A 40GHz Band Monolithic Even Harmonic Mixer With An Antiparallel Diode Pair

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Abstract

A monolithic even harmonic mixer with a new simplified circuit configuration is described. The mixer employs an antiparallel diode pair, open and short circuited stubs as filters for separating RF output signal, IF input signal and LO power from each other. The circuit configuration is suitable for MMIC.

A 40GHz band even harmonic mixer is fabricated on a 1.7mm×2.2mm GaAs substrate, and a conversion loss of 9.5dB and a suppression of the virtual LO leakage of 75dB are achieved.

Introduction

A monolithic even harmonic mixer with an antiparallel diode pair is very effective for transmitters and receivers used in satellite communications, because of lower local oscillator frequency, low supurious level and small size.

However, conventional even harmonic mixers consist of an antiparallel diode pair and waveguide type filters [1][2]. So these circuit configurations become larger and are not suitable for MMIC.

In the case of a millimeter wave even harmonic mixer, it can be so designed that a ratio of IF input frequency f_i to RF output frequency f_o is very small and RF output frequency f_o becomes nearly equal to the even harmonic frequency of LO. Under this frequency relationship, the filters of the even harmonic mixer can be simplified by using open and short circuited stubs. The circuit configuration of the even harmonic mixer with the stubs is suitable for MMIC.

Circuit configuration and operation principles

Fig.1 shows a circuit configuration of the even harmonic mixer. It consists of an antiparallel diode pair, an open and a short circuited stubs, a band pass filter (BPF) with a coupled line and a band rejection filter (BRF) with stubs for RF output signal.

To suppress the virtual LO leakage of which frequency $2n \cdot f_p$ (n=1,2,····) is close to that of RF signal, the mixer employs an antiparallel diode pair [1] as a mixing element. The LO currents I_{d1}, I_{d2} through both diodes are with the same amplitude and in the opposite phase with each other. Thus there are no components of even harmonics of the LO current $(I_{d1}+I_{d2})$ [1]. As a result, the virtual LO $(2n \cdot f_p)$ leakage is suppressed.

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RF output frequency f_o is expressed as follows:

$$f_o = f_i + 2n \cdot f_p \quad (1)$$

To achieve a higher conversion efficiency, the mixer has been designed to be second harmonic one as n=1.

In the case of $f_i/f_p \ll 1$, RF output frequency f_o is expressed as follows:

$$f_o \simeq 2 \cdot f_p \quad (2)$$

Under the frequency relationship, the configurations of filters which separate RF output signal, IF input signal and LO power from each other are simplified by using the stubs as shown in Fig.1. The length of the open and the short circuited stubs is designed to be equal to an electrical length of $\lambda/4$ at LO frequency f_p. So the impedances of the open circuited stub seen from point A and the short circuited stub seen from point B in Fig.1 become zero and infinity, respectively. Thus, at point A the diodes are grounded by the open circuited stub, and the leakages of LO power at other ports are suppressed.

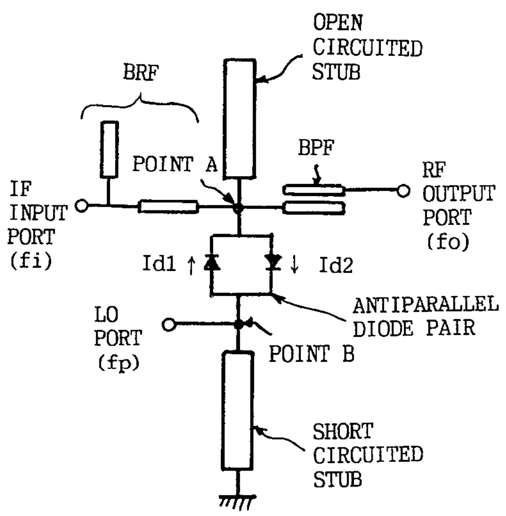

Fig.1 Circuit configuration of the even harmonic mixer.

At RF output frequency f_o, the impedances of the open circuited stub seen from point A and the short circuited stub seen from point B become infinity and zero, respectivly. Thus, at point B, the diodes are grounded by the short circuited stub. By the stub and the BRF, the leakages of RF power at other ports are suppressed.

Moreover, at IF input frequency f_i, the length of these stubs are negligibley small compared with the wavelength. Thus, at point B, the diodes are grounded by the short circuited stub. By the stub and the BPF, the leakage of IF power at other ports are suppressed.

As mentioned above, the circuit configuration of the mixer is simplified and becomes suitable for MMIC. Moreover by fabricating the monolithic diode pair with a good balance, the virtual LO ($2f_p$) leakage is extremely suppressed.

Experimental results

Fig.2 shows the photograph of the 40GHz band monolithic even harmonic mixer. The mixer is fabricated on a GaAs substrate of a 0.1mm thickness. A chip size is 1.7mm×2.2mm.

A Schottky–barrier diode with a series resistance of 14.5Ω and a junction capacitance at 0V of 0.04pF is used in the mixer.

Fig.3 shows the conversion loss between 36GHz and 40GHz. The solid line shows measured values and the dashed curve shows calculated values by the harmonic balance method. The measured conversion loss is better than 10.6dB, and 9.5dB as a minimum value. The measured values agree with the calculated ones.

Fig.4 shows the output spectrum of the mixer operating at LO power of 6dBm and IF input power of −10dBm. In the figure, dots show the calculated power of mixing products. The measured power of the virtual LO ($2f_p$) leakage is −69dBm. The suppression of the virtual LO leakage of 75dB is obtained. The measured power of mixing products agrees with the calculated one.

Fig.5 shows the dependance of the convers ion loss (at a center frequency) on LO power. The solid and the dashed lines show measured and calculated values, respectively. The lowes t conversion loss is obtained at LO power of 6 dBm. The effect of LO power on the conversion loss is small.

Fig.6 shows the power dependance of RF output signal (at the center frequency) on IF input power. Solid and dashed lines show the measured and calculated values, respectively. RF output power at 1dB gain compression is −15.7dBm.

Conclusions

A 40GHz band monolithic even harmonic mixer has been developed. A conversion loss of 9.5dB and a suppression of the virtual LO leakage of 75dB have been achieved.

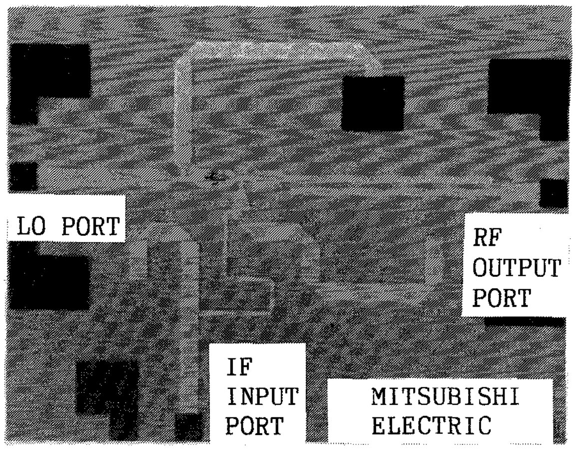

Fig.2 Photograph of the even harmonic mixer fabricated on a GaAs substrate.

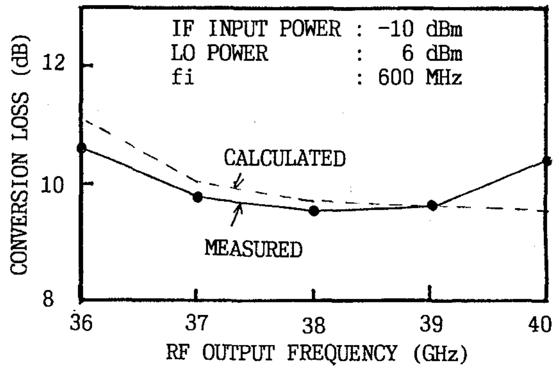

Fig.3 Conversion loss versus RF output frequency.

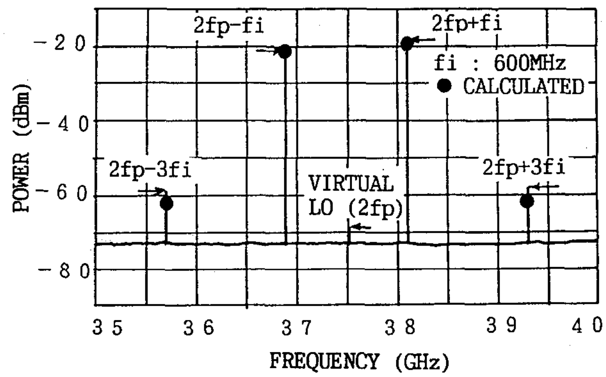

Fig.4 Output spectrum of the mixer operating at LO power of 6dBm and IF input power of −10dBm.

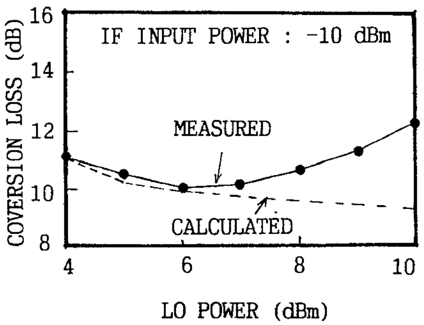

Fig.5 Dependance of conversion loss on LO power.

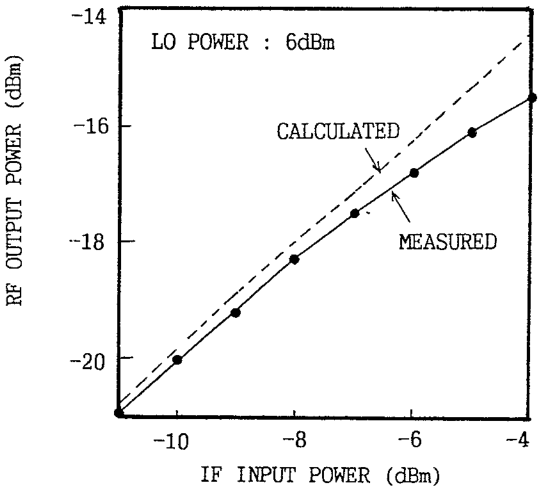

Fig.6 Dependance of RF output power on IF input power.

Reference

[1] M.Cohn,J.E.Degenford and B.A.Newman, : " Harmonic mixing with antiparallel diode pair, " IEEE Trans. on Microwave Theory Tech., vol.MTT-23, 8, pp.667-673, Aug. 1975.

[2] J.Matreci and F.K.David, : " Unbiased, subharmonic mixer for millimeter wave spectrum analyzers, " 1983 IEEE MTT-S International Microwave Symposium Digest, pp.130-132, 1983.