Behaviour of a TWTA with a Single or Multicarrier Input Signal for Telecommunication Applications

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***Abstract* — This paper deals with the evaluation of the traditional Travelling Wave Tube Amplifier (TWTA) output power model completed with an associated power efficiency estimation with multi carrier signal. A 120 W Ka Band linearised TWTA is used to propose a full comparison between simulated and measured results concerning up to four modulated carriers as an input signal. Three different regions of output operating point are proposed, each correlated to a growing complexity needed in signal simulation from CW to all multiplex composed by modulated carriers.**

I. Introduction

The request for mass and efficiency improvement remains the driving factor for the satellite payload system optimization [1]. Taking into account that the power amplification represents nearly 80 % of the entire power consumption of the satellite payload, a great effort is devoted to well choose the best compromise between output power needed, power consumption and level of distortions due to non-linearity. In particular, the TWTA saturation power and operating point have a great impact on the overall sizing of the payload, so a system simulation with some key points is required:

1) Fine knowledge of the input frequency multiplex definition,
2) TWTA classical AM/AM and AM/PM characteristics obtained with accurate power and phase measurements,
3) Accurate model of the power consumption with respect to input power.

We propose, in this paper, a complete modelling of a linearised TWTA, working in Ka frequency band with single and multi carrier input signal. The simulation is then compared with measurements.

II. TWTA Caracteristics and Modelling

The TWTA is composed of a Ka-Band 120 W CW saturation power TWT from Thales Electron Device (TED), an EPC (Electronic Power Conditioner) from ETCA and a lineariser from Alcatel Space. Its overall power efficiency at saturation is 55 %. TWTA was tested using the capabilities of a Transmission System Bench (BST) developed by CNES under internal ATF program for Ka-Band multimedia satellite system test and analysis. Measured AM/AM, AM/PM and power consumption curves with a single CW input carrier at 19.75 GHz are depicted in figure 1 and 2.

The TWTA model is then modelled by:

1) Measured AM/AM and AM/PM curves,
2) A 4th order polynomial approximation of the CW output power with respect to DC power consumption curve.

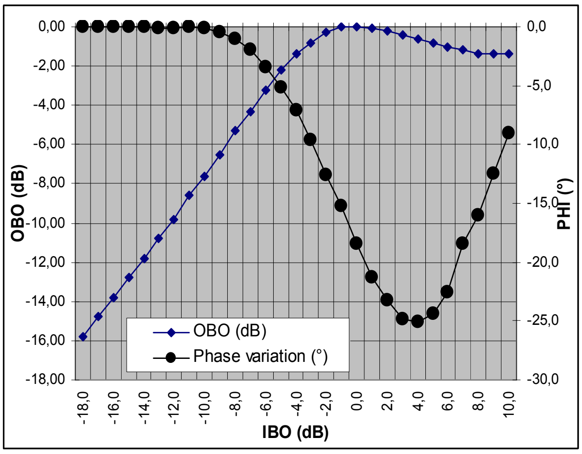

Fig. 1. Measured AM/AM and AM/PM curves of the TWTA

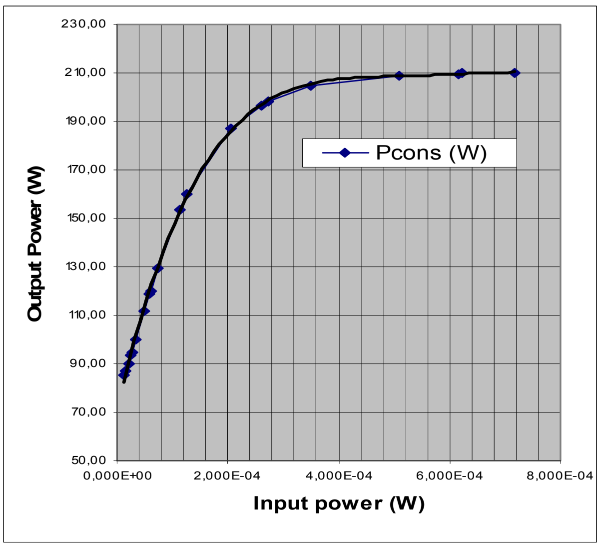

Fig. 2. Measured power consumption curve versus Pin

Simulations are realized with COMmunication LIBrary software (CNES internal simulator development). COMLIB is used to simulate linear and non linear distortions of transmission chains. It is based on a complex envelop simulation method and is used to operate all the simulated results presented in this paper.

III. Power consumption modelling

The average power consumption is obtained for any kind of input signal. The calculation of power consumption based on a quasi-static approach is performed as follows:

1) Definition of the complex input signal envelop composed of N samples in time domain,
2) Computation of input power associated to each sample,
3) Computation of DC power consumption associated to each input power sample with respect to CW power consumption curve,
4) Integration on the signal duration of the N samples of DC power consumption,
5) Determination of the power efficiency defined by output power divided by consumed power.

This methodology is applied to obtain all simulated results presented.

III. Input frequency plan definition

Four scenarios are displayed depending on the number of carriers used in a 36 MHz bandwidth (from 1 to 4). Each carrier is QPSK modulated with a 0.25 roll-off factor. Modulation signals on each channel are completely decorrelated.

The input multiplex is detailed in Table I.

Nb of carriers	carrier	modulation	Rs Ms/s	Roll-off facto r	Distanc e between carriers (MHz)
1	1	QPSK	26	0.25	-
2	1 2		12 12		17
3	1 2 3		8 8 8		11
4	1 2 3 4		6 6 6 6		8.5

Table I. Input multiplex scenarios

IV. Results and discussion

Figure 3 shows the compared results for the first and fourth scenarios represented with 4 carriers in terms of total Output Back Off (OBO, output power related to output saturation power in CW mode) versus Input Back Off (IBO, input power related to input saturation power in CW mode). One can verify that a very good agreement is obtained between simulated and measured results. Maximum total output power difference from CW saturated power is a function of the number of modulated carriers: around 0.5 dB for a single carrier to around 1 dB for 4 carriers. Those values have to be retained for general budget link evaluation. No major further degradation is observed when using more than 4 carriers or white Gaussian noise as input signal.

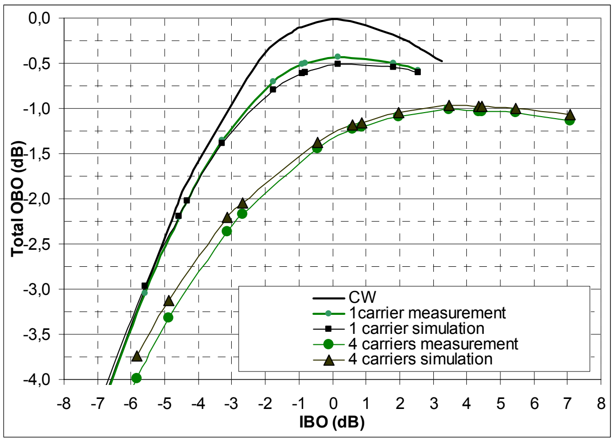

Fig. 3.Simulated and measured output power evolution with CW, 1 or 4 modulated carriers as input signal.

Moreover, the useful power, defined by total power minus noise intermodulation generated by the TWTA, is clearly lower. Fig.4 depicted simulated results obtained with total and useful OBO versus IBO values.

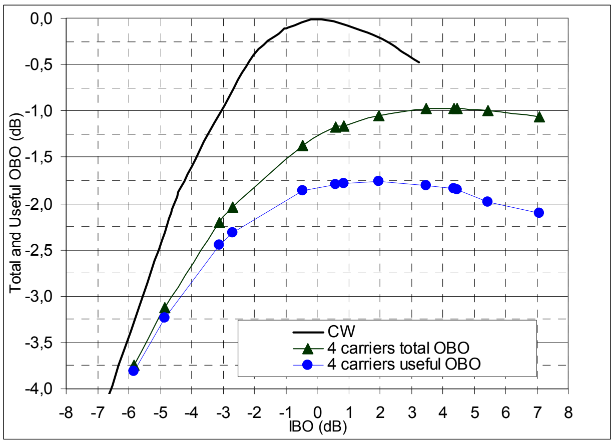

Fig.4. Simulated useful and total output power evolution with 4 carriers input signal

In this case the maximum useful power delivered by the TWTA with a 4 carriers input signal is 0.75 dB lower than maximum total output power and 1.75 dB lower than for a CW carrier. This result must be carefully taken into account when specifying TWTA operating point and maximum output power need. Nevertheless, TWTA Output Back Off specification is generally higher and generates a lower difference between useful and total output power.

Last important parameter concerns power consumption and efficiency. Fig 5 represents 4 carrier measurement and simulated results of the power efficiency versus total OBO.

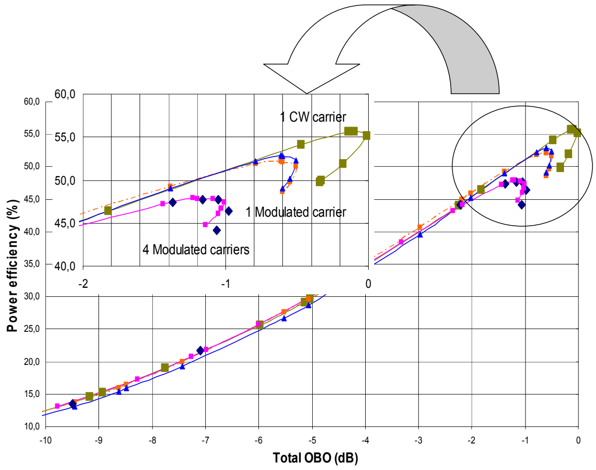

Fig.5. Simulated and measured power efficiency versus total OBO from CW to 4 carriers.

Important results to retain are:

1) Compared measured and simulated power efficiency versus total OBO shows very good agreement in all represented cases,
2) For more than 2 dB of OBO, CW and multi carrier power efficiency evolution are very similar,
3) Nearly 10 points of maximum power efficiency are lost from the CW mode to large multi carrier mode essentially due to signal waveform.

All results, with intermediate scenarios, not represented in this paper, are resumed in Table II.

Nb of carriers	**Total** output power difference from maximum CW Psat (dB)	**Useful** output power difference from maximum CW Psat (dB)	Efficiency points losses from CW maximum
1	0.5	0.7	3
2	1.1	1.7	9
3	1	1.7	8
4	1	1.8	8

Table II. Maximum total and useful output power and maximum efficiency evolution with number of carriers

As a final result, one can observe that 3 different OBO regions can be defined to well represent a linearised TWTA behaviour versus input signal waveform:

1) More than 4 dB total OBO: total output power, useful power and power efficiency are well represented by a CW carrier simulation,
2) Between 4 and 2 dB total OBO: total output power and useful power must be simulated with real input multiplex modulated signal. Power efficiency is still well represented with a CW signal simulation. Note that nearly all multi carrier satellite applications specify TWTA operating point between 4 to 2 dB,
3) Less than 2 dB total OBO: all three parameters need to be simulated with input multiplex signal and modulated carriers.

IV. Perspectives

Work is actually going on and concerns now more particularly the comparison of measured and simulated signal to intermodulation ratio (C/Im) versus output power TWTA operating point and signal waveform. First results show that this ratio, directly useable in budget link evaluation, is very sensitive to mixed amplitude and phase modulations like 16APSK or 16QAM.

V. Conclusion

This paper has presented a linearised TWTA measurement and simulation comparison taking into account for different input signal waveforms. Three operating point regions have been defined in order to well represent TWTA's non linear behaviour. Good results are obtained and show that a very precise simulation of power consumption, one major key factor in satellite payload design, can be done during budget link estimation.

Acknowledgement

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References

[1] E.Bosch, G.Fleury, "Space TWTs Today and their Importance in the Future," 22nd AIAA, 9-12 May 2004, Monterey, California.