2 TO 8 GHZ DOUBLE BALANCED MESFET MIXER WITH +30 DBM INPUT 3RD ORDER INTERCEPT

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ABSTRACT

Typical third order input intercept (IP3) of +30 dBm was achieved from 2 to 8 GHz using a double balanced MESFET mixer operating in the unbiased or passive mode with +23 dBm LO input power. A quality factor is defined to show the efficiency of third order intercept to available LO power. Also, a single balanced MESFET mixer from 4 to 18 GHz with IP3 greater than +25 dBm is discussed.

INTRODUCTION

The dynamic range of many microwave front-ends is still determined by the single and two-tone intermodulation levels of a Schottky diode mixer. Various multiple diode circuit schemes have been devised to improve the isolation, bandwidth and single-tone intermodulation levels, but these circuits still require the familiar trade-off of LO power for third order intercept (IP3) and 1 dB compression points.

Maas (1, 2) showed that low distortion mixing could be achieved with small amounts of LO power, if the unbiased channel of a GaAs MESFET was used as a mixing element. Using this approach, Maas insured that the LO energy leaking across the drain to source terminals was short-circuited, so that the MESFET would not enter the saturation region, but would remain in the linear (ohmic) region, where distortion is at a minimum. Although this design achieved high intermod suppression, its bandwidth was limited by the LO balun and IF transformer. Recent experiments at RHG showed that, by using tapered microstrip baluns, in a novel single balanced configuration, multioctave bandwidths could be achieved. Although our design did not short-circuit the LO energy across the drain to source of the MESFET, similar intermodulation performance to Maas' design at 0 gate bias was attained.

Expanding on the concepts of mixers designed for the UHF frequency range (3 - 6), where double balanced, dual gate MESFET and silicon MOSFET mixers were constructed, RHG designed and tested a unique multioctave double balanced circuit which utilized a ring of GaAs MESFET's and tapered microstrip baluns. The bandwidth of this unit was limited by the MESFET package parasitic reactances used in the ring. This configuration presented a virtual short to the LO energy across the drain to source terminals, and resulted in a +30 dBm IP3. A chip version is being constructed which will eliminate many of the parasitics associated with packaged devices, and will allow for an improved bandwidth.

CIRCUIT DESCRIPTION

Figure 1 shows the low frequency equivalent circuit of the balanced and double balanced MESFET mixers. The single balanced mixer was constructed with two NEC NE710 MESFET's, and the double balanced mixer with a ring of 4 Harris HMF-0304 MESFET's. Figure 2 shows close-up photos of both microwave breadboards, and Figure 3 is a physical model of the 2 to 8 GHz double balanced version.

Since the double balanced mixer employs a ring configuration, it was possible to extract the IF from the source, thus eliminating the need for a diplexing network to separate the RF and IF signals. Isolation is also enhanced due to the symmetry of the ring. This configuration also causes even order products, such as LO - RF (IF), to appear at the source terminal pair, and the odd products, such as 2LO x RF (image) and 0LO - RF (RF), to appear across the drain terminals.

The baluns were etched on a 0.010" thick duroid substrate. A 4:1 impedance transforming balun was used to drive the LO gate terminal pairs, while 50 ohm tapered line baluns were used at the RF (drain) and IF (source) terminals. Figure 4 is the electrical equivalent model of the 2 to 8 double balanced mixer circuit. The theoretical L/C balun sections were obtained by a modified method of moments whereby an inhomogeneous cross section of conductors and dielectrics can be replaced with equivalent charges at all boundaries, and the resulting piecewise homogeneous problem solved by linear equations relating voltage to charge and geometry. The balun equivalent series TEM inductances are obtained from the strip capacitances, with air as a dielectric.

The large signal (LO) MESFET voltages and currents of Figure 5 were obtained numerically by Microwave SPICE (a product of EESOF) using the Curtice MESFET model. This model gave good agreement between the small signal measured, and predicted conversion loss, provided a slight negative bias was used in the theoretical model. As an alternative to the pure numerical model of the mixer, one can gain insight by considering the switching action of the gate in discrete time steps throughout the LO cycle. This quasi-static view of mixing illustrates that each increment of the LO cycle produces a different, and measurable, small signal drain RF conductance and susceptance which, if expanded in a harmonic Fourier series about the LO rate, will yield frequency or conversion Y matrix. In actual practice neither the drain voltage nor current is sinusoidal. Instead, only the incident RF power wave is known, so signal scattering parameters are derived, as shown in Figure 5, which represents the periodic variation of each MESFET's output load reflection coefficient.

EXPERIMENTAL RESULTS

Figure 6 shows the measured conversion loss, isolation and intercept points of the single balanced (4 to 18 GHz), and the microwave double balanced (2 to 8 GHz) mixers, measured at LO powers of +19 dBm, and +23 dBm, respectively. A low frequency prototype of the double balanced mixer was constructed for design verification and its performance with a LO input power of +18 dBm is included in Figure 6.

A typical Schottky mixer obtains an IP3 approximately equal to the LO power minus the conversion loss plus 10 dB. We define a third order quality factor Q(3rd), which is the difference between IP3 to LO power (dB) as a measure of LO power utilization from one mixer to another. A Q(3rd) of 12 dB was obtained for the low frequency double balanced mixer, while a Q(3rd) of 7 dB was obtained for the 2 to 8 GHz double balanced version. A typical Schottky mixer would have a Q(3rd) of approximately 3 dB.

Typical conversion loss for the microwave double balanced mixer is 8 dB and degrades to 9.3 dB at 8 GHz, due to lead lengths and package parasitics. Isolation was greater than 25 dB across the 2 to 8 GHz band. Typical IP3 of +30 dBm at a fixed LO power of +23 dBm was achieved with degradation to +28 dBm at 8 GHz, due to circuit imbalances. Future matched monolithic versions are expected to have superior intermodulation performance.

CONCLUSION

A multioctave double balanced MESFET mixer operating over a 2 to 8 GHz range has been developed. Third order intercepts greater than +28 dBm were obtained over this bandwidth at an LO power of +23 dBm, with typical conversion loss of 8 dB, and LO to RF isolation greater than 25 dB. Furthermore, it was shown that single balanced versions are capable of operating up to 18 GHz.

Future effort on this project will include the evaluation of a monolithic MESFET Quad with a special gate geometry, designed to improve the third order distortion. The FET will be wire-bonded to an alumina substrate, to minimize frequency limiting parasitic reactances.

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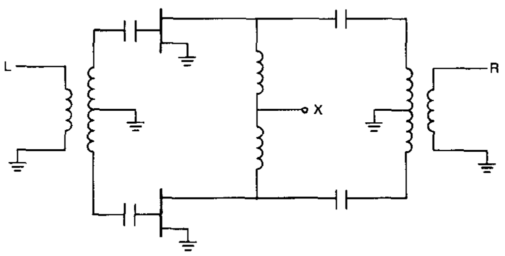
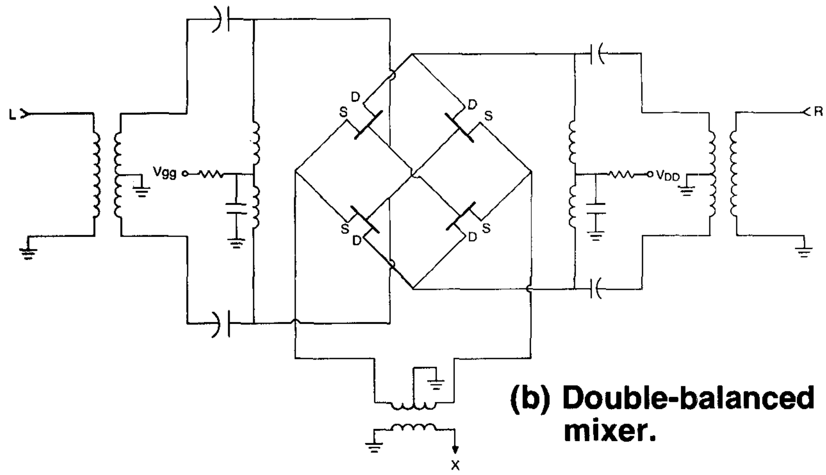
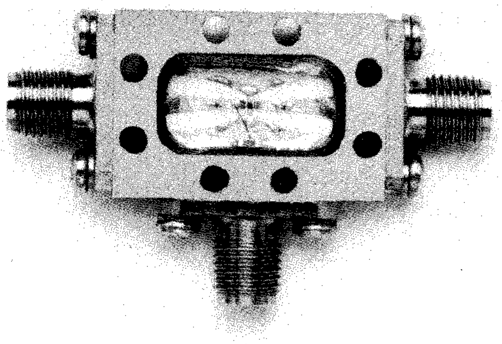


(a) Single-balanced mixer.



(b) Double-balanced mixer.

Fig. 1. Low frequency equivalent circuit.



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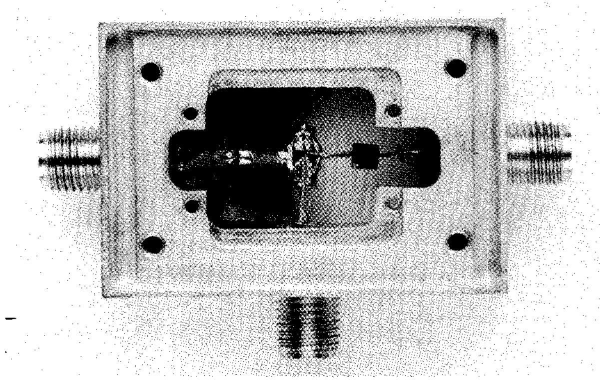

b

Fig. 2. Photograph of (a) Single-balanced mixer. (b) Double-balanced mixer.

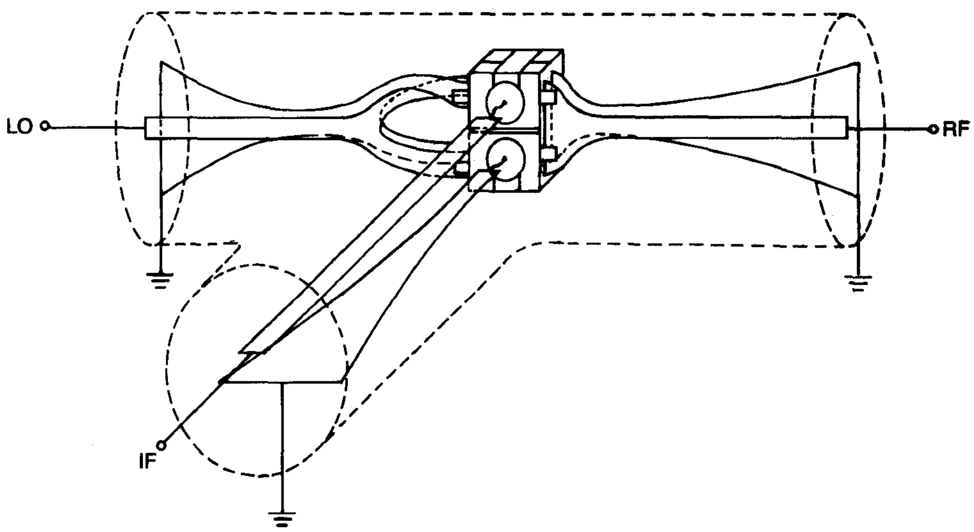

Fig. 3. Physical model of 2 to 8 GHz double-balanced mixer.

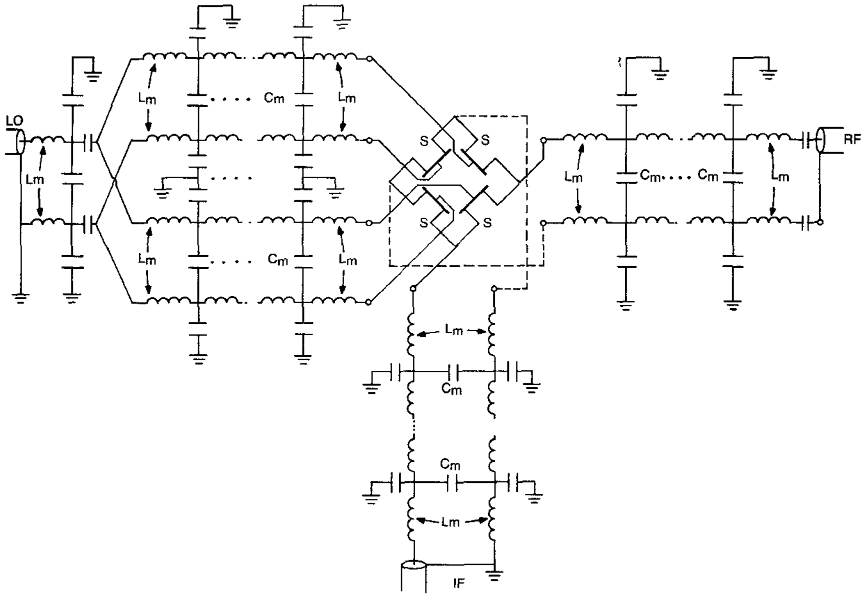

Fig. 4. Electrical equivalent circuit of 2 to 8 GHz double-balanced mixer.

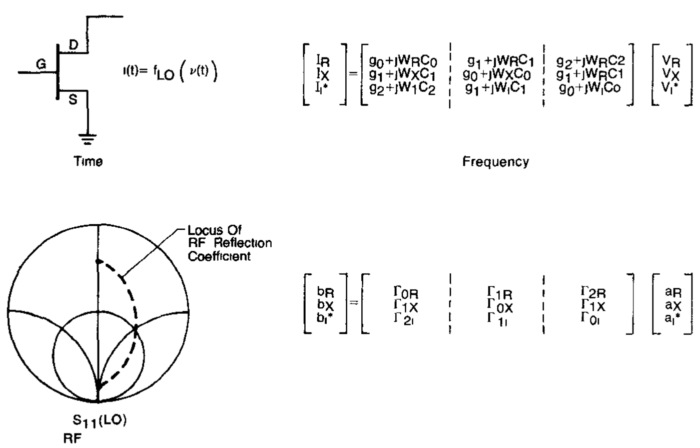

Fig. 5. Y and S matrix of single FET.

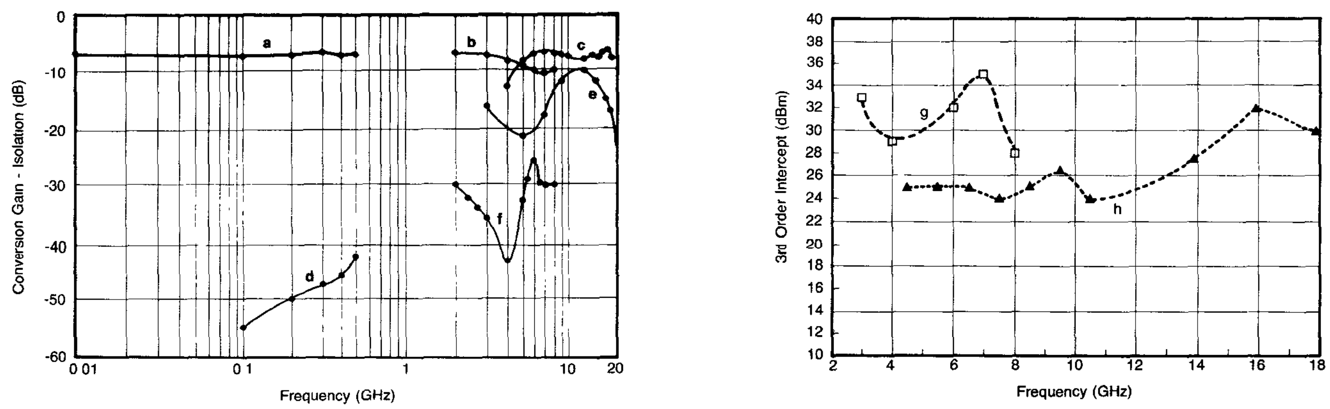

Fig. 6. Measured performance. (a) 0.1 to 0.5 GHz conversion loss. (b) 2 to 8 GHz conversion loss. (c) 4 to 18 GHz conversion loss. (d) 0.1 to 0.5 GHz isolation. (e) 4 to 18 GHz isolation. (f) 2 to 8 GHz isolation. (g) 2 to 8 GHz IP3. (h) 4 to 18 GHz IP3.