A New Technique for Obtaining High Isolations in Microwave Mixers Based on the Concepts of Distributed Mixing and Transversal Filtering

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Abstract

A new technique for obtaining high RF/LO to IF isolations in microwave mixers is reported. The technique is derived from the concepts of transversal filtering and distributed mixing. An MMIC prototype has been developed which measures only 1.4mm x 1.3mm. Over 30dB of RF/LO to IF isolations have been achieved at X-band and Ku-band.

Introduction

Microwave mixers are a crucial element in virtually all transmit and receive systems. Ideally, the mixer downconverts an RF to an IF by the modulation action of the LO on the transconductance g_m. In practice however, the RF and LO also appear at the output and a major concern in mixer design is to find suitable means of isolating these unwanted signals from the wanted signal. In most receiver applications the IF is usually much lower and sufficiently separated from the RF and LO, and so isolation can be obtained simply by using a low pass filter at the output. For applications where the IF and RF bands are very close and possibly overlap (e.g in small-shift frequency translators), it is not possibly to filter out the unwanted band. Balanced mixers are usually used to provide the necessary isolation, but such circuits tend to be large because they commonly require large baluns, although compact balanced mixers without the need for large baluns have recently been demonstrated [1][2]. This paper reports on the development of a successful new technique for separating the wanted signal from the unwanted signals. An MMIC prototype measuring only 1.4mm x 1.3mm has been developed achieving a minimun of 30dB LO-to-IF and RF-to-IF isolations over X and Ku-band.

Origins of the New Technique

The new technique is derived from the concepts of transversal filtering and distributed mixing using FETs [3][4][5]. Fig.1 shows the circuit diagram of the 8-12 GHz bandpass transversal filter reported by Schindler [3]. The delays for each tap are realised by incorporating them into a distributed amplifier type structure, and the taps themselves are realised as FETs of varying gate widths. In comparison, fig.2 shows the circuit diagram of the matrix distributed mixer, which was demonstrated by Robertson [6]. The similarities between the two circuits are enormous although the two functions are quite different. The technique reported here incorporates the two functions of mixing and filtering to develop a new mixer topology which is capable of providing high RF/LO to IF isolations. The isolation is obtained by means of RF cancellation and LO cancellation rather than filtering, and therefore it is not a requirement that sufficient separation should exist between the input and output signals. Thus there is great potential applications of this new technique. This concept of mixing with inherent signal cancellation is entirely new and has not been demonstrated before.

Description of the Technique

The schematic of the new technique is shown in fig.3. Essentially it is that of a distributed mixer but employing also linear amplifying elements. The mixing and amplifying functions are achieved using FETs and these need to be biased appropriately to achieve the desired function. Fig.4 shows graphically how this is done. A summarised description of how the circuit operates is given below.

The RF propagates down the RF line and feeds into the input of each mixer and amplifier element. Likewise, the LO propagates down the LO line but appears only at the input of each mixer element. The mixer elements downconvert the RF to an IF, but some of the RF and LO also appear at the output.

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Since the FETs are not strictly unilateral and there is always some leakage in a practical FET, some of the LO also appears at the amplifier inputs. Thus both RF and LO signals appear at the amplifier inputs, but with a phase delay determined by the delay in the RF line. Hence by optimising the amplifier gain and the delays in the RF and IF lines, it is possible to make the RF and LO, both appearing at the mixer element outputs, cancel with those from the amplifier element outputs. By using many sections, a wide bandwidth can in principle be obtained along with increased conversion gain.

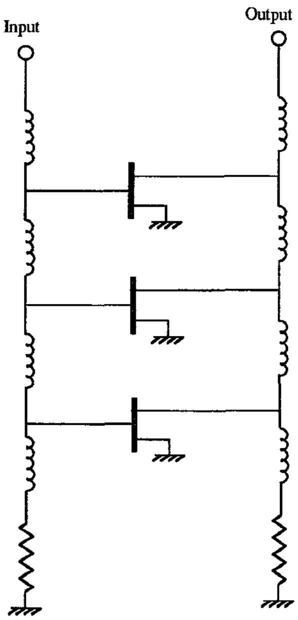

Fig. 1: *Transversal Filter Reported by Schindler et. al.[3]*

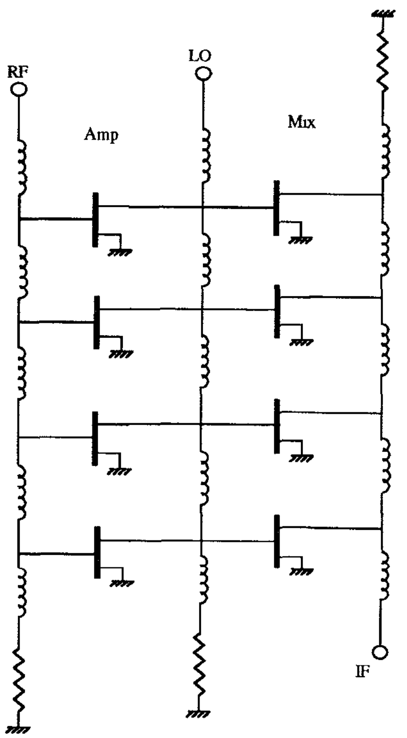

Fig. 2: *Matrix Distributed Mixer Demonstrated by Robertson [6]*

The primary objective of this work was to demonstrate the isolation properties of the new technique and so only a single section design was considered. The chip was to be implemented in monolithic form and so Foundry supplied small and large-signal FET models (for the amplifier elements and mixer elements respectively) were used in the simulations which was perfromed using *Libra*. The mixer was designed to operate over X-band with 0.5GHz IF.

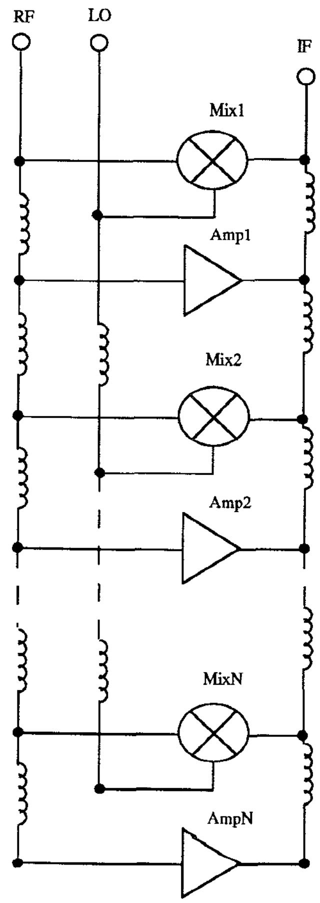

Fig. 3: *The Proposed New Structure*

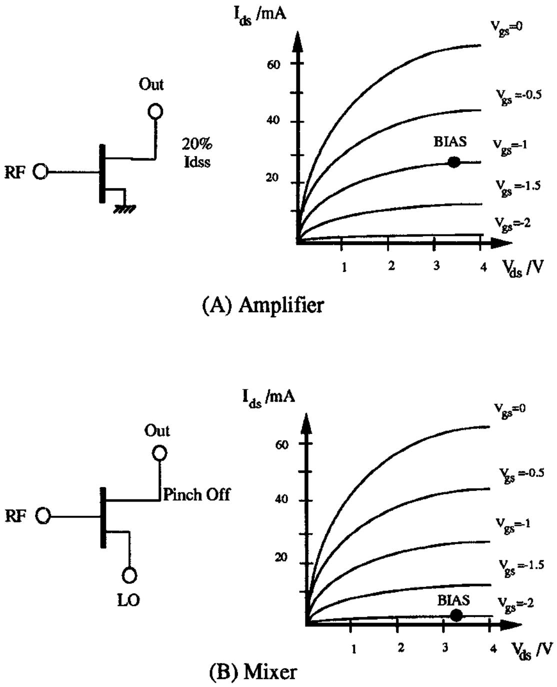

Fig. 4: *FET Biased as a Mixer or Amplifier Element*

Circuit Fabrication

The prototype was realised in monolithic form using the standard GMMT F20 GaAs Foundry process, which is based upon direct ion-implantation into LEC semi-insulating substrates. The MESFETs are fabricated utilising 0.5μm gate lengths with Ti/Pt/Au gate metallisations and SiNi passivation. A two-level metallisation scheme is employed to allow the realisation of crossovers and complex circuit topologies wirhout the need for airbridges. The metallision levels are separated by a composite SiNi and polyimide dielectric layer. Through GaAs vias are used which minimise FET source inductance. The final die thickness is 200μm.

Measurements

A photomicrograph of the complete chip which includes on-chip biasing and measures only 1.4mm x 1.3mm is shown in fig.5.

Measurements were made on-chip using the Cascade Summit probe station. The RF and LO, with -30dBm and 8dBm source power respectively, were swept with a frequency difference equal to the IF.

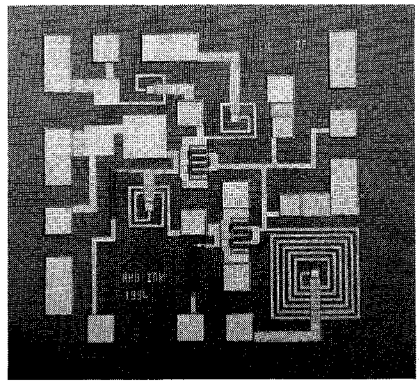

Fig. 5: *Photomicrograph of the Chip*

The RF-to-IF and LO-to-IF isolations are indicated in fig.6. In both cases over 30dB of isolation is achieved over full X-band and Ku-band.

Although the measured IF output did show conversion gain, this was only over a narrow band. The cause of this was the narrowband RF matching (see fig.6). The IF bandwidth can be significantly improved by using wideband RF matching. The IF port match is shown in fig.7.

Conclusions

This paper has reported on the development of a new technique for obtaining high RF/LO to IF isolations in microwave mixers. The technique is derived from the concepts of distributed mixing and transversal filtering. A single-section MMIC prototype measuring only 1.4mm x 1.3mm, has been developed to demonstrate the principle. The prototype includes on-chip biasing and has shown excellent isolation properties, achieving over 30dB of RF to IF and LO to IF isolations over full X-band and Ku-band. The measured IF bandwidth has been disappointing however, and this could easily be improved in a second design by improving the bandwidth of the RF port match. Although the new technique has been demonstrated here using single gate MESFETs, it is expected that the use of dual-gate MESFETs would give better overall performance particularly the RF-to-LO and LO-toRF isolations.

Acknowledgements

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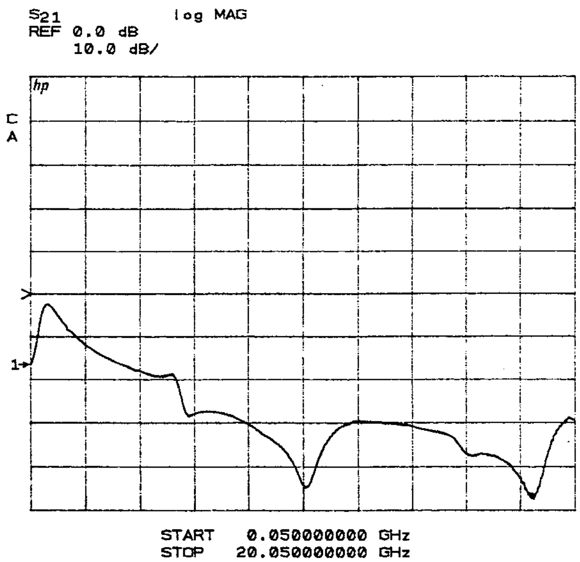
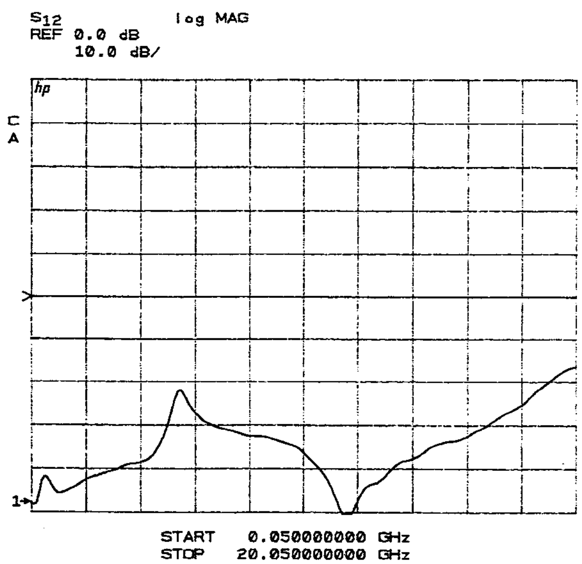


(A) *RF to IF*



(B) *LO to IF*

Fig. 6: *Measured RF/LO to IF Isolations*

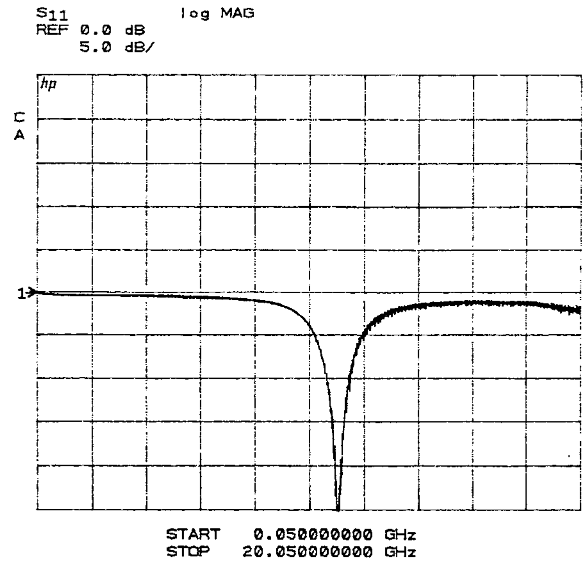


Fig. 7: *Measured RF Match*

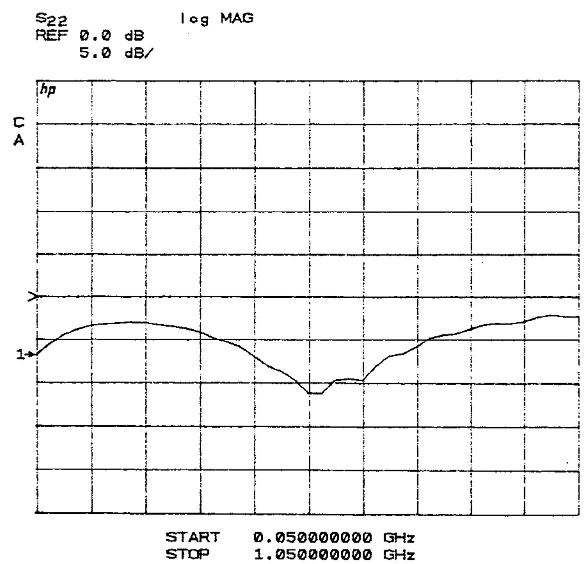


Fig. 8: *Measured IF Match*

References

[1] A.H. Baree & I.D Robertson, "A novel MMIC balanced FET mixer", Proceedings of the 24th European Microwave Conference, Cannes, France, September 1994, pp.805-809.

[2] A.H. Baree, I.D Robertson & J.S. Bharj, "A Compact wide-band MMIC image-rejection mixer chip", Asia Pacific Microwave Conference Proceedings, Tokyo, Japan, December 1994, pp. 241-244.

[3] M.J Schindler & Y. Tajimer, "A novel MMIC active filter with lumped and transversal elements", IEEE Trans., vol. MTT-37, No.12, pp.2148-2153.

[4] W. Jutzi, "Microwave bandwidth active filter concept with MESFETs", IEEE Trans., Vol.MTT-19, No.9, September 1971, pp.760-777.

[5] C. Rauscher, "Microwave active filters based on transversal and recursive principles", IEEE Trans., vol.MTT-33, No.12, December 1985, pp.1350-1360.

[6] I.D Robertson & A.H Aghvami, "A novel 1-14 GHz matrix distributed mixer", Proceedings of the 21st European Microwave Conference, Stuttgart, 1991, pp.489-494.