DEVELOPMENT OF SETUP FOR ON-WAFER PULSE-TO-PULSE STABILITY CHARACTERIZATION OF GAN HEMT TRANSISTOR IN KU-BAND

Romain Pécheux, Guillaume Ducournau, Riad Kabouche, Etienne Okada, Christian Mondolot, Farid Medjdoub

DEVELOPMENT OF SETUP FOR ON-WAFER PULSE-TO-PULSE STABILITY CHARACTERIZATION OF GAN HEMT TRANSISTOR IN KU-BAND

Romain Pécheux [1,2], Guillaume Ducournau [1], Riad Kabouche[1], Etienne Okada[1], Christian Mondolot[2], and Farid Medjdoub[1]

IEMN - CNRS, Institute of Electronics, Microelectronics and Nanotechnology, UMR8520
[1]Av. Poincaré, 59650 Villeneuve d'Ascq, France
[2]Thales Optronique, 2 Av. Gay Lussac, 78990 Elancourt, France

romain.pecheux@etudiant.univ-lille1.fr; farid.medjdoub@iemn.univ-lille1.fr; guillaume.ducournau@iemn.univ-lille1.fr

ABSTRACT

We report on the development of a test bench to extract pulse-to-pulse (P2P) stability On-Wafer in Ku-band. The P2P stability is crucial for RADAR performances. GaN HEMT transistors are a promising candidate for RADAR application. However, they typically generate trapping effects, which can strongly affect the P2P stability. Two methods RMS and Standard Deviation based on temporal analysis are employed to extract the stability indicators. The main idea of the P2P test bench is the use of a homodyne demodulation to recover the envelop of the RF. This setup is also combined to an active load pull towards P2P stability test bench dedicated to the new generation of GaN HEMT transistors in large signal condition close to their operational mode.

1. INTRODUCTION

For future RADAR system, GaN HEMT power amplifiers are the most promising candidate to replace Travelling Wave Tubes (TWT) used up to now. To detect a target, the RADAR system processor has to discriminate the echoes delivered by moving targets (e.g. aircraft, ship) against the echoes delivered by fixed objects (e.g. land, sea) called clutter within received RADAR signals. This principle called Moving Target Indicator (MTI) is based on the detection of waveform variations (phase and amplitude) between successive received pulses. The variations occur for moving target and not for fixed objects. That is why, to prevent a false detection, the transmitter has to generate an accurate repeatability of successive pulses [1]. To evaluate the quality of a transmitter, the pulse-to-pulse stability (P2P) has been introduced as a figure of merit for RADAR applications. The P2P stability quantifies the fluctuation of the envelope (amplitude and phase) over the time between successive RF pulses. Although, GaN HEMTs have a great potential to deliver high power with high efficiencies (PAE=46% in Q-band) in millimeter wave range, trapping effects are typically generated, which have a significant impact on P2P stability of microwave amplifiers [1][3]. Therefore, the need to evaluate the P2P stability is crucial for GaN HEMT transistors. There are already some test benches to characterize the stability On-Wafer in S-band [4] but not yet at higher frequency. This paper presents the development of test bench to evaluate On-Wafer the pulse-to-pulse stability in K-band.

2. PULSE-TO-PULSE STABILITY

To quantify the stability of active component, spectral analysis can be employed [5] but temporal analysis is most commonly used to extract the stability. A specific pulsed RF test signal is used. The signal is composed of N periodic RF pulses defined by the period “T” and the pulse width “τ” or by the duty cycle expressed in percent by τ/T. After homodyne detection used to recover the pulsed envelop, the whole signal is sampled and the P2P stability is calculated at each sampling time “j” across the pulse (Fig.1). For an accurate measurement, all sampling has to fall in the same position in each pulse. To calculate the stability in phase or in amplitude two methods are usually used [5] :

- the Standard Deviation (SD) method, which reveals the difference between pulse and the mean pulse over the train:

$$S_x^{(SD)}(\boldsymbol{j}) = -10\log_{10}\left(\frac{1}{N}\left(\sum_{i=1}^{N}\left(x_{i,j}-\bar{x}_j\right)^2\right)\right) \quad (1)$$

$$\text{With} \quad \bar{x}_j = \frac{1}{N}\sum_{i=1}^{N} x_{i,j} \quad (2)$$

- the Root Mean Square method (RMS) which reveals the difference between consecutive pulse:

$$S_x^{(RMS)}(j) = -10\log_{10}\left(\frac{1}{N-1}\left(\sum_{i=1}^{N-1}\left(x_{i+1,j}-x_{i,j}\right)^2\right)\right) \quad (3)$$

For both expressions, the variable x corresponds to the amplitude and phase in the case of amplitude P2P stability and phase P2P stability, respectively. The indexes of x_{ij} stand for the j^{th} point falling into the i^{th} pulse.

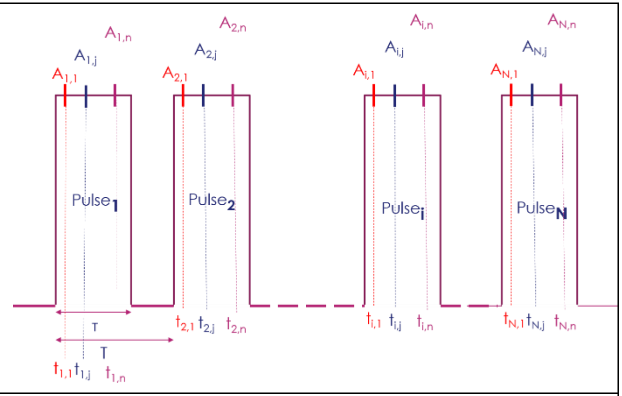

Figure 1 : Time domain pulsed RF signal

3. ON-WAFER STABILITY TEST BENCH

The P2P stability test bench is shown in Fig. 2 [5]. It is based on homodyne demodulation (mixer HMC8191) to capture the envelope of RF signal, by mixing the reference signal (1) and the amplified one (2). A phase shifter (Narda 4582) is used to adjust the RF and LO channel either in-phase or in quadrature-phase to extract P2P phase stability or amplitude stability, respectively. The Analog Digital Converter (ADC) (NI5922) with 15MHz sampling rate associated with 16 bits resolution samples the envelop. A low noise amplifier (LNA femto HVA-10M-60-B with a gain of 40 or 60dB) is placed before the ADC in order to reach the maximum sensitivity of the ADC. Finally, a GPS clock (PXI 6683) synchronizes all elements of this bench. All acquisition and P2P stability treatment are carried out by LabVIEW software. Several hundred pulses can be acquired with pulse width of at least 1µs and for different duty cycles from 1% to 99%.

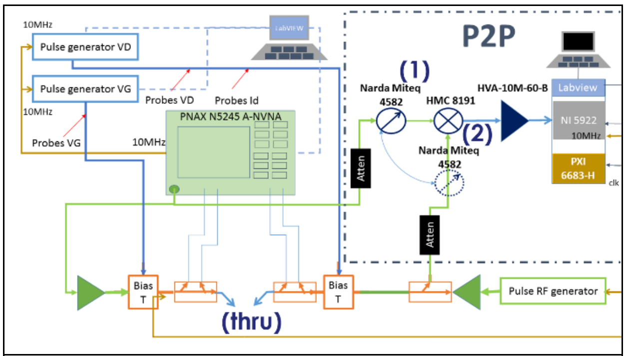

Figure 2 : P2P stability test bench associate with active load pull

In order to establish the stability floor of the test bench, a direct (thru) instead of the Device Under Test was measured with a signal of 100 pulses with a specific characteristics (pulse width and period), which demonstrated a good stability above 70dB. (Fig.3)

To characterize the stability of GaN HEMT transistors in large signal condition, the stability P2P test bench has to be added to an active load pull test bench Fig.2 [6]. In this way, the P2P stability could be evaluated for each transistor close to the operational mode.

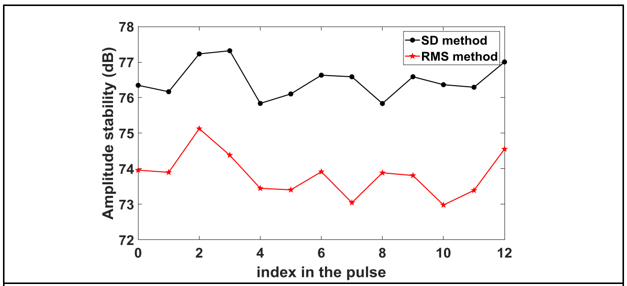

Figure 3 : Maximum amplitude stability obtained with SD and RMS methods in small signal condition

4. PERSPECTIVES

The achievement of this bench will be an important tool to characterize new generation of GaN HEMTs transistors close to their operational mode in Ku-band. Output power density, gain and efficiency are already extracted but the implementation of the P2P test bench adds a new information about the P2P stability, which is a crucial parameter for accurate RADAR system. In the future, it will be interesting to evaluate the P2P stability as a function of bias operation, pulse width, duty cycle and power amplifier classes.

5. REFERENCES

[1] J. Delprato, D. Barataud, M. Campovecchio, G. Neveux, C. Tolant, and P. Eudeline, “Measured and simulated impact of irregular radar pulse trains on the pulse-to-pulse stability of microwave power amplifiers,” *IEEE Trans. Microw. Theory Tech.*, vol. 62, no. 12, pp. 3538–3548, 2014.

[2] Dogmus, E. , Kabouche, R. , Linge, A. , Okada, E. , Zegaoui, M. and Medjdoub, F. (2017), High power, high PAE Q‐band sub‐10 nm barrier thickness AlN/GaN HEMTs. Phys. Status Solidi A, 214: 1600797. doi:10.1002/pssa.201600797

[3] D. Mccann, “Improving upon Pulse-to-Pulse stability in GaN RADAR amplifiers compromised by the presence of GaN trapping effects .,” pp. 634–637, 2015.

[4] S. Fakhfakh, L. Ayari, A. Martin, M. Campovecchio, G. Neveux, and D. Barataud, “On-wafer time-domain measurement of pulse-to-pulse stability for microwave power GaN HEMT,” *IEEE MTT-S Int. Microw. Symp. Dig.*, pp. 617–620, 2017.

[5] M. Cicolani, A. Gentile, S. Maccaroni, L. Marescialli, S. S. Integrati, and V. Tiburtina, “Pulse-to-Pulse Stability Characteristics of Robust Design Centered High Performances / Low Cost T / R Module,” vol. 0, no. September, pp. 1802–1805, 2006.

[6] R. Kabouche, E. Okada, E. Dogmus, A. Linge, M. Zegaoui, and F. Medjdoub, “Power Measurement Setup for on-wafer Large Signal Characterization up to Q-band,” pp. 1–3, 2017.