A Diode Mixer with Harmonic-Distortion Suppression

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***Abstract*— Second- and third-harmonic distortion in a singly balanced diode mixer was reduced significantly by short-circuiting the diodes at the second and third LO harmonics. This verifies earlier predictions that short-circuiting these products should improve IM performance.**

I. Introduction

A SET of intermodulation (IM) frequencies are generated in a mixer, due to the nonlinearity of the diode, when two input signals are applied to a mixer. In 1987, a technique was proposed that can be used to calculate intermodulation very accurately [1]. One conclusion of this work was that intermodulation distortion is minimized by using short circuit embedding impedances at the harmonics of the LO frequency and unwanted mixing frequencies. Although the theory in [1] was tested experimentally, the idea that short-circuit embedding impedances minimize IM was not specifically demonstrated. Thus, we have undertaken an experimental study to determine whether such improvement can be realized in practical circuits.

The intermediate frequency (IF) spectrum of intermodulation frequencies of greatest concern, up to third order, are shown in Fig. 1. The $\omega_2 - \omega_1$, $\omega_1 - \omega_2$ and $2\omega_2 - \omega_1$ components, second and third order intermodulation (IM) products, are usually of great concern. However, the second and third harmonics of the IF frequency, $2\omega_1$ and $3\omega_1$, depend upon the embedding impedances and other mixer parameters in the same way as the intermodulation frequencies, and also have practical importance: they are, in fact, the single-tone IM products

$$\omega_{\mathrm{IF}} = 2\omega_{\mathrm{RF}} - 2\omega_{\mathrm{LO}} \tag{1}$$

and

$$\omega_{\mathrm{IF}} = 3\omega_{\mathrm{RF}} - 3\omega_{\mathrm{LO}}. \tag{2}$$

These components are often called *spurious responses*.

II. Design and Measurements

To determine the effect of embedding impedances on diode-mixer IM, two singly balanced microstrip rat-race mixers [2] were constructed. In one, the diodes were driven directly from the 50-Ω port of the rat-race hybrid, and no tuning was included. The other was identical except for a pair of open-circuit stubs that short-circuited the diodes at the second and third harmonics of the 10-GHz LO frequency. The latter mixer also included matching circuitry designed to present a 50-Ω source impedance to the diodes at the LO fundamental. The bandwidth of the stubs was great enough and the IF frequency, 208 MHz, was low enough so that the mixing frequencies adjacent to these LO harmonics were also terminated in a very low impedance. The stubs are placed as shown in Fig. 2. The mixer was realized in microstrip on 0.031 inch thick duroid substrate with a dielectric constant of 2.33 and 0.7 oz. copper cladding. This low-dielectric-constant duroid was chosen over other materials for ease of manufacturing. Both mixers used Alpha type DMJ6777 diodes from a common production lot.

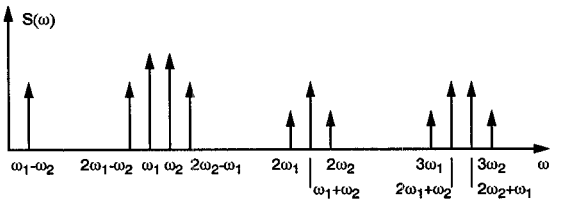

Fig. 1. IF spectrum of IF intermodulation components to third order. The frequencies ω_1 and ω_2 are the linear IF outputs under two-tone excitation.

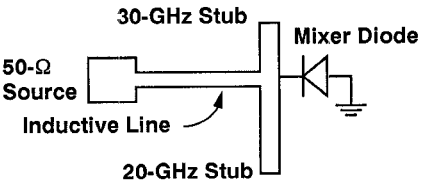

Fig. 2. Diagram of the diode embedding circuit.

The stubs are placed in such a way that the diodes see a short circuit at the desired frequencies (i.e., 20 ± 0.25 and 30 ± 0.25 GHz). The 50 mil long and 20 mil wide transmission line shown in Fig. 2 compensates the parasitic capacitance that these stubs introduce at the LO fundamental frequency, 10 GHz. The circuit was optimized on the Hewlett-Packard MDS circuit simulator to minimize the harmonic impedances seen by the diodes; because of the reactances introduced by the cross-junction discontinuity at the stubs, it was not possible to do this perfectly.

The available power at the RF port was fixed at −10.0 dBm and IM levels were recorded as LO power was varied. The conversion loss, second IF harmonic (P_{IF2}) and third harmonic (P_{IF3}) were recorded. These are compared for the two mixers in Fig. 3–Fig. 5. Fig. 3 shows the mixers' conversion loss.

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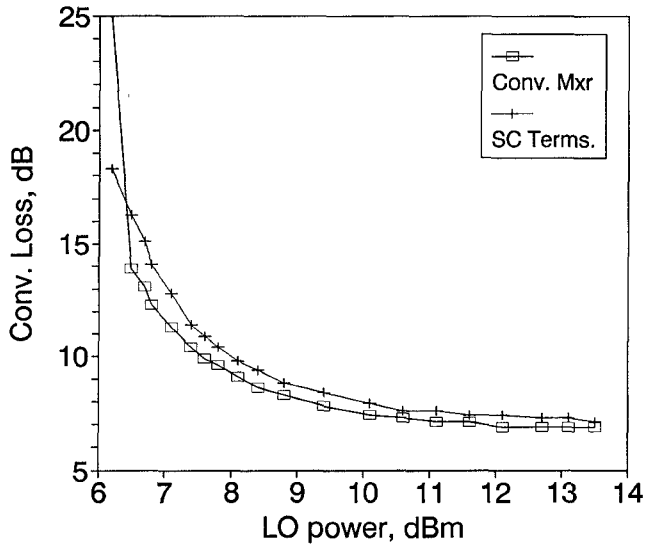

Fig. 3. Conversion losses of the conventional mixer and the one having short-circuit harmonic terminations. The LO frequency is 10 GHz and IF is 208 MHz.

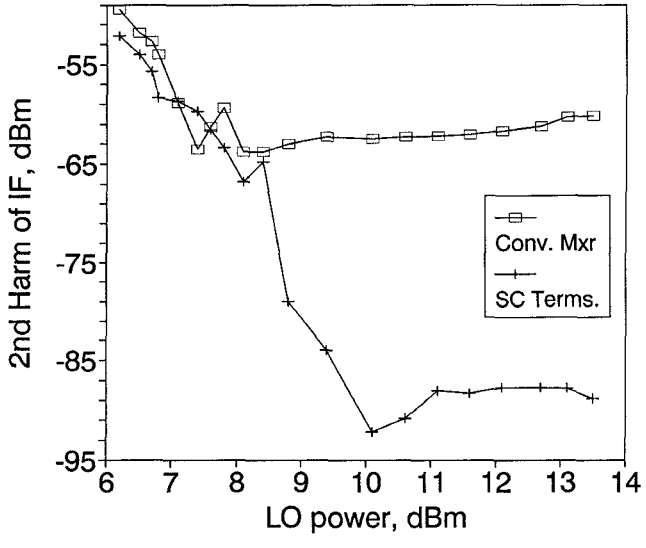

Fig. 4. Comparison of the levels of the fundamental and second harmonics of the IF output of the two mixer circuits. This is the same as the (2,−2) spurious response. P_{in}= −10 dBm.

The conversion losses of the two circuits were almost the same, differing from 1.5 dB at low LO power to 0.2 dB at an LO power of 13.5 dBm. The second-harmonic level,

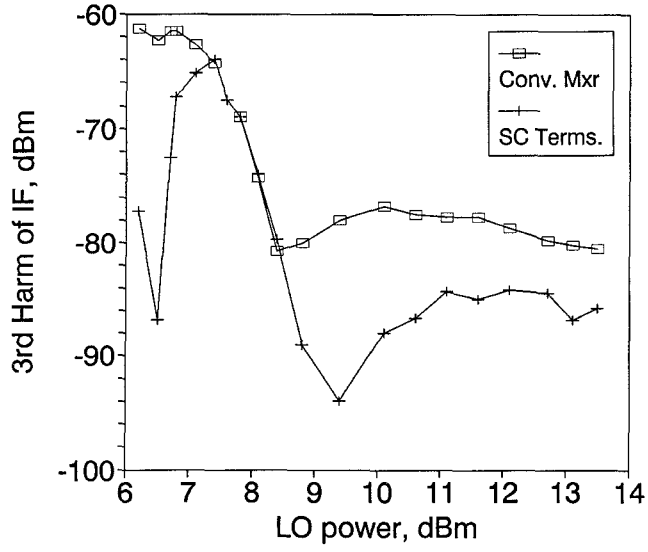

Fig. 5. Comparison of the levels of the fundamental and third harmonics of the IF output of the two mixer circuits. This is the same as the (3,−3) spurious response. P_{in}= −10 dBm.

shown in Fig. 4, was a maximum of 28.7 dB lower in the mixer having the short-circuited LO harmonics, and the third-harmonic distortion level, shown in Fig. 5, was reduced by 8–16 dB at LO levels that provided good conversion loss.

III. Conclusion

This experiment indicates that terminating the second and third LO harmonics and associated mixing frequencies in a short circuit results in substantial reduction in a diode mixer's harmonic distortion. It was found experimentally that the second-harmonic distortion level dropped a maximum of 28.7 dBm, and the third-harmonic distortion level also dropped a maximum of 16 dBm.

Thus, the practical possibility of improving IM distortion levels as predicted by [1] is established. This technique should prove valuable in the lowering of IM distortion levels of diode mixers.

References

[1] S. A. Maas, "Two-tone intermodulation in diode mixers," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-35, pp. 307–313, Mar. 1987.
[2] ——, *Microwave Mixers*. Norwood, MA: Artech House, 1986.