COMPARISON BETWEEN NON-LINEAR MESFET MODELS : A CASE STUDY

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ABSTRACT

There are several types of models exist for microwave MESFET equivalent circuit. These modeling techniques use different mathematical models to describe the same MESFET and give almost similar results. However, there are some differences in the outputs when compared to the experimental measurements. In this paper, two of these dominanttheoretical modelsnamed as TAJIMA model and CURTICE model are applied to the sametypes of MESFETs that are selected in the measure of gate width and length. Comparisons are made withthe measured data sets. It is shown that TAJIMA model worked better on some particular types of the MESFETs because this model includes more parameters than that of CURTICE model, while the CURTICE modelworked better for some other types of MESFETs for different values of gate to source voltage.

KEY WORDS: MESFET, CURTICE model, TAJIMA model, Comparison

1.0 INTRODUCTION

From applications and fundamental research point of view submicron GaAs MESFETs have been a focus of interest. In highly technical analog and digital circuits these devices are used due to their superior noise and gain properties. Usually these models are categorized based on the techniques employed in their development. Broadly speaking, they may be classified as-

- Numerical models
- Physical models

Numerical models have many rigorous field dependent characteristics of carrier velocity in the channel, although more accurate, not suitable for use in circuit design programs dueto their complexity and numerous parameters[1]. A generally accepted DC model based on device fabrication parameters, called physical model, is preferred by the design engineers provided it can predict the device characteristics to a reasonable accuracy. There are several physical models which are used in device simulators to predict MESFET characteristics (CURTICE, KACPRZAK, STATZ, MCCAMANT, RODRIGUIZ, AHMED, MCNALLY, ISLAM, DOBES and TAJIMA). In this paper we will compare between two of these different large signal models by using the measured data and theoretical values for different types of MESFETs.

2.0 CURTICE MODEL

One of the first large signal MESFET models to be described in large-signal circuit simulators was proposed by VAN TUYL and LIECHTI and later simplified by CURTICE. The CURTICE model consists primarily of the voltage controlled current source Ids, gate-source capacitance Cgs, gate-drain capacitance Cgd and the clamping diode Dgs. The Idsterm is a function of the intrinsic gate-source (V_{gs}) and drain-source voltage (V_{gs}) and a time constant which represents the electron transit time under the gate.

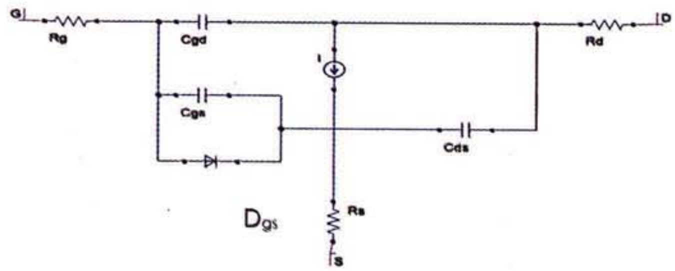

Figure-1: Equivalent circuit for large signal CURTICE model of GaAs-MESFET

The C_{gs} is considered to be a function of the gate-source voltage, but the C_{gd} is considered to be constant although today it is well known that this term is a function of gate-drain voltage. The CURTICE model describes the drain current with respect to the drain-source and gate-source voltages as[2] -

$$I_{ds}(V_{gs},V_{ds}) = \beta(V_{gs}+V_{to})^2\,(1+\lambda V_{ds})\tanh(\alpha V_{ds}) \quad \text{......(1)}$$

Where β, $V_{to,}\alpha$ and λ are the model parameters. The small signal transconductance and output conductance are derived by differentiating with I_{ds} respect to gate-source and drain-source voltage respectively:

$$g_m = \frac{\partial I_{ds}}{\partial V_{gs}} = 2\beta(V_{gs}-V_{to})(1+\lambda V_{ds})\tanh(\alpha V_{ds}) \quad \text{......(2)}$$

$$g_{ds} = \frac{\partial I_{ds}}{\partial V_{ds}} = \beta(V_{gs}-V_{to})^2\left\{\frac{\alpha(1+\lambda V_{ds})}{\cosh^2(\alpha V_{ds})}+\lambda\tanh(\alpha V_{ds})\right\} \quad \text{......(3)}$$

The parameters that have been shown in equation (1) are substituted and I-V ($I_{ds,}V_{ds}$) characteristics for different V_{gs} values are shown in Figureures below. The transconductance and the output conductance equations are plotted with respect to drain-source voltage V_{ds} for 4×150 type of MESFET the other types of MESFETs has nearly the same results with 4×150 and therefore they are not shown here. In this analysis, we have used the MATLAB simulation programs.

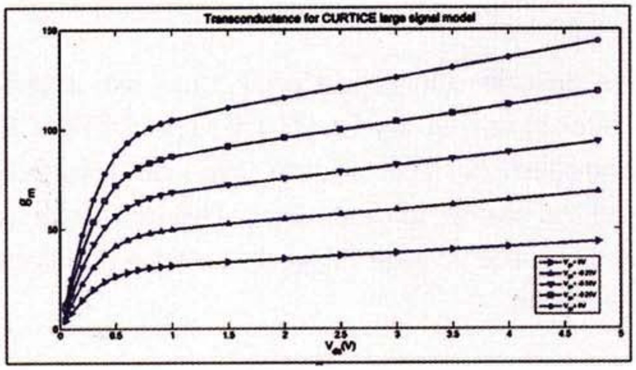

Figure-2: Transconductance of 4x150 MESFET.

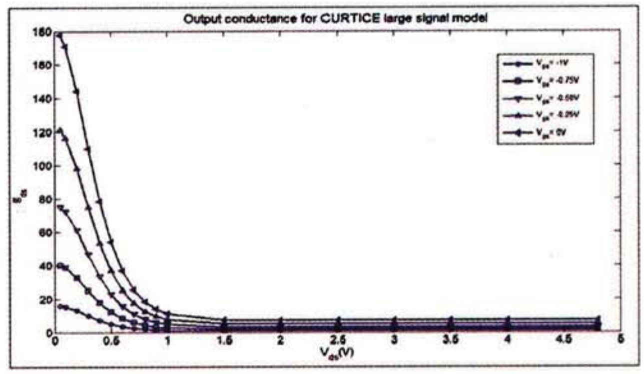

Figure-3: Output conductance of 4x150

Comparison of I - V characteristics of CURTICE Model with measured (solid lines) and theoretical values (dashed lines)-

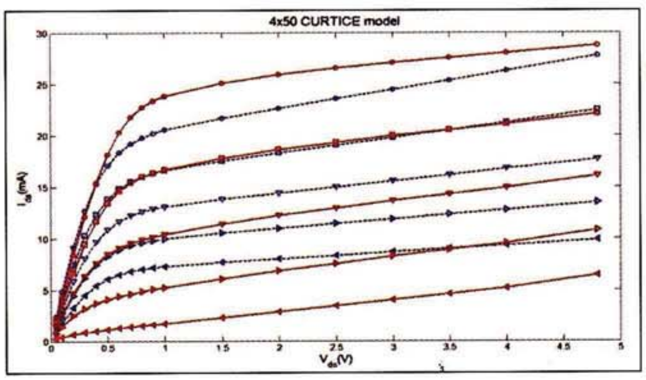

Figure-4: I-V curve for 4×50 MESFET.

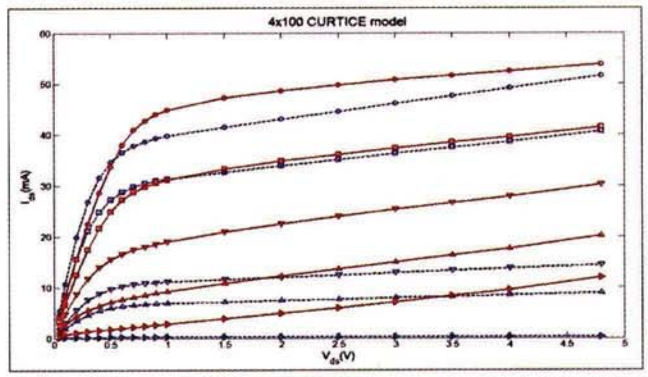

Figure- 5: I-V curve for 4×100 MESFET.

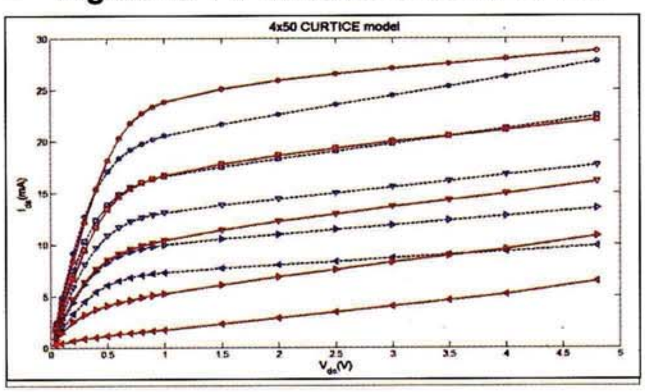

Figure- 6: I-V curve for 4×125 MESFET.

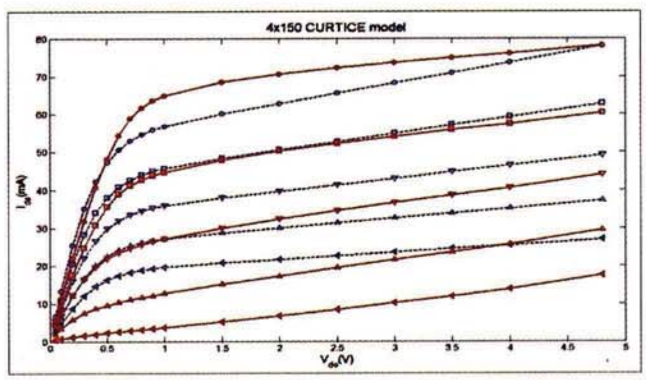

Figure-7: I-V curve for 4×150 MESFET.

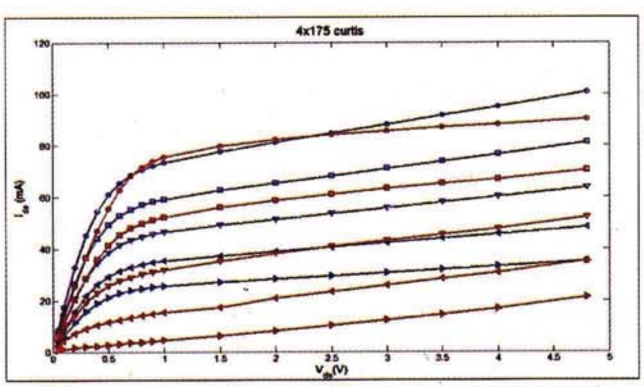

Figure-8: I-V curve for 4×175 MESFET.

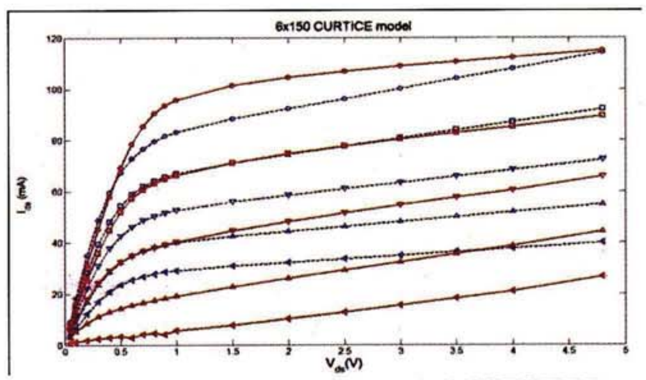

Figure-9: I-V curve for 6×150 MESFET.

Figure-4 ~ Figure-9 show that the results obtained from CURTICE model do not satisfy good approximation with the measured data sets [2], the parameter values are listed on Table 1-1. The results for all these types of MESFETs, the only approximation that we get similar for Vgs ≈ -0.25V is nearly the same as the measured data, and for the other values of gate-source voltage (Vgs) the modeled data do not give good approximations with measured data.

Table 1-1: Parameter values for CURTICE large-signal model[3]

MESFETtype	a	b	d	Q	V_{T0}	g
2×150	3.7729	0.0009	2.1238	4.00	1.2850	-0.1014
4×50	2.9185	0.0030	2.3209	3.3002	-1.9144	0.0807
4×100	3.3962	0.0013	1.6225	4.00	1.2901	-0.1026
4×125	2.9145	0.0094	1.1067	3.1746	-1.8013	0.086
4×150	2.9596	0.0099	1.0604	3.3533	-1.7975	0.0906
4×175	2.8874	0.0210	0.9499	2.9267	-1.6041	0.0929
6×150	2.7912	0.0085	0.7353	3.7057	-1.9699	0.0923

3.0 TAJIMA MODEL

In the reference[2], TAJIMA, WRONA, and MISHIMA (in this paper the model will be denoted as TAJIMA) have proposed, a technique to model the large-signal behavior of GaAs FETs. The proposed expression of I-V characteristics for FET is applied to MESFET measured data[3], and the comparison of measured data and modeled data showed good approximations. TAJIMA's equivalent circuit for FET under large-signal operation is shown in Figure-10.

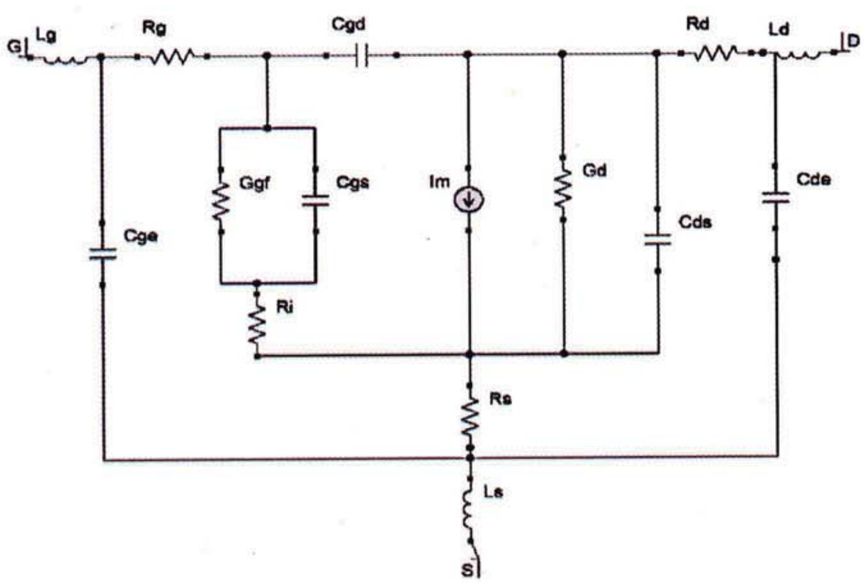

Figure-10: Equivalent circuit for large signal TAJIMA model of GaAs-MESFET.

The element values for large-signal operation vary with time because at large driving levels they become dependent on terminal voltages. TAJIMA considered two of the terminal voltages to be independent and chose the set of Vgs and Vds, Vgs being the voltage across the gate capacitance and Vds across the drain conductance. Restriction of the interest to the signal frequency and ignoring the effects due to higher harmonic components, these voltages can be written as[1]-

$$I_{ds}(V_{ds,}V_{gs}) = I_{d1}.I_{d2} \quad \text{.......(4)}$$

$$I_{d1} = \frac{1}{k}\left[1 + \frac{V'_{gs}}{V_p} - \frac{1}{m} + \frac{1}{m}\exp\left\{-m\left(1 + \frac{V'_{gs}}{V_p}\right)\right\}\right] \quad \text{.......(5)}$$

$$I_{d2} = I_{dsp}\left[1 - exp\left\{\frac{-V_{ds}}{V_{dss}} - a\left(\frac{V_{ds}}{V_{dss}}\right)^2 - b\left(\frac{V_{ds}}{V_{dss}}\right)^3\right\}\right] \quad \text{.......(6)}$$

$$k = 1 - \frac{1}{m}\{1 - \exp(-m)\} \quad \text{.......(7)}$$

$$V_p = V_{p0} + pV_{ds} + V_\phi \quad \text{.......(8)}$$

$$V'_{gs} = V_{gs} - V_\phi \quad \text{.......(9)}$$

where V_{p0} (> 0) is the pinch-off voltage at $V_{ds} \approx 0$, V_{dss} is the drain current saturation voltage, $V\varphi$ is the built-in potential of the Schottky barrier, Idsp is the drain current when $V\varphi = V_{gs}$ and a, b, m, and p are fitting factors that can be varied from device to device. In addition to the fitting factors I_{dsp}, V_{p0}, $V\varphi$, V_{dss} are assumed as the parameters for TAJIMA model.

By differentiating drain current with respect to gate-source voltage and drain-source voltage, the obtained transconductance and output conductance equations for TAJIMA are written below :

$$g_m = \frac{\partial I_{ds}}{\partial V_{gs}} = \frac{I_{d2}}{kV_p}\left[1 - \exp\left\{-m\left(1 + \frac{V'_{gs}}{V_p}\right)\right\}\right] \quad \text{.......(10)}$$

$$g_{ds} = \frac{\partial I_{ds}}{\partial V_{ds}} = I_{d2}\frac{pV'_{gs}}{V_p^2}\left[1 - \exp\left\{-m\left(1 + \frac{V'_{gs}}{V_p}\right)\right\}\right]\left[\frac{1}{V_{dss}} + \frac{2aV_{ds}}{V_{dss}^2} + \frac{3bV_{dss}^2}{V_{dss}^3}\right] \quad \text{.......(11)}$$

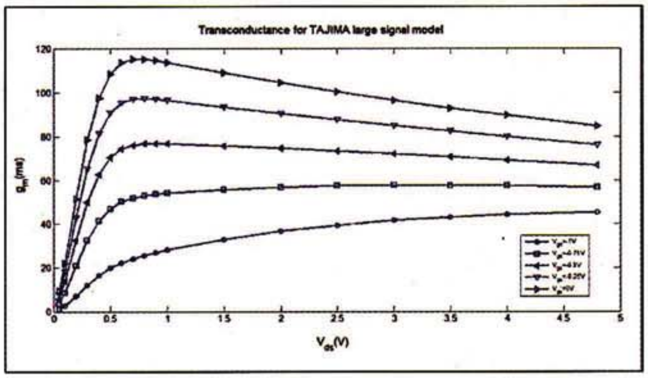

Figure-11: Transconductance of 4 x150

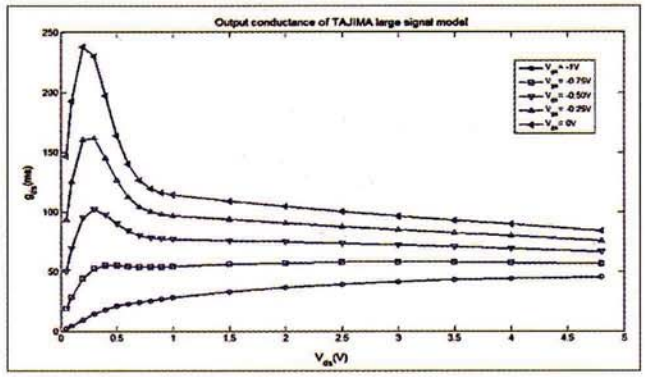

Figure-12: Output conductance of 4 x150

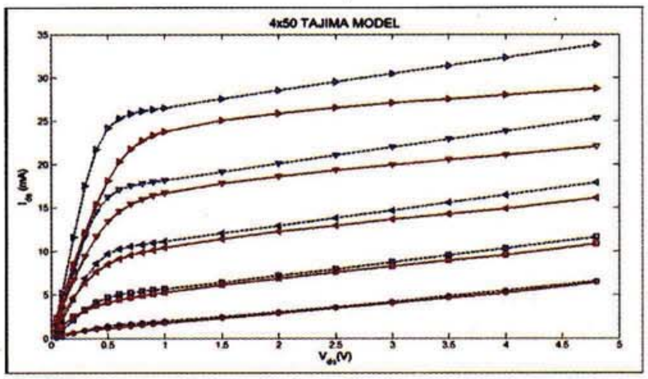

Figure-13: I-V curve for 4×50 MESFET.

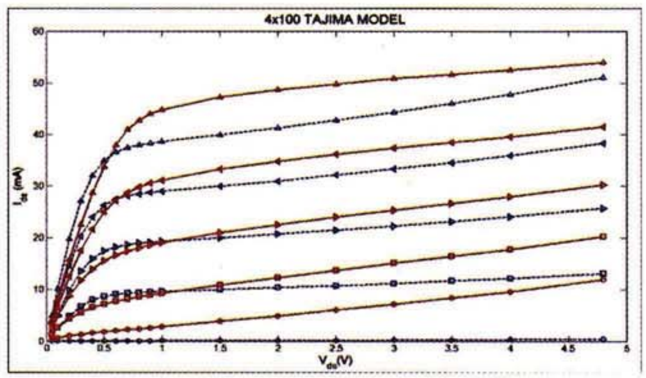

Figure-14: I-V curve for 4×100 MESFET.

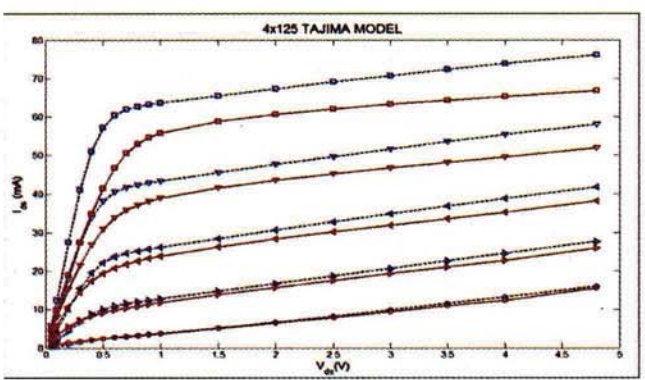

Figure-15: I-V curve for 4×125 MESFET

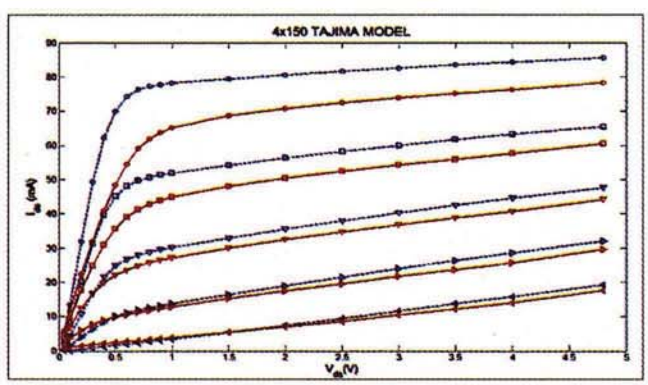

Figure-16: I-V curve for 4×150 MESFET.

Comparison of I-V characteristics of TAJIMA Model with measured (solid lines) and theoretical values (dashed lines)-

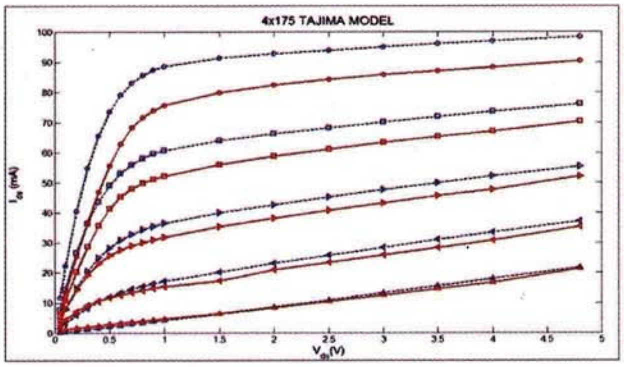

Figure-17: I-V curve for 4×175 MESFET.

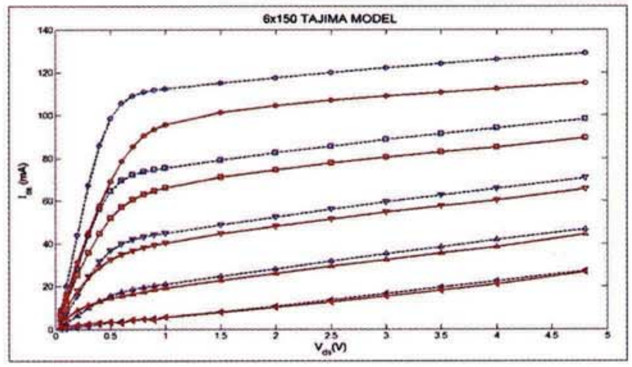

Figure-18: I-V curve for 6×150 MESFET.

Figure-13 ~ Figure-18 show that the TAJIMA large-signal model presents close approximations to measured data except for 2x150 and 4x175 types, the parameters are listed in Table 1-2. The other 6 types 4 x50, 4x100,4x125, 4x150, 4x175 and 6x150 show nearly the same results with the measured data (red colored solid lines)[3]. The former two types are less accurate than the subsequent other types. For V_{gs} = -1V the modeled data of I_{ds} (presented as blue colored dashed lines) have similiarities, but if compared with the CURTICE large signal model, the results obtained from TAJIMA model are better. It can be said that the TAJIMA large-signal model for those measured data is appropriate for some types of MESFETs. The parameters of these types of MESFETs, which are close to each other, are different than the parameters of the other types of MESFETs, which are again close to each other.

Table 1-2: Parameter values for TAJIMA large-signal model[3]

MESFETtype	V	V_{p0}	p	m	I_{dsp}	V_{dss}	a	b
2x150	0.049	-.0.04	0.0005	-1.003	0.00017	0.408	1.313	-0.076
4x50	1.7434	1.2462	0.0984	1.2143	0.1151	0.6234	2.7742	0.6511
4x100	0.036	-0.007	- 0.0017	-2.759	0.0046	0.378	0.897	-0.0712
4x125	0.7989	1.1634	0.1175	1.4603	0.1438	0.6108	2.5096	0.2532
4x150	0.229	1.0867	0.1503	0.8	0.1059	0.8627	6.111	-1.0814
4x175	0.2857	1.0968	0.1269	1.7803	0.1257	0.3606	0.2246	-0.0185
6x150	0.4665	1.1237	0.1282	1.1465	0.1941	0.6411	2.0079	0.6282

4.0 CONCLUSION

A case study has been presented based on some different types of MESFETs that varies in gate width-length and discussed the device characteristics of the two popular large signal models based on physical parameters.Therefore the data can also be used in statistical circuit designs. It is revealed that CURTICE and TAJIMA model works nearly accurate with the theoritical datas for the gate to source voltage of and respectively. But an accurate and sophisticated large-signal model requires the addition of the other elements of the large-signal model that has been omitted due to computation complexities.Therefore, the work can be extended to the other elements of the models provided that the relevant measurements are done already. For future studies, to achieve more accurate approximations of I-V characteristics,one should take the measured data for more types of MESFETs by varying their physical parameters. The modeled function can be approximated to the measured data or the objective function can be minimized by considering the saturation points of Ids current accurately at each Vgs voltage level seperately. This saturation point may help the researcher to divide the Ids function into two parts with respect to Vds voltage, one for Vds voltage of below saturation point and the other for above.

5.0 REFERENCES

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