HBT TECHNOLOGY FOR HIGH POWER X BAND AND BROADBAND AMPLIFICATION.

P.F. ALLEAUME* , Ph. AUXEMERY**, J.P. VIAUD*, H. BLANCK** , M. LAJUGIE*

*Thomson-CSF Microelectronique
29 av CARNOT 91349 MASSY Cedex France.
** United Monolithic Semiconductors
Route départementale 128 91401 ORSAY Cedex France.

Pierre-Franck.Alleaume@TCM.THOMSON-CSF.COM
Philippe.AUXEMERY@UMS-GAAS.COM
Jean-Pierre.VIAUD@TCM.THOMSON-CSF.COM
Hervé.BLANCK@UMS-ULM.DE
Monique.LAJUGIE@TCM.THOMSON-CSF.COM

Abstract - For many applications like active phased array antennas for airborne radar, high power levels are required. To provide high performance and high manufacturing yield at a reduced coast, a MMIC solution is naturally very attractive. This can be achieved by choosing an efficient technology for active components. In this paper, a solution based on the HBT technology is presented.

The 10W class, X band power amplifiers, and 1W, 4.5GHz-18GHz amplifiers were designed using the HBT technology HB20P from UMS. Based on the results obtained, this paper will discuss the capability and the technology improvements needed to reach the power and frequency bandwidth specifications with margin.

I. INTRODUCTION

Airborne radar and electronic warfare applications deal with high power systems. Of course, the available power level of the active components is the major limitation to reach the final performance of the system. So the choice of the technology used for power amplification functions is important. Many publications have presented the power level improvements for the most efficient MMIC technology such as MESFET, PHEMT or HBT. In this study, HPA circuits were designed using a HBT technology. This choice is directly linked with the maximum HF current and voltage available in with HBT. In the case of the UMS technology, the maximum RF power available is around 1.7kW/mm^2 with a maximum Ice current around 333 A/mm^2 in compression mode and a maximum value for Vce around 17V.
Two successive runs of X band and wide-band HPA were designed. The measured performance will be presented. The UMS HBT power technology is going to be described first.

II. UMS HBT PROCESS DESCRIPTION

The process is based on an GaInP/GaAs emitter/base junction. The base is highly carbon-doped. High breakdown voltage is achieved with a thick GaAs collector layer. The process uses a conventional mesa approach and a non-selfaligned base contact. To enhance the reliability an emitter-base ledge is introduced. All optical lithography steps are performed by stepper lithography. Selective dry etching and a deep high-dose proton isolation are also applied. In order to improve the thermal stability of the transistors, a resistive layer is incorporated inside the emitter structure to provide an integrated emitter ballast resistance. Also, a thick layer of gold is used for the emitter air-bridge contacts, which plays the role of an efficient channel for heat sinking. These emitter ballast resistances and thermal drains warrant thermal stability and prevent thermal runaway.

III. X BAND HPA

A. Design Goals

Main design goals for the X Band HPA are output power greater than 5W, power added efficiency (PAE) better than 30% associated with 14dB linear gain. The frequency bandwidth is 9GHz to 10.5GHz.

A 1W class amplifier was also designed to drive this HPA. The needed linear gain is around 14dB.

B. HPA Structure

The circuit is a two stage amplifier, including four transistors with 8 base fingers of 2µm*30µm for the first stage, and 8 transistors with 8 base fingers of 2µm*40µm for the second stage. This structure presents a maximum output power of around 10W at 10GHz. The transistors are recombined two by two for stability and mismatch optimization (Fig. 1).

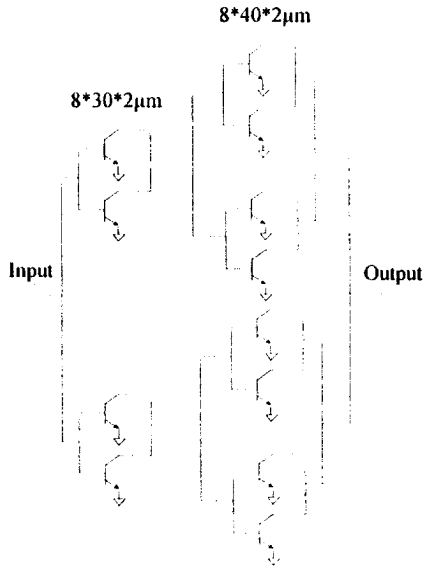

Fig. 1: X band HPA HF structure

Chip size is 4500mm by 4500µm (fig. 2).

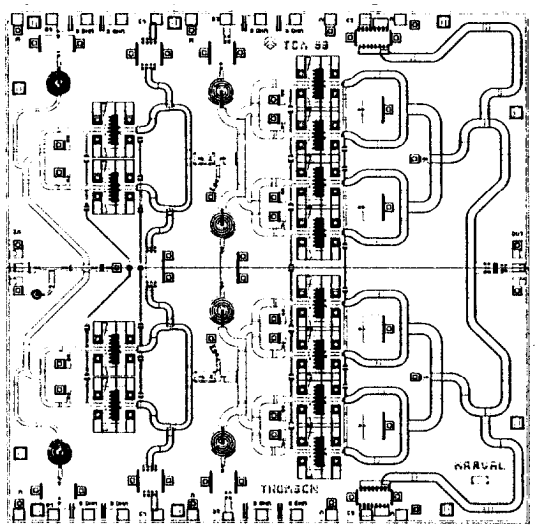

Fig. 2: X band HPA layout.

C. Driver structure.

This driver is a two stage amplifier with 4 base fingers of 2µm*30µm transistor for the first stage, and two 6 base fingers of 2µm*30µm transistors for the second one.

D. X band measurements results.

Test-fixture measurements have been performed under pulsed conditions (both DC and RF, 10% duty cycle). The output power versus frequency (for 10V collector voltage) is drawn for 4 input power levels (+4 dBm, +13dBm, +18dBm, +24 dBm) on figure 3 for the first run circuits.

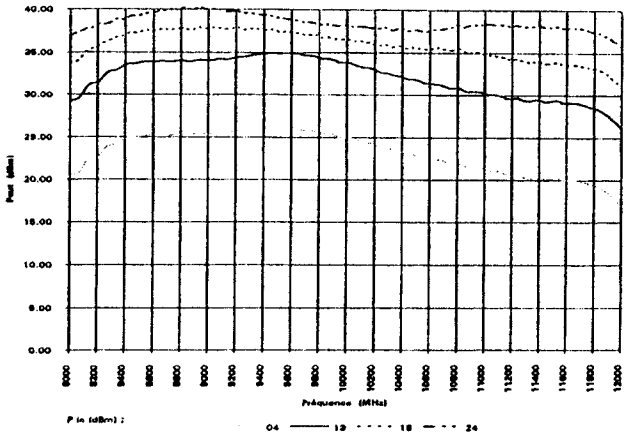

Fig 3: 1st run X Band HPA : Measured Output power versus frequency.

For an input power of 24dBm, the output power is greater than 5W (37dBm) over frequency band. At 9GHz, 10W output power is achieved, associated with 35% PAE and 16dB gain.
Output power design goals have been reached with a first pass. So, the need of a second run is mainly related to the improvement of small signal gain flatness over frequency band.
Last stage transistor periphery is the same as for the first run. 2nd design work has been strongly assumed by the redesign of the inter-stage, due to back simulation data and also linked with a technological evolution.

At time, we don't have finished the measurement campaign for the second run. But, as shown by figure 4, the study of the driver S21 parameter in RF pulsed mode (10%) points out the improvement of the flatness for its response. This measurement has been done for 14 power points included between -2dBm and +18dBm versus frequency. Two curves are done: (a) for collector bias set to 6V and (b) for 10V.

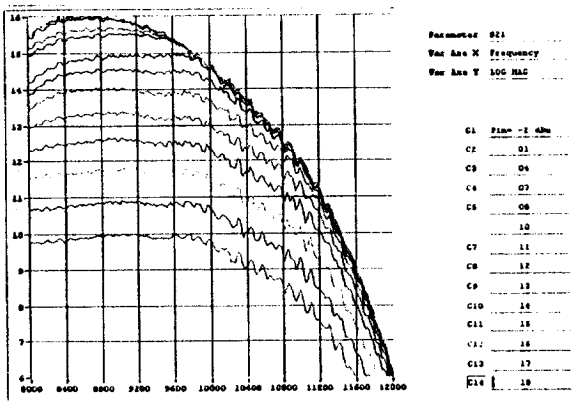

Fig. 4 (a) : 2nd run X driver : S21 pulsed response versus frequency depending input power level. Vce = 6V.

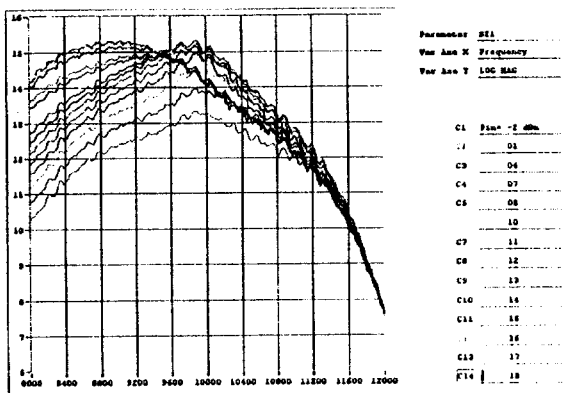

Fig. 4 (b) : 2nd run X driver : S21 pulsed response versus frequency depending input power level. Vce = 10V.

This first result confirms the validity of the simulated results.
So, non-linear simulation results for the HPA are presented here after (Fig. 5):

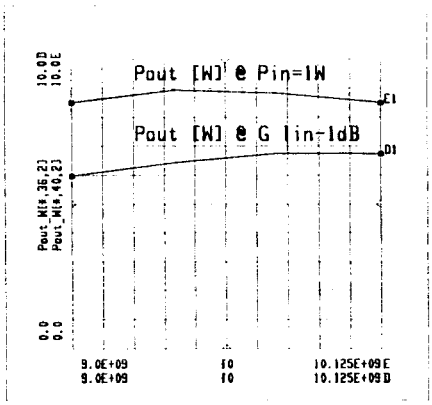

Fig.5: Output power versus frequency.

IV. BROAD BAND [4.5GHz-18GHz] HPA

A. Design Goals

Main design goals for wide band HPA are output power greater than 1W, power added efficiency (PAE) better than 20% associated to 10dB linear gain. The frequency bandwidth is 4.5 GHz to 18 GHz.

B. Circuit Structure

The designed circuits are two stage amplifiers including two 8 base fingers of 2 µm*20µm transistors for the first stage, and four 6 base fingers of 2 µm*30µ m for the second stage. The output stage provides an available output power greater than 1.5W.
The chip size is 4300µ m*3000µ m (see figure 6).

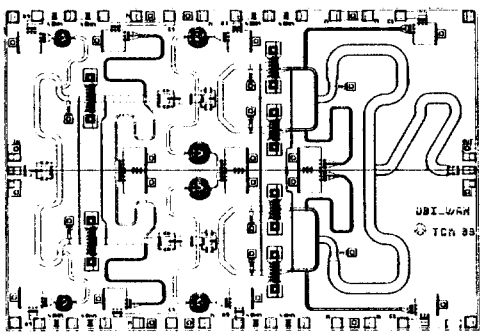

Fig 6 : Wide Bad HPA Layout

C. 1st Run Measurement Results

Test fixture measurements have been performed under pulsed conditions (both DC and RF, 10% duty cycle). The output power versus frequency (for 8V collector voltage) is drawn for 4 input power levels (+1 dBm, +10dBm, +16dBm, +21 dBm) on figure 7.

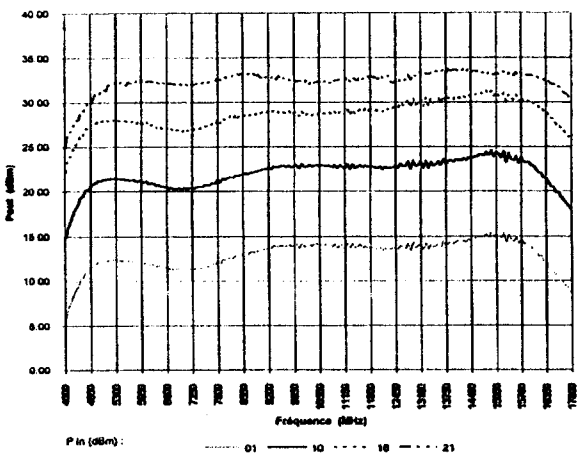

Fig. 7. Broad band HPA : Measured Output power versus frequency.

For an input power of 21dBm, the output power is 1.5W (32dBm) from 4.5 GHz up to 16GHz, associated with more than 20% power added efficiency (PAE).

D. 2nd Run, simulated and measured Data.

Design goal output power has been demonstrated over 4.5 to 16 GHz with this first run. So, the 2nd run is needed to increase frequency band up to 18GHz.

Back simulation, pointed out that the main limitation for operation up to 18GHz was related to the transistor topology itself (it's strongly necessary to decrease parasitic elements). So, the 2nd run, main work has been dedicated to introduce in the design new specific wide band transistor cells provided by UMS.

Small signal simulated data are given here after (figure 8).

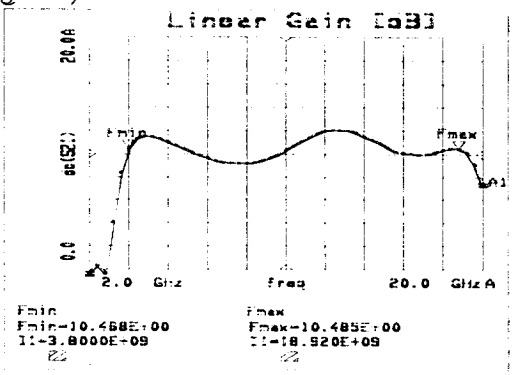

Fig. 8.: Wide band 2nd Run Simulated [S] parameters.

This 2nd run has be completed last June, so at time we have on wafer measurements. Figure 9 presents on wafer power measurements versus frequency.

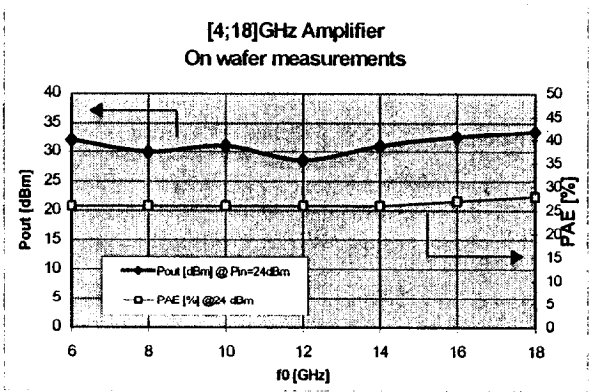

Fig. 9. : Wide band 2nd Run, output power & PAE yield, On wafer measurements.

These first results point out the enlargement of the frequency band to 18GHz. The poor flatness of the power response of the circuit can be explain by on-wafer low frequency oscillations. This classical matter will probably be solved in jig tests.

V. CONCLUSIONS

A first run of X band and wide band HPA has been manufactured and tested, using HBT process from UMS (HB20P process).
These 2 circuits exhibit :

- more than 5W output power for X band HPA (up to 10W, associated to 35% PAE)
- 1.5W output power over 4.5 to 16GHz, associated to 20% PAE for wide band HPA.

So, high power performance has been demonstrated with HBT "HB20P" process.
A second run has been launched in order to improve gain behavior over frequency band, using new topology transistor cells. First measurement results that will be completed for the conference point out that the power performances are reached

VI. REFERENCES

[1] - M. A. KHATIBZADEH, W. LIU, 'I'. HENDERSON, J. SWEDER, S. PIERCE
"High-efficiency X band HBT power amplifier."
IEEE MMWMC Symp., p117-127, May 1994, San Diego.

[2] - F. ALI, A. GUPTA, M. SALIB, B. VEASEL, D. DAWSON
"A 2 watt, 8-14 GHz HBT power MMIC with 20 dB gain and >40% power added efficiency."
IEEE transactions, vol. 42, N°12, p2635-2641, December 1994.

[3] - F. ALI, M. SALIB, A. GUPTA, D. DAWSON
"An 8-15GHz, 1W HBT power MMIC with 16dB gain and 48% peak power added efficiency."
IEEE GaAs IC Symp. Digest, pp 363-366, Oct 1993.

[4] - J. J. KOMIAK, L. W. YANG
"5 Watt high efficiency wideband 7 to 11GHz HBT MMIC power amplifier."
IEEE MMWMC Symp., p17-20, May 1995, Orlando.

[5] - J. P. VIAUD, M. LAJUGIE, R. QUERE, J. OBREGON
"First demonstration of a 0.5W, 2 to 8 GHz MMIC HBT distributed power amplifier based on a large signal design approach".
IEEE MMT-S Digest, vol. 2, pp 893-896, June 1997.