WIDE-BAND SSB SUBHARMONICALLY PUMPED MIXER MMIC

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ABSTRACT

To achieve low conversion-loss and high image-rejection performance in the wide band for up and down conversion, an SSB subharmonically pumped mixer using an inphase RF divider/combiner is proposed. The SSB mixer MMIC is integrated in a small area of 1.8×1.3 mm^2 and shows good performance at 21.6 to 30.8 GHz.

INTRODUCTION

For future personal radio communication systems using higher frequency bands, low-power-consumption and high-cost-performance RF equipment or circuits, are desired. A subharmonically pumped mixer (SHP mixer) using an antiparallel pair of diodes is a most likely candidate for mixers because it can reduce the number of multiplier-stages, requires no DC power, and can be used for both up and down conversion[1][2]. Furthermore, an SHP mixer with a well-matched diode pair does not output any even harmonics. In practical use, single-sideband mixers (SSB mixers) are desired. To achieve low conversion-loss and high image-rejection performance in an SSB mixer, its dividers/combiners have to be extremely accurate in amplitude and phase. A conventional type of SSB mixer for both up and down conversion needs an LO inphase divider and two quadrature hybrids at IF and RF ports[3]. Usually, IF is set at a lower frequency than RF and LO, so the IF hybrid is often excluded from an SSB mixer MMIC because it requires a huge area. The RF hybrid also occupies a large area since it is in proportion to quarter wave length of RF frequency. Therefore, some approaches have been proposed to reduce the hybrid's size[4][5], but, these approaches require the sacrifice of band-width.

In this paper, to achieve high performance in the wide band, an SSB SHP mixer MMIC that employs a lumped Wilkinson divider, in stead of a hybrid, as an RF divider/combiner is proposed. The mixer MMIC also employs the quasi-lumped technique to drastically reduce its size. The novel mixer MMIC works well for a wide bandwidth.

CONFIGURATION OF THE WIDE-BAND SSB SHP MIXER

Conventional SSB mixers for both up and down conversion use an RF quadrature hybrid as an RF divider/combiner. In MMICs, a blanched-line hybrid is generally employed because it is suitable for reducing its size[5]. However, the blanched-line hybrid only works in the narrow band, especially when the reduced in size. On the other hand, a Wilkinson divider outputs well-balanced signals in both amplitude and phase and has lower insertion-loss than blanched-line hybrids, even if its lumped elements reduce the size, for the wide bandwidth. Therefore, to give the SSB mixer high performances in the wide band, the Wilkinson divider is chosen as its RF divider/combiner.

Figure 1 shows the configuration of the wide-band SSB SHP mixer. It consists of two SHP mixers, an LO power divider with a phase shift of $\pi/4$ radians, and an RF inphase power divider/combiner. These are connected to each other as shown in Fig. 1. In this figure, upper-sideband (USB) is chosen as desired signal.

For up-conversion, IF signals with frequency f_{IF} are input to the IF hybrid, then they are divided and fed, $\pi/2$ radians out of phase, into each mixer. LO power with frequency f_{LO} are divided into two signals $\pi/4$ radians out of phase. Then, SHP mixers generate the up-converted signals and the frequencies of their major components are described as $(2f_{LO} \pm f_{IF})$. Between

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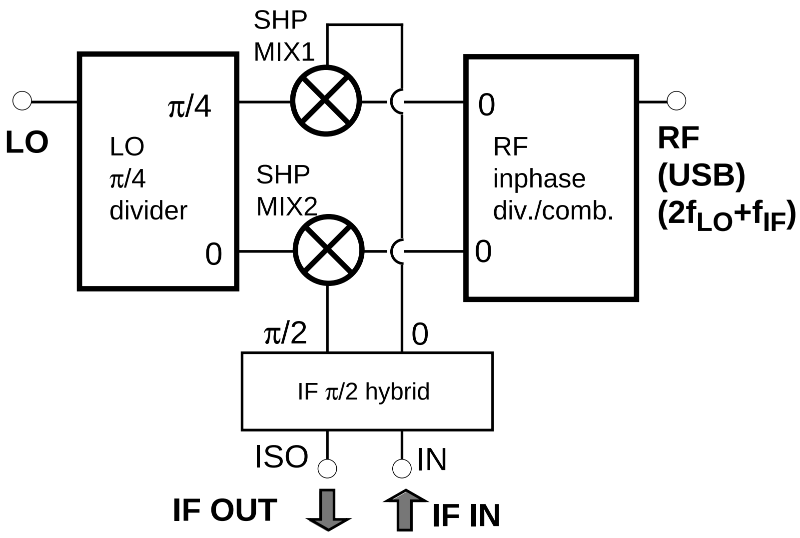

Up Conv.

	IF	2LO	RF-comb.	USB	LSB
MIX1	0	π/2	0	π/2	π/2
MIX2	π/2	0	0	π/2	-π/2

Down Conv.

	RF	2LO	IF-HYB	USB	LSB
MIX1	0	π/2	π/2	0	π
MIX2	0	0	0	0	0

Fig. 1: Configuration of the wide-band SSB SHP mixer.

the RF ports of the mixers, up-converted USB signals ($2f_{LO}+f_{IF}$) are in-phase with each other and LSB component ($2f_{LO}-f_{IF}$) is out of phase, as shown in Fig. 1. The Wilkinson combiner combines all components in phase. Therefore, the desired up-converted USB signal appears at the output while the LSB signal is canceled.

For down-conversion, it also works as an image-rejection mixer similar to the case for up-conversion. But, as shown in Fig. 1, the down-converted USB component appears at the opposite port of the IF hybrid. Therefore, the IF input port and output port can be connected directly with a modulator and a demodulator, respectively. Thus the IF switch, which is conventionally used to change between transmission and receiving, can be left out.

MMIC DESIGN

Figure 2 shows the circuit diagram of the SHP mixer incorporating the SSB mixer MMIC. The mixer has an IF low-pass filter and an RF high-pass filter to isolate RF and IF ports. To isolate the RF port from the LO port, the SHP mixer generally includes two stubs: $\lambda_{LO}/4$ open stub and $\lambda_{LO}/4$ short stub. The former is located near the RF port and the latter is located near the LO port, from the antiparallel pair of diodes. However, the $\lambda_{LO}/4$ transmission line is very long and occupies a large area in an MMIC. To make the stubs compact, each stub is shortened by quasi-lumped method with shunt capacitors. For example, the $\lambda_{LO}/4$ open stub, which is simultaneously "short" at f_{LO}, and "open" at f_{RF} ($= 2f_{LO}+f_{IF} \approx 2f_{LO}$), is shortened with asymmetric shunt capacitors at its ends, as shown in Fig. 3. The capacitances of the quasi-lumped open stub are determined as follows:

$$C_1 = 1 / (2\pi \cdot f_{LO} \cdot Z \cdot \tan\theta)$$
$$C_2 = C_1 / (3 + \tan^2\theta)$$

where Z is line impedance and θ ($0 < \theta < \pi/2$) is electrical length of the stub at f_{LO}. The quasi-lumped $\lambda_{LO}/4$ open stub is compact and effectively suppress LO leakage with low insertion loss at RF frequencies.

The circuit diagram of the SSB SHP mixer MMIC is shown in Fig. 4. The Wilkinson divider consists of lumped elements to make its size compact. The LO power divider with a phase shift of π/4 radians is realized with a lumped Wilkinson

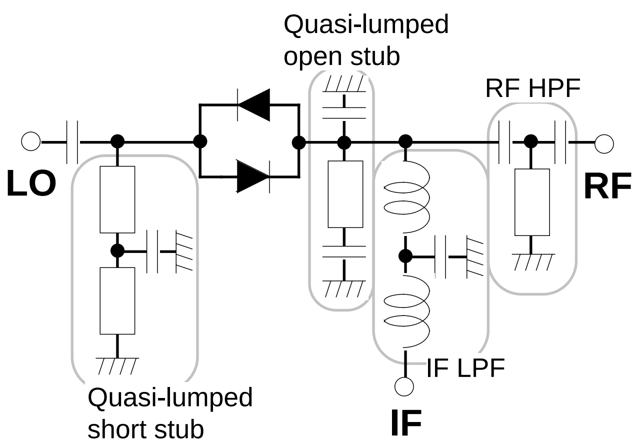

Fig. 2: Circuit diagram of the SHP mixer.

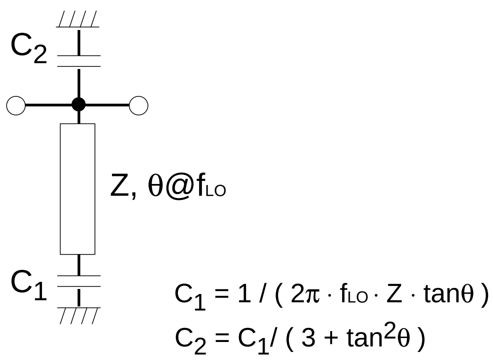

Fig. 3: Quasi-lumped $\lambda_{LO}/4$ open stub.

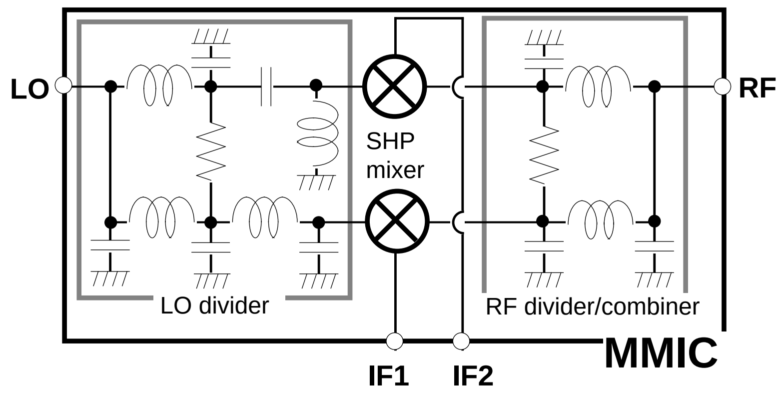

Fig. 4: Circuit diagram of the wide-band SSB SHP mixer MMIC.

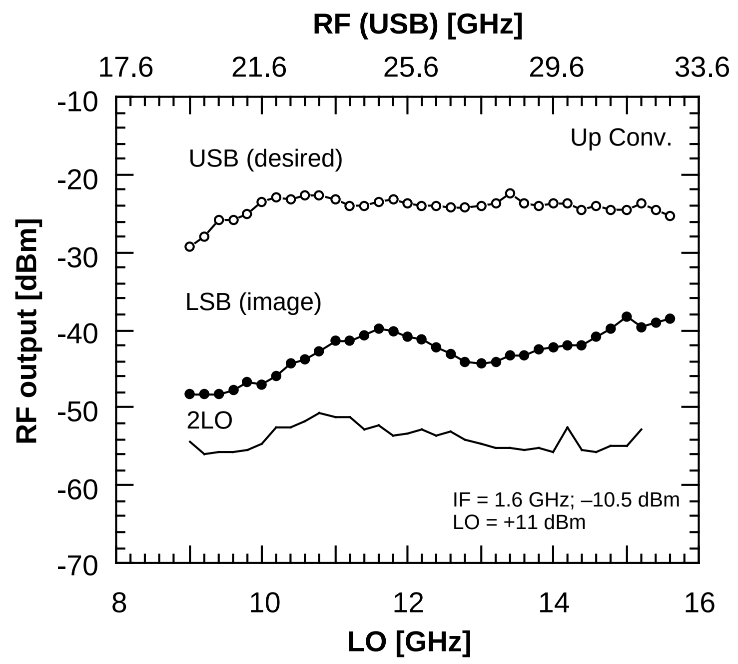

Fig. 6: Frequency responce for up-conversion.

divider and L-C network. It has amplitude and phase imbalance for the wide bandwidth, though, the amplitude imbalance of LO power has little effect on the performance of the SSB mixer.

EXPERIMENTAL RESULTS

Figure 5 shows a photograph of the SSB SHP mixer chip fabricated with the 0.3-μm GaAs MESFET process. By using a uniplanar structure[6] and size reduction technique as described above, the K-band mixer is integrated into a small area of 1.8 mm × 1.3 mm. Each diode is realized by connecting source and drain of the FET, which has 50 μm of the gate width.

Measured frequency response for up-conversion is shown in Fig. 6. IF is fixed at 1.6 GHz and the input power level is –10.5 dBm. Conversion gain is –12.9 ± 1.1 dB and image-rejection ratio is greater than 16 dB for LO frequencies from 10.0 GHz to 14.6 GHz. The second harmonic component of LO (2LO) is well suppressed as shown in Fig. 6. Figure 7 shows measured frequency response for down-conversion. RF input power level is set to –10.0 dBm. Conversion gain of –13.0 ± 1.0 dB and image-rejection ratio of better than 17 dB are obtained for the same frequency range as the up-conversion.

CONCLUSION

A compact and wide-band SSB subharmonically pumped mixer is proposed and tested. The fabricated MMIC chip is

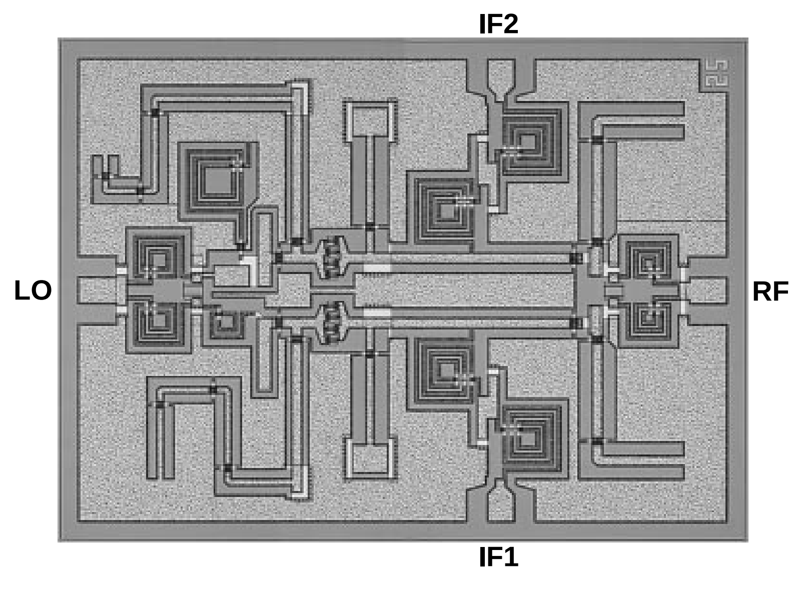

Fig. 5: Photograph of the fabricated SSB SHP mixer chip.

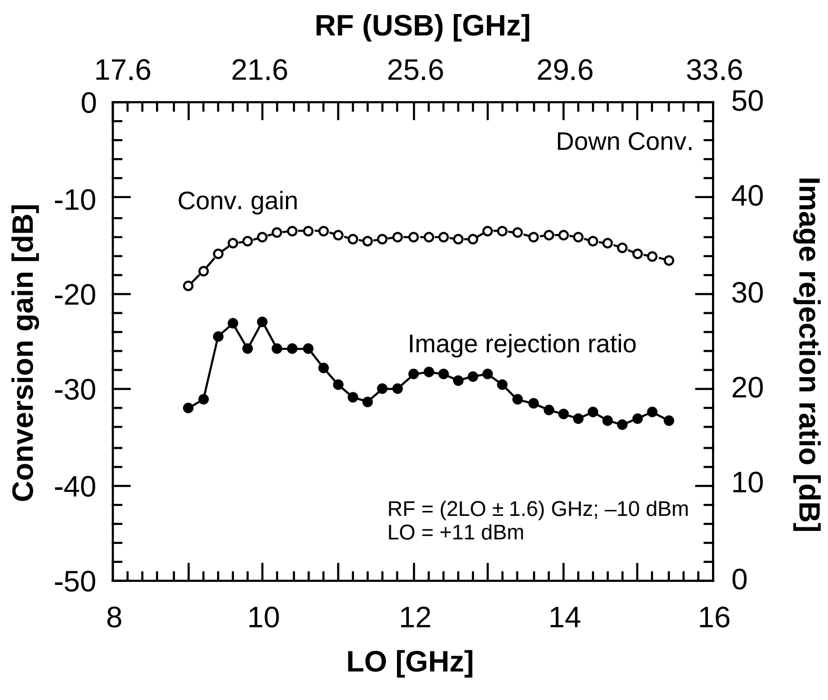

Fig. 7: Frequency responce for down-conversion.

compact with a size of 1.8 mm × 1.3 mm. Measured frequency response is -12.9 ± 1.1 dB of conversion gain and better than 16 dB of image-rejection ratio for up and down conversion at 21.6 – 30.8 GHz of RF frequencies. This SSB mixer will be a key component in the compact transceivers for up-coming personal radio communication systems.

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