your microwave circuit should fit within an enclosure that represents a waveguide below its cutoff frequency, to take advantage of the resulting isolation.

The design goals for the 2304-MHz transverter did not allow me to take advantage of this packaging luxury. If you build a box around the transverter that is 4 inches wide (the width of the board), the waveguide formed by the box has a lower cutoff frequency of approximately 1500 MHz. (For the transverter to be boxed in an enclosure that's a waveguide below cutoff, the width could be no more than 2.35 inches.) So, I had to reduce circuit radiation to isolate the stages, rather than rely on the cabinet serving as a waveguide below cutoff.

I found in earlier versions of the transverter that the primary sources of radiated energy were the bias-resistor leads—especially those that fed dc to parts of the circuit that were hot with RF. In this latest version, the bias to each stage is fed to each MMIC through microstrip traces, which radiate much less energy. Also, where possible, dc is fed to amplifiers at points that are cold to RF—the centers of the adjacent filter elements—to minimize RF coupling into the bias network.

These techniques aren't new, but represent a valuable lesson. This transverter is much less sensitive to packaging effects than earlier versions and the techniques described are equally applicable to your other microwave projects.—*WA8NLC*

*K. Britain, "Works Great! Until You Put It in the Box?," *Proceedings of the 1991 Central States VHF Conference* (Newington: ARRL, 1991), pp 33-34. See the main text's Note 1 for ordering information.

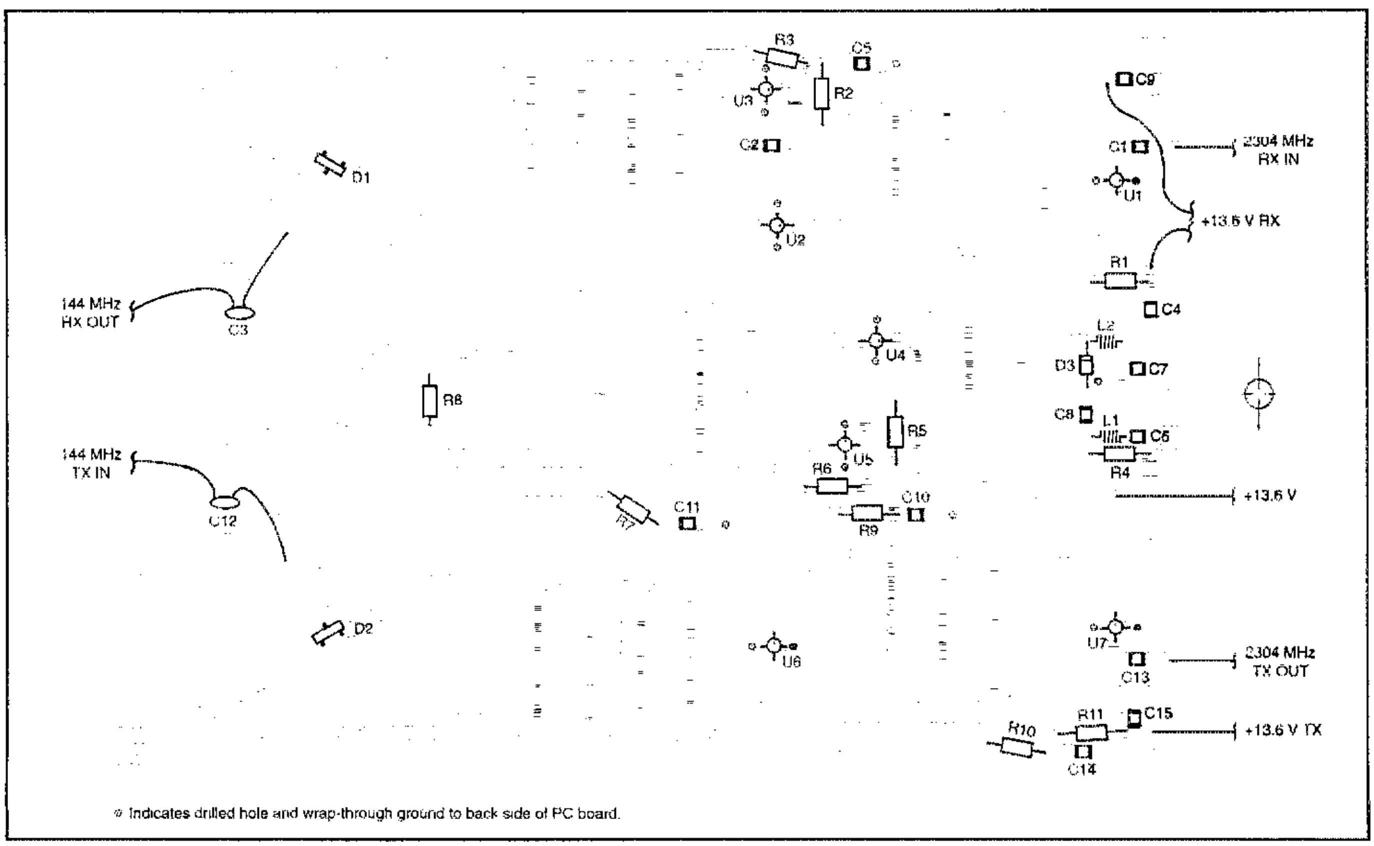


Fig 4—Part-placement guide for the 2304-MHz transverter (not shown actual size). All components mount on the etched side of the board. Feedthrough grounds, indicated by circles, *must* be installed and soldered top and bottom. Follow MMIC manufacturers' lead coding (pin-outs for Avantek and Mini-Circuits devices differ).

3.0 dB, and its higher gain eliminates the need for the third-stage '0185. If you go this route, jumper together the MSA-0185 input and output microstriplines with copper foil the same width as these traces.

Although an MMIC in the first stage terminates an outboard preamplifier with a broadband 50-Ω load, it has a disadvantage: The unfiltered first stage will amplify everything from dc to 3 GHz. If overload is a problem (as it could be at mountaintop sites crowded with commercial radio systems), an INA-03184/MSA-0685 combination can be placed between the two receive filters. This arrangement gives about the same system noise figure as the '0685 front end, but filtering ahead of the first stage rejects out-of-band signals, making this the desired configuration for RF-crowded locations.

Supplying Dc Power to RF Stages

Power is routed to each stage on microstrip traces. Earlier versions of this transverter supplied power through dropping resistors mounted from each MMIC collector (output lead) to +13.6 volts. But at this frequency, resistor leads act as tiny antennas, making lead dress instrumental in avoiding unwanted coupling between stages and around filters. The most troublesome stages in the earlier versions were those using the MSA-0885. These MMICs have a lot of gain below 500 MHz and can also oscillate under some conditions.

In the updated design presented here, quarter-wave chokes and decoupling stubs, connected to these stages at points that are cold to RF, reduce this problem. To enhance low-frequency stability, each bias network includes a 50-Ω termination from the stub to ground through a 0.1-µF bypass capacitor. The balance of the resistance needed to bias the '0885 is then provided by the 130-Ω series resistor. In the transverter's remaining MMIC stages, a simple series-resistor bias network, as specified by the MMIC manufacturer, adequately decouples the RF stages from the dc supply.

A word of caution to those planning battery operation: Unconditionally stable MMICs may become unstable if operated outside the specified current range. This can happen unexpectedly as a battery charge is depleted. The resistor values shown in the schematic are chosen for 13.6-volt operation typical of automotive battery systems. When the devices are biased for 13.6 volts, oscillation may occur below 12.0 volts.

The supply voltage to the receiver section can be left on continuously, but I recommend switching it off during transmit—especially if the receive-converter input stage is unterminated. I also recommend removing dc power from the transmit-converter output stage during receive to minimize leakage of wideband transmitter noise into the receiver front end. This could occur if the isolation in your antenna relay is less than 60 or 70 dB. These dc power considerations are easy to handle with an external IF switch.[13]

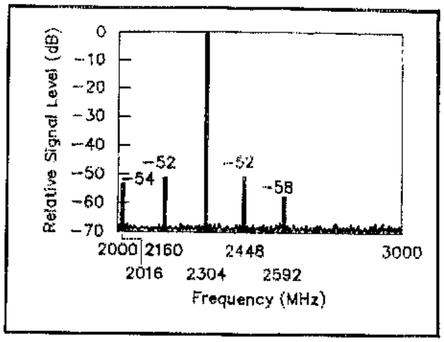


Fig 5—Spectral display of the 2304-MHz transverter output. Power output is approximately 16 mW at 2304.1 MHz. The local-oscillator signal at 2160 MHz is down approximately 52 dB; the 2016-MHz image is down 54 dB; the 2448-MHz product (LO + 2[IF]) is down 52 dB, and the 2592-MHz product (LO + 3[IF]) is down 58 dB.

Mixers

Although packaged double-balanced mixers for the 2.3-GHz range are commercially available, they are quite expensive. The simple single-balanced mixers used here work well. Although they require more PC-board real estate, the specified packaged diode pair costs about $2 each. I included extra connection pads at the IF ports of the mixers to use for optional pi-network attenuators. You can reduce excess transmitter drive at this point if necessary to reach the mixers' 1-mW maximum drive level. If more than 10 dB of attenuation is required to drop your IF drive to 1 mW, use an external attenuator. On the receive side, if your IF rig has a noise figure of 3 dB or better, a 3- to 5-dB pad between the receive-converter output and the IF receiver will provide a better source impedance for the IF rig and reduce excess gain that compromises system dynamic range. Recent editions of *The ARRL Handbook for Radio Amateurs* show how to make resistive pi-network pads using quarter-watt resistors.[14]

Local Oscillator

KK7B's LO, mentioned earlier, is probably the easiest way to supply the transverter with a clean 540-MHz signal at the required drive level (12 to 13 dBm). Only one simple adjustment is required on the oscillator to ensure reliable starting when power is applied. The LO is slightly smaller than the transverter and the two can be mounted back-to-back for a compact package.

Construction

All parts are surface-mounted on the PC board, including several 1/4-watt resistors. Close to the resistor bodies, bend the leads at right angles and clip them short enough to allow the resistors to lie flat against the board. Wrap-through grounds are required under each MMIC ground lead and at several other places in the bias networks and the board edges, as shown in Fig 4. Make these from copper tape or foil. For a thorough discussion of construction details and packaging options, refer to my June 1989 *QST* article on the 3456-MHz transverter.

Due to the very tight dimensional tolerances of the transverter's filters and the many variables in the *QST* printing process, an etching pattern is not included here. The ARRL Technical Department will supply you with a dimensioned copy of the artwork for an 8.5- × 11-inch SASE,[15] but I recommend that you start with an etched board for best results.

Performance

When driven with 1 mW of 144-MHz RF, the transverter produces a clean 2304-MHz signal, as shown in Fig 5. The 1-dB compression point is 10 mW. All spurious products are down from the fundamental output by at least 50 dB. For a receive frequency of 2304.1 MHz, the measured image rejection is more than 70 dB and the measured NF is 4.3 dB.

Be careful to not exceed the transmit mixer's maximum drive rating of 0 dBm (1 mW). If you have extra transmit gain in your final configuration, reduce the transmitter drive as described earlier. (I rarely have this problem as Murphy always guarantees that I am about 2 dB short of what I had planned!)

Station Integration

If you don't want to modify your 2-meter rig for IF use, you'll have to attenuate its output to 1 mW. Assuming that you use a typical 10-watt multimode rig, you'll need 40 dB of attenuation to do so. I reduced the output of my IC-202 by reducing the gain of one of the transmit amplifiers. I have also heard of others reducing the output power of multimode transceivers by simply removing dc from the final amplifier. I have tried this and found that the load presented by different mixers in my transverters caused the actual drive power to vary by several decibels. The addition of a 5- to 10-dB pad on the IF-transmitter output made the drive insensitive to the load and allowed me to use one IF rig with several transverters without concern. This pad can be located on the 2304 transverter board, if you like, in the position shown in Fig 4.

I designed the transverter with separate IF ports for the transmitter and receiver, but if you can reduce your IF rig's output power level to 1 or 2 mW, you may want to simplify this interface to a single cable. In my transverters, I use a single piece of coax between the IF rig and the transverter to handle the transmitted and received signals and to perform TR switching, as shown in Fig 6. In the transverter, a Wilkinson power divider splits and isolates the receive and transmit IF ports. Wilkinson dividers can be built very inexpensively using 70-Ω coax, as shown in Fig 6, or using lumped components.[16] Low-cost hybrid power dividers are also available from Mini-Circuits.

To compensate for the 3-dB divider loss, increase the transmitter drive into the Wilkinson divider to 2 mW (3 dBm). Even

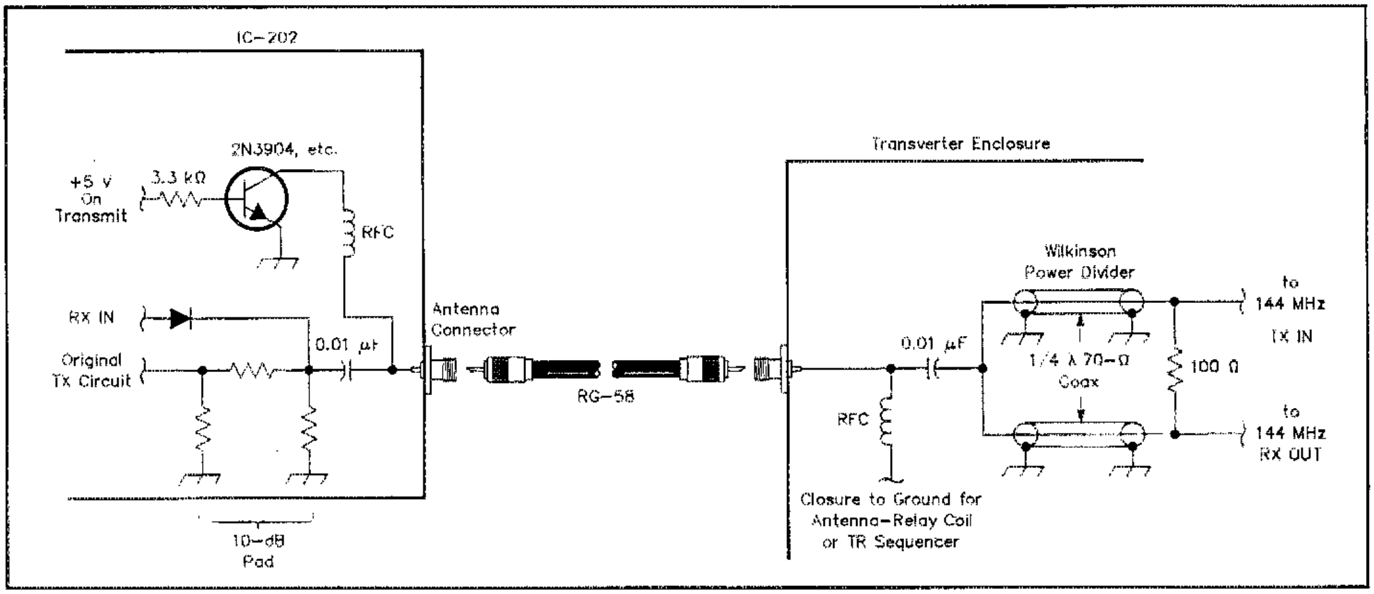


Fig 6—Interconnecting the transverter enclosure to an IF transceiver with a single cable requires putting a dc switching signal on the coax and decoupling it from the RF circuitry. On the transverter side, a Wilkinson power divider (like that used to split the LO between the mixers on the transverter board) divides the IF signal. The two divider outputs feed the IF connections on the no-tune board. This diagram shows the simple internal modifications required in an ICOM IC-202 portable 2-meter transceiver to pad the transmitter output and provide a dc ground during transmit on the radio's antenna connector. Inside the IC-202, gate 2 of Q16 must also be grounded to drop the pre-attenuator output to approximately 10 mW.

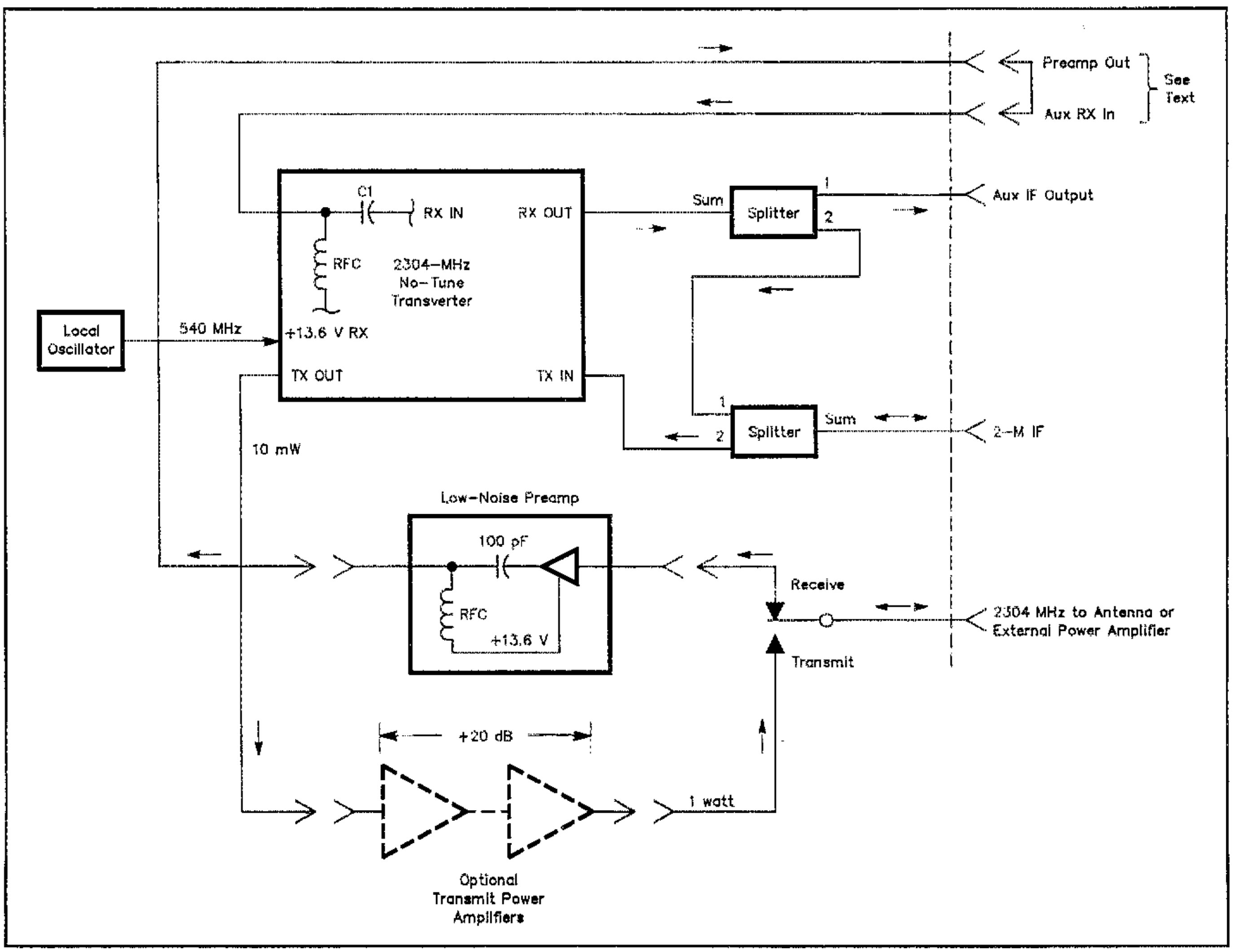


Fig 7—This block diagram of a 2304-MHz station based on the no-tune board shows required connections and details for using two IF receivers, and internal and external preamplifiers. Logical, simple cabling lets you use this transverter as the basis of a high-performance home station or portable setup.

with the extra loss in the receive path, no receiver post-mixer amplifier is needed if your 144-MHz rig has a low noise figure. In fact, just the opposite is often true. Too much gain ahead of the IF rig can severely compromise system dynamic range. In my transverters, I usually place an attenuator between the transverter's 144-MHz IF output and the Wilkinson divider to reduce excess gain. Extra foil pads on the transverter board are provided for a pi-network attenuator. Given the receiver's 20-dB conversion gain, 5 dB of attenuation should be adequate. With the receiver AGC off and a 50-Ω load on the receive-converter input, you should hear a definite increase in background noise when you turn on the transverter. If you use a low-noise preamp, you may need a 15- to 20-dB pad.

The TR circuit shown in Fig 6 provides a ground on transmit through the 2N3904. As shown, it controls the antenna-transfer relay, but in my transverters it controls a TR sequencer.

Additions

In a high-performance home-station transverter, you may want to include a few extras to make the transverter more versatile. For instance, to one of my transverters, I can connect a high-performance IF rig (HF rig with 2-meter converter), in parallel with the IC-202, for serious weak-signal work. Both receivers can be used at the same time to monitor two frequencies. I use the IC-202 for transmitting and casual band scanning. You can easily do the same by adding another 144-MHz Wilkinson divider in the IF line as shown in Fig 6. The auxiliary IF output should be terminated in 50 Ω when a receiver isn't connected to it.

In a high-performance system, you may also want to include a low-noise preamplifier. By locating it at the antenna relay and running a separate receive line from the preamp output to the receive-converter input, you can achieve maximum receive performance and avoid the need for two high-power relays to switch around the preamp at the antenna.[17]

I use an internal low-noise GaAsFET preamp with about 14 dB gain for stand-alone operation, and provide a means of bypassing this preamp when I want to use an external preamp. Fig 7 shows how this is done with a preamp output loop on the rear panel. With the jumper in place, the common port of the internal TR relay connects directly to the feed line for stand-alone use. Opening the loop gives access to the transverter input from the external preamp, bypassing the internal preamp and preserving system dynamic range. If blocking capacitors are added as shown, the **AUX RX IN** jack can supply dc power to whichever preamp is in use.

On the 2304-MHz side of the transverter, several options exist for completing your station. You can add external power amplifiers and receive preamplifiers for improved performance. A TR relay is usually used to switch the antenna between the receiver and transmitter. Dave (WA3JUF) Mascaro's May 1991 *QST* article describes alternatives to this that minimize the need for expensive relays and the power source (often 28 volts dc) necessary to operate them.[18]

A ferrite circulator (or isolator converted to circulator by removing its 50-Ω load and replacing it with a coaxial connector), sometimes available on the surplus market, can provide a low-loss means to share an antenna between a receiver and a transmitter.[19] The beauty of this approach is that these devices are passive and have no moving parts to fail. Mini-Circuits and Anzac also make GaAs switches that can handle up to a couple of hundred milliwatts and would make a neat TR switch. This is a fertile area for further development.

Acknowledgements

Many thanks to Rick Campbell, KK7B, for bringing the simple elegance of MMICs and etched band-pass filters to Amateur Radio microwave equipment design; and to Rus Healy, NJ2L, for constructing and testing prototype transverters.

Notes

[1]This article is based on a design published in J. Davey, "No-Tune Transverter for 2304 MHz," *Proceedings of Microwave Update '89* (Newington: ARRL, 1989), pp 30-34. This book is available for $12 (plus $2.50 postage and handling, or $3.50 for UPS or insured parcel post) from the ARRL Publication Sales Department or from your local dealer.

[2]J. Davey, "A No-Tune Transverter for 3456 MHz," *QST*, Jun 1989, pp 21-26. Also see Feedback, *QST*, Oct 1990, p 31.

[3]R. Campbell, "A Single-Board, No-Tune 902-MHz Transverter," *QST*, Jul 1991, pp 25-29. Also see Feedback, *QST*, Feb 1992, p 39.

[4]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. See Note 1 for ordering information.

[5]R. Campbell, "A Single-Board Bilateral 5760-MHz Transverter," *QST*, Oct 1990, pp 27-31. This article lists, in its end notes, sources for information on microwave antennas and other microwave subjects of general interest.

[6]See Note 2.

[7]R. Campbell, "A Clean, Low-Cost Microwave Local Oscillator," *QST*, Jul 1989, pp 15-21.

[8]Etched boards, complete parts kits and assembled units are available from Down East Microwave, RR 1 Box 2310, Troy, ME 04987, tel 207-948-3741, fax 207-948-5157. Catalog available. Most of the small parts for this project are also available from Microwave Components of Michigan, PO Box 1697, Taylor, MI 48180. Etched boards are available from the author for $40 each postpaid. Foreign orders should include $5 for additional postage.

[9]J. Davey, "Microstrip Bandpass Filters," *Proceedings of Microwave Update '87* (Newington: ARRL, 1987), pp 42-53.

[10]J. Davey, "Microwave Filter Update," *Proceedings of Microwave Update '88* (Newington: ARRL, 1988), pp 1-8.

[11]G. McIntire, "1/2 and 1 Watt 2304/3456 MHz Amplifiers," *Proceedings of Microwave Update '91* (Newington: ARRL, 1991), pp 160-171. See Note 1 for ordering information.

[12]A. Ward, "Simple, Low-Noise Microwave Preamplifiers," *QST*, May 1989, pp 31-36, 75.

[13]Down East Microwave (see Note 8) offers an IF switch that handles 144-MHz RF switching and dc-supply switching. See Product Review, *QST*, Jun 1992, p 56.

[14]Most recently, J. Kleinman and C. Hutchinson, eds, *The ARRL Handbook for Radio Amateurs* (Newington: ARRL, 1991), p 25-39.

[15]Address your request to DAVEY 2304-MHz ARTWORK, Technical Department Secretary, ARRL, 225 Main St, Newington, CT 06111.

[16]E. Franke, "Wilkinson Hybrids," *ham radio*, Jan 1982, pp 12-18.

[17]D. Mascaro, "A High-Performance UHF and Microwave System Primer," *QST*, May 1991, pp 30-33.

[18]See Note 17.

[19]K. Britain, "Circulators and Isolators," *Proceedings of the 1991 Central States VHF Conference* (Newington: ARRL, 1991), pp 31-32.

[20]See Note 1 for ordering information.

Coming Conventions

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August 14-15, 1993—Huntsville, Alabama

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Strays

MANGLED MAIL

☐ What do you do when the post office returns your QSL cards in damaged or defaced condition? One way to deal with it is to let the US Postal Service (USPS) know about the situation. The post office has a "complaint" form—PS Form 4314-C (USPS Consumer Service Card)—available at most post offices. It gives you the opportunity to notify the local post office of letter or card mishandling or damage. Fill out the card and mail it to the postmaster for your city. This may help minimize QSL card damage in the future.—*Joe Carcia, NJ1Q, ARRL Outgoing QSL Bureau*