AN X-BAND BALANCED FINLINE MIXER

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Abstract

Finline technique has been used in a balanced 9-11 GHz mixer with a 70 MHz intermediate frequency. The conversion loss is less than 5 dB with 3.8 dB minimum. The mixer is tunable by variable shorts. It is possible to scale the mixer to mm-wave frequencies.

Introduction

This paper describes the design and performance of a microwave integrated circuit (MIC) balanced mixer that covers the bandwidth of 2 GHz within the X-band with conversion losses of less than 5 dB. The mixer operates with an intermediate frequency (IF) of 70 MHz but the device is able to handle higher IF's up to some GHz.

In the circuit considered here finline technique[1] has been used to realize a mixer which is capable to work well up to mm-wave frequencies. Because the fundamental mode of a finline (H_{10}-mode) is the same as the one of an unloaded waveguide, transitions between these two guides are easy to handle and have very small insertion loss and VSWR over entire waveguide bands. Parasitic radiation which often is a problem connected with planar waveguides especially at higher frequencies can be avoided. So finline has very low losses. Moreover ist offers the same possibilities of integration as other planar circuits.

Although finline seems to be advantageous especially for mm-wave applications we have designed the mixer for a signal center frequency of 10 GHz because at this frequency measurements can be made very exactly.

A Planar Magic T

To realize balanced mixers 90° or 180° hybrids are required. To do this with planar circuits one can use branchline couplers, ring hybrids, parallel-coupled-line couplers, combinations of orthogonal transmission lines like slot lines and coplanar lines, or magic T's. There are several papers which deal with such mixers[2-4] and excellent results have been reported.

We have designed a magic T consisting of a finline-microstrip hybrid junction (Fig.1). The electric field of a wave incident from the left on the slot of a finline (solid arrows) divides itself in equal parts and in antiphase in both the cross arms. So does a wave incident from the right on a microstrip line (dashed arrows) except that this wave will appear in phase in both the cross arms. At nonlinear elements placed in the cross arms the incident waves beat once in phase and once in antiphase. If the microstrip side of the hybrid is used as a local oscillator(LO) input and the finline side as a signal (RF) input in a common IF output the LO currents cancel and the IF currents are in phase. So this arrangement is capable to be used as a balanced mixer.

Because the cross arms are series connected referred to the finline input but parallel-connected referred to the microstrip input their impedance must be chosen to be twice the one of the impedance of the finline input and half the one of the microstrip input. Methods for calculating finline impedances are available from the literature[5,6].

Measurements at the hybrid junction have yielded a maximum power imbalance of 0.3 dB and a maximum phase imbalance of 2 between the cross arm over the entire X-band. That was true for waves incident at the finline side as well as at the microstrip side. These results critically depend on the symmetry of the device. The isolation between the two inputs was 35 dB minimum with 40 dB average. The maximum insertion loss between the finline input and one of the cross arms was 0.4 dB with a 0.2 dB average within the 8.5 to 11.5 GHz band. Looking from the microstrip input the losses were slightly higher due to a higher reflection coefficient: 0.6 dB maximum with a 0.3 dB average were observed within the same frequency band.

Complete Mixer Configuration

The complete mixer is shown in Fig.2. The LO power is fed to the mixer from an unloaded rectangular waveguide via a transition (1) containing a finline taper, a short section of antipodal finline[5], and a 50Ω-microstrip line. The additional metallization (2) prevents the metal-free space below the taper from resonating in the considered frequency band. Measurements at two of such transitions in series have resulted in an insertion loss of less than 1.35 within the 8.5 to 12 GHz band. The RF power is fed to the mixer via a finline taper (3) which is uncritical in its dimensions and has an insertion loss of about 0.1 dB and a VSWR of less than 1.2 over the entire X-band. The impedance of the finline is 200 Ω such that it is matched to the 100Ω cross arms.

The microstrip line carrying the LO power is simultaneously used as IF output. To do this the nonlinear elements are connected with the microstrip by lines (4) terminated in an open circuit. The lines are half a

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wavelength long at the LO center frequency. The nonlinear elements are connected at the middle of the lines. A five section conventional microstrip low pass filter (5) acts as a diplexer between LO and IF. The pass - band insertion loss of the filter which has a cutoff frequency of 3 GHz is less than 1 dB. The RF and LO isolation is better than 35 dB. An 8.2 pF capacitor (6) which blocks the IF from the LO input is connected in series with the microstrip. A remarkable advantage of the mixer is that it is tunable by variable shorts (7). So it is easy to match the RF input and to minimize the conversion loss for different LO power levels over a considerable wide frequency band without a laborious variation of the whole mixer configuration. After tuning the shorts can be fixed by bridging the slots of the cross arms.

Mixer Performance

The mixer was printed on a 0.25 mm teflon substrate (RT/Duroid 5880). GaAs Schottky barrier diodes* and Si beam lead Schottky barrier diodes** were used as nonlinear elements. A conventional X-band waveguide was used to hold the planar structure. Conversion loss data for the mixer are presented in Fig.3 for a fixed LO power of + 12 dBm. For these measurements we used the GaAs diodes. The Si diodes gave slightly worse results. When the shorts were fixed such that the mixer was optimised at an RF frequency of 10 GHz the mixer had a minimum conversion loss of 3.8 dB (solid line) with a SSB noise figure of 5.3 dB at this point. When the mixer was optimised at other frequencies (dashed lines) the overall behaviour was slightly worse but better at specified frequencies. The RF VSWR was better than 1.3 in the 9 to 11 GHz band. The LO VSWR was less than 4.0 which can be improved by properly matching the LO input. The mixer output impedance was about 50 Ω. The LO to RF isolation was measured to be between 25 and 28 dB.

Conclusions

The features of a balanced finline mixer working at X-band have been demonstrated. The main part of the mixer consists of a planar circuit. A waveguide simultaneously serves as a holder and avoids radiation from the planar structure. So the mixer has conversion losses comparable to waveguide mixers but the advantage of a simpler construction. Low-loss variable shorts as used in waveguide technique have proven to be excellent tuning elements. Thus the mixer profits by the advantages of MIC and conventional waveguide technology. Measurements have been executed at X-band but it is possible to scale the device to mm-wave frequencies.

Acknowledgement

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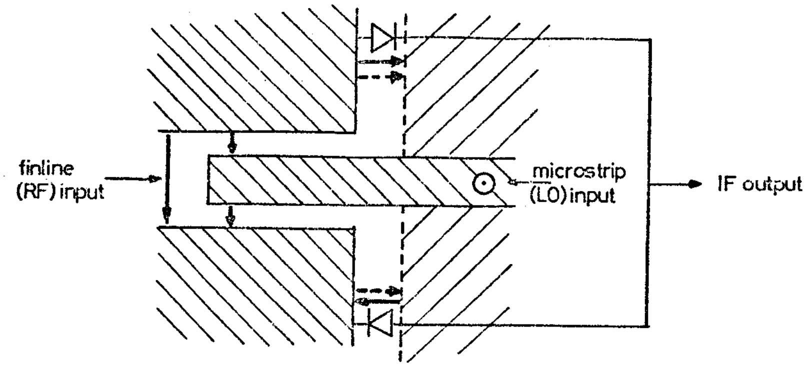
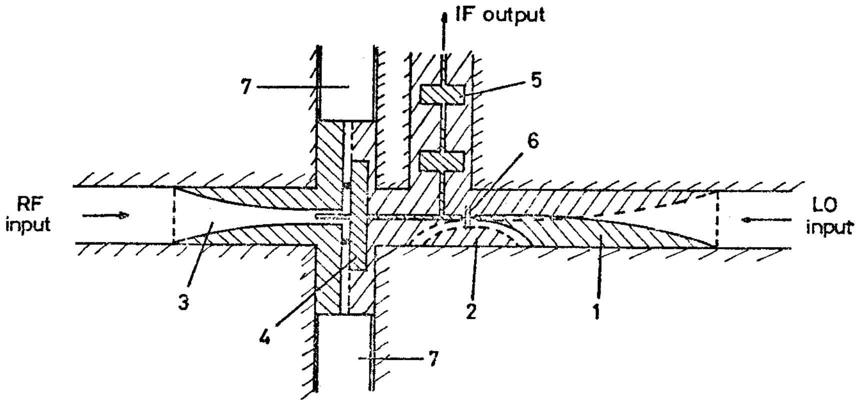


Metallization on the front side of the substrate

Metallization on the back side of the substrate

Fig. 1: The planar magic T



Metallization on the front side of the substrate

Metallization on the back side of the substrate

Waveguide walls

Fig. 2: The complete mixer configuration, (1) waveguide to microstrip transition, (2) additional metallization, (3) finline taper, (4) microstrip stub, (5) low pass filter, (6) block capacitor, (7) variable shorts

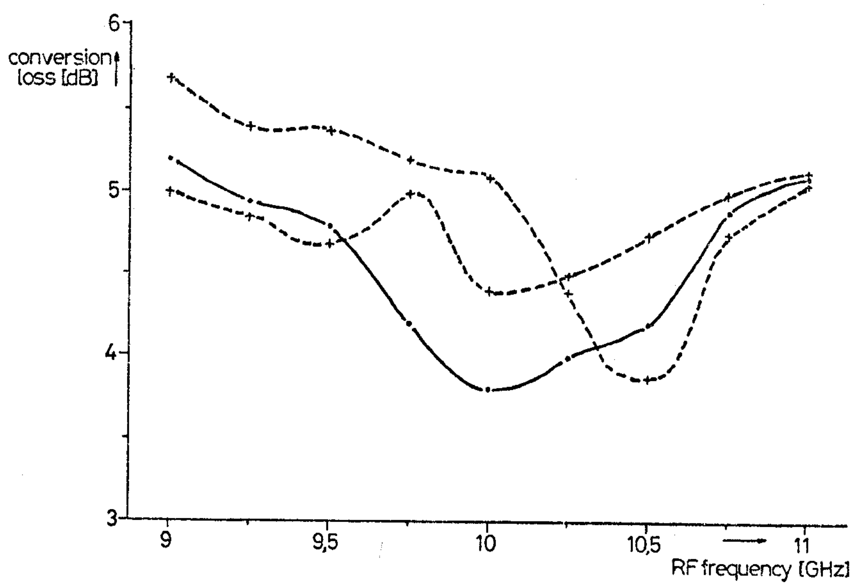


Fig. 3: Measured conversion loss as a function of the RF frequency with a fixed LO power of 12 dBm