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A QUASI-OPTICAL HEMT SELF-OSCILLATING MIXER

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Abstract- A Planar quasi-optical receiver circuit that compactly integrates a coupled slot antenna, and a HEMT self-oscillating mixer on the same substrate is developed for applications in microwave and MMW receiver arrays. The circuit exhibits an isotropic conversion gain of 4.5dB which is 7.5dB higher than the diode circuit previously reported.

INTRODUCTION

Quasi-optical planar receivers that integrate a coupled-slot antenna, a Schottky diode balanced mixer and a Gunn/or MESFET local oscillator have been introduced[1],[2]. These circuits[1][2] are compact self-contained units that utilize the orthogonal even mode/odd mode characteristic of the coupled slotline(CSL) to achieve intrinsic RF/LO and RF/IF isolation. In this paper, we present a quasi-optical circuit that employs a coupled slot antenna, and a HEMT self-oscillating mixer. In addition to the features of the works in [1][2] mentioned above, the HEMT circuit offers two more advantages. First, isotropic conversion gain of 4.5 dB is achieved using HEMTs as opposed to a 3 dB isotropic conversion loss in the Schottky diode mixer circuit[2]. Second, the new circuit is more compatible with the FET based MMIC technology since no diodes are used.

The operation of a HEMT mixer is similar to that of a MESFET mixer. However, due to its high transconductance and almost impurity scattering free current transport mechanism, HEMT mixers are expected to have a lower noise figure and be able to operate at higher frequencies. In the present work, the HEMT self-oscillating mixer is biased to the knee voltage at the drain, and the gate is zero biased. At this bias condition, the device voltage amplification factor

$$u = G_m * R_o \qquad (1)$$

is most sensitive to LO modulation. In (1), G_m is the transconductance, R_o is the output resistance. Also, since the gate is DC open, no gate bias circuit is needed and the circuit complexity is reduced.

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CIRCUIT OVERVIEW

Figure 1 shows the layout of the HEMT self-oscillating mixer circuit. The basic building block of the entire circuit is the connected coupled slot made on the ground plane. The connected coupled slot is used simultaneously as a half-wave resonant antenna for the RF signal received in the even mode and as an embedding circuit for the LO signal propagating in the odd mode. Due to the orthogonality of the even mode and odd mode of CSL, the RF signal and the LO signal are intrinsically isolated, which in turn prevents the LO signal from being injection locked to the RF signal.

Packaged NEC 20383A HEMTs are used. The two packaged devices are placed at the backside of the substrate(microstrip line side). The drain leads of the HEMTs are connected to the microstrip lines(dotted lines). The gate and the source leads are connected to the center conductor of CSL and the edges of the CSL ground plane respectively, by conducting thru-holes. If HEMT chips are used or an MMIC fabrication is employed, the HEMTs could be appropriately placed inside the coupled slot, the gates and the sources would be connected to the center conductor and the ground edges of CSL, respectively, whereas, the drains would be via-hole connected to the microstrip lines.

Figure 2 shows the RF,LO and IF signals polarities with respect to the

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devices. The even mode RF signal received by the coupled slot antenna is fed to the input ports (gate to source) of the HEMTS. The two HEMTs are gate-coupled to form a balanced oscillator. The coupled slot and the microstrip tuning stub (which is connected to the center conductor of the CSL by a conducting thru-hole) form the gate resonator for the balanced oscillator. The IF signals coming out of the drain ports to the microstrip lines are 180° out-of-phase. The two microstrip lines are combined to form a coupled microstrip line(CMS). The IF signals are power combined at the CMS and is propagated as the odd mode of the CMS (fig. 3). The IF signal is coupled out of the circuit by an SMA launcher, with the launcher center tap connects to one microstrip and the outconductor connects to the other microstrip.

CIRCUIT DESIGN PRINCIPLES

The coupled slot dimensions are first determined. The length of the CSL is half-wavelength in the even mode RF signal frequency. In order to match the CSL antenna input impedance to the HEMTs' input impedance, the gate and source leads are connected to the CSL at a small distance away from the center of the half-wavelength CSL.

Figure 4 is a schematic of the oscillator portion of the circuit. The local oscillator is designed approximately by means of small signal S-parameters of the device. First, the gate resonator is designed by finding the length of the microstrip tuning stub (in Fig.1), so that at the drain ports, the output impedances of the HEMTS are $-R+jX$ with the value of $|R|$ being small. Then, the length "d" is determined such that the devices' drain ports see reactance of $-jX$ at the oscillation frequency. Under a large signal oscillation, $|R|$ will be reduced to a negligibly small value and will be cancelled by circuit's radiation and other losses.

The IF output impedance of the HEMT mixer is large[3], Therefore, the characteristic impedance of the two microstrip lines connected to the drains of the HEMTs are designed to be 100 Ω. The two microstrip lines are combined to a coupled microstrip line with an odd mode characteristic impedance of 50 Ω.

CIRCUIT PERFORMANCE

An X-band version of the circuit was fabricated on a RT Duroid substrate. Photographs of the circuit are shown in Fig. 5. To characterize the efficiency of the receiver as a single unit, the isotropic conversion gain, G_{iso}, is used. This quantity is defined as

$$G_{iso} = 10 \times \log(P_{IF}/P_{iso}) \quad \text{dB} \qquad (1)$$

where, P_{IF} is the down converted IF power. The quantity, P_{iso}, is the RF power that would be received if the circuit under test were replaced by an isotropic antenna. Figure 6 shows the changes of G_{iso} and IF frequency with bias voltage changes. The maximum G_{iso} was measured to be 4.5 dB. This result is 7.5 dB higher than the diode circuit previously reported[2]. By placing a quartz hemispherical lens (which focuses the RF energy to the coupled slot) on top of the ground plane, maximum G_{iso} was increased to 12 dB.

CONCLUSION

A quasi-optical HEMT self-oscillating mixer design is described. The mixer circuit is capable of obtaining a conversion gain and has potential applications in both microwave and MM wave receiver array. MMIC technology is also potentially applicable to the fabrication of the circuit.

REFERENCES

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[3] S. S. Maas, "Design and performance of a 45-GHz HEMT mixer," IEEE Trans. Microwave Theory Tech., vol. MTT-34, no. 7, pp.799-803 ,July 1987.

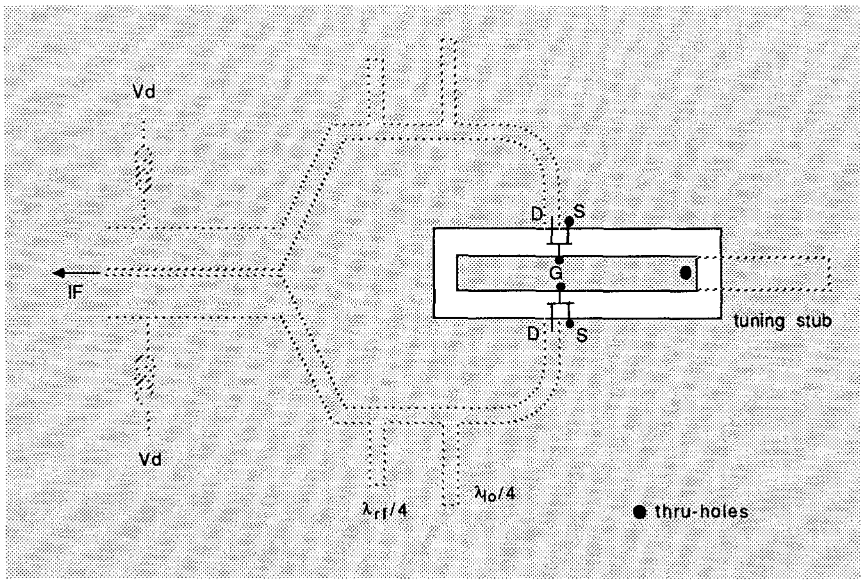


Fig. 1 Circuit diagram of the self-oscillating mixer

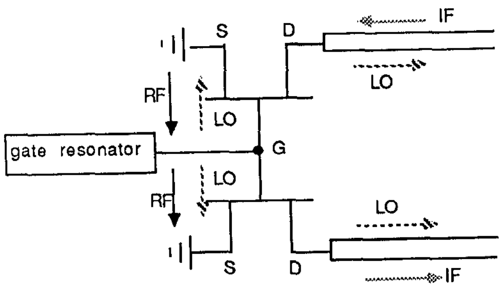


Fig. 2 Signals polarity with respect to the devices

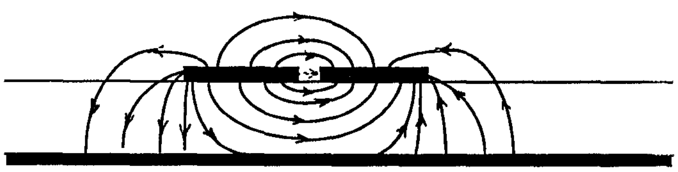


Fig. 3 Odd mode E-field distribution of the coupled microstrip line

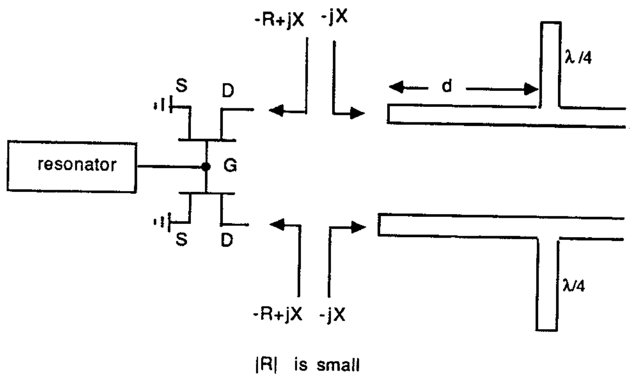
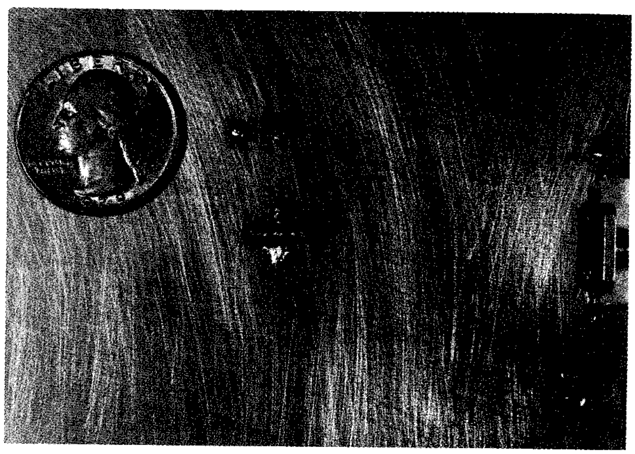


Fig. 4 Designing of the balanced oscillator



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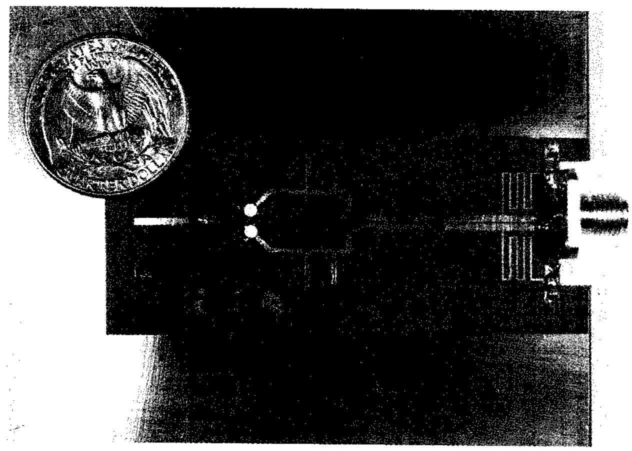

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Fig. 5 Photographs of the circuit

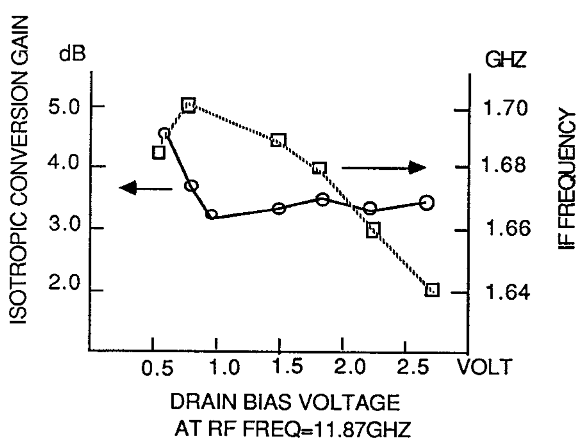

Fig. 6 Isotropic conversion gain and IF frequency vs. bias voltage