A PLANAR INTEGRATED ANTENNA AND RECEIVER FRONT END

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ABSTRACT

A compact, self-contained, and planar circuit that integrates a coupled slot antenna, a balanced mixer, and a Gunn diode local oscillator is described. This circuit utilizes the even/odd mode properties of the coupled slotlines to achieve intrinsic RF-LO and RF-IF isolation.

INTRODUCTION

A novel design of a planar antenna and receiver front end circuit is described. This circuit is a self-contained unit that integrates a coupled slot antenna, a balanced mixer, and a Gunn diode local oscillator in a compact manner. The even/odd mode properties of the coupled slotlines are utilized to achieve intrinsic RF-LO and RF-IF isolations. When the design is extended to the millimeter-wave frequency range, quasi-optical techniques such as the dielectric lense, can be used to focus RF energy onto the coupled slot antenna due to its planar and unenclosed strusture. This circuit is expected to find applications in imaging arrays and low cost receiver modules where compactness and low cost are required.

CIRCUIT OVERVIEW

It is generally known that the coupled slotlines(CSL) support two orthognal modes: even and odd mode. The CSL excited by the odd mode becomes a coplanar waveguide(CPW) which is less susceptible to radiation at discontinuities. When the CSL is short-circuit terminated at both ends and is excited by the even mode, it becomes a pair of slot antennas.

The basic building block of the entire circuit(Fig. 1) is a connected coupled slot (see Fig. 2), which is used simultaneously as an antenna (using the even mode) and in constructing the local oscillator resonator (using the odd mode).

When the coupled slot is used as an antenna, the receiving RF signal couples with the even mode of the CSL. The length L of tne coupled slot (see Fig. 2) is approximately a half-wavelength of the even mode RF signal. Also, the end of the connected coupled slot (see Fig. 2) is a virtual short circuit for the even mode RF signal. Therefore, the coupled slot become a pair of half-wave resonant antennas.

The Gunn diode is placed at one end of the coupled slot (see Fig. 3). The local oscillator signal produced by the Gunn diode and the down converted IF signal are in the odd mode(CPW mode). The local oscillator resonant circuit is made of the tuning stub, the coupled slots, the Schottky diodes, and the microstrip low-pass filter.

From the polarizations of the RF and LO signals (see Fig. 2), we can see that a balanced mixer is formed by placing a pair of Schottky diodes in the slots as shown in Fig. 1. The end of the coupled slots is a virtual short circuit for the even mode RF signal. Whereas, for the odd mode LO and IF signals, it is an open circuit (see Fig. 2). This dual characteristic provides intrinsic RF-LO and RF-IF isolation.

The microstrip low-pass filter and local oscillator tuning stub are fabricated on the backside of the substrate as shown in Fig. 1. To provide DC isolation of the Schottky diodes from the Gunn diode bias, the region

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containing the coupled slot lines is separated from the rest of the ground plane by a DC block line indicated in Fig. 1. This DC block line is an extremely narrow gap in the metallization of the ground plane.

CIRCUIT DESIGN

Planar antenna-mixers and planar CPW oscillator have been reported (1),(2). The circuit here combines a planar antenna, mixer, and oscillator in a compact manner as described in the previous section. The dimensions of the coupled slot antenna are first determined (see Fig 2). The length L is approximately a half- wavelength of the RF signal. The spacing between the two slots, S, should be small compared with free space wavelength so that the two slots receive the RF signal with approximately the same phase. The slot width, W, also needs to be small to eliminate undesired modes.

To design the local oscillator, the impedance of the Schottky diode at the LO frequency is first approximated. Also, we note the low-pass filter presents a short-circuit for the LO signal. The mixer diodes are first positioned at the center of the coupled slot lines. Lengths d_1 and d_2 (Fig. 1) are then calculated so that the Gunn diode, with a -R+jX impedance, sees an embedding circuit impedance of R-jX at the LO frequency.

After the circuit is fabricated, the position of the Schottky diodes is adjusted experimentally so that maximum IF power is obtained. This optimum position of the diodes is where the coupled slot antenna input impedance best matches the diode impedance at RF frequency. In most cases, the optimum position is a small distance away from the original center position. Therefore, the local oscillator is not affected much by the adjusting of diodes position. The tuning stub length, d_1, and the Gunn diode bias voltage provide mechanisms for further tuning of the LO signal.

EXPERIMENTAL RESULTS

The circuit is fabricated on a R/T duroid substrate of thickness 1.57mm. To characterize the circuit performance, the isotropic conversion loss, L_{iso} is used, since L_{iso} is a measurement of system performance as described in (3). L_{iso} is defined as

$$L_{iso}=10*\log(P_{IF}/P_{iso}) \text{ DB} \qquad (1)$$

where P_{IF} is the down converted IF power obtained. P_{iso} is the RF power that would be received if the circuit is replaced by a fictitious isotropic antenna. L_{iso} vs. RF frequency and L_{iso} vs. LO frequency are shown in Figs. 4 and 5. These results are satisfactory, considering that no IF port matching is attempted. Here, the LO frequency is changed by adjusting the bias voltage.

The circuit is also fabricated on a Epsilon-10 substrate of dielectric constant 10.2, and thickness 0.635mm. Comparable performances are obtained using this substrate.

Fig. 6 is the photographs of the circuit fabricated on a R/T duroid substrate.

CONCLUSION

A novel design of an integrated planar antenna and receiver front end is demonstrated. Despite the simplicity of this circuit, satisfactory performances are obtained. Hence, this circuit is suitable for imaging array and low cost receiver module applications at both microwave and millimeter wave frequency ranges.

ACKNOWLEDGMENT

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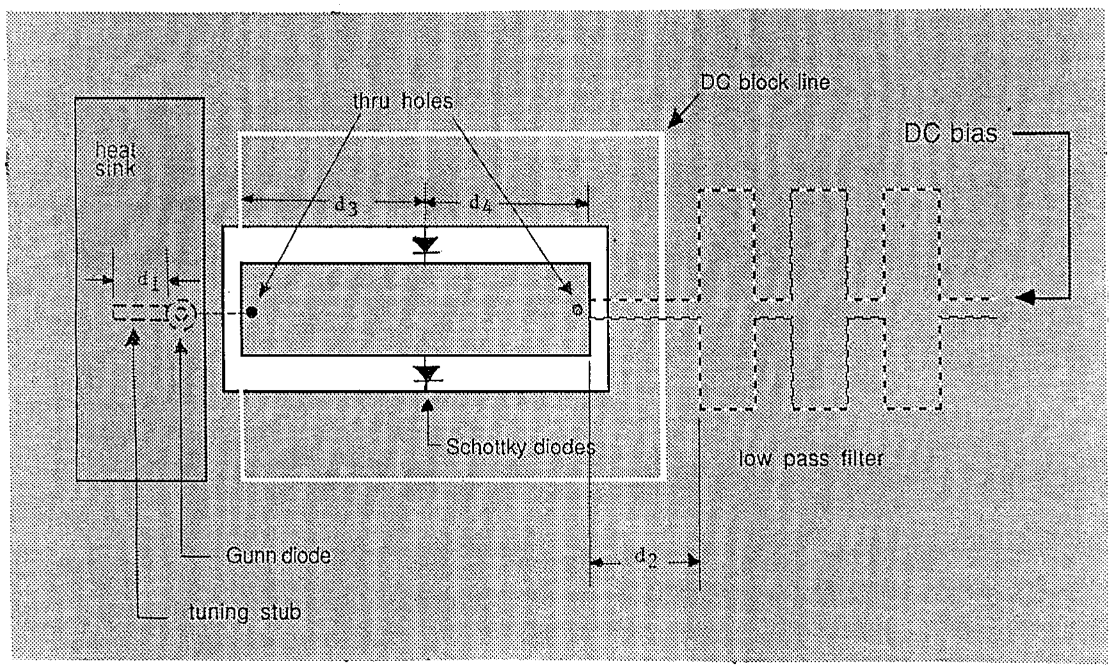


Fig. 1 ' Circuit diagram of the coupled slot antenna and receiver

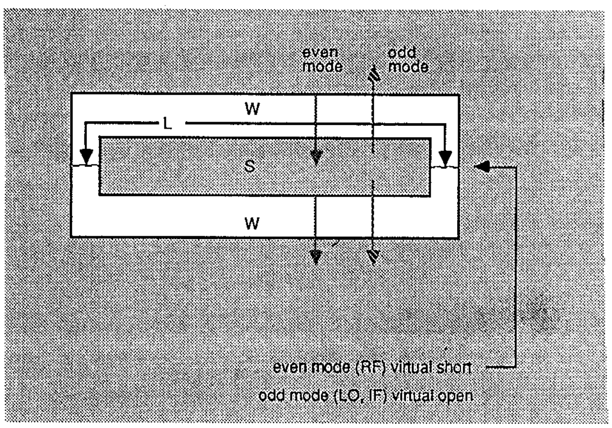


Fig. 2 Connected coupled slot antenna

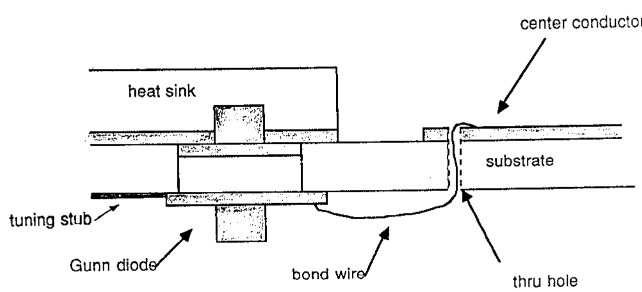


Fig. 3 Cross-section view of the Gunn diode connection

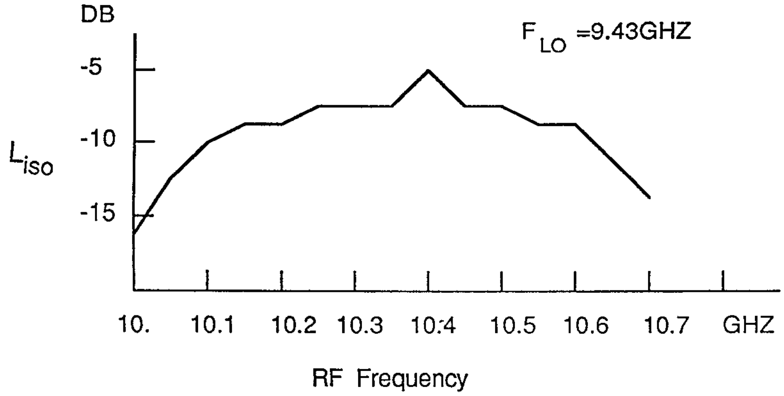


Fig. 4 Isotropic conversion loss vs. RF frequency

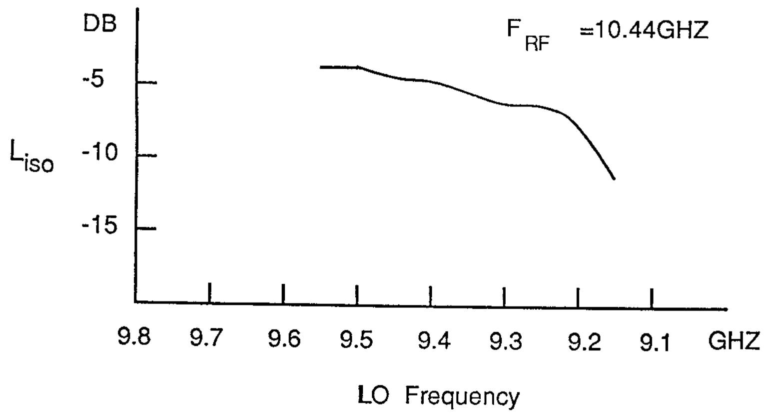
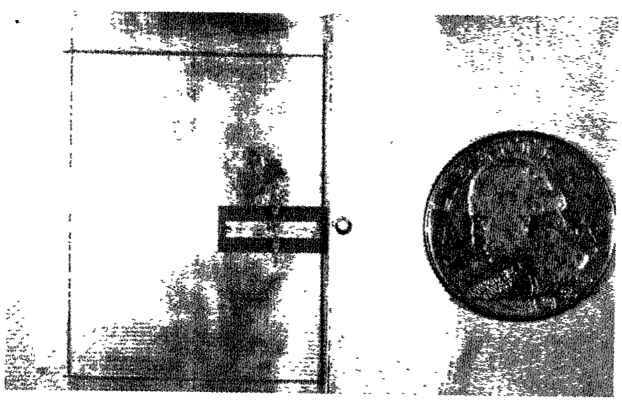


Fig. 5 Isotropic conversion loss vs. LO frequency



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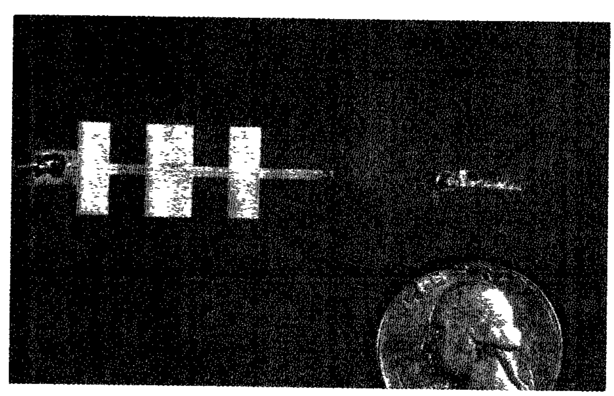

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Fig. 6. Photographs of the circuit fabricated on a R/T duroid substrate