Analysis of Non-Linearities in the MEDIAN System

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Abstract: *The objective of the MEDIAN project developped in the ACTS programme is to study ans built a demonstrator of a WLAN at 60GHz, capable of a 155Mbps useful rate as well as ATM applications. The OFDM modulation scheme has been selected for the transmission. The present paper shows that, despite a typically non constant envelope of the modulated signal, the solid state power amplifier can work close to the 1dB compression point, thus ensuring a good efficiency to the system.*

Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is based on the transmission of a given set of signals on several subcarriers. Each sub-carrier is QAM or PSK/DCPSK modulated. While in Frequency Division Multiplexing (FDM) systems the signals conveyed on the sub-carriers do not overlap in frequency, in OFDM systems they overlap; however, they are, in frequency, orthogonal to each other, and thus they do not interfere, and can be demodulated by using a correlation receiver.

With respect to single-carrier (SC) systems, multi-carrier systems present the advantage of being more robust in applications involving channels affected by severe multipath propagation, such as in a mobile system. With respect to FDM systems, the OFDM architecture is more efficient in terms of bandwidth and the transceiver structure is simply based on DFT circuits.

However, in Radio Systems it is important to consider the distortion introduced in the Transmitter chain and in particular in the High Power Amplifier (HPA), due to the long-tailed distribution (Rayleigh) of the signal amplitude.

The object of this paper is to analyze the effects of non-linearities in the MEDIAN system, and take into account real 60 GHz technologies. In fact, the MEDIAN demonstrator will operate at 300 Mbps, in an indoor environment, at 60 GHz, and will be imbedded in the ATM reality. The modulator of the MEDIAN system is an OFDM modulator.

The paper is organized as follows. In the first section, a description of the HPA which will be in use in the MEDIAN demonstrator, will be given. The behaviour of the HPA will be described in terms of AM/AM and AM/PM characteristics at 58, 60, 61, and 62 GHz. In section 2, we propose a model for a general HPA, and we indicate the procedure for optimizing the model parameters in order to have an optimized fitting between the real HPA and the modeled HPA input/output curves. In the third section, a performance analysis is carried out in terms of maximum obtainable distance at a given frequency and for a given input power. Results are obtained by simulations in which the real HPA characteristics are taken into account. The discussion of the results and conclusion are reported in section 4.

1. The real HPA: measurements.

A0 solid state amplifier has been selected for the MEDIAN demonstrator; at each given frequency, the Output power has been measured versus Input power up to the saturation level, by the mean of a power meter, the input signal being a CW generated by an impatt diod.

Fig.1 shows the block diagram of the test bench used for AM/AM measurement. Direct reading frequency meter enables to adjust the frequency input. Power reference input is made to the output plan of isolator 2. the variation of the input power is gotten by direct reading attenuator, adding in steps of 1 dB up to 30 dB. HPA output power is read on power meter increase of +10 dBm.

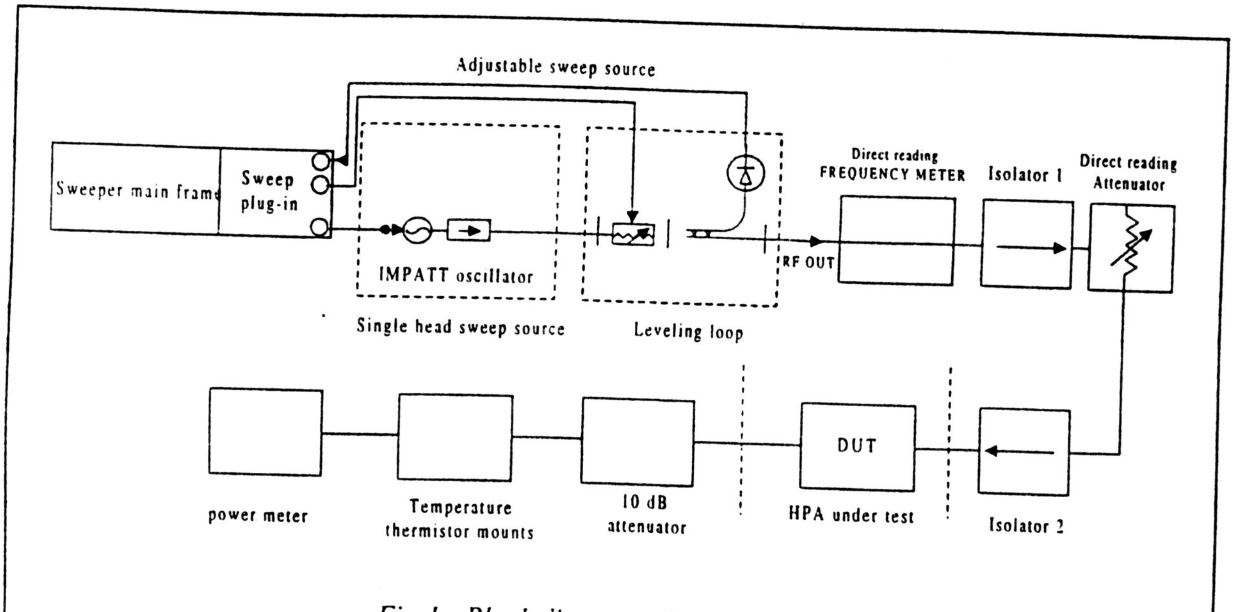

Fig 1 - Block diagram of the test bench

Other measurements using a Network Analyzer have confirmed that for this particular amplifier, the AM / PM compression is quite neglectable (less than 1° shift between linear operation and compression operation) ; this result garantees the validity of the model below.

2. The modeled HPA: optimization of the model parameters.

The selected solid state model for the HPA imposes an input/output relation on the amplitudes only. If x and y are the complex envelopes of the input and output respectively, and if $u(t) = G\,x(t)$, one has:

$$y(t) = u(t)\cdot\frac{1}{\left(1+\left(\frac{u(t)}{\sqrt{W_{sat}}}\right)^{2p}\right)^{1/2p}} \Rightarrow \begin{cases} u(t) & u \ll \sqrt{W_{sat}} \\ \sqrt{W_{sat}}\,e^{j\arg(u(t))} & u \gg \sqrt{W_{sat}} \end{cases}$$

where:

W_{sat} *is* the output saturation power

G *is the* voltage gain

p *is an* approximate curve smoothness parameter

An additional important data is the the output power at 1 dB compression point. We define as P_{in1} the input power which produces the output power at 1 dB compression point.

The above model has been applied to experimental data obtained by Dassault Electronique on a specific HPA operating at 58, 60, 61 and 62 GHz. The parameters of the model have been optimized to obtain the best fit of the experimental data. Results of the optimization procedure show that the model follows very closely the experimental data. Table 1 shows the parameters values at the different frequencies, while Fig.1 shows as example the input-output relation of the real HPA and of the modeled HPA at 62 GHz.

frequency	Power Gain (dB)	Output saturation (dBm)	shape factor p
58 GHz	33.1	13.3	0.85
60 GHz	34.1	14.1	0.9
61 GHz	33.5	13.15	1.1
62 GHz	32.3	15.3	1.15

Table I - Optimized parameters values of the model at the different frequencies.

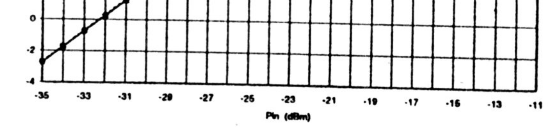

Figure 1. Input-output power relation at 62 GHz. Dotted line for real HPA. Full line for the modeled HPA.

3. Performance analysis

In the MEDIAN system, a number of parameters have been already set. In particular, the following assumptions have been made. The bit rate is 300 Mbits/s.

The trasmitting and receiving antennas gains G_{TdB} and G_{RdB} are such that $G_{TdB} + G_{RdB} = 22$ dB. The receiver noise factor is $F_{dB} = 6.6$ dB. The bit error rate (BER) has been set to 10^{-4}. In addition to free-space attenuation, it is supposed that an additional attenuation may be present which is fixed to $A_s = 9$ dB (oxygen absorption and other causes).

The modulation technique adopted in the MEDIAN system is Orthogonal Frequency Division Multiplexing (OFDM). An important parameter for performance system evaluation is the ratio between the guard time and the symbol period T_g/T_o which has been set to 0.2.

The effective HPA output power will be indicated by W_{ydBm}. When the input to the HPA increases W_{ydBm} increases; However, intermodulation noise also increases with a consequent degradation of the system performance (BER increases).

Under the above assumptions, the system performance have been evaluated by means of a simulation program in which the real HPA characteristics have been taken into account.

In order to obtain reliable results when OFDM modulation is in use, it is important to simulate the system for various OFDM symbols (see ref.1) and indicate whether the reported results correspond to average values or to the worst case value. The results reported in the present paper correspond to a worst case hypothesis.

Table II reports the results obtained at the different HPA operating frequencies, in terms of worst case maximum obtainable distance for a given HPA input power referred to P_{in1} (called input back-off). Results reported in Table II show that the use of the 62 GHz operating frequency is preferable over the 58, 60, and 61 GHz in terms of maximum reachable distance (which is in all cases higher than 10 and lower than 13 meters).They also indicate that at the higher operating frequency it is necessary to back-off the HPA more seriously; however, the output power is still higher at 62 GHz. A motivation for this result is the more knee-shaped input-output relation at the above frequency, is can also visible from the frequency increasing shape factor p found in the modeled HPA and reported in Table Y.

Figure 2 shows the results in more detail at the best operating frequency (62 GHz), for average values. Iso-probability curves in the (distance vs. the input back-off plane) are reported.

Finally, Fig.3 shows, still for 62 GHz, the margin enhancement as a function of the input back-off value for various OFDM symbols.

Table II. Maximum distance and optimum input back-off at BER=10^{-4} in the worst case at the different operating frequencies.

Frequency (GHz)	Distance (worst case)	input optimum back off @10^{-4}worst case (referred to the - 1dB saturation point)
58	10.1	+ 3.4
60	10.7	+ 3.5
61	10	- 2.5
62	13.03	+ 1.3

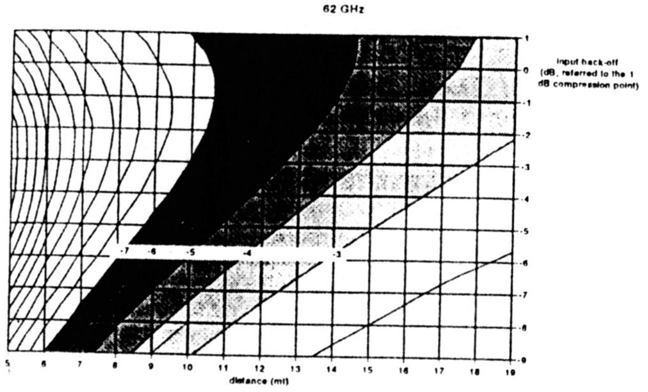

Figure 2. Input back-off referred to the 1dB compression point as a function of the distance and BER

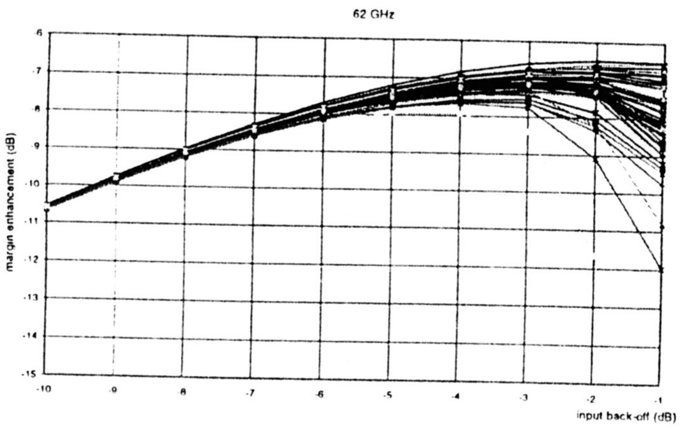

Figure3. Margin enhancement as a function of the input back-off

Conclusions

The OFDM is a quite performing scheme for multipath environnments; the results above show that, despite a typically non constant signal envelope, a good efficiency can be ensured for the system by working close to the amplifier saturation, which is of course important for future applications where portable terminals are limited in energy.

References

M.G. Di Bendetto and P.Mandarini "An application of MMSE Predistortion to OFDM system", IEEE Trans. on Comm., in press.