A Ka-band Monolithic Single-chip Transceiver Using Sub-harmonic Mixer

Yon-Lin Kok, Morteza Ahmadi, Huei Wang, Barry R. Allen and Tzuen Lin

TRW
Space and Electronics Group
One Space Park
Redondo Beach, CA 90278

ABSTRACT

This paper presents development of a Ka-band (38GHz) single-chip transceiver based on GaAs HEMT MMIC technology. The transceiver chip utilizes a sub-harmonic mixer in receiving chain such that LO-to-RF port isolation can be improved by more than 20 dB without sacrificing chip compactness. In addition the dc power consumption can be reduced to about one-half of the conventional transceiver with a direct mixer receiver. To date this single-chip transceiver chip has demonstrated a measured LO-to-RF input port isolation of 62 dB, LO-to-RF transmitter port isolation of 52 dB and a power consumption of 1.0 and 3.4 watt in receive and transmit modes respectively. The receiver noise figure achieves 9 dB across the RF band from 38.0 to 38.6 GHz with an IF of 2.38 GHz under 4 dBm LO drive. The conversion gain was measured to be greater than 17 dB.

INTRODUCTION

During the last decade several efforts have been taken in integrating complex receiver and transmitter functions onto a single MMIC chip with GaAs-based HEMT MMIC technology [1][2]. In a previous paper [2] a successful integration of a 17 chip Ka-band transceiver module into a single-chip transceiver with a compact size of 4.5 by 5 mm^2 was reported. The operation of this Ka-band monolithic transceiver was demonstrated with reasonably good performances on receiver noise figure, conversion gain and transmitter output power [2]. However, the LO-to-RF input port isolation was only 30 dB with an LO-to-RF transmitter port isolation of 35 dB, which is not satifactory for system operation. This paper presents a transceiver design using a sub-harmonic mixer with LO frequency being half of the fundamental frequency in receiver demodulation such that LO-to-RF port isolation can be easily improved by more than 20 dB without sacrificing chip compactness. Furthermore, as a result of turning off all second harmonics amplifiers in the receive mode, this new design reduces the chip over-all power consumption by more than one-half of the conventional direct mixing transceiver [2].

TRANSCEIVER MMIC DESIGN

A block diagram of the transceiver chip is shown in Fig. 1. The receiving input begins with a two-stage, 38 GHz balanced low noise amplifier which is followed by a single-stage single-ended buffer amplifier and an image-reject filter. The sub-harmonic mixer utilizes a single-balanced topology and uses a pair of HEMT gate-diodes as the mixing elements. The IF output of the mixer is extracted through a low-pass filter and is fed into a two-stage single-ended IF amplifier to output the 2.38 GHz IF signal. At the LO input, a single stage 18GHz amplifier will provide enough LO power to be split to drive both the sub-harmonic mixer and the transmitter chain. The transmitter chain starts with an active HEMT frequency doubler which converts the 18GHz LO input to 36 GHz signal band. Next, four stages of single-ended amplifiers are designed to drive the output stage power amplifier. The power amplifier is a balanced two-

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stage design capable of delivering output power greater than 22 dBm. Separate bias inputs are designed for the receiver side, LO amplifier and the transmitter chain respectively. Fig. 2 shows a layout of the monolithic transceiver chip. The chip has a dimension of 4.65x5 mm^2 using 0.15-μm GaAs power HEMT production process.

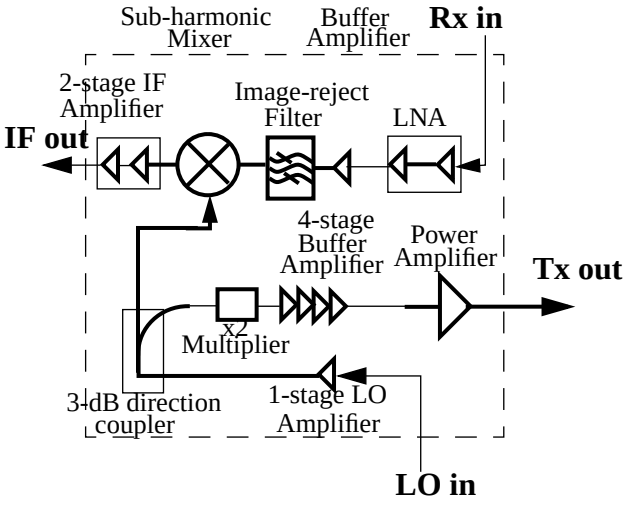

Figure 1 Block diagram of the transceiver MMIC using a subharmonic mixer.

MEASURED PERFORMANCE

Measurements for some key microcells are made and are described as follows. (1) Low noise amplifier: Figure 3 shows the small signal gain/noise figure measurement of the 2-stage balanced low noise amplifier. A 14 dB gain and a 3.5 dB noise figure are achieved. (2) Image reject filter: Figure 4 shows the bandpass filter characteristics of the filter. It provides a 2-dB insertion loss and a greater than 24 dB image rejection. (3) Sub-harmonic mixer: A conversion loss of 15 dB is obtained with a LOx2 (36 GHz) -to-RF isolation of 37 dB (Fig. 5). On-wafer RF testing for the transceiver chip on noise figure, conversion gain and LO-to-RF isolation are performed. Figure 6 plots the measured performance of the chip operating in its receiving mode. It indicates that noise figure less than 9 dB and conversion gain greater than 17 dB have been achieved across the RF band from 38.0 to 38.6 GHz under LO drive of 4 dBm. The LOx2-to-RF receive and transmit port isolations are measured to be greater than 62 and 52 dB respectively, which is about 20 dB improvement over the conventional transceivers using a direct mixer for downconversion. The dc bias currents consumed by the chip with +5 volts applied to the receiver and transmitter bias inputs are nominally 210 mA and 670 mA respectively. The power consumption in receive mode is about 1 watt, only half of that in the conventional direct mixer transceiver.

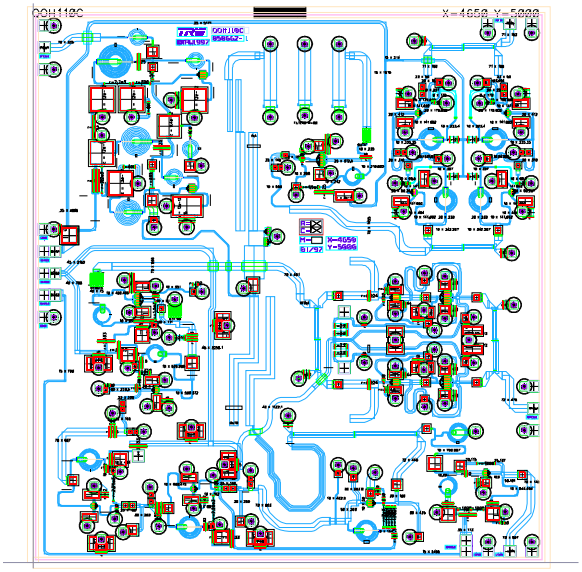

Figure 2 Layout of the sub-harmonic transceiver MMIC.

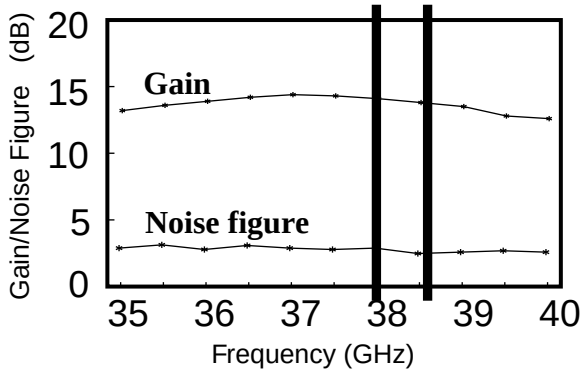

Figure 3 120 GHz sub-harmonic mixer chip layout of the first design corresponding to circuit schematic in Fig. 1.

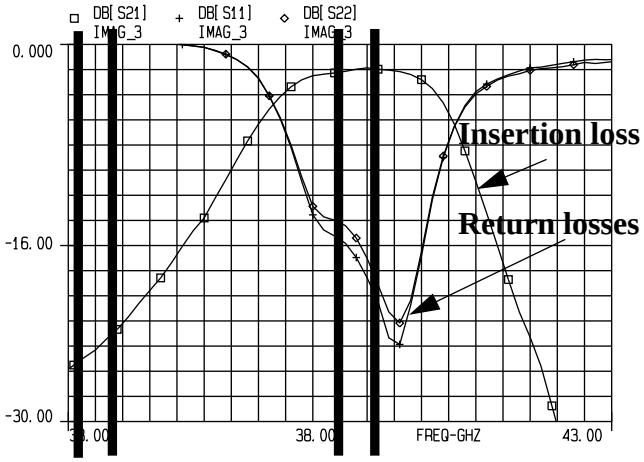

Figure 4 Measurements of the image reject filter indicate that inband (38 - 38.6 GHz) insertion loss is 2 dB and image rejection at 33.5 GHz is about 24 dB

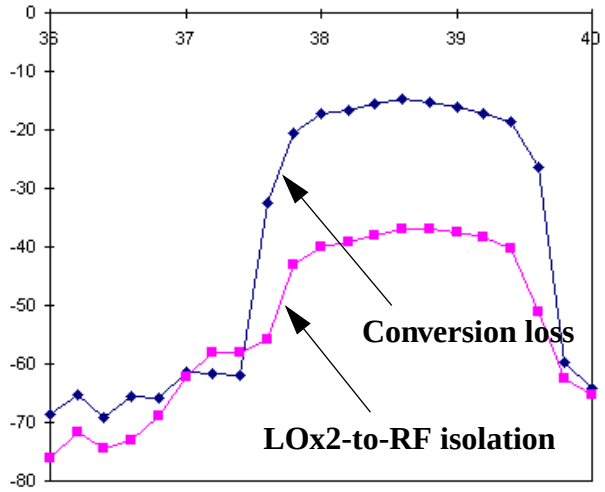

Figure 5 Measurements of the sub-harmonic mixer indicate that inband (38 - 38.6 GHz) conversion loss is about 15 dB and LOx2-to-RF isolation is greater than 37 dB.

CONCLUSION

A Ka-band single-chip transceiver based on GaAs HEMT MMIC-technology utilizing a sub-harmonic mixer is successfully demonstrated. The chip achieves conversion gain and noise figure greater than 17 dB and 9 dB, respectively, across the receiving band of 38.0 - 38.6 GHz. Measured LO-to-RF port isolations are 62 and

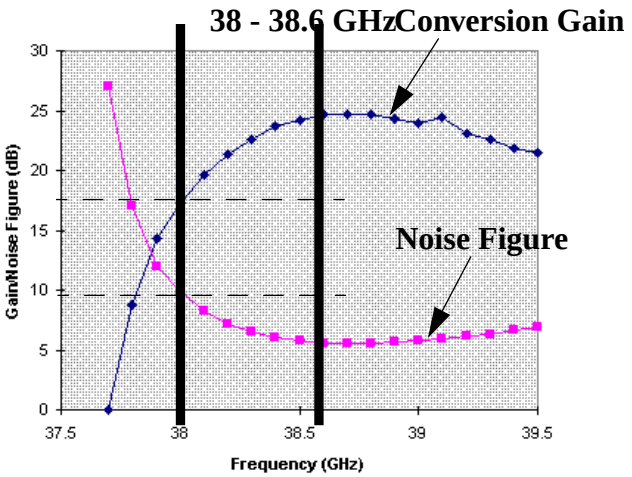

Figure 6 Measured data of the transceiver chip indicate that the noise figure achieves a conversion gain greater than 17 dB and a noise figure less than 9 dB across the RF band from 38 to 38.6 GHz.

52 dB respectively at RF input and transmit output ports. Power consumption at receive mode is dramatically reduced to 1 watt, one-half of that in the conventional direct mixer transceiver.

ACKNOWLEDGEMENT

This work was supported by Department of the Army, Battle field Combat Identification, (Contract No. DAAB07-93-C-K011).

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