BRINGING OPTIMIZED GAN PERFORMANCE TO L-BAND DESIGN.

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Abstract:

The L-band has long been neglected by the GaN community due to the perception that other technologies provided an adequate performance. More recently the success in providing superior capability at higher frequency bands has created the demand for similar devices for the L-band. Wolfspeed has recently introduced a family of high power GaN devices specifically for L-band that in recognition of the extreme power that many such applications require, includes devices with peak power more than 900W from a single ended component. The typical advantage of the GaN technology implies that peak power is not achieved at the expense of other parameters and efficiency at the 70% level and power gain around 15dB is maintained. Internally matched devices are used to guarantee low frequency stability and by increasing the impedance presented at the lead, allow a smaller board match and compact design. The significant overall improvement in performance opens for a dramatic change in system architecture due to smaller, more efficient designs requiring less cooling and occupying less space.

Introduction

In the excitement that GaN has brought to the high power, high frequency community over the last decade the lower part of the radio spectrum has often been ignored. Existing solutions based on LDMOS or even BJT devices were initially deemed as adequate for the less sophisticated and indeed less expensive applications at L-band or even UHF. At the L-band operating frequency range of 1-2 GHz many of the complex, harmonically engineered solutions that have hallmarked recent developments with GaN were in some cases already implemented using other semiconductor technology. The L-band, however, has a number of advantages, apart from the relatively simpler circuit implementation its low transmission loss means less signal degradation and reduced susceptibility to interference, making it a key technology for mission critical systems such as asset tracking and fleet management. Overall it remains a critical element of many applications such as Global Positioning systems, radio, telecommunications, radar and surveillance. The importance of L-band and the fact that GaN devices have reached a price level that is on a par with other mainstream semiconductor technologies has meant that GaN devices that are specifically optimized for L-band are now being developed.

The long range nature of many L-band applications implies that amplifiers can be required to deliver power levels ranging up to as high as hundreds of kilowatts. The high power level implies that efficiency and reliability at high temperature are also critical performance criteria. Such high power levels have often been seen as the domain of vacuum tube technology, although ironically the straightforward design of an L-band circuit has meant that this is a frequency range where the solid state solution has already largely replaced the traditional tube. The introduction of GaN technology enables the combination of optimum efficiency at high power and enhanced reliability even under extreme temperature conditions. Wolfspeed has recently introduced a family of power devices specifically designed for applications in the L-band. The devices are partially internally matched to enhance stability and increase the impedance seen at the package lead. The higher impedance reduces the size of the necessary on-board matching elements allowing for a more compact circuit design. The highest power device currently offered in the dedicated L-band family is the CGHV14800F, specified at 800W nominal peak power with an optimized operating frequency in the range 960MHz to 1500MHz and operated at 50V. Further devices at progressively lower power are the 500W (CGHV14500F) and 250W (CGHV14250F), while a higher power part capable of 1kW peak is in development. Lower power than 250W is available in a generic, unmatched series that operates from DC to 4GHz or above.

Results and performance

The CGHV14800F device represents the highest power single-ended GaN device currently on the market. Operated at 50V the device achieves a peak power density in excess of 8W per mm of device periphery with a typical peak power in excess of 900W across the bandwidth of interest. The high power density implies a significant challenge to the thermal dissipation of such a device. Even under the extremely high efficiency that can be achieved with this device, >70% under class A/B operation, the power dissipation would cause the device to exceed the maximum recommended junction temperature if operated in a continuous wave mode, as such the device is intended for pulsed operation only (pulse length less than 1mS). The internal match of the device restricts operation to the 0.9 to 1.5 GHz band and allows unconditional stability to be achieved, while still providing a power gain of around 16dB at 1.2GHz. The use of a partial internal match implies that a circuit design that further reduces the bandwidth through on-board matching elements can further optimize performance for specific applications.

Figure 1 illustrates the small-signal parameters for the CGHV14800F under 50V operation and a 800mA quiescent current. The results illustrate how the performance of the device rolls off fairly quickly outside the specified band of operation.

Figure 2 illustrates the typical performance achieved in the standard evaluation board designed for operation in the 1.2 - 1.4 GHz band. The amplifier is being operated in a class AB mode with a relatively low quiescent current of 0.8A allowing 65% efficiency or better across the entire band of operation. Peak power under short pulse operation is shown to be over 1kW. It is important to note that the bandwidth demonstrated in this amplifier is a reflection of the circuit design and not the limitation of the device itself.

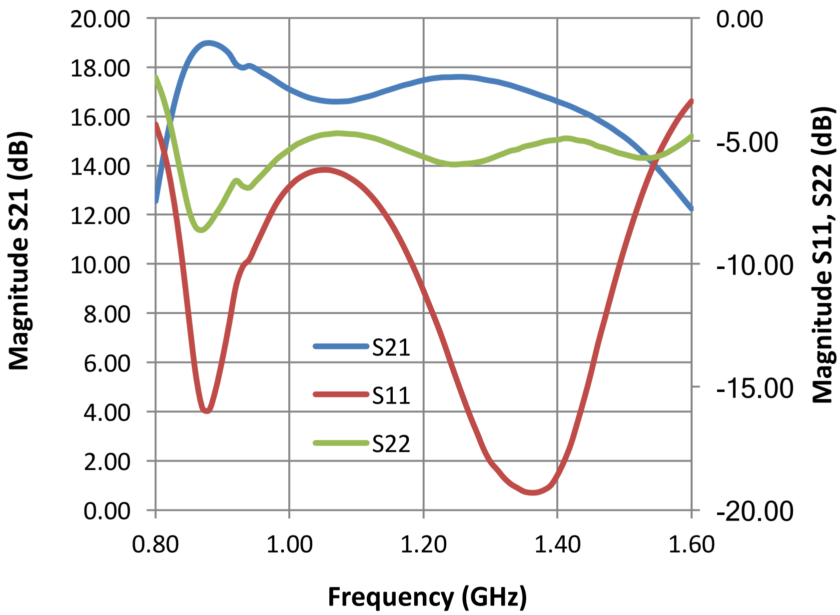

Figure 1. Typical S-parameters (Vds=50V, Idq=0.8A).

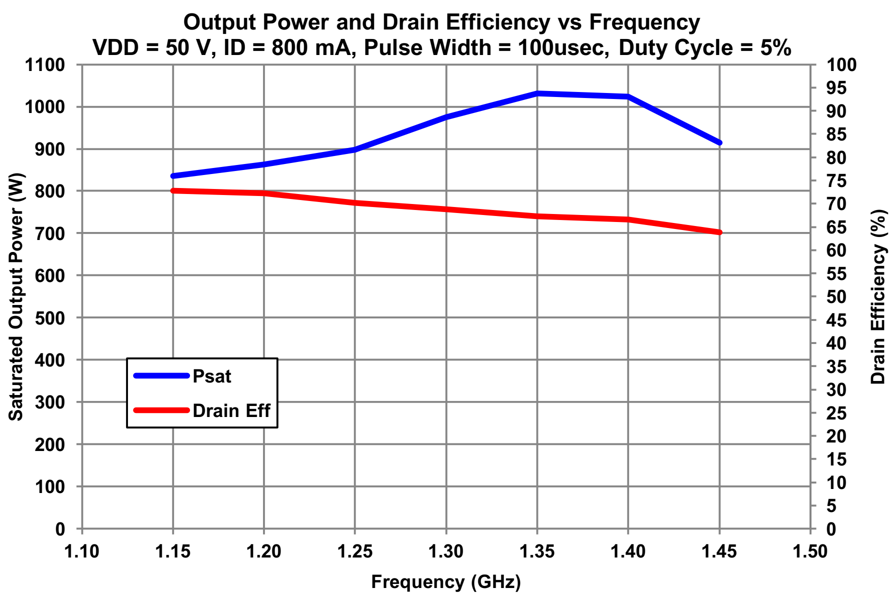

Figure 2. Pulsed saturated power output for the CGHV14800F in a circuit designed for the 1.2-1.4GHz range.(Vds=50V, Idq=0.8A)

One of the further advantages of the GaN technology is the high pulse fidelity in terms of low pulse droop. Figure 3 illustrates the instantaneous power level during the pulse, as can be seen the total power loss during the pulse is approximately 0.15 dBm. Other than the low magnitude of the droop the pulse shows a classical response with a small overshoot and undershoot due to the fact that the measurement circuit is not critically damped.

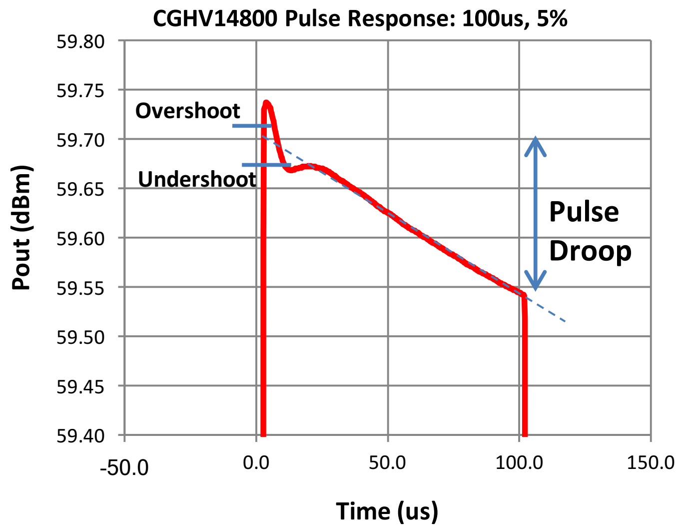

Figure 3. Pulse response for a 100uS pulse length at 5% duty cycle.

The same device can be used over other bands, for example those used for secondary radar systems such as TCAS, DME or IFF applications as illustrated in the results of figure 4. The circuit has this time been tuned for operation in the 1030-1090MHz band and achieves an essentially flat performance across the entire band; again very high power added efficiency is seen. To date the linearity of these devices has not been measured , however, devices based on the same technology, but matched for Telecom applications, show good linear response and suggest that devices should meet the requirements of mode S operation and be suitable for communication applications in this band.

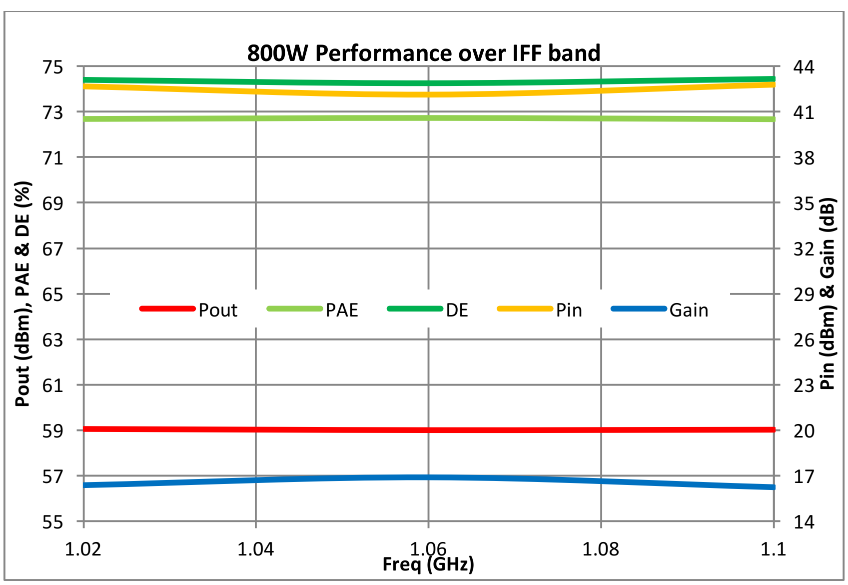

Figure 4. Pulsed power performance for the CGHV14800F in a circuit designed for the 1.03-1.1GHz range.(Vds=50V, Idq=0.8A)

Conclusion

GaN devices are now well established in the mainstream of high power RF technology and are gradually replacing both vacuum electron tubes and traditional semiconductors in most radar applications. Perhaps surprisingly the L-band has not been a focus for GaN technology, however, new products are now emerging that are addressing this deficit. The availability of a high power device that achieves very high efficiency has a significant impact on the system architecture not only in terms of the power delivered, but also in terms of the cooling needed, both of which imply a smaller, more compact design. In addition to the efficient use of power the low power droop even at high power is beneficial to the performance of the radar system. Future development will continue to increase the power delivered from a single device.

Acknowledgements

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