HPA Non Linear Distortions in DVB-T Systems Simulation and Measurement

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ABSTRACT
The new digital standards adopted in Europe for broadcast communication systems use the Orthogonal Frequency Division Multiplexing (OFDM) technique [1][2] which is characterised by non constant envelope signals. This fact is in contrast with the employment of RF High Power Amplifiers (HPAs) which are typically non linear and utilised with low Output Back Off (OBO) in order to maximise the power efficiency. The consequent generation of InterModulation Products (IMPs) is responsible for Bit Error Rate (BER) degradation and Adjacent Channel Interference (ACI). Aim of this work is to present the Itelco experience in this topics, outlining the DVB-T performance dependence from the OBO. Moreover the improvements achievable by AM/AM-AM/PM predistortion and by RF non-linear memory compensation will be analysed both by simulation and measurements.

1. INTRODUCTION

Broadcast systems usually need to handle high power signals in order to maximise the area coverage of each transmitter. By this reason and to maximise power efficiency manufacturers and broadcasting providers force the HPA to work with the lowest OBO. Class–AB HPA are often employed because they represent a good compromise between linearity and power efficiency requirements. The IMPs generated by a HPA depends both on the amplifier non linearity [3] and on the signal envelope distribution. The IMPs power significantly increase when the amplifier works with low OBO and with high variable envelope, because of the great distortion introduced by the signal peak cutting in the amplifier saturation zone. It is possible to distinguish between in-band and out-band IMPs that respectively degrade the BER performance and the ACI of the communication system. OFDM signals are obtained by sums of a large number of independently modulated orthogonal carriers and, by the Central Limit Theorem can be modeled as complex Gaussian process with Rayleigh envelope distribution [4]. As a consequence OFDM signals exhibit a practical Peak-to-Mean-Power Ratio (PMPR) of about 10 dB and therefore they are very sensitive to non-linear distortions [5] [6] [7]. The predistortion techniques [8] represent an adequate solution to reduce the AM/AM and AM/PM instantaneous non linearities introduced by HPAs even if the envelope clipping cannot be avoided also for ideal predistortion [9]. A brief resume of the analytical background is presented in the following Section 2. The BER degradation and the output spectrum re-growth is evaluated in Section 3 both by computer simulations and real measurements on the DVB-T system developed at Itelco. some conclusions are outlined in Section 4.

2. THEORETICAL BACKGROUND

Non-linear distortions may be classified as instantaneous or with memory.

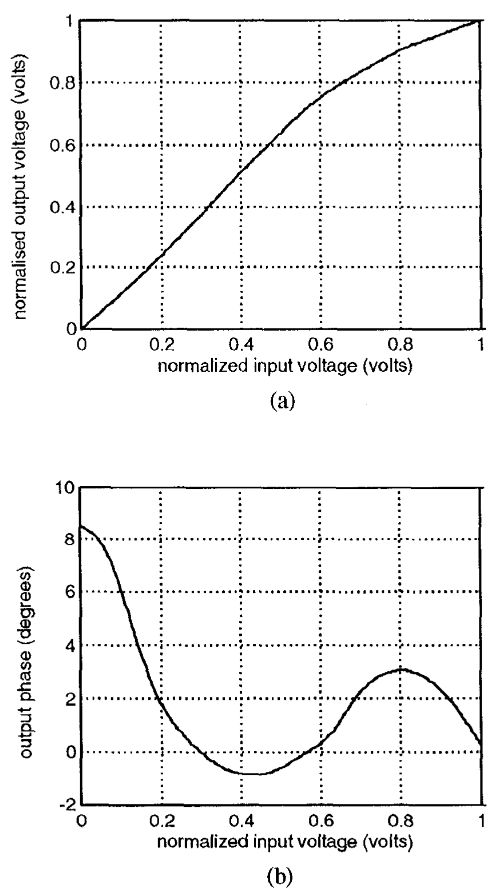


Figure 1: Measured distortions curve. (a) AM/AM, (b) AM/PM

If x(t) is the input to a non-linear instantaneous amplifier, expressed by

$$x(t) = A(t)\cos[\omega_0 t + \theta(t)]$$

the distorted output is:

$$y(t) = g[x(t)] = G[A(t)]\cos[\omega_0 t + \theta(t) + \Phi[A(t)]]$$

where G and Φ respectively represent the AM/AM and the AM/PM distortion curves and describe how the gain and the phase of the output signals change for different values of input power.
The measurement of AM/AM and AM/PM curves performed on a class AB amplifier for DVB-T system are showed in Fig.1.
The hypothesis of memory absence generally holds when all the circuit time constants are much smaller than the reciprocal value of the maximum envelope frequency. The predistortion is an adequate technique to compensate for AM/AM and AM/PM non linearity when non linear memory effects are not present.
The predistortion technique consists in a distortion of the input signal x(t) according to two curves that globally invert $G(A)$ and $\Phi(A)$ [9]. The cascade of the predistorting device with the amplifier gives rise to a global system without AM/PM and with a residual AM/AM that can be modelled as a soft limiter. Therefore the ideal predistorter compensates AM/AM distortions until normalised input voltage is under unity, but it does not avoid clipping when input exceeded this limit.
However Class AB HPA generally evidence non linear memory distortions in addition to the instantaneous ones [10], [11].

The memory effects occur when the non-linear system does not only depend on the present x(t) value but also on the previous ones.
Rapid thermal variations and biasing fluctuations of the amplifier chain are the major causes of non linear memory effects occurrence.
These effects are obviously exacerbated by the highly variable envelope of OFDM signals. In general all these effects can be seen as the variation of the amplifier operating point.
We can consider the memory distortions superimposed to the classical AM/AM and AM/PM.
The amplifier therefore may be represented by a set AM/AM-AM/PM curves each one associated with a different operating point.
In this condition the instantaneous predistortion techniques loose their effectiveness as reported in [12].

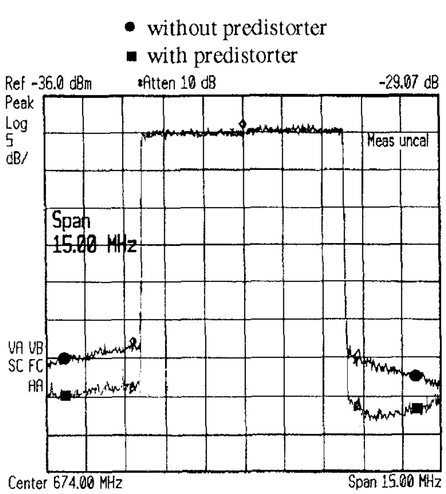


Figure 2: Measured output spectrum with OBO=7.9 dB.

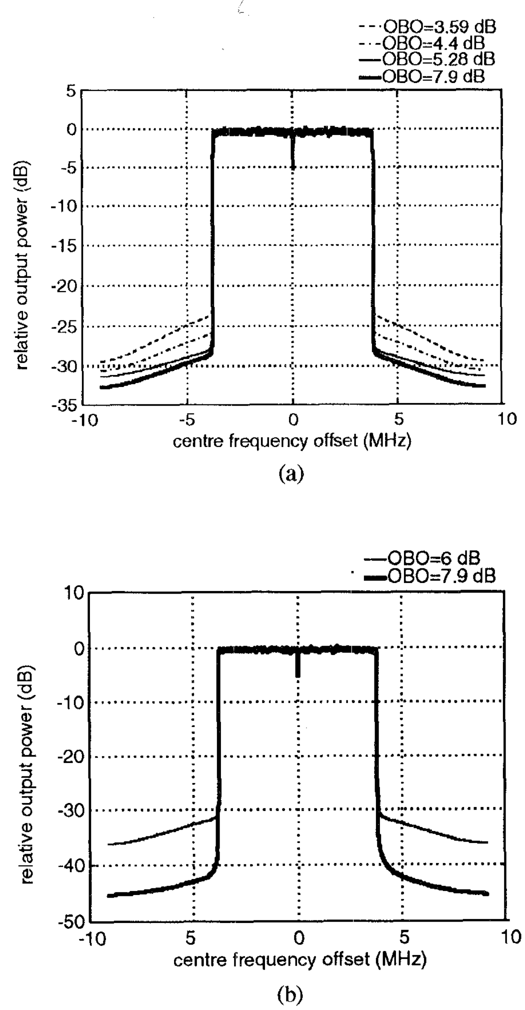
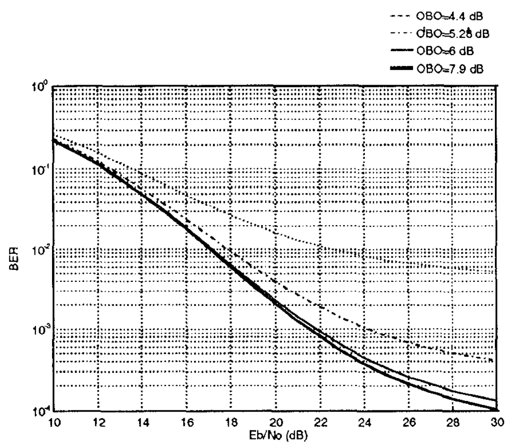


Figure 3: Simulated output spectrum. (a) without predistortion, (b) with predistortion.

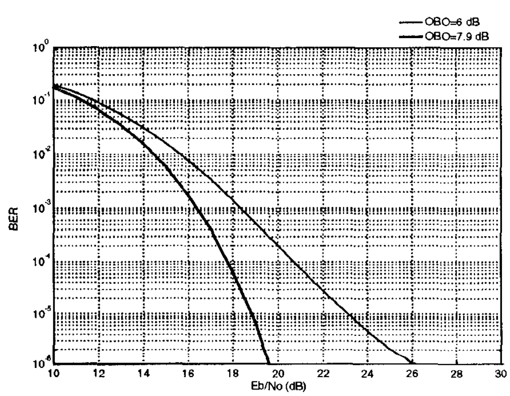
However, the memory distortions can be compensated by the stabilisation of the amplifier operating point obtaining a memory-effect free system which can be characterised by a single AM/AM and AM/PM curves as showed in [12] and well compensated by classical predistortion systems.

3. MEASUREMENTS AND SIMULATION RESULTS

Fig.2 shows the measured output power spectrum density with and without predistorter for an OBO value of about 7.9 dB, while fig.3 shows the simulated spectrum density for several OBO values.
A good agreement between measured and simulated results is outlined for the non predistorted amplifier. The simulations have been performed for 64-QAM modulation.



(a)



(b)

Figure 4: BER performance in AWGN channel without memory effect. (a) without predistortion, (b) with predistortion.

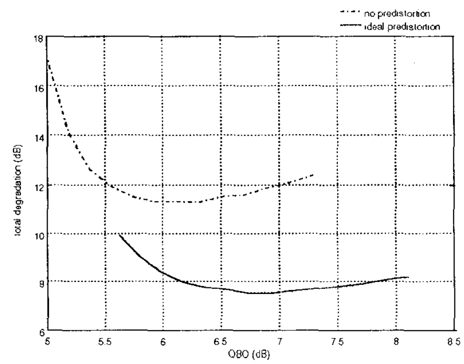


Figure 5: Total degradation curve for BER=10^{-3}.

The predistorter amplifier exhibits a 3 dB penalty of the ACI level (at 4.2 MHz from central frequency) on respect to the ideal predistorter simulation. The amplifier compensation was obtained by a new predistortion strategy presently under development at Itelco and results closer to the ideal ones are expected as soon as all the predistorter components will be optimised. However this and other topics will be object of future works.
It is evident by diagrams that when OBO increases the ACI level decrease as a consequence of the out-band IMP reduction.
A reduction of the OBO produces also a degradation of the BER performance as outlined by fig.4. This means that the power gain obtained by the OBO reduction is paid at the receiver by a higher E_b / N_o ratio in order to obtain the same BER performance. Hence the OBO value that optimises the BER performance is the one that guarantees the best trade off between this two competitive aspects.
A function called Total Degradation is defined to this purpose and is expressed as:

$$TD = (E_b / N_0)_{OBO} + OBO$$

where $(E_b / N_0)_{OBO}$ represents the signal to noise ratio needed to reach a definite BER in non linear environments.
Fig.5 shows the TD curves for BER=10^{-3} both with and without ideal predistortion. The difference between the two minimum TD values represents the effective power gain obtained by predistortion technique for an uncoded BER equal to 10^{-3}.
The OBO values that minimise the two curves represents the optimum value both in non predistorted and predistorted situation.
The optimum OBO value for non predistorted amplifier is lower respect to the predistorted one due to the high AM/PM distortion of the HPA at low input voltage value (see fig.1).

However a system working with this optimum OBO values produces an ACI level too high compared with the DVB-T standard specifications [2] that require an ACI, at 4.2 MHz from central frequency, 36 dB lower than the carrier level. Therefore an OBO higher than the one that optimise the BER performance is required in order to avoid expensive selective filtering of the amplifier output.

4. SUMMARY AND CONCLUSIONS

Sensitivity of DVB-T OFDM signal to non-linear distortions has been investigated characterising non-linear amplifier with AM/AM and AM/PM curves.

It has also been observed that memory effects are present and only compensating them, with appropriate RF techniques, it is possible to use with successful a predistorter to correct AM/AM and AM/PM distortions.

Simulated results show that BER performance and ACI of OFDM signals highly depends on the OBO level. Moreover strategies to choose the optimum OBO value has been suggested.

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