GAN -HEMT DOHERTY POWER AMPLIFIER FOR HIGH POWER AND HIGH EFFICIENCY

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Abstract- This paper discuss the design of high power and high efficiency Doherty power amplifier. Design strategy basically depends upon the elimination of bandwidth and power constraints in basic Doherty amplifier as pointed by Investigation, they are quarter impedance transformer and capacitance at the transistor output terminal. In this work design wideband Doherty power amplifier which is realized by using wideband compensators along with second and third harmonics turning and wideband branch line coupler at the output replaces the quarter Impedence transformer. Simulation results of the wideband band DPA, for the 3.1GHz to 3.75 GHz, gives the drain efficiency 70% - 75% and power added efficiency 65% at about 46-43 dBm output power and gain around 12 dB in the desired band.

Index Terms- Doherty Power Amplifier (DPA), Efficiency, output power,Wider-Band BLC, wideband Compensators.

I. INTRODUCTION

Development of Modern wireless communication ,leads to development of modern communication system like 4G and 3G .Such systems requires, higher data transmission rate ,which can be achieved by higher efficiency and higher peak Average power ratio(PAPR) power amplifiers. In fact, RF power amplifier with high PAPR will reduce the backup efficiency. Different techniques have been proposed to increase backup efficiency, such as Envelope elimination and restoration (ERR) and Doherty Power Amplifier (DPA).The DPA has been accepted widely in base station due to high efficiency.

The BATICHI[9] and QUARESHI[8] works pointed by the DPA suffers the disadvantage that the bandwidth limitations due to quarter wave impedance transformer and the output capacitance of the transistor .Hence DPA is a narrowband amplifier, due to which DPA do not satisfy the multi standard and multiband to suit the requirement of modern wireless communications. Efforts have been made to design a new techniques to increase the Bandwidth of DPA[22-24].This efforts are not successful as expected due to wide operation is not constant over a band ,but some of the good efforts has been done in [8] ,a 20% fractional bandwidth extension achieved by modifying conventional DPA by driver module to properly and separately feed the main and peak stages. By exploiting wideband filters, a 35% fractional bandwidth has been increased in[9]. But, Doherty behavior is not clearly demonstrated and the power utilization factor is not constant in the desired band. In[10],by using frequency reconfigurable matching network with additional external controls, which enables 20% fractional bandwidth .Focus on output combining stages has been done in order to increase the wider-band has been shown by broadband matching real frequency technique in[12]. The work in[13] focuses on input direct coupling of main and peak branches and wide-band ,output matching to improve the wideband. Finally, GaN HEMT Doherty amplifier has been designed based on a simple technique based on wide-band compensators inserted at the output of peak and main amplifiers in [21].

In this frame work, the high efficiency Doherty power amplifier has been designed by allowing wideband signal to DPA for the frequency range 3.1 - 3.75GHz, based on simple techniques based on wide-band components at the output of main and peak amplifier along with second harmonic and third harmonic tuning has been implemented at the upper bandwidth to help gain equalization versus desired frequency. In this design, Impedence Inverter network and Impedance transformer network will be Implemented with the help of the wideband BLC and also eliminating phase shifter at the input of the peak amplifier Fig(1), shows the comparison of different wideband Doherty PA designed so far

Fig(1). Comparison of different wideband DPA work.

Section II deals with the design of proposed DPA and Section III presents and discusses the carried out simulation results and final section draws the conclusions.
II. DESIGN STRATEGY

The schematic block diagram of the propose DPA is as follows in fig (2)

The following techniques are used to improve the bandwidth

**Load modulation for desired band:** conventional DPA is well suited for narrowband amplifier, due to the presence of \( \frac{\lambda}{4} \) (Quarter-Wavelength) as a impedance transformer and output capacitance of the transistor.

The reactance of output capacitances of transistor has been reduced by inserting designed circuit, such that it will reduce the output reactance of the gain HEMT transistor for the given bandwidth. This has been clearly demonstrated in [21], such circuits are called wideband compensators.

**Second harmonic and third harmonic tuning:** As bandwidth increased, we need to increase the gain over the bandwidth, which can be done by optimizing the offset lines of the peak and main amplifiers at the frequency 3.45 GHz in such way that second and third harmonic will be tuned to the fundamental. In fact, we can observe the load impedance is larger at high frequency consisting with second harmonic tuning.

**Impedance Inverter network (IIN):** The Conventional DPA operating principle is based on the idea to modulate the output load of a main active device by using the current generated by an auxiliary active device, which is termed active load modulation. To realize, a \( \frac{\lambda}{4} \) transformer has been inserted between the main device and the load. The quarter wave transmission line (QWL) is called Impedance Inverter Network (IIN), since it transform the load of main device from higher to lower due to the current generated by auxiliary and along with Impedance Inverter transformer Network (ITN). In this work, the [IIN], has been implemented in such a way that the output (current) from main and peak device together we have 90° phase shift, which can be achieved by optimizing the offset lines after wide-band compensators and it will fed to the ports of output BLC. Therefore, load modulation can be achieved with the help of output BLC.

The Impedance Transformer Network (ITN) is used in the conventional DPA to standard output termination, usually 50\( \Omega \). This will be implemented through \( \frac{\lambda}{4} \) transmission line along with output resistance \( R_o \). At this work, the ITN function will be implemented in the output BLC and also which has been optimized such that it will give required bandwidth.

**Input splitter:** As per basic requirement in the basic DPA, the unequal power division is required between the two amplifiers to feed more current to the auxiliary amplifier with equal impedance. It automatically allows the phase between the two amplifier paths by 90°, i.e., driving condition to ensure that \( I_2 \) lags \( I_1 \) by 90°, which is basic requirement in conventional DPA, but in this frame it has been avoided. Finally, it was optimized to allow the required band.

III. EXPERIMENTAL RESULTS OF PROPOSED DPA

The active device i.e., amplifiers used in the realized DPA is commercial packages CGH40025F packed GaN HEMT form CREE Inc., with a 25W output power at 28V drain bias. The amplifier is fabricated on a Rogers HT Duriod 6035HTC with \( \epsilon_r=3.6 \) substrate height H=20mil and thickness \( t=0.035 \text{mm} \) and mounted on brass carrier. The picture die of the amplifier is as shown in fig (3). The fig (4), shows the conduction of experiment. The fig (6), shows the measured results of S11 and S22 in the band of 3.1GHz to 3.75 GHz with 50MHz in step, at VDS=28V and VGs=-2.7V. The DPA is characterized in DC, large signal model from 3.1 to 3.75 GHz with 50 MHz steps. The return loss of the realized DPA exhibit a good magnitude.

The measurement of the realized DPA is shown in the Fig(4)
The measured result power added efficiency as a function of output power is shown in fig(5). From this graph, we can observe the typical Doherty high efficiency region from maximum output power exceeding from 43 dBm to 6 dB back off at all input power sweep.

CONCLUSION

The high efficiency wideband GaN-HEMT Doherty amplifier has been designed for the frequency 3.1-3.75 GHz which is designed using wider-band BLC at the input and output along with wide-band matching with wide-band compensators. Second harmonic to improve efficiency and to achieve gain equalization over frequency. An output power exceeding 45 dBm with drain efficiency over 70% and over 60% at 6 dB back off... The results of the designed DPA is higher than the DPA’s specified in the literature.

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From the fig(7) shows the measured result of the maximum output power together with efficiency, both at maximum output power and at 6 dB back-off vs the excitation frequency. The maximum output power around 46 dBm over the wholeband power corresponding to the maximum power utilization factor of the devices the gain at 6 dB back-off power will equalize around 13 dB. Regarding the efficiency it has found to be between 68% to 73% at saturation, at 6 dB back-off, it is between 62%-65%.

REFERENCES


