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ADVANCED MMIC COMPONENTS FOR KA-BAND COMMUNICATIONS SYSTEMS. A SURVEY.

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ABSTRACT

The key MMIC circuit functions for Ka-Band communication systems have been fabricated. Low noise amplifiers, a medium power amplifier, mixers and DRO have been developed using a common 0.25 μm PMHFET technology allowing a future integration of several key components on a single chip. A voltage controlled oscillator has been realized in a GaInP/GaAs HBT technology for improvement of the phase noise performances. Low noise Schottky diode upconverter and downconverter are also available in 0.25 μm MESFET technology with burried n^+ layer.

INTRODUCTION

A number of civil applications such as motion sensors and communications systems are planned to use the Ka-Band frequency range. An MMIC chip set for the realization of the millimeter-wave front-end has been developed. Millimeter-wave MMICs are attractive for new communications systems from the following point of view:

- compactness
- enhancement of links performances
- decrease of the production costs
- increase of the reliability
- easier maintenance.

A principle block diagram of a millimeter-wave front-end for a communications system is shown in figure 1. A variable gain amplifier is forseen in the transmitter chain in order to control the output power depending on the environment conditions.

Most of the MMIC key components have been fabricated using a 0.25 μm PMHFET technology allowing a future integration of several functions on a single chip. A voltage controlled oscillator has been developed in a GaInP/GaAs HBT technology for improvement of the phase noise performances. Additionally low noise MMIC Schottky diode downconverter and upconverter are available in a 0.25 μm MESFET technology with n^+ buried layer.

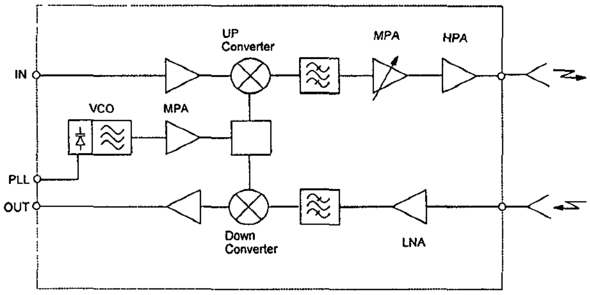

Fig. 1: Principle block diagram of a millimeter-wave front-end for a communications system.

MMIC TECHNOLOGIES

A 0.25 μm PMHFET technology has been established to provide state of the art low noise and power devices and MMICs for the Ka-Band frequency range. For this purpose a singly planar doped single heterojunction structure has been chosen as a compromise between good low noise and good power performances. The typical characteristics of the technology are:

gm_{max} = 600 mS/mm
Ids_{max} = 650 mA/mm
f_T ≥ 90 GHz
f_{max} ≥ 160 GHz
F_{min} = 0.8 dB, Gass = 12 dB at 18 GHz

For low phase noise VCOs a GaInP/GaAs HBT technology has been developed. The HBT device is considered as excellent candidate for active element of low phase noise millimeter-wave oscillator, since it shows low baseband noise compared to MESFET or HEMT devices. The GaInP/GaAs material offers several advantages compared to the conventional AlGaAs/GaAs system with respect to physical properties as well as technological simplification. The main high frequency features of the HBT devices are:

f_T ≥ 50 GHz
f_{max} ≥ 90 GHz

Additionally for the fabrication of low noise mixers a 0.25 μm MESFET technology allowing the integration of Schottky diode and MESFET is available [1]. A deep buried n^+ layer is included under the Schottky diode for reducing the series resistance. The cutoff frequency of the fabricated diodes is greater than 2000 GHz.

MMICs FABRICATED IN 0.25 μm PMHFET TECHNOLOGY

Low noise amplifier

A photo of the fabricated amplifier is shown in figure 2. The stability consideration shows that inductive series feedback is necessary for unconditionally stability of the transistor in the frequency range of operation. Furthermore it is possible to achieve simultaneous noise and input power matching. In order to obtain a broadband circuit with enough gain a three stage amplifier has been chosen. The measurement results presented in figure 3 demonstrate a gain of 18 dB associated with a noise figure of 3 dB in the frequency range 32 GHz-40 GHz.

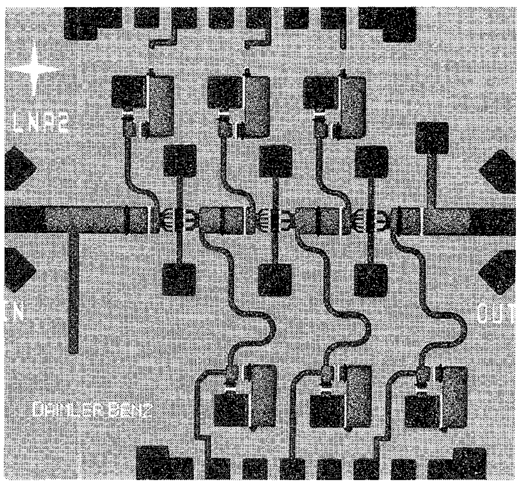

Fig. 2: Photo of the low noise amplifier

Variable gain amplifier

A gain controlled amplifier has been also fabricated by replacing the single gate transistor in the last stage of the previous low noise design by a dual gate transistor. The gain is controlled by the voltage applied to the second gate of the dual gate transistor. A dynamic of more than 25 dB has been obtained. The return losses change only moderately with the gain.

Medium power amplifier

The power amplifier shown in figure 4 is designed as a two stage balanced amplifier. The balanced configuration has been realized by using Lange coupler at the input and output. The measurement results are presented in figure 5. The circuit exhibits an output power of 20 dBm

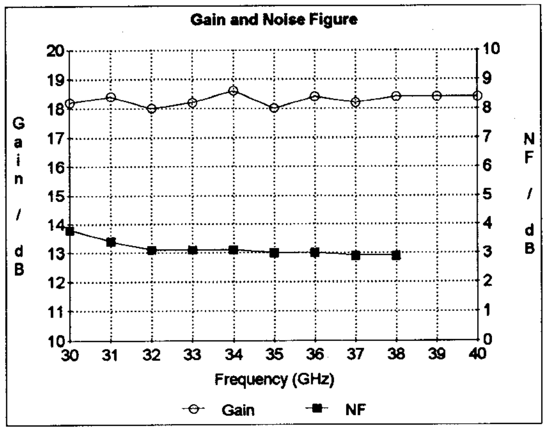

Fig. 3: Measurement results of the low noise amplifier.

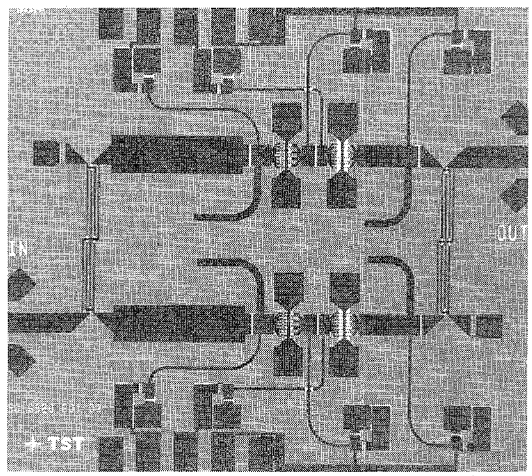

Fig. 4: Photo of the medium power amplifier.

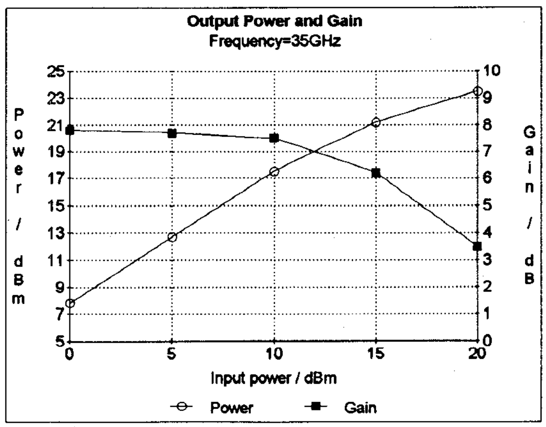

Fig. 5: Measurement results of the medium power amplifier at 35 GHz.

at 1 dB compression and has a flat linear gain of about 8 dB combined with return losses better than 15 dB over the frequency band 26 GHz-40 GHz.

Mixers

Three different mixers have been fabricated. PMHFET Schottky diodes, single gate transistor and dual gate transistor have been used as mixing elements. The circuits have been designed using large signal simlation on a commercial simulator.

The Schottky diode mixer (figure 6) has been realized in a single balanced configuration. The measured conversion loss (figure 7) is better than 8.5 dB in the frequency range 32 GHz-40 GHz with a value of 5.5 dB at 38 GHz.

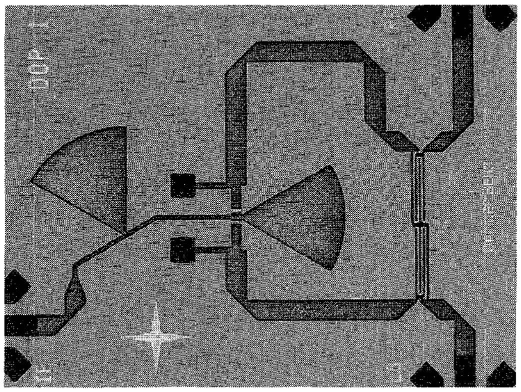

Fig. 6: Photo of the PMHFET Schottky diode mixer.

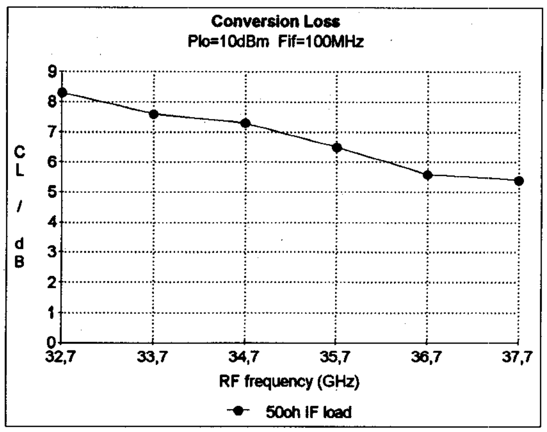

Fig. 7: Measured conversion loss of the PMHFET Schottky diode mixer.

The single gate transistor mixer is a single ended configuration and is developed as a gate mixer. LO and RF signals are fed to the gate via a Lange coupler. It exhibits a conversion gain up to 5 dB in the frequency range 32 GHz to 40 GHz. Detailed results are reported in the session TU3A of this conference.

The dual gate mixer (figure 8) is designed in a single ended configuration. The dual gate transistor is modelled as two single gate transistors in series. The measurement results for two IF impedances are given in figure 9. A conversion gain up to 4 dB in the frequency range 32 GHz to 40 GHz has been achieved.

The developed mixers can only be used in a system in combination with a low noise amplifier because they exhibit a noise figure greater than 10 dB.

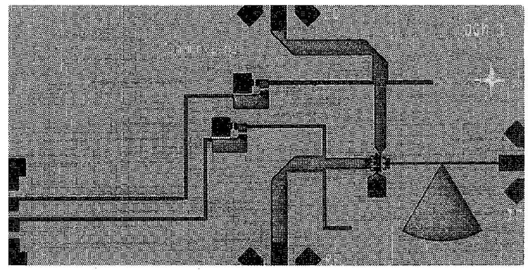

Fig. 8: Photo of the dual gate transistor mixer.

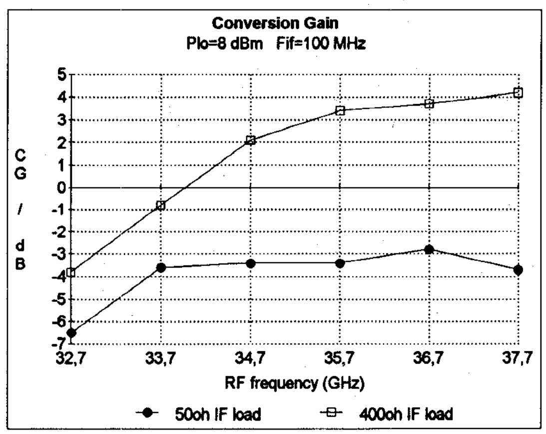

Fig. 9: Measured conversion gain of the dual gate transistor mixer.

Dielectric resonator oscillator (DRO) [2]

To obtain a low phase noise monolithic millimeter wave source, a dielectric stabilization is a well known mean. For the design of the DRO circuit a standard series feedback configuration with the transistor in common source operation is chosen. A fabricated DRO at 36 GHz shows an output power of 11 dBm and a phase noise of -97 dBc/Hz at 100 kHz off carrier. The power deviation is less than -0.02 dB/°C in the 20°C to 80°C temperature range, the corresponding frequency stability is better than -60 kHz/°C.

MMICs FABRICATED IN GaInP/GaAs HBT TECHNOLOGY

Voltage controlled oscillator [3]

A chip photo is shown in figure 10. A series feedback topology with the HBT in commmon emitter configuration is chosen because of its superiour frequency stability, which is due to the high isolation between the frequency determining elements and the oscillator output. The varactor diode is placed between transistor base and ground. As active device an HBT with an emitter area of 2 x 1.5μm x 10μm is used.

The fabricated oscillators show tuning ranges of about 1 GHz at center frequencies of 35 GHz, 37 GHz and 40 GHz. Typical output power levels are between 1 dBm and 3.5 dBm. The dependence of the oscillator phase noise on transistor base current has been demonstrated. Lowest phase noise of -80 dBc/Hz is observed at a base current of 2.3 mA. Maximum output power of 3 dBm is obtained at 2.7 mA.

A phase noise improvement of 5 dB has been achieved compared to a MESFET oscillator.

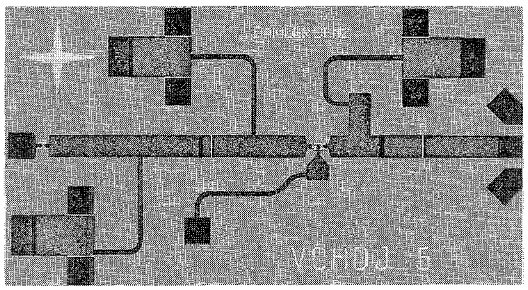

Fig. 10: Photo of the HBT VCO.

MMICs FABRICATED IN A 0.25 μm MESFET TECHNOLOGY WITH N$^+$ BURRIED LAYER

Downconverter and upconverter using Schottky diodes

An accurate large signal equivalent circuit of the diodes has been developed. A single balanced configuration comprising a pair of Schottky diodes, a Lange coupler and matching networks has been used in the design of the down- and up-converters. Large signal simulations have been performed on a commercial simulator. Both circuits operate in self bias configuration.

The downconverter exhibits a conversion loss below 7 dB associated with a single side band noise figure lower than 6.5 dB in the frequency range 30 GHz - 40 GHz. These performances are obtained for a local oscillator power up 3 dBm. Figure 11 shows a measurement example at 36.3 GHz with 4.2 GHz IF frequency. A single side band noise figure of about 5 dB is achieved.

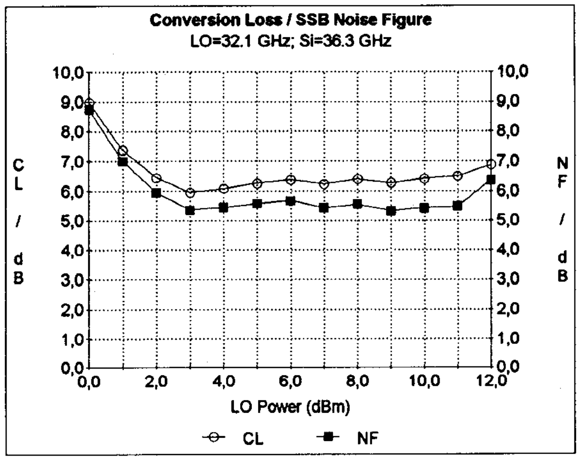

Fig. 11: Conversion loss and single side band noise figure of the low noise downconverter.

The upconverter shows a conversion loss of 8 dB with a signal power of 10 dBm and a local oscillator power of 10 dBm in the frequency range 30 GHz to 40 GHz.

CONCLUSION

Technologies are available for the development of low cost and high volume production of communications systems in the Ka-Band frequency range. In this paper we present the results obtained on the fabricated MMIC key functions. A receiver demonstrator composed of 2 low noise amplifiers, a Schottky diode mixer and a buffer amplifier fabricated in the 0.25 μm PMHFET technology, has been integrated in a packaging with K connectors. A conversion gain of 24 dB associated with a double side band noise figure below 4 dB has been measured at 38 GHz. These results demonstrate the excellent capabilities of the available technologies for the development of Ka-Band communications systems.

ACKNOWLEDGEMENTS

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