Design of Solid state GaN Power amplifier using ADS for S-Band Weather radar applications

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Abstract : In this paper, the design of GaN power amplifier which is operating at a S-band frequency of 3.2 GHz has been proposed. The proposed power amplifier can be designed using ADS (Advanced Design System) software tool. The design steps and its simulated results also shown in this paper. The parameters like gain, stability factor and harmonic balance of this amplifier will be helpful in Weather radar applications.

***IndexTerms* – GaN, ADS Software tool, Gain, Stability factor, Harmonic balance.**

I. INTRODUCTION

In weather radars, the Power amplifiers play the important role during transmission time. Because, it is the final stage of the amplification process before the signal giving to the antenna in transmitting chain of the T/R module in radar systems. Generally, these power amplifiers boost up the signals before transmission.

In earlier days, the devices like TWTAs(Travelling wave tubes), Klystron tubes etc, can be used as amplifiers. But they are very complex to handle due to its bulkiness, time consuming and expensive. To overcome those difficulties, we are going to prefer the Solid state Power amplifier (SSPA) devices.

SSPAs are the present trending one for amplification purpose in radar systems. These solid state devices are generally Compound Semiconductor devices. Examples of these compound semiconductors are GaAs (Gallium arsenide), InP (Indium Phosphide), GaN (Gallium Nitride) etc. Among these, GaN devices plays a crucial role in many applications.

Because GaN is a mature, robust technology with extraordinary reliability. When compared to GaAs, the GaN offers many advantages and is shown as follows:

- High Power Added Efficiency (PAE), which not only saves electrical power usage, but also can reduce the cost and size of SSPAs.
- High Operating Voltage-it operates with a power supply of up to 50 VDC.
- These devices have higher impedances than other technologies.
- Much higher reliability.
- Wider bandwidths.

Additional benefits like industry leading efficiency of operation, reducing cooling requirements and light weight.

In general, the power amplifiers are classified based on the conduction angle, such as:

- Class A: if $2\theta_c = 360°$.
- Class B: if $2\theta_c = 180°$.
- Class C: if $2\theta_c < 180°$.
- Class AB: if $180° < 2\theta_c < 360°$.

Hence, these are called "Conduction angle" amplifiers. Also some other classes like D, E, F, G, S, T etc, are called "Switching" amplifiers.

In this paper, the design of class AB power amplifier has been proposed and designed using ADS Software tool.

II. DESIGN STEPS OF PROPOSED POWER AMPLIFIER

The design steps of proposed power amplifier is as follows:

1. Drain characteristics
2. DC biasing
3. Stability analysis
4. Source pull and Load pull

5. Impedance matching
6. Harmonic balance

Each step is explained as follows:

1.Drain Characteristics:
For any amplifier design, initially the I-V characteristics of the device has to be drawn. Also we are selecting the operating point in which class our device need to be operate.

2.DC biasing:
The term DC biasing is the process of applying dc voltages to establish a fixed level of voltage and current. There are 4 types of biasing like fixed bias, self bias, voltage divider bias and feedback bias.

3.Stability analysis:
It is the important step in any amplifier design. The conditions for stability is:

$$\Delta = S_{11}S_{22} - S_{12}S_{21}$$

$$K = \frac{1-|S_{11}|^2-|S_{22}|^2+|\Delta|^2}{2|S_{12}S_{21}|}$$

$$\mu = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2$$

Where, K is a stability factor and μ is the stability measure, K > 1 and μ< 0, can be considered to be stable.

4.Source pull and Load pull:

The source pull and load pull analysis is used to obtain the source and load impedances at a desired frequency.

5.Impedance matching:
After performing the source and load pull analysis, we obtaining the source and load impedances. Then we can match them at a desired frequency.

6.Harmonic Balance:
It is a frequency domain analysis technique for simulating the nonlinear circuits and systems. This is the final step in any amplifier design.

III. DESIGN OF PROPOSED POWER AMPLIFIER WITH SIMULATED RESULTS IN ADS

Here our device is GaN device, CGHV35150F, its specifications are:

- It is a HEMT (High electron mobility transistor) device.
- Operating frequency : 2.9-3.5 GHz and V_{DD}=28V.
- Gain at 3.2 GHz:13.5 dB, because our device is operating at a frequency of 3.2 GHz.

With these values, the proposed amplifier can be designed and its simulated results in each step is shown below.

1.Drain Characteristics:
Using the FET curve tracer template in ADS, the drain characteristics of our device has to be obtained. It is shown in below figure 2.

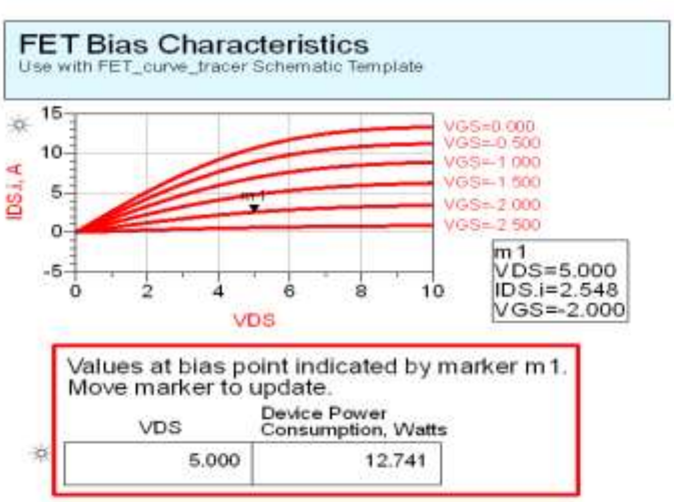


Figure.2. I-V Characteristics of CGHV35150F.

From figure, the marker m1 indicates the operating point as VGS = −2 V, VDS = 5 V and the device is operating in class AB.

2.DC biasing:

After selecting the operating point, we need to apply the dc voltage. Here, voltage divider biasing is used. The circuit schematic is shown in below figure.3.

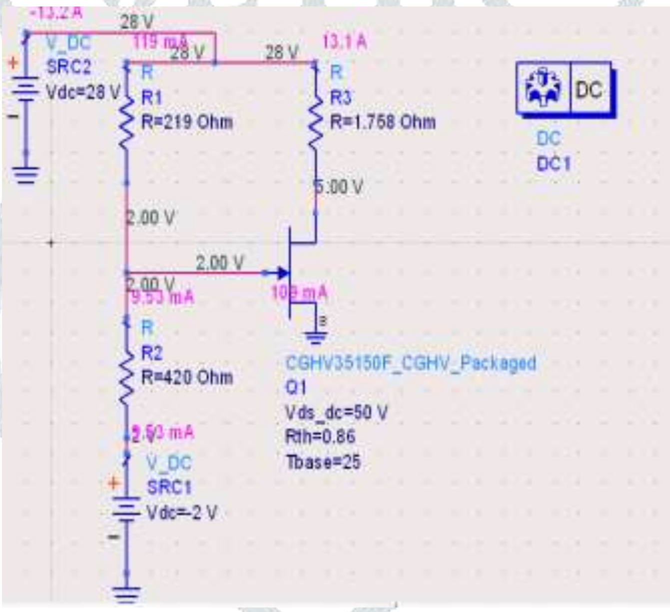


Figure.3. Circuit schematic of Voltage divider biasing.

3.Stability analysis:

For checking the stability, using the biased component in ADS. After simulating, the results is shown in below figure.4.

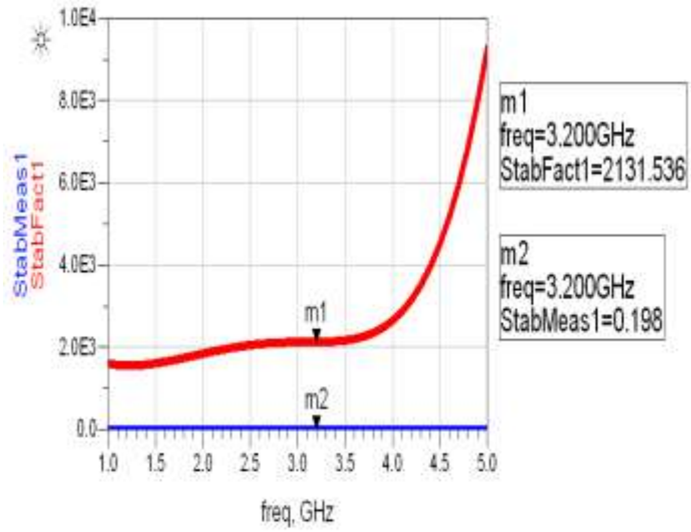
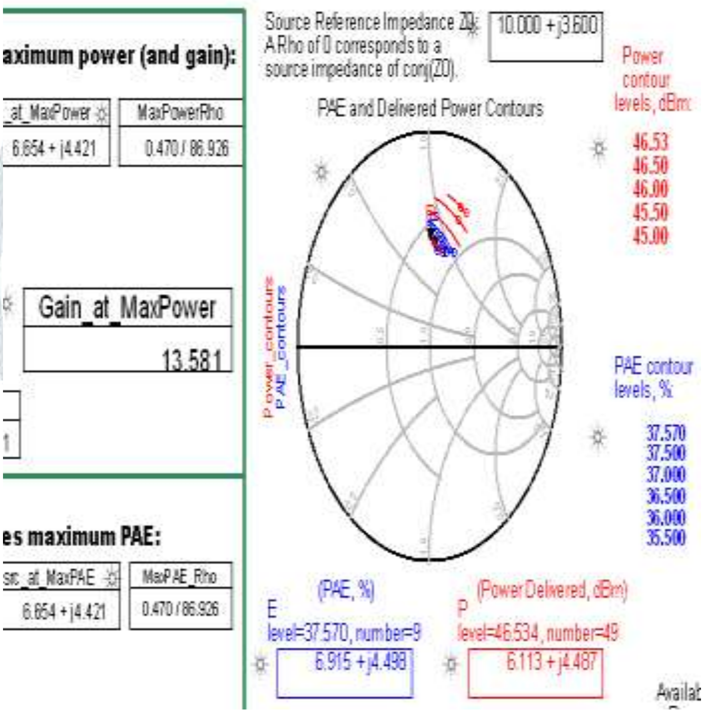


Figure.4. Stability factor and Stability measure at 3.2 GHz.

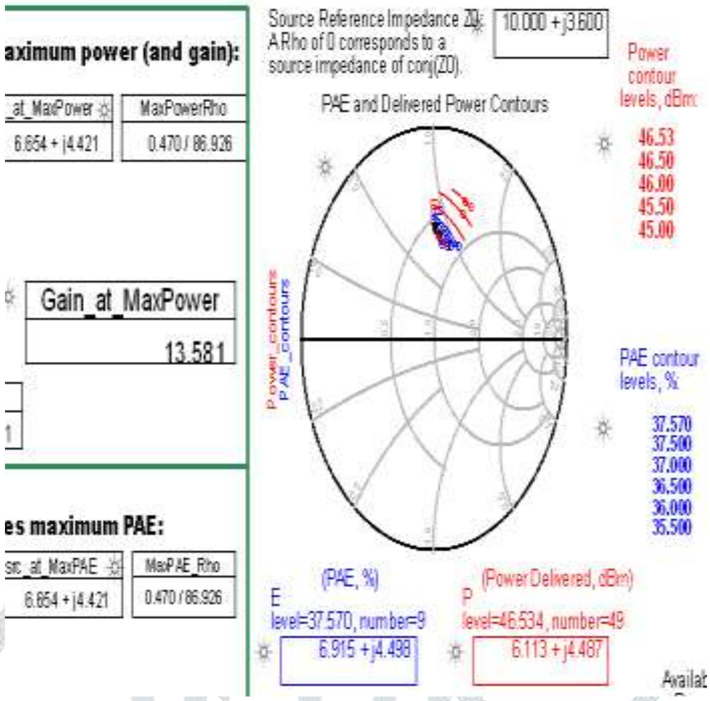
From figure, the stability conditions were satisfied as stability factor, K > 1 and stability measure, μ> 0 at 3.2 GHz.

4. Source pull and Load pull analysis:

It is the step to obtain the source and load impedances ,gain and PAE. The simulated results of both source pull and load pull is shown in below figure.5.



(a)



(b)

Figure.5.(a).Source pull results.
(b).Load pull results.

From figure (a) and (b), the gain obtained is 13.5 dB at 3.2 GHz as per our device specifications and PAE is 37.5%.

5.Impedance matching:

From the source and load pull analysis, we obtain the impedances are 1.2-j*2.0 (source impedance) and 9.2-j*1.4 (load impedance). While matching these impedances using smith chart utility in ADS, the simulated results of this is shown in below figure.6.

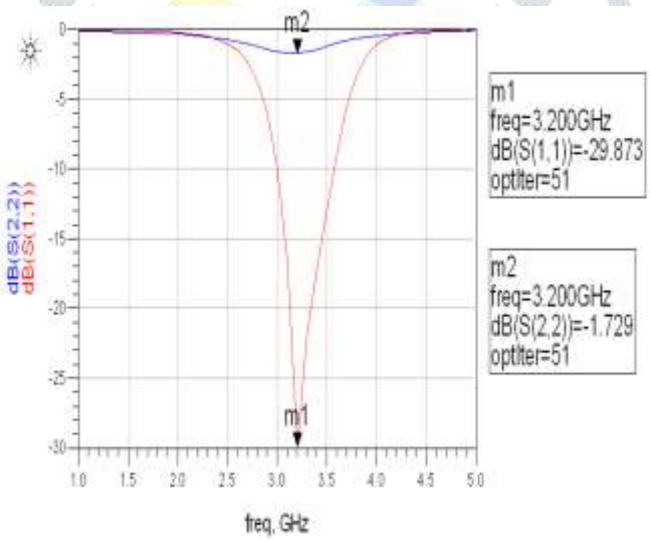


Figure.6. impedance matching results at 3.2 GHz.

From the figure, the source and load impedances tuned at 3.2 GHz.

6.Harmonic balance:

It is the final step to obtain the One-tone or two-tone harmonics. Here, one-tone harmonic simulation was performed. The simulated results at 3.2 GHz is shown in below figure.7.

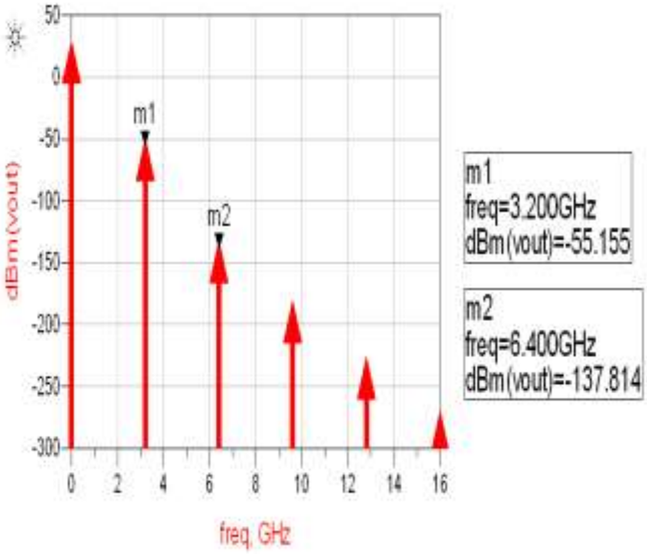


Figure.7. One-tone harmonic balance simulation result at 3.2 GHz.

From figure, the Vout (in dBm) at 3.2 GHz is −55.155 dBm. The difference between harmonics 1 and 2 is,

m2-m1 = 137.814-55.155=82.659 in dBm.

Hence, the proposed power amplifier provides 82.659 dBm , it gives better result at 3.2 GHz.

IV. CONCLUSION

In this paper, the proposed solid state power amplifier provides gain of 13.5 dB, PAE is 37.5%, also it satisfies the stability conditions and provides a harmonic balance result is -55.155 dBm at desired frequency of 3.2 GHz. Hence our device will be useful in s-band weather radar applications due to its performance.

V. ACKNOWLEDGMENT

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