An Accurate Complex Behavior Test Bed Suitable For 3G Power Amplifiers Characterization

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***Abstract* —. In this paper, we propose a realistic, accurate, versatile and thermal-free complex behavior test bed suitable for 3G power amplifiers Characterization. The measurement results using the proposed test bed of a 90-Watts peak power amplifier based on Motorola-LDMOS class-AB amplifier are presented for several signals excitations (W-CDMA, CDMA2000, 8-Tones). These results show a great discrepancies with those obtained by a vector network analyzer (HP-8510C) with a CW excitation for both AM/AM and AM/PM curves. This test bed can also be used for the investigation of the memory effect in RF power amplifiers. This paper presents some measurements that point out this capability. This system has potential benefits in the area of non-linear behavior modeling of power amplifiers and synthesis of accurate predistortion function for linearization purposes.**

I. INTRODUCTION

The high power RF amplifier characterization and modeling has been subject of several studies in the last few years. This attention is explained by the need of a precise and representative behavior model of the non-linearity in design of the high power amplifier and linearizers. This need is particularly perceived in the new wireless communications applications where power amplifiers are derived by wideband digital modulated signals with high peak to average power ratio (e. g. 3G applications signals).

In [1], authors present a dynamic measurement method based on two-tones intermodulation calculation to solve the insufficiency of the static method based on CW signal sweep in the case of varying envelop signals. Furthermore, a non linearity characterization method, in [2], exploiting the similarity between a two-tones test and a BPSK signal test shows a dependency of the non linearity model on the data rate of the signal applied to the input of the power amplifier. Moreover, the authors in [3] show a substantial difference between pulsed, multi-tones and CW measurements applied to an LDMOS power amplifier.

Thus, the dependency of the measurements results on the input signal calls to characterize the power amplifier in conditions as near as possible to the real life conditions to be able to predict its distortions with accuracy.

In this paper we present an automated, precise and versatile test bed to characterize a high power amplifier feed with a modern wideband signal such as WCDMA and CDMA2000 (SR3). In the first section we present the line-up of the high power amplifier used for the measurement. In the second one, we show the details of the new proposed test bed. In the last section, we discuss the obtained results from this test bed and compare them with those obtained from a vector network analyzer and a peak power analyzer. We show also some measurements results highlighting the memory effect phenomenon in the behavior of the amplifier

II. TEST CIRCUIT

A three-stage power amplifier for wireless communication band of 1930-1990 MHz is built for experiment in this work. Its final stage is based on the 20-Watt class AB power amplifier, Motorola LDMOS MRF19085. The second stage is built on the LDMOS MRF19045 amplifier. The first stage is used as a gain block to drive the two other stages. The overall small signal gain of these amplifiers is 58 dB. Its output power of 1dB gain compression is about 49.5 dBm.

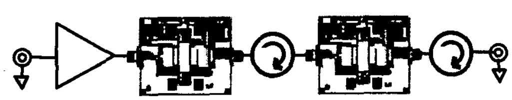

Fig.1. 90 Watt peak power amplifier Line –up

III. TEST SETUP

Figure 2 shows the proposed test bed configuration. This test bed includes the SMIQ Vector Signal Generator in combination with I/Q Modulation Generator AMIQ to generate a digitally modulated signal programmed and set with the Software WinIQSIM™ (ver. 3.6) from Rohde

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and Schwarz. This combination with the SMIQ-B47 option which provides special baseband filters for an enhancement of the adjacent-channel power ratio (ACPR) are used to generate a CDMA2000 and W-CDMA signal to derive the power amplifier to measure. The figure 3 shows the double channel down-converter used to translate input and output signals to an intermediate frequency IF. Attention is especially taken in the design of the down converter in order to get the same mixing function in the two paths. Moreover, an external IF calibration may be applied in order to compensate for the frequency-translation device effect in the results. The IF1 and IF2 outputs of the down-converter feed respectively to the two baseband channels of the vector signal analyser 89610B. An IF frequency of 20 MHz is chosen in our work in order to use the maximum of the 40 MHz bandwidth of the VSA inputs. The Laptop in this test bed is used to run the vector signal analysis software for the acquisition of the two channels baseband waveform signals. It serves as well to collect the error vector modulation at the input and the output of the power amplifier. The delay calibration personality of the VSA is exploited to compensate for the delay between the two channels caused by the group delay of the device under test.

The characterization carrier frequency band of 200 MHz-3 GHz can be extended to millimetre frequency by just changing the mixer used for down conversion.

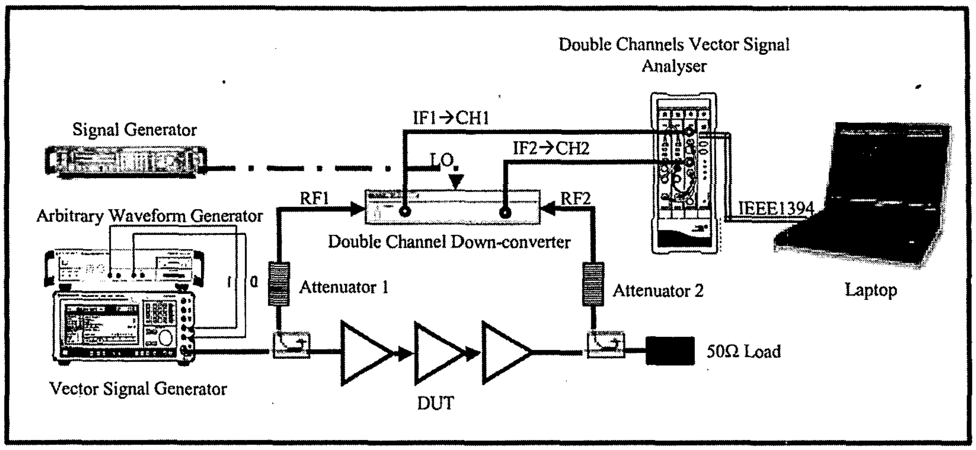

Fig. 2. Proposed Test bed block diagram

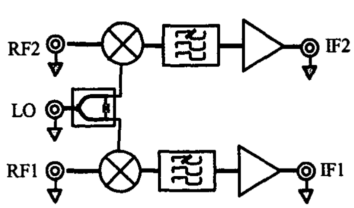

Fig. 3. Double channel down-converter

IV. MEASUREMENTS RESULTS

Using the proposed test bed several measurements have been made on the 90-Watts peak amplifier (20-Watts average). In the first step, we tried to compare the measurement results using the proposed test bed with those obtained with a peak power analyser (PPA) and a vector network analyser (VNA). The signal used to derive the power amplifier for the experiment with the proposed test bed and the PPA is a forward link, multi-carriers (3X) CDMA 2000 signal with a 3.6864 Mcps. The peak to average power ratio of this signal at 0.001% is 12.75 dB. As figure 4 and 5 show, we can observe a good agreement of the gain magnitude and phase compression obtained by a PPA and a great difference with those obtained with a VNA swept continuous wave. The similarity of the magnitude gain compression measurement from PPA and the proposed test bed is due to the fact that the two methods apply an instantaneous characterization. However, the PPA suffers from the lack of information on the phase. The disagreement of the VNA results compare to those obtained from the two previous methods is due to the long time sweep of the VNA. Moreover, The amplifier is not supposed to support a high output power in the high non-linearity region for a long time sweep. This can explain the high gain compression compared to the other results. The measured peak P 1dB of the test circuit obtained by the proposed test bed and the PPA is about 49 dBm. However, the value obtained by the VNA is about 46.5 dBm. This show the inaccuracy of the traditional VNA gain compression measurement compared to an instantaneous characterization based technique.

The proposed test bed was used as well to measure the complex gain compression of the test circuit for different signal excitations. In addition to signal CDMA 2000 used in the other experiments, we feed the test circuit with a forward WCDMA signal of 3.84 Mcps and a crest factor equal to 13.35 dB and an 8 tones signal with a 500 KHz spacing. Figure 6 and figure 7 show respectively the magnitude and phase compression for three signals. We can observe that there exists a great agreement of the complex gain compression for different excitation. The similitude of power amplifier behaviour when excited by three signal can be explained by their high crest factor of the three signals which imply a great variation of the signal envelop and thus a comparable operation condition.

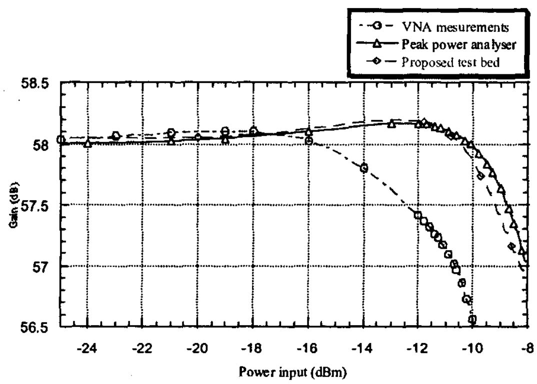

Fig. 4. Gain vs input power measurements with VNA with CW signal, peak power analyser and the proposed test bed with CDMA 2000 signal.

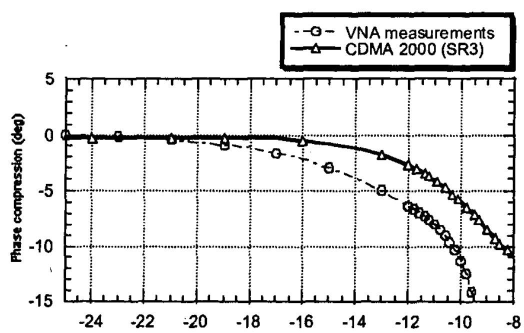

Fig. 5. Gain compression vs input power measurements with VNA with CW signal and the proposed test bed with CDMA 2000 signal.

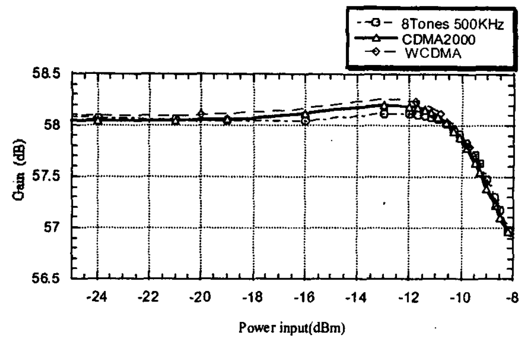

Fig. 6. Gain vs input power measurements for an 8 tones with 500KHz spacing, CDMA2000 (SR3) and WCDMA.

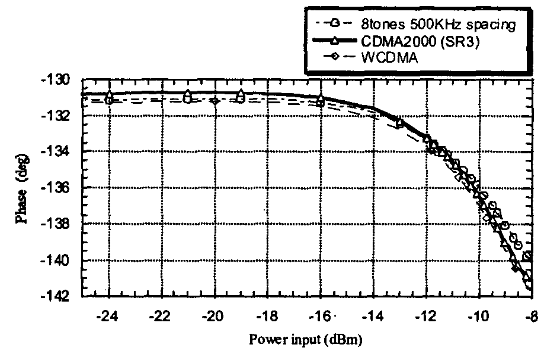

Fig. 7. Phase vs input power measurements for an 8 tones with 500KHz spacing, CDMA2000 (SR3) and WCDMA.

The proposed test is used as well to study the memory effect in power amplifier behaviour. In the literature [4-5], a two-tones signal is usually used to characterize this phenomenon. The drawback of these methods is that a two-tones signal cannot derive the power amplifier in the high non-linearity region because of its low peak-to-average power ratio. We propose in this paper to measure the memory effect under a fixed initial phase 8-tones signal with a crest factor equal to 9dB. Contrary to the literature we use the real-time capture of the input and output signals to the power amplifier to measure this phenomenon. Experiments took place for different tones spacing. Figure 8 and figure 9 show respectively the input and output waveforms in time domain and the output power vs input power of the power amplifier derived with an 8-tones signal with 100 KHz spacing. At this frequency spacing, a hysteresis is clearly observed. However, this phenomenon is not observed for an 8 tones signal with a 500KHz spacing as shown in figure 10 and figure 11. Other measurements were made for several frequency spacings reveal the presence of this phenomenon for a spacing frequency between about 20KHz and 130KHz.

This is can be explained by a thermal memory effect which is present at low frequency spacings as refereed in [6].

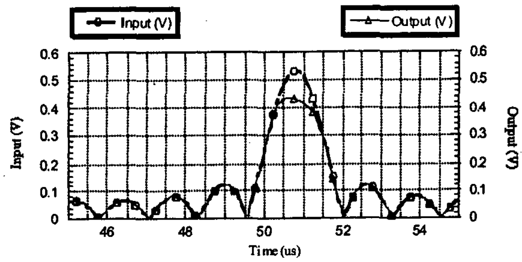

Fig. 8. Input and output waveforms for an 8 tones signal with a 100 KHz spacing.

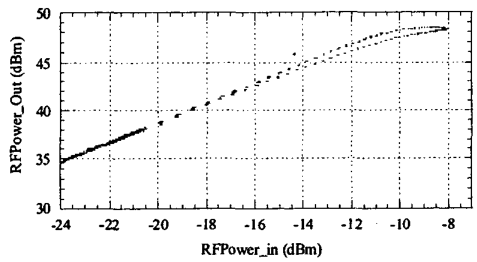

Fig. 9. Output power vs input power for an 8 tones signal with a 100 KHz spacing.

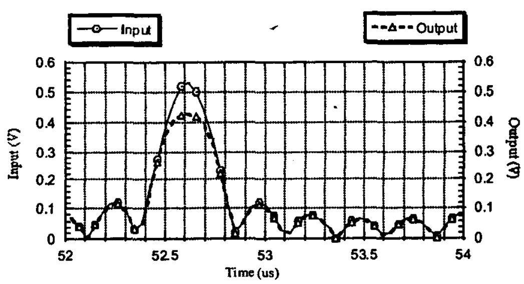

Fig. 10. Input and output waveforms for an 8 tones signal with a 500 KHz spacing.

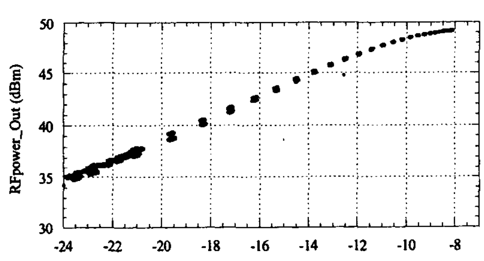

Fig. 11. Output power vs input power for an 8 tones signal with a 500 KHz spacing.

V. CONCLUSION

This paper proposes an accurate complex behaviour capture test bed suitable for the characterization of power devices under realistic test conditions. The test bed was used to characterize a 90-Watts peak LDMOS amplifier under different modulated band limited test signals. This test bed allows the thermal-free characterization of the amplifier over its whole power range. In addition, memory effects can be investigated using the developed test bed. Potential benefits from the results can also be collected using this system in the area of non-linear behaviour modeling of power amplifiers and synthesis of accurate predistortion function for linearization purposes.

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance of Mr. Chan Wang Park in this work.

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