RF GaN HEMT Product and Application for Base Station

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## **Abstract**

**The GaN HEMT was commercialized for RF applications in 2005. In last decade, huge efforts in cost reduction have been made in all processes from SiC substrate to packaging in real products. Currently, GaN HEMTs are widely used in RF applications especially mobile base station which requires low cost solutions. In this paper the history of GaN HEMT products and implementation of inverse Class-F and Doherty power amplifier for base station are presented.**

## Introduction

After its commercialization, the GaN HEMT has been used in a wide array of RF applications, such as base station, radar, space, defense and so on, in frequency ranges from UHF to mm-wave, owing to its excellent material properties such as wide band gap, high breakdown voltage, and high saturated electron velocity.

In the base station application, high efficiency power amplifiers are required to reduce operational (electricity) cost. The GaN HEMT is one of the best solutions for the requirement. However, device cost is also very important as Si-LDMOS, which is fabricated on low cost C-MOS process with reasonable efficiency and power characteristics, is still dominant in the base station market. This is especially true in low frequency bands of less than 2GHz.

In 4G-LTE and 5G telecommunication systems, many spectrums were licensed in 3 to 6 GHz (sub-6 GHz) in FDD and TDD operation. To reduce the number of radio units, multi band operation is also required. This means broad band power amplifiers are needed to support multiple spectrum, simultaneously. The GaN HEMT is a good candidate for this high frequency and broad band power amplifier.

## GaN HEMT Products for Base Station

GaN HEMT products were commercialized in 2005 from Sumitomo Electric Industry (formerly Eudyna in 2004 to 2009). The first product for a base station amplifier was composed of relatively large hermetic sealed packages with internal circuit using ceramic capacitors and discrete GaN die from a 3-inch wafer process [1]. The ceramic package was developed for multiple purpose including radar and space as well as base station applications. In the 4G LTE base station, high efficiency power amplifiers were required to reduce power consumption. The use of a Doherty amplifier efficiency enhancement design technique was one of breakthrough solution for the requirement. 4-inch wafer processes and low cost non-hermetic package were employed to cope with the low-cost requirement [2]. For 5G sub-6 GHz MIMO applications, numerous small power amplifiers are needed. Over molded plastic GaN HEMTs are the best solution for these systems. Recent efforts in 6-inch wafer fabrication has started to reduce the cost and increase throughput of GaN HEMT processes (Fig. 1).

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Fig. 1. Cost trend of GaN HEMT for base station.

To get higher efficiency, internal harmonic technics have been adopted in all products not only in the output side but also on the input side. We will introduce how to implement these design techniques in this presentation.

## GaN HEMT Application in Base Station

The amplifier in a base station operates around 8-9 dB backed off average power from saturation power. To enhance efficiency in this backed off region, a Doherty amplifier is typically used. As is well known, the Doherty amplifier is one of the load modulation techniques using two devices; main and peak amplifiers. The main amplifier reaches saturation at 6 dB backed off from combined saturation power in symmetric Doherty operation. This means the saturation efficiency in each amplifier (especially the main) is also very important. A two-step approach was taken to obtain the best class of efficiency in a Doherty amplifier:

1. Device level efficiency enhancement with harmonic control (inverse Class-F) circuit implementation.
2. Symmetric or asymmetric Doherty combining harmonic controlled devices.

## Harmonic controlled GaN HEMT

We employed an inverse Class-F operation to increase saturation efficiency [3]. The advantages of inverse Class-F is an easier implementation with simple L-C low pass type matching network, which is typically used in high power devices. Fig.2 shows the circuit schematic and a photograph of an internally partially matched inverse Class-F 100 W GaN HEMT, which consists of alumina and high dielectric substrate as inductive and capacitive components respectively. This single stage L-C network controls both fundamental and second harmonic impedance at the same time. Fig.3 shows RF power characteristics of the 100 W inverse Class-F GaN HEMT. More than 70 % drain efficiency with 100 W power at 2.1 GHz and 50 V operation.

  
 (a) (b)  
Fig. 2. (a) schematic of Inverse Class-F operation and   
(b) photo of 100W Inverse Class-F amplifier.



Fig. 3. RF power characteristics of 100 W Inverse   
Class-F GaN-HEMT.

## Broad band GaN HEMT Doherty Amplifier

Many variations of Doherty combining have been proposed. In this paper, a broad-band 1.8-2.2 GHz and 800 W high power three-way Doherty is highlighted.

The circuit implementation of a high-power asymmetric three-way 1.8-2.2 GHz GaN HEMT Doherty amplifier is shown in Fig. 4. Here a half-wave microstrip line is included in the load network of each identical peaking path for better flexibility in a practical implementation while providing sufficient bandwidth capability at the same time.

The test board of a three-way Doherty amplifier based on three dual-path GaN HEMT devices in metal-ceramic flange packages was fabricated on a 20-mil RO4350 substrate. At a 2 dB gain compression point and a supply voltage of 55 V, a peak output power (*P*2dB) of 59.5 dBm and a peak efficiency of 78 % were measured with a linear flat power gain of about 12 dB within the frequency range of 1.8-2.2 GHz (Fig. 5). From the test results it follows that a drain efficiency of greater than 50 % at 8 dB power backoff can be achieved. This means that for a 20 MHz LTE signal with 8 dB *PAR*, an average power of 120 W can be obtained with a drain efficiency of equal or greater than 50 % over most of the entire frequency range.



Fig. 4. Schematic 800 W Doherty amplifier.

A close up of a map

Description automatically generated

Fig. 5. Measured data of 800W Doherty amplifier.

## Conclusions

GaN HEMT evolution was discussed highlighting how device cost has been drastically decreased by packaging improvements and increase in wafer diameter. High efficiency inverse Class-F and broad-band high power Doherty designs were presented showing multiband capability in the range of 1.8-2.2 GHz supporting B1: 2.1 GHz, B2:1.9 GHz and B3:1 .8GHz operation.

## References

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Acronyms

HEMT: High Electron Mobility Transistor

LTE: Long Term Evolution

MIMO: multiple-input and multiple-output