Computation of DC and RF Parameters In Equivalent Circuit of GaAs MESFET

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Abstract

In this paper the important Direct Current (DC) and Radio Frequency (RF) circuit element characteristics for Gallium Arsenide Metal Semiconductor Field-effect Transistor (GaAs MESFET) are presented. The GaAs MESFET is characterized in common source configuration by it's two-port S-parameters.

A computer program MESFETA is constructed and is developed to implement the above MESFET parameters and demonstrate them in the form.

Introduction

Gallium Arsenide Metal Semiconductor Field-Effect Transistor (GaAs MESFET) constitutes one of the most important microwave device which revolutionize the design and performance of power amplifiers for satellite communication and other applications where it provides life and performance advantages over other microwave devices in use.

The basic structure of n-channel Schottky-barrier type GaAs MESFET illustrated in Fig. (1) consists of:

i. Semi-insulating GaAs substrate.
ii. Buffer layer.
iii. Active layer.
iv. Two ohmic contacts (the source and the drain terminals).
v. The Schottkey-barrier electrode (the gate between the ohmic source and drain contracts).

In this paper the important DC and RF circuit elements for several GaAs MESFETs are computed. A program MESFETA is originated and is developed to implement GaAs MESFET parameters. And it is also used to compute its two-port S-parameters at nay desired frequency.

I.DC-parameters of GaAs Field-Effect Transistor (FET):

To determine the value of basic DC-parameters for a GaAs FET the properties of the active channel are being fundamental. These channel properties are characterized by four basic variables: gate length (L), gate width (z), channel thickness (a), and channel doping concentration (N_o).

i. Pinch-off voltage (W_{oo}): [1,2,3,4]

Pinch-off voltage refers to the voltage applied to the gate which totally block the channel independent of V_{dg}. The pinch-off voltage may be calculated from the following relation:

$$W_{oo} = (eN_o a^2) / (2\varepsilon_o\varepsilon_r) \quad \ldots\ldots (1.a)$$
$$= V_p + \phi \quad \ldots\ldots (1.b)$$

where:

e is the electron charge (1.6×10^{-19} coul)

$\varepsilon_o = 8.854 \times 10^{-12}$ (F/m)

ε_r is the relative dielectric constant of the substrate material (for semi-insulating GaAs, $\varepsilon_r = 12.5$)

V_p is the terminal pinch-off voltage and

ϕ is the Schottky-barrier built-in voltage, for aluminum at room temperature, ϕ may be expressed as a function of (N_o) as indicated in [5].

$$\phi = 0.706 + 0.06 \log_{10} (N_o/10^{22}) \quad \ldots\ldots (2)$$

N_o is in m^{-3}

ii. Saturation current (I_s)

The saturation current is the source-drain current after the pinch-off point is reached ($V_{dg} > V_{dg(gat)}$). Is may be given as [1,2].

$$I_s = eN_oV_g az \quad \ldots\ldots (3)$$

Where:

V_g is saturated velocity of the carriers given by [6].

$$V_g = 60L^{-0.56} \quad \ldots\ldots (4)$$

iii. The effective potential (W)

The effective potential difference between the gate and the channel may given as follows [1,2]:

a- at the source side

$$W = W_s = V_{sg} + \phi \quad \ldots\ldots (5)$$

b- at the pinch-off point

$$W = W_p = V_{sg} + \phi - V_p \quad \ldots\ldots (6)$$

For simplicity the following two reduced potentials are introduced:

$$s = (W_s/W_{oo})^{1/2} \quad 0 < s \le 1 \quad \ldots\ldots (7)$$
$$p = (W_p/W_{oo})^{1/2} \quad 0 < p \le 1 \quad \ldots\ldots (8)$$

From eq. (1.b) and eqs. (7,8), V_p may expressed as:

$$V_p = - W_{oo}(p^2 - s^2) \quad \ldots\ldots (9)$$

Evaluation of equivalent circuit parameters

The most common used small-signal equivalent circuit for a MESFET in common source configuration is shown in Fig. (2).

The circuit elements of this equivalent model are described in the following subsections.

i. The transconductance (gmo)

The transconductance under velocity saturation conditions is defined as the ratio of the change in drain current dI_{ds} to the change in gate voltage dV_{sg} holding the potential difference between source V_{ds} constant [1]. Pucel et al. in 1975 [2] evaluated the transconductance (gmo) for the FET transistor in pinch-off region by the following relation:

$$gmo = [W_{oo}/I_{ds}]\, f_g (s,p,\zeta) \quad \ldots\ldots (10)$$

where

$$W_{oo}/I_{ds} = 4\, \varepsilon_o\varepsilon_r N_o\, z/a$$

$$fg(s,p,\zeta) = \frac{(1-s)\cosh(\theta) - (1-p)}{[2p(1-p) + \zeta(L_1/L)\cosh(\theta L - 2P(1-p)} \quad \ldots (11)$$

ζ is a dimensionless potential parameter given as [3].

$$\zeta = E_s L/W_{oo} \quad \ldots\ldots (12)$$

E_s – saturation field (in the epi-layer) given as [3].

$E_s = \nu_s/\mu_o$ . . . . (13)

μ_o – carriers mobility for n-channel given as [17].

$$\mu_o = \frac{850.}{(N_o)^{0.12}} \quad \ldots\ldots\ (14)$$

L – is the physical length of the gate electrode.

L_1 – is the gate length before pinch-off point (Fig. 3), given as:

$L_1 = Lf_1 (s,p) / [\zeta(1-p)]$ . . . . (15)

$f_1(s,p) = p^2 – s^2 (2/3) (p^3 – s^3)$ . . . . (16)

$\theta = \pi L_2^2/2a$ . . . . (17)

L_2 – is the gate length after pinch-off point (Fig. 3)

$L_2 = L – L_1$ . . . . (18)

ii. Determination of the drain resistance ($R_d = 1/g_d$)

Drain resistance is the ratio of the change in drain voltage to the differential change in drain current at a constant gate voltage [2].

$R_d = - dV_{ds} / dI_{ds} \mid V_{sg}$ . . . . (19)

Where p and L_2 depend on I_{ds} [1]

$$R_d = \frac{dV_{ds}}{dI_{ds}} = \frac{dV}{dp}\frac{dp}{dI_{ds}} + \ldots \frac{dL_2}{dI_{ds}} \quad \ldots\ (20)$$

where:

$$\frac{dp}{dI_{ds}} = \frac{1}{g_o E_s z} \quad \ldots\ldots\ldots\ (21)$$

$$\frac{dL_2}{dI_{ds}} = \frac{1}{g_o E_s z}\left\{\frac{2pV_{ds}}{E_s(1-p)} + \ldots\right\} \quad \ldots\ldots\ (22)$$

and

$g_o = \sigma a$ . . . . (23)

σ - is the conductivity of the channel material.

From these questions:

$$R_d = \frac{2p}{g_o z}\ldots \quad \ldots\ (24)$$

which can be simplified to have the following form:

$$R_d = \ldots \quad \ldots\ (25)$$

iii. The parasitic series resistance (R_{ss} and R_{sd})

The parasitic series source and drain resistance (R_{ss} and R_{sd}) consist of the ohmic contact resistance (R_{cs}) and series channel resistance (R_{ch}) between two concerned electrodes.

The simplified form of the source contact resistance is given as [8,3]:

$$R_{cs} = \left[R_{sc}R_s\right]^{1/2}/z \ \coth\left[L_s\sqrt{R_s/R_{sc}}\right] \quad \ldots\ldots\ (26)$$

and the series channel resistance (R_{ch}) is given as:

$$R_{ch} = \frac{L_{sg}R_s}{z} \quad \ldots\ldots\ (27)$$

where R_s is surface resistance (Ωm^2) given by [3]:

$R_s = (e\mu_o N_o a)^{-1}$ . . . . (28)

An empirical expression for specific contact resistance (R_{sc}) is given by [5]:

$$R_{cs} = 4.1\times10^{9}\ldots\sqrt{N_o}\ldots \quad \ldots\ldots\ (29)$$

The value of (R_{ss}) may be obtained as the sum of above two resistances:

$R_{ss} = R_{cs} – R_{ch}$ . . . . (30)

For computation of (R_{sd}) the same expressions are used where (L_{sg}) is replaced by L_{dg}.

iv. The gate resistance (R_g)

As the input signal to the feeding end of the gate travels along the gate metallization to other end, the gate metallization resistance must be considered. According to Refs. [8] and [3] the gate resistance found to be:

$$R_g = \frac{1}{4}\frac{\rho z}{3tL} \quad \ldots\ldots\ (31)$$

where:

ρ – is the specific resistivity (for A1 $\rho = 2.75 \times 10^{-8}$ m)

t – is the thickness of the deposited gate metal film

v. Determination of the gate-to-source capacitance (C_{gs})

The gate capacitance is obtained as the derivative of the charge stored in the depletion layer with respect to gate bias (V_{sg}) when the drain potential is held fixed [9,10].

$$C_{gs} = \frac{\partial Q}{\partial V_{sg}}\Big| V_{ds} \quad \ldots\ldots\ (32)$$

where Q is the depletion layer charge.

Under the condition when the whole channel is entirely in velocity saturation the expression for C_{gs} becomes particularly simple.

Pucel et al. [2] have found an approximate expression for C_{gs}:

$C_{gs} \approx 2\, \varepsilon_o\, \varepsilon_r\, z\, f_c (s,p,\zeta)$ . . . . (33)

Where:

$f_c (s,p,\zeta) = 1.56 + f_{c1} + f_{c2}$ . . . . (34)

with

$f_{c1} = [2L_1/(f_1a)]\{f_g[2p^2(1-p)^2 – f_2]/(1-p) – s(1-s)\}$.....(35)

$$f_{c2} = \ldots \left[\frac{1-p}{a} \ldots\right] \quad ..(36)$$

$$f_1 = p^2 - s^2 - \frac{2}{3}(p^3 - s^3) \quad \ldots\ldots\ (37)$$

and

$$f_2 = \frac{2}{3}(p^3 - s^3) - \frac{1}{2}(p^4 - s^4) \quad \ldots\ldots\ (38)$$

The values of p and s are obtained by solving the following transcendental equation:

$$V_{ds} = V_{po}\left[p^2 - s^2 + \frac{2a}{\pi L}\zeta s \ldots\right] \quad \ldots\ldots\ (39)$$

vi. The drain-to-gate and source-to-drain capacitance (C_{dg} and C_{sd})

The gate-to-drain and source-to-drain capacitances are parasitic elements of GaAs FET.

A closed form expressions for determination of their values are given by Pucel et al. [2] under the conditions $L_s >> L_{sd}$ and $L_d >> L$.

For $L_s = L_d$ and finite substrate thickness (a).

$$C_{dg} = C_{sd} = \varepsilon_o \varepsilon_{r(eff)} Z \frac{K(\bar{k})}{K(k)} \quad \ldots\ldots\ (40)$$

The ratio $\frac{K(\bar{k})}{K(k)}$ is obtained from the following two equations:

$$\frac{K(\bar{k})}{K(k)} = \frac{1}{\pi}\ln\left[2\frac{1+\bar{k}^{1/2}}{1-\bar{k}^{1/2}}\right] \quad \text{for } 0 \le k^2 \le 0.5\ldots\ (41.a)$$

$$\frac{K(\bar{k})}{K(k)} = \frac{\pi}{\ln\left[2\frac{1+k^{1/2}}{1-k^{1/2}}\right]} \quad \text{for } 0.5 \le k^2 \le 1\ldots\ldots\ (41.b)$$

with k for C_{dg} and C_{sd} are given, respectively as:

$$k_{dg} = \frac{L_{dg}}{L + L_{dg}} \quad ....(42.a)$$

$$k_{sd} = \frac{L_{sd}(2L_s + L_{sd})}{L_s + L_{sd}} \quad ....(42.b)$$

According to Cupta et al. in 1979 and 1981 [3,11] the effective dielectric constant is given by:

$\varepsilon_{r(eff)} = [(\varepsilon_r+1)/2]\{\tan[0.775\ln(a/L_{sg})+1.75][k_oL_{sg}/a]$
$[0.04-0.7k_e+0.01(1-0.1\varepsilon_r)(0.25+k_e)]\}$ . . . (43)

with

$$k_s = \frac{L}{L + 2L_{sg}} \quad ....(44)$$

vii. Cut off frequency (f_r)

The cut off frequency of a MESFET in a circuit depends on the way in which the transistor is fabricated. In wide band lumped circuit the cut off frequency is expressed according to Lehovec [12] as follows:

$f_r = gmo / (2\pi C_{gs})$ . . . . (45)

viii. Maximum frequency of oscillation (f_{max})

The maximum frequency of oscillation depends on the device transconductance and the drain resistance in a distributed circuit. It is expressed as postulated earlier by Zaleeg and Lehovec in 1970. The maximum frequency is:

$f_{max} = f_r / 2\,(gmo\,R_d)^{1/2}$ . . . . (46)

II.RF-Parameter of GaAs FET

The RF-amplification occurs when the transistor is dc biased in the saturation region ($V_{ds} > d_{ds(gat)}$) and an RF input signal is applied between gate and source (V_{sg}). This signal will modulate the RF current in the channel and result in an RF component of drain current according to Dilorenzo in 1982 [15].

$I_{ds} = gm\,V_{sg}$ . . . . (47)

Where:

$gm = gmo\,e^{-jwTD}$ . . . . (48)

for a large gain, optimum value of transconductance per unit gate width, or gm/z must be determined.

The parameter gm/z maximizes dc biasing in saturation region and minimizes the gate length, L, to about 1 μm.

Two-port network S-parameters

The microwave frequencies of GaAs FETs are usually characterized in the common-source configuration by its two-port S-parameters [16].

From the analysis of the equivalent circuit given in Fig. (2) the admittance parameters of the GaAs FET can be obtained under the following conditions[17] $wC_{gs}R_i << 1$.

These admittances are:

$Y_{11} = w^2C_{gs}^2(R_i + R_{ss} + R_g)\,\delta^2 + jw\,(\delta\,C_{gs} + C_{dg})$ (49.a)

$Y_{12} = -\,jwC_{dg}$ . . . . (49.b)

$Y_{21} = gmo\,\delta - jw\,[C_{dg} + gmo\,\delta\,\{T_D + \delta C_{gs}\,(R_{ss} + R_g)\}]$ . . . . . . (49.c)

$Y_{22} = \delta\,G_d + jw\,(C_{dg} + C_{sd})$ . . . . (49.d)

Where:

w – is the desired angular frequency equal to 2πf.

$$\delta = \frac{1}{1 + R_{ss}(gmo + G_d)} \quad ....(50)$$

R_i – is the undepleted channel resistance given by [5].

$$R_i = \frac{1}{q\mu_o N_d a z} \quad ....(51)$$

T_D – time required for electrons to traverse the gate length at the scattering – limited velocity given by [3].

$$T_D = \frac{L}{\nu_o}$$

Figure (4) shows the two-port S-parameters in common-source configuration for a single gate GaAs FET. This configuration gives the largest small-signal gain in the amplifier design. And it is usually used in the analysis and determination of S-parameters for the two-port device in microwave frequencies.

The S-parameters are found from the actual Y-parameters (eq. 49) normalized to z_o [12,14,18,19,20].

$$S_{11} = \frac{(1-Y_{11})(1+Y_{22}) + Y_{12}Y_{21}}{(1+Y_{11})(1+Y_{22}) - Y_{12}Y_{21}} \quad ....(53.a)$$

$$S_{12} = \frac{-2Y_{12}}{(1+Y_{11})(1+Y_{22}) - Y_{12}Y_{21}} \quad ....(53.b)$$

$$S_{21} = \frac{-2Y_{21}}{(1+Y_{11})(1+Y_{22}) - Y_{12}Y_{21}} \quad ....(53.c)$$

$$S_{22} = \frac{(1+Y_{11})(1-Y_{22}) + Y_{12}Y_{21}}{(1+Y_{11})(1+Y_{22}) - Y_{12}Y_{21}} \quad ....(53.d)$$

Results and Discussion

The computed DC-parameters of several GaAs MESFETs are summarized in Tables (1a-4b). These include the intrinsic elements (gm, R_i, C_{gs}, R_{ds} and C_{dg}) and extrinsic elements (R_g, C_{sd}, R_{ss}). Which are required to compute the S-parameters for these devices.

The values of intrinsic and extrinsic elements depend on the channel type material and structure dimensions of MESFET .

The common source S-parameters over microwave frequencies ranged from 7-17 GHz under different bias conditions ranged from 5-6 volts are then computed and presented in form of tables.

Conclusion

In this paper the microwave properties of material semiconductor field effect transistors are investigated and analyzed in some details. These properties are the intrinsic and extrinsic elements of MESFETs, their S-parameters Figures.

The program MESFETA is constructed to compute the DC and RE parameters of several, GaAs MESFETs of various gate lengths, active layer thicknesses and doping concentrations with frequency range of operation from 7.17 GHz.

The program is written in fortran 90.

Table (1a) Equivalent circuit parameters of GaAs MESFET (Transistor A)

L = 1.0 μm, a = 0.2 μm, z = 500 μm, $N_o = 0.9 \times 10^{23}$ m^{-3}

Intrinsic element	Extrinsic element
gm = 59.7 mMho T_D = 7.2 ps C_{gs} = 0.53 pF C_{dg} = 0.013 pF R_i = 1.73 Ω R_{ds} = 211 Ω	C_{cd} = 0.014 pF R_g = 2.29 Ω R_{ss} = 3.94 Ω
DC Bias V_{ds} = 6.0 volt V_{sg} = 0.0 I_{ds} = 64.4 mA	

Table (1b) S-parameters of a single cell GaAs MESFET (in common source)

F GHz	$\|S_{11}\|$	/θ°	$\|S_{12}\|$	/θ°	$\|S_{21}\|$	/θ°	$\|S_{22}\|$	/θ°
7	0.848	-92.26	0.032	45.7	2.82	111.6	0.621	-10.1
8	0.831	-100.1	0.033	42.8	2.63	105.6	0.600	10.9
9	0.817	-107.1	0.034	40.4	2.48	100.4	0.594	-11.5
10	0.807	-113.2	0.035	38.4	2.36	95.7	0.588	-12.2
11	0.797	-118.6	0.036	36.8	2.26	91.6	0.584	-12.8
12	0.790	-123.4	0.036	35.4	2.16	87.8	0.580	-13.4
13	0.785	-127.7	0.037	34.4	2.08	84.5	0.577	-14.0
14	0.782	-131.1	0.037	33.5	2.01	81.6	0.574	-14.7
15	0.779	135.0	0.037	32.8	1.94	78.9	0.571	-15.3
16	0.778	-136.1	0.037	32.5	1.28	76.5	0.568	-16.0
17	0.777	-140.9	0.037	31.8	1.83	74.3	0.566	-16.7

Table (2a) Equivalent circuit parameters of GaAs MESFET (Transistor B)

L = 1.0 μm, a = 0.2 μm, z = 500 μm, $N_o = 0.9 \times 10^{23}$ m^{-3}

Intrinsic element	Extrinsic element
gm = 66.0 mMho T_D = 7.2 ps C_{gs} = 0.58 pF C_{dg} = 0.013 pF R_i = 1.43 Ω R_{ds} = 127 Ω	C_{cd} = 0.014 pF R_g = 2.29 Ω R_{ss} = 2.9 Ω
DC Bias V_{ds} = 5.0 volt V_{sg} = 0.0 I_{ds} = 93.5 mA	

Table (2b) S-parameters of a single cell GaAs MESFET (in common source)

F GHz	$\lvert S_{11}\rvert$	/θ°	$\lvert S_{12}\rvert$	/θ°	$\lvert S_{21}\rvert$	/θ°	$\lvert S_{22}\rvert$	/θ°
7	0.853	-97.13	0.027	43.8	2.66	109.8	0.445	-11.2
8	0.838	-105.0	0.028	41.0	2.50	103.9	0.441	-12.0
9	0.827	-111.7	0.029	38.6	2.36	98.8	0.435	-12.6
10	0.818	-117.7	0.030	36.7	2.23	94.2	0.430	-13.2
11	0.810	-122.8	0.030	35.2	2.12	90.2	0.428	-14.0
12	0.805	-127.4	0.031	34.0	2.03	86.6	0.424	-14.6
13	0.801	-131.4	0.031	33.0	1.95	83.3	0.423	-15.3
14	0.799	-135.0	0.031	32.3	1.88	80.5	0.420	-16.0
15	0.797	-138.5	0.031	31.6	1.81	77.9	0.417	-16.8
16	0.794	-141.2	0.031	31.2	1.76	75.6	0.417	-17.5
17	0.796	-143.8	0.031	30.8	1.71	73.5	0.414	-18.3

Table (3a) Equivalent circuit parameters of GaAs MESFET (Transistor C)

L = 1.0 μm, a = 0.2 μm, z = 500 μm, $N_o = 0.9 \times 10^{23}$ m^{-3}

Intrinsic element	Extrinsic element
gm = 63.6 mMho T_D = 6.2 ps C_{gs} = 0.49 pF C_{dg} = 0.016 pF R_i = 1.56 Ω R_{ds} = 141 Ω	C_{cd} = 0.18 pF R_g = 2.54 Ω R_{ss} = 3.9 Ω
DC Bias V_{ds} = 5.0 volt V_{sg} = 0.0 I_{ds} = 68.8 mA	

Table (3b) S-parameters of a single cell GaAs MESFET (in common source)

F GHz	$\lvert S_{12}\rvert$	/θ°	$\lvert S_{21}\rvert$	/θ°	$\lvert S_{21}\rvert$	/θ°	$\lvert S_{22}\rvert$	/θ°
7	0.857	-87.5	0.036	47.1	2.81	115.5	0.503	-13.7
8	0.840	-95.3	0.038	44.0	2.62	109.7	0.481	-14.9
9	0.815	-102.5	0.040	41.4	2.48	104.4	0.474	-15.8
10	0.813	-108.5	0.041	39.2	2.35	99.7	0.468	-16.7
11	0.803	-114.0	0.042	37.3	2.24	95.5	0.463	-17.5
12	0.795	-119.0	0.043	35.8	2.15	91.7	0.459	-18.4
13	0.789	-123.3	0.043	34.5	2.06	88.2	0.455	-19.2
14	0.784	-127.3	0.043	33.4	1.98	85.1	0.452	-20.0
15	0.781	-130.1	0.044	32.6	1.918	82.3	0.449	-21.0
16	0.778	-134.1	0.044	31.8	1.86	79.7	0.447	-21.7
17	0.776	-137.1	0.044	31.2	1.80	77.4	0.445	-22.6

Table (4a) Equivalent circuit parameters of GaAs MESFET (Transistor D)

L = 1.0 μm, a = 0.2 μm, z = 500 μm, $N_o = 0.9 \times 10^{23}\ m^{-3}$

Intrinsic element	Extrinsic element
gm = 59.7 mMho T_D = 7.2 ps C_{gs} = 0.53 pF C_{dg} = 0.021 pF R_i = 1.57 Ω R_{ds} = 135 Ω	C_{cd} = 0.023 pF R_g = 2.29 Ω R_{ss} = 3.7 Ω
DC Bias V_{ds} = 5.0 volt V_{sg} = 0.0 I_{ds} = 81.7 mA	

Table (4b) S-parameters of a single cell GaAs MESFET (in common source)

F GHz	$\lvert S_{11}\rvert$	/θ°	$\lvert S_{12}\rvert$	/θ°	$\lvert S_{21}\rvert$	/θ°	$\lvert S_{22}\rvert$	/θ°
7	0.847	-95.00	0.045	43.4	2.53	109.0	0.467	-17.2
8	0.831	-102.6	0.046	40.4	2.35	103.0	0.441	-18.7
9	0.818	-109.5	0.048	37.8	2.22	97.68	0.435	-20.0
10	0.807	-115.5	0.049	35.7	2.10	92.90	0.429	-21.0
11	0.799	-120.8	0.050	34.0	2.00	88.6	0.424	-22.0
12	0.793	-125.5	0.050	32.6	1.92	84.8	0.421	-23.2
13	0.788	-129.6	0.051	31.4	1.84	81.4	0.417	-24.3
14	0.785	-133.3	0.051	30.4	1.78	78.5	0.415	-25.5
15	0.783	-136.7	0.052	29.6	1.72	75.5	0.413	-26.6
16	0.782	-139.7	0.052	29.0	1.67	73.0	0.411	-27.8
17	0.781	-142.4	0.052	28.4	1.62	70.7	0.407	-29.1

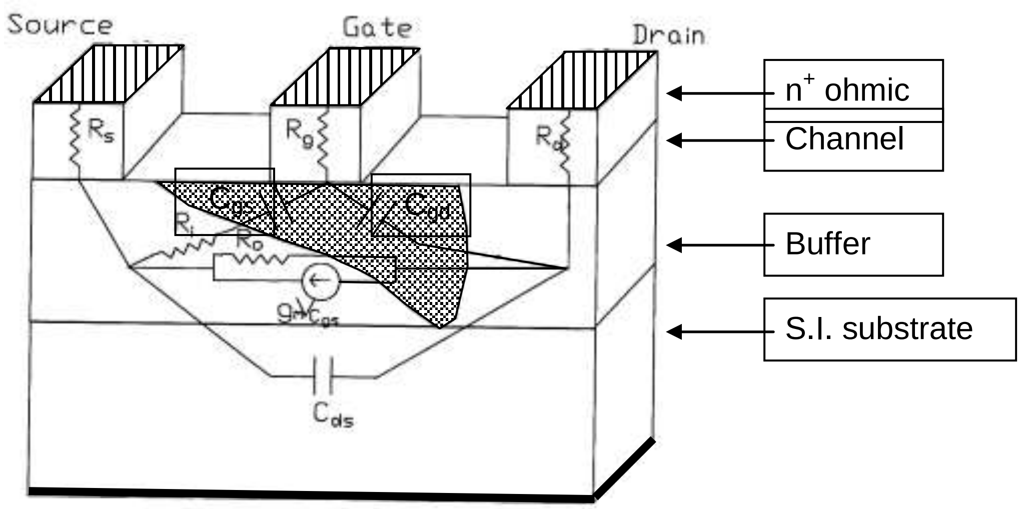

Fig. (1) Gross sectional view of a GaAs MESFET

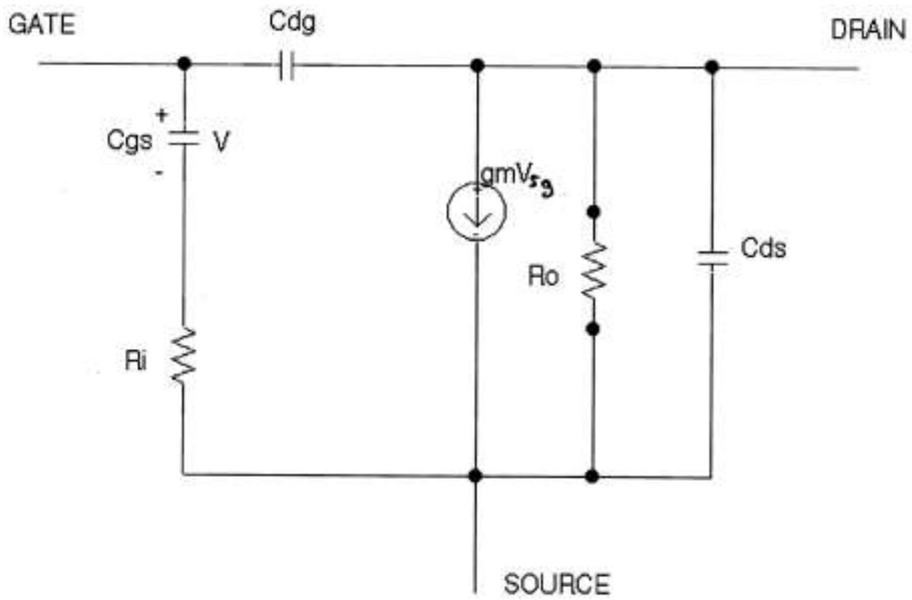

Fig. (2) Equivalent circuit of GaAs MESFET

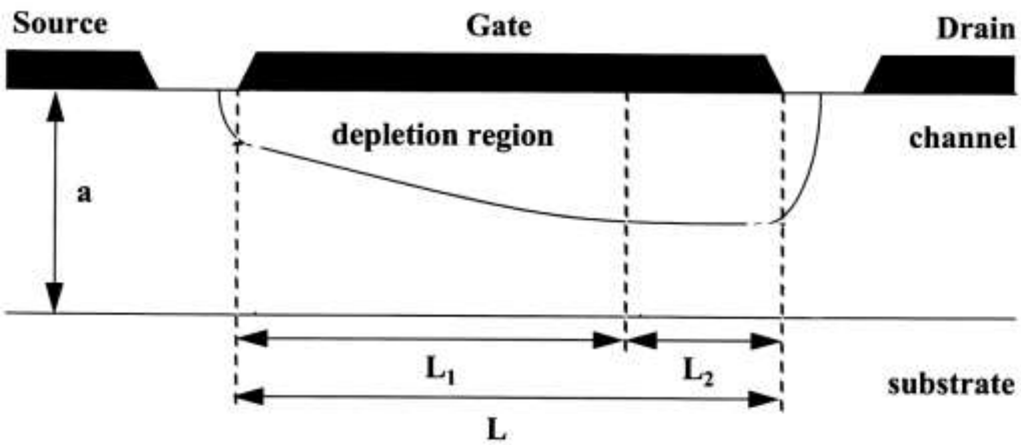

Fig. (3) Baic n-channel GaAs FET cross-section showing delplation region constricting the channel

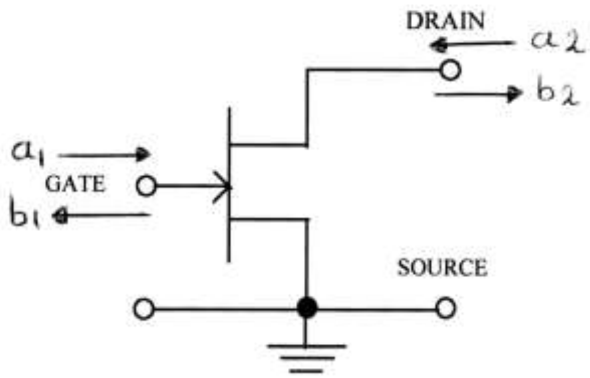

Fig. (4) Two-port S-parameters for common-source MESFET

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حساب التيارالمستمر والتردد الراديوي في الدائرة المكافئة لترانزستورات تاثير المجال لاشباه الموصلات المعدنية من النوع كاليوم ارسنايد

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الخلاصة:

يعرض هذا البحث خصائص العناصر المهمة لدائرة التيار المباشر المستمر والتردد الراديوي لترانزستورات ذو التاثير المجالي لاشباه الموصلات المعدنية من النوع كاليوم ارسنايد.

وقد تم وصف هذا النوع من الترانزستورات في حالة المصدر المشترك من خلال معاملات S ذات المرفأين.

وبهذا الخصوص تم بناء وتطوير برنامج لاستخدام هذا النوع من الترانزستورات ولحساب معاملاته وتم عرضها من خلال الجداول.