Analysis and Development of I-V Characteristics Models for Nanometer Size MESFETs Considering Fabrication Parameters

Thesis1

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Requirements for the Degree

of

Bachelor of Electrical and Electronics Engineering

28th April 2011

DECLARATION

We thereby declare that this thesis is based on the results found by ourselves. Materials of work found by other researcher are mentioned by reference. This theis, neither in whole nor in part, has been previously submitted for any degree.

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Abstract:

The Metal-Semiconductor Field-Effect-Transistor (MESFET) is used as a paragon in RF amplifier due to its lower stray capacitance and immense radiation hardness. It is imperative to develop rigorous I-V characteristic models for nanometer size MESFETs. Therefore, we consider two types of MESFETs, GaAs and high-power SiC MESFETs. For nanometer size GaAs MESFETs, some existing models will be analyzed and by comparing all these models Ahmed *et al.* model [1] has been preferred and modified. An algorithm will be developed for the optimization of model parameters to predict the I-V characteristics of nanometer range GaAs MESFETs with different aspect ratios as well as for different bias conditions. The root mean square (RMS) error technique will be used to compare the models. An improved compact nonlinear DC I-V characteristic model will also be delineated for high-power SiC MESFETs. Due to their high thermal conductivity, the SiC devices dissipate larger power resulting an extensive rise in operating temperature. This self heating increases the crystal temperature and commences a negative differential conductance (NDC) because of the change in mobility of the device. An algorithm will also be developed to find out the optimum model parameters using RMS error method. The proposed models will be compared with the experimental results. The proposed models should be a useful tool for upcoming integrated circuits with GaAs and high-power SiC MESFETs.

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Introduction:

1. MESFET:

MESFET stands for metal semiconductor field effect transistor. It is quite similar to a JFETin construction and terminology. The difference is that instead of using a p-n junction for a gate, a Schottky (metal-semiconductor) junction is used. MESFET is a unipolar device, a converse of bipolar transistor. In a n-type MESFETS, electrons are the particles that give rise current and in p type MESFET, same operation is done by majority carrier holes in the conduction channel.

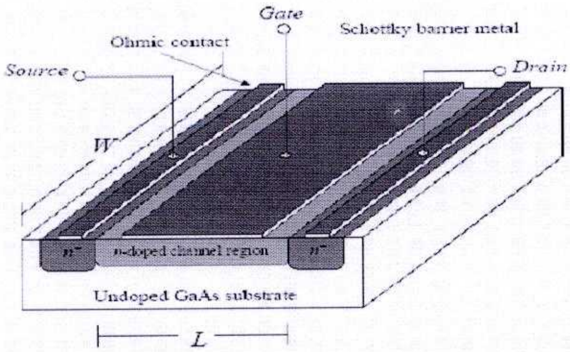


Fig1: Physical structure of MESFET

1.1Functional Structure:

The MESFET differs from the common insulated gate FET in that there is no insulator under the gate over the active switching region. This implies that the MESFET gate should, in transistor mode, be biased such that one does not have a forward conducting metal semiconductor diode instead of a reversed biased depletion zone controlling the underlying channel. While this restriction inhibits certain circuit possibilities, MESFET analog and digital devices work reasonably well if kept within the confines of design limits. The most critical aspect of the design is the gate metal extent over the switching region. Generally the narrower the gate modulated carrier channel the better the frequency handling abilities, overall. Spacing of the source and drain with respect to the gate, and the lateral extent of the gate are important though somewhat less critical design parameters. MESFET current handling ability improves as the gate is elongated laterally, keeping the active region constant, however is limited by phase shift along the gate due to the transmission line effect. As a result most production MESFETs use a built up top layer of low resistance metal on the gate, often producing a mushroom-like profile in cross section

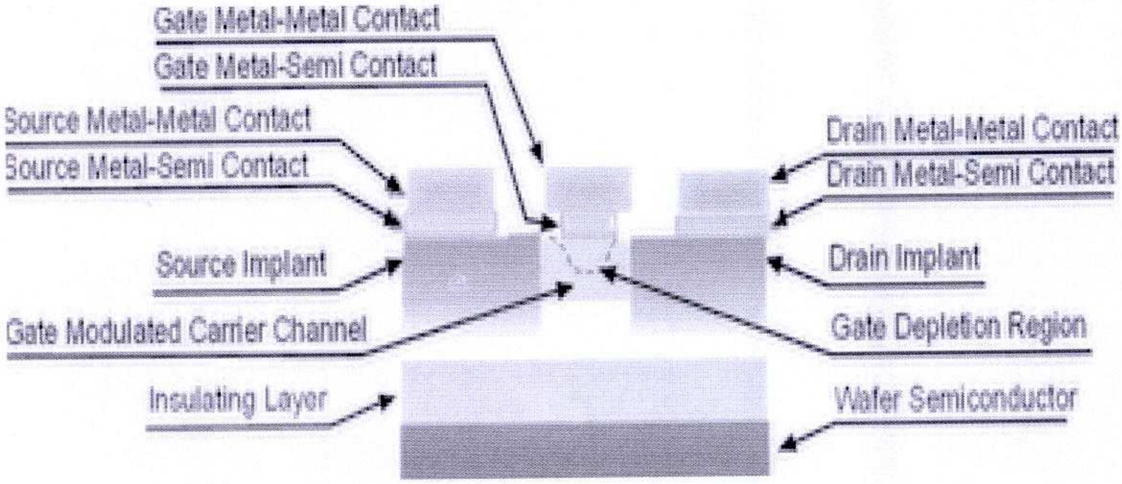


Fig2: MESFET schematic

1.2Application of the MESFET:

Numerous MESFET fabrication possibilities have been explored for a wide variety of semiconductor systems. The GaAs MESFET is widely used as an RF amplifier device. The small geometries and other aspects of the device make it ideal in this application. Besides, it provides for higher electron mobility and in addition to this the semi-insulating substrate there are lower levels of stray capacitance. MESFETs are also used as microwave power amplifiers, high frequency low noise RF amplifiers, oscillators, and within mixers. Also, MESFETs have been used widely in Military communications, Military radar devices, commercial optoelectronics and satellite communications.

In our thesis project we worked on both GaAs and SiC MESFET.

Application of MESFET can be summarized as below—

- RF Amplifiers
- Microwave Power Amplifiers
- Oscillators
- Mixers
- Military communications
- Military radar devices
- Commercial optoelectronics
- Satellite communications

1.3.<u>GaAs MESFET</u>: A Gallium Arsenide (GaAs) Metal-Semiconductor Field-Effect-Transistor (MESFET) is a transistor built with gallium arsenide semiconductor material. The conducting channel is built using a metal-semiconductor (Schottky) junction.

For this form of MESFET, the gate is placed on a section of the channel. The gate contact does not cover the whole of the length of the channel. This arises because the source and drain contacts are normally formed before the gate.

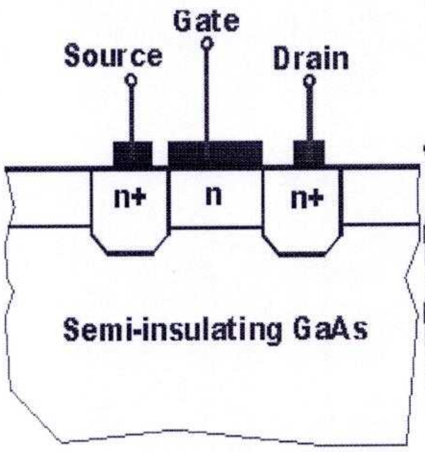


Fig3:Non-self aligned MESFET structure

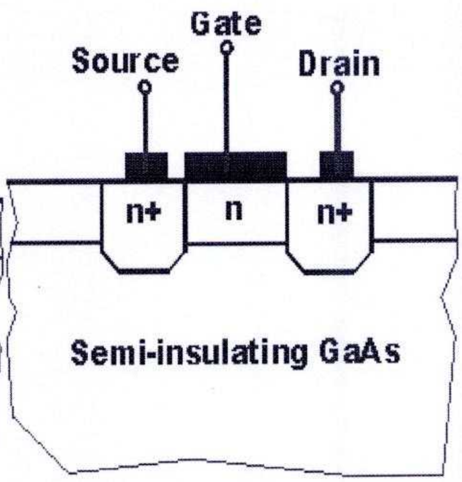


Fig4:Self aligned MESFET structure

This form of structure reduces the length of the channel and the gate contact covers the whole length. This can be done because the gate is formed first, but in order that the annealing process required after the formation of the source and drain areas by ion implantation, the gate contact must be able to withstand the high temperatures and this results in the use of a limited number of materials being suitable.

Like other forms of field effect transistor the GaAsFet or MESFET has two forms that can be used:

1.3.1.Depletion mode MESFET: If the depletion region does not extend all the way to the p-type substrate, the MESFET is a depletion-mode MESFET. A depletion-mode MESFET is conductive or "ON" when no gate-to-source voltage is applied and is turned "OFF" upon the application of a negative gate-to-source voltage, which increases the width of the depletion region such that it "pinches off" the channel.

1.3.2.Enhancement mode MESFET: In an enhancement-mode MESFET, the depletion region is wide enough to pinch off the channel without applied voltage. Therefore the enhancement-mode MESFET is naturally "OFF". When a positive voltage is applied between the gate and source, the depletion region shrinks, and the channel becomes conductive. Unfortunately, a positive gate-to-source voltage puts the Schottky diode in forward bias, where a large current can flow.

1.3.3.Application of the GaAs MESFET:

Semi insulating (SI) GaAs MESFET can be fabricated which eliminates the problem of absorbing microwave power in the substrate due to free carrier absorption. And thus, used in the Microwave Devices. TheGaAs FET / MESFET are widely used as an RF amplifier device. The small geometries and other aspects of the mechanism make it superlative in this submission. Typically a supply voltage of around 10 volts will be used. However care must be taken when designing the bias arrangements because if current flows in the gate junction, it will destroy the GaAS FET. Similarly care must be taken when handling the devices as they are static sensitive. In addition to this, when used as an RF amplifier connected to an antenna, the device must be protected against static received during electrical storms.

The major applications include:

- Radar
- Cellular phone
- Satellite Receivers
- Microwave Devices
- High Frequency

1.4SiC MESFET:

Silicon Carbide (SiC) has been known investigated since 1907 when Captain H. J. Round demonstrated yellow and blue emission by applyingbias between a metal needle and a SIC crystal. SiC.SiC MESFET device is wide energy band gap device. It exhibits high breakdown electric device. It has also high electrical and thermal conductivity. It also exhibits high saturation electron velocity. Its melting point is high and it is chemically inert.

1.4.1The major application-s are:

- Wireless Communication
- Microwave Circuits
- High Power
- High Frequency
- Power Amplifiers

2. I-V CHARACTERISTICs of MESFET:

A current–voltage characteristic is a relationship, typically represented as a chart or graph, between an electric current and a corresponding voltage, or potential difference. the relationship between the DCcurrent through an electronic device and the DC voltage across its terminals is called a current–voltage characteristic of the device.

The ideal model of I-V curve is shown below:

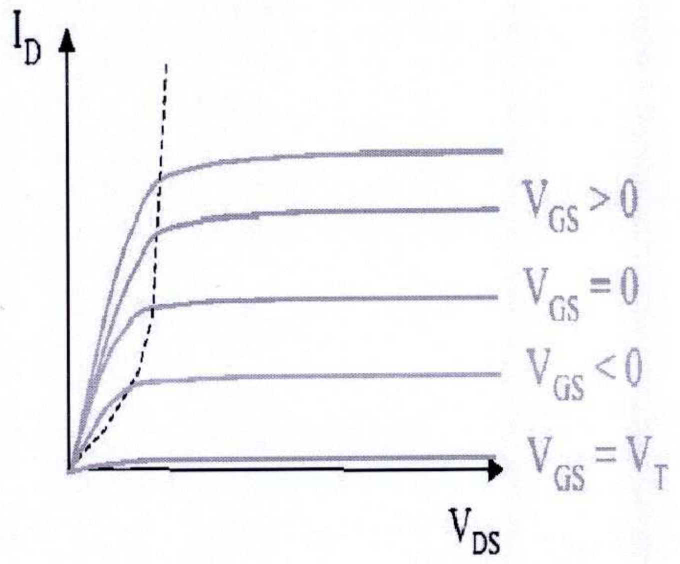


Fig5: I-V characteristics of MESFET

An I-V characteristic of a typical MESFET is similar to that of a MOSFET and JFET. In Fig5 the drain current is plotted against drain-source voltage. Drain current is also a function of gate source voltage. So the individual curve in the Figure represents the dependency of drain current on drain- source voltage for a particular value of gate-source voltage. Form the Figure 5, it is seen thereare two modes of operation of MESFET. There is another mode which isbreakdown mode due to excessive application of drain- source voltage. Increasing of negative voltage at gate electrode, makes the channel fullydepleted, then no current flows. So the voltage at the gate electrode should be such that it is greater than the minimum value of gate voltage that makesthe phenomenon of full depletion, namely threshold voltage. In the Figure it isseen that the current I_D is very low for lower . If we further increase thenegative voltage on gate the channel will stop. So for current conducting region or modes are valid for ,Vgs>Vt,Vt be threshold voltage. Now the individual modes of current conduction are explained below.

2.1.1.Linear Region (0<Vds<Vds.sat):

This region is valid for low value ofVds. From fig 4 it is seen that for low value ofVds , drain current ID which flows from drain to source depends almost linearly on VDS for a particular value of Vgs. As the dependency of Id onVds is linear, so the region is called linear region.
Vds.sat= Vgs-Vto
The Vds.sat is not same for all value of Vgs . With the decrease of Vgs , the value of also Vds,sat decreases.

2.1.2.Saturation region (Vds>Vds,sat):

In linear region, with increase of Vds, Id increases. But after a certain value of Vds , with the increase in Vds, the value of Id does not change considerably. Normally this saturation of Id current is reached at Vds=Vds.sat. Though saturation is achieved, drain current still tends to increase. This is due to the fact that the pinch off point shifts toward the source from the drain; this effectively decreases the channel length. As the channel length is decreased, so current Id increases. Saturation may occur in two different ways for a MESFET depending upon the material used. They are:

- Saturation by pinch off
- Saturation by velocity saturation

2.2.Some of the importance's of I-V model are mentioned below:

- Significant aids to integrated circuit design
- Eliminates the delay of cut and try design approaches
- I-V model opens the door to PC analysis and simulation of the device
- Due to the analysis and simulation in PC is possible, manual gross approximation can be eliminated which often leads to invalidity

2.3.Some of the specifications of I-V model are given below—

- It should be simple
- It should be compact
- It should have minimum number of variables
- It should be such that it takes less CPU execution time
- It should predict the device characteristics regardless of size
- It may be changed during fabrication
- Simulated result should match the actual measurement

3. Some of the previous models are discussed given below:

3.1 Schichman-Hodges Model[1]:

The earliest I-V model for MESFET device may be Schichman-Hodges Model.The introduction of MESFET in modern technology has been arrived on 1966. So in early days of MESFET technology the I-V model is used is Schichman-Hodges Model. This modelimplies the following drain current equation—

$$I_d = 0 \text{ for } V_{gs} < V_{to}$$

$$I_d = \beta V_{ds}\{2(V_{gs}-V_{ds})-V_{ds}\}(1+\lambda V_{ds}) \text{ for } 0 < V_{ds} < V_{gs}-V_{to}$$

$$I_d = \beta(V_{gs}-V_{t0})^2(1+\lambda V_{ds}) \text{ for } V_{ds} > V_{gs}-V_{to}$$

The equation of drain current consists of 3 parts. The device is not turned on if the is lower than the threshold voltage. When Vgsis sufficiently larger than the threshold voltage V_{T0} then the drain current will conduct if a voltage is applied between drain and source terminal.

Limitatons:

This model has only considered the modulation factor, the factor by which drain current depends on V_{ds} in saturation region. In modern modeling, more factors has been considered like there are dependency factor of I_D on V_{ds} in the linear region which is not included here. Dependency of V_{T0} on V_{DS} is also neglected.

3.2 Curtice Model[2]:

The most simplified model and probably the most famous one is Curtice model. Curtice has proposed his I-V model of MESFET in the year of 1980, a decade after Schichman-Hodges.

The drain current equation for the Curtice model is as below—

$$I_d=0 \text{ for } V_{gs}<V_{to}$$

$$I_d=\beta(V_{gs}-V_{t0})^2(1+\lambda V_{ds})\tanh(\alpha V_{ds}) \text{ for } V_{gs}>V_{t0} \text{ and } V_{ds}>0$$

$$\tanh(x)=x \text{ for lower value of } x$$

$$\tanh(x)=1 \text{ for higher value of } x$$

VgsLower than the Vto , threshold voltage; the device is in OFF state. As the gets higher than threshold voltage, the device is ON. In this stage, if drain-source voltage, VDS is applied the current will flow. The interesting part of this model is that the bothlinear and saturation region is modeled in the same equation.

Limitations:

Curtice is simplest one but its accuracy is poor overall and deteriorates considerably with reduced I_D.

3.3 Statz Model[3]:After Curtice, Hermann Statz has realized that the hyperbolicfunction inclusion makes CPU to take more time for calculation. SoHermann Statz has proposed a model in 1987 and he removed thehyperbolic function and deduced equation separately for differentregions.

The drain current equation stated in Statz model is –

$Id=0$ for $Vgs<Vto$

$Vgs>Vto$

$$Id= [\beta(Vgs-Vt0)^2/ b](1+\lambda Vds)[1-[(1-\alpha Vds/3)^3] \text{ for } 0<=Vds<=3/\alpha$$

$$Id= \beta(Vgs-Vt0)^2/1+b(Vgs-Vto)(1+\lambda Vds) \text{ for } Vds>=3/\alpha$$

LIMITATIONS:

Statz model is marginally better than Curtice model in the saturation region but in the linear region this model is slightly worse than the Curtice model.

3.4 Kacprzak-Materka Model [4]

Materka model gives better accuracy both in the saturation and linear region. The error produced in both linear and saturation region is considerable in the previous models. To improve the response of I-V characteristics to fit with the actual values, Kacprzak and Materka had proposed a model which is known as Kacprzak-Materka model and as follows—

$$I_D = 0 \quad for\ V_{GS} < V_{T0} \quad \text{......} \quad (3.11)$$

For $V_{GS}>V_{TO}$

$$I_D = I_{DSS}\left\{1 - \frac{V_{GS}}{V_{T0} + \gamma V_{DS}}\right\}^2 \tanh\left(\frac{\alpha V_{DS}}{V_{GS} - V_{T0} - \gamma V_{DS}}\right) for\ V_{DS} > 0 \ \text{....} \quad (3.12)$$

The model proposes a more complex term of tan hyperbolic function and another parameter has been included here. Actually the inclusion ofmakes to more follows the practical values of . In previous models thedependency of on bias voltage has not been considered. In thisModel it is being considered and gives rise to more accuracy.

Limitations:

Under high current conditions, the accuracy of this model worsens this deterioration increases as the device size decreases. The effect of V_{DS} and V_{GS} over I_{DS} has been ignored.

3.5 MansoorModel[5]:

High frequency metal semiconductor field effect transistors (MESFET's)operating up to mm-wavelength regime have been a focus of interest both firm applications and fundamental research point of view. Commercial applications include analog and digital circuits, which benefits from the superior noise and gain properties of these devices. To improve the performance of a submicron GaAs MESFET, an optimum value of active channel thickness is required. From a designing point of view it is important to know the value of a at which maximum gain can be attained from a given device.

Most recently Monsoor Ahmed has presented a new model, especially designed for the simulation of submicron FET's. according to the accuracy of Kacprzak-materka model degrades very severely when the device size is reduced. This fact is quite understandable because the Kacprzak-Materka model was originally conceived for the simulation of large-signal devices operating at moderate frequencies.

Mansoor. Ahmed has proposed an I-V model suitable for nonlinear small-signal circuit design in 1997.Kacprzak-Materka who started the prediction of behavior of submicron devices, Mansoor model takes this a one step further. Mansoor proposed a model by including a new concept of shift in threshold voltage. Drain current equation of this model is as follows—

$$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_T + \Delta V_T + \gamma \cdot V_{DS}}\right)^2 \tanh\left(\alpha V_{DS}\right)\left(1 + \lambda \cdot V_{DS}\right)$$

Where

α, γ, λ empirical constants

I_{dss}=saturation current at V_{gs}=0v;

V_T=threshold voltage;

ΔV_T=shift in threshold voltages;

These are defined as,

V_T=$(qNa^2/2\epsilon_S)$-$\emptyset_b$

And

ΔV_T=$(4\alpha/3L_g)V_T$

Where

N channel doping density

q Electronic charge

ϵ_S Permittivity of GaAs

$\emptyset_b$Schottky barrier height

L_g gate length

The magnitudes of g_m and g_d can be evaluated from (1) and expressed as follows

$$g_m=2I_{dss}[1-\frac{V_{gs}}{V_{T+\Delta}V_{T+\gamma}V_{ds}}]\ [-\frac{1}{V_{T+\Delta}V_{T+\gamma}V_{ds}}]*\tanh(\alpha V_{ds})\ (1+\lambda V_{ds})\text{..................}(2)$$

$$g_d=I_{dss}[2(1-\frac{V_{gs}}{V_{T+\Delta}V_{T+\gamma}V_{ds}})*$$

He found two factors that may be the reason of discrepancy of Materka model between the observed and simulated characteristics. Two factors are—

- The shift in V_{T0} due to submicron geometry of the device
- The poor control in simulating the output conductance, especially at $V_{GS}=0$.

An algorithm has been developed to simulate the effects of a on the device characteristics. There are several numerical methods, based upon the field distribution inside the channel, which can predict the changed device characteristics as a function of a. But in designing software, a detailed rigorous mathematical model involving too many parameters is not preferred because it is too complicated to handle and cannot be used efficiently by an engineer involved in the process.

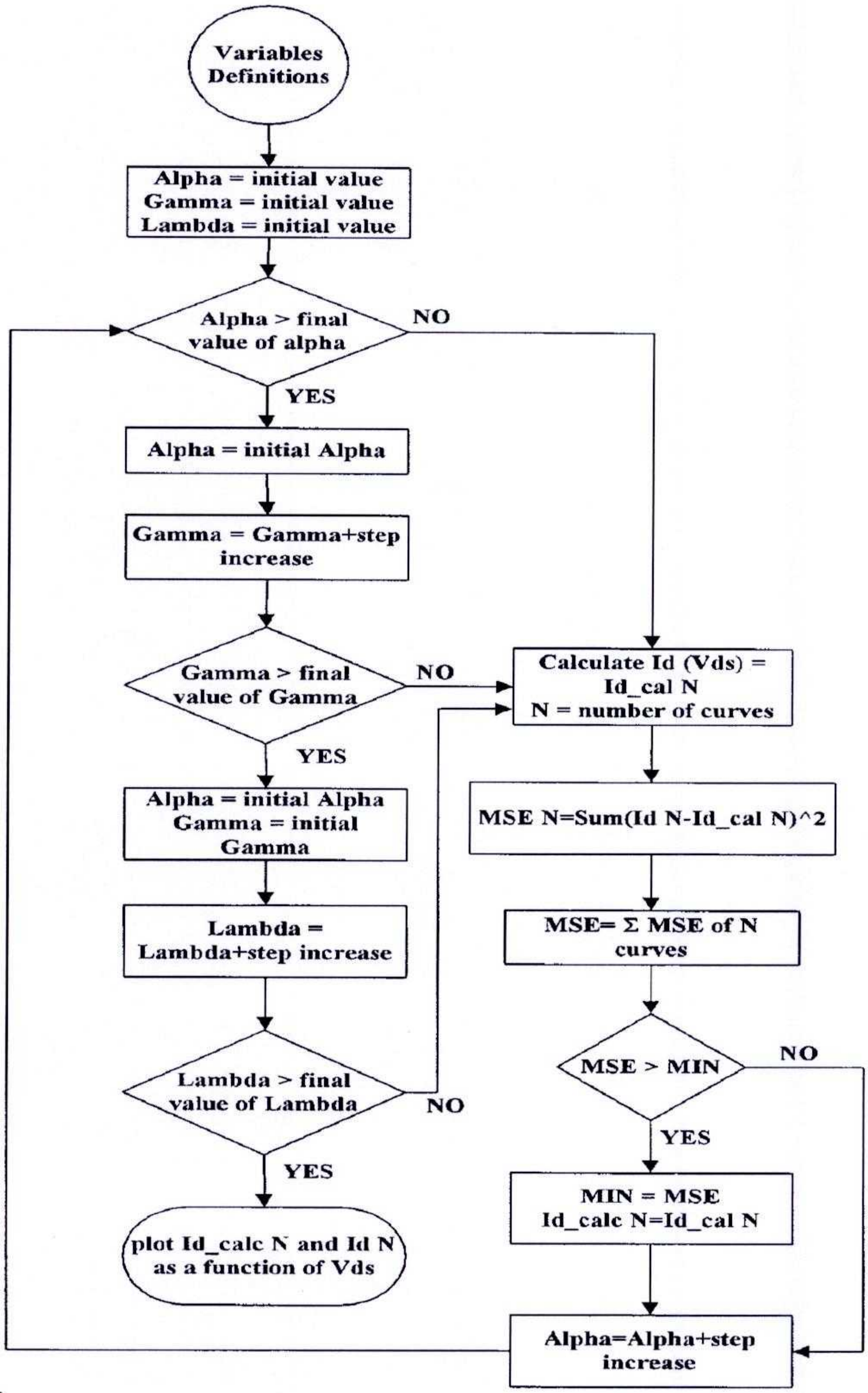


Fig6: Flow chart of Mansoor Ahmed model

For simulation purposes, data is generated on a PC by employing a mechanism illustrated in Fig. 6. The values of $V_T, \Delta V_{T,} I_{dss}$, and are attained from the terminal measurements of the device, and empirical constants were estimated by computing mean square error (MSE) values from the observed and simulated characteristics.

In this process, an algorithm is designed which initially chooses the best possible value ofα by iterating all the values within the prescribed limits. This defines a number in the flowchart called MSE. After evaluating the best value ofα , the algorithm generates all possible combinations of α, γ, λ to calculate the optimal output characteristics. Finally, it plots the device characteristics by selecting the optimum combination of empirical constants that results into the least MSE value. In the flow chart "Id_calc N" represents the simulated value of the output drain current whereas "Id N" denotes the observed drain current.

MansoorAhmed shows both the simulated and the observed characteristic the different GaAs MESFET's having device dimensions and the good agreement found in the figure confirms the validity for small-signal devices and also the simulation algorithm.

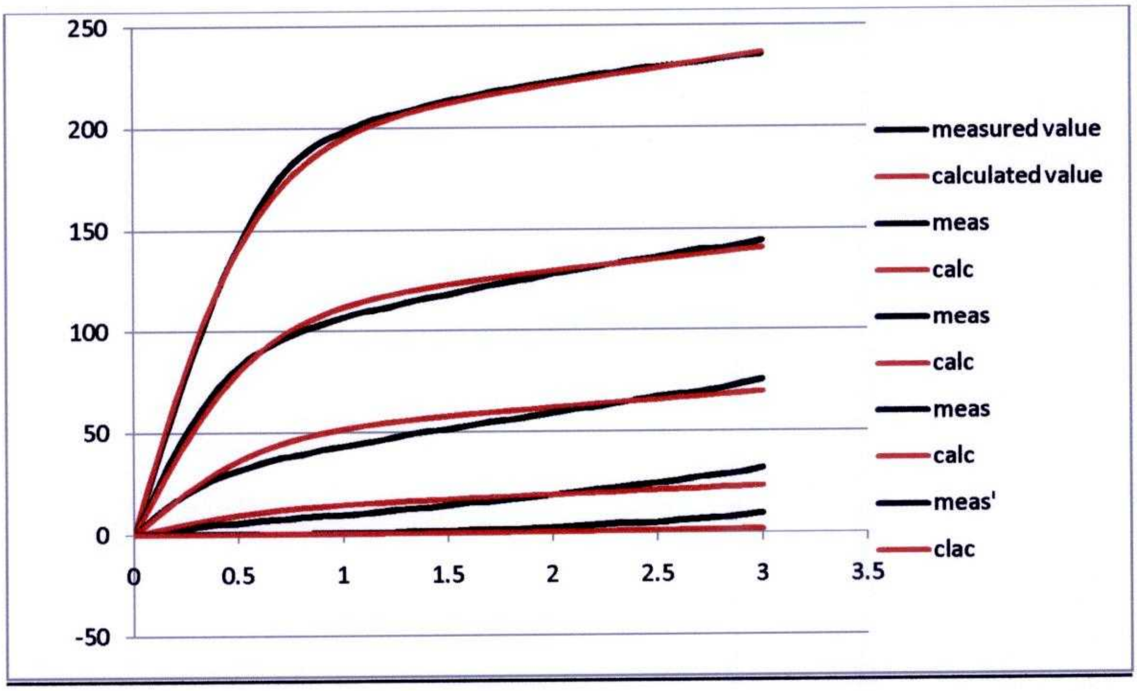


Fig7: I-V curve of Mansoor Ahmed Model

Error1	Error2	Error3	Error4	Erro5
1.0373	1.1773	2.4771	0.5786	2.8746

MSE cal=3.5673 **Avg.RMS Error=0.0874**

We compare both the simulated and the observed characteristics of three different GaAs MESFET's having different device dimensions to get the error in Mansoor Ahmed model. We use three different GaAs MESFET's having different device dimensions curve in G2D software to get the measured value. Then we simulate the equation of Mansoor Ahmed model and get the value of simulated characteristics. Then we compare the both values and get the error of GaAs MESFET's having different device dimensions. After that we calculate the over all MSE.

Mansoor model

device1

Idss =192.000 mA / mm

VT = -2.000V

MSE Calculated = 3.5305

Av. RMS Error = 0.0322

MSE[1]	MSE[2]	MSE[3]	MSE[4]	MSE[5]
2.3	3	4.7	3.5	3.6
obsRMS[1]	obsRMS[2]	obsRMS[3]	obsRMS[4]	obsRMS[5]
199	114	53	18	4.7
calRMS[1]	calRMS[2]	calRMS[3]	calRMS[4]	calRMS[5]
197	116	56	18	1.1
Error1	Error2	Error3	Error4	Error5
1.3	1.4	2.5	0.8	3.6

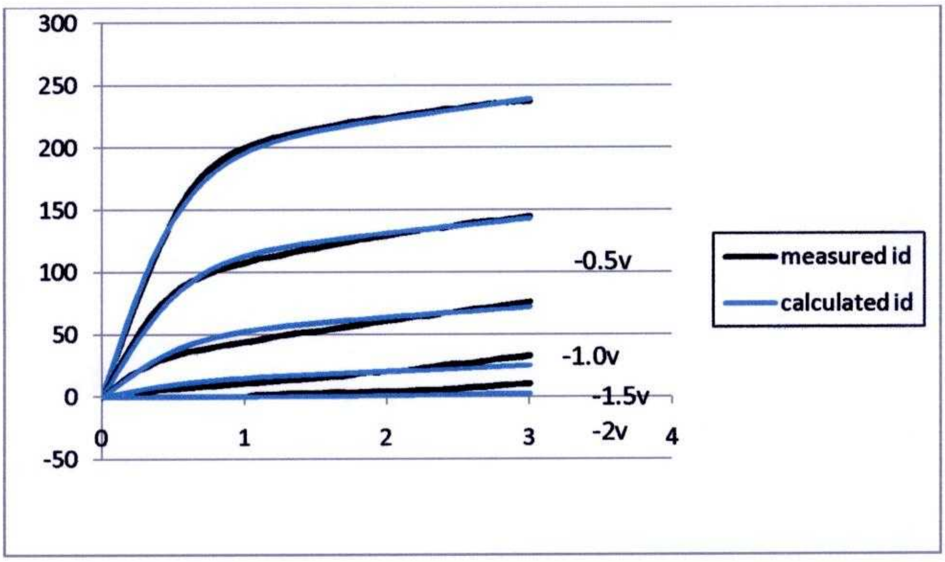
Alpha = 1.7802

Gamma = -0.0739

Lambda = 0.0816

Vds	Ids1(meas.)	Ids1(cal.)	Ids2(meas.)	Ids2(cal.)	Ids3(meas.)	Ids3(cal.)	Ids4(meas.)	Ids4(cal.)	Ids5(meas.)	Ids5(cal.)
0	0	0	0	0	0	0	0	0	0	0
0.1	33	34	21	19	9.3	8.6	1.7	2.2	0	0
0.2	64	67	40	38	18	17	3.4	4.4	0	0
0.3	93	96	58	54	24	25	4.2	6.4	0	0
0.4	119	121	73	69	30	31	5.9	8.3	0	0
0.5	143	142	83	81	33	37	6.8	9.9	0	0.1
0.6	163	159	92	91	36	41	7.6	11	0	0.1
0.7	177	172	97	98	38	45	8.5	12	0	0.1
0.8	187	182	102	104	41	48	9.3	13	0	0.2
0.9	195	190	105	109	42	51	10	14	0	0.2
1	200	196	108	113	44	53	11	15	0	0.3
1.1	204	201	111	116	46	54	12	16	1.7	0.3
1.2	208	205	113	119	48	56	13	16	1.7	0.4
1.3	210	208	115	121	50	57	14	17	2.5	0.4
1.4	213	211	118	123	52	58	14	17	2.5	0.5
1.5	215	213	119	124	53	59	15	18	2.5	0.6
1.6	217	216	122	126	54	60	16	18	3.4	0.7
1.7	219	218	124	127	56	61	17	19	3.4	0.8
1.8	221	219	126	129	58	62	19	19	3.4	0.9
1.9	223	221	128	130	59	63	19	20	4.2	1
2	224	223	130	131	61	64	20	20	4.2	1.1
2.1	225	225	131	133	63	65	21	21	4.2	1.2
2.2	227	226	133	134	64	65	22	21	5.1	1.3
2.3	229	228	135	135	65	66	24	22	5.1	1.4
2.4	231	230	136	136	67	67	25	22	5.9	1.5
2.5	231	231	138	137	69	68	26	23	6.8	1.7
2.6	233	233	140	139	70	69	27	23	7.6	1.8
2.7	235	234	141	140	71	70	29	24	8.5	1.9
2.8	236	236	142	141	73	71	31	24	9.3	2.1
2.9	236	237	143	142	75	71	31	25	10	2.2
3	237	239	145	144	76	72	33	25	11	2.4

Device 1(Mansoor Ahmed):



mansoor model
device 2

Idss =220.000 mA / mm
VT = -2.250V

MSE Calculated = 5.4117 Av. RMS Error = 0.6191

MSE[1]	MSE[2]	MSE[3]	MSE[4]
3.6827	7.0159	5.0941	5.3304

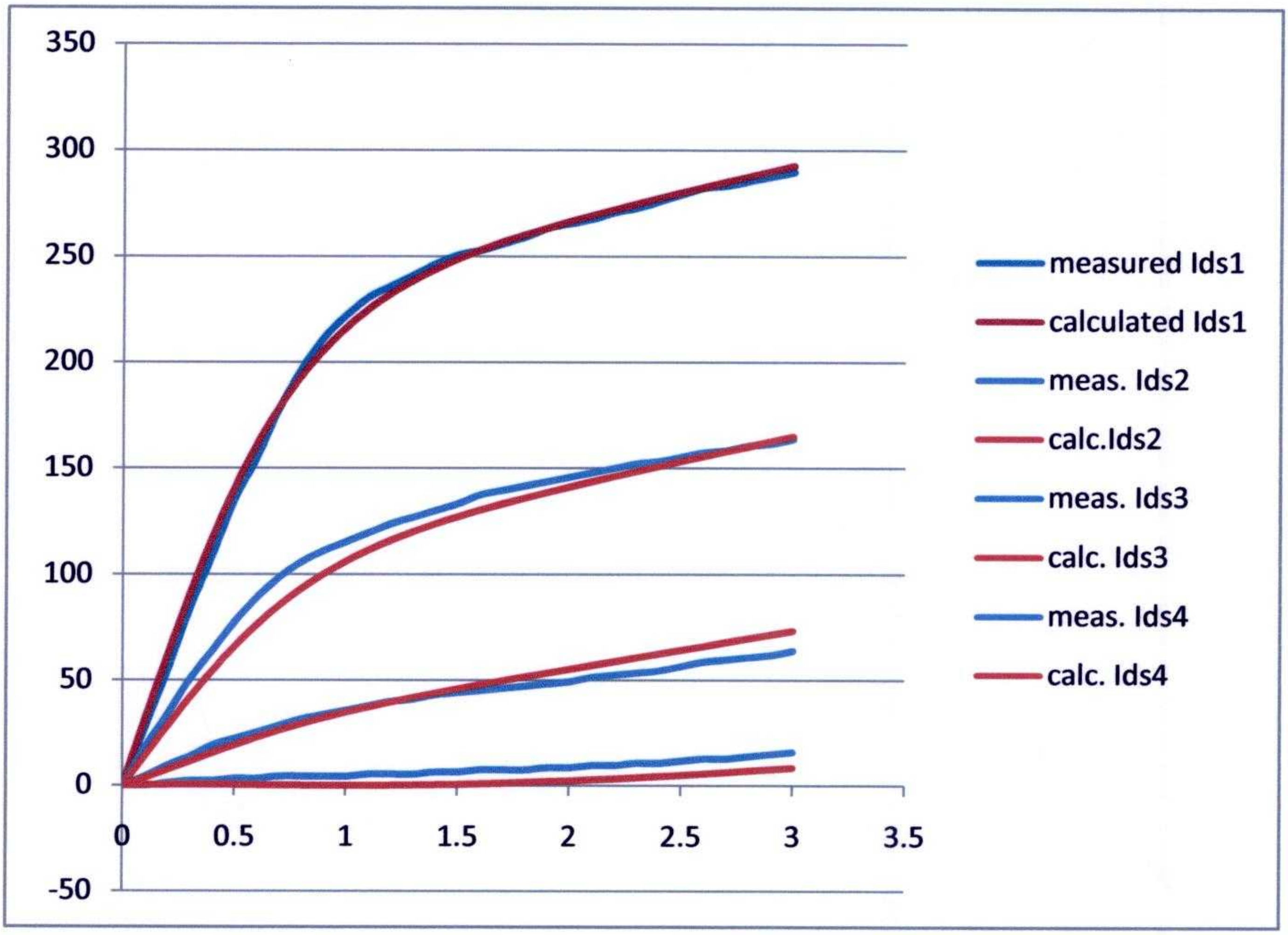
obsRMS[1]	obsRMS[2]	obsRMS[3]	obsRMS[4]
229.8632	126.0965	43.5073	8.1558

calRMS[1]	calRMS[2]	calRMS[3]	calRMS[4]
230.3325	121.2991	47.5667	3.2836

Error1	Error2	Error3	Error4
0.4692	4.7974	4.0594	4.8722

Alpha = 1.4077 Gamma = -0.2528 Lambda = 0.1101

Vds	Ids1(meas.	Ids1(cal.)	Ids2(meas.	Ids2(cal.)	Ids3(meas.	Ids3(cal.)	Ids4(meas.	Ids4(cal.)
0	0	0	0	0	0	0	0	0
0.1	27.27	31.1	17.83	13.98	4.2	3.61	0	0.3
0.2	54.55	61.68	33.57	28.02	9.44	7.47	1.05	0.46
0.3	83.92	90.65	50.35	41.61	13.64	11.43	2.1	0.51
0.4	109.09	117.2	63.99	54.35	18.88	15.36	2.1	0.47
0.5	135.31	140.84	77.62	65.97	22.03	19.16	3.15	0.38
0.6	155.24	161.41	89.16	76.34	25.17	22.75	3.15	0.27
0.7	178.32	178.99	98.6	85.46	28.32	26.11	4.2	0.16
0.8	197.2	193.82	105.94	93.39	31.47	29.23	4.2	0.07
0.9	211.89	206.24	111.19	100.27	33.57	32.11	4.2	0.02
1	222.38	216.62	115.38	106.25	35.66	34.78	4.2	0
1.1	230.77	225.31	119.58	111.46	37.76	37.26	5.24	0.03
1.2	236.01	232.63	123.78	116.04	39.86	39.59	5.24	0.1
1.3	241.26	238.86	126.92	120.12	40.91	41.79	5.24	0.22
1.4	246.5	244.23	130.07	123.8	43.01	43.9	6.29	0.39
1.5	250.7	248.92	133.22	127.16	44.06	45.92	6.29	0.6
1.6	252.8	253.09	137.41	130.28	45.1	47.87	7.34	0.86
1.7	255.94	256.85	139.51	133.2	46.15	49.78	7.34	1.16
1.8	259.09	260.29	141.61	135.96	47.2	51.66	7.34	1.5
1.9	263.29	263.5	143.71	138.62	48.25	53.5	8.39	1.88
2	265.38	266.52	145.8	141.18	49.3	55.33	8.39	2.29
2.1	267.48	269.39	147.9	143.68	51.4	57.15	9.44	2.75
2.2	270.63	272.16	150	146.12	52.45	58.97	9.44	3.24
2.3	272.73	274.85	152.1	148.53	53.5	60.78	10.49	3.77
2.4	275.87	277.48	153.15	150.91	54.55	62.59	10.49	4.33
2.5	279.02	280.05	155.24	153.26	56.64	64.4	11.54	4.92
2.6	282.17	282.59	157.34	155.6	58.74	66.21	12.59	5.55
2.7	283.22	285.1	158.39	157.92	59.79	68.04	12.59	6.2
2.8	285.31	287.59	160.49	160.24	60.84	69.86	13.64	6.89
2.9	287.41	290.07	161.54	162.55	61.89	71.7	14.69	7.61
3	289.51	292.53	163.64	164.85	63.99	73.54	15.73	8.35


350
300
250
200
150
100
50
0
-50
0
0.5
1
1.5
2
2.5
3
3.5
measured Ids1
calculated Ids1
meas. Ids2
calc.Ids2
meas. Ids3
calc. Ids3
meas. Ids4
calc. Ids4

mansoor
model
device3

Idss =350.000 mA / mm
VT = -3.500V

MSE Calculated = 8.3353

Av. RMS Error = 0.5459

MSE[1]	MSE[2]	MSE[3]	MSE[4]	MSE[5]
11.4	9.68	9.26	5.98	1.62

obsRMS[1]	obsRMS[2]	obsRMS[3]	obsRMS[4]	obsRMS[5]
338	213	113	44.7	12.6

calRMS[1]	calRMS[2]	calRMS[3]	calRMS[4]	calRMS[5]
335	212	117	50.4	13.1

Error1	Error2	Error3	Error4	Error5
3.07	1.04	4.07	5.73	0.43

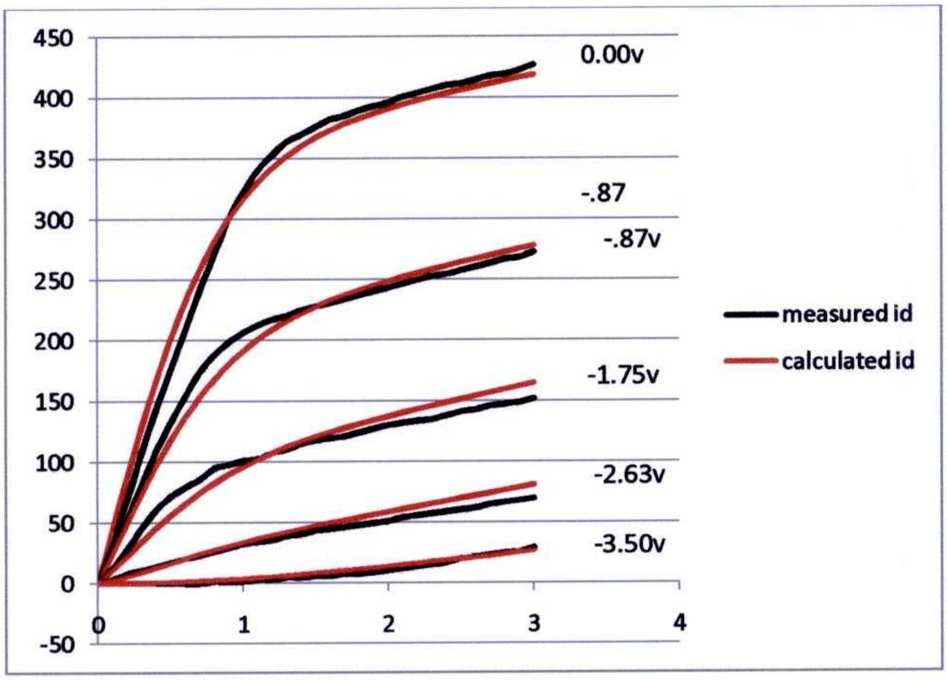
Alpha = 1.2477

Gamma = -0.3984

Lambda = 0.0659

Vds	Ids1(meas.)	Ids1(cal.)	Ids2(meas.)	Ids2(cal.)	Ids3(meas.)	Ids3(cal.)	Ids4(meas.)	Ids4(cal.)	Ids5(meas.)	Ids5(cal.)
0	0	0	0	0	0	0	0	0	0	0
0.1	35.7	43.7	29.5	24.9	12.4	11.2	3.1	2.89	0	0.01
0.2	68.3	86.7	52.8	49.7	27.9	22.7	7.76	6.1	0	0.04
0.3	107	128	80.7	73.7	45	34.1	10.9	9.54	0	0.14
0.4	143	166	109	96.3	60.5	45.1	14	13.1	0	0.31
0.5	175	200	132	117	71.4	55.6	17.1	16.7	0	0.58
0.6	208	231	154	136	79.1	65.3	20.2	20.3	0	0.94
0.7	241	257	174	153	85.3	74.2	23.3	23.8	0	1.4
0.8	270	280	188	167	94.7	82.3	26.4	27.2	1.55	1.95
0.9	299	300	199	180	97.8	89.5	29.5	30.4	1	2.59
1	321	316	206	191	101	96	32.6	33.5	1.55	3.3
1.1	340	330	213	200	102	102	34.1	36.4	3.1	4.09
1.2	352	342	217	209	107	107	35.7	39.2	3.1	4.93
1.3	363	351	220	216	110	112	38.8	41.9	4.66	5.84
1.4	369	360	225	222	115	116	40.3	44.5	4.66	6.8
1.5	376	367	228	228	118	120	43.5	47.1	6.21	7.8
1.6	382	373	231	233	119	124	45	49.5	6.21	8.85
1.7	385	378	234	237	121	128	46.6	51.9	7.76	9.94
1.8	389	383	237	241	124	131	48.1	54.2	7.76	11.1
1.9	393	387	241	245	127	134	49.7	56.5	9.31	12.2
2	396	391	244	249	130	137	51.2	58.8	10.9	13.4
2.1	400	394	247	252	132	140	54.3	61.1	12.4	14.7
2.2	403	397	250	255	133	143	55.9	63.3	14	15.9
2.3	407	400	253	258	135	146	57.4	65.5	15.5	17.2
2.4	410	403	254	261	138	149	59	67.7	17.1	18.6
2.5	411	406	258	264	141	151	60.5	70	20.2	19.9
2.6	414	409	261	267	143	154	62.1	72.2	21.7	21.3
2.7	417	411	264	270	146	157	65.2	74.4	23.3	22.7
2.8	419	414	267	273	147	160	66.7	76.6	24.8	24.2
2.9	422	416	268	275	149	162	68.3	78.8	26.4	25.6
3	427	419	273	278	152	165	69.8	81	29.5	27.1

Device3(Mansoor Ahmed):

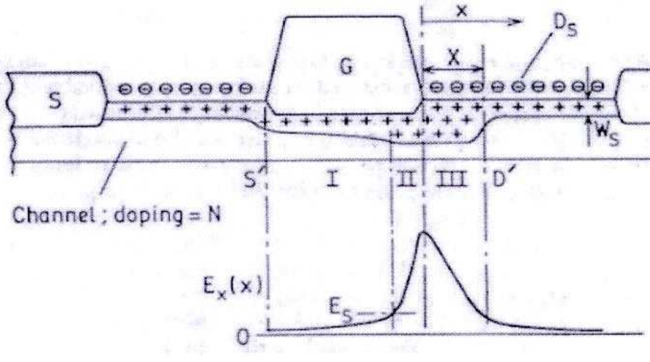


Limitation of this model: The effect of gate to source voltage *VGS* over drain to source current I_{DS} has been ignored.

4. Device Operation in Saturation Region:

4.1 Considering the effect of V_{DS} over I_{DS}:

The gate-source voltage is kept constant and the drain-source voltage is increased positively, so that the depletion extension *X* increases slightly. Electrons deplete from the extreme edge of the space-charge layer to uncover more positive ionic charge. The electric field lines originated by the positive ionic charges will have its maximum strength near the drain side of the gate electrode. This decreases the gate depletion and increases channel thickness under the gate and thereby increasing channel current, *ICH* flowing from source to drain electrodes.



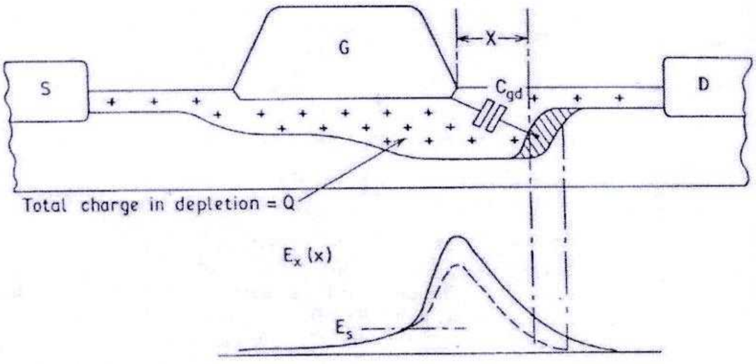


Fig8: Effect of V_{DS} over I_{DS}:

4.2 Considering the effect of V_{GS} on I_{DS}:

In region I the depletion layer expands, the electrons which deplete from the shaded region are transported through the region I,II and III and finally to the drain. Extra positive ionic charge is thus uncovered in the depletion edge due to increase in gate voltage the depletion layer exhibits charge storage properties. The channel current *ICH* is governed by *VGS* through the depletion region.

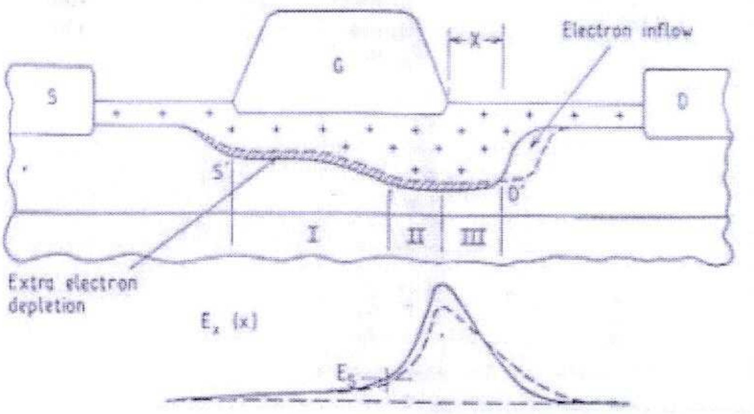


Fig9: Effects of Vgs on Ids

We worked on the development of Mansoor Ahmed model GaAs MESFET and our proposed model is:

Ids= Idss * pow((1 - Vgs[i] / (VT + gamma * Vds[j])),2) * tanh (alpha * Vds[j]) * (1 + lambda * Vds[j]+beta * Vgs[i]) ;

α, γ, λ ,β empirical constants

I_{dss}=saturation current at V_{gs}=0v;

V_T=threshold voltage;

ΔV_T=shift in threshold voltages;

Here we use ßVgs term to solve the deficiency which is not used in Mansoor model.

After working on limitations of Mansoor Ahmed model we simulate an algorithm and observed characteristic of different device dimensions of GaAs MESFET and the good agreement found in the figure confirms the validity for small-signal devices and also the simulation algorithm.

5. Flow chart of our proposed model

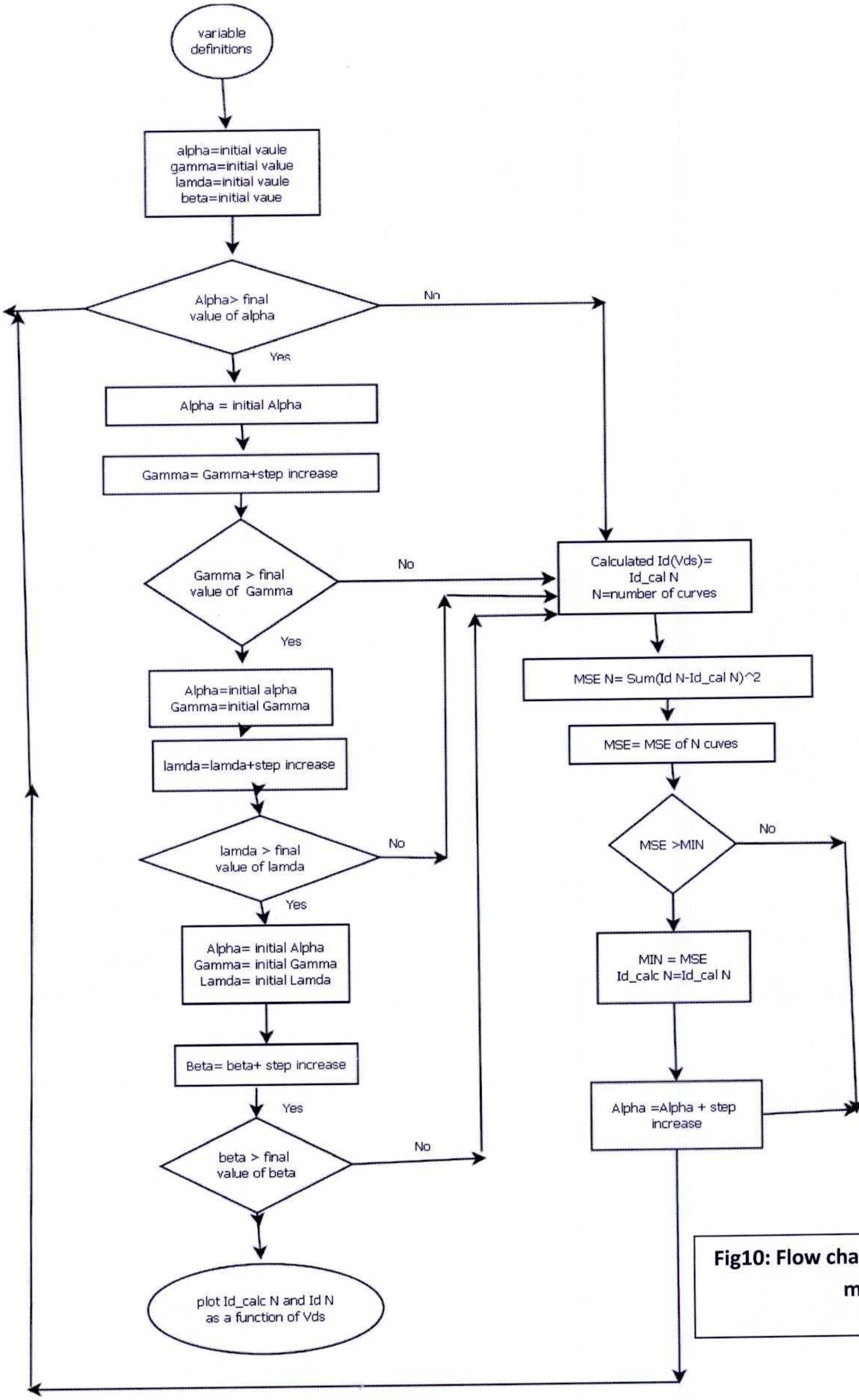


Fig10: Flow chart of our proposed model

proposed model Idss =192.000 mA / mm
device1 VT = -2.000V

MSE Calculated = 2.2448 Av. RMS Error = 0.2470

MSE[1]	MSE[2]	MSE[3]	MSE[4]	MSE[5]
2.5995	2.743	2.1394	2.117	1.3625

obsRMS[	obsRMS[2]	obsRMS[	obsRMS[4]	obsRMS[5]
198.59	114.3862	53.384	18.4695	4.7107

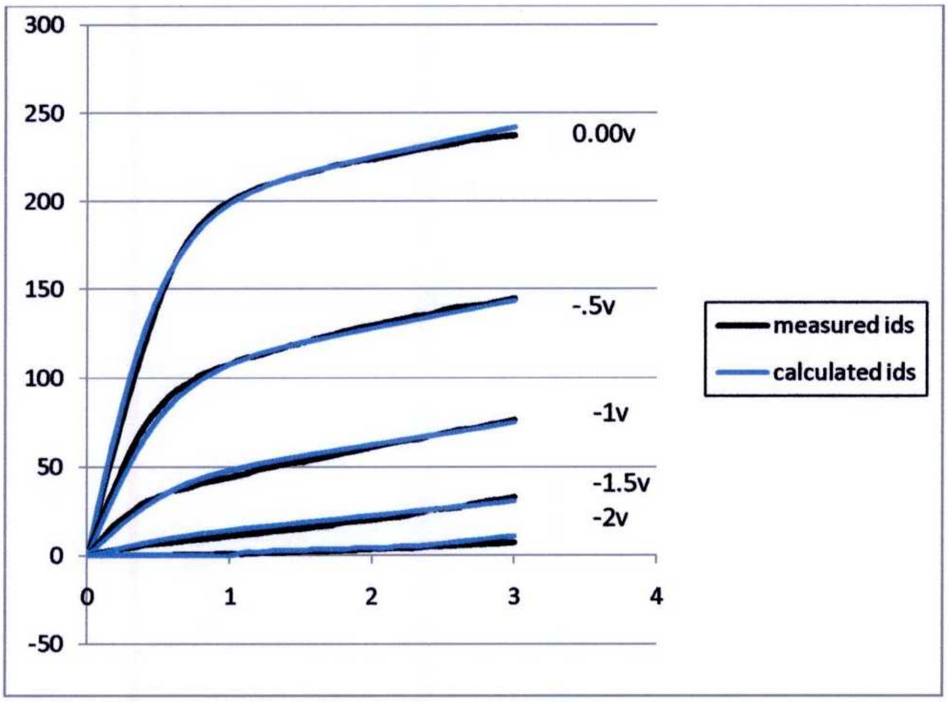
calRMS[:	calRMS[2]	calRMS[:	calRMS[4]	calRMS[5]
199.76	112.8923	54.373	19.4886	3.4224

Error1	Error2	Error3	Error4	Error5
1.1695	1.4939	0.9891	1.0191	1.2883

Alpha = 1.8637 Gamma = -0.1776 Lambda = 0.0845 beta = 0.1885

Vds	Ids1(mea	Ids1(cal.	Ids2(meas.	Ids2(cal.	Ids3(meas.	Ids3(cal.)	Ids4(meas.	Ids4(cal.)	Ids5(meas.	Ids5(cal.)
0	0	0	0	0	0	0	0	0	0	0
0.1	33.05	35.69	21.19	18.28	9.32	7.36	1.69	1.68	0	0
0.2	64.41	69.62	39.83	35.9	17.8	14.64	3.39	3.46	0	0.01
0.3	93.22	99.95	58.47	51.87	23.73	21.4	4.24	5.23	0	0.04
0.4	119.49	125.66	72.88	65.63	29.66	27.39	5.93	6.9	0	0.09
0.5	143.22	146.54	83.05	77.01	33.05	32.51	6.78	8.43	0	0.16
0.6	162.71	163.01	91.53	86.19	36.44	36.79	7.63	9.81	0	0.26
0.7	177.12	175.74	96.61	93.48	38.14	40.33	8.47	11.05	0	0.38
0.8	187.29	185.52	101.69	99.25	40.68	43.28	9.32	12.17	0	0.51
0.9	194.92	193.02	105.08	103.86	42.37	45.75	10.17	13.19	0	0.67
1	200	198.85	107.63	107.61	44.07	47.87	11.02	14.13	0	0.84
1.1	204.24	203.46	111.02	110.71	45.76	49.74	11.86	15.02	1.69	1.03
1.2	207.63	207.2	112.71	113.36	48.31	51.41	12.71	15.87	1.69	1.23
1.3	210.17	210.31	115.25	115.68	50	52.95	13.56	16.69	2.54	1.45
1.4	212.71	212.99	117.8	117.77	51.69	54.4	14.41	17.5	2.54	1.69
1.5	215.15	215.36	119.49	119.7	52.54	55.78	15.25	18.3	2.54	1.93
1.6	216.95	217.52	122.03	121.51	54.24	57.12	16.1	19.1	3.39	2.2
1.7	219.49	219.53	123.73	123.24	55.93	58.42	16.95	19.89	3.39	2.47
1.8	221.19	221.43	126.27	124.92	57.63	59.71	18.64	20.69	3.39	2.77
1.9	222.88	223.26	127.97	126.56	59.32	60.98	19.49	21.5	4.24	3.07
2	223.73	225.04	129.66	128.17	61.02	62.25	20.34	22.31	4.24	3.39
2.1	225.42	226.78	131.36	129.77	62.71	63.51	21.19	23.13	4.24	3.73
2.2	227.12	228.51	133.05	131.35	64.41	64.77	22.03	23.95	5.08	4.07
2.3	228.81	230.21	134.75	132.93	65.25	66.04	23.73	24.79	5.08	4.43
2.4	230.51	231.9	135.59	134.5	66.95	67.3	25.42	25.64	5.93	4.81
2.5	231.36	233.58	138.14	136.07	68.64	68.57	26.27	26.49	6.78	5.2
2.6	233.05	235.26	139.83	137.63	70.34	69.84	27.12	27.35	7.63	5.6
2.7	234.75	236.94	140.68	139.2	71.19	71.12	28.81	28.22	8.47	6.02
2.8	235.59	238.61	141.53	140.76	72.88	72.4	30.51	29.1	9.32	6.44
2.9	236.44	240.28	143.22	142.33	74.58	73.69	31.36	29.99	10.17	6.88
3	237.29	241.94	144.92	143.89	76.27	74.98	33.05	30.89	11.02	7.34

Device1(Proposed Model):



proposed model
device 2

Idss =220.000 mA / mm
VT = -2.250V

MSE Calculated = 4.2994 Av. RMS Error = 0.0746

MSE[1]	MSE[2]	MSE[3]	MSE[4]
3.6558	2.2623	3.6486	6.4919

obsRMS[1]	obsRMS[2]	obsRMS[3]	obsRMS[4]
229.8632	126.0965	43.5073	8.1558

calRMS[1]	calRMS[2]	calRMS[3]	calRMS[4]
229.8814	127.4005	41.164	2.3185

Error1	Error2	Error3	Error4
0.0182	1.3039	2.3433	5.8373

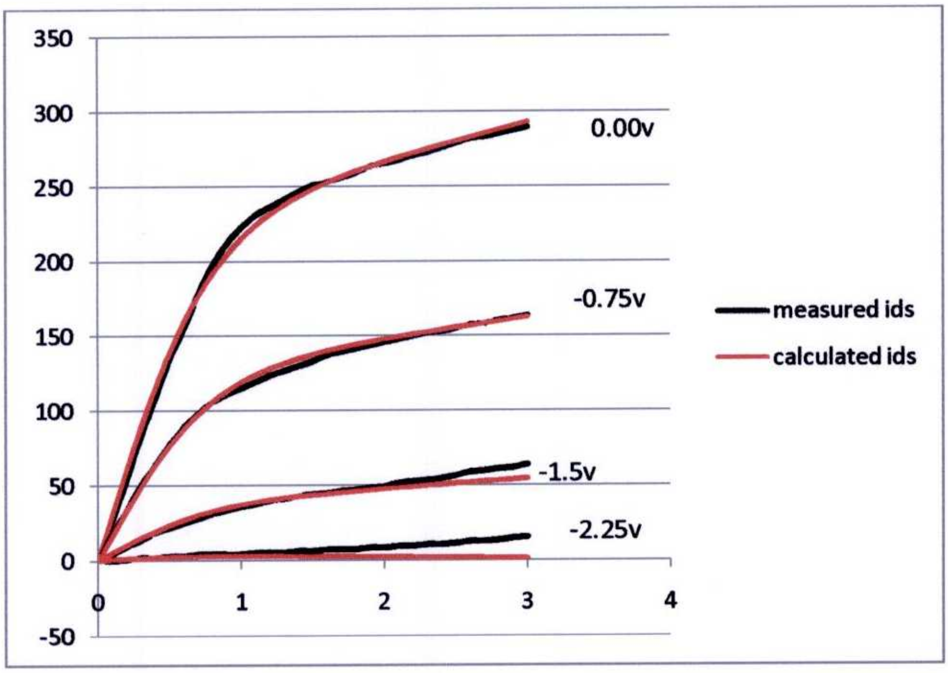
Alpha = 1.3757 Gamma = -0.0429 Lambda = 0.1094 beta = -0.3312

Vds	Ids1(meas.	Ids1(cal.)	Ids2(meas.	Ids2(cal.)	Ids3(meas.	Ids3(cal.)	Ids4(meas.	Ids4(cal.)
0	0	0	0	0	0	0	0	0
0.1	27.27	30.42	17.83	16.87	4.2	5.08	0	0.66
0.2	54.55	60.37	33.57	33.47	9.44	10.11	1.05	1.25
0.3	83.92	88.84	50.35	49.24	13.64	14.94	2.1	1.76
0.4	109.09	115.06	63.99	63.76	18.88	19.42	2.1	2.19
0.5	135.31	138.54	77.62	76.75	22.03	23.47	3.15	2.52
0.6	155.24	159.09	89.16	88.12	25.17	27.05	3.15	2.76
0.7	178.32	176.77	98.6	97.9	28.32	30.17	4.2	2.93
0.8	197.2	191.78	105.94	106.2	31.47	32.86	4.2	3.04
0.9	211.89	204.42	111.19	113.19	33.57	35.16	4.2	3.09
1	222.38	215.05	115.38	119.06	35.66	37.13	4.2	3.1
1.1	230.77	223.98	119.58	124.01	37.76	38.82	5.24	3.08
1.2	236.01	231.54	123.78	128.19	39.86	40.28	5.24	3.03
1.3	241.26	237.98	126.92	131.75	40.91	41.56	5.24	2.96
1.4	246.5	243.54	130.07	134.84	43.01	42.69	6.29	2.88
1.5	250.7	248.4	133.22	137.53	44.06	43.71	6.29	2.79
1.6	252.8	252.71	137.41	139.93	45.1	44.64	7.34	2.7
1.7	255.94	256.6	139.51	142.09	46.15	45.5	7.34	2.6
1.8	259.09	260.15	141.61	144.08	47.2	46.3	7.34	2.49
1.9	263.29	263.44	143.71	145.92	48.25	47.07	8.39	2.39
2	265.38	266.54	145.8	147.66	49.3	47.8	8.39	2.28
2.1	267.48	269.48	147.9	149.31	51.4	48.51	9.44	2.18
2.2	270.63	272.31	150	150.91	52.45	49.21	9.44	2.08
2.3	272.73	275.04	152.1	152.45	53.5	49.89	10.49	1.98
2.4	275.87	277.71	153.15	153.96	54.55	50.57	10.49	1.88
2.5	279.02	280.32	155.24	155.45	56.64	51.24	11.54	1.78
2.6	282.17	282.89	157.34	156.91	58.74	51.9	12.59	1.68
2.7	283.22	285.43	158.39	158.36	59.79	52.56	12.59	1.59
2.8	285.31	287.94	160.49	159.8	60.84	53.23	13.64	1.5
2.9	287.41	290.44	161.54	161.23	61.89	53.89	14.69	1.41
3	289.51	292.92	163.64	162.66	63.99	54.56	15.73	1.32

Vgss

-3

Device2(proposed Model):



proposed model device3

Idss =350.000 mA / mm
VT = -3.500V

MSE Calculated = 7.0522   Av. RMS Error = 0.2039

MSE[1]	MSE[2]	MSE[3]	MSE[4]	MSE[5]
10.1949	8.4817	6.2145	1.1532	5.7308

obsRMS[:	obsRMS[2]	obsRMS[	obsRMS[4]	obsRMS[5]
338.272	213.2524	112.7	44.685	12.642

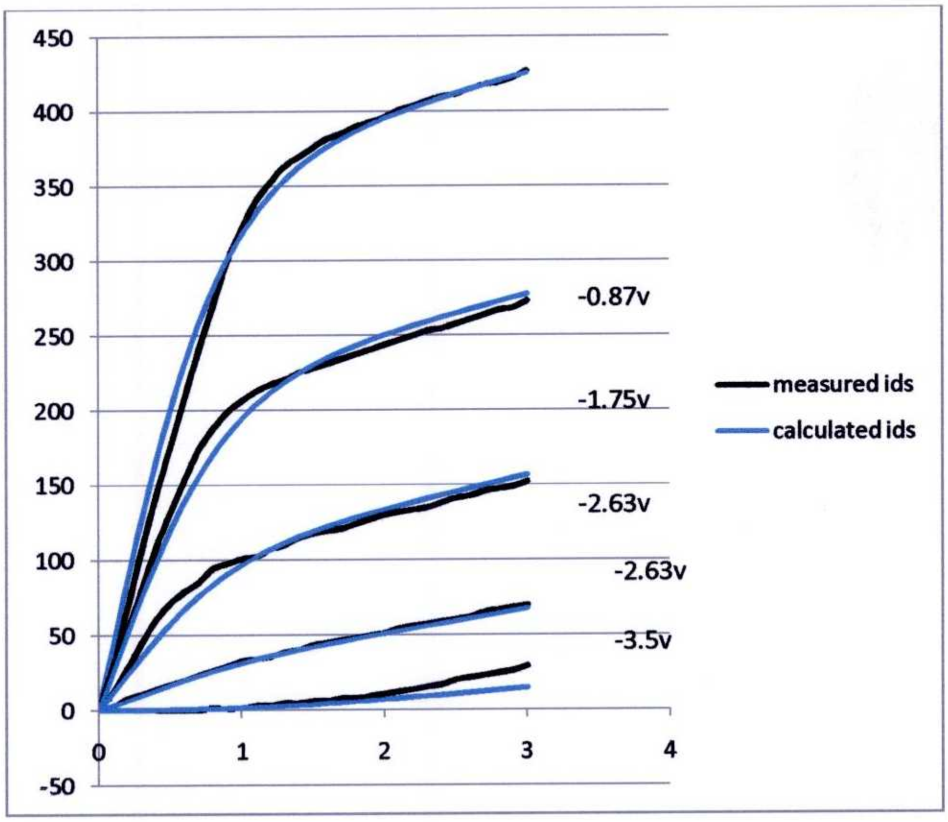
calRMS[1	calRMS[2]	calRMS[:	calRMS[4]	calRMS[5]
338.495	213.7043	113.75	43.6819	6.9857

Error1	Error2	Error3	Error4	Error5
0.2222	0.4519	1.0497	1.0031	5.6559

Alpha = 1.2384   Gamma = -0.2499   Lambda = 0.0704   beta = -0.0470

Vds	Ids1(m	Ids1(cal.)	Ids2(meas.	Ids2(cal.)	Ids3(meas.	Ids3(cal.)	Ids4(meas.	Ids4(cal.	Ids5(meas	Ids5(cal.)
0	0	0	0	0	0	0	0	0	0	0
0.1	35.69	43.49	29.48	25.63	12.41	11.89	3.1	3.13	0	0
0.2	68.28	86.29	52.76	51.07	27.93	23.9	7.76	6.47	0	0.02
0.3	107.1	127.21	80.69	75.6	45	35.69	10.86	9.91	0	0.06
0.4	142.8	165.28	108.62	98.65	60.52	46.97	13.97	13.37	0	0.15
0.5	175.4	199.87	131.9	119.78	71.38	57.51	17.07	16.76	0	0.27
0.6	207.9	230.64	153.62	138.78	79.14	67.18	20.17	20.03	0	0.45
0.7	240.5	257.53	173.79	155.59	85.34	75.92	23.28	23.14	0	0.67
0.8	270	280.73	187.76	170.27	94.66	83.73	26.38	26.07	1.55	0.94
0.9	299.5	300.53	198.62	182.98	97.76	90.67	29.48	28.82	1	1.25
1	321.2	317.31	206.38	193.94	100.86	96.82	32.59	31.39	1.55	1.61
1.1	339.8	331.49	212.59	203.36	102.41	102.28	34.14	33.79	3.1	2
1.2	352.2	343.46	217.24	211.49	107.07	107.13	35.69	36.05	3.1	2.44
1.3	363.1	353.6	220.34	218.52	110.17	111.47	38.79	38.19	4.66	2.9
1.4	369.3	362.22	225	224.66	114.83	115.39	40.34	40.22	4.66	3.4
1.5	375.5	369.61	228.1	230.05	117.93	118.96	43.45	42.16	6.21	3.93
1.6	381.7	376	231.21	234.85	119.48	122.24	45	44.03	6.21	4.49
1.7	384.8	381.6	234.31	239.16	121.03	125.3	46.55	45.84	7.76	5.07
1.8	389.5	386.55	237.41	243.09	124.14	128.16	48.1	47.61	7.76	5.68
1.9	392.6	391	240.52	246.7	127.24	130.88	49.66	49.34	9.31	6.32
2	395.7	395.04	243.62	250.07	130.14	133.48	51.21	51.04	10.86	6.98
2.1	400.3	398.77	246.72	253.25	131.9	135.99	54.31	52.72	12.41	7.67
2.2	403.5	402.24	249.83	256.27	133.45	138.42	55.86	54.4	13.97	8.38
2.3	406.6	405.51	252.93	259.17	135	140.79	57.41	56.06	15.52	9.11
2.4	409.7	408.62	254.48	261.97	138.1	143.12	58.97	57.71	17.07	9.87
2.5	411.2	411.61	257.59	264.69	141.21	145.41	60.52	59.37	20.17	10.65
2.6	414.3	414.5	260.69	267.35	142.76	147.68	62.07	61.02	21.72	11.45
2.7	417.4	417.31	263.79	269.97	145.86	149.92	65.17	62.68	23.28	12.28
2.8	419	420.06	266.9	272.55	147.41	152.15	66.72	64.34	24.83	13.13
2.9	422.1	422.77	268.45	275.1	148.97	154.37	68.28	66.01	26.38	14
3	426.7	425.44	273.1	277.63	152.07	156.58	69.83	67.69	29.48	14.89

Device 3(Proposed Model):

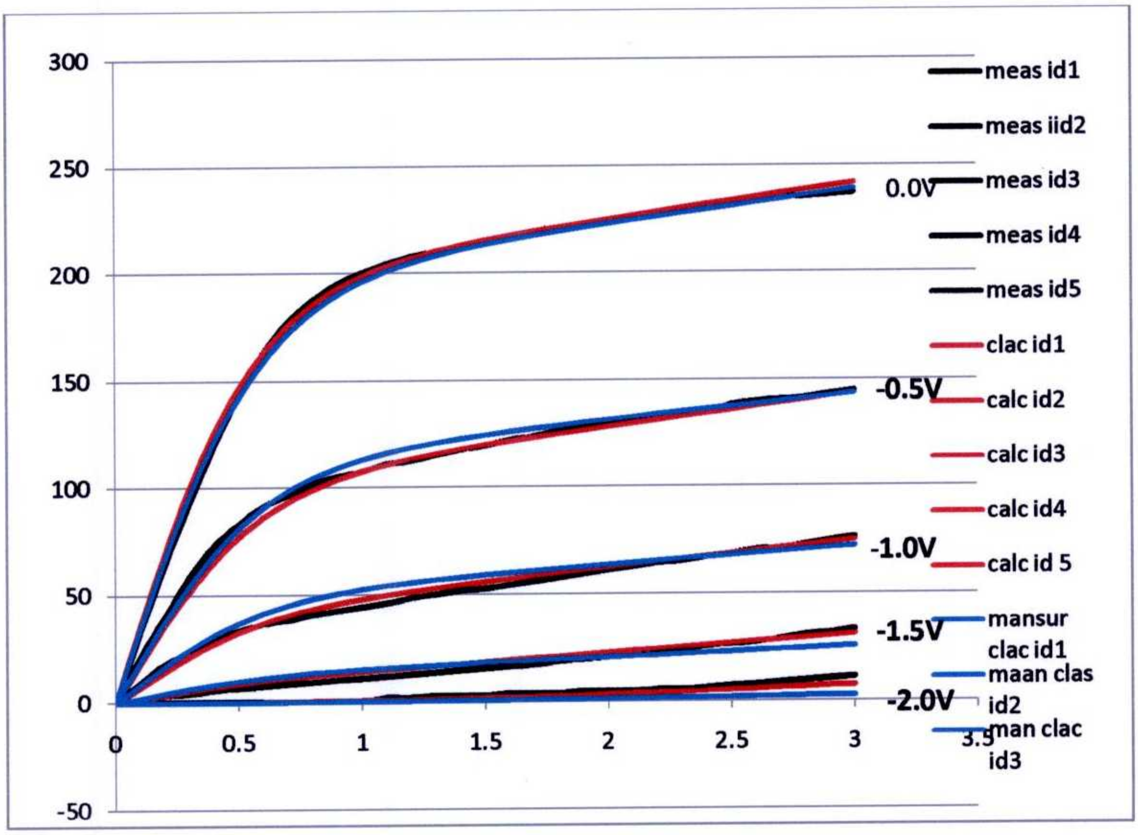


In previous model we saw that every model was worked on GaAsMESFET but not SiC for itsself heating characteristics. But in our project we will work in SiC and developed an I-V characteristic model which fit the experimental data with a high degree of accuracy.

Again we compare both the simulated and the observed characteristics of three different GaAs MESFET's having different device dimensions to get the error in our model following the previous way. Then we simulate our equation of our model and get the value of simulated characteristics. Then we compare the both values and get the error of GaAs MESFET's having different device dimensions. After that we calculate the over all MSE.

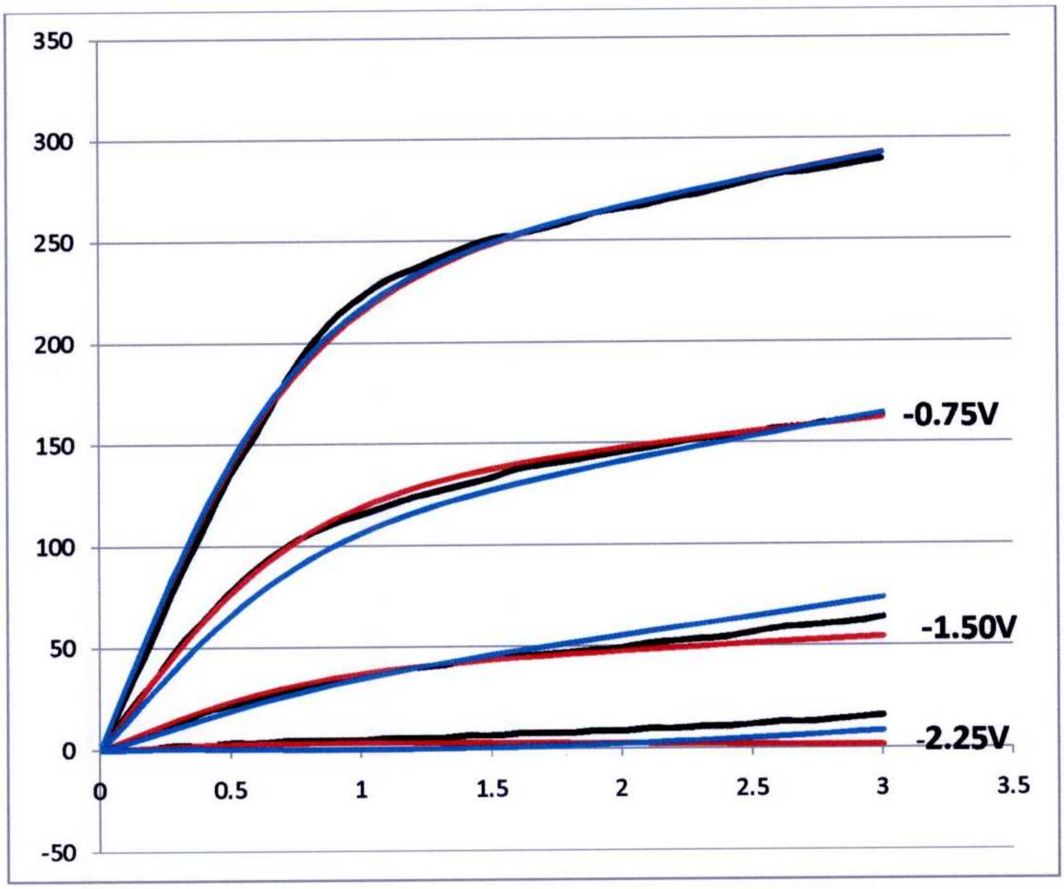
After getting the error of simulated and observed charateristics of three different GaAs MESFET in Mansoor Ahmed model and our proposed model we compare the error in same figure.we also compare the value of MSE. Here we can clearly see that the MSE is less in our proposed model comparing to Monsoor Ahmed model.

For device1:

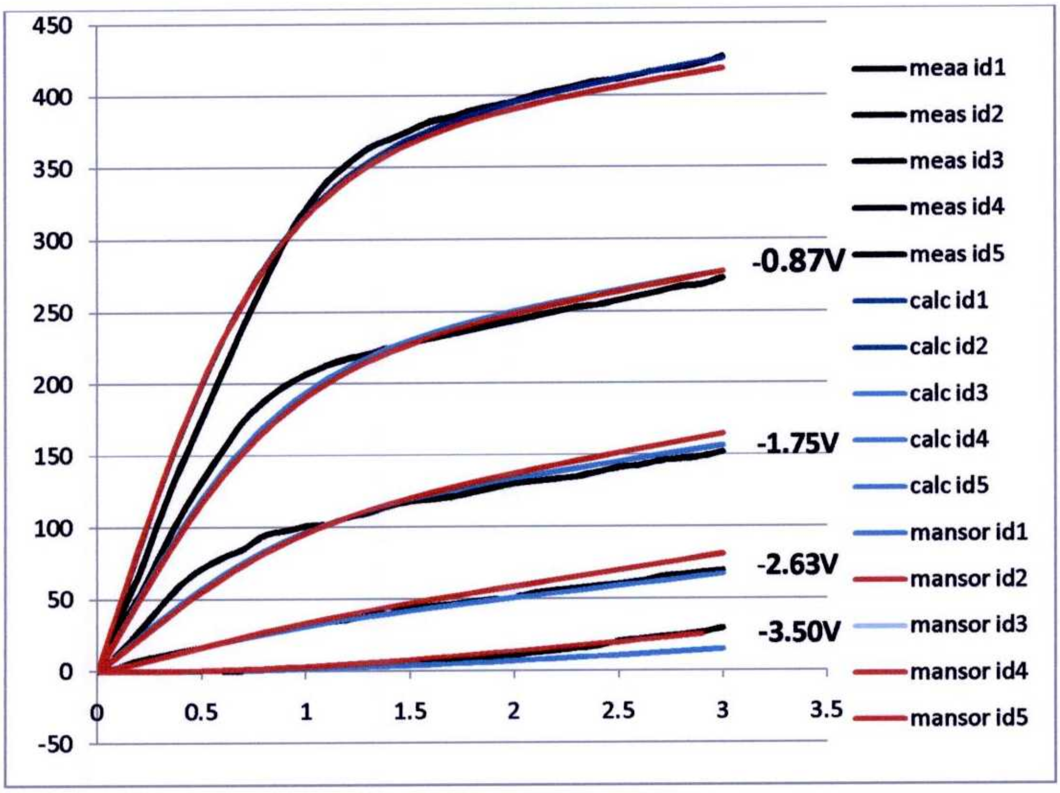


300
250
200
150
100
50
0
-50
0
0.5
1
1.5
2
2.5
3
3.5
0.0V
-0.5V
-1.0V
-1.5V
-2.0V
meas id1
meas iid2
meas id3
meas id4
meas id5
clac id1
calc id2
calc id3
calc id4
calc id 5
mansur clac id1
maan clas id2
man clac id3

For device 2:



For device 3:


450
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2
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3
3.5
-0.87V
-1.75V
-2.63V
-3.50V
meaa id1
meas id2
meas id3
meas id4
meas id5
calc id1
calc id2
calc id3
calc id4
calc id5
mansor id1
mansor id2
mansor id3
mansor id4
mansor id5

5.1.Comparison MSE calculated and Avg.RMS error between OUR MODEL and Mansoor Ahmed Model:

MSE calculated:

Device no	Our model	Mansoor Ahmed model
Device 1	2.2448	3.5303
Device 2	4.2994	5.4117
Device 3	7.0522	8.3353

Avg. RMS Error:

Device no	Our model	Mansoor Ahmed model
Device 1	0.2470	.0322
Device 2	.0746	.6191
Device 3	0.2039	05459

6.SiC MESET:

Silicon Carbide (SiC) MESFET's are emerging as a promising technology for high power devices due to a combination of superior properties of Silicon Carbide, including a high breakdown electric field of 4×10^6 V/cm, high saturated electron velocity of 2×10^7 cm/s and high thermal conductivity of 4.9W/cm-^{0}K. Furthermore, the applications of SiC MESFETs simplify impedance matching and results in efficient power coupling and broad bandwidth compared to Si and GaAs devices.

6.1.Advantageous Properties of Silicon Carbide:

The properties of silicon carbide (SiC), high thermal conductivity, high breakdown field and high electron saturation velocity, have made SiC MESFET a good candidate for microwave power application. Sic MESFETs are now commercially available and possible application areas are communication and radars. SiC MESFETs typically operate at frequencies up to the S-band. The devices are operated at a drain voltage of typically around 50V, and high output power densities, up to 8 W/mm, as well as high drain efficiency values (70%) have been demonstrated.

Silicon Carbide (SiC) MESFETs are currently developed by various companies and laboratories, with the aim of fabricating high power microwave amplifiers. The high breakdown field and thermal conductivity of SiC materials provide the ability to operate such devices at drain voltages much larger than their GaAs counterparts. Besides, the possibility of using semi-insulating substrate now enables a substantial improvement in microwave performance.

Self-heating effects are well-known by engineers involved in the development of GaAs MESFETs. In spite of better thermal conductivity, since in such components the power density per chip will be higher and therefore induces a substantial increase of short distance thermal resistance due to "thermal crowding" effect. To illustrate this fact in a somewhat oversimplified but direct manner, it is worth noticing that the ratio between the break-down field of GaAs and SiC is about the same as the one existing between the thermal conductivities of these two materials. For a given frequency, geometric dimensions will keep roughly dentinal but doping level will be increased by the same ratio and saturated velocity will be higher, so the current density will be also increases. Therefore, pushing SiC to its limits should result in problems of heat dissipation very similar to the ones observed with GaAs devices, when they

6.2.Advantage of SiC MESFET

- Wide Energy Band Gap Device
- High Breakdown Electric Device
- High Electrical and Thermal Conductivity
- High Saturated Electron Velocity
- High Melting Point
- Chemically Inert

Table 1.1:
Advantage of SiC MESFET

Parameter	Si	GaAs	GaP	SiC4H	diomond	GaN
Band Gap (eV)	1.1	1.4	2.3	3.2	5.6	3.4
Work, temp, (K)	150	200	300	500	600	-
Saturation vel (10 cm/s)	1	2	1.1	2	2.7	2.7
Electron mob (cm2/Vs)	1400	8500	350	600	2200	900
Hole mobility (cm2/)Vs	600	400	100	40	1600	150
Breakdown field (V/cm)	0.3	0.4	-	3.5	5	2
Thermal Cond (W/cm K)	1.5	0.54	0.8	4	20-30	1.3

Table1.2

Thermal conductivity of material:

GaN	AlGaN	AIN	SiC	Sapphire
1.30	2.86	4.0	4.9	0.33

6.3.MESFET Specifications:

Comparison of SiC and GaAs MESFET Specifications:

• **Drain Source Voltage and Drain Saturation Current**

– SiC devices have a higher VDSS and a higher IDSS than GaAs devices thereby increasing the power handling capabilities of SiC MESFETs

• **Maximum Frequency**

– SiCfmax is approximately ten times greater than that found in GaAs devices

• **Device Power Dissipation**

– SiC MESFET thermal dissipation greatly exceeds that of GaAs which allows for greater power handling and higher temperatureoperation

6.4.SiC Basic MESFET Structure:

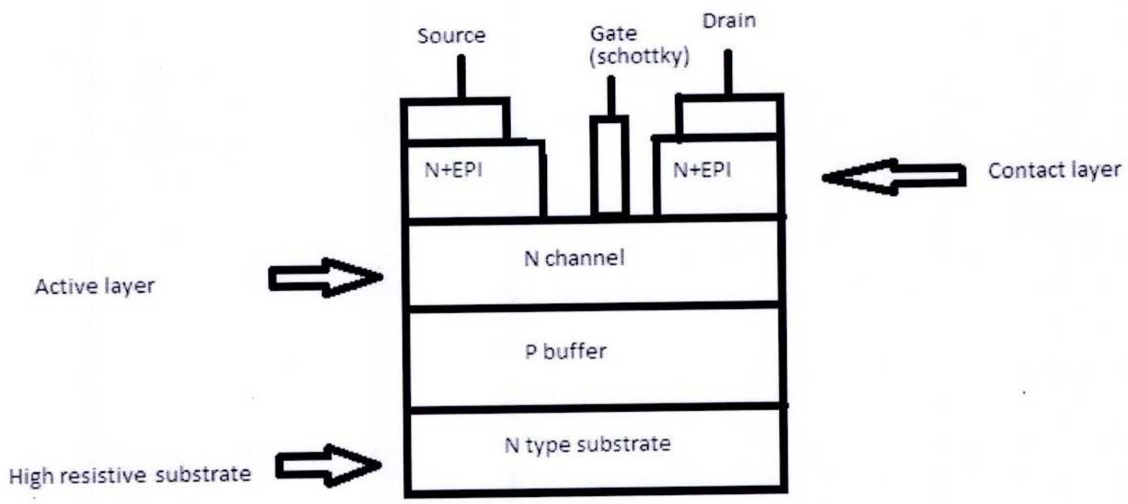

Fig11: Physical structure of SiC

We know before fromMansoor Ahmed has proposed an I-V model suitable for nonlinear small-signal circuit design in 1997.Kacprzak-Materka who started the prediction of behavior of submicron devices, Mansoor model takes this a one step further. Mansoor proposed a model by including a new concept of shift in threshold voltage. To simulate the *I-V* characteristicsas a function of $V_{gs}$and V_{ds} of a uniformly doped GaAs MESFET, the following relationship has been reported in Ahmed *et al*. model [1]:

$$I_{ds} = I_{dss}\left(1 - \frac{V_{gs}}{V_T + \Delta V_T + \gamma V_{ds}}\right)^2 \tanh(\alpha V_{ds})(1 + \lambda V_{ds})$$

where I_{dss} is the saturation current at V_{gs}= 0V, the parameter α determines the drain voltage where the drain current characteristic saturates, γ simulates the effective threshold voltage displacement as a function of V_{ds}, V_T is the threshold voltage and ΔV_T is the geometric shift in threshold voltage. The model presented in equation (1) is modified considering SiC MESFETs' special parameters: i) The high drain operation voltage derived from high critical breakdown voltage; ii)The knee voltage varied greatly with the applied gate voltage due to wide linear operation region; iii) The large pinch-off voltage designed mostly to allow wide signal swing; iv) Self-heating effect generated from high power application in spite of SiC material has high thermal conductivity. The proposed DC I-V characteristics model for SiC MESFETs is presented by the following relationship:

$$I_{ds} = I_{dss}(T) \bullet \left(1 - \frac{V_{gseff}}{V_T(T) + \gamma(T) \bullet V_{ds}}\right)^2 \bullet \tanh\left(\frac{\alpha(T)}{V_{gs} - V_T(T)} \bullet V_{ds}\right)\left(1 + \lambda(T) \bullet V_{ds}\right)$$

Where:

$$V_{gseff} = V_{gs} \bullet (1 + \tanh(\eta(T) \bullet V_{gs})) \quad (3)$$

$$I_{ds}(T) = I_{dss0}(T) + I_{dssT} \bullet T_{sh} \quad (4)$$

$$V_T(T) = V_{T0} + V_{TT} \bullet T_{sh} \quad (5)$$

$$\gamma(T) = \gamma_0 + \gamma_T \bullet T_{sh} \quad (6)$$

$$\alpha(T) = \alpha_0 + \alpha_T \bullet T_{sh} \quad (7)$$

$$\lambda(T) = \lambda_0 + \lambda_T \bullet T_{sh} \quad (8)$$

$$\eta(T) = \eta_0 + \eta_T \bullet T_{sh} \quad (9)$$

$$T_{sh} = I_{ds} \bullet V_{ds} \bullet R_{sh} \quad (10)$$

WhereV_{gseff} is effective gate-source voltage. The model fitting parameters I_{dss0}, α_0, γ_0, V_{T0}, λ_0, and η_0 do not include self-heating effect. I_{dss0} is the saturation drain current at V_{gs}=0V. V_{T0} is the threshold voltage at V_{ds}=0V and γ_0 simulates the effective threshold voltage displacement as a function of V_{ds}. α_0 determines the voltage where the drain current characteristics saturates. λ_0 is the non-zero drain conductance. η_0 is the parameter to present modification of gate-source voltage to consider the effect of p-buffer layer and substrate. I_{dss}(T), V_T(T), γ(T), α(T), λ(T) and η(T) are the corresponding temperature-dependent parameters considering self-heating effect. I_{dssT}, V_{TT}, γ_T, α_T, λ_T and η_T are fitting coefficients of temperature for corresponding parameters. R_{th} is thermal resistance and T_{sh} is temperature raise induced by self-heating effect.

The Superior Properties of SiC MESFET like higher breakdown voltage, higher thermal conductivity and higher saturated electron velocity makes it one of the most promising devices for high frequency and high power.

In previous model we saw that every model was worked on GaAsmesfet but not SiC for its self heating characteristics. But in our project we will work in SiC and developed an I-V characteristic model which fit the experimental data with a high degree of accuracy.

7.OUR FUTURE WORK:

- We came to know from the previous models that none of them were worked on SiC. But in our project Ahmed model will be modified for high-power SiC MESFETs and developed an equations for the best fit of I-V characteristic curves.
- New algorithm has been developed for determining the empirical constants of the proposed model.
- We will use Root Mean Square (RMS) technique which will be utilized to compared the results.

We hope that the proposed model will fit the experimental data with a high degree of accuracy.

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