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DESIGN AND SIMULATION OF A 3-WAY DOHERTY POWER AMPLIFIER FOR ISM BAND APPLICATIONS

Chetan C Chowdhary[*1] & Dr. K Sreelakshmi[2]
[*1&2]Department of TCE, RVCE, Bangalore, India

ABSTRACT

In this paper, the design and working process of the N-way Doherty power amplifier is analyzed. The N-way Doherty technique is the best method available in order to achieve high PAE, gain and power. In this paper, a 3-Way Doherty power amplifier has been designed and simulated using ADS tool and the results are compared with the normal Doherty technique. GaN HEMT technology has been used for the design of this amplifier. This design gives a PAE greater than 85%, gain greater than 10dB, S22 less than -15dB and an output power of 38dBm. The proposed design is suitable for the ISM band which has wide range of applications in modern communication systems.

Keywords: *3-way Doherty power amplifier(DPA), Power amplifier, ADS, GaN HEMT,N-way DPA..*

I. INTRODUCTION

The data rate in modern communication systems has been increasing rapidly. Size, cost and reliability are the key design considerations in modern communication systems. Communication systems with high data rates can be achieved only with the modern transceiver chain and the power amplifiers are the key block of such modern transceiver chain. Power amplifiers with high PAE, gain and power are very essential for such communication systems. Power amplifiers are classified on the basis of class of operation. Doherty is a technique which uses different classes of operation.

Modern communication needs power amplifiers with high output power and efficiency. Linearity is another key characteristic of a good power amplifier. Traditional power amplifiers like class AB and class A amplifiers have low efficiency. This can be overcome by the use of Doherty technique which gives high output power, high efficiency and good linearity.

The Doherty power amplifier (DPA) configuration and design was invented by William H. Doherty of Bell Telephone Laboratories in the year 1936. In this technique, two amplifiers are connected in parallel to each other. The amplifier at the top is termed as the main amplifier and is biased to class AB. The one at the bottom is called the auxiliary amplifier and is biased to class C. The N-way Doherty uses N number of such parallel combinations to achieve high PAE, gain and output power.

This paper introduces a method in which the main amplifier is biased to class F and the remaining amplifiers are biased to class C. In the 3-way Doherty technique, the main amplifier is biased to the switching class and remaining two auxiliary amplifiers are biased to class C mode. Advance Design system (ADS) tool has been used for the design and analysis of the 3-way Doherty amplifier. GaN HEMT technology has been used in order to achieve high gain, efficiency and output power. The device CGH40010F is a GaN HEMT and is capable of achieving the maximum PAE and gain. This device can operate up to a frequency of 6GHz and is designed for the ISM band applications. A 3-way DPA is designed and analyzed for ISM band applications.

II. LITERATURE REVIEW

Table 1 gives a brief comparison of some of the available Doherty amplifier designs. In the first paper, a GaN based hybrid DPA for wide band applications has been designed and analyzed (Ref table 1). [2] proposes the design, characterization and the implementation of DPA for WiMAX applications. A four stage DPA for base station applications has been designed and simulated in [3] and its efficiency is found to be 61%. Efficiency and

output power can be increased by increasing the number of stages [3][4]. A three way 100W DPA with GaN technology for base station applications has been discussed in [4]. [5] presents an asymmetric Doherty power amplifier with a new output combining circuit and its output power is found to be about 43dbm.

TABLE I. DOHERTY PAPERS

Ref	Output power(dBm)	PAE	Gain	Frequency
1	40dBm	55%	10dB	3-3.6GHz
2	43.42dBm	57%	11dB	3.5GHz
3	43dBm	61%	9dB	2.14GHz
4	50dBm	68%	10dB	2.14GHz
5	43.6dBm	60.40%	7.46dB	3.6GHz

III. WORKING PRINCIPLE

The multi- way Doherty amplifier is also known as the *N*-Way Doherty amplifier. It is realized by connecting the power amplifiers in parallel. The topology is built by placing the main amplifier in parallel to *N* - 1 auxiliary amplifier. The schematic diagram of a *3*-Way Doherty amplifier is as shown in figure 1.

The DPA consists of an input power divider circuit (Wilkinson splitter), two power amplifiers arranged in parallel combination and 90ι lines at the input and output sections. Both the power amplifiers have a same output phase of 180ι when they are ON. The main amplifier can be any one of class A, AB, B or F but the auxiliary amplifier should be biased as class C. At low power, the main amplifier is ON and both the auxiliary amplifiers will be in OFF state. At higher power, all the three amplifiers start conducting. When the input power is low, the main amplifier current (□) starts rising and the output impedance of the main amplifier (□) will be 100 ohm. This is because the auxiliary amplifiers are off and act as open circuits. As the input power starts rising, the auxiliary amplifier turns ON and is matched to 50ohm. At high power, the main amplifier saturates and the auxiliary amplifiers start conducting. Due to this, □□ rises and □ decreases from 100ohm to 50ohm.

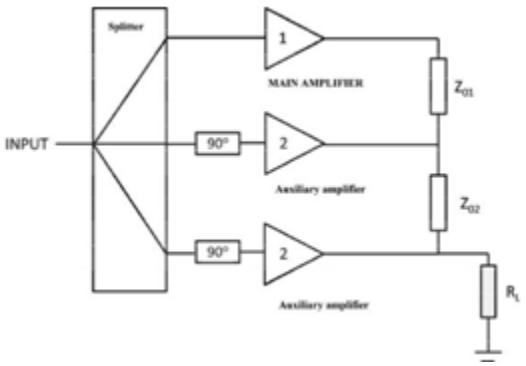

Figure 1. 3-Way DPA

The basic equations required for the design of N-way Doherty amplifiers are given below.

= ….(1)

….(2)

Where I =1, 2….N, k=1(for odd i) or k=2 (for even i), N is the

total number of auxiliary amplifiers.

= (1 -). ….(3)

This paper describes the design of a 3-way Doherty power amplifier. For N=2, the design equations are as follows

= ….(4)

= ….(5)

= ….(6)

= . ….(7)

= (1 -). ….(8)

IV. DESIGN APPROACH

Any RF power amplifier design starts with the selection of the device followed by S-parameter analysis, stability analysis, matching network design, optimization etc. In the proposed 3-way Doherty power amplifier design, both the main and the auxiliary amplifiers are designed using the same method as described above. CGH40010F is the device suitable for the design of 3 -way Doherty technique. Both the main and the auxiliary amplifiers are built

using the same device. This model is provided by the CREE technologies and is capable of producing an average power of 10W.

The main and the auxiliary amplifiers are designed to operate as class F and class C amplifiers respectively. These amplifiers are combined as shown in the figure 1.

Figure 2. Class-F Schamatic

Figure 2 shows the schematic of the main amplifier. The device selected CGH40010F is used for the design of class F amplifier. Microstrip line is used for the matching network design. The substrate parameters are H=1.6mm, Er=4.4, Mur=1, Cond= 5.8E+7, Hu=3.9e+034 mil, T=35 um, TanD=02. The layout is designed using the above substrate parameters and is as shown in the figure 3.

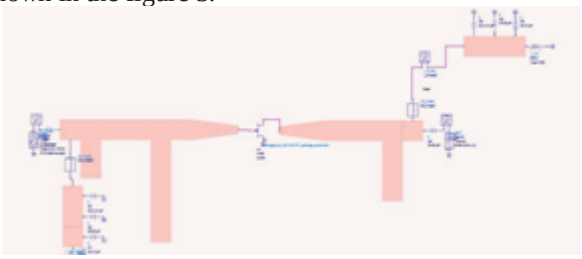

Figure 3. Class-F Layout

Theoretically, the class F amplifier gives 100% efficiency because it has a conduction angle of ș=0. Such switching class amplifiers boost efficiency and output power.

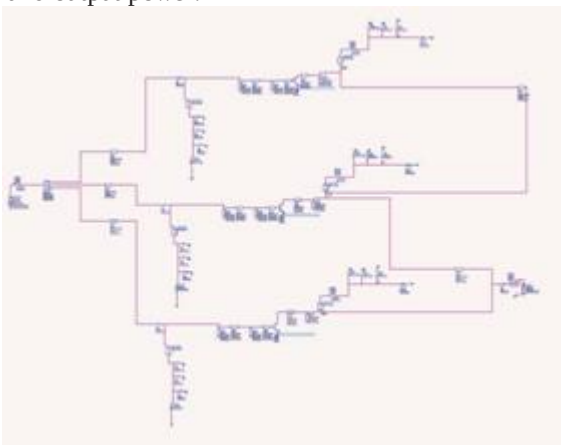

Figure 4. 3-Way DPA Schamatic

Figure 4 shows the schematic of a 3-way DPA. It consists of a power divider circuit at the input section to divide the power equally between the main amplifier and the auxiliary amplifiers. Figure 5 shows the layout 3-way DPA.

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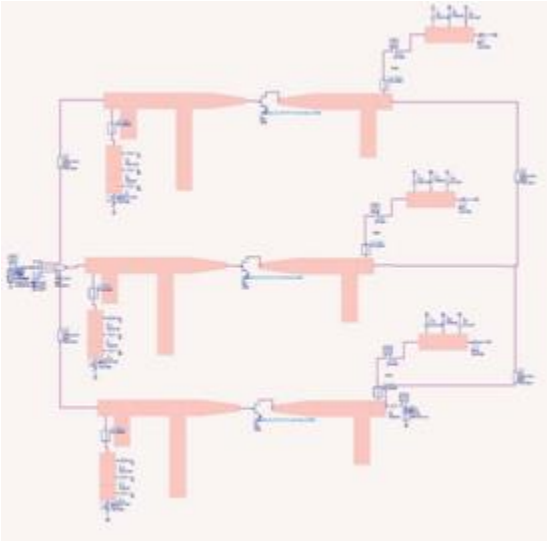

Figure 5. 3-Way DPA Layout

The layout is simulated using ADS tool. Different parameters like output power, input/output reflection coefficients, gain, PAE and VSWR are analyzed as shown in figures 6, 7, 8, 9 and 10. Figure 6 represents output reflection coefficient also known as output return loss. This must be as low as possible for a good RF design. The 3-way Doherty technique gives an output return loss less than -16. Marker m4 denotes dB(S(2,2))=-16.991. This value shows that the output impedance is perfectly matched to a standard value of 50ohm.

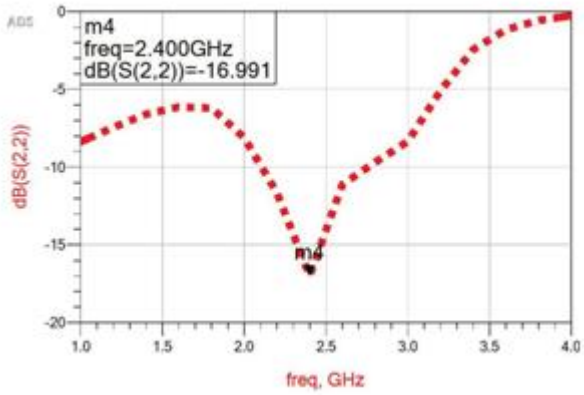

Figure 6. Output Reflection Coefficient

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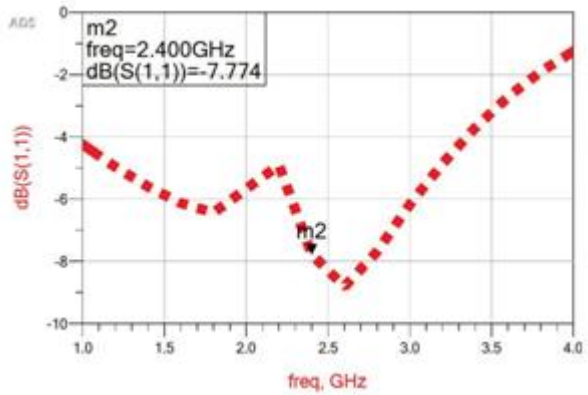

Figure 7. Input Reflection coefficient

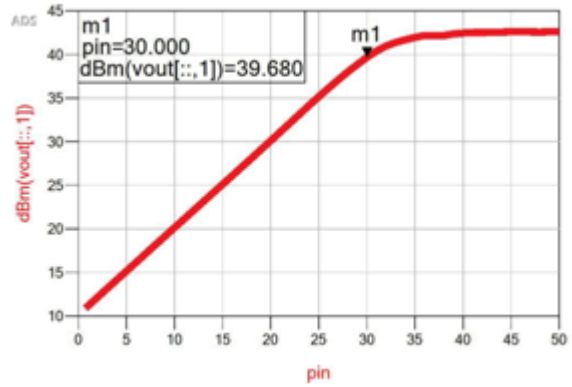

Figure 8. Output Power

Figure 7 represents input reflection coefficient also called as input return loss. The value of input reflection coefficient must be as low as possible. The 3-way DPA design gives input reflection coefficient less than -7. The marker m2 represents dB(S(1,1))= -7.774. This value indicates that the input section is perfectly matched to 50 ohm. Figure 8 represents output power. From figure 8, it can be observed that the output power is 39.68dBm which is greater than 9W.

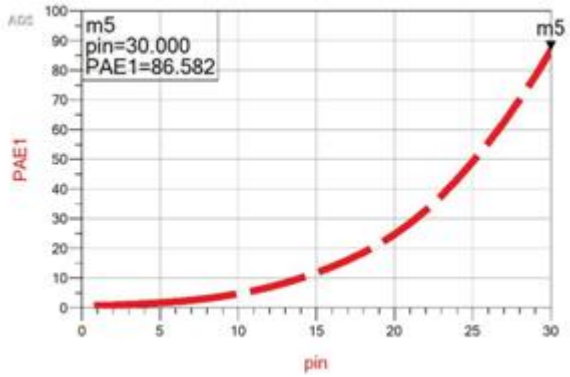

Figure 9. PAE(Power Added Efficiency)

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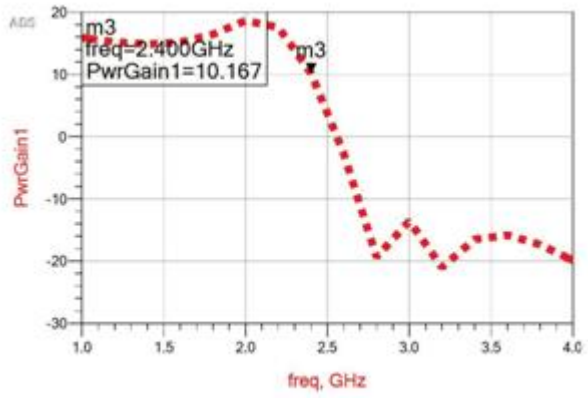

Figure 10. Gain

Figure 9 shows the PAE and marker m5 represents that the 3 way DPA design gives an efficiency of 86.586%. Figure 10 represents gain and marker m3 shows that the gain is 10.167dB.

V. CONCLUSION

3-way Doherty power amplifier is designed, simulated and analyzed using ADS tool. The device CGH40010F from CREE is selected to design the power amplifier. This design has an advantage that it gives efficiency as high as 86% with 10dB gain. This design uses GaN HEMT technology for ISM band applications. The performance can be improved by increasing the number of stages of auxiliary amplifier.

VI. ACKNOWLEDGMENT

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