Radar Detector to Microwave Receiver Conversion

Listen on 10 GHz, cheap.

by Steve J. Noll WA6EJO

The abundance of so-called "police radar detectors" made me wonder if these devices might have a useful application for the amateur microwave experimenter. These self-contained receivers are designed to detect police speed-measuring radar energy around 10.525 GHz (also 24.125 GHz in K-band), just above the 10.0 GHz–10.5 GHz Amateur Radio Service allocation.

Although there are plenty of these devices on the market, many of them are expensive for experimenting with. However, C.O.M.B. Company had been selling the BEL XKR series detector for very reasonable prices. I just couldn't resist! (The C.O.M.B. Company is located at 1405 Xenium Lane N., PO Box 32, Minneapolis MN 55440-9176. Tel. 800-328-0609 or contact BEL-Tronics, 20 Center Dr., Orchard Park NY 14127. Tel. 716-662-0522.)

I opted for the BEL XKR-IX Micro-Eye model although any of the XKR series should be similar. The Micro-Eye is a dual-conversion superheterodyne X-band and K-band detector. Although this article applies specifically to this particular model, other modern detectors may be usable, too.

Inside the Micro-Eye

The Micro-Eye is housed in a 1.25" x 4.25" x 4.5" two-piece plastic case. Opening the case proved to be the most difficult part of the entire project! It's glued shut. Careful and persistent prying with a knife will separate the halves to reveal the high-quality electronics inside.

The detector's circuitry is divided between two printed circuit boards. One board contains the controller section of the detector (not used for this project). The other contains all of the RF circuitry and a horn antenna. These two boards conveniently plug together via a 6-pin connector. See Photos B and C.

The controller printed circuit board contains a couple of comparator ICs (MC3302 and LM393), an LM358 dual op amp, and a 78L05 voltage regulator. A custom controller chip appears in the center of the board. About 60 discrete components round out the circuitry.

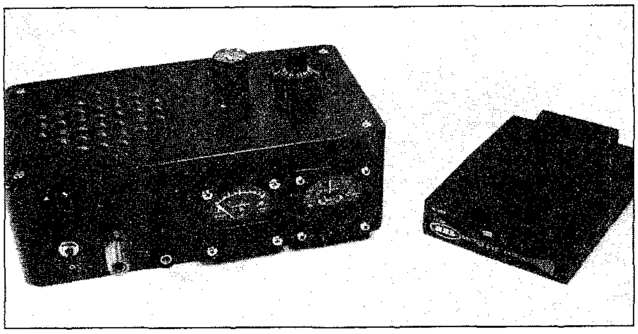

Photo A. The finished product (left) and the original radar detector (right).

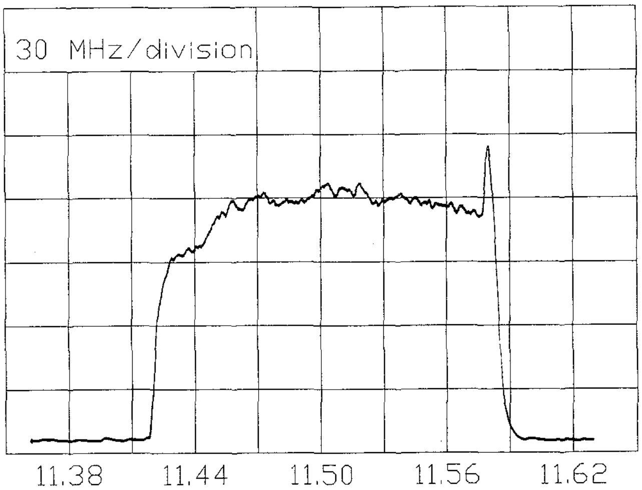

Figure 1. This plot shows the detector's VCO sweeping from 11.4 GHz to 11.6 GHz.

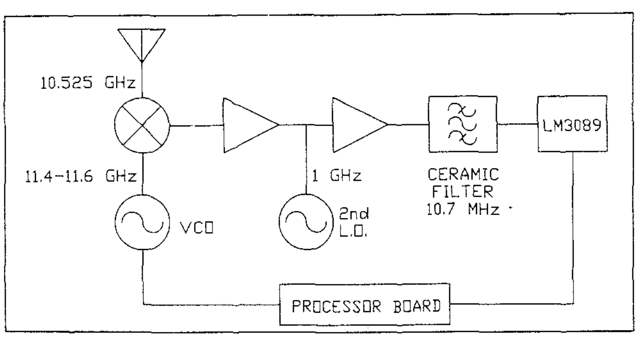

Figure 2. Block diagram of the radar detector.

Metalized, molded plastic covers most of the RF circuit board and forms three sides of the horn antenna. The circuit board itself serves as the fourth side. Some sections of the metalized plastic also provide shielding for the microwave circuitry. A dozen screws fasten the plastic cover to the circuit board. Photo B shows the detector's RF circuit board and metalized plastic horn.

Removing the cover reveals that the microwave circuitry is actually on a third daughterboard, previously hidden underneath (see Photo C). The tiny dimensions of the etched microstrip lines testify to the very high frequencies involved. There are two SOT packaged transistors and a mixer diode in a "beam-lead" package. The mixer diode is incredibly small—only about 0.01" square! Use great care when handling circuit boards with such minuscule devices.

How It Works (More or Less)

Of course, the radar detector instructions didn't include a schematic or theory of operation. Snooping, just plain guessing, and a spectrum analyzer helped me ascertain how this device worked, and whether it could be useful to the microwave experimenter.

Experience dictates that if this is a superheterodyne receiver, it may well radiate some of its local oscillator('s) energy. And sure enough, it does. I pointed a small X-band horn on the input of the spectrum analyzer (a Hewlett-Packard 8551B with a 8441A pre-selector) at the horn of the radar detector and picked up a weak signal sweeping between 11.4 GHz and 11.6 GHz (see Figure 1). The sweep rate was about 40 hertz, but it turns out that this was not the only local oscillator involved.

If this device is meant to receive signals around 10.525 GHz, then there may well be an IF between 11.4 GHz minus 10.525 GHz, and

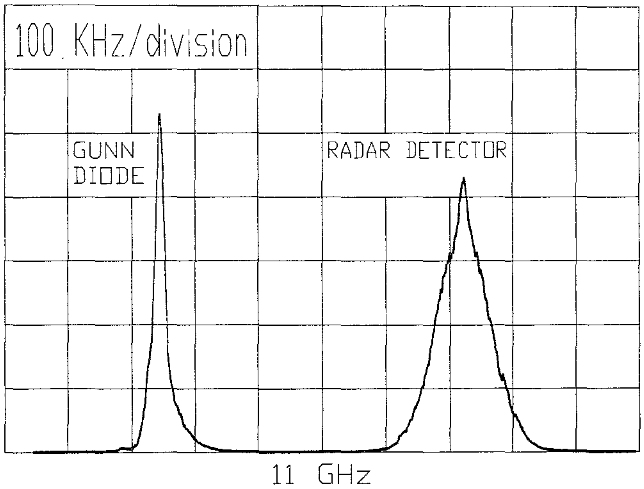

Figure 3. A comparison of the radar detector's VCO stability to that of a Gunn diode oscillator.

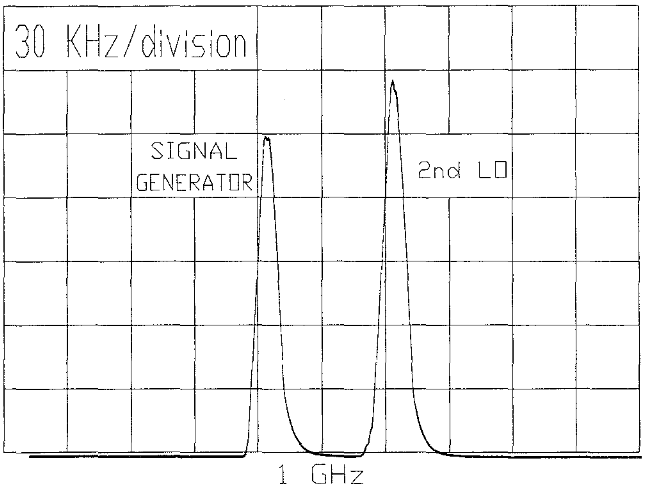

Figure 4. A comparison of the radar detector's second LO stability to that of a signal generator.

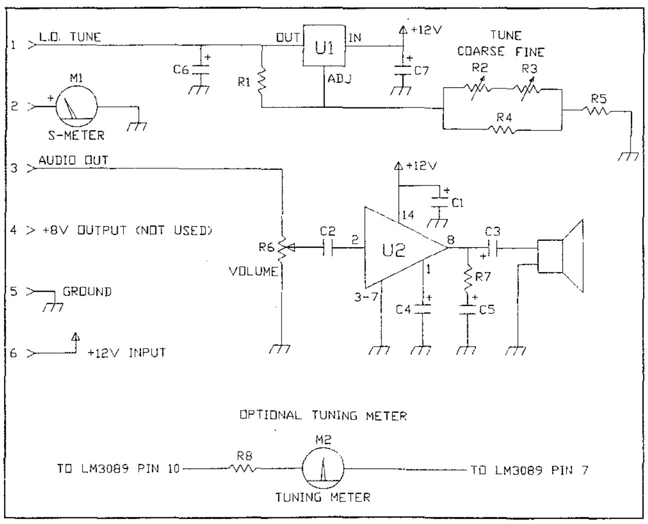

Figure 5. Schematic of the new circuit board.

11.6 GHz minus 10.525 GHz. "Sniffing" around the circuit board with the spectrum analyzer revealed a strong signal at about 1 GHz. This "second LO" signal was not swept in frequency.

Further examination revealed a welcome sight: a standard LM3089 FM Receiver IF System chip! Now here is something familiar with a 10.7 MHz input, an audio output, along with provisions for an S-meter and AFC. The input of the LM3089 is preceded by a 10.7 MHz ceramic filter which in turn is preceded by a couple of what appear to be microwave transistors. The first transistor amplifies the 1 GHz signal from the microwave circuit board and passes it on to the second transistor, which is also fed by the 1 GHz second LO, mixing the received signal down to 10.7 MHz (see Figure 2 and Photo C).

The 1 GHz second local oscillator is a TO-92 packaged transistor, while the first LO is comprised of the two SOT packaged transistors on the microwave daughterboard. This first LO, of course, is actually a VCO (Voltage Controlled Oscillator.)

Actually, the VCO probably generates RF at a lower frequency, the 11 GHz being harmonically generated in the mixer diode. With so many signals, and their possible mixes, it's hard to be sure even with the aid of a spectrum analyzer. The VCO/mixer diode combination also probably generates signals from 22.8 GHz to 23.2 GHz for the reception of K-band speed radars. The sweeping of the first LO frequency is probably done to make sure that any and all signals in the two radar bands are detected, and to make critical RF stage alignment unnecessary. A clever approach.

Modifying the Detector

The presence of the LM3089 FM IF chip hints that the radar detector might be easily adaptable to reception of Amateur Radio Service 10 GHz FM signals, such as those generated by M/A-Com Gunnplexers or Solfan transceivers. Two things still must be done: 1) Stop the first LO from sweeping and make it tunable. 2) Determine if the two LOs have sufficient purity and stability.

It turns out to be quite easy to accomplish the first item. The first LO is powered through one of the pins of the 6-pin connector that connects the RF and controller boards. If that pin is bent so that it doesn't mate with the connector, a variable bench supply can be hooked to it. In my unit, a 3.64 volt DC input made the VCO generate 11.5 GHz, while 5.9 volts yielded 11.0 GHz. The VCO drew only about 1 mA.

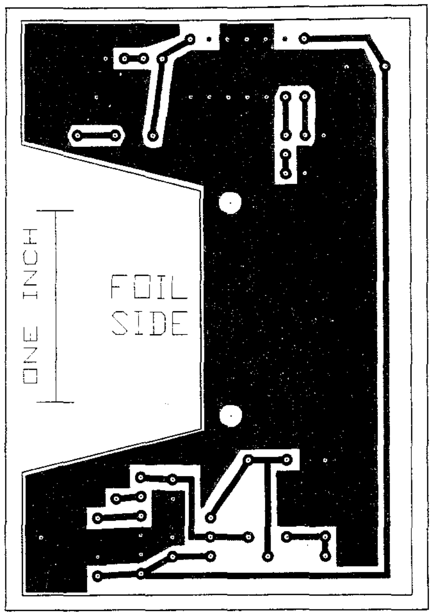

Figure 6. Foil side of the PCB.

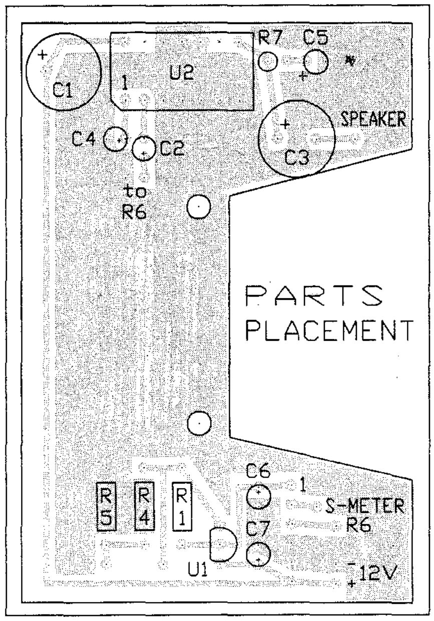

Figure 7. Parts layout.

To check for purity, I observed the first LO signal on the spectrum analyzer side-by-side with a signal generated by a Gunn diode oscillator tuned a few kHz away. Although a Gunn diode signal might not be considered a paragon of purity, it does provide a valid guide, especially since the radar detector will be receiving Gunn diode signals in its new life. Figure 3 shows the result. The first LO signal on the right is much broader than the Gunn diode signal on the left. This is not good.

Note that the significant "pulling" effect of moving one's hand in front of a Gunn diode

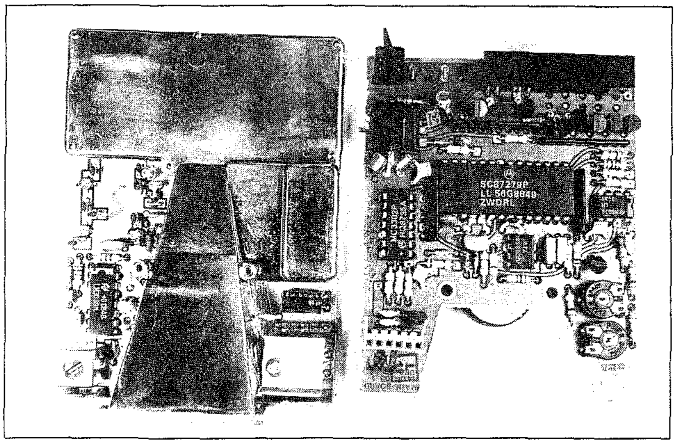

Photo B. Inside the radar detector. RF board on the left. Controller board (not used) on the right.

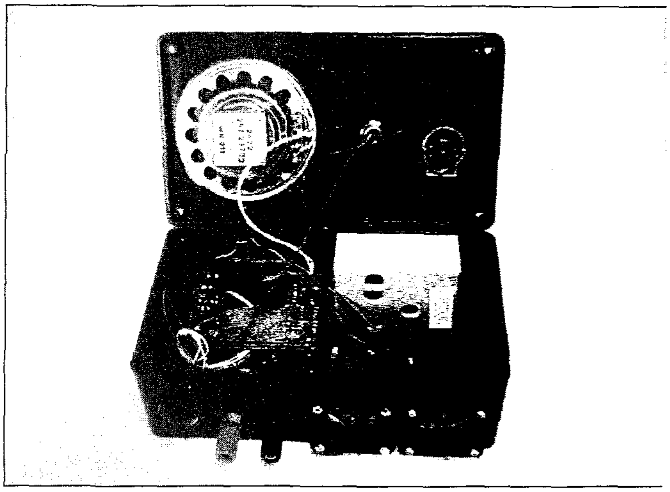

Photo E. The finished unit with the cover open.

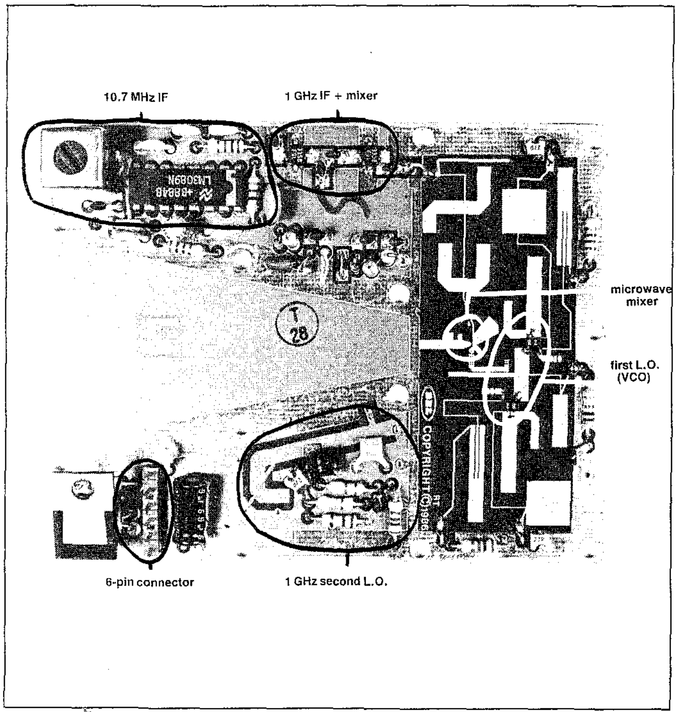

Photo C. A close-up of the RF circuit board after the plastic cover has been removed.

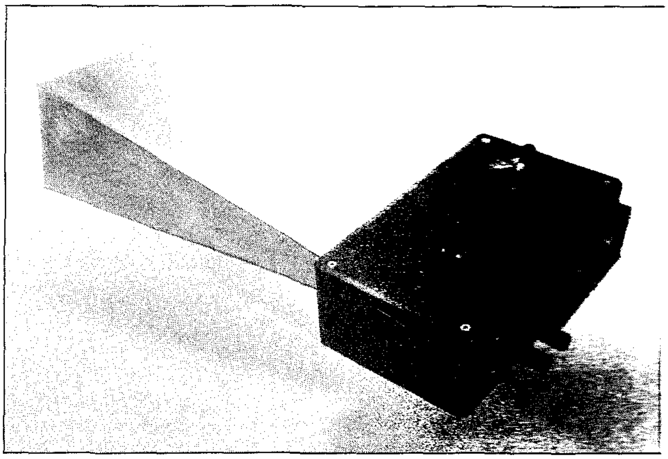

Photo F. The finished unit with the horn extension installed.

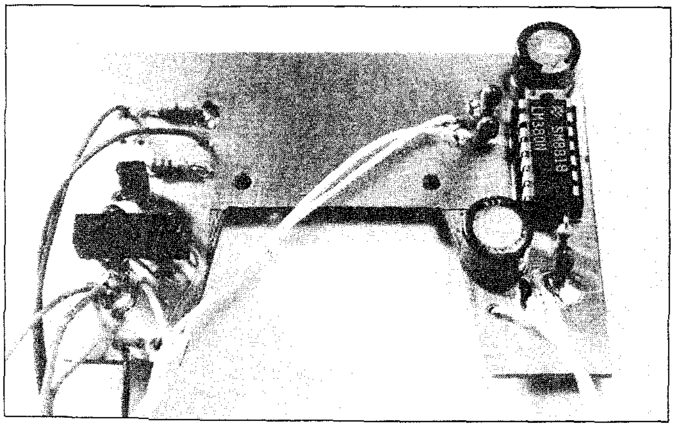

Photo D. The component side of the new printed circuit board.

transmitter horn is absent in the radar detector. The first L.O. is noisy, but reasonably stable.

The 1 GHz second LO signal is much more acceptable. In Figure 4, the 1 GHz LO signal (right) is identical to the signal from a TS-419/U signal generator (left).

At this point we know that the radar detector can receive FM signals due to the presence of the LM3089 IC. Also, it can be tuned to receive in the amateur portion of X-band by powering the VCO used as the first LO with a variable power supply. The question remaining is whether the first LO signal is good enough to receive clear signals from the kinds of transmitters most amateurs presently use on microwave. The easiest check is to just try it.

Checkout

I have had an X-band beacon in continuous operation from a local mountaintop for some 10 years (see my article, "X-band Beacons," in the January 1987 issue of *Ham Radio*). Reception of a familiar, real-world, "known" signal from this beacon would prove the capability of the radar detector.

I rigged up a perfboard circuit with an LM317 variable voltage regulator and an audio amplifier (see Figure 5). This perfboard replaced the detector's controller circuit board. The LM317 circuit used a 10-turn pot for voltage adjustment. This circuit was designed to cover 3.64–5.9 volts, or 11.0 GHz–11.5 GHz, out of the VCO. The audio amplifier, an LM380, was connected to the audio output of the RF board's LM3089. Time for a DXpedition!

At a convenient location near my house, about 10 miles from the beacon, I can get a solid signal. I parked there and just pointed the modified detector through the car window and slowly turned the 10-turn pot—and there was the beacon's MCW ID signal! It wasn't strong, but it was surprisingly stable. And this is using only the radar detector's tiny horn for the antenna. I was sold on the fact that a modified police radar detector should make a great microwave bench-servicing tool and portable field-test receiver.

Further tests performed on the bench revealed that the modified radar detector produced usable audio when receiving signals from my M/A-Com Gunnplexer transceivers. It was also sensitive enough to pick up the 10 GHz calibration signal of a 1N23 diode driven by a 2 meter handheld (see "X-band Calibrator" in the April 1981 issue of *Ham Radio*).

The Final Design

The next step is to tidy up the circuitry, especially the added audio amplifier. Perfboard is not a good medium for high gain amplifiers of any frequency. A printed circuit board's solid groundplane helps keep unwanted oscillations and feedback under control (see Photo D and Figures 6 & 7). Two 10-turn pots with counting dials are very desirable for tuning the VCO. One, R2, serves as coarse tune. The other, R3, is fine tune. R4 and R5 set the range of voltage available. The values shown allow tuning through the entire amateur X-band (10.0 GHz–10.5 GHz).

These values may have to be adjusted to each particular Micro-Eye receiver. Be sure to test the final circuitry before plugging the new circuit board into the radar detector RF circuit board. Note that microphonics, or vibration-induced feedback, may be introduced if the speaker is mounted too close to the molded plastic shield. An S-meter, a zero-center tuning meter, and a frequency meter are optional add-on's.

The new circuit board can use the 6-pin connector that was removed from the unused controller circuit board. The optional zero-center tuning meter wires directly to pins 7 and 10 of the LM3089. The result is a circuit board that plugs into the Micro-Eye RF board, replacing the original controller board.

Packaging is up to you. I found that everything, including a NiCd battery, fit nicely in a 7″ x 4″ x 3″ plastic box (see Photo E).

Parts List

Capacitors, all 16 WVDC or better.	
C1	25 µF electrolytic or tantalum
C2	0.1 µF
C3	100 µF electrolytic or tantalum
C4	4.7 µF electrolytic or tantalum
C5	0.1 µF
C6	1 µF electrolytic or tantalum
C7	1 µF electrolytic or tantalum
Resistors.	
R1	220 ohm ¼-watt fixed
R2	1k 10-turn pot (coarse tune)
R3	100 ohm 10-turn pot (fine tune)
R4	680 ohm ¼-watt fixed
R5	390 ohm ¼-watt fixed
R6	10k pot (volume)
R7	2.3 ohm ¼-watt fixed
Semiconductors.	
U1	LM317L variable voltage regulator
U2	LM380N audio amplifier
Miscellaneous.	
M1	S-meter, 100 µA movement
1	6-pin connector (remove from unused controller circuit board)
2	ten-turn counting dials
1	8 ohm speaker
1	PC board
Note: A blank PC board is available from FAR Circuits, 18N640 Field Court, Dundee IL 60118 for $6 + $1.50 shipping/handling.	
Optional, for center-tune meter.	
M2	100 µA zero-center meter
R8	4.7k ¼-watt fixed

Horn Antenna Extender

The Micro-Eye presents a bit of a problem if you want to change the antenna. Its antenna is rather closely integrated into the entire RF board design. You don't have a handy coax connector or waveguide flange to hook things to. Its horn does work quite nicely, and would probably make a satisfactory feed for a 1′ to 3′ dish.

As an experiment, I made an extension to the integral molded horn, fashioning it from double-sided copper-clad printed circuit board. The extension sleeves inside of the existing horn (see Photo F).

Remember: *You must be very careful not to touch the mixer diode located inside of the horn!*

This extension adds an estimated 8 dB of gain. Field tests verified a marked improvement in signal strength.

You could try modifications I didn't attempt, such as adding an AFC (Automatic Frequency Control), or replacing the horn antenna with an adaptor to a standard waveguide flange or coax connector. The latter modification would allow measurement of the noise figure of the receiver.

The BEL Micro-Eye police speed radar detector is easily modified for reception of the 10 GHz ham band. The cost is low and the performance is quite respectable. This device should serve as a useful accessory for the microwave amateur.

73

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