# A No-Tune Transverter for 3456 MHz

Building microwave gear used to take exotic parts and a roomful of test equipment. Not anymore!

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he development of easy-to-build equipment for the microwave bands has increased dramatically in the past few years. No longer do you have to have a small fortune invested in test equipment to get the satisfaction of building your own station for the bands above 1 GHz. Nor do you have to rely on the availability of surplus components gathered at hamfests—or be lucky enough to live in a high-tech part of the country where surplus is more plentiful—to home-brew your own equipment.

The recent increase in activity on the microwave bands has been well documented in QST and elsewhere. In the past two years alone, amateurs have conquered the difficult EME challenge on 3456, 5760 and 10368 MHz and set impressive distance records on nearly every microwave band through 47 GHz. UHF contest stations now regularly have 2304- and 3456-MHz equipment available. Our knowledge of the propagation characteristics of these bands has also benefited from the increased activity. In the Oklahoma area, Tony Bickel, K5PJR, Larry Nichols, W5UGO, and others have literally written the book on 5760-MHz propagation through their fine efforts on this band.

Commercially manufactured ham equipment from Europe has been available for a few years for the more popular microwave bands, and this equipment has helped to spawn activity. The 3456-MHz band, however, has not been supported by commercial manufacturers as of this writing. Let's not let the lack of commercial equipment stop us from having a little fun! Besides, you can get a lot of enjoyment and personal satisfaction from building your own equipment. I can personally attest to this: My own station uses no commercially manufactured equipment except for the IF rigs.

This article describes a transmitting and receiving conversion module (transverter) for the 3456-MHz band. Any multimode

2-meter transceiver can be used as a tunable IF. The transverter has several features that make it ideal for the newcomer to 3456 MHz and the veteran looking for a simple loaner rig for grid-square expeditions:

- It doesn't require RF alignment or microwave test equipment for proper operation.
- The entire transverter, minus the 552-MHz local oscillator, is contained on one PC board, reducing the need for separate enclosures and expensive RF connectors and cables.
- The transmitter features 10 mW output, and the receiver features a 4-dB noise figure (NF)—performance sufficient for a lot of interesting work on this band.
- Inexpensive diodes and MMIC gain blocks are used to keep the cost low.
- An external receiving preamplifier, transmitter power amplifier and antenna relay can be added to make the unit a high-performance package for fixed or portable operation.
- The transverter can also be used as an IF for the higher microwave bands above 10 GHz.

# Background

The straightforward design of this transverter is a result of two fairly recent developments in the amateur microwave field. First, the introduction of cascadable monolithic-microwave integrated circuits (MMICs) several years ago revolutionized the design of microwave amplifiers. Not only are MMICs inexpensive, but most are unconditionally stable and can be cascaded for increased gain or paralleled for greater power output. Al Ward, WB5LUA, authored excellent articles for QST concerning the use of these devices. You are encouraged to review these articles for a more thorough treatment of the subject.

The second development contributing to

<sup>1</sup>Notes\_appear on page 26.

the design of this transverter is my recent work on microstrip band-pass filters that provide the required selectivity for this system without the need for tuning adjustments. These filters were first introduced to amateurs in 1987 at the Microwave Update Conference in Estes Park, Colorado.<sup>2</sup> A later paper reported on further work to improve the SWR of the filters and compared the microstrip filters to other commonly used filters for the microwave bands.<sup>3</sup>

To avoid taxing your wallet or your patience, I used parts that are inexpensive and easy to get. You should be able to get this transverter up and running for less than \$200. The idea here is to get you on the 3456-MHz band as easily as possible without relying on unique or hard-to-find components.

# Circuit Description

The transverter is divided into three basic sections: transmit mixer/amplifier, receive mixer/preamplifier and local-oscillator multiplier. See Fig 1. Each section is described in the following paragraphs.

# Local-Oscillator Multiplier

The transverter requires an external 552-MHz local oscillator (LO) signal that is multiplied by six in the transverter to obtain 3312-MHz injection for the mixers. For the multiplier circuit, I used an idea developed by Rick Campbell, KK7B, who demonstrated that a simple diode multiplier and inexpensive MMIC gain stages can produce a clean microwave local oscillator.4 Although Rick's design placed each stage in a separate box, I was able to implement the entire multiplier on microstrip using my own printed filters. The printed-filter design idea has since been used to produce a clean 552-MHz LO module that I use as a companion to this transverter,5

The transverter requires +16 dBm (40 mW) of 552-MHz energy from an

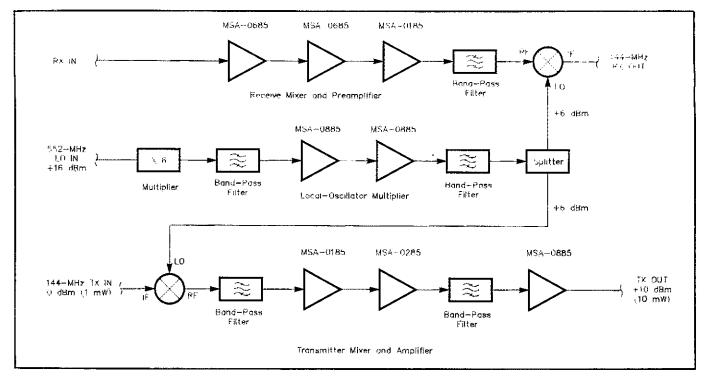


Fig 1-Block diagram of the 3456-MHz transverter.

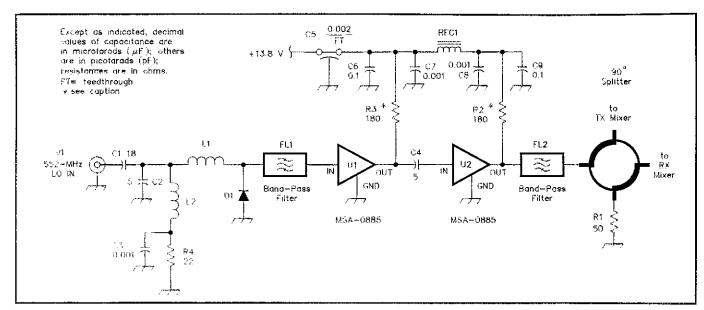


Fig 2—Schematic of the 3456-MHz transverter LO multiplier/amplifier.

- C1—18-pF disc-ceramic or silver-mica capacitor.
- C2, C4—5-pF porcelain chip capacitor. C3, C7, C8—0.001-µF ceramic chip
- (preferred) or disc ceramic capacitor. C5--0.002-μF feedthrough capacitor.
- C6, C9—0.1-μF ceramic chip (preferred) or disc-ceramic capacitor.
- D1—Hewlett-Packard 5082-2835 Schottky diode.
- FL1, FL2—Band-pass filters printed on PC
- board.
  J1—Female chassis-mount SMA connector.
- L1—Inductor printed on PC board.
- L2—3 turns no. 28 enam wire, 0.078-in. ID, closely wound.
- R1-50-Ω chip resistor.
- R2, R3—180-Ω, ¼- or ½-W carbon-film resistor. Note: This value is for 13.8-V
- operation. See text for information on operation at other voltages.
- R4—22· $\Omega$ , ¼-W carbon-film resistor. RFC1—270 μH subminiature molded RF choke. A suitable alternative is 24 turns no. 28 enam wire on an FT-37-72 toroid core.
- U1, U2—Avantek MSA-0885 or Mini-Circuits MAR-8 MMIC.

external LO. As shown in Fig 2, the first stage of the multiplier is a broadly resonant circuit that drives D1, a Schottky-diode comb generator. Following D1 is FL1, the first of two band-pass filters used to select

the desired 3312-MHz output. Two stages of amplification (U1, U2) using Avantek MSA-0885 MMICs bring the level up to +11 dBm. A second filter, FL2, is used to further clean up the LO and reduce broad-

band noise that is generated in the amplifier stages. Following FL2, a 90° hybrid divider splits the LO signal into two equal outputs for injection into the transmit and receive mixers. The LO output level to each mixer

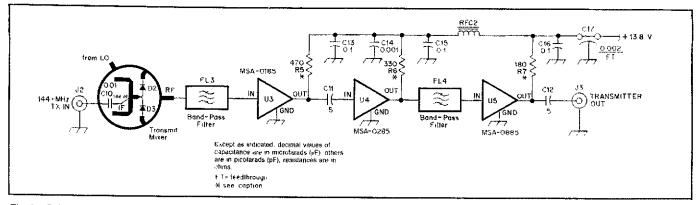


Fig 3—Schematic of the 3456-MHz transverter transmit mixer/amplifier.

C10—0.01-μF disc-ceramic capacitor. C11, C12—5-pF porcelain chip capacitor. C13, C15, C16—0.1-μF ceramic chip (preferred) or disc-ceramic capacitor. C14—0.001-μF ceramic chip (preferred) or

disc-ceramic capacitor. C17—0.002-μF feedthrough capacitor. D2, D3—Hewlett-Packard HSMS-2822 surface-mount diode pair or matched pair of HP 5082-2835 Schottky diodes. See text

FL3, FL4—Band-pass filters printed on PC board.

J2—Female chassis-mount connector, builder's choice.

J3—Female chassis-mount SMA connector. R5—470-Ω, ¼-W carbon-film resistor. Note: This value is for 13.8-V operation. See text for information on operation at other voltages.

R6—330-Ω, ¼-W carbon-film resistor. Note: This value is for 13.8-V operation. See text for information on operation at other voltages.

R7—180- $\Omega$ , ¼- or ½-W carbon-film resistor.

Note: This value is for 13.8-V operation. See text for information on operation at other voltages.

RFC2—270 µH subminiature molded RF choke. A suitable alternative is 24 turns no. 28 enam wire on an FT-37-72 toroid core.

U3—Avantek MSA-0185 or Mini-Circuits MAR-1 MMIC.

U4—Avantek MSA-0285 or Mini-Circuits MAR-2 MMIC.

U5—Avantek MSA-0885 or Mini-Circuits MAR-8 MMIC.

is +6 dBm. Undesired products in the LO output are 35 dB below the carrier.

# Transmit Mixer and Amplifier

The transmit mixer (Fig 3) is a 3/2 wavelength rat-race balanced design from an article by H. Paul Shuch, N6TX.6 The original article described a 1296-MHz mixet etched on G-10 PC-board material. I developed the 3456-MHz mixer by resizing the line lengths and widths for the new frequency and for a Teflon® -fiberglass substrate. To keep the mixer as efficient as possible and maintain high isolation between ports, I used a matched pair of diodes (D2, D3) in a surface-mount package. (As an alternative, a matched pair of conventional wire-lead Schottky diodes can be used with only a slight reduction in LO-to-RF-port isolation.) Isolation between the mixer's LO and RF ports is greater than 20 dB-about as good as any low-cost commercial mixer. Conversion loss—about 9 dB—is a little higher (worse) than most commercial mixers. Impedance matching was not done at the IF port and did not appear to be necessary with the ICOM IC-202A transceiver I use as an IF rig.

I used three stages of amplification and two filters in the transmit-amplifier chain to reach the final 10-mW-output level. The mixer RF port drives FL3, the first 5-pole band-pass filter. Centered at 3500 MHz, FL3 strips image energy (3168 MHz) from the mixer output and also contributes about 20 dB of rejection at the LO frequency. Rejection at the LO frequency is important. With an LO injection level of +6 dBm and LO-to-RF-port isolation of 20 dB, the level of the LO signal at the RF port of the mixer is -14 dBm. For comparison, the desired

signal (the sum frequency at 3456 MHz) is injected at 0 dBm (1 mW) and encounters a 9-dB loss through the mixer to emerge at -9 dBm, only 5 dB above the oscillator feedthrough.

Following the first filter are two amplifier stages (U3, U4) using an MSA-0185/ 0285 combination. With prototype versions of this transverter, I found that correct MMIC choice for these amplifier stages is critical because band-pass filters (FL3. FL4) are present at the input and output of the amplifier strip. The filters are highly reactive out of band where their return loss is very low (in the range of 0 to 3 dB), so the MMICs used in conjunction with the filters must be unconditionally stable. Another consideration is that the microstrip filters were developed with good 50-ohm terminations on each end. The SWR at the input and output ports of the MMIC should be close to 50 ohms within the passband of the filters to maintain flat filter response and low insertion loss. An examination of the S-parameter data for the MSA-0185 and '0285 shows that they are excellent choices for this application.

FL4 was added in later prototypes to reduce mixing products above 3456 MHz that were present in the output. This filter, a modified version of the filters used in the LO multiplier chain, is centered at 3312 MHz. The combination of FL3 centered at 3500 MHz and FL4 centered at 3312 MHz creates a narrow window at 3456 MHz where the two response curves overlap, giving the effect of a much narrower filter. A single narrow-band, higher-Q filter could be used to accomplish this, but the stop-band rejection for one filter would be inferior to that of two filters. Technical references indicate that

the stop-band rejection of a single microstrip filter is only about 40 dB because of surface-wave effects; two separate filters can achieve a total stop-band attenuation of 80 dB. FL3 and FL4 in tandem do a good job of cleaning up the output spectrum.

The final transmit amplifier is an Avantek MSA-0885, chosen for its gain and +10-dBm power-output capability at 3456 MHz. One disadvantage of the '0885 is that it is only conditionally stable: It can oscillate if supply line decoupling is inadequate or if it is terminated in highly reactive loads. U5 should be stable as long as the transmitter-output port is terminated in an impedance close to 50 ohms. If, however, the transverter is used "barefoot" in conjunction with an external antenna relay, I recommend that the dc power to the transmit amplifier section be removed during receive periods so the absence of an antenna load does not cause U5 to oscillate. My prototype units were stable without an output termination, but variations from device to device may cause U5 to oscillate in some transverters. Result: lots of noise in your receiver, making it impossible to hear weak signals!

# Receive Mixer and Preamplifiers

The receive mixer (Fig 4) is identical to the transmit mixer. It is preceded by a 5-pole image-stripping filter, FL5, which is necessary to keep the noise energy at the image frequency from being converted to the IF and degrading receiver sensitivity. In a receive application, 20 to 25 dB of image rejection is all that is necessary to ensure that this does not happen. A 5-pole microstrip filter easily provides this much rejection at the 3168-MHz image frequency.

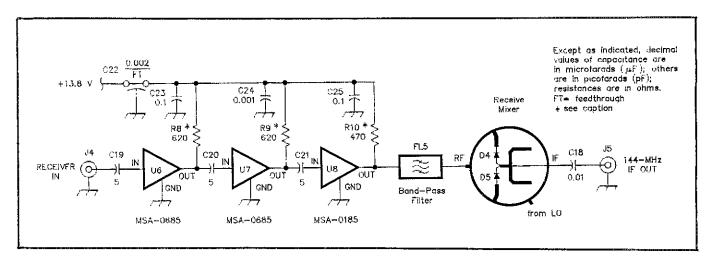


Fig 4—Schematic of the 3456-MHz transverter receive mixer/amplifier.

C18-0.01-µF disc-ceramic capacitor C19-C21-5-pF porcelain chip capacitor. C22-0.002-µF feedthrough capacitor. C23, C25-0.1-µF ceramic chip (preferred)

or disc-ceramic capacitor. C24-0.001-uF ceramic chip (preferred) or disc ceramic capacitor.

D4, D5—Hewlett-Packard HSMS-2822 surface-mount diode pair or matched pair of HP 5082-2835 Schottky diodes. See

FL5—Band-pass filter printed on PC board. -Female chassis-mount connector builder's choice.

J5—Female chassis-mount SMA connector. R8, R9 —620-Ω, ¼-W carbon-film resistor. Note: This value is for 13.8-V operation. See text for information on operation at

other voltages.

R10-470-Ω, ¼-W carbon-film resistor. Note: This value is for 13.8-V operation. See text for information on operation at other voltages.

U8-Avantek MSA-0685 or Mini-Circuits MAR-1 MMIC.

U6, U7-Avantek MSA-0185 or Mini-Circuits MAR-6 MMIC.

The receiver-preamplifier stages were chosen to have good SWR and low noise figure. Preceding FL5 is an MSA-0185 (U8) that terminates the filter well and has a noise figure of approximately 6.5 dB at 3456 MHz. The front end consists of two MSA-0685 stages (U6, U7). The overall receiver noise figure is about 4.4 dB. An outboard preamplifier can be added to make a state-of-the-art setup. Performance of the transverter is summarized in Table 1.

# Construction Hints

The transverter is constructed on 0.031-inch-thick Teflon-glass substrate with a dielectric constant of 2.50. The board is double clad with 1/2-ounce copper. I get my board material from Taconics Plastics, Ltd, Petersburg, NY 12138, part number TLX-9-0310-R5/R5. A word of caution: The filters require that dimensional tolerances of ±0.001 inch or better be maintained in the fabrication of the board. This is the price you must pay for microwave filters that require no adjustments. Because of the critical tolerances necessary and the many variables involved in the QST printing process, an etching pattern is not included in this article. If you are interested in making your own board, send me an SASE for a dimensioned copy of the art-

work. Or, if you wish, you can purchase an etched board from me.7

Construction is as simple as populating the board with the components and mounting the connectors. A parts layout guide is shown in Fig 5. Lead dress can be seen in the photograph of the completed transverter (Fig 6). All of the parts needed to complete the project are available from amateur suppliers, and kits are available as well.8

Be sure to use high-quality porcelain chip

# Table 1 3456-MHz Transverter Performance

3456-3460 MHz Frequency range IF range 144-148 MHz Local oscillator + 16 dBm (40 mW) at 552 MHz required 13.8 V dc at 250 mA Power required

Transmitter

>10 mW (+10 dBm) Output power >30 dBSpurious rejection IF drive level 5 dBm to 0 dBm

Noise figure < 4.5 dB >25 dBImage rejection Net gain 15 dB

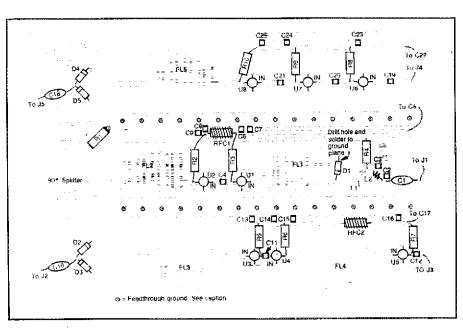


Fig 5—Parts-placement guide for the 3456-MHz transverter (not shown actual size). All components mount on the etched side of the board. Feedthrough grounds, indicated by circles, must be installed and soldered top and bottom; see text. See Fig 7 for mounting details for U1-U8.

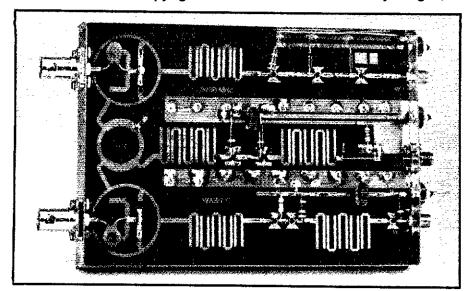


Fig 6—Photograph of a finished 3456-MHz transverter. This unit was built by Zack Lau, KH6CP, in the ARRL lab.

capacitors for coupling between stages. The remaining capacitors can be less expensive ceramic chips or disc ceramics. I used chip capacitors everywhere I could because they make for a neater layout and cost about the same as the equivalent disc-ceramic capacitors

Mini-Circuits offers a line of MMICs equivalent to the specified Avantek parts. The corresponding part numbers are easy to determine. The Mini-Circuits MAR-8 is equivalent to the MSA-0885, the MAR-6 to the MSA-0685, and so on.

I strongly recommend that you enclose the board in a brass box to support the connectors and provide ground continuity to the top side of the board. I used strips of 0.032-inch-thick, ¾-inch-wide brass available at most hobby stores. The entire perimeter of the inside walls is soldered to the top and bottom of the board. This provides a ground connection to the component side in several places, as well as a ground for the input and output connectors.

The board material is soft and bends easily. It is quite tolerant of heat and rework if you misplace a part. I use a 27-watt pencil soldering iron with good results.

Through-the-board wires are required to tie components to ground, as shown on the parts layout. Tiny brass rivets can be used if you have them available, but I used no. 18 bus wire with good results. The ground leads of the MMICs are grounded to a small piece of copper foil under each lead. The foil is wrapped through a clearance hole under each MMIC lead and soldered to the ground plane below (see Fig 7). The cold end of the 50-ohm chip resistor (R1) on the LO power divider should be grounded in a similar fashion.

Keep the bias resistors and chokes close to the board so they don't act as antennas.

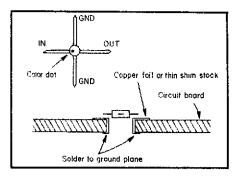


Fig 7-Mounting details for the MMICs.

During testing of the prototypes, I noticed that there is some radiation of RF energy from the surface of the board. This is not a problem unless LO energy gets into the transmitter circuits and shows up in the output. Without any shields at all, the LO is more than 30 dB below the carrier, Best results were obtained when a single cover was placed over the entire open side of the box. Surface-wave energy is reduced when the cover is in place, and the resulting ½-inch height of the cover above the board causes a "waveguide-below-cutoff" effect for the propagation of energy from one part of the circuit to another. The spectrum analyzer display of the transmitter output. shown in Fig 8, was obtained with the cover in place.

In the parts list, I have shown biasresistor values for 13.8-V operation. If only 12-V operation is planned, the bias resistor values should be changed to maintain the correct operating current through each MMIC. Be sure to check resistor dissipation and use ½-W resistors as necessary. The bias current for each MMIC is as follows: MSA-0185, 17 mA; MSA-0285, 25 mA; MSA-0685, 15 mA; MSA-0885, 32 to 35 mA. On one portable expedition, I

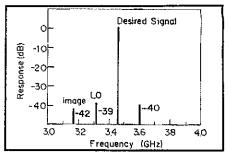


Fig 8—Output spectrum of the 3456-MHz transverter transmitter section.

noticed that the receiver began oscillating after the transverter had been on for a while. I later found that the dry-cell battery had dropped more than 2 V, causing a corresponding drop in the bias current in each MMIC. When operated at lower than rated current, the MMICs are not unconditionally stable. If battery operation is planned, it is a good idea to regulate the power source to the transverter at 10 V or so and adjust the bias resistors accordingly.

For best performance, the mixer diodes should be a matched pair in a microstrip or surface-mount package. The recommended surface-mount pair is the Hewlett Packard HSMS-2822. This part is available from Microwave Components of Michigan (see note 8). I tried wire-lead Schottky diodes like the HP 5082-2835, but the LO rejection was greatly reduced because of imbalance. Although a matched pair of '2835s should work well, I did not have any matched units to test. If you have some microwave mixer diodes you want to try, go ahead and do it-just make sure the diodes are connected cathode to anode, as shown in Figs 3 and 4. The LO rejection can be measured with a power meter at the transmitter-output port by noting the difference between full carrier output and the residual oscillator level.

## Accessories

You will need a few outboard accessories to complete your 3456-MHz station. First, a means of reducing the transmitter output power of your IF rig to 1 mW is required. A recent circuit published in *QEX* not only takes care of attenuating the transmitter, but also provides protected TR switching of the IF line.<sup>9</sup>

On the other end of the transverter, some sort of RF antenna relay is needed. Meeting this requirement may be a little more difficult, because good relays for this band are scarce. I have been fortunate enough to find small SMA-type relays at hamfests in the past, but larger relays with N connectors will probably work. Don't overlook relays equipped with TNC connectors. They are often good to well beyond 3456 MHz. You can take care of any connector mismatch in the jumper cables to the transverter. If you are unsure about

the suitability of a relay for this frequency. ask a knowledgeable friend for advice. Remember, just because a relay has good microwave-quality connectors doesn't mean it will provide low loss and operate at an acceptable SWR at 3456 MHz.

If you can find one used, a circulator makes a neat TR switch. Isolation between the transmitter and receiver ports won't be as good with a circulator as with most relays, but at least you won't need the dc source necessary to operate a relay. If you can't find a circulator, you can use an isolator. I have converted many isolators to circulators by removing the isolator load resistor and installing a coaxial connector in its place.

Several types of antennas are popular at 3456 MHz. The most common 3456-MHz antenna is a small dish in the 2- to 4-footdiameter range. A recent article in QEX shows how to build efficient feed systems for the 3.4, 5.7 and 10.3-GHz bands. 10 For respectable performance without the wind load of a dish, you can now buy loop Yagis for 3456 MHz.11

Feed-line losses are severe at 3456 MHz. For home-station installations, and even for portable operations, a good Hardline, such as Andrew Heliax®, is mandatory. Also, don't overlook the G-line.12 I have used a G-line for a couple of years now, with very good results.

Station performance can be greatly improved with the addition of an outboard receive preamplifier and transmit power amplifier. A state-of-the-art receiving preamp that makes an excellent front end for this no-tune transverter was described in OST.13 Preamps of this design have been duplicated by many amateurs; they deliver good performance without requiring tweaking on a noise-figure meter.

Several options are available for the transmitter. Some amateurs have found surplus traveling-wave tubes (TWTs) to be a great way of generating lots of power on this band. TWTs typically require only a milliwatt or so of drive for full output, so you will have to attenuate the output of the transverter by about 10 dB. I prefer solidstate, however. A receiving-type GaAsFET like the Avantek ATF-10135 can yield up to + 17 dBm quite easily at low cost. Don Hilliard, WØPW, published several good ideas on how to bridge the gap between 10 mW and 1 W.14 Don shows how, for about \$30, you can break the 100-mW level with an Avantek AT-8110 FET. I have built his circuit using a similar device (an Avantek AT-8250) with good results.

## Summary

What can you expect to work on the 3456-MHz band? A recent article in OST discussed the various modes of propagation at 2304 MHz.15 Everything said about propagation there applies just as well to 3456 MHz. Free-space path loss will be a little higher on 3456 MHz (about 3.4 dB higher for a 100-mile path), and foliage losses will likely be greater. Stations using aperture antennas (dishes) have the advantage of increased antenna gains, however. For example, a 4-foot dish has 3 dB more gain at 3456 MHz than at 2304 MHz. The bottom line is that workable distances on 3456 MHz are on par with those on 2304 MHz. All it takes to prove this is a little more activity!

#### Notes

<sup>1</sup>A. Ward, "Monolithic Microwave Integrated Circuits," Part 1: QST, Feb 1987, pp 23-29, 32; Part 2: QST Mar 1987, pp 22-28, 33.

<sup>2</sup>J. Davey, "Microstrip Bandpass Filters,"

Proceedings of Microwave Update '87 (ARRL, 1987), pp 42-53. This book is available from ARRL for \$10 (plus \$2.50 postage and handling, or \$3.50 for insured parcel post or UPS) or from your local dealer.

O Davey, "Microwave Filter Update,"

³Ĵ. Davey, Proceedings of Microwave Update '88, pp 1-8.
This book is available from ARRL for \$12 (plus \$2.50 postage and handling, or \$3.50 for insured parcel post or UPS) or from your local dealer.

4R. Campbell, "A Clean Microwave Local Oscillator," 1296/2304-MHz Conference Oscillator," Proceedings, Estes Park, CO, Sep. 1985.

5An article describing a companion 552-MHz local oscillator will be featured in an upcoming issue of QST. Complete parts kits for a suitable local oscillator, as well as assembled units, are available from Down East Microwave, Box 2310,

RR 1, Troy, ME 04987, tel 207-948-3741. 6H. Shuch, "Rat-Race Balanced Mixer for 1296 MHz," ham radio, Jul 1977, pp 33-39. Etched boards for this project are available from the author for \$40 each. Foreign orders should

include \$5 for additional shipping.

<sup>8</sup>Most of the small parts for this project are available from Microwave Components of Michigan, PO Box 1697, Taylor, MI 48180, tel 313-753-4581. Complete parts kits and assembled units are available from Down East

Microwave (see note 5).

9Z. Lau, "A VHF/UHF/Microwave Transverter IF Switch," QEX, Aug 1988, pp 3-4.

10D. Hilliard, "Antenna Ideas For 3.5, 5.8, and 10.4 GHz," QEX, Jan 1988, pp 3-5.

11Loop Yagis are available from Down East Microwave Constant 5.

wave (see note 5).

12R. Dryden, "G Lines for 1296, 2304 and Above," Proceedings of Microwave Update '87, pp 54-62.

See note 2.

13A. Ward, "Simple Low-Noise Microwave Preamplifiers," QS7, May 1989, pp 31-36, 75.

14D. Hilliard, "2 GHz to 6 GHz Power Amplifiers,"

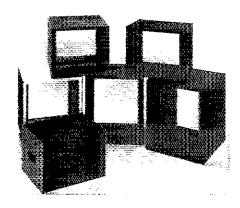
Proceedings of Microwave Update '87, pp 8-92. See note 2.

<sup>15</sup>E. Pocock, "Getting From Here to There on 2304 MHz," QST, November 1988, pp 15-16. "Getting From Here to There on

# **New Products**

#### PFT DESK-RACK CABINETS

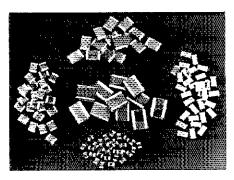
☐ Precision Fabrication Technologies, Inc, has introduced the Mod-U-Desk line of desk-rack enclosures. Mod-U-Desk



cabinets meet EIA standards for 19-inch rack cabinets and cover a size range from 12 to 22 inches (height) and 17 to 23 inches (depth). Adjustable mounting rails allow for flexibility. Suggested retail pricing from \$245. For more information, contact PFT at State Road 16 W, Monon, IN 47959, tel 800-558-7297 (outside Indiana), or 219-253-6666.—Rus Healy, NJ2L

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