High Power SSPA Based on GaN HEMTs for S-band Military Radars

Byeong-Ok Lim, Gil-Wong Choi, Bok-Hyung Lee, Jae-Hee Yoon,
Hee-Chang Park and Hyoung-Ju Kim
Core Technology Group, Samsung Thales
Yongin-City, Gyeonggi-do, Korea, Byeongok.lim@samsung.com

Abstract

In this paper, we have developed a high power solid-state power amplifier (SSPA) for S-band military radars. The SSPA consists of a high power amplifier (HPA) module combined GaN based power amplifier pallets, a drive amplifier (DA) module, a digital control module and a power supply unit. The SSPA shows the total output power of 62 dBm in S-band.

Keywords : S-band, SSPA, Transmitter, GaN HEMT

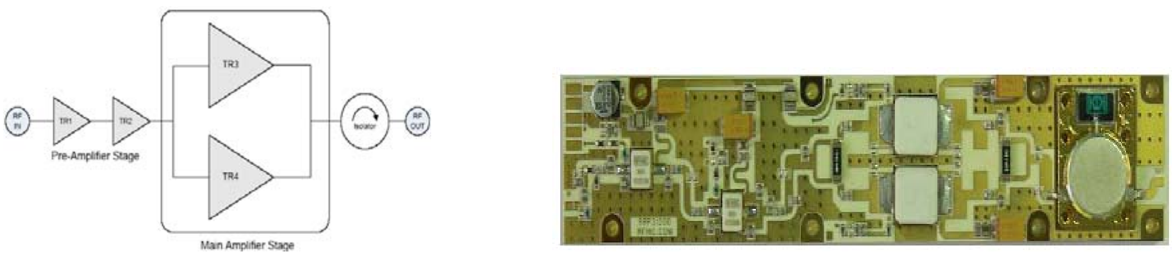
1. Introduction

A high power amplifier with an output power of several kilo-watts is the core element of the radar system for the military application. In past decades, the vacuum-tube electronics such as TWTA (Traveling Wave Tube Amplifier) are used for the high power amplifier. However more powerful solid-state devices have recently become available and then the SSPA is very popular research topic due to its more reliability characteristics than TWTA's such as a power degradation problem [1-2].

The SSPA based on Si BJT and GaAs FET must be constructed from a number of modules to attain a power level of several kilo-watts. So many power modules not only increase the complication of a control system, DC power distribution and RF signal combination but also occupy a great physical space. To achieve a complete high power amplifier for the military applications, the increased output power of each module can effectively decrease the required total amount of modules. In advance of the device technology of GaN with wider bandgap and higher thermal conductivity than GaAs and Si, the SSPAs are able to become more compact and then be used for replacement of the TWTAs in the military radar system [3-4].

In this paper, the S-band SSPA which consists of a HPA module, a DA module, a digital control module, and a power supply unit was designed and fabricated. In order to realize the HPA module, the combining configuration of the GaN HEMTs based power amplifier (PA) pallets was used. The performance of the developed SSPA was measured in the pulse operation.

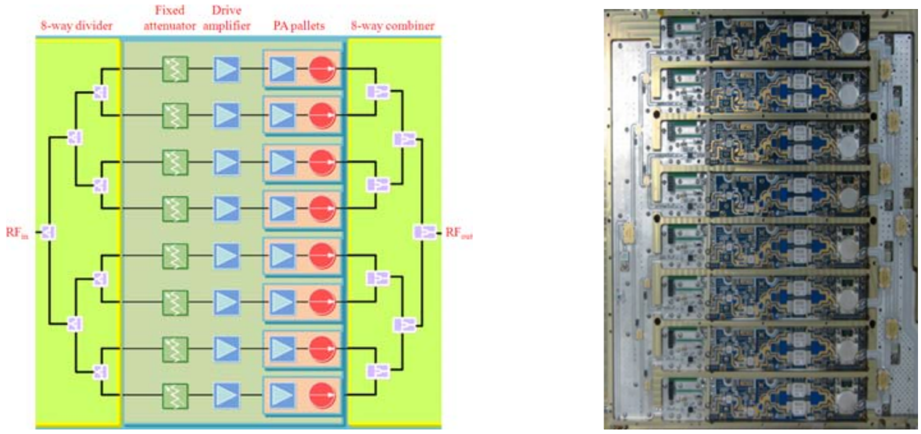
2. GaN HEMTs based High Power Amplifier (HPA) module



(a) (b)

Figure1: The schematic (a) and the top view (b) of the PA pallet based on GaN HEMTs

The PA pallet consists of a main amplifier stage, a pre-amplifier stage and a circulator as shown Figure 1. Two GaN-based HEMTs inter-connected in the parallel balanced configuration are used to improve the VSWR and the reliability characteristics in the main amplifier stage. The GaN-based HEMT is commonly used in the HPA module. Compared to other material devices, the GaN-based HEMT shows the excellent performance such as high power, high efficiency, and high gain performance. The pre-amplifier stage was used in a cascade configuration for low input power. The circulator was used to increase the isolation performance of the power amplifier pallet. In the pulse operation with a width of 200 μsec and the input power of 24 dBm, the fabricated PA pallet shows an output power of 55 dBm, a power gain of 32 dB and a drain efficiency of 40 %. The measured gain flatness and pulse droop are 0.7 and 0.3 dB, respectively.



(a) (b)

Figure 2: The block diagram (a) and the picture (b) of the HPA module

The S-band HPA module was designed to achieve the overall output power and gain, an efficiency, and the effective thermal radiation for high reliability. It consists of the input dividers, the output combiners, the drive amplifiers, and the PA pallets on a PCB board. The block diagram and the photograph of the developed HPA module are shown in Figure 2. The input dividers and the output combiners are presented by LTCC (Low Temperature Cofired Ceramic) technology for high power applications. Between the PA pallets and the input combiners, the fixed attenuators and the drive amplifiers was used for stabilizing and driving of the input power level. The PA pallets combined with 8-way configuration are used to achieve the desired output power and total gain.

3. Solid State Power Amplifier (SSPA)

3.1 Specification

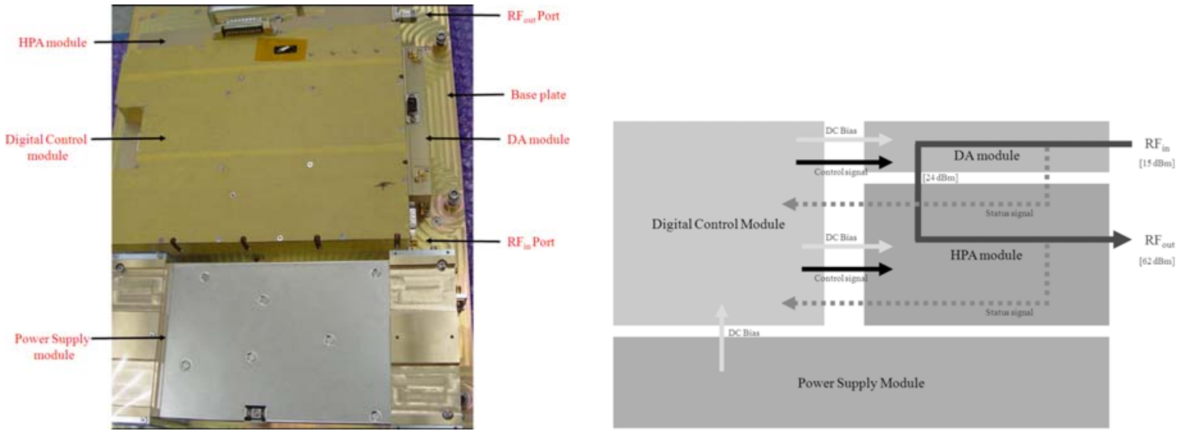
The SSPA was designed to operate in the pulse mode with a width of 22 μsec and the maximum duty cycle of 15.5 %. To derive the total output power of 62 dBm from incoming power of 15 dBm, the SSPA has to have the power gain of 47 dB in S-band. The pulse droop is kept under 0.5 dB for flattening the output power. The designed SSPA has some functions of the error detection such as excess reverse power due to mismatching of cable interconnection, the high temperature alarm in the HPA module, and the different duty cycle of the input control signal. The specification of the SSPA is listed in Table 1.

Table 1: The specification of the SSPA

Frequency	S-band
Input power	15 dBm
Output Power	62 dBm
Duty Cycle	15.5 % (Max)
Pulse width	22 μsec
Pulse Droop	< 0.5 dB
Total Gain	47 dB
Error detection	Reverse power, Temperature, Duty cycle

3.2 Configuration

As shown Figure 3(a), the HPA module which has high thermal radiation is placed upon a base plate designed to flow the cooling air. Total size of the base plate mounted on our radar system is 360 × 550 × 110 mm^3. Due to the limited area of the SSPA, the digital control module is constructed on the HPA module. The power supply unit is a commercial product operating on 3 phases 200 V from the main power source of the radar system.



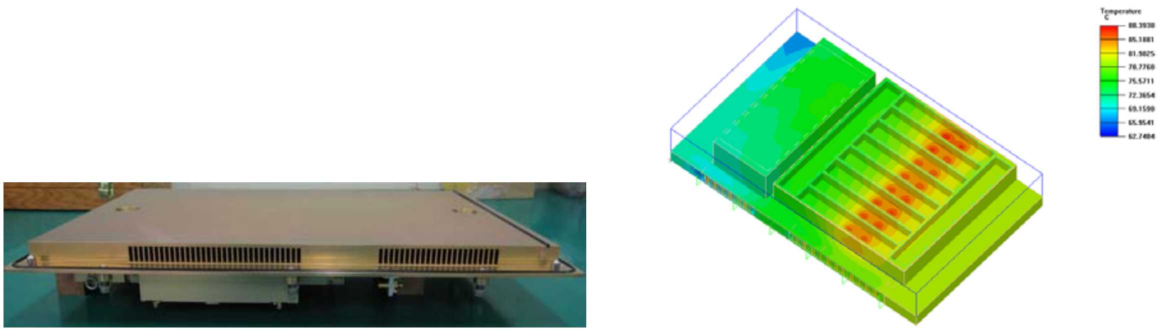
(a) (b)

Figure 3: The configuration (a) and the signal flow (b) of the SSPA

In figure 3(b), the flow configuration of DC, RF and control signals is shown. The digital control module distributes the required DC voltages and control signals to each amplifier module. It also detects some error bits so that protects the other modules against the false operation of the SSPA.

3.3 Thermal consideration

Due to the high thermal radiation of the HPA, the SSPA with the thermal release structure had to be designed. The cooling air with 70.62 CFM flows in the base plate such as Figure 4 (a). Using the commercial simulator, ANSYS ICEPAK, the thermal effect was simulated. From the simulated results in Figure 4 (b), the maximum temperature of the SSPA was 88.4 °C. It is the safe value in the pulse mode operating condition of the radar system.

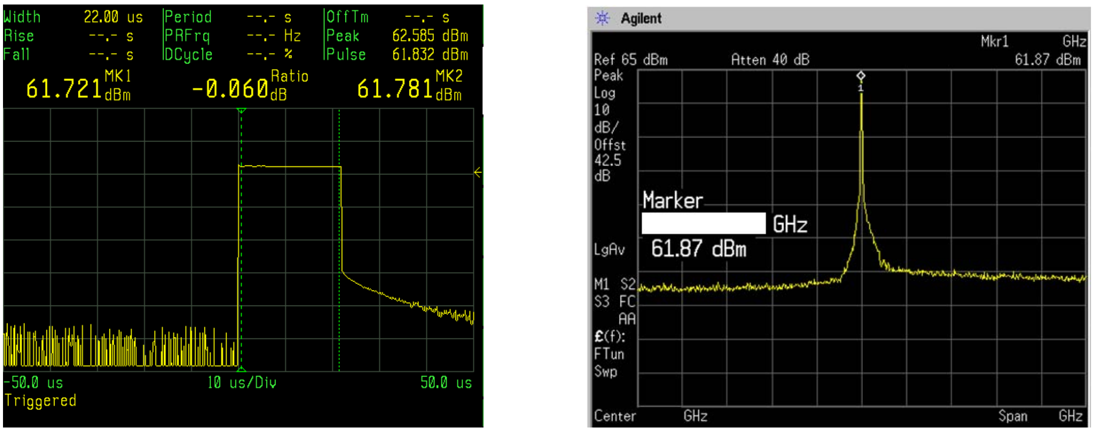


(a) (b)

Figure 4: A side view of the base plate (a) and thermal distribution (b) of the SSPA

3.4 Characteristics of the SSPA

The performances of the developed SSPA were measured in the pulse operation with a width of 22 μsec and the input power of 15 dBm. In Figure 5 (a), the SSPA shows an output power of 62 dBm, a power gain of 57 dB and a pulse droop of 0.06 dB. The measured falling and rising times of the output power were 4 nsec and 10 nsec, respectively. From the results of the spectrum analyze in Figure 5 (b), the spurious level shows below -40 dBc in band.



(a) (b)

Figure 5: Output power performance (a) and in-band spurious characteristic (b) of the SSPA

4. Conclusions

In this paper, the S-band SSPA has been developed for the military radar system. It consists of a HPA module, a DA module, a digital control module, and a power supply unit. The HPA module was fabricated by using the GaN HEMTs based power amplifier. The developed SSPA obtained the output power and the power gain of 62 dBm and 57 dB, respectively.

References

[1] M. Hanczor et al, “12 kW S-band Solid State Transmitter for Modern Radar Systems,” IEEE Transactions on Microwave Theory and Techniques, Issue 12, pp. 2237 - 2242, Dec. 1993.
[2] Ki Ho Kim et al, “1.5 kW, S-Band Solid-State Pulsed Power Amplifier with digitally controlled Automatic Gain control Circuit,” Asia-Pacific Microwave Conference, Yokohama, pp. 714 - 717, Dec. 2006.
[3] A. Maekawa et al, “Gallium Nitride Microwave Transistor Technology for Radar Applications,” MTT-S International Microwave Symposium Digest, pp. 722 - 725, June 2006.
[4] Aethercomm, “Gallium nitride microwave transistor technology for radar applications,” Microwave Journal, Vol. 51, No. 1, pp. 106, January 2008.