

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 Reiser, 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 Reiser's¹ 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.

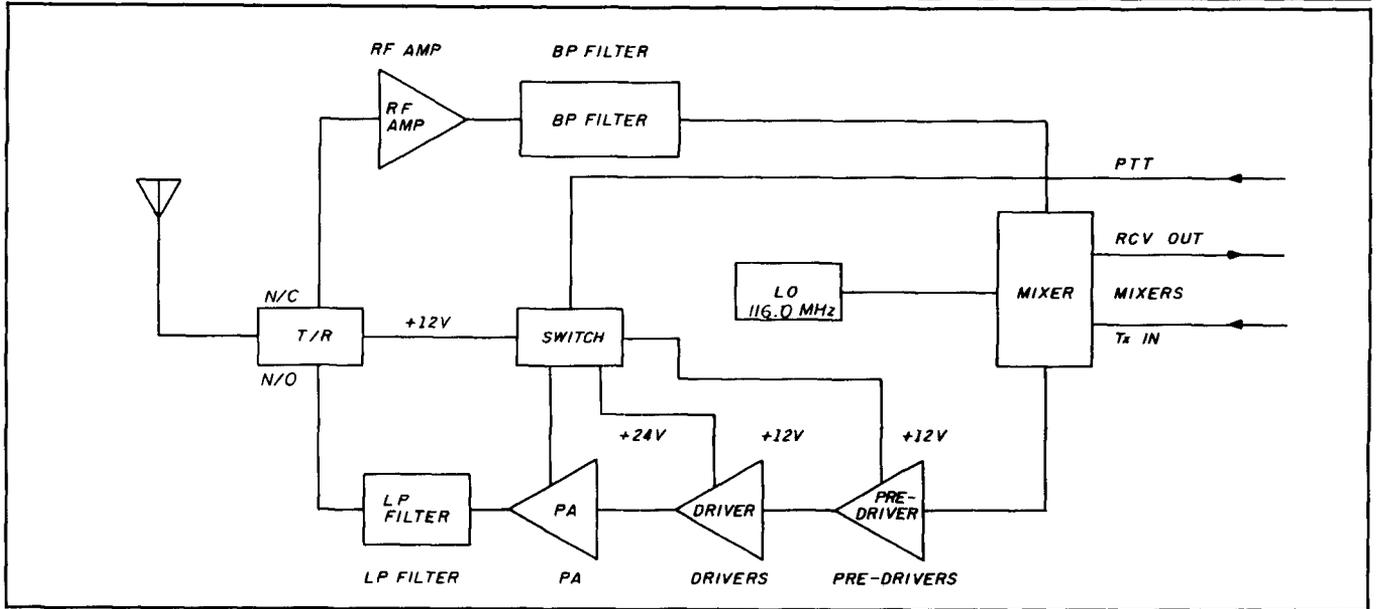
A 116-MHz overtone crystal oscillator provides the LO function for both sides of the transverter (Figure 4). The oscillator is a common base design, largely based on Reiser.³ The output was measured at +13 dBm, allowing the use of a two-way power splitter to provide LO to both mixers.

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 band-pass 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

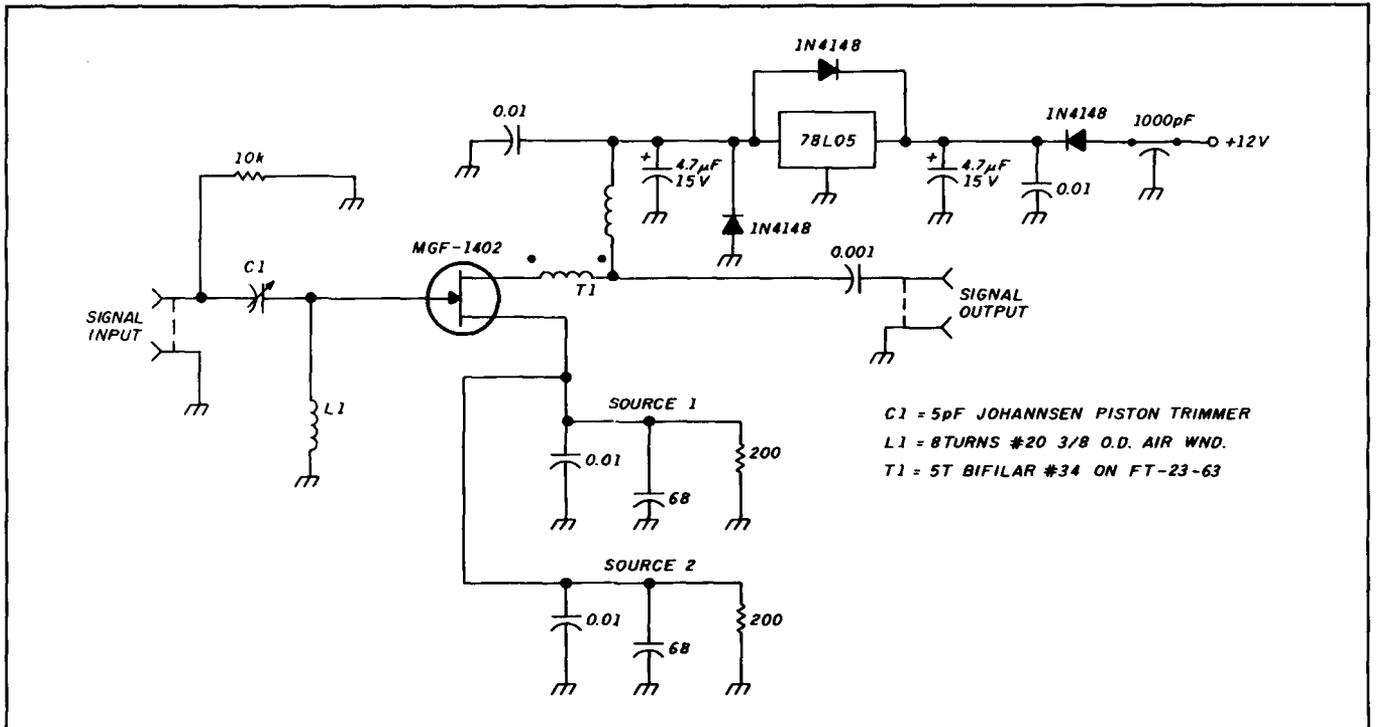
*See parts sources at the end of the article. Ed.

FIGURE 1



Block diagram of the complete transverter.

FIGURE 2



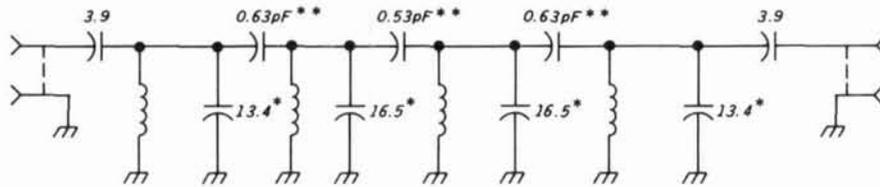
Schematic of the receive input RF amplifier.

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 GaAs-FET front end, and the resulting improvement in dynamic

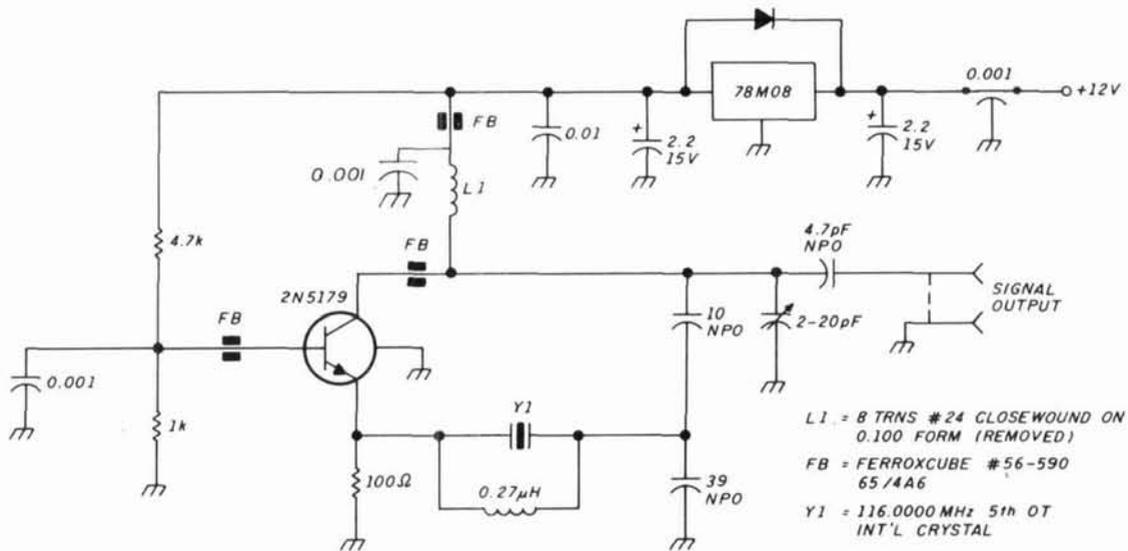
FIGURE 3



ALL COILS COILCRAFT T-113 1 1/2 TURNS 68nH WITHOUT SLUGS
 * RESONATING CAPS 2.5-10pF VARIABLES IN PARALLEL WITH 10pF CERAMIC
 ** COUPLING CAPS 0.25 - 2.5 pF TEFLON TRIMMERS

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

FIGURE 4



L1 = 8 TRNS #24 CLOSEWOUND ON 0.100 FORM (REMOVED)
 FB = FERROXCUBE #56-590 65/4A6
 Y1 = 116.0000 MHz 5th OT INT'L CRYSTAL

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

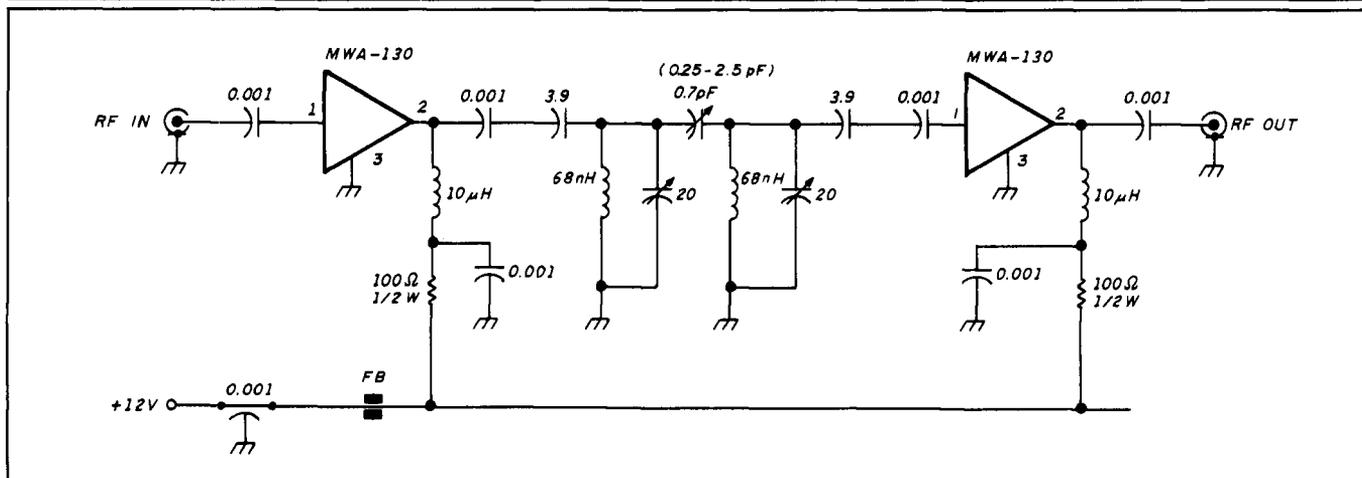
1/2-watt carbon composition, 5 percent

- 100 ohm 2
- 750 ohm 1

1-watt carbon composition, 5 percent

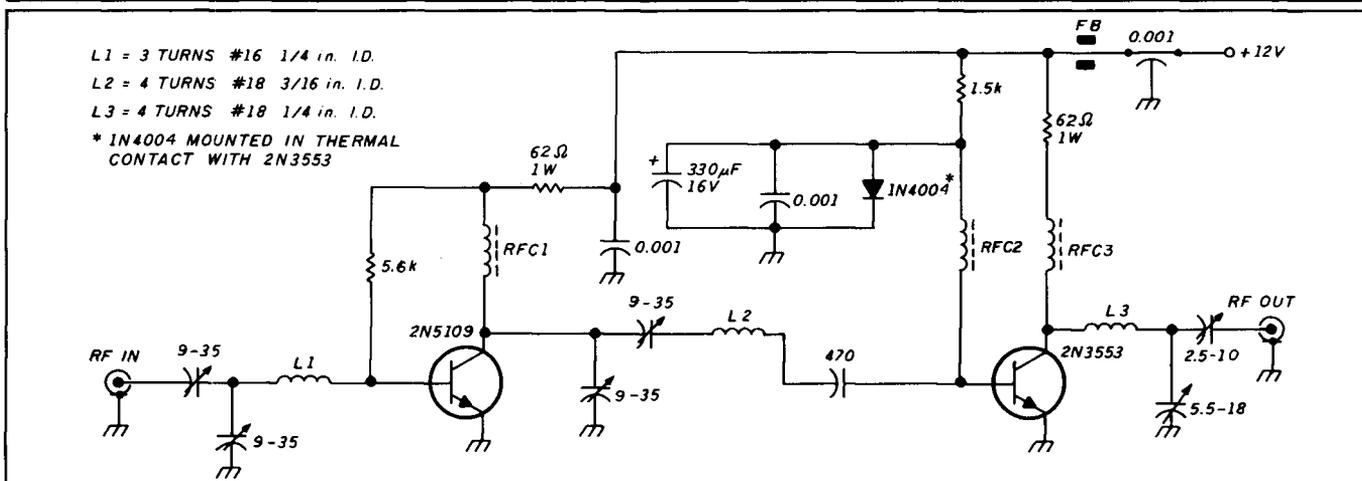
- 62 ohm 2
- 68 ohm 1

FIGURE 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 supposed to recover

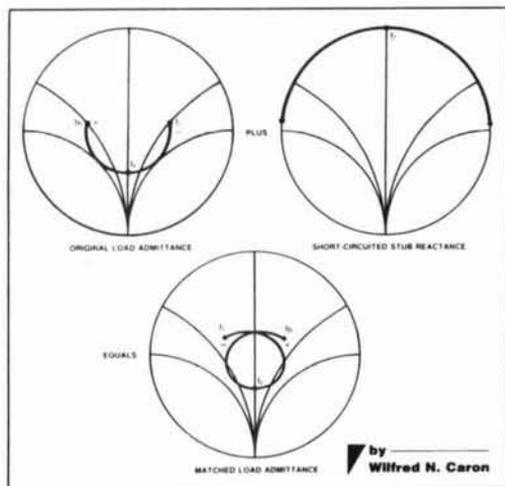
all of the signal lost in the conversion, provide enough filtering to remove significant power on the image frequency, and reduce LO feedthrough. I used MWA-130 amplifiers, modular 50-ohm in-and-out devices in TO-5 cans, because they are easy to use and were available on a surplus board that I scavenged. 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.

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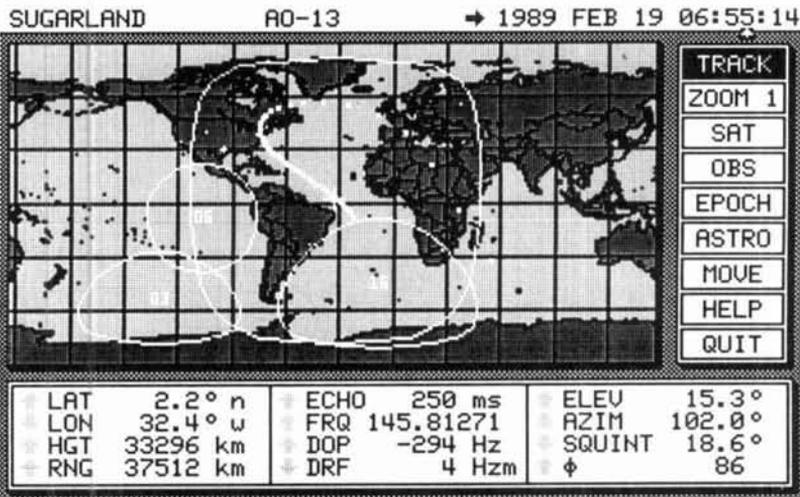
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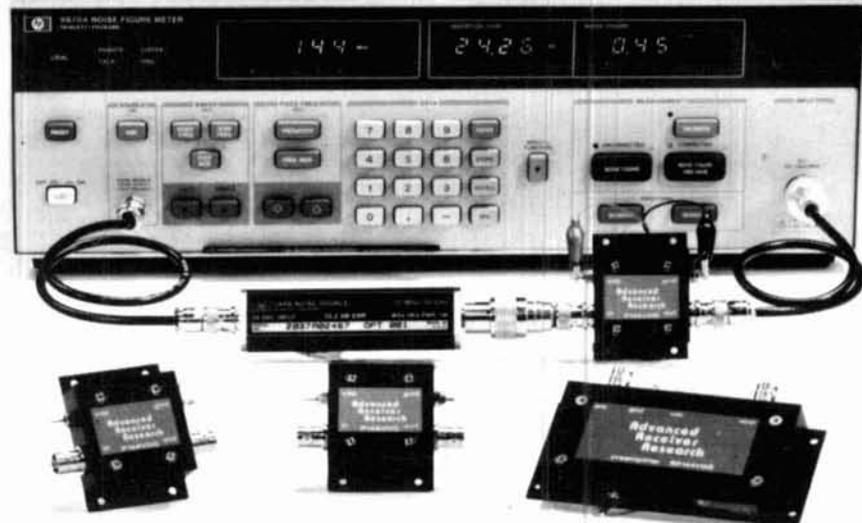
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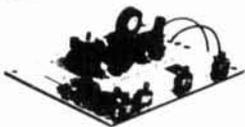
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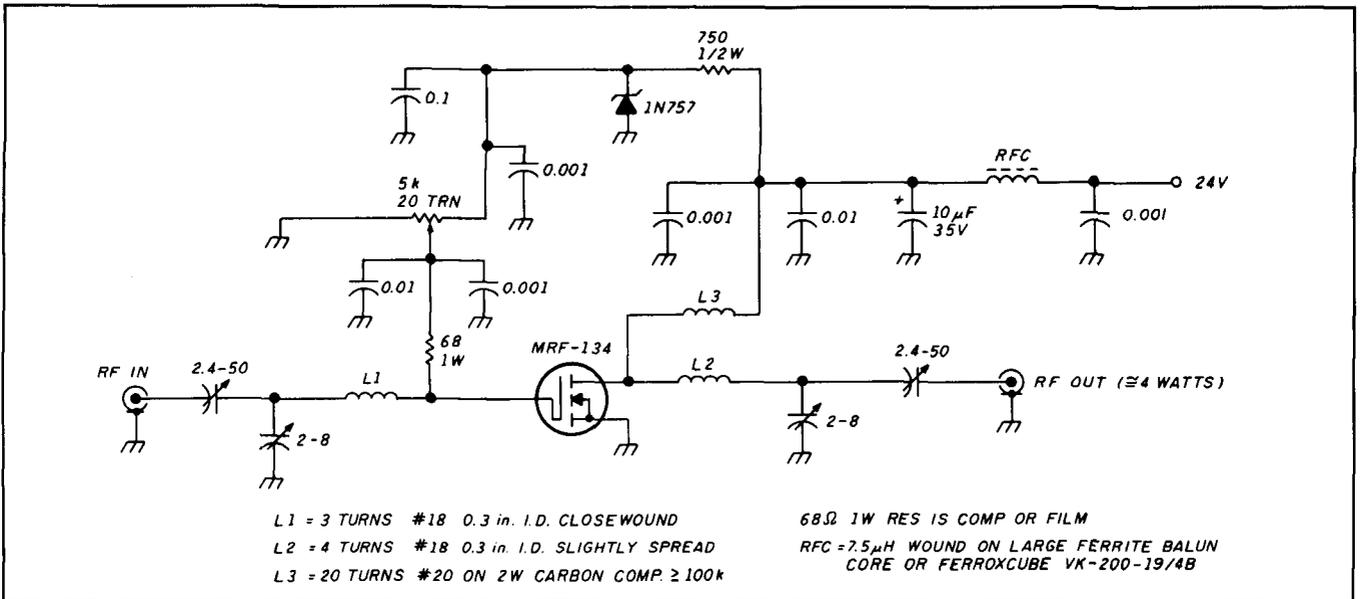
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FIGURE 8



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.

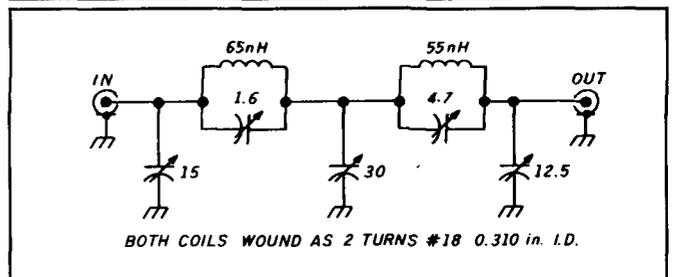
The output filter in **Figure 9** is an elliptical low-pass design. The two parallel resonant circuits are tuned to 313 and 487 MHz with a grid-dip meter; the other caps are adjusted for minimum insertion loss while you watch output power on a wattmeter. My version had a measured insertion loss of under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

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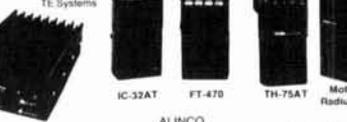
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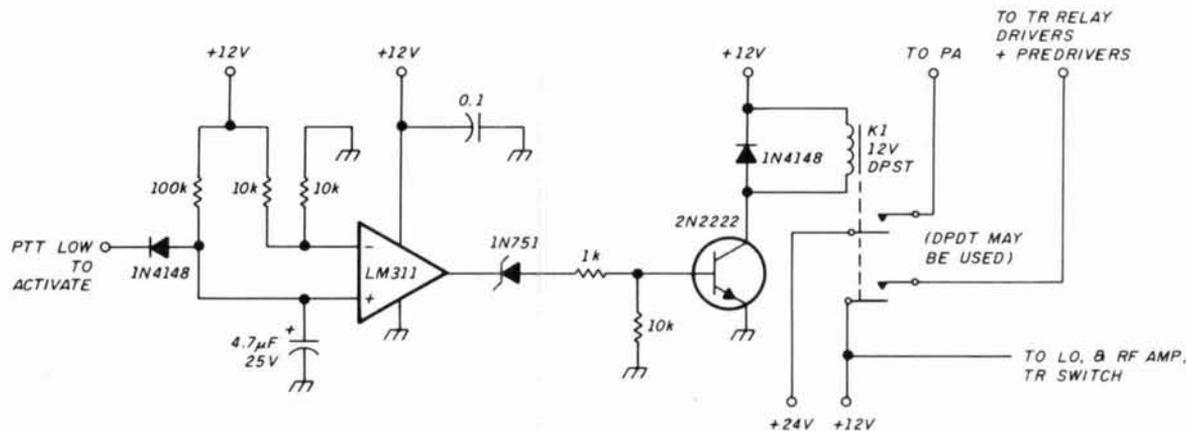
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FIGURE 10



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. **hp**

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REFERENCES

- 1 Joe Resert, 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 Resert, 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.

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