MULTI-OCTAVE BANDWIDTH MICROWAVE MIXER CIRCUITS

Richard C. Van Wagoner
Radiation Systems, Inc.
McLean, Virginia

Introduction. The bandwidth of many microwave systems has been steadily increased over the past few years. Log-periodic and spiral antennas are examples of radiators which have paced the bandwidth expansion drive. Wideband 3-db couplers and phase shifters have followed in close echelon. With the development of YIG filters, experimental local oscillators are now being developed that can be electronically swept over several octaves. All of these components are finding useful application in modern surveillance, tracking and electronic warfare systems.

This paper discusses microwave mixers, or frequency translation circuits, that have been developed to realize the full capabilities of modern systems. Specifically, mixer circuits are presented and discussed which operate across bandwidths as great as 20 to 1.

These mixer designs make use of TEM mode transmission-line components, specifically, integrated strip-transmission-line assemblies. The range of frequencies over which this technique can be used is about 100 to 1, i.e., from approximately 100 MHz to 10 GHz.

Circuit Layout. A conventional balanced microwave mixer circuit is shown in Figure 1. This balanced mixer offers inherent isolation between the signal input and LO input because of the symmetry characteristics of the hybrid junction. The signal energy is divided by the hybrid and distributed equally to the two mixer diodes with the local oscillator energy likewise being evenly divided and fed to the two diodes. The IF energy generated by each of the mixer diodes is then combined into a single IF output.

The principal areas of difficulty in designing this circuit for extremely wide bandwidth operation are the dc return and the RF bypass. Generally, the packaging of the RF bypass and IF output at one end of the mixer diode results in a fairly reactive impedance existing at the other, or RF, end of the diode. For bandwidths on the order of 10 to 20 percent this reactance can be cancelled by using a short circuited stub in the RF line; this provides the necessary dc return. In this manner, the IF and dc connections can be made to the mixer diode while maintaining a matched condition to the RF line so that maximum conversion efficiency is realized. However, severe difficulties are encountered with this technique when the operational bandwidth is extended to the point where tuning stubs are no longer practical.

A microwave mixer circuit which is useful for continuous operation over many octaves has been developed by Radiation Systems, Incorporated, and is shown in Figure 2. Figure 2a is a block diagram of the circuit. The copper path configuration of the strip-transmission-line realization of this circuit is shown in Figure 2b. The RF circuit consists of four lowpass filters and three 3-db quadrature couplers. These couplers are of the tandem type as fabricated by RSi in a 3-layer solid dielectric package. The solid lines in Figure 2b indicate a copper path on the near size of the center dielectric layer while the dashed line indicates the far side circuit.

In operation, a signal fed into the RF input is split by the first 3-db quadrature coupler, and is fed to the lowpass filters on its output ports. The energy is reflected from these lowpass filters, which have a cutoff between the intermediate frequency and the lowest radio frequency. The reflected energy combines at the normally isolated terminal of the coupler. It is then fed to the coupler which is attached to the mixer diodes where it is divided equally to the two diodes. The local oscillator energy is routed to the mixer diodes by a similar path on the other half of the mixer circuit. The IF energy generated by the diodes is reflected from the ground connection immediately behind the diodes so that it travels along the copper paths (shown in Figure 2a) and combined through the coupling capacitors to the IF output.

Another circuit which can be used for extremely wide band operation is shown in Figure 3. Here the four lowpass filters are replaced by two 3 db couplers. The resulting tandem coupler pairs form zero db couplers (all input energy is coupled to the other copper path). This technique is useful for separating the RF and IF energies if their frequencies are widely separated.

Significant advantages of these mixer circuits are:

1. The diodes can be solidly grounded with a coaxial short-circuit very close to the junction of the diode. This results in a very low reactance package that needs no tuning in order to match RF energy into the junction.

2. The separation of IF and RF energies is accomplished utilizing lowpass filters or RF couplers as the only frequency-sensitive components. These components are quite straightforward and simple to fabricate in strip-transmission-line.

3. No dc bias connections are required in the RF portion of the circuit.

While it might appear that the circuit is unusually complex, it should be noted that the components involved are very simple to manufacture utilizing the photoetching techniques. The center dielectric layer, which contains the etched copper paths of two multi-octave bandwidth mixers, is shown in Figure 4.

Practical Considerations. While the basic mixer circuitry presented here has essentially unlimited bandwidth, there are certain practical considerations which limit its useful operating band. One such limitation, which is purely circuit oriented, requires that the IF and RF not overlap. It is obvious that if they do overlap, the lowpass filters could not possibly be used to separate them into isolated ports.

Other limitations are imposed by the components utilized in the circuit. The strip-transmission-line package must be configured to accommodate 3-db couplers of desired bandwidth. As the upper frequency limit on these components is increased, the ground plane spacing must be made progressively smaller to avoid moding. As the lower frequency limit is decreased, the circuit area must be increased to accommodate components that will work at the lower frequency. In addition, the lowpass filters which are used in this circuit must maintain a good stop-band across the full RF bandwidth.

Performance Achieved. These mixer circuits have been tested with point contact, backward and Schottky-barrier diodes from several manufacturers. All have given satisfactory results. Measured conversion loss and input VSWR data are given in Figure 5 for a 20:1 bandwidth mixer using zero db couplers. Identical units have been tested which amplitude track to within ± 1 db. Noise figure measurements taken with a 1.5 db, 30 MHz amplifier are 1 to 2 db higher than the conversion loss values.

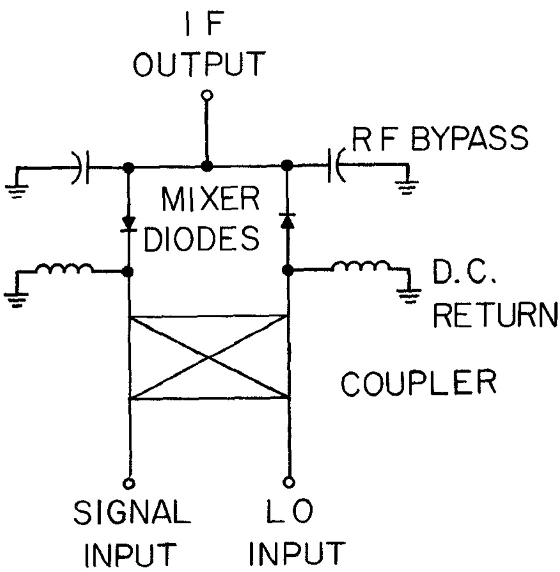

Figure 1. Basic Balance Microwave Mixer Circuit

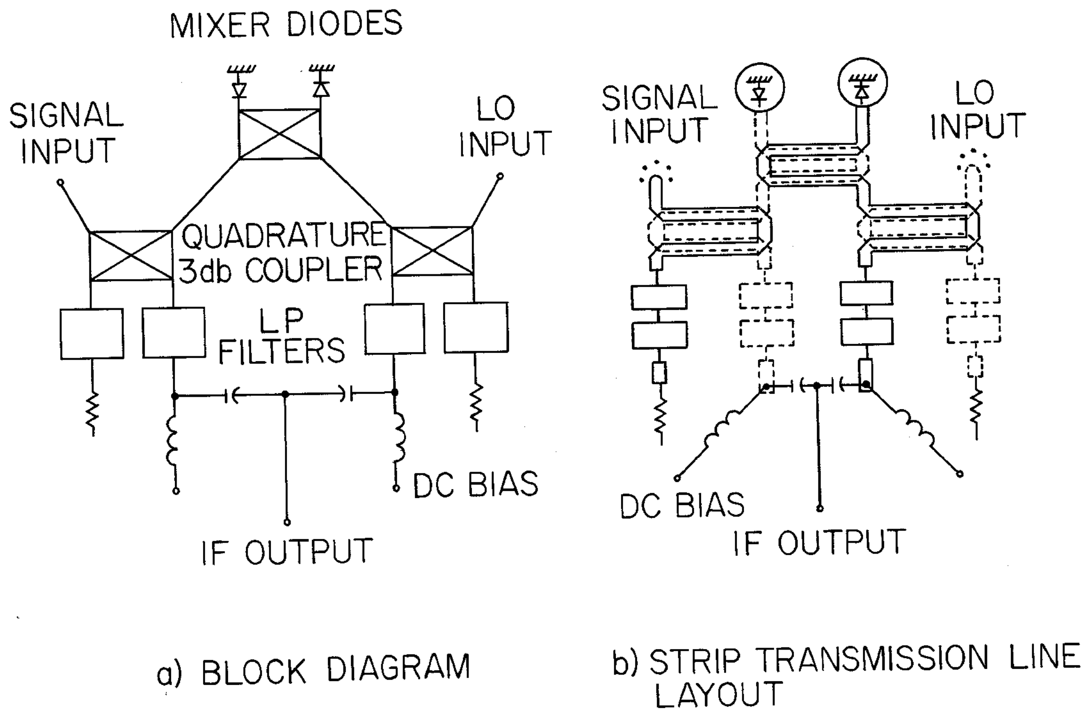

Figure 2. RSi Symmetric Filter Mixer Circuit

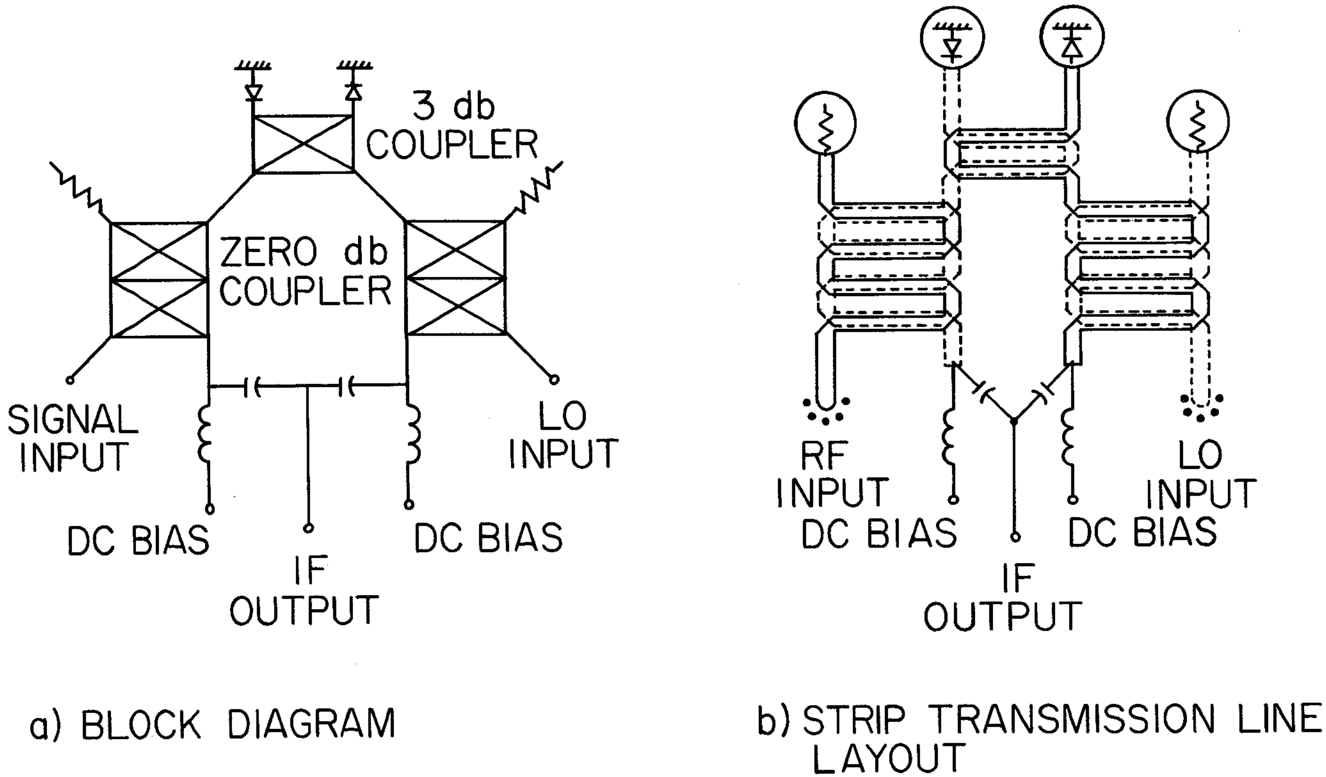

Figure 3. RSi Symmetric Zero db Coupler Mixer Circuit

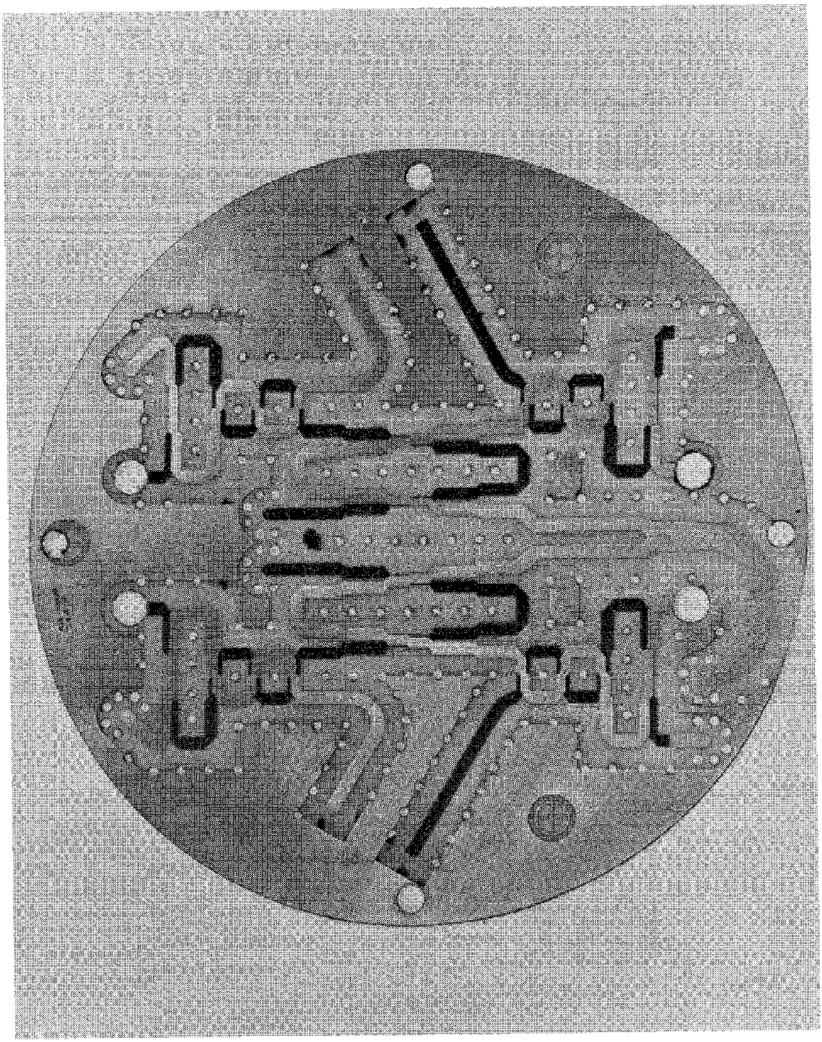

Figure 4. Etched Dual Mixer Board

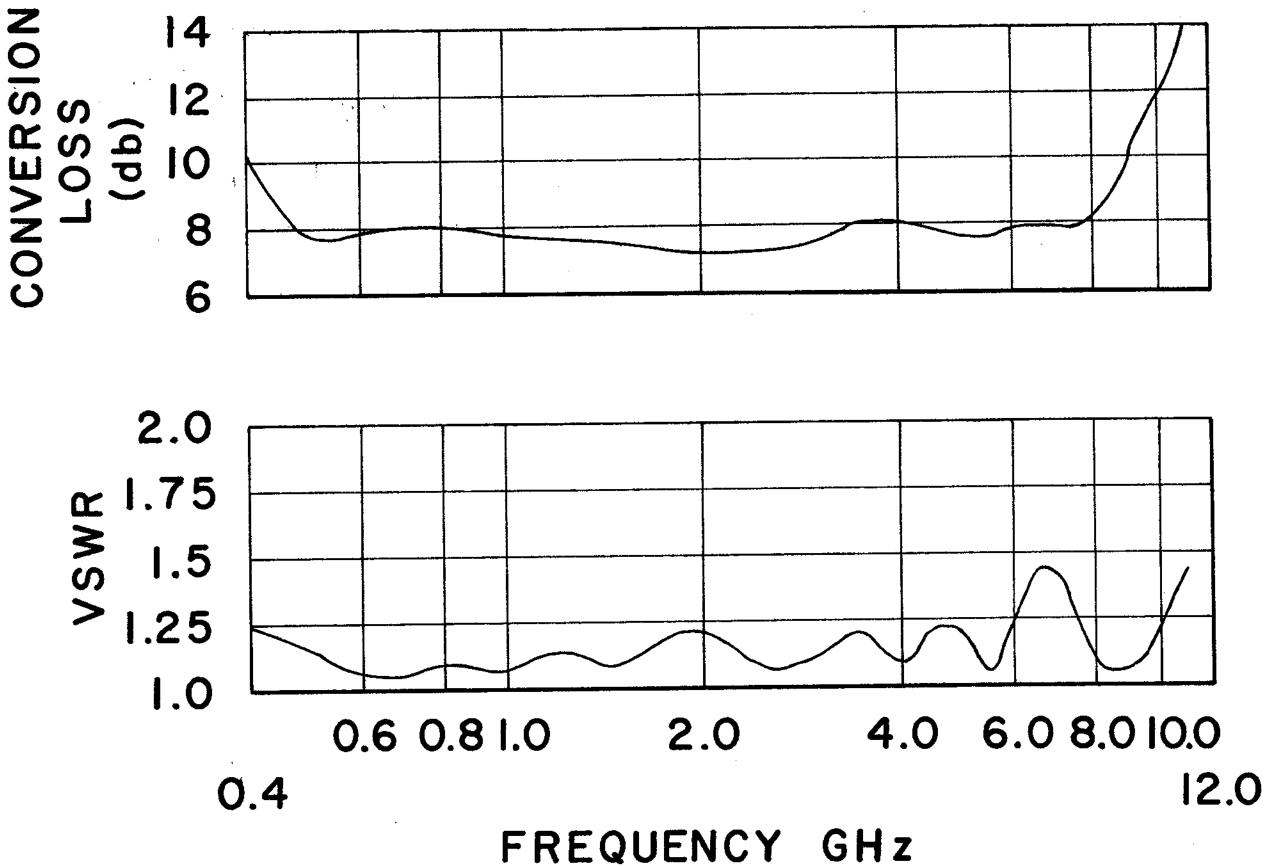

Figure 5. Measured Data of 20:1 Bandwidth Mixer, RSi Type 1264