Summary and outcome of "*Smart Hardware Solutions for Future Mobile Backhaul Transmitters*"

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***Abstract*—This document will give a brief overview of the outcomes from the project "*Smart Hardware Solutions for Future Mobile Backhaul Transmitters*" for which I was awarded the 2013 MTT-S Graduate Fellowship. The main objective of the research project was to propose, design, realize and test radically new components for future microwave transmitters. The foci has been to develop new ideas and techniques that allows for larger bandwidth and higher efficiency of the power amplifiers to be used in the backhaul point-to-point microwave links. The project has contributed to two patents, three journal articles and four conference papers.**

***Index Terms*— Broadband amplifiers, Doherty, gallium nitride, GaN, high efficiency, microwave, MMIC, MTT-S Graduate Fellowship, power amplifiers, wideband.**

I. Introduction

DRIVEN by the users' shift towards more data intensive applications, the demand for wireless communication capacity is increasing at an incredible rate [1]. The increased data rate is accompanied by an upgrade of the wireless networks from 2G and 3G towards 4G network architectures, where wider channel bandwidths and new spectrum allocations combined with packet based protocols are defined to support the higher data rates. When aggregated in the network, this sets new requirements on the mobile network backhaul capacity [2]. Data congestion is therefore of increasing concern for mobile operators and manufacturers of telecom infrastructure equipment.

Fixed point-to-point microwave links are to a large extent used to implement the mobile backhaul. These links allow for a quick and cost efficient deployment of mobile networks for telecom operators. The increased data rate sets new requirements for microwave links and new technologies are needed to meet the demands for improved capacity while keeping the cost for the operator to a minimum. High order modulation schemes are therefore used to maximize the spectral efficiency and link capacity. Unfortunately, this has a detrimental impact on the electrical efficiency of the transmitters, necessitating the use of advanced building practice and active cooling techniques to ensure reliable operation. This increases the manufacturing, installation, and running costs significantly. Although wireless communication systems in general contribute to reduce energy consumption in the society, e.g. through the reduced need for travel, the inefficiency of existing transmitters correspond to a substantial waste of energy. Hence, both from an economical and environmental perspective it is very important to investigate novel transmitter solutions having significantly improved efficiency. Such transmitters will also be required for future potential solar cell driven sites. This project has therefore focused on how to improve the efficiency and bandwidth of the transmitter power amplifier. Novel ideas has been developed and tested at frequencies ranging from 2 GHz up to 9 GHz.

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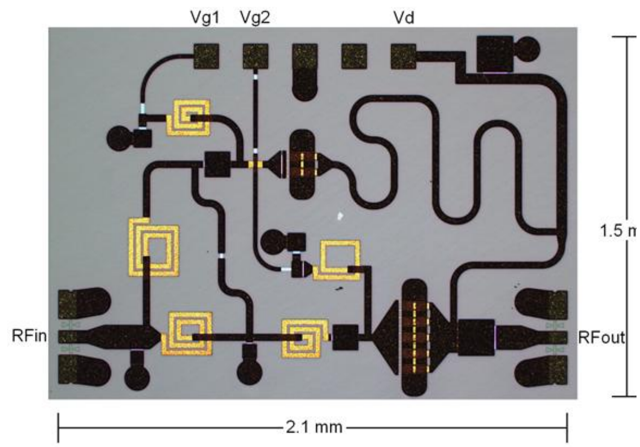

Fig. 1. Photo of the GaN MMIC Doherty PA in [6]. Measurements results showed that PAE_{avg} > 35% was obtained across the 6.8-8.5 GHz frequency range when employing a 10 MHz 7.8 dB PAPR signal. The chip dimensions are 2.1 x 1.5 mm.

II. Project Outcomes

Since the launch of the project in February 2010 most research activity has been focused on how to improve the efficiency and bandwidth of Doherty power amplifiers (DPAs). This work has resulted in six articles [3]-[8] and one patent application [9] where the bandwidth of the DPA by novel techniques has been extended to cover more than an octave of bandwidth. In the articles [3,4] it is shown how the theoretical bandwidth limit of the Doherty PA could be increased by modifying the impedance levels and using asymmetrical drain biases. A demonstrator circuit was fabricated and the measurements showed that drain efficiency >50% was achieved at both full output power and at 6 dB output power back-off across a 1.5-2.4 GHz frequency range. The work was selected as a finalist to the IMS 2012 student competition and was awarded with an honorable mention. The papers [3,4] have recently been complemented by modulated measurements in [5]. The presented idea was of great interest for the industry partner (Ericsson AB) who therefore has filed a patent application [9].

In the article [6] the need of larger bandwidth and efficiency in backhaul microwave link applications was pinpointed by presenting a DPA manufactured in a GaN MMIC process. During the design work it was found that the relatively high impedance levels associated with GaN PAs (compared to GaAs PAs) caused practical problems in terms of narrow transmission lines and high metal losses, and new techniques for designing DPAs was therefore developed. The reported results showed that an average PAE (PAE_{avg}) larger than 35% was obtained across a 6.8-8.5 GHz frequency range when employing a 10 MHz signal with 7.8 dB peak to average power ratio (PAPR). A photo of the circuit is depicted in Fig. 1.

At the time of writing this document, an article describing the design and measurements of a second GaN MMIC DPA is being submitted. The results shows that by employing the technique proposed in [3,4] a single input – single output GaN MMIC DPA with more than 32% PAE_{avg} over 5.8-8.8 GHz bandwidth was obtained. The signal used when measuring the PAE_{avg} was a 20 MHz signal with 8.54 dB PAPR. A photo of the circuit is depicted in Fig. 2. To the best of the authors' knowledge the results in this unpublished work and in [6] both have larger bandwidth than any other published MMIC DPA made at comparable frequencies.

To obtain bandwidths larger than one octave an unconventional brute-force design method was proposed in [7, 8]. A dual RF-input demonstrator PA was designed and more than 45% PAE at 6 dB output power back-off was achieved across a 1.0-3.0 GHz bandwidth. To the best of the authors' knowledge this is the larger reported bandwidth for any GHz-frequency PA with enhanced back-off efficiency.

Research has also focused on how to design dynamic load modulation PAs using varactor techniques. This work has resulted in an article [10] where it is shown how a varactor modulated Class-J PA can give high back-off efficiency The work was also of importance for the industry partner who therefore has filed a patent application [11].

III. Career Plans

The project has resulted in new knowledge of how to design highly efficiency and wideband power amplifiers. However, there is still a long way to go before these ideas end up in commercial products. I therefore hope for a future industry career where I can be a part of bringing new ideas to the market. The MTT-S Graduate Fellowship award has encouraged me to continue my research and motivated me to work even harder to fulfill my career goals.

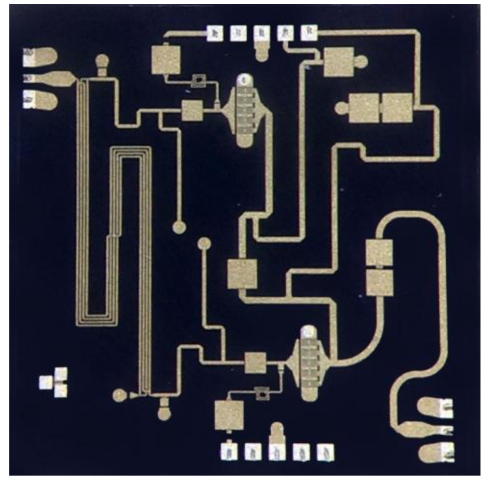

Fig. 2. Photo of the GaN MMIC Doherty PA designed according to the technique proposed in [3,4]. Measurements results showed that PAE_{avg} > 32% was obtained across the 5.8-8.8 GHz frequency range when employing a 20 MHz 8.54 dB PAPR signal. The chip dimensions are 2.9 x 2.9 mm.

IV. IMS-Impression

To participate at the 2013 IMS in Seattle was a truly amazing experience. It's a unique opportunity to meet and discuss research with top researchers and scientists from all over the world. I also had the opportunity to present the paper [7] for which I got a lot of good response and feedback.

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