
IHP

SG13G2

SG13G2 DC CV PMOS LV RF

Rev. 1.2 (190924)

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1 Documentation

1.1 Included Effects in Simulation Model

General	Date, Version	24.09.2019
	Processversion	SG13G2
	Simulator	ADS 2019, Spectre 18.1
	Simulation model	PSP 103.6
	Warning Boundaries	On

Statistic	Corner	x
	Process variations for Monte Carlo Simulation	e
	Mismatch	x
Transistor	DC behavior	x
	Drain diode	x
	Overlap cap.	x
	Junction cap.	x
	1/f Noise	x ₁
	HF / Thermal Noise	-
	Substrate resistance (RF)	x ₂
	Gate resistance (RF)	x ₂
Temperature	-40°C, 25°C, 70°C, 125°C	x

x measured and modelled

x₁ parameters taken from SG13

x₂ measurements are done from a different wafer run than DC model which leads to slight offsets

e estimated and modelled

o not included

- not applicable

1.2 Time range measurement

The verification of the time range measurements is done by the standard IHP verification procedure.

2 Setup

2.1 Measurement Conditions

2.1.1 Measurement Conditions for Transistors

	Sweep	Start[V]	Stop[V]	No. Points	List or f(Vth)
idvg	vg	-500m	1.35	38	
	vb	0	-1.2	7	
	vd	List		3	0.05, 0.6, 1.2
	vs	0		1	
idvd	vd	0	1.35	28	
	vg	Lin f(Vth)	1.35	5	Ref. Setup: idvg Idref: 100.0n Offset: 100.0m Resolution: 1.000m
	vb	0		1	
	vs	0		1	
idvd_vbmin	vd	0	1.35	28	
	vg	Lin f(Vth)	1.35	5	Ref. Setup: idvg Idref: 100.0n Offset: 100.0m Resolution: 1.000m
	vb	-1.2		1	
	vs	0		1	
idvd_vth	vd	0	1.35	28	
	vg	List f(Vth)		3	Ref. Setup: idvg Idref: 100.0n Offset: -200.0m Resolution: 1.000m Steps: 200.0m 200.0m
	vb	0		1	
	vs	0		1	
idvd_vth_vbmin	vd	0	1.35	28	
	vg	List		3	Ref. Setup: idvg

		f(Vth)			Idref: 100.0n Offset: -200.0m Resolution: 1.000m Steps: 200.0m 200.0m
	vb	-1.2		1	
	vs	0		1	
RF idvg	vg	0	1.35	28	
	vd	List		3	0.05, 0.6, 1.2
RF idvd	vd	0	1.35	28	
	vg	0	1.35	5	
RF sdut	freq	100MEG	47.6G	31	
	vd	0	1.35	10	
	vg	0	1.35	10	

2.1.2 Measurement Conditions for Capacitance

	Sweep	Start[V]	Step[V]	Stop[V]	High Node	Low Node
Junction Bulk-Drain	1 VHI	5	-200m	-200m	B	D
Junction Bulk-Source	1 VHI	1	-20m	-300m	B	S
Oxide	1 VHI	-1.35	50m	1.35	B	G
Overlap	1 VHI	1.35	-50m	-1.35	G	D

2.2 Devices

2.2.1 Setup of DC Test Devices

Name	W[um]	L[um]	AD[um ²]	AS[um ²]	PD[um]	PS[um]	NRD	NRS	NF	Comment	Size Category
W10u0_L10u0_S549_5	10	10	3.4	3.4	20. 7	20. 7	0	0	1		Large

W0u15_L10u0_S555_3	150 m	10	101 m	101 m	1.3 4	1.3 4	0	0	1		Narrow
W10u0_L0u13_S548_2	10	130 m	3.4	3.4	20. 7	20. 7	0	0	1		Short
W0u15_L0u13_S554_3	150 m	130 m	101 m	101 m	1.3 4	1.3 4	0	0	1		Small
W10u0_L0u14_S548_3	10	140 m	3.4	3.4	20. 7	20. 7	0	0	1		L Scale
W10u0_L0u18_S548_5	10	180 m	3.4	3.4	20. 7	20. 7	0	0	1		L Scale
W10u0_L0u5_S549_1	10	500 m	3.4	3.4	20. 7	20. 7	0	0	1		L Scale
W10u0_L1u2_S549_2	10	1.2	3.4	3.4	20. 7	20. 7	0	0	1		L Scale
W10u0_L5u0_S549_4	10	5	3.4	3.4	20. 7	20. 7	0	0	1		L Scale
W10u0_L2u0_S549_3	10	2	3.4	3.4	20. 7	20. 7	0	0	1		L Scale
W10u0_L0u15_S548_4	10	150 m	3.4	3.4	20. 7	20. 7	0	0	1		L Scale
W0u6_L10u0_S552_1	600 m	10	204 m	204 m	1.8 8	1.8 8	0	0	1		W Scale
W0u18_L10u0_S554_1	180 m	10	103 m	103 m	1.3 4	1.3 4	0	0	1		W Scale
W0u3_L10u0_S553_2	300 m	10	102 m	102 m	1.2 8	1.2 8	0	0	1		W Scale
W05u0_L10u0_S550_3	5	10	1.7	1.7	10. 7	10. 7	0	0	1		W Scale
W02u0_L10u0_S551_1	2	10	680 m	680 m	4.6 8	4.6 8	0	0	1		W Scale
W02u0_L2u0_S550_5	2	2	680 m	680 m	4.6 8	4.6 8	0	0	1		LW Scale
W0u18_L0u14_S553_4	180 m	140	103 m	103 m	1.3 4	1.3 4	0	0	1		LW Scale
W0u18_L0u15_S553_5	180 m	150	103 m	103 m	1.3 4	1.3 4	0	0	1		LW Scale
W0u6_L0u5_S551_4	600 m	500	204 m	204 m	1.8 8	1.8 8	0	0	1		LW Scale
W0u6_L1u2_S551_5	600 m	1.2	204 m	204 m	1.8 8	1.8 8	0	0	1		LW Scale
W0u3_L0u14_S552_3	300	140	102	102	1.2	1.2	0	0	1		LW

	m	m	m	m	8	8					Scale
W0u6_L0u13_S551_2	600 m	130 m	204 m	204 m	1.8 8	1.8 8	0	0	1		LW Scale
W0u6_L0u18_S551_3	600 m	180 m	204 m	204 m	1.8 8	1.8 8	0	0	1		LW Scale
W0u3_L0u15_S552_4	300 m	150 m	102 m	102 m	1.2 8	1.2 8	0	0	1		LW Scale
W02u0_L0u13_S550_4	2	130 m	680 m	680 m	4.6 8	4.6 8	0	0	1		LW Scale
W0u15_L0u14_S554_4	150 m	140 m	101 m	101 m	1.3 4	1.3 4	0	0	1		LW Scale
W05u0_L0u13_S550_1	5	130 m	1.7	1.7	10. 7	10. 7	0	0	1		LW Scale
W0u15_L0u15_S554_5	150 m	150 m	101 m	101 m	1.3 4	1.3 4	0	0	1		LW Scale
W0u3_L0u18_S552_5	300 m	180 m	102 m	102 m	1.2 8	1.2 8	0	0	1		LW Scale
W0u3_L0u13_S552_2	300 m	130 m	102 m	102 m	1.2 8	1.2 8	0	0	1		LW Scale
W05u0_L5u0_S550_2	5	5	1.7	1.7	10. 7	10. 7	0	0	1		LW Scale
W0u15_L0u5_S555_2	150 m	500 m	101 m	101 m	1.3 4	1.3 4	0	0	1		LW Scale
W0u3_L0u5_S553_1	300 m	500 m	102 m	102 m	1.2 8	1.2 8	0	0	1		LW Scale
W0u15_L0u18_S555_1	150 m	180 m	101 m	101 m	1.3 4	1.3 4	0	0	1		LW Scale
W0u18_L0u13_S553_3	180 m	130 m	103 m	103 m	1.3 4	1.3 4	0	0	1		LW Scale
W0u15_L0u12_S554_2	150 m	120 m	101 m	101 m	1.3 4	1.3 4	0	0	1		Addition al
W10u0_L0u12_S548_1	10	120 m	3.4	3.4	20. 7	20. 7	0	0	1		Addition al
W10u0_L0u13_S382_2	10	130 m	3.4	3.4	20. 7	20. 7	0	0	1		Short
W10u0_L0u13_T356_S3 82_2	10	130 m	0	0	0	0	0	0	1		Short

2.2.2 Setup of CV Test Devices

Name	W[um]	L[um]	NF	AD[um ²]	AS[um ²]	PD[um]	PS[um]	Comment	Size Category
Junction Capacitance Bulk - Drain									
CJBDarea_S351B_1			1	37.5 K		850		B-High, S/D-Low	BD Area
CJBDperim_S351B_2			1	28.6 K		102K		B-High, S/D-Low	BD Perim
Junction Capacitance Bulk - Source									
CJBSarea_S351B_1			1	0		0		B-High, S/D-Low	BS Area
CJBSperim_S351B_2			1	0		0		B-High, S/D-Low	BS Perim
Oxide Capacitance									
Cox_S346K_4	160	250	1					B-High, G-Low	Oxide
Overlap Capacitance									
Cgds3_S351B_13	400	10	40	79.8	79.8	436	436	G-High, S/D-Low, B+Sub-GND	Overlap 2 GDS
Cgds2_S351B_12	6.6 K	250 m	66 0	1.26 K	1.26 K	6.87 K	6.87 K	G-High, S/D-Low, B+Sub-GND	Overlap 1 GDS
Cgds1_S351B_11	8K	130	80	1.52	1.52	8.32	8.32	G-	Overlap

		m	0	K	K	K	K	High, S/D- Low, B+Sub -GND	GDS
Cgdsb2_S351B_12	6.6 K	250 m	66 0	1.26 K	1.26 K	6.87 K	6.87 K	G- High, S/D+B -Low	Overlap 1 GDSB
Cgdsb1_S351B_11	8K	130 m	80 0	1.52 K	1.52 K	8.32 K	8.32 K	G- High, S/D+B -Low	Overlap GDSB
Cgdsb3_S351B_13	400	10	40	79.8	79.8	436	436	G- High, S/D+B -Low	Overlap 2 GDSB

3 Corner Devices

3.1 Target Values vs. Simulated Values

3.1.1 W = 10.00u, L = 130.0n, NF = 1

	Slow			Typic.			Fast		
	Target	Sim.	Error [%]	Target	Sim.	Error [%]	Target	Sim.	Error [%]
VT	-520m	- 358m	31.21	-460m	- 358m	22.24	-410m	- 358m	12.75
Ron*W	-	-	-	2.2	2.21	0.62	-	-	-
Ion/W	-160	-232	-45.01	-205	-232	-13.18	-260	-232	10.76
log(Ioff/W)	-11.5	-9.82	-3.67	-10.4	-9.82	-2.44	-9.5	-9.82	1.72

3.1.2 W = 10.00u, L = 10.00u, NF = 1

	Slow			Typic.			Fast		
	Target	Sim.	Error [%]	Target	Sim.	Error [%]	Target	Sim.	Error [%]
VT	-400m	-266m	33.51	-350m	-266m	24.02	-300m	-266m	11.35
Ion/W	-2.45	-3.12	-27.33	-2.7	-3.12	-15.54	-2.95	-3.12	-5.75

3.1.3 W = 150.0n, L = 130.0n, NF = 1

	Slow			Typic.			Fast		
	Target	Sim.	Error [%]	Target	Sim.	Error [%]	Target	Sim.	Error [%]
VT	-560m	-357m	36.29	-470m	-357m	24.09	-380m	-357m	6.12
Ion/W	-240	-2.44K	-918.77	-315	-2.44K	-676.21	-390	-2.44K	-526.94

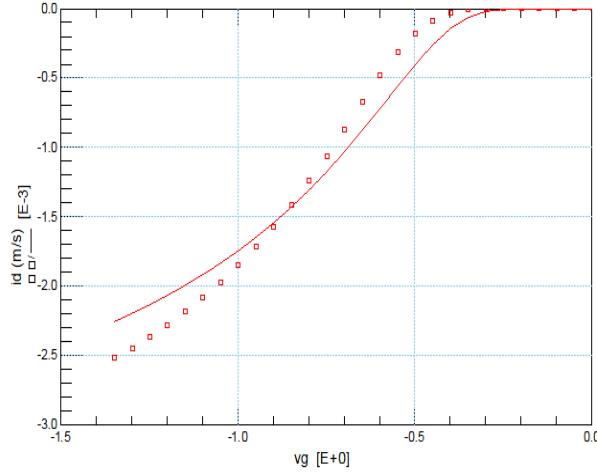
3.1.4 W = 150.0n, L = 10.00u, NF = 1

	Slow			Typic.			Fast		
	Target	Sim.	Error [%]	Target	Sim.	Error [%]	Target	Sim.	Error [%]
Ion/W	-3.25	-4.96	-52.58	-3.85	-4.96	-28.8	-4.45	-4.96	-11.43

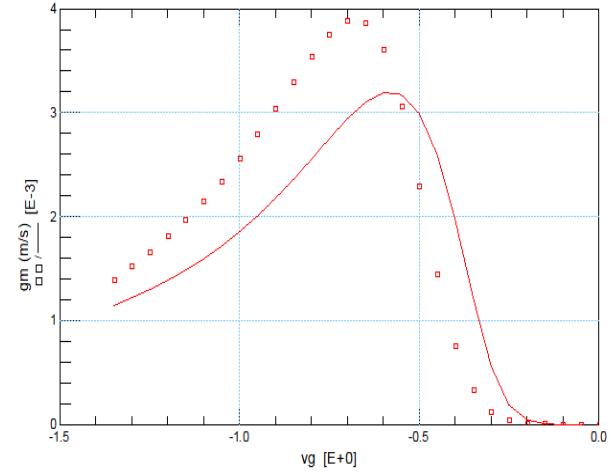
4 RF Transistors

4.1 NF10_WF10u0_L0u13_S453A_61

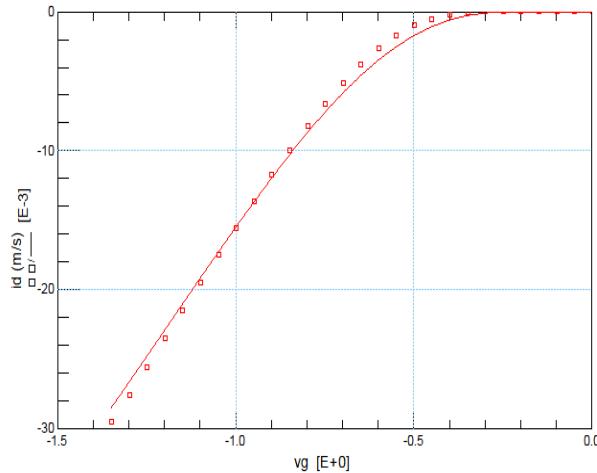
$IdVg$, $T = 27^\circ\text{C}$



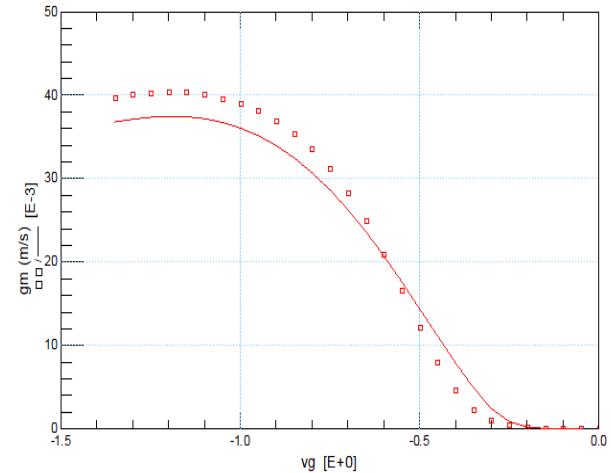
$$Id = f(Vg) \text{ @ } Vd = -0.05\text{V}$$



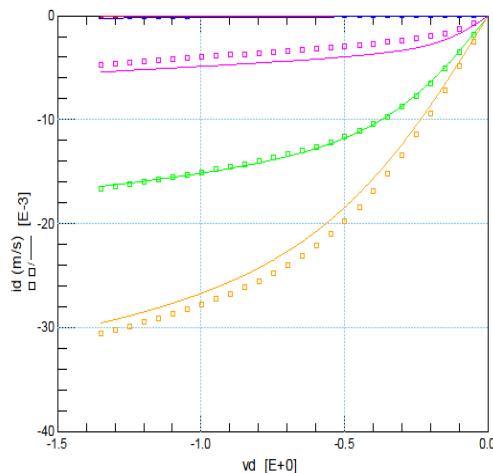
$$gm = f(Vg) \text{ @ } Vd = -0.05\text{V}$$



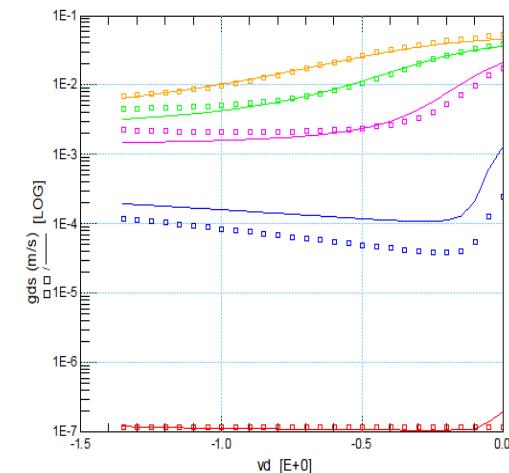
$$Id = f(Vg) \text{ @ } Vd = -1.2\text{V}$$



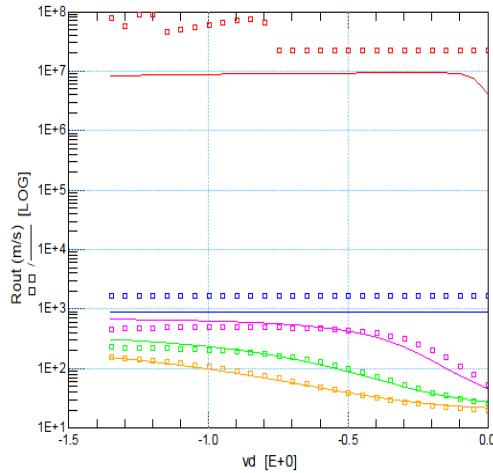
$$gm = f(Vg) \text{ @ } Vd = -1.2\text{V}$$

IdVd, T = 27°C

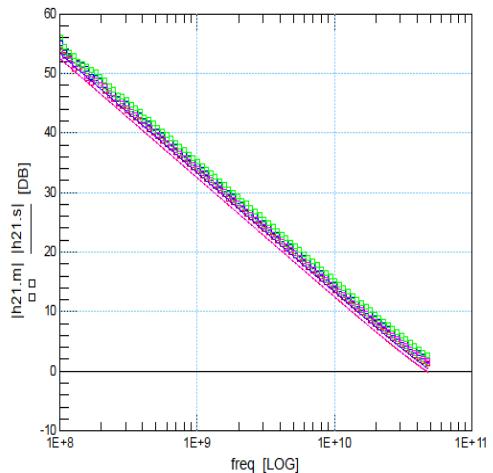
$$Id = f(Vd)$$



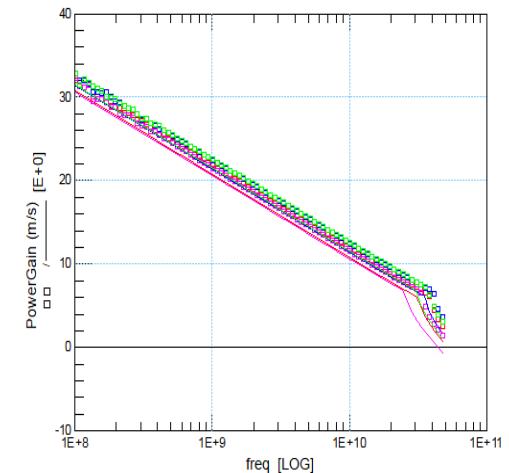
$$gds = f(Vd)$$



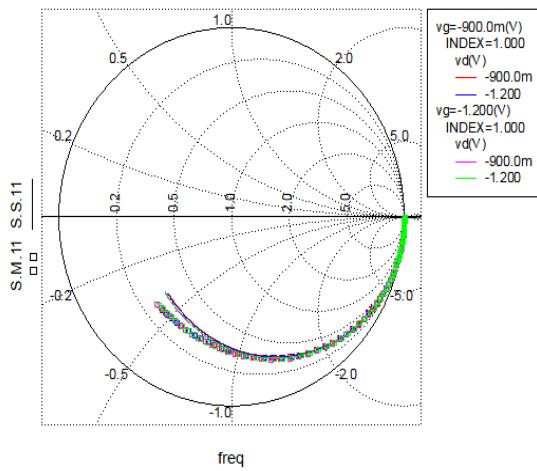
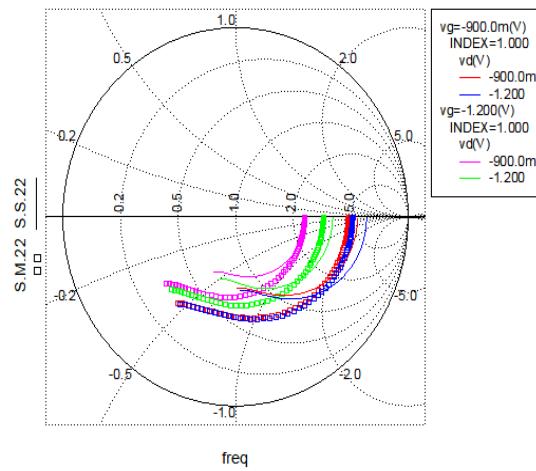
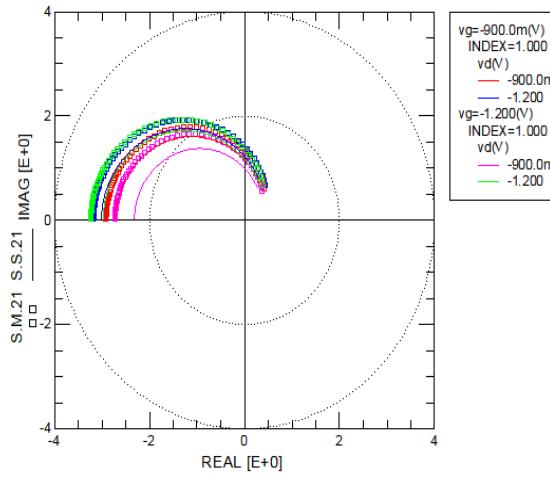
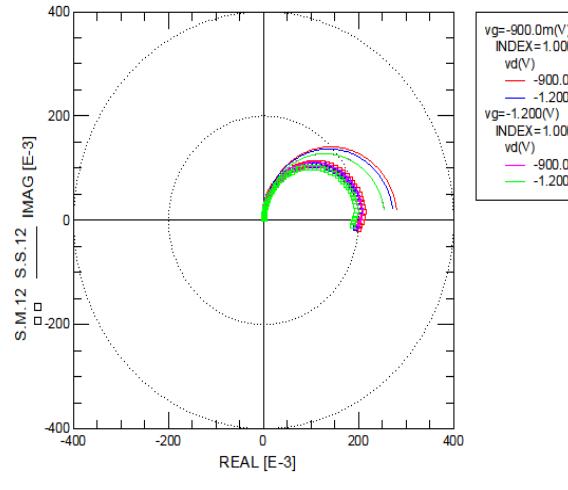
$$Rout = f(Vd)$$

S-Parameter, T = 27°C

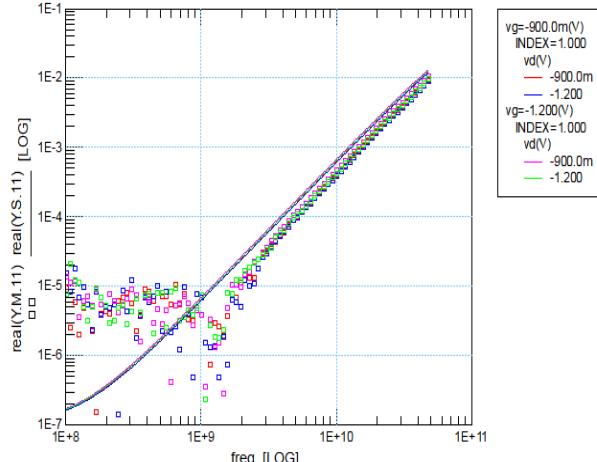
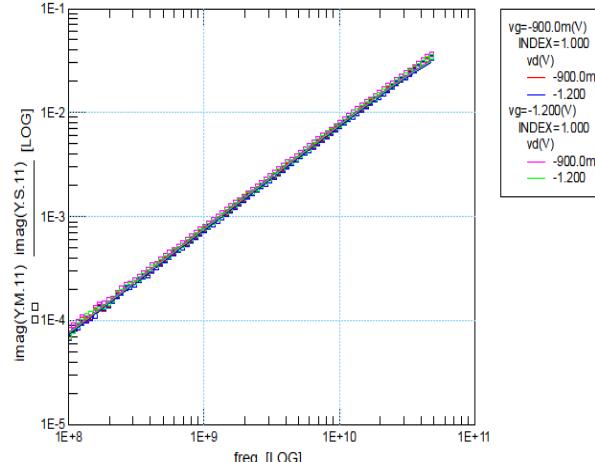
$$|h21| = f(Vg, Vd)$$

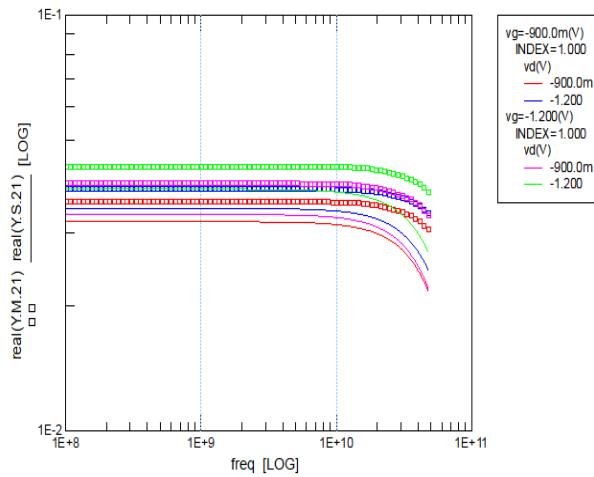
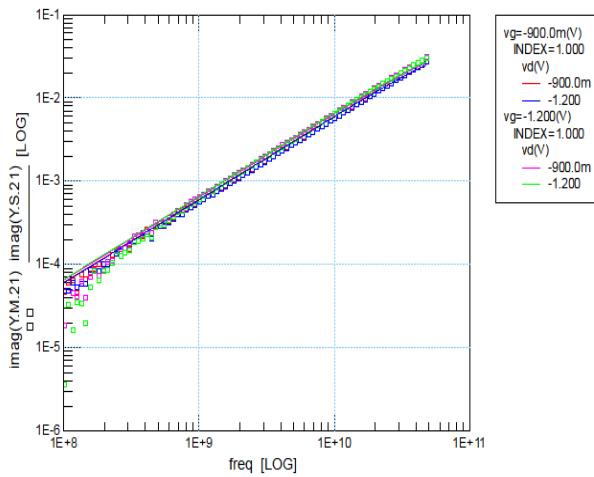
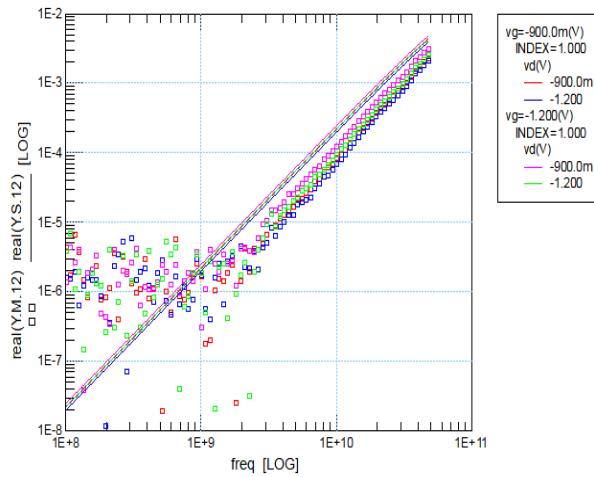
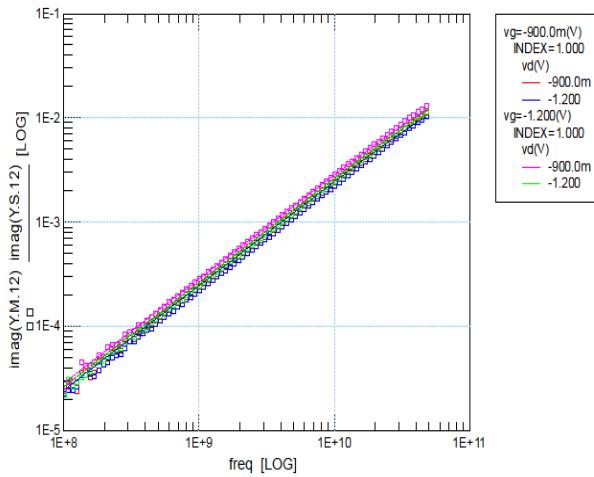
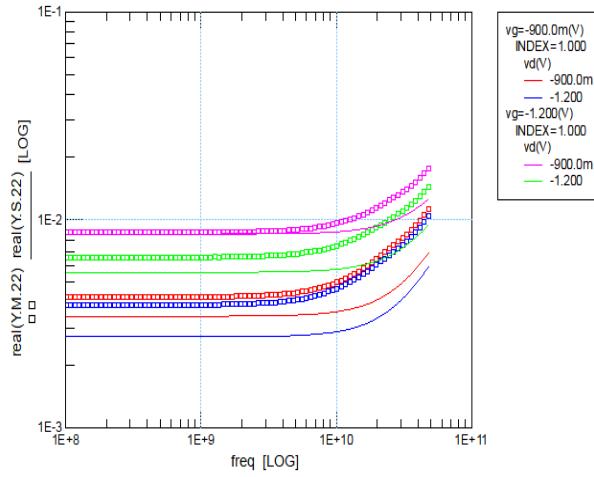
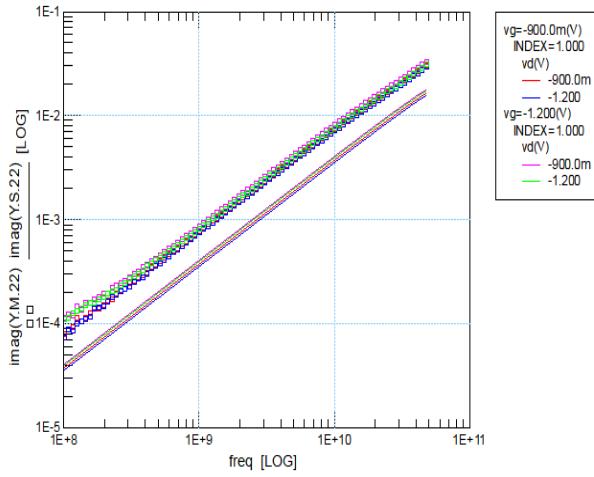


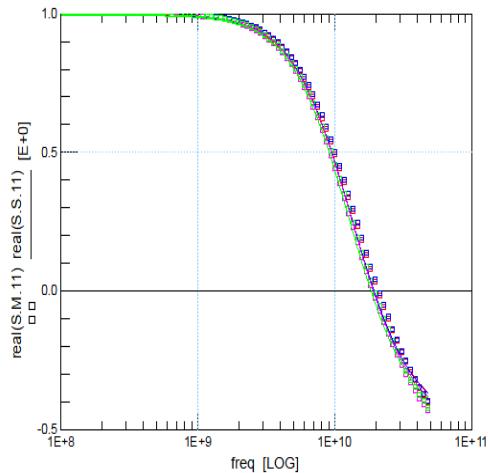
$$MSG/MAG = f(Vg, Vd)$$

 $S_{11} = f(V_g, V_d)$  $S_{22} = f(V_g, V_d)$  $S_{21} = f(V_g, V_d)$  $S_{12} = f(V_g, V_d)$

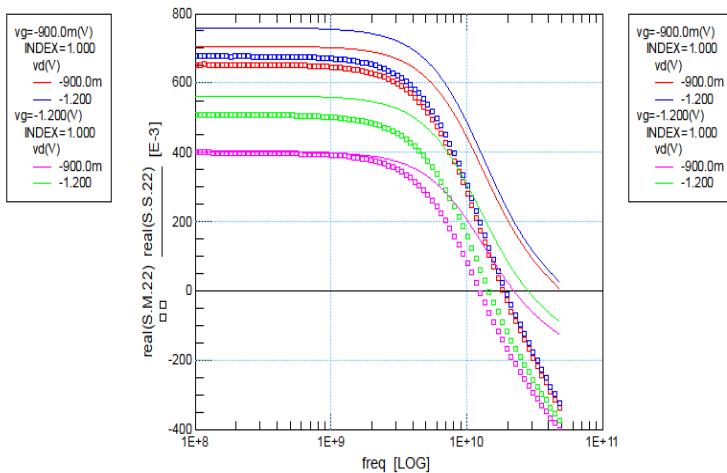
Y-Parameter, $T = 27^\circ\text{C}$

 $\text{re}(Y_{11}) = f(V_g, V_d)$  $\text{im}(Y_{11}) = f(V_g, V_d)$

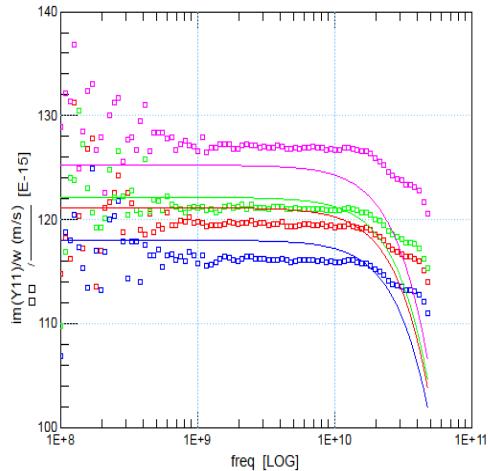
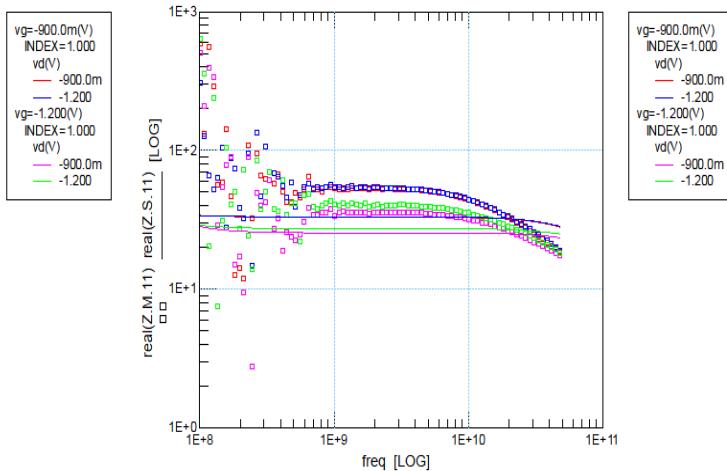
re(Y₂₁) = f(V_g,V_d)im(Y₂₁) = f(V_g,V_d)re(Y₁₂) = f(V_g,V_d)im(Y₁₂) = f(V_g,V_d)re(Y₂₂) = f(V_g,V_d)im(Y₂₂) = f(V_g,V_d)

Verify Plots, $T = 27^\circ\text{C}$ 

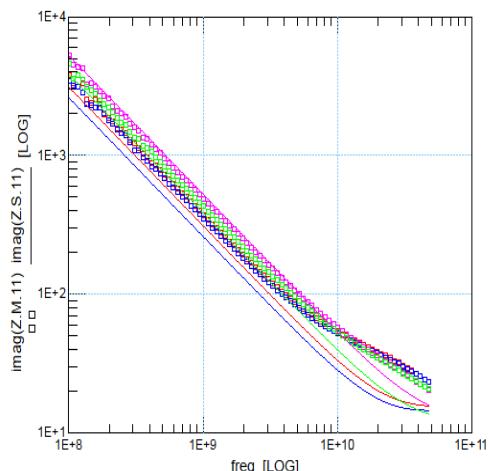
re(S11) = f(Vg, Vd)



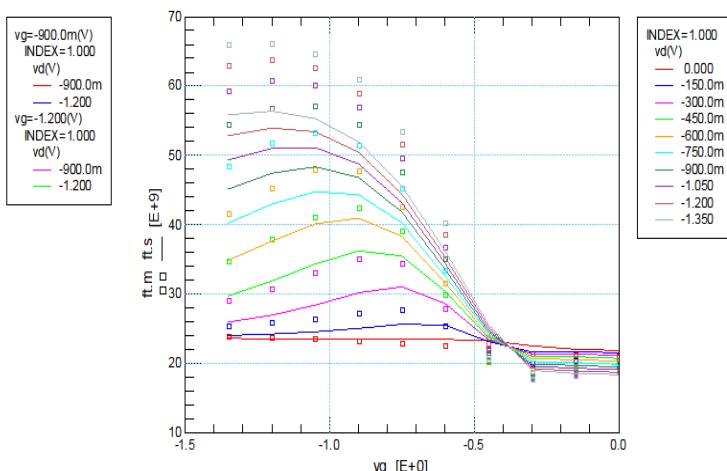
re(S22) = f(Vg, Vd)

im(Y11) divided by ω 

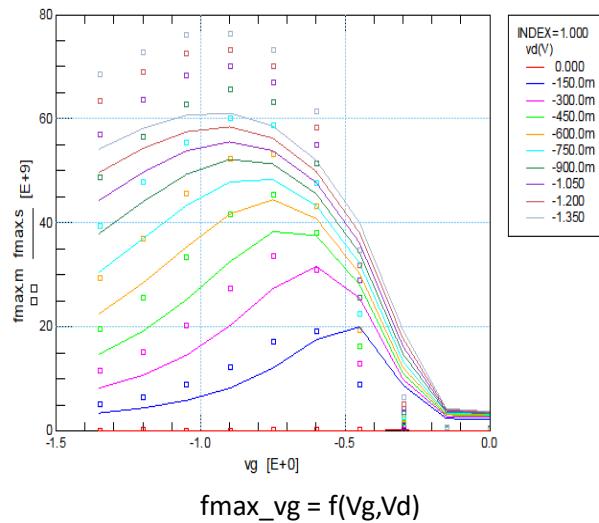
re(Z11) = f(Vg, Vd)



im(Z11) = f(Vg, Vd)

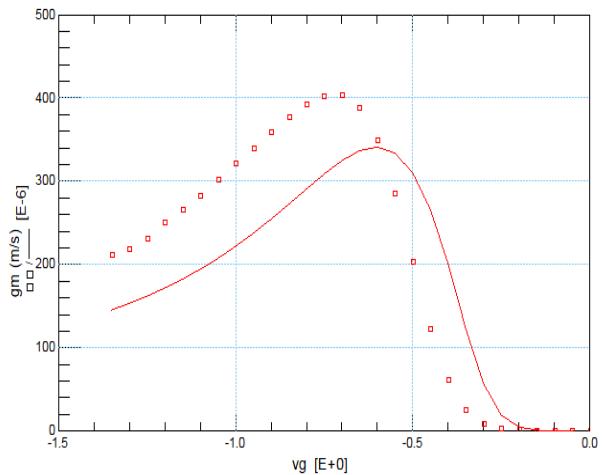
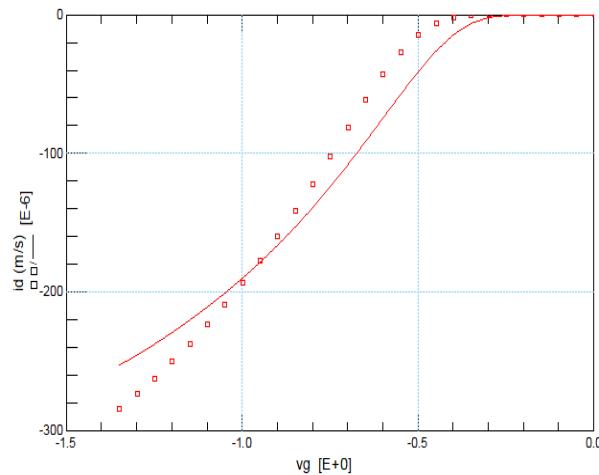


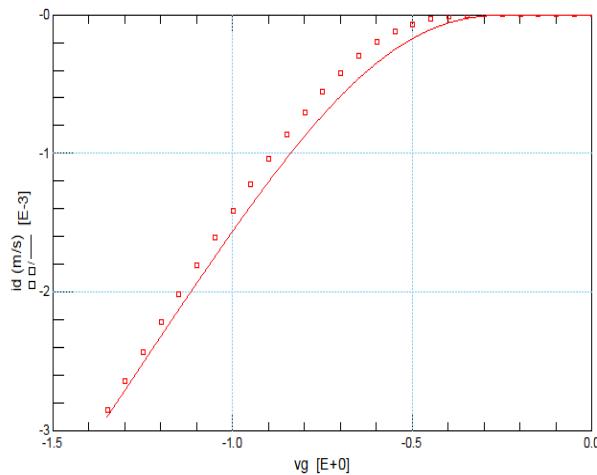
fT_vg = f(Vg, Vd)



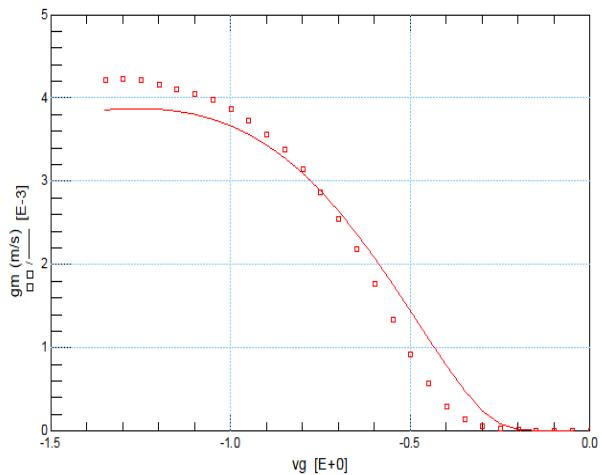
4.2 NF01_WF10u0_L0u13_S453A_73

$I_d V_g$, $T = 27^\circ\text{C}$



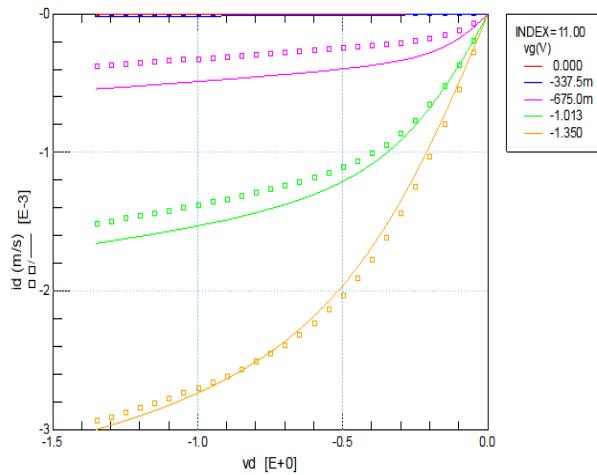


$$Id = f(Vg) @ Vd = -1.2V$$

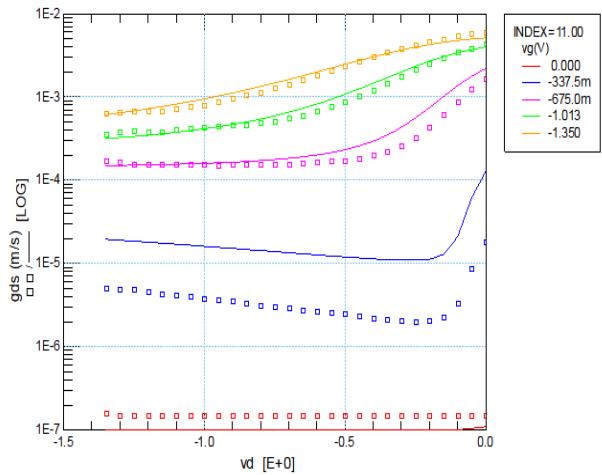


$$gm = f(Vg) @ Vd = -1.2V$$

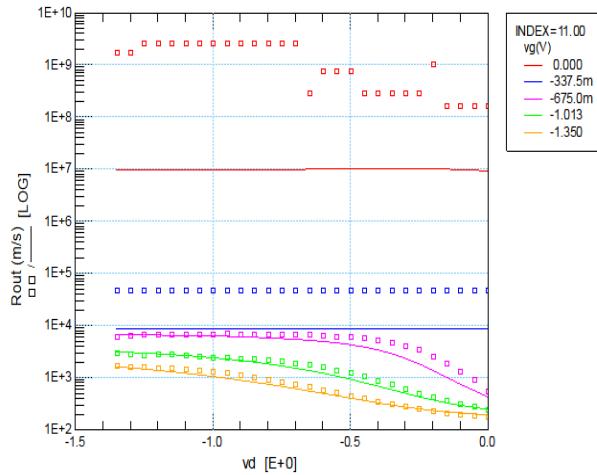
IdVd, T = 27°C



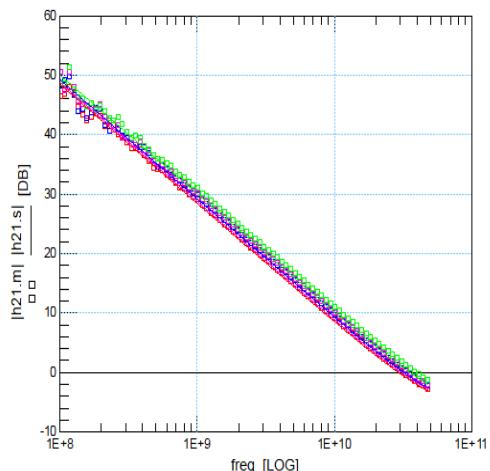
$$Id = f(Vd)$$



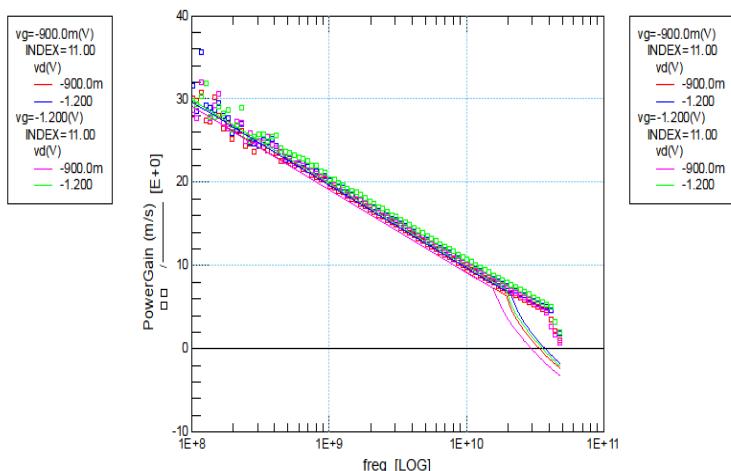
$$gds = f(Vd)$$



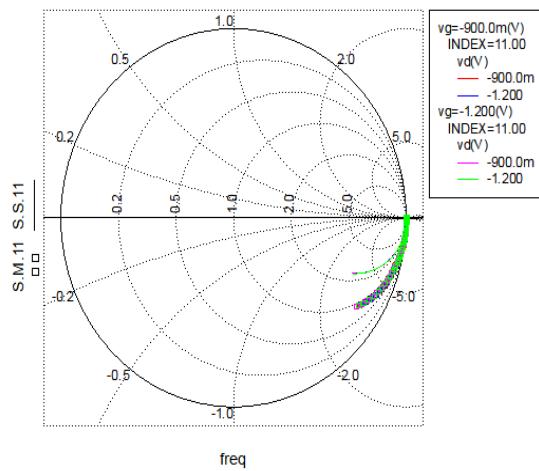
$$Rout = f(Vd)$$

S-Parameter, T = 27°C

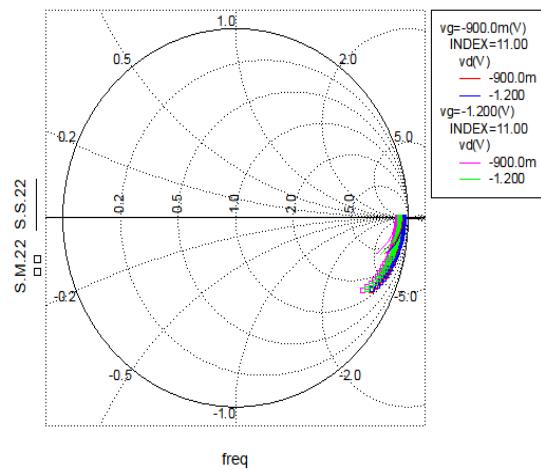
$$|h21| = f(Vg, Vd)$$



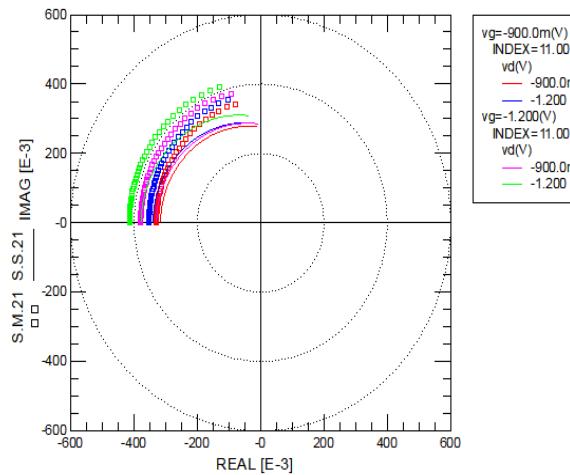
$$MSG/MAG = f(Vg, Vd)$$



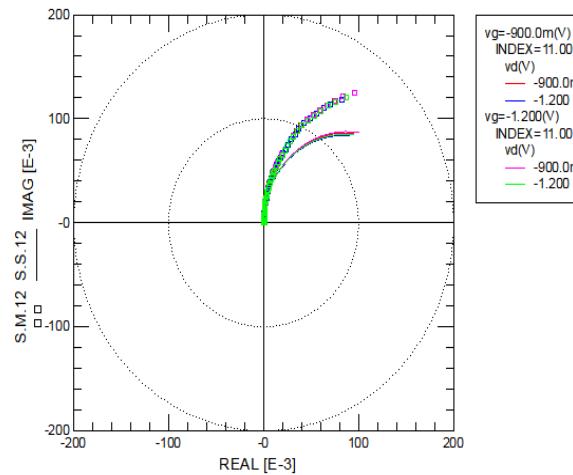
$$S11 = f(Vg, Vd)$$



$$S22 = f(Vg, Vd)$$

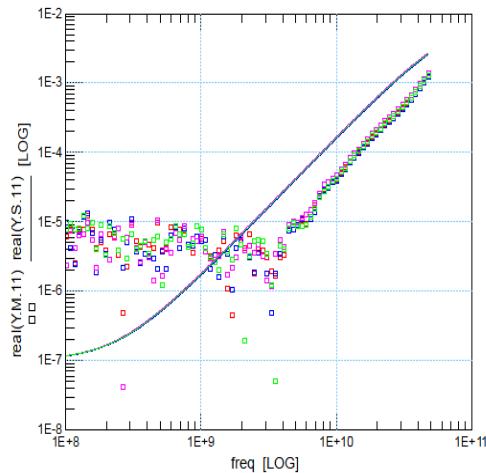


$$S21 = f(Vg, Vd)$$

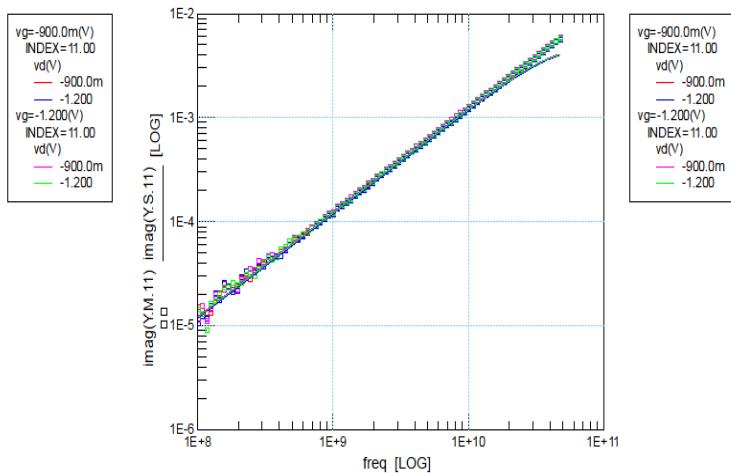


$$S12 = f(Vg, Vd)$$

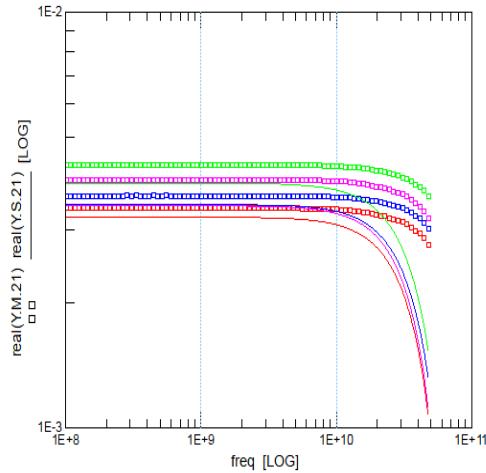
Y-Parameter, T = 27°C



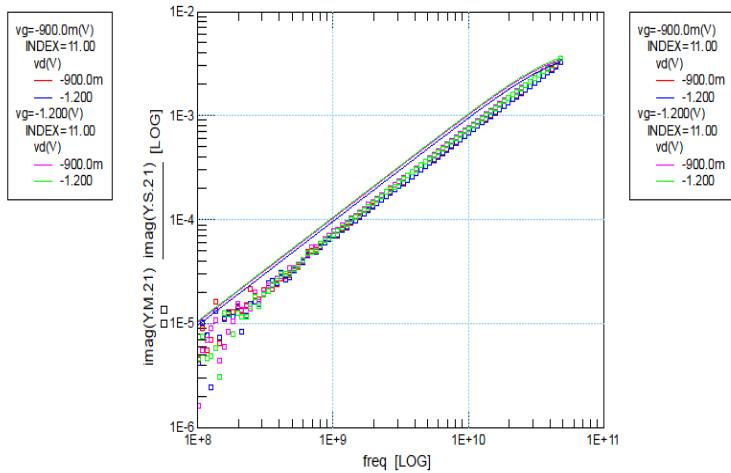
$$\text{re}(Y_{11}) = f(V_g, V_d)$$



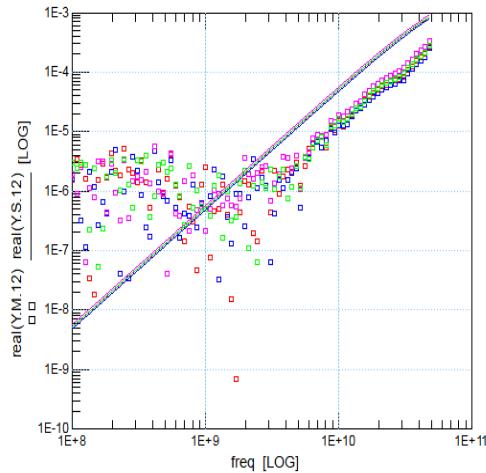
$$\text{im}(Y_{11}) = f(V_g, V_d)$$



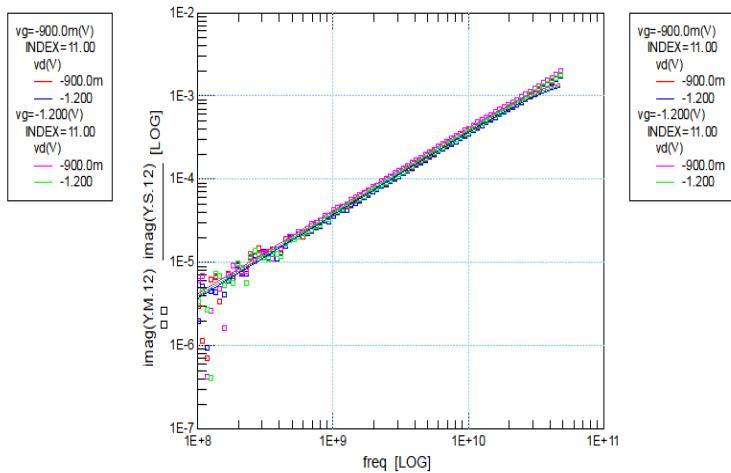
$$\text{re}(Y_{21}) = f(V_g, V_d)$$



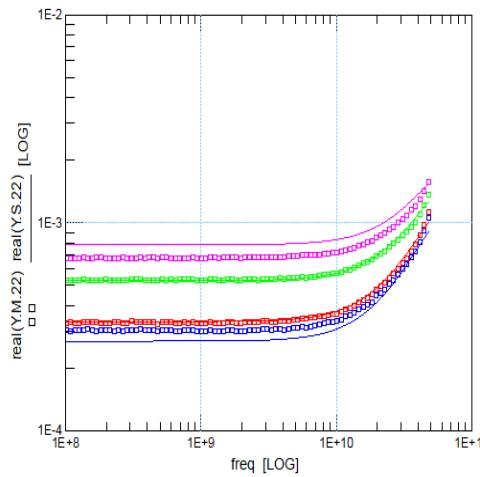
$$\text{im}(Y_{21}) = f(V_g, V_d)$$



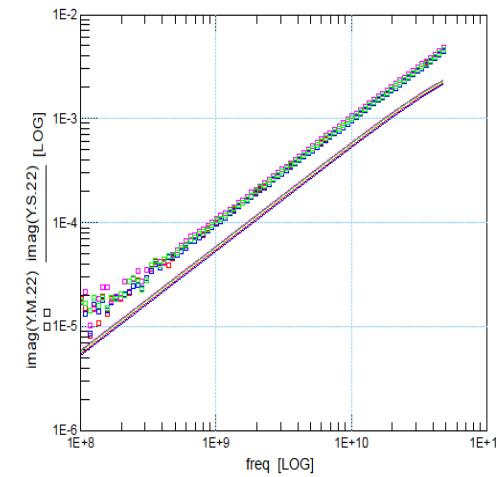
$$\text{re}(Y_{12}) = f(V_g, V_d)$$



$$\text{im}(Y_{12}) = f(V_g, V_d)$$

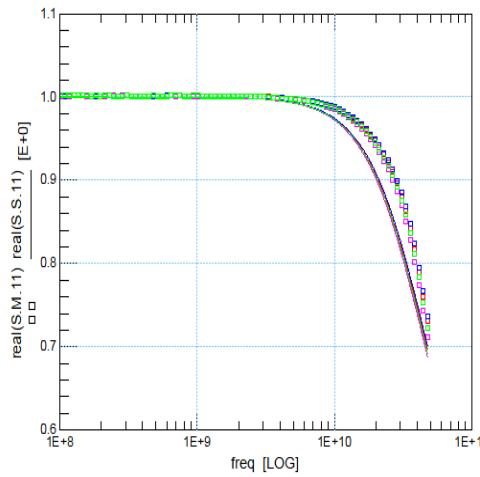


re(Y22) = f(Vg, Vd)

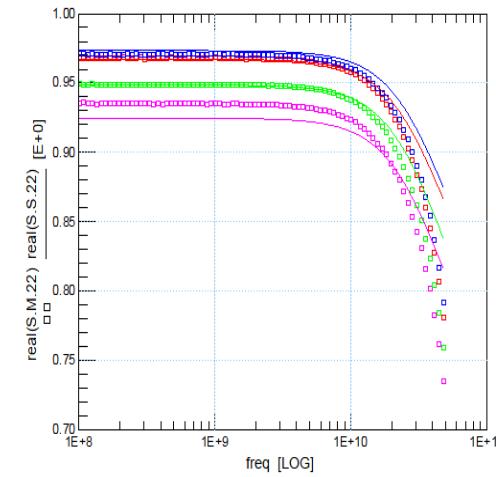


im(Y22) = f(Vg, Vd)

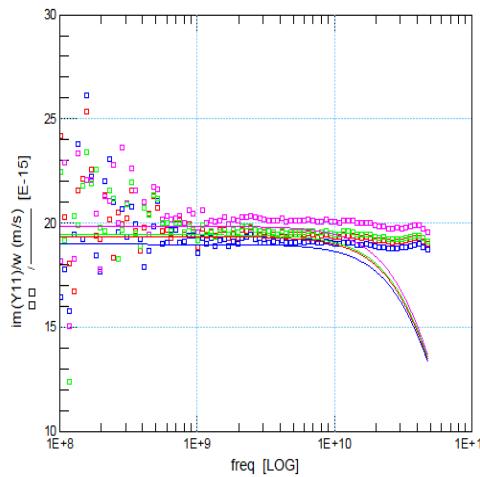
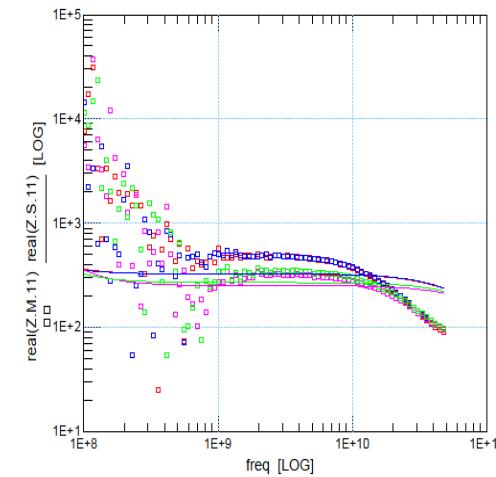
Verify Plots, T = 27°C



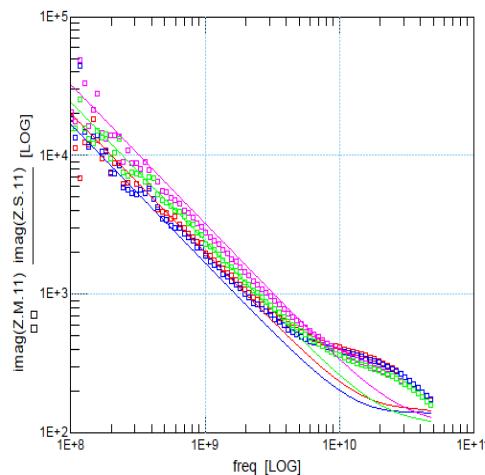
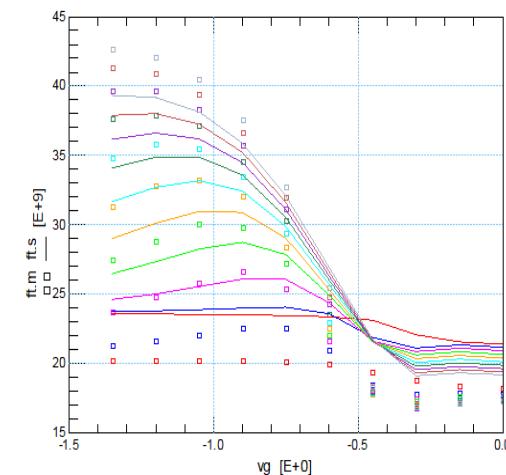
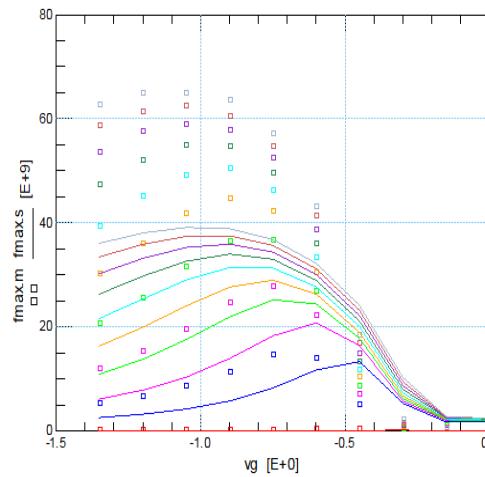
re(S11) = f(Vg, Vd)



re(S22) = f(Vg, Vd)

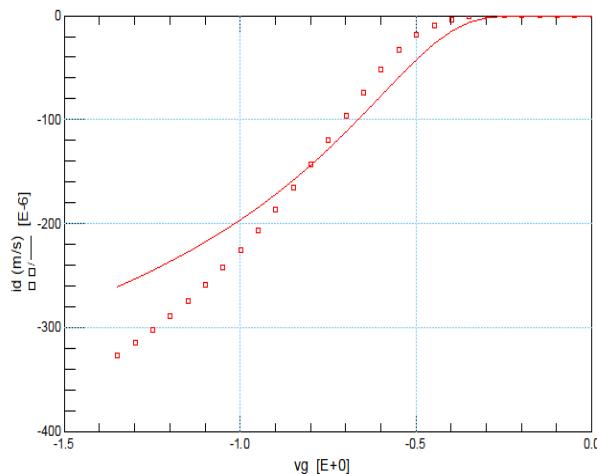
im(Y11) divided by ω 

re(Z11) = f(Vg, Vd)

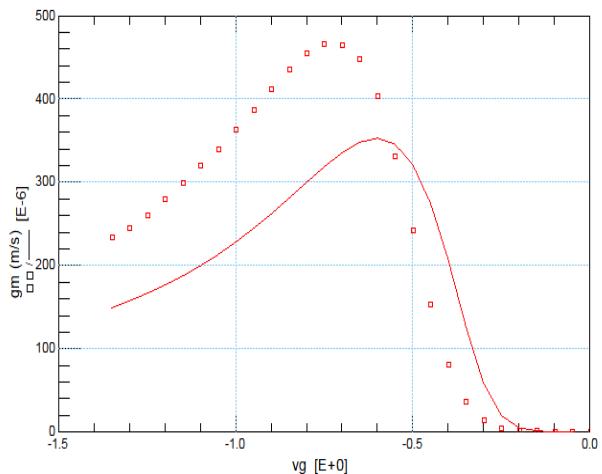
 $\text{im}(Z_{11}) = f(V_g, V_d)$  $fT_{vg} = f(V_g, V_d)$  $f_{\text{max}}_{vg} = f(V_g, V_d)$

4.3 NF04_WF02u5_L0u13_S453A_65

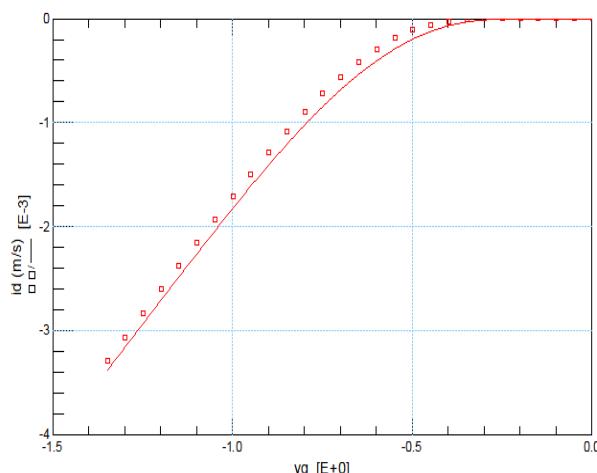
$IdVg$, $T = 27^\circ\text{C}$



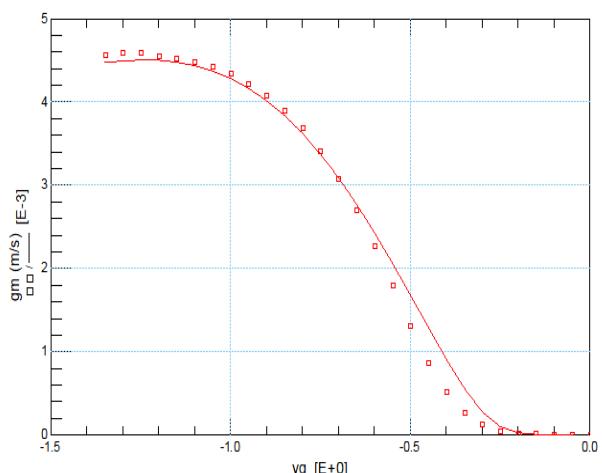
$Id = f(Vg)$ @ $Vd = -0.05\text{V}$



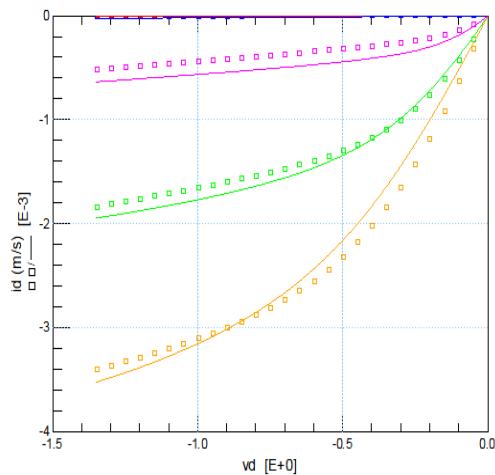
$gm = f(Vg)$ @ $Vd = -0.05\text{V}$



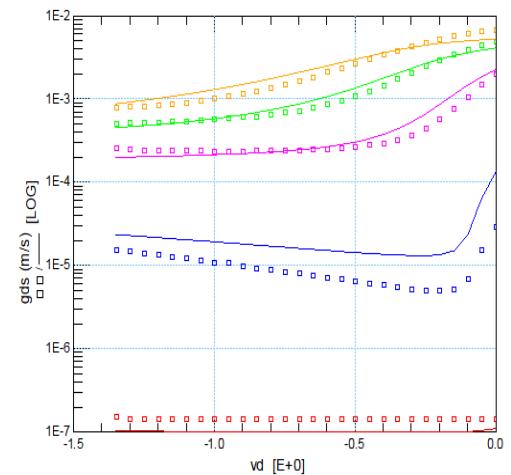
$Id = f(Vg)$ @ $Vd = -1.2\text{V}$



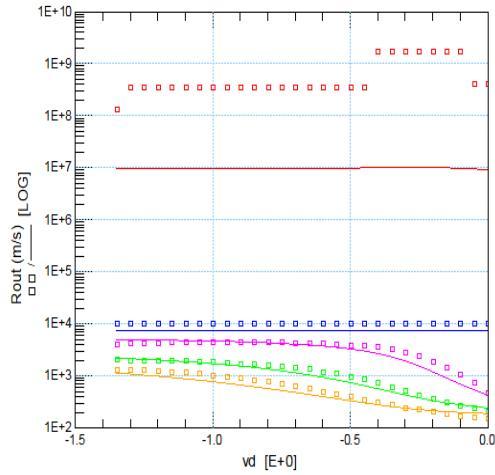
$gm = f(Vg)$ @ $Vd = -1.2\text{V}$

IdVd, T = 27°C

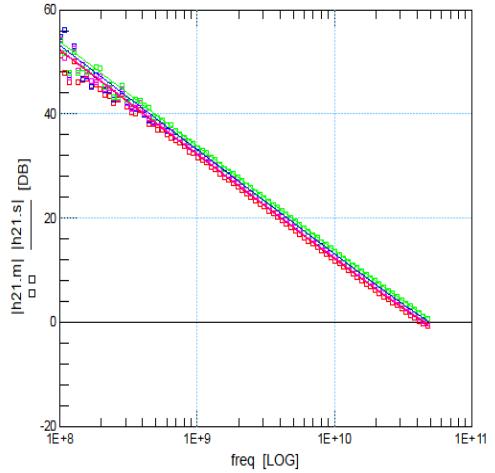
$$Id = f(Vd)$$



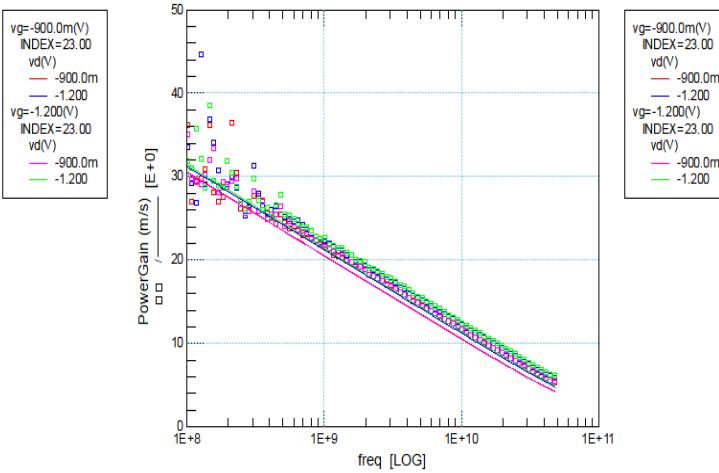
$$gds = f(Vd)$$



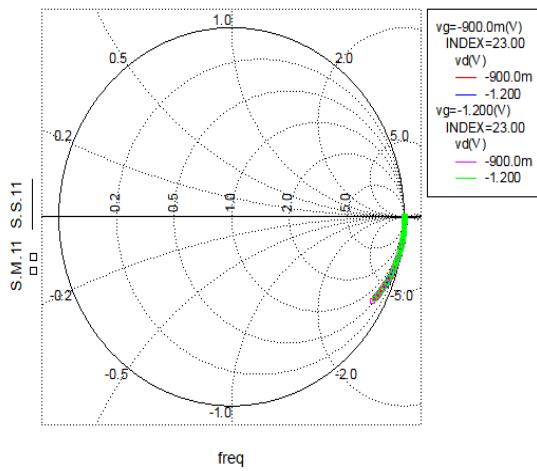
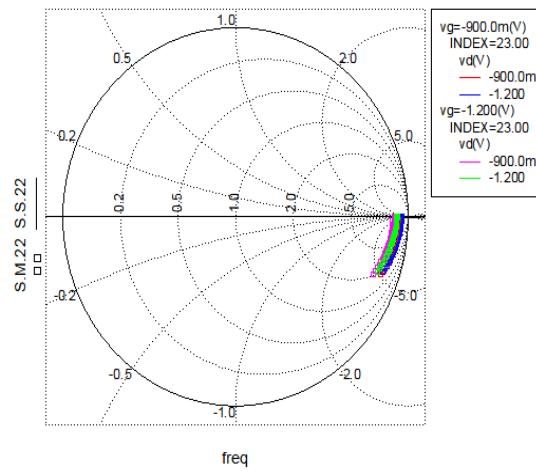
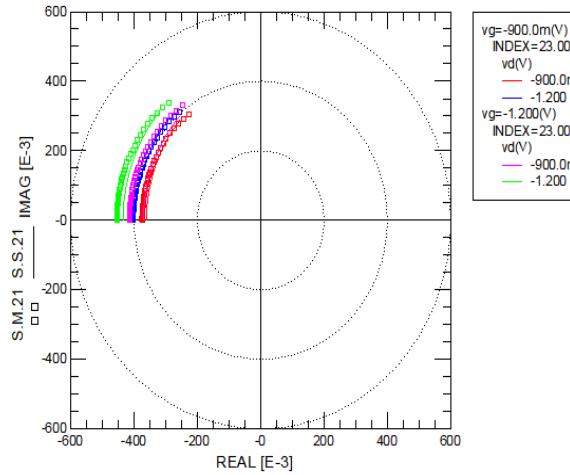
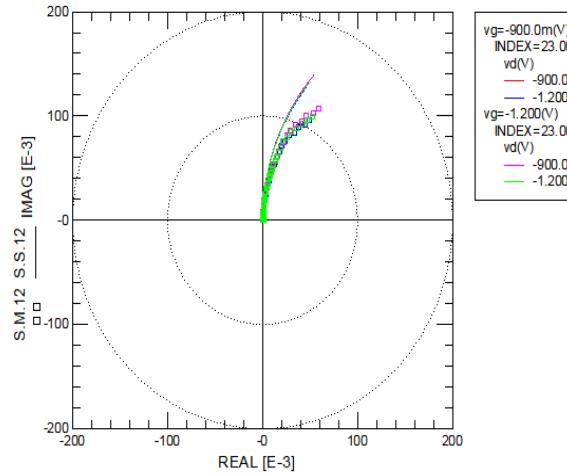
$$Rout = f(Vd)$$

S-Parameter, T = 27°C

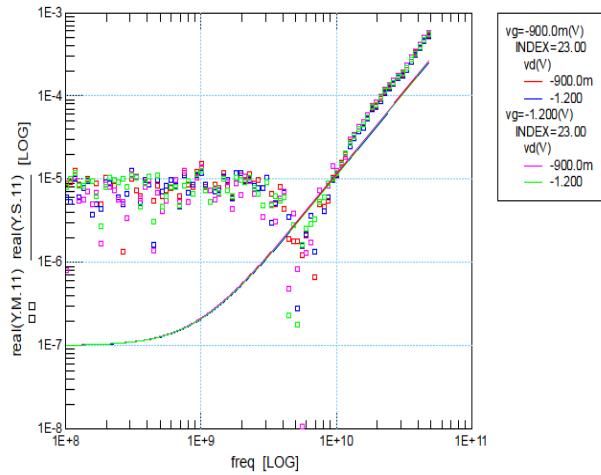
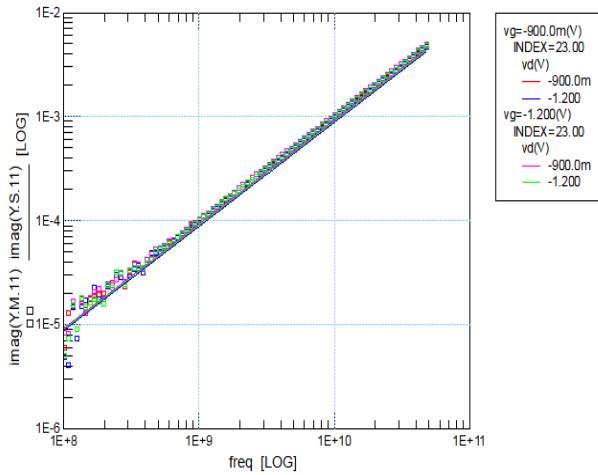
$$|h21| = f(Vg, Vd)$$

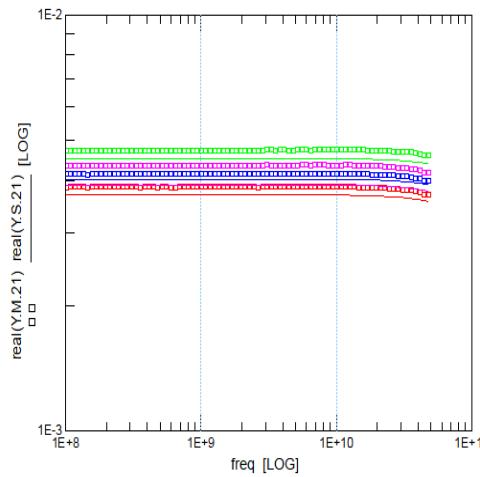


$$MSG/MAG = f(Vg, Vd)$$

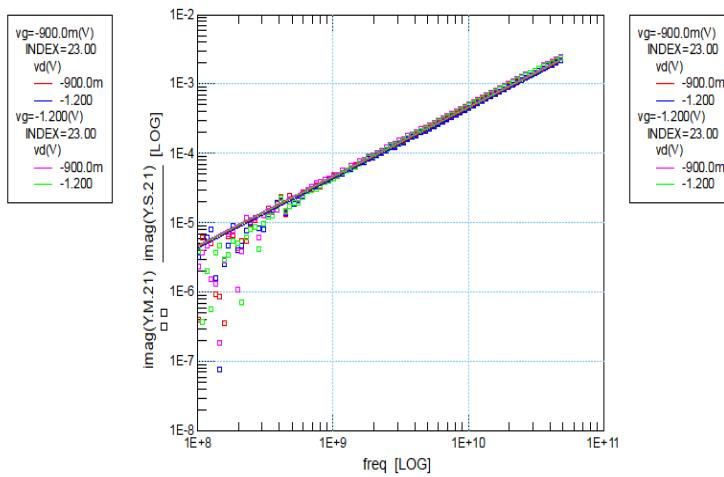
 $S11 = f(Vg, Vd)$  $S22 = f(Vg, Vd)$  $S21 = f(Vg, Vd)$  $S12 = f(Vg, Vd)$

Y-Parameter, $T = 27^\circ C$

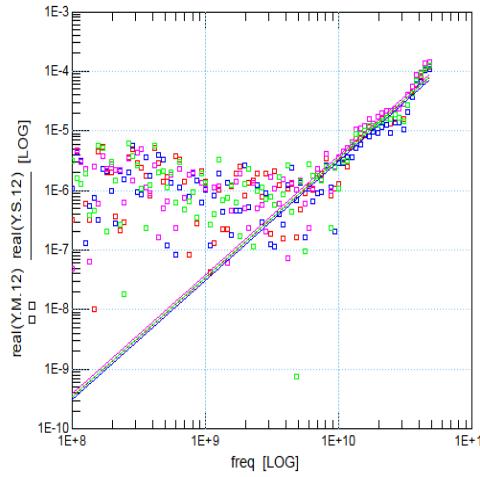
 $re(Y_{11}) = f(Vg, Vd)$  $im(Y_{11}) = f(Vg, Vd)$



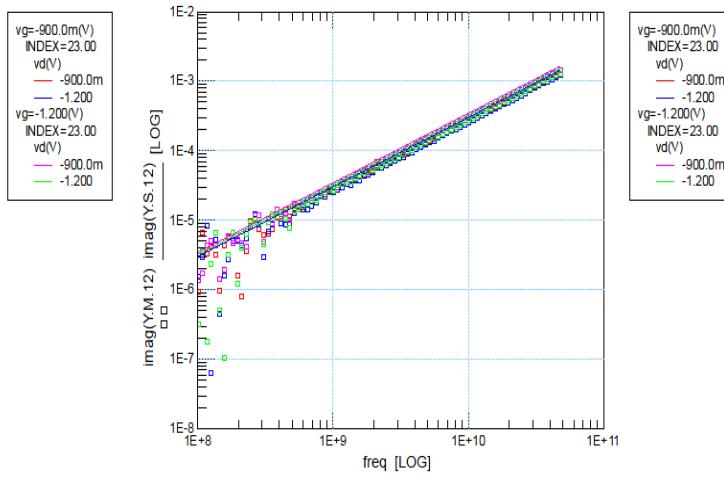
re(Y21) = f(Vg,Vd)



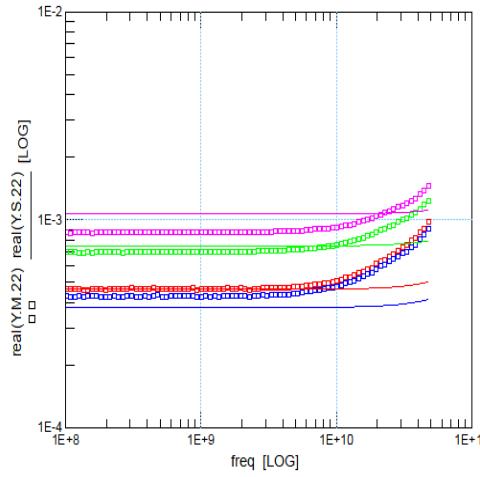
im(Y21) = f(Vg,Vd)



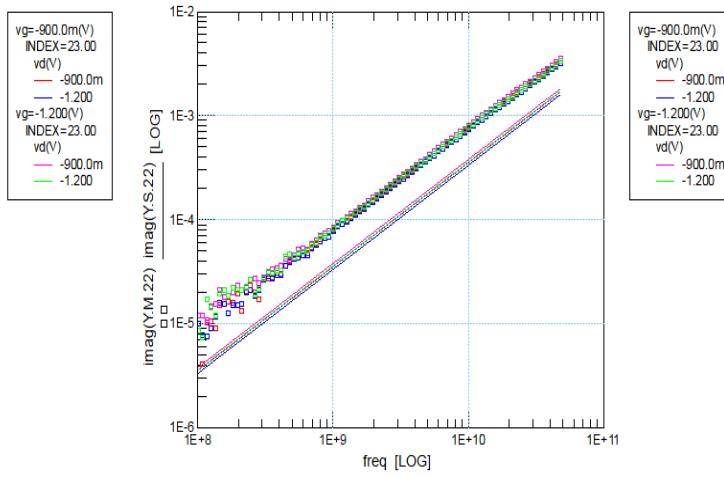
re(Y12) = f(Vg,Vd)



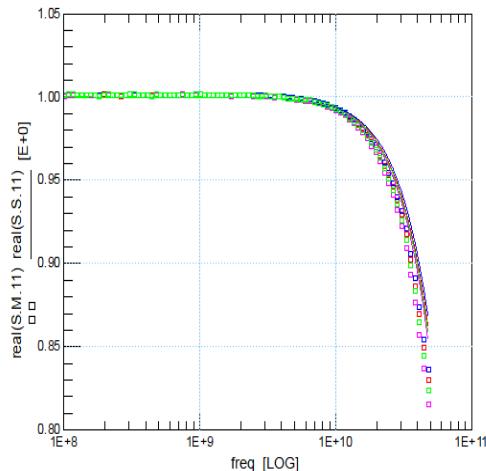
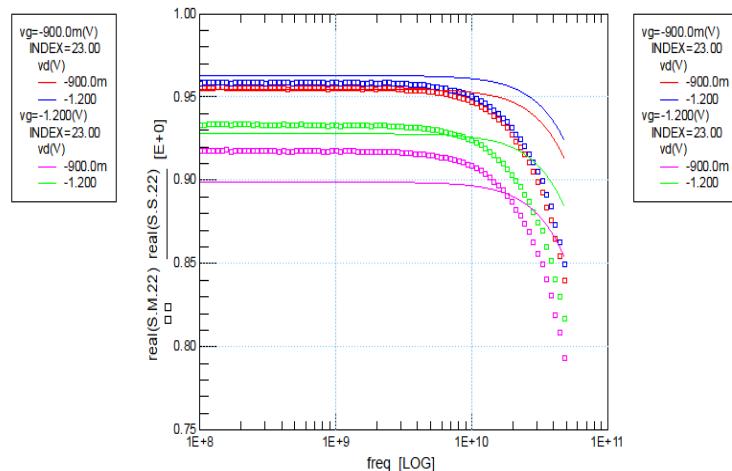
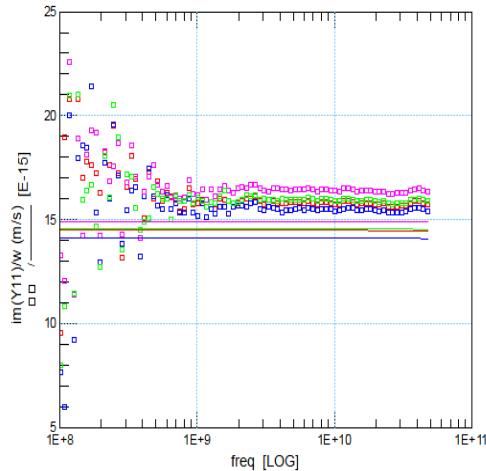
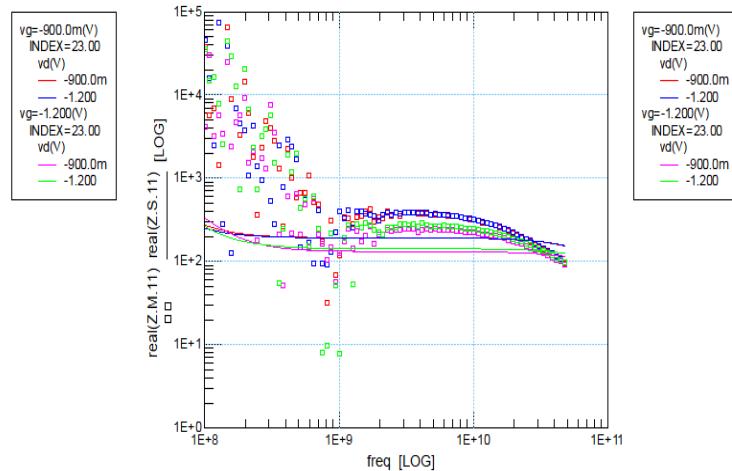
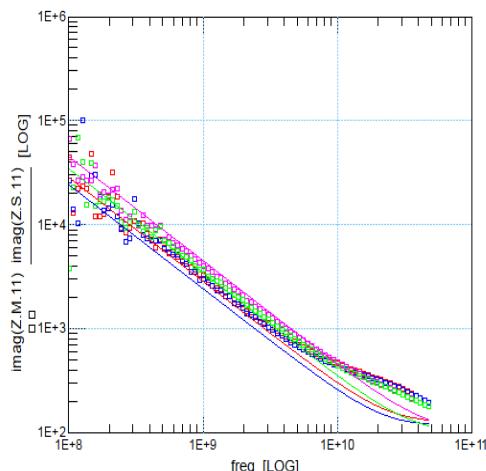
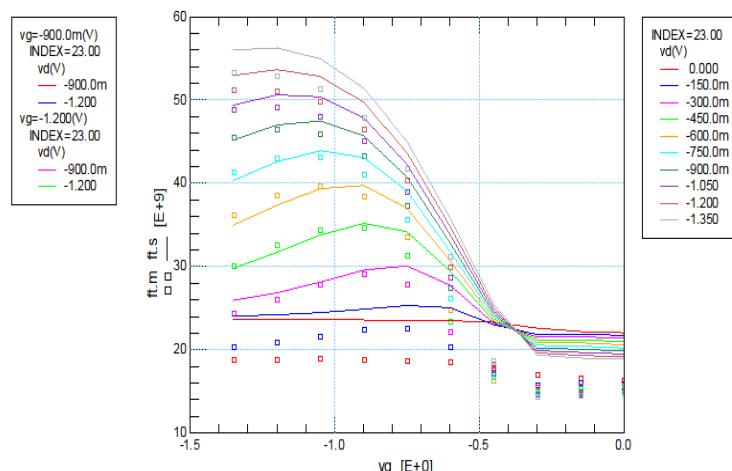
im(Y12) = f(Vg,Vd)

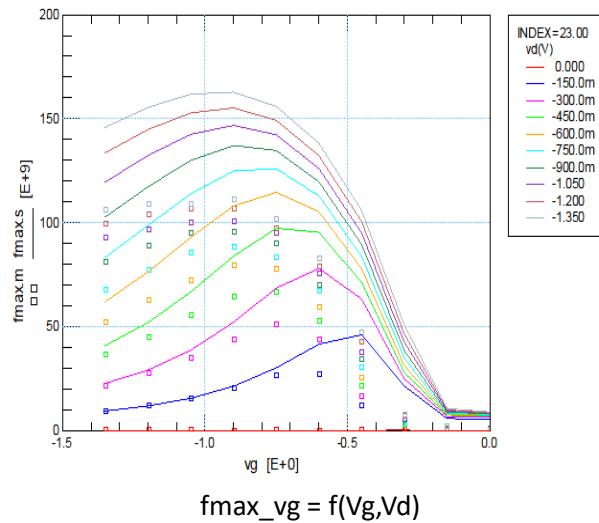


re(Y22) = f(Vg,Vd)



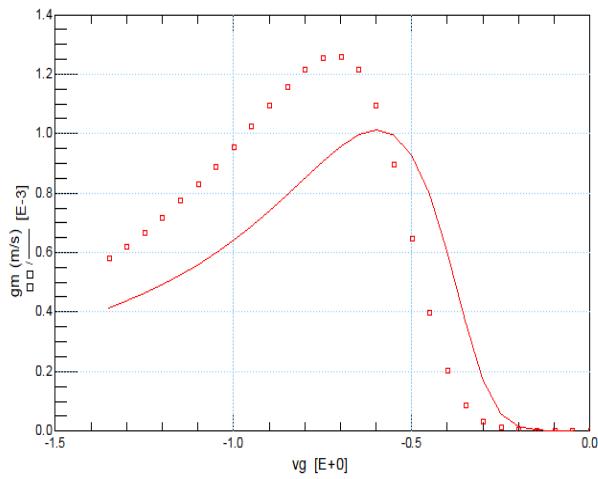
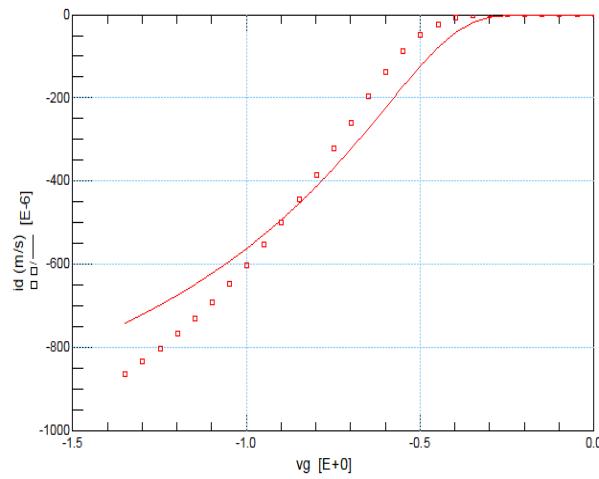
im(Y22) = f(Vg,Vd)

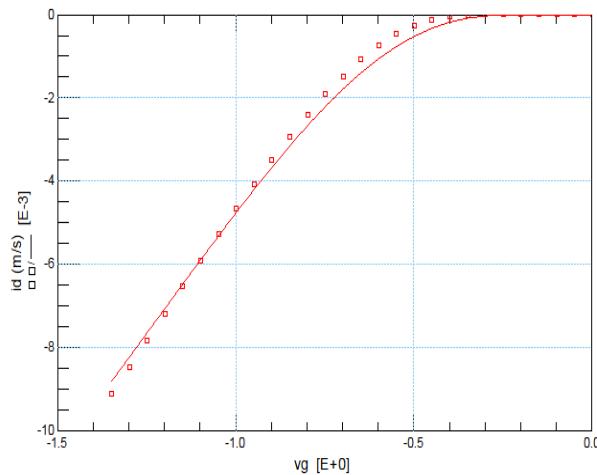
Verify Plots, $T = 27^\circ\text{C}$  $\text{re}(S11) = f(Vg, Vd)$  $\text{re}(S22) = f(Vg, Vd)$  $\text{im}(Y11) \text{ divided by } \omega$  $\text{re}(Z11) = f(Vg, Vd)$  $\text{im}(Z11) = f(Vg, Vd)$  $fT_{vg} = f(Vg, Vd)$



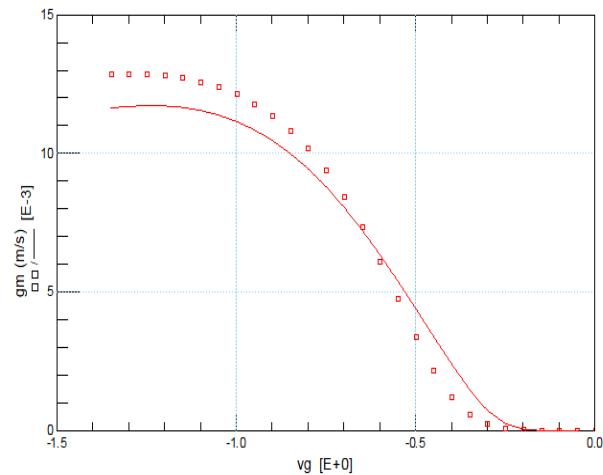
4.4 NF04_WF07u5_L0u13_S453A_70

$I_d V_g$, $T = 27^\circ\text{C}$



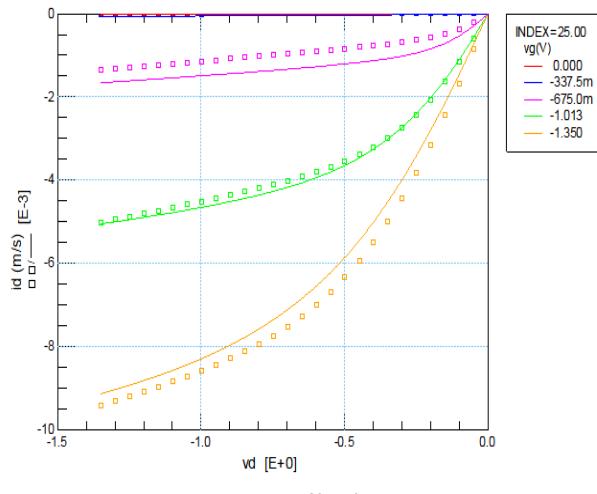


$$Id = f(Vg) @ Vd = -1.2V$$

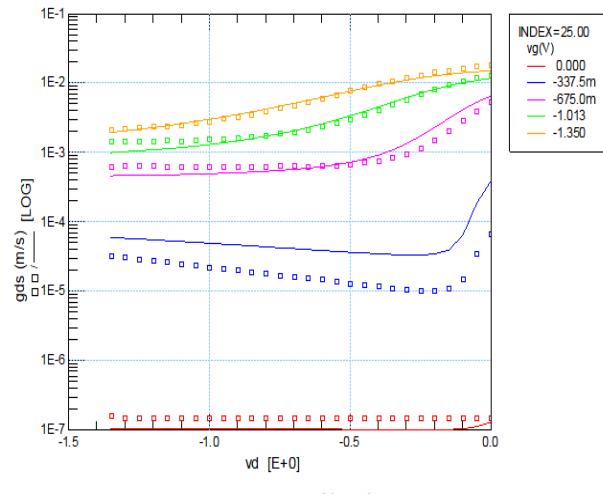


$$gm = f(Vg) @ Vd = -1.2V$$

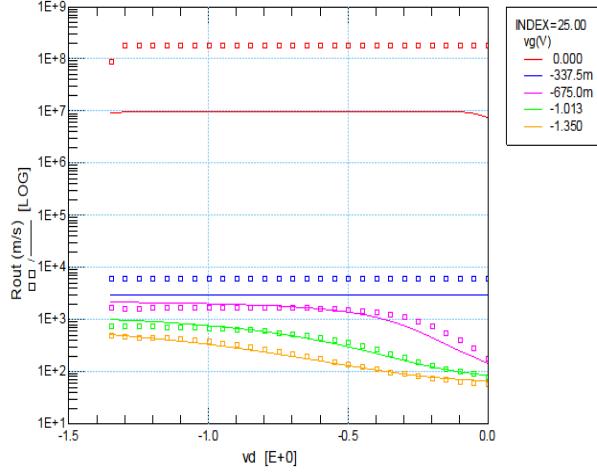
IdVd, T = 27°C



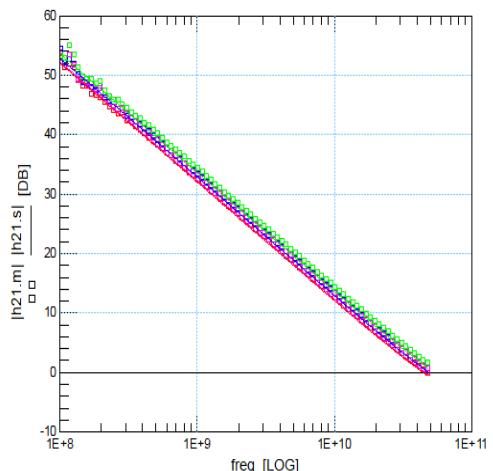
$$Id = f(Vd)$$



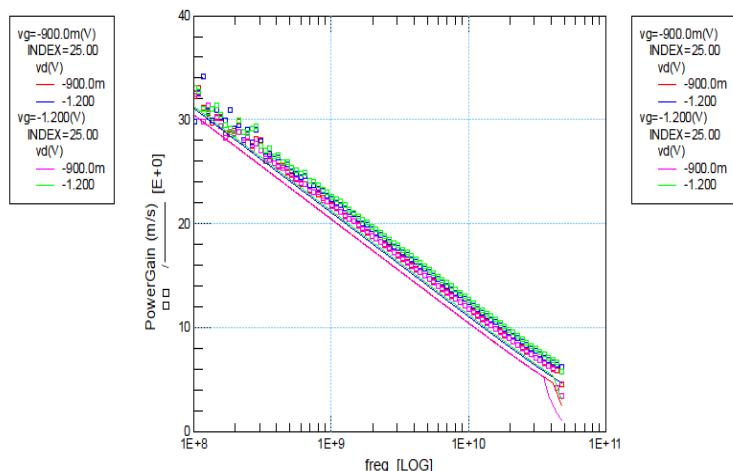
$$gds = f(Vd)$$



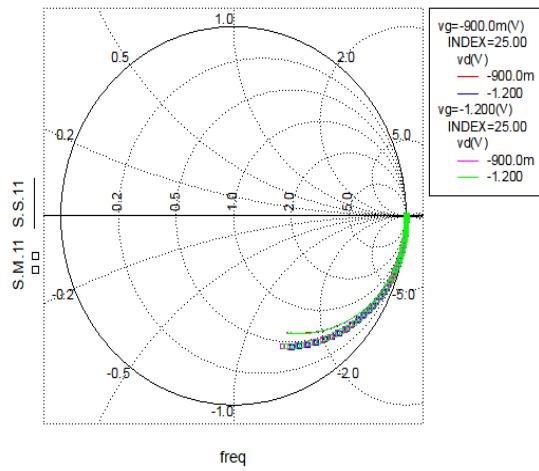
$$Rout = f(Vd)$$

S-Parameter, T = 27°C

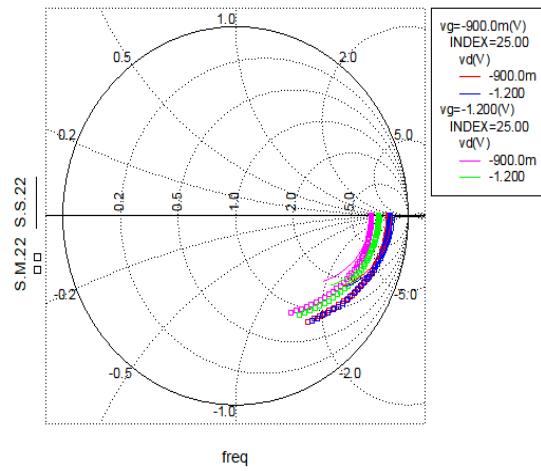
$$|h21| = f(Vg, Vd)$$



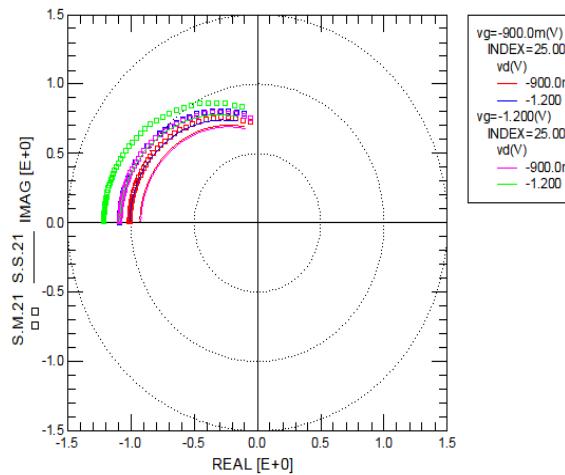
$$MSG/MAG = f(Vg, Vd)$$



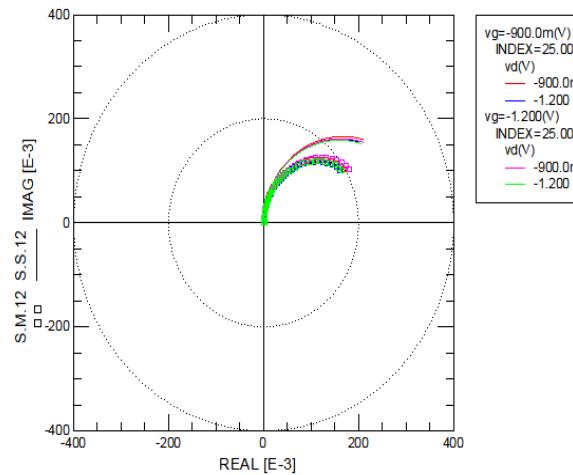
$$S11 = f(Vg, Vd)$$



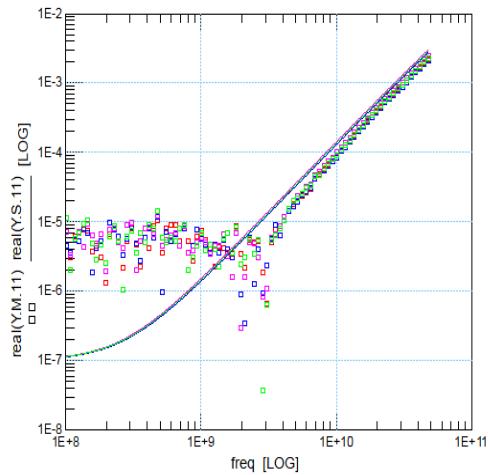
$$S22 = f(Vg, Vd)$$



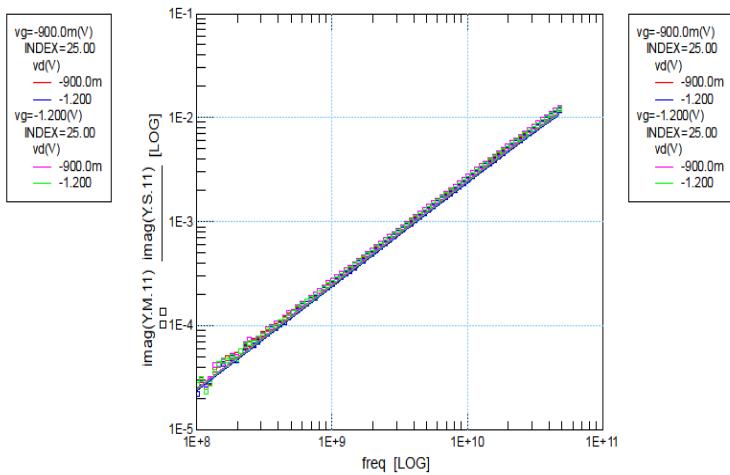
$$S21 = f(Vg, Vd)$$



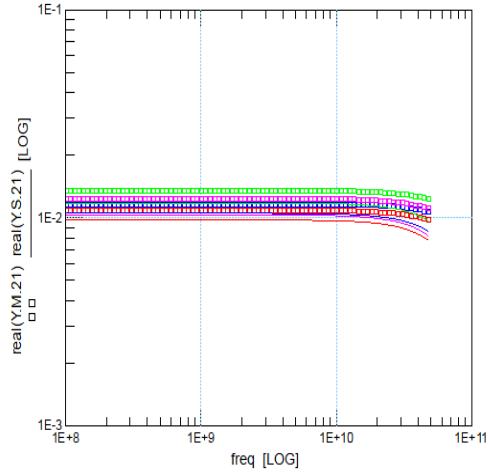
$$S12 = f(Vg, Vd)$$

Y-Parameter, T = 27°C

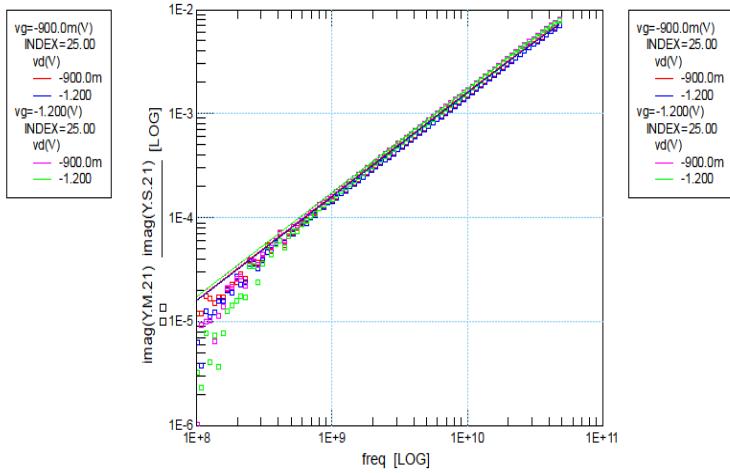
$$\text{re}(Y_{11}) = f(V_g, V_d)$$



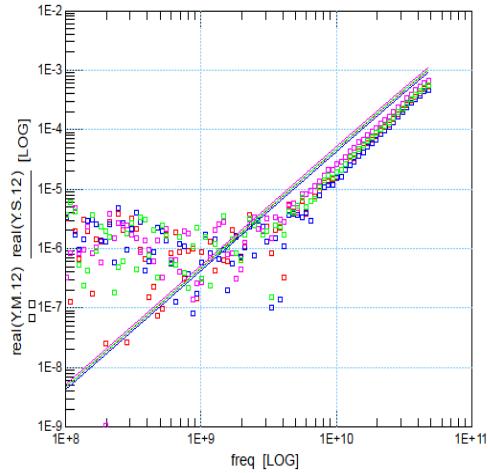
$$\text{im}(Y_{11}) = f(V_g, V_d)$$



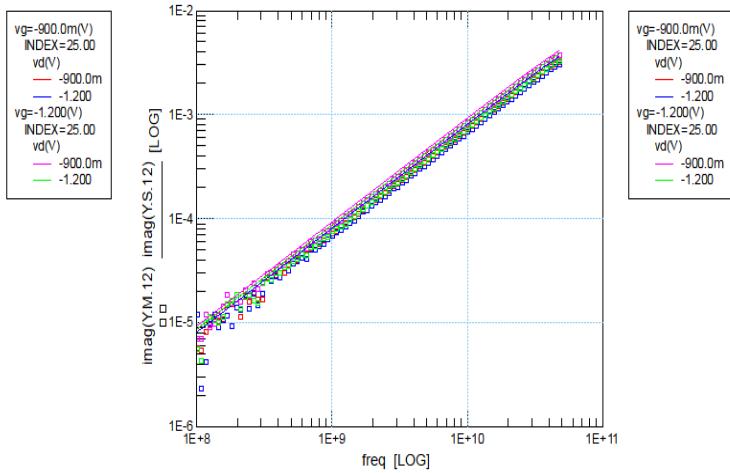
$$\text{re}(Y_{21}) = f(V_g, V_d)$$



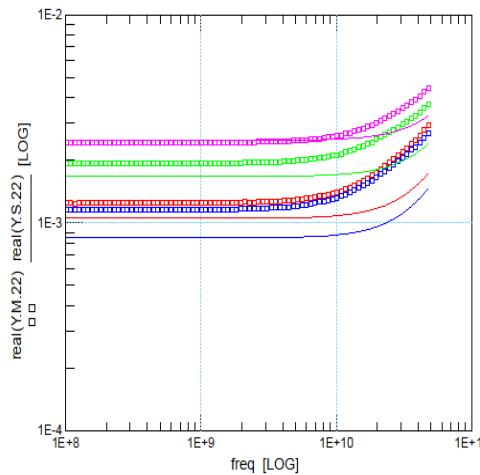
$$\text{im}(Y_{21}) = f(V_g, V_d)$$



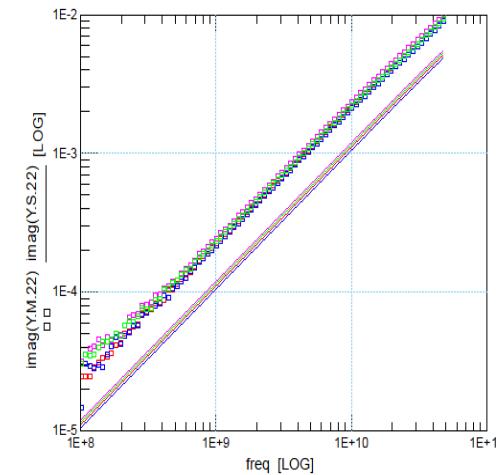
$$\text{re}(Y_{12}) = f(V_g, V_d)$$



$$\text{im}(Y_{12}) = f(V_g, V_d)$$

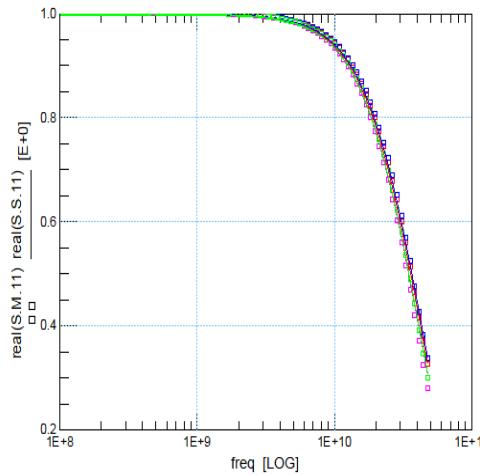


$$\text{re}(Y22) = f(Vg, Vd)$$

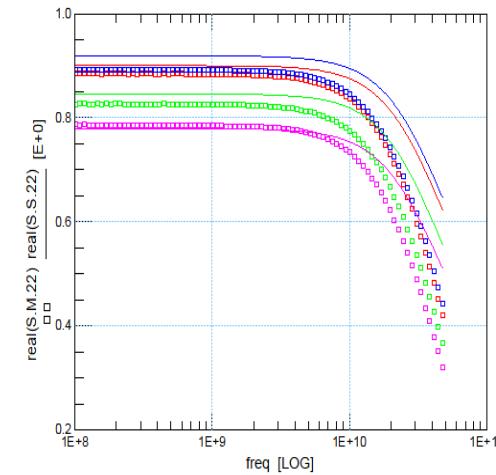


$$\text{im}(Y22) = f(Vg, Vd)$$

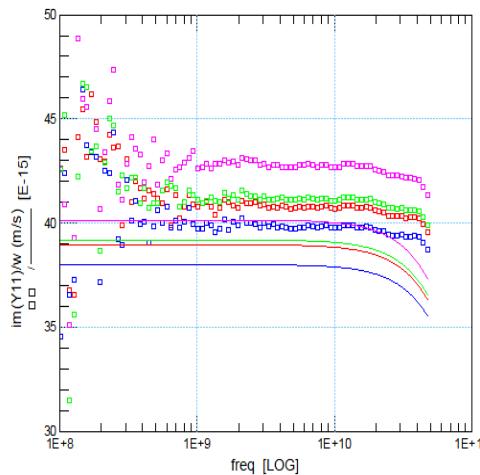
Verify Plots, T = 27°C



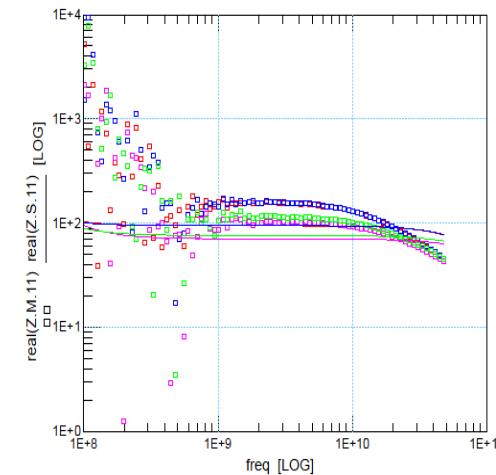
$$\text{re}(S11) = f(Vg, Vd)$$



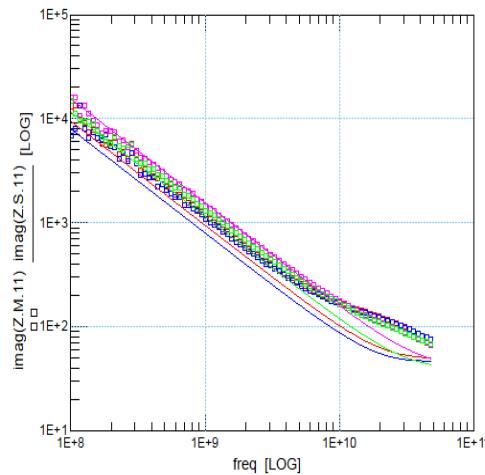
$$\text{re}(S22) = f(Vg, Vd)$$



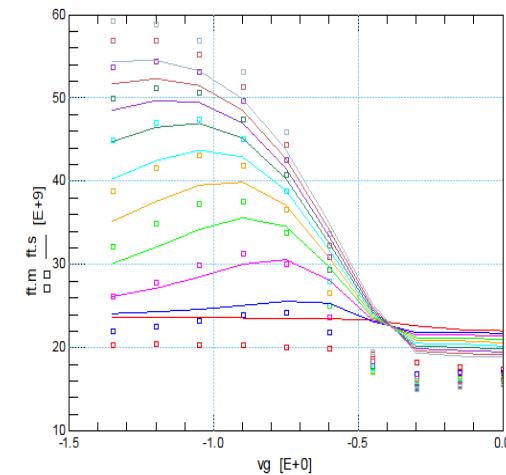
$$\text{im}(Y11) \text{ divided by } \omega$$



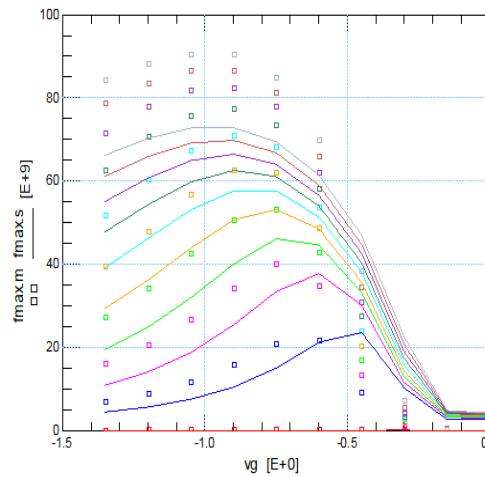
$$\text{re}(Z11) = f(Vg, Vd)$$



$$\text{im}(Z_{11}) = f(V_g, V_d)$$



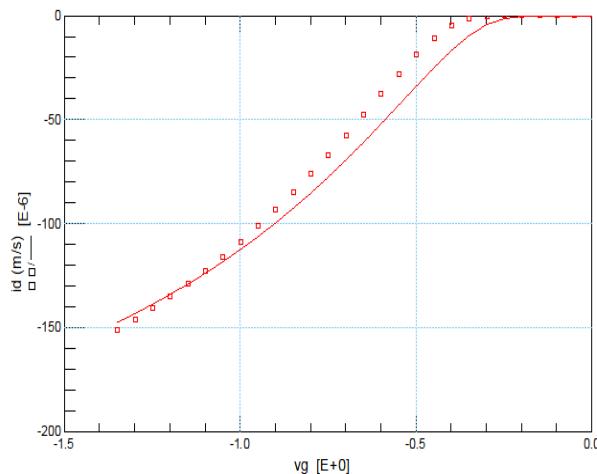
$$fT_{vg} = f(V_g, V_d)$$



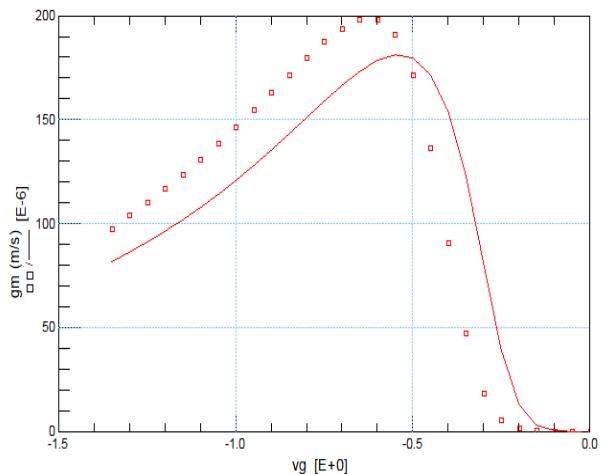
$$f_{\max,vg} = f(V_g, V_d)$$

4.5 NF04_WF05u0_L0u5_S453A_64

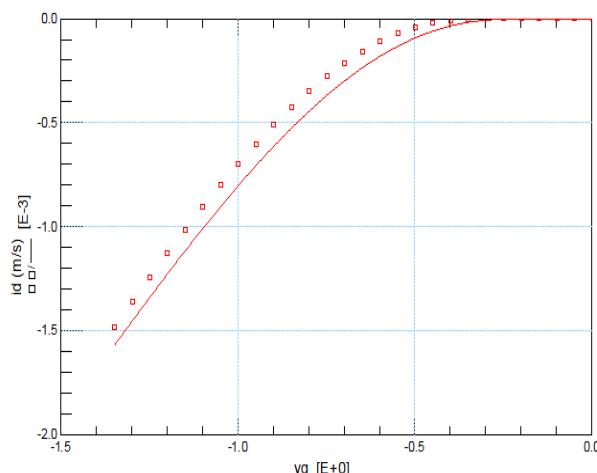
$IdVg$, $T = 27^\circ\text{C}$



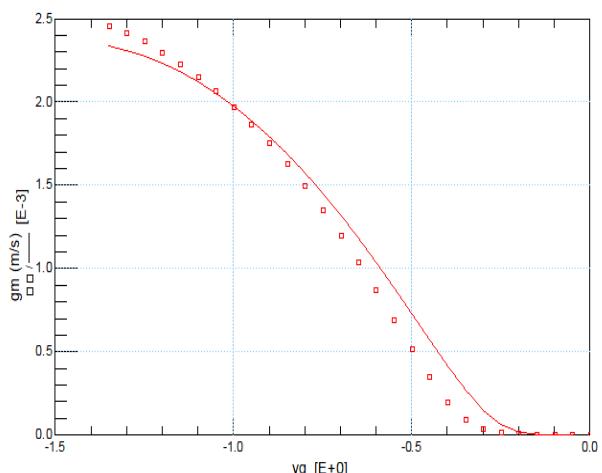
$Id = f(Vg) @ Vd = -0.05\text{V}$



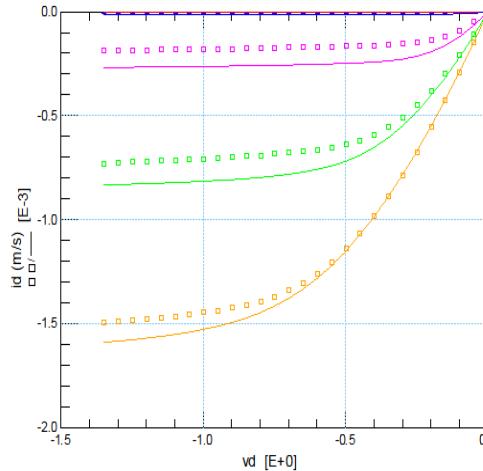
$gm = f(Vg) @ Vd = -0.05\text{V}$



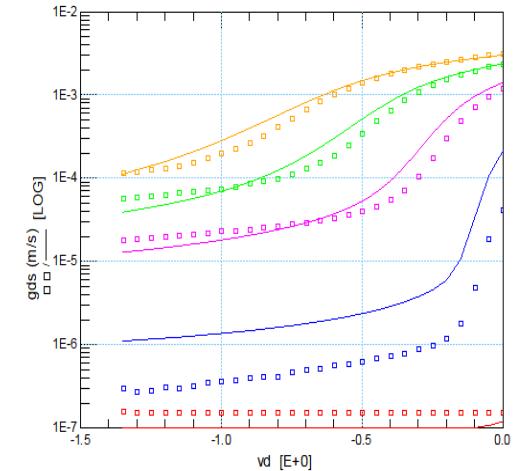
$Id = f(Vg) @ Vd = -1.2\text{V}$



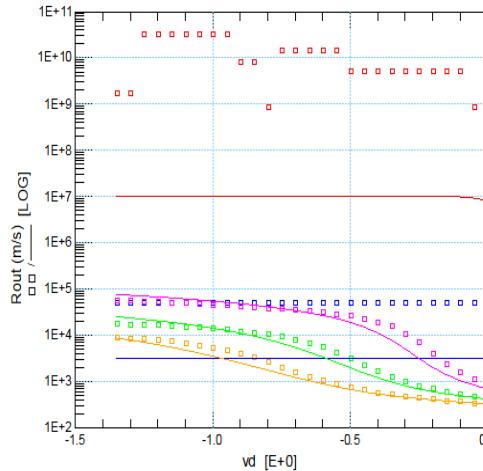
$gm = f(Vg) @ Vd = -1.2\text{V}$

IdVd, T = 27°C

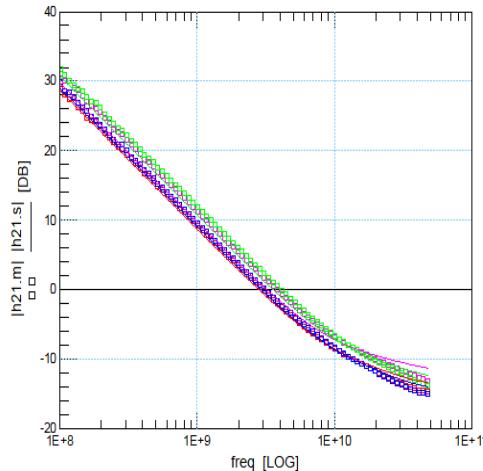
$$Id = f(Vd)$$



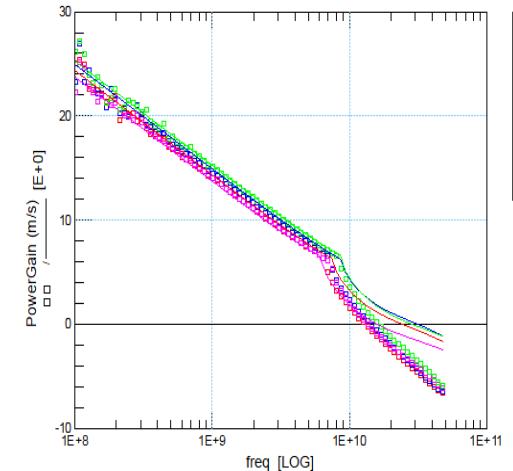
$$gds = f(Vd)$$



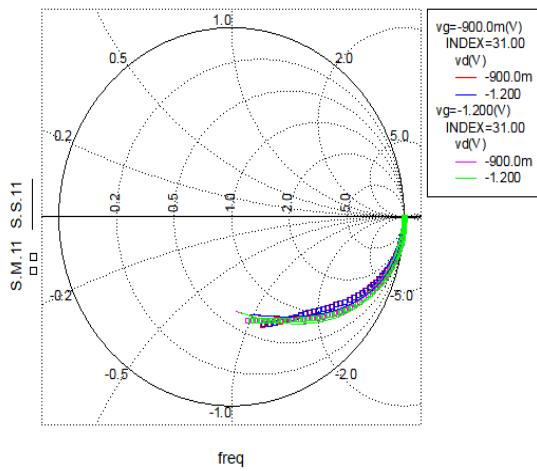
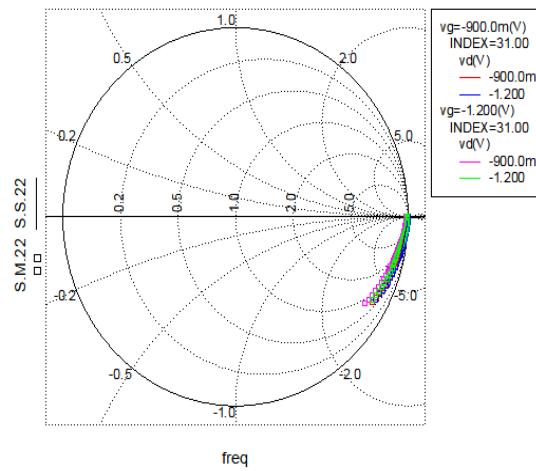
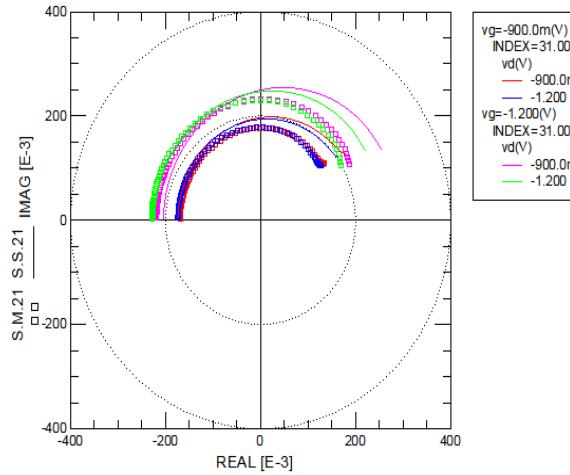
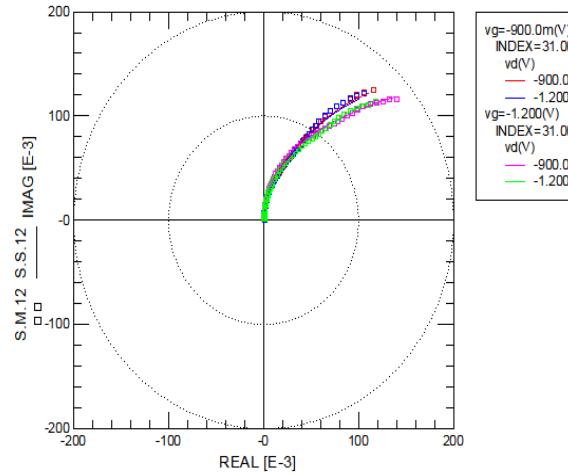
$$Rout = f(Vd)$$

S-Parameter, T = 27°C

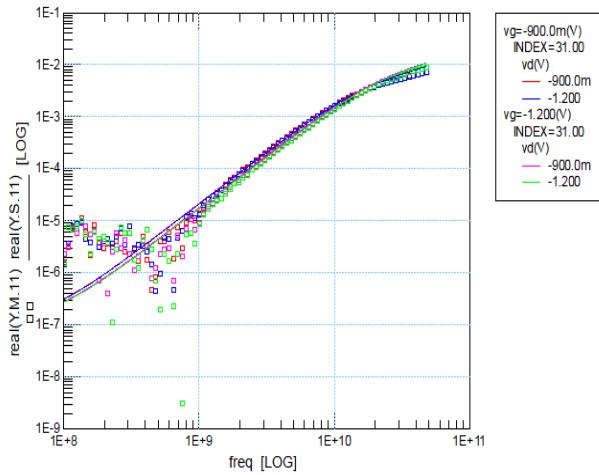
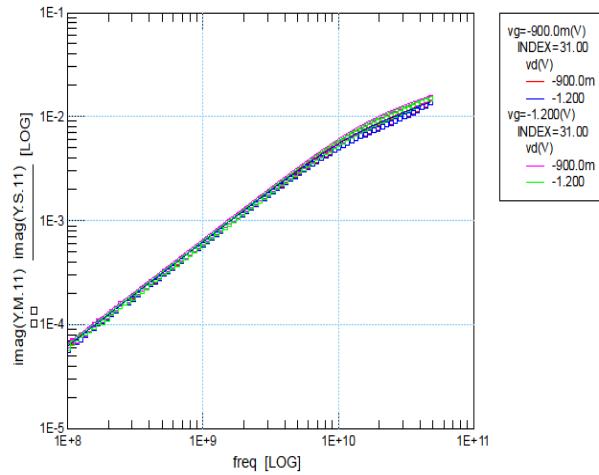
$$|h21| = f(Vg, Vd)$$

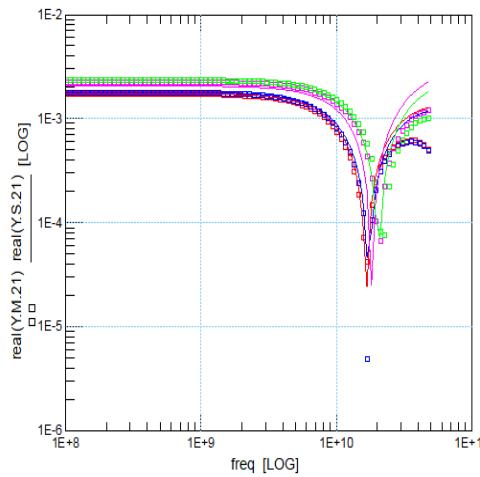
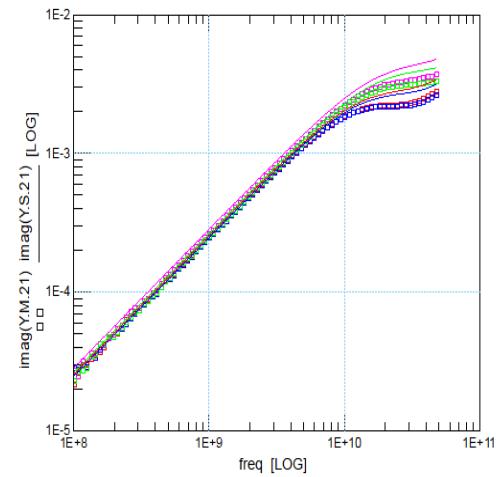
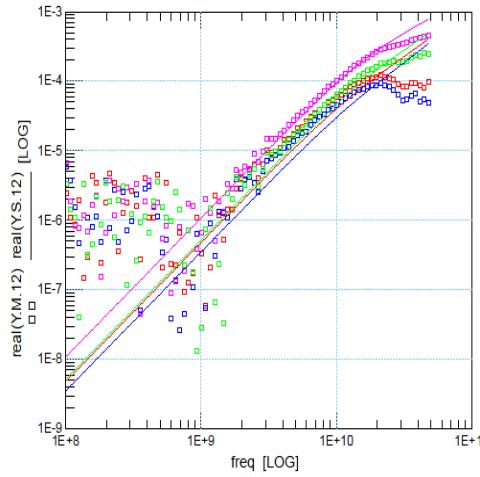
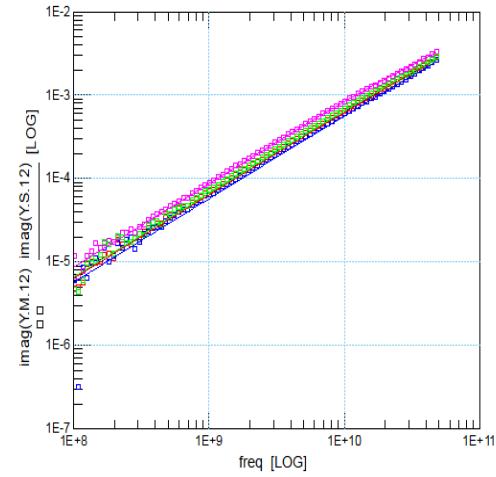
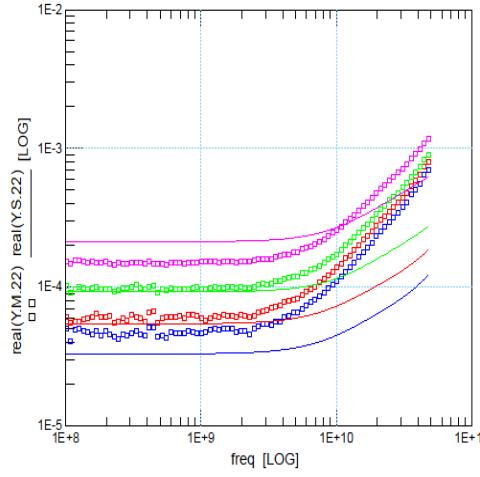
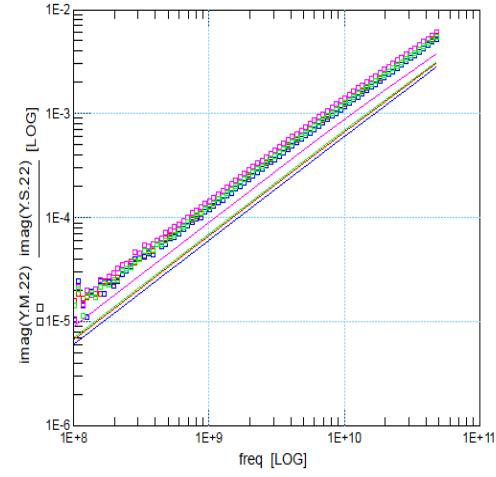


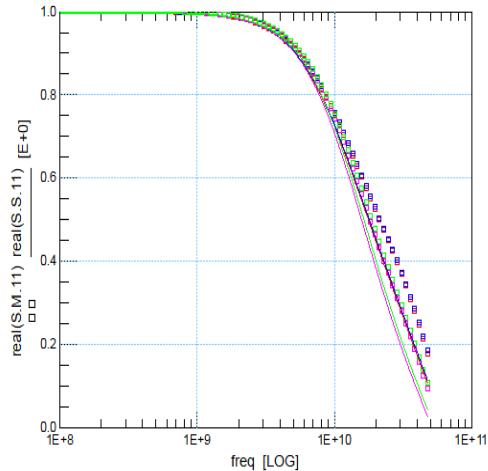
$$MSG/MAG = f(Vg, Vd)$$

 $S11 = f(Vg, Vd)$  $S22 = f(Vg, Vd)$  $S21 = f(Vg, Vd)$  $S12 = f(Vg, Vd)$

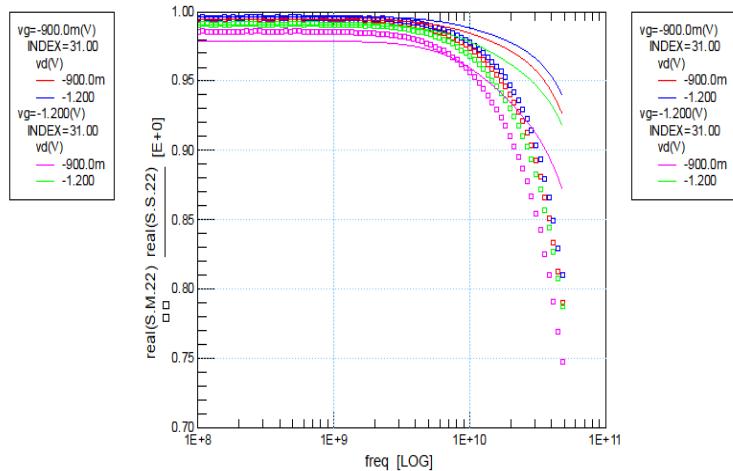
Y-Parameter, $T = 27^\circ\text{C}$

 $\text{re}(Y_{11}) = f(Vg, Vd)$  $\text{im}(Y_{11}) = f(Vg, Vd)$

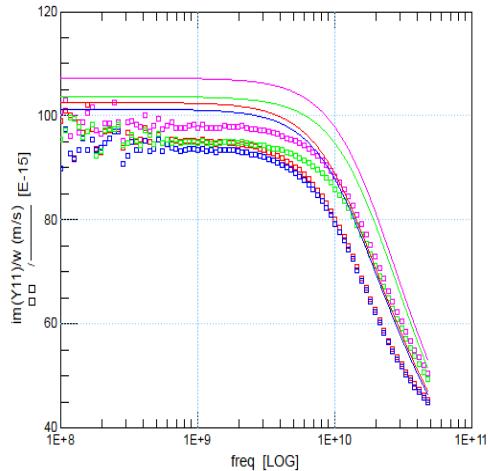
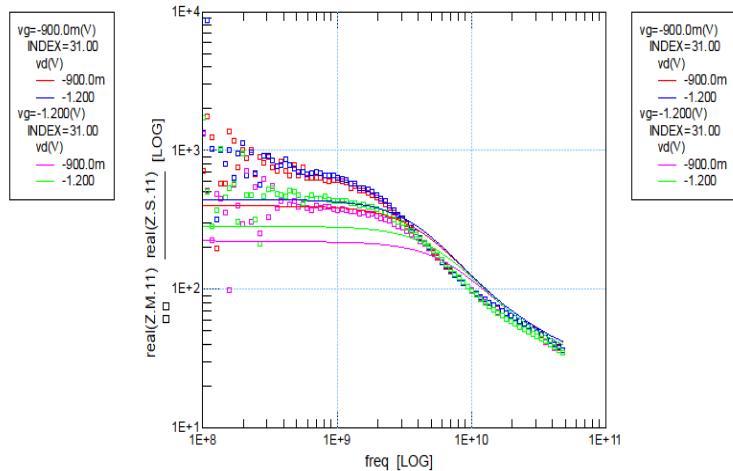
re(Y₂₁) = f(V_g, V_d)im(Y₂₁) = f(V_g, V_d)re(Y₁₂) = f(V_g, V_d)im(Y₁₂) = f(V_g, V_d)re(Y₂₂) = f(V_g, V_d)im(Y₂₂) = f(V_g, V_d)

Verify Plots, $T = 27^\circ\text{C}$ 

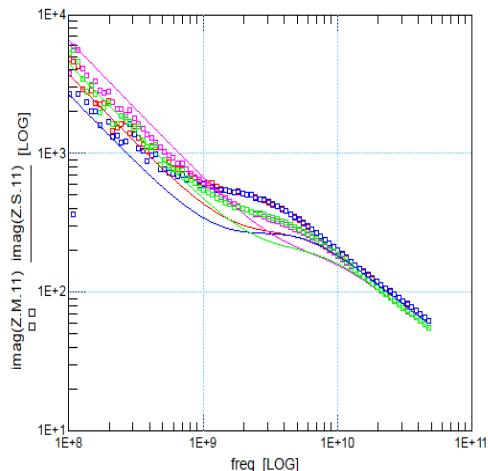
re(S11) = f(Vg, Vd)



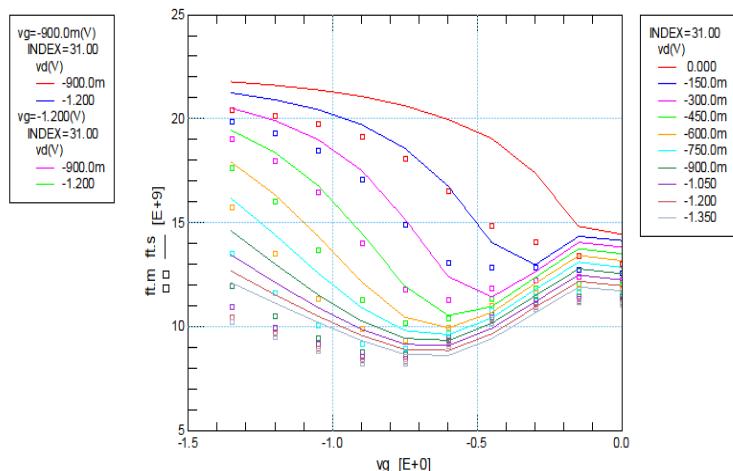
re(S22) = f(Vg, Vd)

im(Y11) divided by ω 

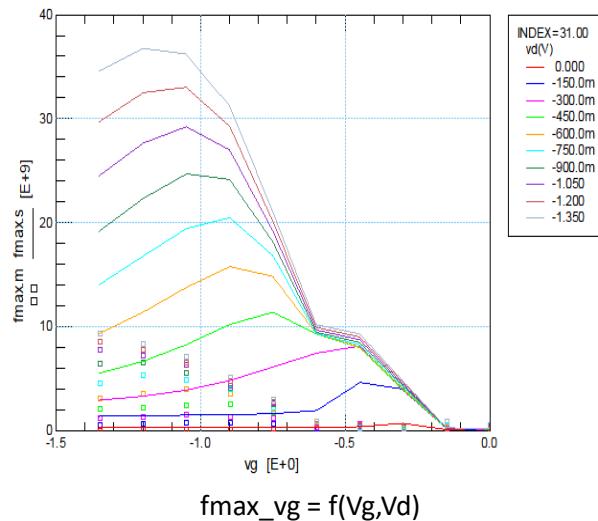
re(Z11) = f(Vg, Vd)



im(Z11) = f(Vg, Vd)

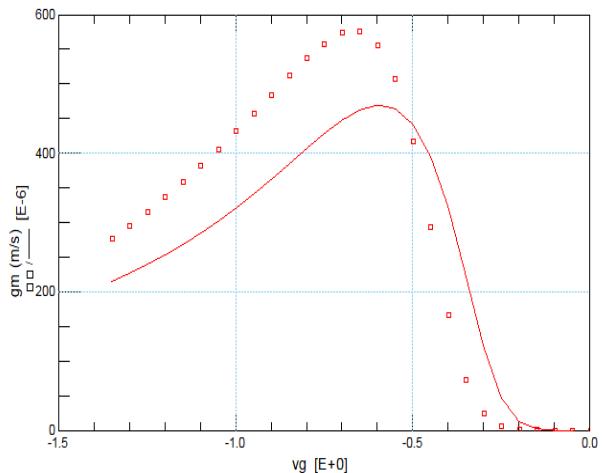
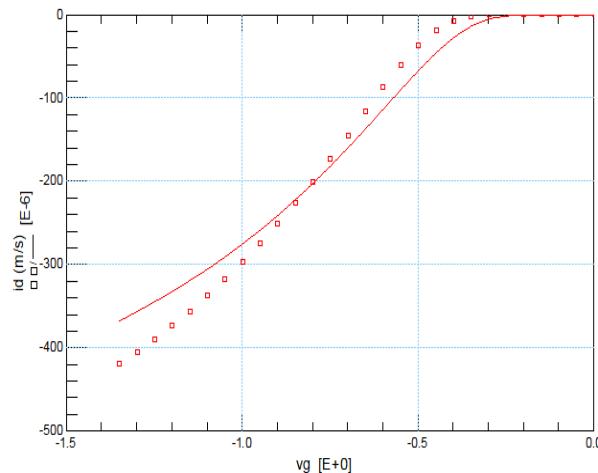


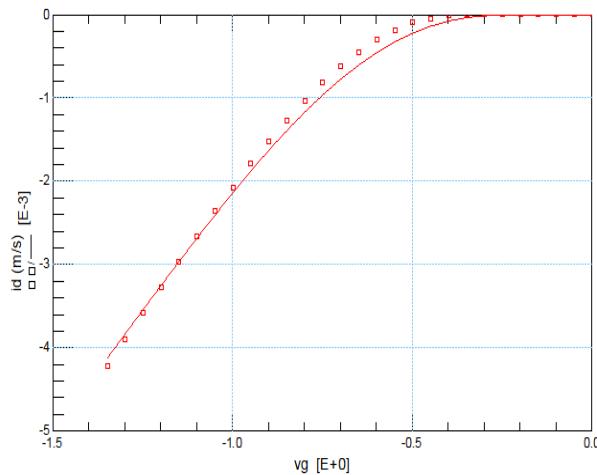
fT_vg = f(Vg, Vd)



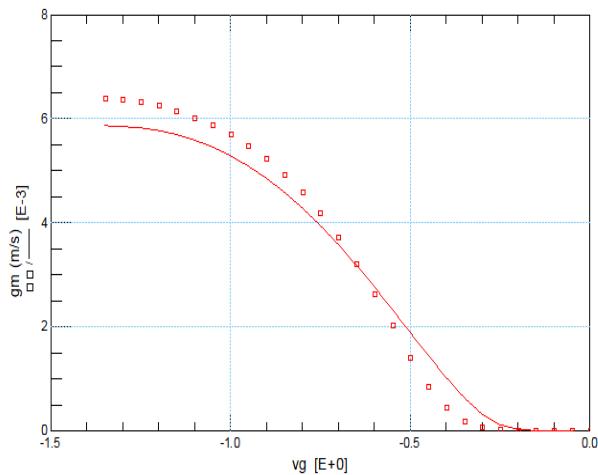
4.6 NF04_WF05u0_L0u18_S453A_63

I_dVg , $T = 27^\circ C$



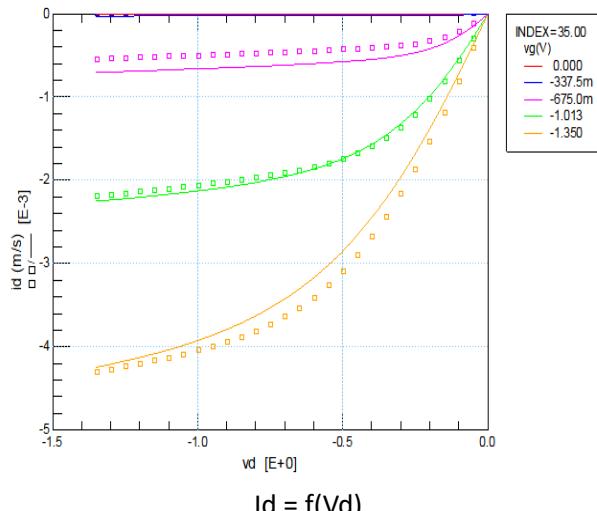


Id = f(Vg) @ Vd = -1.2V

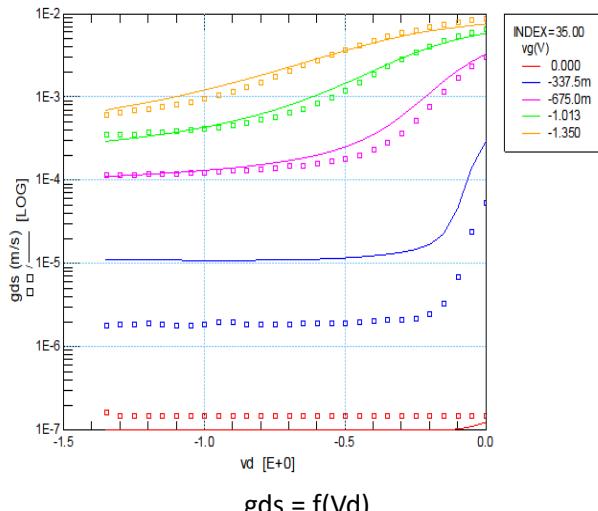


gm = f(Vg) @ Vd = -1.2V

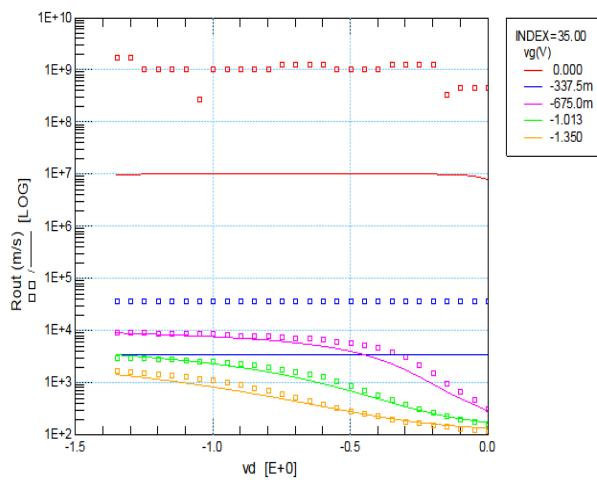
IdVd, T = 27°C



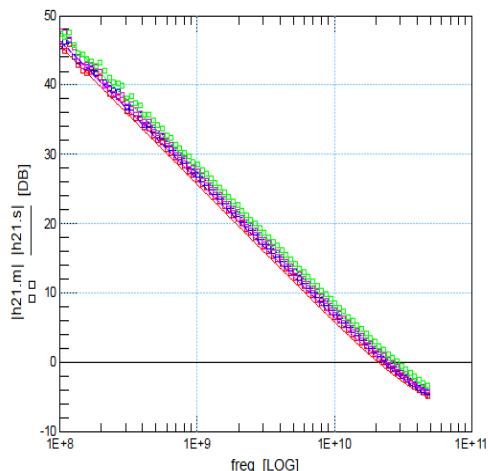
Id = f(Vd)



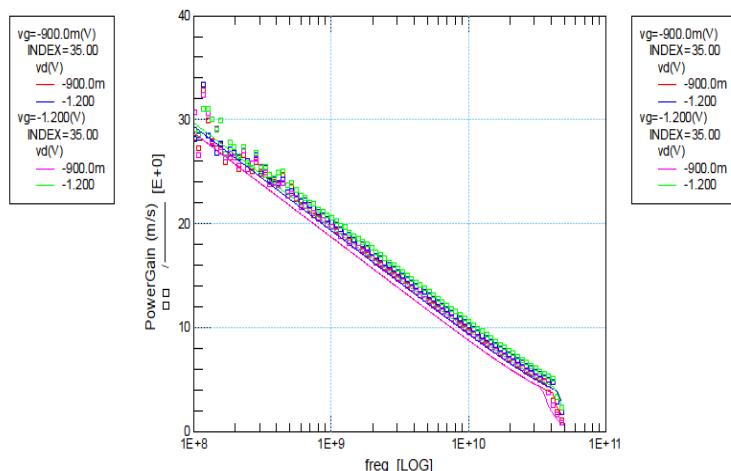
gds = f(Vd)



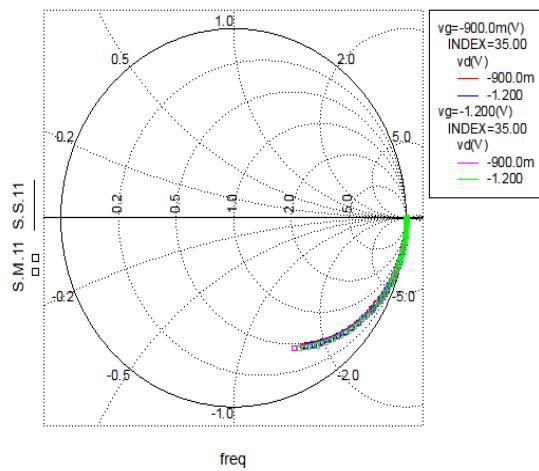
Rout = f(Vd)

S-Parameter, T = 27°C

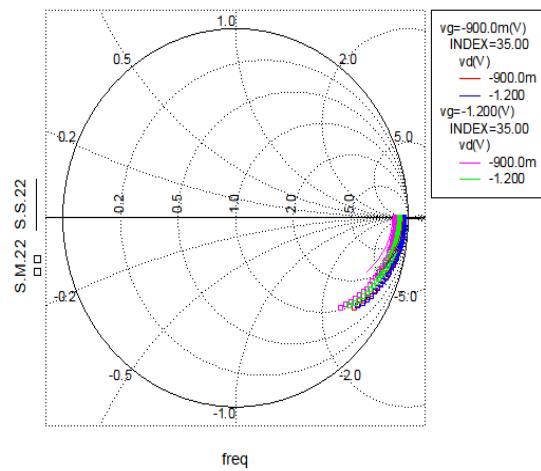
$$|h21| = f(Vg, Vd)$$



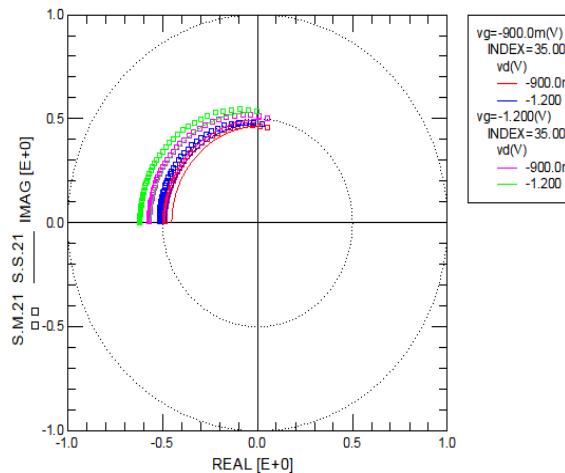
$$MSG/MAG = f(Vg, Vd)$$



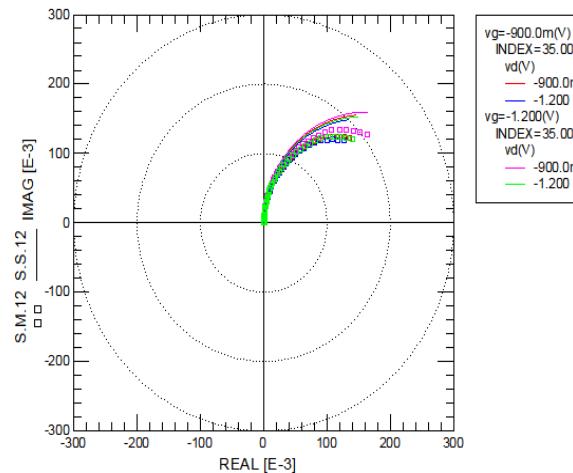
$$S11 = f(Vg, Vd)$$



$$S22 = f(Vg, Vd)$$

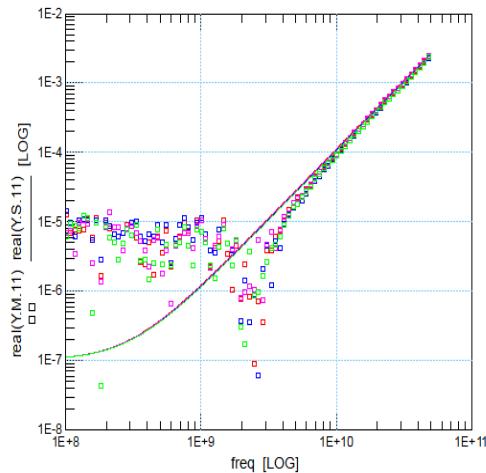


$$S21 = f(Vg, Vd)$$

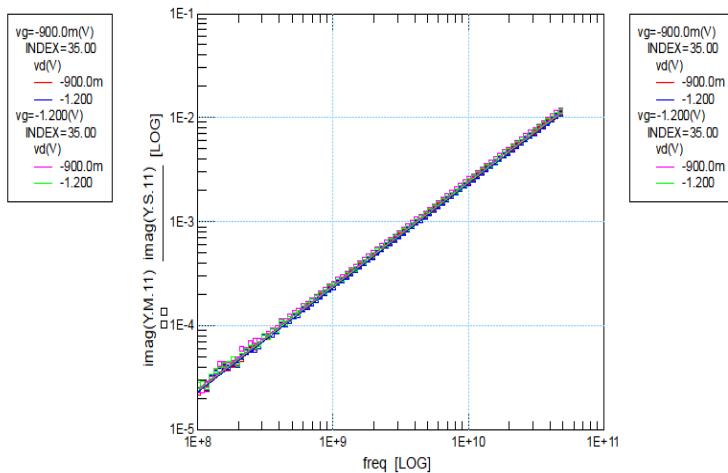


$$S12 = f(Vg, Vd)$$

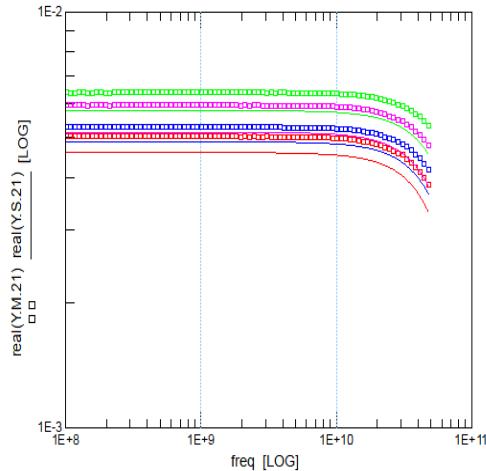
Y-Parameter, T = 27°C



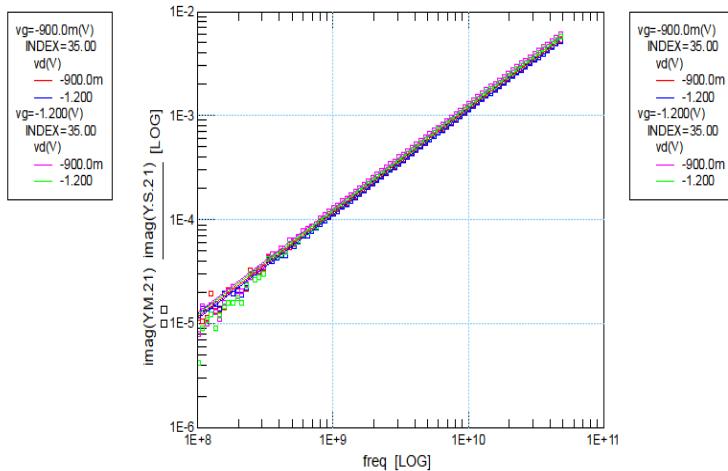
$$\text{re}(Y_{11}) = f(V_g, V_d)$$



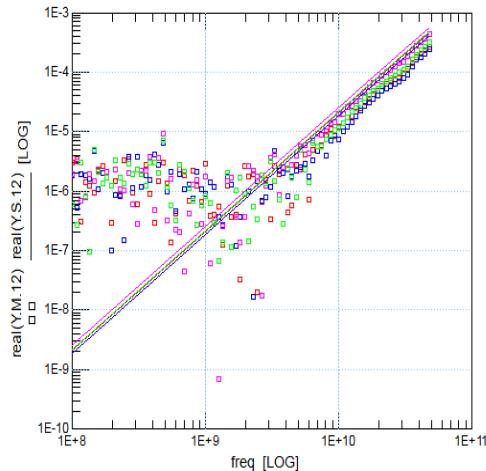
$$\text{im}(Y_{11}) = f(V_g, V_d)$$



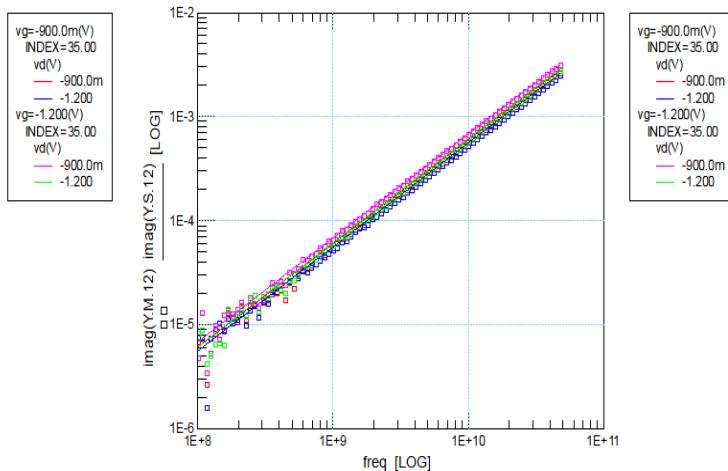
$$\text{re}(Y_{21}) = f(V_g, V_d)$$



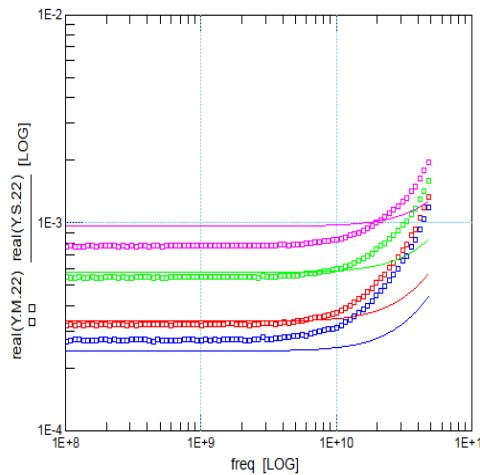
$$\text{im}(Y_{21}) = f(V_g, V_d)$$



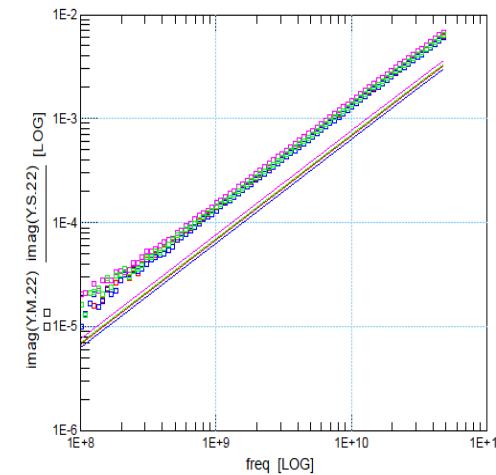
$$\text{re}(Y_{12}) = f(V_g, V_d)$$



$$\text{im}(Y_{12}) = f(V_g, V_d)$$

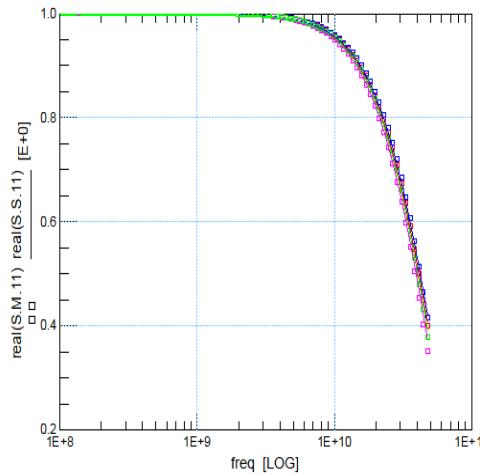


$$\text{re}(Y22) = f(Vg, Vd)$$

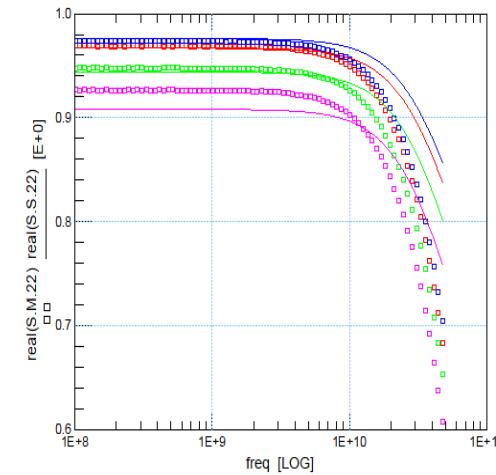


$$\text{im}(Y22) = f(Vg, Vd)$$

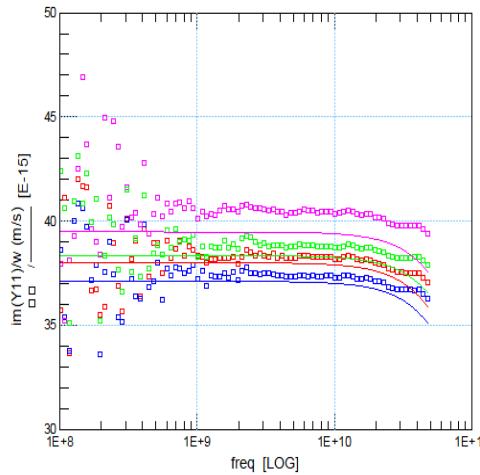
Verify Plots, T = 27°C



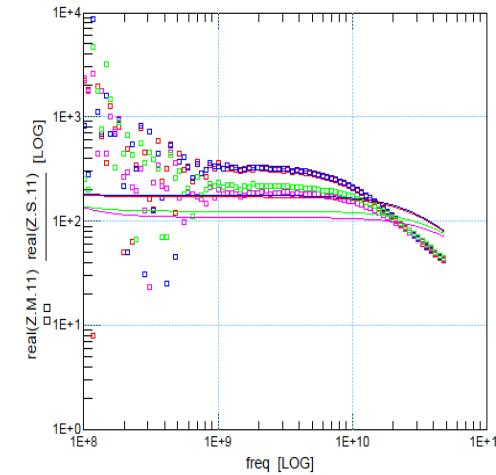
$$\text{re}(S11) = f(Vg, Vd)$$



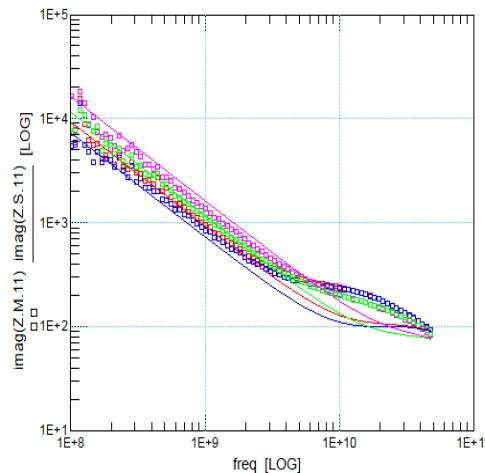
$$\text{re}(S22) = f(Vg, Vd)$$



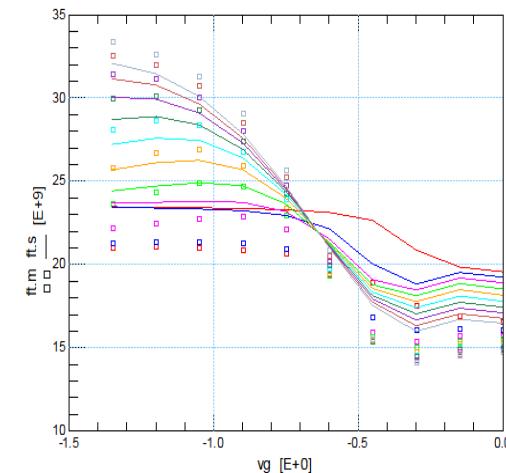
$$\text{im}(Y11) \text{ divided by } \omega$$



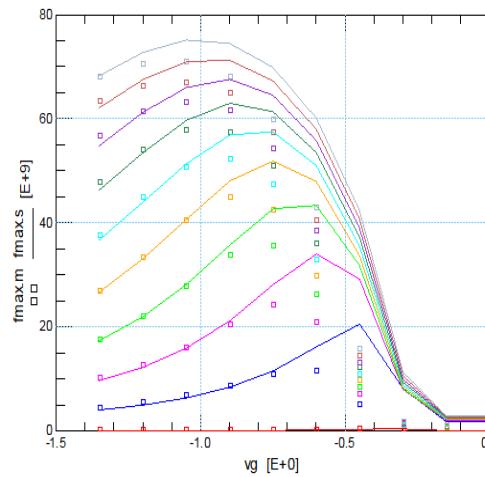
$$\text{re}(Z11) = f(Vg, Vd)$$



$$\text{im}(Z_{11}) = f(V_g, V_d)$$



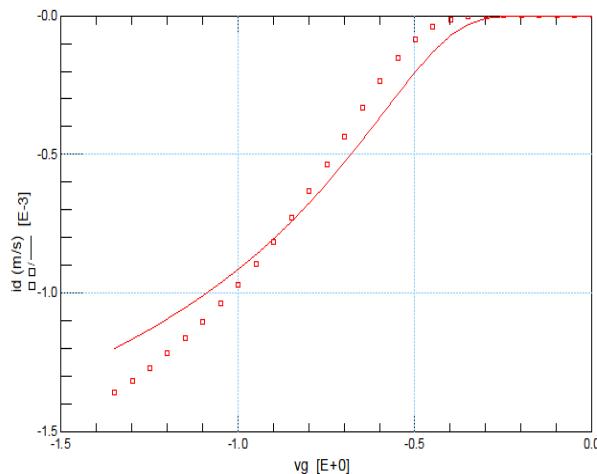
$$fT_{vg} = f(V_g, V_d)$$



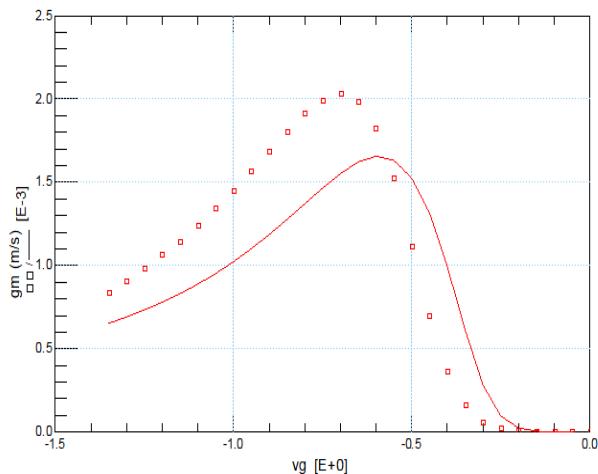
$$f_{\max,vg} = f(V_g, V_d)$$

4.7 NF05_WF10u0_L0u13_S453A_72

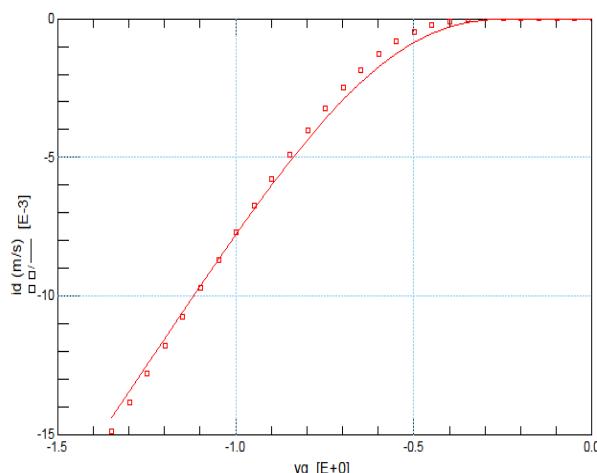
$IdVg$, $T = 27^\circ\text{C}$



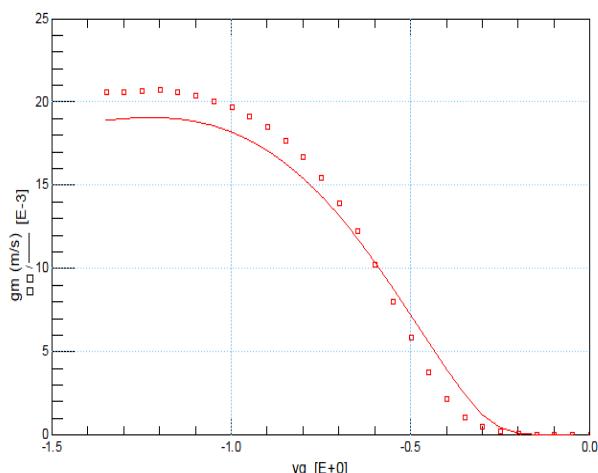
$Id = f(Vg)$ @ $Vd = -0.05V$



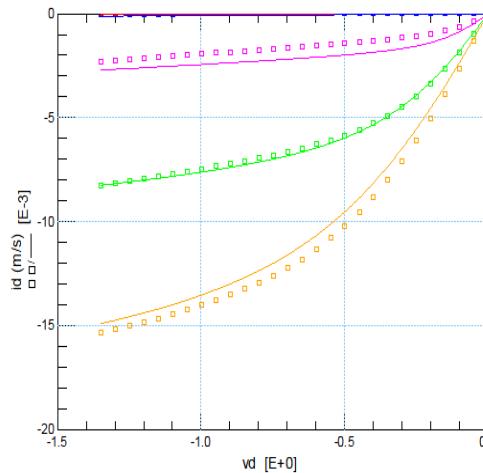
$gm = f(Vg)$ @ $Vd = -0.05V$



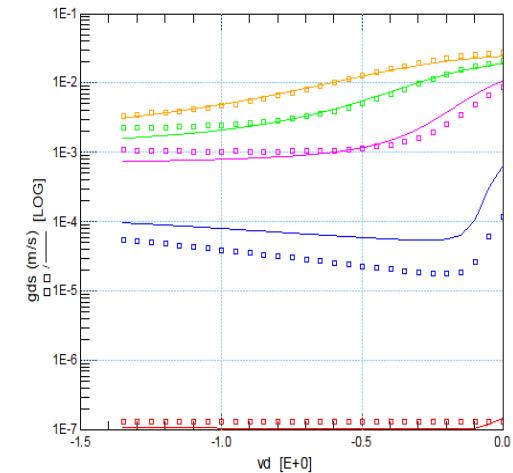
$Id = f(Vg)$ @ $Vd = -1.2V$



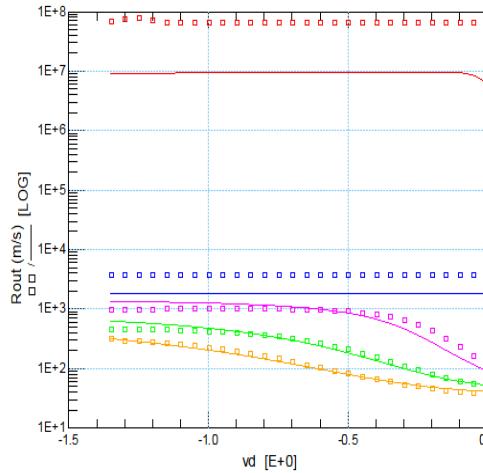
$gm = f(Vg)$ @ $Vd = -1.2V$

IdVd, T = 27°C

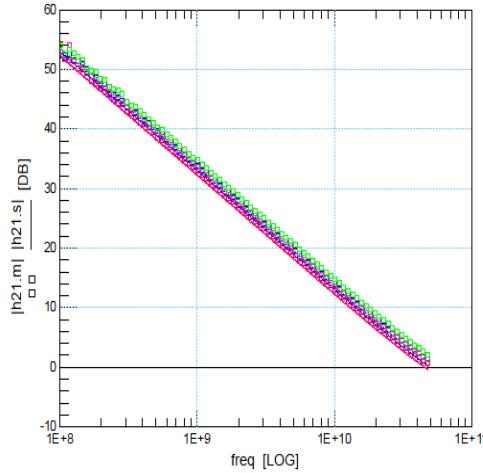
$$Id = f(Vd)$$



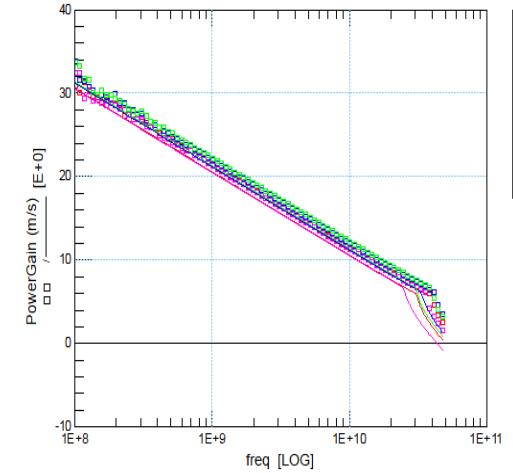
$$gds = f(Vd)$$



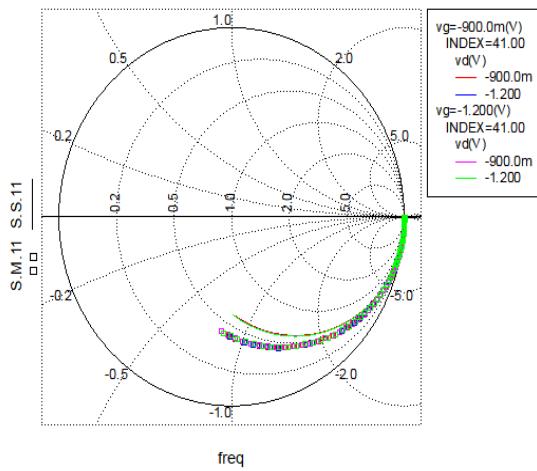
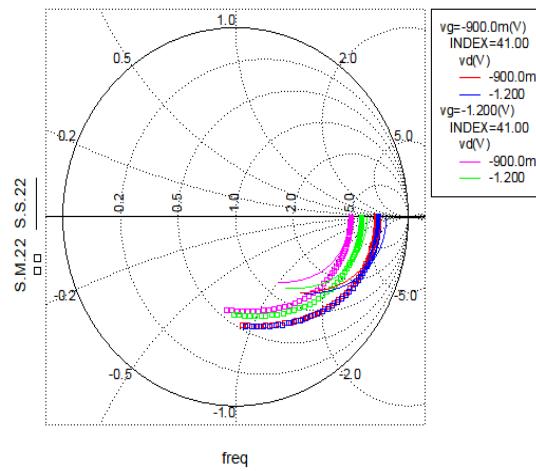
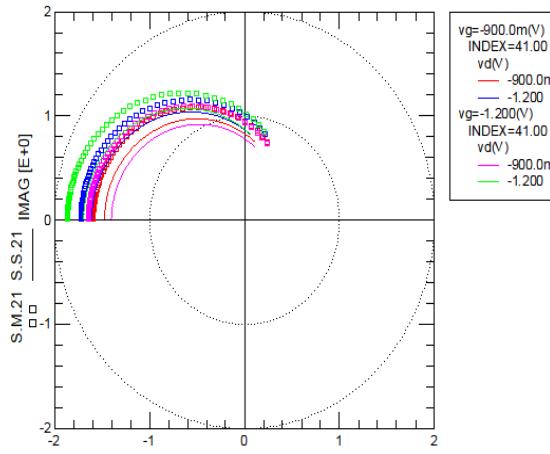
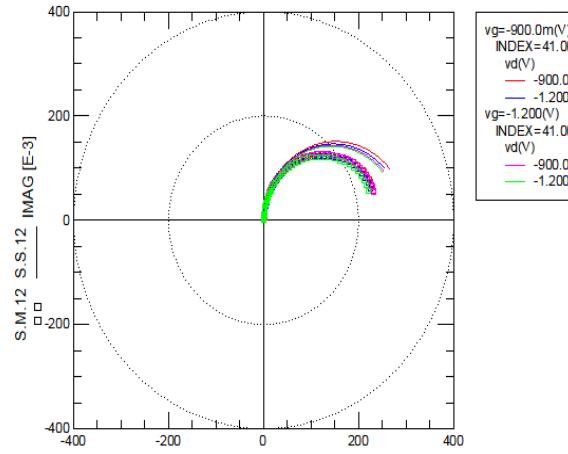
$$Rout = f(Vd)$$

S-Parameter, T = 27°C

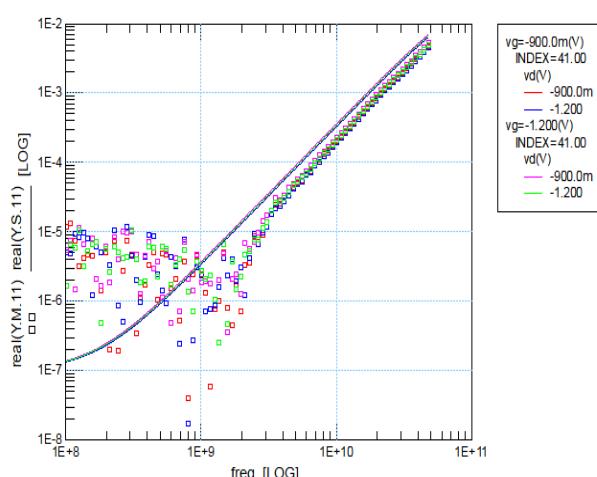
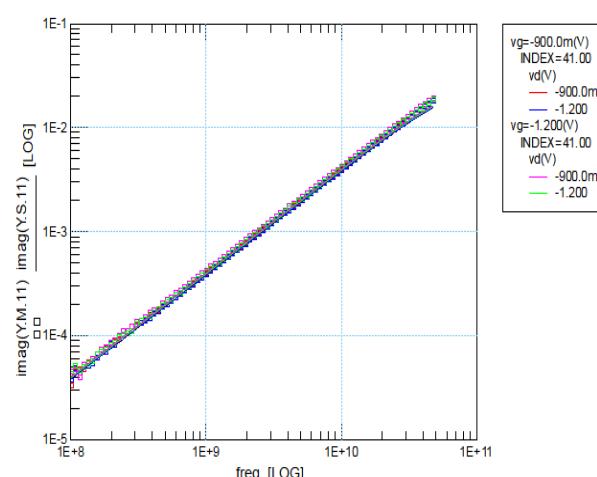
$$|h21| = f(Vg, Vd)$$

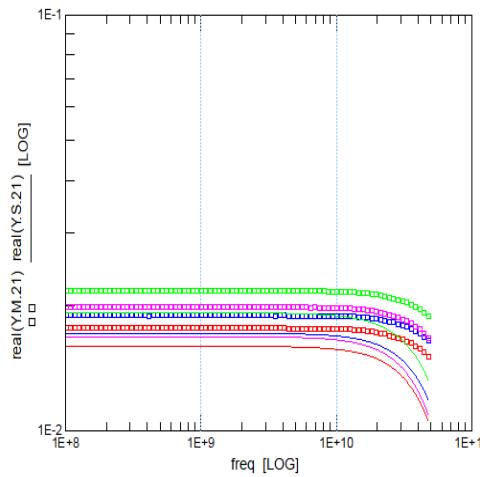


$$MSG/MAG = f(Vg, Vd)$$

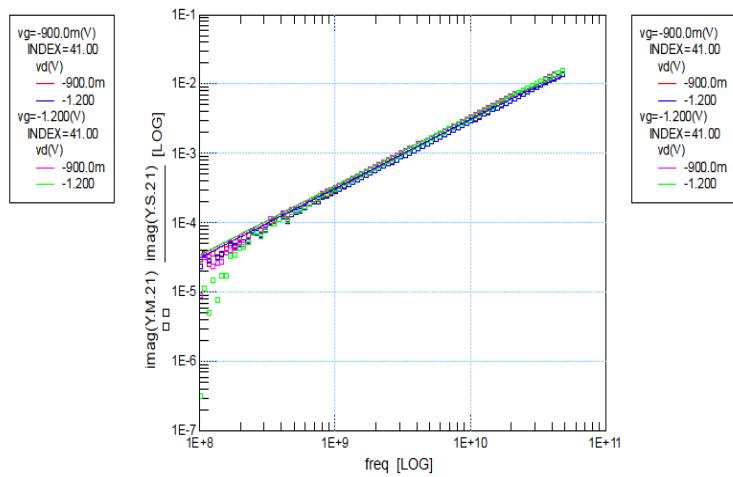
 $S_{11} = f(Vg, Vd)$  $S_{22} = f(Vg, Vd)$  $S_{21} = f(Vg, Vd)$  $S_{12} = f(Vg, Vd)$

Y-Parameter, $T = 27^\circ C$

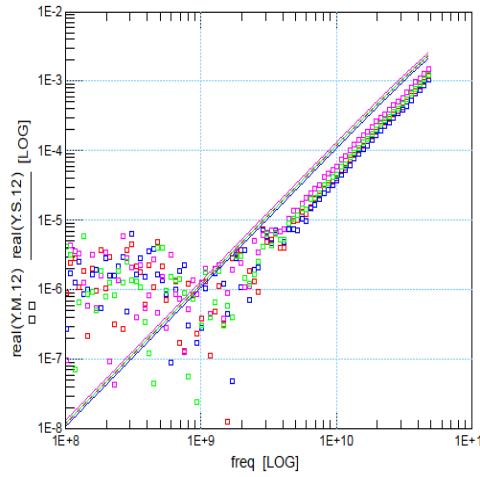
 $re(Y_{11}) = f(Vg, Vd)$  $im(Y_{11}) = f(Vg, Vd)$



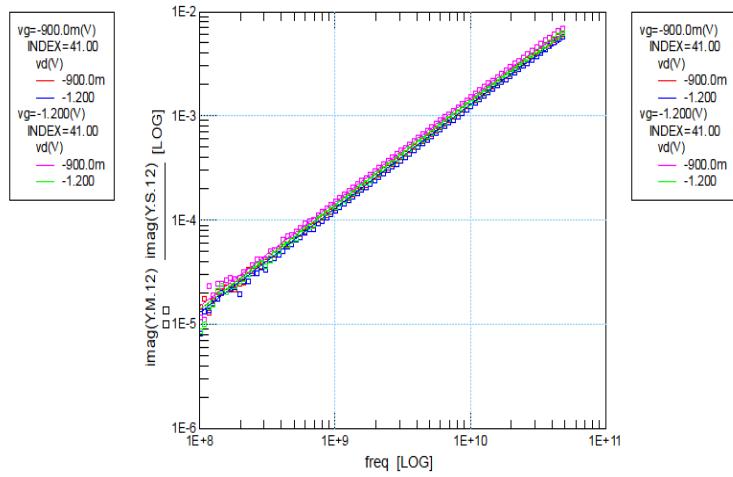
re(Y21) = f(Vg,Vd)



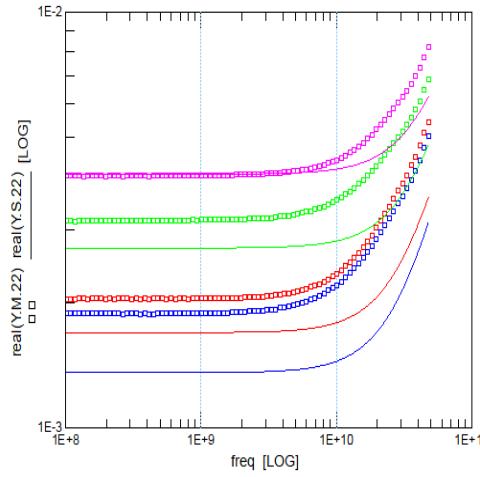
im(Y21) = f(Vg,Vd)



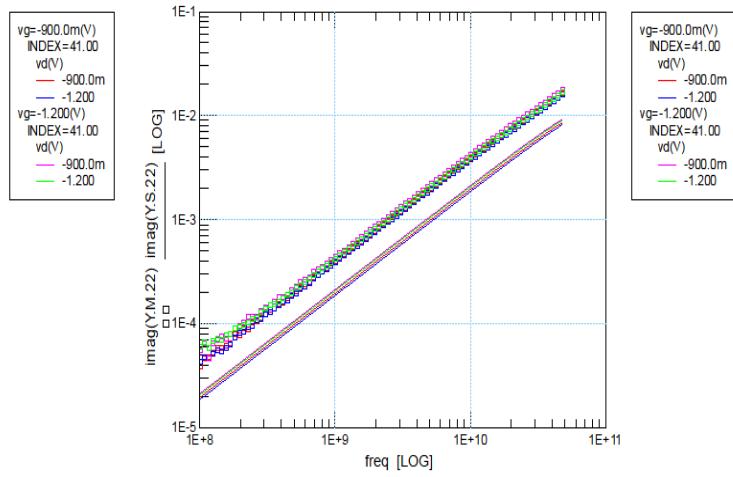
re(Y12) = f(Vg,Vd)



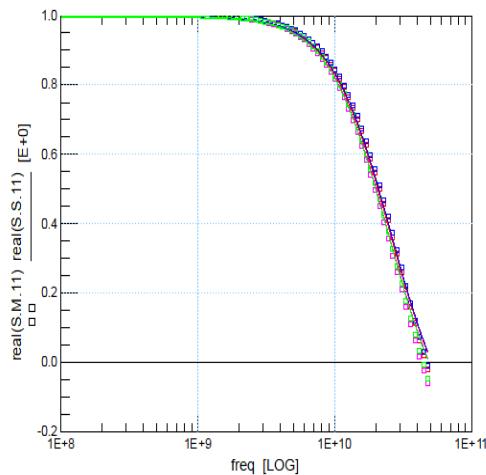
im(Y12) = f(Vg,Vd)



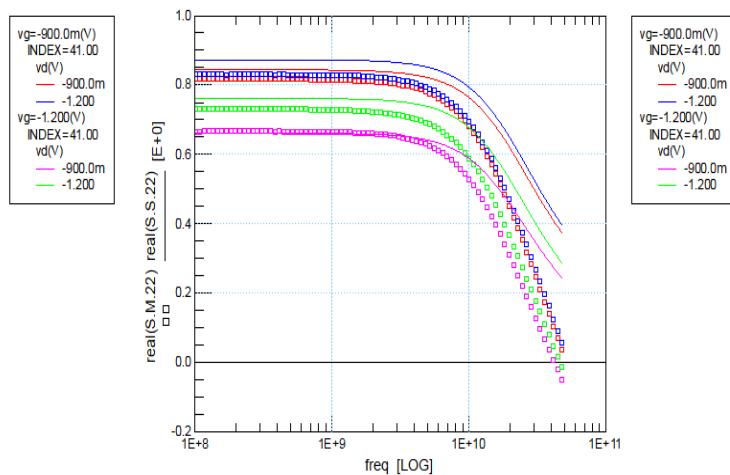
re(Y22) = f(Vg,Vd)



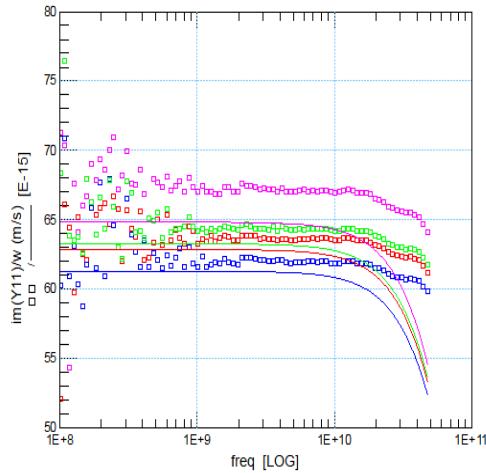
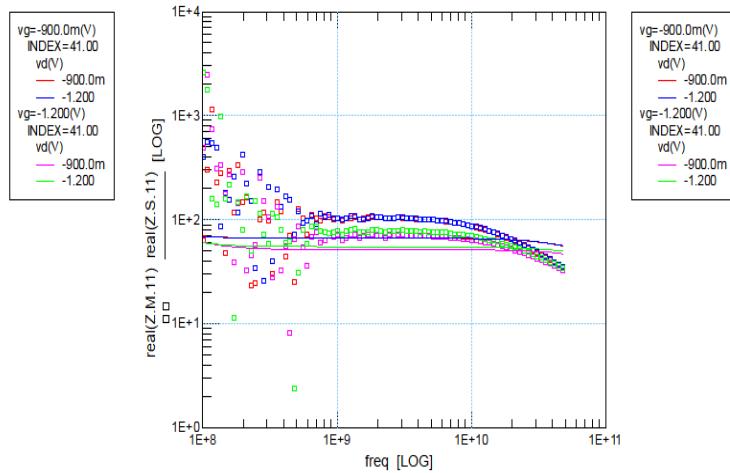
im(Y22) = f(Vg,Vd)

Verify Plots, $T = 27^\circ\text{C}$ 

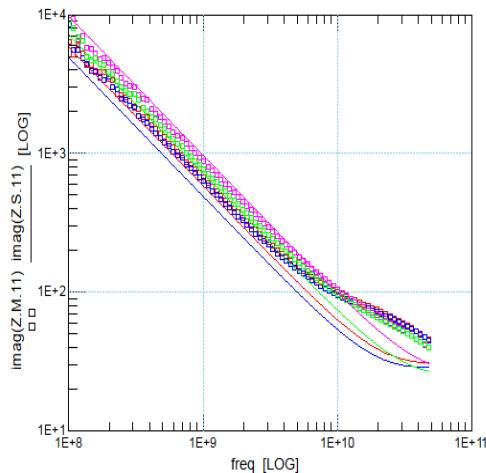
re(S11) = f(Vg, Vd)



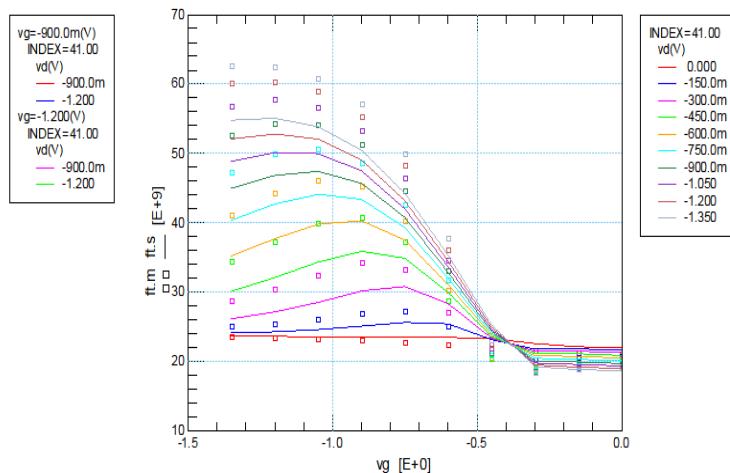
re(S22) = f(Vg, Vd)

im(Y11) divided by ω 

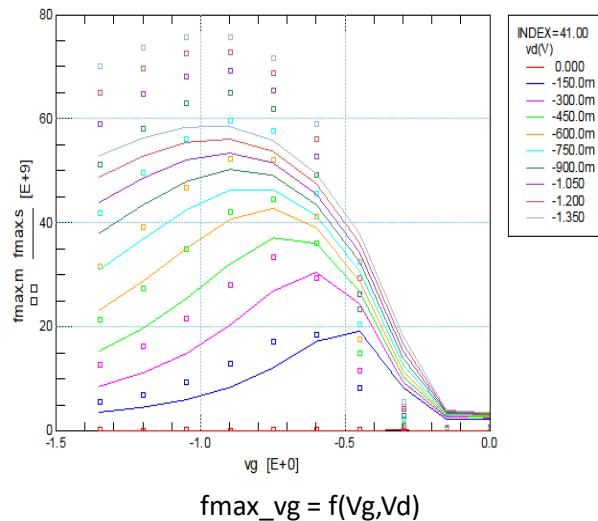
re(Z11) = f(Vg, Vd)



im(Z11) = f(Vg, Vd)

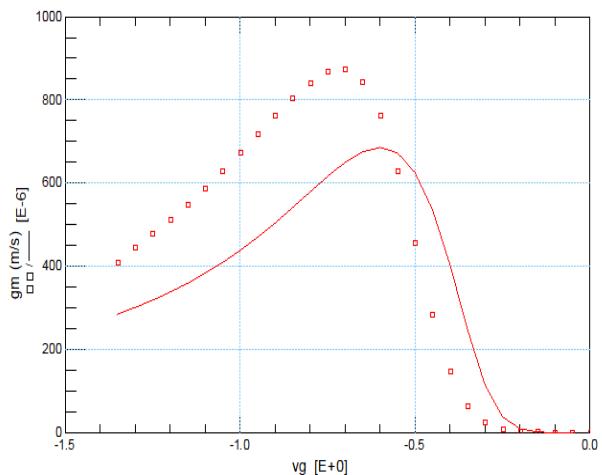
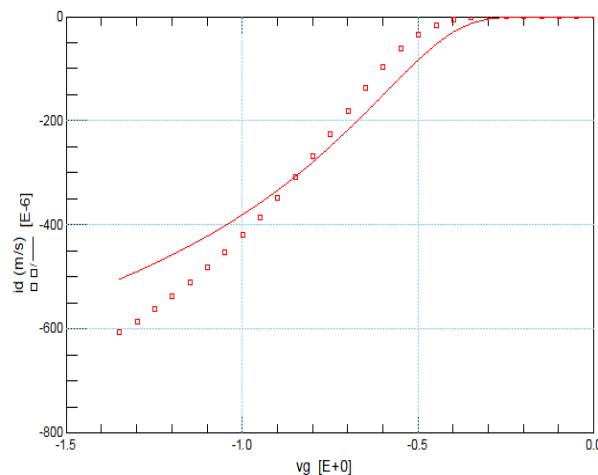


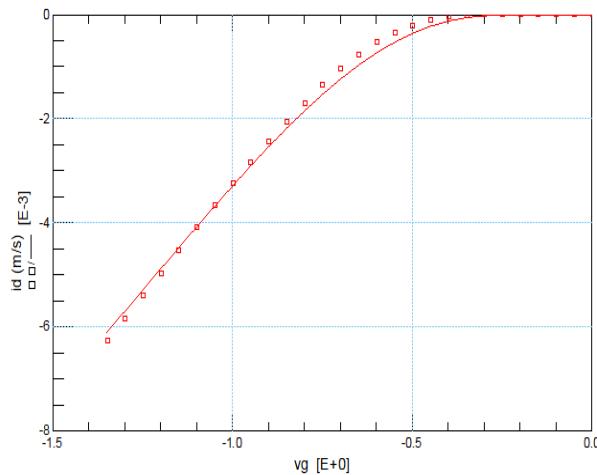
fT_vg = f(Vg, Vd)



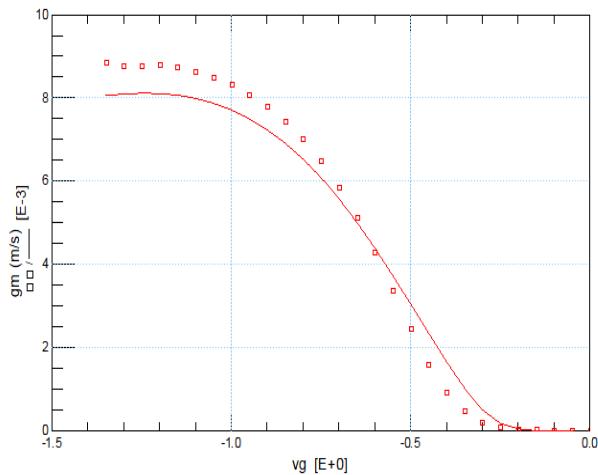
4.8 NF04_WF05u0_L0u13_S453A_62

$I_d V_g$, $T = 27^\circ\text{C}$



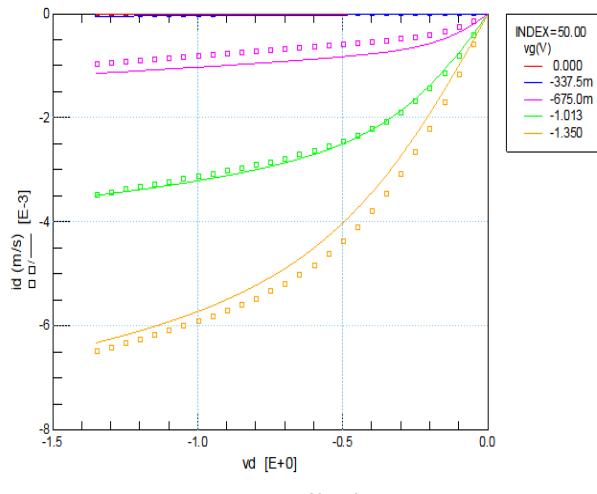


$$Id = f(Vg) @ Vd = -1.2V$$

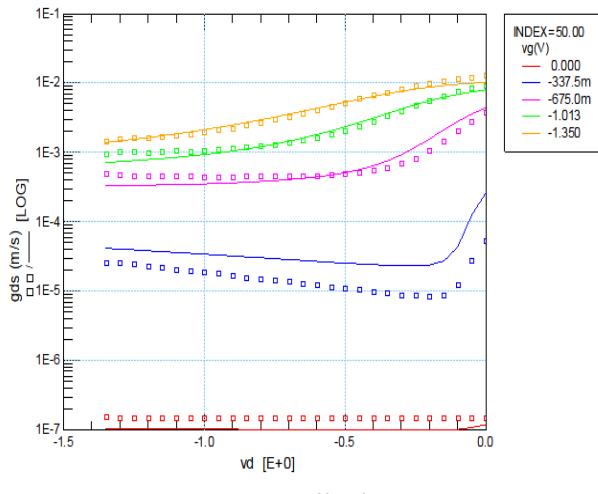


$$gm = f(Vg) @ Vd = -1.2V$$

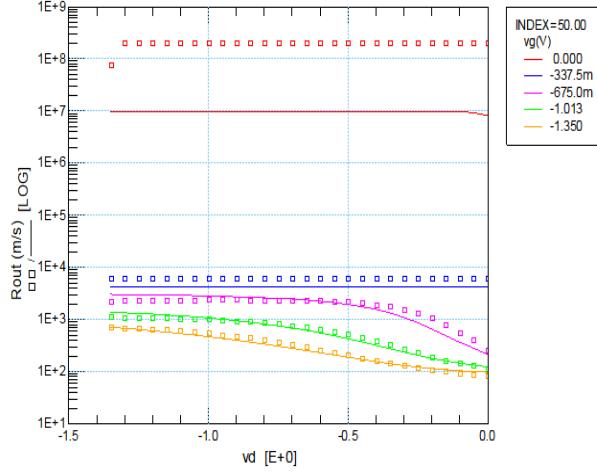
IdVd, T = 27°C



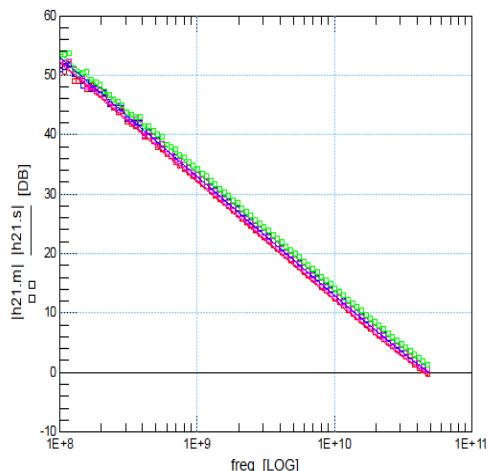
$$Id = f(Vd)$$



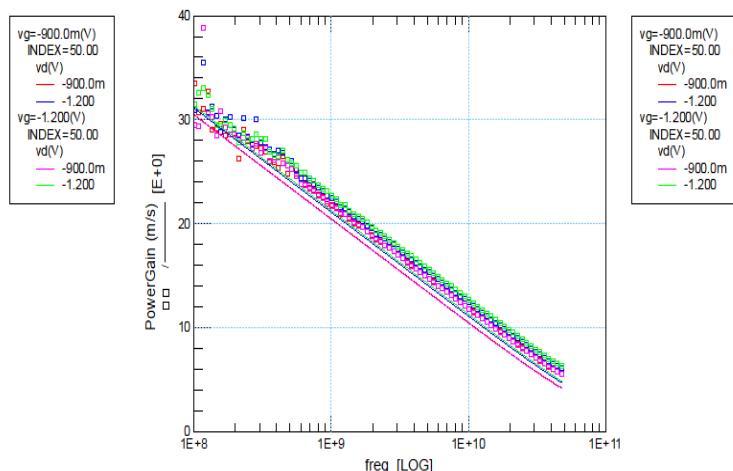
$$gds = f(Vd)$$



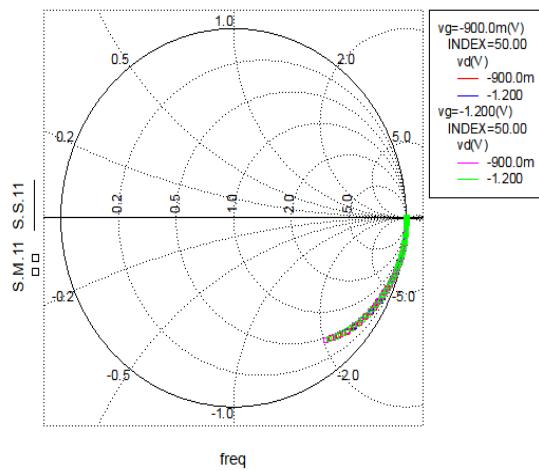
$$Rout = f(Vd)$$

S-Parameter, T = 27°C

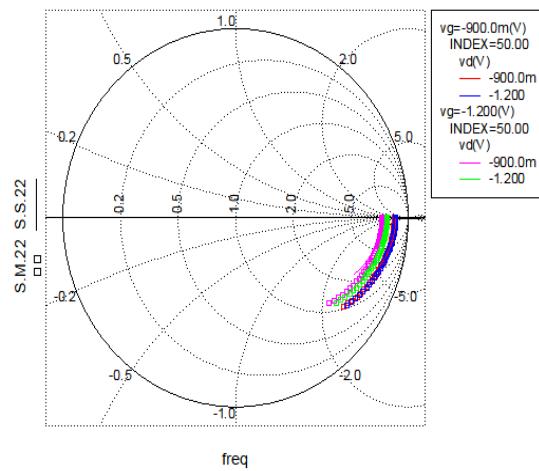
$$|h21| = f(Vg, Vd)$$



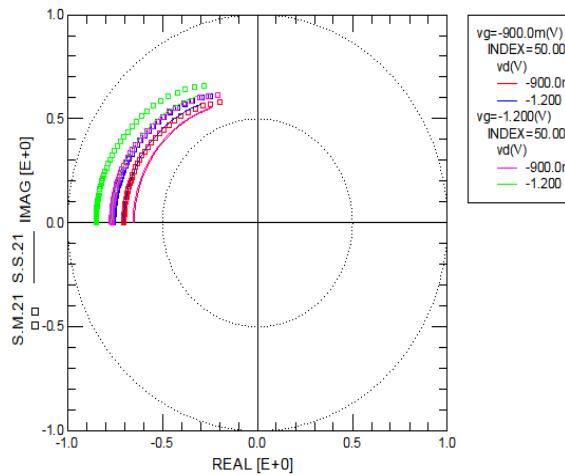
$$MSG/MAG = f(Vg, Vd)$$



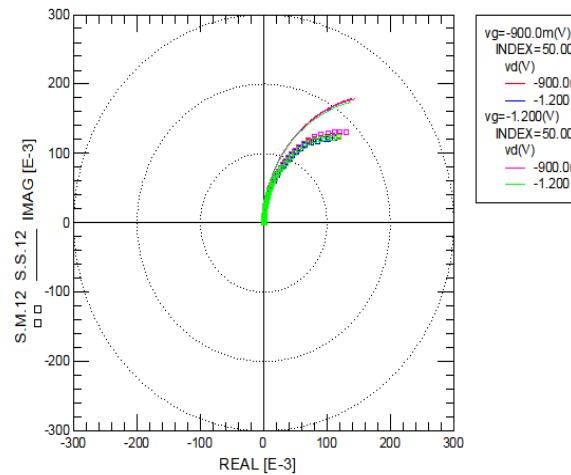
$$S11 = f(Vg, Vd)$$



$$S22 = f(Vg, Vd)$$

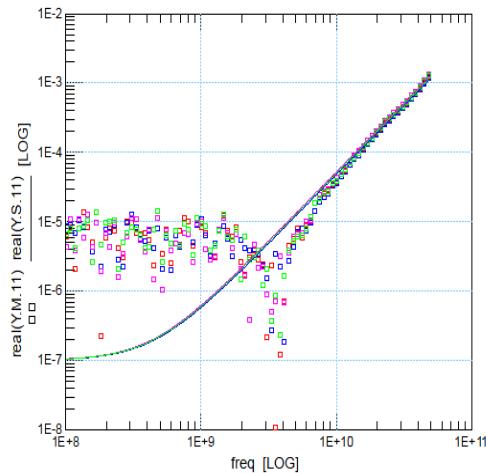


$$S21 = f(Vg, Vd)$$

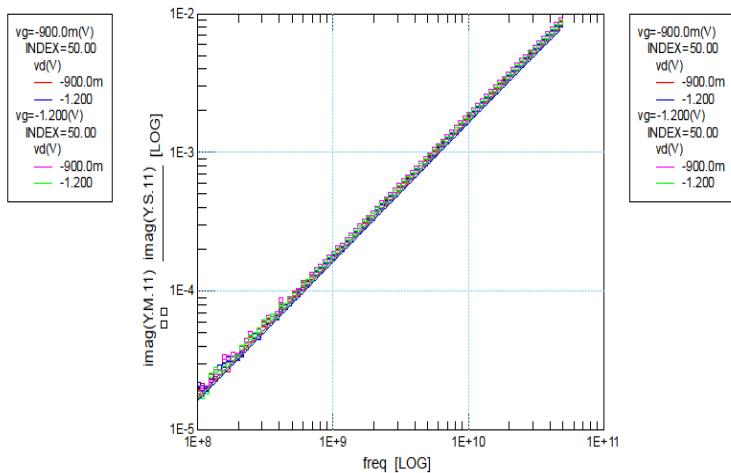


$$S12 = f(Vg, Vd)$$

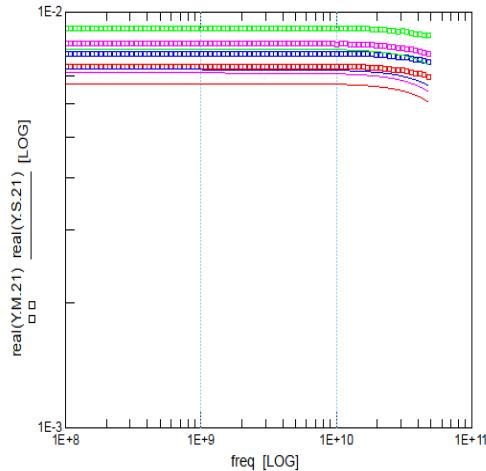
Y-Parameter, T = 27°C



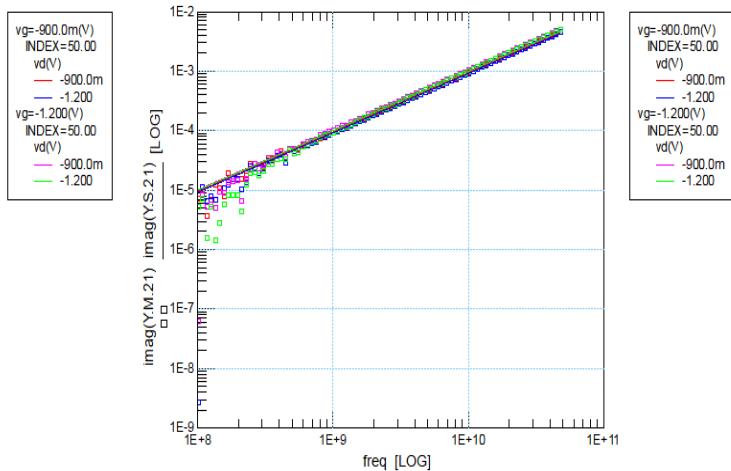
$$\text{re}(Y11) = f(Vg, Vd)$$



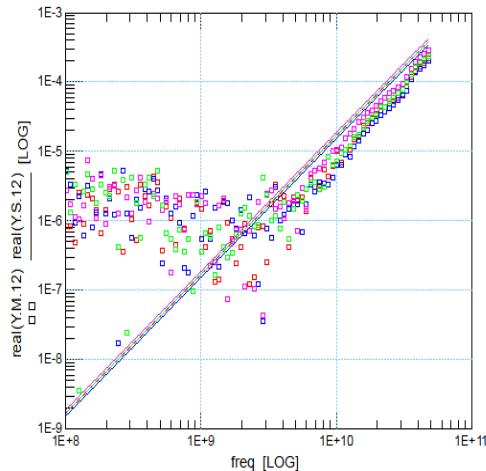
$$\text{im}(Y11) = f(Vg, Vd)$$



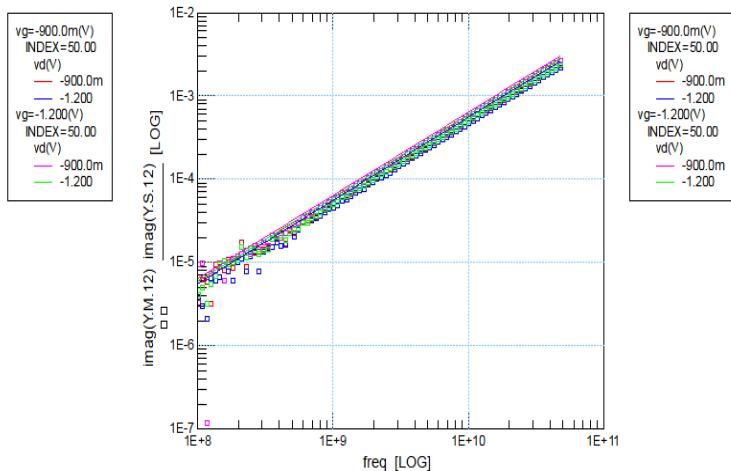
$$\text{re}(Y21) = f(Vg, Vd)$$



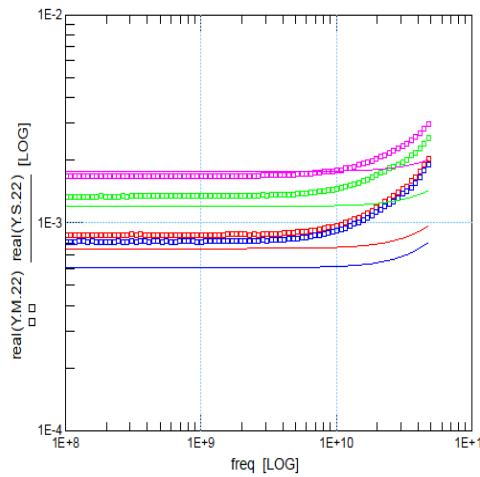
$$\text{im}(Y21) = f(Vg, Vd)$$



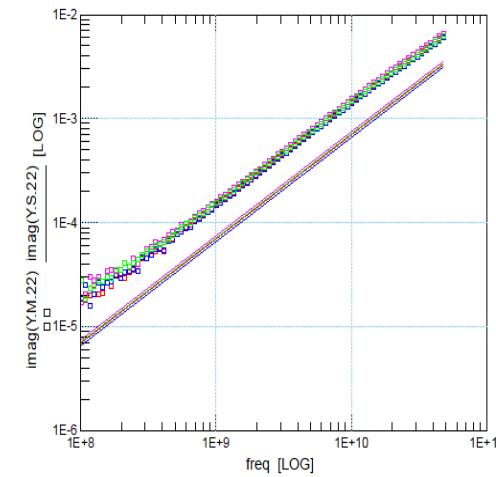
$$\text{re}(Y12) = f(Vg, Vd)$$



$$\text{im}(Y12) = f(Vg, Vd)$$

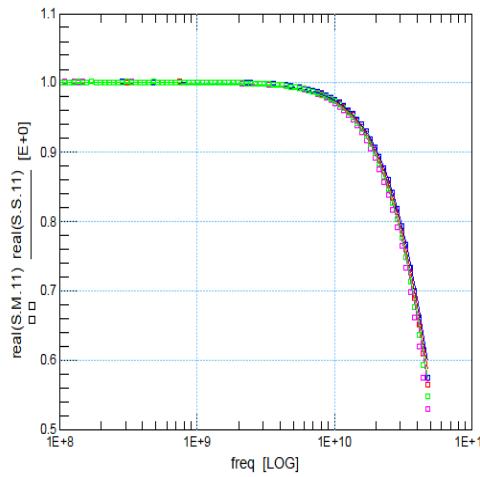


re(Y22) = f(Vg, Vd)

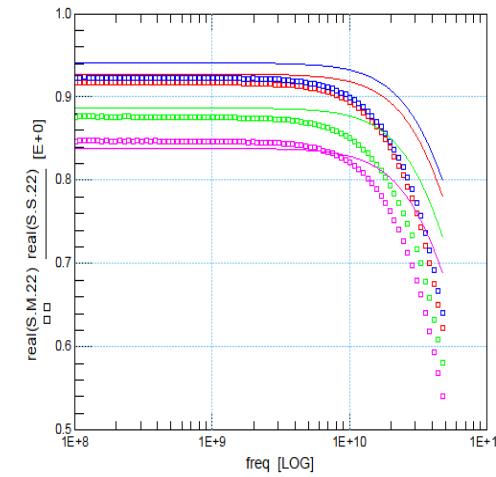


im(Y22) = f(Vg, Vd)

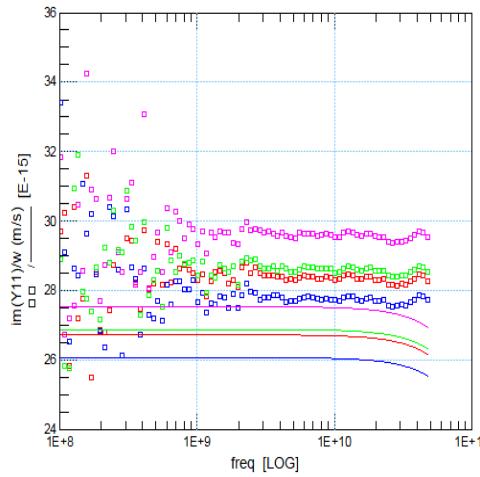
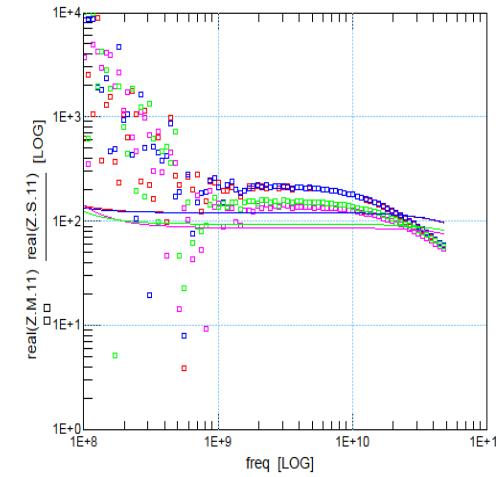
Verify Plots, T = 27°C



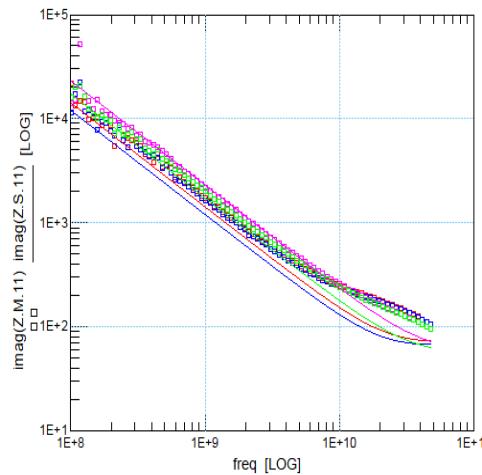
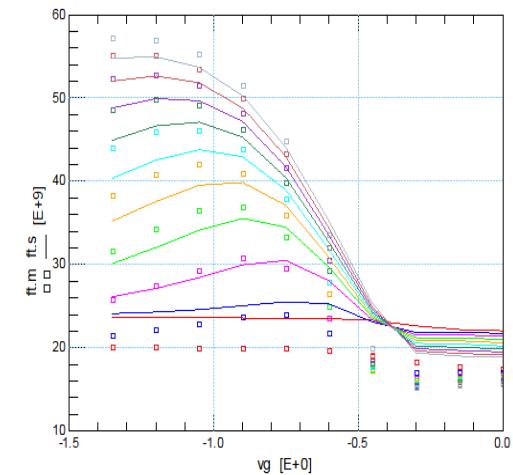
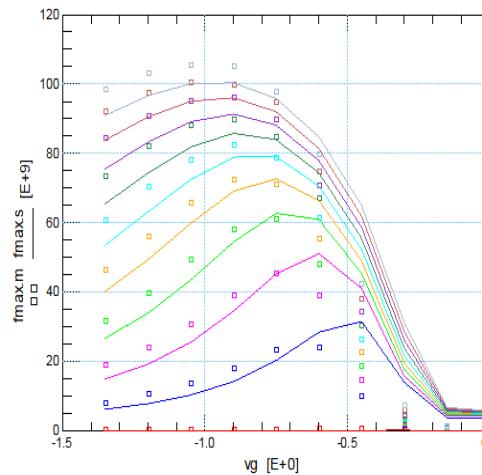
re(S11) = f(Vg, Vd)



re(S22) = f(Vg, Vd)

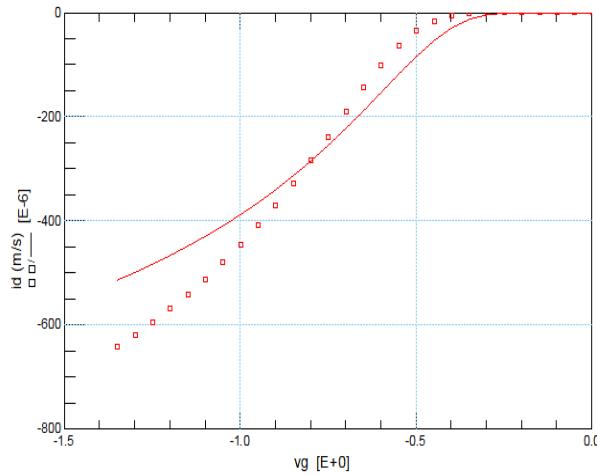
im(Y11) divided by ω 

re(Z11) = f(Vg, Vd)

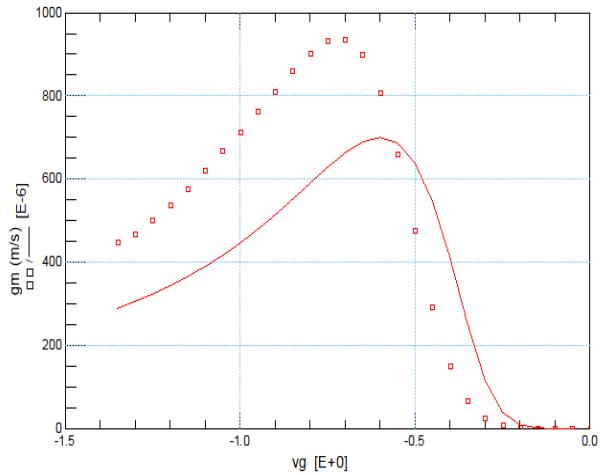
 $\text{im}(Z_{11}) = f(V_g, V_d)$  $fT_{vg} = f(V_g, V_d)$  $f_{\text{max}}_{vg} = f(V_g, V_d)$

4.9 NF08_WF02u5_L0u13_S453A_71

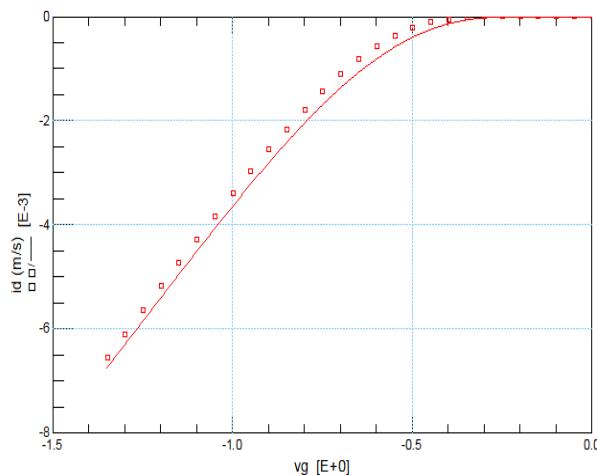
$IdVg$, $T = 27^\circ\text{C}$



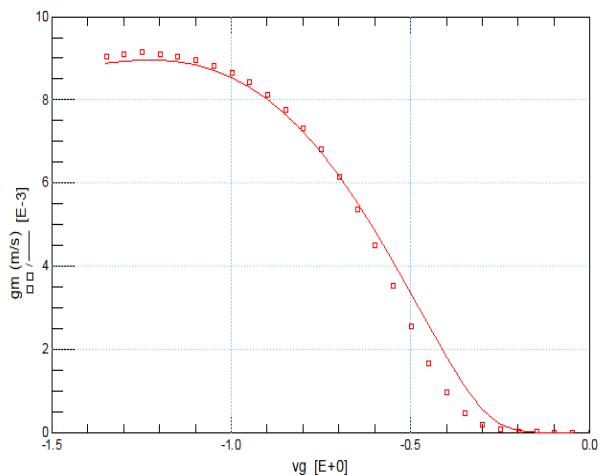
$Id = f(Vg)$ @ $Vd = -0.05\text{V}$



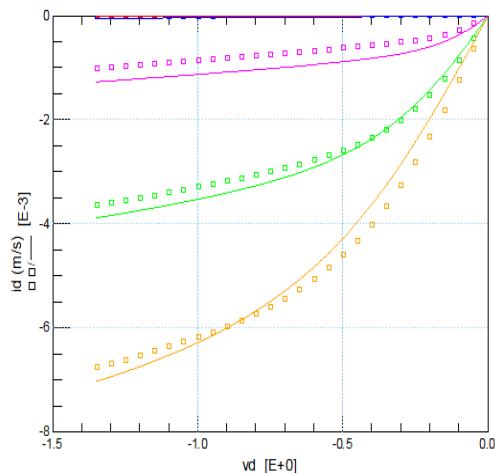
$gm = f(Vg)$ @ $Vd = -0.05\text{V}$



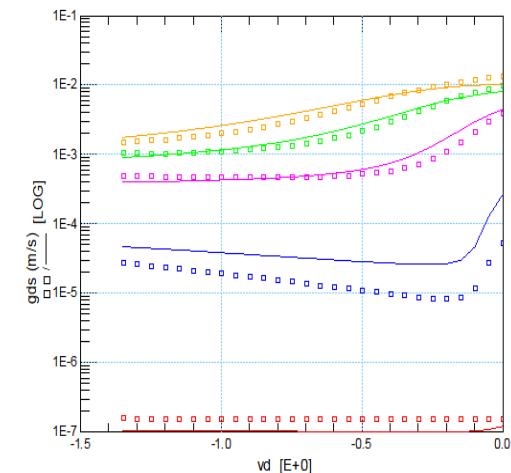
$Id = f(Vg)$ @ $Vd = -1.2\text{V}$



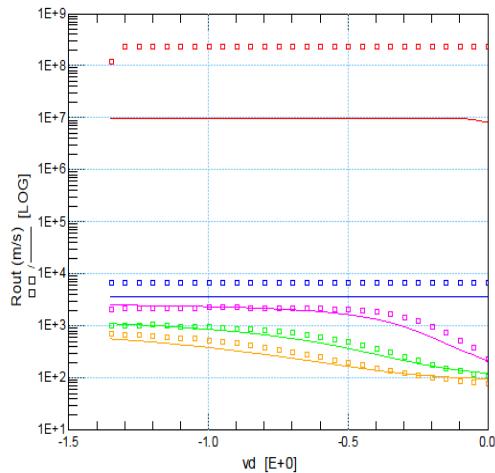
$gm = f(Vg)$ @ $Vd = -1.2\text{V}$

IdVd, T = 27°C

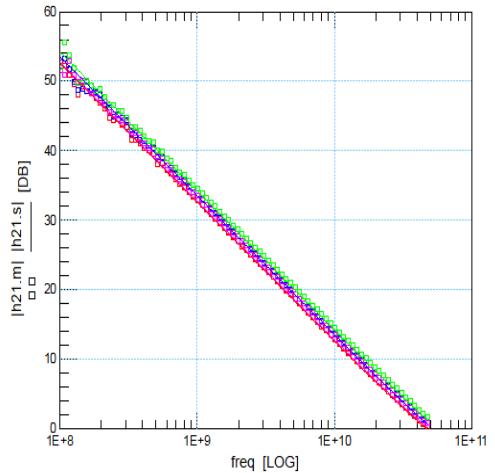
$$Id = f(Vd)$$



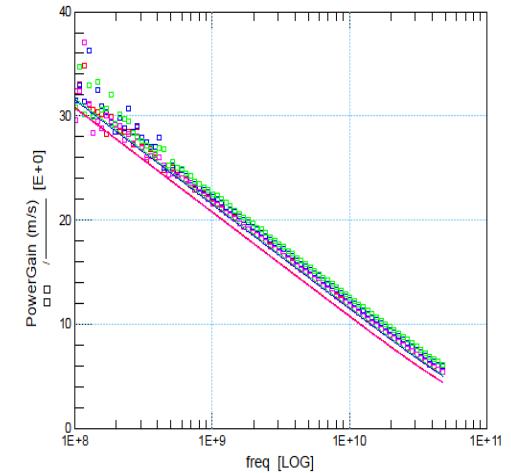
$$gds = f(Vd)$$



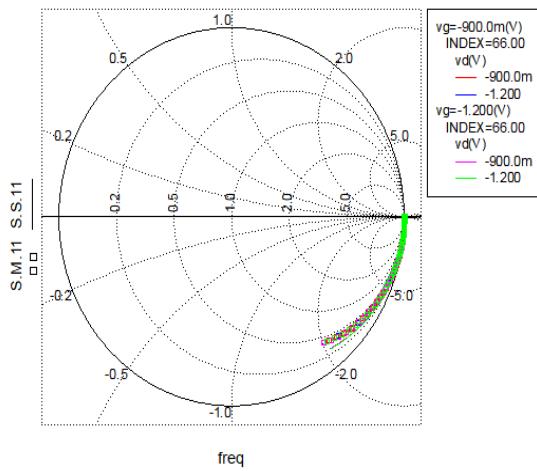
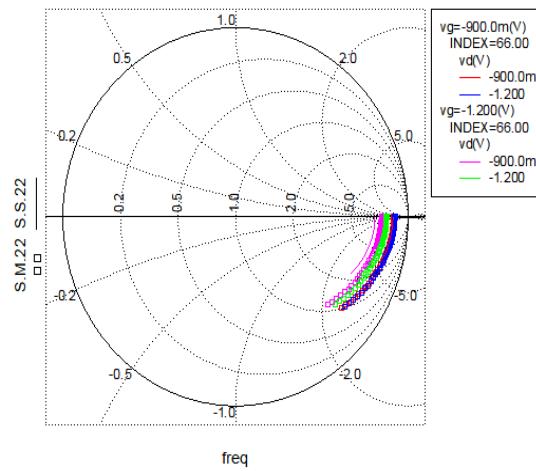
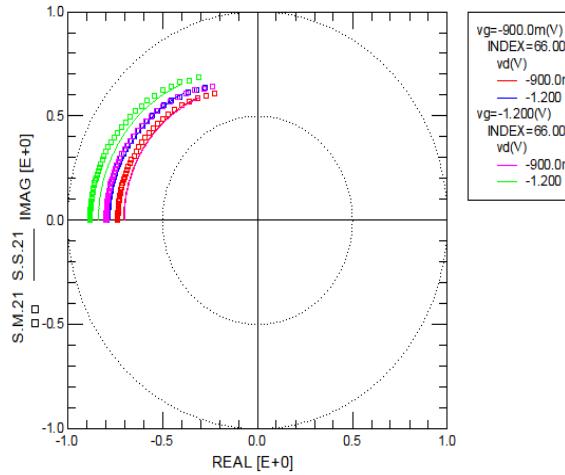
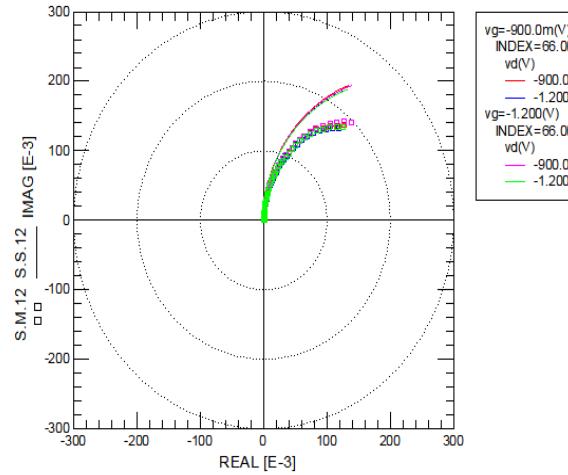
$$Rout = f(Vd)$$

S-Parameter, T = 27°C

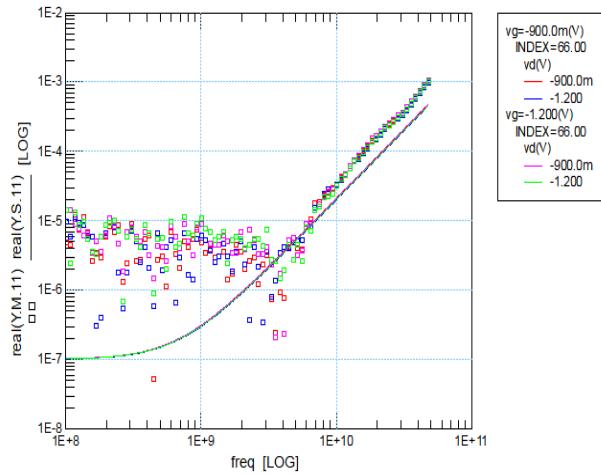
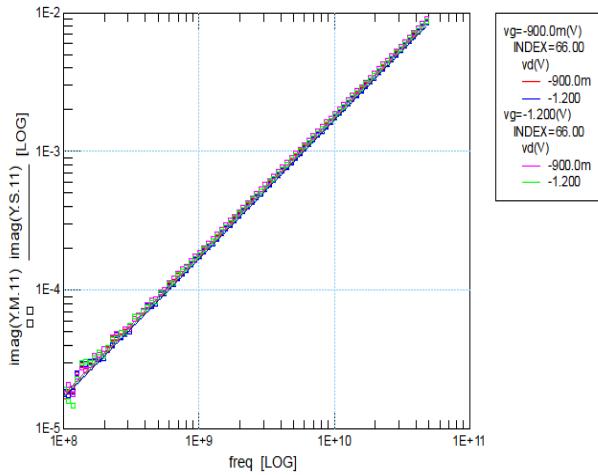
$$|h21| = f(Vg, Vd)$$

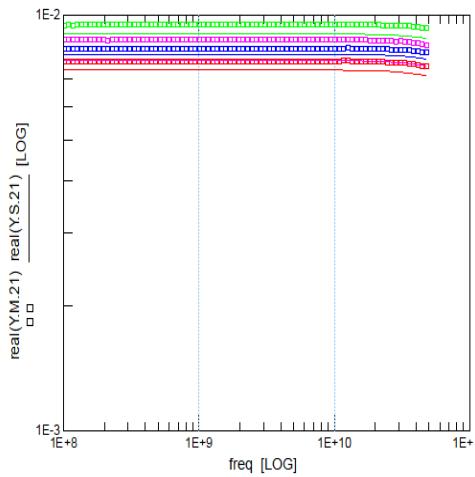


$$MSG/MAG = f(Vg, Vd)$$

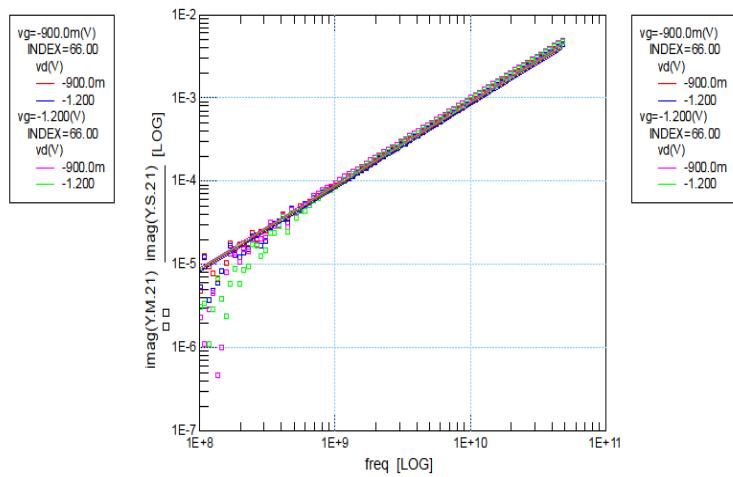
 $S_{11} = f(Vg, Vd)$  $S_{22} = f(Vg, Vd)$  $S_{21} = f(Vg, Vd)$  $S_{12} = f(Vg, Vd)$

Y-Parameter, $T = 27^\circ\text{C}$

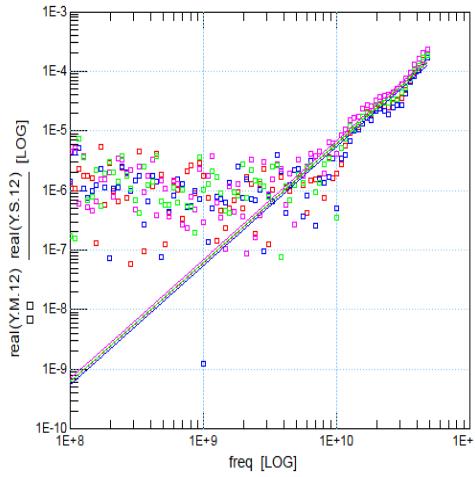
 $\text{re}(Y_{11}) = f(Vg, Vd)$  $\text{im}(Y_{11}) = f(Vg, Vd)$



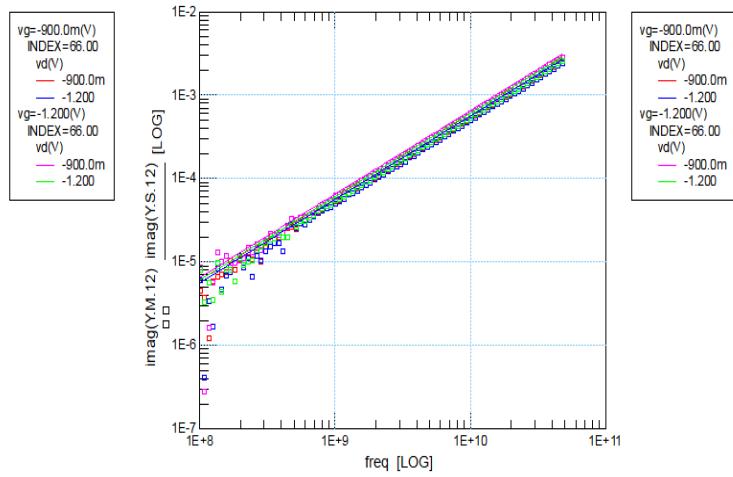
re(Y21) = f(Vg,Vd)



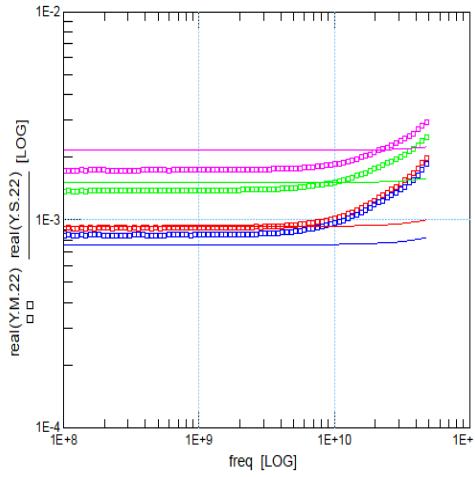
im(Y21) = f(Vg,Vd)



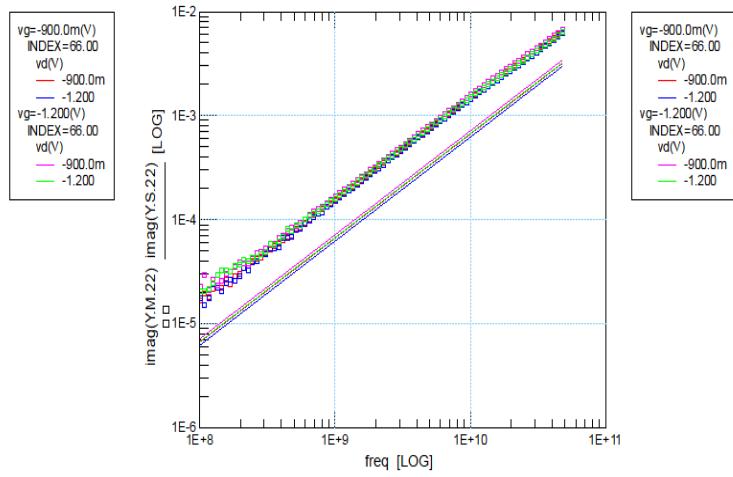
re(Y12) = f(Vg,Vd)



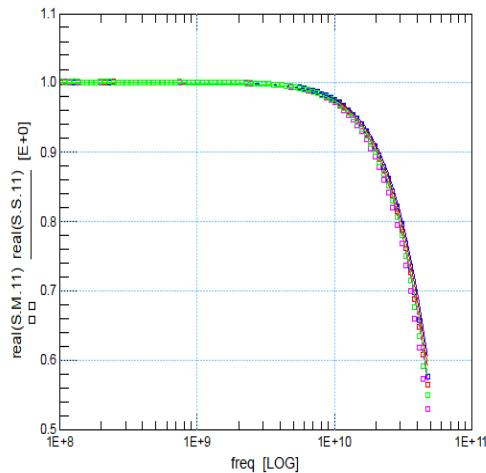
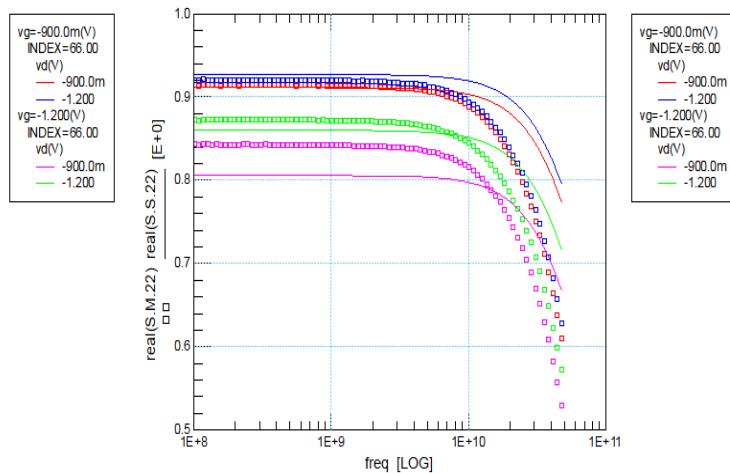
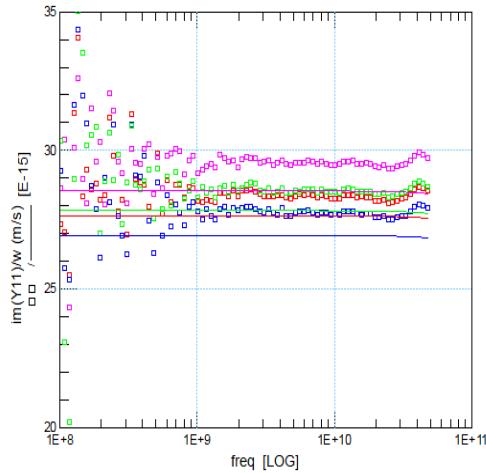
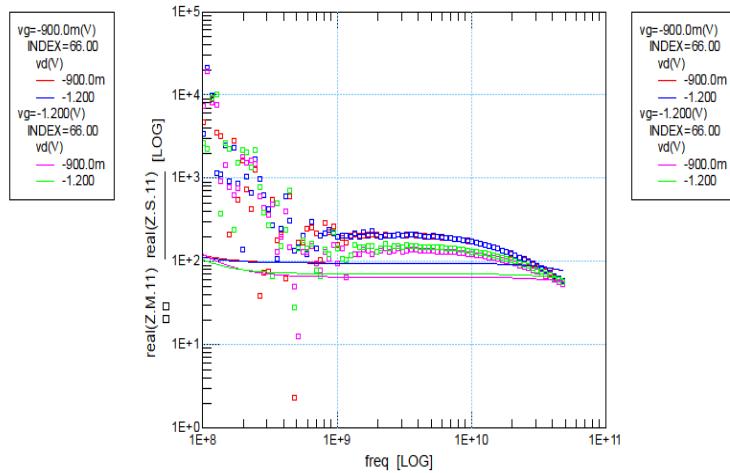
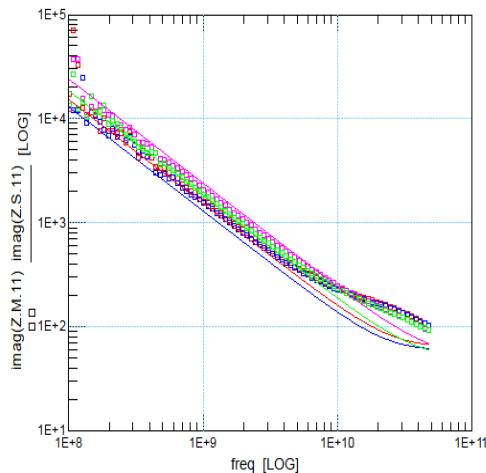
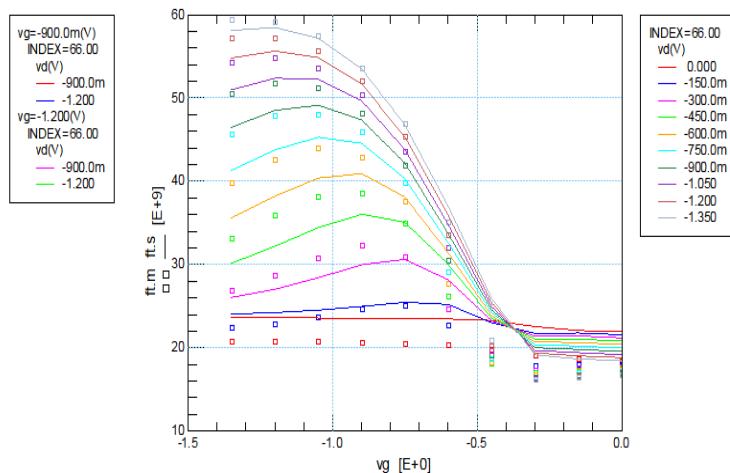
im(Y12) = f(Vg,Vd)

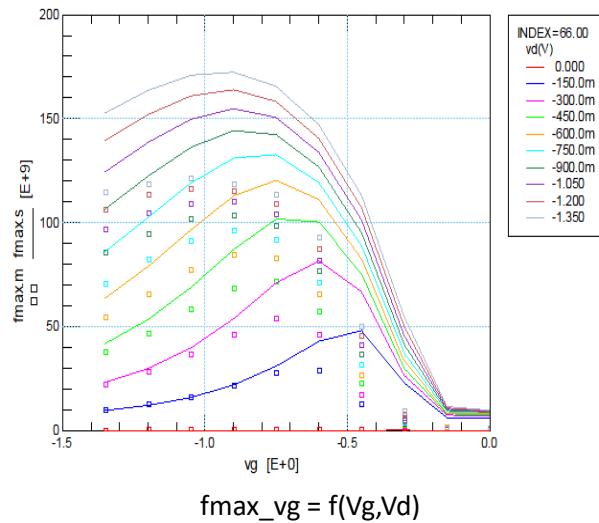


re(Y22) = f(Vg,Vd)



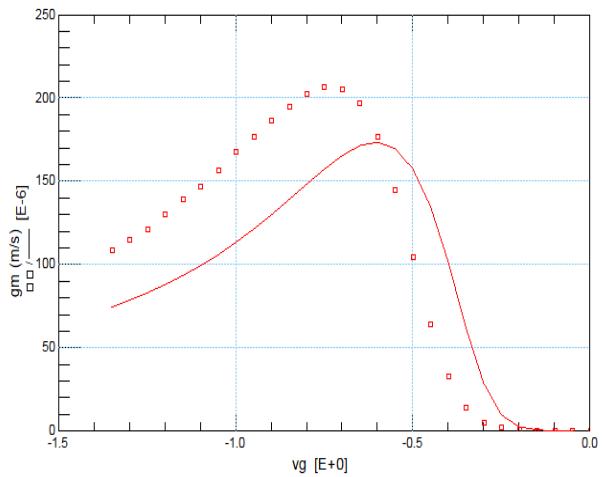
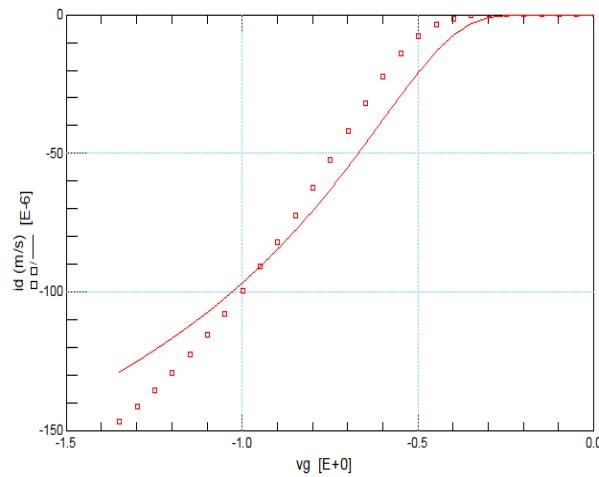
im(Y22) = f(Vg,Vd)

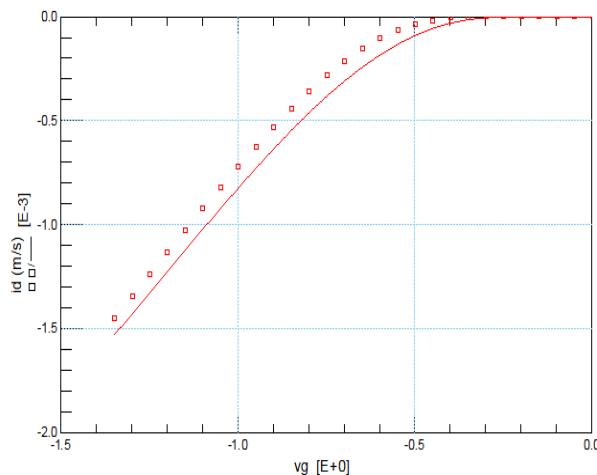
Verify Plots, $T = 27^\circ\text{C}$  $\text{re}(S11) = f(Vg, Vd)$  $\text{re}(S22) = f(Vg, Vd)$  $\text{im}(Y11) \text{ divided by } \omega$  $\text{re}(Z11) = f(Vg, Vd)$  $\text{im}(Z11) = f(Vg, Vd)$  $fT_{vg} = f(Vg, Vd)$



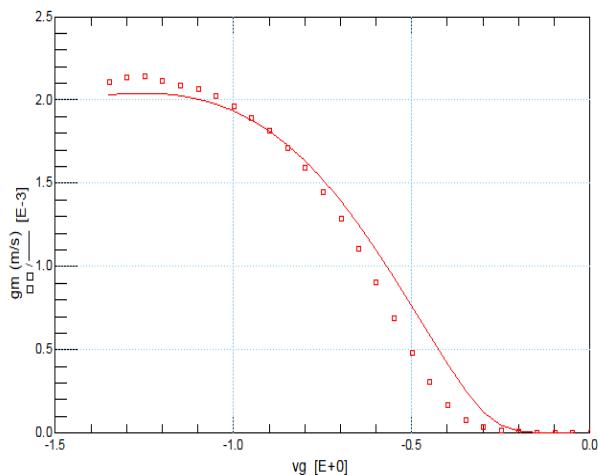
4.10NF01_WF05u0_L0u13_S453A_75

I_d vs V_g , $T = 27^\circ\text{C}$



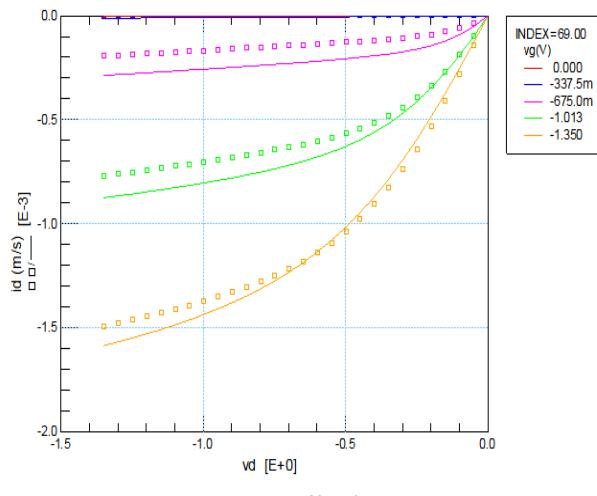


$$Id = f(Vg) @ Vd = -1.2V$$

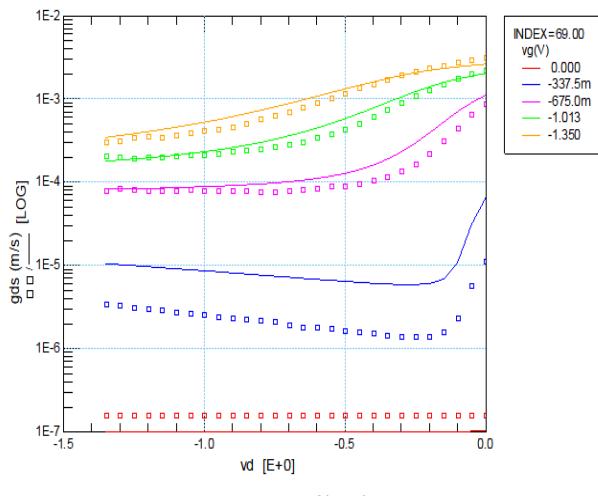


$$gm = f(Vg) @ Vd = -1.2V$$

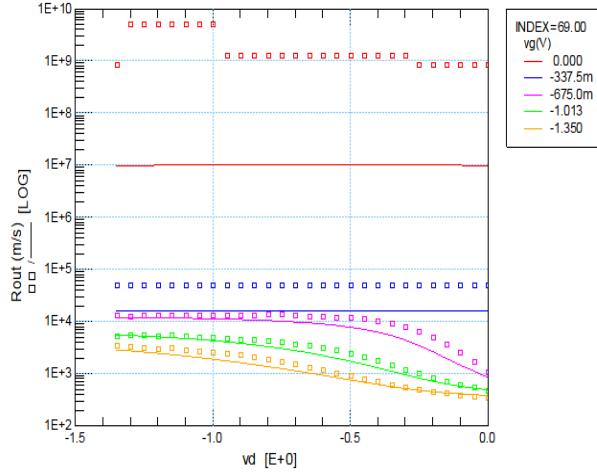
IdVd, T = 27°C



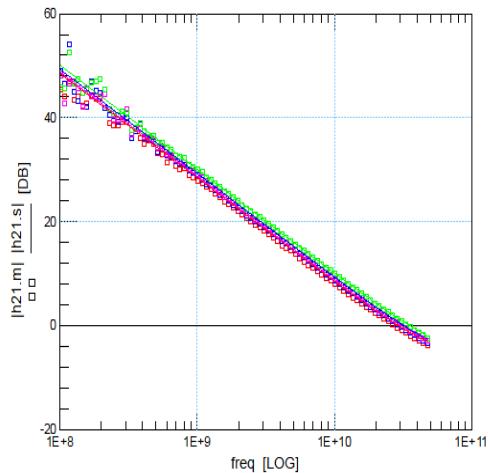
$$Id = f(Vd)$$



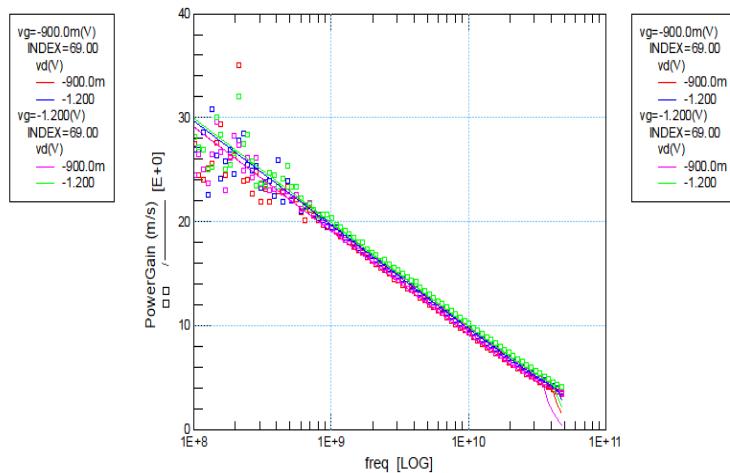
$$gds = f(Vd)$$



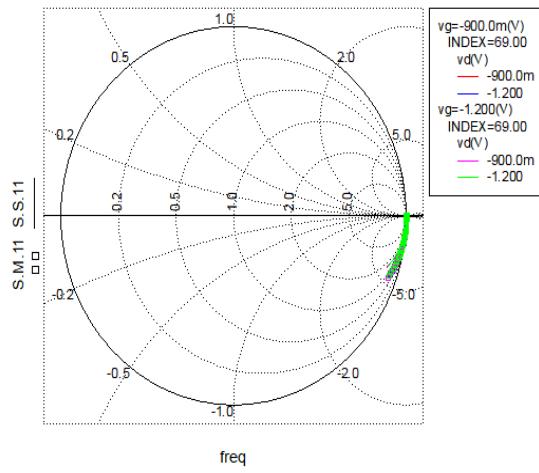
$$Rout = f(Vd)$$

S-Parameter, T = 27°C

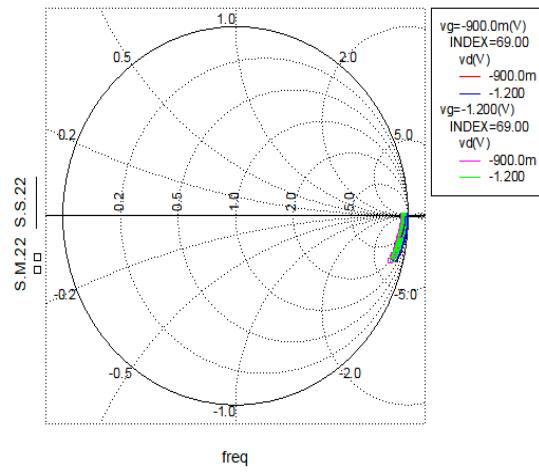
$$|h21| = f(Vg, Vd)$$



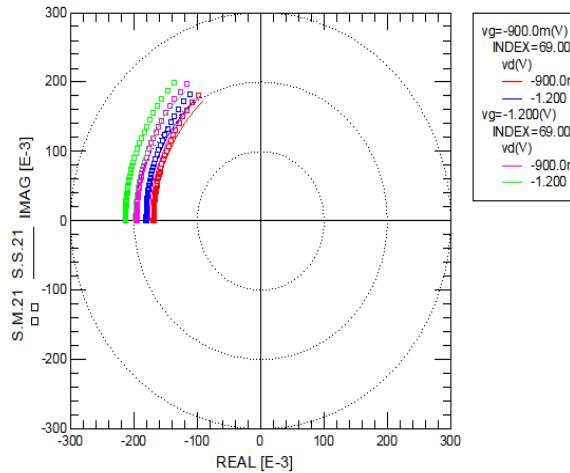
$$MSG/MAG = f(Vg, Vd)$$



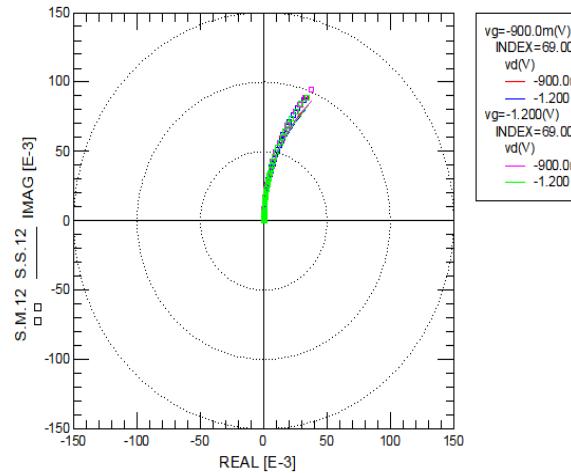
$$S11 = f(Vg, Vd)$$



$$S22 = f(Vg, Vd)$$

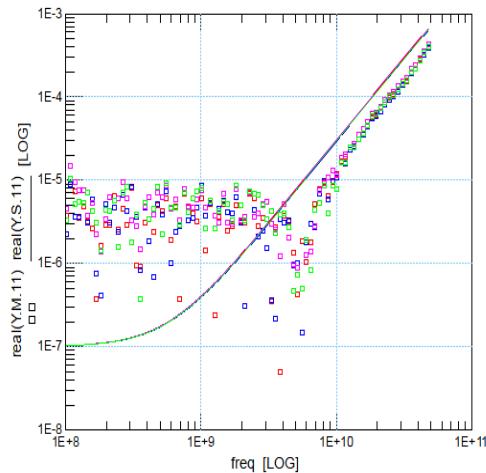


$$S21 = f(Vg, Vd)$$

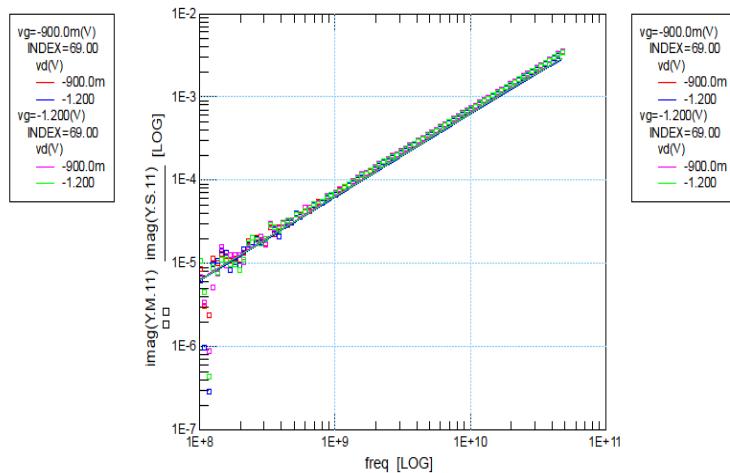


$$S12 = f(Vg, Vd)$$

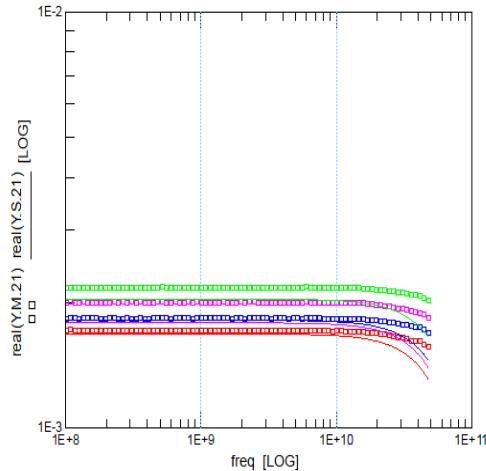
Y-Parameter, T = 27°C



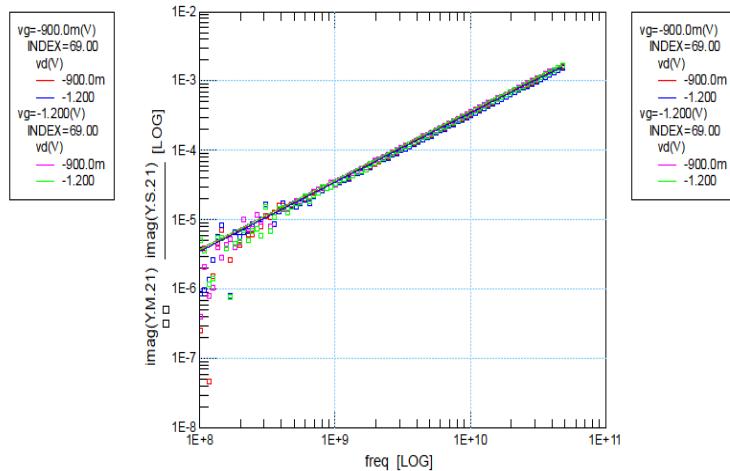
$$\text{re}(Y11) = f(Vg, Vd)$$



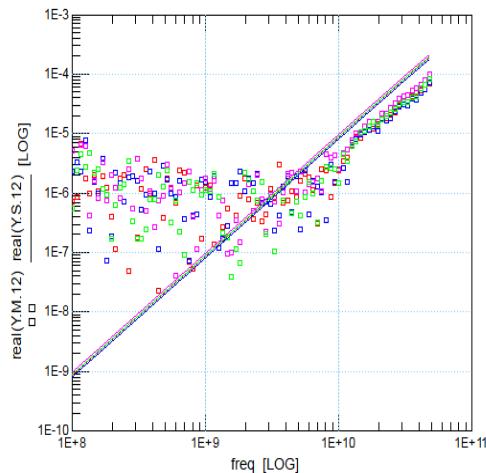
$$\text{im}(Y11) = f(Vg, Vd)$$



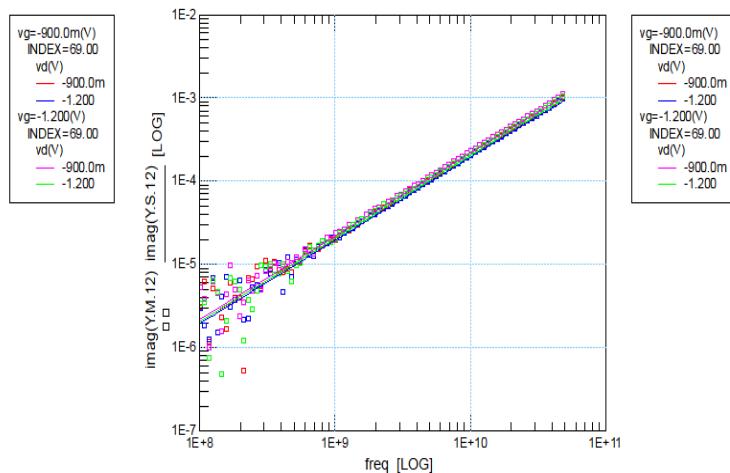
$$\text{re}(Y21) = f(Vg, Vd)$$



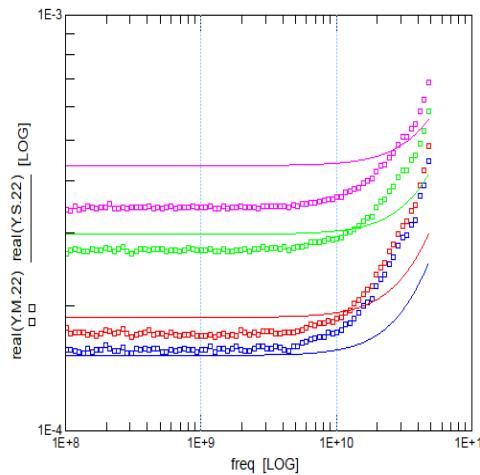
$$\text{im}(Y21) = f(Vg, Vd)$$



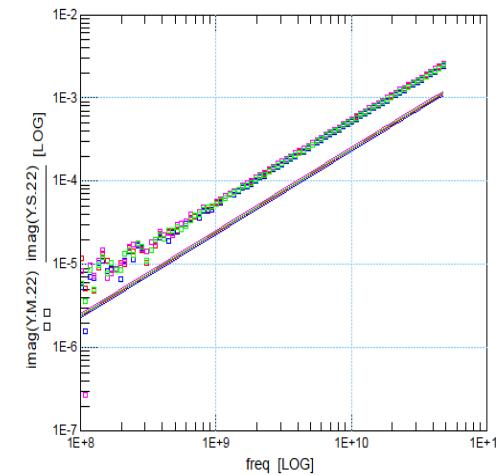
$$\text{re}(Y12) = f(Vg, Vd)$$



$$\text{im}(Y12) = f(Vg, Vd)$$

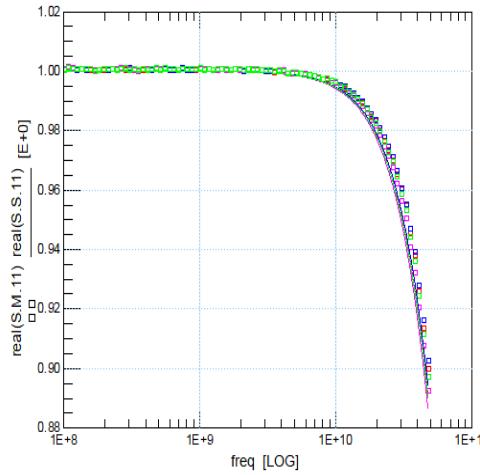


$$\text{re}(Y22) = f(Vg, Vd)$$

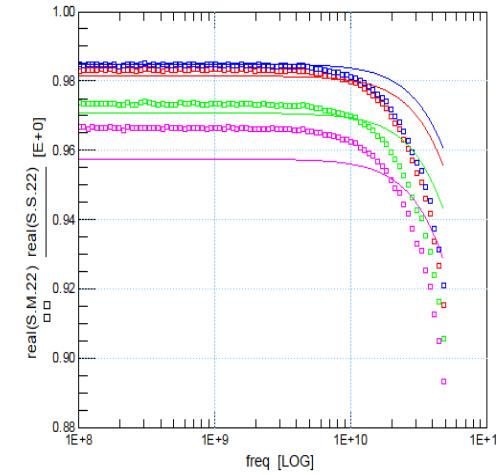


$$\text{im}(Y22) = f(Vg, Vd)$$

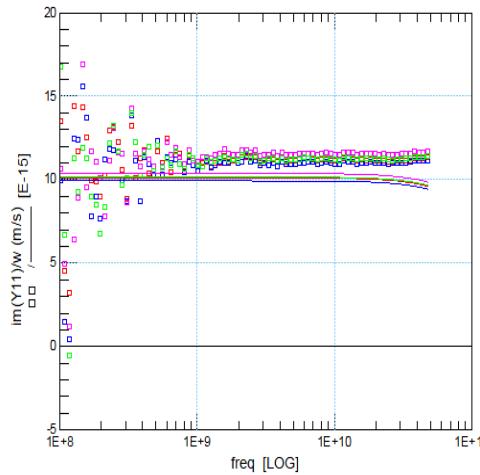
Verify Plots, T = 27°C



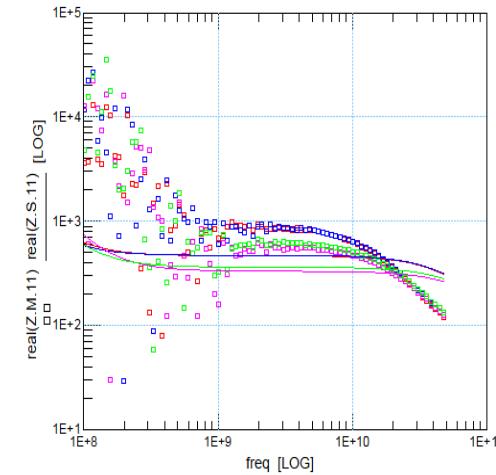
$$\text{re}(S11) = f(Vg, Vd)$$



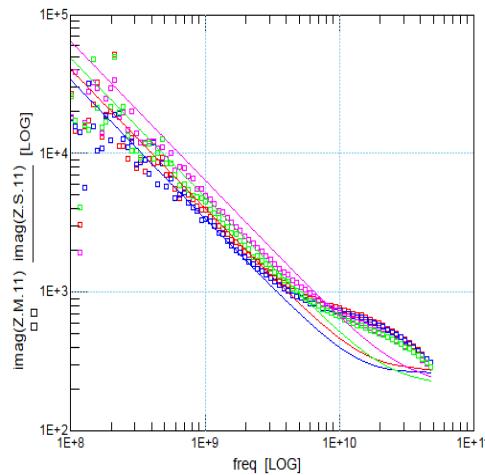
$$\text{re}(S22) = f(Vg, Vd)$$



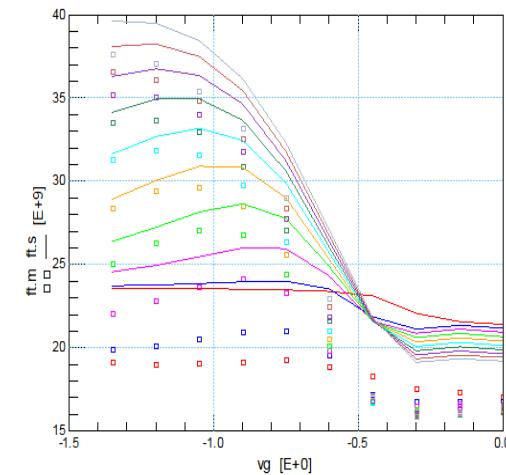
$$\text{im}(Y11) \text{ divided by } \omega$$



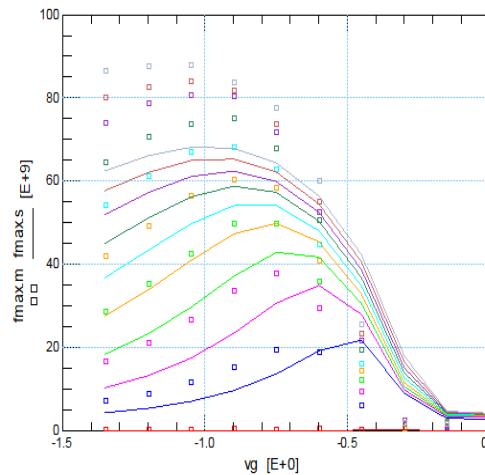
$$\text{re}(Z11) = f(Vg, Vd)$$



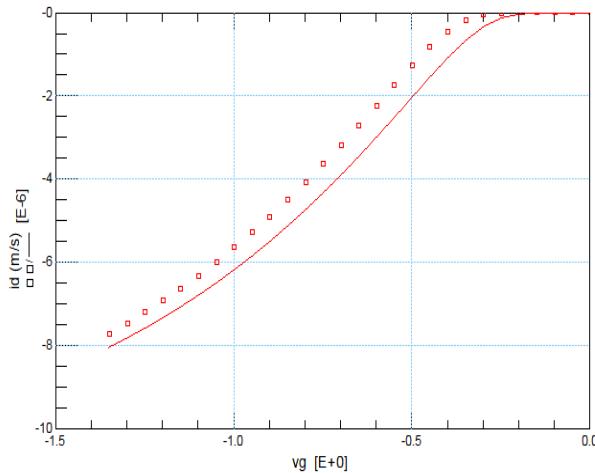
$$\text{im}(Z_{11}) = f(V_g, V_d)$$



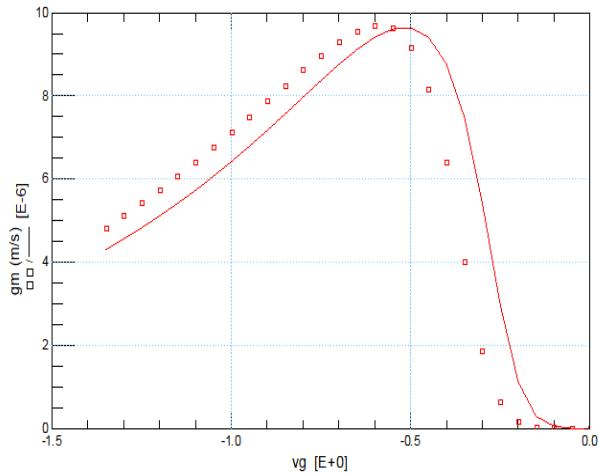
$$fT_{vg} = f(V_g, V_d)$$



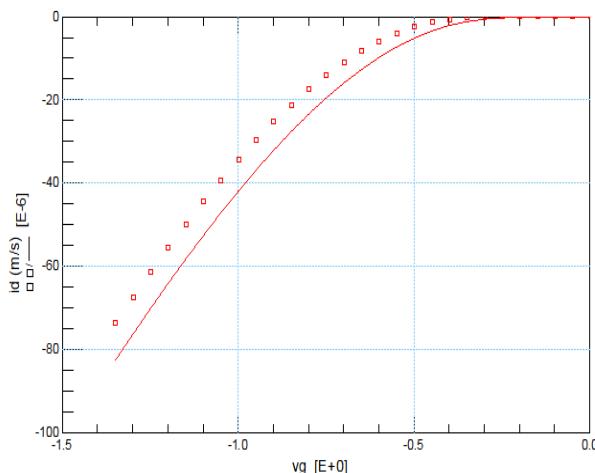
$$f_{\text{max}}_{vg} = f(V_g, V_d)$$

4.11NF04_WF05u0_L10u0_S453A_13**IdVg, T = 27°C**

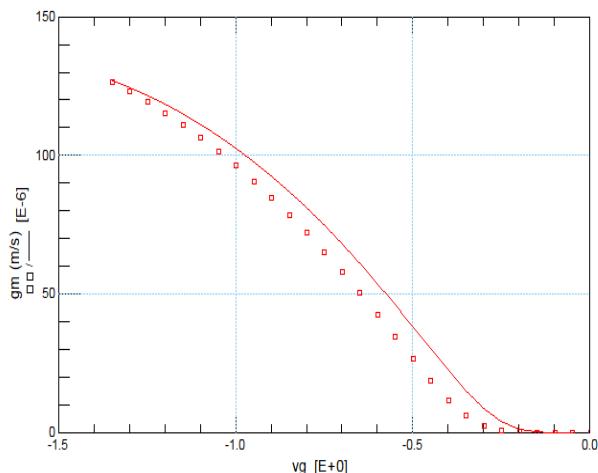
$$Id = f(Vg) @ Vd = -0.05V$$



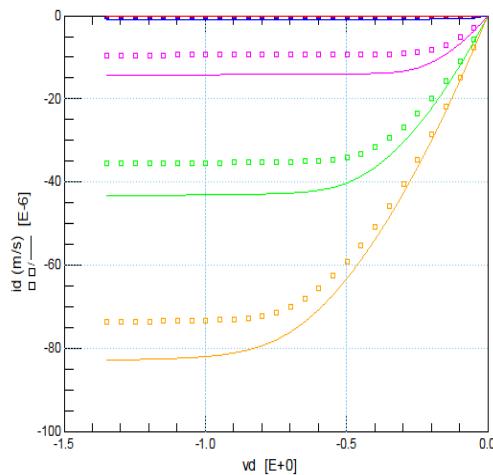
$$gm = f(Vg) @ Vd = -0.05V$$



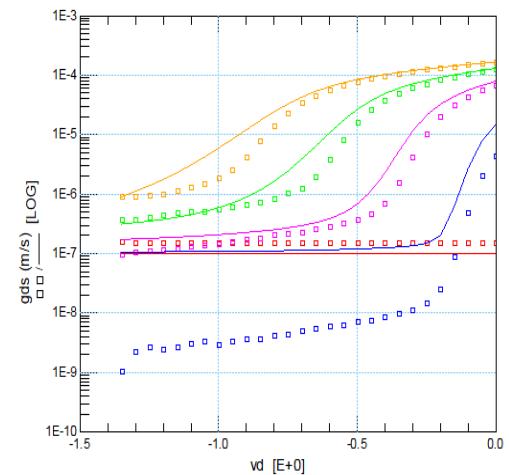
$$Id = f(Vg) @ Vd = -1.2V$$



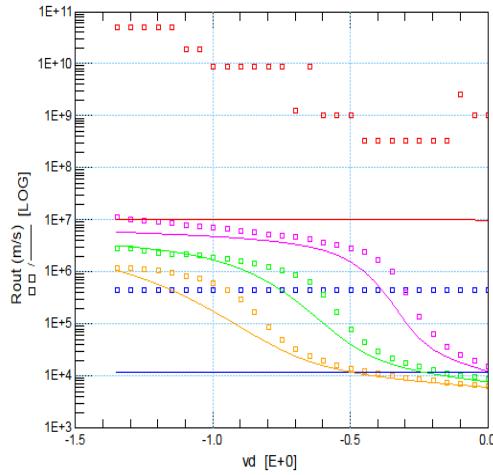
$$gm = f(Vg) @ Vd = -1.2V$$

IdVd, T = 27°C

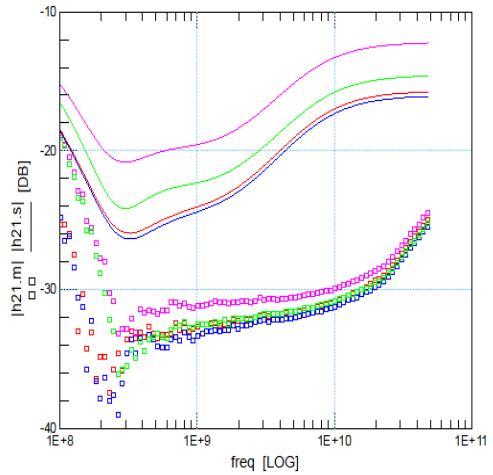
$$Id = f(Vd)$$



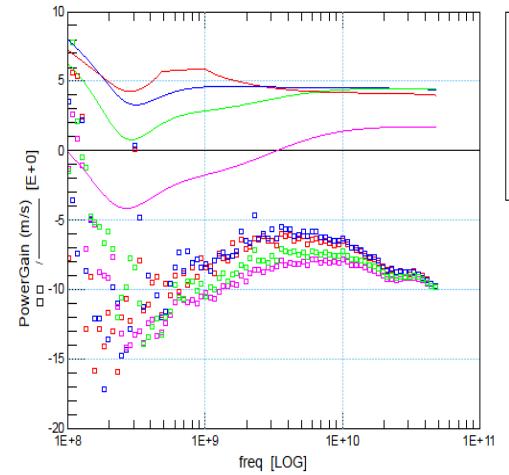
$$gds = f(Vd)$$



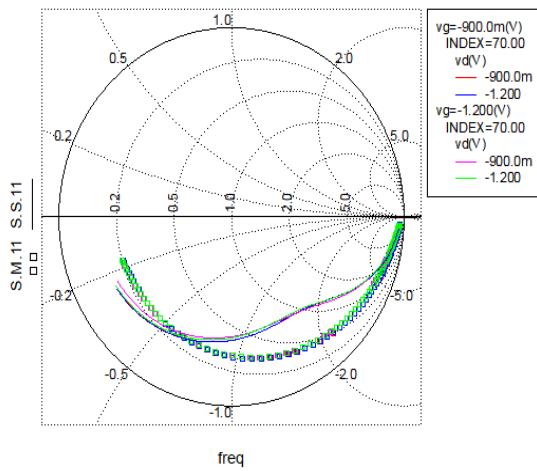
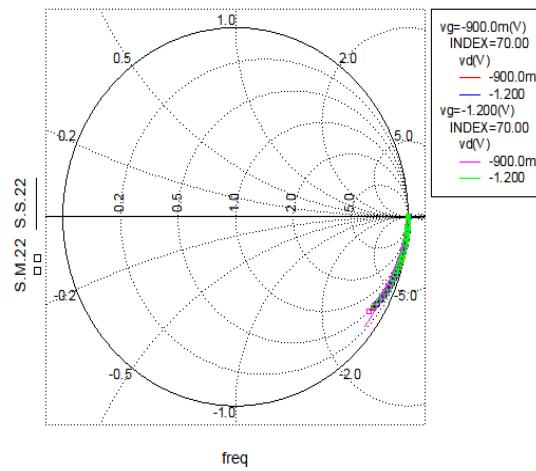
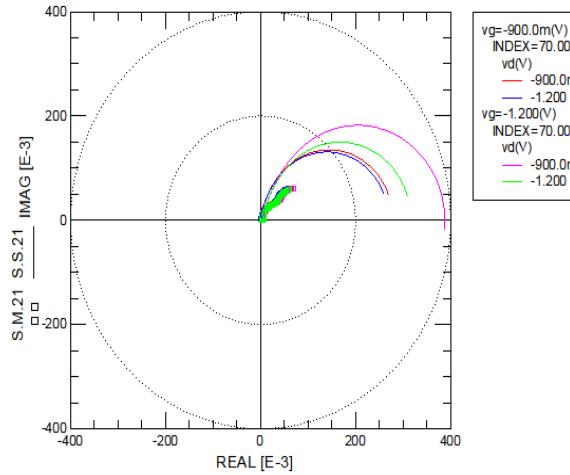
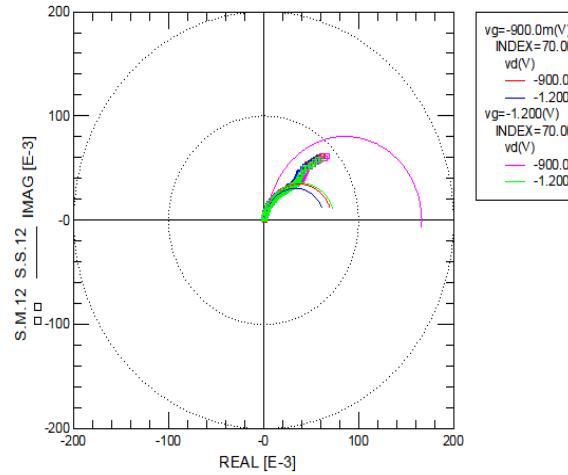
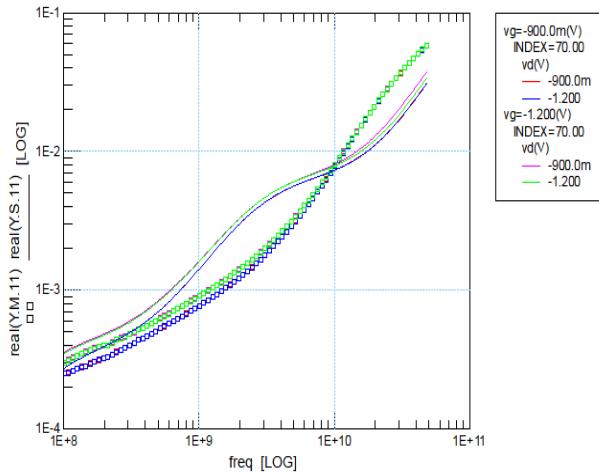
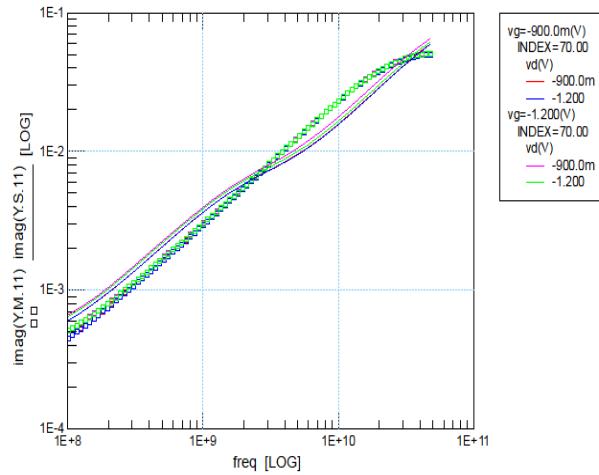
$$Rout = f(Vd)$$

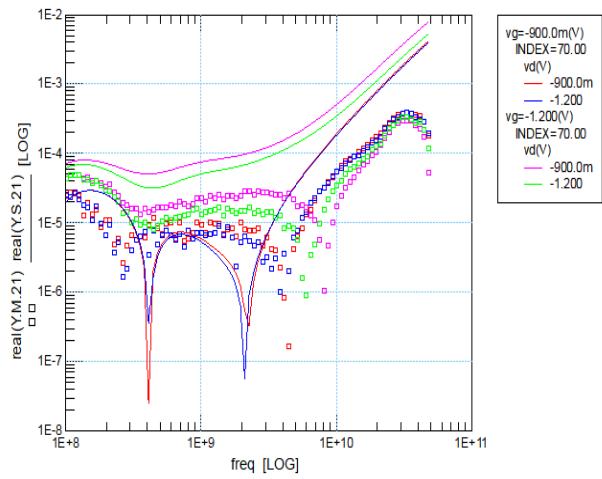
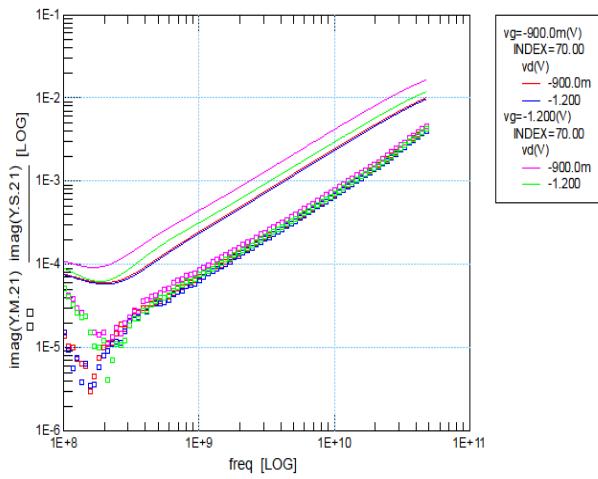
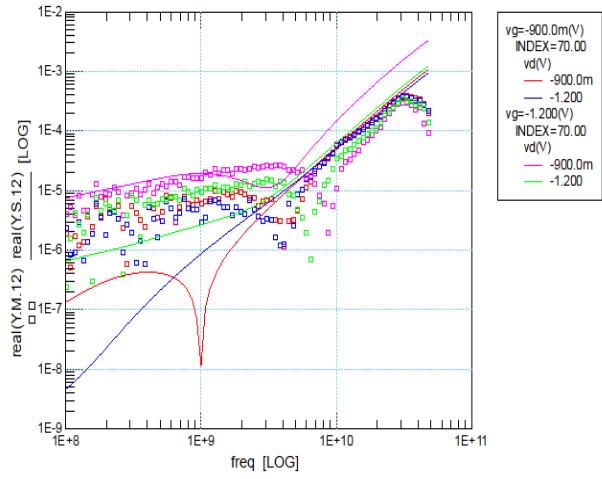
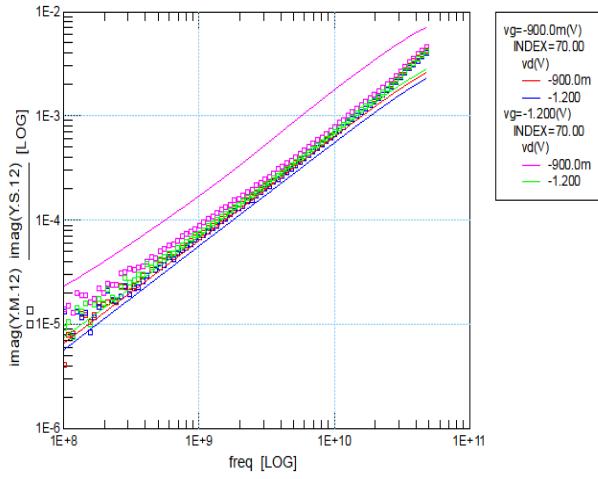
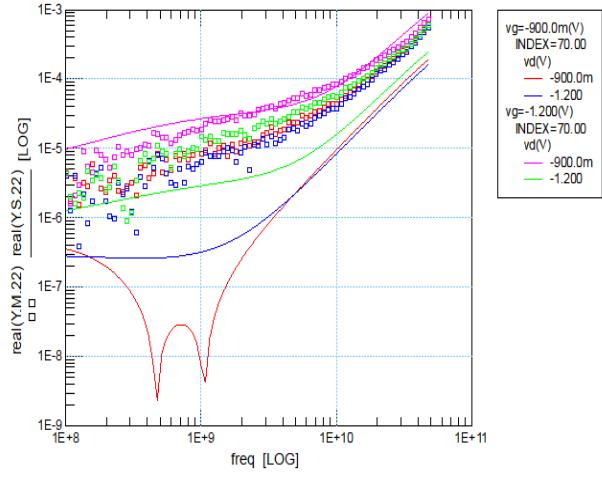
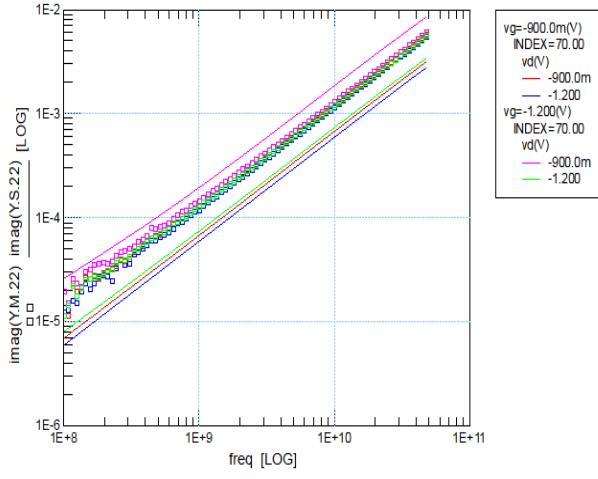
S-Parameter, T = 27°C

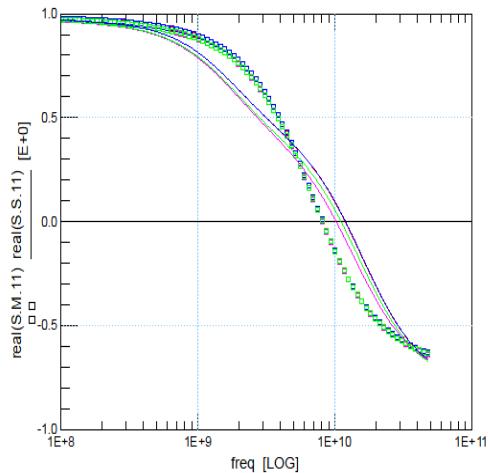
$$|h21| = f(Vg, Vd)$$



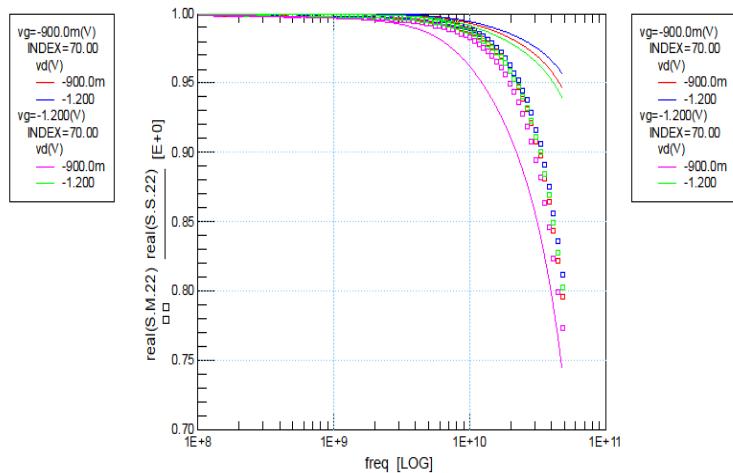
$$MSG/MAG = f(Vg, Vd)$$

 $S11 = f(Vg, Vd)$  $S22 = f(Vg, Vd)$  $S21 = f(Vg, Vd)$  $S12 = f(Vg, Vd)$ **Y-Parameter, T = 27°C** $re(Y11) = f(Vg, Vd)$  $im(Y11) = f(Vg, Vd)$

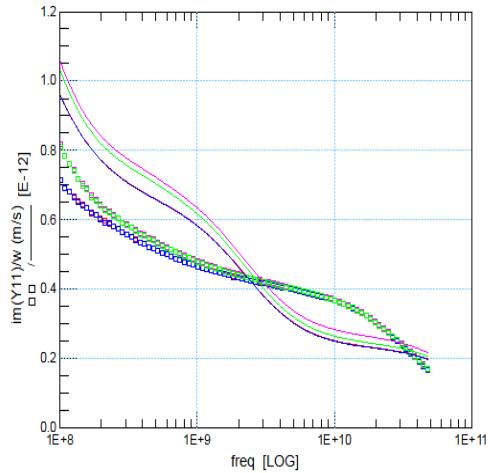
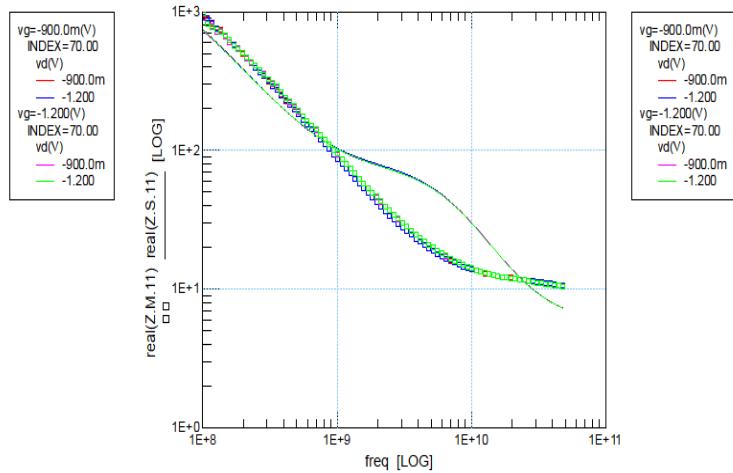
 $\text{re}(Y_{21}) = f(\text{Vg}, \text{Vd})$  $\text{im}(Y_{21}) = f(\text{Vg}, \text{Vd})$  $\text{re}(Y_{12}) = f(\text{Vg}, \text{Vd})$  $\text{im}(Y_{12}) = f(\text{Vg}, \text{Vd})$  $\text{re}(Y_{22}) = f(\text{Vg}, \text{Vd})$  $\text{im}(Y_{22}) = f(\text{Vg}, \text{Vd})$

Verify Plots, $T = 27^\circ\text{C}$ 

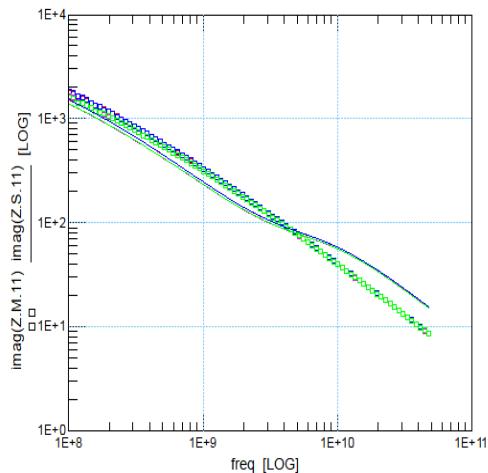
re(S11) = f(Vg,Vd)



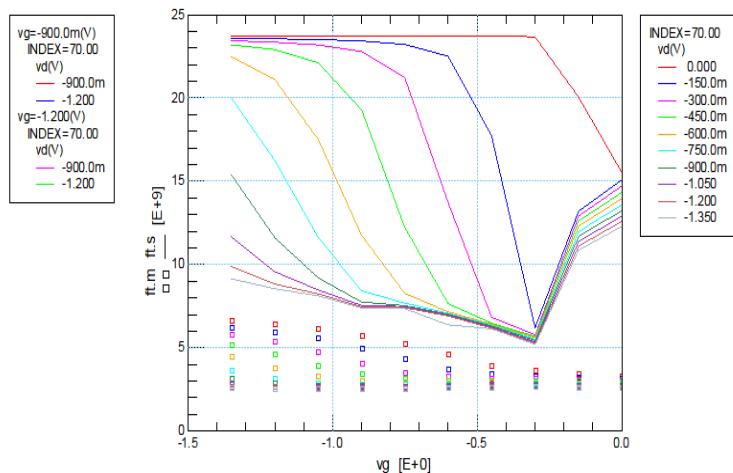
re(S22) = f(Vg,Vd)

im(Y11) divided by ω 

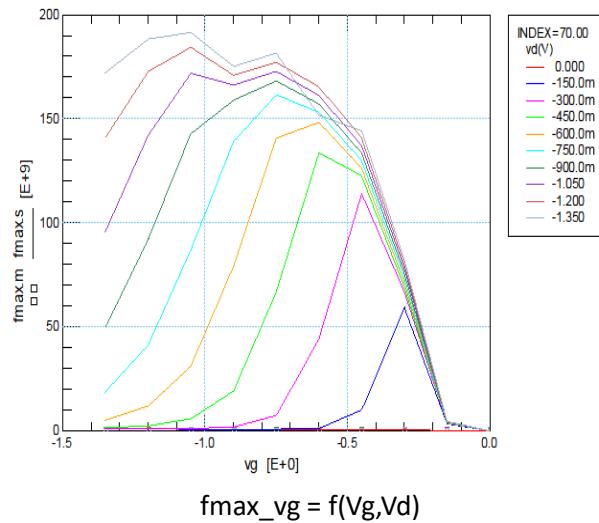
re(Z11) = f(Vg,Vd)



im(Z11) = f(Vg,Vd)

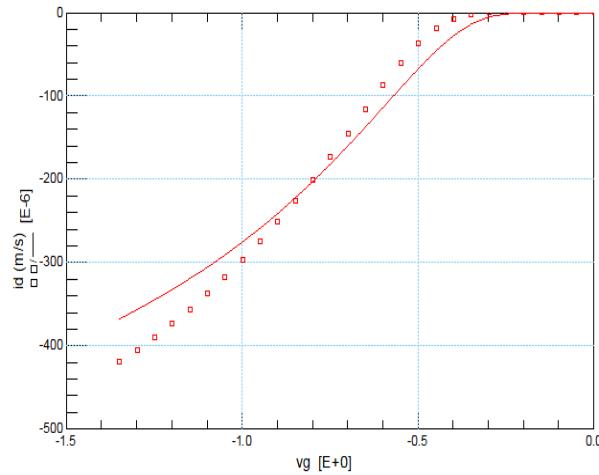


fT_vg = f(Vg,Vd)

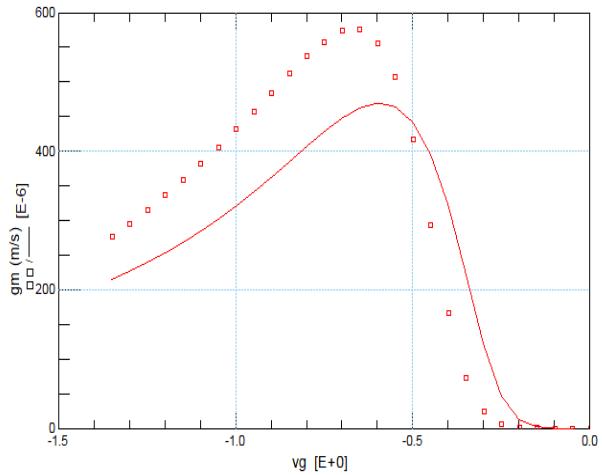


4.12 NF04_WF05u0_L0u18_post_63

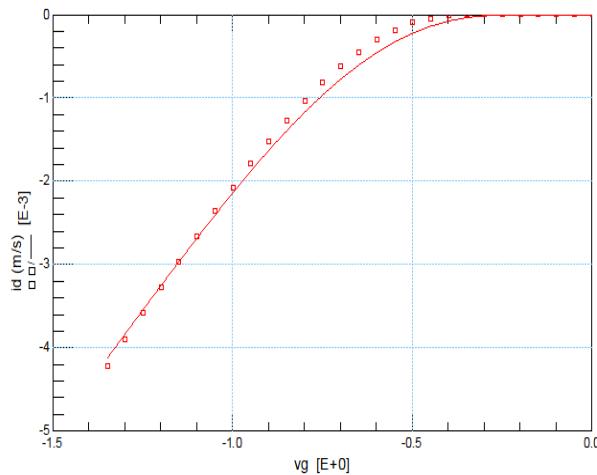
I_d vs V_g , $T = 27^\circ\text{C}$



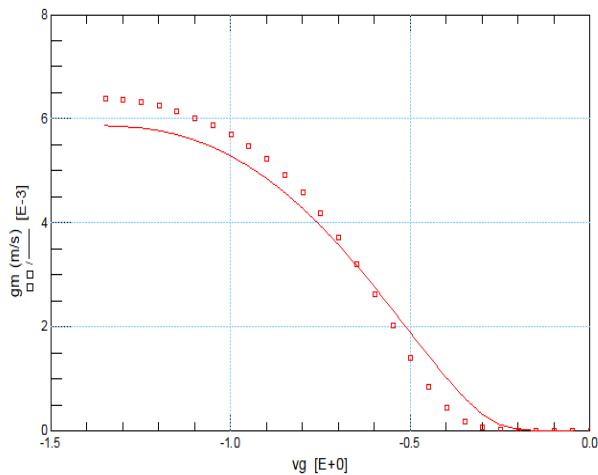
$$I_d = f(V_g) \text{ @ } V_d = -0.05\text{V}$$



$$g_m = f(V_g) \text{ @ } V_d = -0.05\text{V}$$

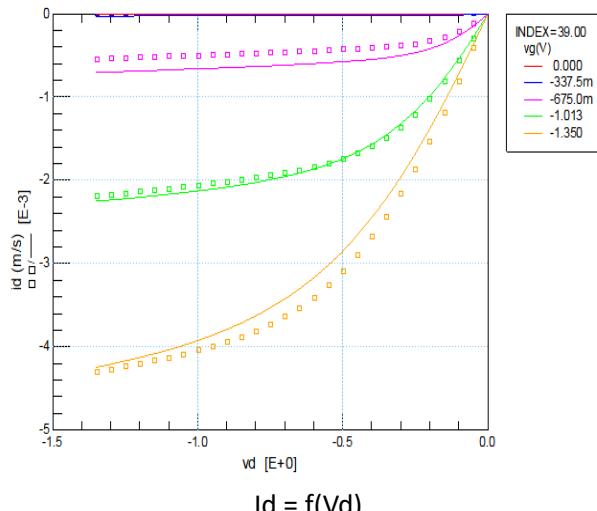


Id = f(Vg) @ Vd = -1.2V

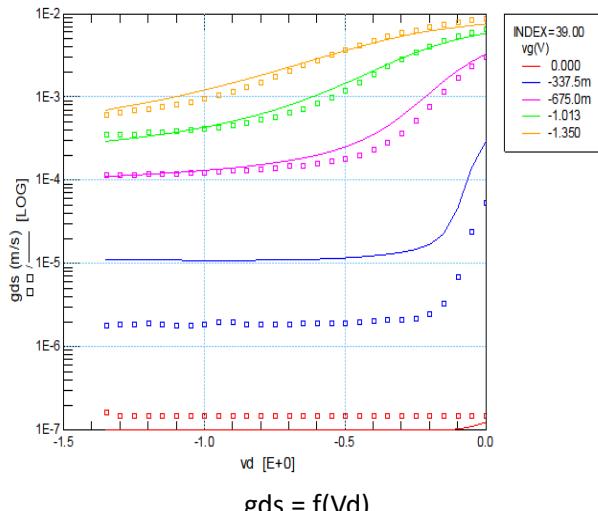


gm = f(Vg) @ Vd = -1.2V

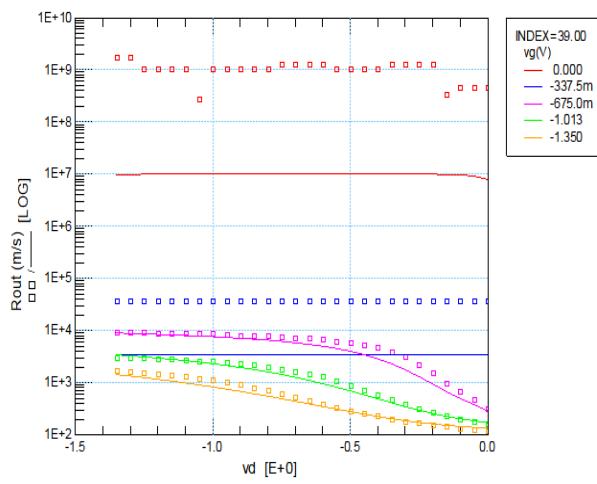
IdVd, T = 27°C



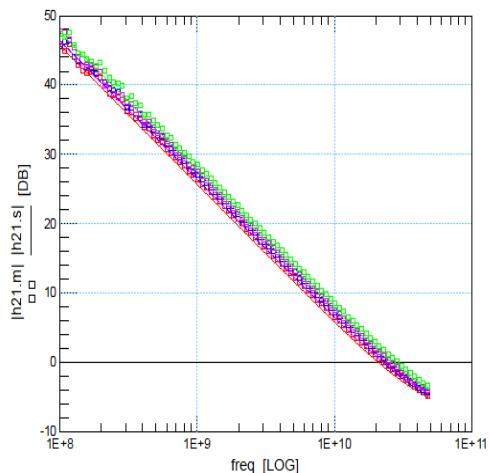
Id = f(Vd)



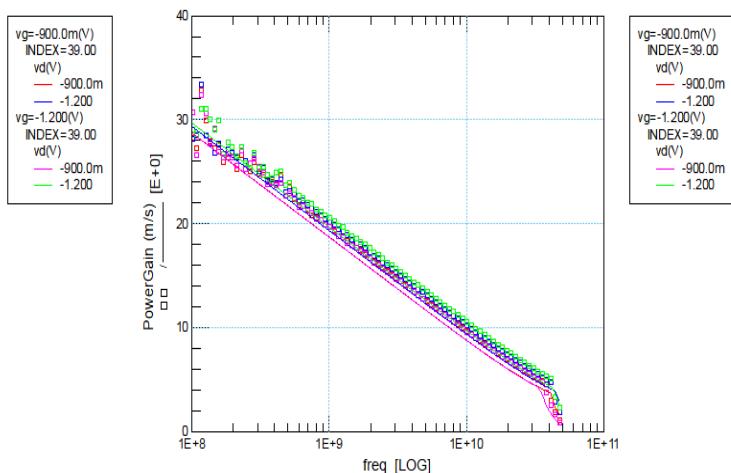
gds = f(Vd)



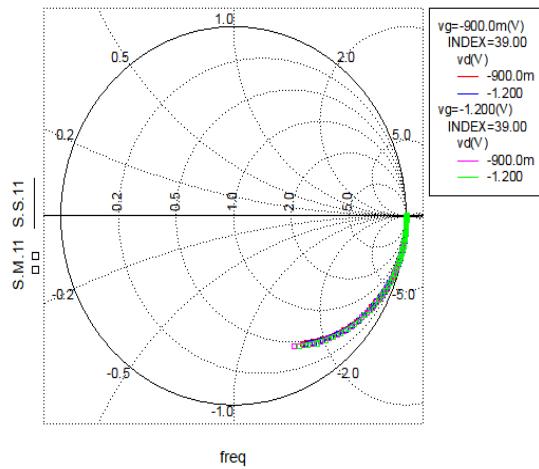
Rout = f(Vd)

S-Parameter, T = 27°C

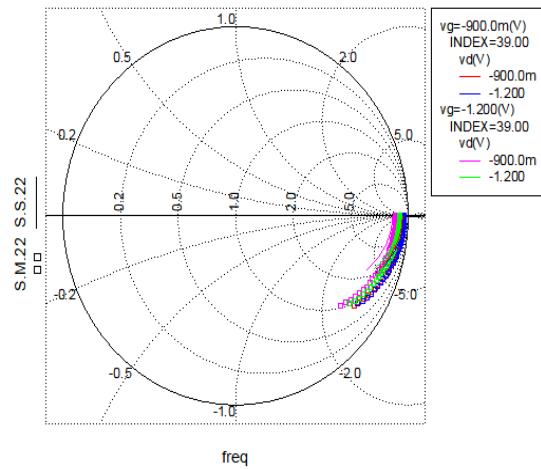
$$|h21| = f(Vg, Vd)$$



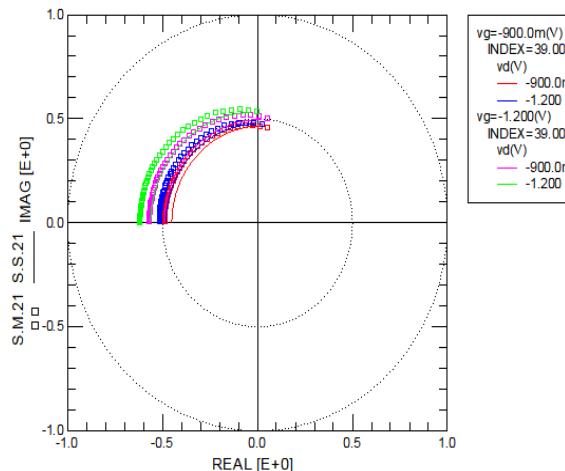
$$MSG/MAG = f(Vg, Vd)$$



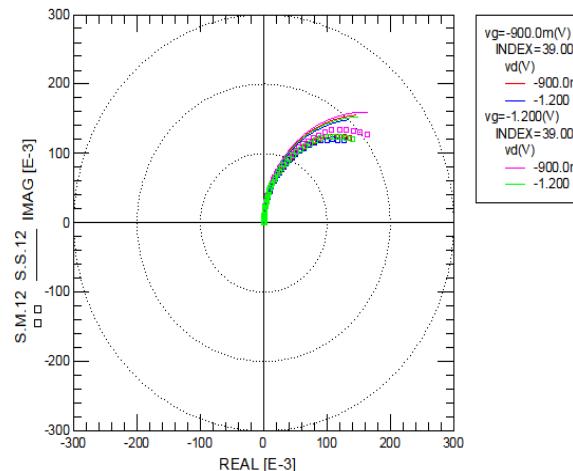
$$S11 = f(Vg, Vd)$$



$$S22 = f(Vg, Vd)$$

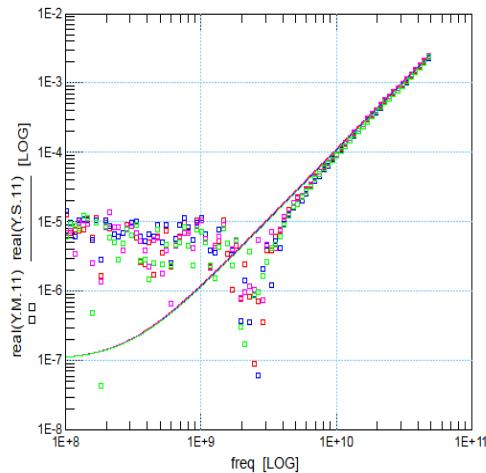


$$S21 = f(Vg, Vd)$$

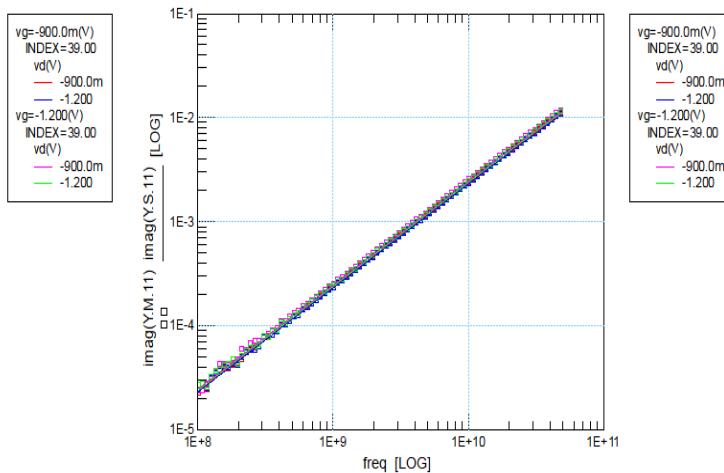


$$S12 = f(Vg, Vd)$$

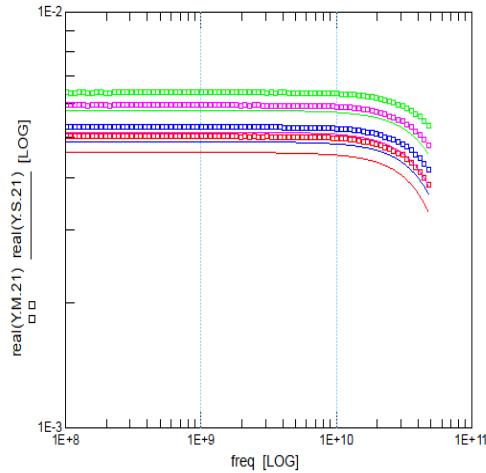
Y-Parameter, T = 27°C



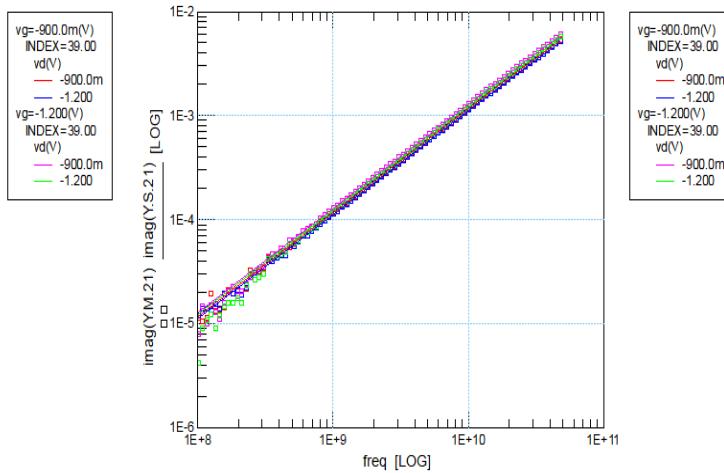
$$\text{re}(Y_{11}) = f(V_g, V_d)$$



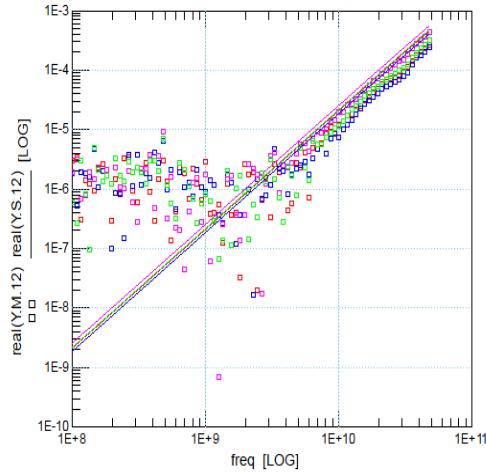
$$\text{im}(Y_{11}) = f(V_g, V_d)$$



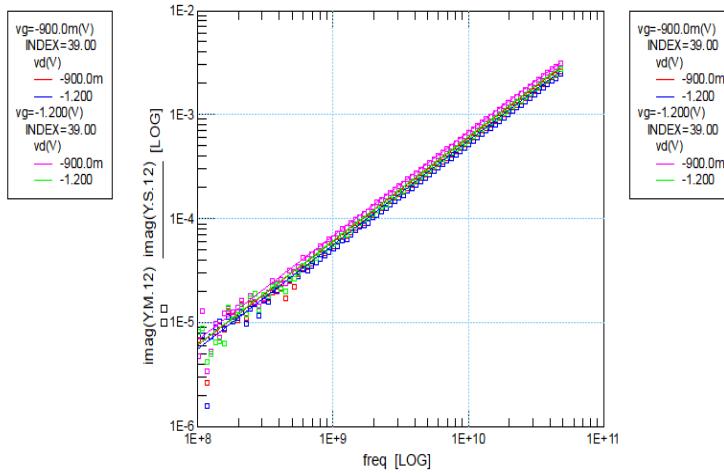
$$\text{re}(Y_{21}) = f(V_g, V_d)$$



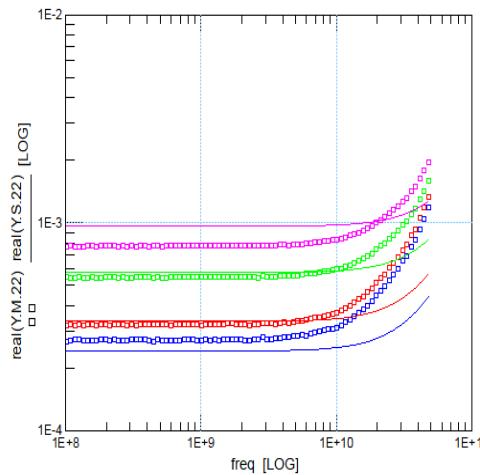
$$\text{im}(Y_{21}) = f(V_g, V_d)$$



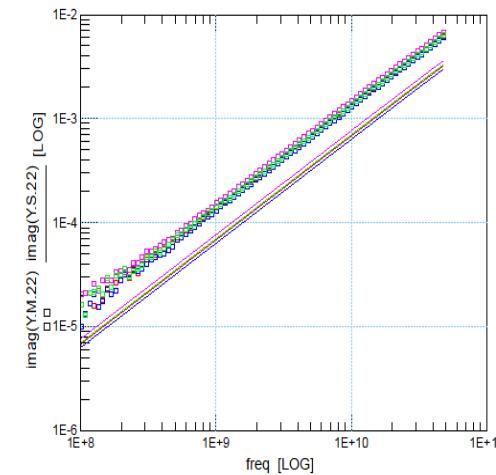
$$\text{re}(Y_{12}) = f(V_g, V_d)$$



$$\text{im}(Y_{12}) = f(V_g, V_d)$$

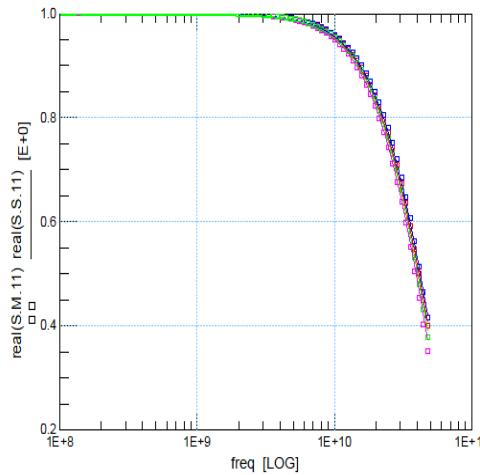


$$\text{re}(Y22) = f(Vg, Vd)$$

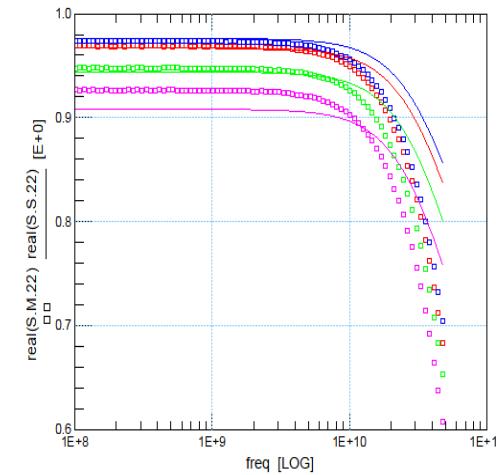


$$\text{im}(Y22) = f(Vg, Vd)$$

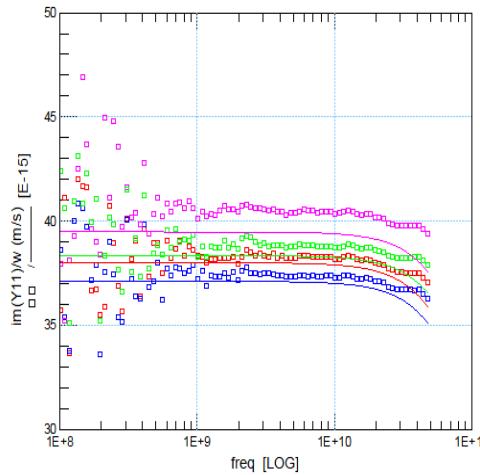
Verify Plots, T = 27°C



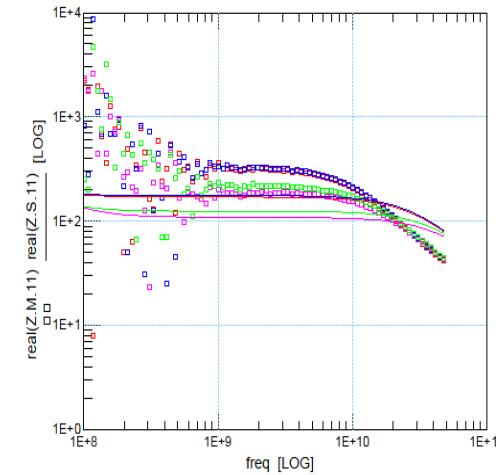
$$\text{re}(S11) = f(Vg, Vd)$$



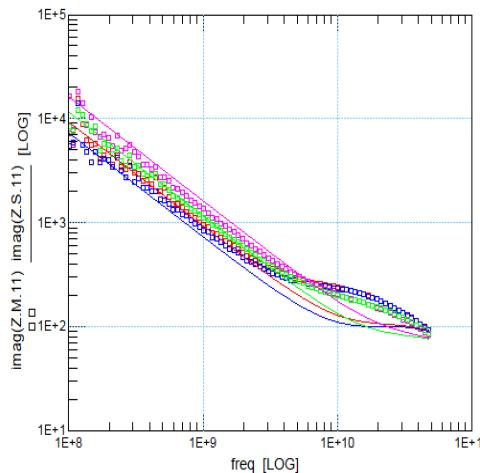
$$\text{re}(S22) = f(Vg, Vd)$$



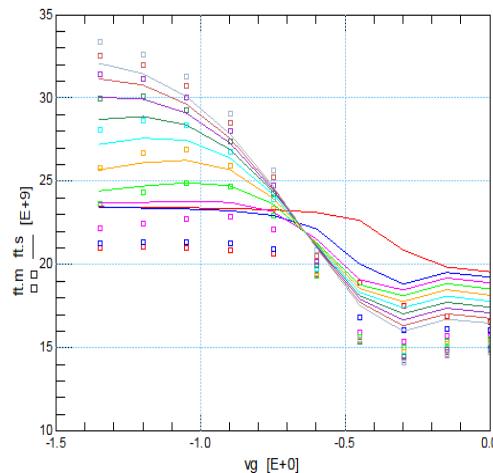
$$\text{im}(Y11) \text{ divided by } \omega$$



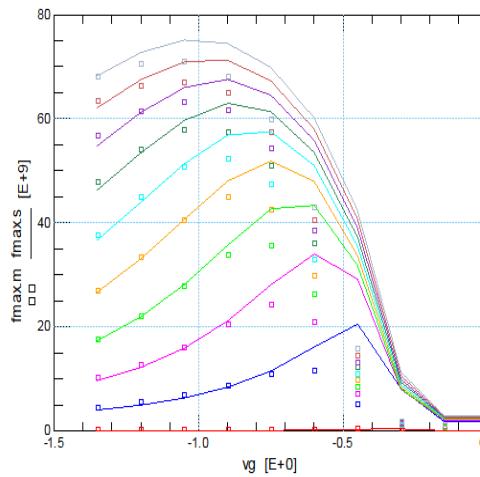
$$\text{re}(Z11) = f(Vg, Vd)$$

 $\text{im}(Z_{11}) = f(V_g, V_d)$

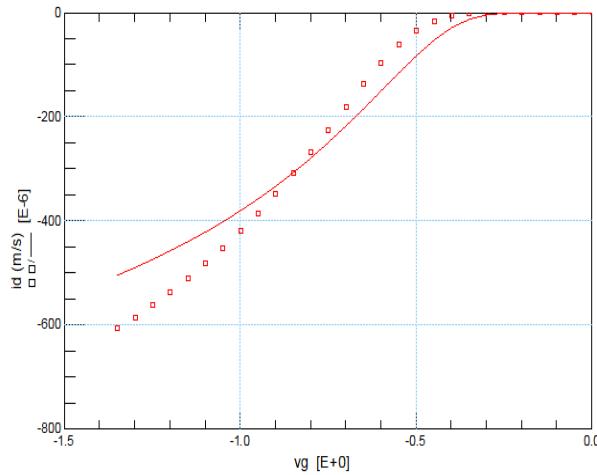
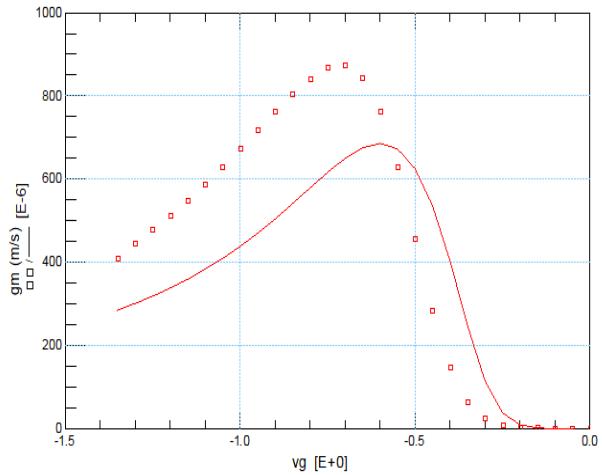
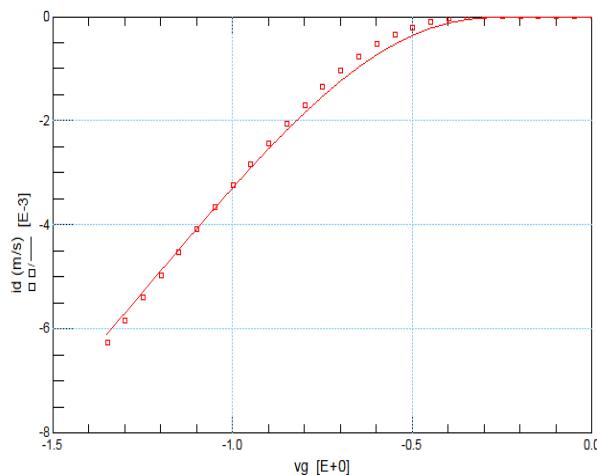
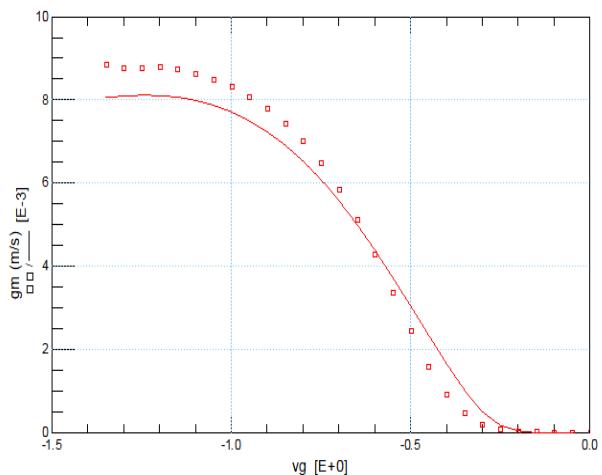
vg=-900.0m(V)
INDEX=39.00
vd(V)
-900.0m
-1.200
vg=-1.200(V)
INDEX=39.00
vd(V)
-900.0m
-1.200

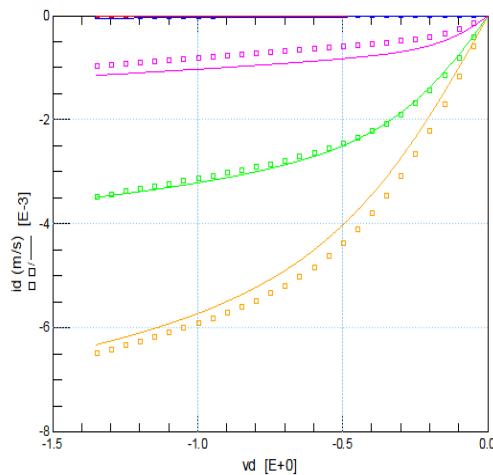
 $fT_{vg} = f(V_g, V_d)$

INDEX=39.00
vd(V)
0.000
-150.0m
-300.0m
-450.0m
-600.0m
-750.0m
-900.0m
-1.050
-1.200
-1.350

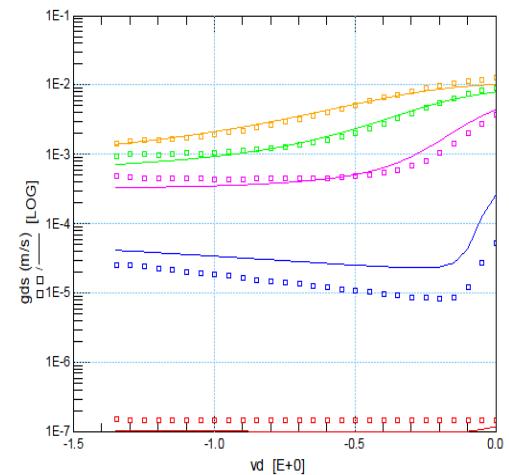
 $f_{\text{max}}_{vg} = f(V_g, V_d)$

INDEX=39.00
vd(V)
0.000
-150.0m
-300.0m
-450.0m
-600.0m
-750.0m
-900.0m
-1.050
-1.200
-1.350

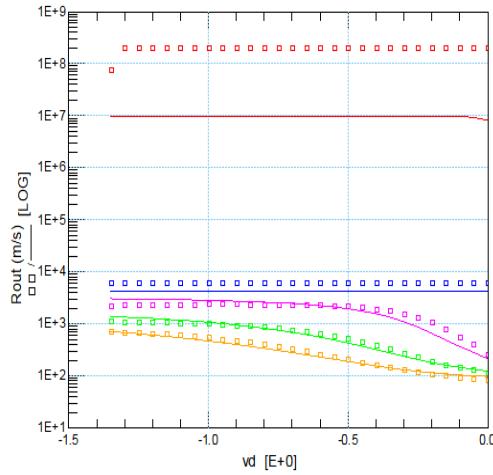
4.13NF04_WF05u0_L0u13_post_62**IdVg, T = 27°C** $Id = f(Vg) @ Vd = -0.05V$  $gm = f(Vg) @ Vd = -0.05V$  $Id = f(Vg) @ Vd = -1.2V$  $gm = f(Vg) @ Vd = -1.2V$

IdVd, T = 27°C

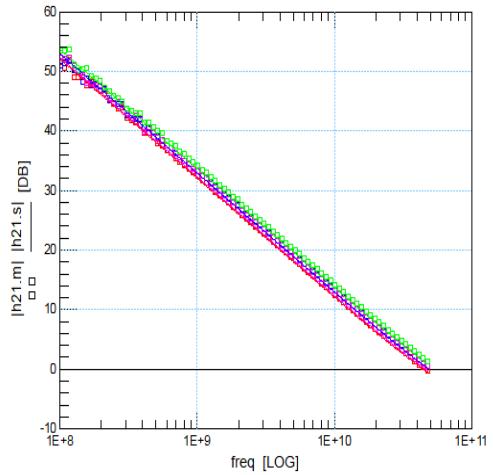
$$Id = f(Vd)$$



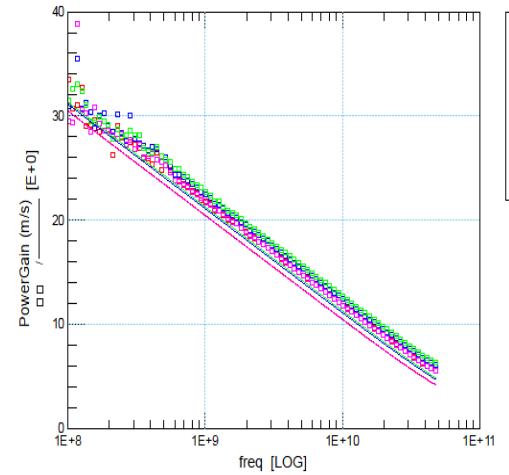
$$gds = f(Vd)$$



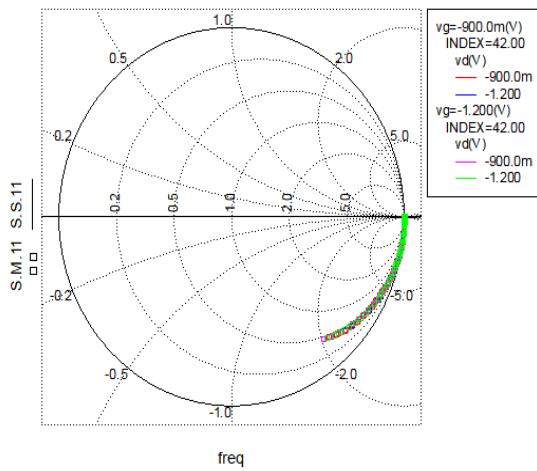
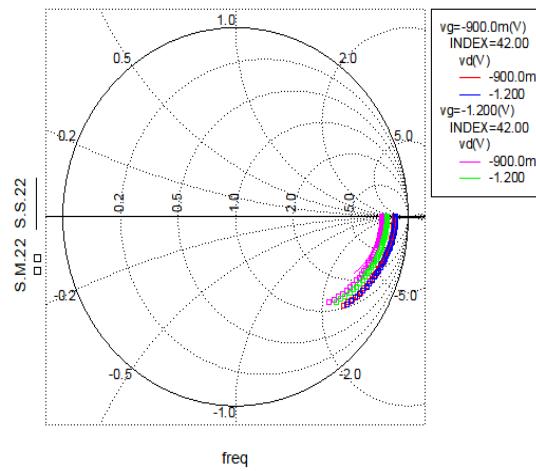
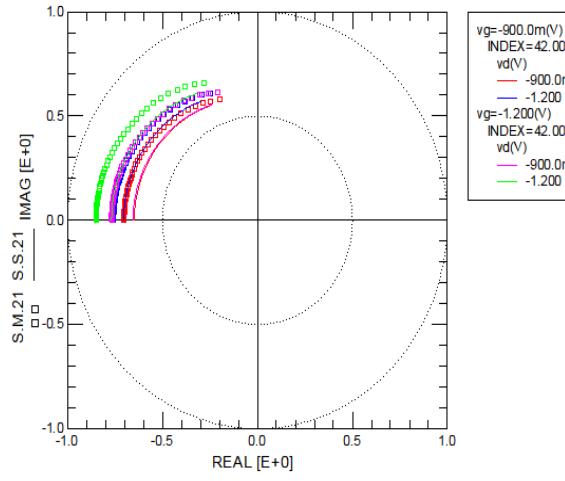
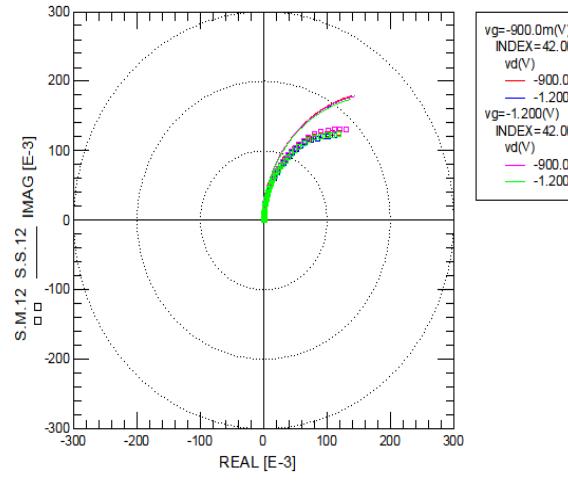
$$Rout = f(Vd)$$

S-Parameter, T = 27°C

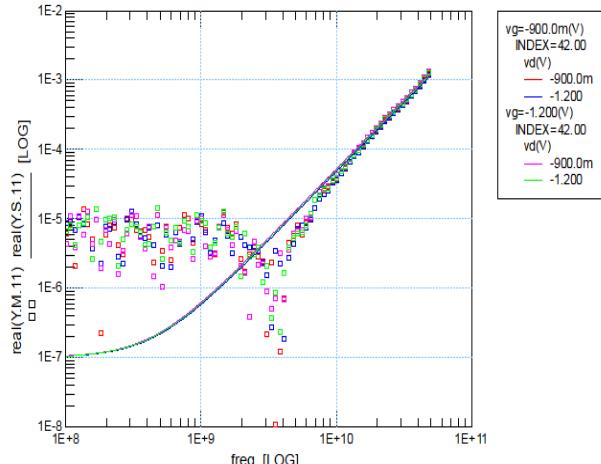
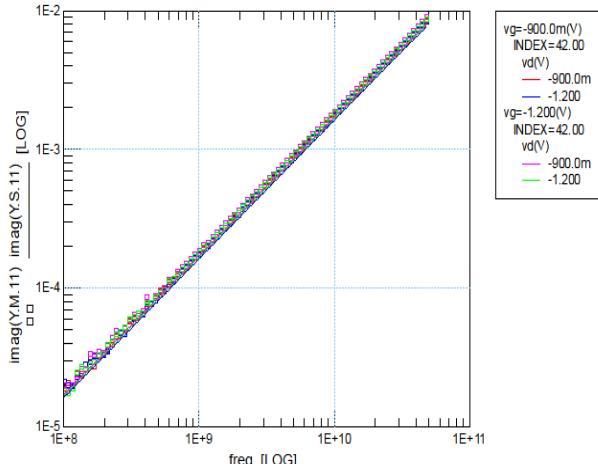
$$|h21| = f(Vg, Vd)$$

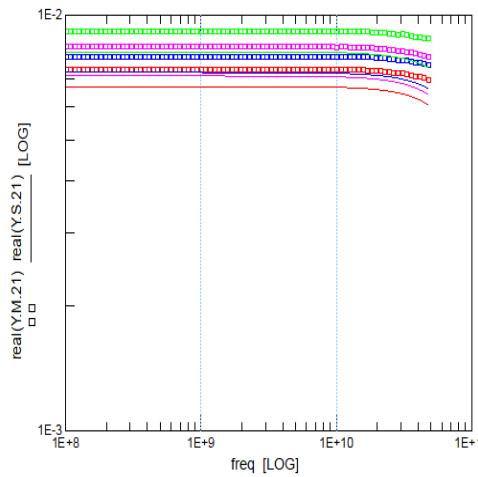
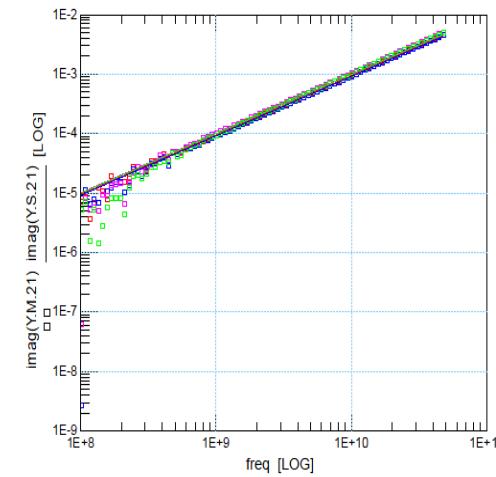
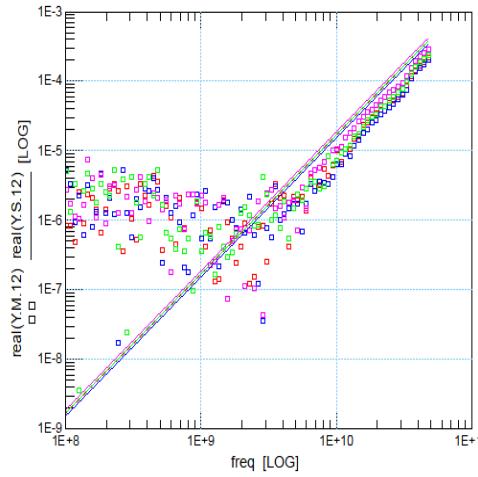
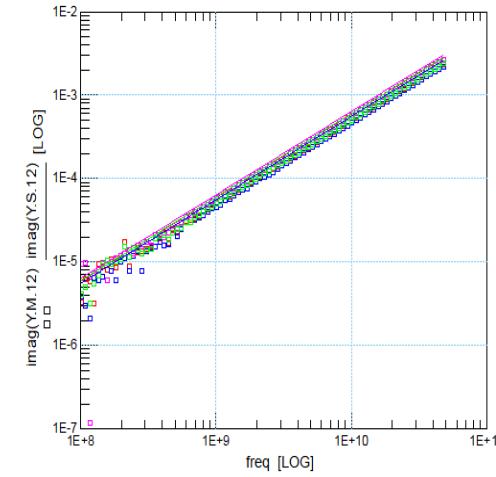
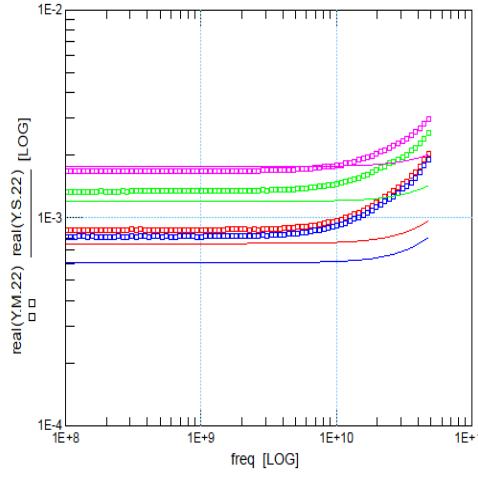
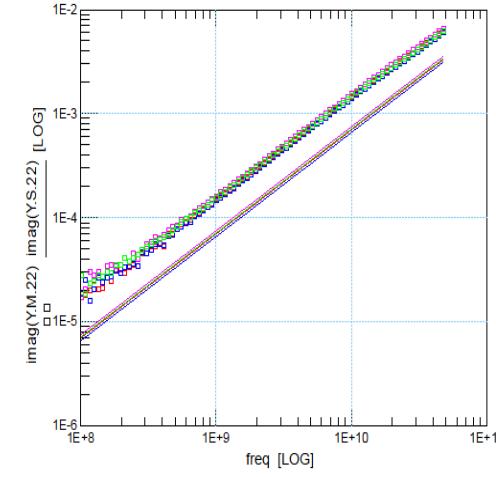


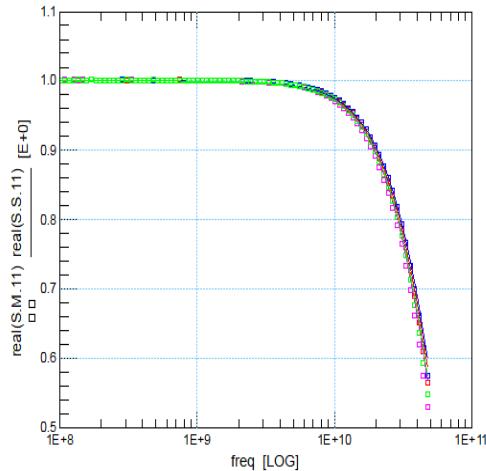
$$MSG/MAG = f(Vg, Vd)$$

 $S11 = f(Vg, Vd)$  $S22 = f(Vg, Vd)$  $S21 = f(Vg, Vd)$  $S12 = f(Vg, Vd)$

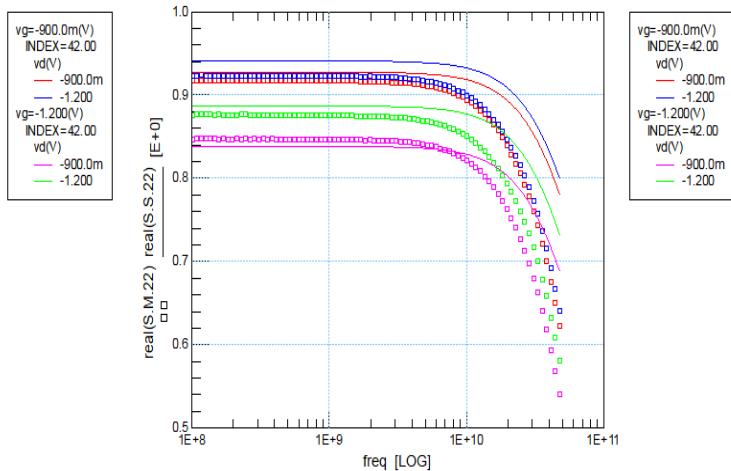
Y-Parameter, $T = 27^\circ C$

 $re(Y_{11}) = f(Vg, Vd)$  $im(Y_{11}) = f(Vg, Vd)$

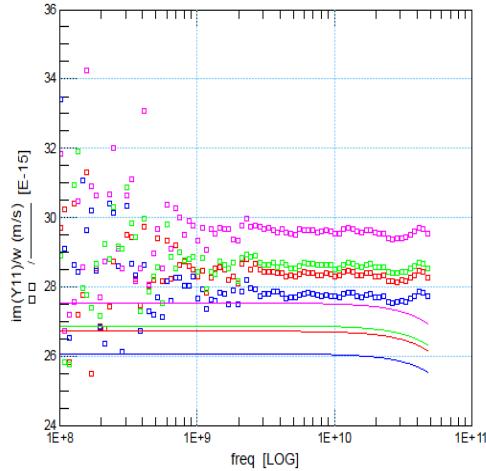
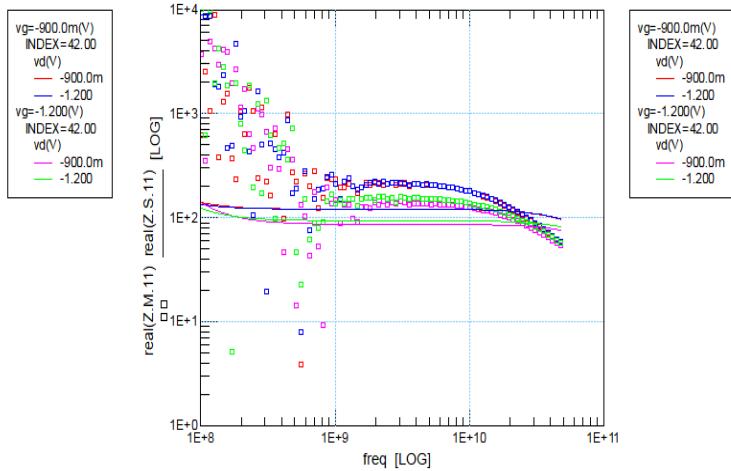
re(Y₂₁) = f(V_g, V_d)im(Y₂₁) = f(V_g, V_d)re(Y₁₂) = f(V_g, V_d)im(Y₁₂) = f(V_g, V_d)re(Y₂₂) = f(V_g, V_d)im(Y₂₂) = f(V_g, V_d)

Verify Plots, $T = 27^\circ\text{C}$ 

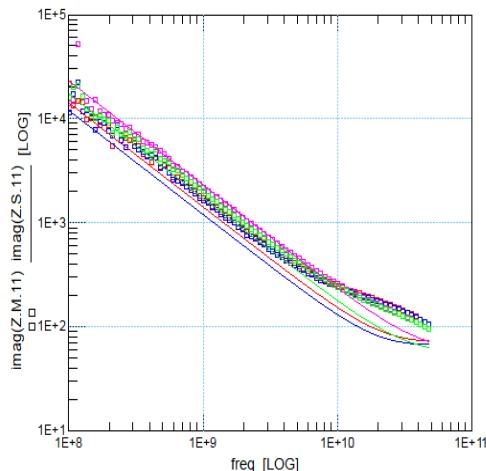
re(S11) = f(Vg, Vd)



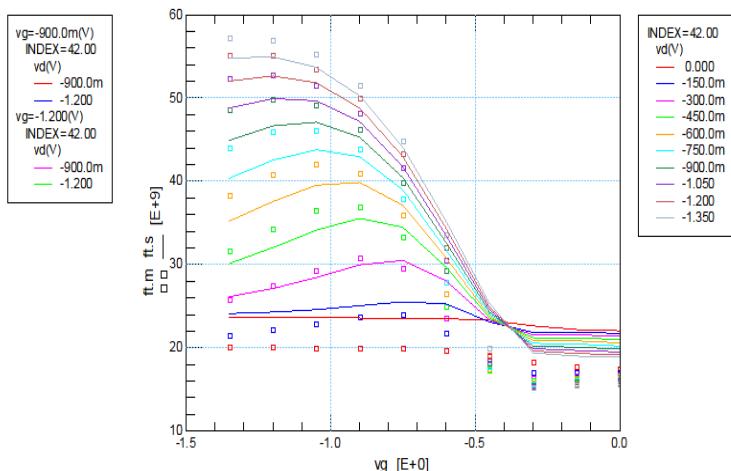
re(S22) = f(Vg, Vd)

im(Y11) divided by ω 

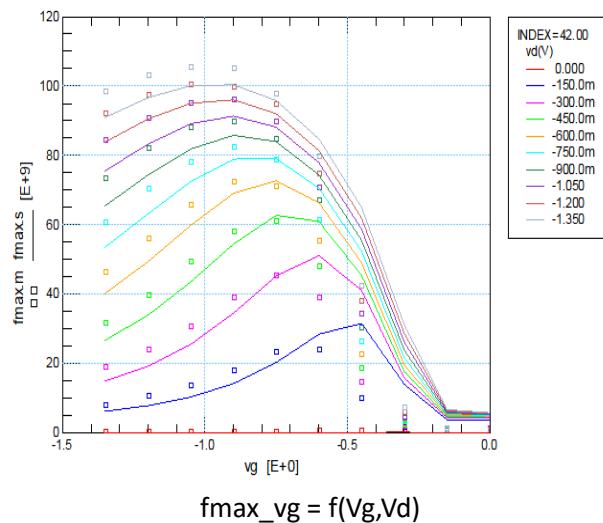
re(Z11) = f(Vg, Vd)



im(Z11) = f(Vg, Vd)



fT_vg = f(Vg, Vd)



5 Flicker Noise

Flicker noise model parameters are taken from the SG13 simulation models.

5.1 Measurement Conditions

Not defined as no flicker noise measurements are yet done on SG13G2 devices.

5.2 Devices

Not defined as no flicker noise measurements are yet done on SG13G2 devices.

6 Change History

Revision	Device	Changes
190606	All	Initial version
190730	All	Adjust temperature and RF behavior
190924	Summarized Results	Legend added