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Design and Implementation of 100W GaN HEMT Power Amplifier in UHF band

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Abstract

This paper presents design and implementation of a power amplifier using packaged GaN HEMT (High electron mobility transistor) device and delivering an output power of 100W at 1-dB compression in UHF (400-450 MHz) band. To drive this 100W power amplifier, a driver amplifier delivering 10 W linear output power has also been designed. Both the amplifiers have been designed and integrated in the total chain delivering an output power of 1KW.

1. Introduction

High power amplifiers are key components in modern era electronics used in base stations, phased array radars and high power electronic warfare systems. To cater efficiently for such high power requirements GaN is emerging as one of the most promising technology. GaN HEMT is being widely used for high power applications owing to its superior high voltage and high temperature performance resulting in higher power efficiency and better thermal management [1][2].

SSPL has been working for the development of GaN HEMT discrete device process technology on SiC substrate. Currently the team at SSPL has successfully demonstrated GaN HEMT devices with a power density of 5 W/mm at 28 V and 10W/mm at 50V operation. The team at SSPL has developed various power amplifier and power combiner modules using indigenously developed devices as well as commercially off the shelf available GaN HEMT devices [3][4]. Recently the team at SSPL has carried out indigenous development of UHF 1 KW RF power amplifier finding application in tele-command and communications system. The developed system is for import substitution. Both the amplifiers discussed in this paper have been used in a cascaded form in RF chain delivering an output power of 1KW [5]. Four such BPA (basic power amplifier) giving an output power of 100W at P1dB have been combined to realize a BPM (basic power module) of 350 W, which subsequently has been combined using a four way combiner to deliver a total power of more than 1KW. This paper discusses detailed design and implementation of 10W driver amplifier and 100W power amplifier module.

2. Driver Amplifier

The design of the driver amplifier has been carried out using CGH40045F packaged device from CREE. The device has been biased in class-AB and operated at a drain voltage of 28V. The driver amplifier has been designed to give a small signal gain better than 19 dB, input as well as output return losses better than 10 dB throughout the desired band of 400-450MHz. Unconditional stability of the device is achieved using a series RC network. The output matching impedance is chosen as an intermediate between optimum impedance for best power and best gain match [6].

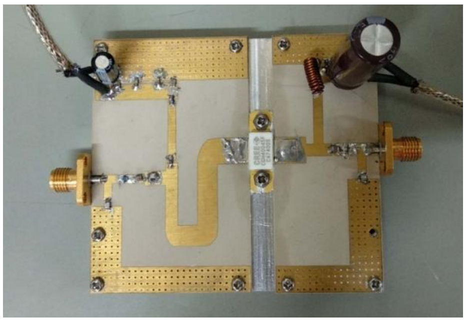

Figure 1. Fabricated and assembled 10W linear driver amplifier

A low pass matching network comprised of inductors, capacitors and transmission lines has been used to match the input for maximum gain. The circuit has been fabricated on Roger 6035 HTC and is shown in the figure.1. The measured small signal performance results of the fabricated circuit are shown in the figure. 2.

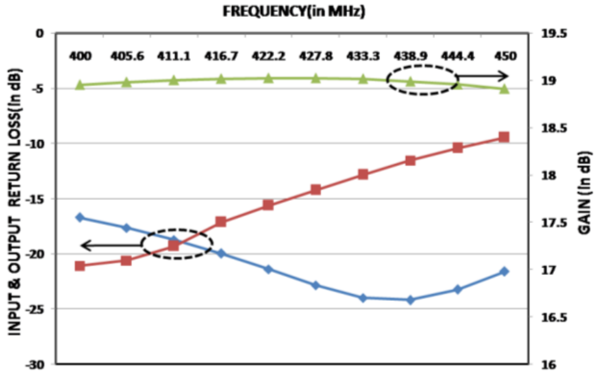

Figure 2. Measured s-parameters of driver amplifier

The measured gain of the amplifier is 19±0.2dB and input output return losses are better than 10 dB throughout the desired band. This driver amplifier has been characterized to deliver 10W linear output power as shown in figure 3.

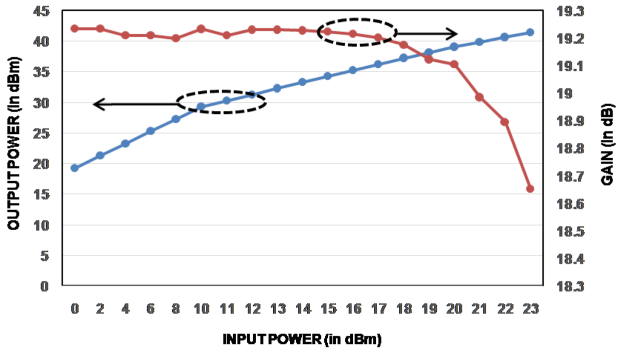

Figure 3. Measured output power and gain versus input power

3. Power Amplifier

Design and realization of the 100W power amplifier has been done using CGH40120F packaged device from CREE. Load pull simulations have been carried out to find the optimum impedance (Ropt) of the device for best power performance. Inductors capable of carrying high current have been used as bias chokes to isolate DC and RF paths. Also, a bank of capacitors having different values ranging from 39 pF to 220 µF have been used in bias network. The track widths of the transmission lines have been designed as per the current flowing in them. Matching has been done using inductors, capacitors and transmission lines having varying impedances. The circuit has been fabricated on Roger 6035 HTC with 2 oz copper clad thickness, which has been selected to increase the current carrying capacity of transmission lines. figure 4 shows the picture of fabricated circuit.

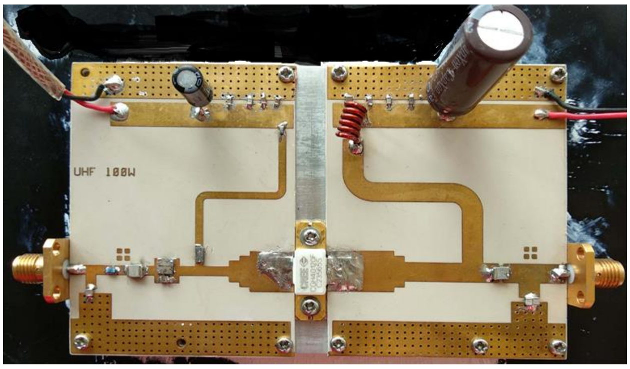

Figure 4. Fabricated and assembled 100W power amplifier

The small signal s-parameter performance is shown in figure.5 below.

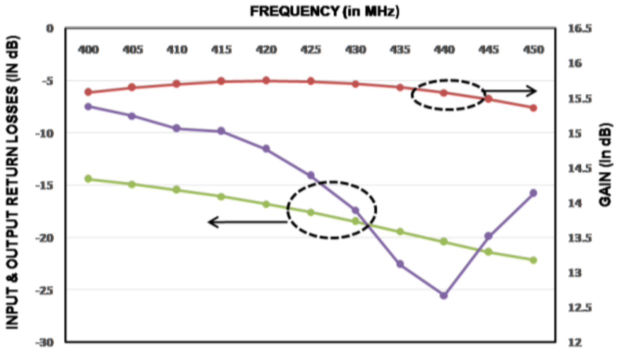

Figure 5. Measured s-parameter performance of 100W power amplifier

Circuit simulations as well as complete layout electro-magnetic simulations have been carried out in Keysight Advanced Design System platform. The power characterization results have been shown in figure 6. The fabricated circuit is capable of giving an output power of 49.63dBm at 2.5dB compression.

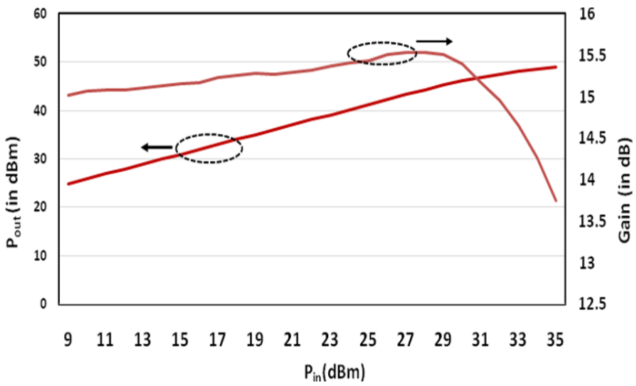

Figure 6. Measured output power and gain versus input power

As per the power budgeting of complete 1KW chain, the BPA (basic power amplifier) must give an output power of 100W at P1dBc.

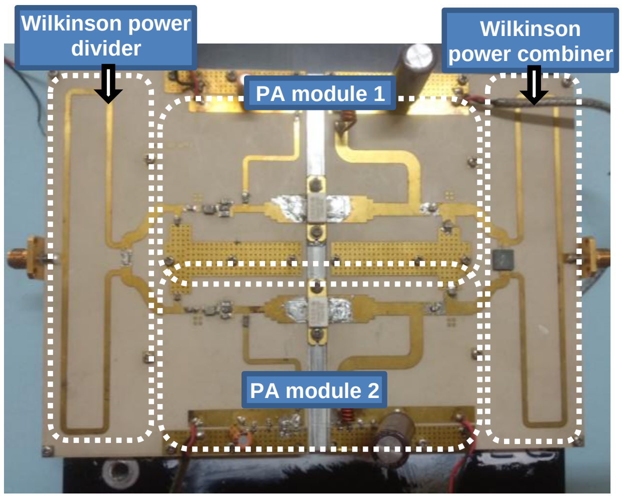

Figure 7. Fabricated circuit

The fabricated single module of PA is capable of delivering 49.63dBm at 2.5dB compression. Hence, two such modules have been combined using Wilkinson power combiner and divider [7][8]to achieve 100W total output power at 1dB compression. The fabricated circuit is shown in figure 7.

For better heat distribution and thermal management, a thermally conducting paste with very high thermal conductivity has been applied below the PCB before mounting it on an aluminum carrier plate. During measurement, a forced air cooling mechanism as shown in the measurement set up in Figure 8 has been used to protect device and PCB from damage due to overheating.

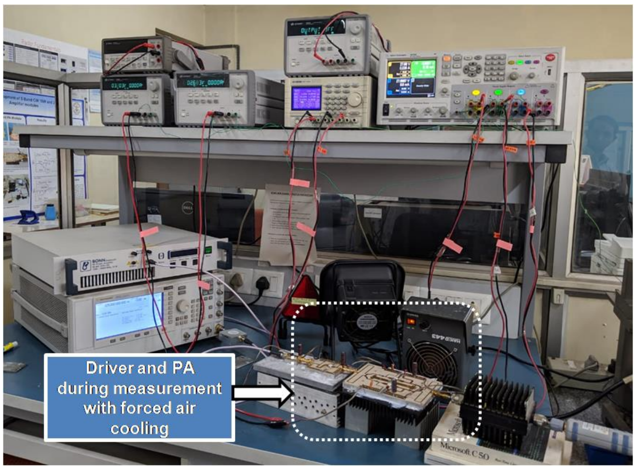

Figure 8. Power Measurement setup

The measured output power and gain performance of the circuit at 425 MHz is shown below in figure 9.

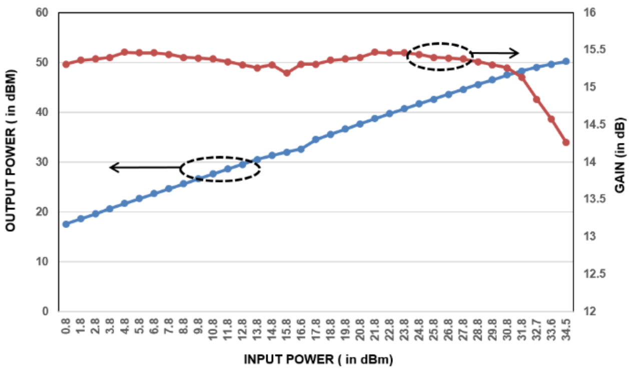

Figure 9. Measured output power and gain versus input power

The measured circuit is giving an output power better than 50 dBm (100W) at 1dBc throughout the band. The output of the circuit has also been fed to a spectrum analyzer to measure the level of harmonics present in the output spectrum. figure 10 shows the output as seen in the spectrum analyzer with a 40.5 dB attenuator placed before for protection. The level of harmonics present in the spectrum has been summarized in the table 1 shown below

TABLE 1.
MEASURED LEVEL OF HARMONICS IN OUTPUT SPECTRUM

Fundamental frequency	2nd Harmonic Level (with ref. to fundamental)	3rd Harmonic level (with ref. to fundamental)	4th Harmonic level (with ref. to fundamental)
423MHz	-31dBc	-75dBc	-48dBc

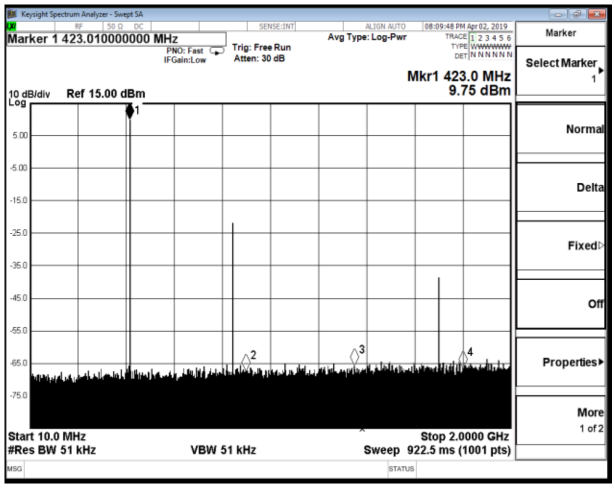

Figure 10. Measured output spectrum with an attenuator placed before spectrum analyzer for protection.

4. Conclusion

The driver amplifier and power amplifier have been thoroughly characterized throughout the desired frequency band of operation. GaN HEMT based power amplifier is delivering an output power of 100W at 1-dB compression in UHF (400-450 MHz) band. The driver amplifier with 10 W linear output power is also demonstrated. Further work towards integration of these modules for the complete 1KW RF amplifier has also been completed

5. Acknowledgements

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6. References

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