ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Design and analysis of RF power amplifier using thin film passive components at 3.5GHZ.

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Manuscript Info

Manuscript History:

Received: 18 January 2016
Final Accepted: 29 February 2016
Published Online: March 2016

Key words:
Thin film components, WIMAX, 0.30µm GaAs technology.

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Abstract

RF power amplifier plays a major role in deciding the overall interpretation, cost, and reliability of the wireless system, Reliability and electrical performance is improved through the use of fewer components and use of more electrically consistent parts with lower-loss factors respectively. To reduce chip size, miniaturization and incorporation of passive components plays a significant role. This can be achieved by placing capacitors and resistors based on thin film technology.

The main purpose of the work is to achieve both high gain, high output power and to reduce the chip size using thin film passive components. The design is implemented using 0.30µm GaAs technology, which consumes low power (around 1 Watt). The power amplifier is designed and simulated for 3.5GHz frequency usually adopted in WIMAX applications. The Design is simulated and verified using Agilent's Advanced Design System software (ADS) 2013. This circuit achieves gain of 13.359dB and output power of 10.186dBm which is compared with a Power amplifier designed with lumped components from ADS. There is 10% improvement in gain and output power with thin film components.

Introduction:-

In transmitters to drive antenna requires signal with larger power, to accomplish above requirement RF power amplifier used to convert a low-power signal into a high power signal. Amplifier designed to have large competence, acceptable reflection co efficient on the input and output, large output Power at 1dB compression, better gain, and minimum heat dissipation. In transmitting end, Power amplifiers are present at the end of wireless system and they have to provide amplification before signal gets transmitted. To provide amplification, channel losses between transmitter and receiver should be minimum.

In production of semiconductor devices, thin film technology is employed. In performance and in process control, thin film technology has improved rapidly in the last twenty years. Thin film technology provides thickness control at 10-2µm and line definitions below 1µm and hence it results in compact design. It reduces the number of components in a circuit function. Not only the size of the chip shrinks, but also assembly time and cost of the chip reduces. Components of an RF amplifier circuit are gain devices, input and output matching circuits or coupling networks. RF amplifier amplifies the weak signal without adding extra noise or distortion.

Layout and methodology:-

Layout of power amplifier is broken into three parts, they are

- Biasing Network
- Stability Network
- Matching Network

Step 1: Biasing Network

Biasing networks provides excitation for transistors hence they are significant segment of power amplifier layout. Biasing methods are commonly same for all transistors but vary with transistor technology. The particular application decides the biasing network. Larger drain voltage and drain current required for huge value applications. For all transistors maximal grant drain voltage is commonly set by the manufacturers. Maximal grant drain voltage should achieve maximum gain. The maximal grant drain voltage for standard devices is two to ten volts and for high-voltage devices it may be as high as fifty to hundred volts. As per the datasheet of the transistor (A-2).The optimum value of Vds for power amplifier is 10V and best PAE. As per the datasheet of the transistor, the optimum value of drain voltage for power amplifier is 10V.

The elements essentially used to select bias point are output power, PAE, nonlinearity distortion, oscillation suppression, and power dissipation, noise figure and gain. Gate to source voltage lean on class of operation, gain and power added efficiency.

Step 2: stability network

To ensure amplifier not to oscillate in environment, two-port networks are very important. It may be stable or potentially unstable, but oscillation leads to product malfunction. Unstable behavior is produced by the certain source or load terminations in the circuit and it is conditionally stable design. Extreme care must be taken to avoid the presence of source or load terminations that provide oscillations, in case of conditionally stable design method. This applies to all frequencies in-band and out-of-band. The stability factor is theoretically calculated by

$$K = \frac{1-|S11|^2-|S22|^2+|D|^2}{2|S12||S21|} \ldots\ldots\ldots\ldots\ldots\ldots\ldots[1]$$

Where, $D = S_{11}S_{22} - S_{12}S_{21}$

Unconditionally stable design approach stable at all frequencies. It guard's against unexpected oscillations and grants all source or load consequence, reflection coefficient degree between 0 and 1.

Step 3: Matching Network

The input and output impedance should be matched to get large power from Field Effect Transistors (FET). For the maximum power transfer, the source impedance and the load impedance must be a conjugate match, that is the resistive parts must be the same and the imaginary parts must be the same magnitude but opposite polarity.

Impedance transformation has many advantages: (1) Enable maximum power transfer between a source and load network. (2) The performance of the circuit is tuned by source or load impedances to obtain better performance. Source impedance determines the noise offering in case of low noise amplifier.

II IMPLEMENTATION

The design is carried out by using ADS simulation tool. The drain voltage applied for this simulation is 3.0 V and the obtained drain current is 29.47 mA. The simulation is performed at a frequency range of 3.5 GHz.

1.Biasing Network

For biasing FET dual supply network is used, i.e. gate-source and drain-source junctions had their own different biasing sources as shown in the Figure 1

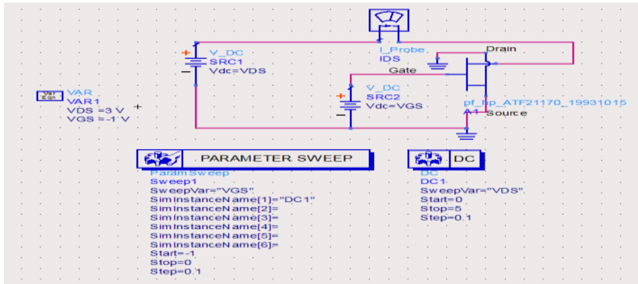

Figure 1: Schematic of DC Biasing network of the transistor

Verification of stability condition:-

S parameter used to obtain stability of FET bias circuit. The S-parameter circuit is obtained by terminating the bias circuit by terminating resistors of 50Ω as shown in Figure 2.

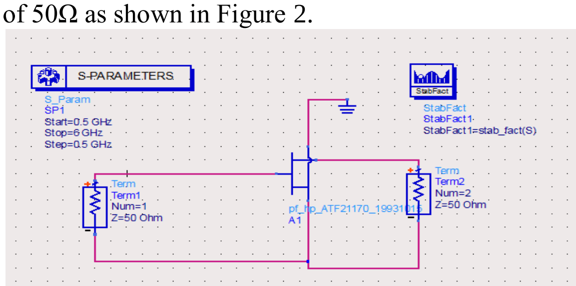

Figure 2: Schematic diagram of S-Parameters simulation

Input and output impedance:-

The S11 value indicates the input impedance when it is normalized and this value is multiplied to the characteristic impedance of the circuit, i.e., 50Ω. Similarly, the S22 value indicates the output impedance of the circuit when it is normalized and is as shown in figure 3.

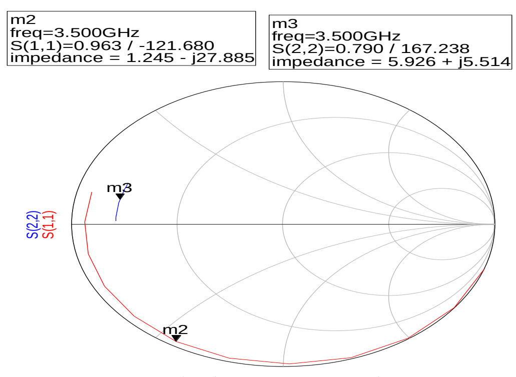

Figure 3: Plot of S11 and S22 on smith chart before matching

Design of input and output matching circuits:-

The input and output matching circuits were designed using the smith chart tool available in ADS.

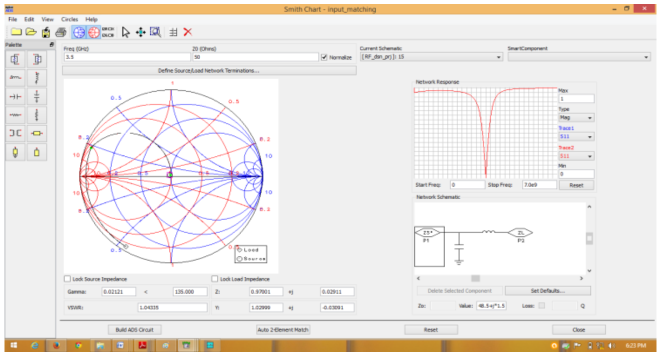

Figure 4: Smith chart utility for input matching

Figure 4 shows smith chart utility for input matching and figure 5 shows smith chart utility for output matching.

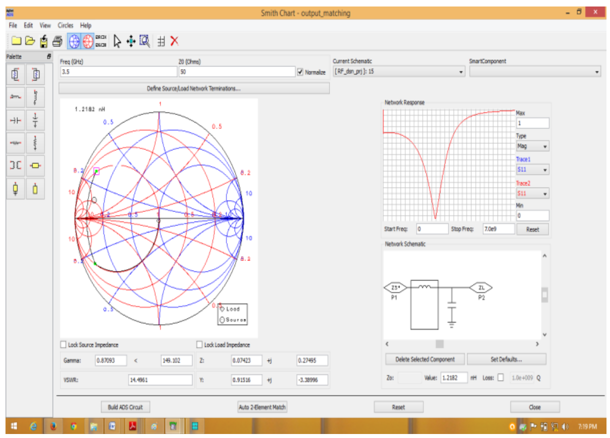

Figure 5: Smith chart utility for output matching

After matching, the input impedance is (51.758+ j 1.248) Ω and output impedance is (49.921-j 0.014) Ω at 3.5 GHz.

Single Stage Power Amplifier:-

Single stage power amplifier is as shown in figure 6. The stability factor, S parameter values, output spectrum, output power and gain at 1dB compression are observed for this circuit.

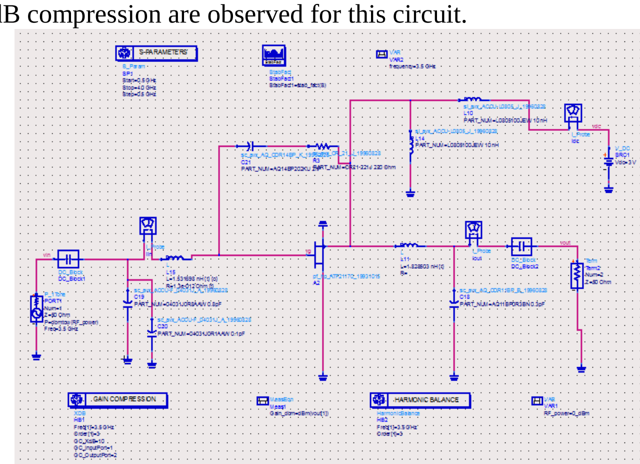

Figure 6: Schematic diagram of single stage power amplifier

Simulation results:-

The schematic of the power amplifier was implemented using ADS and the performance parameters of the power amplifier are given below

I-V Curve of transistor:-

The value of Vds is 3 V and Vgs is -1 V. I-V curves are obtained by the simulation of the circuit given in Figure 1.

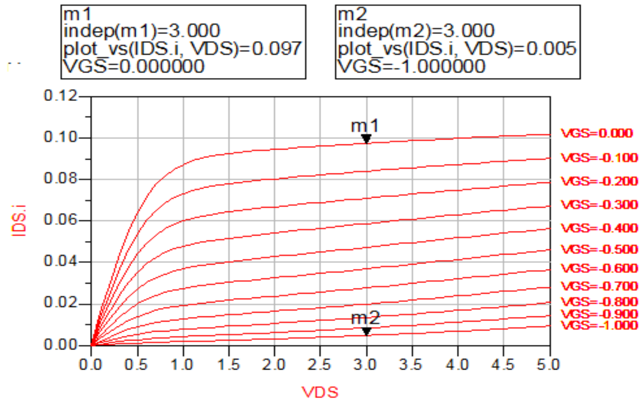

Figure 7: Plot of I-V curve of the transistor

Stability Factor:-

The transistor is unconditionally stable because the stability factor is 1.464 and it is shown figure 8.

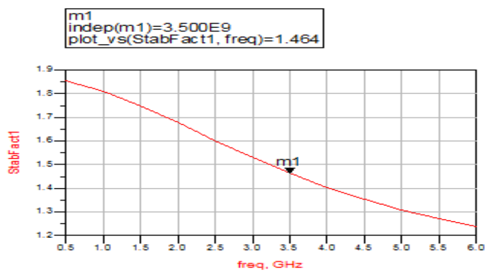

Figure 8: Plot of stability factor calculation

S -Parameter values:-

Figure 9 shows the S-Parameter values

- S11 = -19.458dB (input reflection co-efficient)
- S21 = 13.359dB (forward transmission co-efficient)
- S12=19.270dB (reverse transmission co-efficient)
- S22 = -16.587dB (output reflection coefficient)

The S21 value indicates the gain of the amplifier. The amplifier gain in the interested frequency range is above 13.359dB.

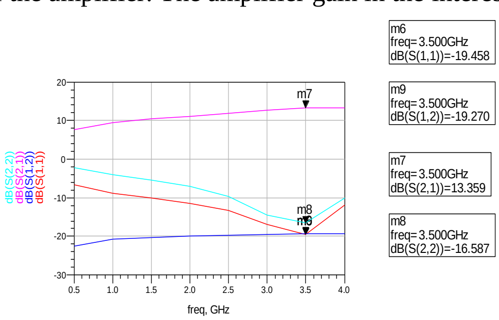

Figure 9: Calculation of S-Parameter values

Output Power:-

The power amplifier has an output power of 10.186dBm and it is shown in figure 10.

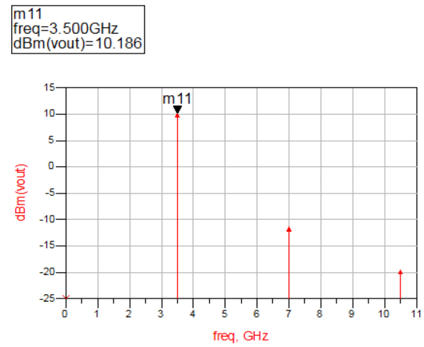

Figure 10: Plot of Output power

Gain at 1 dB Compression Point:-

Figure 11 shows the gain at1dB compression point and its value is 11.096dB. The 1 dB compression point is defined as the level of power that causes the gain to drop by 1 dB from its small signal value.

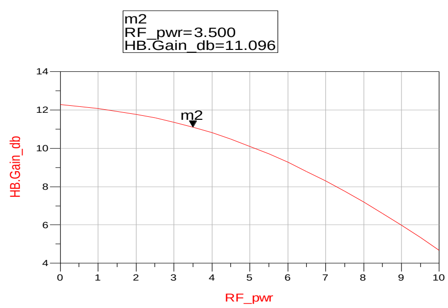

Figure 11: Gain at 1dB compression point

Performance parameters:-

The performance parameters of power amplifier such as gain, stability and output power are tabulated in table 1.The obtained values are gain as 13.359 dB, Stability as 1.24 and Output power as 10.186 dBm and it is compared with power amplifier circuit with lumped elements [6].There is an increase in gain and output power when circuit designed with thin film passive components.

Table 1: Performance Parameters

Performance Parameters	**Amplifier with thin film Components**	**Amplifierwith lumped elements[6]**
Gain(dB)	13.359	10.116
Stability	1.24	1.19
Output Power(dBm)	10.186	9.17

Schematic Layout of power amplifier with thin film passive components:-

Figure 12 shows the schematic layout of power amplifier with thin film passive components.

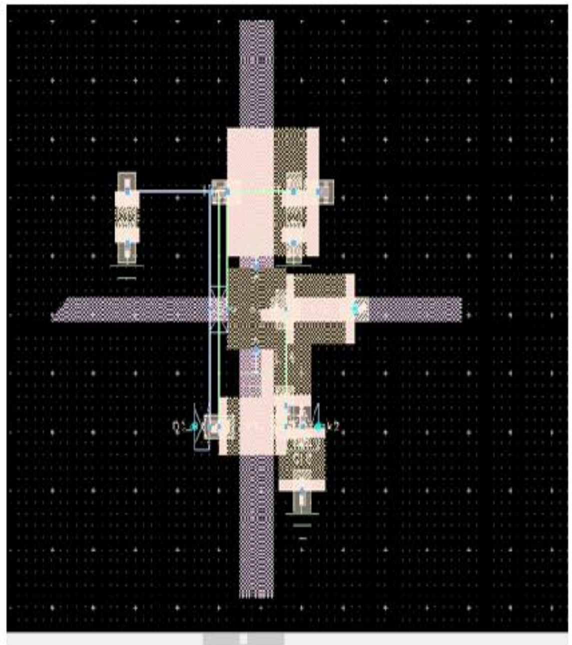

Figure 12: Schematic Layout of power amplifier

Conclusion:-

The RF power amplifier with thin film passive components at centre frequency of 3.5GHz has been designed. The 3.5GHz power amplifier was designed for WIMAX application by using 0.30 µm GaAs technology with a gate width of 250 µm. Software Agilent ADS 2009 was used for simulation. It has been demonstrated that at 3.0 V drain voltage has achieved a gain of 13.359 dB, input and output reflection co efficient are -19.458 dB , -16.587 dB respectively. Comparison of parameters gain, output power and stability factor is done with respect to a PA designed with lumped elements at centre frequency of 3.5 GHz resulted in 10% improvement.As the stability factor of power amplifier is greater than 1 and hence the designed amplifier is unconditionally stable. If the matching of the system is improved by dual stage structure, the performance of the system and output power can be improved.

Acknowledgement:-

This work was supported by Centre of Excellence (COE), Macro electronics and Agilent Lab, Telecommunication Engineering, R V College of Engineering.

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