Demonstration of Flexible 240W GaN SSPA for Space Application

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INTRODUCTION

EADS Astrium has for some time been investigating the use of Gallium Nitride GaN technology targeted at future SSPAs for communications and navigation applications. Initial work was focused on establishing that GaN technology had achieved a sufficient level of technological maturity to allow the credible use in space. Qualification work has now been successfully completed against EADS Astrium requirements which are based on industry standards for microwave semiconductors. It has been established [1], that the MTTF for GaN devices at a junction temperature T_j of 150C to 160C equals or exceeds that of GaAs at a junction temperature T_j =110C as illustrated in Fig.1.

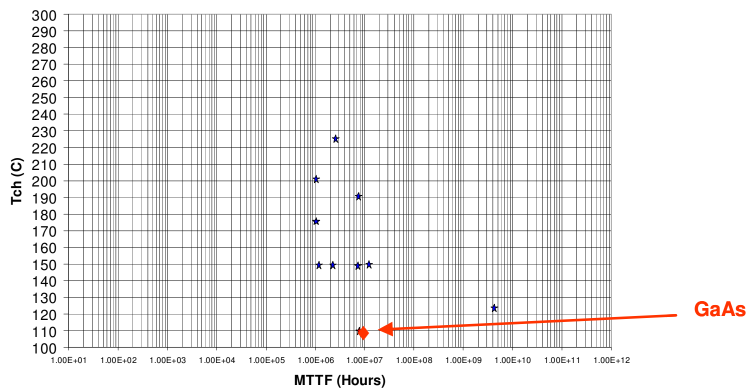

Fig.1. GaN Reliability Data from: Cree, Nitronex, RFMD, Triquint, SEDI, Mitsubishi, HRL, MIT

The paper presents the performance of a 200W S Band Gallium Nitride (GaN) SSPA with flexible output power capability. This pre-flight demonstration unit incorporates proven flight design features, and all active components are fully space qualified. By incorporation of elements of the EADS Astrium adaptive “Flexamp” technology, the SSPA demonstrates high efficiency over a 6dB output power range, with a consequential DC power saving of over 80W at 6dB Output Power Back-off compared to fixed class A/B operation. It is considered that this SSPA pioneers the way towards a new class of EADS Astrium high power spaceflight SSPA products incorporating GaN technology. The SSPA measures 213 mm x 90 mm x 56 mm when including the EPC, and has a mass of 1200 grams.

SSPA ARCHITECTURE

The amplifier architecture is shown in Fig.2. It is seen that the design features commandable automatic level control (ALC), this being a feature of at least one of the SSPA’s target applications.

Input signal pre-amplification and control is carried out in an adjustable GaAs MMIC based input stage which has a sense input driven from an output RF signal detector situated just prior to the final output isolator. The input stage is implemented as a conventional metal package MCM. Medium power linear amplification is provided by a two stage GaN driver amplifier. This MIC module is illustrated in Fig. 3. It was necessary for the mechanical envelope of the driver module to exactly fit the available area in the overall RF housing which is a standard design used on several EADS Astrium flight programmes. The driver design therefore incorporates inter-stage matching to minimise the size of the RF circuits and the carrier has an internal dividing wall to prevent instability. The complete driver amplifier module measures 62 mm x 40 mm.

The measured performance of the driver amplifier module is shown in Fig. 4 revealing the essentially flat gain of 32 dB from 2.2 GHz through to 2.32GHz. It should be noted that both stages of the driver amplifier operate with the same drain bias as used in the subsequent power modules.

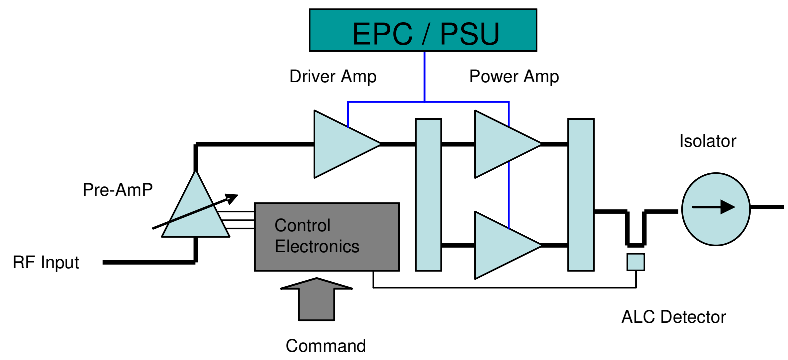

Fig.2. SSPA Electrical Architecture

The driver amplifier feeds two identical GaN power amplification stages via a 3dB splitter. The final power amplification is realised as two identical modules using individual 90W rated devices matched to 50 Ω impedance. The output from the power stages is combined using a commercial combiner. The final output is via a Trak isolator and a TNC style connector.

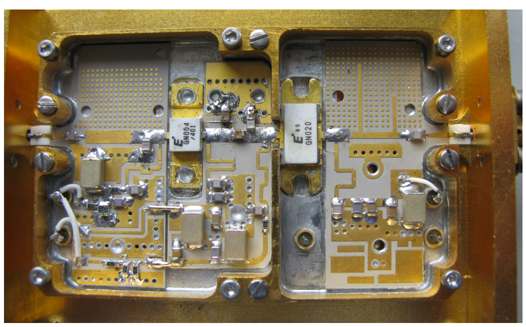

Fig.3. Two Stage GaN Driver Amplifier Module

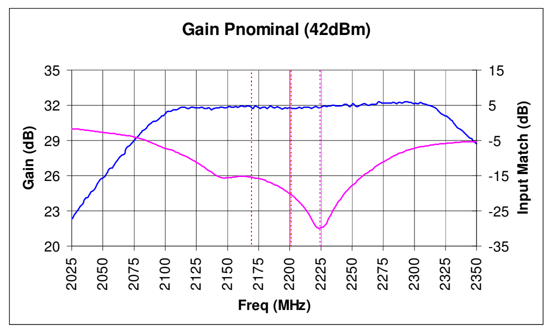

Fig.4. Driver Amplifier Performance

The complete amplifier RF Tray excluding the Electronic Power Conditioner (EPC), normally mounted above the RF Tray, is illustrated in Fig.5 and is a proven flight design implemented with a majority of space qualified components.

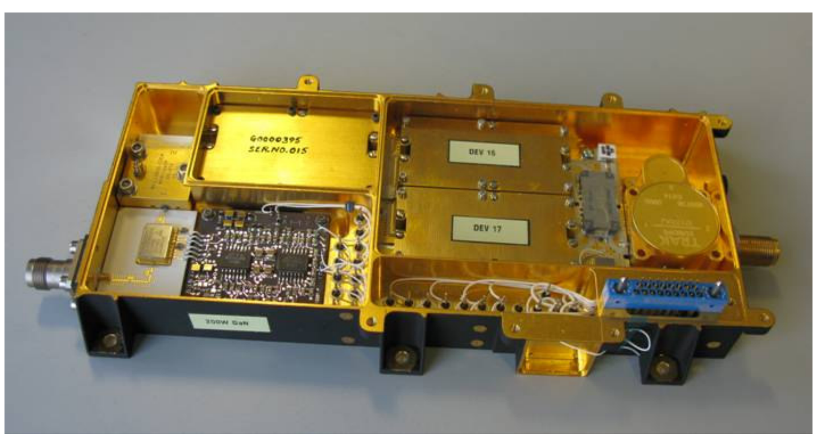

Fig.5. Photograph of the Complete 240W SSPA RF Tray

SSPA MEASURED PERFORMANCE

For the purposes of this demonstration, testing was performed using both laboratory power supplies and finally with the EPC, allowing verification of the complete SSPA efficiency as described below.

Fig.6, illustrates the gain frequency response of the complete amplifier in fixed class A/B operation (V_{ds}=50V). In the output power range 200W to 100W it is seen that the response remains flat as the amplifier comes out of compression (ALC disabled). The useful bandwidth is 2.110GHz to 2.245GHz.

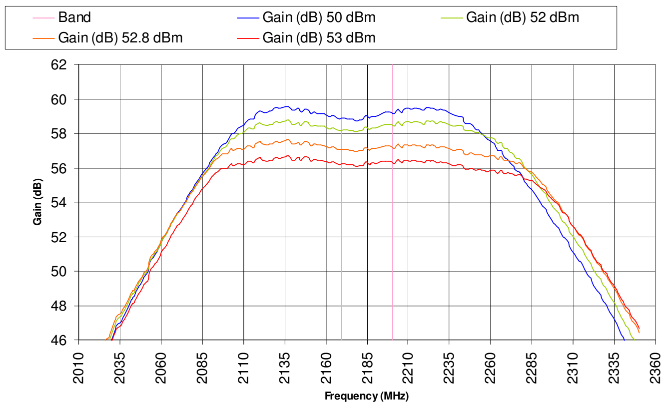

Fig.6. Measured SSPA RF tray Gain against frequency with 4 different input powers

EADS Astrium has evolved an operating concept for SSPAs which has been dubbed "Flexamp" [2]. This method of operating the S-band GaN SSPA has been evaluated using both external power supplies and with the EPC. The "Flexamp" control allows the intelligent adjustment of the drain bias voltages for the amplifier stages subject to the desired requirement, normally constant efficiency or constant linearity over a range of output powers.

The essential advantage of using Flexamp is that the amplifier efficiency or linearity can be maximised over a broad output power range when compared to standard class A/B operation. With Flexamp this is achieved autonomously as the input drive to the amplifier is varied and, if required, simultaneous compensation of gain and phase can be applied for applications that require accurate tracking between units. With a suitable command interface the same operation can be achieved in steps by ground command.

Fig.7. illustrates the performance of the GaN SSPA RF tray in both fixed class A/B operation and with Flexamp control applied via a bench power supply. In this case the Flexamp operation is set to maintain maximum efficiency whilst not exceeding 3dB gain compression. It is seen that with Flexamp applied, better than 47% efficiency is maintained over a 5dB output power range.

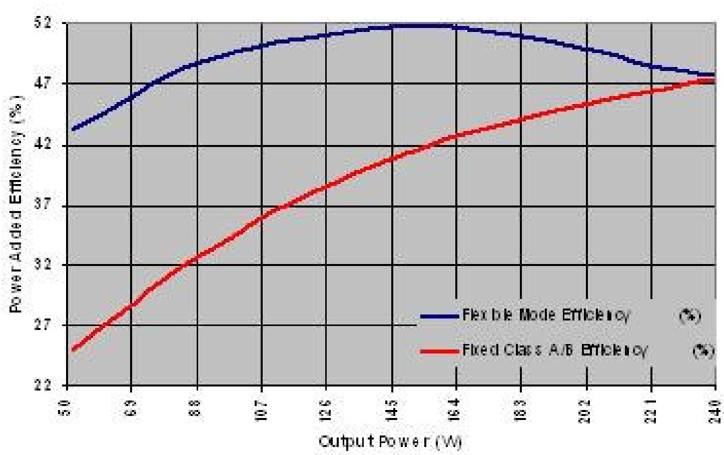

Fig.7. RF Tray Output Power and Efficiency

Following the RF Tray characterisation the amplifier was connected to the EPC and the performance of the complete SSPA was measured in both the "Flexamp" and fixed class A/B modes of operation. Results are illustrated in Fig.8.

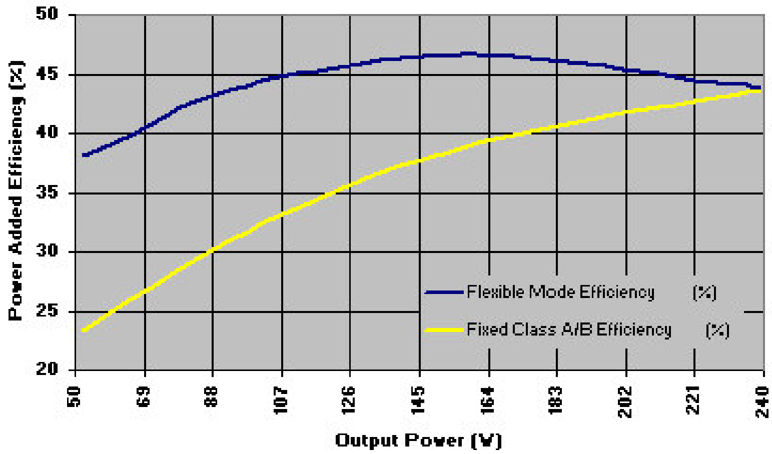

Fig.8. Output Power and Efficiency of the Complete SSPA in Flexible and Fixed Operating Modes

As expected there is a reduction in the overall SSPA efficiency due to the EPC, particularly at the lower power levels where the EPC efficiency falls below it peak. Nevertheless, a peak efficiency of 47% is achieved in flexible mode and better than 40% is maintained over the output power range 69W to 240W. Compared to class A/B operation, a DC power saving of 85W is demonstrated at 6dB Output Back Off.

An assessment of the SSPA RF tray linearity has also been undertaken using modulated signals such as used in some satellite navigation systems. The linearity and output power performance exceed that seen by current GaAs based amplifiers as well as providing a power added efficiency improvement of more than 4%.

FLIGHT OPPORTUNITY

Building on the success of the 240W S Band demonstrator, an 80W S Band SSPA is currently in Engineering Model development targeted at a real flight opportunity. This is a single ended version of the demonstrator and incorporates Silicon Aluminium Metal Matrix Composite for the driver and output stage carriers for improved heat transfer to the satellite payload. The design also incorporates features to prevent multipactor breakdown, which is clearly an increased risk at such high RF output power levels.

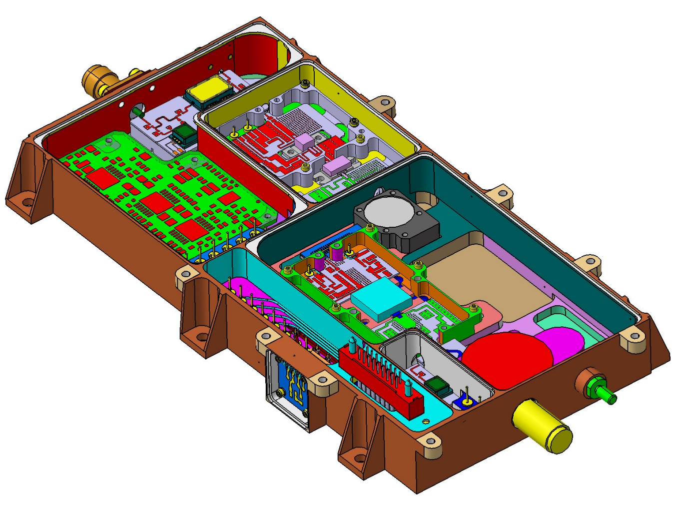

Fig.9. CAD Layout of Engineering Model 80W S Band RF Tray

CONCLUSION

EADS Astrium has realised an S-band GaN demonstration SSPA using mainly space qualified flight components in conjunction with a space qualified EPC. This amplifier has demonstrated an output power of up to 240W at 2.18GHz with an efficiency of 44% and has commandable output power, permitting powers from 110W to 210W to be delivered with better than 45% efficiency.

Preliminary measurements of linearity performance show good results this demonstration suggests that use of GaN SSPA will provide significant benefits for future communications, navigation and remote sensing satellite systems.

Building on this and previous work EADS Astrium is currently developing a GaN SSPA for flight use.

REFERENCES

[1] Green C R, Seymour C D, Goss M D, "Powering the Space Communications Pipe – Tomorrows Amplifiers Today" CEAS 2009 European Air and Space Conference, Manchester, UK

[2] Seymour. C D, "RF Power Amplifiers" European Patent Application number: EP20070733659 20070504 Patent Number EP2022168(A1)