HARMONIC MIXING WITH AN ANTI-PARALLEL DIODE PAIR

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Abstract

The analysis and experimental evaluation of a new harmonic mixer configuration capable of yielding lower conversion loss and circumventing the local oscillator noise sideband problem is presented.

Summary

An analytical and experimental investigation of the properties of an anti-parallel diode pair has shown that it has unique and advantageous characteristics as a harmonic generator or harmonic mixer. In the latter application, which is treated in this paper, it will be shown that this circuit provides:

1. Reduced conversion loss by reactively terminating the fundamental mixing products,
2. Lower noise figure through suppression of local oscillator noise sidebands, and
3. Suppression of direct video detection.

These results are obtained without the use of either filters or balanced circuits employing hybrid junctions.

Analysis of the anti-parallel diode pair circuit of Figure 1 (a) reveals that the composite time varying conductance, g(t), has even symmetry and Fourier components consisting of a dc term and even harmonics of the local oscillator frequency (ω_{LO}). Application of a voltage waveform $V=V_{LO}\sin\omega_{LO}t + V_s \sin \omega_s t$ to the usual asymmetric diode characteristic results in a diode current having all frequencies $m f_{LO} \pm n f_s$. Reference to Figure 1 (b) shows that the total current of the anti-parallel diode pair contains only frequencies for which m + n is an odd integer. The terms in which m + n are even, i.e.even harmonics, fundamental mixing products ($\omega_s - \omega_{LO}$ and $\omega_s + \omega_{LO}$), and the dc term flow only within the diode loop and thus only through the low forward resistance of the two diodes. The effects of diode unbalance on these idealized results have been analyzed and will be presented.

In order to verify many of the predicted characteristics, an anti-parallel pair of GaAs Schottky barrier diodes were shunt mounted across a slot line. A 3 GHz local oscillator input and a 4 GHz low level signal were impressed at the slot line input. A photograph of the output spectrum is shown in Figure 2. Note that the output at $3f_{LO}$ is much greater than that at $2f_{LO}$, and the absence of fundamental mixing products, $f_s - f_{LO}$ and $f_s + f_{LO}$, and the relatively large 2 GHz IF output due to second harmonic mixing ($2f_{LO} - f_s$).

The degradation of receiver noise figure due to local oscillator noise sidebands is circumvented in even harmonic mixing (m even, n = 1) in an anti-parallel diode pair as shown in Figure 3. LO noise sidebands (f_{NL} and f_{NH}) whose separation from the LO (f_{LO}) equals the IF (f_{IF}) generate IF noise which only circulates within the diode loop when they mix fundamentally with the LO. Second harmonic mixing of these noise sidebands with the virtual LO ($2f_{LO}$) produces noise which is not within the IF amplifier pass band.

An existing microstrip mixer was modified to accommodate a series mounted anti-parallel diode pair (see Figure 4) so as to evaluate second harmonic mixing at 12 GHz using a 7 GHz LO. A measured curve of the total circuit conversion loss (including the insertion loss of the band pass and low pass filters and microstrip to coaxial line transitions) as a function of fundamental LO drive is shown in Figure 5. Although no attempt was made to optimize the signal and IF impedance matches, the 8 dB total conversion loss was comparable to that obtained by fundamental mixing at 12 GHz.

In the past, harmonic mixing has usually been employed primarily at millimeter and submillimeter wavelengths where sufficiently high frequency local oscillators required for fundamental mixing were unavailable, insufficiently reliable, or prohibitively expensive. The conversion loss obtained by harmonic mixing had been shown to be typically 3 to 5 dB greater than that which could be obtained by fundamental mixing at the same signal frequency[1,2]. An analysis[3,4] has shown that so large a degradation should not exist, but it assumes that fundamental mixing between the signal and LO is suppressed. Fundamental mixing will, however, take place unless the harmonic mixer provides a reactive termination for these mixer products. That is difficult to accomplish, e.g. in the case of second harmonic mixing the fundamental mixing difference frequency ($f_s - f_{LO}$) is close to the LO frequency. In the anti-parallel diode pair mixer, however, the fundamental mixing products flow only through the relatively low forward resistance of the two diodes which form a closed loop. The conversion loss improvement is analogous to that obtained when the image frequency is short circuited in an image enhancement mixer.

A millimeter wave second harmonic mixer ($f_s \approx 60$ GHz, $f_{LO} \approx 30$ GHz) is currently under development. The anti-parallel diode pair structure designed to be inserted in a WR-15 waveguide is shown in Figure 6. The Westinghouse developed high cutoff frequency GaAs Schottky barrier diodes are mounted on a .025" thick alumina substrate which is metallized only on the surface shown. The smaller metallic end cap connects to the center conductor of the coaxial IF output port. The results of measurements on this structure will be reported.

References

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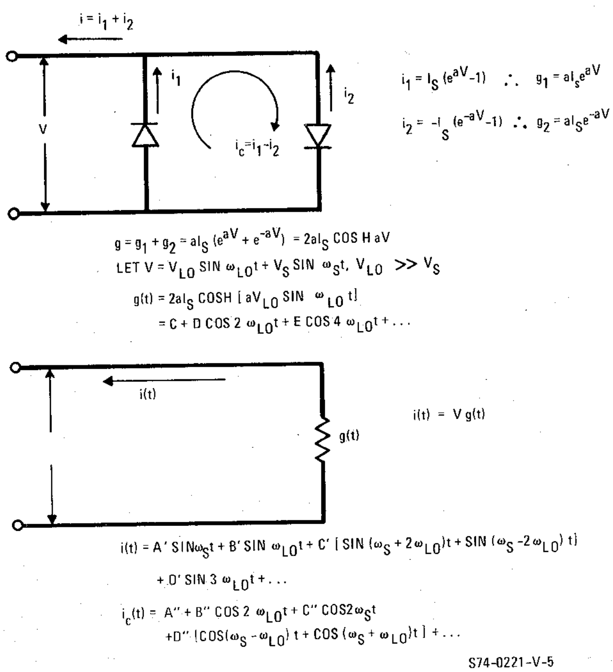

Figure 1: Analysis of the anti-parallel diode pair.

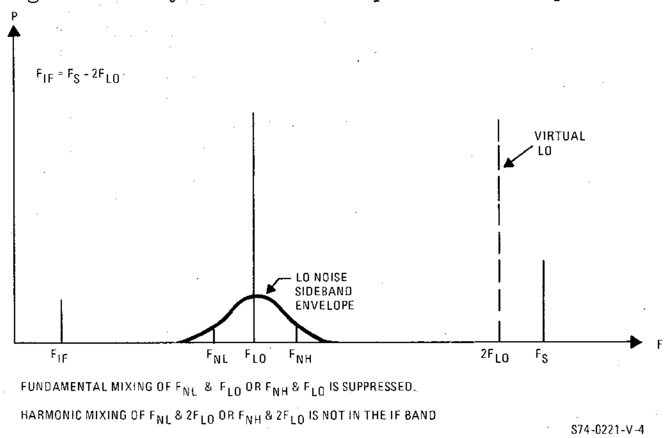

Figure 3: Local osc. noise suppression in harmonic mixing.

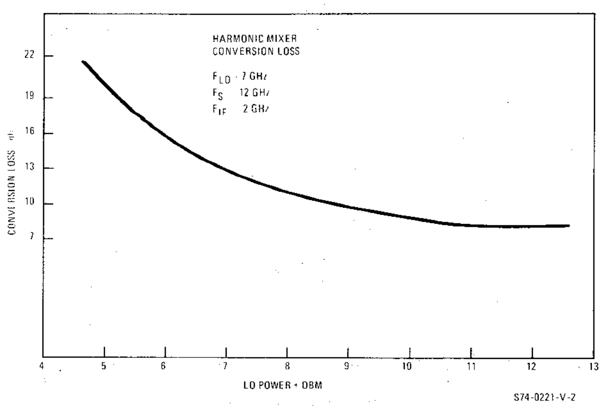

Figure 5: Harmonic mixer conversion loss.

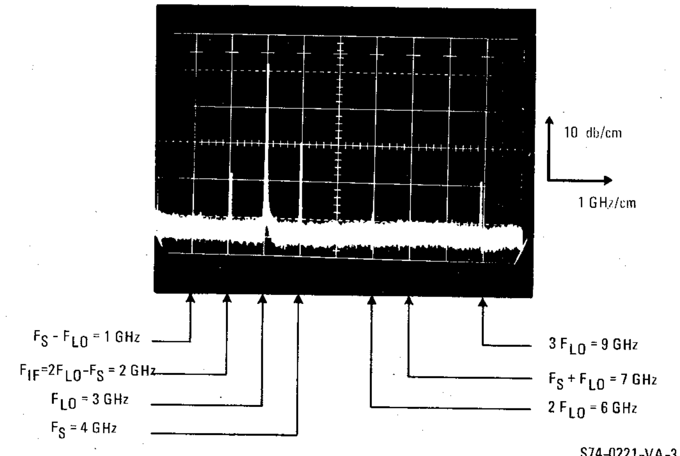

Figure 2: Output spectrum of anti-parallel diode pair on a slot line.

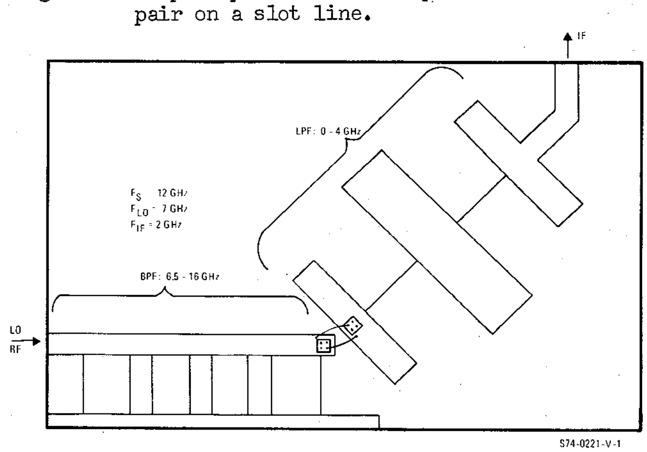

Figure 4: MIC second harmonic mixer.

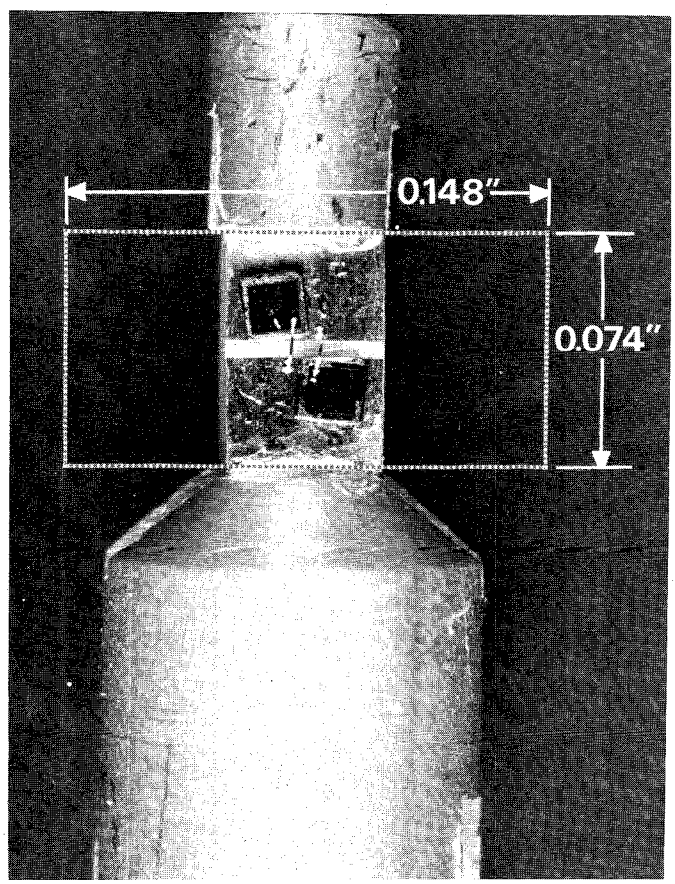

Figure 6: Millimeter wave anti-parallel diode pair structure. →