Broadband High Efficient X-band MMIC Power Amplifiers for Future Radar Systems

A.P. de Hek, F.L.M. van den Bogaart

TNO Physics and Electronics Laboratory , P.O. Box 96864, 2509 JG The Hague, The Netherlands

Abstract

The results of a power amplifier chip set for future radar systems are discussed. Excellent broadband frequency behaviour is shown. A driver amplifier with 50% band width and an output power of more than 1.3 Watt is discussed. A high power amplifier with 30% bandwidth, 5 Watt output power and a Power Added Efficiency of more than 30% is demonstrated. The driver amplifier results demonstrate the capabilities of the pseudomorphic HEMT technology for the development of broadband single chip power amplifiers for future radar systems.

Introduction

Active phased array antenna's form the basis of future advanced radar systems. These phased array antenna's may contain several thousand Transmit Receive (TR) modules. To make such systems economically realisable integration of the TR modules is necessary. This can be realised by reducing the number of MMICs used in a TR module. A picture of a typical future TR module is shown in figure 1.

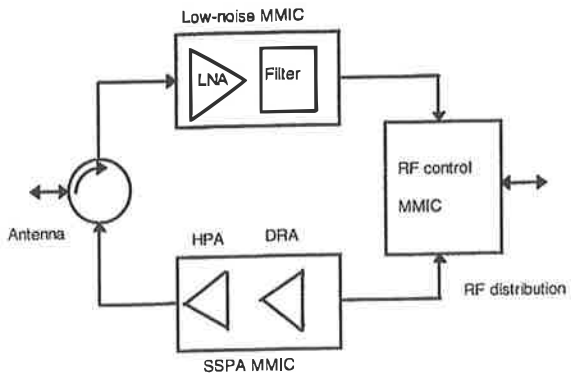

Figure 1: Typical architecture of future TR modules

Developments performed by TNO regarding the Low Noise Amplifier with filter and the RF control MMIC are discussed in [1].

The by TNO developed high efficient broadband power amplifier chip set is discussed in the next sections. The chip set consists of one Driver Amplifier and one High Power Amplifier. These amplifiers have been developed in the scope of the WEAG/TA1/CTP8.1 programme.

This programme was carried out by a consortium consisting of Siemens, Dassault Electrotechnique, Fraunhofer-IAF and TNO-FEL.

Driver Amplifier

The driver amplifier is developed in the pseudomorphic HEMT (PHEMT) process of IAF. This process consists of 0.3 µm HEMTs, E-beam gate technology, MIM capacitors and airbridges. The viaholes and backside processing of the presented amplifier are performed by Siemens.

The goal of the amplifier depicted in figure 2 was to demonstrate that it is possible to develop broadband power amplifiers at X-band with high gain (≈ 30 dB) at a small chip size.

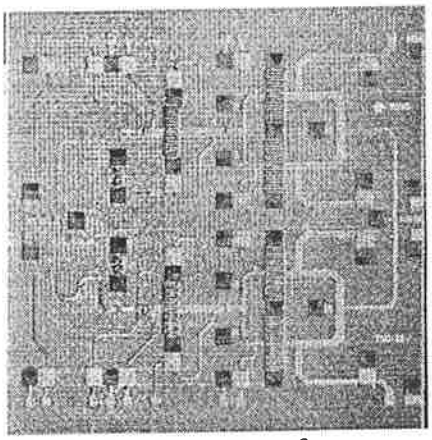

Figure 2: Driver Amplifier,chip size 14.4 mm²

The advantage of the used PHEMT technology over MESFET technology is the increased gain at X-band of the output amplifier stage 12 dB compared to 7 dB. This increased gain makes the realisation of small size power amplifiers possible.

The measurement results of the driver amplifier are depicted in figure 3. The measurement results show that an amplifier has been developed with an output power of more than 1.3 W and 28 dB gain. These results have been obtained between 8 - 13.2 GHz. This shows the potential of the used PHEMT technology for the development of small sized broadband High Power Amplifiers.

At this moment TNO is developing a broadband single chip power amplifier consisting of both driver and High Power Amplifier. With an enhanced version of the PHEMT technology of IAF that has an output power of 1 W/mm FET size.

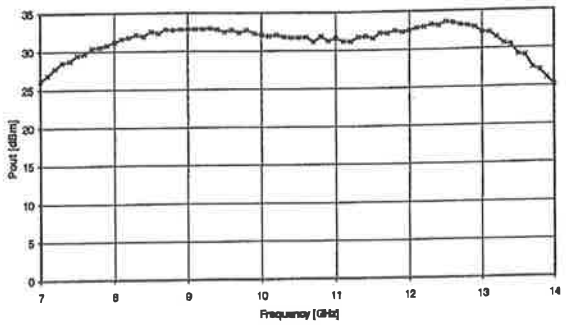

Figure 3: CW measurement result Driver Amplifier (Ps=3 dBm)

High Power Amplifier

A 5-Watt High Power Amplifier is developed in the Siemens DIOM20HP process (Refs [1] and [2]). This process consists of 0.5 µm MESFETs, a self aligned gate technology, localised ion implementation, MIM capacitors, via holes and airbridges. This technology offers high performance, high reliability and good reproducibility at low costs.

A photograph of the realised High Power Amplifier is shown in figure 4. The measured large-signal measurement results are depicted in figure 5.

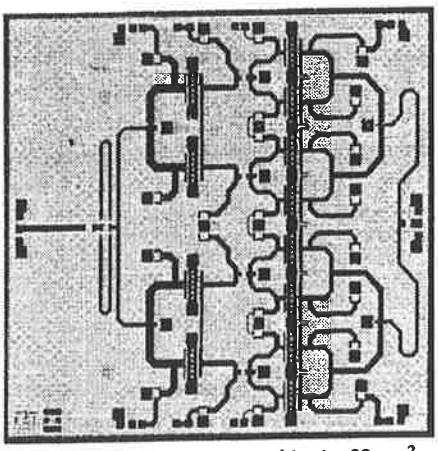

Figure 4: 5-Watt High Power Amplifier, chip size 22 mm²

The measurement results show that an excellent performance has been obtained. The pulsed output power is more than 5-Watt over a 30% bandwidth. The Power Added Efficiency is more than 30% over a 30% bandwidth. At 8.8 GHz a peak output power of 7-Watt and a Power Added Efficiency of 40% has been measured.

MESFETs with a reduced drain-source spacing, but well within the maximum tolerable temperature limits, are used to reduce amplifier size. The output matching of the transistors is based on measured load-pull data. The load-pull data is obtained with an in-house developed unique high-power on-wafer active load-pull system that is capable of providing load impedances with reflection coefficients up to 1.

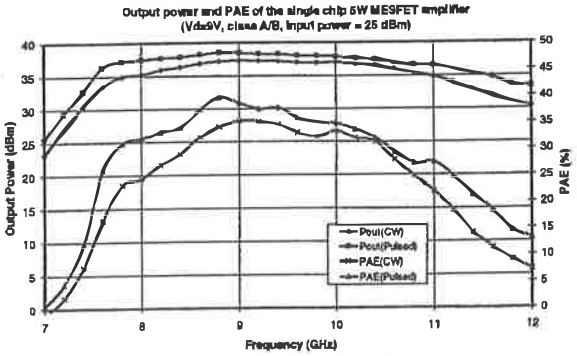

Figure 5: Measurement results 5-Watt High Power Amplifier

Multiple-order input, interstage and output matching networks are used in order to obtain the required bandwidth. Careful attention is paid to make the amplifiers stable. Stability analysis is carried out for all odd and even modes using open-loop transfer function techniques. Amplifier design is carried out with HP-EEsof software using the EEFET3 transistor models. Parameter extraction for this model is optimised to obtain a good agreement over the required bandwidth between model predictions and measured transistor performance under high power conditions and under optimum load conditions. Parameter extraction is carried out on transistors with exactly the same size as those used in the high power amplifier. A typical exemple is shown in fugure 6.

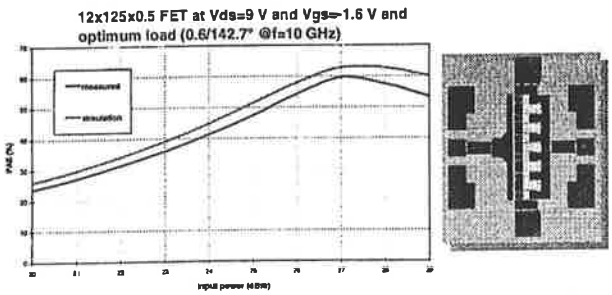

Figure 6: Agreement between modelled and measured PAE of the transistor shown on the right side.

Conclusions

The driver amplifier developed in the PHEMT process of IAF has a frequency bandwidth of more than 50%, an output power of more than 1.3 Watt and a gain of more than 28 dB. The in the Siemens DIOM20HP process developed High Power Amplifier shows and excellent output power of more than 5-Watt over a frequency band of 30% at X-band. The power Added efficiency is more than 30% over this frequency band.

References

1. F.L.M. van de Bogaart, "*Application Specific MMICs for Advanced Active Phased-Array Antenna's*", Cost 245 Proceedings, pp. 289 - 294, June 1996.
2. F.L.M. van de Bogaart, A.P. de Hek, A. De Boer,"*MESFET High-Power High-Efficiency Amplifiers at X-band with 30% bandwidth*", GAAS96 Symposium proceedings, June 1996.

Frank E. van Vliet

Eindhoven University of Technology

COBRA
Interuniversity Research Institute
Communication Technology: Basic Research and Applications

**** WOCSDICE 97 ****

21st Workshop on Compound Semiconductor Devices and Integrated Circuits

May 25-28, 1997
Scheveningen, The Netherlands

Sponsored by:

EOARD
ERO
ONR
Aixtron
JEOL
A. De Jong B.V.
Oxford Instruments GmbH
III-V's Review
TNO-FEL
IOP Electro-Optics