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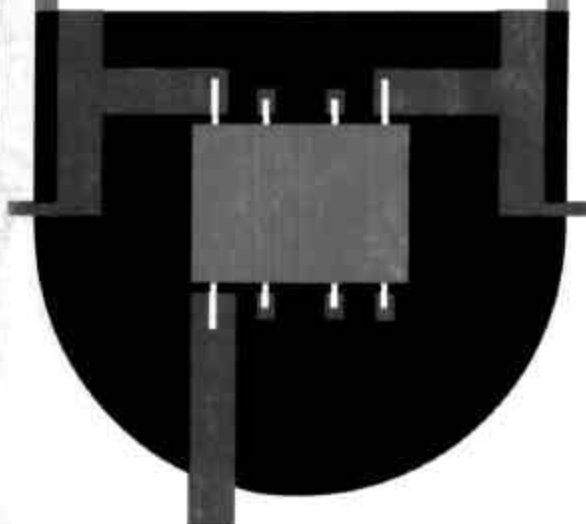
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# *ham* **radio**

*magazine*

JULY 1975

## UHF DOUBLE- BALANCED MIXERS



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July, 1975  
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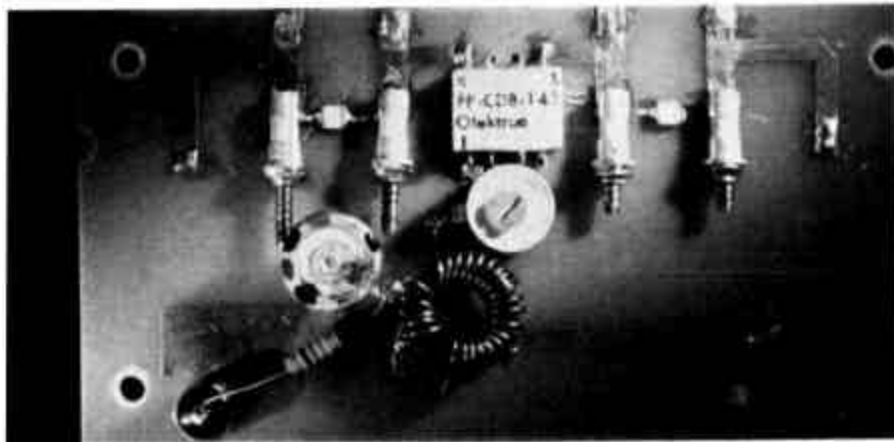
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## how to use double-balanced mixers on 1296 MHz

Modern commercial  
uhf double-balanced  
mixer modules  
improve the performance  
of 1296-MHz converters

Diode balanced mixers have received considerable attention as bilateral mixers for transceiver applications. In a previous article,<sup>1</sup> I outlined a transceiver converter for 1296-MHz ssb including construction details for two suitable homebrew single balanced-mixers. Recent price breakthroughs have now brought within the reach of the serious experimenter several commercial double-balanced mixers which are adaptable for transmit, receive and transceive conversion well into the microwave region. This article describes the use of such mixers in the 23 cm band.

### mixer modules

Since a number of manufacturers offer flatpack double-balanced mixers with identical lead arrangements, a circuit board can be designed which will accommodate a variety of mixer modules. These mixers, some of which are listed in **table 1**, vary primarily in conversion loss and power handling capabil-

Paul Shuch, WA6UAM, San Jose, California 95124

ity. All of the mixers listed here will withstand the injection levels used in the 1296-MHz ssb transceive converter (i.e., 40 mW of local-oscillator injection and 12 mW PEP of applied i-f power in the transmit mode).

functionally equivalent to a popular design which many amateurs have built for lower frequency applications.<sup>2</sup> In theory, all that is necessary to use the mixers is to mount the flatpack device on a circuit board containing connectors

**table 1. Partial listing of flatpack double-balanced mixers suitable for use on the 1296-MHz band. Conversion loss shown is worst cast for the specified frequency range; it may be less at spot frequencies within the overall range. Mixers are listed in order of ascending single-quantity price. Manufacturer's addresses are listed below.**

manufacturer	model	frequency range	conversion loss	approximate price
Olektron Corporation	FP-CDB-145	0.5-1350 MHz	9.0 dB	\$29
Merrimac Industries	DMF-2A-750	50-1500 MHz	9.0 dB	\$40
Vari-L Company	DBM-158	500-1500 MHz	7.5 dB	\$50
Lorch Electronics	FC-200ZF15	10-1500 MHz	8.5 dB	\$59
Watkins-Johnson	M4A	10-1500 MHz	8.5 dB	\$60
Anzac Electronics	MD-614	600-2000 MHz	7.5 dB	\$75

Anzac Electronics, 39 Green Street, Waltham, Massachusetts 02154

Lorch Electronics, 105 Cedar Lane, Englewood, New Jersey 07631

Merrimac Industries, 41 Fairfield Place, W. Caldwell, New Jersey 07006

Olektron Corp., 6 Chase Avenue, Dudley, Massachusetts 01570

Vari-L Company, 3883 Monaco Parkway, Denver, Colorado 80207

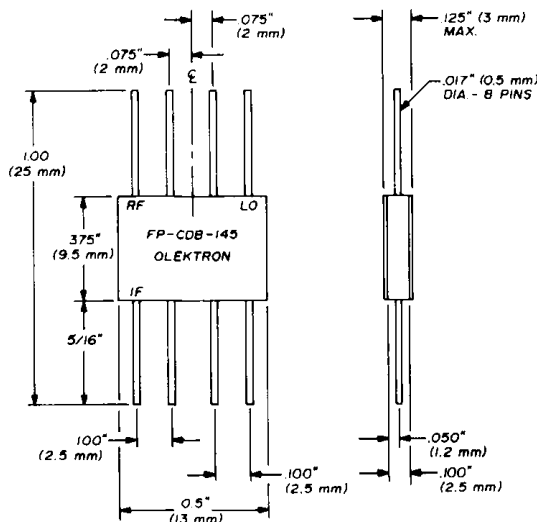
Watkins-Johnson Company, 3333 Hillview Avenue, Palo Alto, California 94304

The commercial flatpack double-balanced mixers all contain a ring of four hot-carrier diodes, typically in a beam-lead pill package, along with two wideband balun transformers. They are

(to each of the three ports) and provide a good ground path for those terminals which must be grounded. Other features can be added to the circuit board to enhance its performance in a particular application.

The circuit board presented in this article is designed to permit transceive conversion to the 23 cm band while providing image filtering at the rf port, spurious response filtering at the local-oscillator port, and resonating the i-f port to 28 MHz.\* Provisions are also made for monitoring mixer current in the dc return to the i-f port.

The prototype of this assembly uses an Olektron model FP-CDB-145 flatpack mixer. Its physical configuration (which is typical of all the flatpack mixer modules) is shown in fig. 1. The Olektron device is the least expensive of the



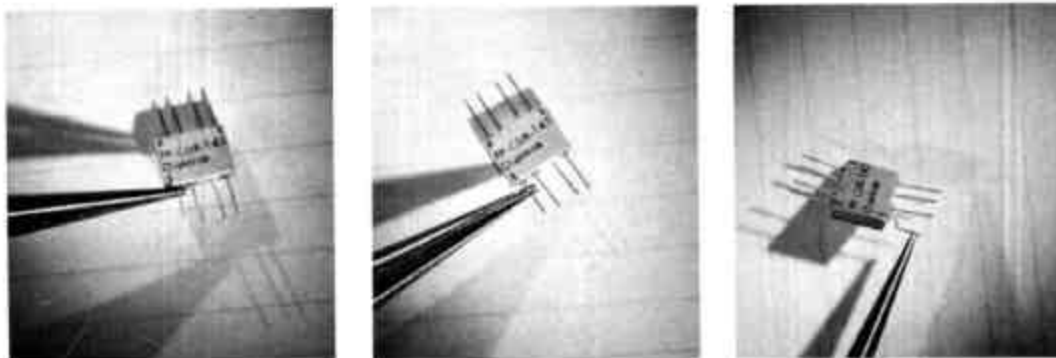
**fig. 1. Physical dimensions and pin layout of typical flatpack double-balanced mixer module.**

\*Other intermediate frequencies may be used by suitable modification of components L5, L6 and C7 in fig. 2.

mixers listed in **table 1**, and offers electrical characteristics which are completely satisfactory for the 1296-MHz transceiver application (see **table 2**). Should lower conversion loss be required, you may wish to substitute one of the more expensive mixers listed in **table 1**. However, as you might expect, each 1 dB of improvement in conversion

with connectors, this filtering is readily incorporated on the circuit board on which the mixer is mounted. In **fig. 2**, components L1 through L6 and C1 through C7 serve this purpose.

As was mentioned previously, it is possible to use any of the flatpack mixers simply by mounting them on a board containing the appropriate con-



To bend the leads on the delicate double-balanced mixer package, first grasp the pins with long-nose pliers very close to the package and bend the lead downward at 90 degrees (left). Then grasp the lead at the bend and form the lead straight out from the package (center). The desired lead configuration is shown on the right.

loss is offset by a corresponding 1 dB increase in cost.

### bandwidth considerations

When applying any of the readily available commercial mixers to narrow-band service, you should be aware of their inherently broad frequency response. The Oelektron unit, for example, is designed for operation from 500 kHz to 1350 MHz. The very bandwidth which is so beneficial in many applications may well prove a detriment here as an absence of selectivity at the rf and local-oscillator ports invites out-of-band spurious responses. My homebrew mixer designs have incorporated frequency-selective circuitry at the various ports. To alleviate interference problems related to unnecessary bandwidth, such filtering should be added externally to any of the commercial mixers. Unless the mixer module is already provided

connectors for interfacing to the three ports. Upon attempting this simplistic approach in a 1296-MHz transceiver converter, however, I found myself with more birdies than the Audubon Society, and enough image to run for office. Only upon incorporating the filtering provisions of **fig. 2** did the melange of signals emanating from the mixer become manageable.

### diode current monitoring

Often it is desirable to monitor mixer diode current during converter operation. This is especially useful while tuning local-oscillator chains, or for determining the adequacy of the i-f injection applied in the transmit mode. Unfortunately, most commercial mixers make no direct provision for monitoring diode current. Again, this feature may be added to the board on which the mixer is mounted.

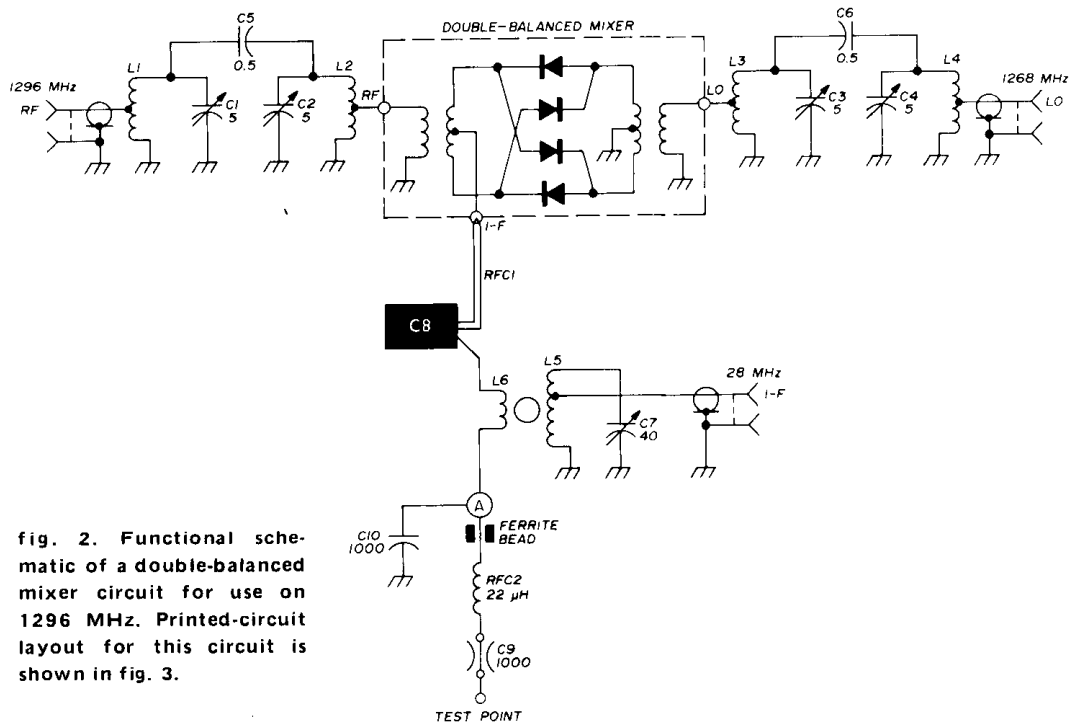


fig. 2. Functional schematic of a double-balanced mixer circuit for use on 1296 MHz. Printed-circuit layout for this circuit is shown in fig. 3.

C1-C4	1.5 pF ceramic piston trimmer (Triko 201-01M or equivalent)	L1-L4	44-ohm 0.1 wavelength shorted microstripline, 0.125" (3mm) wide, 0.5" (13mm) long, tapped 0.2" (5mm) from grounded end
C5,C6	0.5 pF chip capacitor (ATC-100 or equivalent)	L5	1.2 μH, 19 turns no. 22 AWG on Amidon T50-10 toroid core, tapped 5 turns from cold end
C7	10-40 pF ceramic trimmer	L6	5 turns no. 22 AWG on same core as L5
C8	25-ohm quarter-wavelength open-circuited microstripline, 0.3" (7.5mm) wide, 1.14" (29mm) long	RFC1	50-ohm microstripline, 0.1" (2.5mm) wide, 1.20" (30.5mm) long
C9	1000 pF feedthrough capacitor	RFC2	22 μH molded inductor
C10	1000 pF standoff capacitor		
DBM	double-balanced mixer module (Olektron FP-CDB-145 or similar, see table 1)		

The circuit of fig. 2 incorporates a current monitoring provision. Point A is normally connected directly to ground. If the ground is omitted, rectification by the diode quad results in a dc component; relative current may be monitored by measuring the voltage drop with a sensitive vtvm connected between point A and ground. Additionally, proper operation of the mixer requires point A to be at rf ground. Therefore, effective bypassing of *all* rf components must be provided. Bear in mind that the local-oscillator to i-f isolation is only on

the order of 16 dB. Thus, with 40 mW of local-oscillator injection, and without adequate bypassing, a disruptive 1 mW of local-oscillator energy will appear on the bias test point.

In my application the local-oscillator and rf frequencies are sufficiently close (1268 and 1296 MHz, respectively) to be adequately bypassed by capacitor C8, an open-circuited quarter-wavelength microstripline of low characteristic impedance. Grounding the i-f component (28 MHz in this case) is accomplished with bypass capacitor C10. In

addition to the bypassing components, an rf choke and ferrite bead are used to isolate the bias test point from any remaining i-f, local-oscillator or rf signals.

tors of the BNC, TNC or SMA variety. Fig. 6 details the fabrication of these launchers and shows a method for mounting them to the circuit board.

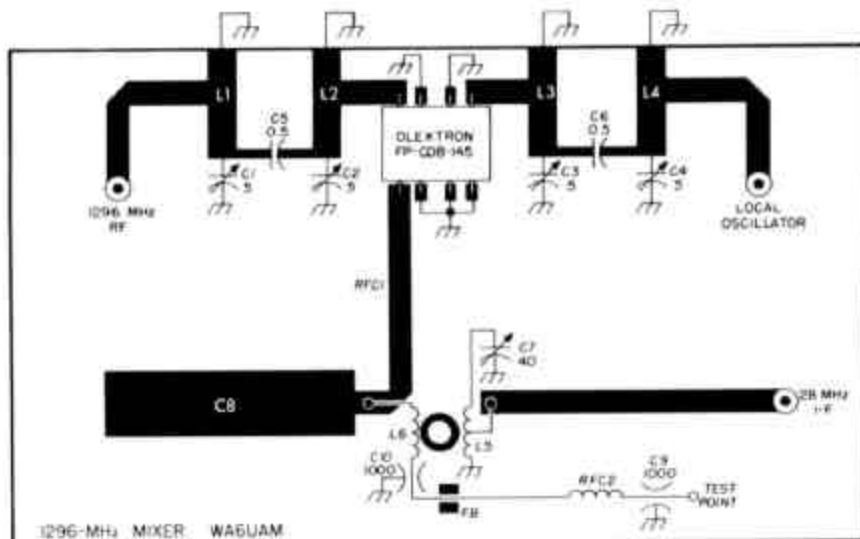


fig. 3. Double-balanced mixer circuit for 1296 MHz which uses microstripline construction. Component details are listed under fig. 2. Full-size printed-circuit board is shown in fig. 4.

### construction

Construction of the printed-circuit mixer assembly is shown in fig. 3. Full-sized artwork for the circuit board is shown in fig. 4. The microstripline dimensions are for use with 1/16 inch (1.5mm) thick G-10 fiberglass-epoxy board, double clad with 1 ounce copper. When building the board be sure to leave an unetched ground plane on the opposite side of the board.

Microstripline inductors L1, L2, L3 and L4 are grounded by pieces of copper foil which are wrapped around the board edge to the ground plane as shown in fig. 5. Holes are drilled in the board so the tuning-screw terminals of capacitors C1, C2, C3 and C4 can be connected directly to the ground plane. Minimum lead lengths are imperative.

Interfacing of the rf, i-f and local-oscillator ports is accomplished by microstripline launchers which can be built from flange-type coaxial connec-

Mounting of the fragile double-balanced mixer module should be deferred until all other components are in place. Holes are then drilled to permit direct through-the-board grounding of all mixer pins not connected to micro-



Double-balanced mixer layout for 1296 MHz, showing component placement on the printed-circuit board (see fig. 3).

**table 2. Electrical specifications for the Olektron model FP-CDB-145 double-balanced mixer module.**

Frequency response	RF port	0.5 to 1350 MHz		
	LO port	0.5 to 1350 MHz		
Conversion loss, typical	500 MHz	6.5 dB		
	1000 MHz	7.5 dB		
	0.5 to			
	1350 MHz	9.0 dB		
Isolation, minimum	LO/RF	RF/IF	LO/IF	
	500 MHz	30 dB	20 dB	20 dB
	1000 MHz	20 dB	15 dB	15 dB
Local-oscillator power	+7 to +13 dBm (5 to 20 mW)			
Diodes used	hot carrier			
Temperature	-54°C to +100°C			

striplines. The leads to the rf, local-oscillator and i-f terminals are bent down at right angles to the plane of the substrate, then out at 90 degrees so they lie on top of the microstriplines to which they are soldered.

When you're bending the leads of the mixer module, use extreme care so you do not fracture the delicate metal-glass lead seal. It is advisable to grip each lead with a pair of small needle-nosed pliers at the point where the lead just exits the flatpack; then bend the lead down on

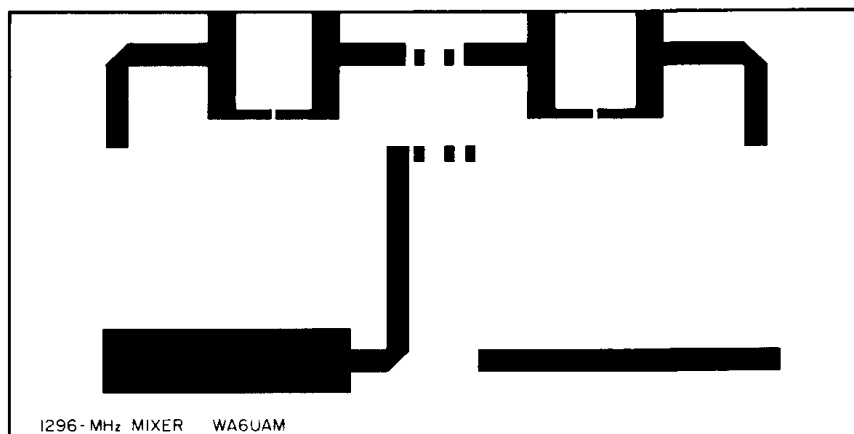
the far side of the pliers. For the local-oscillator, rf and i-f leads use the pliers to grip each lead just below the first bend when making the second bend. See the accompanying photograph for clarification (page 10).

### tuneup and operation

In addition to bandpass filtering, proper adjustment of the resonators at each port of the double-balanced mixer assembly will provide the required impedance matching. An excellent technical note from Anzac Electronics<sup>3</sup> describes the disastrous side effects of improperly terminating the various ports of a double-balanced mixer. As can be seen from **table 3**, a worst-case combination of reactive mismatches to all three ports can result in an overall degradation in mixer conversion loss of 3.5 dB, with a corresponding increase in third-order intermodulation products up to 30 dB.

When tuning the mixer assembly it is imperative to adjust each tuned circuit so that its associated mixer port sees a nonreactive 50-ohm termination. This is accomplished by adjusting the local-oscillator filter for maximum diode current, and adjusting the rf and i-f filters for minimum single-sideband conversion loss.

Initial adjustment of the local-oscillator port is most easily accomplished



**fig. 4. Full-size printed circuit board for the 1296-MHz double-balanced mixer. Material is 1/16" (1.5 mm) G-10 fiberglass-epoxy board, double clad with 1 ounce copper.**



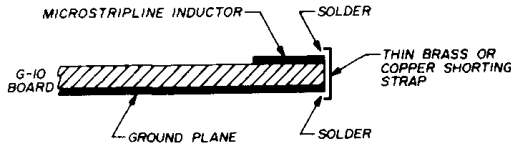


fig. 5. Method of properly grounding inductors L1, L2, L3 and L4 with thin shorting straps to the ground plane on the reverse side of the board.

by coupling in a +5 to +13 dBm local-oscillator signal (3 to 20 mW) and adjusting trimmers C1 and C2 alternately for maximum relative diode current, as indicated on a sensitive vtvm at the bias test point. Preliminary adjustments of the rf filter, to assure that the mixer is not tuned up on the image frequency, should be performed by coupling 10 milliwatts or so of 1296-MHz energy from a signal generator into the rf port and adjusting C3 and C4 for a maximum reading at the test point with *no* local-

oscillator injection. If a grid-dip oscillator, tuned to 28 MHz, is link-coupled through a coax cable to the mixer's i-f connector, the i-f tank circuit can be tuned for a dip with C7.

Final adjustments to C3, C4 and C7 can be made by connecting the mixer to a local-oscillator chain, i-f receiver and weak signal source, and tweaking for optimum signal-to-noise ratio. *Do not* adjust C1 and C2 at this time as optimizing diode current with the local oscillator connected has the effect of impedance-matching the local-oscillator port. While it is true that the mixer's conversion loss will vary with local-oscillator injection level (see fig. 7), to minimize third-order intermodulation products, changes in the local-oscillator injection level should be accomplished by padding the output of the oscillator, *not* by mismatching the mixer's local-oscillator port.

table 3. Effect of reactive terminations on double-balanced mixer performance. Mixer terms are defined below. (Data courtesy the Engineering Department, Anzac Electronics.)

termination condition	conversion loss	rf compression level	rf desensitization level	harmonic modulation products	third-order IM products
RF Port = 50 ohms IF Port = reactive load LO Port = 50 ohms	can vary $\pm 3$ dB	can vary $\pm 3$ dB	can vary $\pm 3$ dB	can vary $\pm 20$ dB	can vary $\pm 20$ dB
RF Port = 50 ohms IF Port = 50 ohms LO Port = reactive source	no effect if LO drive adequate	no effect if LO drive adequate	no effect if LO drive adequate	can vary $\pm 10$ dB	can vary $\pm 10$ dB
RF Port = reactive source IF Port = 50 ohms LO port = 50 ohms	typically $\pm 0.5$ dB for 2:1 vswr*	$\pm 0.5$ dB	$\pm 0.5$ dB	no first order effect	no first order effect

\*Increases proportional to mismatch.

**Harmonic modulation products:** Output responses caused by harmonics of the local-oscillator and rf signal and their mixing products.

**RF compression level:** The rf input power level that causes the conversion loss to increase by 1 dB.

**RF desensitization level:** The rf input power of an interfering signal that causes the small-signal conversion loss to increase by 1 dB.

**Intermodulation products:** Harmonically related distortion products caused by multiple rf signals and their harmonics mixing with each other and the LO producing signals at new frequencies.

The most elegant method of adjusting this mixer, of course, is to tune all ports for minimum indicated noise figure on an automatic noise meter system. However, those amateurs blessed with access to such equipment are cautioned to verify their results with a crystal-controlled weak-signal source to guard against resonating the rf port's filter at the image frequency. When properly adjusted, this mixer's image rejection is on the order of 18 dB.

My prototype mixer assembly, shown in the photographs, indicates a ssb noise figure of 10.5 dB, measured with a Hewlett-Packard 340 B Automatic Noise Meter and an AIL 7010 argon discharge noise head. Local-oscillator injection at optimum noise figure is +10.5 dBm. The measured noise figure of the dual-gate mosfet i-f amplifier which followed this mixer during noise measurements is 1.0 dB. There-

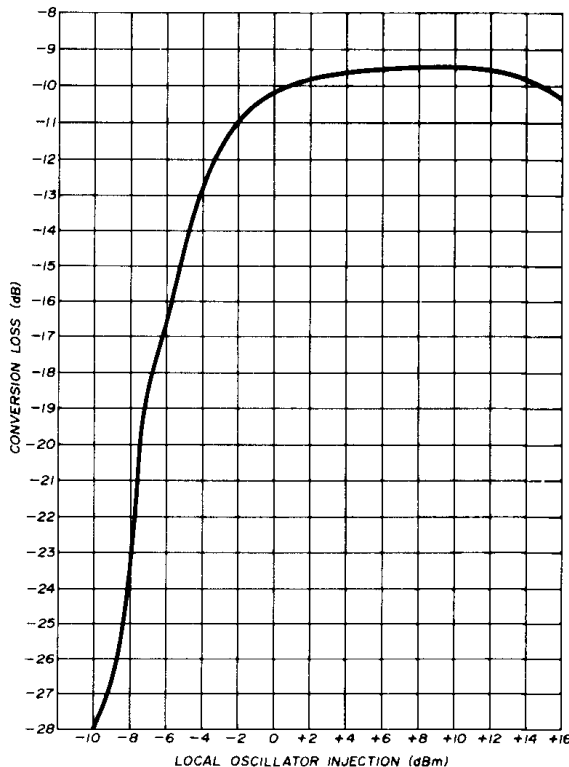


fig. 7. Measured conversion loss of the 1296-MHz double-balanced mixer circuit as a function of local-oscillator injection level.

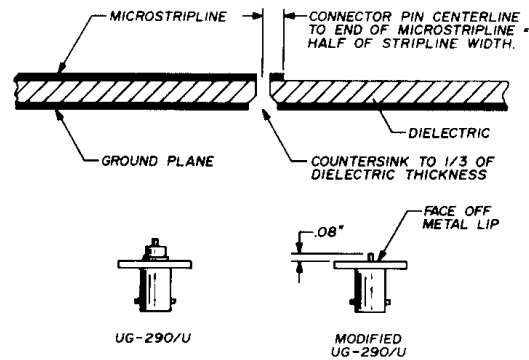


fig. 6. Technique for modifying flange-type coaxial connectors for microstripline launchers. Same method can be used with BNC, TNC or SMA coaxial connectors.

fore, if you accept the published figure of 9.0 dB for the conversion loss of the flatpack mixer module, the filter loss at the rf port is on the order of 0.5 dB.

The 9.5 dB conversion loss of this mixer assembly is on a par with my homemade mixer designs while offering the improved isolation and reduced harmonic modulation product density characteristic of the double-balanced arrangement. Performance of this mixer in the receive mode is wholly satisfactory for line-of-sight communications on the 23 cm band. Should beyond-the-horizon communications be desired, a single stage of low-cost preamplification<sup>4</sup> will reduce overall system noise figure below 5 dB. With the addition of a low-noise stage I have brought my system noise figure down to 2.2 dB.

#### references

1. H. Paul Shuch, WA6UAM, "1296 MHz SSB Transceiver," *ham radio*, September, 1974, page 8.
2. William J. Ress, WA6NCT, "Broadband Double-Balanced Modulator," *ham radio*, March, 1970, page 8.
3. "Reactive Loads - The Big Mixer Menace," Technical note, Anzac Electronics, 39 Green Street, Waltham, Massachusetts 02154.
4. H. Paul Shuch, WA6UAM, "Microstripline Preamps for 1296 MHz," *ham radio*, April, 1975, page 12.

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