A 180-GHz Monolithic Sub-Harmonic InP-Based HEMT Diode Mixer

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***Abstract*—A 180-GHz monolithic subharmonic diode mixer is developed using 0.08-μm pseudomorphic InAlAs/InGaAs HEMT MMIC process on a 2-mil-thick InP substrate. This mixer demonstrates a conversion loss of better than 16.5 dB from 175 to 182 GHz with an LO drive of 13 dBm at 96 GHz. This is the first demonstration of a monolithic subharmonic HEMT diode mixer in this frequency range. The design and measurement of this monolithic microwave integrated circuit (MMIC) mixer and the waveguide-to-microstrip line transitions of the test-fixture are presented.**

***Index Terms*—HEMT, InP, MMIC, subharmonic mixer.**

I. Introduction

HIGH-FREQUENCY mixing function is very important for millimeter-wave (MMW) receiver applications. Subharmonic mixers have the advantages of availability of lower LO frequency source and good RF-to-LO isolation compared with fundamental mixers [1], [2]. These features are more significant at high MMW frequency range. Due to the advancement of monolithic microwave integrated circuit (MMIC) technology, the MMW subharmonic diode mixers can be implemented via monolithic approach. For example, a 38-GHz mixer with 16th-harmonic LO frequency using GaAs-based HBT diodes was reported [3]. GaAs-based HEMT diodes were also used to design a 38-GHz mixer with second harmonic LO to improve the LO-to-RF isolation [4]. For higher MMW frequency applications, InP-based HEMT MMIC's are usually considered for its high gain and low noise characteristics. Sixty- and 120-GHz subharmonic diode mixers were demonstrated using a 0.1-μm InGaAs/InAlAs/InP HEMT process with reasonable conversion loss performance [5]. The motivation of this work is to explore the capability for this diode mixer approach up to 180 GHz with a more advanced MMIC technology.

This letter reports a MMIC subharmonic mixer at RF frequencies at 180 GHz using a 0.08-μm gate length, 2-mil-thick InP-based HEMT MMIC process. It shows a measured conversion loss between 14.5 to 16.5 dB for RF frequency from 175 to 182 GHz with an LO power of 13 dBm at 96 GHz. This is the first attempt of an MMIC subharmonic diode mixer at this frequency with encouraging results.

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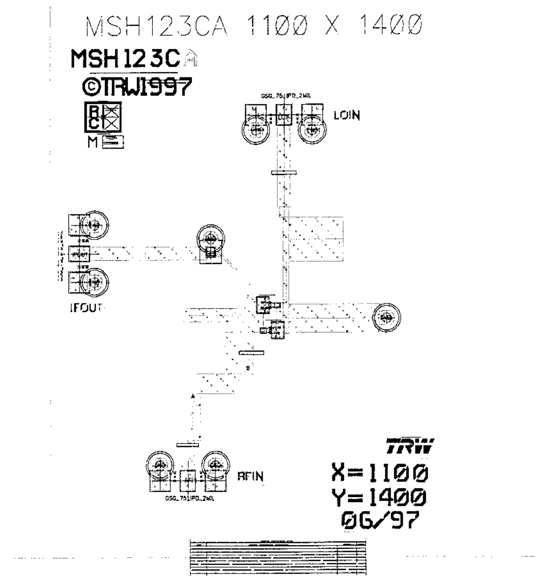


Fig. 1. The layout of the 180-GHz subharmonic MMIC mixer with a chip size of 1.1 mm × 1.4 mm.

II. Circuit Design

The 180-GHz subharmonic mixer is designed to downconvert an RF signal of 166 to 187 GHz to an IF of 5 to 27 GHz by mixing it with the second harmonic of a 96-GHz LO signal. A pair of antiparallel HEMT diodes, each having two gate fingers of 0.08-μm gate length and total periphery 20 μm, are used as the mixing elements. The InP HEMT MMIC process is the same as the 190-GHz MMIC LNA reported earlier [6]. This 40-μm-wide HEMT diode has a series resistance (R_s) of 6 Ω and a junction capacitance (C_{jo}) of 0.051 pF. The mixer circuit design utilizes quarter-wavelength open-stub and short-stub at each end of the diodes pair to achieve good isolation between LO and RF ports. LO port matching is attained by reactive matching techniques using microstrip-lines while RF port matching is obtained with a cascaded two sections of edge-coupled line filters. IF signal is tapped through a low-pass network and is connected to one end of the diodes opposite to the dc-shorted end. All passive matching structures were analyzed by a full-wave EM simulation tool (Sonnet software). The chip layout for the 180 GHz subharmonic mixers is shown in Fig. 1. The chip size is 1.1 mm × 1.4 mm.

The harmonic balance simulation was performed to predict the mixer performance. With an LO frequency at 96 GHz of 10-dBm drive and RF sweep from 165 to 187 GHz, a

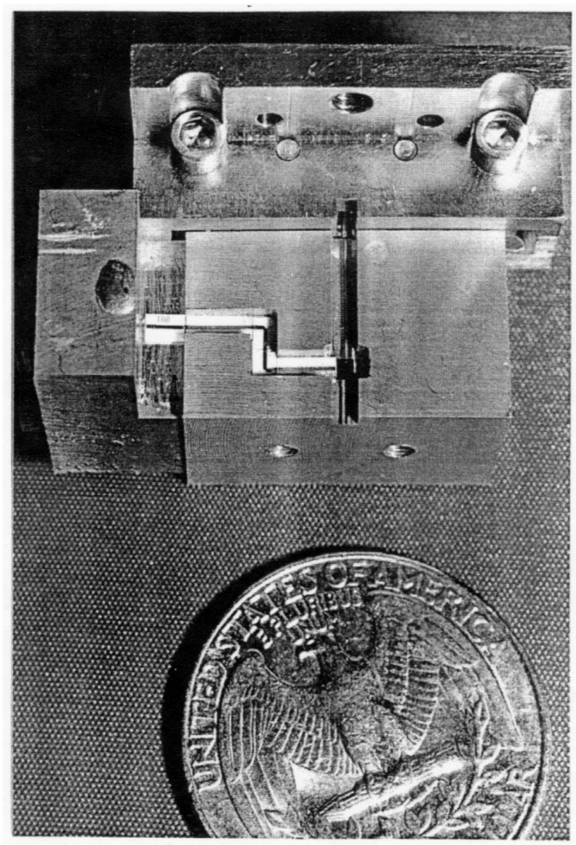
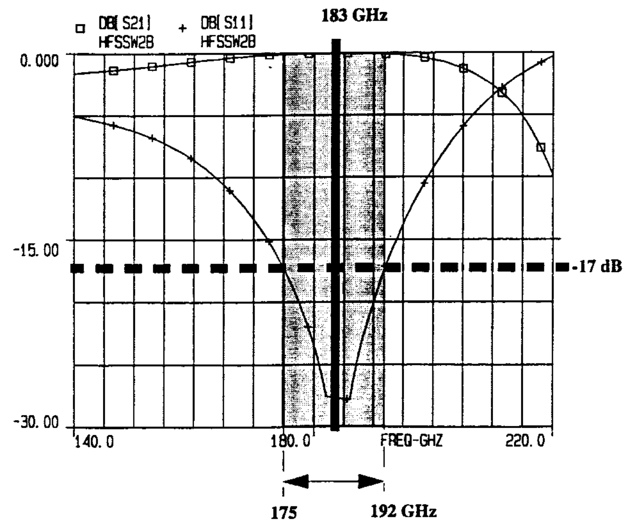


Fig. 2. The mixer chip is mounted in fixture for testing. Waveguide-to-microstrip line transitions are designed and connected to the LO port and the RF port (not shown) of the mixer carrier center block.

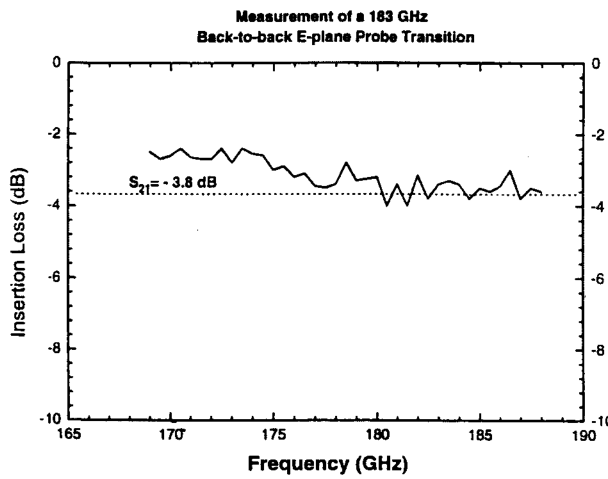
conversion loss of 14 dB was obtained. The RF-LO, RF-IF, LO-IF, LO(fundamental)-RF, and LO(second harmonic)-RF isolations were better then 30, 17, 35, 25, and 150 dB, respectively. The conversion loss versus LO power were also investigated and the $P_{\rm out}$ (IF) versus $P_{\rm in}$ (LO) curve is saturated after LO power exceeds 11 dBm.

III. Circuit Measurement

The mixer was mounted in a waveguide test-fixture with E-plane probes to couple the RF and LO signals from microstrip lines to WR-10 W-band (75–110 GHz) and WR-5 D-band (140–220 GHz) waveguides, as shown in Fig. 2. The probes was designed by utilizing a waveguide-to-microstrip cross-junction structure, similar to the designs reported previously [7]–[9]. The full-wave EM analysis software package HFSS was used for the design. The simulated insertion loss and return loss of a pair of the back-to-back transitions for this 180-GHz mixer in the D-band WR-5 waveguide are plotted and Fig. 3(a). The simulated insertion loss is very low since lossless metal and materials are assumed. The measured insertion loss from 168 to 187 GHz is about 3–4 dB, as shown in Fig. 3(b). Compared with previous work, the back-to-back insertion loss of a pair of D- and W-band transition being 3 dB [9] and 1.4 dB [8], respectively, with return loss better than 10 dB, this measured insertion loss performance seems to be reasonable.



(a)



(b)

Fig. 3. (a) Simulated insertion loss and return loss of a single-ended 180-GHz E-plane probe transition. (b) Measured insertion loss of a pair of the 180-GHz transitions connected back-to-back.

The MMIC subharmonic diode mixer was measured in the waveguide test-fixture. Conversion loss of the mixer was measured as a function of the RF frequency swept from 165 to 187 GHz. The LO drive was fixed at 96 GHz to 13 dBm. The IF signal of the mixer, varying accordingly from 5 to 27 GHz, was read from a spectrum analyzer and the conversion loss was plotted in Fig. 4. The conversion loss is 16–18 dB within an RF band from 175 to 182 GHz, as indicated in the plot. The conversion loss data of Fig. 4 include waveguide fixture loss. For the bare MMIC mixer chip performance, a 1.5-dB correction factor at the RF port (assuming half of the back-to-back transition loss) should be subtracted and thus results in a conversion loss number to be 14.5 to 16.5 dB at RF from 175 to 182 GHz.

IV. Summary

The development of a 180-GHz MMIC subharmonic mixer using a pair of antiparallel diodes based on the 2-mil InP-based

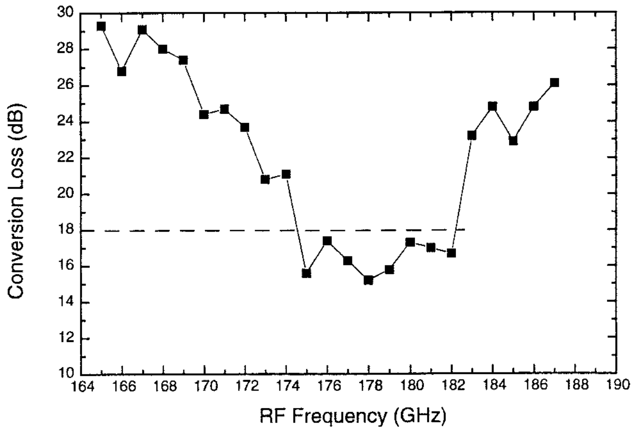


Fig. 4. Conversion loss of the 180-GHz subharmonic mixer measured at RF frequency from 165 to 187 GHz. The LO frequency and power were fixed at 96 GHz and 13 dBm, and the IF frequencies varies accordingly from 5 to 27 GHz. The data include waveguide fixture loss.

HEMT process is presented. Measurement results showed that the subharmonic mixers achieved conversion loss of better than 16.5 dB in an RF band from 175 to 182 GHz with an LO drive power of 13 dBm at 96 GHz. The success of this 180-GHz subharmonic mixer will provide a vehicle for extending the useful spectrum of MMW technology for commercial and military applications.

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