POWER AMPLIFIER LINEARIZATION USING CARTESIAN FEEDBACK

A.GUY[*,**], C. GALY[*], J.F. VILLEMAZET[**], J.F. SAUTEREAU[***], J.L. CAZAUX[**]
[*]Université Paul Sabatier 118 route de Narbonne 31068 Toulouse, France
[**]Alcatel Space Industries 26 avenue J.F. Champollion BP 1187 31037 Toulouse, France
Phone : +33 (0)5 34 35 69 01, Fax : +33 (0)5 34 35 69 47
E-mail : Alexandre.Guy@space.alcatel.fr
[***]UPS-LAAS/CNRS 7 avenue Colonel Roche 31400 Toulouse, France

ABSTRACT

We present in this paper a synthesis of power amplifier linearization techniques.
SSPA have to operate in their best capabilities for telecommunications applications. They have to present in the same time high efficiency PAE and low non-linearities.
After a description and simulation results of the different families of linearization techniques, Cartesian Feedback experimental results are shown.

INTRODUCTION

SSPA are formed by an association of a control section plus a driver and high power amplifiers (HPA) (*Figure 1*).
To obtain high PAE, we have to use SSPA in non-linear area of AM/AM and AM/PM characteristics.
This brings about harmonic generation and intermodulation products, 3rd and 5th order ones can not be filtered with traditional techniques.
These may be critical for telecommunications uses if the transmitting signal includes numerous carriers.
We so have to optimize a compromise between good PAE and low intermodulation products level. Several techniques allow this, called linearization methods.
Most important linearization methods have been studied through simulation with Libra and Omnisys (HP-Eesof). Usually, the HPA should be linearized.
System originality and electrical performances have been the criterion of our choice between all these techniques.

MAIN POWER AMPLIFIER LINEARIZATION TECHNIQUES

After a bibliographical research, different linearization techniques could be classified in two families. We have distinguished (*Figure 2*) those acting around the active module (Family 1) from those acting on bias of HPA (Vds or Vgs) (Family 2).
To compare the simulation results, we chose the same HPA which is actually used in satellite payloads.
The methodology used is the following one. The output power (P_{out}), PAE and carrier to intermodulation ratio (C/I) of HPA are known. These linearization techniques are simulated to get improved P_{out}, PAE, C/I.
It is important in this study to have a criterion of comparison on efficiency/linearity trade-off (7), and to have application requirements of the system. Results of this comparison are given in *Figure 3*.
We briefly list the synthesis made:

- Predistortion (1) permits to increase the C/I for more than 10 dB. This technique is already known for TWTA applications but the best results are obtained before the saturation.
- Feedback systems (Adaptive Double Envelope Feedback: ADEF (5)) show that for a low improvement of C/I, PAE is degraded.

- Feedforward (2) gets at the same time good C/I but decreases the P_{out} and the PAE.
- Indexing of amplifier saturation point (acting on Vds) (6) gives a well improvement of C/I for a given PAE. Consequently, for a C/I given, this technique allows the minimal consumption and that is very important for an equipment on board.
- The LINC (4) is actually investigated.
- To improve the linearity without important changing of consumption power, the Cartesian Feedback (3) seems to be more suitable. A linearity improvement of 10 dB is obtained.

Its baseband treatment giving these simulated results, lead us to a study of the Cartesian Feedback loop experimentally. Indeed, this technique could be used in coming payloads.
Indexing technique would be used in addition with it for PAE improvement.

CARTESIAN FEEDBACK SYSTEM

The Quadrature Phase Shift Keying (QPSK) transmitter includes the amplifier to be linearized (*Figure 4*). The phase modulated RF carrier by baseband signals, is also amplitude modulated by the filtering of these signals, to limit the spectrum bandwidth. As a result, the non constant envelope is subject to amplifier 's nonlinearities, that involves a regeneration of sidelobes on output spectrum.

The degree of spectrum regeneration is characterised by the adjacent channel power ratio (ACPR).

ACPR is defined as the ratio of the power existing in the adjacent channel to the power in the main channel.

Therefore, there will be an upper and a lower ACPR, which in general will not be equal to each other. Here, we consider an average ACPR between the upper and the lower values.

A fraction of the RF output signal is applied to the input of the demodulator. Suitably scaled, the down-converted signal is then substracted from the input signal. The error signal thus generated becomes the necessary predistorded drive to linearize the nonlinear RF amplifier.

To show the feasibility of this method, a breadboard made up of elements used by Alcatel in current satellite payloads, was constructed (*Figure 6*). The carrier and modulation frequency are 1.55 GHz and 100 KHz respectively. Gain (MG) and phase ($M\varphi$) margins are calculated to make sure that the loop will be stable. We find : MG=6.9 dB and $M\varphi$=56.6 °. Practical results are given in *Figure 7*.

The three important amplifier specifications are channel power, ACPR and efficiency. We compare the closed-loop to the open-loop, considering these three parameters.

With the same channel power (*Figure 8*), the PAE decreases of 4.5 points but an improvement of 10 dB of the ACPR is achieved.

The channel power and the PAE increase of 4.1 dB and 21.6 points respectively at the same ACPR (*Figure 9*).

CONCLUSION

This paper summarizes the basis techniques which are available to generate high-power linear RF signals using both transmitter and amplifier linearization.

The feasibility of Cartesian Feedback method to linearize a solid state power amplifier was proved. It enables linearization of SSPA with a 100 KHz modulation frequency. Achieved results and its baseband treatment involve an application in future regenerative payloads.

Better intermodulation suppression of higher data rates can be obtained if baseband amplifiers, modulators and demodulators could be fabricated on the same chip, to minimize the electrical length.

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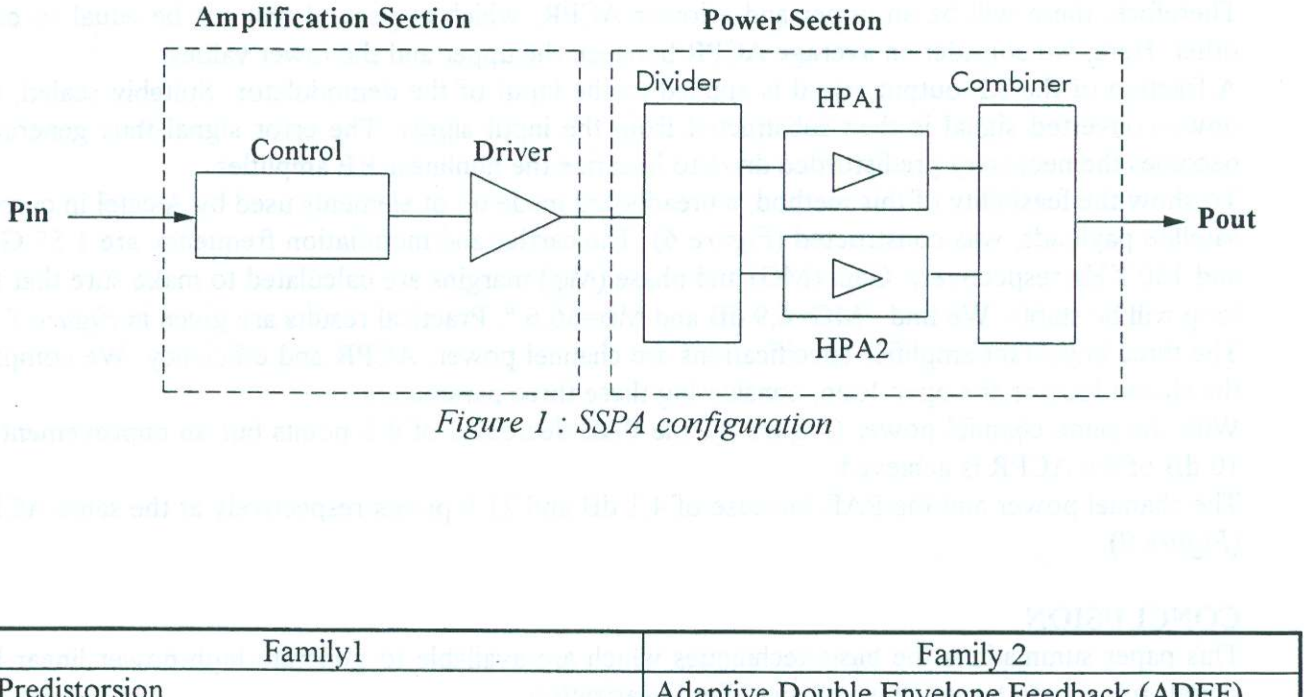


Figure 1 : SSPA configuration

Family1	Family 2
Predistorsion Feedforward Cartesian Feedback Linear Amplification with Nonlinear Components (LINC)	Adaptive Double Envelope Feedback (ADEF) Indexing of amplifier saturation point

Figure 2 : Different families of linearizers of power amplifier

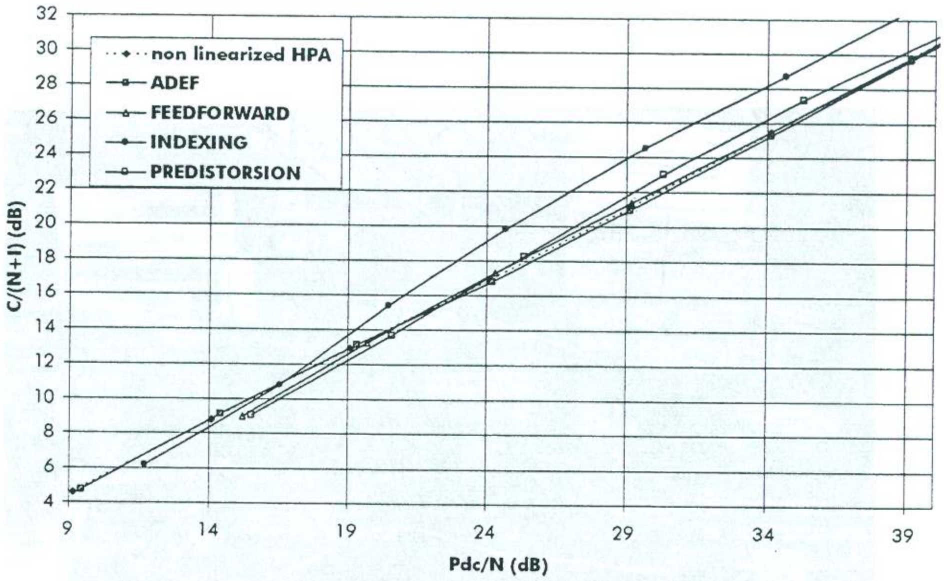


Figure 3 : Comparison of main linearizers

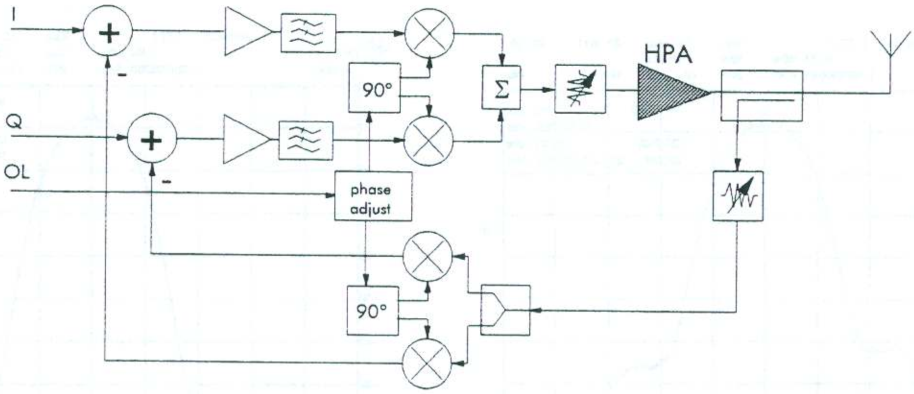
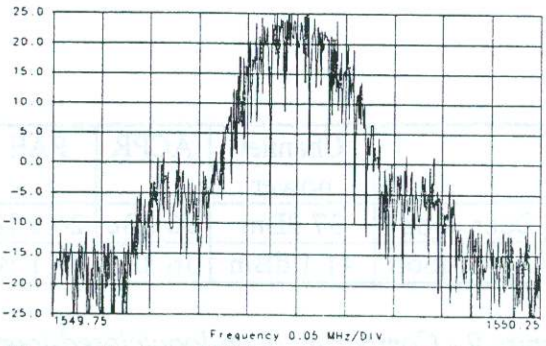


Figure 4 : Block diagram of Cartesian Feedback transmitter



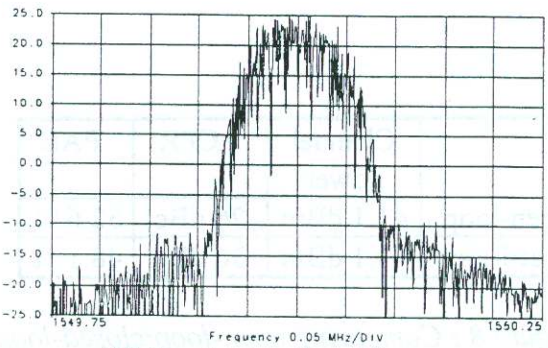


Figure 5 : *HPA output : open-loop (Omnisys simulation)* *HPA output : closed-loop (Omnisys simulation)*

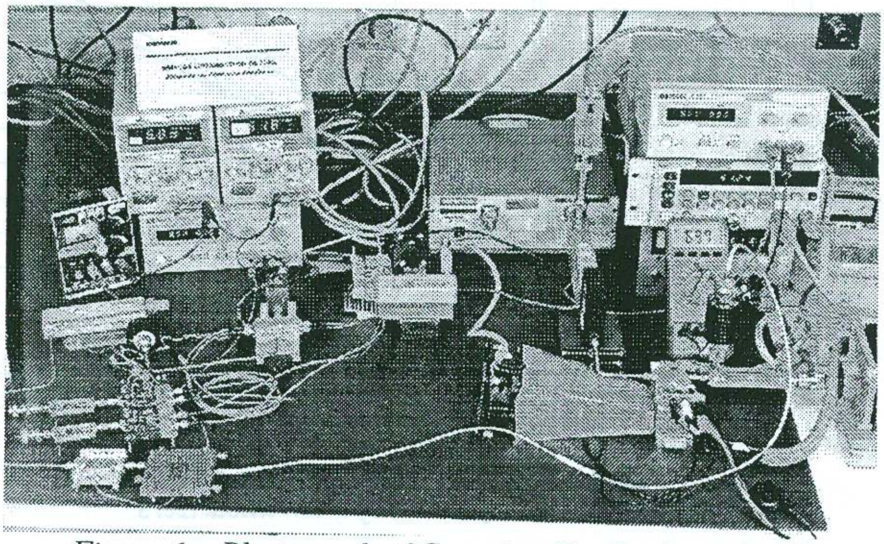


Figure 6 : Photograph of Cartesian Feedback test bench

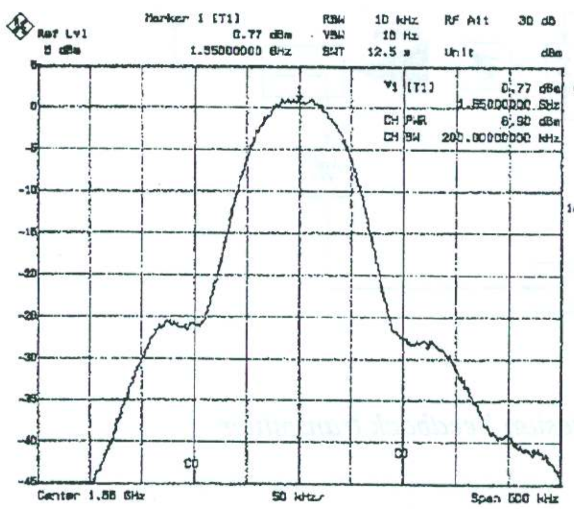
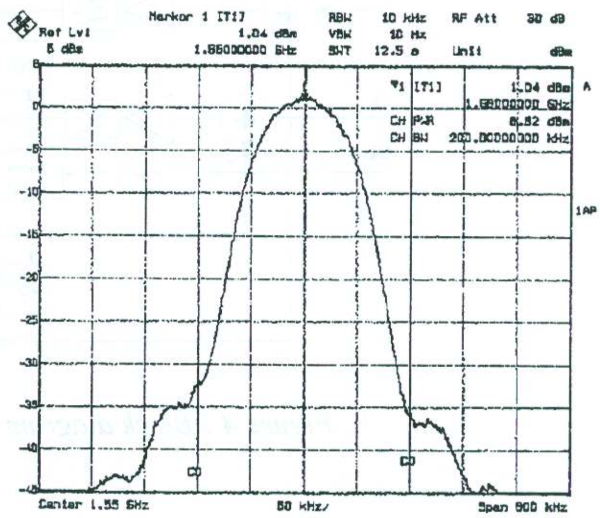


Figure 7 : HPA output : open-loop (experimental result)



HPA output : closed-loop (experimental result)

	Channel power	ACPR	PAE
Open-loop	41.1 dBm	26 dBc	52.6 %
Closed-loop	41.1 dBm	36 dBc	48.1 %

Figure 8 : Comparing open-loop/closed-loop at same channel power

	Channel power	ACPR	PAE
Open-loop	37 dBm	36 dBc	26.5 %
Closed-loop	41.1 dBm	36 dBc	48.1 %

Figure 9 : Comparing open-loop/closed-loop at same ACPR