Advances in GaAs/GaN Technology and Design for T/R Module Application

Synthetic Aperture Radars (SARs) and Active Electronically Scanned Antenna (AESA) systems have demonstrated to be the effective solution for next-generation radar systems for Land, Naval, Avionic and Space applications.
These systems are based on core elements like the Transmit-Receive (T/R) Module which can be adopted in several hundreds or even thousands elements and whose demanding performance, design and implementation will force the development of component technologies.

For this reason, key system technologies (i.e. T/R modules) are strategic and in full evolution.

The continuous request for improved system performance at low cost oriented world-wide professional electronic industry to adopt COTS wherever possible and, when necessary, to design custom components on “dual-use” technologies (TOTS) made available by commercial open Foundries. Such approach for procuring GaAs/GaN “high-tech” components for professional electronic application revealed however to be less attractive, and in some cases at high risk. In fact, the extreme volatility of the commercial RF technology sector implies obsolescence and at times reliability issues while critical high performance components (i.e. GaAs/GaN HPAs) are often prone to export license limitations.

To overcome such drawback, many defence companies are developing independent technological capabilities, with the specific aim to control “enabling technologies” that are still necessary to ensure standing at the system-level competitive edge at the.

Up to now the vast majority of solid-state microwave communication and radar electronics is based on GaAs semiconductor technology. Mature active device technologies (MESFET, PHEMT, MHEMT and HBT) are currently implemented to satisfy present market requirements, worth approximately more than 20 billion euros.

Such technologies have found a specific usage within the Tx/Rx modules for Radar, Avionics, Missile and Space applications.

While presenting technological capabilities at the Selex ES GaAs/GaN Foundry, reducing as much as possible the above limitations, we will show the power PHEMT technology, as applied for the production of high performance MMICs for T/R Modules. In particular, manufacturing procedures are based on two highly reproducible and consolidated PHEMT production technologies: the 0.5 µm Gate length technology for applications up to 10 GHz, and 0.25 µm PHEMTs for applications up to 18 GHz.
Nevertheless, GaN HEMTs have recently become a commercial reality, being an increasingly popular choice when high power, linearity and robustness are required.

AlGaN/GaN HEMT power amplifiers have been aggressively pursued recently, due to their superior material properties, such as wide band gap, high breakdown electric field, high 2-Dimensional Electron Gas (2DEG) carrier density and mobility.

The high breakdown electric field allows AlGaN/GaN HEMTs to operate at high drain voltage, whereas the high 2DEG carrier density and mobility translate into high current density. High operating voltage and high current density guarantee a superior high power density and high efficiency, which reduces the required chip size. Chip-level impedance is therefore higher, thus easing the impedance matching challenge.

Given the large breakdown voltage of HEMT devices in AlGaN/GaN technology, it is also possible to adopt such technology to design robust receiver components. GaN technology has in fact already demonstrated the capability for low noise performance: even with a technology optimized for high power applications, good and robust Low Noise Amplifiers (LNA) can be implemented.

Furthermore, the high power handling of the same technology justifies its adoption also for SPDT switch design and implementation, thus replacing the actual ferrite circulators in T/R modules.

For the abovementioned reasons, particular attention will be posed to the Foundry's involvement in National and European research programmes, aiming at achieving an industrially viable GaN-HEMT MMIC technology within the next two years.

This technology, in fact, still requires a careful analysis to obtain the highly reliable, high performance devices, thus avoiding issues related to current density reduction due to surface states and buffer traps, gate and drain lag transients, or RF performance limitations due to non-linearities in the source resistance.

Possible solutions to these detrimental effects have been identified in the optimisation of SiN passivation and introducing field-plated layouts. Thanks to the use of field plates, manufacturers are now able to add such devices to their HEMTs portfolio, capable of operating at higher drain voltages.

In this scenario, Selex ES Foundry has developed and optimized the GaN-HEMT process for manufacturing high power HPAs and robust LNAs as requested by narrow- and wide-band applications.

The 0.5 µm GaN technology has been developed for high-performance and reliable power applications up to C-Band. This technology shows a very low Current Collapse effect (<5%) and, as a consequence, an Output Power Density that increases linearly with the Drain bias, up to 7 W/mm at 25V Vds with a very stable Drain Efficiency.

The technology based on 0.25 µm gate length device, actually in assessment for Space Qualification, has been developed for power applications up to Ku-Band frequency.

The Output Power Density for this process is comparable to the half-micron solution and shows a linear increase with the Drain bias, for Drain voltages in the range 15-30 V, while Drain Efficiency remains almost constant and higher than 60%.