A millimeter-wave broadband monolithic even harmonic image rejection mixer.

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Abstract

This paper describes a millimeter-wave broadband monolithic even harmonic image rejection mixer with a ring connected anti-parallel diode pair. This mixer employs an even harmonic mixer with a ring connected anti-parallel diode pair to reduce the LO leakage. Also it employs the balanced type mixer with the Marchand balun to broaden the frequency range. Furthermore, the configuration of the image rejection mixer can suppress the image components.

The chip size of the developed millimeter-wave broadband monolithic mixer is 1.2 mm x 2.9 mm on a GaAs substrate. Conversion loss is less than 15.9 dB and image rejection ratio is more than 12.5 dB from 24 to 44 GHz. Broadband characteristics can be achieved by the proposed configuration.

Introduction

In recent years, a millimeter-wave utilization has been studied for short distance radar systems and high speed data communication systems[1]. In these systems, size and cost reductions are required. Hence millimeter-wave mixers are required to suppress spurious level of a mixer to use a small sized filter for RF signals. As millimeter-wave mixers, there are Schottky-barrier diode mixers[2][3] and HEMT mixers[4][5]. In these diode mixers, even harmonic mixers with an anti-parallel diode pair (APDP) have been proposed[2][6]. These even harmonic mixers can mix the input signal and the even harmonics of LO without a multiplier. So, these mixers are suitable for the millimeter-wave transceivers[7]. Also, these even harmonic mixers have a technical feature of extreme low virtual LO leakage that locates nearby a desired RF signal. This virtual LO leakage is the second harmonic of LO in the even harmonic mixers.

We have already developed 40 GHz band and 60 GHz band even harmonic mixers using open and short circuited stubs[2][8]. However, these mixers don't have broadband characteristics.

This paper describes the millimeter-wave broadband monolithic even harmonic image rejection mixer with a Marchand balun to broaden the frequency range. This mixer consists of the Marchand balun[9] and the ring connected APDP (RAPDP) [10]. Furthermore this mixer employs the configuration of the image rejection mixer with the Lange coupler and the Wilkinson divider.

In the following discussion, the configuration and the experimental results are

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indicated for the developed millimeter-wave broadband monolithic even harmonic image rejection mixer .

Configuration

A configuration of the even harmonic image rejection mixer is shown in Fig.1. This mixer consists of two unit mixers, an in-phase divider for LO, a 90-degree combiner for the RF signal and an external 90-degree divider for the IF signal. The phase relations of the image rejection mixer is shown in Table 1. By the dividers, LO is divided in-phase and IF signal is divided in 90-degree. These signals are mixed by the each unit mixer. RF signals produced at each mixer are in 90-degree. Desired RF signals (USB) are combined in-phase by the 90-degree hybrid circuit. On the other hand, undesired RF signals (LSB) are combined in out-of-phase and are canceled. This even harmonic mixer with an APDP can mix the IF signals (f_{if}) and the second harmonic of LO ($2f_{LO}$), and produce the RF signal ($2f_{LO}+f_{if}$). Also, second harmonic of LO can be canceled in the APDP.

A configuration of the developed millimeter-wave broadband monolithic even harmonic image rejection mixer with RAPDPs is shown in Fig.2. The unit mixer has a configuration of the balanced mixer which consists of the RAPDP and the Marchand balun. This balun has broadband characteristics as the 180-degree balun. High isolation characteristics between the LO and RF ports can be achieved by the RAPDP in broadband. Degradation of image rejection ratio can be reduced by improving LO to RF isolation of the mixer[11]. For the in-phase divider, Wilkinson divider is employed. Also this Wilkinson divider has a function of impedance transformer. For the 90-degree hybrid circuit, Lange coupler is employed

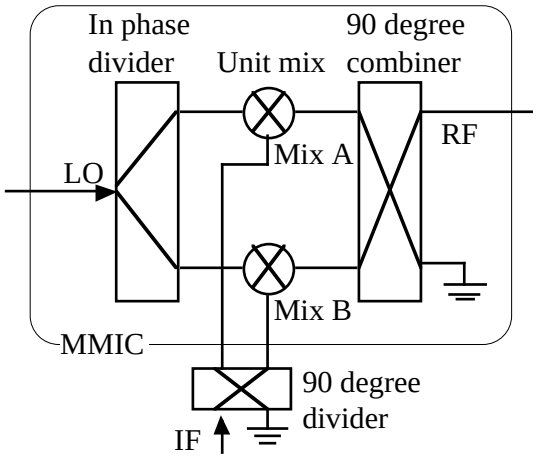

Fig.1. A configuration of the even harmonic image rejection mixer

Table 1. The phase relations of the image rejection mixer

Unit mix					Output	
	IF	2LO	2LO+IF	2LO-IF	2LO+IF (USB)	2LO-IF (LSB)
Mix A	0	0	0	0	¸/2	¸/ 2
Mix B	¸/2	0	¸/2	- ¸/2	¸/2	- ¸/2

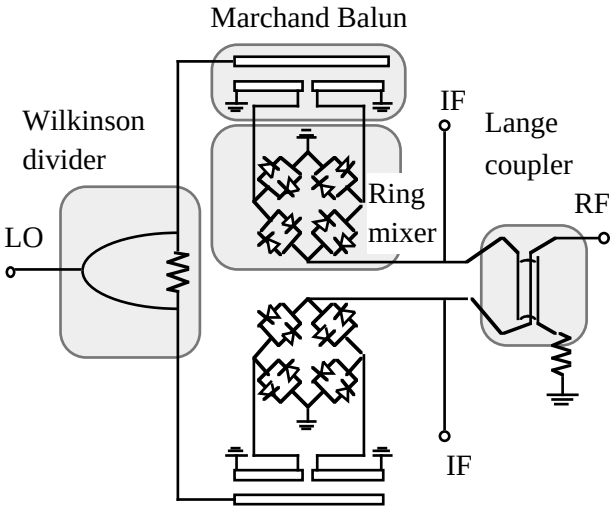

Fig.2. A configuration of the developed millimeter wave broadband monolithic even harmonic image rejection mixer with RAPDPs.

for broadband characteristics. The 90-degree hybrid circuit for IF signal is connected outside of the monolithic mixer.

Experimental results

A photograph of the developed millimeter-wave broadband monolithic even harmonic image rejection mixer is shown in Fig.3. The chip size of the mixer is 1.2 mm x 2.9 mm. The thickness of the GaAs substrate is 100μm. The RF output power versus LO power of the mixer is shown in Fig.4. Conversion loss is 14.5 dB at LO power of 16 dBm. This conversion loss includes 3 dB loss of the external 90-degree hybrid circuit for the IF signal. The RF output power versus RF frequency of the mixer is shown in Fig.5. Conversion loss is from 13.1 to 15.9 dB. Image rejection ratio is from 12.5 to 20 dB. Second harmonic of LO versus USB is from 20 to 35 dBc. These values are obtained within the frequency range of 24 to 44 GHz.

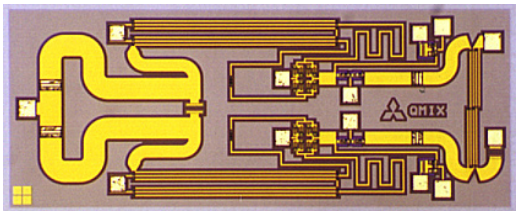

Fig.3. A photograph of the developed millimeter-wave broadband monolithic even harmonic image rejection mixer. The chip size of the MMIC is 1.2mmx2.9mm.

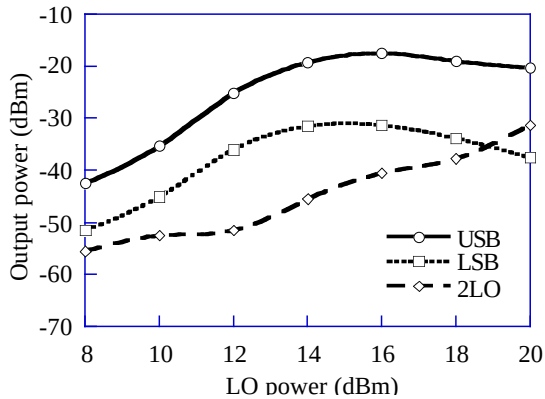

Fig.4. The RF output power versus LO power of the mixer. The RF frequency is 35 GHz. The IF frequency is 10 MHz and the IF input power is -3 dBm.

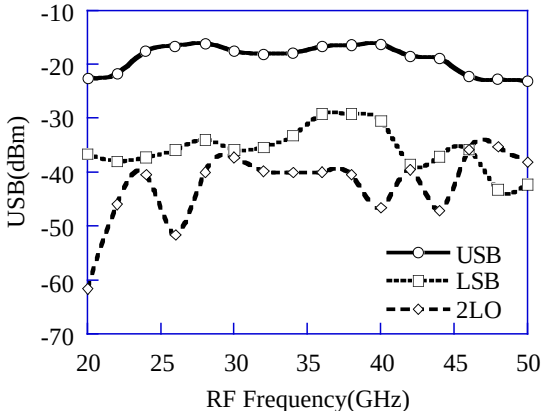

Fig.5. The RF output power versus RF frequency of the mixer. Broadband characteristics can be achieved by this configuration of the mixer. The LO input power is 16 dBm. The IF input power is -3 dBm and the IF frequency is 10 MHz

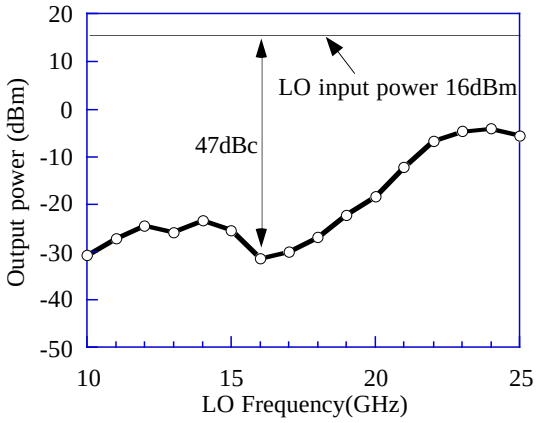

Fig.6. LO to RF isolation characteristics. The broadband characteristics can be achieved by employing the configuration of the balanced mixer with the Marchand balun.

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Furthermore LO to RF isolation characteristic is shown in Fig.6. LO to RF isolation is from 20 to 47 dB within the LO frequency range of 10 to 25 GHz. Broadband characteristics can be achieved by the proposed configuration.

Conclusion

This paper has described the millimeter-wave broadband monolithic even harmonic image rejection mixer with RAPDP. This mixer employs the balanced type mixer with the Marchand balun to broaden the frequency range.

Conversion loss is less than 15.9 dB and image rejection ratio is more than 12.5 dB from 24 to 44 GHz. Broadband characteristics can be achieved by the proposed configuration.

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