A 78–114 GHz Monolithic Subharmonically Pumped GaAs-Based HEMT Diode Mixer

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***Abstract*—A W-band subharmonically pumped (SHP) diode mixer is designed for fixed LO frequency operation. It is fabricated on a 4-mil substrate using 0.15 μm GaAs PHEMT MMIC process. The on-wafer measurement results show that the conversion loss is about 10 to 14 dB across the W band, as a 10 dBm 48 GHz LO signal is pumped. To our knowledge, this is the state-of-the-art result on low-conversion-loss wideband MMIC SHP diode mixer. The packaged module measurement shows a similar result. Both the simulation and measurement results are shown in good agreement.**

***Index Terms*—MMIC, millimeter-wave mixer.**

I. Introduction

SUBHARMONICALLY pumped diode MMIC mixers have been fabricated with frequency up to 210 GHz [1]–[3]. Compared to the fundamental mixers, SHP mixers have the advantages of availability of lower LO frequency source, better RF-to-LO isolation, and separated RF/LO input paths. The SHP mixer also gives better LO phase noise cancellation [4]. These advantages make it suitable as down-conversion devices in wideband receivers for millimeter-wave astronomy, especially for cosmology observation such as Array of Microwave Background Anisotropy [5]. In this paper, we present the design and measured performance of a W-band, low conversion loss, MMIC SHP diode mixer. Compared to previous research [1]–[3], [6], our design has widest bandwidth, lower conversion loss and better flatness, as shown in Table I. Simulation, on-wafer test data and packaged circuit module test data of our design show a flat conversion loss over 78–114 GHz at 10 dBm LO power level. To our knowledge, this is the first report of a packaged MMIC SHP diode mixer with over 36-GHz RF bandwidth operated in W-band under fixed LO frequency.

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TABLE I
COMPARISON OF MMW SHP MIXERS PERFORMANCE

RF Frequency (GHz)	Conversion Loss (dB)	Features
205-215	12.5-15.7	GaAs HEMT diode CPW MMIC with external bias [1]
83-97	8.0-10.0	GaAs diode hybrid MIC [6]*
110-120	14.3-20.0	InP HEMT diode MMIC with fixed LO frequency [3]
50-57	12.0-13.0	InP HEMT diode MMIC with fixed LO frequency [3]
175-182	14.5-16.8	InP HEMT diode MMIC with fixed LO frequency [2]
78-114	10.0-14.0	This research

II. Circuit Design

The W-band SHP mixer is designed to down-convert 85 to 105 GHz RF signal to IF frequency of 0.5 to 10 GHz by mixing with the second harmonic of a 48 GHz LO signal. A pair of anti-parallel GaAs HEMT diodes, with two gate fingers of 0.15 μm gate length and 20 μm total periphery, is used as the mixing elements. Diode model parameters are obtained by scaling from the standard model for a four finger, 90 μm total periphery diode provided by TRW foundry service. The cutoff frequency of the device model is around 350 GHz.

The basic mixer circuit structure is adapted from the typical SHP diode mixer structure [6], [7], and our circuit emphasizes symmetry of the RF and LO circuit near the diode pair to suppress the higher-order mode excited by the asymmetric microstrip tee junctions.

The MMIC chip layout is shown in Fig. 1 with the size of 1.5 mm $\times$ 2.0 mm. A pair of LO frequency quarter-wavelength open stubs and a pair of RF half-wavelength short-circuit stubs are used to improve the isolation between RF and LO. One of the open stubs is connected to the IF matching network at the half way point to keep the input impedance at the shunt point almost shorted circuit over the desired RF frequency band. After the shunt point, another RF-quarter-wavelength section was connected to keep the diode seen less affected by the IF load impedance. Due to the modeling limitation of spiral inductor at higher frequencies, we use a short section of high-impedance line to given effective series inductance along with shunt MIM capacitors to form the L-C low-pass IF network to keep a wide and flat passband.

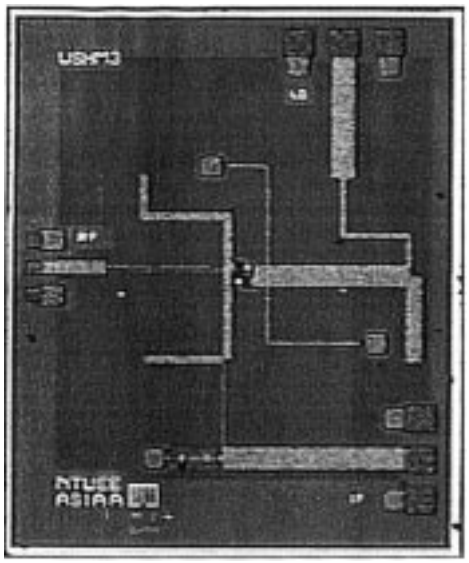


Fig. 1. A 78–114 GHz SHP mixer circuit chip.

TABLE II
SUMMARY OF SHP MIXER PERFORMANCE

	Simulation	On-wafer Test
Frequency Range	75-115GHz	78-114GHz
Conversion Loss	10-17dB	10-14dB
RF Matching	< -3dB	< -7dB
LO Matching	< -12dB	-5dB (*1)
IF Matching	< -12 dB	-8-10dB
LO-RF Isolation	30dB	20.5dB
LOx2-RF Isolation	-	>40dB
RF-LO Isolation	20dB	5dB (*2)

III. CIRCUIT PERFORMANCE

A. Simulation Results

The SHP mixer is simulated using HP/EEsof harmonic balance analysis. The critical matching circuit structures, especially the RF coupled-line bandpass filter and microstrip tee junctions, are simulated using Sonnet EM-software to ensure reasonable accuracy. The simulated conversion loss over 75–110 GHz RF frequencies is about 10–15 dB with 7–12 dBm LO power. Simulation of the RF input return loss gives about 5–11 dB over 78–103 GHz, LO return loss gives about 12 dB at 48 GHz, and IF output return loss gives about 7 dB over 1–21 GHz, respectively.

B. On-Wafer Measured Results

The SHP conversion loss is measured with −10 dBm RF input power over 78–114 GHz. An Anritsu model 68 087 synthesizer with an external power amplifier is used to provide LO signal at 48 GHz, while the IF output is measured with a power meter. The measured results show that the conversion loss is 10–14 dB for a 10 dBm LO power.

In addition, the input response at RF, IF, and LO ports are measured using an HP8510C vector network analyzer. Under 10 dBm LO power, the RF return loss is about 7 dB and IF return loss is 8–10 dB. The minimum return loss under small-signal LO input is measured at 48 GHz.

The measured result of LO-RF isolation is about 20.5 dB. The second harmonic of LO to RF isolation is more than 42 dB and RF to LO isolation (without LO pumping) is around 5 dB. The comparison between simulation and measurement results of the SHP mixer are listed in Table II.

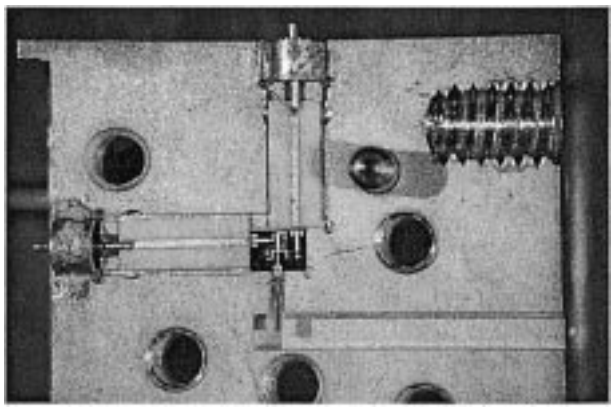
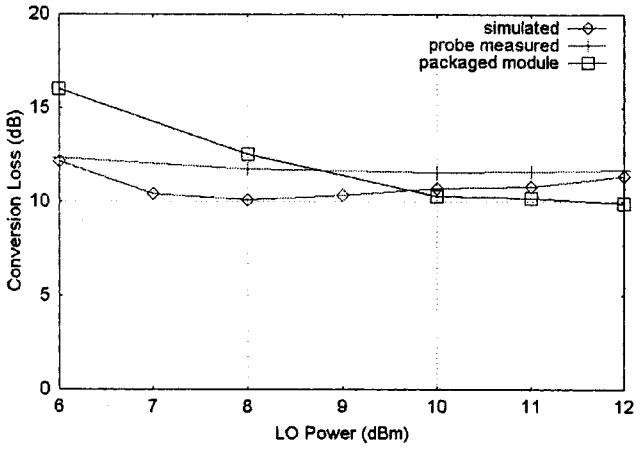
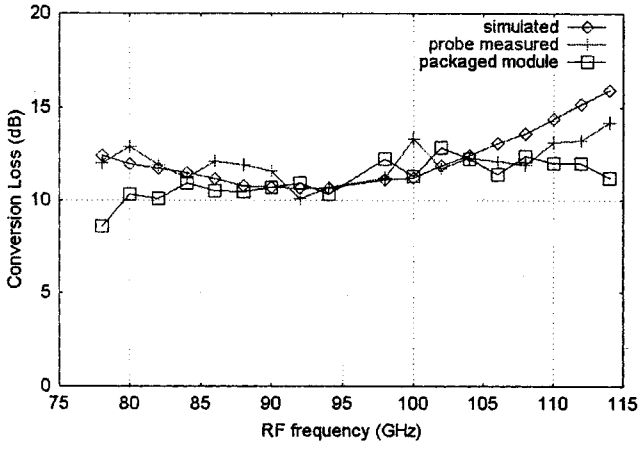


Fig. 2. SHP mixer bottom block with chip, microstrip to WR-10 probe for RF and 50 Ω line sections for LO and IF.



(a)



(b)

Fig. 3. Simulated and measured results of conversion loss (a) at different LO power levels, with RF at 90 GHz and (b) over 78–114 GHz with 10 dBm LO power level.

C. Packaged Module Measured Results

In order to make the MMIC circuit work as a component of the proposed receiver system [5], a split mixer block is designed based on the waveguide to microstrip transition probe proposed in [8]. Fig. 2 shows the mixer block under assembling, with WR-10 rectangular waveguide RF input, coaxial LO input and IF output. With the similar measurement setup except the probe station we get the conversion loss measured result around 8.5–13 dB for a 10 dBm, 48 GHz LO power over 78–114 GHz RF frequency. Fig. 3 shows the simulated, on-wafer- and packaged-measured MMIC SHP down-conversion loss.

IV. Conclusion

In this letter, the design and test of a full W-band double-sideband SHP MMIC diode mixer using 0.15 μm PHEMT process is presented. The measured conversion loss shows a good down-conversion performance over the W-band.

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