A NOVEL MONOLITHIC HEMT HARMONIC MIXER AT Q-BAND

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Abstract

A novel Q-band monolithic harmonic mixer has been designed and fabricated using the 0.15 μm pseudomorphic InGaAs/GaAs HEMT process for the first time. This high performance mixer is capable of downconverting a Q-Band RF signal with the 12th, 14th or 16th harmonic of a S-band LO signal to produce a signal suitable for a phase lock loop. This compact mixer consists of antiparallel HEMT Schottky diodes with a lumped element IF and LO diplexer and a RF band-pass filter. Measured data shows agreement between simulations and measurements. Total chip Size is 1.0 mm x 2.5 mm.

Introduction

Harmonic mixers are useful in frequency synthesizers, input circuits of spectrum analyzers and in phase lock loop circuits [1]. The diode harmonic mixer is a low-cost solution to a number of series passive or active mixers in a phase-locked loop. This is particularly true in lightweight communication electronics where DC power dissipation and weight and size are critical. By mixing a high frequency signal with multiple harmonics of the LO, frequency conversion can be attained at much lower cost, since an oscillator at lower frequency is available at lower cost than one at higher frequency. The harmonic mixer is useful in PLL applications where low phase noise is important. Using the harmonic mixer in the feedback of a PLL greatly reduces the synthesizer feedback divide number, which increases loop gain and allows wider loop bandwidths.

In the past, harmonic mixers have been manufactured as MIC hybrids [2][3]. These circuits are relatively large (compared to a GaAs IC) and expensive to manufacture due to assembly costs. Monolithic harmonic mixers provide smaller size (area of less than 3.0 mm^2 at Q-band), and excellent repeatable performance.

The harmonic mixer is part of a receiver chip set designed and manufactured for commercial digital radio application [4].

Design

The harmonic mixer was designed to downconvert an RF signal of 35.0 to 40.0 GHz to an IF of DC to 1.5 GHz by mixing it with the 12th, 14th or 16th harmonic of an S-band (2-3 GHz) LO frequency. The mixing elements are a pair of antiparallel 0.15 μm HEMT Schottky diodes. This mixer uses 4-finger, 28 μm FET Gates as diodes (Fig. 1 & 2). The RF is filtered through a band-pass edge-coupled transmission line filter, limiting the RF range to 35.0 - 40.0 GHz and eliminating unwanted LO harmonics from reaching the RF input. A quarter wavelength stub is used in order to attenuate the RF signal at

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the input of the IF/LO diplexer. Both of the Q-band portions (the RF structures mentioned above) were simulated using an electromagnetic simulation software. Experience taught us that Libra™ models are not accurate at dielectric constants above 10 and at high frequencies. Since odd shapes were used and the transmission lines were close enough to each other to intoduce coupling, EM models proved more accurate. The IF/LO diplexer is made of lumped element high pass and

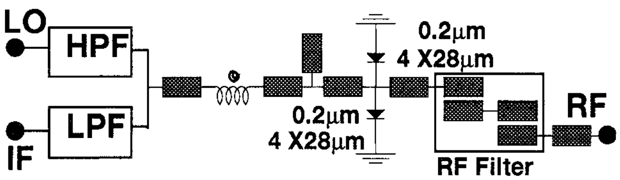

Fig. 1 Harmonic Mixer Schematic

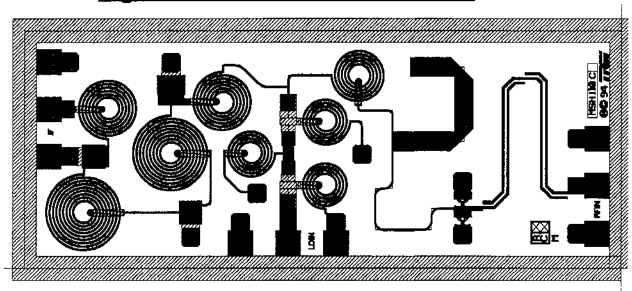

Fig. 2 Harmonic Mixer Layout

low pass filters using thin film nitride capacitors and spiral inductors. The circuit was proccessed using the 0.15 µm TRW power HEMT process, which has excellent power capability as well as good low noise properties and the chip size is 1.0 mm by 2.5 mm.

Performance

Wafer-probe measurements of the harmonic mixer were performed at an LO drive level of +17.0 dBm and concentrated only on conversion loss resulting from the mixing of the RF with the 16th harmonic of the LO. The conversion loss of the the harmonic mixer does not decrease monotonically with LO power as would occur in a fundemental mixer (Fig. 3). This is a result of the harmonic mixing of the signals. The optimum LO drive level for the mixer is between 16.0 to 17.0 dBm. Although the mixer's conversion loss has nulls at certain LO levels,

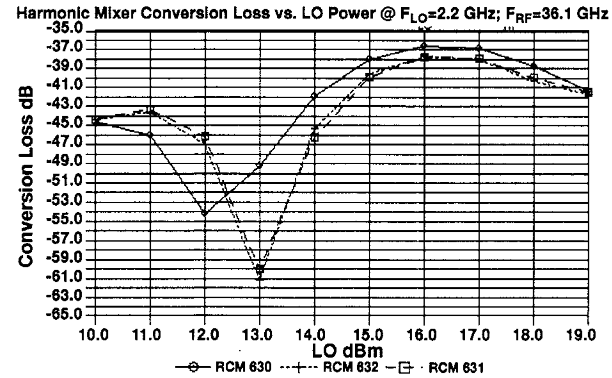

Fig.3 Harmonic Mixer Conv.Loss Vs LO Power

from peak to peak there is improved conversion loss. The measurements corresponding to the mixing with the 16th harmonic of the LO showed 34.5 dB conversion loss (Fig. 4) versus 35.0 dB conversion loss sim-

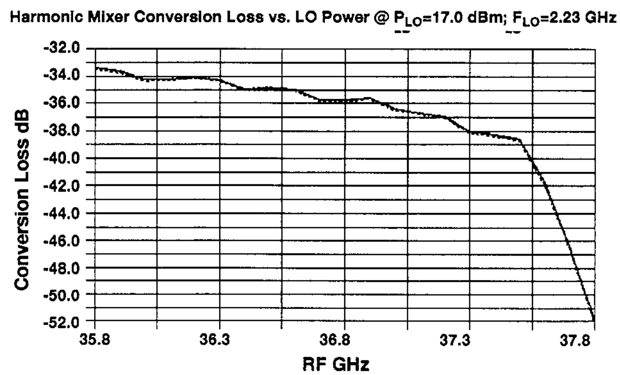

Fig. 4 Harmonic Mixer Conv. Loss Vs RF

ulated performance. RF return loss, at various LO frequencies, was measured at better

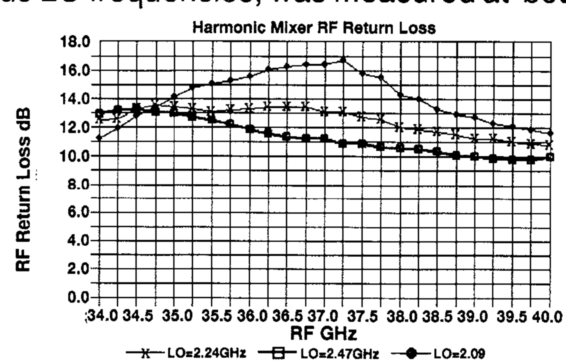

Fig. 5 Harmonic Mixer RF Return Loss

than 10 dB (Fig. 5). The IF return loss was better than 10.0 dB for IF < 900 MHz but degraded at higher frequency (Fig. 6). The

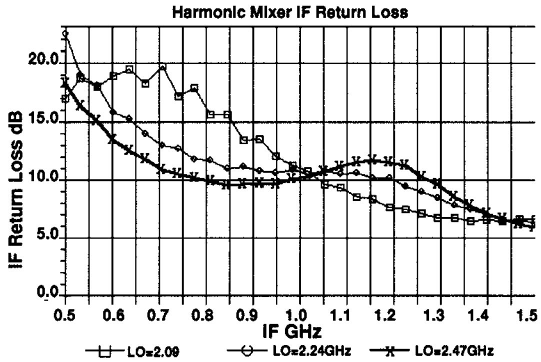

Fig. 6 Harmonic Mixer IF Return Loss

degradation above 900.0 MHz is a result of the tight window (0.5 GHz) between the passband of the high-pass and low pass filters in the LO/IF diplexer, which was specified as IF from DC-1.5 GHz and LO from 2.0-3.0 GHz. The performance needed is very difficult to obtain with monolithic lumped elements, since the monolithic components don't have high enough quality factors, and more stages would needed to acheive the adequate isolation. Measurements of LO harmonic isolation from the RF port were made (Fig. 7). The results show that the LO

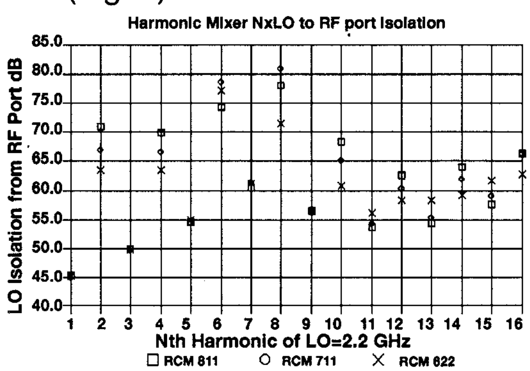

Fig. 7 Harmonic Mixer LO Harmonic to RF Port Isolation @ F_{LO}=2.2 Ghz

harmonic isolation from the RF port is better than 45.0 dB.

Fixtured measurements (Figs. 8,9, 10,11 &12) were performed and the results correlate to the wafer probe data that is presented above.

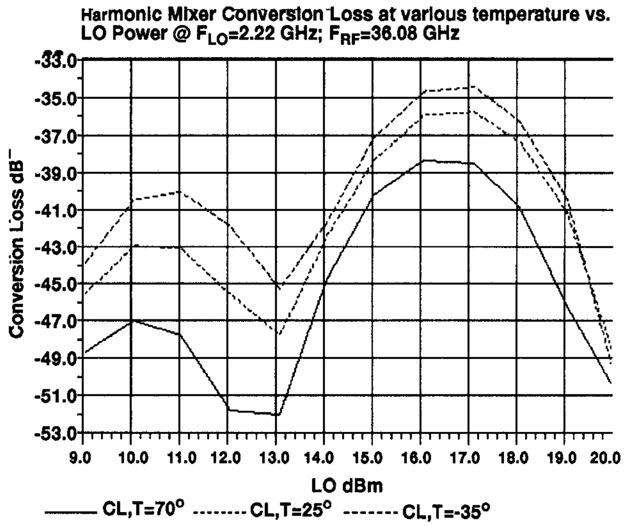

Fig. 8 Harmonic Mixer Conv. Loss vs. P_{LO} at various Temperature *

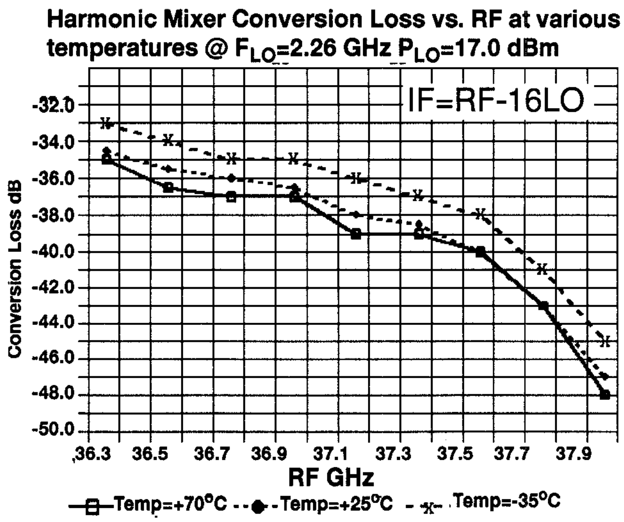

Fig. 9 Harmonic Mixer Conversion Loss at various Temperature vs. RF *

Conclusions

State-of-the-art performance of a monolithic harmonic mixer was demonstrated. The harmonic mixer was designed to be a compact MMIC, and the performance recorded in this paper was achieved in first pass.

* Data supplied by CMTL.

Harmonic Mixer Conversion Loss vs. RF at various temperatures @ F_{LO}=2.22 GHz P_{LO}=17.0 dBm

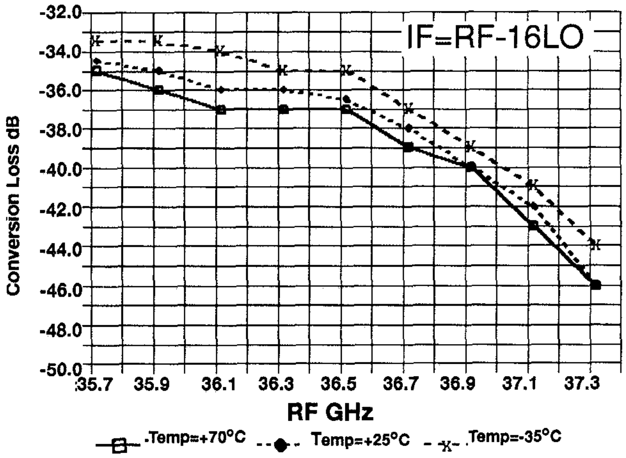

Fig. 10 Harmonic Mixer Conversion Loss at various Temperature vs. RF *

Harmonic Mixer Conversion Loss vs. RF at various temperatures @ F_{LO}=2.18 GHz P_{LO}=17.0 dBm

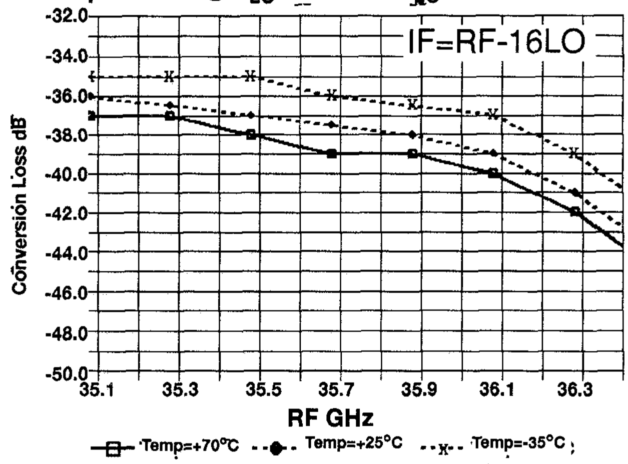

Fig. 11 Harmonic Mixer Conversion Loss at various Temperature vs. RF *

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Harmonic Mixer LO harmonic Isolation from IF Port vs. F_{LO} @ P_{LO}=17.0 dBm

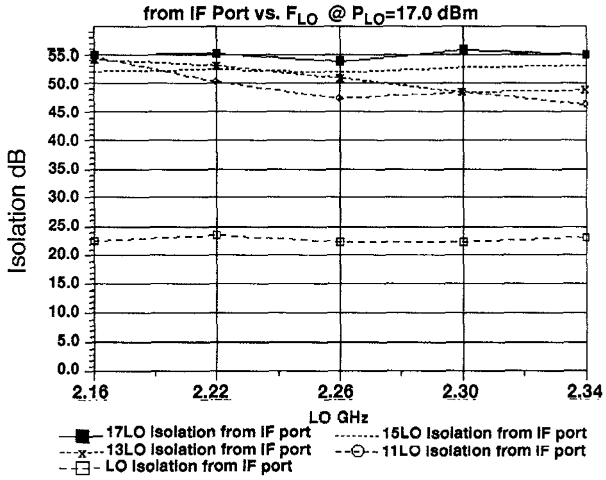

Fig. 12 Harmonic Mixer LO harmonic to IF Port Isolation vs. F_{LO} *

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