A Dual Mixer for 5760 MHz with Filter and Amplifier

This mixer for both transmit and receive sides of a transverter provides good performance.

By Paul Wade, N1BWT

At Microwave Update '92 in Rochester, I presented a description of my modular building-block approach for assembling a transverter for 5760 MHz.[1] I've used this transverter for 3 years, and recently NJ2L described his transverter that uses the same mixer, so perhaps it's time to describe what we've learned and add some improvements.[2]

Mixer

The heart of any transverter system is the mixer, and there are few choices available for 5760 MHz. A recent article by N2SB described a transverter assembled from surplus components.[3] Many components used in the 5.9 to 6.4-GHz microwave relay band work well and are readily available at flea markets, but surplus mixers for this band are scarce, so homebrewing is necessary. One option, the KK7B no-tune transverter, has a simple bilateral mixer for this band, used for both receive and transmit, so switching is needed to use separate power amplifier and receive preamp.[4] Having separate mixers for transmit and receive is preferable so that each path may be optimized.

The KK7B transverter has a 1296-MHz IF, probably because of the difficulty of reproducibly making a sharp filter—or any other high-Q circuit—on a printed-circuit board at this frequency. The dimensions are too small and critical for normal printed-circuit tolerances.

Another transverter, with separate transmit and receive mixers, was described (in German) by DJ6EP and DC∅DA and subsequently reprinted in *Feedpoint* and *73*.[5,6] They also described a modification to use a surplus phase-locked microwave source as the local oscillator and made PC boards available, making it even more attractive. I assembled and tested a unit, but the results were abysmal. No apparent mixing was taking place and the only output was strong LO leakage. Closer examination of the mixer circuit suggested that it might be a harmonic mixer, operating with a half-frequency LO. This suspicion was confirmed when we located someone who could fake enough German to translate the article. At 5.7 GHz, the LO input impedance is effectively a short circuit and measures exactly that, preventing it from working as a normal mixer.

It was obviously time for a new design. Some time ago, I designed and built a series of balanced mixers using

[1]Notes appear on page 13.

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90° hybrid couplers from 1296 to 5760 MHz.[7,8,9] Since these worked well as receivers, two mixers were integrated with a third 90° hybrid coupler as a power splitter on a small Teflon PC board. The layout is shown in Fig 1. As expected, it worked well as a receive mixer, with about 7 dB of conversion loss. However, it worked poorly as a transmit mixer, with transmit conversion loss of around 25 dB. This nonreciprocal performance was a mystery until Rick, KK7B, steered me to an article that worked out the math explaining why a 90° hybrid-coupler balanced mixer works as a downconverter but not as an upconverter.[10] I had only worked out the downconverter case and assumed that it would be reciprocal.

One reason for choosing the 90° hybrid coupler is because it is a low-Q structure that uses wide, low-impedance transmission lines, so that dimensions are not extremely critical and performance should be reproducible.

The KK7B mixer used a 6/4-λ rat-race coupler, so the next version, shown in the photograph of Fig 2, used this structure for the transmit mixer (Notes 4 and 9). Line widths are somewhat narrower than the 90° hybrid coupler, but it is still a low-Q structure, so it should still be reproducible. This unit had much better transmit performance, about 8 dB of conversion loss, but its noise figure was not quite as good as the original receive mixer, so the original receive mixer was retained.

The final version integrates "pipe-cap" filters like those in the DJ6EP transverter onto the mixer board (Note 5). These are copper plumbing pipe caps for 3/4-inch copper tubing, with probes 7/32-inch long and tuned with an 8-32 screw. Fig 3 is a cross-section sketch of a pipe-cap filter. Dimensions are from the measurements WA5VJB made on individual filters.[11] PC board layout is shown in Fig 4, and the only other components on the board are the mixer diode pairs and a 51-Ω chip resistor termination. IF attenuators like those in some of the no-tune transverters would also fit and are recommended for the transmit side. No through holes are needed for grounding—the radial transmission line stub acts as a broadband RF short. The diodes I used (Hewlett-Packard HSMS-8202) are inexpensive Ku-band mixer diode pairs; they are available from Down-East Microwave, as are the mixer boards.

Mixer Construction

Construct the circuit using minimal lead length on a Teflon PC board, with soldered sheet brass around the perimeter for SMA connector attachment. This is the procedure I use: The copper pipe-cap filter should be installed first, on the ground-plane side of the board. In preparation, I drill tight-fitting holes for the probes and make clearance holes in the ground plane around the probe holes. Then I measure from the holes and scribe a square on the ground plane that the pipe cap just fits inside. Next I prepare each pipe cap by drilling and tapping (use lots of oil) the hole for a tuning screw, then flattening the open end by sanding on a flat surface. Then I apply resin-paste flux lightly to the open end and the area around the screw hole. A brass nut, added to extend the thread length, is held in place by a temporary stainless-steel screw. (Solder won't

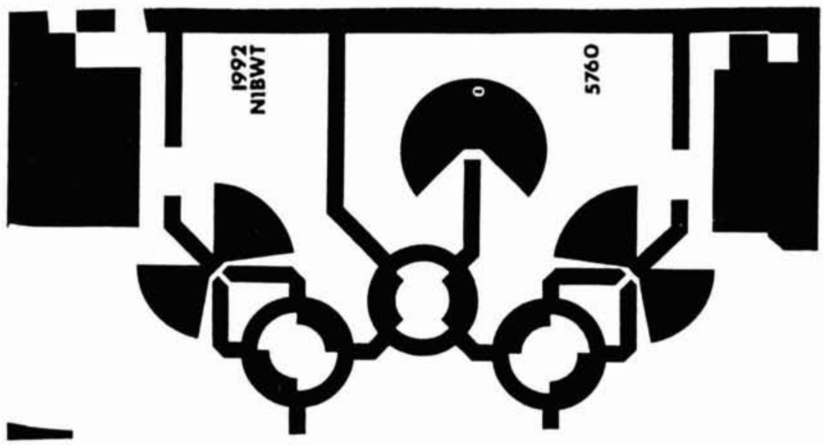

Fig 1—First dual mixer layout

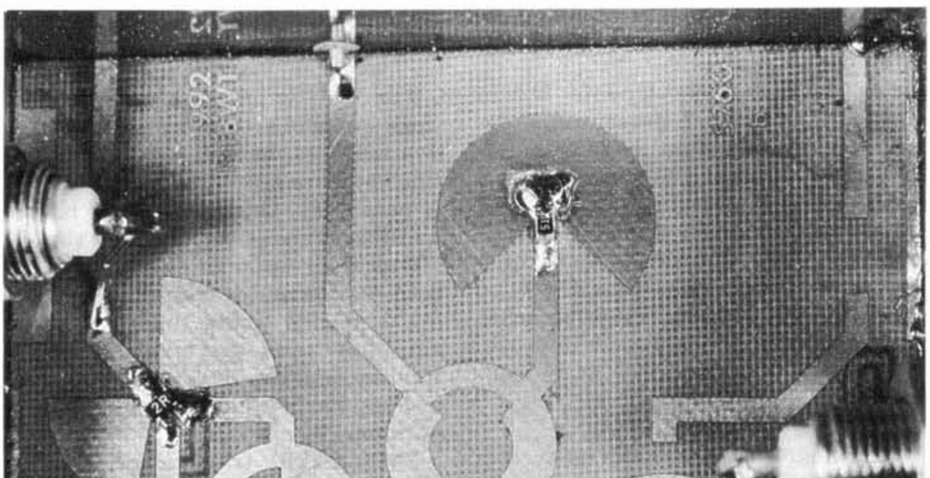

Fig 2

stick to it.) Then I center the open end of the cap in the scribed square on the PC board—the flux holds it in place. Finally, I fit a circle of thin wire solder around the base of each pipe cap and nut, push down gently, and heat each pipe cap for a few seconds with a propane torch until the solder melts and flows into the joints. Don't be shy with the torch—melt the solder quickly and remove the heat.

After everything cools, the temporary stainless-steel screw should be replaced with 3/4-inch long brass tuning screws and locknuts. The remainder of the assembly is performed with a soldering iron, using the photograph of Fig 2 as a guide.

Local Oscillator

Microwave local oscillators normally start with a crystal in the 100-MHz range, followed by a string of multipliers. For 5760 MHz, a multiplication factor of 50 to 60 is necessary—not an easy task. Fortunately, there are many surplus phase-locked microwave sources (often called PLO bricks) available, made by companies such as Frequency West and California Microwave. These units were used in the 5.9 to 6.4-GHz communication band and provide more than enough LO power for the mixer (a 6-dB attenuator was needed with mine). Some units have an internal crystal oven; after a few minutes warm-up, stability is comparable to that of a VHF transceiver. Operation and tune-up of these units has been described by KØKE, WD4MBK and AA5C.[12,13,14] The sources can be used unmodified to provide high-side LO injection, above 5760 MHz, or modified to operate below 5760 for normal low-side injection.[15] Unless you are obsessive about direct digital readout, high-side injection using LSB and reverse tuning is perfectly acceptable. For CW operation, there is no difference.

Most of the available sources operate on −20 V. This is only a problem for portable operation. WB6IGP has described a +12 to −24-V converter, and surplus potted converters are occasionally found.[16] A three-terminal regulator IC provides the −20 V. In order to prevent switching noise generated by the converter from reaching the LO, the converter is contained in a metal box with RFI filtering on both input and output.

Waveguide Band-Pass Filter

A good filter is essential for a serious microwave station, particularly for mountaintop operation. Most accessible high places are crowded with RF and microwave sources, so the RF environment is severe. On other bands, I've seen no-tune transverters with only printed filters fold up and quit in mountaintop environments.

If high-gain amplifiers are used, a good filter is necessary. When I added a surplus power amplifier like the one used by N2SB, the additional 40 dB of gain was enough to amplify the LO leakage through the pipe-cap filter to about 1/4-W (Note 3). Not only is this wasted power, it is also outside the ham band.

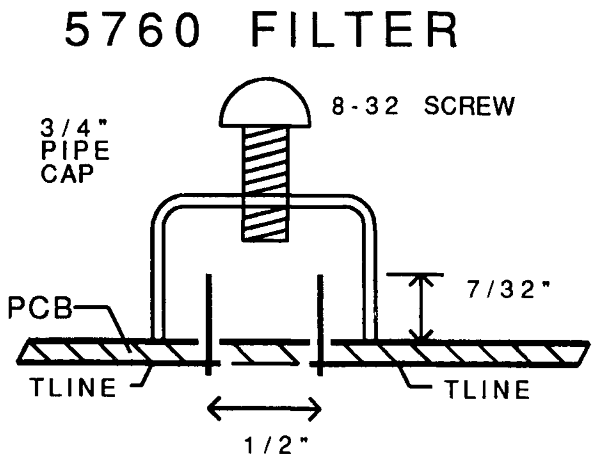

Fig 3—Pipe-cap filter cross-section

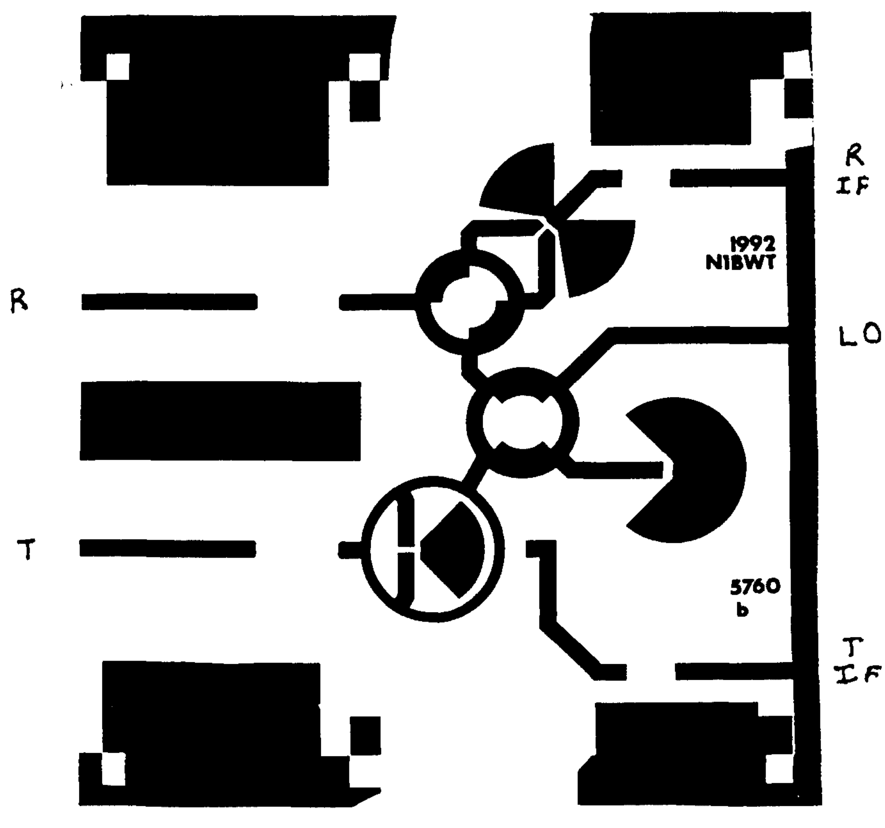

Fig 4—Layout of dual mixer with filters

The best filter I've tried is a waveguide post filter, such as the 10-GHz ones described by N6GN.[17] It is easily built using only a drill, tuning is smooth and non-critical and the performance is excellent. Glenn was kind enough to calculate dimensions for 5760 MHz using standard wave-guide and hobby brass tubing, as shown in Fig 5. Dimensions are for WR-137 waveguide for 5800 MHz; reducing the spacings a hair will give a little more tuning range. I built two units—the second, with careful fit and flux cleaning, had 0.4 dB of loss, while the first, with sloppy fit and soldering, had 0.5 dB of loss. Both units measured as shown in Fig 6, with steep skirts (135-MHz wide at 30 dB down) and no spurious responses detectable (>70 dB down). Tuning was smooth and easy; with high-side LO injection, the LO and image frequencies are outside the tuning range, so 5760 is the only output that can be found while tuning.

Construction hint: Make sure the holes are carefully measured and centered in the waveguide. Centerpunch lightly. Using a drill press, start the holes using a center drill, then drill them out a few drill sizes undersize. Then enlarge them one drill size at a

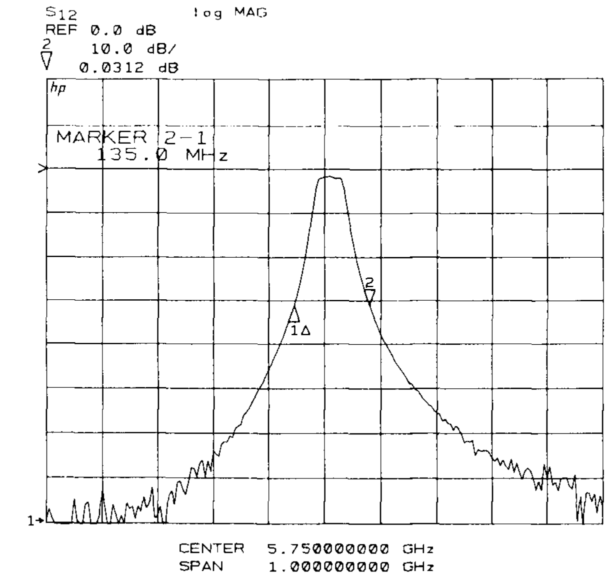

Fig 6—Measured performance of waveguide filter

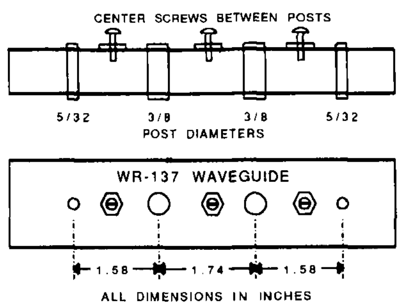

Fig 5—Waveguide filter for 5760 MHz

Table 1—GaAs MMIC Amplifier Performance

Freq	*Gain*	*Return loss*		*|S12|*
MHz		*input*	*output*	
1296	19.2 dB	–3.9 dB	–9.7 dB	–48 dB
2304	20.6	–5.8	–9.7	–37
3456	21.0	–6.4	–10.8	–32
5760	15.4	–7.5	–14.5	–28
10368	7.1	–7.4	–13.9	–20

Noise figure was about 5 dB at 10368 with a 3-dB second stage.

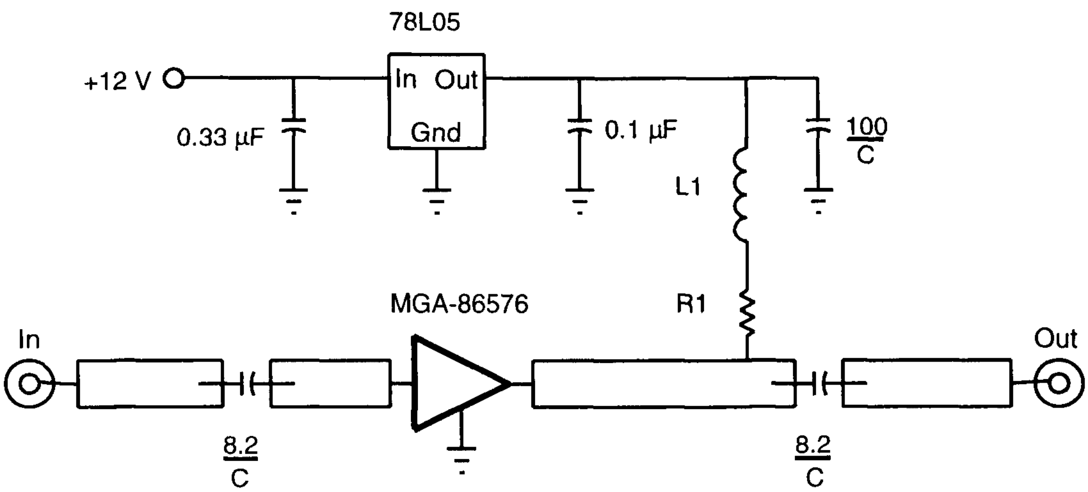

Fig 7

time until the tubing is a snug fit. Solder on a hot plate using paste-rosin flux.

GaAs MMIC Amplifier

Until recently, affordable MMIC devices only worked well at frequencies below 4 GHz. Some devices still had a little gain at 5760 MHz, so it was possible to make an amplifier using multiple low-gain stages.[1,18] A new GaAs MMIC, the MGA-86576 (also available from Down-East Microwave) offers excellent performance to 8 GHz at a very reasonable price. I built an amplifier using one on a scrap of Teflon PC board with a 50-Ω transmission line printed on it. It is important to keep the ground leads very short, so I cut a tight-fitting hole through the board and mounted the MMIC with the ground leads on the ground side of the board and the input and output leads bent up through the hole in the board to the input and output transmission lines. A schematic diagram of this simple amplifier is shown in Fig 7.

The amplifier has about 15 dB of gain and is capable of a few milliwatts of output power, so it would be suitable for a low-power rover station or as a driver for a power amplifier. It also works well as a receiving preamplifier, with a noise figure around 2 dB. The amplifier is quite broadband, with similar noise figure down to 1296 MHz (gain falls off below 1 GHz); measured performance is shown in Table 1.

Conclusion

The dual mixer and two of the GaAs MMIC amplifiers described above could be the foundation of a decent rover station for 5760 MHz, and the addition of a waveguide filter is the next step toward a high-performance station. An obvious next step would be to integrate the MMIC amplifiers onto the dual mixer board; I haven't gotten around to that yet.

Notes

[1]Wade, P., N1BWT, "Mixers, etc., for 5760 MHz," *Proceedings of Microwave Update '92*, ARRL, 1992, pp 71-79.

[2]Healy, R., NJ2L, "A Modular, High-Performance 5.76-GHz Transverter," *QEX*, March 1995, pp 12-15.

[3]Cook, R., N2SB, "5760 MHz from the Junkbox," *QEX*, May, 1994, pp 20-24.

[4]Campbell, R., KK7B, "A Single-Board Bilateral 5760-MHz Transverter," *QST*, October 1990, pp 27-31.

[5]Wesolowski, R., DJ6EP, and Dahms, J., DCØDA, "Ein 6-cm-Transvertersystem moderner Konzeption," *cq-DL*, January 1988, pp 16-18.

[6]Houghton, C. L., WB6IGP, "Above and Beyond," *73*, December 1990, pp 61-62.

[7]Wade, P., WA2ZZF, "A High-Performance Balanced Mixer for 1296 MHz," *QST*, September 1973, pp 15-17.

[8]Wade, P., WA2ZZF, "High-Performance Balanced Mixer for 2304 MHz," *ham radio*, October 1975, pp 58-62.

[9]Keen, H. S., W2CTK, "Microwave Hybrids and couplers for Amateur Use," *ham radio*, July 1970, pp 57-61.

[10]Chang, K. W., Chen, T. H., Wang, H. and Maas, S. A., "Frequency Upconversion Behavior of Singly Balanced Diode Mixers," *IEEE Antennas and Propagation Society Symposium 1991 Digest, Vol 1*, pp 222-225, IEEE, 1991.

[11]Britain, K., WA5VJB, "Cheap Microwave Filters," *Proceedings of Microwave Update '88*, ARRL, 1988, pp 159-163.

[12]Ericson, K. R., KØKE, "Phase Lock Source Update," *Proceedings of Microwave Update '87*, ARRL, 1987, pp 93-95.

[13]Osborne, C., WD4MBK, "Surplus Microwave Local Oscillators, Evaluating and Modifying Them," *Proceedings of Microwave Update '88*, ARRL, 1988, pp 33-41.

[14]McIntire, G., AA5C, "Phase-Locked Microwave Sources," *Proceedings of Microwave Update '91*, ARRL, 1991, pp 113-136.

[15]Houghton, C. L., WB6IGP, "Above and Beyond," *73*, November 1991, pp 66-68.

[16]Houghton, C. L., WB6IGP, "Above and Beyond," *73*, July 1990, pp 68-69.

[17]Elmore, G., N6GN, "A Simple and Effective Filter for the 10-GHz Band," *QEX*, July 1987, pp 3-5.

[18]Hilliard, D., WØPW, "2 GHz to 6 Hz Power Amplifiers," *Proceedings of Microwave Update '87*, ARRL, 1987, pp 78-92.

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For more information contact: Al Ward, WB5LUA, 2306 Forest Grove Estates Road, Allen, TX 75002 or Kent Britain, WA5VJB, 1626 Vineyard, Grand Prairie, TX 75052-1405.

Feedback

Whoops! Figures 8 and 10 are interchanged in R. Dean Straw's, N6BV, July 1995 QEX article "The Effect of Local Terrain on HF Launch Angles." The captions are correct.