BALANCED V-BAND DC-BIASED MIXER WITH WIDE (12-GHZ) RF/IF BANDWIDTH

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ABSTRACT

This paper describes the design and performance of the first balanced dc-biased millimeter-wave mixer with a wide (12-GHz) instantaneous RF/IF bandwidth. Relative to the prior art, the new mixer requires less LO drive and yet provides the superior IM suppression provided by a balanced design.

INTRODUCTION

To address the needs of future electronic warfare (EW) systems, a new generation of downconverters is required. Such downconverters would incorporate mixers having a wide instantaneous bandwidth (to minimize the number of channels) and modest local oscillator (LO) drive requirements (to allow a single LO to be shared among several sector modules). In addition, the mixers should be mechanically small, suited to batch processing techniques, and balanced to provide superior suppression of intermodulation (IM) products.

Although wideband, balanced millimeter-wave mixers have been developed [1]. These designs were self-biased and typically required an LO power of +13 dBm for optimum performance. Applying dc bias would reduce the drive requirement and still allow the use of the high-barrier low-parasitic diodes [2], which have proven to be well-suited to millimeter-wave applications. Although dc bias has been effectively applied to single-ended [3] and balanced mixers with low IF's [4], the prior art has not addressed the balanced high-IF (18-GHz) application.

This paper describes the design and performance of the first balanced dc-biased millimeter-wave mixer with a wide (6-18 GHz) IF.

MIXER DESIGN

To address the needs of future EW systems, a mixer was designed with these performance goals:

Mixer Type	Single Balanced
LO Drive	+4 dBm (max)
RF Band	60-72 GHz
IF Band	6-18 GHz
LO/RF Isolation	20 dB (min)
Conversion Loss	8 dB (typ)
Volume	1 cu in. (max)

The RF band was chosen such that the design could be easily scaled down or up (26-110 GHz) to cover a wide range of system applications.

Based on a study of candidate circuits, the configuration shown in Figure 1 was chosen for the design. The circuit includes a ring hybrid, which provides the required LO/RF excitation at the output arms. Each output arm includes a set of coupled lines, which functions both as a transformer and a band-pass filter for the RF and LO signals. At 18 GHz, however, the coupled lines are sufficiently short to approximate a favorable open-circuit termination for the IF circuit.

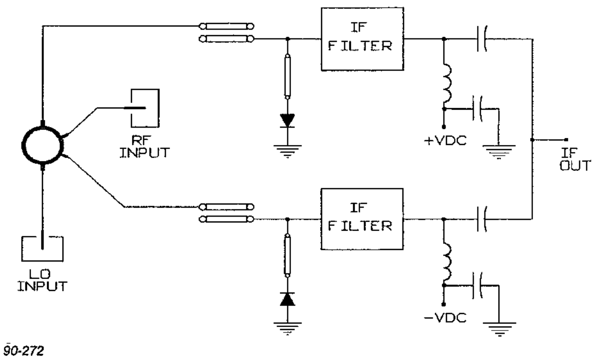

Figure 1. Mixer Equivalent Circuit

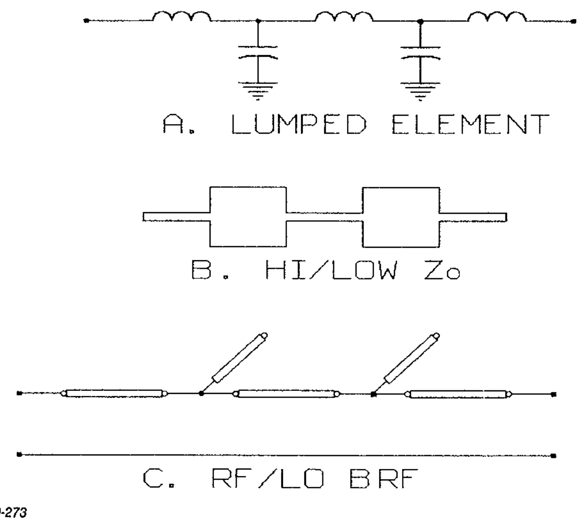

Figure 2. Candidate IF Filters

After passing through the coupled lines, the RF/LO signals enter shunt arms, each of which contains a transformer and a high-cutoff beam-lead diode [2]. The IF output is extracted through filters and a bias network consisting of lumped-element inductors and beam-lead capacitors.

Although the preferred mixer circuit could be realized in microstrip or stripline, the latter was chosen to maximize the unloaded Q, and thereby minimize the conversion loss. It was decided that the mixer would be constructed in suspended-substrate stripline, utilizing 10-mil Duroid 5880 as the substrate material. With suitable housing dimensions (44 by 62 mil), Z_0's in the range of 32 to 140 ohms can be easily achieved, and the higher-mode cutoff frequency is 84 GHz.

Since the IF filters are connected in parallel with the 50-ohm output port, each filter is designed to be matched in a 100-ohm system. The filter design proved to be particularly challenging, given this requirement, the wide separation between the IF and RF bands, and the limited range of realizable Z_0 in a single-mode housing.

Figure 2 shows three approaches to the IF filter design. The lumped-element approach of Figure 2A serves as a convenient starting point in the filter synthesis. However, low-loss, lumped-element realization is not practical in stripline at millimeter wavelengths. The lumped-element circuit can be approximated by the conventional circuit of Figure 2B or by the band-reject filter (BRF) of Figure 2C.

Figure 3 compares the calculated performance of the candidate IF filters. As shown, the low-pass filter reenters in the RF band. Although the performance could be improved by increasing the ratio between the minimum and maximum Z_0's [5], this is not possible in the preferred single-mode housing. Also shown in Figure 3 is that the BRF provides 35 dB of LO rejection and adequate (>20 dB) rejection in the RF band. Moreover, by optimizing Z_0 in the shunt stubs, low loss can be achieved in the IF band. Consequently, the BRF was chosen for the mixer design.

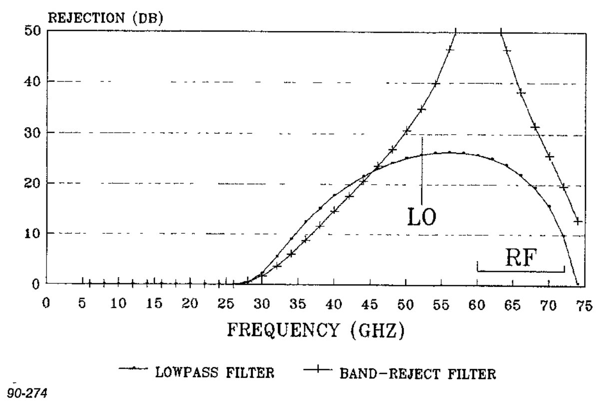

Figure 3. Calculated Response of Candidate IF Filters

The RF/LO matching network was optimized with the aid of the equivalent circuit of Figure 4. Included in the circuit are a series transformer of length L1, the coupled lines (L2), another transformer (L3), the diode parasitics, and a short line (L4) which models the finite length between the diode and the chassis ground. Although the IF filter has little effect on the RF/LO match, for completeness, this filter was also included in the circuit. Using a computer-aided technique, the variables in the circuit were optimized to provide a calculated return loss of 7 dB or better across the RF/LO band.

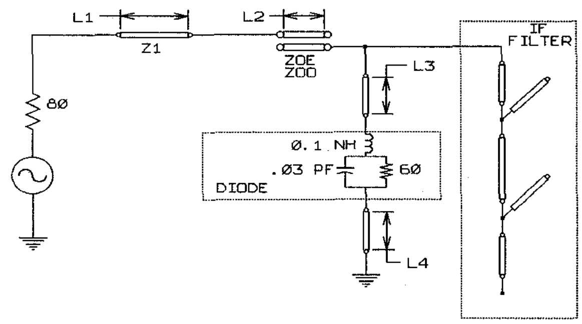

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Figure 4. Equivalent Circuit for RF/LO Matching Circuit

CONSTRUCTION AND TESTING

After completing the electrical and mechanical designs, the mixer of Figure 5 was constructed. The split-block housing contains stripline channels, which are compatible with numerical milling techniques. The RF and LO ports, which are located on the opposite broad walls of the housing, include probe transitions [6] from waveguide to stripline. The SMA output connector and the dc-bias pins are colocated on one narrow wall. The housing has a volume of less than three-quarters of a cubic inch.

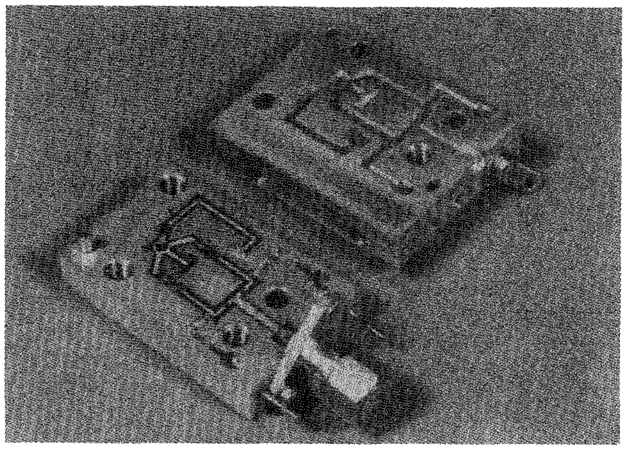

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Figure 5. Mixer Prototype

Initial measurements showed that the RF match was satisfactory, but trimming of the LO port was necessary to improve the return loss. After trimming, the conversion loss of Figure 6 was measured. As shown, the loss is 8.1 ±1.2 dB across the 12-GHz design band, given a moderately low LO input of +4 dBm.

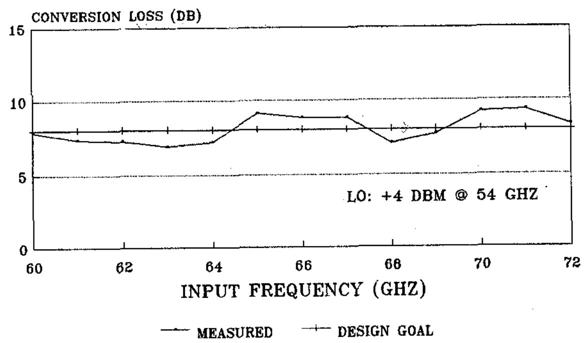

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Figure 6. Measured Conversion Loss

The measured LO/RF isolation is plotted in Figure 7. For dc-bias currents greater than 1.1 ma, the isolation is 20 dB or better. Moreover, at the optimum bias for conversion loss (2 ma), the isolation is 27 dB.

Additional measurements show that the 1-dB compression point is typically +1.5 dBm across the design band.

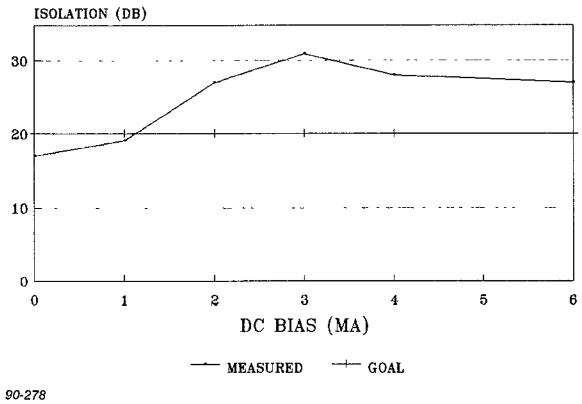

Figure 7. LO/RF Isolation

CONCLUSION

This paper has described the design and performance of the first balanced dc-biased millimeter-wave mixer with a wide (12-GHz) instantaneous RF/IF bandwidth. Relative to the prior art, the new mixer requires less LO drive and yet provides the superior IM suppression provided by a balanced design. The mixer includes an unique IF-output filter which avoids the reentry problems associated with conventional high/low-Z_0 designs. The mixer design is applicable to a new generation of EW systems, which cover wide millimeter-wave bands with a small number of mixers and shared LO's.

References

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