MODIFIED DOHERTY POWER AMPLIFIER FOR WIDER BAND

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ABSTRACT

Wireless communication system are developing rapidly, due to which new standards like WIMAX and 4G Long Term Evaluating (LTE) with a purpose of achieving high data rate result in high end applications such as high speed internet, video conferences and broadband width. These applications require mobile base stations at the transmitter as well as at receiver (T/R) to support features like multiple bands, multiple modes, higher BW and less power consumption. The design and implementation of multi-standard transceivers for wireless mobile system is very complex task. In this paper we discuss the design of a wider band Doherty Amplifier, which operational frequency of 3 GHz to 3.75 GHz. The development of proposed DPA is based on techniques of inserting wider band compensators along with second and third harmonic tuning at the output of the GaN HEMT main and peak amplifier. In this work, the basic constraints in the basic DPA is λ/4 impedance transformer has been eliminated with the help of Branch Line Coupler (BLC). The designed amplifier gives the drain efficiency 70% - 75% at about 46-43 dBm output power and gain around 12 dB in the desired band.

Key words: Compensators, Doherty Power Amplifier (DPA), Gan Field Effect Transistors (FET), Wider-Band BLC.

1. INTRODUCTION

Modern wireless communications demands to increase the transmitted data per hertz in order to utilize the spectrum effectively. In order to increase the data per hertz, a signal with high Peak to Average Power Ratio (PAPR) is required. Unfortunately RF power amplifier with high PAPR will reduce so far by the backup efficiency techniques such as envelope the backup efficiency. The above problem can be addressed by envelope tracking amplifier and Doherty Power Amplifier DPA. Among these two DPA has been accepted for adaptation since it is easy to implement.

High back efficiency of DPA leads to use in base stations widely. BATICHI [9] and QUARESHI [8] work reveals that the DPA suffers the disadvantage that the bandwidth limitations due to quarter wave impedance transformer in the output capacitance of the transistor. Therefore the DPA works in single band (narrowband) and they do not satisfy the multi standard and multiband to suit the requirement of modern wireless communications. On the other hand the 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]. In this work a standard topology has been adopted, 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].

The proposed wideband PA is designed for 3.1 -3.75GHz frequency range. In this, simple techniques has been designed based on wide-band components at the output of main and peak amplifier along with second harmonic tuning has been implemented at the upper bandwidth to help gain equalization versus desired frequency. The basic feature has been adapted in this design by function of quarter wave transmission line (IN and TN) as in basic DPA will be implemented by using of the help of the wideband BLC.

The following table shows the comparison of different wideband Doherty PA designed so far

<table>
<thead>
<tr>
<th>Reference</th>
<th>Frequency[GHz]</th>
<th>Output power[Watts]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[8]</td>
<td>1.72-2.0 GHz</td>
<td>20 W</td>
</tr>
<tr>
<td>[9]</td>
<td>1.5-2.1 GHz</td>
<td>20W</td>
</tr>
<tr>
<td>[11]</td>
<td>1.6-2.75GHz</td>
<td>20W</td>
</tr>
<tr>
<td>[12]</td>
<td>2.1-2.9 GHz</td>
<td>13W</td>
</tr>
<tr>
<td>[21]</td>
<td>3.1-3.6GHz</td>
<td>20W</td>
</tr>
<tr>
<td>This work</td>
<td>3.1-3.75 GHz</td>
<td>37W</td>
</tr>
</tbody>
</table>

This paper organizes the section II deals with the proposed design of DPA and Section III presents and discusses the carried out simulation results and final section draws the conclusions.
2. DESIGN OF PROPOSED DPA

A. The block diagram of the proposed DPA is as follows in fig (a)

![Block Diagram](image)

**Figure A**

B. Improve the bandwidth in the proposed DPA, through following strategies

- Wide band Load modulation for required bandwidth
- Gain equalization with the second harmonic and third harmonic tuning.
- Wide band Branch line coupler for Implementation of Impedance Inverter Network [IIN] and Impedance Transformer Network [ITN] with the help of wide band BLC

**Wide-band Load Modulation for required bandwidth**

The conventional DPA is well suited for narrowband amplifier, due to the presence of $\lambda/4$ (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 wide-band compensators, which are designed such that reflection co-efficient of at the input **transistor is** equal to the reflection co-efficient of at the output of wide-band compensators on the whole-band

![Diagram](image)

**Figure B**

By transmission line theory, in order to get $\bar{\text{in}} = \bar{\text{L}}$, the following equations are satisfied

\[
S' = \begin{bmatrix} \pm 1 \\ \pm 1 \\ 0 \end{bmatrix} \quad \text{......... (1)}
\]

\[
\bar{\text{IN}} = S'_{11} + S'_{21}S'_{12} \bar{\text{L}} \Rightarrow \bar{\text{IN}} = \bar{\text{L}} \quad \text{(2)}
\]

\[
1 - S'_{22} \bar{\text{L}} S'_{11} = S'_{22} = 0 \quad \text{.......... (3)}
\]

\[
|S'_{21}| = |S12| = L \quad \text{..... (4)}
\]
Gain equalization with the second harmonic and third harmonic Tuning
The characteristic of the basic DPA is high gain at one frequency (narrow band). At this work the basic objective is to increase the bandwidth in the range of 3.1GHz to 3.75GHz. Equally we need to increase the power gain over the designed bandwidth. To achieve this requirement the tuning frequency has been set around 3.45GHz and optimizing the length of the output offset lines of the main and peak amplifiers in such a way that the second and third harmonic will be tuned to the fundamental and hence this can be interpreted as tuning for second and third harmonic at the output of peak and main amplifier. Due to which the main amplifier behaves as a tune load stage at the lower portion of the band and gradually becomes second harmonic are obtained through the gate and drain bias network. This can be achieved by using quarter wave which behaves as open circuit at fundamentals. In generally, we can observe the load impedance is larger at high frequency consisting with second harmonic tuning

Quarter wave Impedance Inverter
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 as active load modulation. To realize, a $\lambda/4$ transformer has been inserted between the main device and the load. The quarter wave transmission line ($\lambda/4$) is called Impedance Inverter Network, since it transform the load of main device from higher to lower due to the current generated by auxiliary and along with Impedance Transformer Network [ITN].

At this work, the Impedance Inverter Network [ITN] has been implemented in such a way that the output (current) from main and peak device together we have $90^\circ$ 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.

ITN with the help of wider band BLC
The Impedance Transformer Network [ITN] is used in the conventional DPA to standard output termination, usually 50Ω. This will be implemented through $\lambda/4$ transmission line along with output resistance $R_L$. 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.

BLC as unequal power Input Splitter
The wider-band branch line coupler is used as input splitter to split unequal power division with equal impedance. The unequal power division is required to feed more current to operate auxiliary amplifier. It automatically allows the phase between the two amplifier paths by $90^\circ$ i.e driving condition to ensure that $I_M$ lags $I_A$ by $90^\circ$, which is basic requirement in conventional DPA, due to which phase compensator has been incorporated in conventional DPA. Therefore, phase compensators have been avoided in this work. Finally it was optimized to allow the required band.

3. EXPERIMENTAL RESULTS OF REALIZED PROPOSED DPA
The active device i.e., amplifier used in the realized DPA is commercial packages CGH40025F packed GaN HEMT form CREE Inc., with a 25W output power at 28V
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drain bias. The DPA is characterized in DC, large signal model from 3.1 to 3.75 GHz with 50 MHz steps.

The schematic diagram of proposed DPA is shown in fig (c), which is simulated by using AWR microwave office.

![Schematic Diagram of Proposed DPA](http://www.iaeme.com/IJECET.asp)

**Figure C** Complete Schematic Diagram of the Proposed DPA

The fig (d) shows the simulated result of S11 and S (2, 2) and s(2,1) in the desired band at V_{DS}=28V and V_{gs}=-2.88V (I_{DS}=238 milliamp) for the main and V_{DS}=28V and V_{gs}=-10V for the peak amplifier. The return loss of the proposed DPA exhibit a good magnitude, which has been achieved due to electromagnetic simulation exploited for the most critical microstrip structures example junction between strips very different width

![Return Loss of DPA](http://www.iaeme.com/IJECET.asp)

**Figure D** Return Loss of DPA in the band 3.1 -3.75GHz

The drain efficiency of the DPA as a function of output power is as shown in fig(e) for the 3.1,3.45 and 3.75GHz excitations. From this graph we can observe the typical Doherty high efficiency region from maximum output power exceeding from 44 dBm to 6 dB back off at all simulator frequency.
From the fig(f) and fig(g), the maximum output power together with efficiency and gain respectively, both at maximum output power and at 6 dB back-off vs the excitation frequency. The maximum output power higher than the 46 dBm over the wholeband power corresponding to the maximum power utilization factor of the devices and the gain at 6 dB back-off power will equalize around 13 dB. Regarding the efficiency, it has found to be between 70% to 75% at saturation, at 6 dB back-off, it is between 60% to 65%.
The simulated results exhibit a small signal gain higher than 13 dB which is as shown in the fig(g)

4. CONCLUSION
The 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 tuning to achieve gain equalization over frequency. An output power exceeding 46 dBm with saturated efficiency over 70% and over 60% at 6 dB back-off. The results of the designed DPA compares the DPA’s specified in the literature.

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REFERENCES
Modified Doherty Power Amplifier For Wider Band


