A HIGH-PERFORMANCE 2-METER TRANSVERTER

Modular approach makes construction and modification easy

By Bob Lombardi, WB4EHS, 1874 Palmer Drive, Melbourne, Florida 32935

It seems that many VHF/UHF enthusiasts say they became interested in this part of the spectrum after having worked just about all of the DX available on HF. This wasn't the case for me. The possibilities of 2-meter operation appealed to me on their own merits. There is OSCAR, moonbounce, meteor scatter, SSB, CW, and a host of propagation modes to explore.

My interest in these modes of communication led me to review their requirements. I realized that commercial rigs available at the time didn't have the two main features I was looking for — a low noise figure and a selectable CW filter. Like many before me, I decided to build a transverter for my HF rig. These were my design goals:

- low noise figure, in keeping with the state of the art;
- output power in the range of 5 watts, with excellent linearity (third-order IMD at least 30 dB down);
- good rejection of a nearby NOAA weather radio relay (at least 40 dB down);
- moderate gain (enough to overcome the front end noise of the HF rig);
- good dynamic range.

I adopted a modular design approach advocated by Joe Reisert, W1JR, and others. I like this design because it gives me the ability to get sections working and tied together quickly. This, in turn, makes the project seem less like a constant uphill battle. Also, the modular method with its replaceable sections is a great benefit when you come up with a better design. The block diagram of the transverter appears in **Figure 1**.

Receive strip

The receive side input (**Figure 2**) is a GaAsFET low-noise amplifier (LNA) that uses a circuit similar to Reisert's[1] and to those in general FET applications notes. The device is a single gate MGF-1402 made by Mitsubishi; it's available from several sources.* The 10-k resistor on the input bleeds off static buildup. Any value around 10 k will work, as long as you use a carbon composition resistor. (I had a persistent and elusive oscillation; it was caused by the metal film resistor I was using!) I used diodes around the regulator to protect against regulator latch-up or inductive spikes from the T/R relay. The amplifier had a noise figure of under 0.75 dB and a gain of 23 dB, as measured on an Ailtech noise figure meter and HP network analyzer.

The filter (shown in **Figure 3**) was described in an earlier article.[2] I wanted the filter to be narrowband enough to pass all 4 MHz of the band, and still provide over 40 dB of rejection at 162.55 MHz. It provides nearly 55 dB, at a cost of about 5 dB of insertion loss. At this point, however, there was gain to burn to meet the design goals of about 10 dB of gain in the complete transverter.

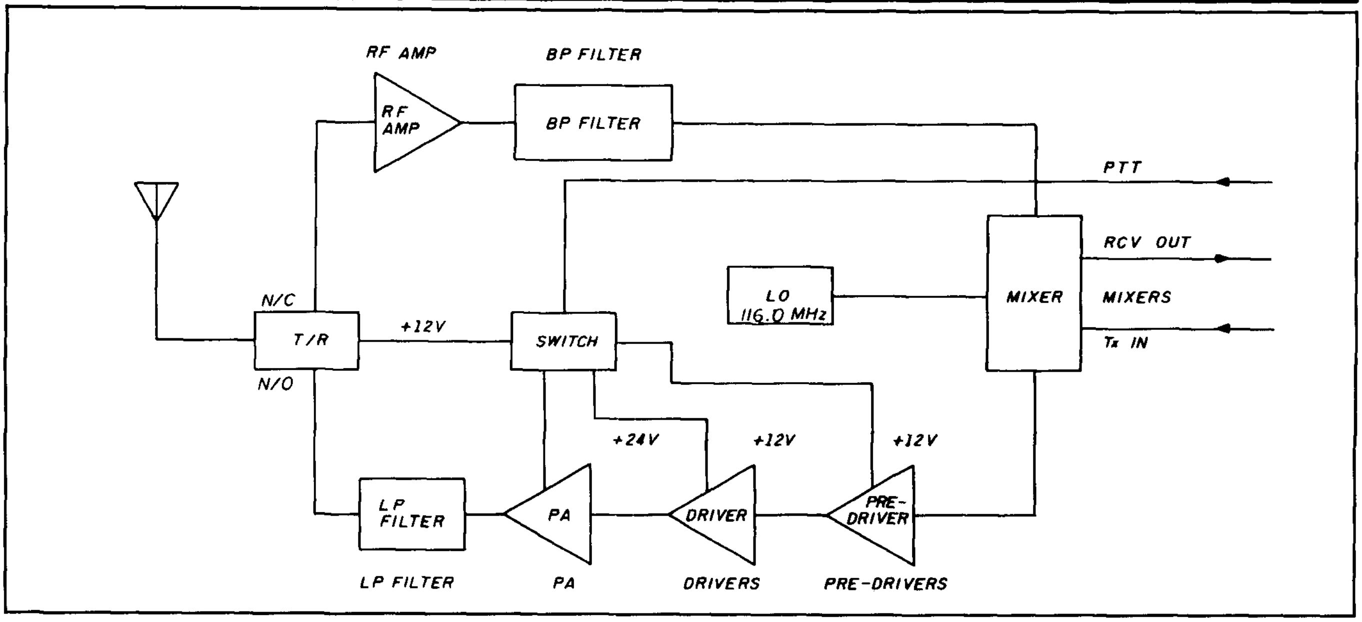
A 116-MHz overtone crystal oscillator provides the LO function for both sides of the transverter (**Figure 4**). The oscillator is a common base design, largely based on Reisert.[3] The output was measured at +13 dBm, allowing the use of a two-way power splitter to provide LO to both mixers.

The receive mixer is a Mini-Circuits SRA-1000 (see **Figure 5**). It is essentially the same as their SRA-1 in this application. The IF output goes into a diplexer and 24 to 34-MHz bandpass filter. In band, the diplexer (the parallel-resonant circuit and 51-ohm resistor) presents an open circuit, and no signal flows in the resistor. As the frequency changes the reactive components tend to short out the tank circuit, allowing signal to flow into the termination and to ground. The mixer sees the 51-ohm resistor at these frequencies.

The receiver input stage is largely responsible for determining the system noise figure, and the noise figure is degraded by any losses in front of it. If you're new to the field of low-noise design, this explains what must seem like the unconventional design of the transverter; i.e., the amplifier ahead of the filter. (This is a common design technique in microwave receiver

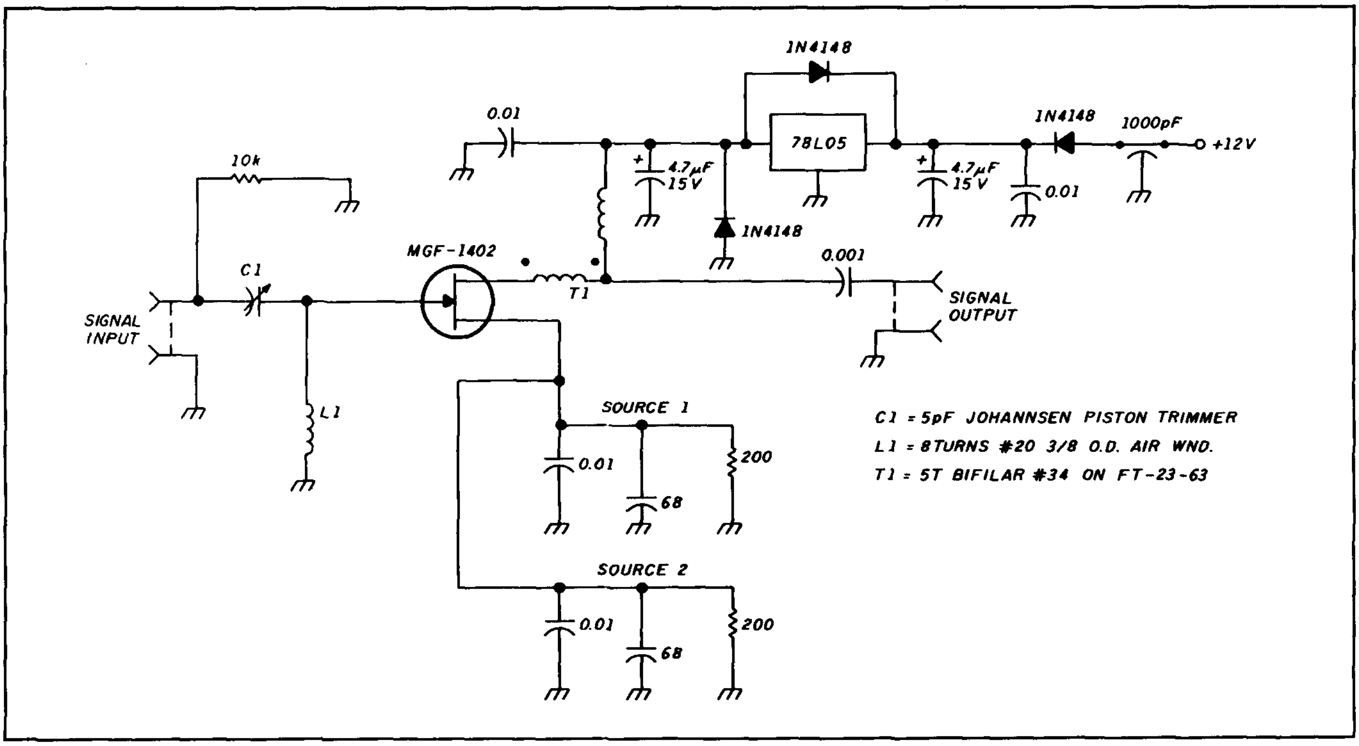
*See parts sources at the end of the article. *Ed.*

FIGURE 1



Block diagram of the complete transverter.

FIGURE 2

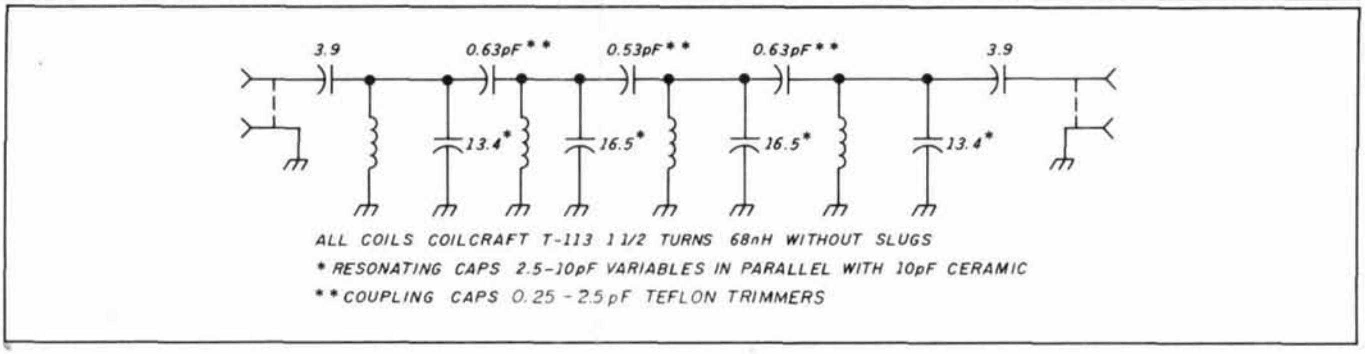


Schematic of the receive input RF amplifier.

design, like TVROs.) To minimize the effects of losses in front of the amp, I used foam-flex (hardline) coax as the feedline, with short flexible jumpers of RG-214/U where required.

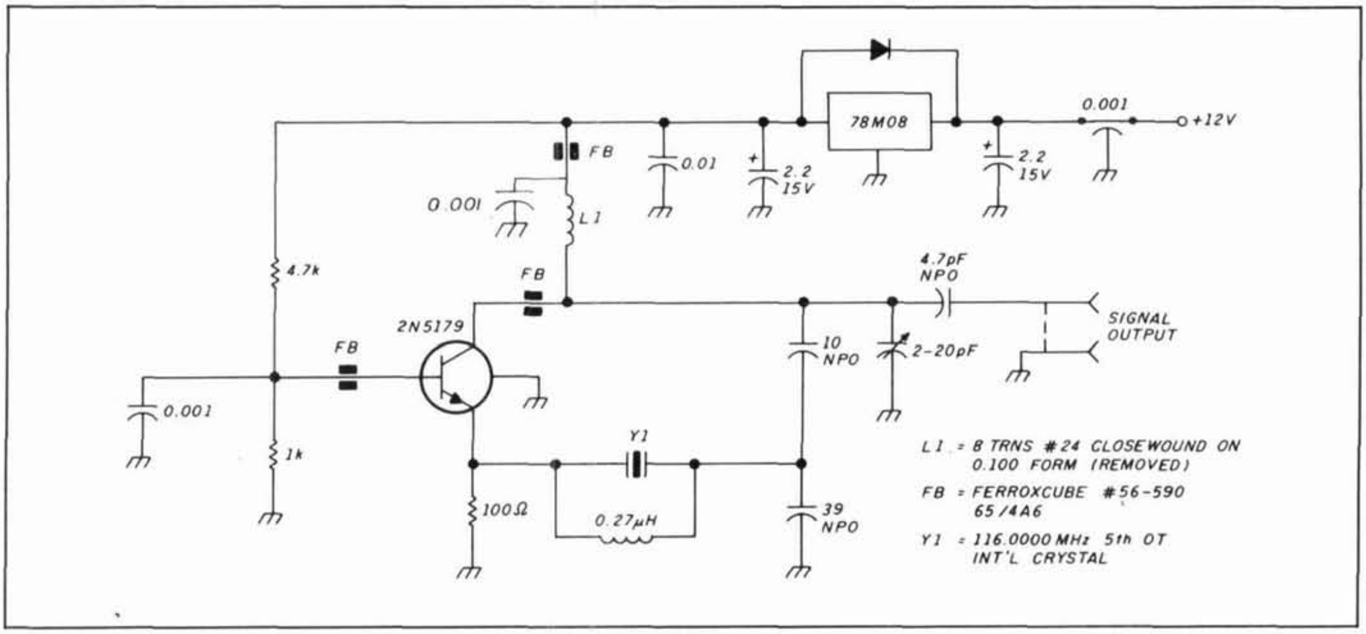
Other hams have told me on the air that my low noise figure is unnecessary in 2-meter SSB because ground noise predominates. While this maybe true, my idea all along was that receiver noise shouldn't be a limiting factor if I wanted to swing my antennas up for OSCAR — or anything else I might try. When you add that to the high intercept point of the GaAsFET front end, and the resulting improvement in dynamic

FIGURE 3



Details of the BP (bandpass) filter on the receive line.

FIGURE 4



Local oscillator using a 116-MHz overtone crystal.

Parts list

CAPACITORS

Electrolytic or tantalum

1.5 µF/15 volts	1 each
2.2 µF/15 volts	1 Radio Shack 272-1435
4.7 µF/15 volts	3 272-1024
10 µF/35 volts	1 272-1025
330 µF/16 volts	1 272-1030 (470 µF)

Ceramic, monolithic dipped, 50 volts (Z5U or X7R)

68 pF	2
470 pF	1
0.001 µF	20
0.01 µF	10
0.1 µF	1

Ceramic, monolithic dipped, 50 volts (COG or NPO)

3.9 pF	4
4.7 pF	1
10 pF	8
27 pF	1
39 pF	1
47 pF	2
270 pF	2

Trimmers—all values in pF

0.25-2.5 Teflon	4 BP filters
0.5-5 glass/air	1 GaAsFET amp
1-5 pF ceramic	5
2-20 ceramic	5
2-8 mica	2 PA
2.4-50 mica	2 PA
2.5-10 ceramic	5
9-35 ceramic	4
5.5-18	1*

*Most of these came from my junkbox, the result of years of hamfest buying. Try Communications Concepts, Inc., and other Some of these could be made into more parts of one value.

RESISTORS

1/4-watt carbon composition, 5 percent

51 ohm	1
100 ohm	1
200 ohm	2
1 k	2
1.5 k	1
4.7 k	1
5.6 k	1
10 k	4
100 k	1

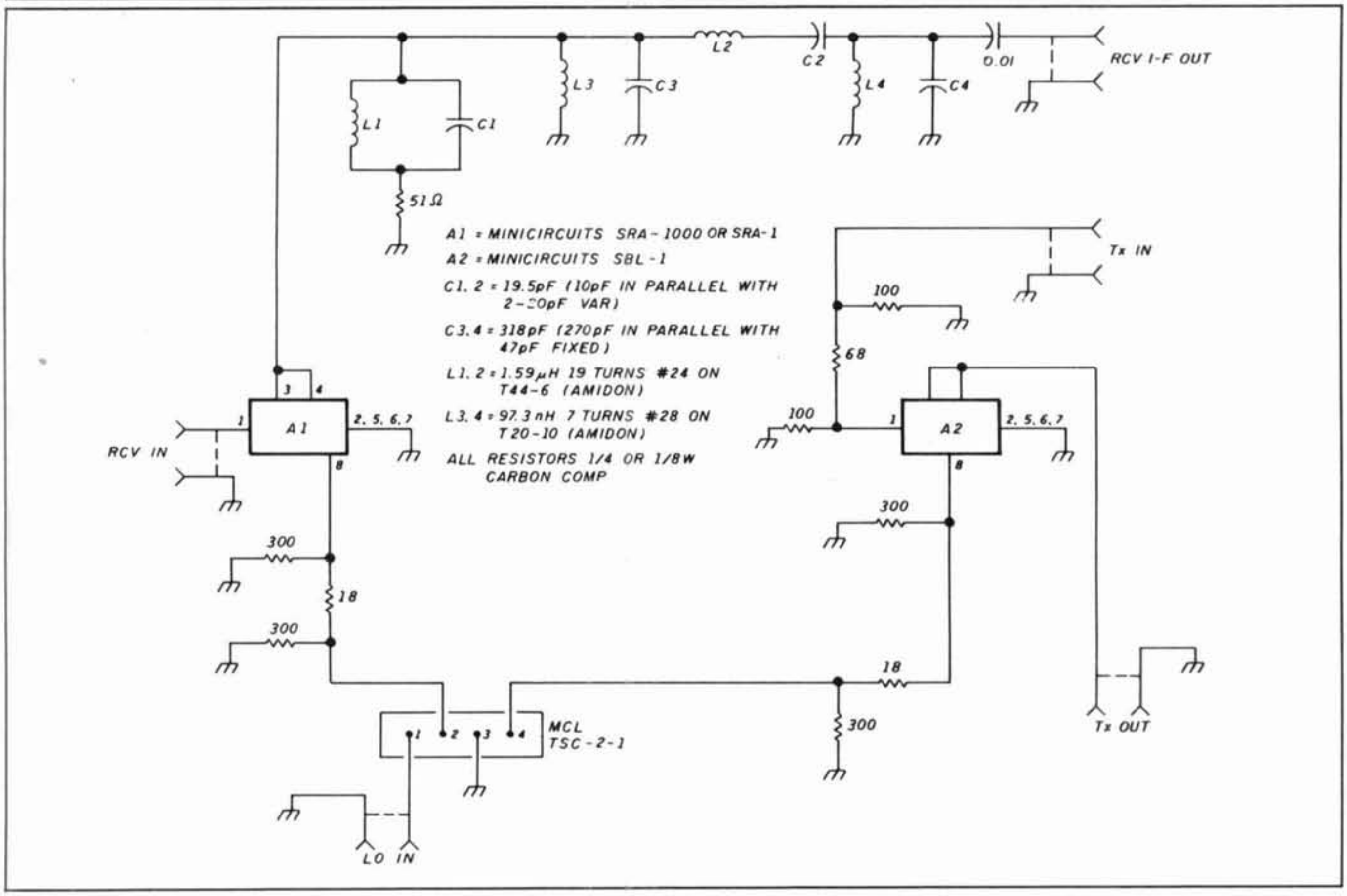
1/2-watt carbon composition, 5 percent

100 ohm	2
750 ohm	1

1-watt carbon composition, 5 percent

62 ohm	2
68 ohm	1

FIGURE 5



Receive and transmit mixer schematic.

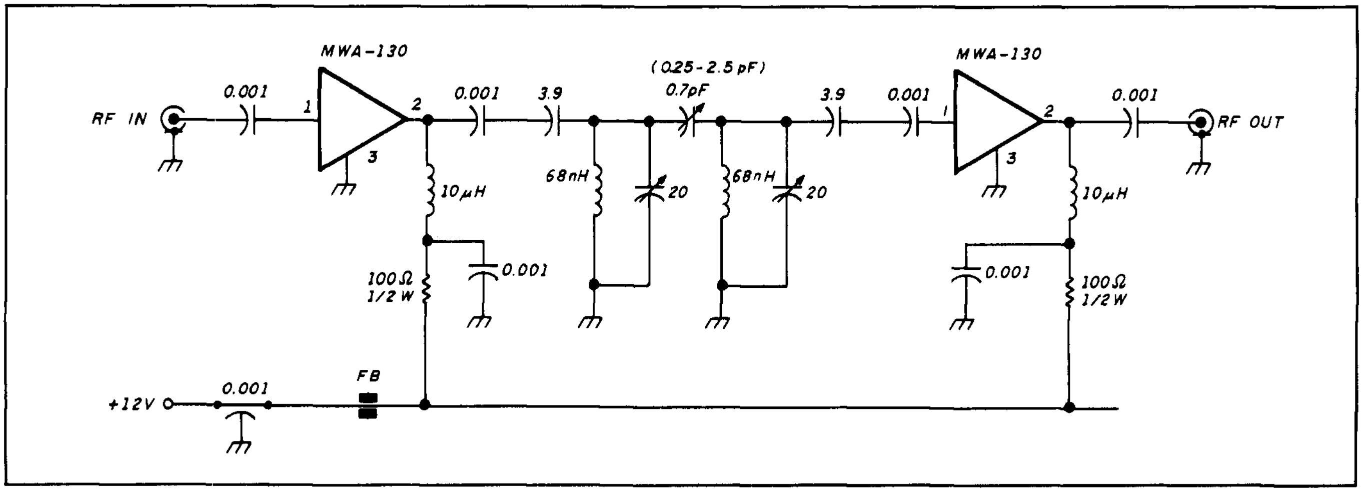
2-watt carbon composition	
Any value over 100 k (used as coil form)	
1/8-watt carbon composition, 5 percent	
18 ohm	2
300 ohm	4
68 ohm	1
100 ohm	2
SEMICONDUCTORS	
Diodes	
1N4148 general purpose	6 (widely available)
1N4004 rectifier	1
1N757 9-volt zener	1
1N751 5-volt zener	1
Transistors	
2N2222 NPN	1
2N3553 NPN	1 RF Parts Company
2N5109 NPN	1 RF Parts Company
2N5179 NPN	1 RF Parts Company
MGF-1402 GaAsFET	1 RF Parts Company
MRF-134 powerFET	1 RF Parts Company
OTHERS	
MWA-130 amplifier modules	2 Communications Concepts
78L05 5-volt regulator	1 (widely available)
78L08 or 78M08 8-volt regulator	1 (widely available)
LM-311 comparator	1 (widely available)

MISCELLANEOUS PARTS	
Ferrites	
FT-23-63	1 Amidon
Beads, Ferroxcube type 4A6	4 Amidon (cross-reference)
Two-hole balun (for RFC on driver assembly)	
BLN 43-2402	3 Amidon
Ferroxcube VK200-19/4B	1 Amidon (cross-reference)
TOROIDS	
T44-6	2 Amidon
T20-10	2 Amidon

Note: The exact ferrite bead used in most cases isn't critical. It should present several microhenries of inductance at the operating frequency.

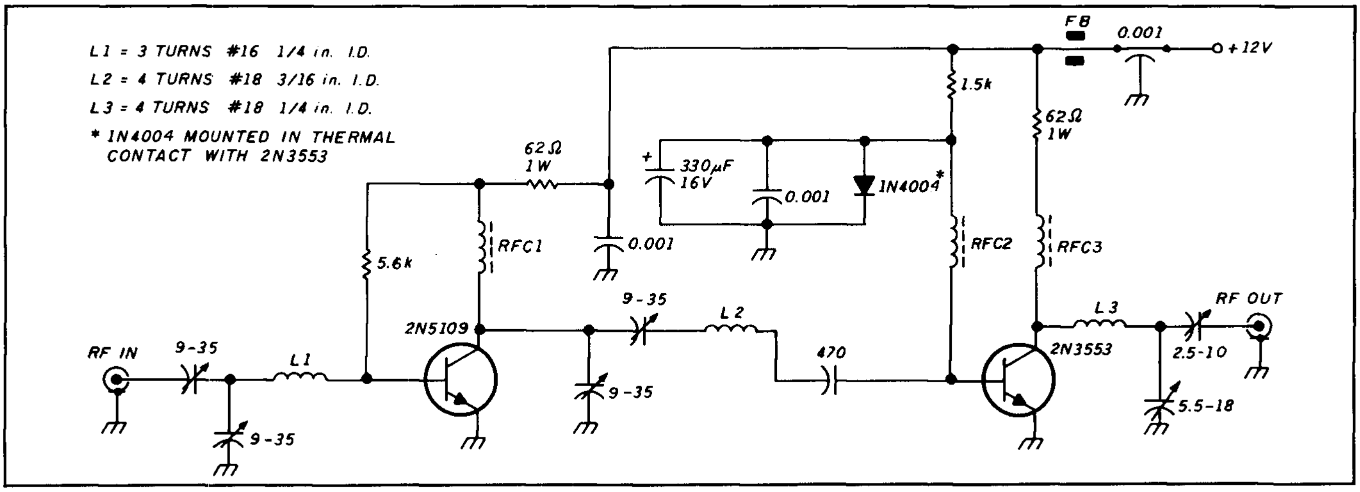
OTHER PARTS	
SBL-1 mixer	1 Mini-Circuits, others
SRA-1	1
TSC-2-1 power splitter	1 Mini-Circuits, others
116-MHz fifth overtone crystal	1 ICM
5-k multiturn pot	1 Radio Shack
T/R power switch relay 12 volt	1 Radio Shack
T/R coaxial relay 12 volt	1 Communications Concepts
RF coaxial connectors	15 SMA female (as required)
Coaxial jumpers	(as required)
Boxes	(as required)
Feedthrough capacitors	0.001 μF 50 volts (as required, 1 per box)
10μH molded chokes	2

FIGURE 6



Transmit predriver schematic.

FIGURE 7



Driver chain schematic. RFC 1-4 = 4 turns of no. 20 wire through a two-hole ferrite balun. Amidon no. BLN 43-2402.

range, the GaAsFET still seems the most logical choice.

My initial test of the receive side yielded good results. While conducting tests with WA4GHK (15 miles south), it was easy to copy K4DZP in Miami (over 160 miles south) — despite my makeshift indoor antenna!

Transmit chain

The transmit portion of the transverter presents its own problems; the biggest is linearity. A rule of thumb for diode ring mixers (like the SBL-1 used here) is to have the input signal at least 10 dB below the LO for best linearity (see **Figure 5**). Because one of my design goals was to achieve very good linearity from the transmitter, the first thing I did was pad the input drive (+3 dBm) from my HF rig. The resulting level was about −7 dBm, 14 dB lower than the LO drive. Since all the pads were made with the closest value resistors, and the mixer itself contributes loss, I measured the conversion loss of the transmit mixer. It was 17.7 dB.

The pre-driver stage in **Figure 6** is suppposed to recover all of the signal lost in the conversion, provide enough filtering to remove significant power on the image frequency, and reduce LO feedthrough. I used MWA-130 amplifiers, modular 50-ohm in-and-out devices in TO-5 cans, because they are easy to use and were available on a surplus board that I scavenged. The power out at this point is 4 mW (+6 dBm).

The actual drivers are two transistors, a 2N5109 and a 2N3553 (see **Figure 7**). The first device is a well-known VHF linear transistor; the second is a 28-volt, TO-5 can device capable of 2 watts if run class C. This was originally to have been a three-transistor strip with 1 watt out from a third 2N3553, but I was never able to get them to more than 500 mW and still remain linear with a 12-volt supply. I tried many variations of bias circuits, matching networks, and pc layouts. The two-device strip I settled on produces 18 dB of gain, or about 250 mW out.

The final amp is a Motorola MRF-134 TMOS powerFET that delivers just over 4 watts out and a clean, linear signal (third-order intermod down just over 30 dB). See **Figure 8** for details.

Receive Only	Freq. Range (MHz)	N.F. (dB)	Gain (dB)	1 dB Comp. (dBm)	Device Type	Price
P28VD	28-30	<1.1	15	0	DGFET	$29.95
P50VD	50-54	<1.3	15	0	DGFET	$29.95
P50VDG	50-54	<0.5	24	+12	GaAsFET	$79.95
P144VD	144-148	<1.5	15	0	DGFET	$29.95
P144VDA	144-148	<1.0	15	0	DGFET	$37.95
P144VDG	144-148	<0.5	24	+12	GaAsFET	$79.95
P220VD	220-225	<1.8	15	0	DGFET	$29.95
P220VDA	220-225	<1.2	15	0	DGFET	$37.95
P220VDG	220-225	<0.5	20	+12	GaAsFET	$79.95
P432VD	420-450	<1.8	15	−20	Bipolar	$32.95
P432VDA	420-450	<1.1	17	−20	Bipolar	$49.95
P432VDG	420-450	<0.5	16	+12	GaAsFET	$79.95
Inline (rf switched)						
SP28VD	28-30	<1.2	15	0	DGFET	$59.95
SP50VD	50-54	<1.4	15	0	DGFET	$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	$109.95
SP144VD	144-148	<1.6	15	0	DGFET	$59.95
SP144VDA	144-148	<1.1	15	0	DGFET	$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	$109.95
SP220VD	220-225	<1.9	15	0	DGFET	$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	$109.95
SP432VD	420-450	<1.9	15	−20	Bipolar	$62.95
SP432VDA	420-450	<1.2	17	−20	Bipolar	$79.95
SP432VDG	420-450	<0.55	16	+12	GaAsFET	$109.95

Every preamplifier is precision aligned on ARR's Hewlett Packard HP8970A/HP346A state-of-the-art noise figure meter. RX only preamplifiers are for receive applications only. Inline preamplifiers are rf switched (for use with transceivers) and handle 25 watts transmitter power. Mount inline preamplifiers between transceiver and power amplifier for high power applications. Other amateur, commercial and special preamplifiers available in the 1-1000 MHz range. Please include $2 shipping in U.S. and Canada. Connecticut residents add 7-½% sales tax. C.O.D. orders add $2. Air mail to foreign countries add 10%. Order your ARR Rx only or inline preamplifier today and start hearing like never before!

Advanced Receiver Research

Box 1242 • Burlington, CT 06013 • 203 582-9409

✓ 132

2 METER AMPLIFIERS • ATV CONVERTERS

DISCOVER THE WORLD OF FAST SCAN TELEVISION:

AMATEUR TELEVISION CONVERTERS

ATV-2	420-450 MHz		$ 44.95 Kit
ATV-3	420-450 MHz	GaAs-Fet	$ 49.95 Kit
ATV-4	902-928 MHz	GaAs-Fet	$ 59.95 Kit

Available in: Kit or Assembled/Tested

Add $ 2.00 For Shipping and Handling

RF Amplifiers Per Motorola Bulletins

Complete Parts list for

140 Watt or 300 Watt HF Amplifiers per Motorola Bulletins
AN-758, AN-762, EB-27A, EB-63

CAMBION RF CHOKES
0.15 uh, 0.22 uh, 0.33 uh
4.7 uh, 10.0 uh .... $ 1.20

MIXERS
SBL-1 DBL. Bal. Mixer .... $ 6.50
SBL-1X DBL. Bal. Mixer .... $ 7.95

FERROXCUBE DEVICE
VK200-20/4B RF Choke .... $ 1.20
56-590-65-3B Ferrite Bead .... $ .20

POWER SPLITTER/COMBINER
2-30 MHz, 600 Watts (2 Port or 4 Port)

BROADBAND TRANSFORMERS PER MOTOROLA BULLETINS

We Also Stock Hard-To-Find Parts:

KEMET CHIP CAPACITORS
METALCLAD MICA CAPACITORS
SEMICONDUCTORS
RF POWER TRANSISTORS

For detailed information, please call or write for our free catalog

VISA

CCI Communication Concepts Inc.

121 Brown Street • Dayton, Ohio 45402 • (513) 220-9677

master charge

✓ 133

antenneX©

"The Magazine For Antenna Experimenters"

IF YOU -

- Have a lousy mobile signal on all bands?
- Need an inexpensive beam for 10 meters?
- Unsure about using vert vs horiz antenna?
- Need a low noise antenna for 160 meters?
- Want to design an antenna just for you?
- Need a program for design and plotting?
- Need to solve a unique problem?
- Know the best antenna for hamsats, etc.?
- Need a disguised mobile antenna?
- Want a cheap automatic coupler system?
- Just want to learn more about antennas?

THEN SUBSCRIBE TO - *antenneX©*

12 MONTHLY ISSUES is only $11.97 for USA and possessions. $17.00 foreign.

antenneX©

P.O. Box 8995 Dept. 19
Corpus Christi, TX 78412

✓ 131

Electronic Repair Center

Servicing

Amateur **Commercial Radio**

The most complete repair facility on the East Coast.
Large parts inventory and factory authorized warranty service for Kenwood, Icom and Yaesu.

SEND US YOUR PROBLEMS

Servicing "Hams" for 30 years, no rig too old or new for us.

HAMTRONICS, INC.

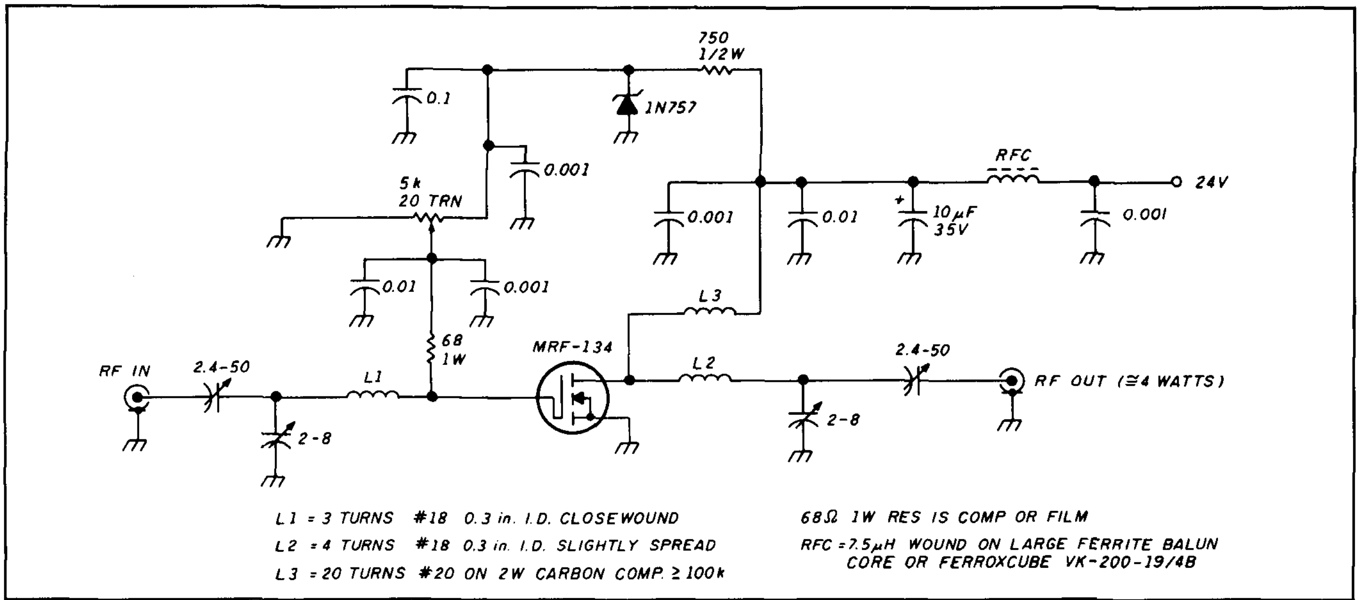
4033 Brownsville Road
VISA **Trevose, Pa. 19047** MasterCard
215-357-1400

CATALOGS

HAM	SWL
➤Transceivers	➤Receivers
➤HF-VHF-UHF	➤Antennas
➤Antennas	➤Tuners
➤RTTY-Packet	➤Heaphones
➤Receivers	➤RTTY-FAX
➤Books & Accs.	➤Books & Accs.
Only $1 Postpaid	**Only $1 Postpaid**

Send to: **Universal Radio**
1280 Aida Drive Dept. HR
Reynoldsburg, OH 43068

FIGURE 8



Final amplifier using an MRF-134.

All design decisions are tradeoffs. For example, using the MRF-134 created the need for a small 24-volt supply — but I gained advantages in other areas. First, the FET is guaranteed to deliver rated power into a 30:1 VSWR at any phase angle (no delicate device here!); second, it's capable of more gain in one package than a bipolar; and last, it worked the first time I tried it — a very enjoyable experience after my trials and tribulations with the '3553s.

The circuit is taken largely from the *Motorola RF Data Book* applications note.[4] Component changes are based on availability and personal preferences. In any RF power amplifier it's essential to keep the ground leads of the device as close as possible to ground on the board. I connected top and bottom foil with a strip of copper shim stock at the point where the source leads leave the device package. The FET itself is on an extremely overrated heat sink; after extended key down periods everything remains at ambient temperature.

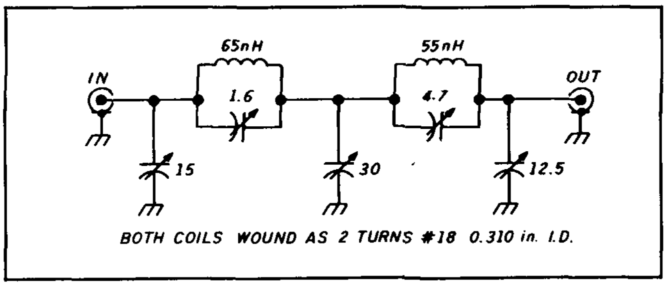
The output filter in **Figure 9** is an elliptical low-pass design. The two parallel resonant circuits are tuned to 313 and 487 MHz with a grid-dip meter; the other caps are adjusted for minimum insertion loss while you watch output power on a wattmeter. My version had a measured insertion loss of under 0.2 dB.

I used a simple comparator on the PTT line from the HF rig to do the T/R switching (see **Figure 10**). The relay is DPDT. It switches 12 and 24 volts to the transmit amplifiers and 12 volts to the antenna relay (a Dow-Key relay I picked up at a local hamfest). The relay provides over 40 dB of isolation during transmit; the GaAsFET sees −4 dBm, well within its capabilities. (I leave it powered on continuously.) This relay should be adequate at power levels of up to 100 watts.

Construction and alignment

This is a sophisticated project and you'll need building experience. If you've had experience with other RF circuitry, you'll find it presents few special challenges. I used pc boards

FIGURE 9



Schematic of the transmit LPF (low pass filter).

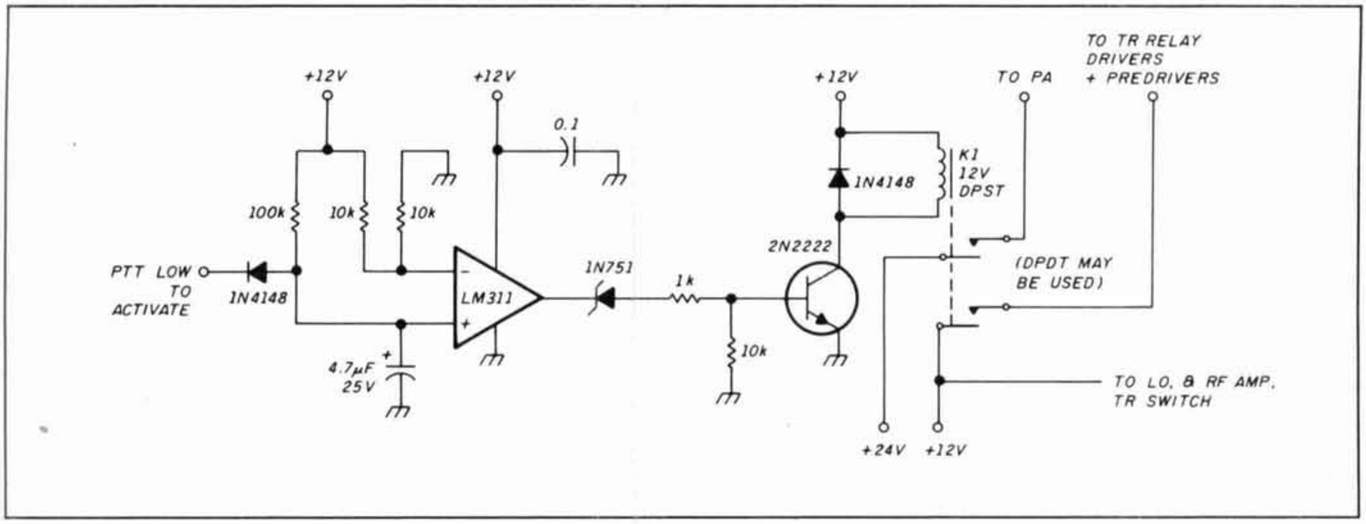
for the GaAsFET RF amplifier, filters, and all transmit stages. The LO, mixers, and the T/R switching boards are built "dead bug" style; they function quite well that way. If you are an experienced builder who uses point-to-point techniques at these frequencies, you may want to use that method. I used SMA connectors on small-diameter coax (RG-188) for signal interconnects. You may prefer to use BNCs. Likewise, I used pc board material for housing circuits — you may prefer commercially made enclosures.

I've already mentioned the need to keep grounds short on the final amplifier; the same holds true for the driver stages. This is the strongest argument for using pc boards for these stages. The emitters of the driver transistors are grounded immediately, with minimal lead length.

There are no "peculiarities" of alignment. Align the filters separately, tuning them as desired. It's best to align the transmit stages with a spectrum analyzer. Tune the drivers for best output while observing third-order intermod. This will not occur at maximum power out. The same applies to the final amplifier.

Ideally, the GaAsFET should be aligned with noise figure instrumentation. If that isn't available, tune for maximum noise level by ear, and then detune slightly. The optimum noise fig-

FIGURE 10



T/R switch schematic.

ure match isn't far from max gain, but that's about as quantitative as I can get.

Performance

On-the-air results have been good. I actually used the transverter for quite a while at the 250-mW level, and surprised myself by working most of peninsular Florida. I made some of my best contacts with an indoor antenna and the pieces of my project spread across my desk. Moving up to 4 watts put me within 3 dB of the mainstream of off-the-shelf 2-meter SSB rigs (that's about half of one S-unit), and to a level that could be used with commercial amplifiers. It also netted me contacts with five southeastern states using a small antenna at rooftop height.

I'd like to thank Jim Hagan, WA4GHK, for his part in the conceptual design of this circuit and for helping me with on-the-air tests.

Parts sources

Digi-Key
701 Brooks Avenue South, PO Box 677,
Thief River Falls, Minnesota 56701-0677
A broad line of passives, semiconductors, and tools

Mini-Circuits
PO Box 350166, Brooklyn, New York 11235-0003
Mixers, splitters, hybrids, etc.; will sell to individuals

Amidon Associates
12033 Otsego Street, North Hollywood, California 91607
Toroids, ferrites, inductive components

Communications Concepts, Inc
121 Brown Street, Dayton, Ohio 45402
RF parts and kits, hard-to-find trimmers, chip caps, transistors, ATV parts

RF Parts
1320 Grand Avenue, San Marcos, California 92069
RF power devices, GaAsFETS, and many other transistors

REFERENCES

1. Joe Reisert, W1JR, "Low Noise GaAsFET Technology," *Ham Radio*, December 1984, pages 99-112
2. Bob Lombardi, WB4EHS, "Build Narrowband Filters," *Ham Radio*, March 1986, pages 10-21
3. Joe Reisert, W1JR, "High Dynamic Range on 2 Meters," *Ham Radio*, November 1985, pages 54-64
4. Technical Staff ed., *Motorola RF Device Data Book*, Arizona, 1986