26 GHz-Band Full MMIC Transmitters and Receivers Using a Uniplanar Technique

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Abstract

26 GHz-band full MMIC receiver and transmitter package modules have been demonstrated for the first time, using a uniplanar technique. Each module, including a PLL-stabilized local oscillator, is packed into a single package that measures one cubic centimeter. The receiver module consists of seven MMICs, which has an RF-IF conversion gain of 25 dB and a noise figure of 7.5 dB. The transmitter module consists seven MMICs, which has an IF-RF conversion gain of 8 dB and an output power of 5 dBm. A novel uniplanar MMIC power amplifier that is externally connected to the transmitter module has an output power of 20 dBm.

Introduction

MMICs are expected to have a major positive impact on the reduction of cost and size as well as increase the reliability of the microwave equipment used in various fields.

The authors have previously proposed a new MMIC structure, called "uniplanar MMIC", and presented uniplanar MMICs for full MMIC receiver application [1],[2]. Its uniplanar structure employs coplanar waveguides and slotlines as the fundamental transmission lines, instead of the commonly used microstrip-lines. The structure eliminates the need to polish the substrate and make via-holes, which simplifies the manufacturing process and improves chip yield. The testing and selection of satisfactory chips is facilitated because the RF performance of these uniplanar MMICs can be measured on the wafer before dicing. On-wafer testing is one of the most important items for multi-chip modules to achieve high module yields. The features of this uniplanar approach provides reductions in the cost and size of MMIC multichip modules.

Package module configuration

(a) Receiver module

Figure 1 shows the block diagram for the 26 GHz-band single-package receiver module and a photograph of it. This module consists of a PLL-stabilized local oscillator block and a down converter block. The local oscillator block consists of five monolithic chips, i.e., a 6 GHz-band voltage controlled oscillator (VCO), a 6 GHz-band amplifier, a frequency quadrupler, a 25 GHz-band cascode amplifier, and a 1/64 frequency divider and phase/frequency comparator (PFC) IC. The down converter block consists of a 26 GHz-band low noise amplifier and a front-end MMIC which has a 26 GHz-band amplifier, a mixer, and a 1 GHz-band IF amplifier.

The receiver package module, including the 25 GHz local oscillator, converts a 26 GHz input signal to 1 GHz IF signal. This local oscillator frequency can be changed by adjusting the 100 MHz-band reference frequency. The module requires only a reference oscillator and a loop filter as its external components.

The VCO signal is split in two. One supplies to the 6 GHz-band amplifier as a local source, and the other goes to the frequency divider. The PFC checks the frequency difference between the divider-output signal and the reference signal until the local frequency is locked. After the frequency locks, it checks their phase difference until the phase locks.

The front-end MMIC has a conversion gain of 20 dB. Chip size is only 2.0 mm x 2.0 mm. The single-stage low noise amplifier has a noise figure of 4 dB with a gain of 7 dB at 26 GHz.

(b) Transmitter module

Figure 2 shows the block diagram for the 26 GHz-band single-package transmitter module and a photograph of it. This module consists of a

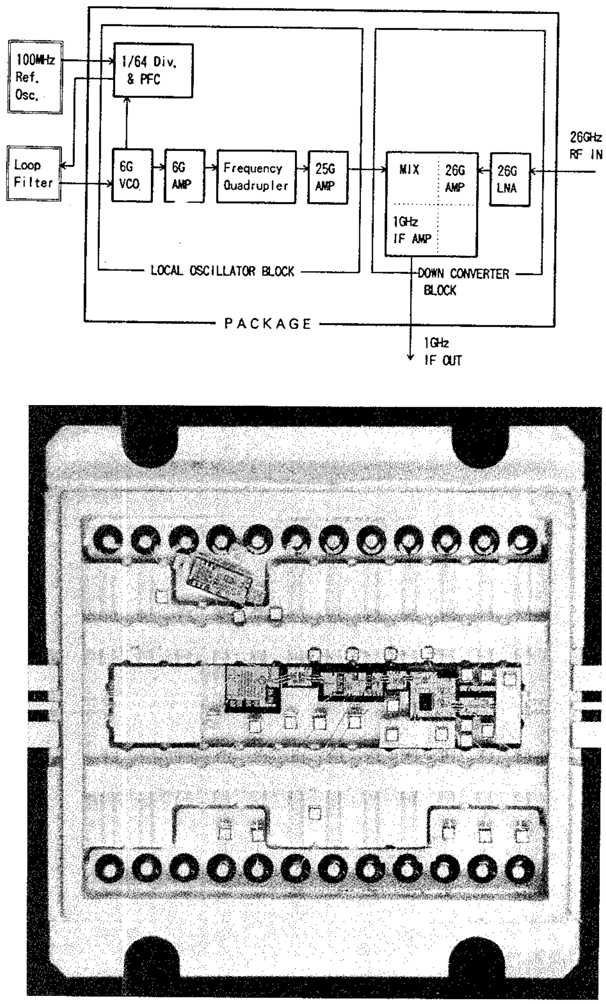

Fig. 1 Block diagram of the 26 GHz full MMIC receiver and a photograph of the receiver package module.

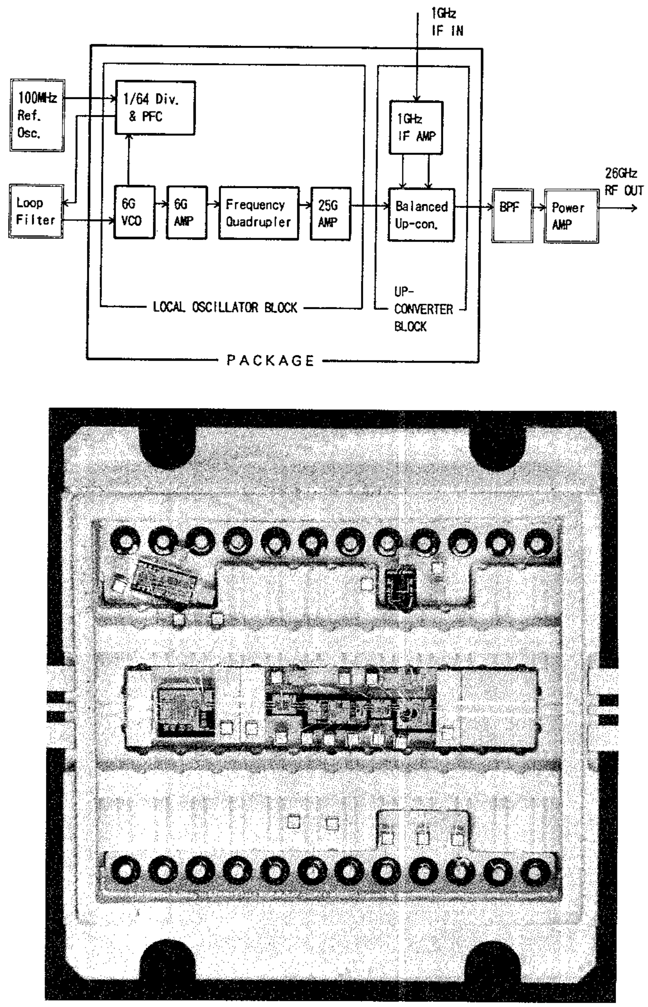

Fig. 2 Block diagram of the 26 GHz full MMIC transmitter and a photograph of the transmitter package module.

PLL-stabilized local oscillator block and an up-converter block. The local oscillator block has the same configuration as that of the receiver module. The up-converter block consists of a balanced up-converter and a 1 GHz-band differential amplifier.

The transmitter package module, including the 25 GHz local oscillator, converts a 1 GHz IF signal to 26 GHz output signal. The module requires a bandpass filter and a power amplifier in addition to a reference oscillator and a loop filter as its external components.

Packaging

A new ceramic package for multi-chip MMIC modules has been developed. The package dimensions are 21 mm x 17 mm x 3 mm, as shown in Figs. 1 and 2. The package is formed by a multi-layer ceramic frame metalized on all sides of the individual layers [3]. It is partitioned into three rooms by a metalized ceramic wall. The center cavity dimensions were designed to remove TE_{101} mode resonances beyond the operating frequency of 26 GHz. The frequency divider and PFC IC, which is a digital IC, was put into another cavity in order to avoid interaction with the analog ICs. Coplanar waveguides and through-wall coplanar waveguides for the RF I/O ports are designed for 50-ohms. The glass feedthrough I/O pins, which are coaxial waveguides buried in the metal base, are used as the IF or DC ports.

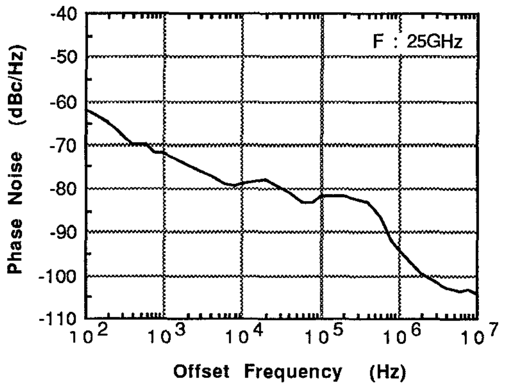

Fig. 3 SSB phase noise of a PLL-stabilized local oscillator block.

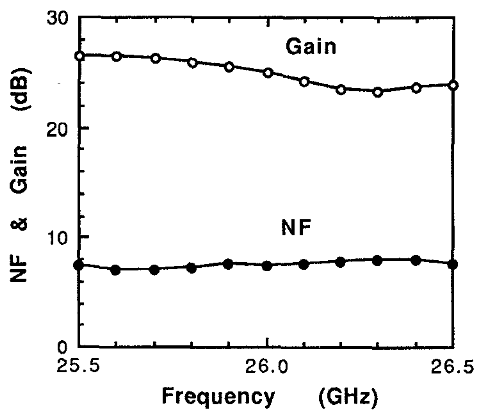

Fig. 4 Gain and Noise figure performance of the receiver package module.

Measured performance

(a) Local oscillator block

Figure 3 shows SSB phase noise of the PLL-stabilized local oscillator block. The output and reference frequencies are 25 GHz and 97.65625 MHz. Phase noise is suppressed up to 300 kHz off-carrier by PLL technique. The phase noise is less than -70 dBc/Hz at 1 kHz offset from the 25 GHz carrier. Output power of the local oscillator block, which can be varied by changing the control voltage of the 25 GHz-band cascode amplifier, was around 10 dBm.

(b) Receiver module

Figure 4 shows the measured noise figure and the gain for the module at 1 GHz-IF. The module has a noise figure of 7.5 dB with a gain of 25 dB in the 26 GHz-band.

(c) Transmitter module

Figure 5 shows 26 GHz of output power versus 1 GHz of input power for the single packaged transmitter module shown in Fig.2. This module has a conversion gain of 8 dB and an output power of 5 dBm, without power amplifiers. Figure 6 shows the output spectrum of the transmitter module. The balanced up-converter configuration provides good local signal suppression of more than 30 dB, as shown in Fig.6.

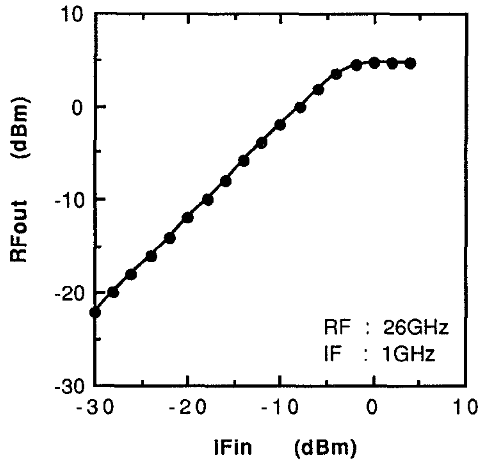

Fig. 5 RF output power versus IF input power of the transmitter package module.

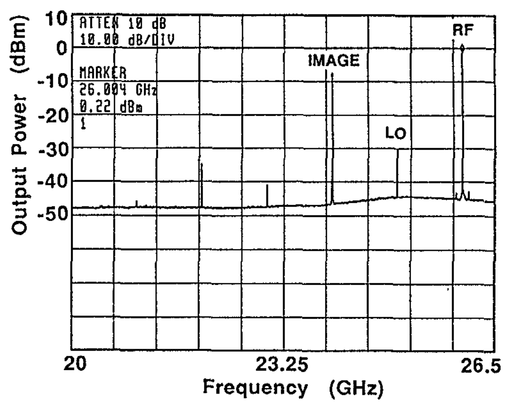

Fig. 6 Output spectrum of the transmitter package module.
[IF = 1 GHz, LO = 25 GHz]

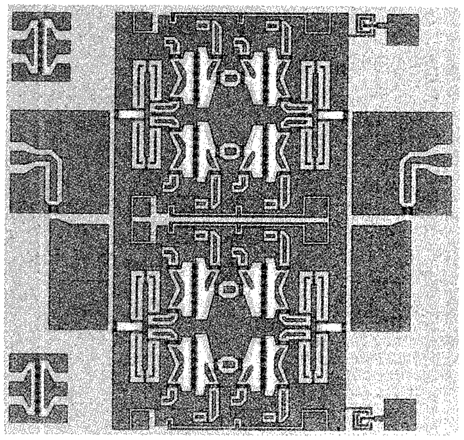

Fig. 7 Photograph of the uniplanar power amplifier. (chip size : 2.5 mm x 2.5 mm)

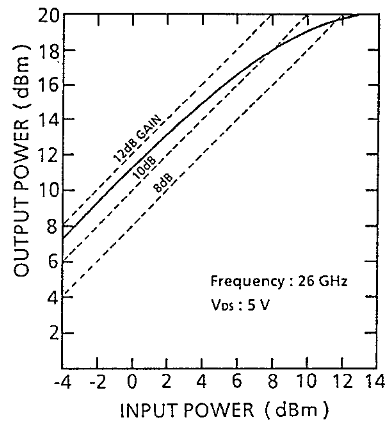

Fig. 8 Output power versus input power of the uniplanar power amplifier.

Uniplanar power amplifier and its measured performance

Figure 7 shows a uniplanar MMIC power amplifier. The amplifier consists of four 50-ohm-interface unit amplifiers and two 4-way power dividers. The 4-way divider employs a series divider (slot line T-junction) and two parallel dividers (coplanar waveguide T-junctions) whose combination realizes a 50-ohm input/output 4-way divider with a very wide frequency range. Since we used 0.3 x 240 μm FETs that were developed for small signal application, a saturated output power of the two-stage unit amplifier was 14 dBm. The uniplanar power amplifier has a saturated output power of 20 dBm and a linear gain of 11 dB as shown in Fig.8. This result shows that the uniplanar 4-way power dividers operate as well as expected.

Conclusions

We have developed 26 GHz-band full MMIC transmitter and receiver package modules for the first time, using a uniplanar technique. Each module, including the PLL-stabilized local oscillator, was packed into a single package measuring one cubic centimeter. Since the RF performance of these uniplanar MMICs can be measured on the wafer before dicing, the selection of satisfactory chips is facilitated. By using this uniplanar technique, an almost perfect module yield can be obtained, in spite of the seven MMIC chip assembly in the transmitter and receiver modules.

The applications that we envision for the uniplanar technique include satellite communications, subscriber radio, mobile communications, optical communications, etc.

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