We Must Be Dreaming

A home-brew receiver project!

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With last summer's hamfest season promising all sorts of new occupants for the parts bin, I felt it was time to make room by cleaning out some of the previous several years' good finds. Homebrewing several HF receivers with Gilbert cell front ends taught me the perils of 40 meters—QRPers and half-megawatt broadcasters sharing the same band certainly tests dynamic range. As an SWL, I wanted to receive both. A receiver that would cover, say, 6.5 to 7.5 MHz seemed like both a challenging project and a way to clear space for this year's hamfest-find-of-the-century.

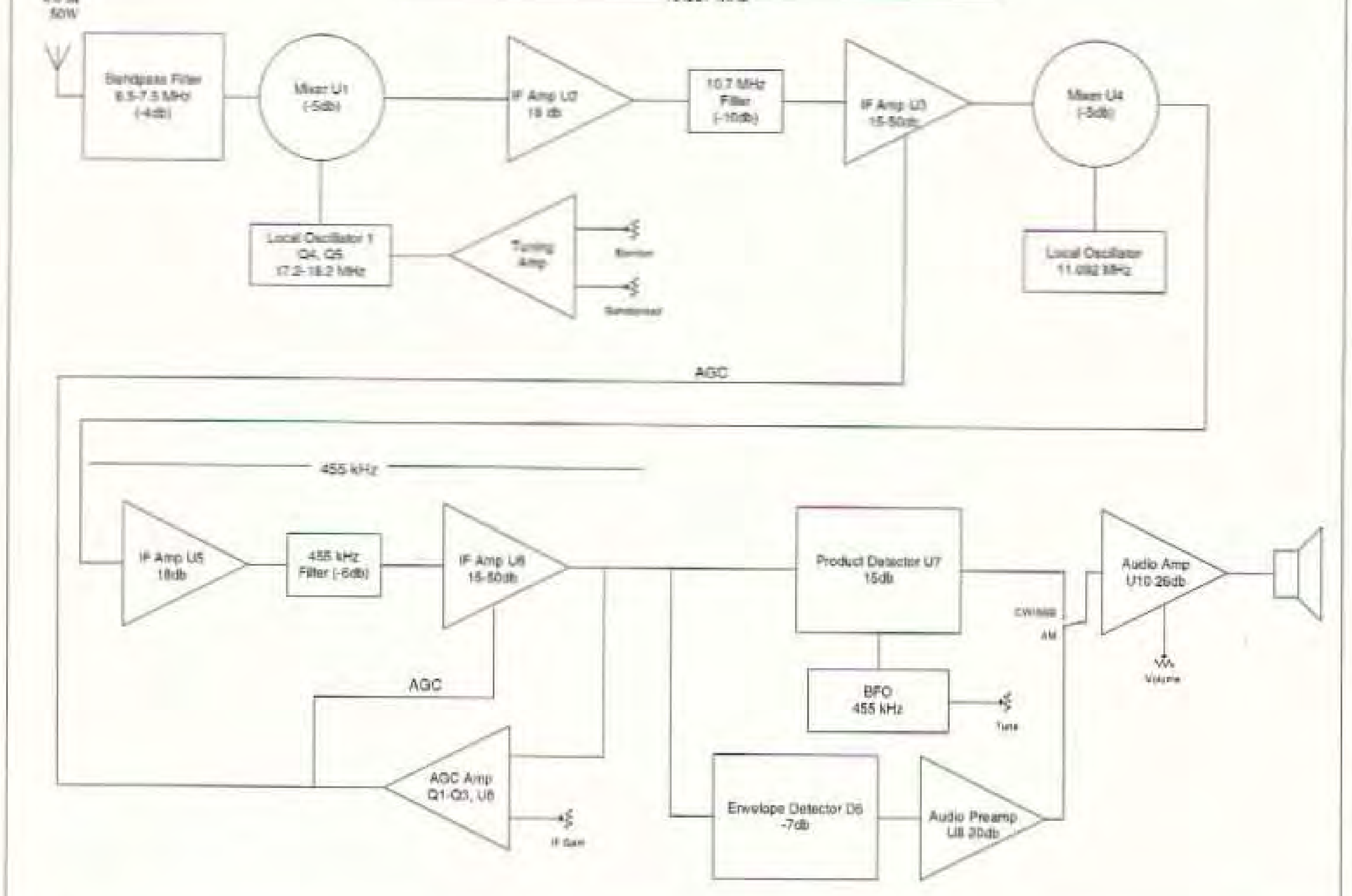

Fig. 1. Block diagram.

The circuit

Fig. 1 is the block diagram. Overall gain requirements were based on a 0.5 µV signal at the antenna delivering 0.25 W into an 8 Ω speaker, or 134 dB. Originally, the intent was to use OH2GF's synchronous detector for AM (*A Synchronous Detector for AM Transmissions*, Jukka Vermasvuori OH2GF, *QST*, July 1993). This requires 15 mV input into 50 Ω, so 90 dB gain is required before the detector, and 44 dB in the detector and audio sections. Ultimately, difficulty obtaining the NE604 or a suitable single-chip substitute in a standard DIP package led me to use a diode detector for AM and adapt OH2GF's product detector for CW and SSB.

The circuit is dual-conversion to improve image rejection. Double balanced diode mixers are used to generate the 10.637 MHz first IF and 455 kHz second IF. Ceramic filters are used between the first and second stages of each IF train. The MMIC first stages make up for mixer and filter losses, and provide 50 Ω terminations for the mixers. The AGC-controlled second stages provide the bulk of the gain.

The first local oscillator and BFO are both varactor-tuned. The BFO tuning voltage range is determined by two 10 k trimpots, with which my junk box still overflows. First local oscillator tuning voltage is developed through what may seem to be a needlessly complex circuit. The bandspread control is a 10-turn pot with nice smooth action, begging to be pressed into service, but at 100 Ω and 1/8 W, it cannot by itself supply a wide enough voltage difference to tune the varactors over the desired 1 MHz range. An op amp is therefore used to multiply the difference between the bandset and bandspread wiper voltages to produce between 2 V and 5 V at its output, corresponding to between 17 pF and 11 pF of tank capacitance, for a frequency range of 17.2 MHz to 18.2 MHz. The buffer amplifier adapted from a circuit in Hayward and DeMaw (*Solid State Design for the Radio Amateur,* Wes Hayward W7ZOI and Doug DeMaw W1FB; first local oscillator adapted from LO and BFO circuits for the 160 meter receiver in Chapter 6) isolates the oscillator and matches it to the 50 Ω first mixer local oscillator port. L9 adjusts the match to provide 0.5 V_{rms} (+7 dBm) injection.

The second local oscillator is a Pierce circuit using a readily available inexpensive crystal. At 11.092 MHz - 455 kHz = 10.637 MHz, the first IF is slightly off the usual 10.7 MHz, but the bandwidth of the first ceramic filter easily accommodates this. Similarly, the 10.7 MHz transformer has sufficient tuning range to adjust for a peak oscillator output of around 0.5 V_{rms} into the second mixer local oscillator port.

AGC is developed by amplifying second IF output through Q1 and Q2, rectifying through D6 and D7 and filtering the signal, and amplifying the resulting control signal through Q3 (see *1993 ARRL Handbook for Radio Amateurs;* AGC derived from Chapter 12, Fig. 43). The unity gain op amp functions as an inverter and level shifter, where the IF gain control sets the quiescent AGC voltage at pin 1 of U8 to between 4.5 and 6 V. As the second IF output increases, AGC voltage increases, reducing the gain of both MC1350s. AGC may be turned on and off by a push/pull switch mounted on the IF gain control, allowing IF gain to be adjusted manually even when AGC is used.

The other half of U8 is an audio preamplifier used to boost the envelope detector output to something near the output of the product detector. U7 has a conversion gain of around 15 dB, while the diode detector has a loss of around 7 dB. Most full-carrier AM signals in this receiver's range are broadcasters, so the 20 dB gain of the preamplifier is quite sufficient. Audio output is provided by U10, which

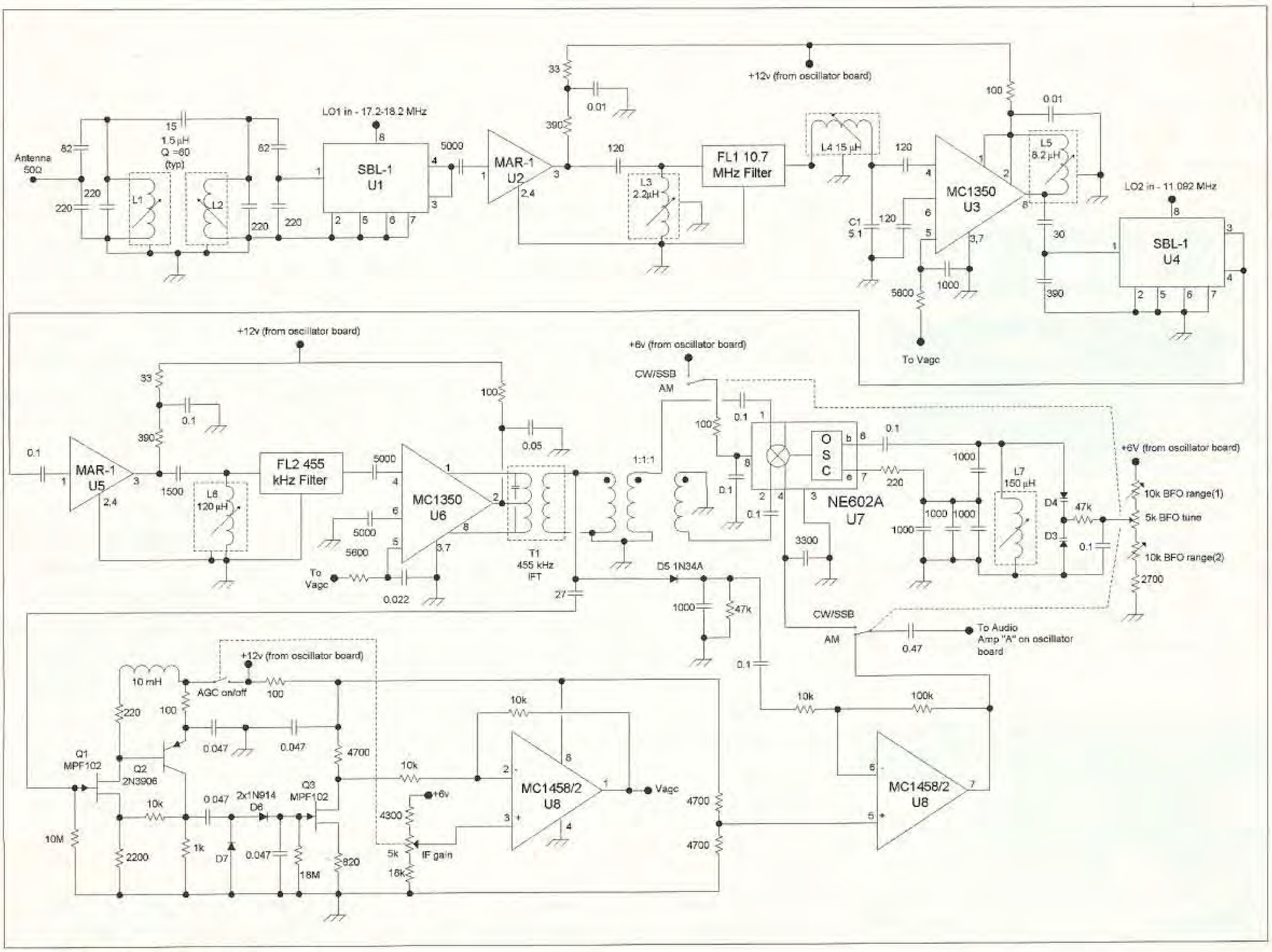

Fig. 2. Front end board schematic.

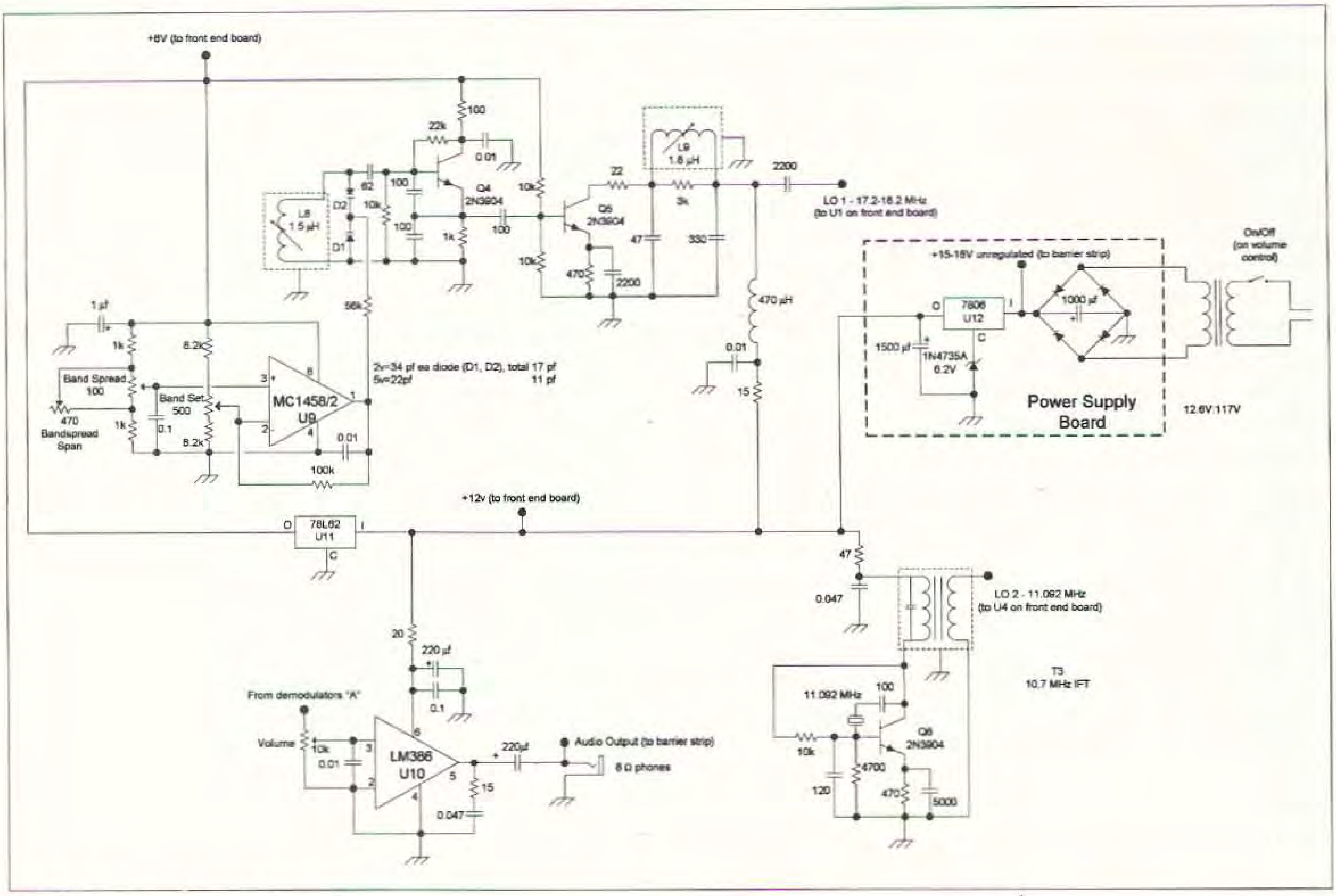

Fig. 3. Oscillator board schematic.

gives another 26 dB gain. The AM-CW/SSB switch is a 4PDT push/pull unit mounted on the BFO tuning control (just like the AGC switch and IF gain control), one section used to select AM or CW/SSB, and the other to turn the BFO on only in CW/SSB mode.

The power supply was added as an afterthought—the original board set was intended to be experimental and never make it off the work bench, but it worked well enough to justify a permanent power supply. The fact that the junk box had plenty of 6 V three-terminal regulators and zeners, but no 12 V units, accounts for the multiplicity of regulators. Those with different parts on hand may wish to replace U12 and the zener with a 7812. Auxiliary power connections allow operation off +12 V DC regulated, or +15 to +18 V unregulated. Total current required at +12 V is about 90 mA.

Construction

The circuit is laid out onto two five-inch by three-inch single-sided PC boards. The oscillator board shown in **Fig. 5** has the first local oscillator and tuning amplifier, the second local oscillator, and the audio power amplifier. Each local oscillator section is partially shielded. The front end board shown in **Fig. 4** holds the remainder of the circuit and has no overall shielding. Both boards have a good deal of unused space, but not so much that they could be easily combined onto one five-by-three-inch board. Most of the coils are shielded, so the circuit is well behaved even with the oscillator shields removed.

A three-inch by five-and-three-eighths-inch by six-inch box houses the boards and controls, with enough room left over for the power supply perfboard. Alas, the power transformer would not fit inside, so it's mounted on the outside of the rear panel. A barrier strip on the rear brings out the antenna, audio, ground, and auxiliary power connections.

Alignment

It is possible to roughly align the radio by tuning the two IF transformers "by ear" until some usable signal is

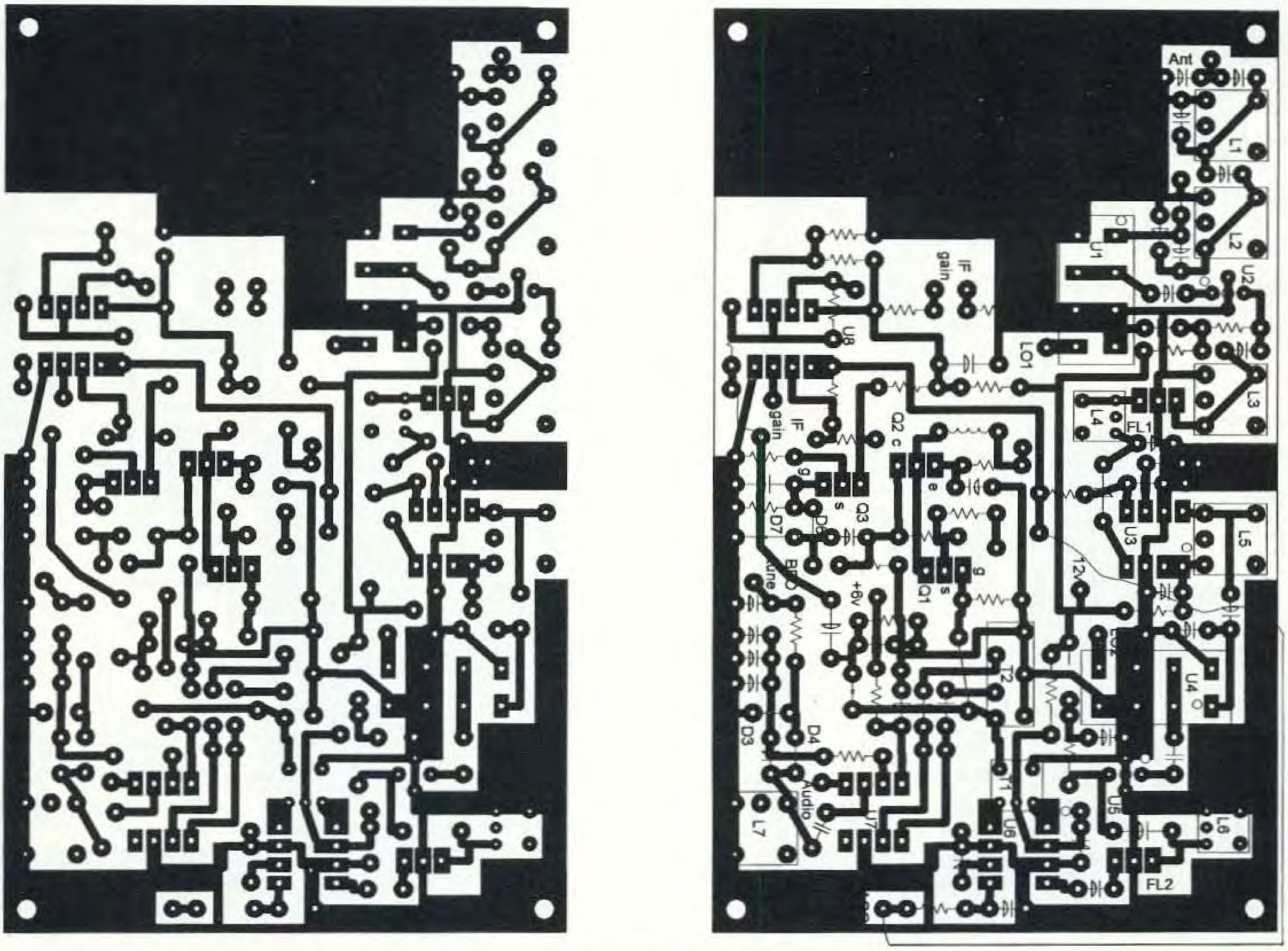

Fig. 4. (a) Front end board. (b) Parts layout from foil side.

found, and then adjusting L6, L5, L4, L3, L2, and L1 for peak signal. A more exact method follows, requiring a signal generator covering 7 MHz, voltmeter with RF probe or some other way of measuring RF voltages up to 20 MHz, and frequency counter.

With bandset and bandspread controls at center, the first local oscillator center frequency should be set to the center of the tuning range, 17.7 MHz, by adjusting L8's slug. L9 should then be adjusted for maximum injection into U1 pin 8, which should be around 0.5 V_{rms}. Adjust T3 for maximum second local oscillator injection into U4 pin 8, again around 0.5 V_{rms}. BFO frequency is centered by setting the two BFO range trimpots to their maximum values, centering the BFO tune control, and adjusting L7 so the signal at U7 pin 7 is at 455 kHz. The voltage at the wiper of the BFO tune control now corresponds to 455 kHz. The trimpots are then adjusted to give the desired range (say, 1500 Hz) on either side of 455 kHz.

Attach the signal generator to the antenna terminals and insert a 1 mV 7 MHz signal, reducing signal level as you proceed with alignment and overall gain increases. You should be able to find this signal with the bandspread and bandset controls. Attach both the counter and voltmeter to the secondary of T1. Rock the bandspread back and forth and adjust T1 for peak voltage near 455 kHz. Proceed backward toward the antenna, adjusting L6, L5, L4, and L3 for peak signal. With the exception of L5, these are elements of low-Q tuned circuits. Adjustment will have very little effect and is not critical.

L1 and L2 establish the shape of the input filter. You may wish to peak both coils to favor a particular frequency, or adjust them so one peaks

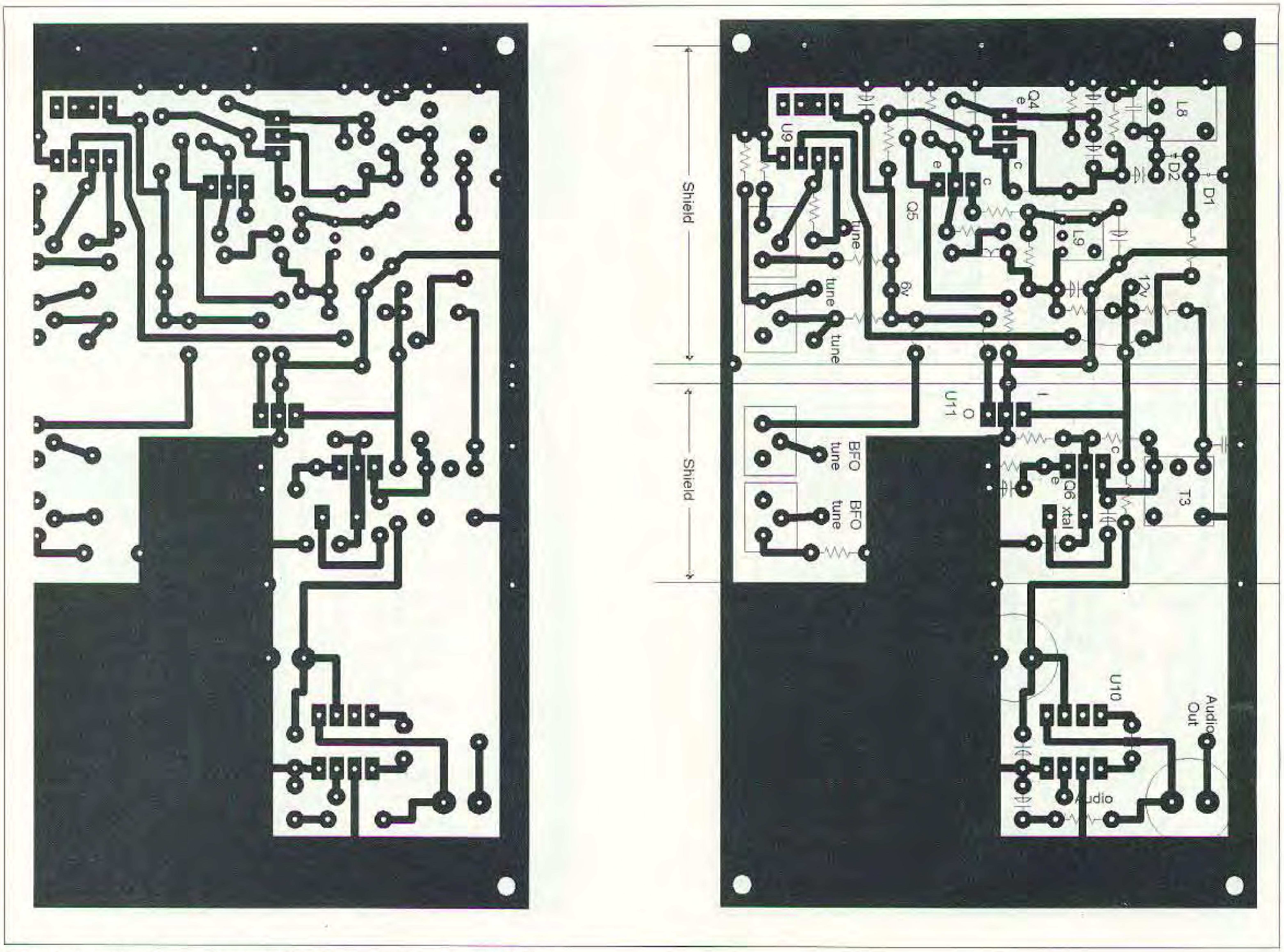

Fig. 5. (a) Oscillator board. (b) Parts layout from foil side.

below the center of the tuning range, and one above center, giving a flatter response.

Antenna

My unit was first tested on Field Day, so there were plenty of signals to practice with. Even with plenty of signals (and don't forget, lots of atmospheric noise), a short length of wire on the antenna will not suffice. At 16 feet of elevation, I have a dipole cut for 6.5 MHz, and a 75-foot random wire. Both these antennas, plus a cold water pipe ground, worked well.

Photo A. *Receiver shown with frequency counter and speaker. Note how the speaker, which normally accompanies my Heathkit SB-310 receiver, dwarfs both the radio and frequency counter.*

Operation

The bandset control can tune AM signals by itself if you have patience, but then that's what the bandspread control is for. I have my bandspread span trimpot adjusted to give about 80 kHz/revolution, which is fine for AM. Decrease bandspread span resistance, giving a smaller tuning range, if you concentrate on CW and SSB. When the BFO is on, set the BFO tune pot to center and locate the signal, then adjust for the desired sideband and audio quality.

I generally set audio gain to about one-third, turn on AGC, and use the IF gain control (which functions even with AGC on) to adjust overall gain. The AGC responds to severe atmospheric noise in an annoying way, so in that case I turn it off. There is plenty of overall gain, and enough audio to drive a speaker quite nicely.

Modifications

If you adhere to my "use the junk box" rule, you may wish to change the circuit to match your own hoard of parts. The first local oscillator, for example, could use a nice vernier-driven variable capacitor in lieu of the

Parts List

D1, D2	MV209 29 pF varactor
D3, D4	MVAM108 500 pF varactor
D5	1N34A germanium diode
D6, D7	1N914 silicon diode
FL1	10.7 MHz ceramic filter, 230 kHz bandwidth
FL2	455 kHz ceramic filter
L1, L2, L8	1.5 µH slug tuned
L3	2.2 µH slug tuned
L4	15 µH slug tuned
L5	8.2 µH slug tuned
L6	120 µH slug tuned
L7	150 µH slug tuned
L9	1.8 µH slug tuned
T1	455 kHz IF transformer
T2	13 trifilar twisted turns on FT-37-77 core
T3	10.7 MHz IF transformer
U2, U5	MAR-1 MMIC wideband amplifier
U1, U4	SBL-1 double balanced mixer
U3, U6	MC1350 RF/IF amplifier
U7	NE602A mixer/oscillator
U8, U9	LM1458 dual op amp
U10	LM386 audio amplifier
U11	78L62 low power +6 V regulator
U12	7806 +6 V regulator

***Table 1.** Parts list.*

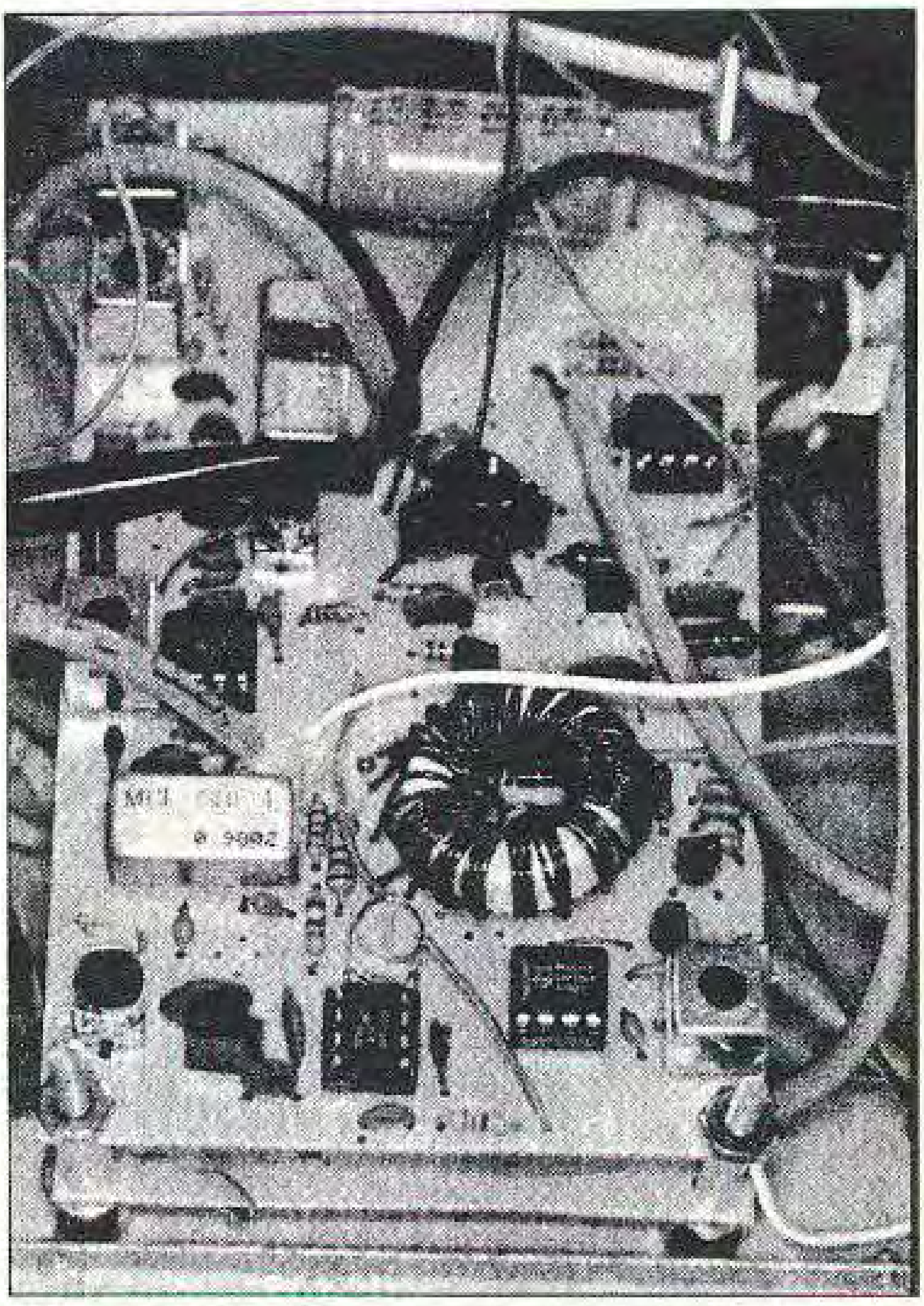

Photo B. Inside view. Large toroid is T2.

varactors, thereby entirely eliminating U9 and the bandset control. The same is true for the BFO. Both these modifications would improve frequency stability, which is a little wild for the first couple of minutes, but very solid thereafter.

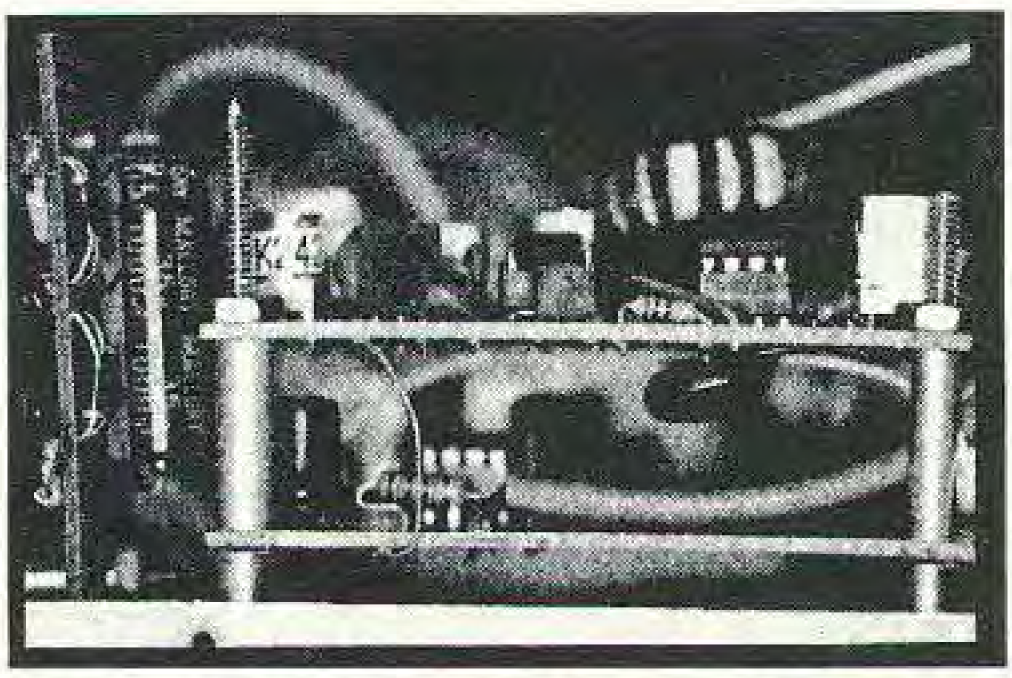

Photo C. Inside view showing stacked PC boards and power supply perfboard.

There is enough space on the front end board to accommodate all of OH2GF's demodulator. The biggest component, T2, is already there. The SWL in particular should read OH2GF's article cited above before going ahead with the whole circuit or an AM-only version. Don't plagiarize my excuse about not being able to find an NE604!

L3, L4/C1, and L6 are impedance matching components. The circuit has sufficient gain that these components can probably be eliminated entirely. The π-section filter using L9 should not be removed, though: U1 and U4 like to see 50 Ω at each port. Speaking of filters, replacing the front end filter with one centered on 28.4 MHz would allow the low end of 10 meters to be tuned, with the first local oscillator used as is, but tuning on the low side. A single-stage RF amplifier might be needed to get the noise figure to a reasonable level.

There is only one second IF bandwidth: 6 kHz, determined by FL2. This is fine for AM, but a little wide for SSB and very wide for CW. An audio bandpass filter could be built from another op amp, and U9 has a spare section that could be used for this purpose. 73

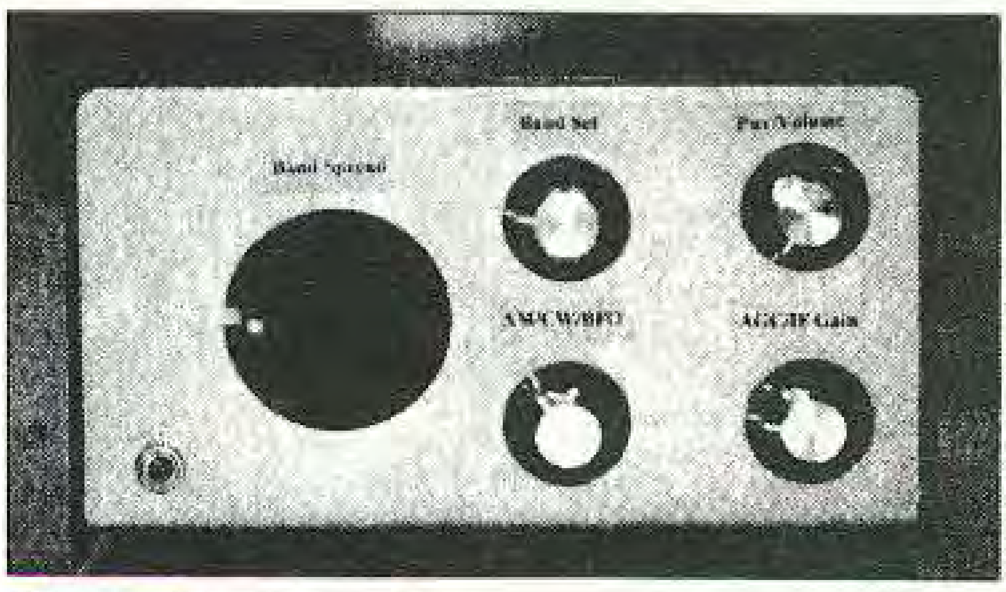

Photo D. Front view.