SIMPLE BALUN-COUPLED MIXERS

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ABSTRACT

Economical double-sideband (two diode) and single-sideband (four diode) double-balanced broadband mixers use balun-coupled planar circuits suitable for any dielectric constant substrate, since slot line or coplanar waveguide is not used.

Introduction

Mixer noise figure reduction progress has reached a plateau. Emphasis is presently being given to field-effect transistor (FET) low-noise amplifiers (LNA) that have noise figures surpassing the best mixer noise figures ever reported. Performance goals for single-sideband (SSB) mixers (that follow an LNA) exchange mixer conversion loss for lower cost, broad and flat IF passbands, consistent performance in manufacturing and higher reliability. See the informative discussion on SSB mixers by Terry Oxley.[1]

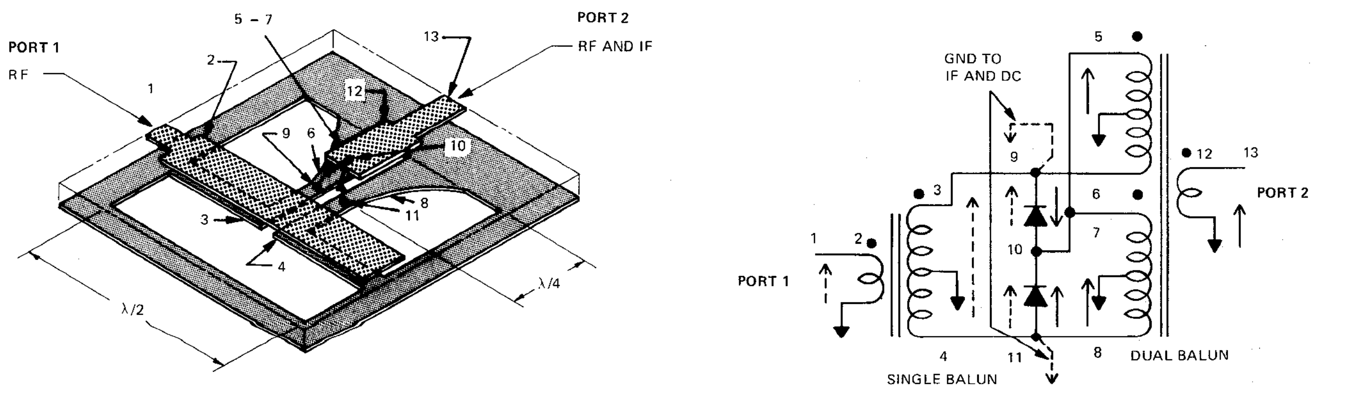
This paper describes a promising mixer design concept that may be constructed on plastic or ceramic substrates and does not use slot line or coplanar waveguide.

Balun-Coupled Mixers

Basic Circuit

The basic circuit is a double-balanced mixer design that uses the minimum limit of two diodes. Figure 1 illustrates the planar microwave layout with the corresponding low-frequency equivalent circuit that may even be used in its lumped constant form. A microstrip line at Port 1 is connected to a planar balun. The balun secondary line pair 3-4 is joined to each half of a bifurcated ground plane extension of a microstrip line at Port 2. The labels on the planar layout and equivalent circuit drawings directly relate to one another. The Port 2 return lines at the end of the quarter-wave long extension from the ground plane may be described as a dual output balun having terminal pairs 5-6 and 7-8. Terminals 6 and 8 are the same potential to the Port 2 signal so they may be joined without coupling to the Port 1 balun secondary lines 3 and 4. By joining the Port 2 secondary lines 5 and 7 that are at the same potential, the sending end terminal 10 is formed. The return lines for terminal 10 are lines 6 and 8.

A cascaded diode pair connected between terminals 9 and 11 will be series connected for the Port 1 signal and parallel connected for the Port 2 signal. Vectors near the diodes on the equivalent circuit diagram show the phasing technique that isolates Ports 1 and 2. The IF signal is present on the Port 2 sending line terminal 10. Since the IF ground returns are the secondary lines of the Port 1 and 2 baluns, the usable IF frequency range should be high.



PLANAR LAYOUT

LOW FREQUENCY EQUIVALENT CIRCUIT

FIGURE 1
BASIC BALUN COUPLED MIXER CIRCUIT

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Typical Double-Sideband Mixer Circuit

An example of an up- or down-converter circuit that outputs both sidebands appears in figure 2. The pi-shaped RF rejection filter passes the IF, but rejects the RF signal by at least 30 dB. The IF rejection filter[2] passes the RF, but rejects the IF signal at 70 MHz by at least 50 dB.

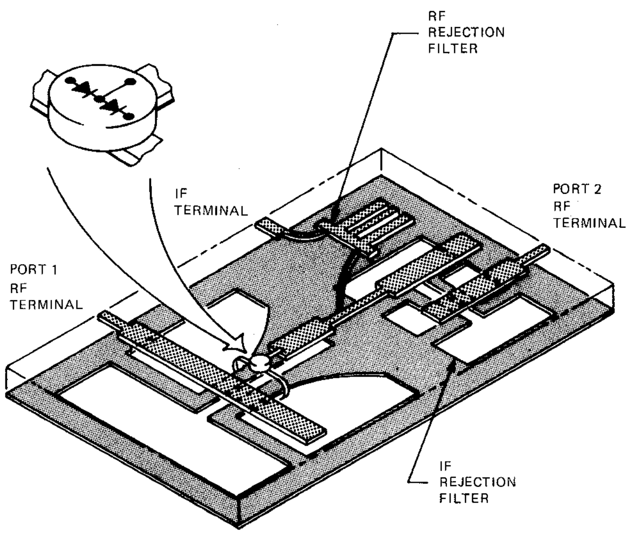


FIGURE 2
DOUBLE SIDEBAND FREQUENCY CONVERTER WITH RF AND IF REJECTION FILTERS

Typical Single-Sideband Mixer

The basic circuit used to form a single-sideband mixer is given in figure 3. The labels on the planar circuit and the low-frequency equivalent circuit correspond to make a direct comparison possible. A ring or a crossover diode quad package may be connected to the planar circuit even though a crossover quad is shown. Note that the balun secondary connections provide an ideally perfect isolation between Port 1 and the two 90-degree signals from Port 2 at terminals A-B-C-D, where the diode quad is connected. Ideally perfect isolation also exists between the two 90-degree signals from Port 2, because each of the dual-balun secondaries drives one and only one of the four diodes, and common connections 5-10 and 7-12 provide no coupling.

The balun-coupled SSB mixer is similar electrically to previous designs[3,4] but does not use slot line that requires a high dielectric constant substrate.

Performance of a 6-GHz Balun-Coupled Single-Sideband Mixer

Although an endless variety of planar layouts may be made from the equivalent circuit shown in figure 3, one example only will be shown in figure 4. This planar layout differs from that in figure 3 by using a branch line 90-degree RF hybrid with two IF rejection filters and a parallel plate-type of balanced transmission line from the Port 1 balun secondary output. The cross-connection in the figure 3 planar layout between lines 7 and 12 is provided in the figure 4 example by the balanced transmission line on the microstrip conductor side of the substrate. Bus wire feedthroughs make this crossover connection to the ground plane side secondary lines 7 and 12.

A ring quad diode package has two of its opposing leads joined to the two 90-degree dual-balun primaries. The other two leads are connected to the upper and lower plates of the balanced transmission line from the Port 1 secondary.

A 5-dB conversion loss is obtained in the common carrier band (5925 to 6425 MHz) for the signal frequency that is fed to Port 1. The local oscillator is fed to Port 2, 70 MHz away at a 7-dBm level. The substrate consists of 38.4-gm (1-oz) double-clad copper, 0.4-mm (0.015-in.) thick dielectric 3M 217 Teflon fiber-glass material.

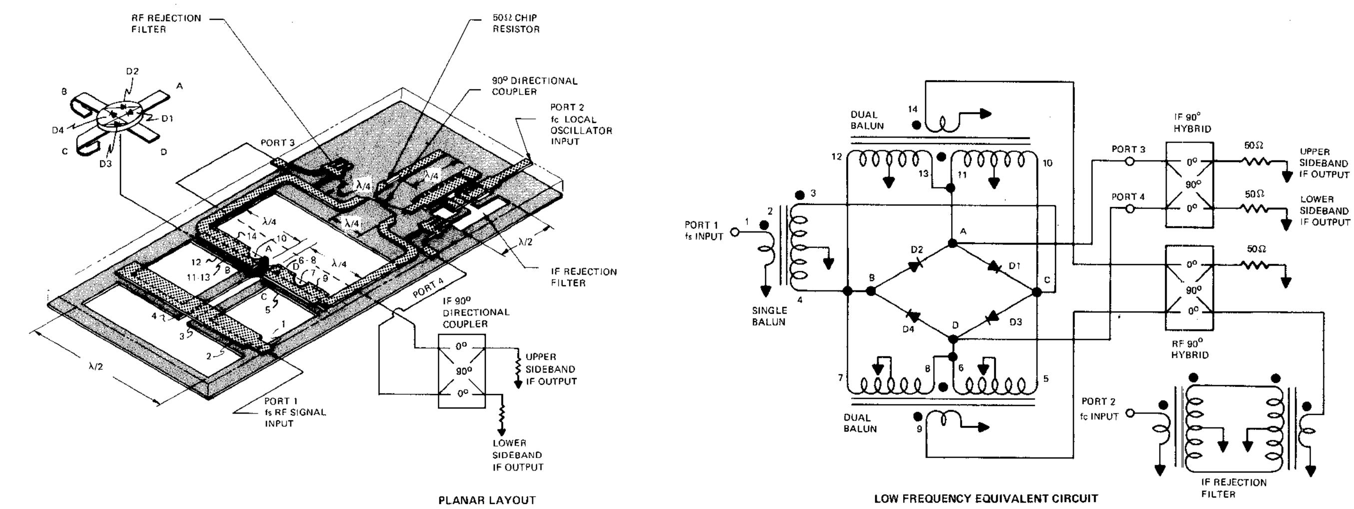
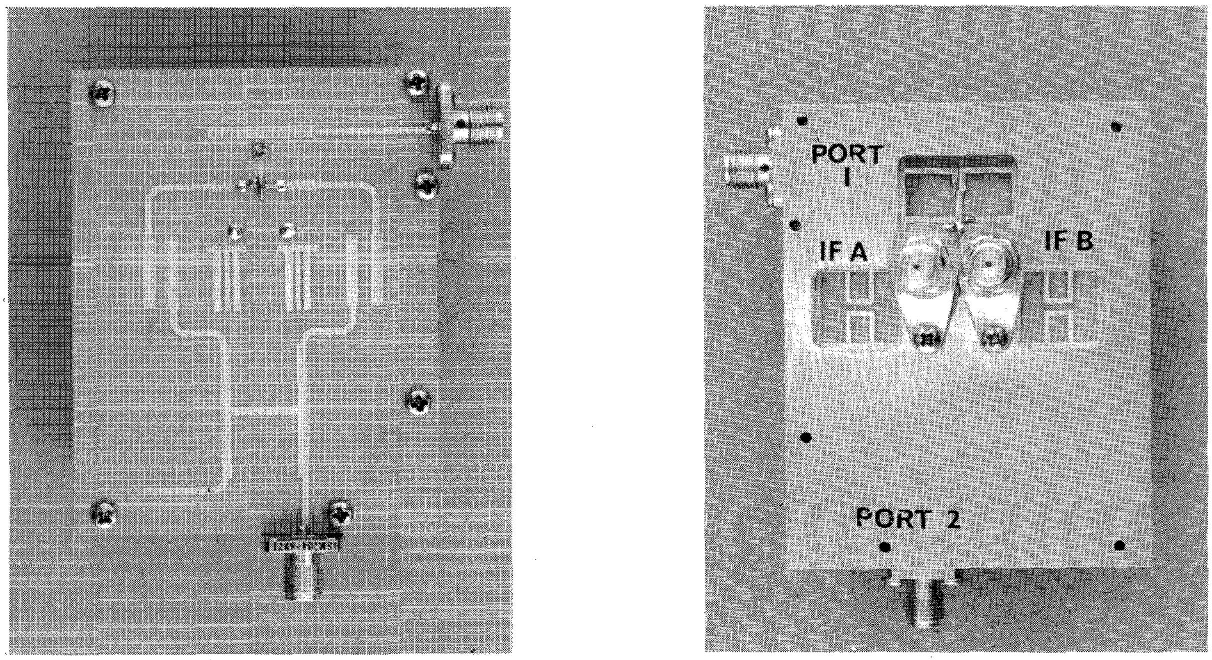


FIGURE 3
SINGLE SIDEBAND FREQUENCY CONVERTER



A. TOP VIEW

B. BOTTOM VIEW

FIGURE 4
6-GHz SSB BALUN-COUPLED MIXER

Conclusion

The balun-coupled mixer concept may be configured many different ways to suit individual requirements. No limitation on the dielectric constant of the substrate is known. The substrate may be mounted on a sheet metal plate and attached with screws at the connector interfaces, making a solder connection to the ground plane unnecessary. Isolation is inherently high for all signals in the mixers.

Because the image frequency is contained in the diode quad for the SSB mixers, the IF bandpass is flat and the turning range is broad.

References

[1]T. H. Oxley, "Phasing Type Image Recovery Mixers," 1980 IEEE MTT-S International Microwave Symposium Digest, pp 270-273.

[2]Ben R. Hallford, "A Designer's Guide to Planar Mixer Baluns," Microwaves, December 1979, Vol. 18, No. 12, pp 53-57.

[3]L. E. Dickens and D. W. Maki, "A New "Phased-Type" Image Enhancement Mixer," 1975 IEEE MTT-S, International Microwave Symposium Digest, pp 149-151.

[4]J. B. Cochrane and F. A. Marki, "Thin-Film Mixers Team Up to Block Out Image Noise," Microwaves, March 1977, Vol. 16, No. 3, pp 34-84.