1.3 GHz Singled Ended Amplifier Design

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Design Requirements

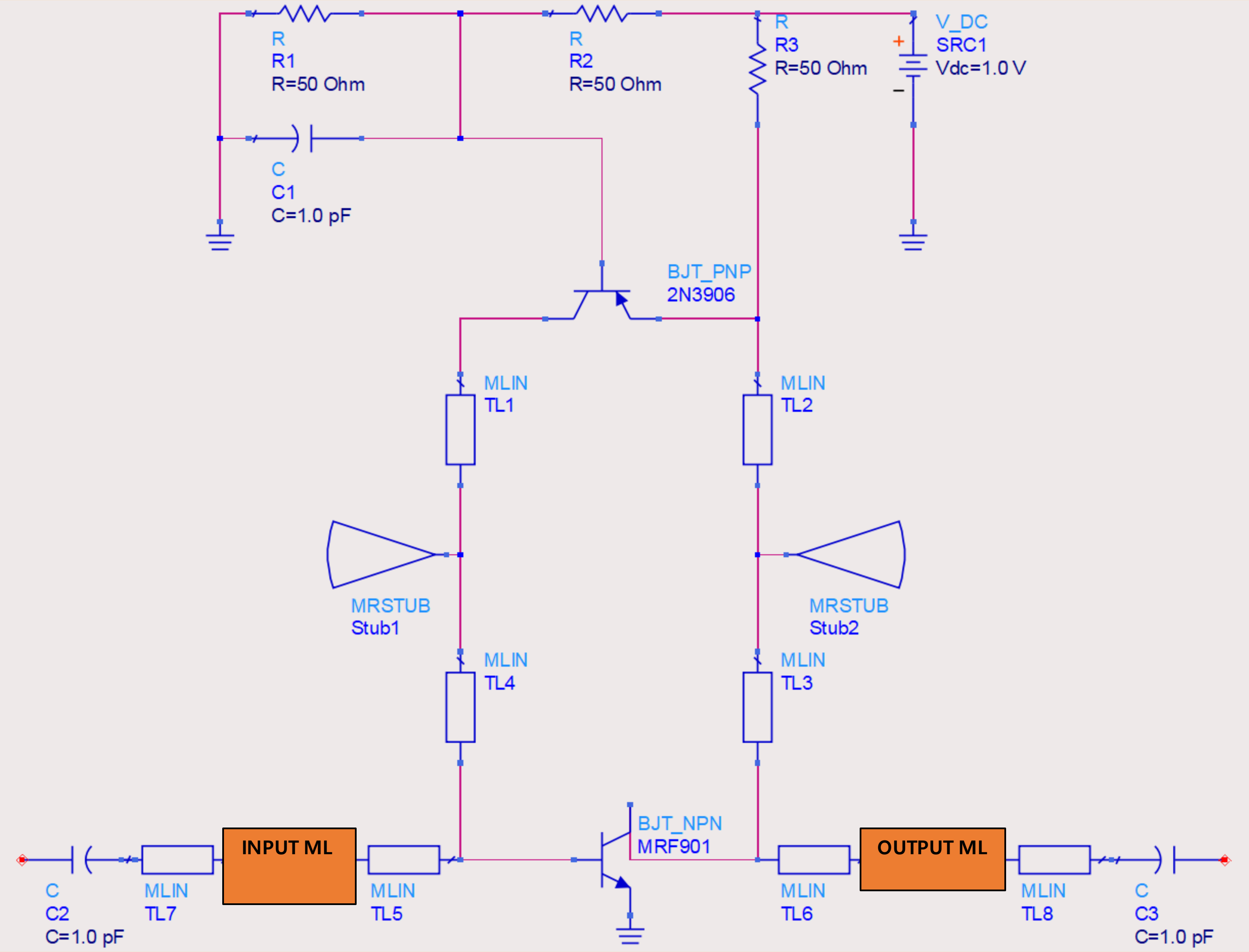
Focusing on maximizing the gain and minimizing return loss.

+11dB Single-Ended Transistor Amplifier

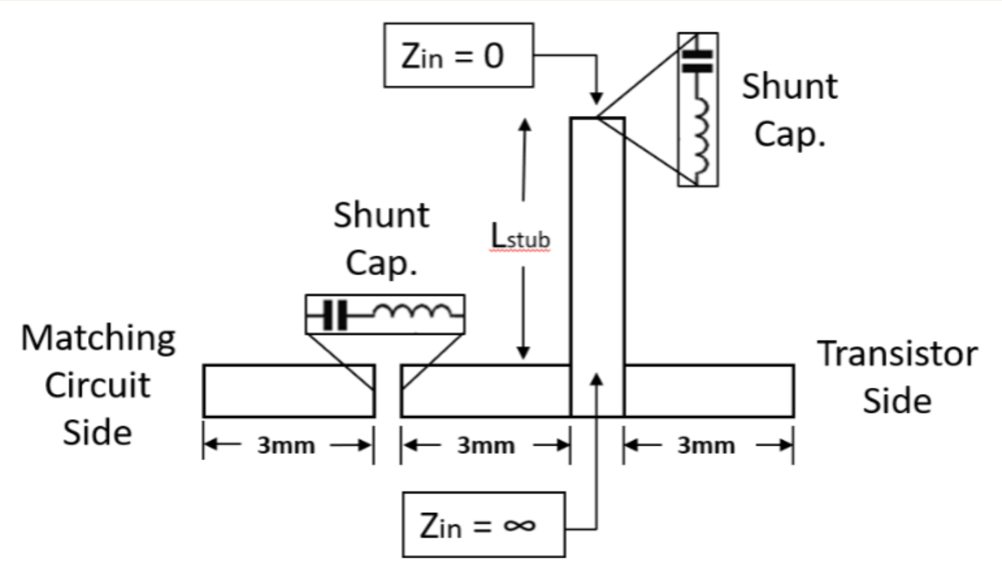
Center frequency of 1.3 GHz

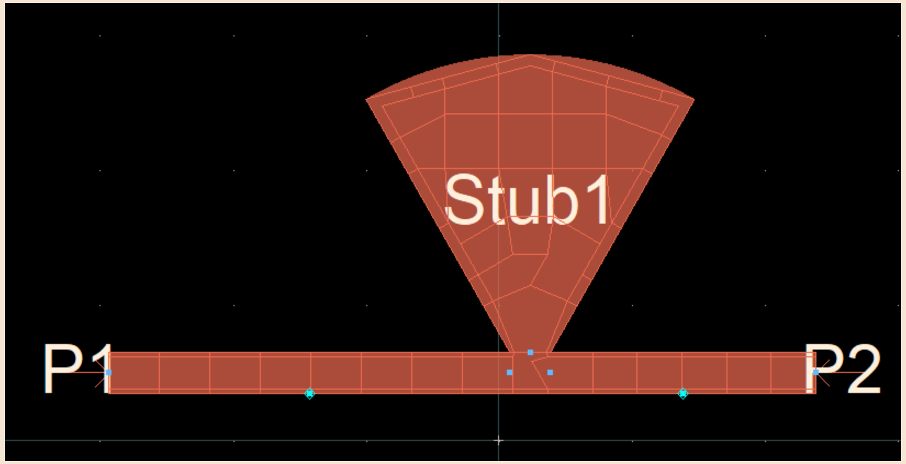
VSWR = 2:1

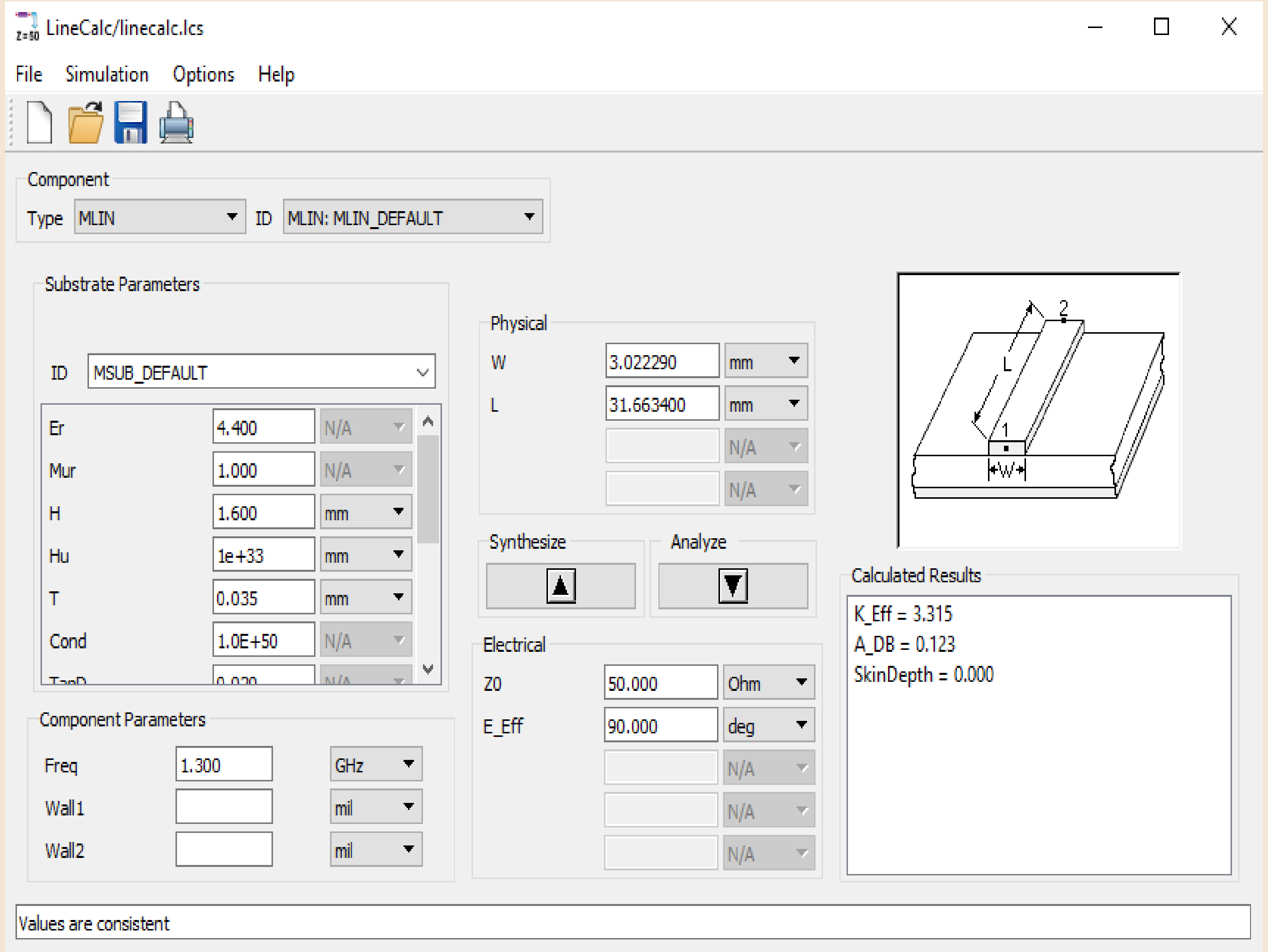
Circuit


R
R1
R=50 Ohm
R
R2
R=50 Ohm
R
R3
R=50 Ohm
V_DC
SRC1
Vdc=1.0 V
C
C1
C=1.0 pF
BJT_PNP
2N3906
MLIN
TL1
MLIN
TL2
MRSTUB
Stub1
MRSTUB
Stub2
MLIN
TL4
MLIN
TL3
BJT_NPN
MRF901
INPUT ML
OUTPUT ML
C
C2
C=1.0 pF
MLIN
TL7
MLIN
TL5
MLIN
TL6
MLIN
TL8
C
C3
C=1.0 pF

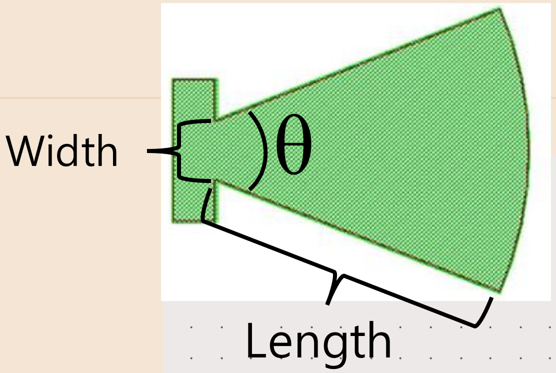
Bias Transmission Line

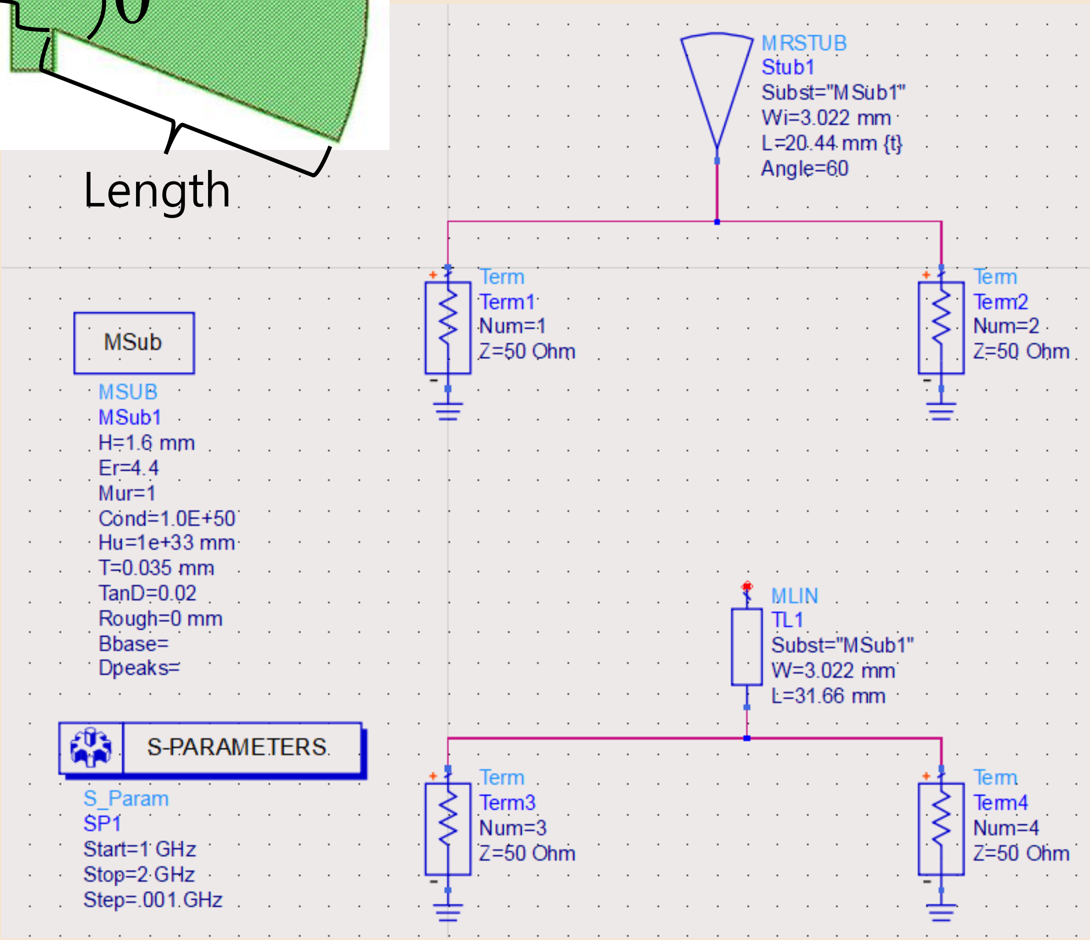


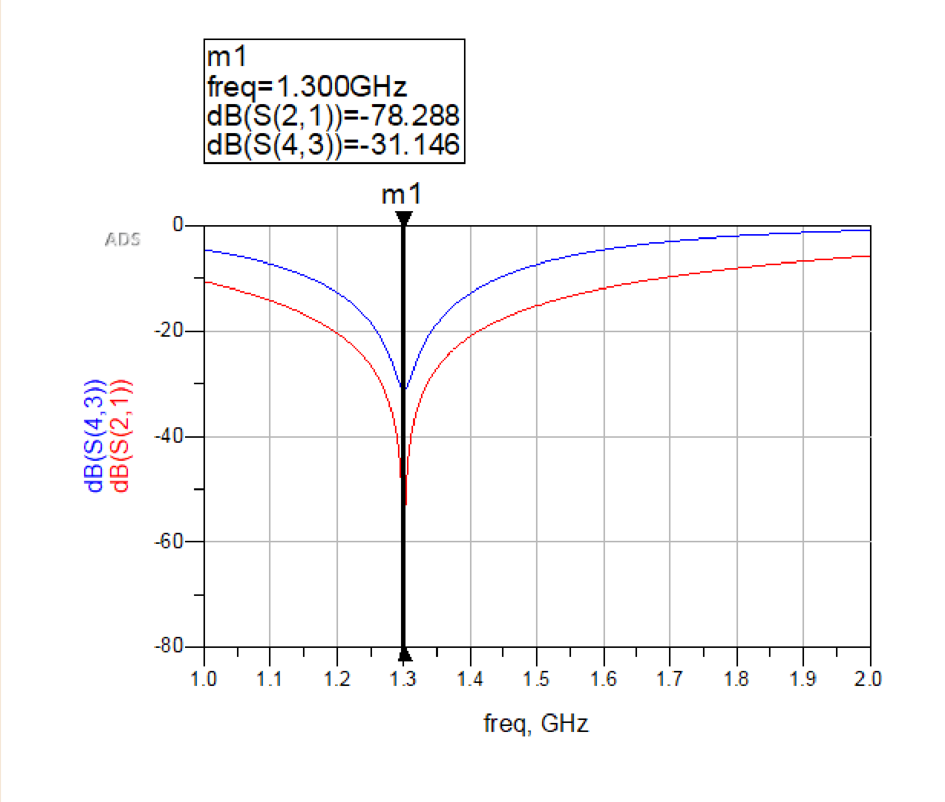




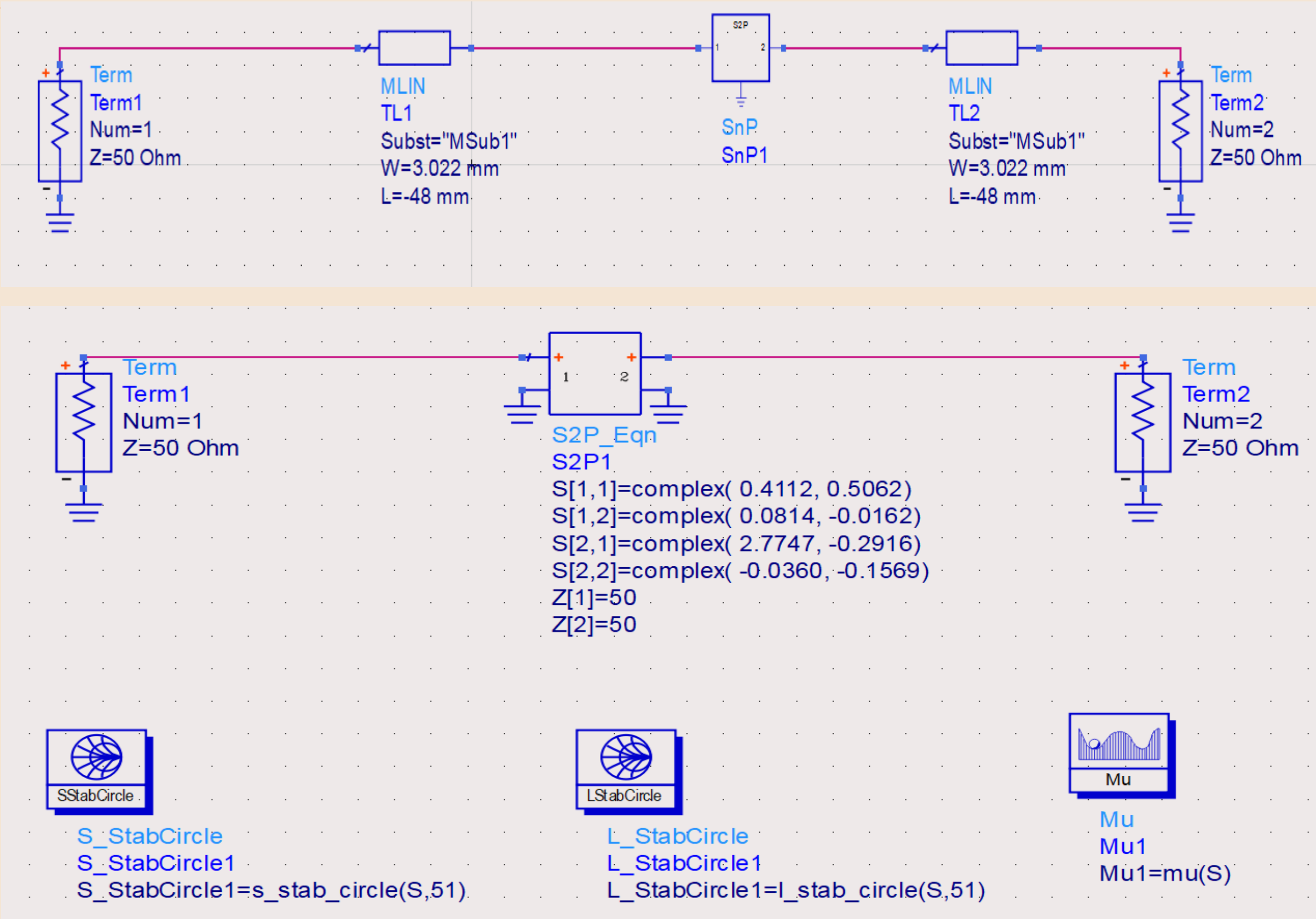
Radial vs Straight Stub

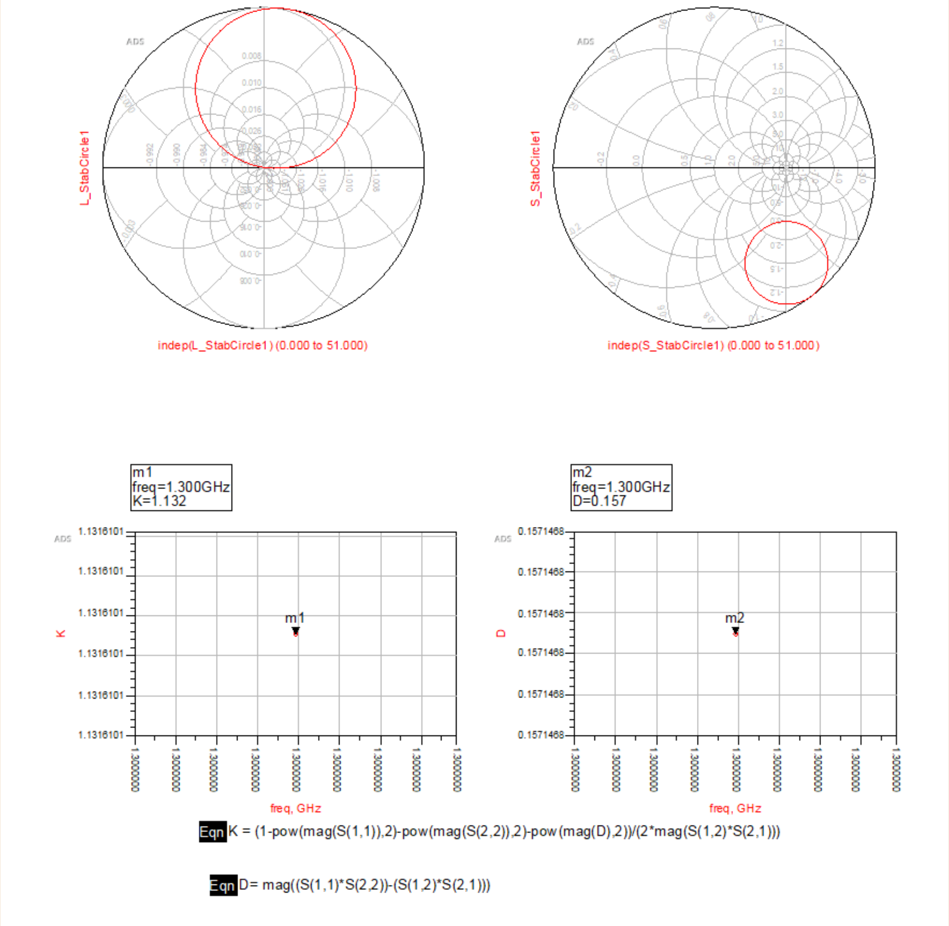






SNP File from VNA





Calculations

$$D = S_{11}S_{22} - S_{12}S_{21}$$

$$K = \frac{1-|S_{11}|^2-|S_{22}|^2+|D|^2}{2|S_{12}S_{21}|}$$

$$B_1 = 1 + |S_{11}|^2 - |D|^2 - |S_{22}|^2$$

$$C_1 = S_{11} - DS_{22}^*$$

$$B_2 = 1 + |S_{22}|^2 - |D|^2 - |S_{11}|^2$$

$$C_2 = S_{22} - DS_{11}^*$$

A 2-port is unconditionally stable if:

$K > 1$ and $|D| < 1$

$$\Gamma_{ms} = \frac{B_1 \pm \sqrt{B_1^2 - 4|C_1|^2}}{2C_1} \qquad \Gamma_{ml} = \frac{B_2 \pm \sqrt{B_2^2 - 4|C_2|^2}}{2C_2}$$

Available Power Gain:

$$G_A \equiv \frac{\mathrm{P_{avo}}}{\mathrm{P_{avs}}} = \frac{|S_{21}|^2\,(1-|\Gamma_S|^2)}{(1-|S_{22}|^2)+|\Gamma_S|^2(|S_{11}|^2-|D|^2)-2Re(\Gamma_S C_1)}$$

Transducer Power Gain:

$$G_T \equiv \frac{\mathrm{P_{out}}}{\mathrm{P_{avs}}} = \frac{|S_{21}|^2\,(1-|\Gamma_S|^2)\,(1-|\Gamma_L|^2)}{|(1-S_{11}\Gamma_S)(1-S_{22}\Gamma_L)-S_{12}S_{21}\Gamma_L\Gamma_S|^2}$$

$$Z_X = Z_o\frac{1+\Gamma_X}{1-\Gamma_X}$$

$$G_{A,max} = \left|\frac{S_{21}}{S_{12}}[K \pm \sqrt{K^2-1}]\right|$$

MATLAB

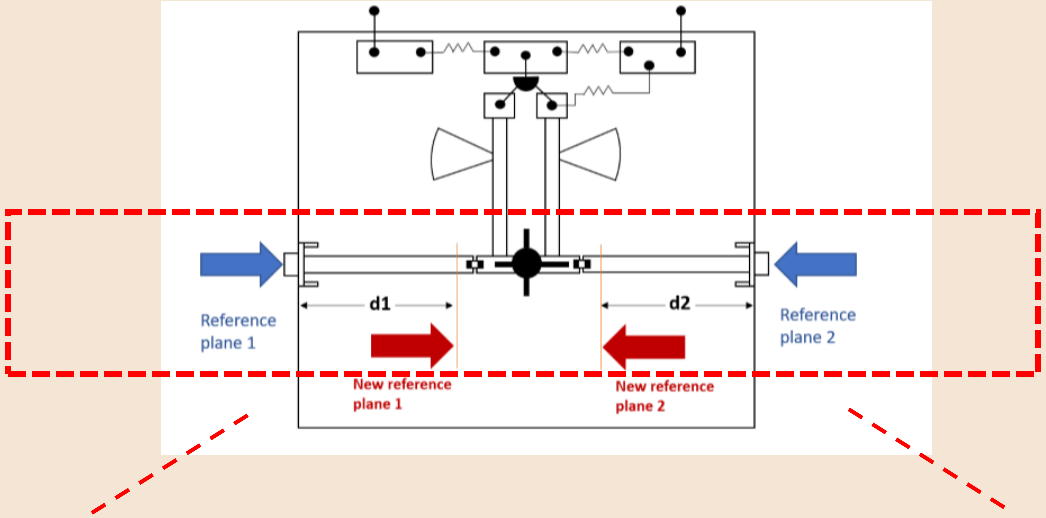
```
clear
close
%%% Matching Network Design %%%
phasor = @(mag,ang) mag*cosd(ang)+1j*mag*sind(ang);   %phasor(mag/ang) to a complex number (Real/Img)
S11 = phasor(0.65,50.76);
S12 = phasor(0.083,-11.2399);
S21 = phasor(2.79,-6.00);
S22 = phasor(0.161,-102.937);

%%%%Gains and others
D = 0.157;     %From ADS simulation
K = 1.132;     %From ADS simulation

B1 = 1 + abs(S11)^2 - D^2 - abs(S22)^2;
C1 = S11 - D*conj(S22);
B2 = 1 + abs(S22)^2 - D^2 - abs(S11)^2;
C2 = S22 - D*conj(S11);

Rs = (B1 - sqrt(B1^2 - 4*abs(C1)^2))/(2*C1);      %Reflection of the source
Rl = (B2 - sqrt(B2^2 - 4*abs(C2)^2))/(2*C2);      %Reflection of the load

Zs = 50 * (1+Rs)/(1-Rs)                           %Impedance of the source side
Zl = 50 * (1+Rl)/(1-Rl)                           %Impedance of the load side

GA = [(abs(S21)^2)*(1-abs(Rl)^2)]/[(1-(abs(S22)^2))+(abs(Rs)^2)*((abs(S11)^2)-((D^2))-2*real(Rs*C1))]    %Available Power Gain

GT = [(abs(S21)^2)*(1-abs(Rs)^2)*(1-(abs(Rl)^2))]/[abs((1-(S11*Rs))*(1-S22*Rl)-(S12*S21*Rl*Rs))^2]       %Transducer Power Gain

GuT = [(1-(abs(Rs))^2)/abs(1-S11*Rs)^2]*(abs(S21)^2)*[[1-abs(Rl)^2]/[abs(1-S22*Rl)^2]]                  %Unilaterial Transducer Power Gain

Gmax = abs((S21/S12)*[K - sqrt(K^2-1)])                                                                 %Maximum Available Gain
```

Workspace

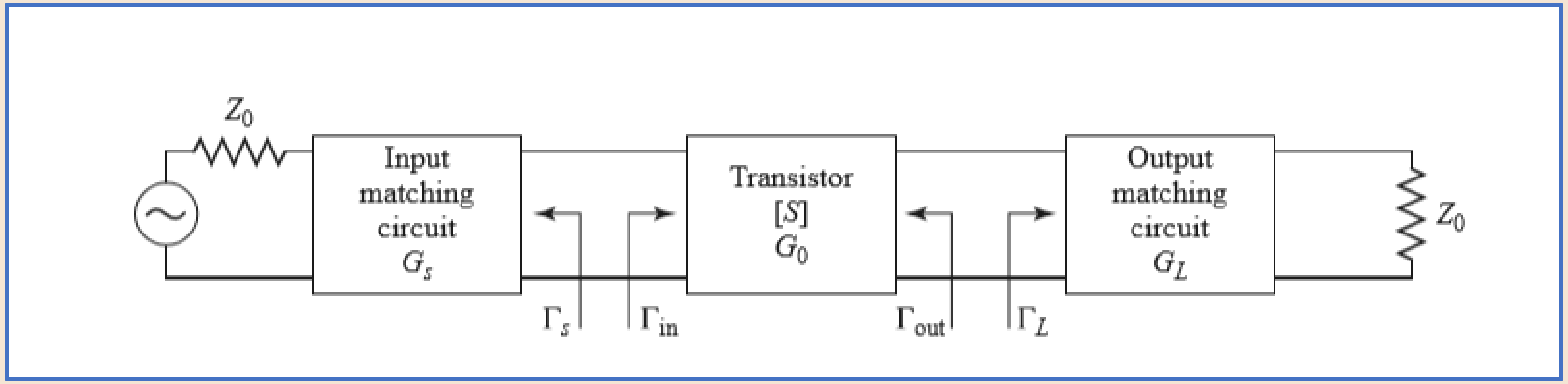
Name	Value
B1	1.3719
B2	0.5788
C1	0.4168 + 0.4788i
C2	-0.1006 - 0.0779i
D	0.1570
GA	9.5734
Gmax	20.2193
GT	13.7703
GuT	13.4797
K	1.1320
phasor	@(mag,ang)mag*cos...
Rl	-0.1831 + 0.1418i
Rs	0.4407 - 0.5062i
S11	0.4112 + 0.5034i
S12	0.0814 - 0.0162i
S21	2.7747 - 0.2916i
S22	-0.0360 - 0.1569i
Zl	33.3247 + 9.9844i
Zs	48.2884 - 88.9500i

Matching networks

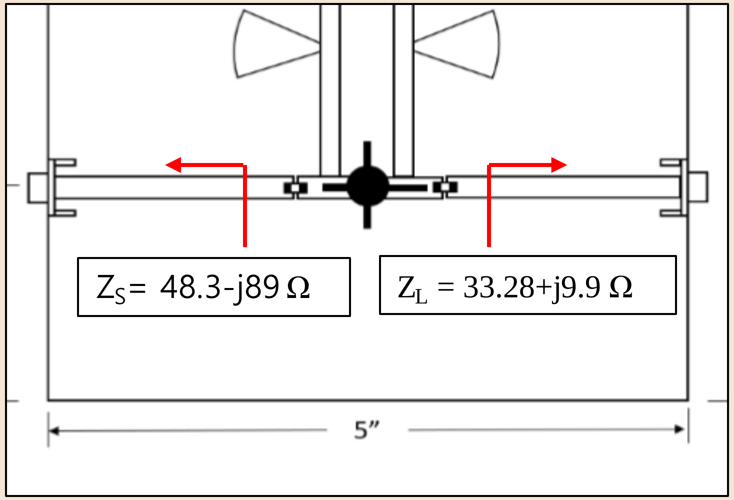
Z_S Side



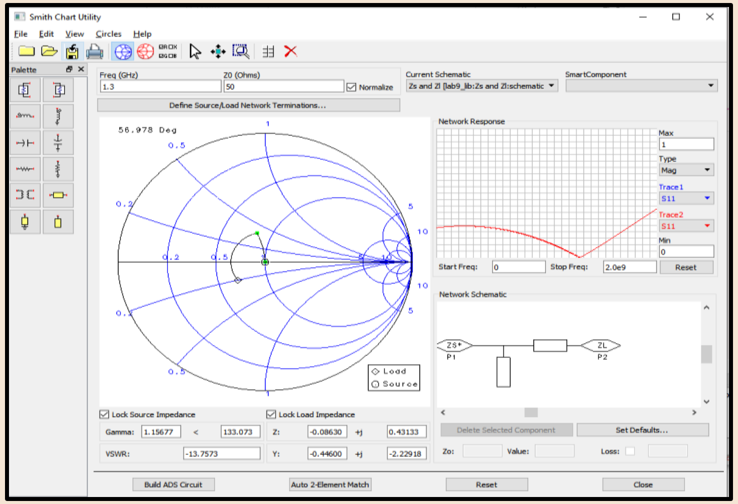
Z_L Side



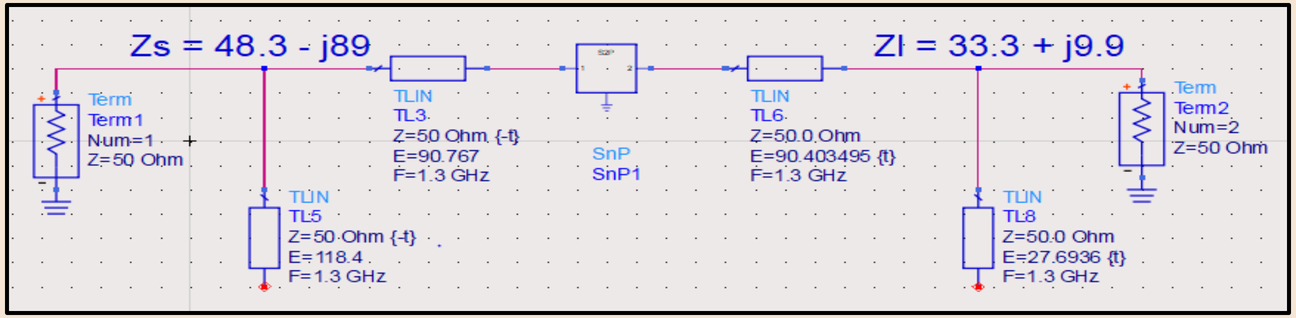
Matching network cont.



1. Calculate Z_S and Z_L for MN

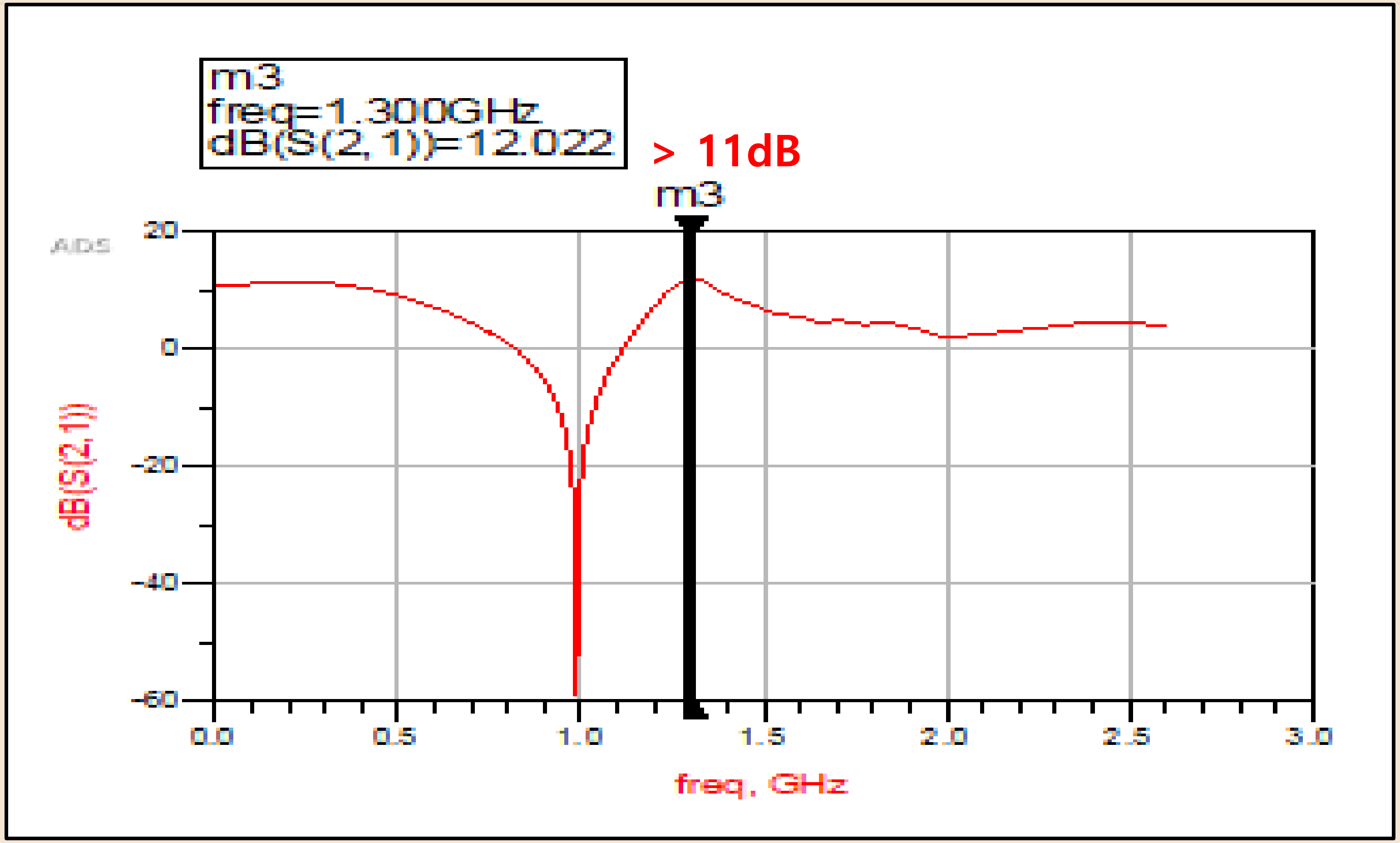


2. Smith chart tool to find TX line length



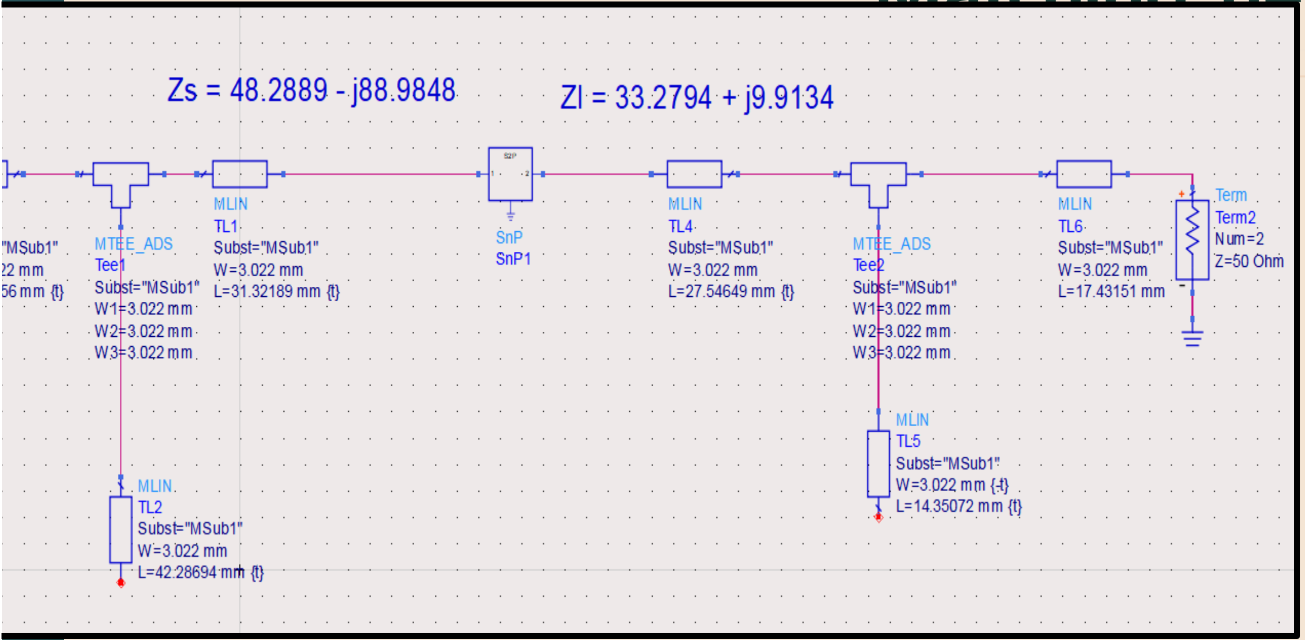
3. Simulate the 2-port power gain

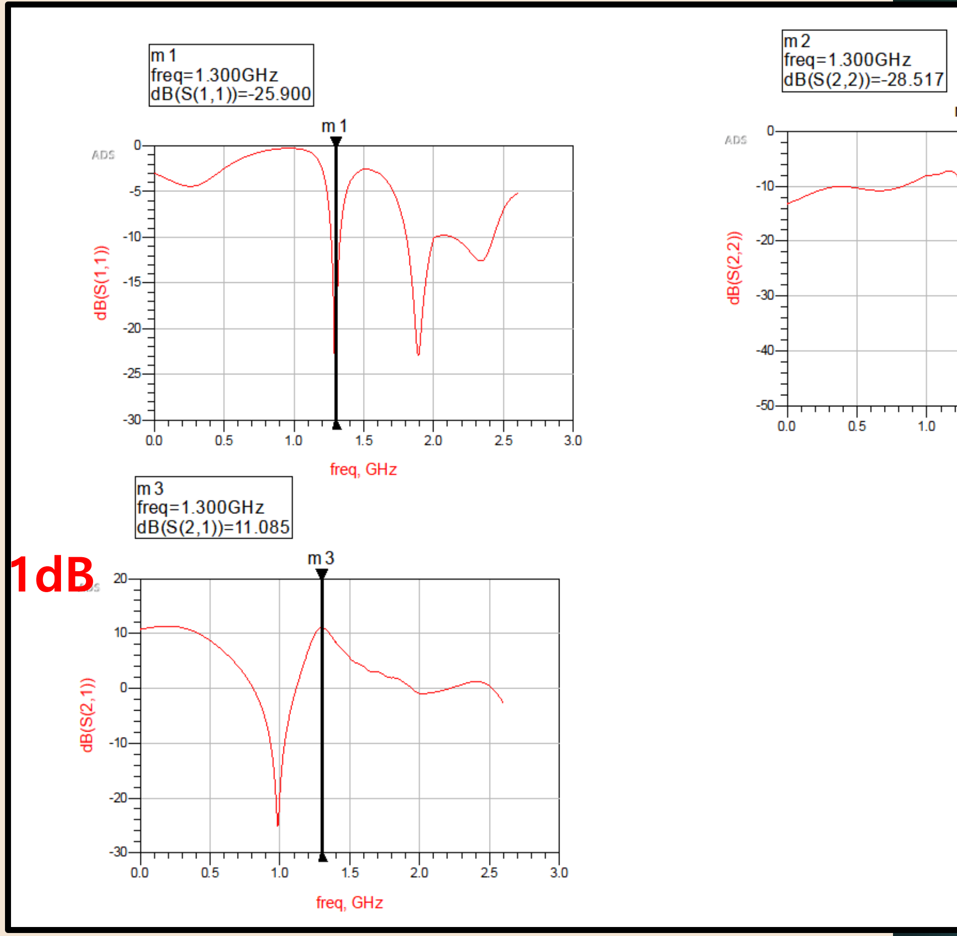
Matching network cont.



Power gain > 11dB achieved

Matching network cont.



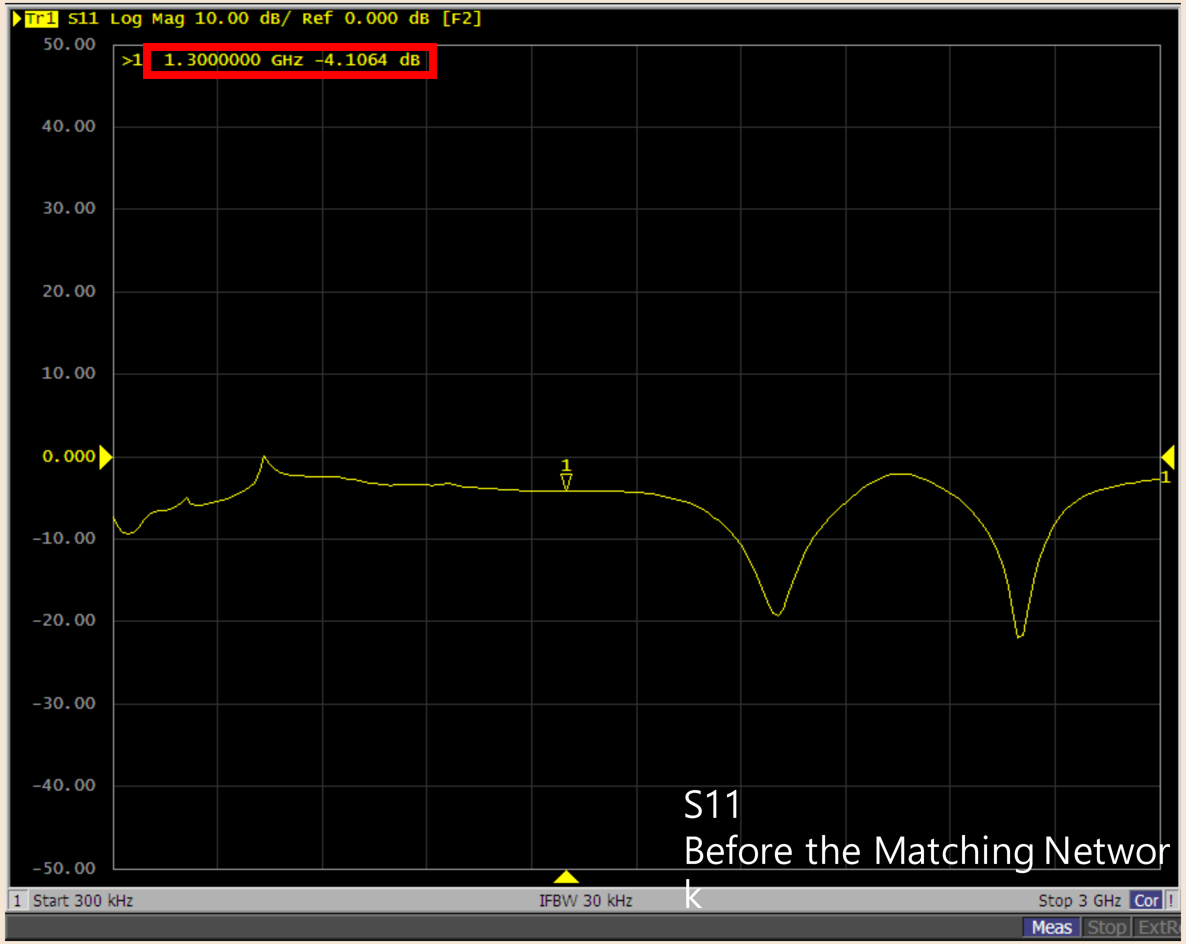


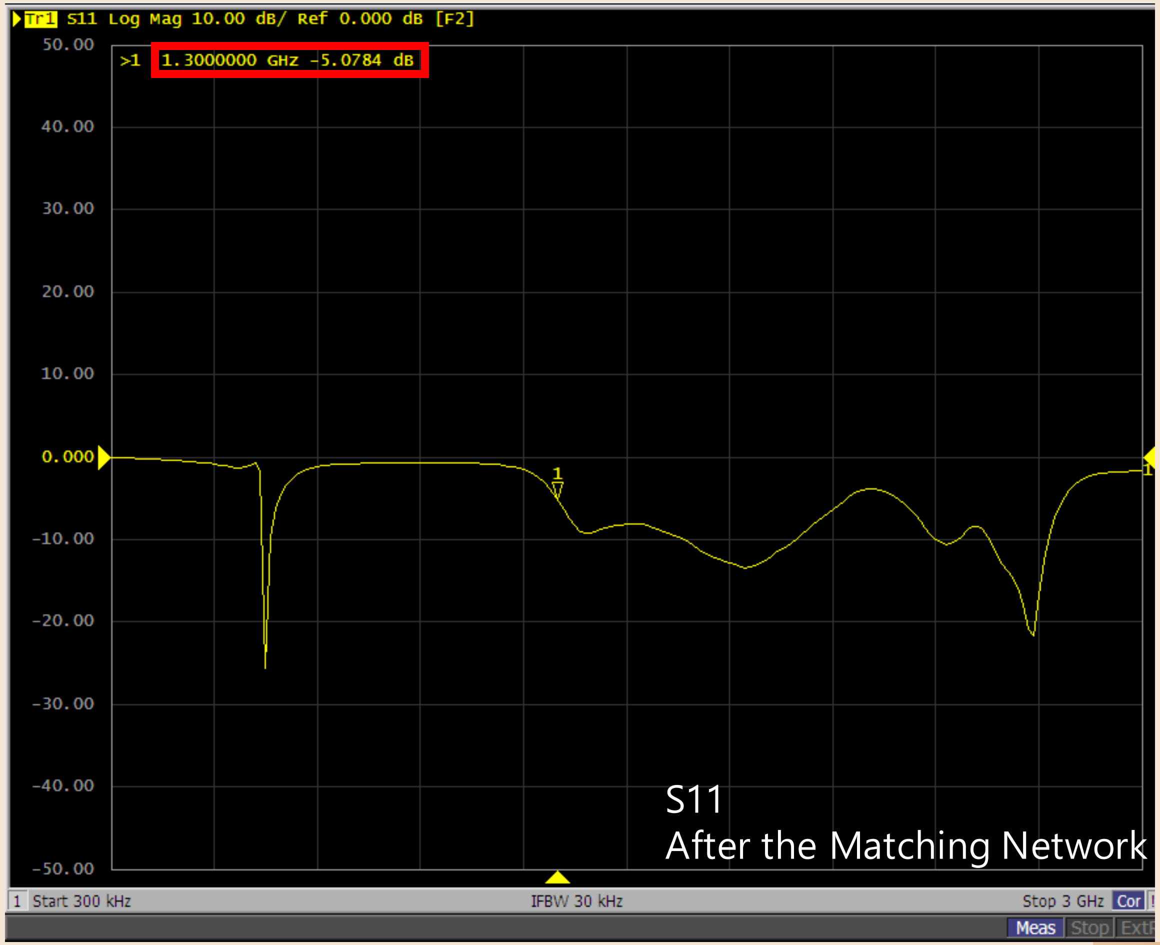
> 11dB

Simulation with actual length

Empirical Result; Return Loss

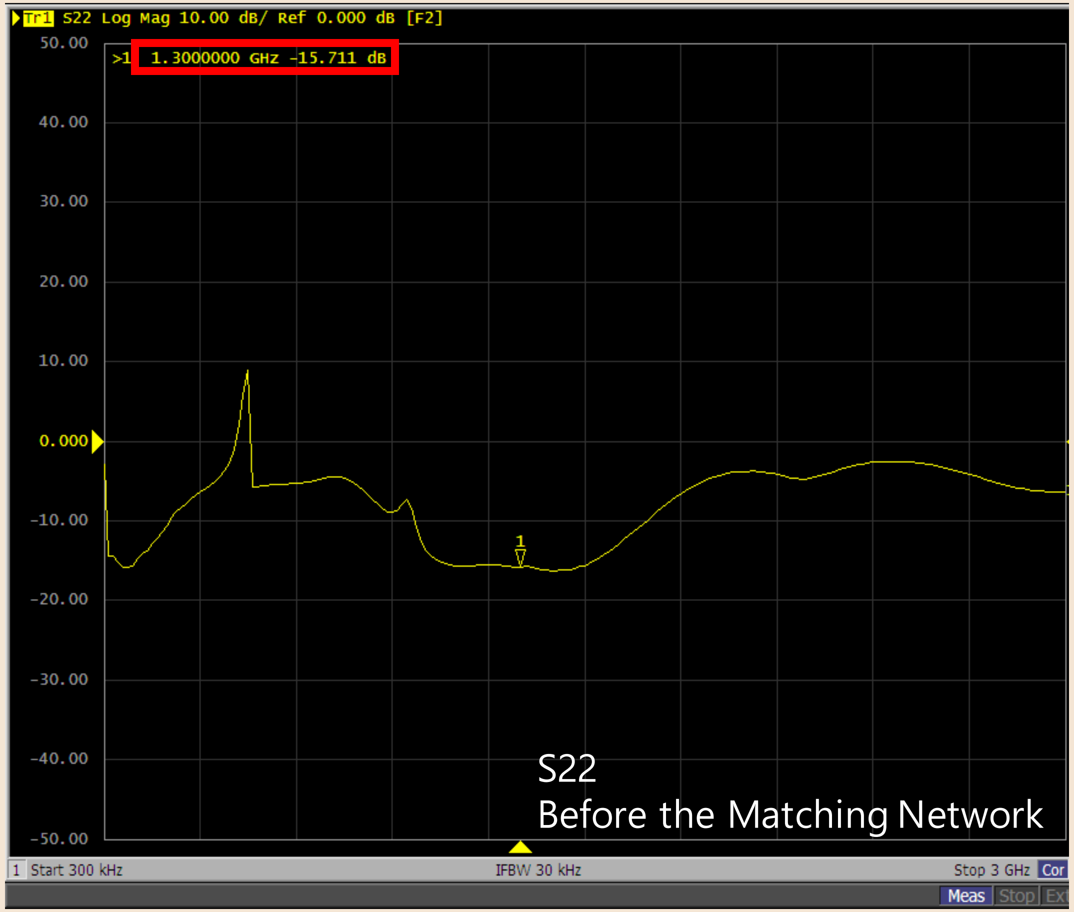
Initial attempt

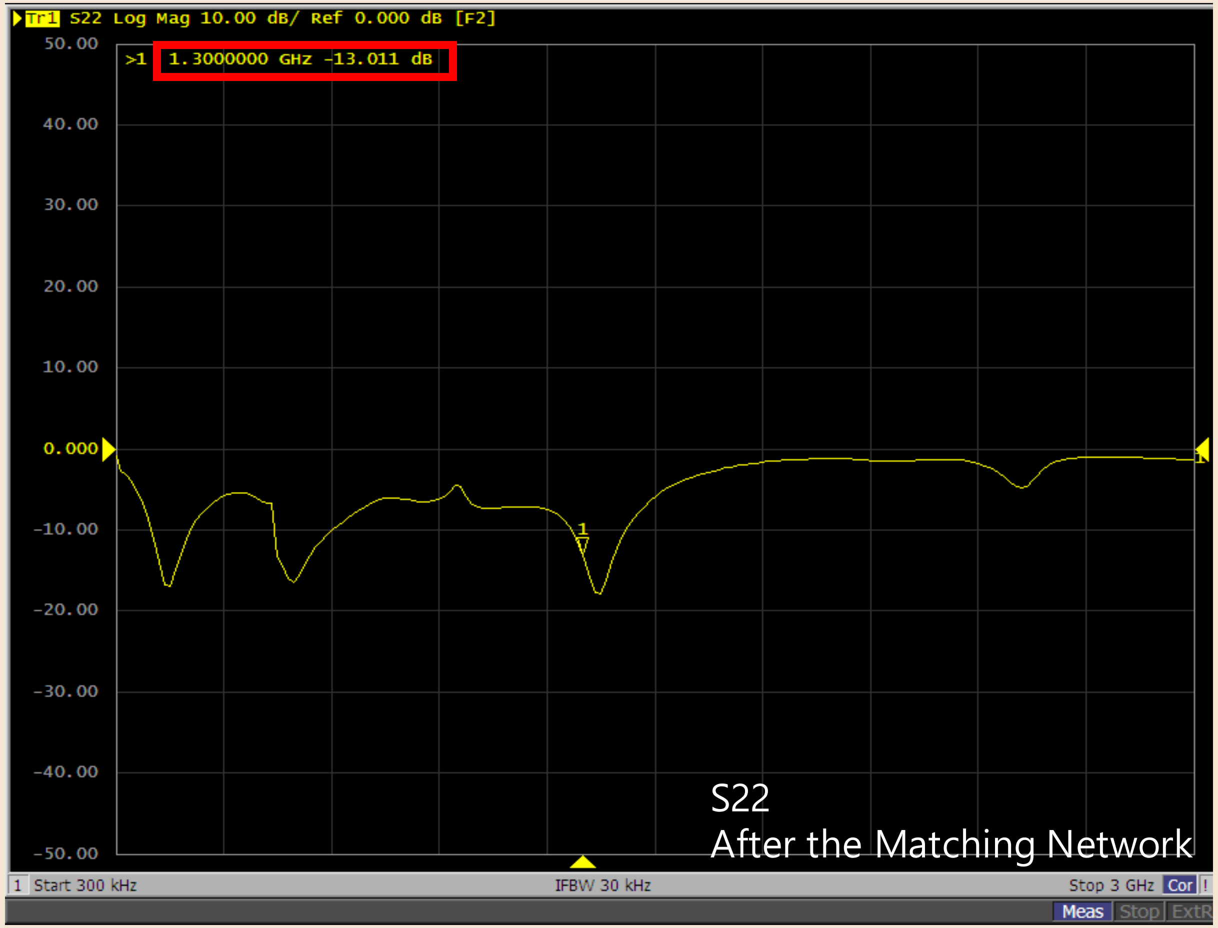




Empirical Result; Return Loss

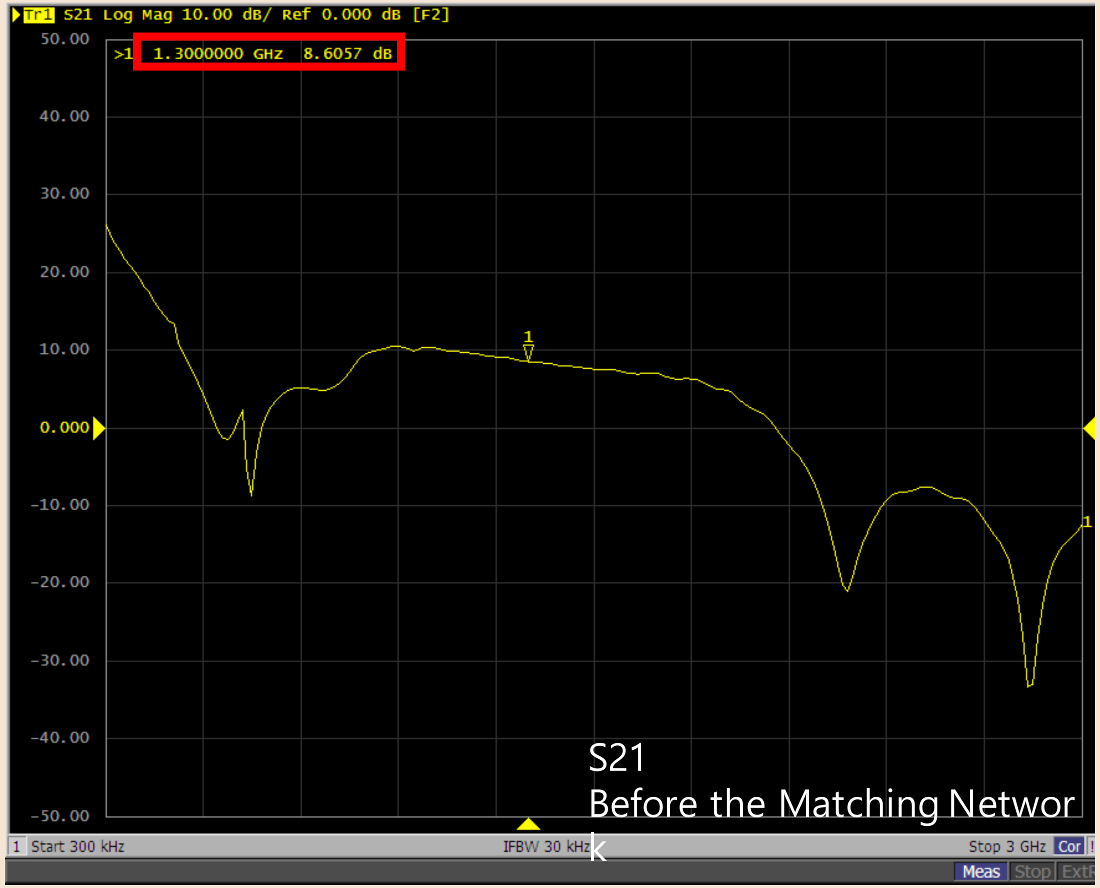
Initial attempt

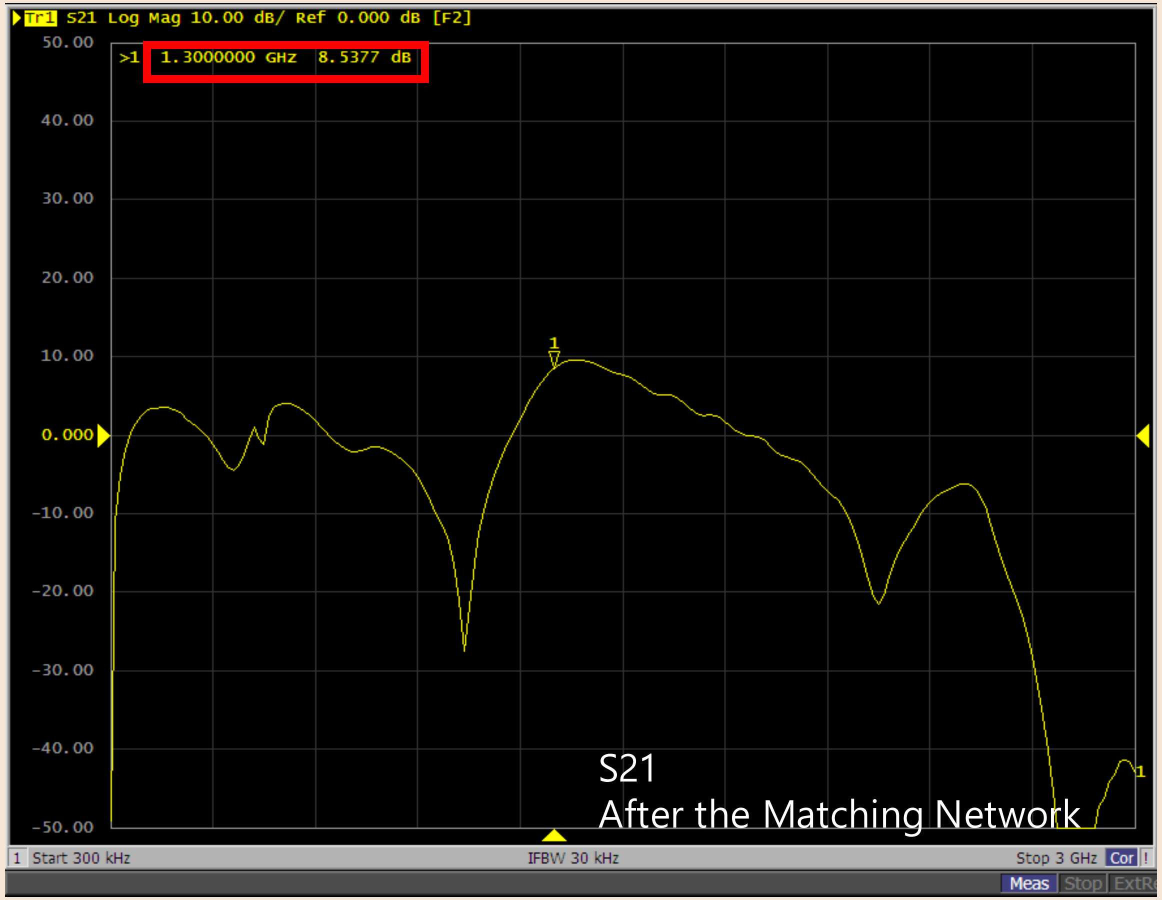




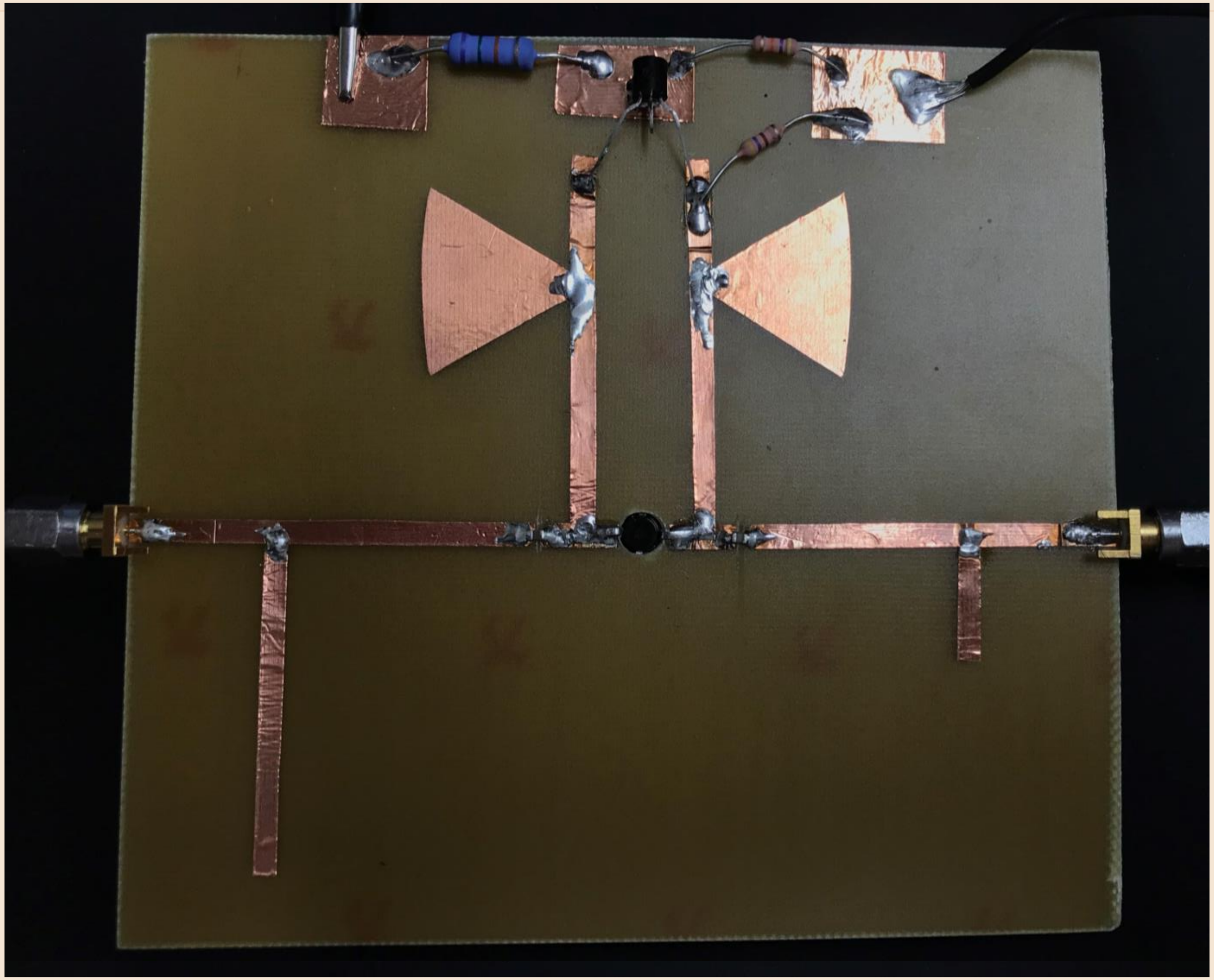
Empirical Result; Gain

Initial attempt



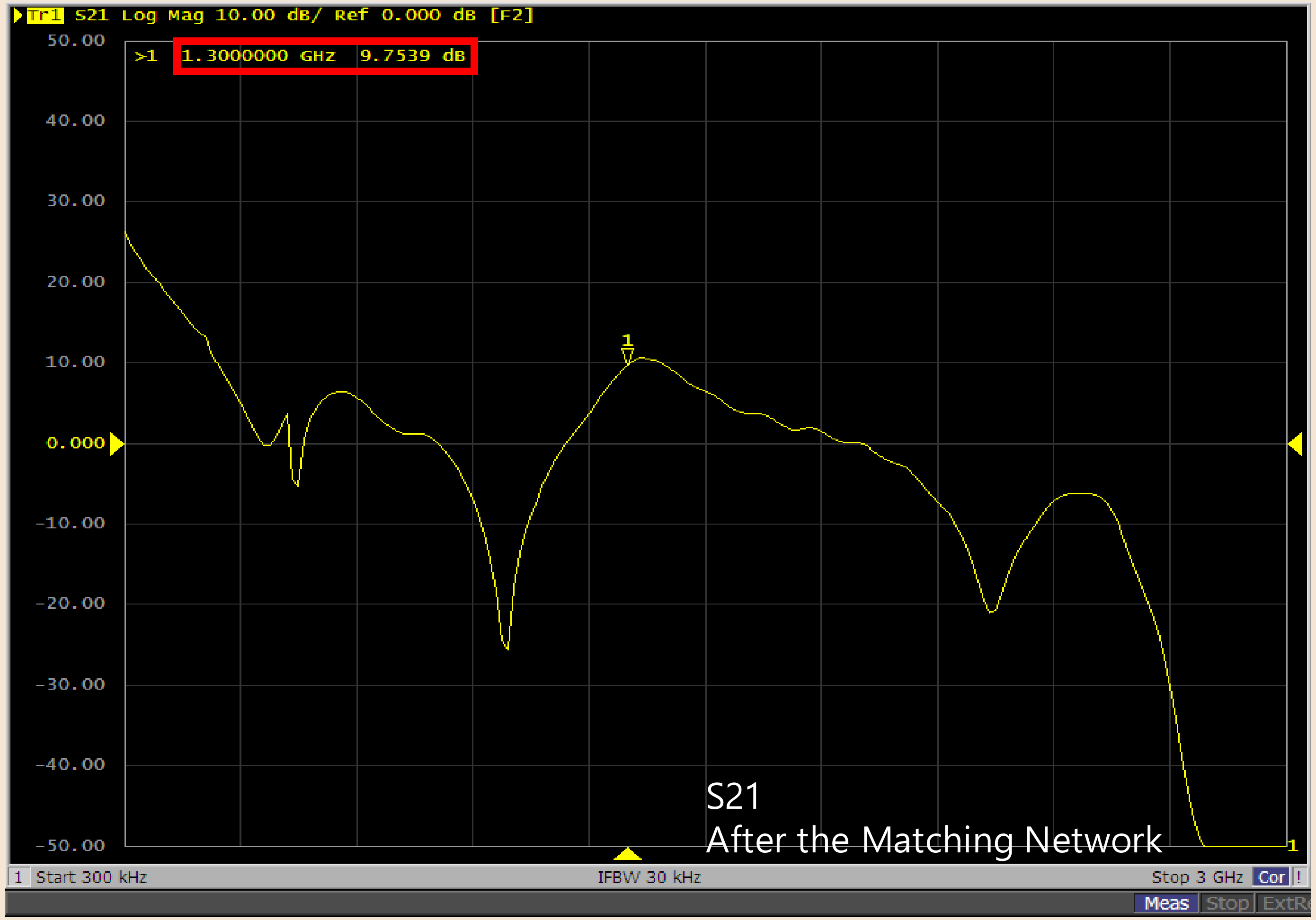


Empirical Result; Circuit



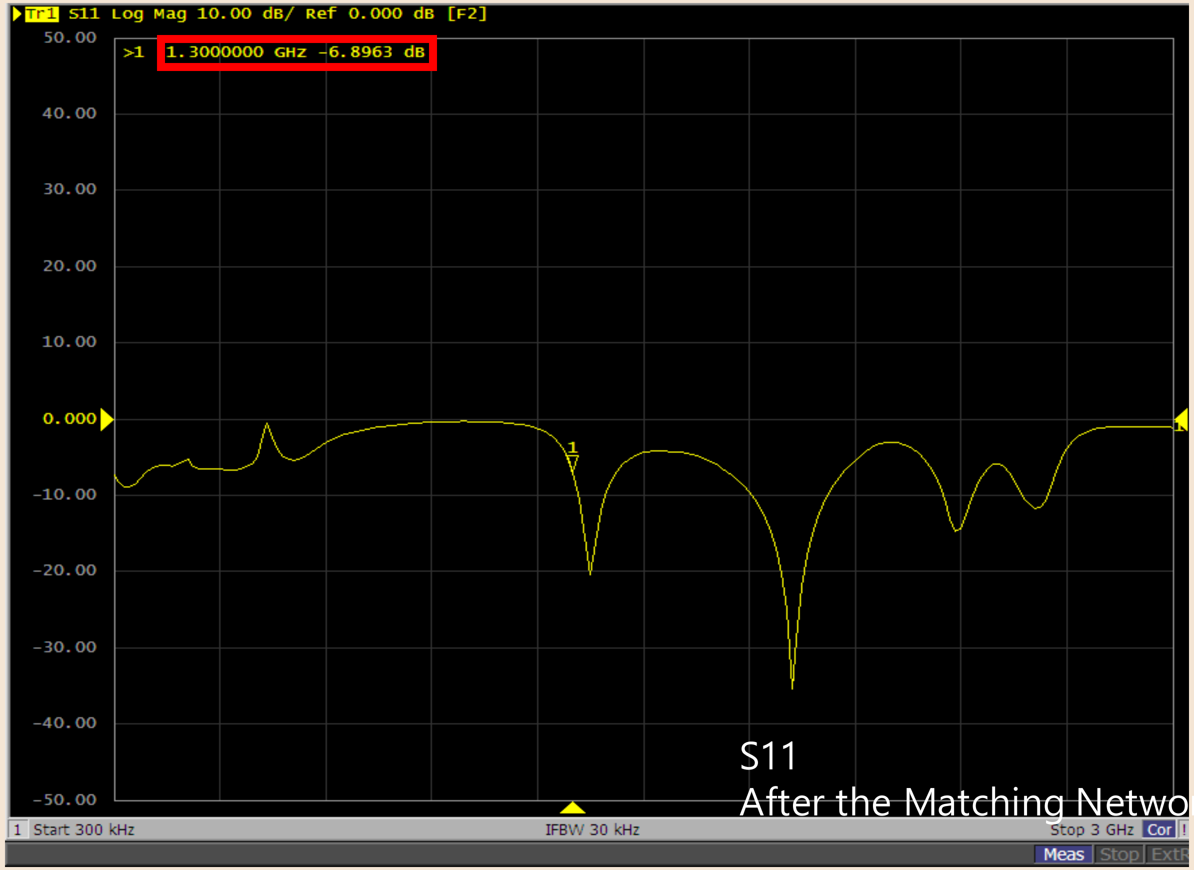
Empirical Result; Gain

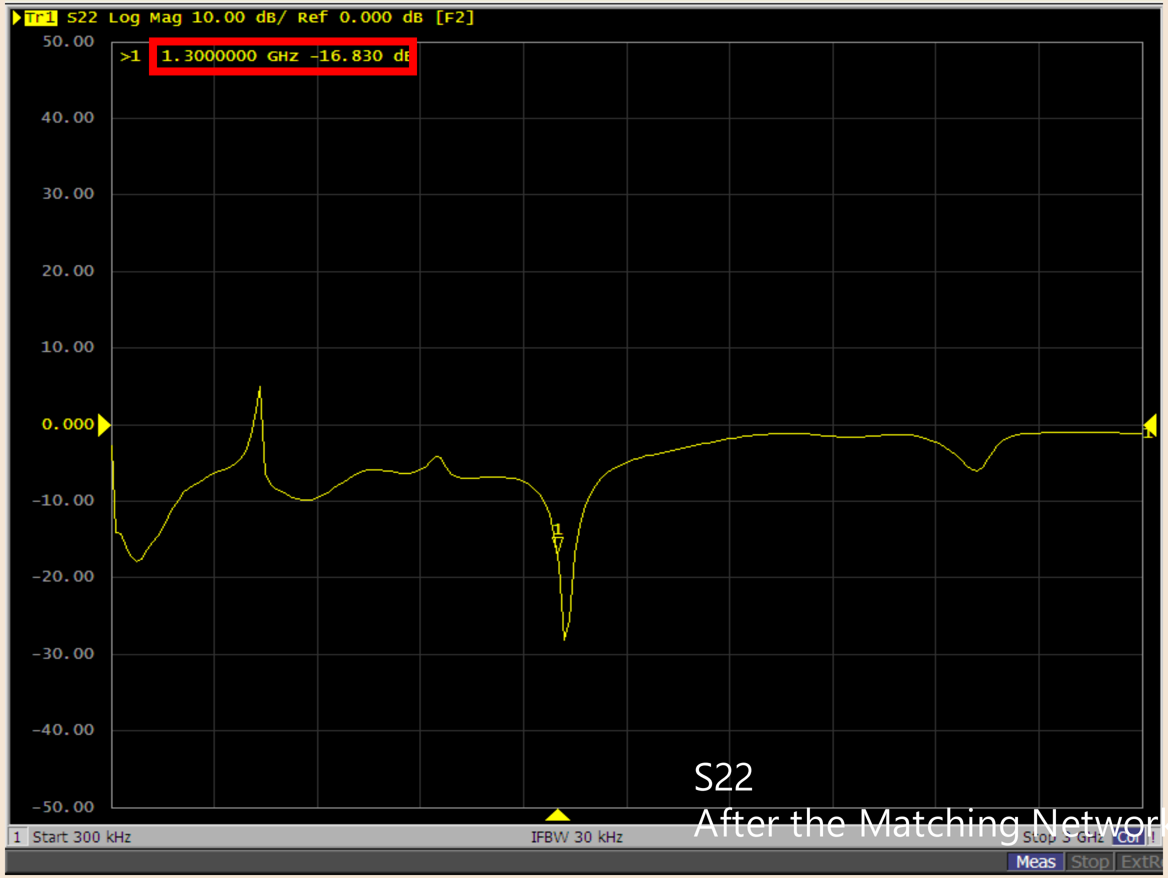
Final attempt



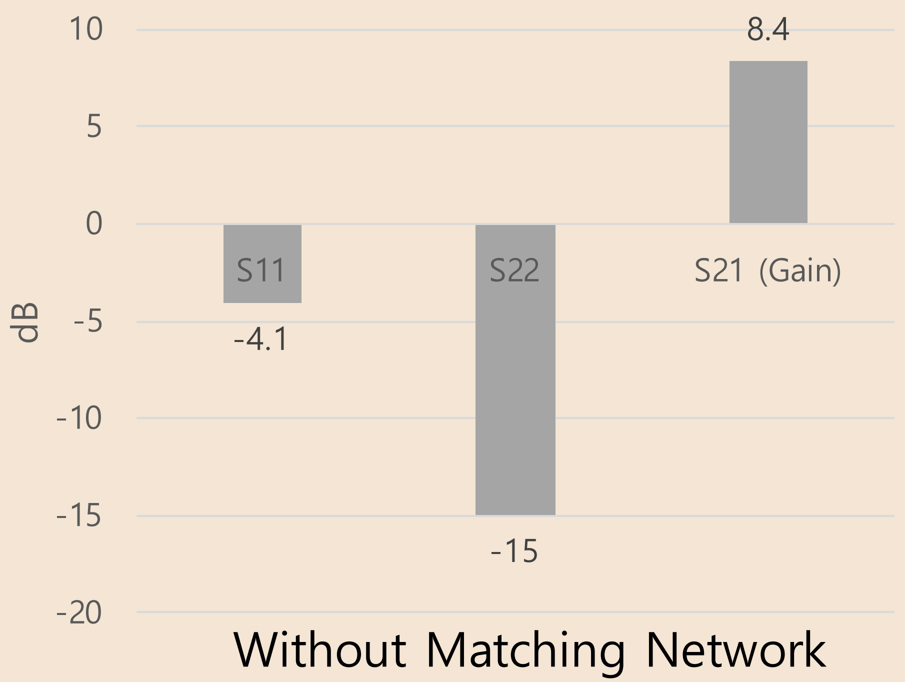
Empirical Result ; Return Loss

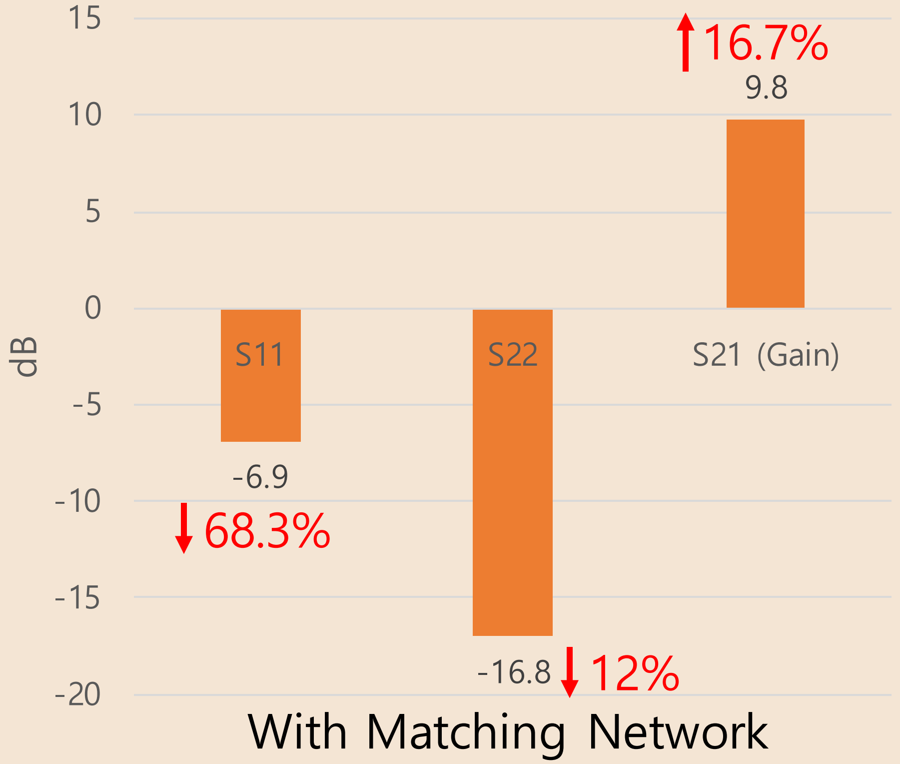
Final attempt





Conclusion


10
5
0
-5
-10
-15
-20
dB
S11
S22
S21 (Gain)
8.4
-4.1
-15
Without Matching Network


15
10
5
0
-5
-10
-15
-20
dB
S11
S22
S21 (Gain)
16.7%
9.8
-6.9
68.3%
-16.8
12%
With Matching Network

Challenges Faced

- SMA broke during testing → Solder and Board Placement
- MATLAB results vs SNP results → Check for Typos (Interpret as Output Impedance)
- Inaccurate placement of Stubs
- Tuning ADS Values → Consistent measurements

What happens if the frequency is increased?