Subharmonically Pumped Image Rejection Mixer for K-band Applications

Moon-Que Lee[1], Seong-Mo Moon[1], Keun-Kwan Ryu[2], Dong-Phil Jang[3], In-Bok Yom[3]

[1]University of Seoul, 90 Cheonnong-dong, Dongdaemun-gu, Seoul, 130-743, Korea
[2]Hanbat National University, Daejon, Korea
[3]Electronics and Telecommunications Research Institute, Daejon, Korea

***Abstract* — A balanced single side-band (SSB) mixer employing a sub-harmonic configuration is designed for up and down conversions in K-band. The designed mixer uses anti-parallel diode (APD) pairs to effectively eliminate even harmonics of local oscillator (LO) spurious signal. For the more, to reduce the odd harmonics of LO at RF port, we employ a balanced configuration for LO. The fabricated chip shows 12 ±2dB of conversion loss and image-rejection ratio of about 20dB for down conversion at RF frequencies of 24-27.5GHz. As an up-conversion mode, the designed chip shows 12dB of conversion loss and image-rejection ratio of 20 ~ 25 dB at RF frequencies of 25 to 27GHz. The odd harmonics of LO are measured below -37dBc.**

***Index Terms* — Mixers, MMIC Mixers, Microwave Mixers, Image-rejection mixer, subharmonically pumped mixer.**

I. INTRODUCTION

Subharmonically pumped mixers (or subharmonic mixer, SHM) at high frequencies have the advantage over fundamental mixers in that they require half-frequency local oscillator sources. In general, as the frequency increases, the quality of resonator used for oscillator degrades. Also the locking the K-band VCO is difficult, since commercially available step recovery diodes operate only up to 18GHz. Therefore, high quality oscillators at high frequencies such as K-band are expensive.

A subharmonically pumped mixer using anti-parallel diode pairs can be a good candidate for both up and down conversions because it can reduce the number of multiplier stages and requires no dc power [1],[2]. Furthermore, APD can suppress even harmonics of LO. However in practical situation mixers operate, odd harmonics as well as even harmonics of LO should be suppressed enough in order to maintain low spurious operation. In this paper, to effectively eliminate odd harmonics as well as even harmonics of LO at RF port, a balanced subharmonically pumped image rejection mixer (IRM) is proposed.

II. CONFIGURATION OF THE BALANCED SUBHARMONIC IMAGE REJECTION MIXER

The designed balanced single side-band (SSB) mixer, as shown in Fig. 1, is composed of an in-phase power divider, two baluns for LO, four APD pairs, two IF matching circuits, and a quadrature hybrid (Lange coupler) at RF port. The quadrature hybrid at IF for image rejection is excluded from MMIC mixer chip because it requires a large chip area. Subharmonically pumping is implemented by using APD pairs. Image rejection function is achieved by RF quadrature, LO in-phase divider, and off-chiped IF quadrature. LO signal through the in-phase power divider is fed into Marchand baluns to make a balanced signal so the odd harmonics are eliminated at the APD output. Also, since APD does not inherently produce even harmonics of LO, the LO spurious signals of the balanced subharmonic image rejection mixer can be effectively suppressed.

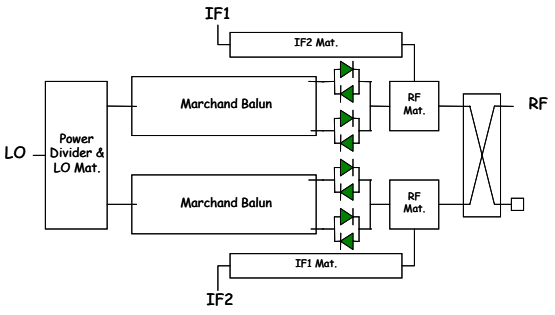

Fig. 1. Configuration of the balanced SSB mixer.

The image rejection ratio may degrade due to overall amplitude and phase imbalances caused by the not matched diodes or non-symmetry of the layout. Mainly imbalance occurs from layout non-symmetry since diodes

fabricated on a single chip MMIC are generally well matched. To make a good symmetry of the connection of APD pairs, the two paths between the input and output of APD are designed to have the same phase delay. Fig. 2 shows the designed layout of APD pairs.

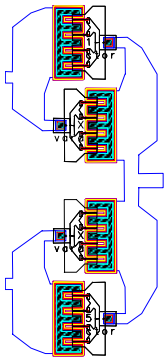

Fig. 2. The layout of APD pairs

To reduce chip size, the in-phase power divider of LO at X-band is implemented by lumped and distributed elements as shown in Fig. 3 [3],[4].

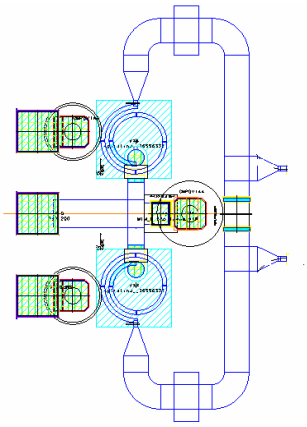

Fig. 3. Quasi-lumped power divider.

III. Experiment Results

Fig. 4 shows the photograph of the balanced subharmonic image rejection mixer fabricated with the 0.15-μ m PHMET process. Chip size is 3 mm x 1.5mm. APDs are realized by connecting source and drain of PHEMT, which has a gate width of 200-μ m.

The designed balanced subharmonically pumped IRM shows good spurious rejection ratio. Fig. 5 shows the harmonics of LO at RF port. Odd harmonics (LO and 3LO) as well as even harmonics (2LO) are well suppressed. Fig. 6 shows the test configuration of the designed MMIC chip. IF quadrature is realized by a 90º branch line hybrid at 1GHz. The measured amplitude and phase ratio of IF quadrature including the IF cables is 0.08dB ∠ 6.3º.

Fig. 7 shows the frequency response for the low side LO injection, when the mixer operates as a frequency down-converter. The fabricated chip shows 12±2dB of conversion loss and image-rejection ratio of abut 20dB for down conversion at RF frequencies of 24-27.5GHz. Fig. 8 shows the measured conversion loss characteristics on LO input power for down-conversion. Conversion loss saturates for LO power from 8 dBm.

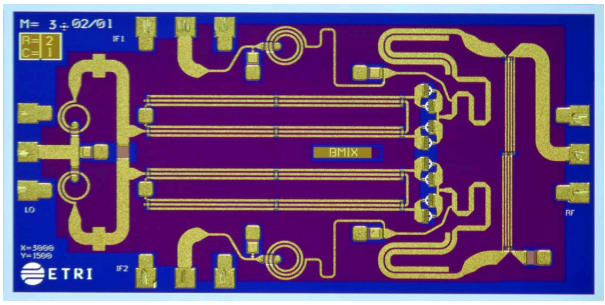

Fig. 4. Photograph of the fabricated balanced SSB mixer.

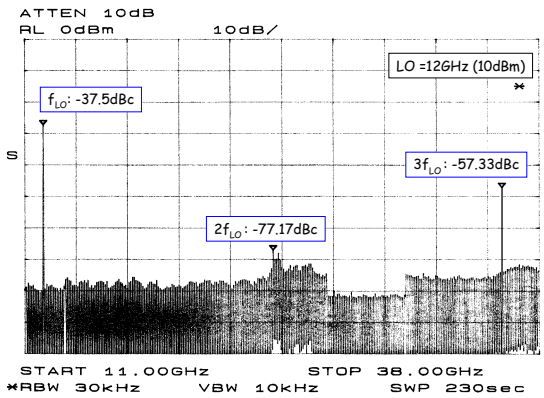

Fig. 5. Power spectrum of LO at RF port. The power of LO = 10dBm.

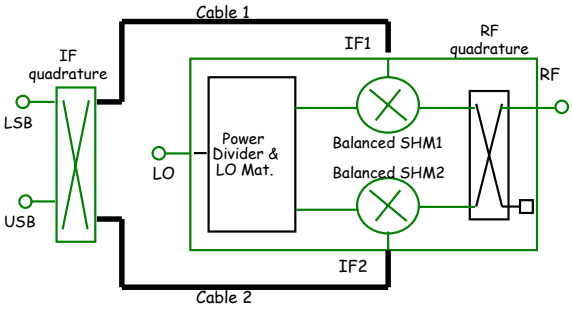

Fig. 6. Test configuration of the subharmonically pumped image rejection mixer.

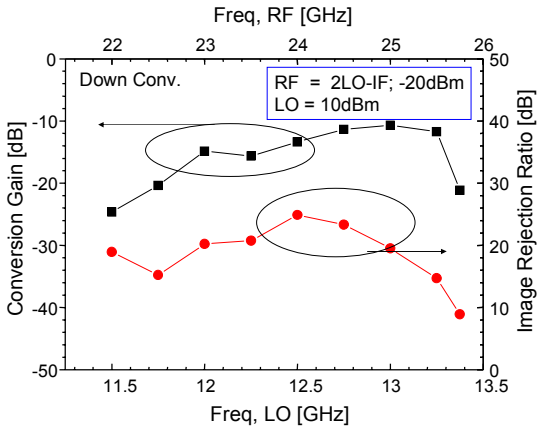

Fig. 7. Down conversion characteristics for low side LO injection.

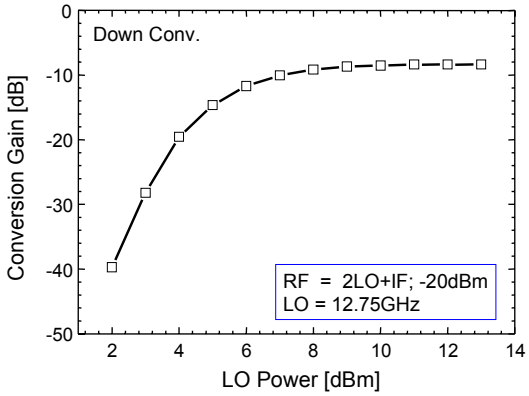

Fig. 8. Conversion Gain characteristics versus LO power.

Fig. 9 shows the frequency response for low side LO injection, when the mixer operates as a frequency up-converter. The measured data shows conversion loss of about 12 dB and image-rejection ratio of abut 20~25 dB at RF frequencies of 25-27GHz. Fig. 10 shows the measured RF output power on LO input power for up-conversion. Unlike the down-conversion mode, up-conversion saturates for LO power above 10 dBm. Fig. 11 shows input/output characteristics at an LO input of 10 dBm. The 1-dB compression of the up-conversion is achieved with an IF power of about 5 dBm. The 1-dB compression of the up-conversion was achieved with an IF power of about 5 dBm. All spurious signals were measured below -25dBc.

IV. Conclusions

A balanced subharmonically pumped image rejection mixer was designed and tested at K-band. The fabricated MMIC chip shows the conversion loss of about 12 dB and image rejection of 20dB at RF frequencies of 24 ~ 27.5GHz. Balanced configuration afford to the good odd and even harmonics suppression of LO of -37 dBc. This subharmonically pumped IRM will be a good candidate for K-band up/down mixers requiring low spurious signals.

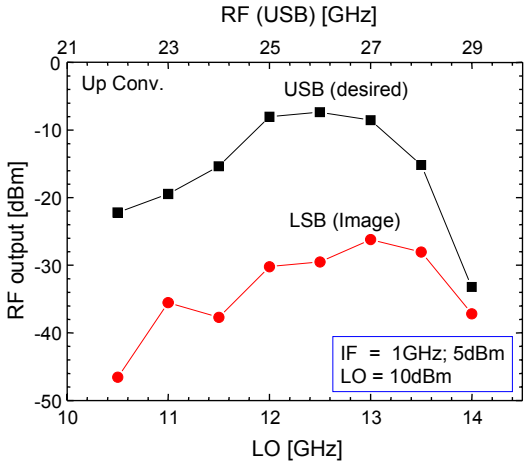

Fig. 9. Frequency response of the mixer for up-conversion.

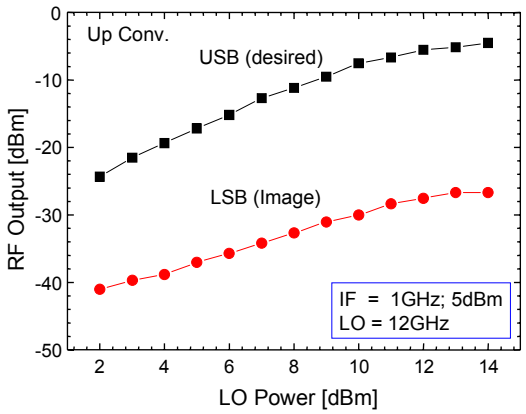

Fig. 10. RF output characteristics versus LO power for up-conversion.

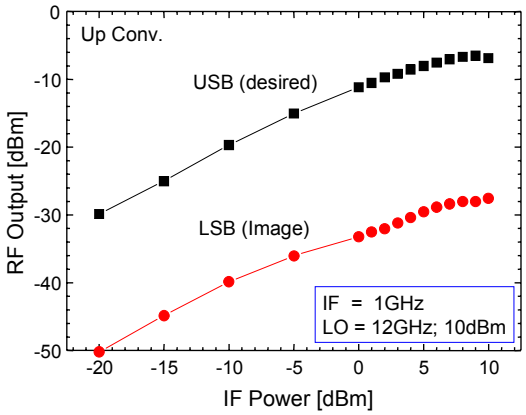

Fig. 11. RF output characteristics versus IF power for up-conversion.

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