School
K. J. Somaiya ~~College~~ of Engineering, Mumbai-77
(A Constituent College of Somaiya Vidyavihar University

Batch: A2 Roll No.: 16010322014
Experiment / assignment / tutorial No. 10
Grade: AA / AB / BB / BC / CC / CD /DD
5/11/25

Signature of the Staff In-charge with date

TITLE: Design of Microwave amplifier for the specified gain and its matching circuit.
AIM: To design Microwave amplifier for the specified gain using MATLAB/Smith software

OUTCOME: Design microwave amplifiers.

Parameters

Design an amplifier to have a gain of 11 dB at 4.0 GHz. Plot constant gain circles for G_S = 2 dB and 3 dB, and G_L = 0 dB and 1 dB. Calculate and plot the input return loss & overall amplifier gain from 3 to 5 GHz. The FET has the following S parameters ($Z_0 = 50\Omega$)

f(GHz)	S_{11}	S_{21}	S_{12}	S_{22}
3	$0.80\angle-90°$	$2.8\angle100°$	0	$0.66\angle-50°$
4	$0.75\angle-120°$	$2.5\angle80°$	0	$0.60\angle-70°$
5	$0.71\angle-140°$	$2.3\angle60°$	0	$0.58\angle-85°$

Stepwise-Procedure:

Using MATLAB commands or using Smith software

1. Input the s parameter for the given BJT/FET
2. Input frequency of operation
3. Input the specified gain in dB.
4. Check the stability condition for the given amplifier
5. Calculate G_{Smax}, G_{Lmax}, G_0 in dB.
6. Calculate FTUmax
7. For I/P side or source calculate the parameters of I/p gain circles.
8. For O/P or Load calculate the parameter of O/P gain circles.
9. Plot I/P & O/P gain circles on the smith chart

Theoretical Calculations:

Complete theoretical design of amplifier:

Since $S_{12}=0$ and $|S_{11}|<1$ and $|S_{22}|<1$, the transistor is unilateral and unconditionally stable. from (11.47) we calculate the maxi matching section gains as

$$G_{S\,max} = \frac{1}{1-|S_{11}|^2} = 2.29 = 3.6\,dB$$

$$G_{L\,max} = \frac{1}{1-|S_{22}|^2} = 1.56 = 1.9\,db$$

Gain of the mismatched transistor is

$$G_0 = |S_{21}|^2 = 6.25 \cancel{\approx 8.0dB} = 7.95\,dB \approx 8.0\,dB$$

So the max. unilateral transducer gain is

$$G_{TU\,max} = 3.6+1.9+8.0 = 13.5\,dB$$

$G_S = 3dB$	$g_S = 0.875$	$C_S = 0.706\angle 120°$	$R_S = 0.1668$
$G_S = 2dB$	$g_S = 0.691$	$C_S = 0.627\angle 120°$	$R_S = 0.294$
$G_L = 1dB$	$g_L = 0.806$	$C_L = 0.520\angle 70°$	$R_L = 0.303$
$G_L = 0dB$	$g_L = 0.640$	$C_L = 0.440\angle 70°$	$R_L = 0.440$

$G_S = 2dB$ & $G_L = 1dB$, for overall amplifier gain of 11dB.

Comparison of key amplifier design parameters:

Simulated	Theoretical
Transistor gain G_0 = 8.0dB	8.0 dB
I/P Gain GS_{max} = 3.6 dB Gmax = 13.46	3.6 dB 13.5dB
Reflection coefficient at I/P =Γ_S 0.3~~45~~29 ∠12~~2~~0°	0.34 ∠120°
Reflection coefficient at O/P TL =Γ_L ~~0.228 ∠72°~~ 0.229 ∠71°	0.22 ∠70°

Conclusion:

Comment on the selection of Γ_S and Γ_L

In this experiment, a microwave amplifier was designed to achieve a specific gain of 8.0 dB at frequency
The amplifier parameters, such as the reflection coefficient at the input and output (Γ_S and Γ_L), were calculated & plotted using MATLAB or Smith software. The i/p & o/p gain circles were also analyzed to understand the amplifier's performance.
The selection of (Γ_S & Γ_L) played a crucial role in maximizing the gain & maintaining the stability of the amplifier
The practical transistor gain achieved was approximately 8.0 dB, which closely aligns with theoretical predictions.
This demonstrates that the amplifier design methodology effectively met the design specifications, validating the procedure and theoretical calculations for microwave amplifier design.

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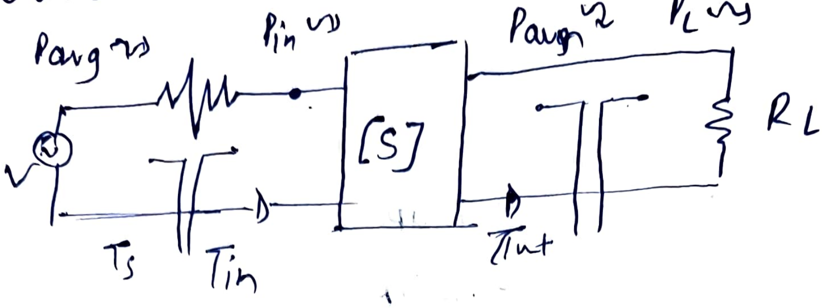
* Post Lab Subjective Questions

1. Derive relation for transducer power gain of an



Pavg : power available from source

PL : power deliverable to load

Pin : Power input

Pavn : Power available from n/w

Transducer power gain $G_T = P_L / P_{avs}$

available power gain $G_A = P_{avn} / P_{avs}$

Operating power gain $G_P = P_L / P_{in}$

Conjugate matching → $P_{in} = P_{avs}$ when $\Gamma_{in} = \Gamma_S$

$P_{avn} = P_L$ $\qquad \Gamma_{out} = \Gamma_L$

$G_T = G_A = G_P$ when $\Gamma_{in} = \Gamma_S$ & $\Gamma_{out} = \Gamma_L$

Transducer power gain G_T derivation

$$G_T = \frac{P_L}{P_{avs}}$$

So, power derived from load

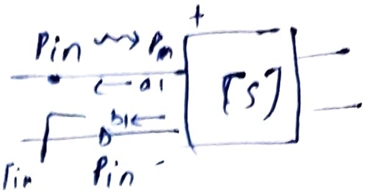
$P_L = \frac{1}{2}|b_2|^2 - \frac{1}{2}|a_2|^2 = \frac{1}{2}[b_2^2 - a_2^2]$, we know

that, $\Gamma_L = \frac{a_2}{b_2} \Rightarrow a_2 = \Gamma b_2$ $\quad P_L = \frac{1}{2}(b_2^2(1-\Gamma_L^2)) - (1)$

...e relation for radius and center of constant gain at input and output section.

...es available at source

...in = $P_{in}^{+} - P_{in}^{-} = \frac{1}{2}|a_1|^2 - \frac{1}{2}|b_1|^2$ —(1)



we know that $\Gamma_{in} = b_1/a_1$

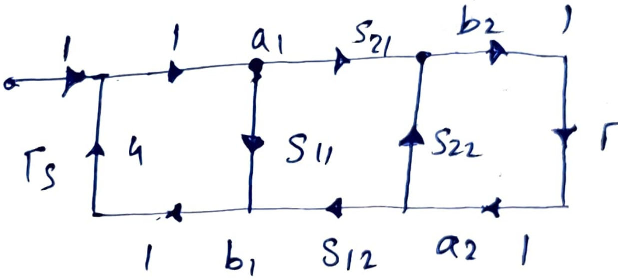
$$P_{in} = \frac{1}{2}(a_1)^2 \left(1 - \Gamma_{in})^2\right\} \quad \text{—(2)}$$

$P_{in} = P_{avs}$ when $\Gamma_{in} = \Gamma_S$

$$\therefore P_{avs} = \frac{1}{2}(a_1)^2 \left(1 - (\Gamma_S)^2\right)$$

$$G_T = \frac{P_L}{P_{avs}} = \frac{|b_2|^2}{|b_S|^2}\left[1 - \Gamma_L^2\right] \quad \text{—(3)}$$

Signal flow graph:



mason's gain formula:

$$\frac{b_2}{b_S} = \frac{\gamma_1 \Delta_1}{\Delta} = \frac{S_2}{1 - (S_{11}\Gamma_S + S_{22}\Gamma_L + S_{12}S_{21}\Gamma_S\Gamma_L) + (S_{11}\Gamma_S S_{22}\Gamma_L)}$$

Putting value in eq (3)

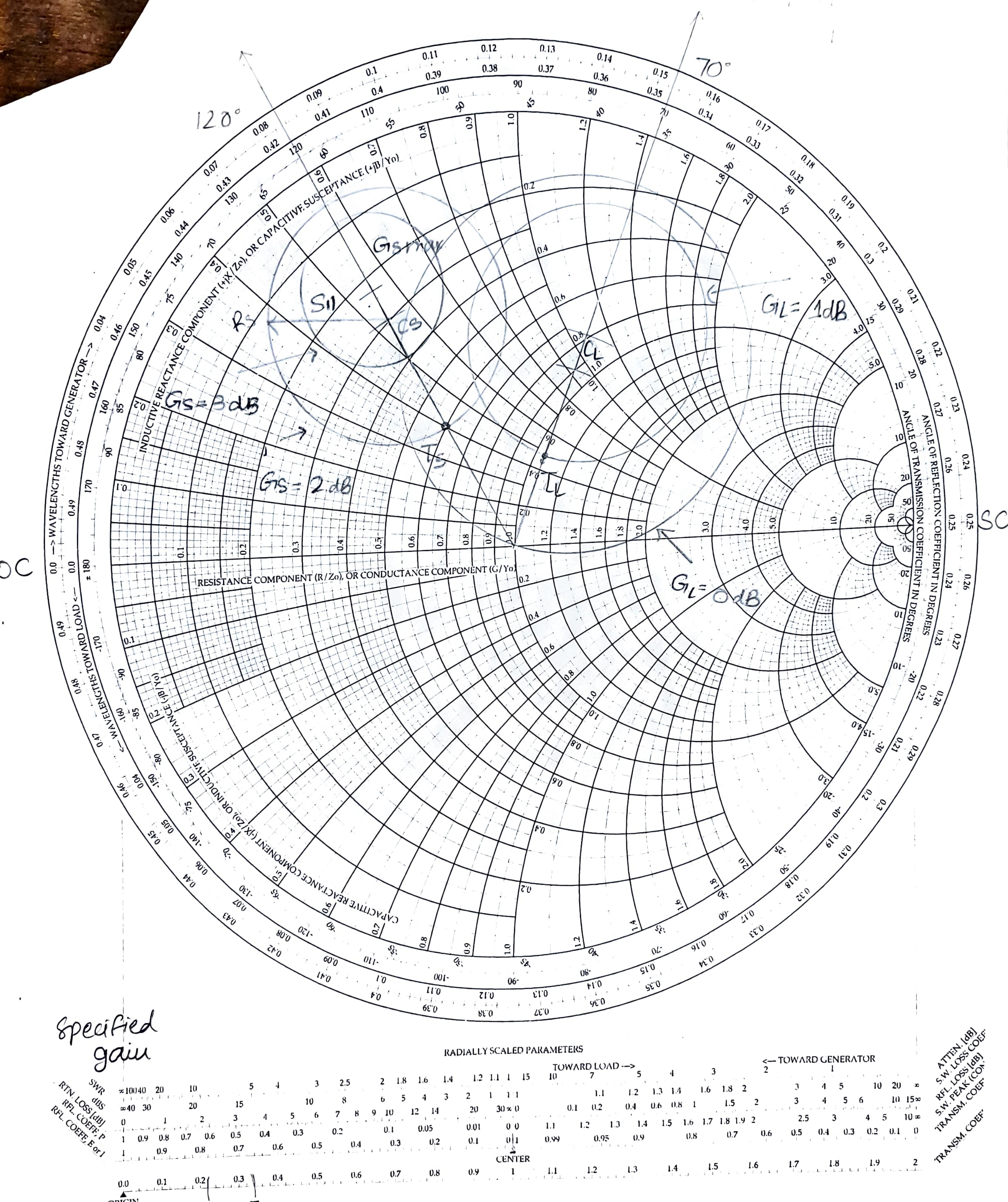
$$G_T = \frac{|S_{21}|^2 (1 - \Gamma_L)^2 (1 - \Gamma_S)^2}{\left((1 - S_{22}\Gamma_L)(1 - \Gamma_S \Gamma_{in})\right)^2}$$

$$G_T = \left[\frac{1 - \Gamma_S^2}{(1 - \Gamma_{in}\Gamma_S)^2}\right]\left[\underset{\substack{\uparrow \\ G_0}}{|S_{21}|^2}\right]\underbrace{\left[\frac{1 - |\Gamma_L|^2}{|1 - S_{22}\Gamma_L|^2}\right]}_{G_L}$$

$G_T = G_S \cdot G_0 \cdot G_L$ — desired

The Complete Smith Chart

Black Magic Design



Specified gain

Γ_L Γ_s

$0.22\angle 70^\circ$ $0.34\angle 120^\circ$

1dB

$C_L = 0.520$

$R_L = 0.303$

0dB

$C_L = 0.440$

$R_L = 0.440$

2dB

$C_S = 0.627$

$R_S = 0.294$

3dB

$C_S = 0.706$

$R_S = 0.166$

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$G_L = 1\,dB$

$10\log_{10}(G_L) = 1$

$\log_{10}(G_L) = 0.1$

$G_L = 10^{0.1}$

$G_L = 1.258$

$\simeq 1.26$

$g_L = \frac{G_L}{G_{Lmax}} = \frac{1.258}{1.56} = 0.8064$

ii) $G_L = 0\,dB$

$10\log_{10}(G_L) = 0$

$\log_{10}(G_L) = 0$

$G_L = 10^0$

$G_L = 1$

$g_L = \frac{G_L}{G_{Lmax}}$

$g_L = \frac{1}{1.56}$

$g_L = 0.640$

$C_L = \frac{g_L S^*_{22}}{1-(1-g_L)|S_{22}|^2}$

$R_L = \frac{\sqrt{1-g_L}\,(1-|S_{22}|^2)}{1-(1-g_L)|S_{22}|^2}$

1dB

$$C_L = \frac{(0.8064)\ 0.60\angle-70^\circ}{1(1-0.8064)\ |0.60\angle-70|^2}$$

$$= 0.520\angle 70^\circ$$

0dB

$$C_L = \frac{(0.640)\ 0.60\angle-70^\circ}{1(1-0.640)\ |0.60\angle-70^\circ|^2}$$

$$= 0.440\angle 70^\circ$$

1dB

$$R_L = \frac{\sqrt{1-0.8064}\ (1-|0.60\angle-70^\circ|^2)}{1-(1-0.8064)\ |0.60\angle-70|^2}$$

$$= 0.303$$

0dB

$$R_L = \frac{\sqrt{1-0.640}\ 0.60\angle-70^\circ}{1(1-0.640)\ |0.60\angle-70^\circ|^2}$$

$$= 0.440\ \cancel{\angle 70^\circ}$$

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$G_S = 2\,dB$

$2\,dB = 10\log_{10}(x)$

$\frac{2}{10} = \log_{10}(x)$

$0.2 = \log_{10}(x)$

$x = 10^{0.2}$

$x = 1.584$

$g_s = \frac{x}{G_{smax}}$

$= \frac{1.584}{\cancel{3.6}\ 2.29}$

$= \cancel{0.44} = 0.6917$

IV] $G_S = 3\,dB$

$3\,dB = 10\log_{10}(x)$

$\frac{3}{10} = \log_{10}(x)$

$0.3 = \log_{10}(x)$

$x = 10^{0.3}$

$x = 1.995$

$g_s = \frac{x}{G_{smax}}$

$= \frac{1.995}{\cancel{3.6}\ 2.29} = \cancel{0.554}\ 0.8711$

$C_S = \frac{g_s S_{11}^*}{1-(1-g_s)|S_{11}|^2}$

$R_S = \frac{\sqrt{1-g_s}\,(1-|S_{11}|^2)}{1-(1-g_s)|S_{11}|^2}$

$2\,dB = \frac{0.691(0.75\angle -120^\circ)}{1-(1-0.691)|0.75\angle -120^\circ|^2}$

$= 0.627\angle 120^\circ$

$2\,dB = \frac{\sqrt{1-0.691}\,(1-|0.75\angle 120^\circ|^2)}{1-(1-0.691)|0.75\angle -120^\circ|^2}$

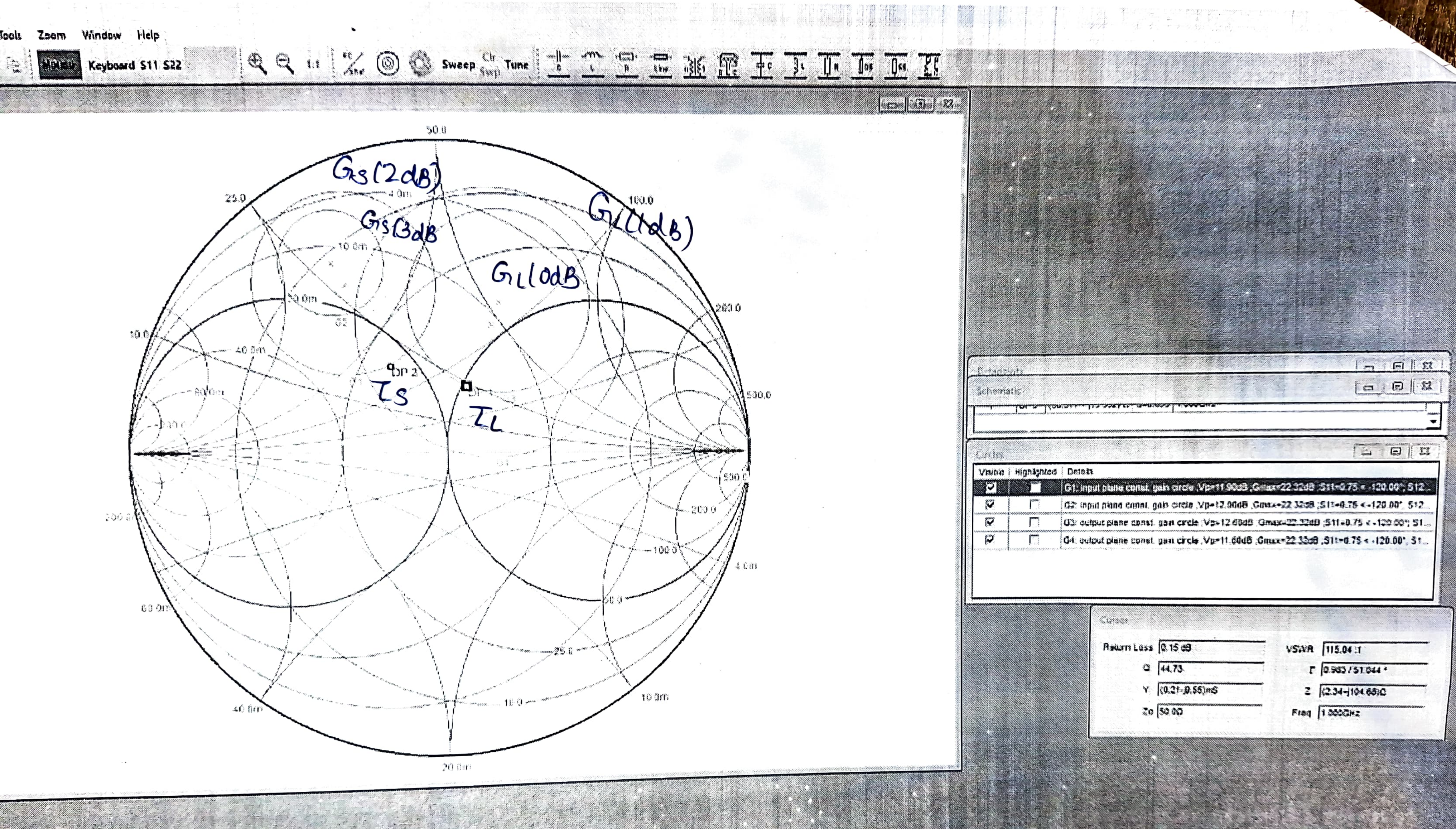
$= 0.294$

$3\,dB = \frac{0.871(0.75\angle -120^\circ)}{1-(1-0.891)|0.75\angle 120^\circ|^2}$

$= 0.706\angle 120^\circ$

$3\,dB = \frac{\sqrt{1-0.871}\,(1-|0.75\angle -120^\circ|^2)}{1-(1-0.871)|0.75\angle -120^\circ|^2}$

$= 0.166$


Tools Zoom Window Help
Keyboard S11 S22
Sweep
Tune
Gs(2dB)
Gs(3dB)
GL(1dB)
GL(0dB)
Γs
ΓL
Circles
Visible
Highlighted
Details
G1: input plane const. gain circle ,Vp=11.90dB ,Gmax=22.32dB ;S11=0.75 < -120.00°; S12
G2: input plane const. gain circle ,Vp=12.90dB ,Gmax=22.32dB ;S11=0.75 < -120.00°; S12
G3: output plane const. gain circle ,Vp=12.60dB ,Gmax=22.32dB ;S11=0.75 < -120.00°; S1...
G4: output plane const. gain circle ,Vp=11.60dB ,Gmax=22.32dB ;S11=0.75 < -120.00°; S1...
Return Loss 0.15 dB
Q 44.73
Y (0.21-j9.55)mS
Zo 50.0Ω
VSWR 115.04 :1
Γ 0.983 / 51.044 °
Z (2.34+j104.68)Ω
Freq 1.000GHz