An Even Harmonic Mixer using Self-Biased Anti-Parallel Diode Pair

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Abstract — **This paper presents a novel even harmonic mixer using self-biased anti-parallel diode pair (APDP). Resistors for self-bias are employed in APDP, and voltage differences in D.C. arise at each diode when LO power is applied. As increasing of LO power, voltage differences become larger, so maximum voltages of LO wave added to each diode are almost constant and conversion loss of the mixer is kept constantly. In the developed L-band even harmonic mixer using self-biased APDP for a direct conversion receiver, fluctuation of voltage conversion gain is below 1dB with LO power of from 0dBm to14dBm.**

I. INTRODUCTION

An even harmonic mixer (EH-MIX) using anti-parallel diode pair (APDP) is effective technique especially for millimeter-wave region, because its LO frequency is a half of other fundamental pumped mixer [1][2]. Also this mixer has technical features of extremely low even order spurious responses and emissions. At the output of the mixer, band pass filter for 2LO, which is corresponding to LO leakage in the fundamental pumped mixer, is not required. So the EH-MIX is applied to millimeter-band up-converter [3]-[5].

Also we had proposed an EH-MIX applied to a direct conversion receiver [6]-[8]. The direct conversion receiver that converts RF signal to baseband signal directly is suitable for small sized mobile terminal. But second order mixing products arise at the quadrature mixer, the receiver is not so sensitive as much as the heterodyne receiver. We had used EH-MIX employing APDP in the quadrature mixer for the direct conversion receiver, and had achieved sufficient sensitivity for mobile terminal.

Though conversion loss of the EH-MIX using APDP is almost same as that of the fundamental pumped mixer, it will be degraded rapidly as increase of LO power [9]. Such a tendency will be conspicuous in the EH-MIX for the direct conversion receiver because it uses high load resistances to improve voltage conversion gain [6]-[8]. Though a direct conversion receiver has a simple configuration, high performances are required in RF circuits including quadrature mixer. So slight increase of conversion loss of the mixer degrade sensitivity of the receiver.

In this paper, we propose an EH-MIX using self-biased APDP. The APDP is composed of diodes and resistors for self-bias, and they are connected in series. When LO is applied to APDP, rectification current occurred in the each diode, and voltage differences arise in the each resistor. These voltage differences reduce maximum voltage of LO wave, and they become larger with increase of LO power. So maxim voltages of LO wave applied to each diode is almost constant and conversion loss is kept constantly.

II. CONFIGURATION

Figure 1 shows the configurations of the EH-MIX using APDP. Figure 1(a) and 1(b) show conventional, and proposed EH-MIX, respectively. In the proposed EH-MIX shown in figure 1(b), resistors R_C for self-bias are connected with each diode in series, and capacitors C_1 are connected with each resistor in parallel. Though resistors

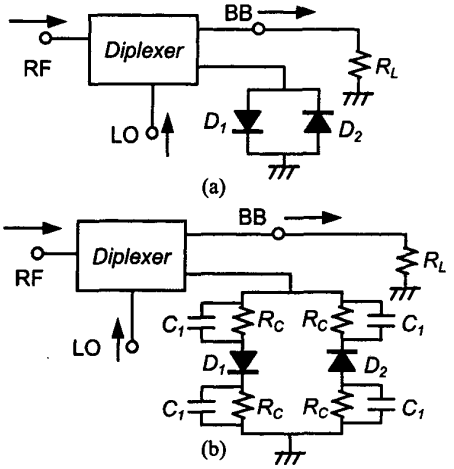

Fig. 1. (a) Even harmonic mixer (EH-MIX) using conventional anti parallel diode pair (APDP). (b) Proposed EH-MIX using self biased APDP.

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required at the only cathode side of diodes in principles, they are connected in the both sides of diodes so that the balance of APDP would not degrade, and even order mixing products would not arise.

Proposed EH-MIX will be applied to a direct conversion receiver [10]-[12], so the relationships between frequencies of LO (f_p), input RF signal (f_{rf}) and output baseband (BB) signal (f_{bb}) are represented as

$$f_{bb} = f_{rf} - 2f_p, \quad f_{rf} \approx 2f_p. \qquad (1)$$

Capacitors C_1 are set their value to pass RF signal and LO wave. The BB signal arising in the diodes passes through resistors R_C and a diplexer, and goes out to load resistance R_L. This R_L is designed higher than 50Ω to improve voltage conversion gain [6]-[8].

Figure 2 shows the relationship between V-I characteristic of APDP, applied LO waveform and current waveform in the conventional EH-MIX. In generally, Diodes D1 and D2 have same V-I characteristics, so V-I characteristic of APDP is anti-symmetric. When a LO wave, which has an amplitude V_p, is added to the APDP, the LO and its harmonic currents including rectification current I_{pdc} are occurred in D1 at positive cycles of the LO wave, and in D2 at negative cycles of the LO wave. In the conventional EH-MIX using the APDP, there is optimum current duty ratio for the lowest conversion loss [9]. As increase of LO power, the current duty ratio changes, and the conversion loss increase. In the proposed APDP, self-bias voltages V_{Rc} caused by rectification currents I_{pdc} arise in each resistor R_C. Figure 3 shows voltages of the proposed APDP caused by rectification currents. In each diode, voltage differences V_0 between anode and cathode of the diodes are

$$|V_0| = 2|V_{Rc}| = 2 I_{pdc} R_C. \qquad (2)$$

Thus, voltage $-V_0$ and V_0 are applied to the LO wave at D1 and D2, respectively. Maximum amplitudes of LO wave applied to diodes become $|V_p - V_0|$ as shown in figure 4. As increase of LO power, higher V_p and higher I_{pdc} are obtained, so almost constant $|V_p - V_0|$ and current duty ratio are obtained. Thus, conversion loss of EH-MIX using self-biased APDP can be kept in constant.

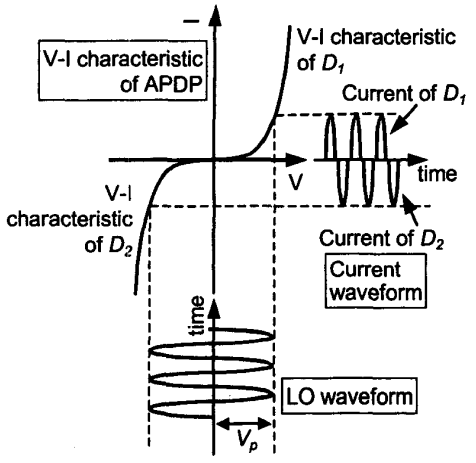

Fig.2. Relationship between V-I characteristic of APDP, applied LO waveform and current waveform in the conventional EH-MIX.

III. CALCULATED SELF-BIAS VOLTAGE AND VOLTAGE CONVERSION GAIN

A. Self-bias voltage

Figure 5 shows LO wav e amplitude V_p(V) and self-bias voltage V_0 caused by rectification current in the self-biased APDP calculated by the Harmonic balance (HB) method. Parameters used for calculations are shown in

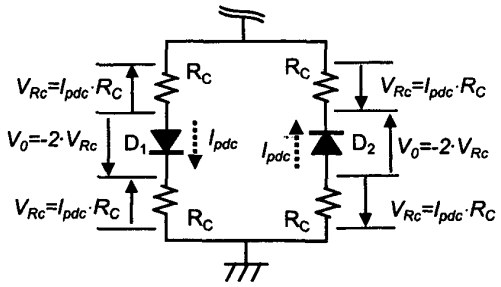

Fig.3. Voltage differences and rectification currents in the self-biased APDP. V_0 is voltage difference between anode and cathode of the each diode.

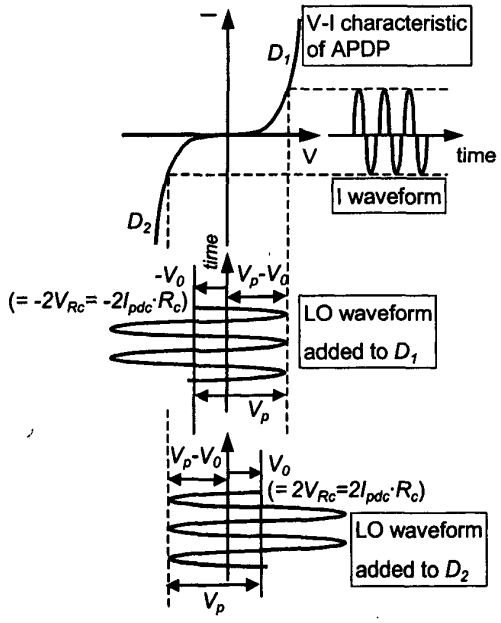

Fig.4. Relationship between V-I characteristic of APDP, applied LO waveform and current waveform in the EH-MIX using self-biased APDP.

table 1. As increase of LO power, higher LO wave amplitude V_p and lower self-bias voltage V_0 are obtained. So, as shown in figure 6, maximum voltage of LO wave $|V_p-V_0|$ is almost flat in the self biased APDP, though it increase in the conventional APDP.

B. Voltage conversion gain

Figure 7 shows voltage conversion gain of the EH-MIX with proposed APDP and conventional APDP. Parameters shown in table 1 are used for calculation. Load resistance R_L is set to higher than 50Ω so that it can be achieve higher voltage conversion gain. As shown in figure 6, voltage conversion gain of EH-MIX using proposed APDP is almost constant from −10dBm to 20dBm of LO power.

III. EXPERIMENTAL RESULTS

An L-band EH-MIX using self-biased APDP was developed. It is a unit mixer of qudrature mixer for direct conversion receiver [10]-[12]. It consists of self-biased APDP fabricated on SiGe-MMIC [10] and an external diplexer. The photograph of developed self-biased APDP is shown in figure 8. Resistors for self-bias in the APDP are 400Ω. The EH-MIX has matching circuit for RF signal and differential output port for BB signal. Load resistances R_L at differential BB port are both 2.7kΩ. The BB signal is measured after amplified by a differential voltage amplifier.

Figure 9 shows measured voltage conversion gain of the EH-MIX using self-biased APDP except differential voltage amplifier. RF input signal was 2GHz-band and its power was -25dBm (=-38dBV at input port). LO frequency was 1GHz-band, and BB signal was 500kHz. Fluctuation of G_C was below 1dB with LO power of from 0dBm to 14dBm and the calculated result using HB method well agrees with measurement result.

Figure 10 shows the measured intermodulation distortion characteristics of the EH-MIX using self-biased

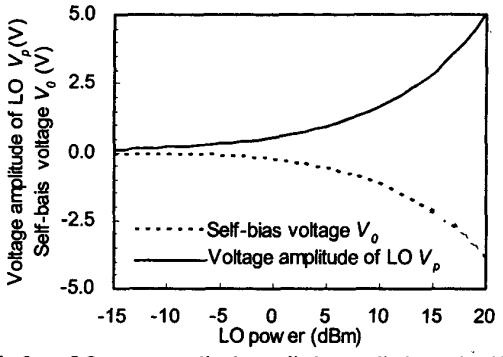

Fig.5. LO wave amplitude applied to a diode, and self-bias voltage of the diode caused by rectification current in the self-biased APDP.

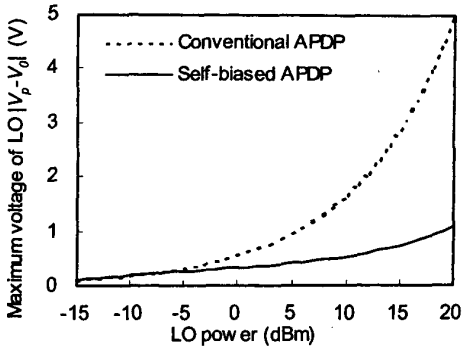

Fig.6. Maximum voltage of LO wave in the conventional and self-biased APDP.

Table I PARAMETERS FOR CALCULATION

Diode	Saturation current : I_S	117.8e-9 A
	Ideality factor : η	1.082
	Series resitance : R_S	3.0 Ω
Resistors for self bias : R_C		300 Ω
Load resistance : R_L		5.4 kΩ

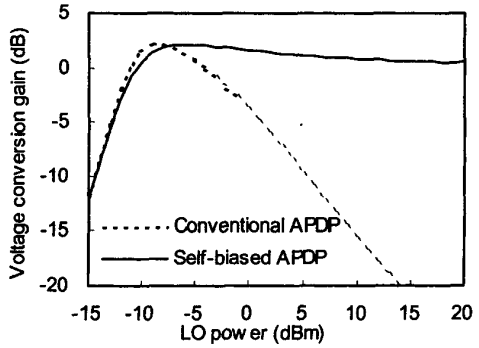

Fig.7. Voltage conversion gain of the EH-MIX using self-biased APDP and conventional APDP calculated by the harmonic balance method.

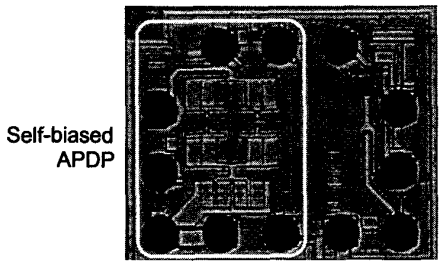

Fig.8. The photograph of the developed self-biased APDP including LNA fabricated on SiGe-MMIC [10].

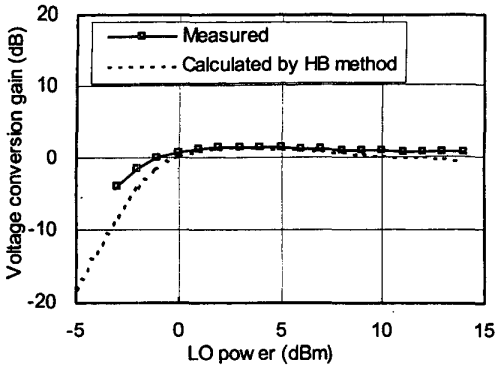

Fig.9. Measured voltage conversion gain of the developed EH-MIX using self-biased APDP. RF input signal was 2GHz-band and its power was -25dBm(=-38dBV). LO frequency was 1GHz-band, and BB signal was 500kHz.

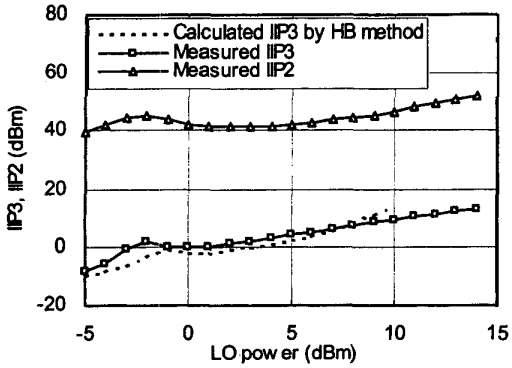

Fig.10. Measured intermodulation distortion characteristics of the developed EH-MIX using self-biased APDP. RF input signals are 2GHz-band and they are separated 150 kHz each other. Their power was -25dBm(=-38dBV/tone). LO frequency was 1GHz-band, and BB signals ware 500kHz, 650kHz respectively.

APDP. RF input signals were 2GHz-band and they were separated 150 kHz each other. Their power were -25dBm (= -38dBV)/tone. LO frequency was 1GHz-band, and BB signals are 500kHz, 650kHz. IIP3 of more than 0dBm and IIP2 of more than 40dBm were achieved. These results satisfied requirements of direct conversion receivers for W-CDMA terminal [10]-[12].

V. CONCLUSION

EH-MIX using self biased APDP was proposed. Employing resistors for self bias in APDP, maximum voltage of LO wave added to each diode would be almost constant, and conversion gain was kept in constant in spite of increasing LO power. A fluctuation of voltage conversion gain was less than 1dB with LO power of from 0dBm to 14dBm in a developed L-band EH-MIX.

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