A Compact Subharmonically Pumped MMIC Self Oscillating Mixer for 77 GHz Applications

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Abstract

A novel 77 GHz MMIC self oscillating mixer is presented with measured results. The mixer achieves mixing and doubling simultaneously using a single pHEMT. The mixer exhibits a measured conversion loss of 12 dB at 77 GHz and an average measured conversion loss of 15 dB from 70 to 85 GHz which compares well with simulated results.

Introduction

It is essential that the millimetre-wave front ends of W-Band (75-110 GHz) systems be compact, reliable, efficient and low cost to meet the demands of commercial applications. These demands can be met by using a simple, compact design which uses as few active devices as possible. Existing systems [1] downconvert the received signal using a seperate mixer and LO, therefore requiring at least two devices and a relatively large amount of valuable MMIC space.

This work differs from other solutions by employing a single device to achieve self oscillation, mixing and doubling simultaneously thus, reducing MMIC area usage, improving reliability, improving fabrication yield and reducing power consumption.These factors make this design desirable for low cost commercial applications. Use of the second harmonic means the device is only required to oscillate at half the RF, thus making this design compatible with lower cost MMIC gate fabrication techniques. Although a pHEMT is used in this study this design approach allows other devices such as MESFETs [2] and HBTs [3] to be used. Such devices cannot operate in their fundamental mode at W-Band but still could be used in this design. To the authors' knowledge this is the first demonstration of a subharmonically pumped MMIC self oscillating mixer operating at W-band.

Self Oscillating Mixer Design

The self-oscillating mixer consists of a common source feedback oscillator and a gate mixer. The active device is a 4 x 15 μm pHEMT and is embedded in an appropriate network so as to synthesise a one-port negative resistance looking into the drain. A novel feedback network was designed to generate a negative resistance at the drain at 39 GHz and also to ensure that the impedance looking into the gate of the device at 77 GHz could be matched with a passive network. The feedback is realised using open or short circuit 50 Ω stubs. The source was required to be short circuited to prevent the device from generating a negative resistance at 77 GHz. This was achieved by attaching a 77 GHz quarter-wave open circuit stub to one of the source terminals. This short circuits the source at 77 GHz and presents capacitive feedback at 39 GHz. A 77 GHz half-wavelength short circuited stub is connected to the second source terminal. This stub presents a short circuit at 77 GHz and 39 GHz and also provides a DC return path for the gate and drain bias as shown in Figure 1.

Since the source feedback stubs are of a fixed length, the gate feedback is optimised to create the

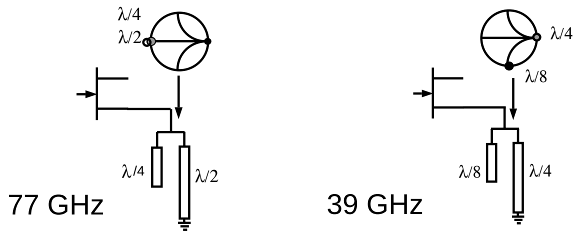

Figure 1: *Novel Feedback Network*

largest possible one-port negative resistance at the drain. The gate feedback network consists of a length of 50 Ω transmission line connected to a RF bandpass filter. The length of this transmission line is determined by finding the embedding reactance that created the optimum one-port negative resistance at the drain. Once the required reactance is found it is converted to a physical length of transmission line. The resulting novel feedback network enables self oscillation to occur and also allows a RF to be efficiently injected into the circuit so as to allow mixing.

The free running oscillation was produced by using a single stub matching network to present the load impdeance:

$$z_l = \frac{-r_d}{3} - jx_d \quad (1)$$

where r_d is the negative resistance at the drain which is determined by simulations and x_d is the drain reactance. This match produces the maximum power at the fundamental free running oscillation.

MMIC layout

The MMIC was designed using foundry models for both the active device and the passive microstrip elements. Bias is applied to the drain of the device using an external bias tee for simplicity. No external bias network is required for the gate since the maximum transconductance occurs at $V_{GS} = 0V$. The short circuited gate feedback stub provides a DC return path and therefore the correct bias of 0V. The RF was coupled into the gate feedback circuit by means of a single element quarter wave coupler centred at 77 GHz. The schematic of the MMIC is shown in Figure 2 a photograph of the fabricated chip is shown in Figure 3.

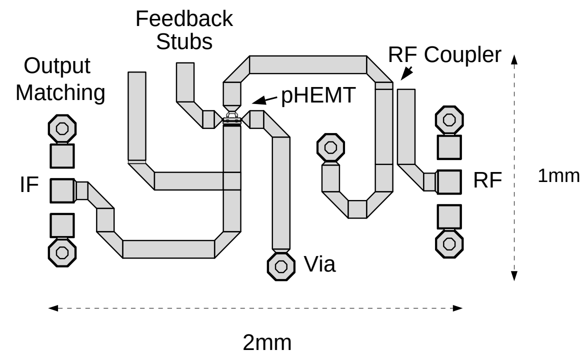

Figure 2: *Schematic of MMIC*

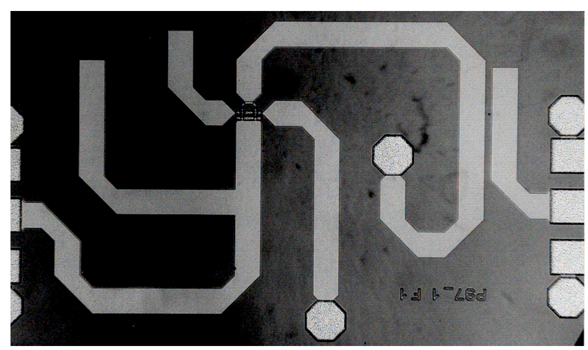

Figure 3: *Photograph of MMIC*

Measurments and Results

The measurement arrangements are shown in Figure 4. An external low pass filter was used to supress mixing products other than the IF. Removal of this filter enabled LO power and frequency measurements to be made.

Figure 5 shows the fundamental free running oscillation and Figure 6, its second harmonic. The oscillator was designed to operate at 39 GHz with a

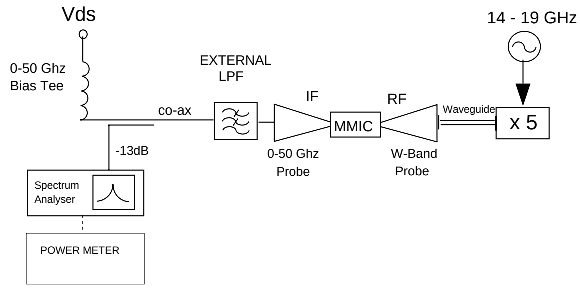

Figure 4: *Measurement Setup*

power of 6 dBm. The measured data (38.42 GHz, 5.8 dBm)shows excellent agreement with predictions.

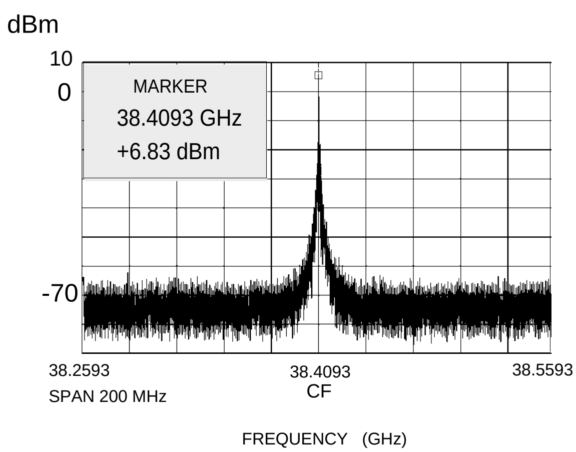

Figure 5: *Fundamental Free Running Oscillation* $V_{DS} = 4V, V_{GS} = 0V$

The free running oscillation frequency could be tuned over a 0.85 GHz range by varying the drain voltage. The drain voltage tuning also caused a variation in the power of the self oscillation as can be seen in Figure 7. As expected this range is increased to 1.7 GHz for the second harmonic.

A signal was then applied to the RF port and conversion loss measurments were taken. Good agreement between simulations and measurments were observed as shown in Figure 8. The differences arise from the upper frequency limitations of the passive and active models used. The models show good

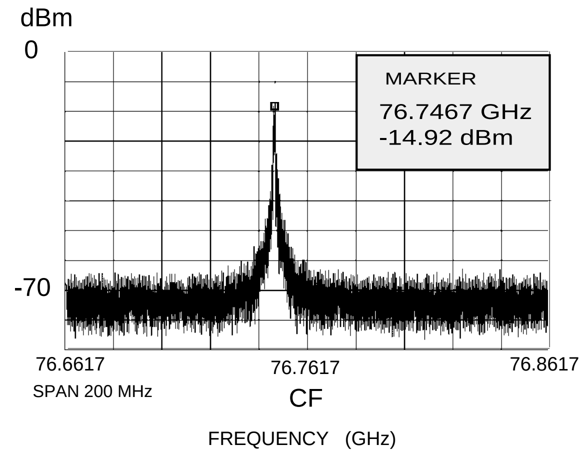

Figure 6: *Second harmonic* $V_{DS} = 4V, V_{GS} = 0V$

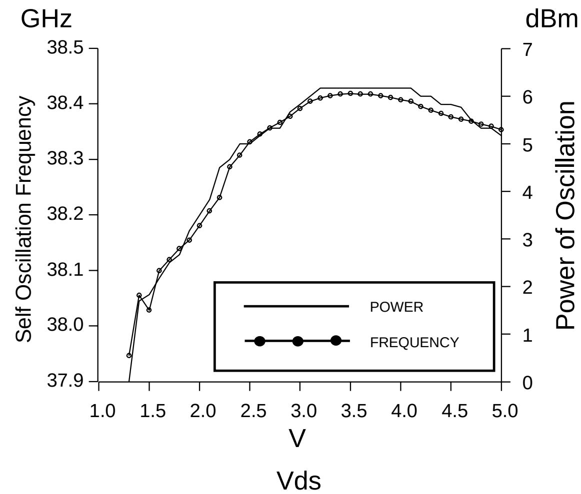

Figure 7: *Tuning Range of Free Running Oscillation.* $V_{DS} = 4V, V_{GS} = 0V$

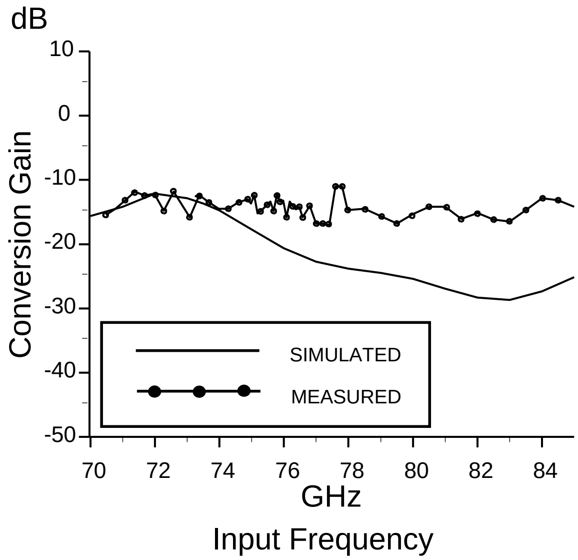

Figure 8: *Measured and Simulated Conversion Gain from 70 to 85 GHz*

agreement up to 60 GHz but accuracy reduces beyond this frequency. The mixer has been operated up to 95 GHz where it exhibits a conversion loss of 28 dB.

Conclusion

A novel MMIC self oscillating mixer which uses a single device to achieve mixing and doubling has shown an average measured conversion loss of 15dB from 70 to 85 GHz. The measured results exhibit good agreement with simulated results. The free running oscillation displays a tuning range of 1.7 GHz which compares well with the 1.8 GHz predicted range. At 77.6 GHz the mixer exhibits a measured conversion loss of 11.0 dB. This mixer makes a significant contribution to lowering the complexity and cost of 77 GHz systems.

Acknowledgments

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