DESIGN AND ANALYSIS FOR MIXER AND AMPLIFIER FOR AMATEUR RADIO APPLICATION

By

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18233

Dissertation submitted in partial fulfilment of

the requirement for the

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CERTIFICATION OF APPROVAL

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Approved by,

_____

(Dr. Mohd Azman bin Zakariya)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or person

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(MOHAMAD AIMAN BIN OTHAMAN)

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Praise to the Almighty Allah S.W.T I manage to finish this report within the time frame that is set by Universiti Teknologi Petronas (UTP) successfully and also giving me the privilege as well as the health to complete the report. I would like to give me deepest thank you notes to my supervisor Dr. Mohd Azman bin Zakariya for guiding me and supervised all of my work and for giving me a deeper appreciation towards the work that I dedicated my time and energy to. Furthermore I would like to express my uttermost gratitude to him for all the inputs, guidance and motivation to make sure that I will finish my final year project within the time frame.

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ABSTRACT

The main objective of this project was to clarify on the Amateur Radio Application, mainly focus on the transmitter side. Signal-to-Noise Ratio (SNR) has always been the main concern in Radio Communication; it is required to have a high SNR margin but compromisation on the cost of fabrication and vice versa. Optimization of components will be done in this project in highlight that the final product to have an optimum or balance in terms of cost of production, SNR margins and variety of input signal. For this project, it is focus on the up-conversion of the frequency mixer as well as the Class C amplifier. Radio communication transmitter works by mixing a Radio Frequency (RF) with a Carrier Frequency and the resulting signal of the mixing process is a signal that is twice the bandwidth than its original input signal. The simulation for this project will show the components that will be used later in circuit fabrication therefore; acknowledgement regarding the cost of production and the result will display the Noise and Signal configuration and from the information obtained shall be calculated for the SNR margin. The simulation will be done on the existing design and modification will be done on the existing design so that optimization of the final product can be done. The recommendation for this project is to specify on the type of data modulation and to use various simulation tools to further validate on the circuit design.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Radio Communication was first invented by an Italian Inventor named Guglielmo Marconi back in 1895. The first transmitted signal was sent from England to Newfoundland and for the next two years, the transmitted signal is received which is the letter 'S'. As the technology goes by, the improvement of radio communication keep growing and growing and soon the experimenters and amateurs were involve vigorously improving the technology for the betterment of the future.

One of a good example of mixer is Heterodyning. Heterodyning is a process where two frequencies are mixed to form a new frequency. This process is invented by Canadian Inventor named Reginald Fessenden and one of the problems that he wants to overcome is that the signal is not audible or loss due to transmitting, by adding the other frequency, he can reduce the loss of signal when transmitting [2]. Furthermore, on the receiving side Band Pass Filter can filter out the unnecessary frequency to gain back the original frequency. One of the frequencies added to the transmitted signal is called the carrier frequency and the purpose of carrier frequency is to "carry" the data from the fixed frequency to the receiver end.

There are some importance factor that can give an impact to the performance of a mixer; selection of diodes, transistor, the conversion gain, and noise figure. Thus, the purpose of the project is to design and give the possible solution for the best mixer to work under all circumstances. There are three type of mixer than can be categorized; unbalanced mixer, single balanced mixer and double balanced mixer. The types of the mixers will further discuss deeper in the report.

The usage of amplifier during transmitting a signal also plays an important role, firstly, an amplifier increases the power of a signal, the main function of an amplifier is to decrease the loss of signal during transmission and the loss during transmission is called attenuation because the output power of a signal is much lower than the input power. Thus, the amplifier boosts up the power of the signal to overcome the attenuation.

There are a lot of configurations of an amplifier, for this projects discussion regarding the best configuration of an amplifier that works best with the correct mixer will be explained thoroughly. The main focus of this project is to optimize the overall signal-noise ratio at the output. Not only that, some of the factors of components selection plays an important role in output optimization, for instance in the amplification part, there are several parts that needed to be taken upon consideration. Type and value of transistor and resistor needed to take upon calculation to work best with the configuration of the mixer as well.

1.2 Problem Statement

Mixers are subsequently generally utilized as a part of the analog/RF front end of beneficiaries. In these applications, frequently the mixer must be intended to handle a wide element scope of signal power on the input. The mixer can be utilized for demodulation, in spite of the fact that the trend is to digitize taking after a low IF recurrence and execute the demodulation work digitally. They can likewise be utilized as simple multipliers to give gain control. In this application, one input is a DC or gradually differing signal which when increased by the RF/IF signal will control the level of pick up or lessening. In transmitter applications, the mixer is frequently utilized for up-conversion or modulation. In this application, the info signal level can be chosen to improve the general Signal-To-Noise Ratio (SNR) at the output.

1.3 Objectives

The main focus of this study is:

1. To simulate the design of mixer and amplifier for Amateur radio application
2. To analyse the design parameters for Class C amplifier and mixer design.
3. To evaluate between the simulated result with the existing result for optimum performance evaluation.

1.4 Scope of Study

The main scope of this project is:

1. The design of amplifier is focused on the Class C Power Amplifier Type
2. The operation of the desired Radio Frequency (RF) Components are tested between 1MHz to 1GHz
3. The model of the design is simulated with Agilent Advanced Design System (ADS)

1.5 Relevancy and Feasibility

Based on the research done for this project, there are some aspects that are taking into account such as the wide dynamic range of the signal power to the input and high performance standard for an optimum input signal level. Radio Frequency (RF) mixer is one of the crucial elements in the RF design with the correct configuration and design; improvement of the performance and the overall design of this project are for Amateur Radio application [10]. Another important parameter that will be taking upon consideration is the RF power amplifier and the basic principle of an RF amplifier is to boost or converts a low-power RF signal to a higher power so that the signal lose to the different factor can be reduce.

CHAPTER 2

LITERATURE REVIEW

Mixer is one of the important ingredients to reduce the losses during transmission of data and it is also one of the important parts to increase the Signal-to-Noise Ratio (SNR). The main function of increasing SNR is to strengthen the transmitting signal so that the signal is immune to any interference from other source of disturbance. Furthermore, a new signal is formed when two or more audio signal is combined together [1]. Some of the available type of mixer is adding mixer and multiplication mixer. For a new spectrum to form, a multiplication mixer must be used because if addition mixer is used it will combine their amplitude and the frequency is not affected by this mixer. This is an example for just superimposition [1]. Another type of mixing is called multiplication mixing. This form an entire new spectrum when two signal are multiply together, the formed signal will have some common components in its spectrum but the output signal can be represented by $(f_1 + f_2)$, $(f_1 – f_2)$ [1].

On the transmitter, there are important elements that needed to be considered. Those elements are data signal, mixer, local oscillator, filter, amplifier and antenna. These are the basic element of a transmitter. For mixer there are some circuit elements that needed to be configured and carefully selected for example the selection of diode for multiplying mixer, there are some diodes can be used in mixer, but different diode have different effect on the output such as SNR.

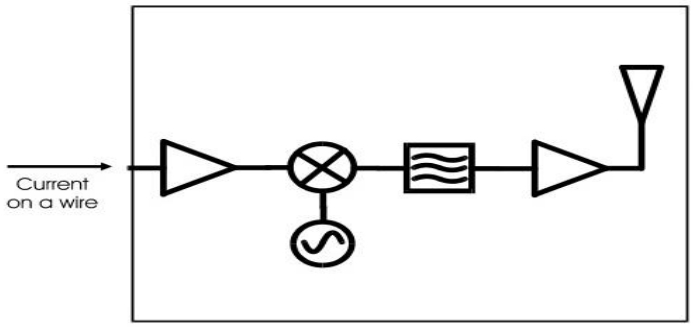


Figure 2.1: Basic Transmitter Block Diagram [3]

As shown in the figure below, the selection of Operational Amplifier (Op-Amp) is important to form the correct Amplitude Modulation (AM). For AM transmission, carrier frequency is important because the carrier will reduce the loss during transmission. The output of the mixer will undergo filtration to remove the unnecessary signal and will further amplify for transmission.

Both resistive and reactive parameters of a transistor mixer are imparted similarly as oscillator amplitude and the small-signal quiescent parameters. The frequencies of the three signals in a mixer, being different, and offer three effective circuits: one in respect of the midway repeat yield, one as displayed to the radio-recurrence source and one as acquainted with the oscillator source. The proposed circuits offer a supportive technique for blender circuit outline up to the frequencies at which the little banner proportionate circuit is material [9].

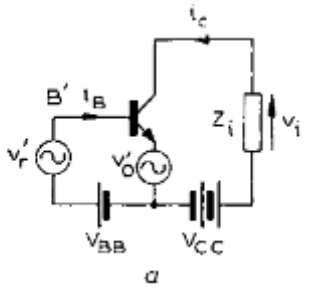


Figure 2.2: Simple Transistor Mixer circuit [9]

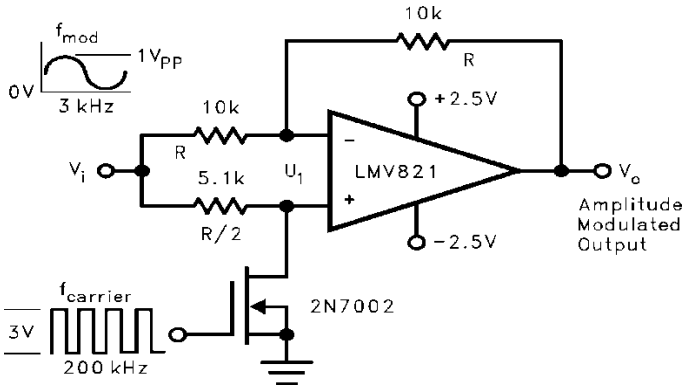


Figure 2.3: Simple Op-Amp Mixer for Amplitude Modulation [3]

The basic on constructing a Band-Pass Filter (BPF) is the selection of two major circuit elements which is resistors and non-polarized capacitor [4]. The reason BPF is chosen for this project is because it can remove unneeded frequency for transmitting purposes, although noise will go through the filter, but the major unwanted frequency is removed during this process [4]. This part is crucial because amplification the signal straight out of the mixer without filtering the signal first not only it amplify the signal, but the noise as well [1]. There are three parameters that needed to be defined first by the designer which is the lower cut-off frequency, higher cut-off frequency and the value of resistor [4].

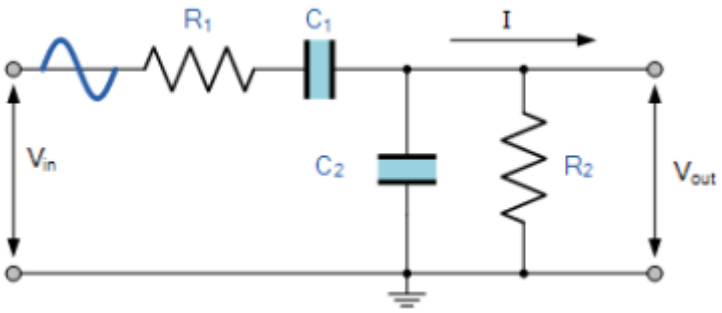


Figure 2.4: Simple Band-Pass Filter [4]

The last part before transmitting a signal is to amplify the signal, after filtration, some of the signal power will lose or absorb by the circuit element [1]. To ensure the signal has enough power to be transmitted, power amplifier is needed to overcome the power shortage. There are a lot of methods to amplify the signal such as using an Integrated Circuit (IC), Op-Amp, and transistors. In this project the most suitable method of designing the circuit is using transistors [5].

There are few classes of amplifier that needed to be study before selecting the correct one. There are 4 main classes of amplifier, for Amplitude Modulation Single-Sided Band the amplifier that are appropriate for the project is Class C amplifier. Class-C amplifier is customarily characterized by a narrow current heartbeat characterized with specialist substantial numbers of harmonics [8]. Class C amplifier are regularly utilized as a part of high recurrence sine wave oscillators and certain sorts of radio recurrence enhancers, where the beats of current created at the speakers yield can be changed over to finish sine rushes of a specific recurrence by the utilization of LC resounding circuits in its gatherer circuit [6]. There are two types of characteristic of a Class C amplifier, which is, the

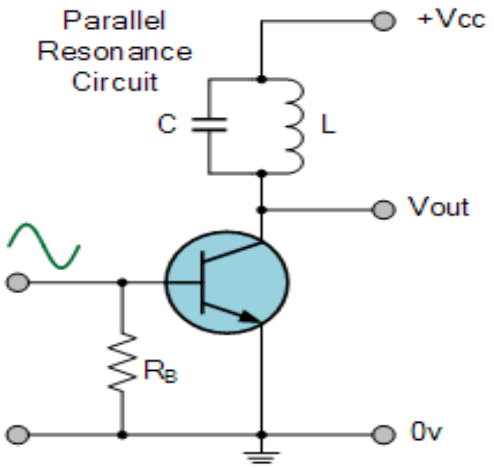
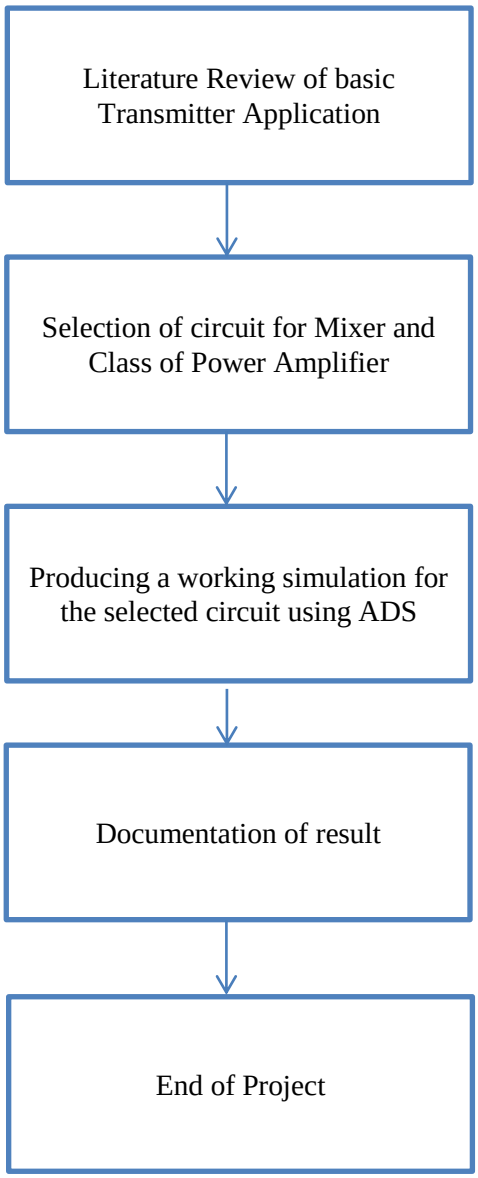


Figure 2.5: Class C Amplifier [6]

CHAPTER 3

METHODOLOGY

3.1 Flowchart of the project



3.1.1 Literature Review

Literature review for this project is conducted to get the basic ideas of what Amateur Radio was, the history behind it and the technology behind it. Furthermore, Mixer and Amplifier play an important role in transmitting signal for Amateur Radio. Technical papers about the technology of mixer and amplifier were read and studied for this purpose. The filter used in transmitting the signal is Band-Pass Filter (BPF), the main reason BPF is used is because, and the bandwidth of a signal can be filter out easily by BPF [7].

3.1.2 Selection of circuit for Mixer and Amplifier

There are a lot of factors for the circuit element selection for Mixer and Amplifier, among the factor is noise tolerance, some of the circuit elements are sensitive to noises and those types of circuit elements that needed to be avoided for this project. Among the circuit elements that are selected were Resistors, Capacitors, Transistors and Operational Amplifier (Op-Amp). In constructing the Single-Ended Mixer for this project, there are a few type of mixer that can be choose such as unbalanced mixer, single and double balanced mixer [11]. For this project, Double Balanced Gilbert Cell (GC) Mixer is chosen due to its simplicity and effectiveness. For this project, an active mixer is chosen because the design has the ability to produce conversion gain, optimized design for Integrated Circuit (IC) Implementation as well as, the ability to sustain the Intermodulation Distortion (IMD) when the mixer circuit is implemented. The first step on design any active mixer, DC analysis has to be implemented so that the saturation point of the MOSFET is obtained [12]. Furthermore, DC analysis is done to obtain the appropriate bias condition for the device width that follows the specification of the project [12]. After the result of DC analysis is obtained, Radio Frequency (RF) Analysis is completed to analyse the parameters of the mixer for example, the conversion gain versus RF input, Noise Figure versus RF input as well as the tabulation of the data. Besides that, it is necessary that the device operates in saturation mode so that the values for g_m and C_{gd} can be obtained. Furthermore, high values for g_m and low values for C_{gd} are compulsory for implementing active circuit so that high current gain is obtain.

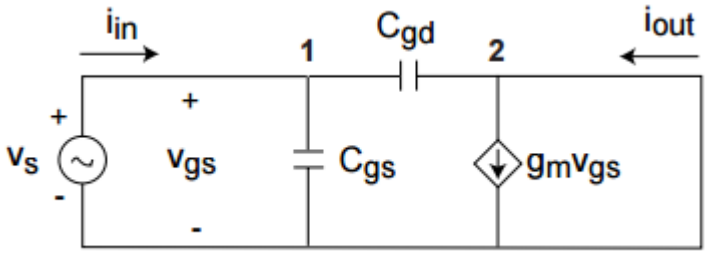


Figure 3.1: Simplified Circuit for MOSFET in Saturation mode

$$\frac{I_{out}}{I_{in}} = \frac{\sqrt{\left(g_m^2 \omega^2 C_{gd}^2\right)}}{\omega(C_{gs}+C_{gd})} \quad (1)$$

Based on figure above, obtaining the current gain can be obtained by using node analysis, thus the final equation is equivalent to (1). Based on the equation shown, the values for g_m and C_{gd} are required to be high and low respectively so that the current gain can be obtain as high as possible.

3.1.3 Simulation using Advance Design System (ADS)

For the third methodology, the purpose of the simulation is to obtain the necessary data from the desired circuit design and calculation to comply with the objective of this project, which is to obtain the optimum performance design of the circuit. Some of parameters that needed to be evaluated for mixer are, Signal-To-Noise Ratio, Bandwidth of the filtered signal and noise. For the amplifier, we will analyse the output signal and we will compare the signal before and after the harmonic filter is apply. For this project, Harmonic Balance simulation is selected because by using this type of simulation, the number of harmonics for the Local Oscillator and Radio Frequency can be set initially as well as the maximum order for the mixer simulation, therefore any unwanted harmonics can be deleted or avoided prior before the simulation even started [12].

3.1.4 Documentation of result

The final step is to document all the necessary information of the fabricated PCB. Some of the information needed for the final documentation is to see whether is the design parameters met the criteria set earlier during proposal phase and to see whether the objectives of this project is met. All the necessary calculations, analysis and graphical forms will be included in the final documentation.

3.2 Gantt Chart and Milestone Planning

Milestone planning is important to plan the workflow of the project as well as to pin point the important factor that needed to be focus on such as familiarizing with the software used in this project which is Advance Design System (ADS). Besides that, project report submission and presentation needed to be noted on the planner so that all the marking criteria are met. Based on the Gantt chart below is self-explanatory. Based on the timeline set by UTP, the final year project is divided into two semesters; the first half of the semester is when all the necessary research takes place and the second semester is where all the implementation of the project is done. There are a total of three submissions that needed to be completed in FYP 1 which is, Extended Proposal where the initial research and literature review takes place, Proposal Defence is the presentation of the initial findings and expected outcome of the whole project and lastly is the Interim Report where the final report of FYP 1 and the continuation of the project will be continued on FYP 2. As for FYP 2, There are four submissions in total, the first one is the Progress Report will be submitted on week 8 is the based on the final report of FYP 1 and the initial result obtain, in Progress Report submission will mainly focus on the current result and outcome as well as the continuation work of the previous submission. Pre-Sedex presentation is mainly focus on the presentation of our project through poster presentation where each of the students is required to make a complete poster in according to the respective projects. The Final Report is the final submission of each of the student that needed to undergo where all the working result and all the necessary data have been captured and carefully analysed in the report. The final viva will be done on the study week where external examiner will judge the presentation throughout the whole FYP process.

Activities	Week														
FYP 1 Progress and Milestone (September 2016)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Title Selection															
Preliminary Research & Literature Review															
Familiarize with ADS software															
Existing Circuit Identification															
Designing Optimized Mixer															
Designing Optimized Class C Amplifier															
FYP 1 Assessment															
Extended Proposal															
Proposal Defence															
FYP 1 Report (Draft Interim)															
FYP 1 Report (Final Interim)															
FYP 2 Progress and Milestone (January 2017)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Simulation of Designed Circuit															
Result Comparison															
Modification of Designed Circuit															
Examine the findings															
FYP 2 Assessment															
Submission of Progress Report															
Pre-Sedex Presentation															
Submission of Draft Report															
Submission of Final Report															
Final Viva															

Table 3.1: Gantt chart

3.3 Key Milestone

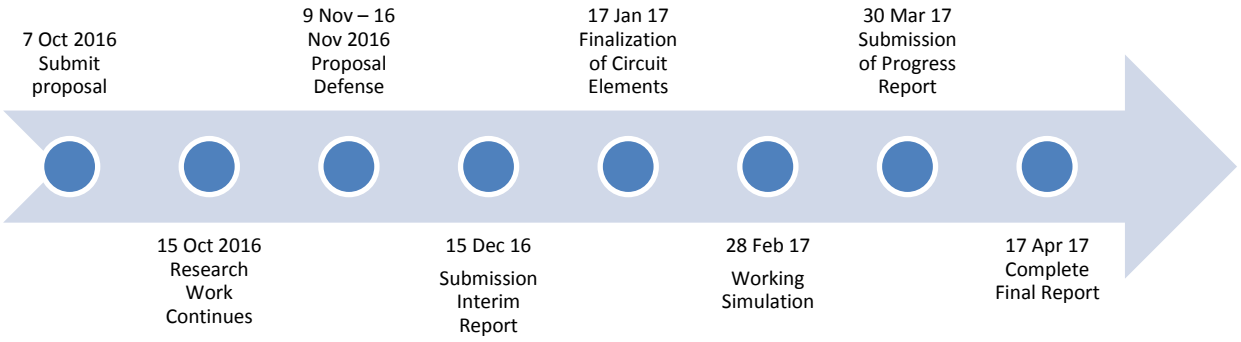


Figure 3.2: Key Milestone

3.1 Tools

3.1.1 Software

- Advance Design System (ADS)

  The software is used to design and simulate the required design of the project. To obtain the desired result this software is much needed in order to complete the designing phase as well as the implementation phase. For the designing phase, trial and error method are done to obtain the desired parameters for future use, the parameters that we will be observing is the type of Metal-Oxide-Semiconductor Field-Effect-Transistor (MOSFET) we will be using and other parameter as well. For the implementation phase, we will be comparing the simulated result with the existing circuit to observe the difference between the designed circuits with the existing circuit.

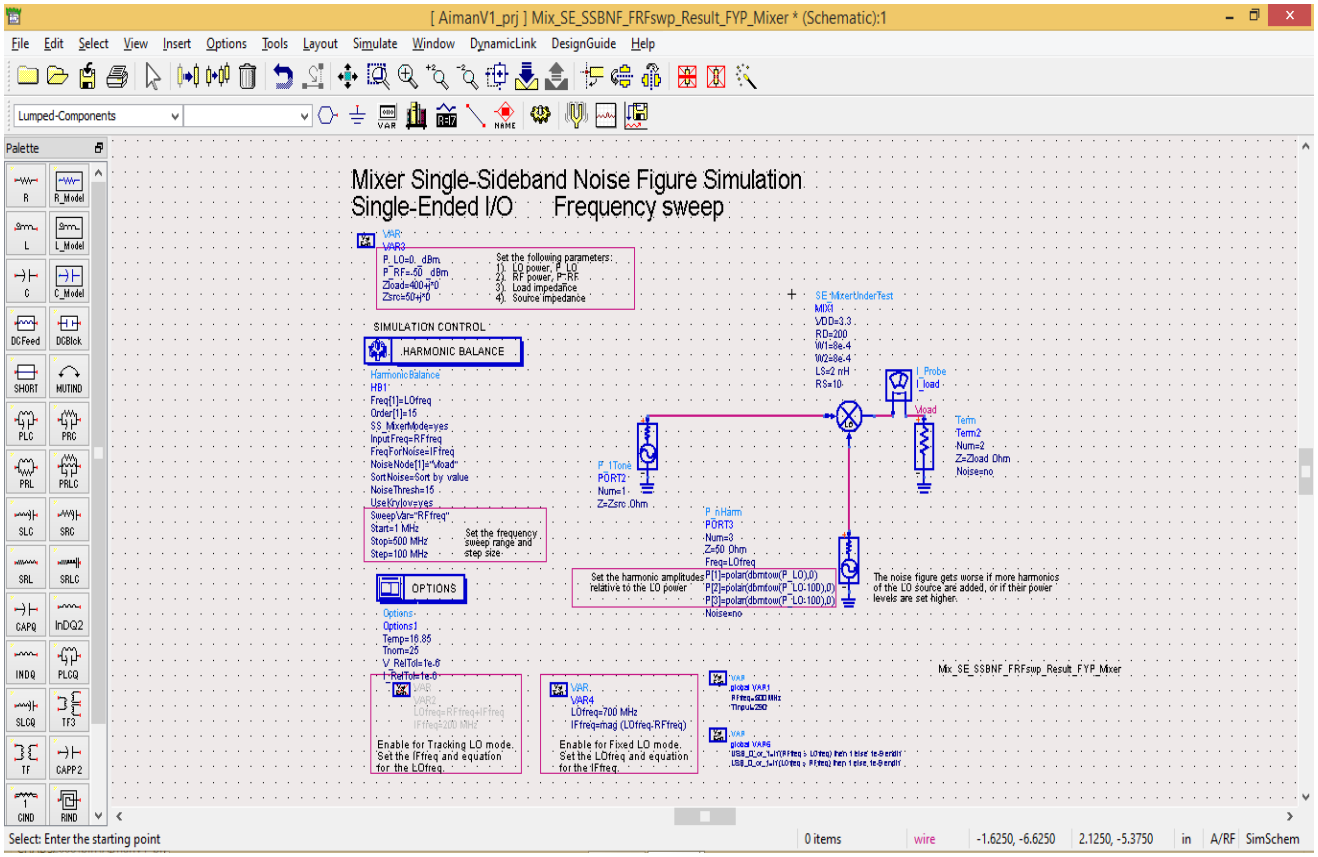


Figure 3.3: Simulated Mixer Circuit using ADS Software

CHAPTER 4

RESULTS AND DISCUSSION

This chapter explain the analysis results of the proposed design which are based on the simulation works. The initial design of the proposed Mixer and its respective design parameters analysis are described and explain accordingly. The critical parameters had been discussed in this chapter consist of type of mixer used, frequency range, input impedance and conversion gain as well as noise figure. The performance of the Mixer and related the design parameters that discuss and analyse in in detail throughout this chapter.

4.1 DC Analysis (N-Channel MOSFET)

Figure 4.1 shows a N-Channel MOSFET and configuration for the proposed design of mixer. The configuration consist of 2 DC Sources, which is connected to the MOSFET labelled MOSFETM1.The DC source 2 is connected to the Source gate and the current probe is connected to the between the DC source 1 and Drain gate. The voltage VGS1 is varied from 2.5V to 4V with increment 0.5V step and the VGS2 is fixed at 4V. This configuration is used to test the DC characteristic of the MOSFET. The DC simulation and Parameter Sweep is used to varies the result of DC simulation and evaluate the DC characteristic of the MOSFET. The DC of VGS1 is swept from 2V to 3V with increment of 0.25V step for plotting the I-V Characteristic Curve.

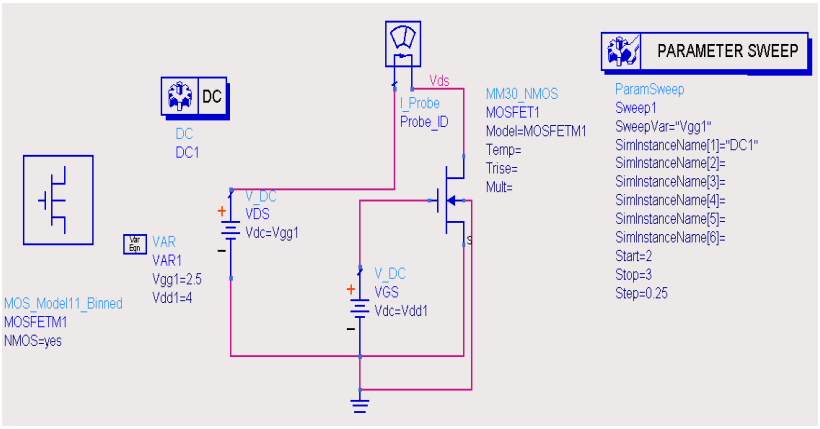


Figure 4.1: DC Analysis of N-Channel MOSFET

This simulation result shown in Figure 4.2 depicted a variation curve for the V_{gg1} (Input voltage) versus I_probe (Output Current) characteristics. The result of this simulation produces a value of output transistor conductance which is depending on the values of V_{gg1} and I_Probe as shown in Figure 4.3. The DC analysis is used to obtain the output characteristic of the N channel MOSFET and to obtained the transistor's output conductance (transconductance), g_m. Initially, the output conductance is obtained by setting the bias point at linear range and the bias point which is determined by V_{dd1} and $V_{DSAT.}$ For the value of V_{DSAT} is selected by the subtraction of the values between V_{GS} and $V_{T.}$ The values of V_T are determined when the MOSFET start to operate or turn on which is equivalent to 0.7V and V_{GS} is obtained when the MOSFET starts to conduct or saturate which is equivalent to 3.6V.

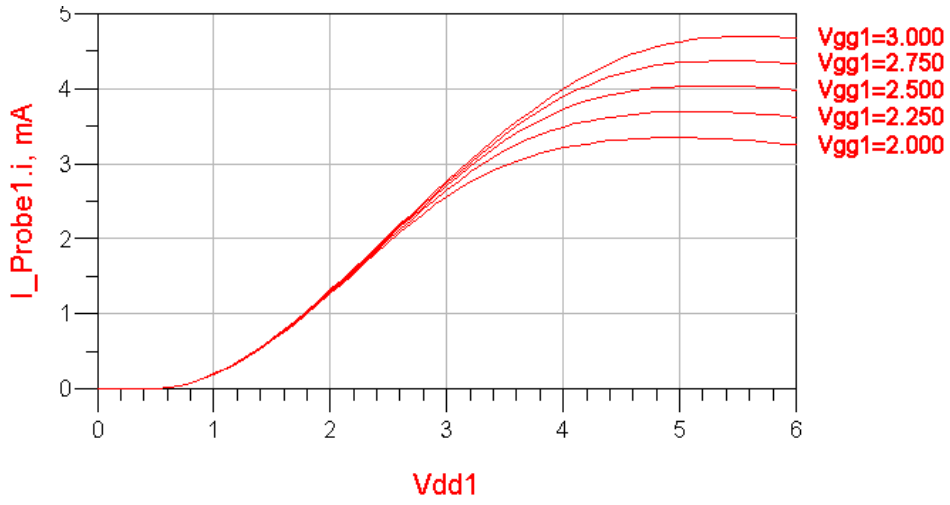


Figure 4.2: Drain Current, I_D vs V_{DS} Curve

The result of transconductance value due to variation of V_{gg1} from 2V to 3V with increment of 0.25V is shown in Figure 4.3. There are 5 curve for each V_{gg1} input voltage. The value of the transcoductance is selected as 0.001℧ which is referring to the point of V_{gg1} is equal to 2.5V. At this point, the saturation of the MOSFET is equivalent to V_{DS} where it generates voltage which is much higher than $V_{DSAT.}$

Voltage Gate to Source, V_{GS}	Drain Current, I_D	Transconductance, g_m
2.00 V	0.00332 A	0.00138 ʊ
2.25 V	0.00368 A	0.00141 ʊ
2.50 V	0.00403 A	0.00144 ʊ
2.75 V	0.00437 A	0.00146 ʊ
3.00 V	0.00470 A	0.00147 ʊ

Table 4.1: Values for V_{GS}, I_D, g_m

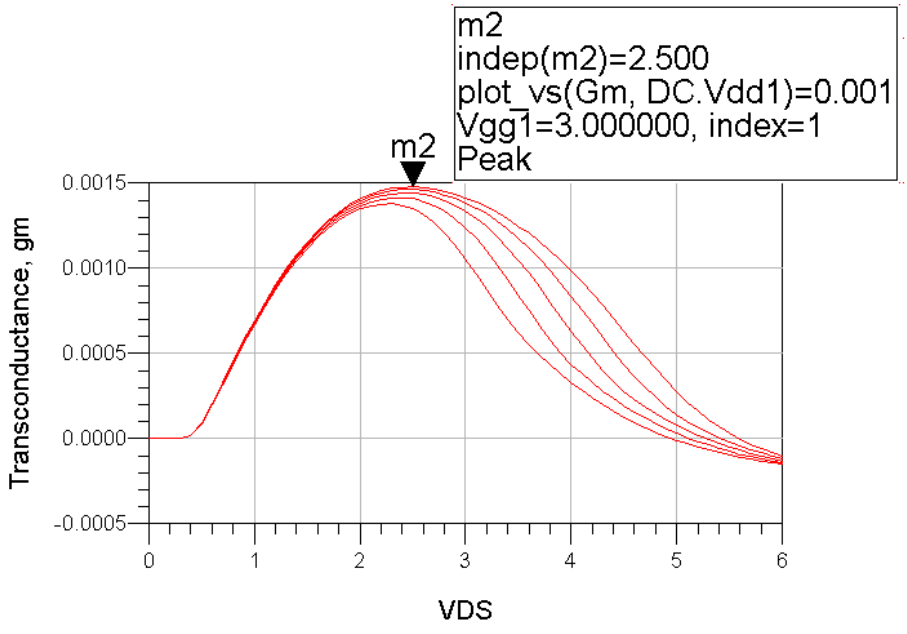


Figure 4.3: DC Characteristic Graph for N-Channel MOSFET

4.2 Active Metal-Oxide-Semiconductor (MOS) Single-Ended Mixers

Based on the simulation result shown below, the type of mixer that has been used for this project is Gilbert Cell Active Mixer configuration because in this project Single-Sideband transmission is the main criteria on the Amateur Radio Application. This simulation is controlled by the Harmonic Balance simulation and the main reason for harmonic balance simulation is used in this project has been stated in Chapter 3: Methodology. For this simulation, there are a few parameters that needed to be set, Local Oscillator's Power, Radio Frequency's Power, Load Impedance and Source impedance. There are two port that are connected to the mixer, the first port is the RF signal and the second port is the LO signal, these port are interconnected in the full mixer circuit which will be discussed on the next section as well as the effect of these parameters. There are 5 parameters that needed to be kept constant throughout the simulation which is the Voltage Source, Resistor value, Width of the MOSFET and Impedance value which is the combination of inductor and resistor. Next, the input RF frequency is swept at 1MHz and ends at 1 GHz with increment of 100MHz. All noise has been omitted because the result should base solely on the effect of these parameters as well as the component selected in this project. The value of the Local Oscillator's Frequency is set to be 700MHz and the simulation's result will show the effect of the LO frequency versus RF frequency that will be discuss in the next section.

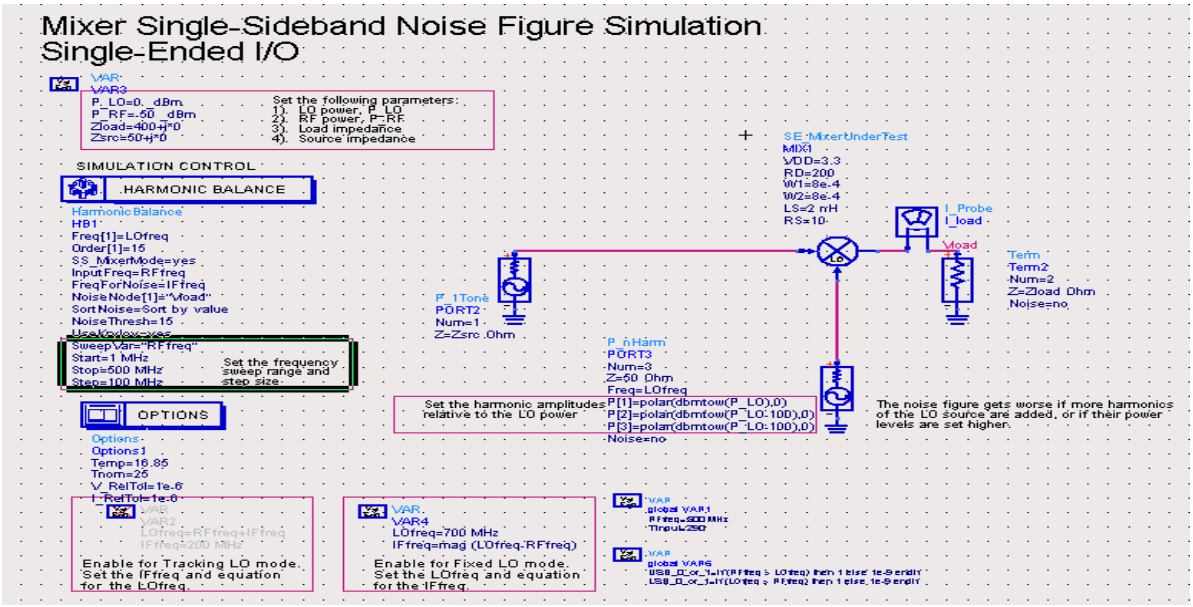


Figure 4.4: Mixer simulation on Advance Design System (ADS)

This section will discuss on the important section of the complete mixer circuit. The mixer is breakdown into 3 main section, Differential LO Generation, Input Matching Network matching at 900MHz and lastly is the Gilbert Cell Active Mixer. Based on the Figure 4.4 shown below, the ports for LO signal and RF signal is connected to the mixer circuit for mixing the two signals. Before the signal is injected to the mixer, further modification towards the signal have to be done beforehand to avoid any damages or inaccurate value when mixing these two signals. The modification of these signals will be discuss in the next section as well as the effects of the modification.

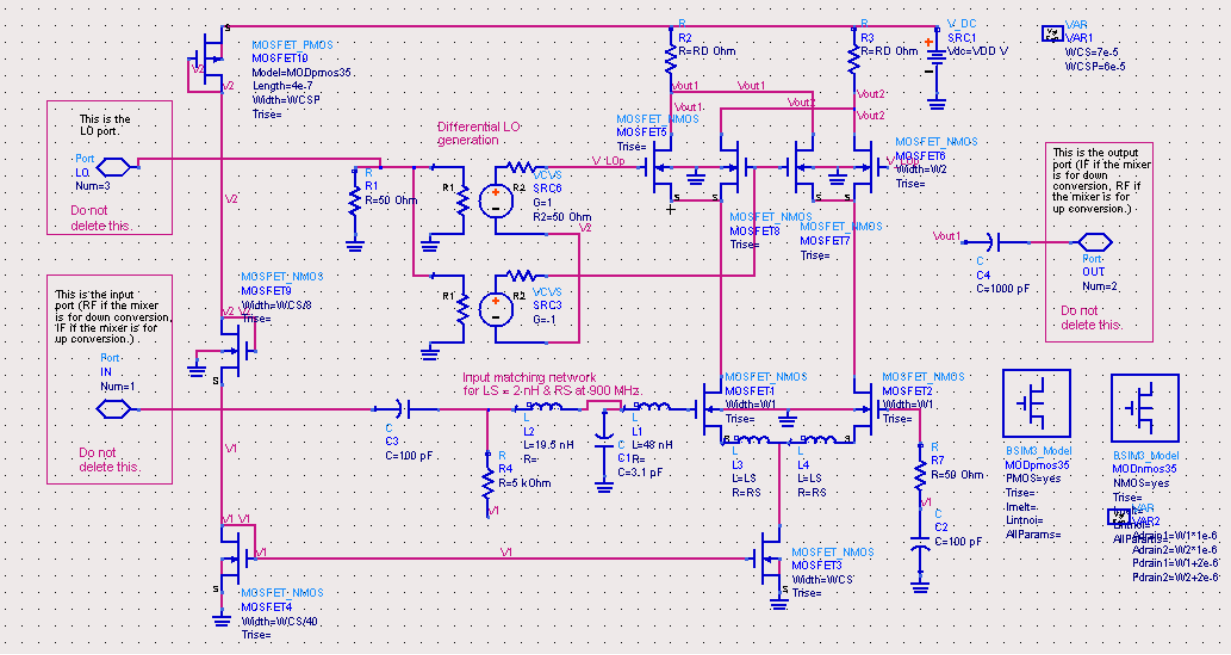


Figure 4.5: Complete Mixer Circuit Diagram

The whole mixer circuit will be connected to a voltage source tagged V_{dd} and the value for the port is 3.3V. The resistor tagged R_L is connected from the input voltage and the Drain part of the MOSFET which has the value of 200Ω and the impedance tagged R_S is the combination of an Inductor which has the value of $2e^{-9}$H and a Resistor that holds the value of 10Ω. The port that handled the LO signal is connected to a modification circuit called Differential Local Oscillator Generation. The circuit consist of 2 Voltage Controlled Voltage Source (VCVS) and each of the VCVS is controlled with a gain of positive and negative gain. The main reason of the difference values in gain to have a different value LO signal which

means the output of the signal will have a different levels which is positive and negative signal and the output of the modified LO signal will be connected to the MOSFET W_2. The positive signal of the LO output will be connected to the Gate part of the MOSFET and the negative signal will be connected to the Source of the MOSFET. The RF port will be connected to the Input Matching Network configuration and the configuration is a series connection of a resistor, 2 inductors and 2 capacitors that configured to work at 900MHz. The values of each components is 5kΩ, $19.5e^{-9}$H, $48e^{-9}$H, $100e^{-12}$F and $3.1e^{-12}$F respectively. The output of the configuration is connected to the gate part of the MOSFET W_1 .

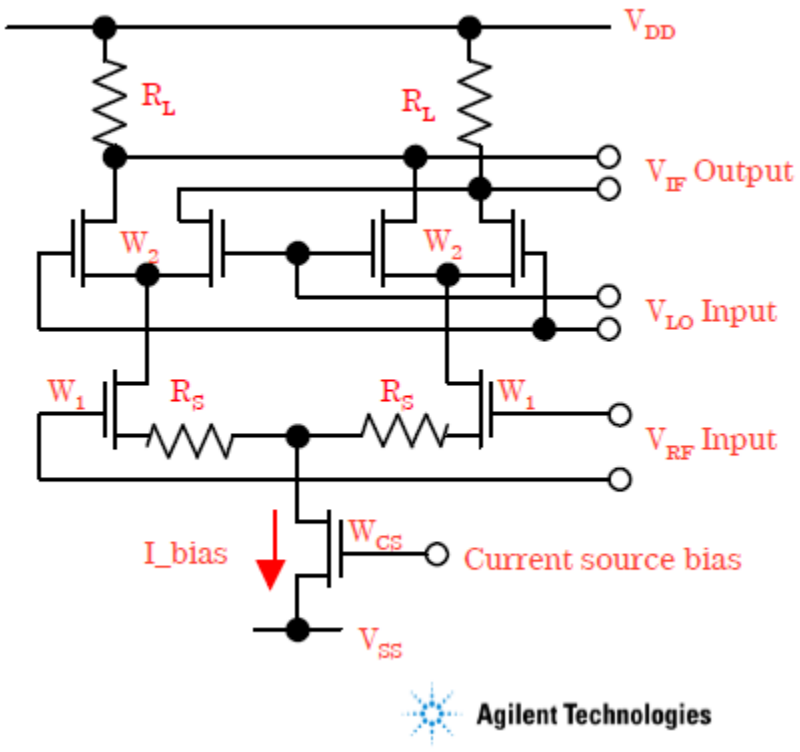


Figure 4.6: Port Connection to Gilbert Cell Active Mixer [19].

4.2.1 Differential Local Oscillator (LO) Signal Generation

The selected LO Frequency which is 700MHz is a digital form and the frequency cannot be inserted into the mixer as it is, the frequency must be converted into smaller signal and coupled to the input transistor [13]. But for this project Voltage Controlled Voltage Source (VCVS) is used for the generation of differential LO and the main reason VCVS is used and not transistors and resistors is because the design is much simpler and the gain of the VCVS can be easily inputted into the design. For this project, +1 and -1 are selected for the gains of the differential LO generation. Furthermore, the necessity of differential LO is to have a stable isolation between LO to IF and LO to RF [13]. Besides that, based on the gain of the VCVS the output conversion of the generation is split into two signal, positive voltage and negative voltage [13].

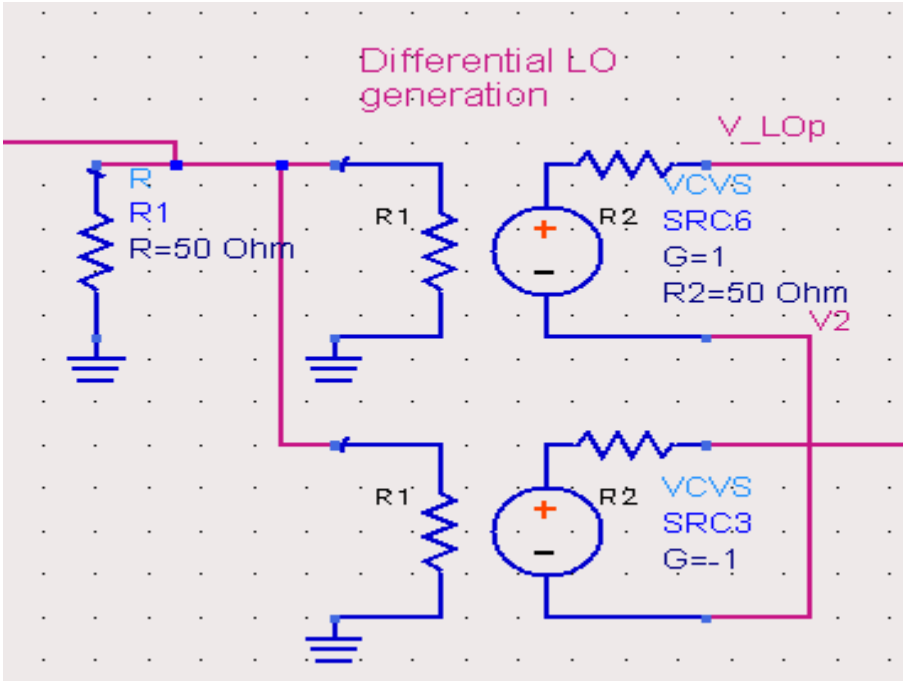


Figure 4.7: Differential Local Oscillator Generation

4.2.2 Input Matching Network

Matching network is important in any communication engineering and the main function of matching network is to maximize the transfer of energy from a different level to another level [15]. Besides the maximizing the power transfer, another function of the input matching network is to reduce the reflection of signal in the output load [16]. Based on the figure shown below, the matching network consist of a series connection of passive elements which is has the following values 100pF capacitor, 5kΩ resistor, 19.5nH inductor, 3.1pF capacitor and 48nH inductor. These values are matched and worked optimally at 900MHz. the input of the matching network is connected to the RF signal port that are swept from 1MHz to 1GHz with an increment of 100MHz. The main reason that matching network is matched at 900MHz is to maximize the power that the RF signal can produce. If the matching network is matched at a lower frequency, the power of the signal will not be maximized when the signal is injected to the mixer.

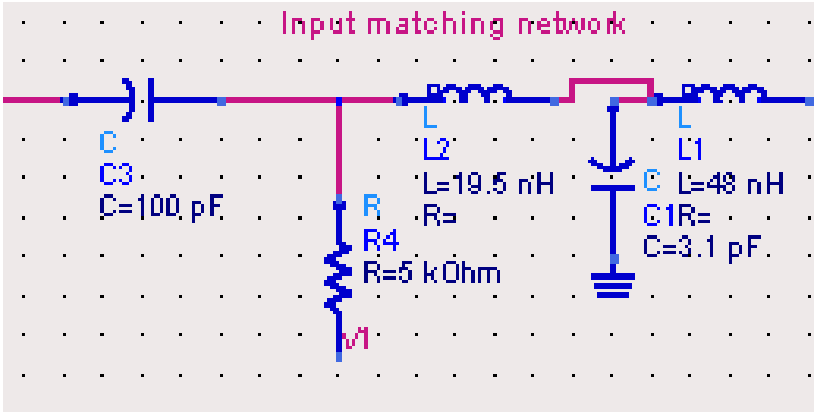
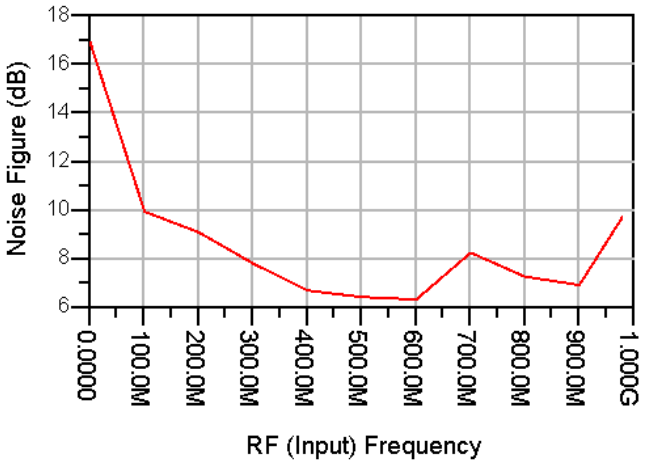


Figure 4.8: Input Matching Network at 900MHz

4.2.3 Gilbert Cell Active Mixer Result

Furthermore, as stated in the objective above for this project, the frequency range set for this project are set from 1 MHz to 1GHz as for the Local Oscillator (LO) frequency configuration is set to 700 MHz. Next is the noise figure, as for 1 MHz of the input frequency has the highest noise figure value this is because when comparing to the LO to the input frequency, 1 MHz has the highest margin so that it is vulnerable to noise and losses to the surrounding for 1GHz, it is easily observed that this particular frequency has the lowest noise margin. Noise figure is very important in designing an RF mixer this is because any noise introduced in the early stage will cause the performance of the whole application to decrease [10]. For this section, the result will be separated into 2 sections; the overall noise factor with comparison to RF frequency and the overall conversion gain which is the conversion from RF and LO to Intermediate Frequency (IF). These 2 factors complement each other whereas the lower the noise factor, the higher the conversions gain. As per Figure 4.10, it is observable that the signal achieves the state of instability due to RF is much higher than LO.

a. Noise Factor : There are many different type of noise that are contributed in the result shown below, some of the example of the noise existed in the Double Balance Gilbert Cell Mixer is uncorrelated noise, white noise, thermal noise and LO noise [18]. The result shown below are the result of the noise existed in the output signal alone and the way for the noise to be calculated is when comparing the RF signal with the LO signal. Thus, the difference in the signal will give the noise factor as shown in the figure below. Observably, the noise factor is decreasing when the RF signal increases this is because the higher the RF signal and closer to the LO signal, the contributed noise figure is significantly lower. But if the RF signal exceeds the LO signal, the result is no longer linear. Further improvement on the mixer design so that the LO signal can accommodate a variation of RF signal and also giving a lower Noise Figure.

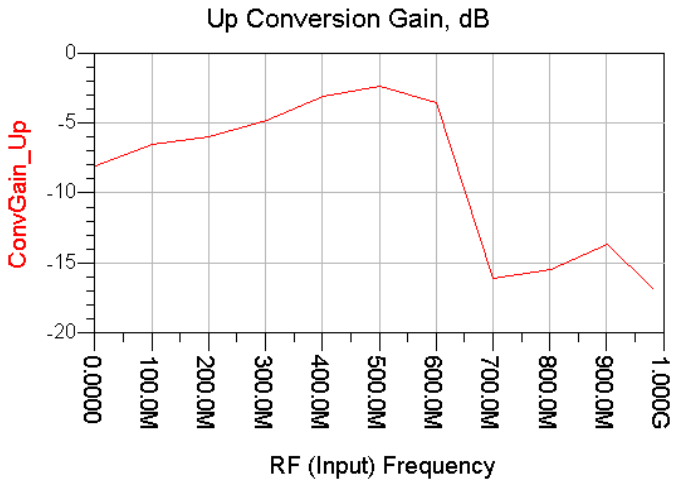


Input Frequency	LO Frequency
1.000 M	700.0 M
101.0 M	700.0 M
201.0 M	700.0 M
301.0 M	700.0 M
401.0 M	700.0 M
501.0 M	700.0 M
601.0 M	700.0 M
701.0 M	700.0 M
801.0 M	700.0 M
901.0 M	700.0 M
980.0 M	700.0 M

(a) (b)

Figure 4.9: (a) Noise Factor vs Input RF Frequency (b) Input frequency vs LO frequency

b. Up-Conversion Gain: As mentioned beforehand, up-converter mixer is for transmitter application and down-converter mixer for receiver application. This project is focus on the transmitter application thus only up-conversion gain is calculated. The mathematical model of the gain is discussed beforehand. As shown in the result below, the conversion gain is linearly increasing until it reaches its peak frequency which is 600MHz then the gain is decreasing up to a point it achieves an instability point where the gain is increasing and decreasing till the end of the selected RF signal. The conversion gain is determined by the ratio of the power at the output frequency and the power at the input frequency where the LO signal is kept constant. Therefore, when the conversion gain starts to decrease it shows that the output power is much higher than the input which in this case is the LO signal, thus the gain is too small for the mixer and to utilize these frequencies, amplifier must be used to amplify the signal to the nominal stage.



RF (Input) Frequency	Noise Figure, dB	Up Conversion Gain, dB
1.00 M	16.9	-8.11
101. M	9.95	-6.53
201. M	9.11	-6.01
301. M	7.82	-4.79
401. M	6.71	-3.11
501. M	6.45	-2.33
601. M	6.35	-3.56
701. M	8.27	-16.1
801. M	7.28	-15.4
901. M	6.94	-13.6
980. M	9.72	-16.8

(a) (b)

Figure 4.10: (a) Up-Conversion Gain, dB (b) Tabulation of Result for Gilbert Cell Mixer simulation.

4.3 Class C Amplifier

For the simulation of Class C Amplifier, Bipolar Junction Transistor (BJT) is used instead of the usual MOSFET. The main reason BJT is used instead of MOSFET is because the configuration of the whole network is much simpler compared to MOSFET, thus bring us to the objective of this project; optimization of components used in this project. For the amplifier, there are 2 voltage source connected in the circuit. The first voltage source is an AC source connected to the Base side of the BJT and the second DC source is connected to the Collector side of the BJT with an RF choker circuit. RF chokes is basically an inductor which are connected to the collector side and their function is to block any signal besides DC signal [17].

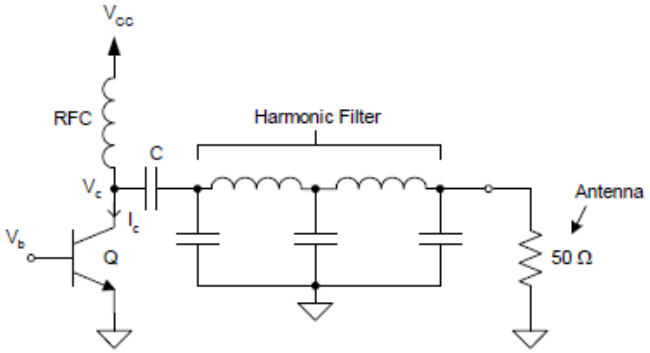


Figure 4.11: Class C Amplifier with RF Choke, Harmonic Filter and Antenna

The RF chokes only works at a design frequency in this case is 7MHz, if the designated signal is much lower than 7MHz a much bigger inductor is needed to block any unwanted signal [17]. When designing the Class C amplifier, an important factor that needed to be considered is the Q factor or Quality Factor, when the Q factor is significantly high, which means the amplifier has a higher loss which brings to lower precision or less efficient but a high Q factor means that it has a better noise isolation towards the amplifier [17]. Thus, some factor needed to be compromise in building this circuit. Besides that, Harmonic Filter is also connected to the configuration and the filter is designed to work within the designated frequency. The main contribution of the filter is to filter out any unwanted high order harmonics so that the output signal will have the same sinusoidal signal same as the input signal. The result will show the difference in output signal if the presence of Harmonic filter and the absence of it to have a clearer view of the output signal. For this project, the RF chokes is represent by the inductor in the collector side which have the value of $18e^{-6}$H and the Harmonic Filter is also connected to the collector side which have the following configuration as stated in the Figure 4.11 below.

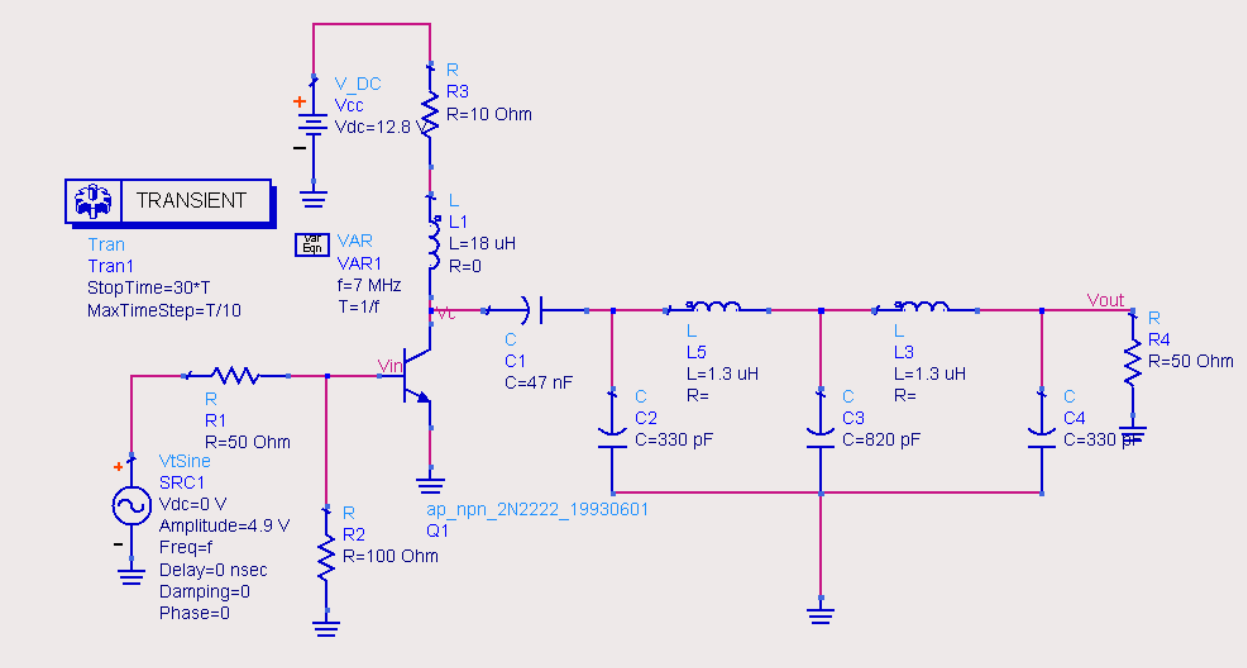


Figure 4.12: Complete Circuit for Class C Amplifier

Based on the result shown below, the output signal is as nearly as perfect sinusoid signal because the harmonic filter is connected to the network and without the presence of the harmonic filter; the output signal will have a different configuration but have the same values. The functionality of the harmonic filter is to have a low in voltage noise and power factor correction. Based on the Figure 4.12, the absence of the harmonic filter makes the output signal more distorted when compared to Figure 4.11.

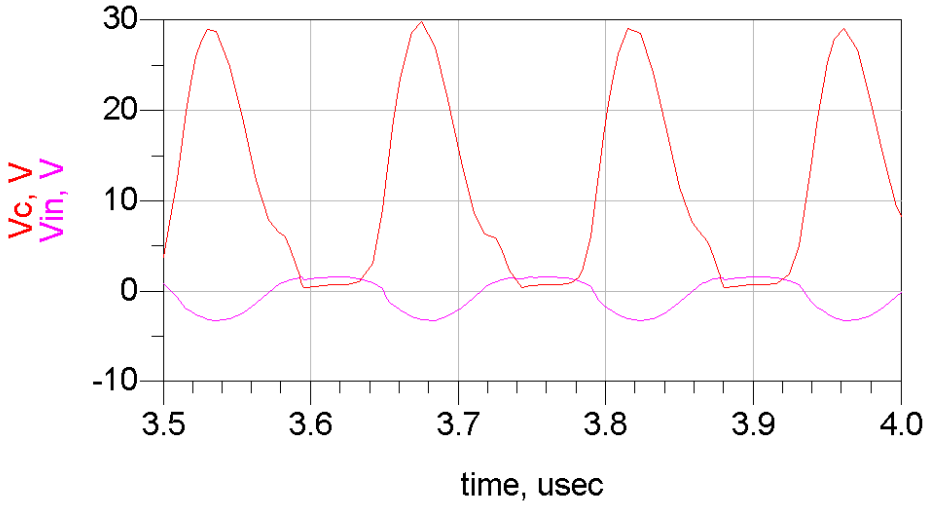


Figure 4.13: Class C Amplifier Output in presence of Harmonic Filter

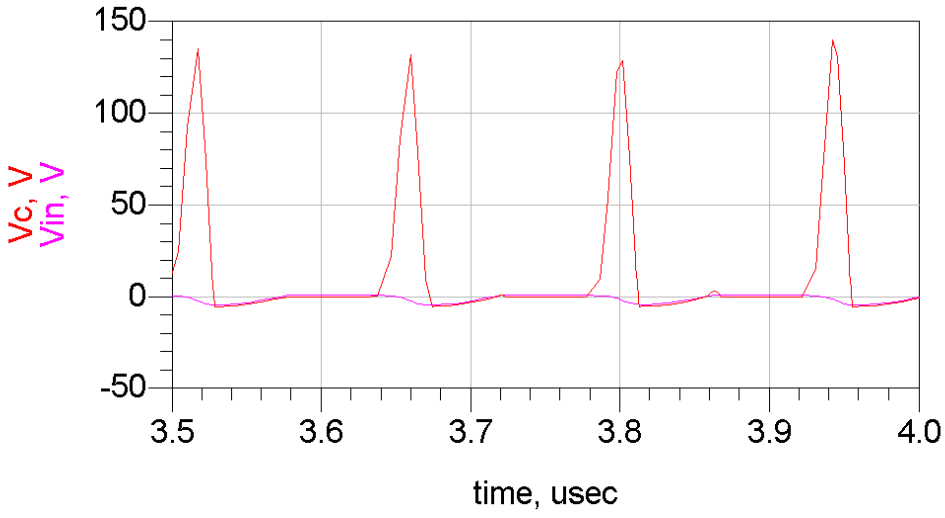


Figure 4.14: Class C Amplifier Output in absence of Harmonic Filter

4.4 Summary

As a summary and future work progress from the simulation result there are some parameters that needed to be revaluate in such that the Class C amplifier and Mixer output must be tally. For that, further calculation and trial-and-error method needed to be reviewed so that these 2 networks can be matched perfectly together. As based on the simulation result obtained and discussion written above, all of the objectives are met but there are always room for improvement in terms of simplicity of the circuit as well as further optimization of the selected parameters and calculations.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project is undergoing upon its finishing stage, so far the author has able to simulate the design of mixer and amplifier based on the application of Amateur Radio. This is shown on the Chapter 4: Result and Discussion. Furthermore, the author also able to simulate the working principle of N-Channel MOSFET by using DC analysis and by using the analysis the author is able determine its transconductance by reviewing the DC Curve. Based on the Mixer design, the author to choose to use Active Mixer due to its high linearity and the design that the author choose is Double-Balanced Gilbert Cell Mixer. The advantages of using the following design are its high conversion gain, high local oscillator to radio frequency and local oscillator to intermediate frequency isolation and low power usage for DC requirement [14]. Furthermore, the author also able to design and simulate Class C amplifier and the main reason the author choose Class C amplifier is because of its ability to amplify high frequency sine wave and its high efficiency. For mixer design, the author is able to separate three main sections; the first one is Double Balanced Gilbert Cell Active Transistor Mixer, Differential Local Oscillator Generation and Input Matching Network. The following sections have its own purpose in producing an accurate Intermediate Frequency as an output.

5.2 Recommendation

In the process of developing the simulation, some complication arise when the selecting the N-Channel MOSFET. Some of the model are not available in the library thus, modification towards the design have to be compromise in terms of width, threshold voltage and other parameter to suit the model used for this simulation. As a recommendation, the author would suggest to use other simulation software or have access to external source for enabling the completion of this project. Furthermore, the usage of the Multiphase Local Oscillator signal injection to further increase the noise tolerance towards the mixer design,

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