high-performance balanced mixer for 2304 MHz

Construction details for a hot-carrier diode mixer using stripline design that can provide a 7-dB noise figure at 2304 MHz

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In a previous article about a 1296 MHz balanced mixer[1] I mentioned using a similar circuit for 2304 MHz. This elicited several requests for information about the 2304 MHz mixer shown in **fig. 1**. However, since I felt that the ceramic board construction was beyond the facilities available to most amateurs, I was unable to respond. Since I was curious to see if simple construction techniques would still work at 2304 MHz, I finally made the version shown in **fig. 2** which uses an ordinary printed-circuit board. To my surprise, the second version exhibits *better* performance than the "professional" one.

The basic design, shown schematically in **fig. 3**, is identical to the 1296 MHz mixer described in *QST* and consists of a 3 dB quadrature-hybrid coupler, quarter-wave stubs for bypassing, and a low-Q pi network for i-f impedance matching. The major difference is the use of 1/32 inch (0.8mm) double-clad, G10 epoxy-fiberglass circuit board, rather than 1/16 inch (1.5mm), to maintain a reasonable aspect ratio. The line dimensions shown in **fig. 4**, however, are more critical because of the thinner board and higher frequency.

I cut the printed-circuit mask directly to size on Rubylith* with a knife and a ruler so it should be possible to duplicate the layout with tape or by cutting the pattern directly into the copper and peeling away the excess. Dimensions A through E, and especially line widths A and B, should be within 0.005 inch (0.1mm) of the values shown for best results.

construction

Construction is exceedingly simple, requiring only a drill and a vise. The circuit board is attached to a shelf in a 2-3/4 x 2-1/8 x 1-5/8 inch (70x54x41mm) Minibox. The shelf dimensions are shown in **fig. 5**. Use enough screws to keep the board flat against the shelf and to provide a ground path for capacitor C4. Metal screws have no effect if they are kept away from the microstrip transmission lines. Approximate placement of the screws can be seen in **fig. 2**.

Critical parts are the blocking capacitors, C1 and C2, the connectors, and, of course, the mixer diodes. The blocking capacitors should be low-loss chip capacitors, preferably physically small to maintain a low vswr. The same considerations, loss and vswr, also apply to the connectors; SMA type connectors similar to the ones shown are available very reasonably from E. F. Johnson.

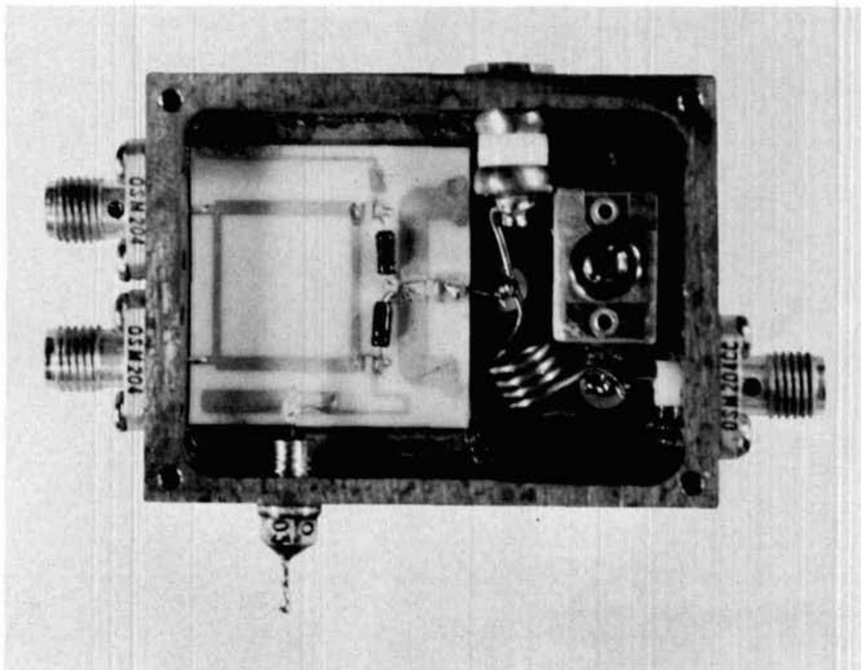


fig. 1. Original balanced mixer for 2304 MHz used ceramic substrate. Small blobs are silver paint used for fine tuning.

adjustment

Adjustment is the height of simplicity. A two-meter converter is connected to the i-f output, and a *clean* 1 to 2 milliwatts at 2160 MHz is fed into the LO connector. Apply about 1.5 mA of bias current to the diodes and apply a

*"Rubylith" is a trademark of Ulano Co.

moderately strong signal at 2304 MHz. When the bias current and i-f trimmer capacitor are adjusted for maximum signal, the tune-up is completed.

performance

A testimonial to the performance of this mixer is that, at the Eastern VHF/UHF Conference earlier this year, the original version won a certificate for the lowest noise-figure 2304 MHz converter. The measured noise figure was 7.1 dB (i-f noise figure, 2 dB), but, in the interest of fairness, W1JAA insisted that 3 dB be added because of the poor image rejection, so the final noise figure was 10.1 dB. The new version described in this article measures *2 dB better*! The mixer has a conversion loss of 6.1 dB.

Noise figure, both theoretical and measured, is the sum of conversion loss plus i-f noise figure. With a 1 dB noise figure at two meters, an overall noise figure of approximately 7 dB could be realized. This should compare favorably with most other mixers at this frequency; W2CQH's interdigital mixer[2] may be better, but it is also more complex. Isolation between the local-oscillator to the rf ports measures 22 dB; this indicates that the hybrid coupler is working properly and that the diodes are well matched to 50 ohms (any power reflected from the diodes will decrease the isolation).

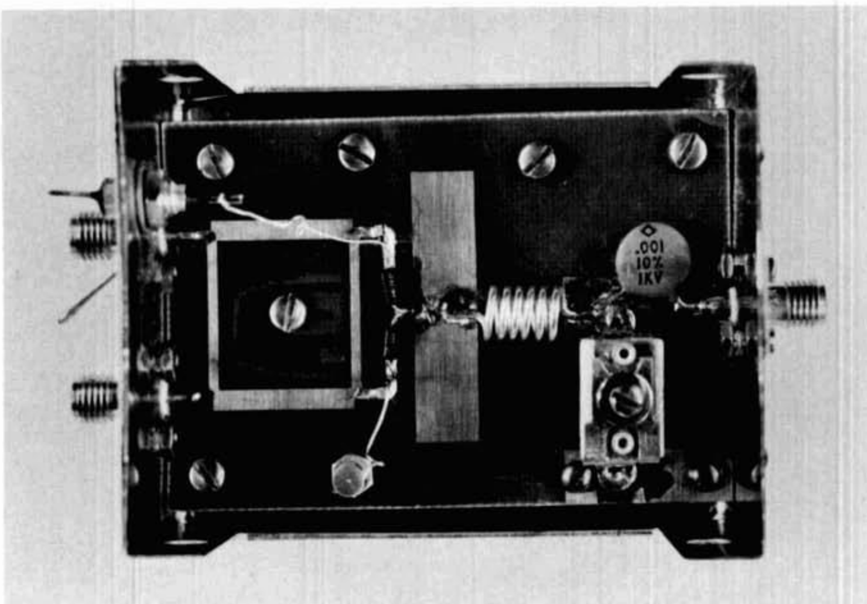
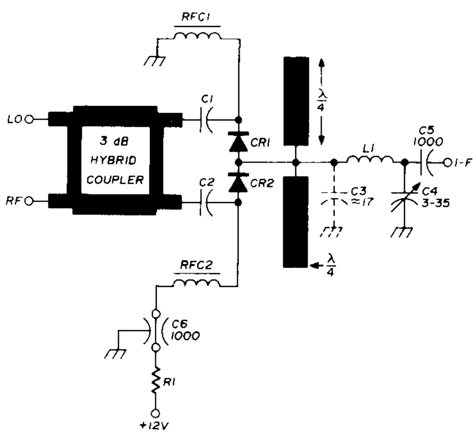


fig. 2. Balanced mixer for 2304 MHz using G10 printed-circuit board. No tuning is necessary.

dc bias

A few words about the value of dc bias in mixers may be in order. I have not seen any other amateur designs which include biasing of the mixer diodes, whereas it is fairly common practice in commercial mixers. Prior to building my first balanced mixer (for 1296 MHz), I made some measurements of diode impedance versus rf signal power (LO) and bias current. The conclusion was that, with dc bias, less



C1,C2	50 to 1000 pF chip capacitor (not critical, see text)
C3	stray capacitance of quarter-wave-length stubs (≈17 pF)
C4	3-35 pF mica trimmer (Arco 403)
C5	1000 pF disc ceramic
C6	1000 pF feedthrough bypass
CR1,CR2	hot-carrier diodes rated for 3 GHz operation (H-P 5082-2535, H-P 5082-2565, Alpha D5501, matched pair not essential)
L1	6 turns no. 18 (1.0mm), 3/8" (9.5mm) long, wound on 3/16" (5mm) mandrel
R1	5k to 15k, vary to set diode bias current
RFC1,2	1 turn no. 30 (0.25mm), wound on 1/16" (1.5mm) mandrel
J1-J3	SMA connector (OSM 215 or E. F. Johnson 142-0297-001)

fig. 3. Schematic diagram of the balanced mixer for 2304 MHz. Dc bias is provided to the diodes to minimize LO requirement. Full-size printed-circuit layout is shown in fig. 4.

LO power is required to raise the diode impedance to 50 ohms, and the impedance is less sensitive to the drive level.

We are, in essence, substituting readily available dc power for hard-to-get rf power! This is borne out by the fact that my mixers work fine at LO levels of one milliwatt, while other, similar designs[3,4] specify around three milliwatts. Also, Tilton recently mentioned[5] several balanced mixers which were rejected by *QST* – their poor performance was apparently due to lack of LO power. Addition of dc bias might have helped significantly.

Bias current is not critical (in this mixer minimum conversion loss was achieved with 1.8 mA of diode current), but it can be varied from 1.0 to 2.6 mA with only a 1 dB increase in loss. With no bias, however, conversion loss increased to 13 dB. Small changes in LO power, simulating normal drift, also had a minimal effect.

One final advantage of dc biasing may be to force the diodes to operate at the same current, and hence at similar impedance, for no attempt at diode matching or individual tuning was made in order to achieve the stated performance.

balanced-mixer design

I have received several queries about designs for other frequencies. These can be made by direct scaling from this design or the 1296 MHz version, following these guidelines:

1. Dimension A is for a characteristic impedance, Z_o = 50 ohms, and B for Z_o = 35 ohms. No change is required if the same board material is used.

2. Dimensions C and D are one-quarter wavelength long at a frequency halfway between the signal and LO frequencies (2232 MHz in this case).

3. Dimension F is one-quarter wavelength long at the signal frequency (2304 MHz).

4. Dimension G is one-quarter wavelength long at the local-oscillator frequency (2160 MHz).

5. Wavelength in microstrip line is a function of Z_o, so use a graph of Z_o and λm if you change board material (different dielectric constant).

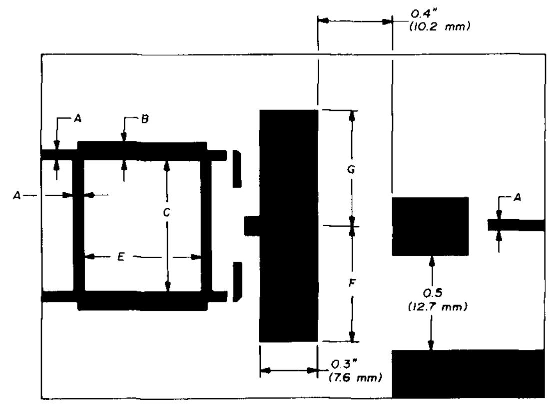
6. Dimension E is D minus A.

7. Use a low Q i-f circuit which matches the impedance of the diodes (100 to 200 ohms at the i-f).

If the same board material is used (1/32 inch G10) scaling dimensions C, D, F and G directly by the ratio of the frequencies will work fine. As mentioned above, good isolation from the LO to rf ports is an indication that everything is working properly; measure this after all other adjustments have been made.

conclusion

The balanced mixer will provide excellent performance which is easily duplicated and maintained. Use of a low-loss filter at the input is recommended to improve image rejection; there are no other responses if a clean local-oscillator signal is used. A preamplifier may be used for even lower noise figure, and the mixer will provide a low vswr load for the preamp to help stability. However, unless you really need the small (and costly) improvement a preamp provides, the mixer alone has two major advantages — it is much harder to burn out, and it will *not* oscillate.



	dimensions	
A	0.053"	(1.3mm)
B	0.096"	(2.4mm)
C	0.696"	(17.7mm)
D	0.678"	(17.2mm)
E	0.625"	(15.9mm)
F	0.610"	(15.5mm)
G	0.650"	(16.5mm)

fig. 4. Full-size printed-circuit board for the 2304-MHz balanced mixer. Microstrip dimensions shown at right may be scaled to other frequencies (see text).

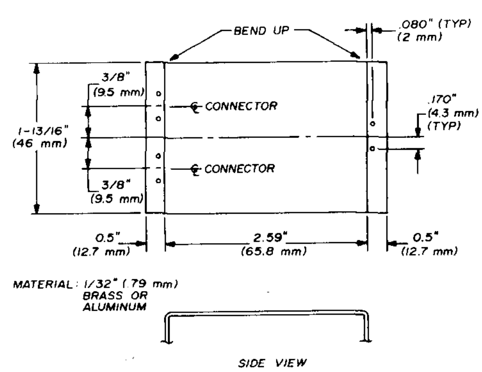


fig. 5. Shelf dimensions for installing the balanced mixer in a standard Bud CU-3000A Minibox.

references

1. Paul Wade, WA2ZZF, "A High-Performance Balanced Mixer for 1296 MHz," *QST*, September, 1973, page 15.
2. Reed Fisher, W2CQH, "Interdigital Converters for 1296 and 2304 MHz," *QST*, January, 1974, page 11.
3. Kurt Bittman, WB2YVY, "Easy-to-Make 1296-MHz Mixer," *73*, July, 1972, page 33.
4. Leroy May, W5AJG and Ben Lowe, K4VOW, "A Simple and Efficient Mixer for 2304 MHz," *QST*, April, 1974, page 15.
5. Ed Tilton, W1HDQ, "Hot-Carrier-Diode Balanced Mixers in UHF Front Ends," (Technical Topics), *QST*, April, 1974, page 51.

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