Design of Millimeter Wave Oscillator

By

Syed Ahmad Salikin Bin Sd Agil
15538

Dissertation submitted in partial fulfillment of the requirements for the
Bachelor of Engineering (Hons)
(Electrical Electronic)

May 2014

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CERTIFICATION OF APPROVAL

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Approved:

____

Dr. Wong Peng Wen
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
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May 2014

CERTIFICATION OF ORIGINILATY

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 references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SYED AHMAD SALIKIN SD AGIL

ABSTRACT

Millimeter waves (mm-waves) are a spectrum frequency that ranges from 30 GHz until 300 GHz. Mm-waves is situated after microwaves and before infrared waves in frequency spectrum list. They also sometimes can be called as Extremely High Frequency (EHF). This group of frequency has wavelength (λ) between 1-mm until 10-mm scale. That is the reason why there are known as millimeter wave. Meanwhile, oscillator is an electronic circuit that can delivers repeated waveforms. Waveforms that deliver rely on upon how we plan the oscillator circuit. There are many applications of millimeter wave oscillator in our modern world nowadays. For example, this technology is widely used in communication, daily electronic gadgets, and also in military. Millimeter wave oscillators are the main segment that create electronic indicator to send the data through any type of medium, to the destination needed. Because of their important role in engineering technology, especially for telecommunications, it is very important for us to understand the operational principle and also designing the millimeter wave oscillator. Thus, by doing this project, hopefully we can understand more regarding this segment of spectrum. This task centers exclusively on the configuration of a millimeter parts and programming reenactment in direct schematic outline and additionally micro strip design. Negative conductance technique is utilized to plan a solid millimeter oscillator.

ACKNOWLEDGEMENT

In completion of this Final Year Project, I would like to express my deepest gratitude to all parties that involve in making my learning very interesting and meaningful. Throughout the period, I have learned a lot of new things and gain many experiences that will be valuable for my future career path.

First and foremost, I would like to express my deepest appreciation toward my supervisor, Dr. Wong Peng Wen for his great supervision, continuous support, precious guidance and understanding which truthfully help me throughout completing this project. His knowledge in this field has offered me a better understanding on my project. I would like to thank him for spending his time to teach me and encouraged me to learn as much as possible while doing this project despite of his busy schedule lecturing in UTP.

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Thank you.

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LIST OF ABBREVIATIONS

GaAs – Gallium Arsenide
FET – Field-Effect transistor
MESFET – Metal Semiconductor Field Effect Transistor
DC – Direct current
RF – Radio frequency
BJT – Bipolar junction transistor
Mm-wave – Millimeter wave
FYP – Final year project

CHAPTER 1
INTRODUCTION

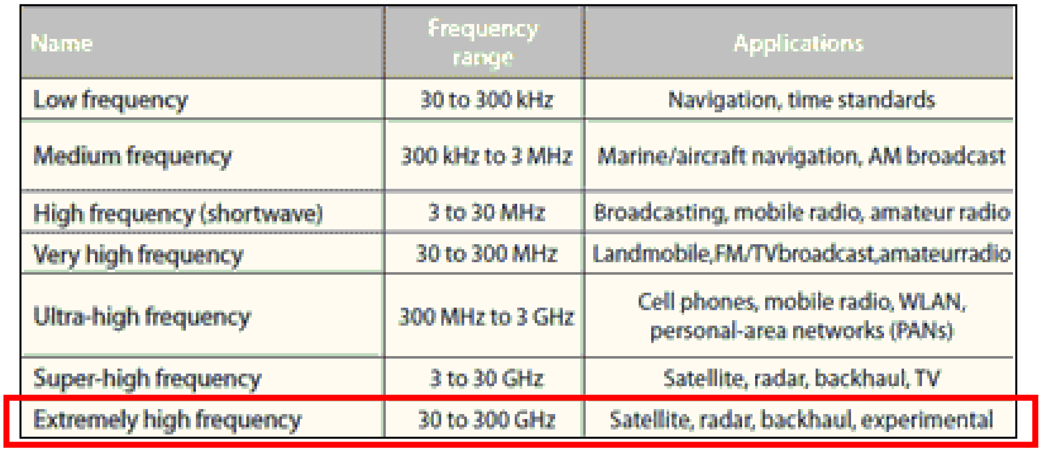
1.1 Background study.

Today's development of technology in communications, especially for wireless applications is growing rapidly among us. Telecommunication's technology is looking to expand more their capacity of transmission and also the oscillators range. Engineering technology, regardless of any industry, especially for telecommunications is competing among themselves to create millimeter wave gadgets with better execution, better usefulness, yet smaller in size, low power utilization and also user friendly.[1]

Millimeter wave Oscillator.

An oscillator is an electronic gadget that creates repeated waveform through the usage of amplification and feedback design. [2]

Millimeter wave are electromagnetic waves which places in Extremely High Frequency (EHF) with frequencies range from 30GHz to 300GHz, and wavelength between 1mm until 10mm. [3] Table 1 below shows the type of radio spectrum respective with their frequency and applications.



Name	Frequency range	Applications
Low frequency	30 to 300 kHz	Navigation, time standards
Medium frequency	300 kHz to 3 MHz	Marine/aircraft navigation, AM broadcast
High frequency (shortwave)	3 to 30 MHz	Broadcasting, mobile radio, amateur radio
Very high frequency	30 to 300 MHz	Landmobile,FM/TVbroadcast,amateurradio
Ultra-high frequency	300 MHz to 3 GHz	Cell phones, mobile radio, WLAN, personal-area networks (PANs)
Super-high frequency	3 to 30 GHz	Satellite, radar, backhaul, TV
Extremely high frequency	30 to 300 GHz	Satellite, radar, backhaul, experimental

TABLE 1: Standard definitions of radio spectrum segment

In Figure 1 below, demonstrates how oscillator works in transmitting millimeter wave frequency. Millimeter oscillator changes over from DC (Direct Current) to RF (Radio Frequency) power. The produced RF power indicator will enter the mixer and from there, it will help to carry the message through filter, linearizer and then to amplifier. Finally, the antenna will transmitted the data receive from the amplifier. [4]

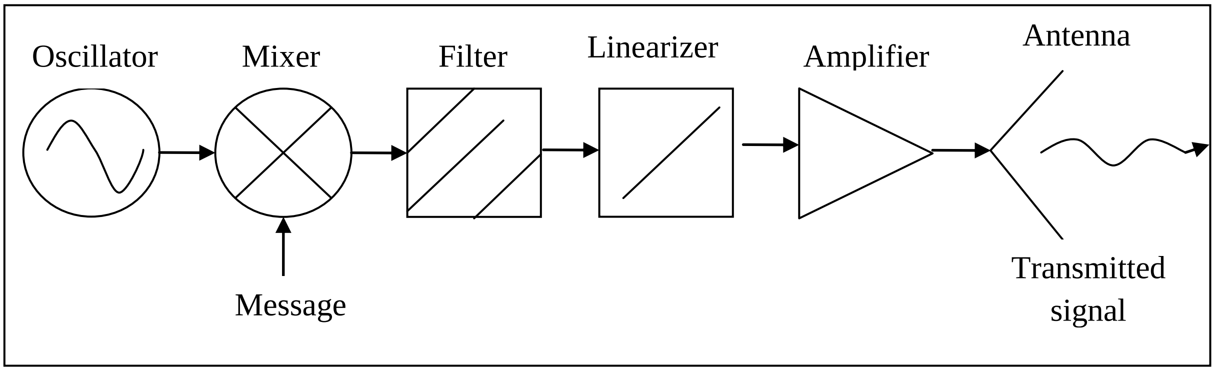


FIGURE 1: Schematic of a transmitter millimeter framework.

There are a lot of rooms for improvements in millimeter wave technology nowadays. There are plenty of gap that need to be fix so that millimeter wave applications can be fully utilized, especially in telecommunications sector. To become friendlier user, it is advisable to create a millimeter wave system that can be tune over a variety of frequencies. It also recommended to create a system that has better phase noise performance, easy to use and smaller in size. The most popular problem regarding the millimeter wave is when the input oscillator cannot be executing perfectly, due to unreasonable phase shift in the feedback path. This problem happen in millimeter wave input oscillator. So, researches have come out with a solution, which is using a system called negative conductance method. Using this technique is proven to create a dependable oscillator.

1.2 Problem statement.

- The subsystem designs have been a great challenge due to the loss and dispersion at millimeter wave.

Other group of wave spectrum, which is situated below millimeter wave, have low transmission rate, which is around 1 Gbit/s only. Unlike them, digital data rates for millimeter waves are much higher. Information rates transfer in the millimeter-wave range, can be achieve around 10 Gbits/s or more.

While this spectrum looking very promising for future use in development of communications technology, however, it has its own limit. This millimeter spectrum isn't very helpful for different kinds of wireless technology. It has its confinements. Creating a system that can be more useful and moderate has been the test for today’s designers and engineers.

Restricted working range is the one of the key limitations of millimeter waves nowadays. For millimeter waves, the wavelength is very small, that is 1mm to 10 mm only. In many cases, this limitation limits the range to less than 10 meters, at any reasonable power levels.

The free space loss in dB is computed with:

$$L = 92.4 + 20\log(f) + 20\log(R)$$

Where,

R = line-of-sight (LOS) distance between transmit and receive antennas (Km)

f = frequency (GHz)

For example, the loss at 10 meters at 60 GHz is:

$$L = 92.4 + 35.6 - 40 = 88\ dB$$

However, if the designers use high transmits power, good receiver sensitivity and high antenna gains, it can overcome this loss.

Additionally, the air absorbs millimeter waves, limiting their extent. Rain, mist, and any moisture circulating everywhere make signal attenuation high, decreasing transmission distance between sender and receiver elements.

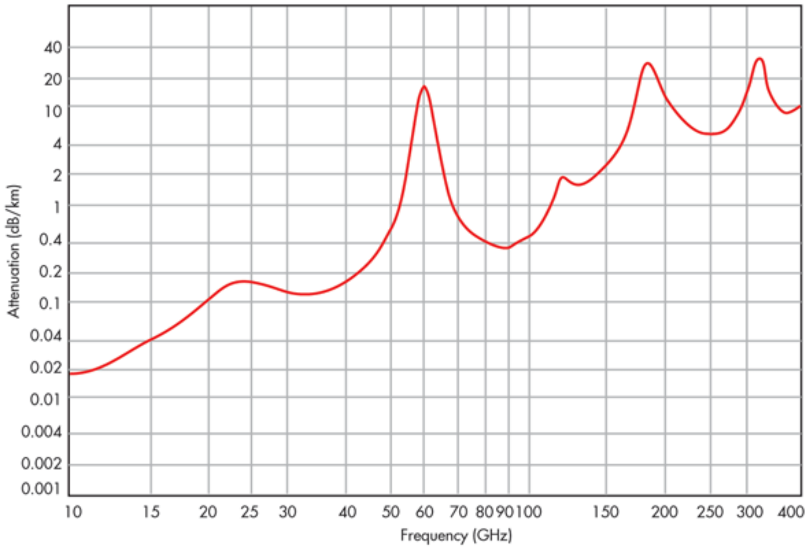


FIGURE 2: Signal loss at sea level

Figure 2 above demonstrates the plot of sign lessening adrift level versus log frequencies indicates how oxygen (at 60 GHz) and water at alternate crests in the climate essentially build indicator constriction. By selecting a frequency within the curve valleys can minimizes this loss.

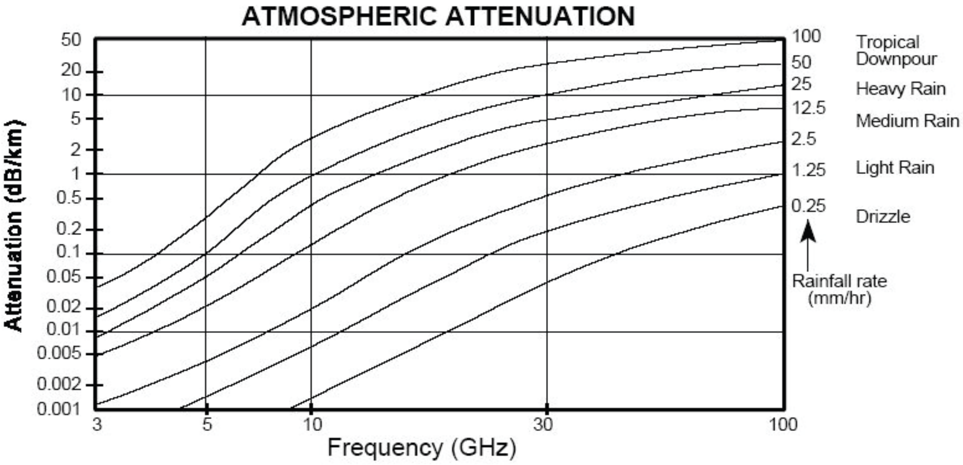


FIGURE 3: Atmospheric attenuation

1.3 Objective and scope

Objective

I. To understand the concept of mm-wave and design the mm-wave oscillator
II. To demonstrate the project with working prototype.

The main objective of this project is to know what millimeter wave is and understand how it works. After this goal is expert, the second target, which is to plan the millimeter wave oscillator, is sought after. So as to attain second goal, the author have to comprehend what is oscillator and what kind of oscillator circuits that he need to use to finish this project. At that point, the author has to apply electrical circuit's information to outline and manufactured that circuit.

Scope

The main important scope for this project is synthesizing negative conductance topology in a circuit design. The project starts by studying and revising the fundamentals of fabricating circuit and produce a type of measurements using spectrum analyzer. It is important for the author to gain deeper understanding about circuit designing in theory and also in practical. This project also will cover how to design and analyses millimeter wave oscillator using distributor elements.

CHAPTER 2

LITERATURE REVIEW

Oscillator usually contains an active device and a passive frequency determining component. There are two type of oscillator that can be design. The first one is fix frequency oscillator, and the other one is tunable frequency oscillator. For tunable frequency oscillators, it will have a varactor. While for fix frequency oscillators, the frequency deciding framework is a dielectric resonator, [5]

Six methods are available to diminish the phase noise in oscillators, according to Purdie. It could logically exhibited that expand in Q’s oscillator component prompts to build the element of stability, which are the circuit that can be turned over have higher likelihood to channel out unwanted noise or unwanted harmonics.

6 systems that can diminish phase noise are:

1) Expand reactive energy by method for a higher RF voltage over the resonator. Utilize lower LC degree.
2) Choose device with low flicker noise; this might be diminished by RF feedback.
3) Maximize Qu of the resonator
4) The yields circuits must be confined from the oscillator circuit and take low power as could be allowed.
5) Avoid device immersion and attempt to utilize anti parallel (consecutive) tuning diodes.
6) Choose active device with the most minimal NF.

Besides that, Snowden also discussed the fundamentals limitations on power output of transit time devices. Performance of an oscillator is highly depending on the minimum power output of the system. Amplification is produce by maximum frequency, which can be stated as,

$$f_{max} = \frac{1}{2\tau}$$

, where τ is the normal time for change conveys to transverse the dynamic area of the device. [7]

Power output for frequency is

$$P \ = V_{pk} - pk \ I_{pk} - pk$$

Since $P_{I_{max}} \propto \frac{1}{f_{max}}$ and $P_{I_{max}} \propto \frac{1}{f_{max}}$,

$$P_{\max} = \frac{K_D}{f_{max^2}}$$

, where K_D fix and value is fluctuates on gadget material parameters and device geometry.

Figure 4 below shows the fundamental negative conductance oscillator circuit.

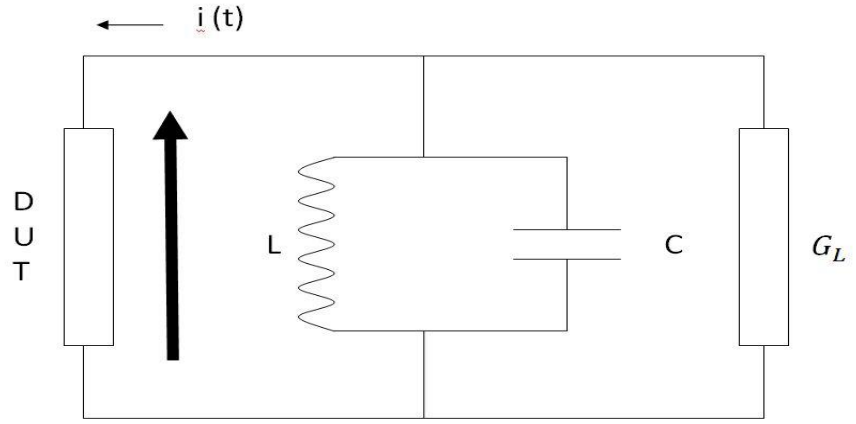


FIGURE 4: The fundamental negative conductance oscillator circuit.

Component	Function
Negative conductance (DUT)	Supply energy to manage oscillations motions
Tuned network/L & C circuit	Finding motions frequency
Load conductance (G_L)	Determine amplitude of oscillations

TABLE 2: Oscillator circuit components and their functions.

After that, the relationship between device conductance and passive circuit components are found. Since the time depending device current and voltage bring about a non-linear which is tricky to solve for all t, the result at or close t = 0 is acquired by perceiving littler estimation value of voltage and current.

$$\frac{di}{dt} = \frac{di}{dv} \cdot \frac{dv}{dt} = g\frac{dv}{dt}$$

, where g = small signal / increment conductance of device.

From the quasi-linear second order differential equation,

$$\frac{d^2v(t)}{dt^2} + \frac{1}{c}(G_L + g)\frac{dv(t)}{dt} + \frac{v(t)}{LC} = 0$$

The solution of the form $v(t) = Ae^{st}$

$$S_{1,2} = -\frac{1}{2C}(G_L + g) \pm j\left[\frac{1}{LC} - \frac{(G_L + g)^2}{4C^2}\right]^{\frac{1}{2}}$$

$$= \alpha + jw$$

.

To obtain sinusoidal oscillatory growth,

$$\alpha > 0, \text{ hence } G_L < -g$$

$$\omega > 0, \text{ hence } -G_L + \sqrt{\frac{4C}{L}} > g > -G_L - \sqrt{\frac{4C}{L}}$$

Circuit design criteria for negative conductance oscillators to concentrate maximum power output, also being discuss in research by Snowden. [7] First of all, substantial signal behavior of negative conductance device is studied.

L and C circuit in FIGURE 4 is supplanted by a two-port frequency determining system (see FIGURE 5). The load conductance is currently summed up load admittance and negative conductance component is an amplitude and frequency dependent admittance. Thus,

$$\bar{Y}(A,\omega) = \bar{G}(A,\omega) + j\overline{B}(A,\omega)$$

$$\bar{Y}(0,\omega) = g + jb$$

The conditions for steady state oscillation in a negative conductance circuit are

$$-\bar{G}(A,\omega) + G(\omega) = 0$$

$$\overline{B}(A,\omega) + B(\omega) = 0$$

, where

$-\bar{G}(A,\omega)$ = device conductance

$\overline{B}(A,\omega)$ = device susceptance

$G(\omega)$ = load circuit conductance

$B(\omega)$ = load circuit susceptance

A = amplitude of oscillation (voltage)

ω = steady state frequency.

The power yield in steady state is dictated by,

$$P_{out} = \frac{|\bar{G}|{A_0}^2}{2}$$

when $G = \left|\bar{G}_{opt}\right|$,

$$P_{out} = \frac{|\bar{G}(A,\omega_0)|A^2}{2}$$

The adequacy of oscillation when maximum force is produced, A_{opt} is controlled by

$$\frac{dP_{out}}{dA} = 0$$

or

$$\frac{d|\bar{G}(A,\omega_0)|}{dA} \cdot \frac{A^2}{2} + |\bar{G}\ (A,\omega_0)|\ .A = 0$$

On the off chance that device conductance is a linear function of oscillation amplitude, conductance component is,

$$|\bar{G}(A,\omega_0)| = |g|\left(1 - \frac{A}{A_m}\right)$$

and

$$\frac{dP_{out}}{dA} = |g|A(1 - \frac{3}{2}\frac{A}{A_m})$$

Thus the power output is maximum when

$$A = A_0 = A_{opt} = \frac{2}{3}A_m$$

or when

$$|\bar{G}(A,\omega_0)| = \frac{|g|}{3}$$

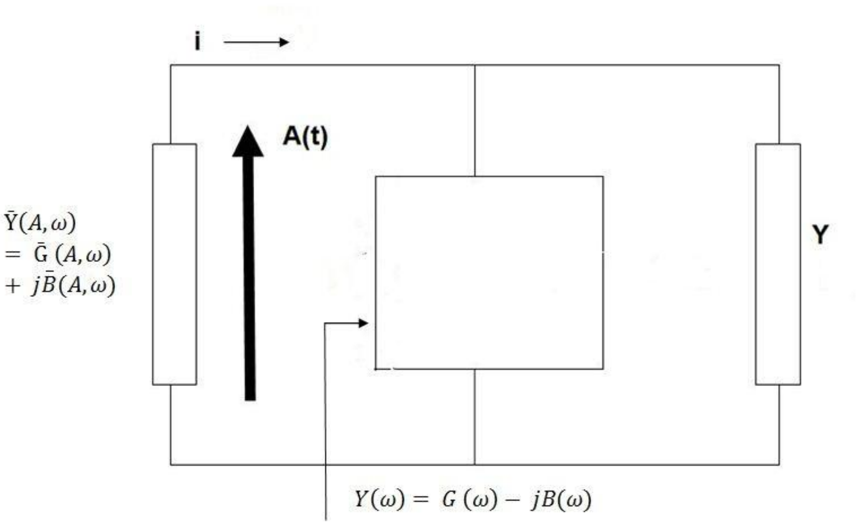
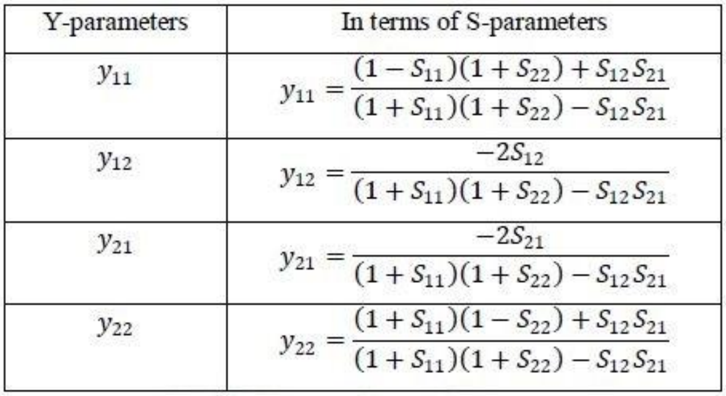


FIGURE 5: General topology of a negative conductance oscillator

Calculations of Y-parameters using S-parameters

FETs are usually described by scattering parameters (S-parameters). S-parameters normally can be found in the data sheet of the transistors. It is provided by the manufacturer as references for their users to make things easier. Although the parameters is already provided, but in many cases, the theoretical values are often different from the practical values. So it is recommended to calculate the given parameters first then compare the value with the result of computers simulations. FET also can be identifying by using admittance parameters (Y-parameters). Table below shows the relationship between Y-parameters and S-parameters.



Y-parameters	In terms of S-parameters
y_{11}	$y_{11} = \frac{(1-S_{11})(1+S_{22})+S_{12}S_{21}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$
y_{12}	$y_{12} = \frac{-2S_{12}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$
y_{21}	$y_{21} = \frac{-2S_{21}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$
y_{22}	$y_{22} = \frac{(1+S_{11})(1-S_{22})+S_{12}S_{21}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$

TABLE 3: S-parameters and Y-parameters

Diagram below shows the circuit topology of two port device after synthesizing.

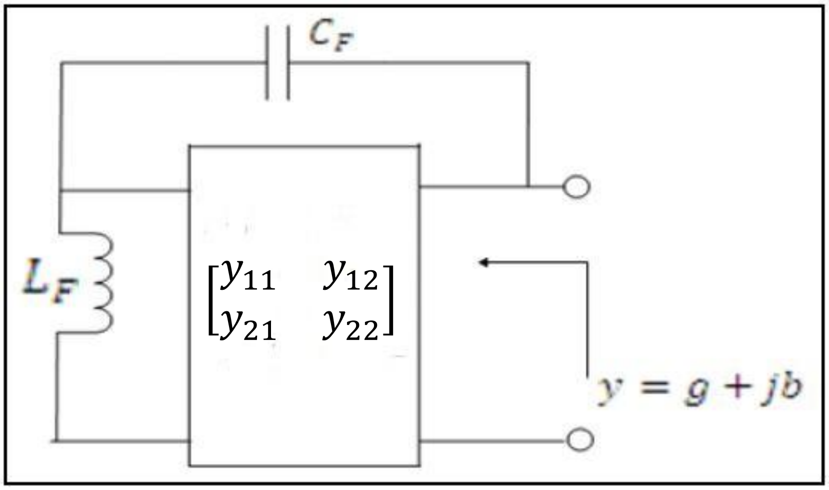


FIGURE 6: Two port device after synthesizing.

Diagram in FIGURE 6 above can be simplified to FIGURE 7 by using formula given below.

$$\begin{bmatrix} y'_{11} & y'_{12} \\ y'_{21} & y'_{22} \end{bmatrix} = \begin{bmatrix} y_{11} + Y_P & y_{12} - Y_P \\ y_{21} - Y_P & y_{22} + Y_P \end{bmatrix}, Y_p = j\omega C_F$$

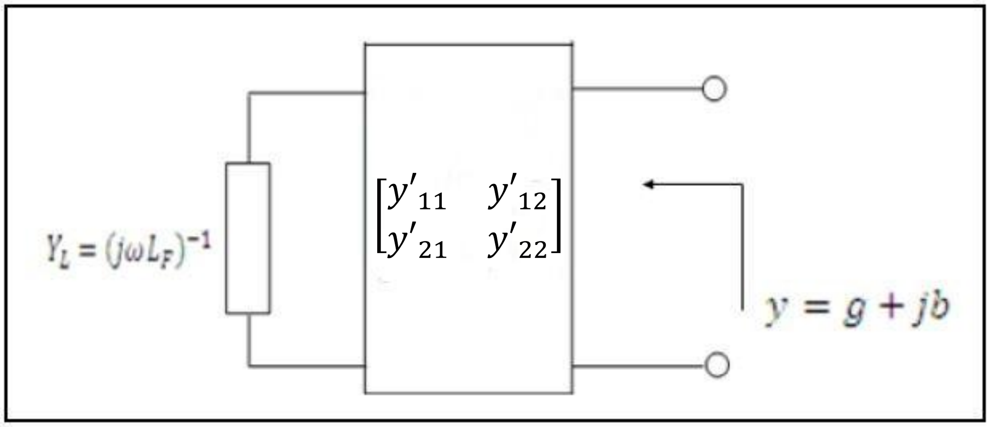


FIGURE 7: Simplified of two port device

CHAPTER 3

METHODOLOGY

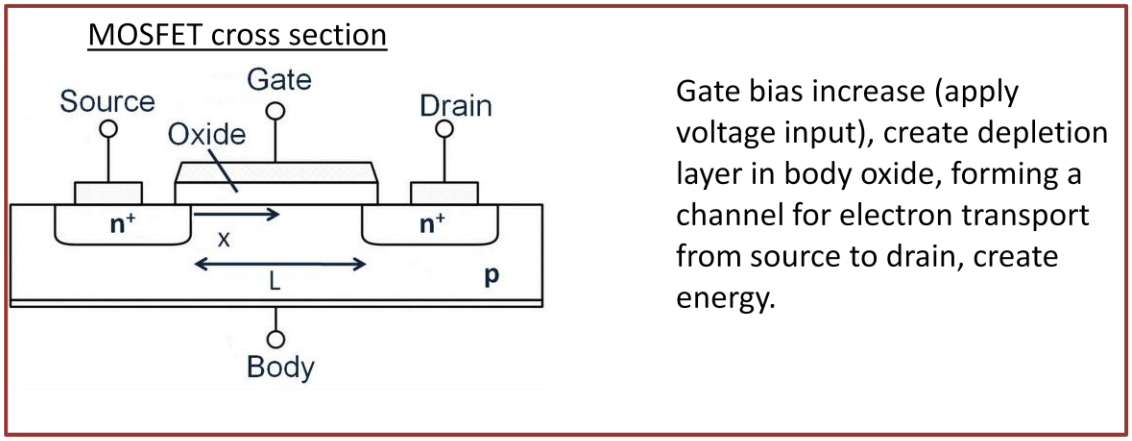
In completing this project, first need to break down the task into a few separate parts and afterward dissect it parts by parts. The first part is to know what the necessary output frequency that is need for this project. Output value is very important because it can be used to determine how to design the circuit. Output frequency also is important because it can be used to choose the right transistor that can create same frequency as needed [7], [8].

After that, the circuit can be design, as per the need of the project's objective. Bear in mind, that the output of this project will also be determined by the value of other components, such as inductor, capacitor and also the input of voltage and current values. So, the author needs to measure and find the correct and suitable value for those parameters so that the needed output frequency can be achieved.

Picking the right transistor is very crucial. A High-electron-versatility transistor (HEMT), also known as Heterostructure FET (HFET) or otherwise as Modulation Doped FET (MODFET) is picked as the transistor to be use in this project. In MOSFET, the channel between the band gaps is using doped, known as doped region. But in case of HEMT transistor, it is a field-impact transistor which has heterojunction as their channel to join an intersection between two materials. There are wide variety combinations of material in this transistor, depend on the application of the devices. In this case, the combination of Gaas and AlGaas is used.

Gadgets consolidating more indium for the most part show better high-frequency execution, while in recent years, gallium nitride HEMT's have pulled in consideration because of their high-power execution. HEMT transistors can work at higher frequencies than normal transistors, up to millimeter wave frequencies, and are utilized as a part of high-frequency items, for example, mobile phones, satellite TV receivers, voltage converters, and radar gear.

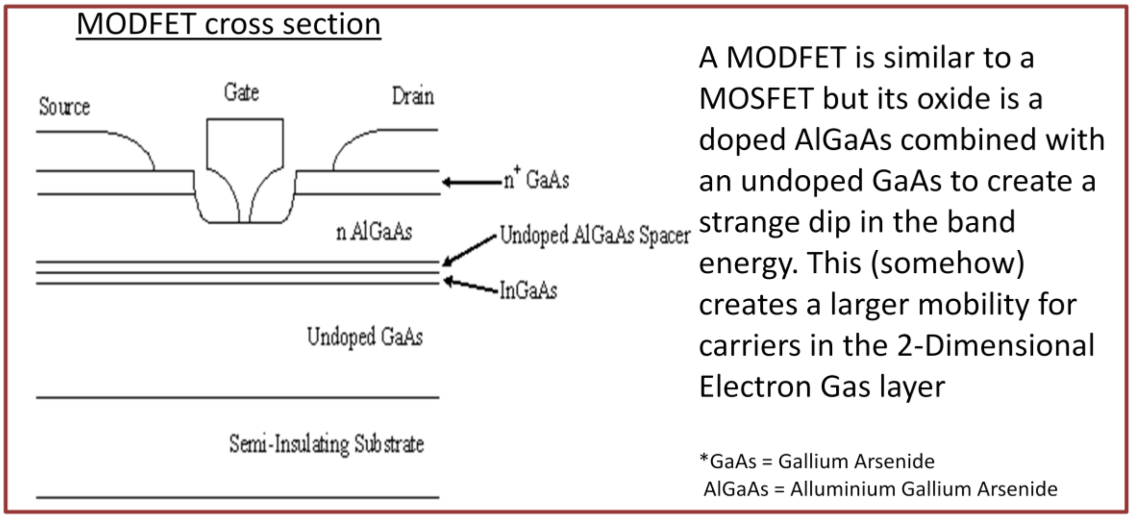
FIGURE 7 (a) and 7 (b) shown below is the diagram of differences between MOSFET and MODFET in terms of their cross section and also how they functions.



MOSFET cross section

Gate bias increase (apply voltage input), create depletion layer in body oxide, forming a channel for electron transport from source to drain, create energy.

FIGURE 8 (a): MOSFET



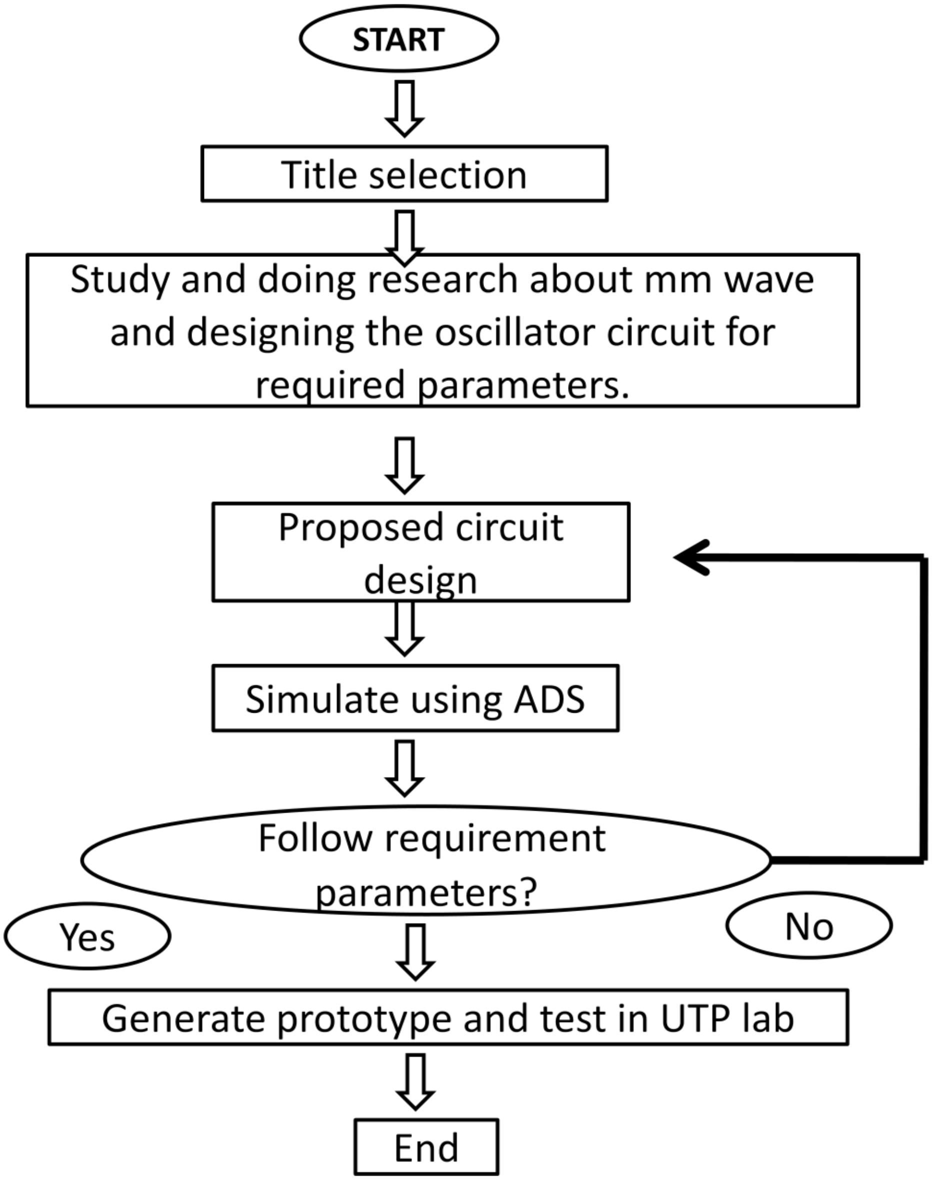
MODFET cross section

A MODFET is similar to a MOSFET but its oxide is a doped AlGaAs combined with an undoped GaAs to create a strange dip in the band energy. This (somehow) creates a larger mobility for carriers in the 2-Dimensional Electron Gas layer

*GaAs = Gallium Arsenide
AlGaAs = Alluminium Gallium Arsenide

FIGURE 8 (b): MODFET

3.1 Project flow



3.2 Key Milestone

Activity	Status	Week
Final year project 1		
Finding project title	Done	1
FYP 1 briefing	Done	1
Literature review	Done	1-6
Submission of extended proposal	Done	6
Proposal defense presentation	Done	9
Finding suitable component	Done	10-12
Calculations of parameters	Done	12-14
Submission of Interim Report	Done	14
Final year project 2		
Submission of Progress report	Done	8
Schematic design/Software simulation	Done	8-11
Pre-EDX	Done	11
Submission of draft report	Done	13
Submission of Final report & technical paper	Done	14
Final Viva	N/A	15

TABLE 4: Key milestone of the project.

3.3 Gantt Chart

Final Year Project 1														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Title selection	🟥													
Research about the project		🟥	🟥	🟥	🟥									
Extended proposal						🟥								
Finding suitable component							🟥	🟥	🟥					
Proposal defense									🟥					
Calculations of the parameters									🟥	🟥	🟥	🟥	🟥	
ADS simulation									🟥	🟥	🟥	🟥	🟥	
Submissions of Interim report														🟥

TABLE 5: Gantt-Chart for FYP 1

Final Year Project 2														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Parameters calculation	🟥	🟥	🟥	🟥	🟥	🟥	🟥							
Design and simulation	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥						
Progress report								🟥						
Pre-EDX											🟥			
Draft report													🟥	
Final report & Technical paper														🟥
Viva presentation														🟥

TABLE 6: Gantt-Chart for FYP 2

3.4 Tools

Software	
Advanced Design System (ADS) 2008 and 2011.05	Use to design the circuit schematic and also for simulation purposes.
Microsoft Office	To prepare FYP reports.

TABLE 7: Tools

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Design Procedure

1) Design specification

Oscillator specification	
Frequency	13GHz
Power output	27mW
Load impedance	50Ω

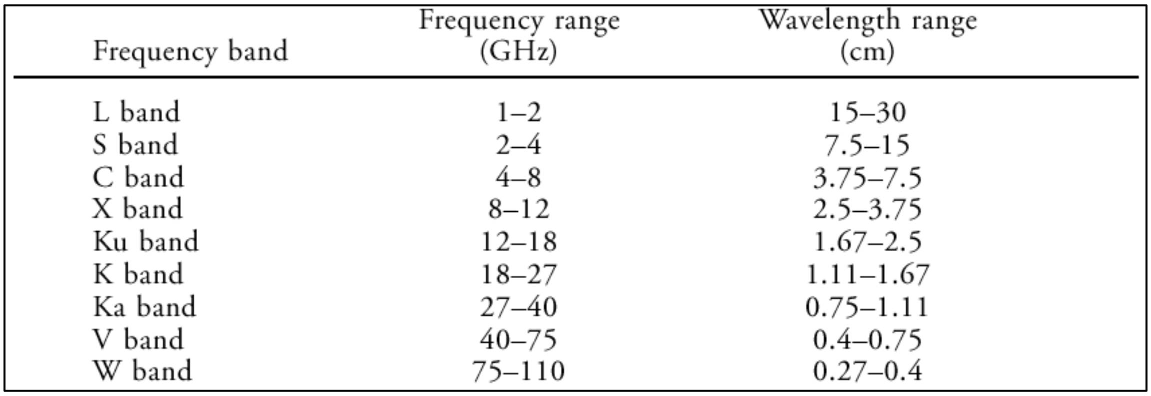
TABLE 8: Design specification of oscillator

Design of oscillator for this project is been determined as the table 6 above. The frequency is determined at 13GHz with power output of 27mW and load impedance of 50Ω.

2) Choosing the transistor.

For this project, MESFET transistor is more suitable to be use compare to other types of transistors. The most suitable type of transistor that can be choose is GaAs MESFET because it can provide high oscillator output frequency, high power output and more efficient.

The required frequency for this project is 13 GHz. That frequency is situated in Ku frequency band, which is range from 12 to 18 GHz with wavelength range of 16.7 mm to 25 mm. The most suitable transistor that can be use is GaAs MESFET NE76038 transistor. This transistor can produce output frequency up until Ku band, which is in the range or required parameters.



Frequency band	Frequency range (GHz)	Wavelength range (cm)
L band	1–2	15–30
S band	2–4	7.5–15
C band	4–8	3.75–7.5
X band	8–12	2.5–3.75
Ku band	12–18	1.67–2.5
K band	18–27	1.11–1.67
Ka band	27–40	0.75–1.11
V band	40–75	0.4–0.75
W band	75–110	0.27–0.4

TABLE 9: Spectrum frequency table

3) Select Quiescent Operating Point for the transistor

Selection of Quiescent Operating Point (QOP) is based on the maximum value of allowed voltage and current swing. A suitable choice of QOP is shown in figure 8 below.

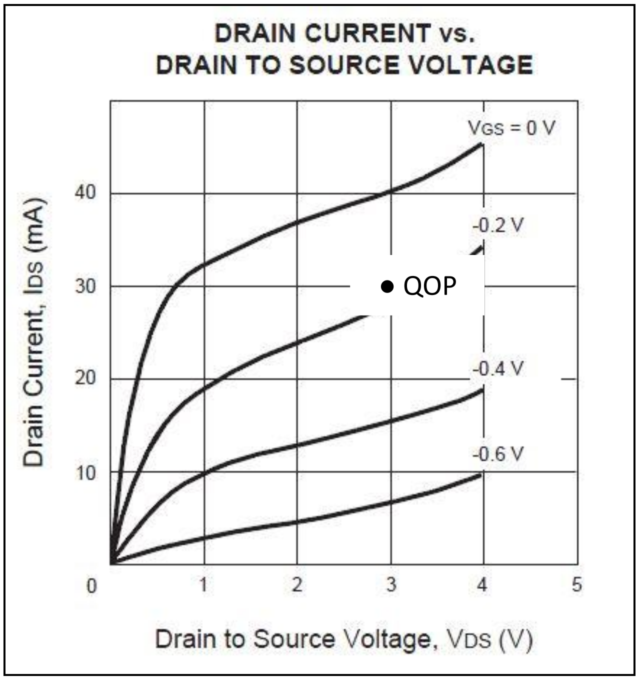


FIGURE 8: Output characteristic of NE71383B

4) Finding $g_m$and g_o

The value of $g_m$and $g_o$is determined by using the formula below,

$$g_m = \left[\frac{\partial I_D}{\partial V_{GS}}\right]_{QOP}$$

By referring to QOP in figure 8,

$$g_m = \left[\frac{30m}{0.18}\right]$$
$$= 0.167$$

$$g_o = \left[\frac{\partial I_D}{\partial V_{DS}}\right]_{QOP}$$

$$g_o = \left[\frac{30m}{3}\right]$$
$$= 0.167$$

5) Finding C_{gd} and C_o

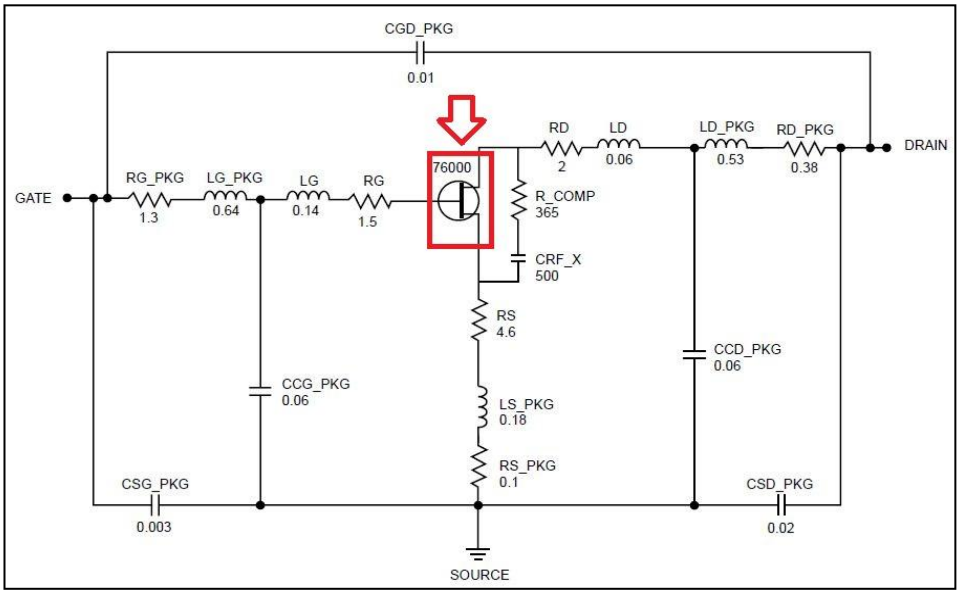


FIGURE 10: Schematic for NE76038

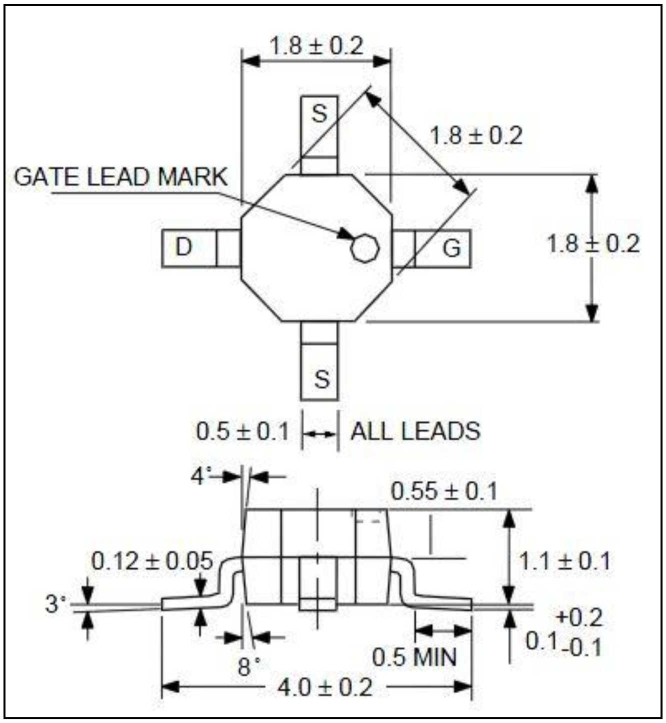
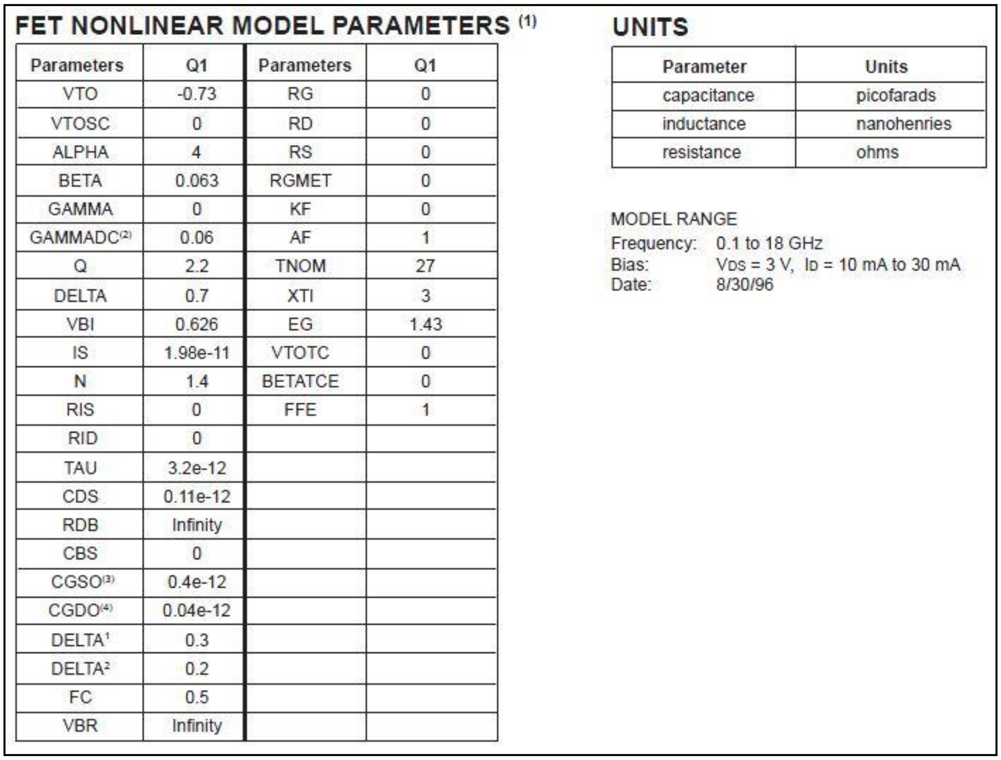


FIGURE 11: Outline dimensions of NE76038 (units in mm)



FET NONLINEAR MODEL PARAMETERS (1)

Parameters	Q1	Parameters	Q1
VTO	-0.73	RG	0
VTOSC	0	RD	0
ALPHA	4	RS	0
BETA	0.063	RGMET	0
GAMMA	0	KF	0
GAMMADC(2)	0.06	AF	1
Q	2.2	TNOM	27
DELTA	0.7	XTI	3
VBI	0.626	EG	1.43
IS	1.98e-11	VTOTC	0
N	1.4	BETATCE	0
RIS	0	FFE	1
RID	0		
TAU	3.2e-12		
CDS	0.11e-12		
RDB	Infinity		
CBS	0		
CGSO(3)	0.4e-12		
CGDO(4)	0.04e-12		
DELTA^1	0.3		
DELTA^2	0.2		
FC	0.5		
VBR	Infinity		

UNITS

Parameter	Units
capacitance	picofarads
inductance	nanohenries
resistance	ohms

MODEL RANGE
Frequency: 0.1 to 18 GHz
Bias: V_{DS} = 3 V, I_D = 10 mA to 30 mA
Date: 8/30/96

FIGURE 12: NE76038 nonlinear model parameter

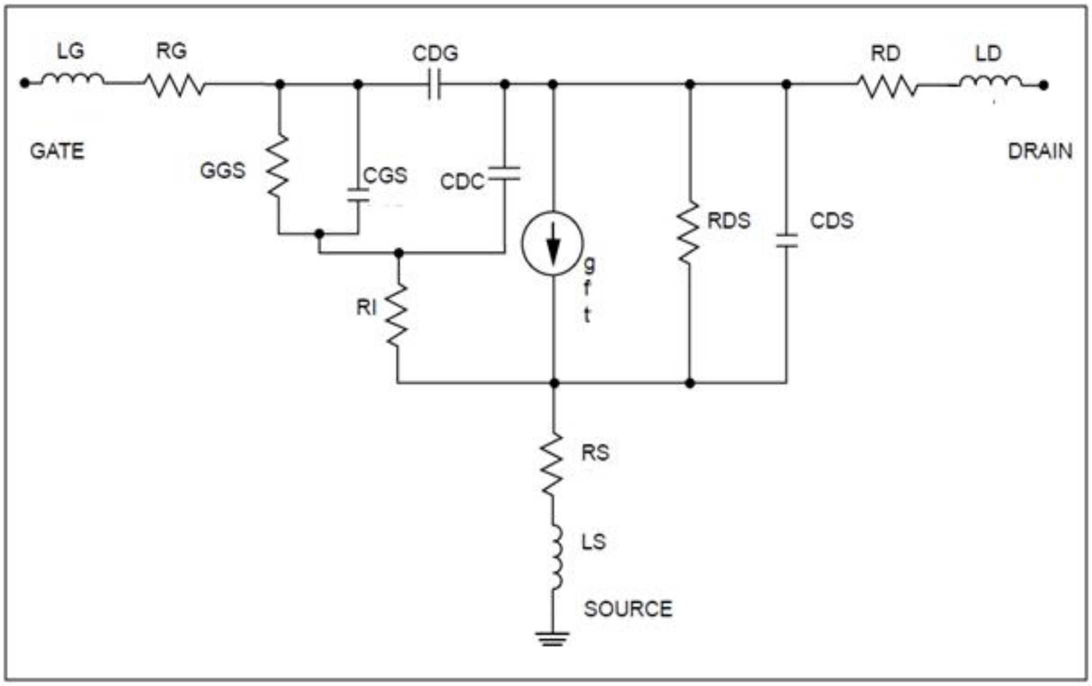


FIGURE 13: NE76038 linear model schematic

Model parameters of the this project are determined by matching the circuit diagram in Figure 13 above with the simple small signal equivalent circuit in Figure 14 below.

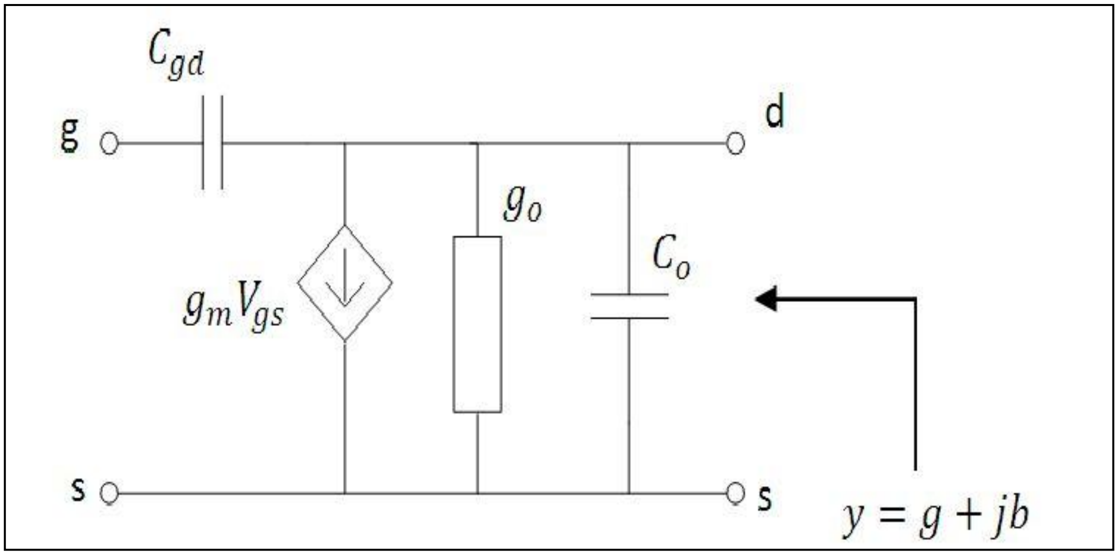


FIGURE 14: Small signal equivalent circuit

The resulting value is record in Table 6 below.

Parameters	Values
C_{gd}	0.04pF
C_o	0.25pF
g_o	0.01S
g_m	167mS

TABLE 10: Model parameters.

6) Finding k for maximum negative conductance

$$k = \frac{2\,g_o + g_m}{2(g_o + g_m)}$$

$$= \frac{2(0.01) + 0.167}{2(0.01 + 0.167)}$$

$$k = 0.528$$

7) Finding the synthesized device admittance

Synthesizing of device is then done by adding the circuit in figure 13 into the figure 8.

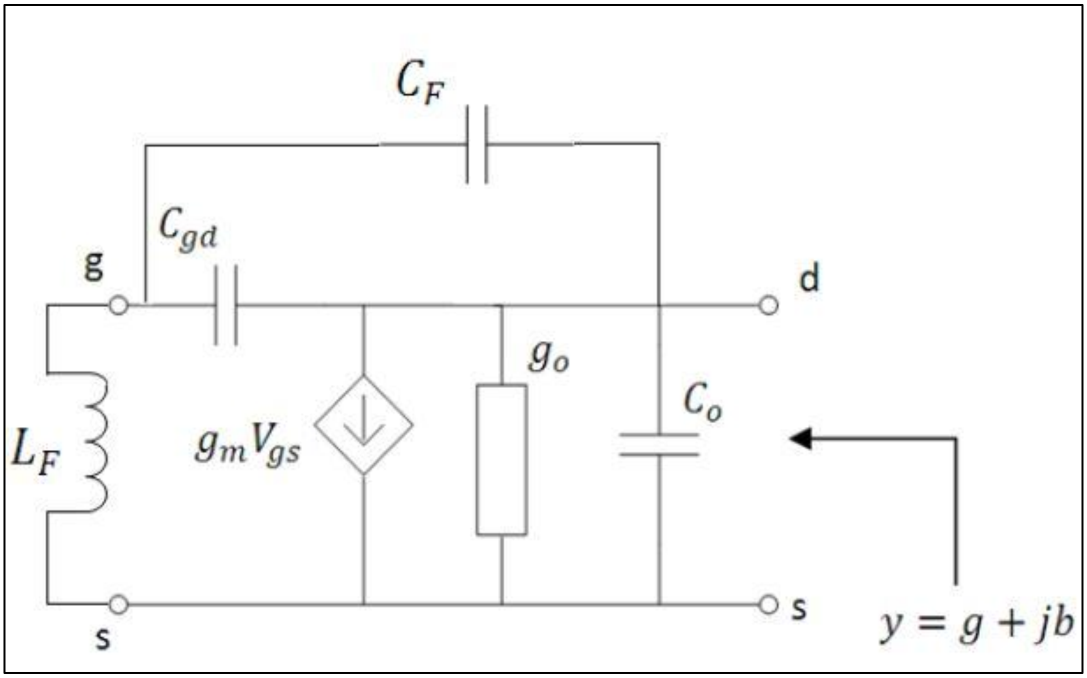
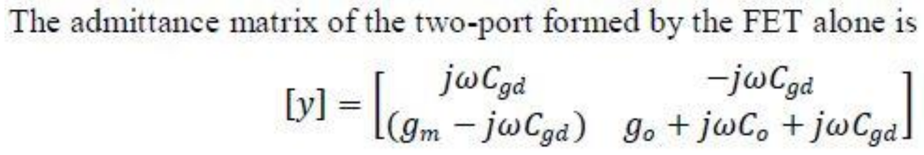
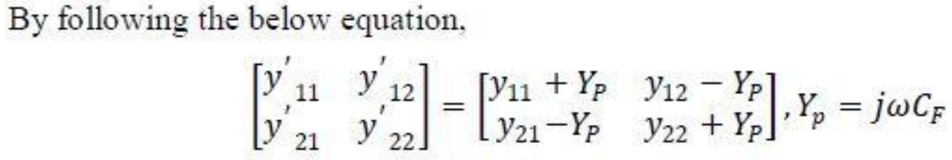


FIGURE 15: Simple small signal equivalent circuit with feedback element



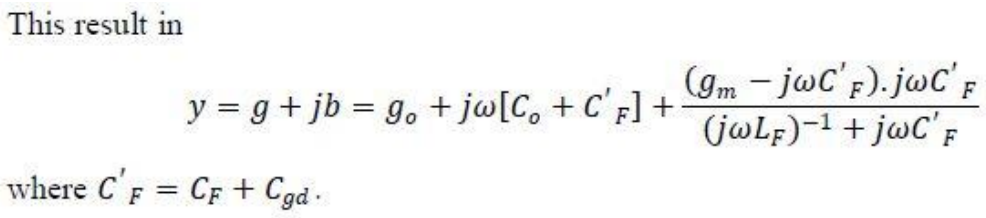
The admittance matrix of the two-port formed by the FET alone is

$$[y] = \begin{bmatrix} j\omega C_{gd} & -j\omega C_{gd} \\ (g_m - j\omega C_{gd}) & g_o + j\omega C_o + j\omega C_{gd} \end{bmatrix}$$



By following the below equation,

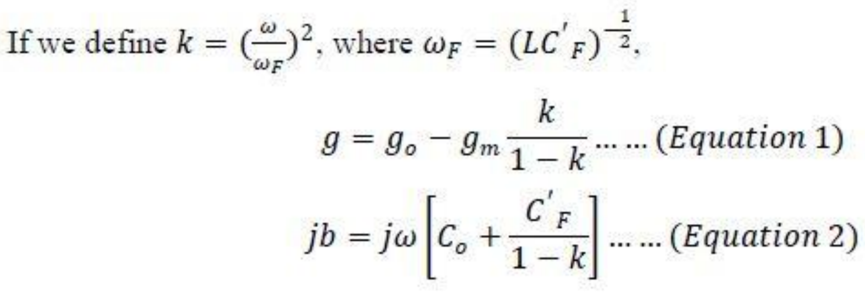
$$\begin{bmatrix} y'_{11} & y'_{12} \\ y'_{21} & y'_{22} \end{bmatrix} = \begin{bmatrix} y_{11} + Y_P & y_{12} - Y_P \\ y_{21} - Y_P & y_{22} + Y_P \end{bmatrix}, Y_p = j\omega C_F$$



This result in

$$y = g + jb = g_o + j\omega[C_o + C'_F] + \frac{(g_m - j\omega C'_F).j\omega C'_F}{(j\omega L_F)^{-1} + j\omega C'_F}$$

where $C'_F = C_F + C_{gd}$.



If we define $k = (\frac{\omega}{\omega_F})^2$, where $\omega_F = (LC'_F)^{-\frac{1}{2}}$,

$$g = g_o - g_m \frac{k}{1-k} \dots\dots (Equation\ 1)$$

$$jb = j\omega \left[C_o + \frac{C'_F}{1-k} \right] \dots\dots (Equation\ 2)$$

$$g = 0.01 - 167m\ \frac{0.528}{1 - 0.528}$$

$$= -0.1768S$$

For equation 2, we let $C_f = 0$.

Then,

$C'_f = C_{gd} = 0.04p$.

$$jb = j(2\pi * 13G)\left[0.25p + \frac{0.04p}{1 - 0.528}\right]$$

$$= j0.0273$$

The value of inductance L_F is found according to the formula stated below,

$$k = (\frac{\omega}{\omega_F})^2 \ldots \ldots (Equation\ 3)$$

$$\omega_F = (LC'_F)^{-\frac{1}{2}} \ldots \ldots (Equation\ 4)$$

$$L_F = \frac{{\omega_F}^{-2}}{C'_F}$$

$$L_F = \frac{\left(\frac{\omega}{\sqrt{k}}\right)^{-2}}{C_{gd}}$$

$$L_f = \frac{\left(\frac{2\pi * 13G}{\sqrt{0.528}}\right)^{-2}}{0.04p}$$

$$L_f = 1.978nH$$

After all parameters are calculated, the value is then tabulated in the Table 11 below.

Parameters	Value
k	0.528
g	-0.1768S
jb	j0.0273
L_f	1.978nH (capacitive)

TABLE 11: Model parameters

8) Design Frequency Determining Network.

The operating frequency can be found by putting susceptance $-jb_{opt}$ parallel with synthesized device admittance. Energy storage element also is needed in order to increase the power spectral density. That energy storage element then will be realized by the susceptance$-jb_{opt}$, together with the open circuit stub (in real world, microstrip short circuit is more difficult to fabricate), by a transmission line of length $n\,\lambda_g$.

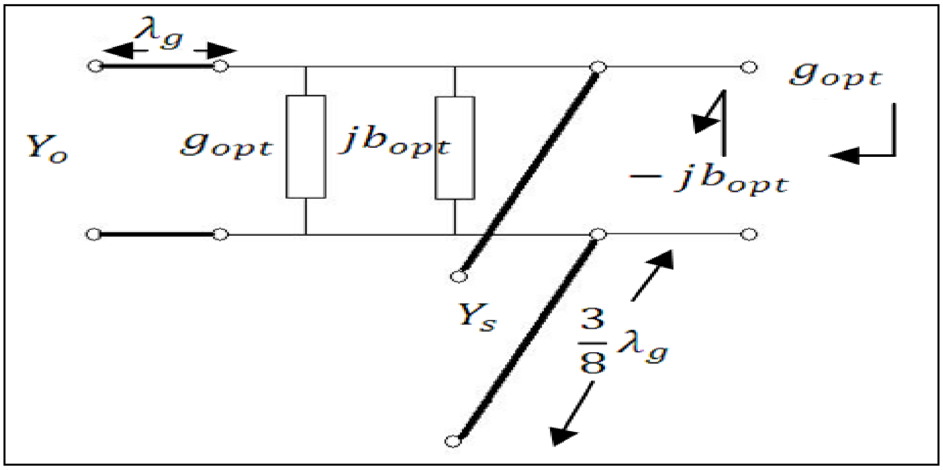


FIGURE 16: Oscillator circuit together with Frequency Determining Network and Energy storage network.

$$-jb_{opt} = jY_s tan\beta l$$

or if

$$l = \left[\frac{2(2n+1)+1}{8}\right]\lambda_g$$

$$-jb_{opt} = -jY_s$$

Then,

$$Y_s = 0.0273S$$

$$= 27.3mS$$

$$l_s = \frac{3}{8}\lambda_g$$

Energy Storage Element also is defined as

$$Y_o = 20mS$$

$$l_o = \lambda_g$$

9) Design matching network

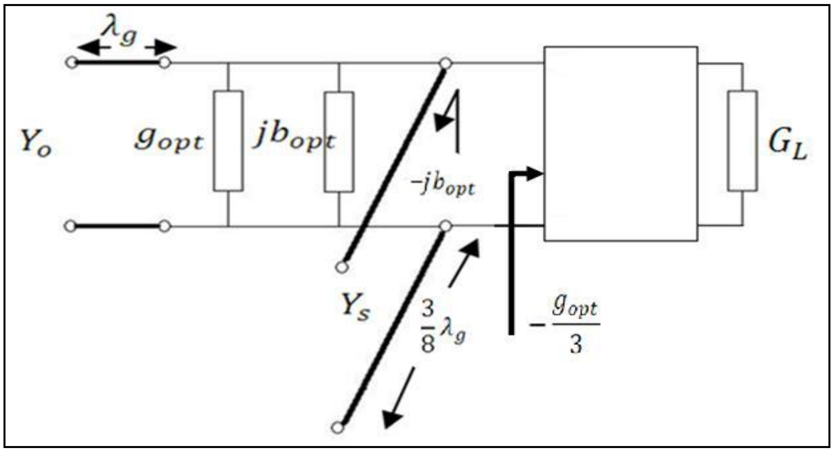


FIGURE 17: Oscillator circuit including Frequency Determining Network, Energy Storage Element and Power Maximization Network.

Load admittance is transform to -0.0589S and this is best achieved using a $\frac{\lambda g}{4}$ transformer as shown below,

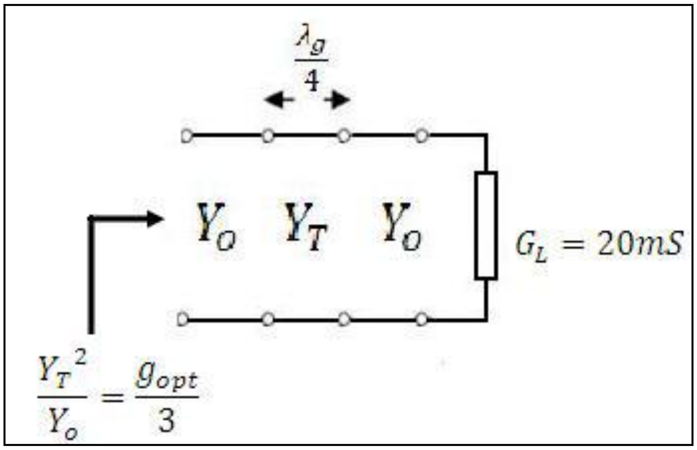


FIGURE 18: Principle of $\frac{\lambda g}{4}$.

The transformer admittance is thus given by,

$$\frac{{Y_T}^2}{Y_o} = \frac{g_{opt}}{3}$$

$$Y_{\boldsymbol{T}} = \sqrt{\frac{g_{opt}}{3}} * Y_o$$

$$Y_T = \sqrt{0.0589 * 20m}$$

$$Y_T = 0.0343$$

= 34.3mS

Completed circuit diagram for RF aspect of oscillator is shown in figure below. Table 12 shows the admittance value (Y_s, Y_o, Y_T) needed in frequency determining network and matching network.

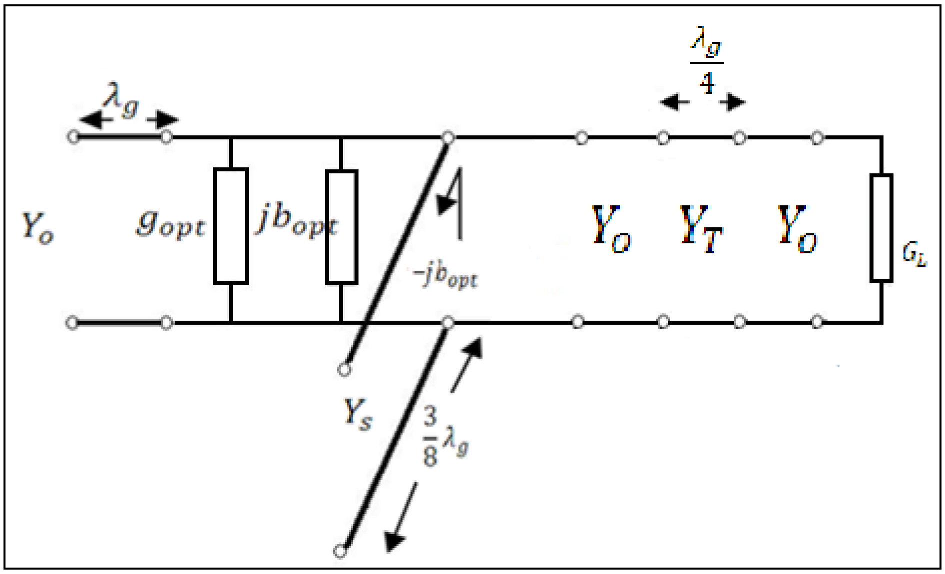


FIGURE19: Oscillator circuit for RF aspects

Parameter	Value
Y_s	27.3mS
Y_o	20mS
Y_T	34.3mS

TABLE 12: Model parameters

4.2 Result in ADS simulation

Figure 20 shown below is the circuit for resonator in ADS simulation. A resonator is a device or system that shows resonance or resonant behavior, which can naturally, oscillates at some frequencies.

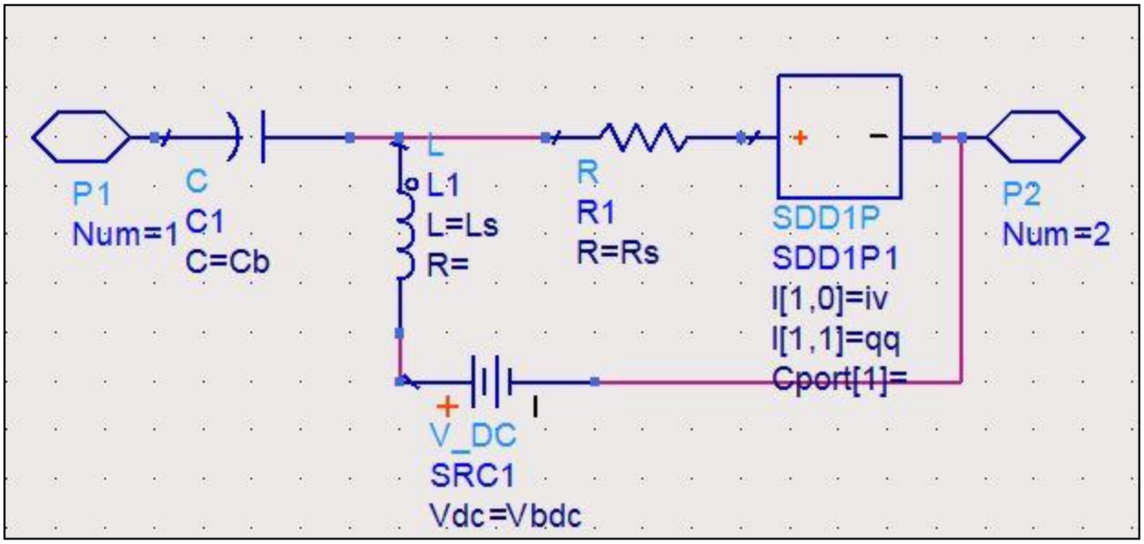


FIGURE 20: Resonator circuit

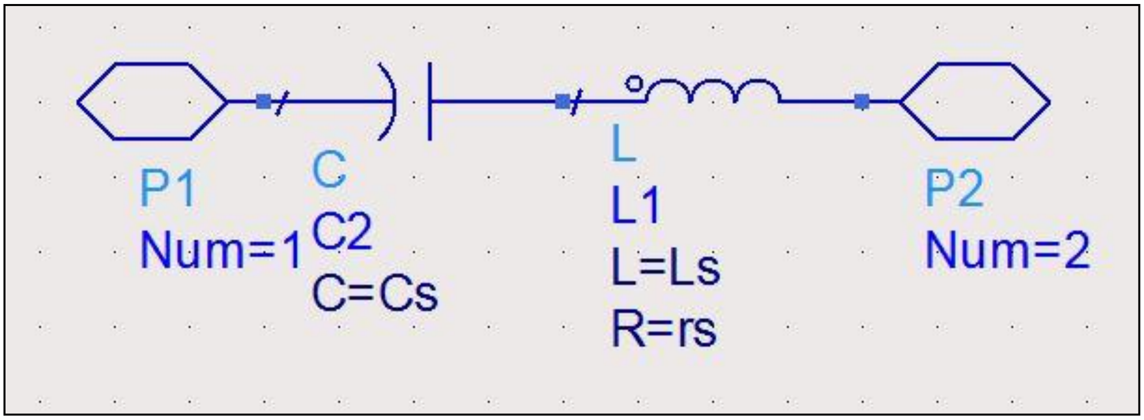


FIGURE 21: LC circuit

LC circuits are utilized either for creating signs at a specific frequency or choosing a sign at a specific frequency from a more complex sign.

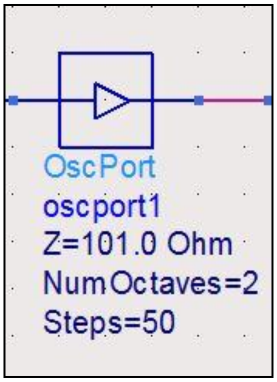


FIGURE 22: OscPort Component

The main purpose of simulating an oscillator using harmonic balance simulator is to find both the oscillation frequency and the output spectrum of the oscillator. We can use two methods to find both of them. One of the methods is by using OscPort (FIGURE 22). OscPort is a component that is inserted into the feedback loop of a single-ended oscillator.

This part is embedded either in the feedback loop of the oscillator, or between the parts of the circuits that have negative resistance and the resonator. OscPort is important because ADS will need it to monitor the loop gain of the circuit and altering the amplitude and frequency of oscillator.

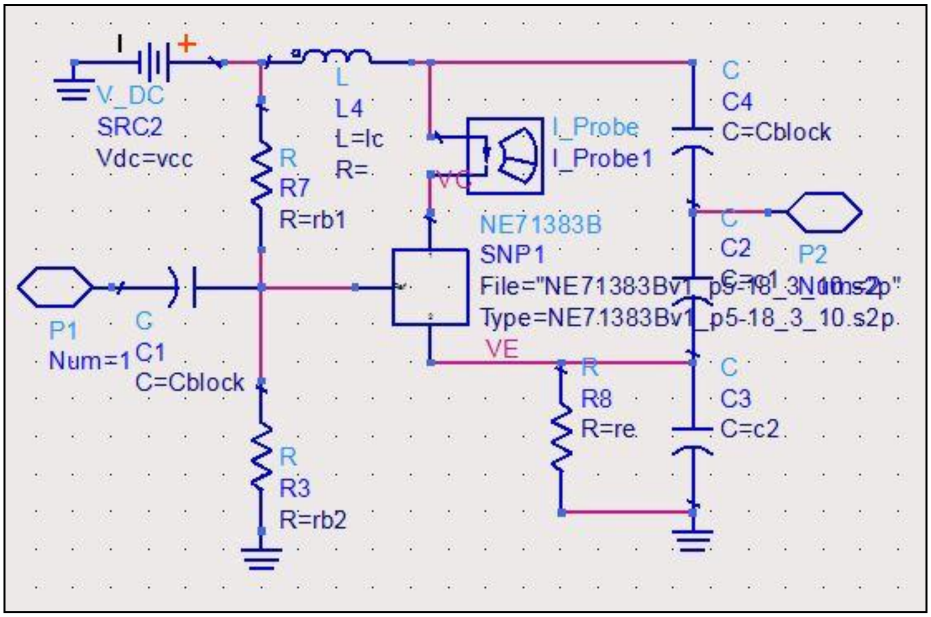


FIGURE 23: Oscillator circuit containing NE71383 transistor.

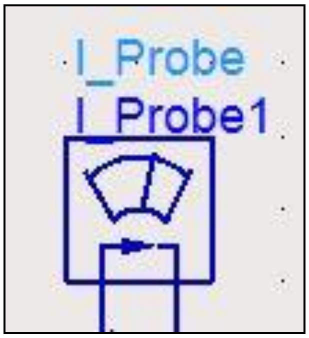


FIGURE 24: Current probe

Current Probes is use to points a node in the circuit where to measure and save current values. It is added to a schematic to collect current data at that point in the circuit.

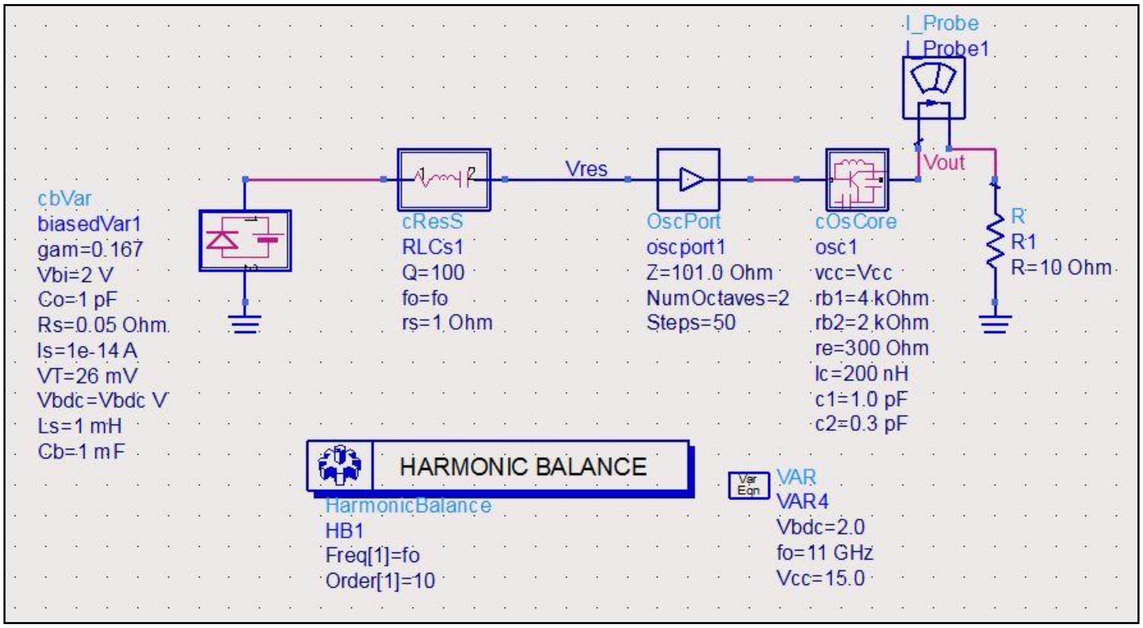


Figure 25: Complete circuit diagram

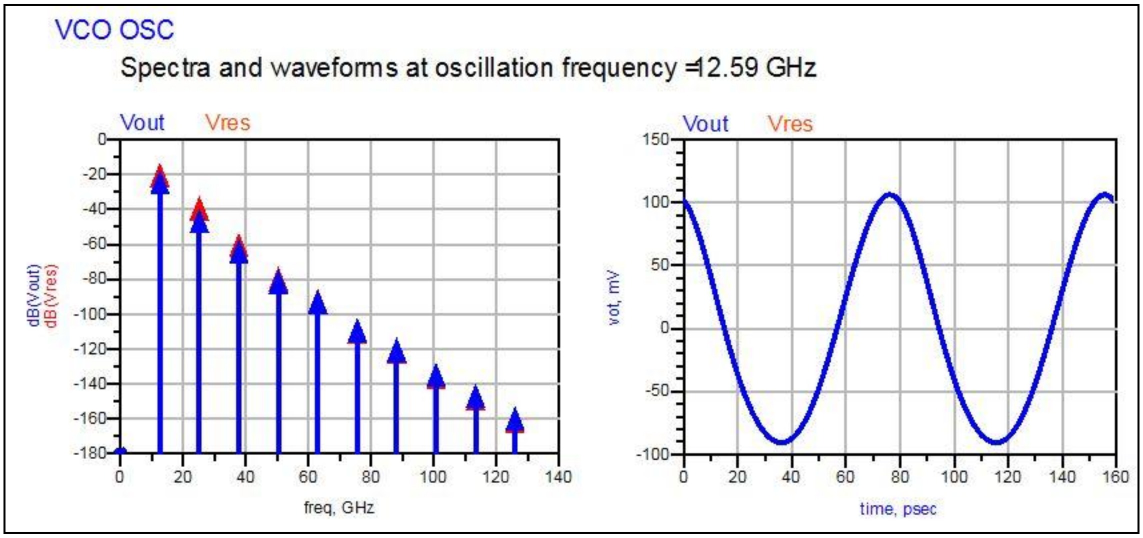


FIGURE 26: Output waveform

The results of simulation in the above image shows output and resonator voltages of the circuit. It also provides oscillations frequency and the corresponding time-domain waveform.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

All in all, this final report records the hypothetical parts of this undertaking. The essential comprehension, investigates and discoveries on the related theme are indicated in divided section.

The operation of millimeter oscillator is theoretically analyzed. Concentrated literature review is done to verify the writer comprehend the subjects of study well. Besides that, a better approach to design millimeter wave oscillator is identified, by using negative conductance method.

For the future plan and work, the design procedures need to be double check again, according to the design specifications and requirements. The author also needs to check again the value and parameters for the components in the circuit. In order to achieve this, a lot of researches and reading need to be done in the future.

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