EUROPEAN MMIC ACTIVITIES

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Abstract

This paper reviews the principal activities of Europe in the field of MMIC's. 7 companies are included, two in each of England, France and Germany and one in Italy. An emphasis is made on original contributions from the different groups. These include specific MMIC components designs, architectures, mm applications, modelling, libraries and packaging. A summary of the European approach for applications where this new technology will have a major impact will be given.

Introduction

In this talk I will try and give an overview of the main MMIC activities in 4 European countries. The European continent has a specific approach to MMIC applications which falls between that of the U.S. which is mainly motivated by military applications and of the Japanese which is oriented more towards civil and telecommunication applications although with time these divisions tend to overlap. In any case the two types of applications are present in most European programmes. There is however a restriction as in most cases in the world, for the military material that can be published. There is also considerable interest in the subject in the European universities and laboratories (1, 2, 3) which have enriched the modelling and libraries of foundries of several pilot lines (4, 5).

This paper will try and highlight some features which show specifically MMIC advantages and originality.

FRANCE There are two industrial groups in France, Thomson and the Philips Group (LEP/RTC).

The Thomson effort has concentrated in the last 5-6 years on producing an industrial production line mainly for use for in-house applications (although it is now being offered outside the company). The operation has always emphasized the foundry mode with microwave (O,5 μ, air bridges, vias ...), digital (LP-BFL) and analogue (ADC's ...) integrated circuits. The accent being on reproducibility the library indicates both nominal values (generally in algebraic form) and guaranteed dispersions for "right first time" optimisation. Fig 1 gives an example of the dispersion values (as % of the nominal value of one type of transistor), (0,5 x 150 μ gate), over wafer and from wafer to wafer.

DISPERSIONS OF LIBRARY VALUES OF THE MAIN ELEMENTS OF TRANSISTOR TH 2 - 21,5
(0,5 X (2 X 75 µM)

ELEMENTS	STANDARD DEVIATIONS (%) OVER 1 WAFER		STANDARD DEVIATIONS SLICE TO SLICE	
	AT I_{DSS}	$I_{DSS/2}$	AT I_{DSS}	$I_{DSS/2}$
C_{GS}	4.9	4.8	8.0	6.0
C_{GD}	4.7	4.5	6.7	5.4
C_{DS}	3.5	4.2	8.1	8.0
G_M	2.9	1.7	9.0	9.5
T_{AU}	3.7	4.2	16.5	13.9
R_{DS}	6.2	6.4	15.0	14.0
RI	6.2	3.1	15.8	17.8
L_G	3.5	3.1	21.0	21.0
L_D	1.9	2.7	16.0	16.0
F_C	3.7	3.8	15.6	10.2
F_{MAX}	2.8	2.5	7.0	6.2

FIG 1 : EXAMPLE from Thomson MMIC Library

An example of specific MMIC design is the power amplifier seen in Fig 2 (C Band 1W) in which the whole amplifier (3 stages) is arranged in a tree structure based on identical modular stages with one input and two outputs (6). The very good phase matching that is possible in MMIC's enables a much better thermal structure than conventional high power FET's, indeed there is no longer an impedance or thermal limitation to higher powers. The size of the circuit (yield) is the only limit.

1988 IEEE MTT-S Digest

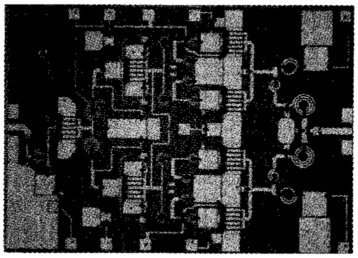

FIG 2 : Thomson MMIC, 1W C-band Amplifier

An X-band Phase Array Module is shown in Fig 3. It has the following characteristics :

3 sub units : Commands, Switch + Phase Shifters and Attenuators, Power Amplifier and Receiver Amplifier and a miniature circulator; Bandwith > 10%; Output power : 1W; Input noise figure : < 4 dB; Attenuator and Phase shifter : 5 bit ; Power consumption : 3W; Size : (15 x 13) mm x 150 mm; Weight : 50 grams (could be reduced).

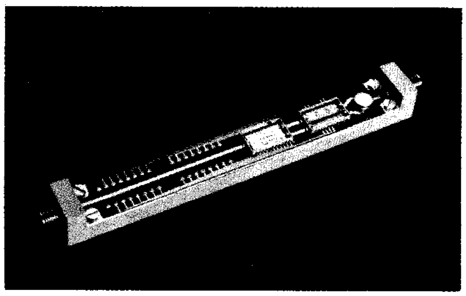

FIG 3 : X-band Phase Array Module of Thomson

An original modular MMIC package is seen in Figs 4 and 5 in which the MMIC is mounted inside an alumina well, the bottom plate of which is engraved both sides with plated metal holes which interconnect to the outside (for R.F or D.C). The well can be hermetically sealed with a cap (7).

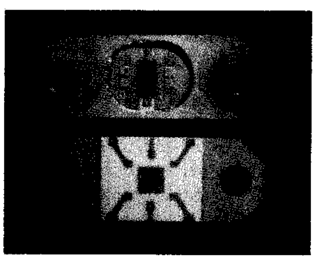

FIG 4 : Hermetical Package for MMIC (Thomson)

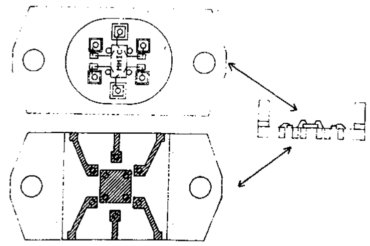

FIG 5 : Mounting details of FIG 4

The Philips group in France (LEP/RTC) has always been interested in civil applications and were the first to make a completely integrated DBS receiver (8)

Fig 6 illustrates an interesting example of an FMCW radar circuit for an Altimeter made in the Philips organisation (LEP + TRT) in which the MMIC performance is much superior to that of conventional MIC circuits (9). The bandwidth is much higher (40% instead of 8%) and above all, by carefully tailoring the transistors and using a balanced structure the modulator has excellent carrier rejection (40 dB). Here again the distinct advantage is due to the very close phase match between parallel elctrical paths that is only possible in MMIC.

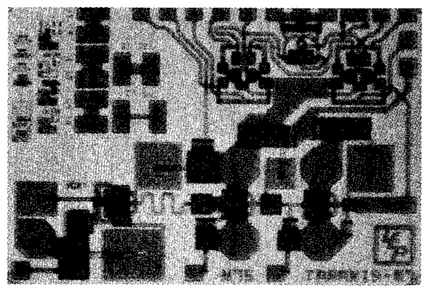

FIG 6 : LEP/TRT S-band Dual Phase Modulator for Radioaltimeters

Germany

Two main industrial groups (AEG, Siemens) are concerned with MMIC's and there is a strong university activity (Aachen, Duisbourg, Darmstadt,...) and also government agencies (Frauenhöfer Institut and DBP Darmstadt).

AEG are concentrating on mm-wave MMIC's. Their 35 GHz receiver is shown in Fig 7 (10,11). An original feature of this work is the structure of the active layer. High performance diodes were made by using an n^+ implanted buried layer and overgrowing by epitaxy the n active layer (which is later isolated by B implantation). There is a 1 GHz I.F amplifier also on-chip. The f_c of the diode was 520 GHz and the noise figure was 6,5 dB. The conversion gain was 6 dB.

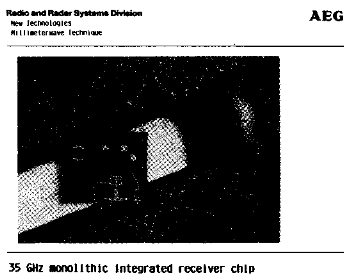

FIG 7 : AEG. 35 GHz MMIC Receiver

Siemens who were the first to market MMIC amplifiers in the world, have been concentrating on civil application until recently (12). Some examples will be given during the talk.

U.K The two main companies in Great Britain involved in MMIC's are Plessey and GEC.

Some examples of recent circuits developed at Plessey (13) are shown in Figs 8,9 and 10. Fig 7 is a beautiful picture of a one pound coin and barely visible beside it the guts of a C-band phase array radar module on one chip consisting of a low noise amplifier, a travelling wave broad-band amplifier, switches, and switched filter phase shifters. The noise figure is better than 3,5 dB..

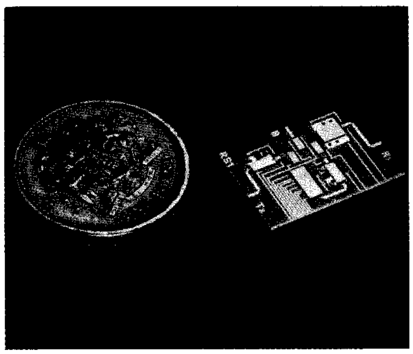

FIG 8 : Plessey S-band Phase Array Module

Figure 9 shows the switched filter phase shifter in more detail. It covers the frequency range from 2 to 8 GHz and shows the one 45° bit. The circuit consists of series of L, C elements and a shunt inductance that are switched in and out of different phase paths by parallel FET's. Fig 10 is the same function but the circuit is reduced to half the size. They have invented a new function : the Switched Inductor-FET.

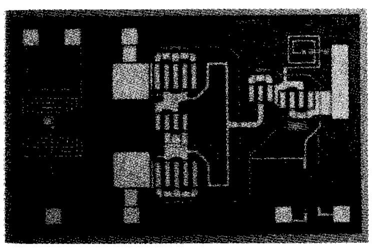

FIG 9 : SWITCHED FILTER PHASE SHIFTER from PLESSEY

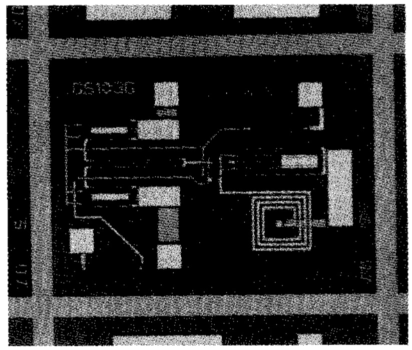

FIG 10 : The same FILTER (FIG 9) but twice as small

At GEC several novel designs have been used in MMIC circuits (14). An original PIN switch (SPDT) is shown in Fig 11. It is still in MMIC technology but it will handle a power of over 1W. The insertion loss, isolation and band width are shown in Fig 12; Banwidth 1-20 GHz, Isolation 40 dB at 10 GHz. Fig 13 shows another novel medium power distributed amplifier. It has 20 fets! and is tapered towards the output. The power in 1W, the bandwidth 5 to 15 GHz. This illustrates another means of distributing the power consumption over the whole chip which is only possible in MMIC technology. They have also made 94 Ghz Schottky diode balanced mixers, 4b phase shifters and wide-band amplifiers.

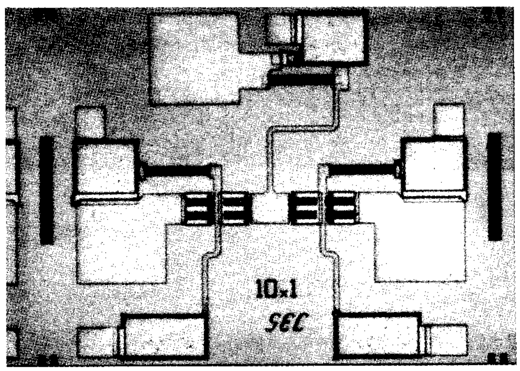

FIG 11 : GEC PIN MMIC SWITCH

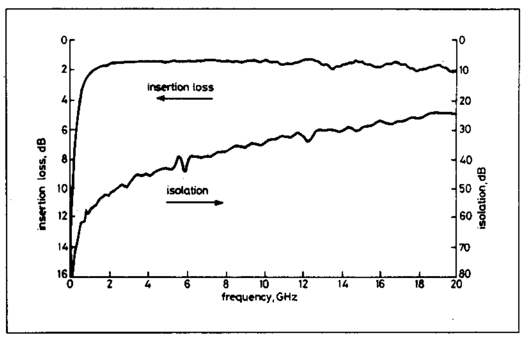

FIG 12 : GEC SWITCH Performance

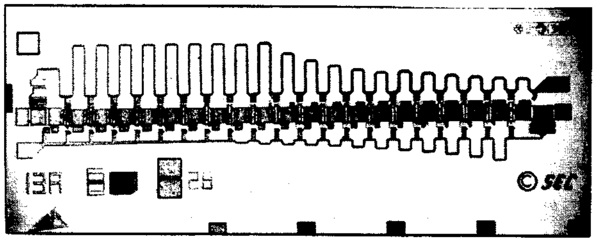

FIG 13 : GEC WIDE BAND DISTRIBUTED AMPLIFIER

Italy In Italy the MMIC activities mainly interest Telettra and CISE. They have proposed another original power approach (15) which distribute the transistor over the surface of the GaAs in a 2 dimensioned matrix (Fig 14). This has the advantage of having better heat dissipation than a standard power FET and higher impedance levels. It is possible thanks to an original air-bridged gate structure whereby each gate is the pillar portion of an arched Roman viaduct! This is used to make a 21 to 25 GHz half a Watt, output power amplifier. They are also very interested in civil applications (16) - mobile radio, DBS where low power microwave functions are particularly useful. An example is low noise L-band amplifier with 20 dB gain but only 40mW power consumption.

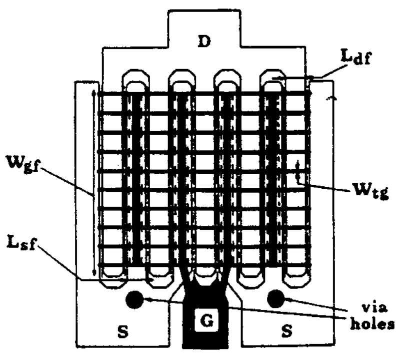

FIG 14 : CISE/TELETTRA POWER FET

Conclusions

I have tried in the minute time I had to prepare this paper, to collect as many examples as possible of the extended and varied work that is going on in Europe. I have packed as many photographs as possible into 4 pages (is this a record?) and more will come in the oral presentation. However the idea is to give a flavour of the European attitude to MMIC's, the wide range of applications, low frequencies to mm range, civil and military.

I have also tried to emphasize the original contributions that Europe has to offer in new design concepts and particular MMIC thinking which is profoundly changing the Microwave world at this time.

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