Technical and Commercial Aspects of GaAs MMICs for Enhanced Mobile Communication.

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1. Introduction

The mobile communication market is the current driving force of the European telecommunication industry with remarkable growth rates. In March 1990 about 2.5 million mobile communication systems have found application in Europe with a forecast of more than 90 million DECT-GSM-PCN systems up to the year 2000.

This situation is of great benefit for the semiconductor industry in general and the GaAs components suppliers especially. The reason is that GaAs components maintain their sophisticated performance - low NF and high PAE - under the stringent low power consumption conditions of a handheld. Moreover, the established low-loss GaAs MMIC technology allows in the meantime the production of small SMDs at a reasonable price.
In the following, we describe a complete set of GaAs and Silicon devices suitable for the new digital communication systems.

2. System Description

The second generation of mobile communication services is characterized by the change from analog to new digital transmission techniques. The main digital systems to be considered worldwide are summarized in Table 1.
The new system standard is fixed by the GSM (Group Special Mobile) telephone system. GSM is a full featured telephone network which allows communication (receiving and calling) with automatic allocation of all users. The system can be accessed with various types of user equipment: from lightweight microportables up to high power mobile transceivers. The system will automatically transfer users from one base station to another if the car is moving between zones. GSM is a cellular system for mobile and handheld communication. It will be the first mobile communication standard to be introduced all over Europe. A first version at 900 MHz is being introduced and will be followed by a second generation at 1800 MHz in 1994 developed to increase the number of channels from 992 to 2992. This latter system is called PCN (Personal Communication Network) or DCS 1800. The expected user range is 1-8 km compared to about 35 km for the 900 MHz GSM. DECT (Digital European Cordless Telephone) is the digital counterpart of the CT1-CT2 analog telephone working at 900 MHz. In addition, DECT can be used as private wireless PABX. This system will improve todays paging systems to full intercompany telephone networks. Operating frequency is about 1.9 GHz and typical user range is up to 250 m.

System	Description	Frequencies	Max. Power
GSM	Cellular European net with int.roaming	890-915 MHz 935-960 MHz 200 kHz	20 W
DCS 1800 (PCN)	Cellular European net with int.roaming	1710-1785 MHz 1805-1880 MHz 200 kHz	1 W
ADC (D-AMPS)	Cellular radio (North America)	824-850 MHz 869-895 MHz 30 kHz	6 W
JDC	Cellular radio (Japan)	940-960 MHz 810-830 MHz 25/50 kHz	?
CT2	European cordless phone and telepoint system	864-868 MHz 864-868 MHz 100 kHz	10 mW
DECT	European cordless telephone	1880.92-1898.208 1880.928-1898.208 1.728 MHz	250 mW (450 mW)

Table 1: Mobile communication system

3. General Components Concept

Fig. 1 shows a schematic block diagram of a complete receiver - transmitter unit which consists of an RF part, a signal processor, a multifunction interface, a microprocessor, and a frequency synthesiser. Those areas where GaAs components can be used have been identified. The RF part with the receiver components preamplifier and mixer, and transmitter branch with the power amplifier chain, should be fabricated in GaAs technology.

The specifications of the systems are such, that many features are best fulfilled by GaAs components giving the following benefits: low current consumption, low battery voltage requirement, high linearity, low noise figure (receiver), high power added efficiency, PAE, (transmitter). Fig. 2 a, b shows a performance comparision of the most prominent parameters, NF and PAE, for GaAs and Si Bipolar transistors. Si technology is highly competing with GaAs in terms of price and maturity but especially at 1.8 GHz operation frequency clear performance advantages with comparable price levels can be expected from GaAs devices. This is not obvious for the VCO and T/R switch where the Si bipolar transistor and diode technology is still dominant. Todays enhanced Siemens Si Bip transistors show a transit frequency of 25 GHz, a typical NF of about 1.3 dB and associated gain of more than 20dB at 2 GHz (see Fig. 3).

In any case todays state-of-the-art RF components (discretes and MMICs) in GaAs and Si have to demonstrate 3V-low current capability, high performance up to 2.5 GHz, surface mount packaging and attractive large-volume prices.
A product line-up suitable for 900 MHz up to 2.5 GHz is shown in Fig. 4. Based on this component set, which represents a mixture of GaAs and Si parts, the current and future component strategy will be discussed in the following.

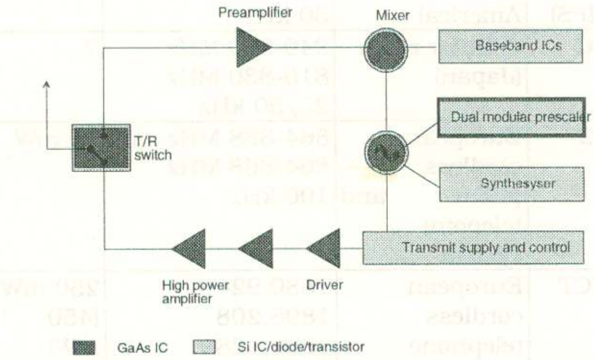

Fig. 1: Schematic Block Diagram of a typical GSM, PCN or DECT receive / Transmit unit

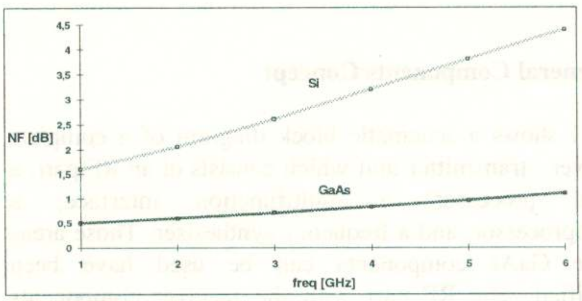

Fig. 2a: Noise Figure for GaAs and Silicon Transistors

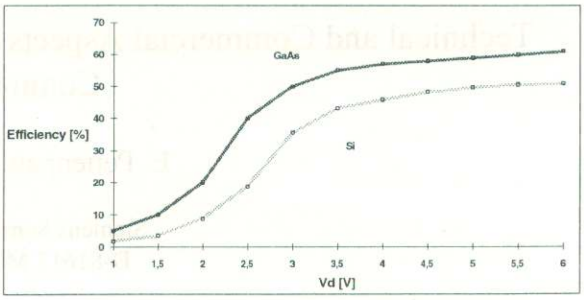

Fig. 2b: Efficiency for GaAs and Silicon Transistors

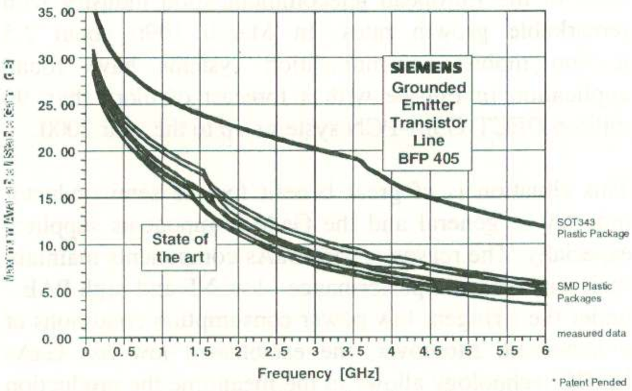

Fig. 3: Siemens Emitter Grounded Transistor Line. A series of transistors with outstanding performance

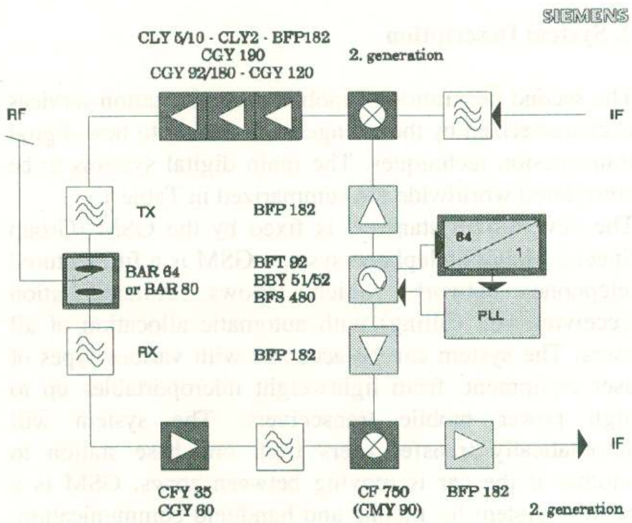

Fig. 4: Devices for the GSM, PCN, DECT RF part. (by courtesy of Siemens)

4. Receiver Part

The requirements for all systems discussed in Table 1 are similar, i.e. low NF and intermodulation distortion areimportant. The current generation fabricated is based on a 0.5 µm MESFET as preamplifier followed by an MMIC mixer with the described performance:

The GaAs mixer MMIC shows a simple but very effective circuit topology. It is a DG FET configuration with source LO allowing the desired low current - low voltage - low LO level operation. At 1.8 GHz, a conversion gain of 14 dB with a SSB-NF of about 5 dB and 15 dB isolation has been measured with an LO power of 0 dBm. The next generation of preamplifier, a 1-stage 50 Ω-MMIC, is already available in first samples. Fig 5 contains a chip photograph of the LNA MMIC based on a reactively matched feedback configuration with active load and unipolar voltage supply. The performance revealed 12 (15) dB of gain and 1.5 (1.3) dB NF at 2.5 (5) mA between 1.7 and 2.0 GHz. A simple adaption to all band of interest between 900 and 2500 GHz is possible.

For the VCO we currently recommend a Si bipolar transistor and a 3 V optimised varactor diode with sufficient capacity shift and Q factor.

A longterm development strategy requires a permanent device improvement. As a result, a one-chip receiver unit containing a preamplifier, mixer, postamplifier and LO is already in process.

Function	Type	Device	G dB	NF dB	IP3 dBm	Package
Preamplifier	CFY 35	MESFET	17	0.5	0	SOT 143
	CGY 60	MMIC	12	1.5		MW-6
Mixer	CF 750	MMIC	14	5.0	- 1	SOT 143

Table 2: Performance of Receiver Components at 1.8 GHz (I = 2.5 mA, 3V)

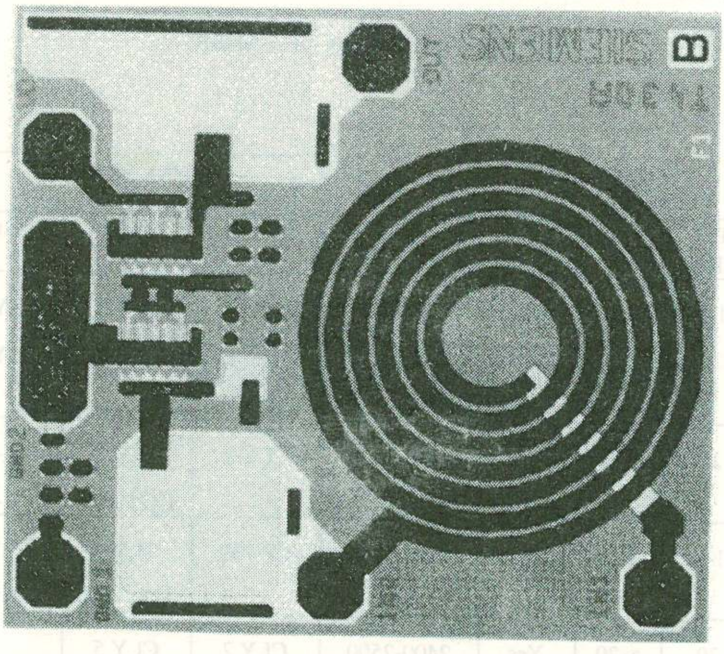

Fig. 5: GSM, DECT, PCN GaAs LNA MMIC

5. Transmittter Part

For the transmitter part, a less uniform picture is visible since the systems have different output power and gain control requirements. In any case this part shows the highest power consumption and as a result the questions of the PAE and 3V-supply are of major importance.

The system related device specifications and selection are summarized in Table 3. The currently used devices for the 3-stage High Power Amplifiers (HPAs) are the GaAs Power MESFETs CLY 2, 5, 10 with up to 1000 mW output power. Very high drain efficiencies of 50 - 60 % have been measured at only 3 V supply voltage. A short summary of the P-MESFET test results are shown in Table 4. The devices are assembled in a standard or modified SOT 223 SMD package.

The next important step is the monolithic integration of the GaAs power amplifiers for DECT, GSM and PCN systems. The first MMIC available is a 3-stage DECT HPA. The device is specified with 27 dBm output power, PAE of > 35% and IP3 > 30 dB again with 3 V supply voltage and 50 Ω terminations. Fig 6 contains a chip photograph of the DECT HPA realized on 2 mm^2 chip area. The device is mounted in a modified 12-pin SOT 223 package called MW-12.

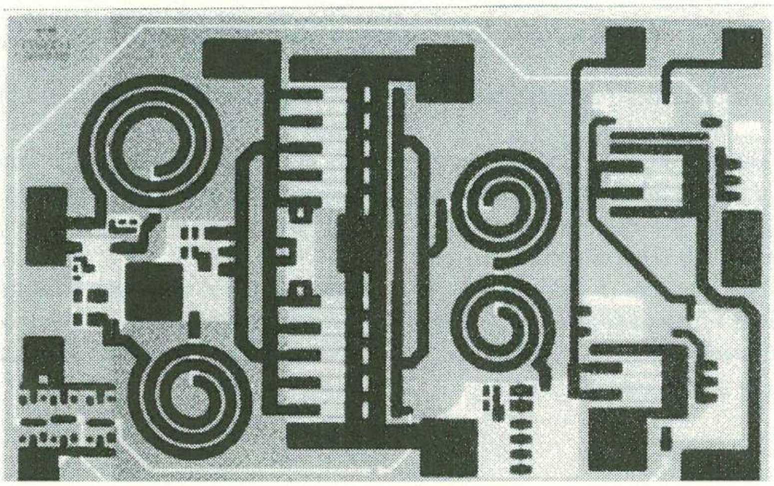

Fig. 6: DECT GaAs HPA MMIC

Application	Performance					Device Selection			Device Generation
	Pi dBm	PO dBm	PAE %	VGA	F MHz	1. Stage	2. Stage	3. Stage	
1. GSM ADC JDC	>-11	31-32	> 30	Yes	890 -915	BFP 183 -	CLY 2 CGY 120	CLY 10 CGY 92	SiBip; P-MESFETs P-MMICs
2. DECT	>-5	27	35	No	1880-1900	CLY 2 -	CLY 5 CGY 190	- -	P-MESFETs P-MMIC
3. PCN	>-18	31-32	> 30	Yes	1710-1785	CF 739 -	CLY 2 CGY 120	CLY 5 CGY 180	DGFET,P-MESFETs P-MMICs
4. w-LAN	0	20	> 20	Yes	2400-2500	CLY 2	CLY 5 CGY 250	-	P-MESFETs P-MMIC

Table 3 : Power Amplifier Generation and Specification

In comparison to DECT, the GSM and PCN HPAs need higher output power and gain accompanied by a gain regulation stage. As a result, a 2-chip MMIC solution is foreseen for both systems. A GSM/PCN Variable Gain Amplifier (VGA) based on a 2-stage DG FET feedback configuration with 50 Ω terminations is also available in first samples (Fig. 7). The VGA MMIC is specified with 12 dBm output power at 1 dB compression and 50 dB gain control range. This device is ideally suited to drive the GSM/PCN final P-HPA MMIC stages requiring 31 to 32 dBm output power. In this case, first PCN HPA MMIC are under test and GSM MMIC will be made available in April 94.

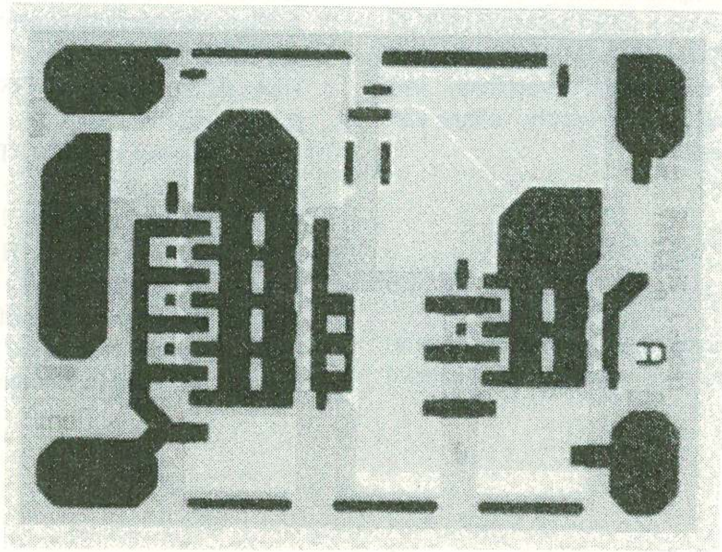

Fig.7 : GSM, PCN GaAs VGA MMIC

Device Type	$P_{(-1dB)}$ [dBm]	G_n [dB]	η_D [%]	f [GHz]	V_{DS} [V]	I_D [mA]	Package
CLY 2	23	15	> 60	1.8	3	175	MW 6
CLY 5	27	9.5	> 55	1.8	3	350	SOT 223
CLY 10	29	9.0	> 55	1.8	3	700	SOT 223

Table 4 : Test results of GaAs power MESFETs

6. Device Technology

The above described GaAs devices have been fabricated using the well-known 3"-wafer process DIOM 15 (1-3). It comprises a planar process up to the gate deposition with localized ion implantation, selfaligned gate technology realized by i-line wafer stepper, and airbridge crossovers. The only option for the different low noise and power devices is the adaption of the channel profile. Based on this process, more than 20 million MESFETs and 500 000 MMICs have been fabricated.

The often adressed cost advantages of Si compared to GaAs are not as high as expected for the mobile communication devices. The reason is that processing, testing and packaging can be realized on a comparable cost level due to the fact that identical or similar production resources can be used. As a result, higher GaAs costs are coming from the pure material part, i.e. this contribution is small compared to the overall costs.

7. Conclusions

A set of GaAs/Si SMD devices for the new GSM, DECT and PCN mobile communication systems has been described. The advantages of GaAs for the RF part in terms of LNA and mixer NF and IP3, and especially PAE of the HPAs have been demonstrated. The GaAs MMICs available are LNAs with 1.5 dB NF and mixers with a SSB-NF 5.0 dB. In first samples available are a DECT HPA MMIC (P = 27 dBm, PAE = 35%) and a GSM/PCN VGA MMIC. The GSM/PCN HPA MMICs are in a phase of design and test completion, respectively. All devices have been optimized for 3 V supply voltage and will be available as SMD parts.

Acknowledgement

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