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Low Spurious Image Rejection Mixer for K-band Applications

Moon-Que Lee† , Keun-Kwan Ryu* and Hyeong-Seok Kim*

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 the local oscillator (LO) spurious signal. To reduce the odd harmonics of LO at the 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 the LO are measured below -37dBc.

Keywords: Image-rejection mixer, Microwave mixers, Mixers, MMIC mixers, subharmonically pumped mixer.

1. 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 the oscillator degrades. As well, locking of 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 the LO. However, in practical situations in which mixers operate, odd harmonics as well as even harmonics of the LO should be suppressed sufficiently in order to maintain low spurious operation. In this paper, to effectively eliminate odd harmonics as well as even harmonics of the LO at the RF port, a balanced subharmonically pumped image rejection mixer (IRM) is proposed.

2. 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 the RF port. The quadrature hybrid at IF for image rejection is excluded from the MMIC mixer chip because it requires a large chip area. Subharmonic pumping is implemented by using APD pairs. Image rejection function is achieved by RF quadrature, LO in-phase divider, and off-chipped 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 the LO, the LO spurious signals of the balanced subharmonic image rejection mixer can be effectively suppressed.

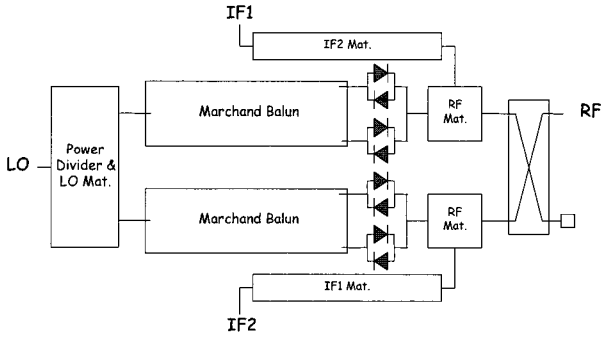

Fig. 1 Configuration of the balanced SSB mixer.

The image rejection ratio may degrade due to overall amplitude and phase imbalances caused by unmatched diodes or non-symmetry of the layout. Imbalance mainly occurs from layout non-symmetry since diodes fabricated

† Corresponding Author: Department of Electrical and Computer Engineering, University of Seoul, Seoul, Korea. (mqlee@uos.ac.kr)
* Department of Electrical and Computer Engineering, University of Seoul, Seoul, Korea.
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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 the APD are designed to have the same phase delay. Fig. 2 shows the designed layout of APD pairs.

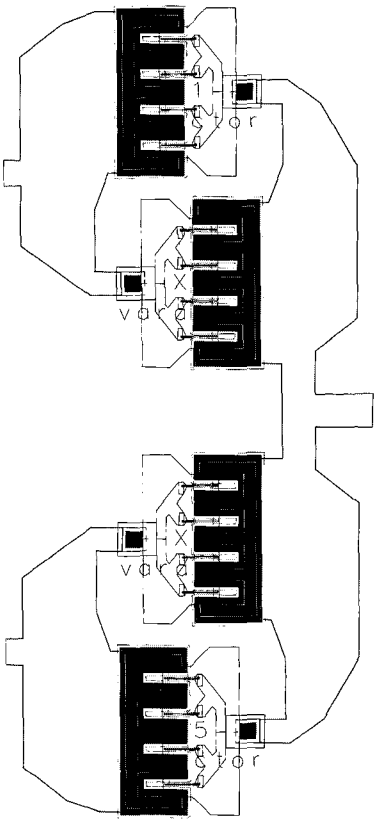

Fig. 2 The layout of APD pairs

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

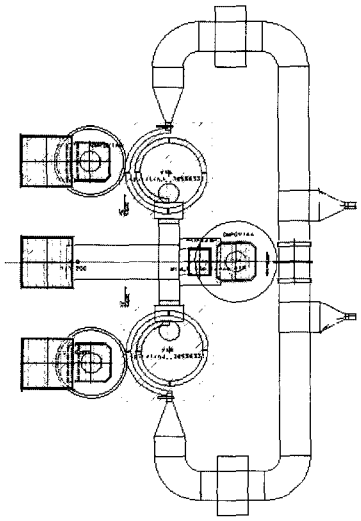

Fig. 3 Quasi-lumped power divider.

3. Experiment Results

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

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

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 displays the measured conversion loss characteristics on LO input power for down-conversion. Conversion loss saturates for LO power from 8 dBm.

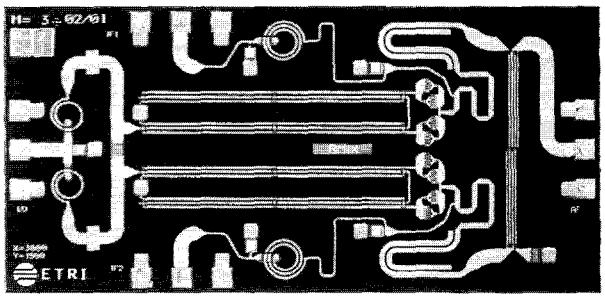

Fig. 4 Photograph of the fabricated balanced SSB mixer.

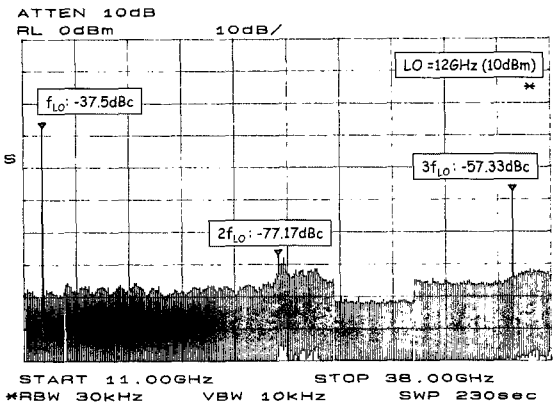

Fig. 5 Power spectrum of LO at RF port. The power of LO = 10dBm.

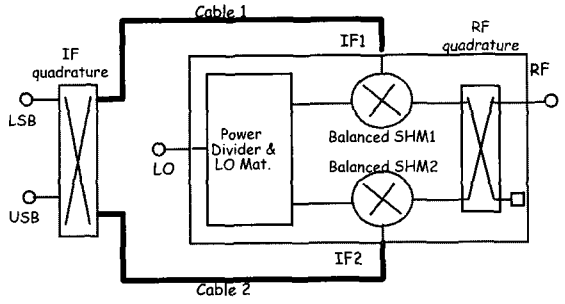

Fig. 6 Test configuration of the subharmonically pumped image rejection mixer.

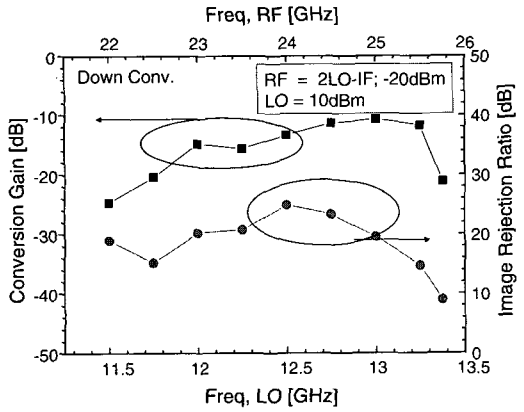

Fig. 7 Down conversion characteristics for low side LO injection.

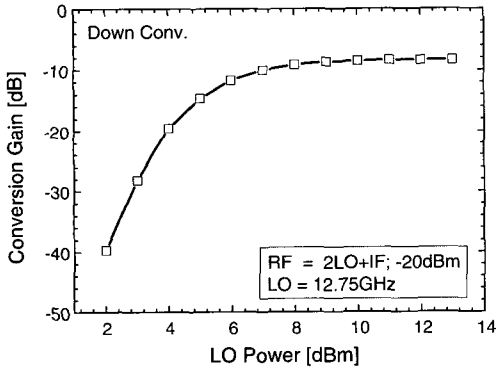

Fig. 8 Conversion Gain characteristics versus LO power.

Fig. 9 presents 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 about 20~25 dB at RF frequencies of 25-27GHz. Fig. 10 displays the measured RF output power on the LO input power for up-conversion. Unlike the down-conversion mode, up-conversion saturates LO power above 10 dBm. Fig. 11 shows input/output characteristics at a 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.

4. 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 affords good odd and even harmonics suppression of the LO of -37 dBc. This subharmonically pumped IRM will be a fine candidate for K-band up/down mixers requiring low spurious signals.

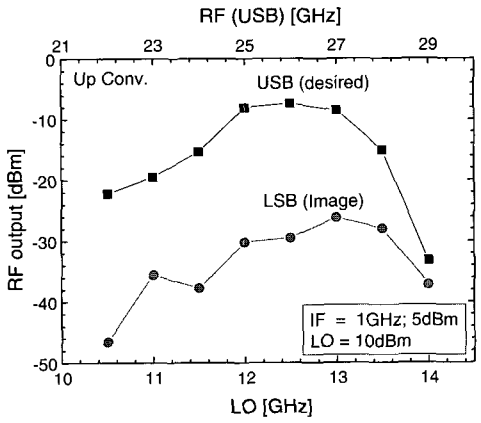

Fig. 9 Frequency response of the mixer for up-conversion

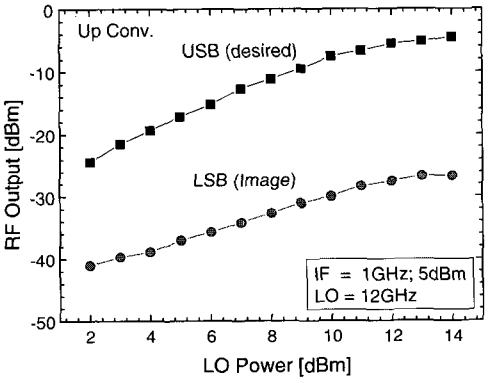

Fig. 10 RF output characteristics versus LO power for up conversion.

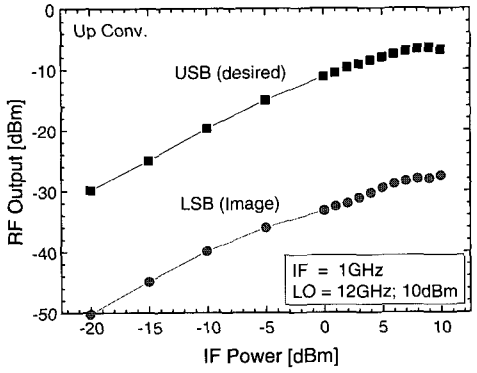

Fig. 11 RF output characteristics versus IF power for up-conversion.

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Moon-Que Lee

He received his B.S. degree in Electrical and Electronics Engineering from the Korea Advanced Institute of Science and Technology (KAIST), Daejon, Korea, in 1992, and his M.S. and Ph.D. degrees in Electronics Engineering from Seoul National University, Seoul, Korea, in 1994 and 1999, respectively. Following graduation, he joined the Satellite Communications System Department, Electronics and Telecommunications Research Institute (ETRI), Daejon, Korea, as a Senior Member of the Research Staff where he was involved with the development of microwave components and millimeter-wave MMIC's for satellite payloads. He is currently an Assistant Professor in the Department of Electrical and Computer Engineering, University of Seoul, Seoul, Korea. His research interests are the design of RF-CMOS and MMIC.

Keun-Kwan Ryu

He received his B.S., M.S. and Ph.D. degrees in the Department of Electronic Communication Engineering from Kwangwoon University, Seoul, Korea, in 1992, 1994 and 2000, respectively. From 2000 to 2003, he was with the Satellite Communications System Department, Electronics and Telecommunications Research Institute (ETRI), Daejon, Korea, as a Senior Member of the Research Staff. He is currently a Full-time Lecturer in the Department of Electronics, Hanbat National University, Daejeon, Korea. His research interest is the design of Microwave Circuits.

Hyeong-Seok Kim

He was born in Seoul, Korea, on October 9, 1962. He received his B.S., M.S. and Ph.D. degrees in the Department of Electrical Engineering from Seoul National University, Seoul, Korea, in 1985, 1987 and 1990, respectively. From 1990 to 2002, he was with the Division of Information Technology Engineering, Soonchunhyang University, Asan, Korea. In 1997, he was a Visiting Professor at the Electrical Computer Science Engineering, Rensselaer Polytechnic Institute, Troy, New York, USA. In 2002, he transferred to the School of Electrical and Electronics Engineering, Chungang University, Seoul, Korea as an Associate Professor. His current research interests include numerical analysis of electromagnetic fields and waves, analysis and design of passive and active components for wireless communication as well as electromagnetics education.