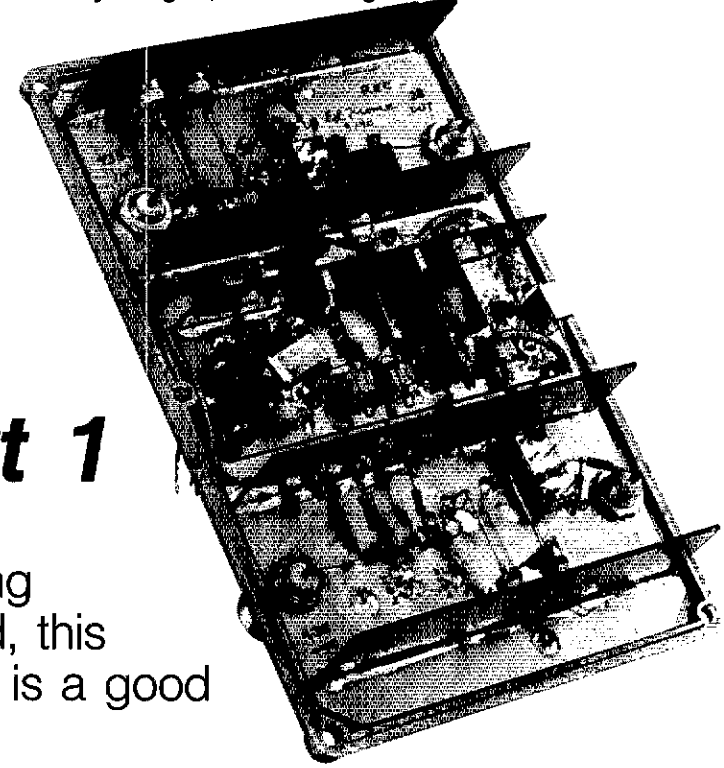
A High-Performance, Easy-to-Build 432-MHz Transverter—*Part 1*



If you've been thinking of making the move up to the 70-cm band, this inexpensive construction project is a good way to do so!

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432 MHz (70 cm) is a truly interesting band. For the operator, it provides all manner of ham activity, from local FM to OSCAR and EME (earth-moon-earth, or moonbounce). On satellites, modes B, J, L and S—four of the five modes available on current birds—use 70 cm. For SSB and CW fans, several-hundred-mile terrestrial paths are routine, and periodic propagation enhancements produce amazing results. And for the *really*-weak-signal guys, many stations are active on EME, some strong enough to contact using only a single Yagi antenna! In fact, I've used the transverter I'll describe in this article to make EME contacts with a medium-power amplifier and two 19-element Yagis.

For the builder, 70 cm is a band where both lumped and distributed circuit elements are usable and physically manageable. Antennas are small, allowing high gain in a compact package, yet large enough to not require the construction precision needed for higher-frequency antennas.

In many areas, 432 suffers from a lack of regular use. This is part of a vicious circle in which the cost of equipment makes the band sparsely populated, which in turn causes people not to buy equipment, which *keeps* the band underpopulated, and so on. The best way to break this cycle is to add low-cost converters to HF rigs. *Transverters,* which combine receive and transmit converters in a single package, are available for 432 MHz in assembled form from manufacturers such as Microwave Modules and SSB Electronics, and in kit form from Hamtronics. In this two-part article, I'll present a good, easily reproducible 70-cm transverter made from commonly available parts. I'll also make interfacing and switching suggestions.

Ah, building UHF equipment! Some usually rational hams recoil in horror at the thought of it. Complicated construction techniques are bad enough, but alignment can be akin to black magic—especially if you don't have a local technical guru, right?

Wrong.

Although home-brewing UHF gear was once formidable, advances in component technology have nearly eliminated the hassle. Back when we had only discrete tubes and transistors, just making a simple RF amplifier could be daunting. And mixers were simply a nightmare. Tweak, poke and pray. But, technology has come to the rescue, and new components have appeared on the scene that make home-brewing 432 gear easier than ever—almost foolproof, in fact.

The most significant of these technological innovations is the MMIC (monolithic microwave integrated circuit). These incredible devices are complete, inexpensive, 50-ohm linear gain blocks, some with dc-to-gigahertz frequency ranges. They're typically unconditionally stable, meaning you can terminate the input or output with any load impedance without causing oscillation or device destruction. A bias resistor and, in some cases, an RF choke, are all the external components MMIC amplifiers require. No more tweaking to get an amplifier running! Need more gain at a certain stage? Add another MMIC. And MMICs cost only a few bucks each.[1]

The second foolproofer is the prepackaged double-balanced mixer, or DBM. These are broadband, passive, diode-ring mixers that offer excellent intermodulation performance and LO suppression. Passive mixers were once held in disfavor because their conversion loss required extra stages of external amplification, but with MMICs, those gain stages are now easy to implement. Passive diode-ring mixers start at around $5 each; the transverter uses two of them, as explained later.

The third "make-life-easier" device is the "brick," or hybrid RF-amplifier module. These replace the entire power-amplifier chain in a transmitter. They have lots of gain (a few milliwatts of input typically give many watts of output), require no tuning, and are available in linear and class-C versions for many bands. They're not cheap (by comparison to discrete transistors), but they're worth every penny.

A question you may have: "Doesn't all this fancy stuff cost more than discrete components?" In dollars, probably. But I've been playing this game for a while, and I have a box full of cheap stuff that doesn't work. That makes the more costly stuff that *does* work seem a lot less expensive!

All these devices lend themselves well to transverter design. The transverter detailed here incorporates the following design philosophy: It's easy to build and tune, requires no special circuit boards or other parts, and offers good performance. It's designed to be built dead-bug style on pieces of double-sided, unetched printed-circuit

[1]Notes appear on page 23.

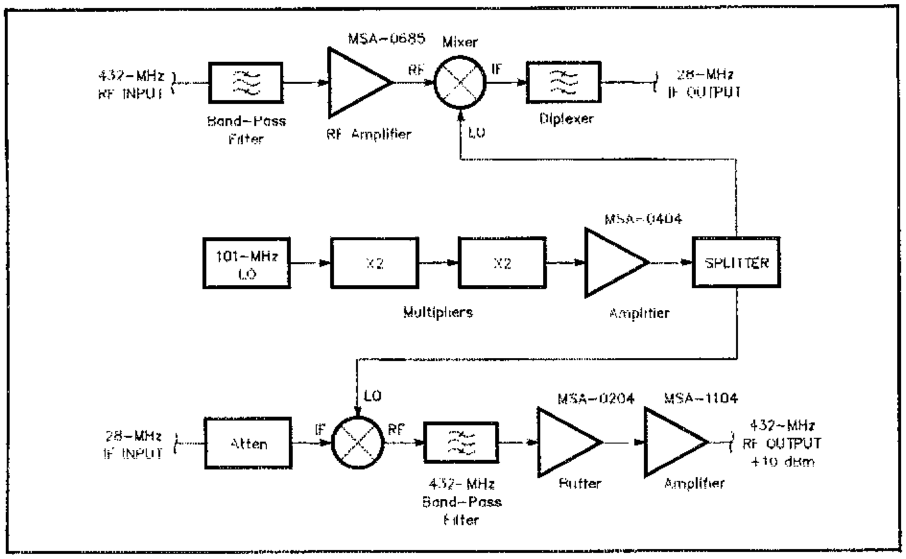


Fig 1—Block diagram of the 432-MHz transverter.

board. I built mine into the lid of a Bud CU-124-B cast-aluminum enclosure. You need only a diode RF probe[2] and a DMM for alignment, and the finished product works well enough to be part of a moonbounce station. Local-oscillator (LO) crystal selection determines the band segment (terrestrial, satellite or FM) on which you can use the transverter.[3]

Design

The block diagram (Fig 1) shows the function of each of the transverter's three stages: the local oscillator, transmit converter and receive converter. The LO uses a crystal in the 101-MHz range, followed by two frequency doublers and an MMIC amplifier. The MMIC is driven hard (but within its ratings) and maintains a constant output-power level over a wide range of input levels. This compensates for constructional variations and ensures that enough LO drive is available for the mixers. The divider provides 7 dBm (5 mW) at each output, which is the proper drive level for the Mini-Circuits (MCL) SBL-1X mixers.

Receive Converter

The receive section of the transverter looks almost too simple to work, but offers surprisingly good performance and is quite rugged. A band-pass filter and single stage of amplification (a low-noise MMIC) feed the receive mixer, which is followed by a diplexer filter. The diplexer properly terminates the mixer; it passes the desired IF (28 MHz) and dissipates other mixing products in a 50-ohm load.[4] By itself, the receive converter has approximately a 3-dB noise figure and 10 dB of conversion gain. This performance level is suitable for local use, but an external preamplifier is necessary for weak-signal work. The preamplifier determines the characteristics of the receiving system and should be mounted at the antenna for best performance. Many designs are suitable; see any recent ARRL *Handbook* for construction details.[5] A single-JFET design is suitable for local FM use, but low-noise, high-gain GaAsFETs are necessary for satellite and weak-signal work.

The simple filter used in this transverter does not offer exceptional unwanted-signal rejection, but it's adequate in most parts of the US. If you need better filtering, review the band-pass filter designs shown in the *Handbook*.

Transmit Converter

The transmit section is also straightforward. A low-level signal in the 10-meter band is fed to another mixer, where it combines with the LO signal. A filter selects the desired mixing product, then two stages of MMIC amplification raise the 70-cm signal to 8 to 10 dBm (6 to 10 mW). After the transverter, a band-pass filter described in part 2 suppresses the LO and image signals that get through the simple output filter. An RF-sealed (completely shielded) LO chain also contributes to good LO suppression, as discussed later.

An external amplifier, consisting of a bipolar transistor driving a brick, raises the transverter output to 10 watts. This output level is fine for most local communication and for driving a solid-state power amplifier. Following the amplifier with a pair of 4CX250s[6] or a 3CX800A7-based power amplifier will give you what it takes to make moonbounce contacts and enjoy other very-weak-signal work.

This transverter requires external transmit/receive (TR) switching. I prefer to run separate transmit and receive feed lines to the antenna, where the TR relay is mounted near the feed point. The receive preamplifier is connected directly to the TR relay's normally open contact, and an RG-213 feed line runs from the preamp output to the transverter. In my installation, the relay must be energized during receiving. This ensures that the preamp is disconnected from the antenna (and protected from static) when not in use.

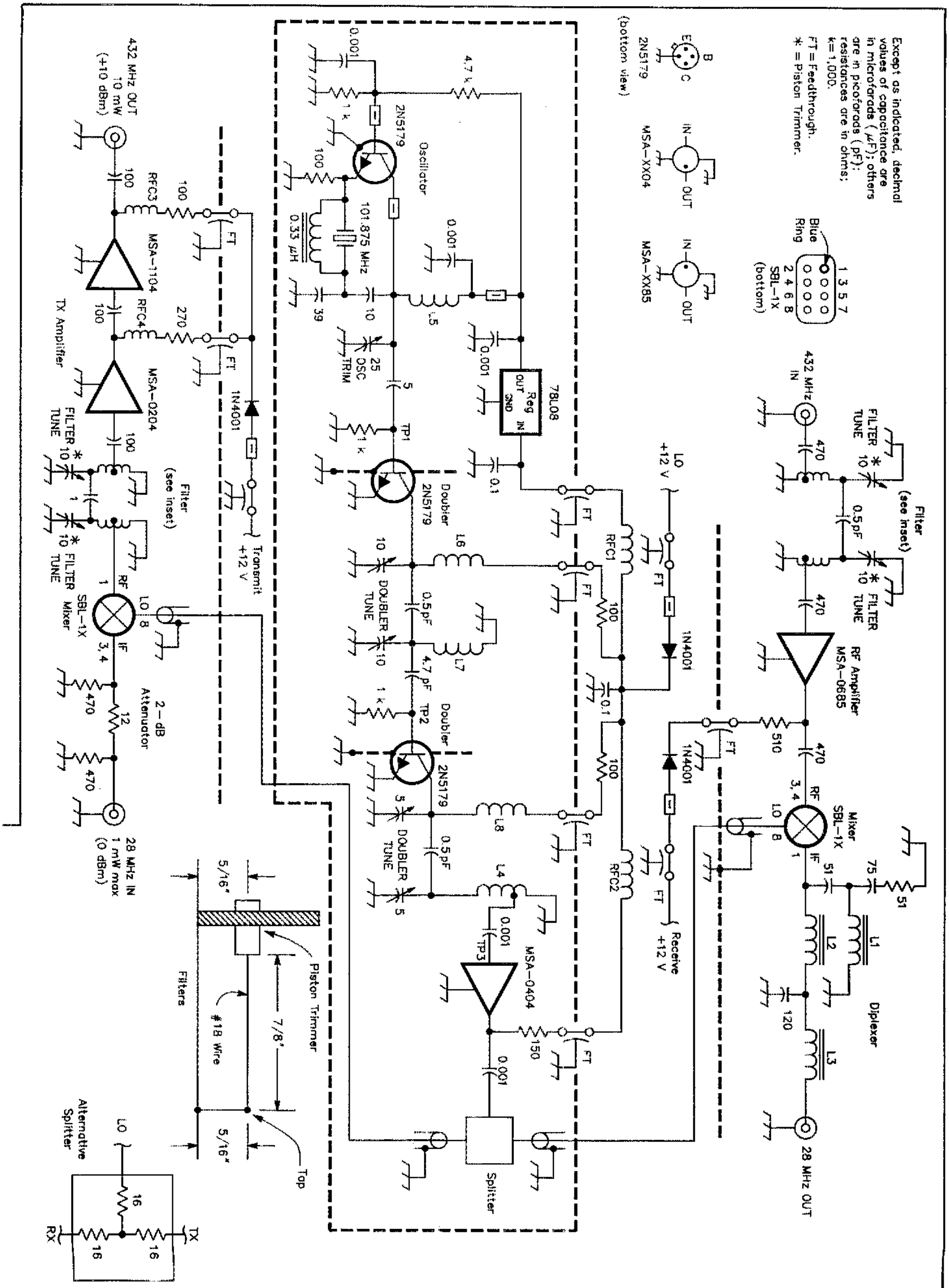
The transmit (normally closed) relay contact should be connected to the rig via a low-loss cable, such as Belden 9913 or Hardline. Although two feed lines may seem an overly expensive approach, it has real advantages.[7] Were a single feed line used, two relays would be required to switch the preamp in and out of the signal path. And decent relays usable at 70 cm are usually more expensive than good feed lines. Also, separate feed lines eliminate the possibility of transmitting into your preamp —an expensive and embarrassing exercise that otherwise, eventually, will happen.

Construction and Alignment

The transverter circuit is shown in Fig 2. Physical layout (see Fig 3) should follow the schematic. See the sidebar, "Sources of Parts," for tips on obtaining the components used. Each section (LO, transmit converter and receive converter) can be built separately on pieces of double-sided circuit board, then mounted in either common or separate enclosures. The LO should be enclosed in a completely shielded box for maximum suppression of unwanted LO radiation; the shield has been removed for the photos. The MMIC amplifiers require a bias resistor and, in most cases, an RF choke in series with the bias resistor. You can wind the RF chokes from small (#24) enameled wire, or, as I did, from a section of the resistor lead, as shown in the photos. Although these chokes should have at least six turns for optimum performance, I've had no problems with MMIC stability. If

Fig 2—Schematic of the 432-MHz transverter. The LO is inside a box made of PC-board material and hobby brass, and the converter stages are bordered by PC-board shields. All MMIC-biasing resistors are ½-watt carbon-composition units; others are ¼-watt units. All feedthrough capacitors are 0.001-µF units; all other nonvariable capacitors are miniature ceramic discs.

L1—5 turns #24 enameled wire on a T-25-6 toroid.
L2—10 turns #24 enameled wire on a T-25-6 toroid.
L3—6 turns #24 enameled wire on a T-25-6 toroid.
L4—3½ turns #20 wire, 0.11 in. ID, ¼ in. long, tapped 1 turn from grounded end.
L5—8 turns #24 enameled wire, 0.11 in. ID, closewound.
L6, L7—7 turns #20 wire, 0.11 in. ID, 3/8 in. long.
L8—3½ turns #20 wire, 0.11 in. ID, ¼ in. long.
RFC1, RFC2—10 turns #24 enameled wire, 0.11 in. ID, closewound.
RFC3, RFC4—2 turns #24 wire (resistor lead), space wound.


Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k = 1,000.
FT = Feedthrough.
* = Piston Trimmer.
2N5179 (bottom view)
MSA-XX04
MSA-XX85
Blue Ring
SBL-1X (bottom)
Oscillator
101.875 MHz
Doubler
2N5179
78L08
TX Amplifier
MSA-1104
MSA-0204
RF Amplifier
MSA-0685
MSA-0404
SBL-1X Mixer
2-dB Attenuator
Diplexer
Splitter
Alternative Splitter
432 MHz OUT 10 mW (+10 dBm)
432 MHz IN
28 MHz IN 1 mW max (0 dBm)
28 MHz OUT
LO +12 V
Transmit +12 V
Receive +12 V
Filter (see inset)
Filters
Piston Trimmer
#18 Wire
Top

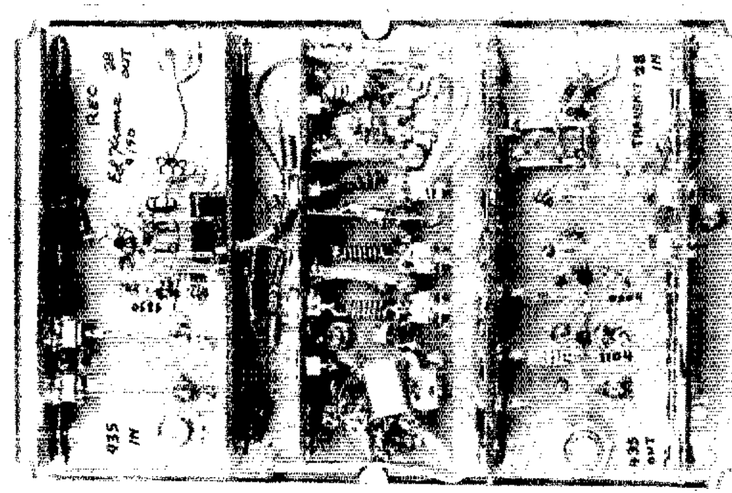


Fig 3—An inside view of the prototype 432-MHz transverter, built into a Bud CU-247-B cast-aluminum box (Hammond's 1590D is equivalent). The receive converter is at the left; the local oscillator, doublers and LO power divider are in the center; and the transmit converter is at the right. Note the brass shield around the receive-mixer LO input. The LO should also be completely shielded.

you encounter signs of oscillation (excessive current drain, output with no drive applied, or a nonlinear output-to-input-power relationship), add turns to the RF chokes.

Local Oscillator

The crystal-oscillator design was popularized by Joe Reisert, W1JR.[8] In my experience, this design is most likely to work right the first time you fire it up, which is the major objective in this kind of project. A series-resonant, fifth-overtone crystal is used. I use a 101.875-MHz crystal, since it produces an LO frequency of 407.5 MHz. My converter is used with an HF transceiver that tunes below 28 MHz, but not above 30 MHz. With this LO I can work both satellites and terrestrial modes with a single LO crystal. 432.1 MHz tunes to 24.6 MHz, and the high end of LUSAT's 25-kHz-wide passband, 437.15 MHz, converts to 29.65 MHz. Details of crystal-frequency selection and IF interfacing are covered in Part 2.

Build the crystal oscillator first, including the 1-kΩ resistor at TP1 (use Figs 2 and 3 as guides). Attach an RF probe to TP1, apply 12 V dc to the LO and slowly tune the LO trimmer, **OSC TRIM**, for maximum output. The oscillator will start suddenly, and its output will drop off more slowly on one side of peak than the other. Tune slightly off peak to the slowly changing side. This ensures reliable LO starting. Cycle the power a few times to make sure that the LO always starts when powered up. This design operates the crystal in a high-Q mode, and I've never seen one oscillate at any frequency other than that marked on the crystal.

After the oscillator is working, add the doubler stages and terminate the second one with a 50-Ω resistor at TP3. The construction technique shown works well. Film trimmers (10 mm diameter) are mounted horizontally with their two ground legs soldered to inverted **U**-shaped brackets made from 0.01-inch-thick brass strip, 1/8 inch wide and high enough off the board (about 1/8 inch) to support the trimmers. Space all tank-circuit inductors 1/2 inch apart and shield them from each other with brass sheet, as shown in Fig 3.

Doublers

Although many frequency-multiplication schemes are possible, I've found the class-C doublers used here (which multiply frequency by means of their inherent nonlinearity) to be the easiest to get working. This circuit uses simple class-C frequency multipliers that have the advantage of drawing no current when the stage isn't conducting. (Class-A devices like MMICs draw the same amount of current all the time, whether they are amplifying signals or just dissipating heat.) With class-C multipliers, the absence of multiplier current drain provides a useful tune-up check.

The doublers each use double-tuned tank circuits that are designed to be unable to tune to the doubler's input frequency. Tuning an individual stage is simply a matter of attaching the RF probe to the output of each tank circuit, starting with the first doubler (at TP2) and tuning each trimmer for the first peak output reading from the fully meshed (maximum capacitance) position. Remember that the first peak is the one you want; frequency multipliers create lots of other higher harmonics, too. When both doublers are functioning properly, add the MMIC buffer stage and LO divider. Keep a milliammeter in the dc line during tune up, and watch the current to be sure that nothing draws an inordinate amount.

Be sure to include all the feedthrough and bypass capacitors and RF chokes shown in the schematic to keep the circuit stable. Place shields wherever frequency changes occur and where you want to suppress unwanted signals. See the photos for shielding guidance.

The LO is fed into a Mini-Circuits power divider, which I used because I had one on hand.[9] An alternative resistive splitter that works just as well is shown in an inset in Fig 2.

Converter Stages

Constructing and tuning the converter stages is also straightforward. Lay them out as shown in the schematic and photos. The receiver filter requires high-quality piston trimmers, which are also recommended for the transmit filter. I mounted two vertical, parallel pieces of double-sided PC-board material 1-3/4 inches apart and soldered them to the ground plane. The piston trimmers are soldered 1/2 inch apart, 5/16 inch above the ground plane, in two holes drilled in one of the vertical pieces. All other components (including the mixers) are mounted dead-bug style on the ground plane.

Mount the mixers with their LO-input pins close to a vertical wall so that the mixers can be connected to the LO divider via miniature coax routed through small holes in the PC-board shields. You can use MCL's SBL-1 mixers in lieu of the SBL-1X units I used, but note that they have different pin-outs. Keep all leads as short as possible. Use feedthrough capacitors where the dc lines come through shield walls. Make several through-board grounds (one near each mixer, MMIC, tuned circuit, and such) by soldering wires to each side of the circuit board through small holes drilled through the board. Shield each mixer/amplifier section with a **U**-shaped hobby-brass cover tack-soldered around the verti-

Sources of Parts

The following suppliers carry components necessary for building this transverter. Write to them for catalogs.

Down East Microwave, RR1 Box 2310, Troy, ME 04987, telephone 207-948-3741 (MMICs, mixers, S-AU4 and M57745 hybrid amplifier modules, MCL power divider, transistors, other parts).

Microwave Components of Michigan (Norm Alred, WA8EUU), PO Box 1697, Taylor, MI 48180 (MMICs, mixers, piston and film trimmers, transistors, other parts).

RF Parts, 1320-16 Grand Ave, San Marcos, CA 92069 (hybrid amplifier modules, transistors).

Communications Concepts, Inc (CCI), 508 Millstone Dr, Xenia, OH 45385 (RF power amplifier parts and kits, mixers, parts).

cal walls after everything is working properly, as shown in the photos.

As you can see, if you were expecting the worst, constructing a 432-MHz transverter is nothing like you may have imagined. In fact, it's pretty easy. Next month, I'll cover transverter alignment, antenna switching, interfacing the transverter with your HF transceiver, and alternatives for preamplifiers and power amplifiers.

Notes

[1]A. Ward, "Monolithic Microwave Integrated Circuits," Part 1, *QST*, Feb 1987, pp 23-29, 32; Part 2, Mar 1987, pp 22-28, 33.

[2]A suitable RF probe is described in C. Hutchinson and L. Wolfgang, Eds, *The ARRL Handbook for Radio Amateurs*, 1991 edition (Newington: ARRL, 1990), p 25-9. I built my version into a 2-inch-long piece of ¼-inch brass tubing attached to one end of a short piece of RG-58.

[3]It's also possible to switch between several LO crystals to cover different band segments without much extra work. This technique is outlined on page 10-3 of *The ARRL Handbook for Radio Amateurs*, 1991 edition (see note 2).

[4]P. Drexler, "The Diplexer Filter: A Method for Enhancing Double Balanced Mixer Performance," *Proceedings of the 1987 Mid-Atlantic States VHF Conference* (Newington: ARRL, 1987), pp 87-92.

[5]*The ARRL Handbook for Radio Amateurs*, Chapter 32.

[6]R. Knadle, "High-Efficiency Parallel Kilowatt for 432 MHz," Part 1, *QST*, Apr 1972, pp 49-55; Part 2, *QST*, May 1972, pp 59-62, 79.

[7]Dave Mascaro, WA3JUF, explains the reasons for this in his May 1991 *QST* article, "A High-Performance UHF and Microwave System Primer."

[8]J. Reisert, "VHF/UHF Receivers," *Ham Radio*, Mar 1984, pp 42-46.

[9]MCL part LPS-109-4. This power divider is expensive ($18 in single quantities), but the less-costly MCL PSC-2-1 divider ($11) should work just as well in this application. This part, as well as the mixers, MMICs and other parts used in the transverter, are available from Down East Microwave. See the sidebar, "Sources of Parts," for more information.

New Books

RADIO AURORAS

By Charlie Newton, G2FKZ. Published by the Radio Society of Great Britain, Cranborne Rd, Potters Bar, Herts EN6 3JE, England. 1991. Softcover, 7¼ × 9½ inches, 93 pp. Available from the ARRL for $18.

Reviewed by Emil Pocock, W3EP

VHF operators have enjoyed making contacts via auroral scatter for nearly 50 years, but until now, no comprehensive treatment of radio aurora propagation specifically written for radio amateurs has been available. That void has now been filled with Charlie Newton's *Radio Auroras*, a slim volume crammed with technical and practical information. Newton has been involved in aurora research in Europe for more than 30 years, much of that time as a member of the Radio Society of Great Britain's Propagation Studies Committee and as the Aurora Coordinator for the International Amateur Radio Union. He is thus well placed to bring professional research and amateur practices together.

Radio Auroras is divided into an introduction and seven chapters, conveniently broken down by numerous headings and subheadings. Charts, figures and maps, which appear on nearly every page, are clear and easy to interpret. The book's primary strength is that it neatly integrates current aurora theory with radio amateur observations; its weaknesses stem from a dense writing style and disappointingly brief treatments of such things as Doppler effects, bands other than 144 MHz, and auroral-E phenomena. A bibliography of articles in amateur publications, especially to items that could serve as introduction and background, would have been a welcome addition to the short list of technical references at the end of each chapter.

The introduction provides a brief history of the discovery of radio aurora, early professional interests in the phenomenon and theoretical work done through the 1950s. Newton gives Scottish and Scandinavian amateurs credit for making the first aurora contacts during the late 1940s, although as early as May 1939, *QST* reported Americans making aurora contacts on 56 MHz. This isn't a serious oversight, but the European perspective throughout the book may be distracting to American readers. Nevertheless, it should be made clear that radio auroras behave no differently in Europe than in North America at the same geomagnetic latitudes.

Most of the first half of the book provides the technical background necessary for understanding solar activity, the earth's magnetic field and the appearance of aurora. I found some of these explanations a bit difficult to comprehend without careful study, not because they assumed a familiarity with astrophysics or contained complicated mathematics (neither was the case), but because a great deal of information was condensed into a small space. Discussions of the relationships between solar and terrestrial magnetic fields, how and why solar electrons precipitate into the ionospheric E-layer, and the resulting extraordinary ionization we know as the aurora are most enlightening. Consideration of the Harang discontinuity is especially noteworthy, as this phenomenon has been largely overlooked by US VHF enthusiasts and helps explain predictable lulls in radio aurora activity and certain kinds of auroral-E propagation. Other features of radio aurora are given disappointingly little attention: Discussion of Doppler shifting is limited to just one paragraph, yet the Doppler buzz and center-frequency shift are one of the most distinctive features of aurora-scattered VHF signals.

The second half of *Radio Auroras* places emphasis on practical applications of aurora theory and on European amateur experiences on 144 MHz. The field-aligned characteristics of radio aurora scatter, with their implications for station location and long-distance contacts, are considered in Chapter 4. Newton derives the concept of the "boundary fence" as a guide for estimating a station's maximum range via aurora and provides ample considerations of station geography, antenna elevation and relative signal strength over various path configurations. Chapter 5, which promises discussions of auroras on bands other than 2 meters, is the weakest portion of the book. Much of this chapter deals with 50-MHz pre-auroral enhancements to the F layer and the "Thule-type" auroral-E (which is not familiar to US operators), rather than with aurora propagation *per se*. Other types of auroral-E effects are ignored. There is little discussion of radio aurora on other VHF and UHF bands. Perhaps these omissions can be attributed to the short period of time Europeans have had access to 50 MHz, but greater insights into aurora at 432 MHz and higher, where Europeans have long operated, would have added to this chapter.

The final two chapters review years of European operating experiences and analyses of data generated from hundreds of 144-MHz logs. Discussions of 11-year, annual and daily aurora cycles that emerged from data collected during solar cycles 19 and 21 review well-known phenomena. Analyses of the great aurora of March 1989 places this extraordinary event firmly in the context of previous theoretical discussions and provides a nice case study to conclude the book. Europeans seem more interested in the number of contacts reported as an analytical tool to gauge general aurora activity, rather than on the southerly extent of the aurora, time and geography of longest contacts, and relative effects among the various frequency bands, which are more typical for US studies. These different but complimentary approaches make direct comparisons of European and American experiences difficult, but with so much interest in propagation in Europe and North America, cooperative transatlantic studies would make a natural next step in amateur investigations. Certainly *Radio Auroras* has made a significant contribution in this direction.

A High-Performance, Easy-to-Build 432-MHz Transverter—*Part 2*[†]

With this project, getting started on 432 MHz is easy and inexpensive.

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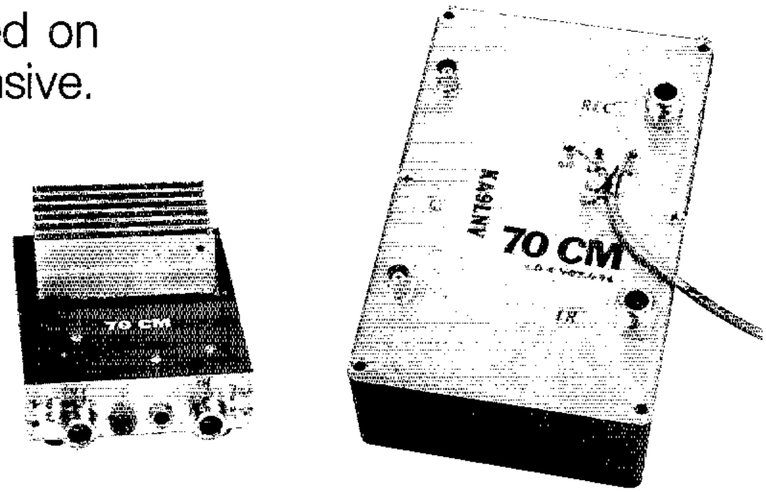


Operating on our 432-MHz band is interesting and rewarding. So is building your own equipment for this band. In Part 1 last month, I described the theory and construction of this simple, inexpensive transverter. In this concluding part, I'll cover transverter alignment, a two-stage, 10-W power amplifier, interfacing the transverter with your other station equipment, and some operating tips.

Switching

Although the transverter's transmit and receive sections can run at the same time, it's good practice to power only the active stage. Power the LO continuously and switch power between the transmit and receive sections as required. You can do this with a small dc relay wired to the transceiver's PTT line. This relay can also provide control for the antenna relay and an external amplifier. If you use separate transmit and receive feed lines, TR sequencing is usually not required. If you run high power on a high-duty-cycle mode (FM or ATV, for example), you should use TR sequencing to ensure that the TR relay has switched and settled before the final amplifier sends its lightning bolt up the feed line. Otherwise you may end up hot-switching the relay, which frequently results in an arc that vaporizes those nice, expensive gold-plated relay contacts. Sequencing is discussed in the *Handbook*.[10]

Transverter Alignment

Before beginning the tune-up phase, see the sidebar "IF Interfacing" for specifics on how to use the transverter with your 24- to 30-MHz IF transceiver. To tune the transmit section, terminate its output with a 50-Ω resistor and attach an RF probe across the resistor. With the LO connected and functioning, apply a 0-dBm (1-mW) 28-MHz signal to the transmit-converter input. The mixer outputs the sum and difference of the IF and LO inputs. Select the desired higher-frequency (sum) mixing product by tuning the band-pass filter trimmers for the first output peak, tuning from the minimum-capacitance (plates fully unmeshed) position. I recommend improving the transverter's transmit filtering to help suppress the unwanted LO and image signals in the transmitted output. The sidebar "A Simple, Low-Power 70-Cm Band-Pass Filter," presents the ARRL Lab's solution. Fig 4 shows the transverter's output spectrum with this filter in line.

Once the transmit-converter filter is tuned, experiment with the IF-drive level while observing the signal level with the RF probe. At low drive levels, the output level

[†]Part 1 appeared in August 1991 *QST*, pages 19-23.
[10]Notes appear on page 21.

IF Interfacing

Most modern transceivers have provision for transverters, typically including a separate receiver input and low-level transmit output, as well as PTT functions. Consult your rig's documentation for specifics. If your transceiver's low-level output is greater than 1 mW (0 dBm), increase the transverter's input attenuation accordingly. See any recent ARRL *Handbook* or *The ARRL Electronics Data Book* for details on 50-Ω attenuators. If you can't determine the rig's output level from the documentation, you can get a ballpark idea of what it is by using an RF probe, although it will not be very accurate.* Terminate the transverter output with a 50-Ω resistor, then connect an RF probe across the resistor and read the dc voltage at normal drive levels. One milliwatt produces 0.224 V RMS across 50 Ω. Whatever the output, determine the attenuation required to get down to 0 dBm, then add 3 dB more input attenuation than you think you'll need. You'll probably need to modify the attenuator to adjust the input level, so your objective here is simply to avoid incinerating anything during the tune-up process.

As an illustration, I use a Kenwood TS-430S HF transceiver with this transverter. Since its transverter-port output level is specified as 5 mW (7 dBm), I expected to need 9 dB of attenuation (7 dB more than the 2 dB built into the transverter's input). In practice, I ended up with a total of 12 dB of attenuation between the units. This provides a solid 10 W out on 70 cm at normal TS-430S drive-control settings. (The lower-than-expected drive requirement results from higher-than-expected gain in the MRF911 driver-amplifier stage.)

Even though the TS-430S can't transmit in normal operation except inside the ham bands, it can drive its transverter port outside the ham bands. This allows me to use a single LO crystal to cover a wide range of frequencies. If your rig will not transmit below 28 MHz, select the crystal frequency based on the following equation:

$$F_x = (F_{dm} - 28) \div 4 \quad \text{(Eq 1)}$$

where F_x is the required crystal frequency and F_{dm} is the low end of the desired frequency range. For example, coverage of 432 to 434 MHz with a 28- to 30-MHz IF requires a 101-MHz crystal.—*KA9LNV*

*J. Grebenkemper, "Calibrating Diode Detectors," *QEX*, Aug 1990, pp 3-8.

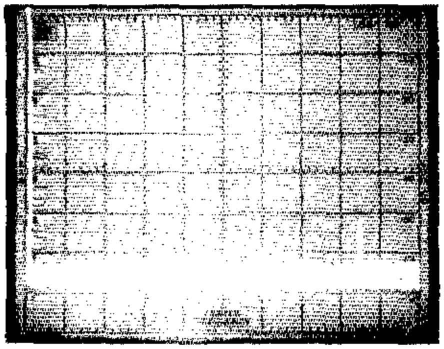


Fig 4—Spectral display of the 432-MHz transverter's output using the filter described in the sidebar "A Simple, Low-Power 70-Cm Band-Pass Filter." Power output is approximately 6.3 W at 432.1 MHz. The fundamental has been notched by 38 dB to prevent spectrum-analyzer overload. Each horizontal division is 100 MHz; vertical divisions are each 10 dB.

will follow the input linearly. Above some input level, you'll see that the output no longer increases. This is called *saturation*; keep the drive level below this point. To avoid unintentional overdrive that can result in a fried transmit mixer, run your IF rig at normal drive levels and adjust the transverter's input attenuator as required to match this level.[11] Never put more than 1 mW (0 dBm) into the transmit mixer.

Substituting an MSA-0104 MMIC (19 dB gain) for the 0204 (12 dB gain) either allows the use of a lower IF-drive level or provides somewhat higher 70-cm output power (up to 13 dBm, or 20 mW). If you use an MSA-0104, change its bias resistor (Fig 2) from 270 to 390 Ω.

Align the receive section by peaking both filter trimmers on a received signal. If you live in an area where strong out-of-band signals overload the transverter's front end, you may want to add a filter like the one described in the sidebar between your preamplifier and the transverter. Keep in mind, though, that those unwanted signals may overload the preamplifier if it's not designed to handle appropriately high signal levels, so post-preamplifier filtering may not solve all overload problems. In such extreme cases, you may need to use a low-loss, high-Q cavity filter *before* the preamplifier to eliminate overload. The loss of such a filter is particularly important, as it adds directly to the system noise figure.

The Power Amplifier

The amplifier shown in Figs 5 and 6 is a two-stage design. The first stage uses an MRF911 bipolar transistor to raise the transverter's 10 mW to 100-200 mW. The output stage is very simple: A Toshiba S-AU4 linear brick takes the MRF911's output to more than 10 W. (A 25-W brick [Mitsubishi M57745] is also available.) I used the S-AU4 because the M57745's

A Simple, Low-Power 70-Cm Band-Pass Filter

This shielded, double-tuned filter, designed by ARRL Lab Engineer Zack Lau, KH6CP, is simple to build and tune, yet effective at minimizing unwanted image and LO signals in your 432-MHz signal. The inductive elements consist of two short pieces of UT-141 (a semirigid coaxial cable available in small quantities at many hamfests and from Down East Microwave and Microwave Components of Michigan*). In conventional double-tuned filters, the inductors are simply parallel, unshielded conductors. Shielding these conductors substantially improves filter performance.

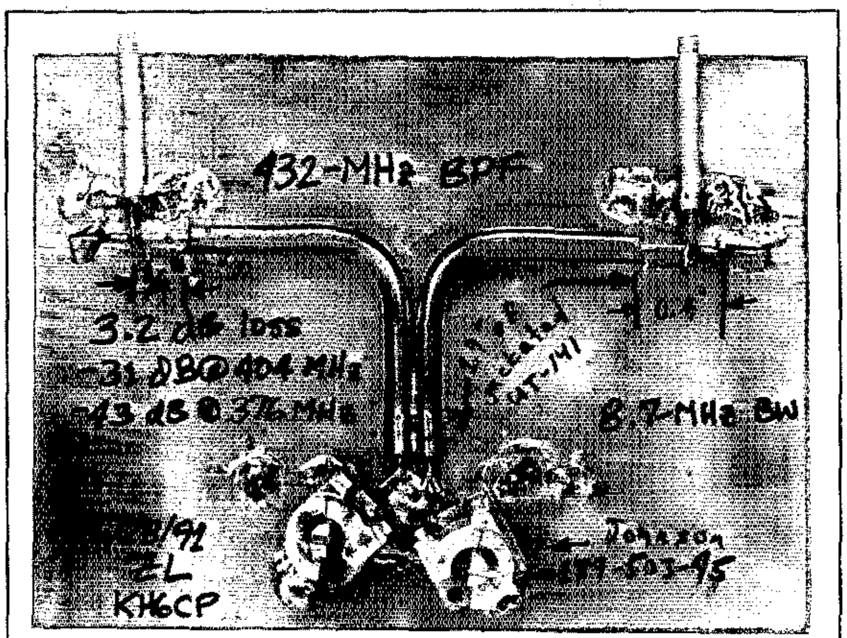
Following the dimensions shown in the photograph, build the filter on a scrap of PC board or a sheet of hobby brass. Strip about 0.6 inch of one end of each piece of UT-141 and bend the center conductors downward at the 0.4-inch points so they can be soldered to the ground plane. Strip about 0.2 inch from the opposite ends of the UT-141 pieces. Bend the UT-141 sections at their halfway points and solder them to the ground plane at each end, as shown in the photo. Then, mount the Johnson 189-503-45 trimmers (available from Microwave Components of Michigan, Mouser Electronics and several other sources) close to the ground plane by soldering their rotor leads to the ground plane. Solder their stators to the UT-141 cables using the shortest possible connections. Once the opposite ends of the UT-141 center conductors are soldered to the PC board, connect the input and output taps (short sections of RG-174 or RG-188 coaxial cable, or similar coax) to the UT-141 at points ¼ inch from the ends of the jackets (0.15 inch from the grounded ends of the center conductors).

The filter is *bilateral*—it makes no difference which lead is the input and which is the output. To tune the filter, preset the capacitors as shown in the photo and place the filter after the transverter's transmit section. Connect a 50-Ω resistor (with very short leads) across the filter's output, key the transverter, and adjust the capacitors for maximum RF output across the load resistor, using an RF probe to monitor the load voltage.

The filter needn't be enclosed in a shielded box, as its inductive elements are inherently shielded, and coupling to and from other parts of the circuit is minimal. You can mount the filter inside or outside the transverter case.

Although not negligible, this filter's 3.2-dB tuned loss poses no problem when placed between the transmit-converter output and the 10-W amplifier, because the amplifier stages have more than enough gain to overcome the filter loss. The filter's benefits are substantial, though: It provides an additional 31 dB of LO suppression, 43 dB of image rejection and a 3-dB bandwidth of 8.7 MHz, making for a clean spectral output from the transverter described in this article, as shown in Fig 4.—*Rus Healy, NJ2L, Assistant Technical Editor*

*See the sidebar in Part 1, "Sources of Parts."



The 432-MHz band-pass filter consists of four parts mounted on a 2½- × 3½-inch unetched PC board.

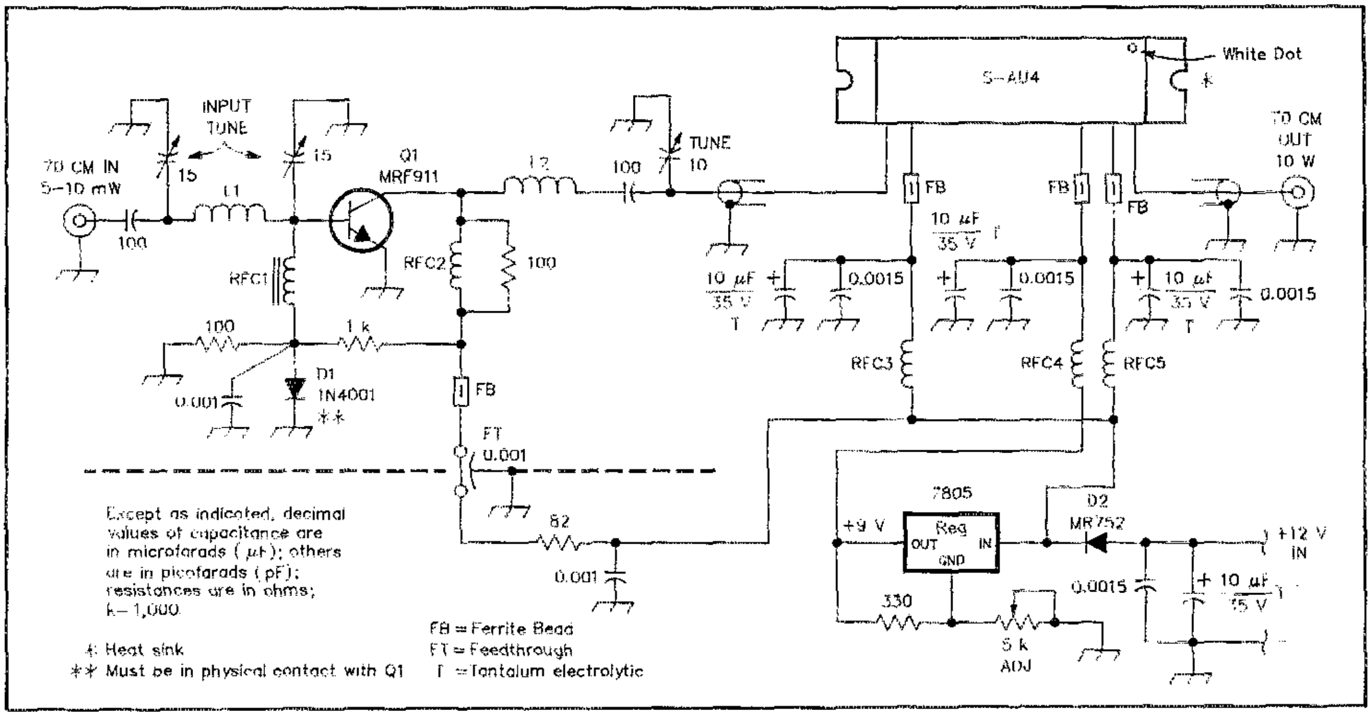


Fig 5—Schematic diagram of the 10-W 432-MHz power amplifier. During adjustment, monitor the currents drawn by Q1 and the S-AU4. Q1's quiescent and maximum currents are 0.012 A and 0.05 A, respectively; those for the S-AU4 are 0.2 A and 2.5 A. Typical operating current for the S-AU4 is about 2 A.

L1—1 turn #18 enameled wire, ¼ inch ID, closewound.
L2—2 turns #18 enameled wire, ¼ inch ID, closewound.
RFC1—1-µH RF molded or toroidal choke.
RFC2—10 turns #22 enameled wire, 0.11 inch ID, closewound on a 100-Ω, ¼-W resistor.
RFC3-RFC5—8 turns #22 enameled wire, 0.2 inch ID, closewound.

Fig 6—Inside view of the 10-W power amplifier. At left is the first amplifier stage; the MRF911 is partially obscured by the thermal-compensation diode. At right is the bias regulator. The S-AU4 hybrid amplifier module is mounted at the top, with its associated bypass capacitors and RF chokes. The input section is built on a scrap of PC board; a PC-board shield isolates it from the dc supply and bias components.

25 W would provide only marginal performance on AO-13 mode B, and the S-AU4's 10 W is a common drive requirement for higher-power commercial amplifiers. You may need more than 10 W to drive a higher-power amplifier (such as one that uses a 3CX800A7). If you use an M57745, follow Mitsubishi's recommendations. The S-AU4's $50 cost may seem high, but this amplifier module is downright cheap compared to the aggravation of getting to that power level with discrete components.

I built the amplifier in two sections. The MRF911 stage is built dead-bug style on a piece of double-sided PC board alongside a vertical PC-board shield to which the dc feedthrough capacitor is mounted. Mica trimmers are mounted vertically with their two ground legs soldered to the ground plane and the hot (stator) leg bent outward from the body. Short leads and a clean physical layout are important. Space the input-network trimmers 5/8 inch on center. Mount the inductors perpendicular to the ground plane, 1/16 inch above it. A 1N4001 diode (D1) in physical contact with the MRF911 provides temperature compensation.

The brick requires a heat sink. The 2 × 3 × 1-inch finned heat sink visible in the title photo is adequate for SSB and CW, but if high-duty-cycle modes are your cup of tea, use a larger heat sink. Bolt the brick directly to the heat sink or to an aluminum chassis with the heat sink on the other side. Use thermally conductive compound between mating surfaces.

Ferrite beads, bypass capacitors and chokes must be as close to the brick as possible. Use Fig 6 as a guide. *Before* connecting the bias supply to the brick, set its output to 9 V dc. I raised the output of a 7805 5-V regulator to 9 V in my amplifier because I had the 7805 on hand and because the bias current is nearly constant, but a 7809, LM2941T, LM317 or other regulator that's intended for 9-V use would serve better here.

Amplifier Adjustment

Tune-up is quite easy. Because the brick is a class-AB linear device and rejects out-of-band signals well, its dc current drain can be used to align the MRF911 stage. Purists may cringe at this trick, but it works and requires no sophisticated test equipment. Terminate the output with a 50-Ω load that can handle at least 10 W continuously. Separately monitor the currents drawn by the MRF911 and the S-AU4. The MRF911 current must vary linearly with drive level; if it does not, the device is saturated or oscillating.

Apply drive and adjust the driver-stage trimmers to obtain maximum current drain (but not over 2.5 A) from the S-AU4. This combination has lots of gain; therefore, it may be necessary to reduce the drive level during tune-up. Don't drive the amplifier into saturation. Be sure that the current drawn by both stages drops to almost nothing when you remove drive. If it doesn't, something in the transmitter chain is oscillating. Check to be sure that you've correctly installed all the ferrite beads and bypass capacitors.

Summary

This 70-cm transverter requires neither fancy circuit boards nor exotic alignment techniques. It's easy and inexpensive to build, reliable and offers good performance. With a suitable preamp, power amplifier and antenna, I use mine daily for terrestrial, satellite and EME communications. (For preamplifier ideas, consult *The ARRL Handbook for Radio Amateurs.*)

Acknowledgment

Thanks to Terri Hurd for using her AutoCad skills to assist me with the original schematics for this project.

Notes

[10]Sequencers and two sequencer projects are described in C. Hutchinson and L. Wolfgang, editors, *The ARRL Handbook for Radio Amateurs*, 1991 edition (Newington: ARRL, 1990), Chapters 23 and 32.

[11]*The ARRL Handbook*, Chapter 25, and page 2-7.

Ed Krome, an Extra Class ham, was first licensed in 1963 as WN9HOC, and later as WA9ONE. He earned a BS degree in mechanical engineering from Rose-Hulman Institute of Technology, and a Masters in Business Administration from Xavier University. He's a Registered Professional Engineer in Indiana.

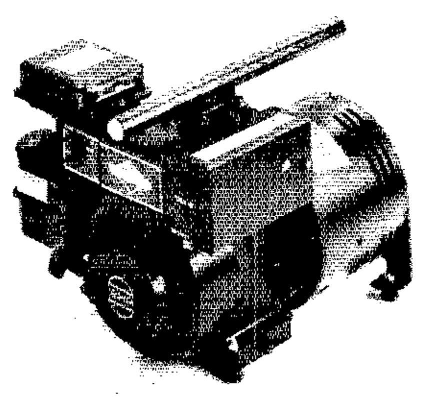
Ed is Manager of Engineering for the Reeves Mechanical Adjustable Speed Drives division of Reliance Electric Company. His ham-radio interests include VHF/UHF equipment construction, weak-signal work and satellite operation. He's built equipment for 2 meters through 10 GHz, and has made 432-MHz moonbounce QSOs using the transverter described in this article driving a 200-W amplifier and two small Yagis (with a two-stage preamplifier mounted at the antenna).

New Products

The ARRL and QST *in no way warrant products described under the New Products banner.*

GENERATOR

☐ The Winco Dyna LC1500 lightweight portable generator uses a 3-hp Briggs & Stratton gasoline engine with solid-state ignition and is rated at 1500 W maximum, 1250 W continuous at 120 V ac, 60 Hz. It weighs 65 pounds and can run up to 2½ hours before refueling. The retail price is $448 from Signal Core Generator, 521 N Fourth St, Telford, PA 18969-2132; tel 215-723-8223.



QSL ORGANIZERS

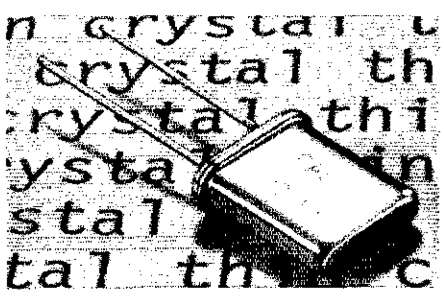
☐ The Azimuth QSL Awards Library is a set of three-ring binders with 20 clear-vinyl slip-in pocketed pages that each hold six 4- × 6-inch QSL cards. Custom albums are available for DX Century Club (DXCC), Worked All Zones (WAZ), Worked All States (WAS) and generic use. Each retails for $19.95 plus $2.50 s/h. A package of 20 additional pages is $12.95. Azimuth Awards Library, 3612 Alta Vista, Santa Rosa, CA 95409; tel 800-882-7388 or 707-577-8007; fax 707-573-1482.

SOFTWARE UPGRADE FOR TEN-TEC PARAGON

☐ The Paragon Software Enhancement Kit is user-installable and provides several new features for Ten-Tec's MF/HF transceiver: band registers, selectable main tuning rate, 10-minute timer and dual offsets with simultaneous TX and RX offsets. The price is $72 plus $3 s/h. Giehl Electronics, PO Box 18335, Cincinnati, OH 45218.

THIN CRYSTALS

☐ HC-52/U quartz crystals are designed for use in portable equipment where space is at a premium. The metal-can enclosures measure 8 mm wide × 2.3 mm thick. The crystals (also known as the HC-45 Slim-Line) are available from 5-360 MHz, require 0.1-mW drive and feature ± 2.5 ppm frequency stability. Prices range from $1.90 to $6 each. Raltron Electronics Corp, 2315 NW 107th Ave, Miami, FL 33182; tel 305-593-6033; fax 305-594-3973.

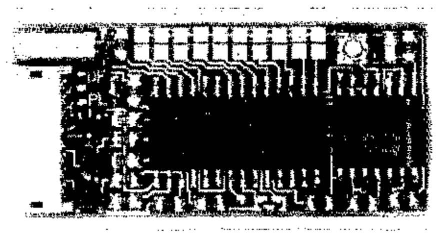


ATV FILTER

☐ The FL-407 Vestigial Sideband Filter is designed for use on 420-440 MHz amateur television. The 7-pole interdigital design provides sideband suppression and filtering, may be used alone or in pairs for repeater applications. The unit comes with N connectors and measures 2-1/8 × 8-13/16 × 20-5/8 inches. Retail price is $249. International Crystal Mfg Co Inc, PO Box 26330, Oklahoma City, OK 73126; tel 800-426-9825; fax 800-322-9426.

MICROMINI CTCSS ENCODER/DECODER

☐ The TS-64 is a small continuous-tone coded squelch system (CTCSS) encoder/decoder designed for hand-held FM transceivers. It measures 0.78 × 1.7 × 0.25 inches and can be programmed with any of 64 crystal-stabilized CTCSS tones between 33 and 254.1 Hz using six jumpers. It features a time-out timer, receiver high-pass filter, busy-channel lockout and operates on 6-20 V dc. Suggested retail price is $64.95. Communications Specialists Inc, 426 W Taft Ave, Orange, CA 92665-4296; tel 800-854-0547 or 714-998-3021; fax 714-974-3420.



PENETRANT-SOLVENT

☐ MO-10 Moist-Out removes moisture from circuit boards and acts as a light lubricant and penetrant that repels airborne contaminants. It can also remove corrosion and its dielectric strength is 45 kV. MO-10 comes in 55-gallon drums, 5-gallon pails and 16-oz plastic pump-spray bottles. The bottles retail for $6.39 (plus s/h) and *QST* readers get a 10% discount. Contact George Fennell, N3EQE, at Muscle Products, 188 Freeport Rd, Butler, PA 16001; tel 800-227-7049 or 412-283-0567; fax 412-283-8310.