MMIC TECHNOLOGY IN EUROPE FOR MILLIMETERWAVE APPLICATIONS

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ABSTRACT

Presently several european companies are developing GaAs based components for millimeterwave applications. State of the art for Europe today is that HEMT devices are available with f_{max} up to 280GHz, MMIC Schottky mixer/receiver circuits up to 94GHz, 60GHz low noise amplifiers with 10 to 12 dB gain and around 5dB noise figure are demonstrated as well as first MMIC oscillators up to 80GHz.This paper reviews the european technology programmes for the development of III-V based mm-wave components and describes the state of the art.

Keywords: MM-wave, MMICs, GaAs, FETs, HEMTs, PMHFETs

INTRODUCTION

Based on existing developments for advanced military projects the millimeterwave technology in Europe is presently being pushed by strong demands for civil sensor systems such as needed for traffic applications. In parallel this technology is becoming available for new communication systems with specific properties. Extremely broad communication channels become available and systems are being developed for links between fixed as well as mobile partners.

To become economically viable MMIC based components have to be developed and made available to system designers. Key elements for the frequency range between 20GHz and 100GHz presently are FETs and Schottky diodes in combination with a broad variety of passive elements. As lumped elements are very difficult to design for this frequency range, mainly waveguide elements are used for circuit designs. In several precompetitive ESPRIT projects, in some transnational military programmes and in several national programmes the development of technology, devices, circuits and some demonstrator systems is supported. In the following sections some of the programmes and published results are described.

MMIC TECHNOLOGY IN EUROPE

Presently seven major european companies have to be named as the partners for GaAs MMIC technology in Europe. They are:

- Alcatel-Teletttra
- Alenia
- Daimler Benz
- GEC - Marconi
- Philips Microwave
- Siemens
- Thomson Compossants Microondes

Beside the industrial partners the german Fraunhofer-Institut (IAF) and the belgian IMEC have to be mentioned as non industrial facilities being capable of fabricating GaAs MMICs. Several other research institutes especially at the universities are contributing to the development of advanced technologies and devices.

Nearly all industrial parties are presently developing or already offering devices also for application in the mm-wave range. Major MMIC programmes for mm-wave programmes are known from Daimler Benz (Telefunken) and from Thomson while first demonstrators are reported from Philips Microwave and from GEC. For the non industrial parties only first demonstrator MMICs by the IAF are known.

CONTRIBUTIONS BY ESPRIT PROJECTS

In the frame of at least four ESPRIT projects the challenging reqirements of mm-wave MMICs are presently addressed. Nearly all of them are very much driven by specific applications and end at least with the availability of MMICs. In some projects even demonstrator systems become available.

In the **GIANTS** project the technology based on InGaAs-channel FETs is developed. Based on that technology a 20GHz low noise amplifier is fabricated by Thomson with a minimum noise figure of less than 3dB and a gain of more than 15dB.

A complete set of MMICs for applications in the 20GHz to 35GHz region is presently developed in the **AIMS** project by Daimler Benz and by Thomson. For a short hop communication link at 28GHz the entire transmitter and receiver chain will be developed as MMICs. These circuits are fabricated using MESFET and HEMT technology as well. A MESFET VCO at 29GHz is available as well as MESFET T/R switches and and a 28GHz HFET LNA. Fig.1 shows the layout of a 28GHz SPDT switch. In Fig.2 the performance of the low noise PMHFETs is demonstrated. The power amplifier for the transmitter is presently under development. Here two competing concepts are investigated: A HFET power MMIC using the pseudomorphic InGaAs/GaAs matrial seems to be the most promising candidate at the present time while for future applications an amplifier using the fairly new heterobipolar transistor technology might be even better especially in terms of efficiency. The power amplifer is targeted to deliver 500mW output power. The mixer circuit is based on dual gate HEMT technology.
A second system for a 35GHz airport surveillance radar frontend is under developement using identical technology: The HBT technology is used for the VCO MMIC while all amplifiers and the mixer MMIC are based on the PMHFET.

A similar set of MMICs is developed for a 20GHz/30GHz VSAT ground terminal by Thomson. Here especially a 28GHz synthesizer has to be mentioned, using VCO and analogue frequency divider MMICs. This part of the system is already available with excellent phase noise margins of better than -120dBc at 100KHz offset in the locked mode. Using a double side doped PMHFET presently the 30GHz power amplifier is being developed. Fig.3 shows the principal structure of this material system while power measurements are given in Fig.4. The final PMHFET-MMIC amplifier is intended to deliver an output power of 1W at 30GHz.

The freqency of operation is further increased in the demonstrator circuit of the project **MONOFAST**. This consortium around the organizer Glasgow University is building a MMIC for operation at 44GHz. This demonstrator is essentially intended to demonstrate the integration of advanced technologies and design tools to try to increase the yield.

A new project called **CLASSIC** is started in 1992 focussing on the development of nonlinear elements for sensor and communication systems in the 60GHz range. Based on single and dual gate PMHFETs power amplifiers, converters, and oscillator circuits are developed as MMICs by Thomson and by Daimler Benz. This work will be supported by specific modelling and simulation efforts. Also included is an attempt to assess the possible advantages of coplanar waveguide technology in comparison to the conventional microstrip line layout.

RESULTS FROM MILITARY PROGRAMMES

As mentioned in the introduction GaAs millimeterwave technology was originaly developed in the frame of military programmes for sensor applications and for specific communication systems. The frequencies are essentially given by the absorption in the air. So systems were developed for the 35GHz and the 94GHz window and for the 60GHz absorption peak. For the fabrication of low loss and low noise receiver circuits at 35GHz, 60GHz, and 94GHz a sophisticated GaAs technology was developed by Telefunken electronic and Telefunken Systemtechnik enabling the integration of Schottky diodes with MESFETs. Excellent mixer diodes were demonstrated with cut off frequencies in excess of 3THz !. Using these diodes mixer MMICs (here:M^3ICs) were produced exhibiting a conversion loss of 6dB with a noise figure (DSB) of 4dB for the 94GHz version. Integrated IF-amplifiers demonstrated a gain of > 18dB with a noise figure of < 1.7db at an IF-frequency of o.5-2GHz. A photo of a receiver chip is show in Fig.5. This type includes a Lange-coupler for 94GHz operation. In the frame of the same work a cooperation with the partner SEL led to the development of a family of MESFET oscillator MMICs around 30GHz. A frequency doubler MMIC based on diodes provided the oscillator signal for the 60GHz. A chip photograph of the doubler MMIC is shown in Fig.6. In parallel a technology for providing low noise mm-wave amplifiers was developed by Thomson. One of the most notable results was a 60GHz HEMT LNA MMIC with more than 10dB of gain.

NATIONAL EFFORTS

In Germany and in France national activities were started aiming at the development of GaAs mm-wave MMIC know-how. These activities are generally a small part of a major effort to develop the GaAs technology for IT purposes. In Germany in a first programme (1986 to 1990) beside the development of HEMT technology first MMICs for applications in the mm-wave regime were developed based on HEMTs as well as on MESFETs. Telefunken electronic developed a MESFET oscillator chip, a buffer amplifier and a mixer MMIC forming the key elements of a radar speed sensor at 24GHz for use in cars. Using the at that time new HEMT technology a set of MMICs was developed at the IAF in Freiburg and at Daimler Benz in Ulm. Both teams developed 60GHz LNAs resulting in 10db to 12dB gain and a noise figure around 5dB. While the Daimler LNA was designed using microstrip lines the IAF design (cooperation IAF and ANT) used coplanar waveguide structures avoiding the use of via holes.

In a second phase of the german programme (1991 - 1995) the technology for the HEMT MMICs is extended towards 80GHz applications. In this programme Siemens is also extending their work towards mm-wave MMIC.

In France the second industrial partner beside Thomson is Philips Microwave (PML). While they mainly concentrate on the lower microwave region they recently entered the millimeterwave arena with first PMHFET MMICs which were developed in cooperation with the university of Lille, CHS. A 52-60GHz image rejection mixer MMIC, a 80GHz oscillator MMIC, and a 61-64GHz amplifier MMIC were shown.

FOUNDRY SERVICE FOR MILLIMETERWAVE MMICs

Presently Daimler Benz, GEC-Marconi, Philips and Thomson are offering GaAs foundry service. Siemens is not offering a foundy service but their production process, which in effect is similar. On the 1991 European Microwave Conference Daimler Benz annouced its 0.25um HEMT process to be available also to foundry customers. The same process but with PMHFETs is available on request. The situation seems to be similar for Thomson as announced recently.

While GEC-Marconi and Siemens both offer discrete 0.25um HEMTs on the market only GEC seems to make this available in their foundry in 1992. First samples are said to be already shipped to selected customers. This action is intend to extend to foundry service to a F40 and perhaps a F60 process.

The PML foundry announced the availability of a first 0.5um PMHFET foundry process for mid 1992. The 0.25um PMHFET process is intended to be available by the end of 1993. Today development on colaborative basis is already provided.

SUMMARY

The european GaAs MMICs world shows only fairly small markets in the civil area to be already open. On the other hand several very interesting applications are presently emerging giving the chance for real large volume markets. The GaAs based mm-wave technology in Europe is in fairly good shape. Best european developments are able to compete with the american technology leaders. While the MMIC technology could be mastered as shown for several application, the question remains concerning the economical survival of all present competitors.

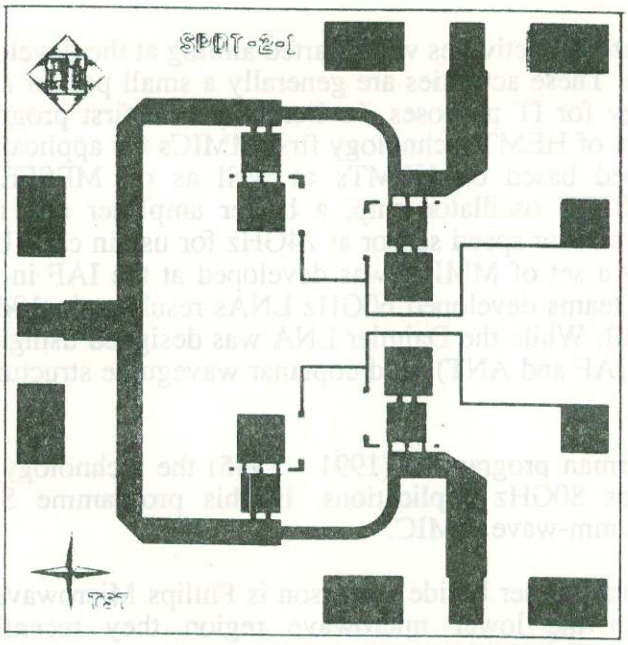


Fig.1: Layout of a 28GHz MESFET SPDT switch (Daimler Benz)

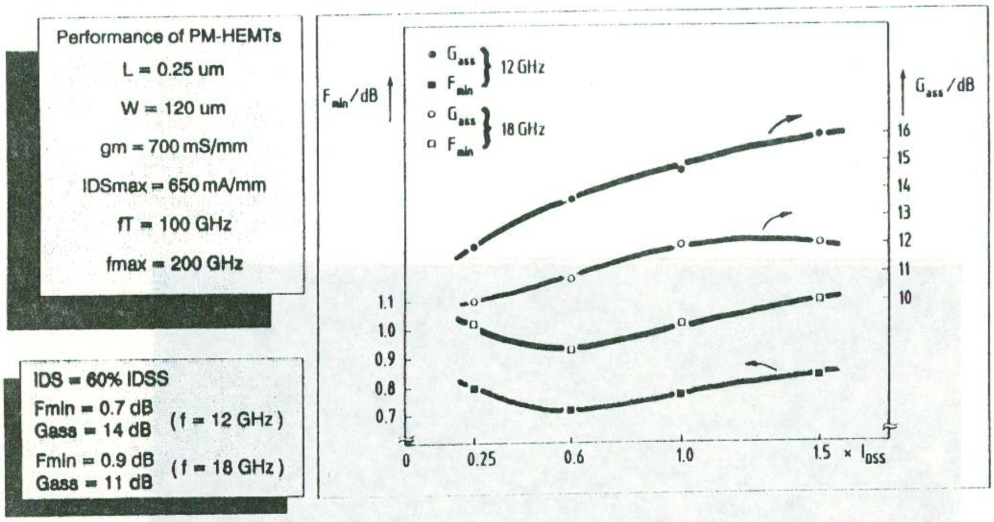


Fig.2: Performance of low noise PM-HEMTs (Daimler Benz)

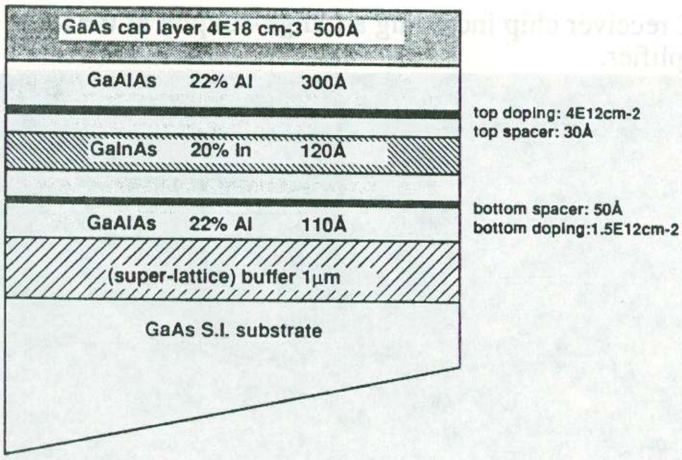
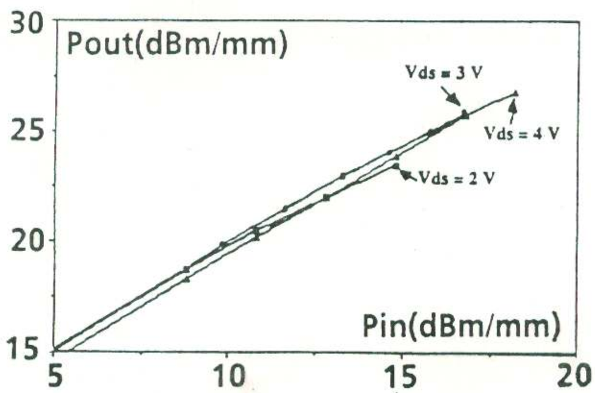


Fig.3: Double-Hetero PMHEMT structure with doping at both side of the channel. Structure designed for power application.
(Thomson)



Vds (V)	Vgs (V)	Ids (mA/mm)	Pout (mW/mm)	Gain (dB)	Dr. Eff. (%)	P.A.E. (%)
2	0	350	200	8.9	28.6	25
3	0	420	380	9.5	30.2	28
4	0	460	480	9.1	26.0	23

Fig.4: 30GHz gain compression curves and power added efficiency measured at CHS on Thomson DH-PM-HEMTs.
Gate: $2x0.18x50um^2$

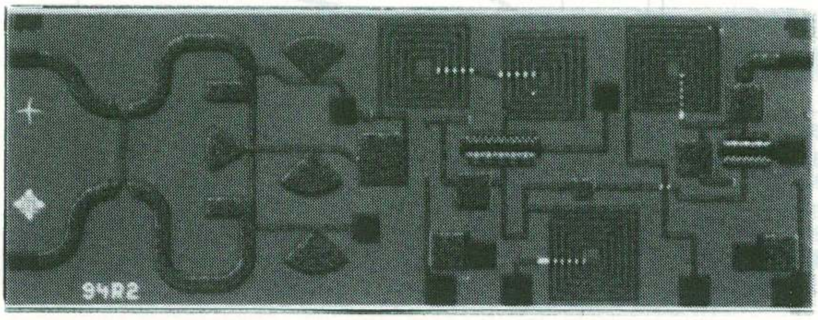


Fig.5: Photo of 94GHz M3IC receiver chip including a Lange-coupler at the input and incorporating an IF amplifier.

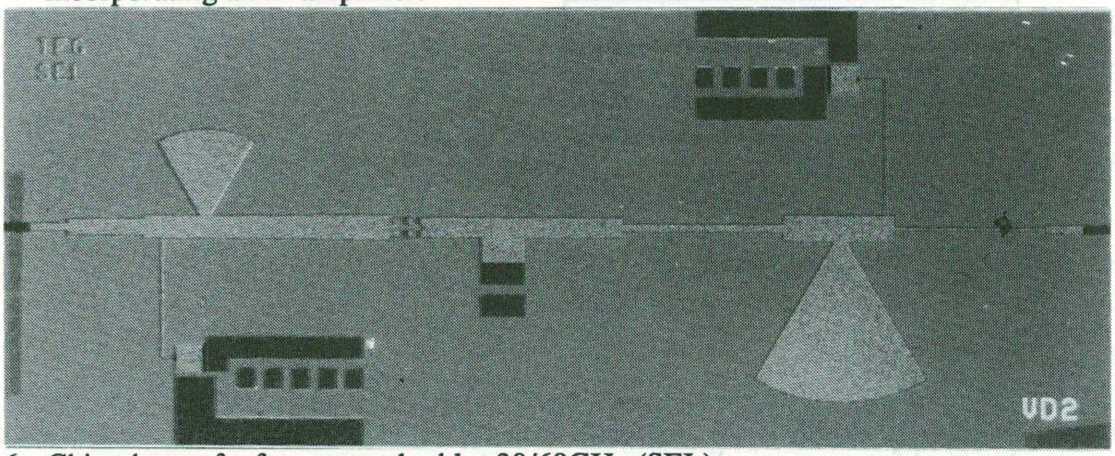


Fig.6 Chip photo of a frequency doubler 30/60GHz (SEL)

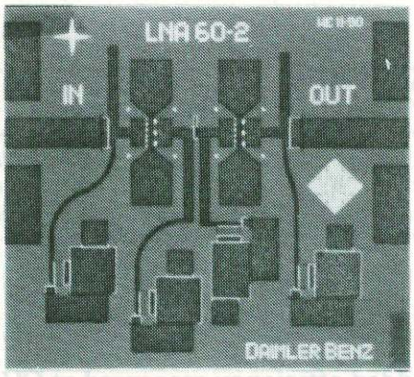


Fig.7: Photo of 60GHz LNA chip (Daimler)