DESIGN AND SIMULATION OF POWER AMPLIFIER AT 10 GHz FOR X-BAND RADAR APPLICATIONS

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DESIGN AND SIMULATION OF POWER AMPLIFIER AT 10 GHz FOR X-BAND RADAR APPLICATIONS

by

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FINAL REPORT

DESIGN AND SIMULATION OF GaAs pHEMT POWER AMPLIFIER AT 10GHz FOR X-BAND RADAR APPLICATIONS

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LIST OF ABBREVIATION

ADS	Advanced Design System
CMOS	Complementary Metal Oxide Semiconductor
DC	Direct Current
EM	Electromagnetic
FET	Field Effect Transistor
GaAs	Gallium Arsenide
GaN	Gallium Nitride
HEMT	High Electron Mobility Transistor
LAN	Local Area Network
MESFET	Metal-semiconductor Field-Effect Transistor
MMIC	Monolithic Microwave Integrated Circuit
PAE	Power Added Efficiency
pHEMT	Pseudomorphic High Electron Mobility Transistor
RF	Radio Frequency
SAR	Synthetic Aperture Radar

REKA BENTUK DAN SIMULASI UNTUK PENGUAT KUASA GaAs pHEMT PADA 10 GHz UNTUK KEGUNAAN APLIKASI X-BAND RADAR

ABSTRAK

Kertas kerja ini mengkaji reka bentuk dan simulasi X-band GaAs pHEMT penguat kuasa. Tenaga yang dipancarkan melalui rangkaian penghubung di penguat kuasa RF adalah lebih tinggi kerana penguat RF terletak pada akhir pemancar radio yang membekalkan kuasa RF untuk antena penerima. Penguat kuasa yang ideal menukarkan kuasa DC ke dalam kuasa isyarat keluaran di bawah kawalan lelurus masukan RF dari penjana isyarat. Konsep penguat kuasa adalah ia memerlukan operasi tidak lelurus disebabkan oleh rangkaian lelurus tidak boleh beralih kuasa dari satu frekuensi ke frekuensi yang lain. Julat frekuensi untuk X-band adalah antara 8 GHz hingga 12 GHz. Reka bentuk RF penguat adalah bergantung kepada ciri-ciri terminal transistor yang diwakili oleh S-parameter. Penyerakan parameter (S-parameter) transistor ini menawarkan nilai yang penting untuk melaksanakan analisis seperti kestabilan, DC pincangan, kerugian balikan masukan (S_{11}), kerugian balikan keluaran (S_{22}), kecekapan tambahan kuasa dan keuntungan kuasa (S_{21}). Advanced Design System (ADS) digunakan untuk mereka bentuk litar skematik, simulasi reka bentuk dan menghasilkan reka bentuk susun atur. Penguat kuasa ini direka dalam konfigurasi peringkat satu untuk dipadankan sepenuhnya pada masukan dan keluaran 50Ω galangan. Transistor yang dipilih untuk diaplikasikan di dalam projek ini adalah HMC996LP4E iaitu penguat jenis GaAs pHEMT MMIC. Sedia ada transistor digunakan dalam reka bentuk untuk mendapatkan keputusan yang disasarkan. Tiada padanan luar diperlukan oleh kerana ia telah siap sedia terbina. Reka bentuk susun atur direka berdasarkan skema dan dimensi transistor yang digunakan. Reka bentuk susun atur dicetakan di atas papan substrat RO4003 dan diukur menggunakan penganalisis rangkaian. Voltan longkang berat sebelah ditetapkan pada 5V, voltan get bias ditetapkan pada 0V dan dapatan voltan kawalan ditetapkan pada -4v. Kuasa masukan dari penjana isyarat ditukar di antara -12dBm hingga + 12dBm. Kesimpulannya, penguat kuasa yang dihasilkan dalam projek ini menunjukkan purata keuntungan pada 12.09dB dan kerugian keluaran pada -4.07dB disamping PAE dihasilkan sebanyak 68.25% pada 10GHz.

DESIGN AND SIMULATION OF GaAs pHEMT POWER AMPLIFIER AT 10 GHz FOR X-BAND RADAR APPLICATIONS

ABSTRACT

This paper reviews a design and simulation of X-band GaAs pHEMT power amplifier. The energy that is emitted through link module at RF amplifier is more as RF amplifier is located at the end of radio transmitter which supplied RF power for the receiving antenna. Ideal power amplifier converts DC power into output signal power under the linear control of an RF input from signal generator. Power amplifier concept requires non-linear operation since linear networks cannot shift power from one frequency to another. The frequency range for X-band is between 8 to 12 GHz. RF amplifier design depends on the terminal characteristics of the transistor as represented by S-parameter. Scattering parameter (S-parameter) of the transistor provides the significant values to perform analysis such as stability, DC biasing, input return loss (S_{11}), output return loss (S_{22}), power added efficiency (PAE) and power gain (S_{21}). Advanced Design System (ADS) is used to design the schematic circuit, simulate the design and generate layout design. The power amplifier is designed in a single stage configuration to fully match a 50Ω input and output impedance. The transistor chosen is HMC996LP4E which is GaAs pHEMT MMIC amplifier. The off-shelf transistor is employed in the design in order to obtain the targeted results. No external matching is needed for the transistor as it is already built in. The layout design is designed based on the schematic and dimension of the transistor. Then, the layout is fabricated onto RO4003 substrate board and measured using network analyzer and spectrum analyzer. The drain bias voltage is set at 5v, gate bias voltage is set at 0v and gain control voltage is set at -4v. The input power from signal generator is varied between -12dBm to +12dBm. Based on the result measurement, the power amplifier developed in this project provides power gain of 13.44dB and output return loss (S_{22}), at -4.07dB with PAE of 68.25% at 10 GHz.

Chapter 1

INTRODUCTION

1.1 Overview

The development of wireless communication systems in recent years happen rapidly as these systems become vital in this modern lifestyle. In this era, telecommunication devices as known as RF front-end are facing a rapid growth that are highly demanding for high efficiency power amplifier which require low cost, compact equipment and high speed data transfer in radio access networks (Hui et al.,2015). Wideband high power amplifier are usually used in base station of wireless communications, military equipment, satellite downlinks, commercial applications and transceiver (T/R) modules of phased array radars (Qinyang et al.,2015). In contrast for radar applications such as synthetic aperture radar (SAR), there is increasingly instant demand in high degree of compactness and reliability that have led to a wideband power amplifiers design in X-band which is primarily used in military (Rocco et al,.2013).

Signal transmission required signal power but, the problem is that its generation is restricted by the device performance. Distortion that occurs in communication channels, radar applications, and TV transmissions is developed from power amplifier (Lixia et al,.2015). Therefore, radar applications are targeted to utilize a highly linear power amplifier to not distort RF signals. Based on that matter, monolithic microwave integrated circuits (MMICs) power amplifier are used to achieve high performance by utilizing a wide range of semiconductor processes.

In order to satisfy the demand of the market, Gallium Arsenide (GaAs) pseudomorphic high electron mobility transistor (pHEMT) are employed. These devices can full-fill the needs for a wide category of military and satellite applications since pHEMT technology had shown its record on high reliability (Matthew et al,.2003).

This project focused on designing a single stage power amplifier specifically for X-band radar. The requirements for X-band high power single chip amplifier circuit design are: operating frequency at 10 GHz, gain higher than 10 dB, achieve optimum output power within the frequency range and power-added efficiency (PAE) as high as possible. On the other hand, this project also targeted to improve the performance and have high efficiency in order to increase the data rate transmission.

1.2 Problem Statement

In designing a high-efficiency power amplifier, a 50-Ω input and output impedance have to fully match. Commonly, commensurate transmission lines also known as microstrip lines are used to design the matching networks. Unfortunately, in previous work (Siddik and Malik,2015), microstrip lines are not suitable to manufacture because its characteristics impedance variation is irregular. Instead of that matter, mixed elements are implemented in that design and it is feasible to manufacture. However, the value of lumped elements is hard to be identified to obtain a good matching network. Thus, microstrip line is recommended to be used as it ease the matching design process and perhaps the s-parameter of the transistor used, play an important role of having good characteristics impedance variation.

The market growth of communication systems such as synthetic aperture radar (SAR) increase abruptly that demand a low-cost X-band MMIC power amplifier. The problem is that the type of transistor used in previous works (Siddik and Malik,2015; Davide et al,.2014) which are Gallium Nitride (GaN) power amplifier is quite expensive to be utilized in the market. Instead, GaAs power amplifier is more economical to be employed as it is high yield and low manufacturing cost.

In addition, for future development of wireless communications and local area network (LAN) applications, the main aspects that should be focused on are high power-added efficiencies (PAE), low noise figure and achieve excellent performances. Thus, the usage of field effect transistor (FET) in previous works (Lixia et al,2015; Hui et al.,2015; Siddik and Malik,2015; Phat et al.,2015) should be replaced with pHEMT as it has a superior velocity and mobility of electron gas which allow these transistors to achieve high gain well in millimeter wave region.

1.3 Objectives

- To design schematic and simulate the performance of PA at 10 GHz for X-band radar application in ADS.
- To design layout for an off-shelf HMC996LP4E GaAs pHEMT MMIC PA in ADS.
- To fabricate and measure the input return loss (S_{11}), insertion loss (S_{21}) and PAE of the PA.

1.4 Project Scope

For this project, GaAs pHEMT MMIC is employed to achieve better performance and consume low cost. Analysis for stability, DC biasing and available gain is performed based on the S-parameter of the transistor used which is HMC996LP4E. Transmission lines are used to construct matching networks for high PAE over X-band frequency. This project used Advanced Design System (ADS) as simulation tools to optimize the power amplifier design. The operating frequency is set to be 10GHz. The designed layout is fabricated onto Rogers 4003c board. The fabricated board will be tested using Network Analyzer to analyze the results so that the practical and simulated results are comparable.

1.5 Thesis Outline

The first chapter of this thesis is consist of overview that explains about the background of this project and highlights the problem statement based on the limitation of previous works. Objectives and project scope also has been stated in this part.

Chapter two is the summarization of the literature review of some related journals by extracting some important points. The design used in the journals are being compared by using a table.

Chapter three describes the method used to construct this project. Detail description further explains together with the experimental method that has been taken to accomplish this project.

Chapter four shows the simulation and experimental results of this PA in this project. The results of both simulation and experimental are compared and justifications are made in order to verify the performance of the PA.

Chapter 5 concludes the whole project achievement and stated out the final outcome of the developed PA. Recommendations for future improvements are also included so that this project can be improved and implemented in radar application.

Chapter 2

LITERATURE REVIEW

2.1 Background

Nowadays, wireless technology evolution is moving towards the concept of building capacity and obtaining higher data rates. There are a few factors that play an important role towards shaping the success of future wireless technologies which are size, cost, and energy consumption. In the aspect of 5G concept for the next generations' wireless communication systems, X-band is comprehensively targeted with a wide range of applications in point-to-point radio, point-to-multipoint radio, test equipment, sensors and future wireless communications.

X-band frequency range is between 8-12GHz. Among radar applications that used X-band frequency range are continuous-wave, pulsed, synthetic aperture radars (SARs) and phased arrays. SARs play an important role on earth observation which capable of monitoring ground images continuously despite to light and weather conditions (Davide et al.,2014). SARs systems are targeted to improve the system performance in the future in terms of coverage and resolution even for missions with longer duration. Battery life of a device can be extended by improving its efficiency and also data transfer rate efficiency can be increased by improving its linearity.

Generally, the design of the proposed power amplifier will be further discussed in terms of stability, gain, PAE, output power, and insertion loss.

2.2 Structure Topology

The power amplifier is made up of two isolators, matching networks, DC bias circuit and GaAs pHEMT as the transistor. Power amplifier and signal source are protected by the isolators in case the matching networks may face some problems that cause the microwave circuit to produce high power reversal (Hui et al.,2015).

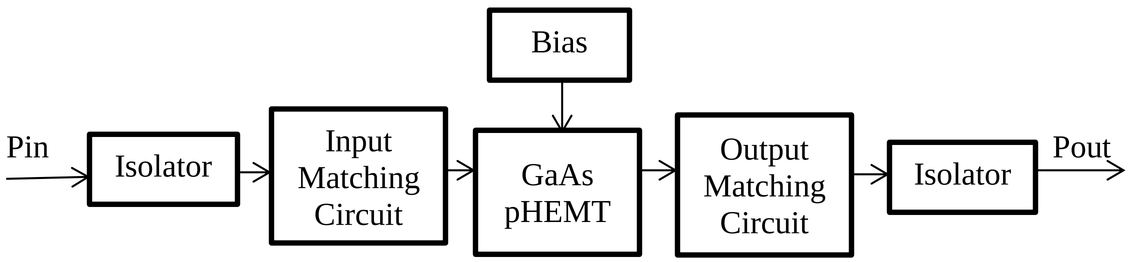

Figure 2. 1: Overall Schematic of Power Amplifier (Hui et al.,2015)

Based on Figure 2.2, the bias network which consists of DC feed and DC block is designed. DC feed provides DC voltage for the transistor in the mean time isolating RF signal whereas DC block prevents DC bias voltages from being changed when the amplifier is connected to other circuits (Phat et al.,2015).

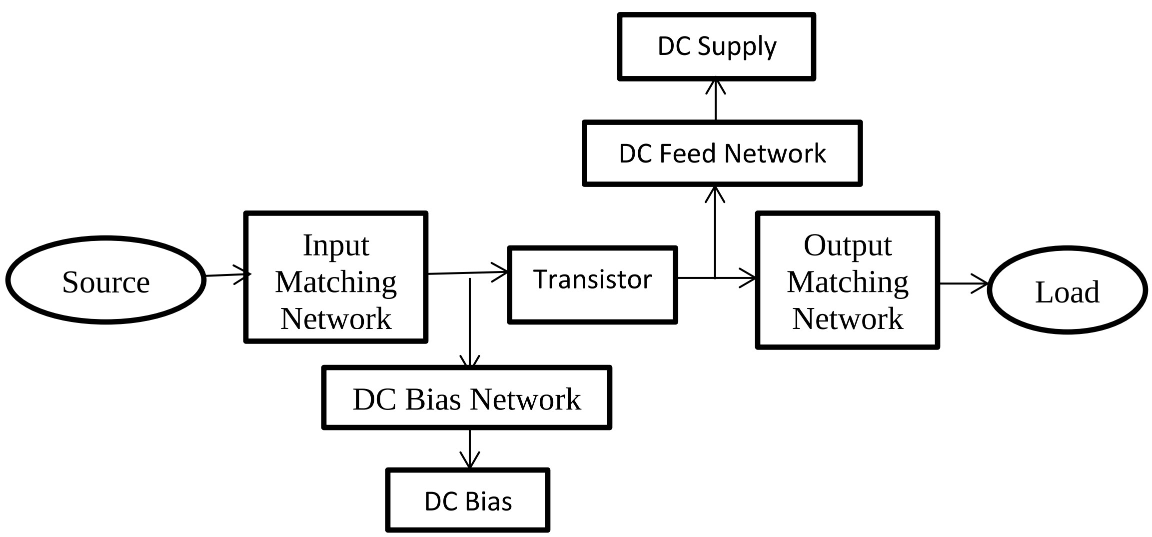

Figure 2.2: Block Diagram of Basic Power Amplifier Design

Based on the depletion mode bias network, there is two type of biasing that commonly used for pHEMT. Figure 2.3 shows that the circuit use drain voltage as positive supply and gate voltage as negative supply. The source is grounded. The feature of this circuit is it provide high gain, high efficiency, and low noise.

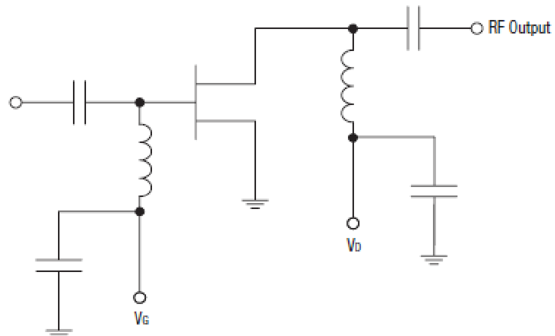

Figure 2.3: Gate and Drain Biased Separately (B.Razavi, 2013)

Thus, the circuit needs to be biased with DC biasing. Design of bias circuit is important to provide stability for DC power to be amplified, keep a high degree of isolation between microwave signal and DC power, and also minimize the insertion loss as low as possible. In this project, an off-shelf transistor is used and the DC bias network was designed on the chip to supply the required bias voltages. Matching circuit plays an important role to obtain the desired frequency, gain, output power, and bandwidth. There is no external matching needed as the matching was designed internally for the off-shelf transistor.

2.3 Power Class Mode

Power amplifier is more emphasized on output power and consumed power ratio which is also influenced its efficiency and distortion rate. Thus, majority power amplifier circuit applied either class A or class AB amplifier (Lixia et al.,2015).

Class-A power amplifier is the most linear among all types of amplifier in which the output signal is almost similar to the input signal of the amplifier. Moreover, the conduction angle of the transistor is 360^{0} as in Figure 2.4. The DC power consumption of class-A mode is independent of output signal amplitude (M. Pozar, 2012). The problem is that only a small output power can be obtained due to its large power consumption that led to wasteful of power. This class mode usually being used in small-signal amplifier.

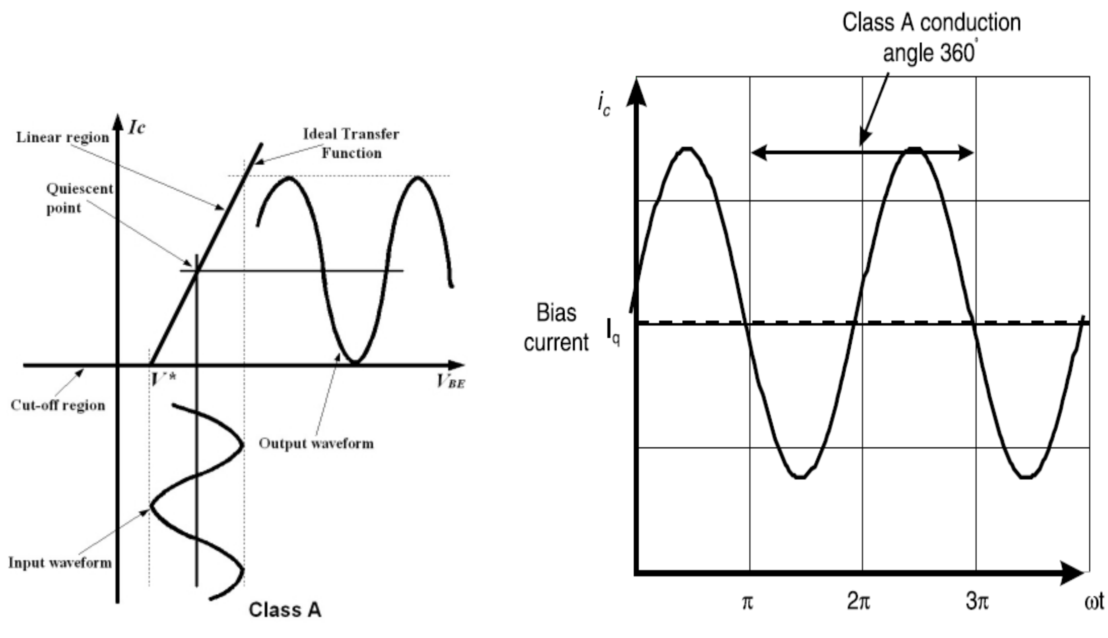

Figure 2.4: (i) Class-A Bias (ii) Class-A Conduction Angle (K.Marian, 2015)

Class-B mode conducts only half-rectified current waveform which have a conduction angle of 180^{0} as in Figure 2.5. The efficiency varies with the output voltage. Unfortunately, they are less linear compared to class-A mode. So, a typical class-B amplifier may produce a little harmonic distortion that has to be filtered from the amplified signal.

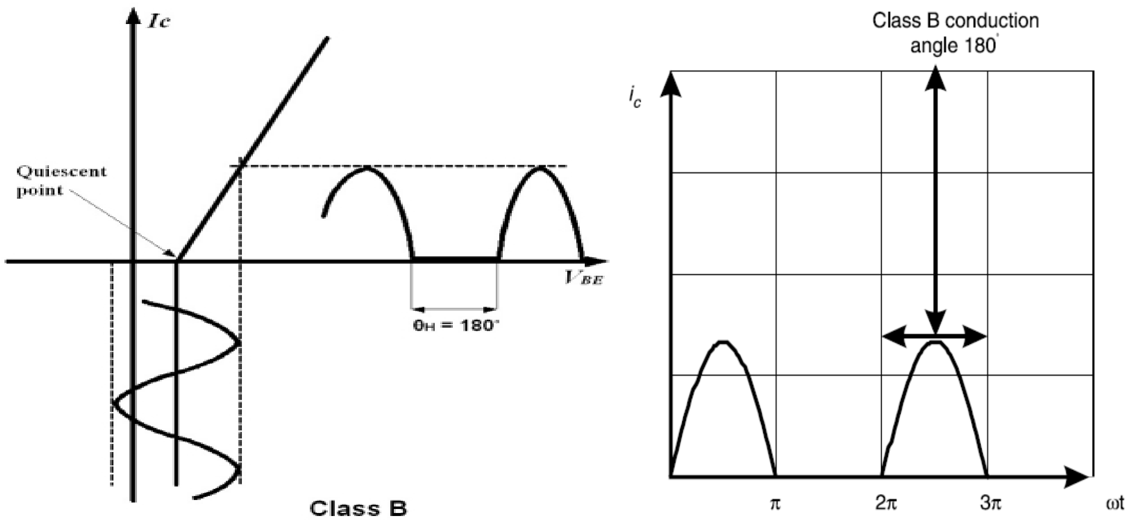

Figure 2.5: (i) Class-B Bias (ii) Class-B Conduction Angle (K. Marian, 2015)

The performances of the class-AB power amplifier are between class-A power amplifier and class-B power amplifier in terms of efficiency and linearity. In this class mode, the transistor will turn ON for more than half a cycle of conduction in class-B, but less than a full cycle of the input signal of conduction in class A as shown in Figure 2.6. Besides, some of collector current conducts longer than a half-cycle cause the reduction of the even harmonic distortion (Lixia et al.,2015).

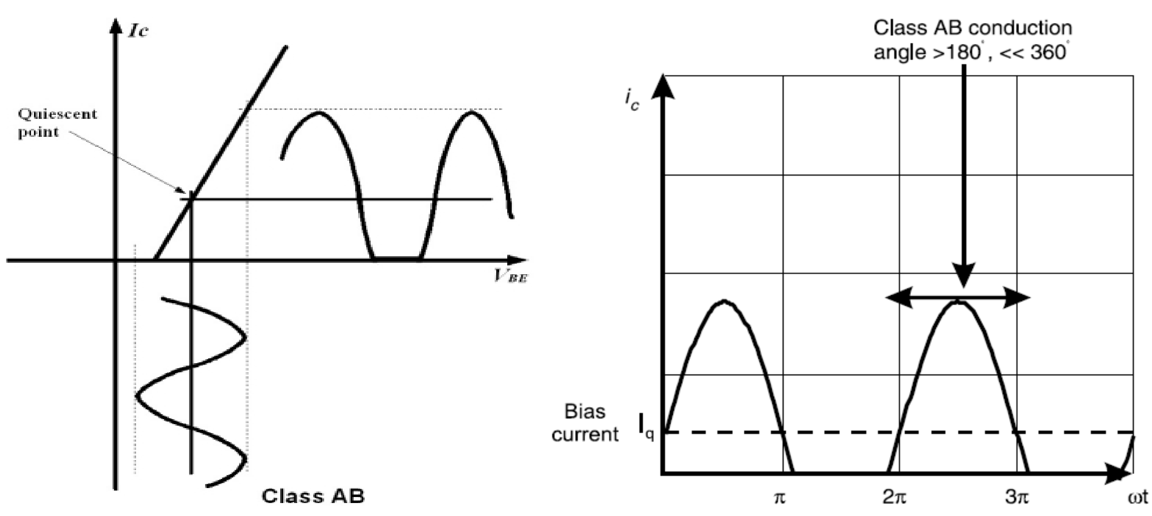

Figure 2.6: (i) Class-AB Bias (ii) Class-AB Conduction Angle (K. Marian, 2015)

Based on the three class modes, class AB amplification is chosen to be implemented in the circuit design as it will improve the reduction of harmonic distortion and it is balanced between linearity and efficiency.

2.4 Type of Transistor

In contrast to the monolithic CMOS integration approach used for the transceiver, the RF front-end utilized non-CMOS technologies such as GaAs, GaN, and SiGe MMIC process. These non-CMOS technologies are employed for high breakdown voltage active devices to obtain high quality and high level of integration (Dimitris,1999).

There are a lot of techniques and technologies had been developed in order to boost the capabilities of the devices. Based on previous work (Qinyang et al.,2015), GaAs pHEMT MMIC is utilized to achieve high performance in term of efficiency as it covered full X-band of output power.

pHEMT is the most popular devices for power applications when the operating frequency is high and required exceedingly high speed, low noise figure, and high PAE. When it came to high frequency operation, pHEMTs offer the absolute choice due to their high gain that can reach up to millimeter-wavelength and provided good power performance (Dimitris,1999).

Besides, GaAs-based FET are also famous in the markets of X-band because of its characteristic of having low power requirement, high efficiency, and better stability. FET is utilized in this device technology due to its non-linear characteristic in which drain-source capability and linearity of gate changes with respect to drain-source and gate-source voltages (Pramod and Ravi,2013). However, its velocity and mobility of electron gas in the transistor cannot compete with high mobility and velocity of electron gas in pHEMT. Thus, FET cannot achieve high gain well in millimeter wave region.

GaN HEMT has drawn much attention for radar applications as it has shown excellent capabilities in term of high power, high efficiency and high gain correspond to high voltage operation based on the great material properties of GaN (Chen et al.,2007). GaN can inherent high voltage withstand capacity. Furthermore, GaN HEMT amplifiers are also capable of delivering high performance as compared to GaAs HEMT regardless of their smaller peripheries.

GaAs devices have power limit since they cannot tolerate with high voltages, current and heat levels of silicon like GaN (Dimitris,1999). It needs to be combined in networks to boost its power level as high as possible. GaN's magnificent characteristics are high power density and it is also known because of its ability to disperse heat from a small package (Dimitris,1999).

GaN production consumes high cost as the volume increased because the materials are expensive and its process to make devices are costly. Thus, GaAs dominates the markets of wireless communication system. In this project, a GaAs pHEMT MMIC analog amplifier is employed as their features can comprehend with the specifications of the project and it is affordable.

2.5 Matching Network

The vast range of operating frequency band of power amplifier requires matching networks design that converted optimum impedance into the source and load impedance which are 50Ω in the whole frequency band as depicted in Figure 2.7. The frequency response of matching circuits can be adjusted by altering the width, characteristics impedance and length of each stepped line (Phat et al.,2015). In X-band, microstrip lines are commonly used rather than lumped components.

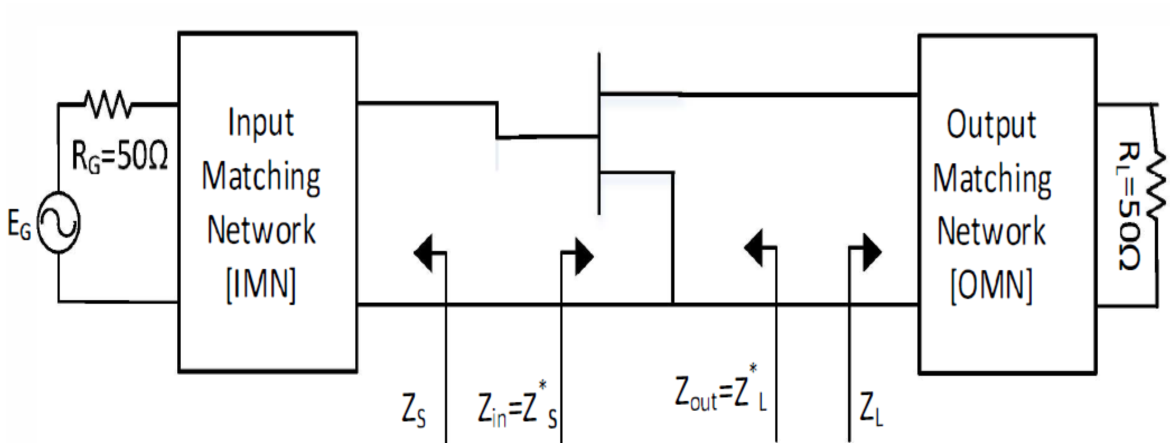

Figure 2.7: Simplified Power Amplifier Schematic (Siddik and Malik,2015)

The key to designing matching network is to obtain the maximum power transfer over input and the output matching networks. Input matching network is generated to match R_G = 50Ω to the load-pull input impedance Z_{in} (jω) =$Z *_S$(jω). Output matching network is designed to match the load-pull measured output impedance Z_{out}(jω) =$Z *_L$(jω) of the active device to R_L=50Ω (Siddik and Malik,2015).

By using conjugate matching technique in matching network design, the load obtains maximum power transmission and high efficiency. Input matching network is placed between Gate and Source in which Source is grounded, whereas output matching network is placed between Drain and Ground. The impedance of both input and output port are designed using 50Ω microstrip line so that they can be matched to 50Ω. Matching circuits are designed by using Advanced Design System (ADS) software in order to ease the computation. There are three steps to do the matching circuit (Hui et al.,2015):

- Determine the S-parameter based on the required frequency of the transistor chosen. ADS software can be used to calculate the input and output impedance.
- The Smith Chart and microstrip line calculator are used to calculate the length and width of the microstrip lines (Figure 2.8) in the matching network according to the input and output impedance of the tube.
- Lastly, the matching circuit and the transistor are cascaded to form the circuit of power amplifier.

So, matching with transmission lines are the best to be utilized in this project as it is easy to debug and provide better stability. The type of transmission that is commonly used is microstrip line as described in previous work (Pramad and Ravi,2013; Lixia et al.,2015; Hui et al.,2015; Phat et al.,2015; Ken et al.,2014).

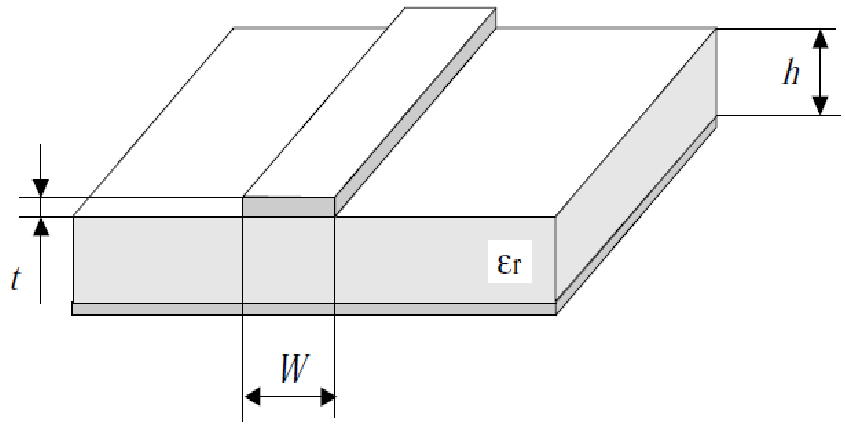

Figure 2.8: Microstrip Line Schematic (A.Grebennikov,2005)

2.6 S-Parameter

Power amplifier design relied on the terminal characteristics of the transistor as represented by S-parameters. S-parameter provided the necessary values to do the analysis for stability, maximum gain, frequency, and noise figure. S-parameter also used to characterize a multipoint linear network. Figure 2.9 showed the structure of a two-port network. The incident (a1, a2) and reflected (b1, b2) waves can be expressed as:

$$b_1 = S_{11} a_1 + S_{12} a_2 \qquad (2.1)$$

$$b_2 = S_{21} a_1 + S_{22} a_2 \qquad (2.2)$$

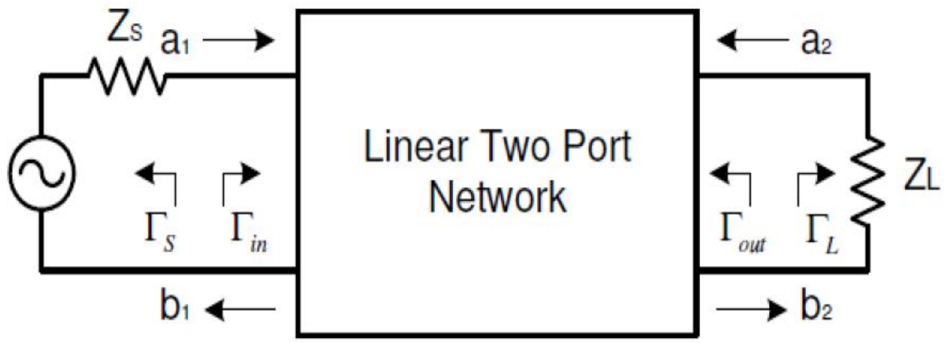

Figure 2.9: Two-port Network Showing Incident and Reflected Waves

(M.Pozar,2012)

S-parameter can be expressed as follows:

$$S_{11} = \frac{\text{Reflected power from the network input}}{\text{Incident power at the network input}} \quad (2.3)$$

$$S_{22} = \frac{\text{Reflected power from the network output}}{\text{Incident power at the network output}} \quad (2.4)$$

$$S_{21} = \frac{\text{Power delivered to the load}}{\text{Power available from source}} \quad (2.5)$$

$$S_{22} = \frac{\text{Reflected power delivered to the source}}{\text{Incident power on the network output}} \quad (2.6)$$

2.6.1 Stability

The stability of transistor can be determined by S-parameter method in the design of power amplifier. Stability can be analytically proven by using this equation (M.Pozar,2012) :

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2] + |\Delta|^2}{2 \mid S_{12} . S_{21} \mid} > 1 \qquad (2.7)$$

$$\mid \Delta \mid = \mid S_{11} . S_{22} - S_{12} . S_{21} \mid < 1 \qquad (2.8)$$

The power amplifier will be unconditionally stable if the calculated value satisfied the Rollet's condition and then, the design will be verified in ADS tool. $|S_{11}| < 1$ and $|S_{22}| < 1$ also must be satisfied so that the device is unconditionally stable. Stabilization of the active device was designed with the aim to reach an unconditional stability at every frequency, in the meantime achieve a flat gain behavior in the operating frequency band.

2.6.2 Noise

Noise is an unwanted signal that is generated internally in the channel which degraded the desired signal response. The degradation of response can be in the form of fluctuations in signal amplitude of the magnitude, phase and spectral content. There are three main types of noise which are thermal, flicker and shot noise as being described in previous work (Pramod and Ravi,2013).

In RF system, noise factor (F) is the term for noise. Noise figure (NF) is noise factor expressed in decibels (dB) unit:

$$F = \frac{SNR\ at\ the\ input}{SNR\ at\ the\ output} \qquad (2.9)$$

$$N = 10 \log (F) \qquad (2.10)$$

2.6.3 Gain

In RF amplifier theory, there are three most important kinds of definition for power gain which consisted of transducer power gain (G_T), operating power gain (G_P) and available power gain (G_A).

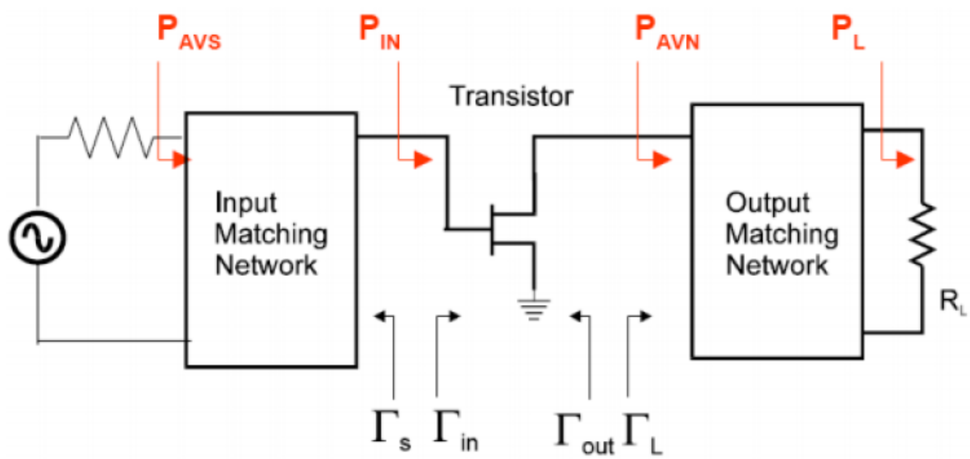

Figure 2.10: Single Stage Power Amplifier with Input and Output Matching Network

(Rogers and Plett,2003)

$$G_T = \frac{P_L}{P_{AVS}} = \frac{\text{Power delivered to load}}{\text{Power available from source}} \qquad (2.11)$$

$$G_P = \frac{P_L}{P_{IN}} = \frac{\text{Power delivered to load}}{\text{Power input to the network}} \qquad (2.12)$$

$$G_A = \frac{P_{AVN}}{P_{AVS}} = \frac{\text{Power delivered to load}}{\text{Power input to the network}} \qquad (2.13)$$

2.6.4 Efficiency

Drain efficiency is the direct ratio of output power to input DC power. The formula can be expressed as (M.Pozar,2012):

$$\eta = \frac{P_{RF_{OUT}}}{P_{DC}} = \frac{P_{RF_{OUT}}}{V_{DC} \cdot I_{DC}} \qquad (2.14)$$

Power-added efficiency (PAE) is taken into account of the input RF power when it comes to calculation of efficiency. This is the most significant figure of merit when comparing single amplifiers. The formula can be expressed as (M.Pozar,2012):

$$PAE = \frac{P_{RF_{OUT}} - P_{RF_{IN}}}{P_{DC}} = \frac{P_{RF_{OUT}} - P_{RF_{IN}}}{V_{DC} \cdot I_{DC}} \qquad (2.15)$$

2.7 Comparison

Table 2.1: Comparison of Journals Based on the Specifications

Reference	(Lixia et al. ,2015)	(Hui et al., 2015)	(Siddik and Malik,2015)	(Qinyang et al., 2015)	(Davide et al.,2014)
Device Technology	GaAs FET	GaAs FET	GaN FET	GaAs pHEMT	GaN HEMT
Class Mode	AB		AB	AB	AB
Frequency (GHz)	9.3 – 9.4	8.2	8 - 10	8 – 12	8.8 – 10.4
Gain (dB)	10	8.1	10	27	25
PAE (%)	44.4	33.62	50	54	38
Pout (dBm)	24.5	31.25	47	41.8	18.5
Stage	1	1	3	3	2

2.8 Summary

Based on the comparison of the journals above, GaAs pHEMT showed the best outcome according to the specifications. GaAs pHEMT is also cheaper than GaN technology and it is affordable to be implemented in this project. Besides, it showed great performance in term of efficiency, gain and output power. Transmission line is used for matching as it reduced the size of bias network and eliminated passive components which are expensive and lossy at high frequency. The circuit is designed using the microstrip line instead of lumped elements which could improved stability factor and maximum gain. Class AB is chosen to be utilized in this project as it provided enough linearity to not distort RF signal.

Chapter 3

METHODOLOGY

3.1 Overview

In the previous chapter, the contribution of previous engineers and researchers in the scope of power amplifier's specifications and properties were discussed. Their characteristics and design formulas are explained in more details. In this chapter, the main objective is to justify the method used to design power amplifier using ADS and process to design the layout for fabrication. A proper project implementation flow is important to ensure that the process ran smoothly and met the design specifications. Each step in the process of designing power amplifier is being discussed in details so that the aim and objectives of this project are achieved.

3.2 Project Implementation Flow

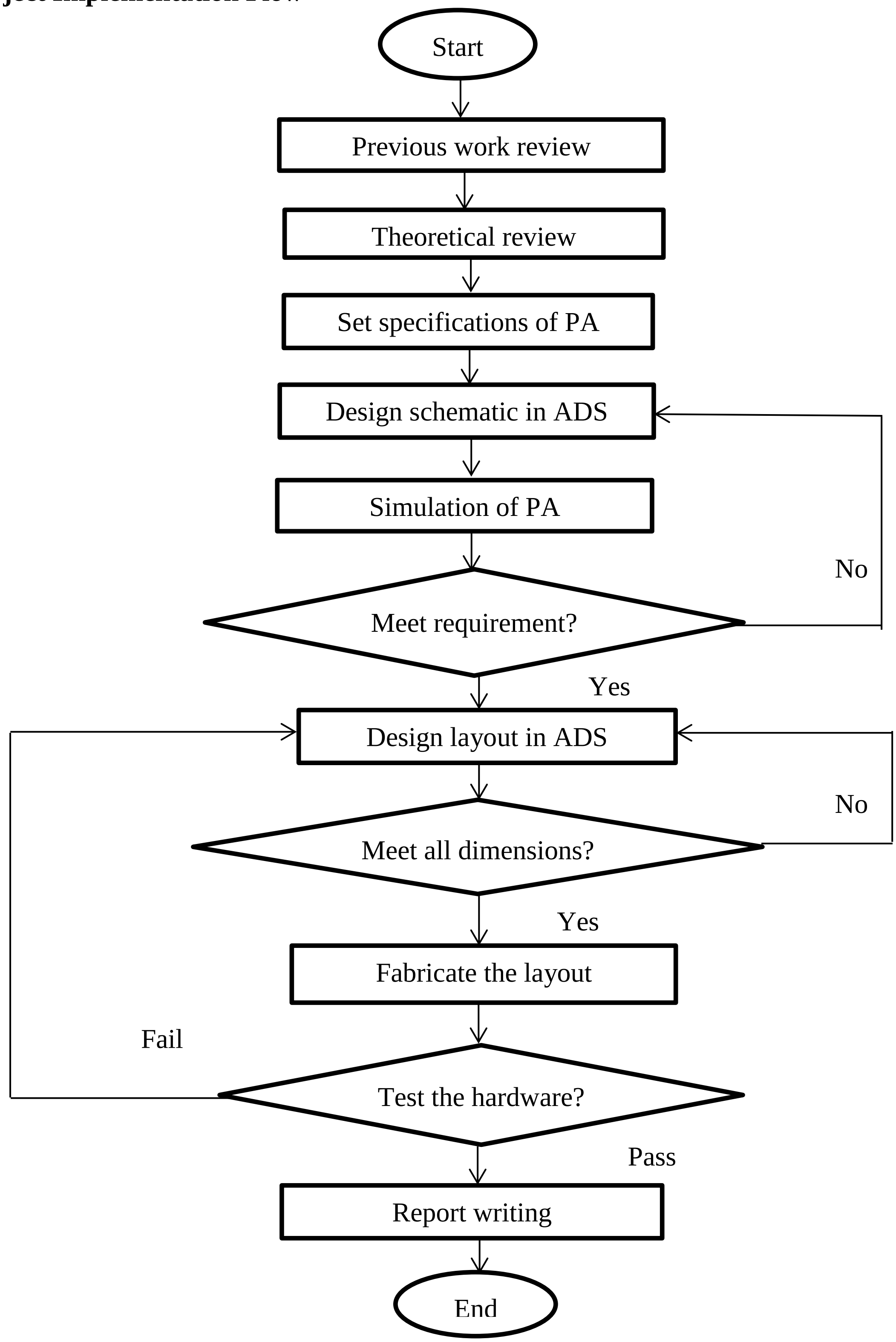

Figure 3.1: Summarization of the Whole Process

The descriptions of the flow chart are as below:

1. Start:

   The design started with determining the objectives that needed to be achieved in this project.

2. Previous work review:

   Review a few journals and researchers paper to get the idea for the project and analyzed through their previous work to determine the limitations.

3. Theoretical review:

   Acknowledged the concept of power amplifier theoretically in more detail.

4. Set specifications of PA:

   Based on the reviews, the specifications of PA is set as follow:

Table 3.1: Specifications of PA

Parameter	Value	Unit
Operating frequency	10	GHz
Input return loss	-9	dB
Linear gain	±16	dB
Output power	23	dBm
PAE	>30	%

5. Design schematic in ADS:

   The schematic structure is designed using ADS software. The design is modified until it met the expected result.

6. Simulation of PA:

   The design is simulated to see whether the outcome met the requirements.

7. Design layout in ADS:

   The layout is designed using ADS software.

8. Fabricate the layout:

   The finalized layout design is fabricated onto Roger Duroid 4003c board at PCB lab.

9. Report writing:

   The report is being written after the results have been collected.

10. End:

    The project ended as the objectives of the project are achieved.

3.2.1 Schematic Design

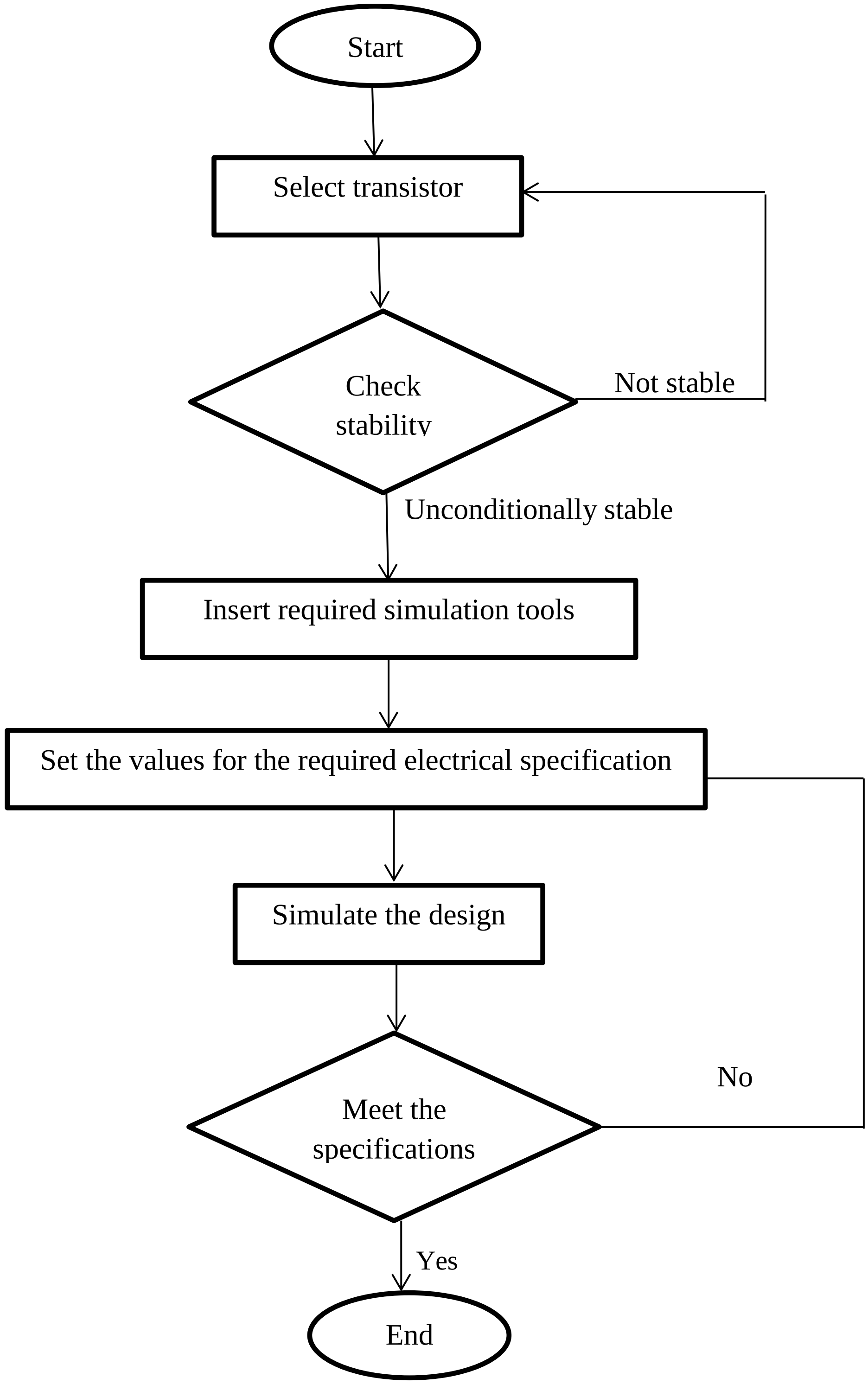

Figure 3.2: Design Schematic in ADS

The descriptions of the flow chart are as below:

1. Start:

   The design started with determining the objective of designing schematic that needed to be achieved.

2. Select transistor:

   The analog device that has been selected is HMC996LP4E which is a GaAs pHEMT MMIC analog variable gain amplifier.

3. Check stability:

   The circuit is constructed in ADS to check the stability as in Figure 3.3:

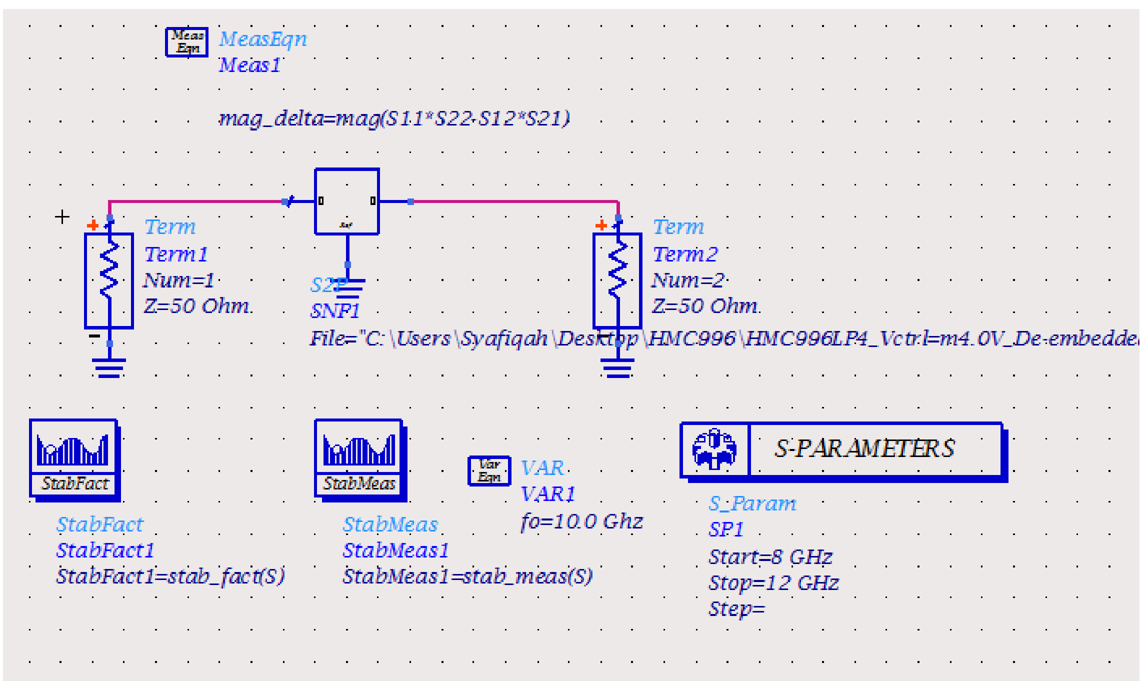

Figure 3.3: Circuit to check stability