A 77GHz MMIC Transceiver Module for Automotive Forward-Looking Radar Sensor

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Abstract

A 77GHz MMIC transceiver module consisting of a power amplifier, a low noise amplifier, a drive amplifier, a frequency doubler and a down-mixer has been developed for automotive forward-looking radar sensor. The MMIC chip set was fabricated using 0.15μm gate-length InGaAs/InAlAs/GaAs mHEMT process based on 4-inch substrate. The power amplifier demonstrated a measured small signal gain of over 20dB from 76~77GHz with 15.5dBm output power. The chip size is 2mm x 2mm. The low noise amplifier achieved a gain of 20dB in a band between 76~77GHz with an output power of 10dBm. The chip size is 2.2mm x 2mm. The driver amplifier exhibited a gain of 23dB over a 76~77 GHz band with an output power of 13dBm. The chip size is 2.1mm x 2mm. The frequency doubler achieved an output power of –6dBm at 76.5GHz with a conversion gain of –16dB for an input power of 10dBm and a 38.25GHz input frequency. The chip size is 1.2mm x 1.2mm. The down-mixer demonstrated a measured conversion gain of over -9dB. The chip size is 1.3mm x 1.9mm. The transceiver module achieved an output power of 10dBm in a band between 76~77GHz with a receiver P1dB of -28dBm. The module size is 8 x 9.5 x 2.4mm^3. This MMIC transceiver module is suitable for the 77GHz automotive radar systems and related applications in W-band.

I. Introduction

The millimeter-wave automotive radar systems are key technology for the future adaptive cruise control systems. With increased awareness and interest in safety issues on vehicular transportation, a variety of obstacle detectors has been researched and developed, among which a forward looking automotive radar has received a special attention as considered to be an essential element to complete a vehicular safety system[1].

This paper describes the successful development of an MMIC transceiver module for automotive radar systems by using 0.15μm gate-length InGaAs/InAlAs/GaAs mHEMT technology on GaAs substrate thinned to 100μm[2][3]. The transceiver module consists of a power amplifier, a low noise amplifier, drive amplifier, a frequency doubler and a down-mixer. Fig. 1 shows a generalized block diagram of the RF front-end of automotive radar system.

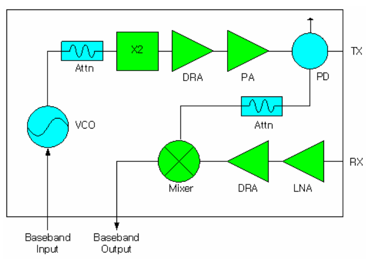

Fig. 1. A generalized block diagram of the RF front-end of automotive radar system.

II. MMIC Chip Set and Transceiver Module

4-stage MMIC PA and DA were designed by using mHEMT devices of 2-finger 100μm (2f100) and 4-finger 200μm (4f200). The circuit simulation was accomplished by the use of the harmonic balance simulator with the HP root model for the active device. The external DC biasing conditions of V_d and V_g were 1.5V and –0.3V, respectively, and the total current consumption of the MMIC PA was 180mA. In the case of DA, the external DC biasing conditions of V_d and V_g were 1.5V and –0.4V, respectively, and the total current consumption was 150mA. The on-wafer measurement was performed using HP PNA N5250A 110GHz network analyzer. The photographs and measurement results of the fabricated MMIC PA and DA are presented in Fig. 2 and Fig. 3, respectively.

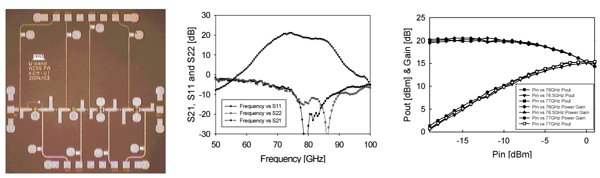

Fig. 2. The Photograph and measurement results of the MMIC power amplifier.

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The PA demonstrated a measured small signal gain of over 20dB from 76-77GHz with 15.5dBm output power. The chip size was 2mm x 2mm. Our PA results demonstrated the highest output power and gain among all the reported 77GHz MMIC PAs for automotive radar systems using 0.15µm GaAs HEMTs. The DA exhibited a gain of 23dB over a 76-77 GHz band with an output power of 13dBm. The chip size was 2.1mm x 2mm.

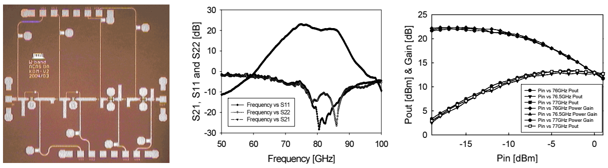

Fig. 3. The Photograph and measurement results of the MMIC drive amplifier.

For the LNA, a 4-stage single-ended architecture using a common-source stage was chosen for the low noise figure and moderate gain with a mHEMT device of 2-finger 100µm gate width. The external DC biasing conditions of V_d and V_g were 1V and –0.5V, respectively, and the total current consumption of the LNA was 60mA. The LNA achieved a gain of 20dB in a band between 76 and 77GHz with a noise figure of 6dB. The chip size was 2.2mm x 2mm. The photograph and measurement results of the LNA are presented in Fig. 4.

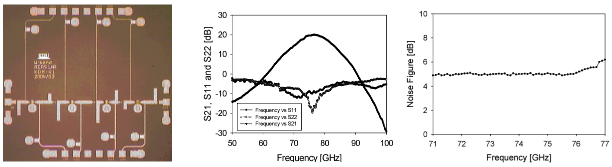

Fig. 4. The Photograph and measurement results of the MMIC low noise amplifier.

The photograph and measurement result of the frequency doubler are presented in Fig. 5. The external DC biasing conditions of V_d and V_g were 1.5 and –0.7V, respectively, and the total current consumption was 8mA. The frequency doubler achieved an output power of –6dBm at 76.5GHz with a conversion gain of –16dB for an input power of 10dBm and a 38.25GHz input frequency. The chip size was 1.2mm x 1.2mm.

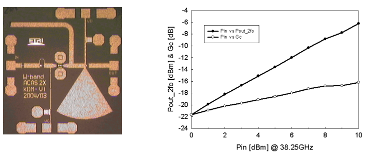

Fig. 5. The Photograph and measurement result of the MMIC frequency doubler.

The down-mixer demonstrated a measured conversion gain of over -9dB. The photograph and measurement result of the down-mixer are presented in Fig. 6. The chip size is 1.3mm x 1.9mm.

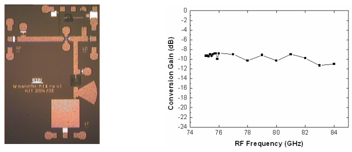

Fig. 6. The Photograph and measurement result of the MMIC down-mixer.

In input and output port of the MMIC module, the WR-10 waveguide is employed because it is suitable for a W-band frequency range. The transceiver module achieved an output power of 10dBm in a band between 76~77GHz with a receiver P1dB of -28dBm. The module size is 8 x 9.5 x 2.4mm^3. The external DC biasing conditions of voltage was 5V and the total current consumption of the module was 1.7A.The photograph and measurement results of the transceiver module are presented in Fig. 7.

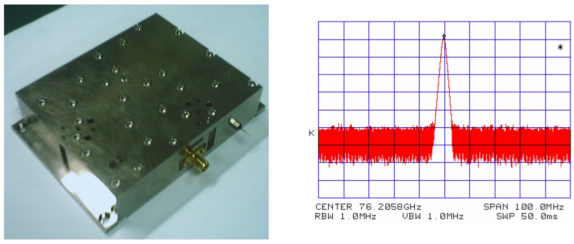

Fig. 7. The Photograph and measurement result of the transceiver module.

III . Conclusion

This paper describes the successful development of an MMIC transceiver module for automotive radar systems by using ETRI's 0.15µm InGaAs/InAlAs/GaAs mHEMT technology on a 4-inch GaAs substrate. The transceiver module consists of a power amplifier, a drive amplifier, a low noise amplifier, a frequency doubler and a down-mixer. This MMIC transceiver module is suitable for 77GHz automotive radar systems and related applications in W-band.

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