K-band Monolithic Double-Balanced Resistive Mixer with Integrated Balanced Oscillator

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***Abstract* – A balanced oscillator has been used to provide the balanced LO signals for a double-balanced resistive mixer, in an integrated monolithic circuit. This first reported balanced oscillator/ resistive mixer chip operates at 25.5GHz with low levels of LO leakage and spurious intermodulation products.**

I. INTRODUCTION

Double-balanced mixers provide inherent port isolations, LO AM noise rejection, even-order mixing product suppression and high dynamic range. These desirable mixer properties, however, rely on the availability of accurate balanced signals. Traditionally, this is achieved through the use of baluns. Various balun configurations have been proposed for applications in MMIC design. At frequencies up to approximately 20GHz baluns can be realised with lumped elements [1-2]. Alternatively, active baluns can be used [3] although they are often over complex, sensitive to operating conditions, require many DC bias connections, and have poor noise and linearity performance. More recently, baluns using CPW-slotline and other transitions have been demonstrated [4-5], and the Marchand coupled-line balun has been widely adopted for MMIC mixer design [6-10]. All these balun circuits, however, use considerable chip area, and in commercial products it is evident that the area used by the semiconductor devices is very small compared to that used by the baluns.

This paper presents a double-balanced resistive mixer that does not employ any LO balun, but instead uses the outputs of a balanced oscillator [11] to directly drive the LO inputs of the balanced mixer. The balanced (or push-pull) oscillator/mixer combination is frequently employed at low microwave frequencies [12-13], where push-pull circuits are favoured because of their insensitivity to grounding inductance. This paper presents the first reported monolithic double-balanced resistive mixer to be driven by an integrated balanced oscillator. The double-balanced resistive mixer is known to achieve very low levels of intermodulation [14], so this technique may be of considerable interest in high performance receivers.

The balanced oscillator, shown in Fig. 1, has two outputs that are mutually locked in anti-phase. The balance between these signals depends on the inherent symmetry of the oscillator circuit. Therefore, in the monolithic realm where circuit components exhibit good uniformity, highly balanced signals can be obtained across the oscillator operating frequency range. This will significantly enhance the performance of the balanced mixer in terms of LO leakage and spurious signal suppression. This precise balance of the circuit is verified by investigating by amplitude and phase balance of down-converted IF signals. The measured performance of the integrated frequency converter is also presented.

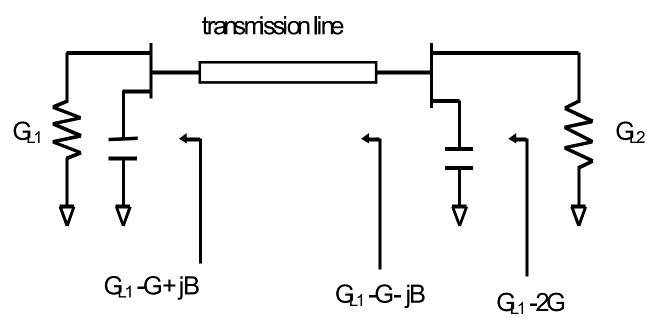

Fig. 1 Balanced oscillator topology

II. CIRCUIT STRUCTURE

The double-balanced mixer circuit block diagram is shown in Fig. 2. It consists of an arrangement of four mixing elements, an RF balun and a balanced oscillator for the LO. The balanced oscillator is similar to that described in [11]. It employs two 2 x 50 µm PHEMTs with capacitive source feedback. The balanced oscillator outputs are directly coupled to the gates of the resistive PHEMTs, while the balanced RF is applied to the drains. The balanced RF signals are obtained using a Marchand type balun, consisting of two interdigital couplers. The two anti-phase generated IF signals are extracted separately from the sources of the mixing PHEMTs. This allows the overall balance of the signals to be evaluated over the operating frequencies of the double-balanced mixer.

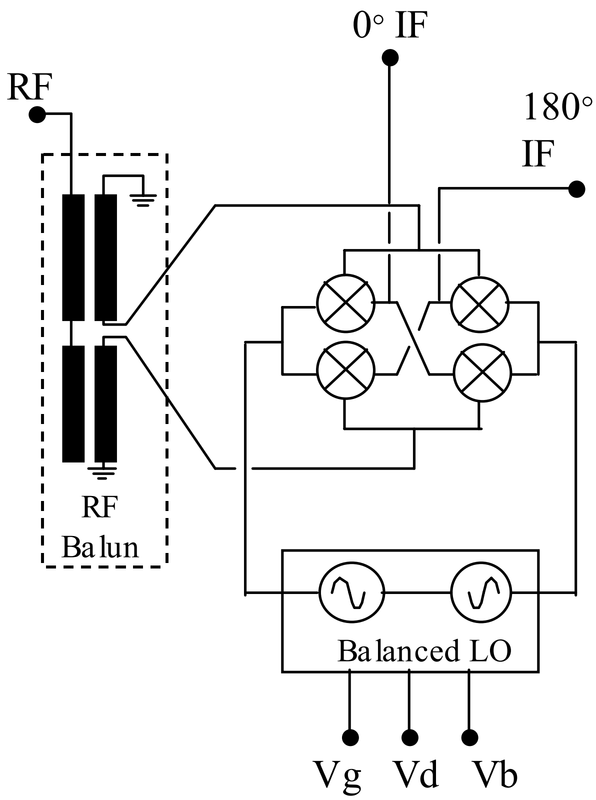

Fig. 2 Block diagram of the double-balanced mixer with integrated balanced oscillator

Fig. 3 shows a microphotograph of the fabricated double-balanced mixer MMIC, which measures 2.1mm x 1.4mm. The circuit was fabricated using the EONCOM PHEMT process. This process features 0.25-µm gate-length PHEMTs on a 100 µm thick GaAs substrate. The mixing elements are 2 x 50µm resistive PHEMTs, and can be seen at the centre of the chip. On the left hand side is the RF input port and balun, and the balanced oscillator is in the lower half, with DC pads along the lower edge. The two IF outputs are at the top and right edges.

III. MEASURED PERFORMANCE

The MMIC was measured on a Cascade Microtech probestation. All RF connections to the chip were made using 100-µm-pitch coplanar probes while DC biasing was applied through probe needles. A stable LO-to-RF leakage signal of –20dBm at 25.5GHz was measured at the RF port when the balanced oscillator was biased at Vd=2V and Ids=20mA. An RF signal of –20dBm, which was varied around 25 GHz, was then applied to the RF port. The two downconverted IF signals were then displayed on the oscilloscope.

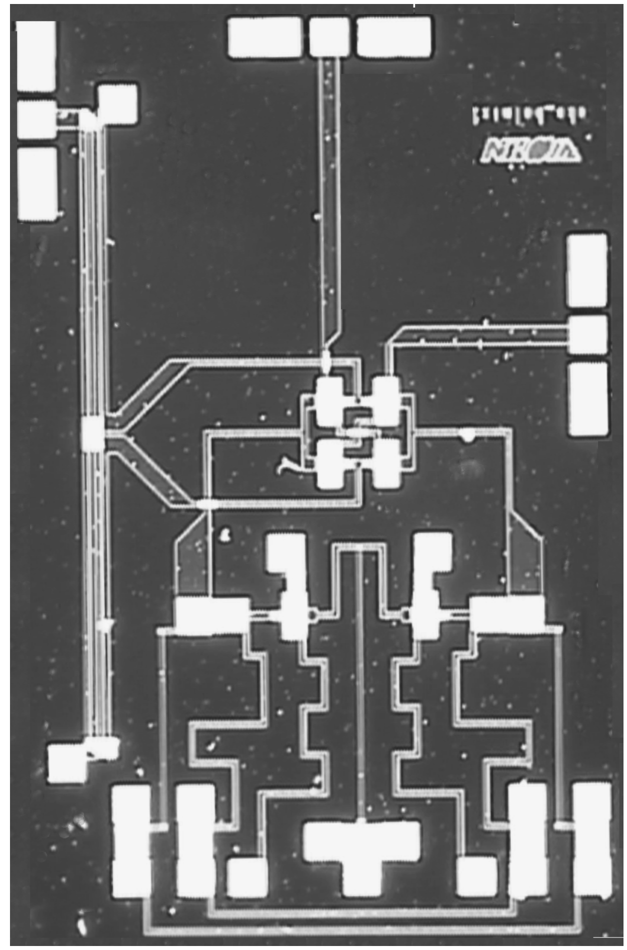

Fig. 3 Chip microphotograph

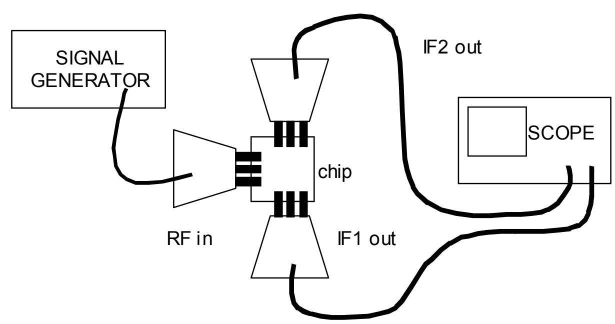

Fig. 4 Measurement set up without IF combining

Fig. 5 shows the typical display waveforms obtained. The good amplitude and phase balance of these IF waveforms verifies the proper operation of the balanced oscillator within the downconverter. The two IF signals were then combined using an external hybrid coupler, Mini-Circuits type ZFSCJ-2-1, which has an insertion loss of about 1 dB at 0.5GHz. Fig. 6 shows the resulting conversion loss obtained as the RF is varied below and above the fixed LO frequency of 25.5GHz. The mixer exhibits an average conversion loss of 12 dB across the IF passband; the roll-off above 800 MHz is caused by the external hybrid coupler. The high conversion loss was later traced to the excessive insertion loss of 5dB in the RF balun at 25GHz. This can be attributed to the over-coupling of the interdigital couplers, resulting in a dip at the centre of the balun passband. An even-order (2,-2) spurious response suppression of more than –40dBc was also measured across the IF passband.

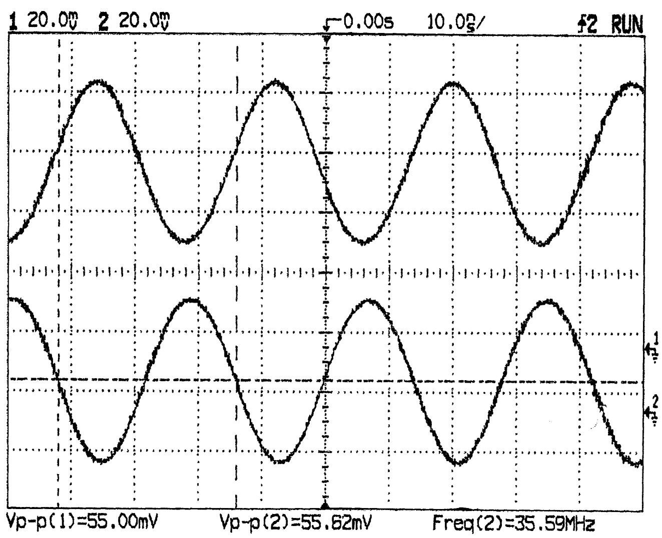

Fig. 5: Oscilloscope display of the balanced downconverted IF from an RF of 25.536 GHz.

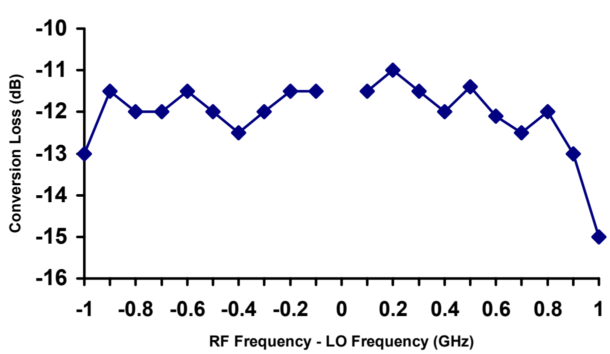

Fig. 6: Conversion loss with fixed LO frequency of 25.5GHz

IV. CONCLUSIONS

In the pursuit of further circuit miniaturisation, without compromising performance, a balanced oscillator has been integrated on-chip to serve as the balanced LO for a double-balanced resistive mixer. By investigating the amplitude and phase balance of the downconverted IF signals, the overall signal balance of the mixer was verified. As the input LO signals are well balanced, the resulting mixer exhibits low levels of LO leakage and even-order spurious response. Therefore, the balanced-oscillator / resistive mixer integration presents a compact alternative to the use of LO baluns commonly encountered in monolithic double-balanced mixers.

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