N-16

INVESTIGATION OF A SINGLE-SIDEBAND MIXER ANOMALY

Ben R. Hallford
Rockwell International
Collins Transmission Systems Division
P.O. Box 10462
Dallas, Texas 75207

ABSTRACT

Investigations into a higher than expected conversion loss phenomena in a single-sideband (SSB) balun-coupled mixer revealed an unusual feedthrough mechanism. The tests also showed the image frequency voltage to be short-circuited with a ring diode quad and open-circuited with a bridge diode quad.

Introduction

Early measurements on the balun-coupled SSB mixer gave conversion loss figures of 5 to 6 dB when using a ring diode quad.[1] The behavioral theory for this type of mixer indicated a potential conversion loss of 2 dB. This paper summarizes the surprising conclusions taken from the detailed report to be submitted for the December 1983 IEEE/MTT-S Transactions.

SSB Mixer Description

The low-frequency equivalent circuit and planar layout drawing of the SSB mixer are shown in figure 1. Numbered points on the equivalent circuit correspond with the same numbers on the planar layout. Photographs of the mixer assembly used in the tests appear in figure 2. The ring and bridge diode quads were each installed in this mixer.

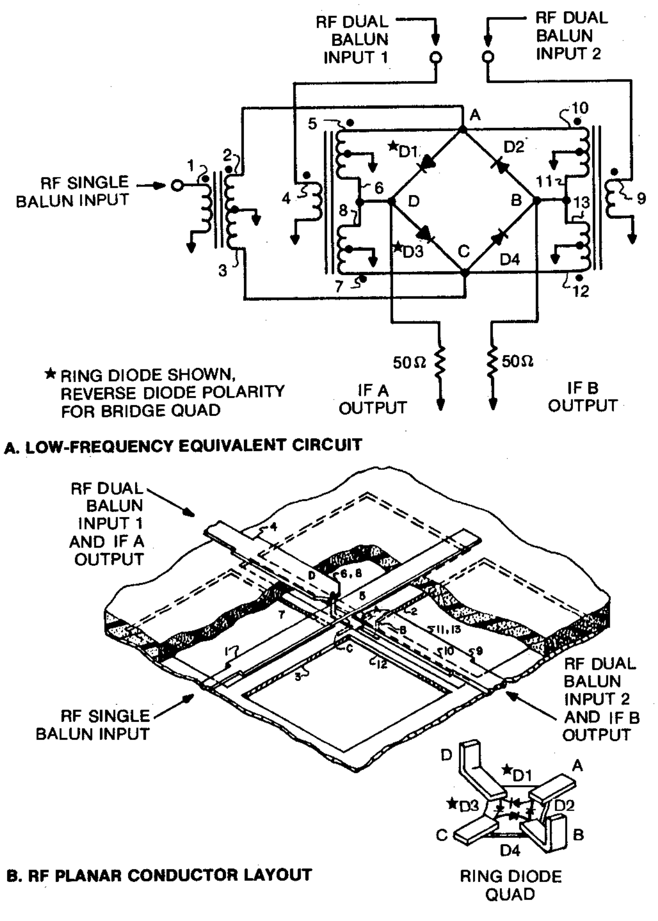

Figure 1. SSB Mixer Circuit Description Used for Testing.

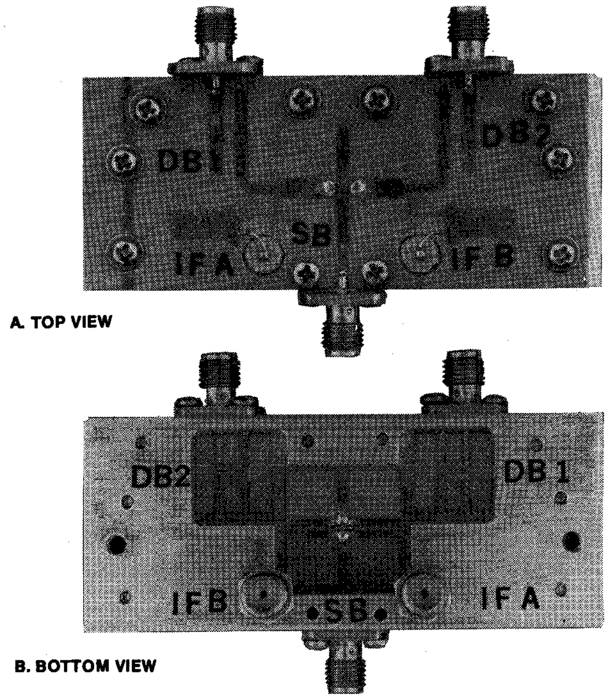

Figure 2. SSB Balun-Coupled Mixer Used for Testing.

The mixer layout diagram is shown in figure 3 to define diode connection arrangements, balun identification, and the RF signal and local oscillator (LO) levels and frequencies. This diagram is used in the description of later tests to identify test conditions.

Signal Frequency in Single Balun Using Ring Diode Quad

The signal is normally connected to the single balun for minimum conversion loss. The phase of the LO in dual balun 1 (DB1) was incremented over 360° to measure the amplitude, phase, and impedance of the two intermediate frequency (IF) outputs shown in figure 4. Several interesting observations are made from these results:

- The IF levels were not at a minimum at the ±90° LO phases, even though the image frequency in the f_s line was at a minimum and the IF impedance was also at a minimum, indicating maximum image current flow.
- The IF levels were not in phase and even appeared to be 180° out of phase.
- Since the two mixers were believed to be independent, image frequency involvement was suspected due to the radical change of the IF impedances and the location of greatest IF level variations being in the vicinity of the ±90° LO phases, where the two image frequency vectors were 180° out of phase in each half of the ring quad.

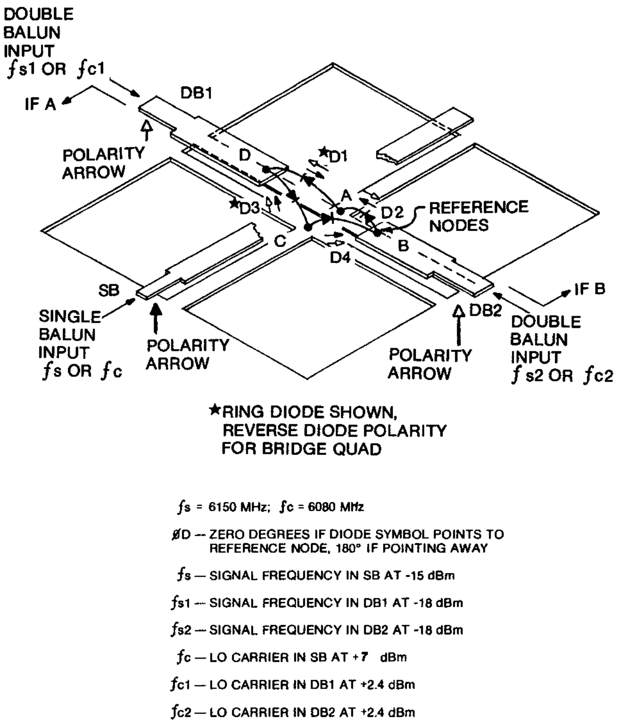

Figure 3. SSB Balun-Coupled Mixer Test Conditions, Layout Diagram

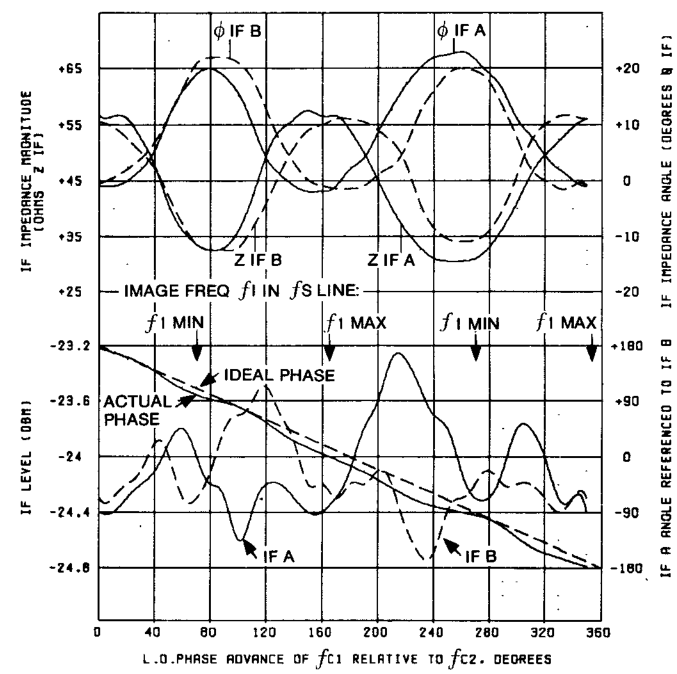

Figure 4. Signal in Single-Balun, LO in Each Dual-Balun, Ring Quad.

LO Carrier in Single Balun, Only One Signal in Dual Balun

The LO was fed to the single balun to remove any interaction of the image frequency on the IF levels. Table 1 gives the data taken when the signal was fed to only DB1 or DB2. A reference mixer was used in all tests and fed from the same LO and signal sources to provide a reference angle to each of the SSB mixer IF outputs. Results of the relative phase calculations show an RF signal was fed to the mixer section that had no input with a phase that led the input signal by about 95° when referenced to the same node as the input signal. This caused the feedthrough-generated IF to lead the normally generated IF by about 95°.

Although a feedthrough IF signal is identified, it is 22 dB below the normal IF and would cause no noticeable level change of the normal IF.

Table 1. LO in Single Balun, Signal in Only One Dual Balun, Ring Quad.

A SIGNAL $fs1$ INPUT TO DB1 ONLY

IF A = -24.2 dBm AT +66 8°
IF B = -46 dBm AT +161°
Z IF A = 68 5 OHMS AT -20°
Z IF B = 72 OHMS AT -17 5°

IF A LAGS IF B 94.2°

RELATIVE PHASE TABLE

	DIODES			
	D1	D3	D2	D4
REF NODE	D	D	B	B
φs1	0	0		
φs2	94 2	94 2 ←	→ 274 2	274 2
φc	180	0	180	0
φIF s = φs - φc	180	0	94 2	274 2
φD	0	180	180	0
φIF s + φD	180	180	274.2	274 2
	IF A		IF B	

NOTE: IF B IS 21 8 dB BELOW IF A. ASSIGN VALUES TO GET IF A, THEN, USING ANGLE OF IF B RELATIVE TO IF A, SOLVE FOR φs2 RESULTS SHOW φs2 THAT IS A FEEDTHROUGH TO LEAD THE INPUT φs1 94 2° AT REFERENCE NODE D

B. SIGNAL $fs2$ INPUT TO DB2 ONLY

IF A = -46 dBm AT -5°
IF B = -23.8 dBm AT -101.7°
Z IF A = 68 OHMS AT -15°
Z IF B = 69 OHMS AT -22°

IF A LEADS IF B 96 7°

RELATIVE PHASE TABLE

	DIODES			
	D1	D3	D2	D4
REF NODE	D	D	B	B
φs1	-83 3	-83 3 ←	→ 96.7	96 7
φs2			0	0
φc	180	0	180	0
φIF s = φs - φc	96 7	-83 3	180	0
φD	0	180	180	0
φIF s + φD	96 7	96 7	0	0
	IF A		IF B	

NOTE: IF A IS 22 2 dB BELOW IF B. ASSIGN VALUES TO GET IF B, THEN, USING ANGLE OF IF A RELATIVE TO IF B, SOLVE FOR φs1 RESULTS SHOW φs1 THAT IS A FEEDTHROUGH TO LEAD THE INPUT φs2 96.7° AT REFERENCE NODE D

LO in Single Balun, Both Signals in Dual Baluns

By feeding both signals in the dual baluns and changing the phase of the signal in DB1, the mixer behavior could be observed again without the image frequency involvement. The image frequency from each signal input line remained at the same level as the phase of the DB1 signal was changed, confirming the removal of any effects from the image frequency.

The IF levels were observed to change about 1.5 dB and to reach peaks and valleys at the ±90° signal phase differences. The puzzling thing about this data was that the two IF levels were 180° out of phase, so that a peak of IF A would occur at a dip for IF B. If the image frequency was not involved and the feedthrough IF was too low in level to change the normal IF, then what component would be strong enough to cause a 1.5-dB IF level variation?

Explanation of the Anomalous IF Level Changes

Data from the test with the LO in the single balun and both signals in the dual baluns is listed in table 2. The IF level variations may be observed as the phase of the signal in DB1 was changed. The anomalous signal will be called a phantom. Its level and phase may be determined by calculating the change that had occurred to the IF B mixer section level when only one signal was fed to the dual balun.

The calculations of this phantom vector level and phase are shown in table 2. Note that it is nearly 10 dB below the IF B level, and its phase changes with the signal frequency phase change. The IF B output was chosen to show this, because the phase of the signal that generated IF B was not changed.

The key to unlock this mystery is the angle of about 95° that the phantom vector leads the IF A vector. This is the same angle calculated for the feedthrough IF in table 1. The phantom is thus a feedthrough vector.

An understanding of the high level for the phantom vector is reached from figure 3. Recall that with only one signal input, the feedthrough IF has a low level.

Table 2. LO in Single Balun, Signal in Each Dual-Balun, Ring Quad, Phantom Vector Calculated in IF B.

RF PHASE fs1 REF fs2 DEGREES	IF A MAG dBm	IF A ANGLE DEGREES	IF B MAG dBm	IF B ANGLE DEGREES	CALCULATED PHANTOM VECTOR IN IF B FROM IF A SIDE MAG dBm	CALCULATED PHANTOM VECTOR IN IF B FROM IF A SIDE ANGLE DEGREES	PHANTOM PHASE REF TO IF A PHASE-DEGREES
16.6	-23 7	98.3	-23 7	255 7	-36 6	193.8	95 5
51 0	-23.9	130.8	-23 5	256 8	-34 9	236 7	105.9
108 3	-24.6	186 6	-23.3	258.4	-32 9	259 2	72.6
170.3	-23 8	255 4	-23 6	262 8	-34 1	320.2	64.8
209.1	-23.2	301.3	-24.3	264 4	-32 0	38.5	97.2
257.5	-23.1	348.4	-24.8	259.2	-30 6	74.8	86.4
321.8	-23.5	45.2	-24 0	254.2	-34 6	133.5	88 3

It is only when both signals are applied that the large IF changes are seen. This means that the voltage difference between the dual-balun primaries is changing as the phase difference of these signals occurs at nodes D and B. Conduction will take place from node D through diodes D3 and D4 to node B in one direction, and through diodes D2 and D1 in the other direction. One solution to this strange occurrence is to use a bridge quad to interrupt this signal flow.

Signal in Single Balun, Both LO Carriers in Dual Baluns, Using Bridge Quad

The curves in figure 5 are the same type as figure 4, except that now a bridge quad is used. The IF levels are reasonably balanced at the ±90° LO phases, where the SSB mixer will be operated. Some interaction is indicated, but it is beyond the normal operating range. Note that the IF impedances are now at a maximum at the ±90° LO phases.

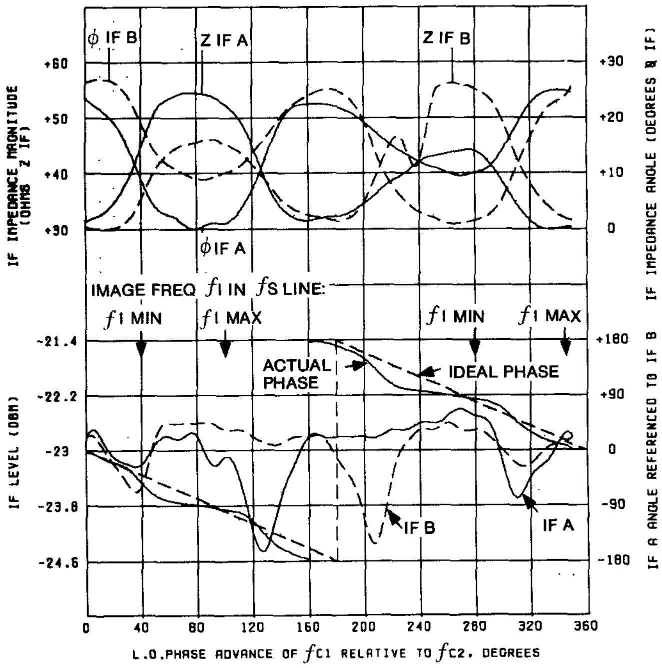

Figure 5. Signal in Single Balun, LO in Each Dual Balun, Bridge Quad.

Image Frequency Voltage Terminations

In the case of the ring quad, it is obvious that a 180° phase difference of the image frequency voltage on each half of the diode quad would cause a flow of current around the closed ring diode path only. There is no coupling of the image frequency voltage to any output path, so the full image frequency current should flow in the diode quad only. We may say that the ring diode quad results in a shorted image voltage condition.

When one considers that the reversal of the diode polarity in the bridge quad stopped the flow of signals from one mixer section to the other, then one must also conclude that the image frequency current path in the bridge quad is interrupted. Since no coupling exists to the image frequency voltage, a conclusion must be made that the image frequency voltage is open-circuited using the bridge quad. This conclusion is strengthened by the peaking of the IF impedance magnitudes at the ±90° LO phases in figure 5.

Conclusion

The anomalous behavior of the SSB balun-coupled mixer should not diminish its utility, because it does have the capability for wide-band operation. The SSB mixer with the 90° RF hybrid, described in reference 1, was operated from 4700 to 7500 MHz, with more than 20-dB image response rejection in the IF output (refer to article scheduled to be published in August 1983 Microwave and RF).

References

[1]Ben R. Hallford, "Single-Sideband Mixers for Communications Systems," 1982 IEEE/MTT-S International Microwave Symposium Digest, June 15-17, pp. 30-32.