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THE IMAGE REJECTION HARMONIC MIXER

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Abstract

Image channelization techniques are combined with antiparallel diode harmonic mixing to create a new type of mixer: the Image-Rejection Harmonic Mixer (IRHM). Such a mixer features: (1) adaptability to wide-bandwidth coverage with inherent image suppression, (2) simplified construction versus fundamental image rejection mixers, and (3) easier local oscillator implementation. Performance of an S-band mixer is shown.

Introduction

ECM, communications, and direction-finding receivers all share the common problem of differentiation between the signal of interest and its image. In communication receivers where bandwidths are narrow, filters can be inserted in front of the mixer. In wide-band applications, another image suppression technique is usually employed: a mixer that inherently separates image and real frequencies. These image-rejection mixers (IRMs) usually employ either balanced or double-balanced mixers as the frequency conversion components. We propose the use of an antiparallel diode pair harmonic mixer as the frequency conversion component. This simplifies circuit implementation while providing improved spurious suppression over a balanced mixer.

Image Rejection Mixers

The conventional IRM (Figure 1) requires an RF quadrature coupler, a resistive in-phase power divider, two mixers, and an IF quadrature coupler. In addition, implementation of the mixers requires another RF quadrature coupler or balun circuitry. The two mixer channels must be well matched in amplitude and phase to obtain good performance. The sideband channelization techniques it employs make it adaptable to wide-bandwidth systems that have closely spaced local oscillator and signal frequencies. Implemented in a strip transmission-line medium, this configuration can result in a "trapped port," which is undesirable, especially if it is to be part of a microstrip circuit. Usually, double-balanced mixers are used because of their superior spurious suppression. However, this is reflected in a need for increased local oscillator power.

Harmonic Mixing

In 1975, Schneider and Snell[1] and Cohn et al.[2] described novel antiparallel diode pair mixers (Figure 2). These mixers represented a major improvement in harmonic mixing. They exhibited reduced

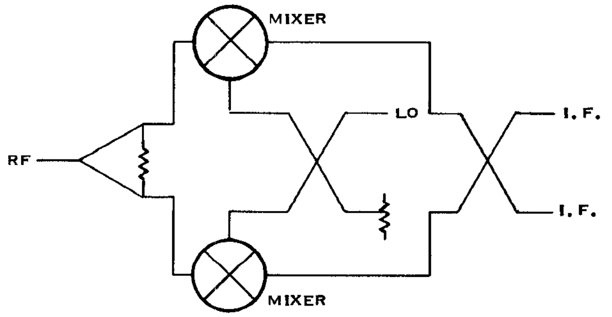

Figure 1

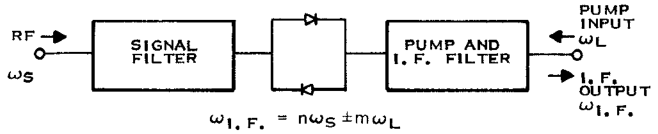

Figure 2

conversion loss by suppressing fundamental mixing products, suppression of local oscillator noise sidebands and self-protection against large peak inverse voltages. The conductance waveform of the diode pair contains a dc term and only even harmonics of the local oscillator, so the mixer is inherently insensitive to fundamental mixing. Because of the opposite polarity of the diodes, a dc return is not required since the dc component of the total current simply circulates within the loop formed by the two diodes.

Optimum conversion loss for harmonic mixing has been shown to occur at somewhat lower local oscillator levels than for fundamental mixing. Engleson[3] reported optimum conversion loss occurring at 0.6 mW for a second harmonic mixer.

Image Rejection Harmonic Mixing

Image rejection harmonic mixing combines the sideband channelization techniques of conventional IRMs with harmonic mixing. The image rejection harmonic mixer is shown in Figure 3. Only two quadrature couplers are used along with two antiparallel diode pairs. The RF coupler diplexes the RF and LO signals while the highpass filters reflect the I.F. signals generated in the diodes. The lowpass filters remove the sum and higher order frequency terms and contribute to RF-to-I.F. isolation. The LO-to-RF isolation is dependent on the match to the diodes. The VSWR at all ports is good because of the quadrature couplers.

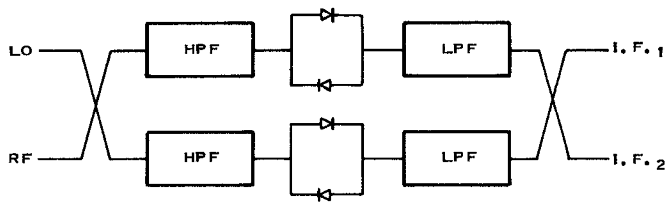

Figure 3

Cohn et al.,[2] develop the time varying differential conductance for an antiparallel diode pair as:

$$g = 2\,\alpha\, i_s \cosh \alpha V \tag{1}$$

where α is the diode slope parameter, i_s is the saturation current, and V is the applied voltage. The applied voltage waveform for the pump and signal is:

$$V = V_{LO} \cos \omega_{LO} t + V_s \cos \omega_s t \tag{2}$$

and the total current external to the diode loop is given by:

$$i = A\cos\omega_{LO}t + B\cos\omega_s t$$
$$+ C\cos 3\omega_{LO}t + D_t\cos 5\omega_{LO}t$$
$$+ E\cos(2\omega_{LO} + \omega_s)t + F\cos(2\omega_{LO} - \omega_s)t$$
$$+ G\cos(4\omega_{LO} + \omega_s)t + H\cos(4\omega_{LO} - \omega_s)t$$
$$+ \ldots$$

$$i = \sum_{\substack{m,n=0 \\ m+n=odd}}^{\infty} A_k \cos(m\omega_{LO} \pm n\omega_s)t \quad (3)$$

where A, B, C, . . . are constants that relate α, L_s, V_s, and V_{LO}. As Cohn[2] observes, the total current contains only frequency terms $mf_{LO} \pm nf_s$ where m + n is an odd integer, i.e., m + n = 1, 3, 5, ...

Now consider the configuration of Figure 3, in which two antiparallel diode pairs are fed through a –3.01-dB quadrature coupler. Assume perfect amplitude split and 90-degree phase difference between the two arms of the couplers. At one diode pair, the applied voltage is:

$$V = \frac{V_{LO}}{2}\cos(\omega_{LO}t + 90°) + \frac{V_s}{2}\cos\omega_s t \quad (4)$$

while at the other diode pair

$$V = \frac{V_{LO}}{2}\cos\omega_{LO}t + \frac{V_s}{2}\cos(\omega_s t + 90°) \quad (5)$$

Considering only the fundamental of ω_s, then for the case where $m\omega_{LO} > \omega_s$, the I.F. output from each of the diode pairs after lowpass filtering is:

$$X = \sum_{m=2,4,6\ldots}^{\infty} A_k \cos(m\omega_{LO}t + m\,90° - \omega_s t)$$

$$Y = \sum_{m=2,4,6\ldots}^{\infty} A_k \cos(m\omega_{LO}t - 90° - \omega_s t) \quad (6)$$

Summing these signals in the I.F. coupler, the resultant signals appearing at the I.F. outputs are:

$$IF_1 = \frac{1}{2}\sum_{m=2,4,6\ldots}^{\infty} A_k \cos[m\omega_{LO}t + (m+1)\,90° - \omega_s t] + \cos[m\omega_{LO}t - 90° - \omega_s t]$$

$$IF_2 = \frac{1}{2}\sum_{m=2,4,6\ldots}^{\infty} A_k \cos[m\omega_{LO}t + m\,90° - \omega_s t] + \cos[m\omega_{LO}t - \omega_s t] \quad (7)$$

For the case where $\omega_s > m\omega_{LO}$, the I.F. output can be shown to be:

$$IF_1 = \frac{1}{2}\sum_{m=2,4,6\ldots}^{\infty} A_k \cos[\omega_s t - m\omega_{LO}t - (m-1)\,90°] + \cos[\omega_s t + 90° - m\omega_{LO}t]$$

$$IF_2 = \frac{1}{2}\sum_{m=2,4,6\ldots}^{\infty} A_k \cos[\omega_s t - m\omega_{LO}t - m\,90°] + \cos[\omega_s t + 180° - m\omega_{LO}t] \quad (8)$$

These results are summarized in Table I for various values of m. Figure 4 shows the vector relationships for the second harmonic case.

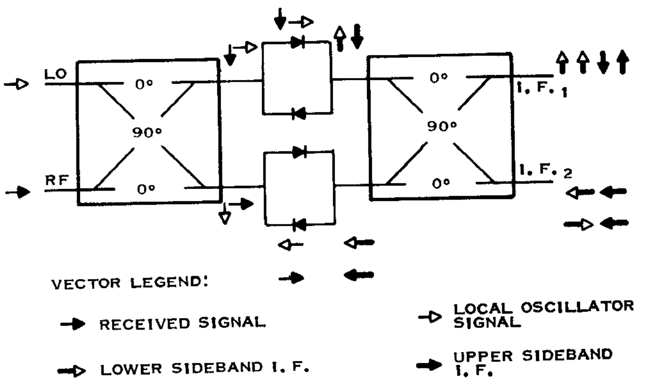

Figure 4

TABLE I. I.F. OUTPUTS

	$m\omega_{LO} > \omega_s$		$\omega_s > m\omega_{LO}$	
M	IF_1	IF_2	IF_1	IF_2
2	$\cos(2\omega_{LO} - \omega_s)t - 90°$	0	0	$\cos(\omega_s t - 2\omega_{LO})t + 180°$
4	0	$\cos(4\omega_{LO} - \omega_s)t$	$\cos(\omega_s t - 4\omega_{LO})t + 90°$	0
6	$\cos(6\omega_{LO} - \omega_s)t - 90°$	0	0	$\cos(\omega_s t - 6\omega_{LO})t + 180°$

Advantages of This Configuration

Because the IRHM can be implemented with simple, totally etched components, its reproducibility is enhanced. This is essential where multiple receiver channels have critical amplitude and phase matching requirements. Also, since the RF input uses a quadrature hybrid, input VSWR can be less than 1.5:1 and the IRHM can be easily integrated with amplifiers, antenna feed networks, etc., without the use of an isolator.

Another advantage of the IRHM is suppression of harmonic intermodulation products. For a second harmonic IRHM, the terms that produce "I.F. spurs" (for I.F. bandwidths less than 0.2 ω_s) are of the form:

$$2 \times \omega_{LO} \pm X\, \omega_s \quad (9)$$

where X = 1, 2, 3, . . ., n.

Notice that half these terms have m + n = even, and these are not contained in the output of the diode pair. This also applies to any spur that can be created by m + n = even, i.e., 1 × 3, 1 × 5, 3 × 5, etc.

S-Band Mixer Performance

A prototype mixer has been fabricated and tested (Figure 5). The mixer consists of a single-section stripline coupler—with the diodes, lowpass filters and I.F. coupler—mounted in microstrip. The highpass filters consist of single short-circuited lines and are contained in the stripline coupler. Individually packaged HP5082-2207 diodes were used. Conversion loss and image rejection are shown in Figure 6, for second harmonic mixing with a 70-MHz I.F. Local oscillator power was +3 dBm. The 1-dB compression point was typically −5 dBm. Return loss at both RF and LO ports was >20 dB.

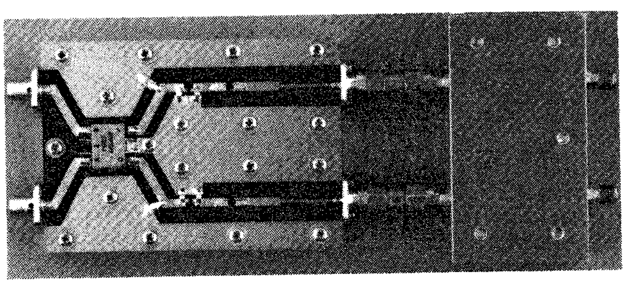

Figure 5

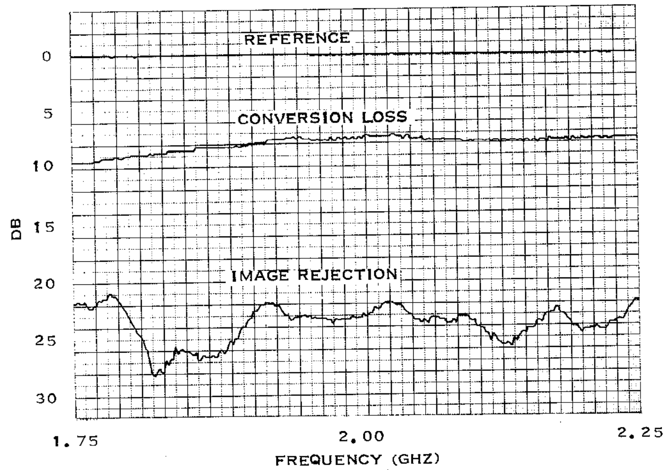

Figure 6

Conclusion

A new type of mixer, the Image Rejection Harmonic Mixer, has been developed. It has wide bandwidth adaptability and can easily be integrated into microstrip circuitry.

An S-band prototype was demonstrated. The prototype had 25 percent bandwidth and >20-dB image rejection.

References

1. M.V. Schneider and W.W. Snell, Jr., "Harmonically Pumped Stripline Down-Converter," *IEEE Trans. Microwave Theory Tech.*, Vol. MTT-23, (March 1975) pp. 271-275.

2. M. Cohn, J.E. Degenford, and B.A. Newman," Harmonic missing with an antiparallel diode pair," *IEEE Trans. Microwave Theory Tech.*, Vol. MTT-23, (August 1975) pp. 667-673.

3. M. Engelson, "Performance of Harmonic Diode Mixers," *Microwaves*, Vol. 6, (August 1967) pp. 32-38.

4. J.B. Cochrane and F.A. Marki, "Thin Film Mixers Team Up to Block Out Image Noise," *Microwaves*, Vol. 16, (March 1977) pp. 34-40, 84.

5. B.R. Hallford, "Track Phase States to Check Mixer Designs," *Microwaves*, Vol. 19, (June 1980) pp. 52-60.