Antenna & Amplifier Laboratory Findings

COMPONENTS AND WIRELESS TECHNOLOGY ORAL LAB EXAM – 01/04/2025

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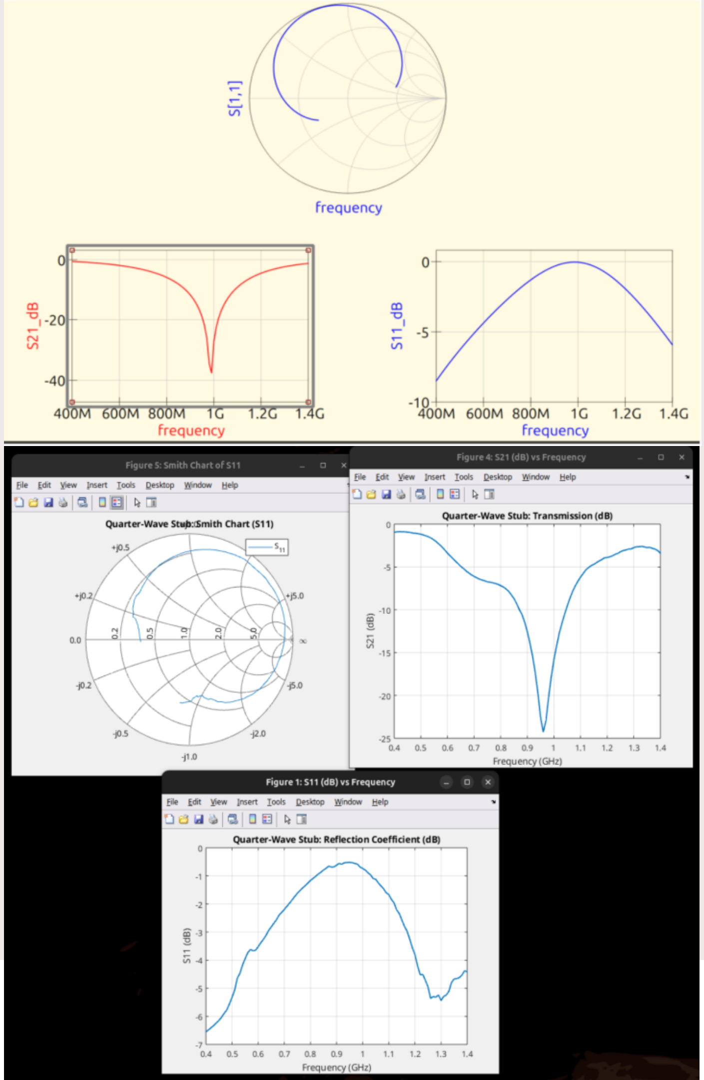
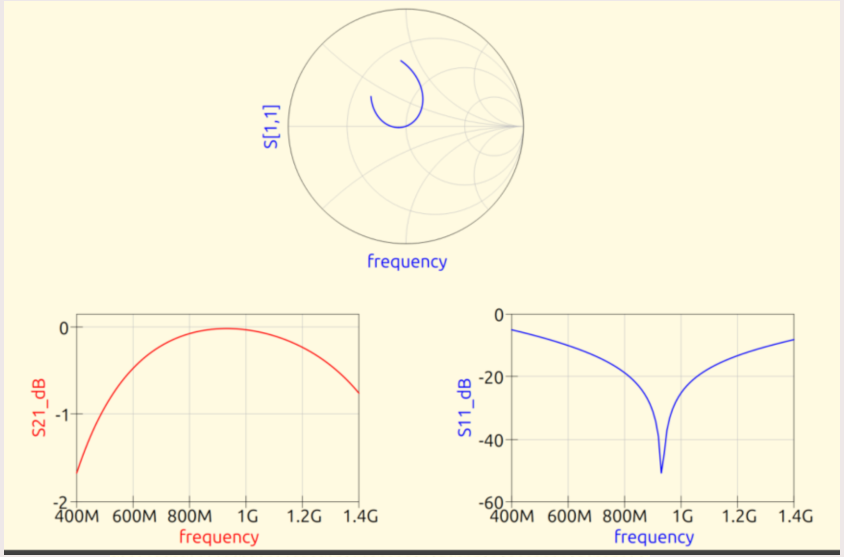
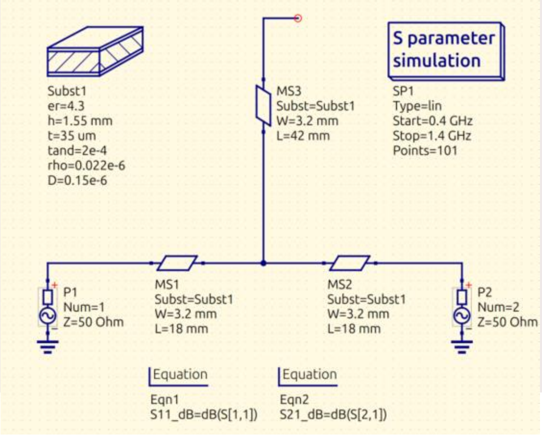
Lab 2 Findings – Quarter-Wave Stub Analysis

- At 1GHz, open stub behaves nearly like a short on the main line -> low reflection, high power transfer.
- At 500 MHz, it is not ¼-wave -> mismatch and higher reflections.
- Stub is coplanar waveguide with approximately 50 ohms characteristic impedance.
- Reflection at 1 GHz: magnitude ~ 0.9188, phase ~ 1.47°, Zin ~ 1083 + j326 ohms.



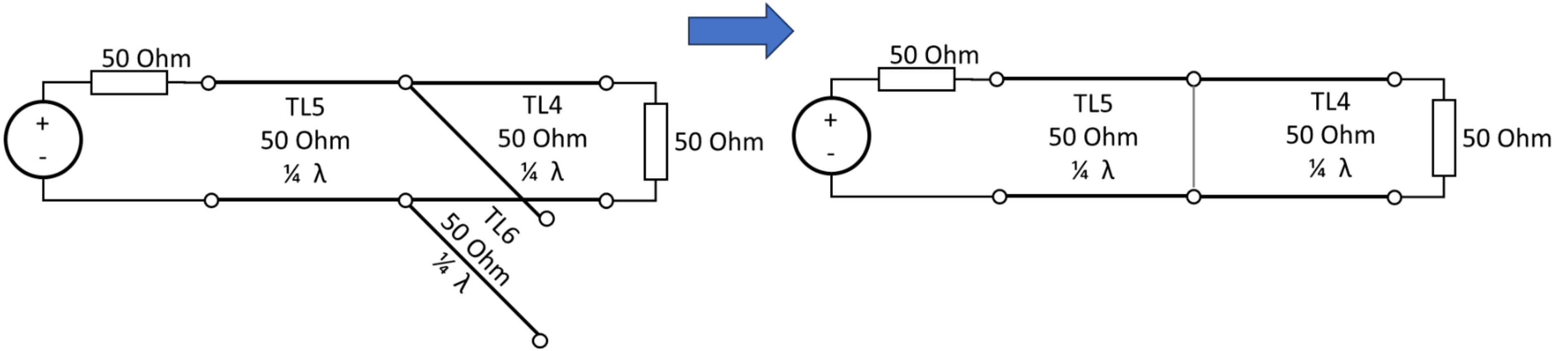


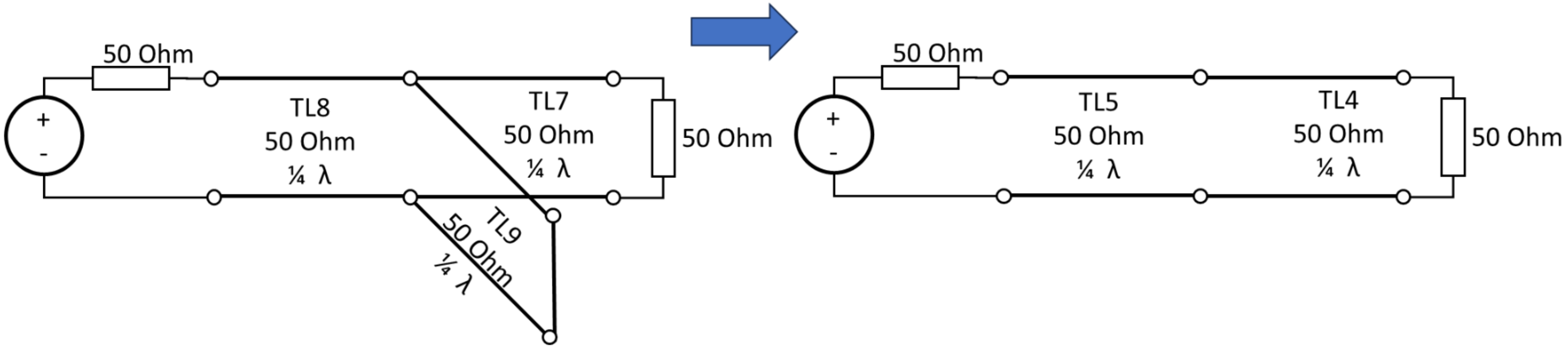


Additional Observations & Shorted Stub

- Measured results closely match simulations; slight offsets from cable losses/environment.
- Component can be used for impedance matching (e.g. antenna feed).
- Short-circuited stub inverts effect: minimal S11 at design freq and a passband response.
- Final check in QUCS: results confirm the transformation properties of both open- and short- circuited stubs.

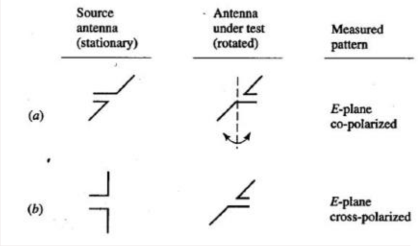
Extra: Expected Differences between Open- and Short- Stub

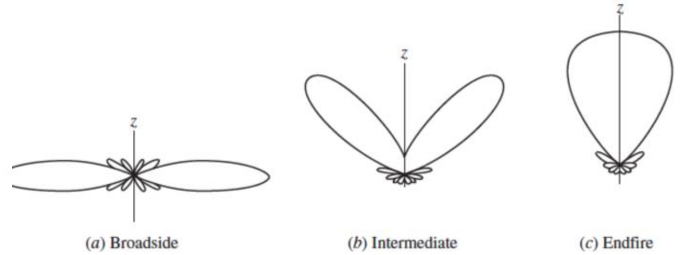




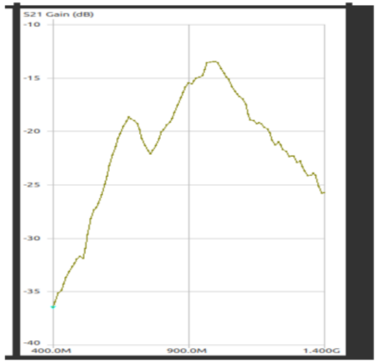
Lab 3 Antenna Measurements – Key Findings

- **S11 and Power Transfer:** Dipole around 1GHz shows good match (<-10dB), meaning most power is delivered; bringing a hand close disrupts the near field, raising S11 (less power delivered).
- **Alignment (Port 2):** Best transmission with both dipoles broadside (maximum radiation), worst when endfire or cross-polarized.
- **Polarization:** Co-polarized dipoles yield highest S21; cross-polarized yields minimal coupling.
- **Friis Equation Gain:** Measured gain is lower than simulation; real-world losses (cables, environment) cause differences.

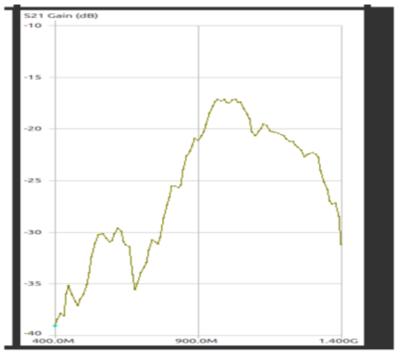




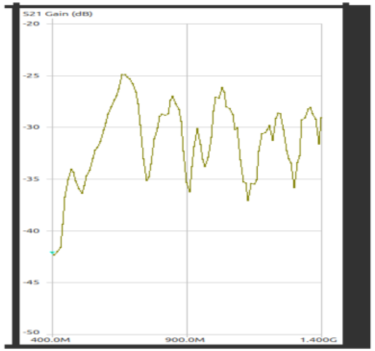
Broadside facing dipoles:

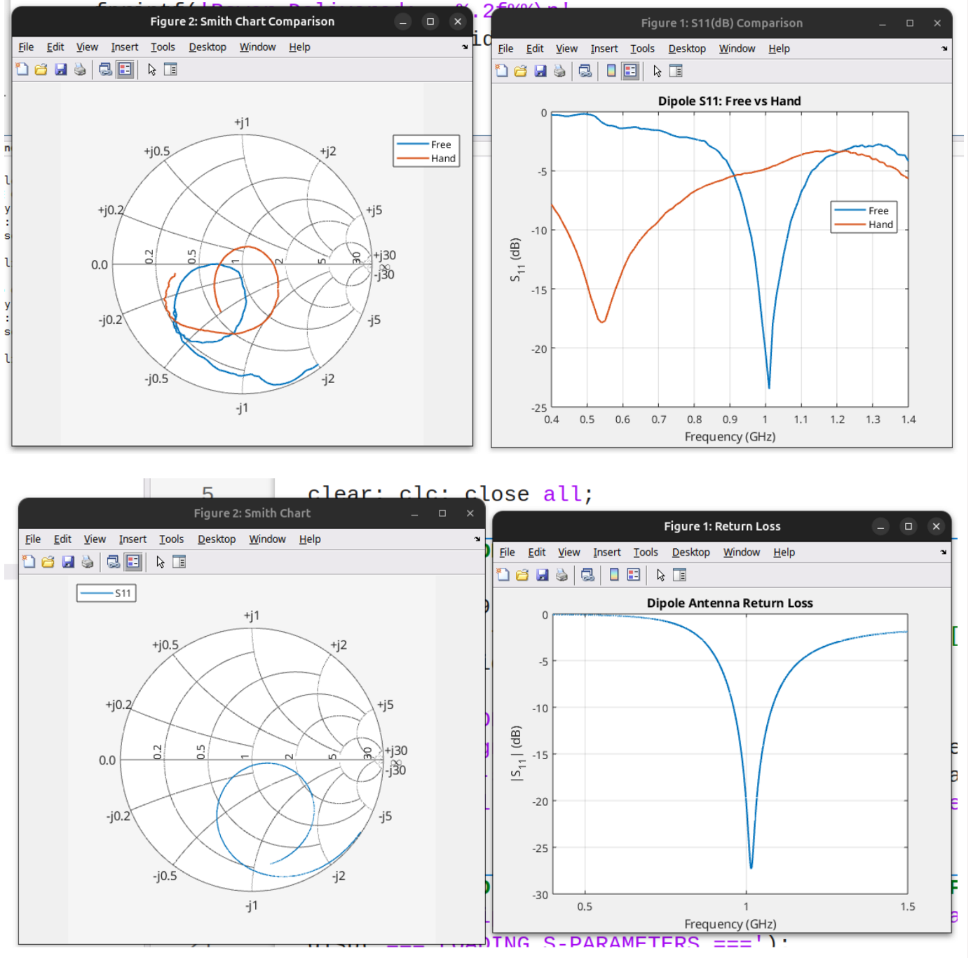


Endfire facing dipoles:



Co-polorized can be observed above, and cross polarized can be seen below:

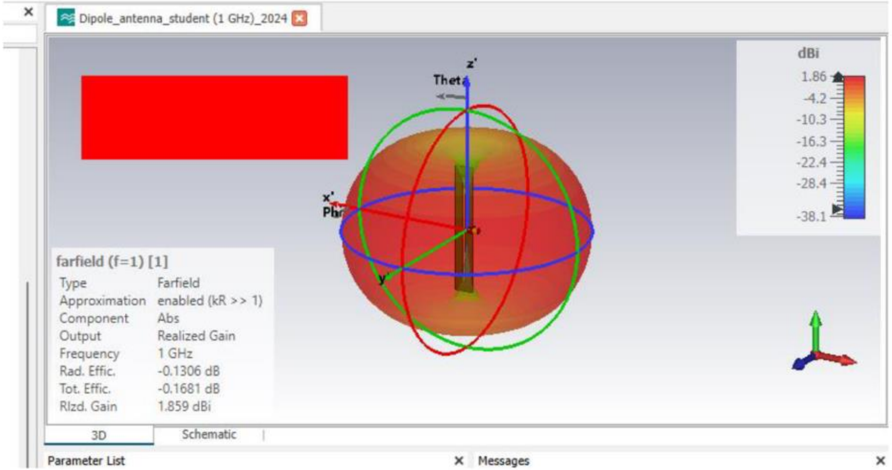




Antenna Simulations – CST & Comparisons

- **Dipole Length & Resonance:** ~150mm at 1.2GHz. After minor adjustments (114mm at 1GHz), S11 dips below -10dB near target frequency.
- **Radiation Pattern & Gain:** Classic doughnut shape, ~2dBi for an ideal half-wave dipole in free space; simulation close if well-meshed.
- **Symmetry & Polarization:** Pattern is symmetric (centre-fed), linear polarization from current along one axis.
- **Mesh Convergence:** Adaptive meshing confims S11 and far-field stabilized. Most cells near feed/edges (highest field gradient).

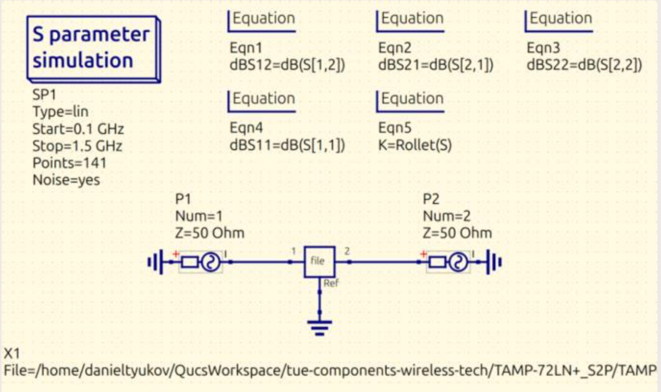
Extra: CST showing dipole resonance

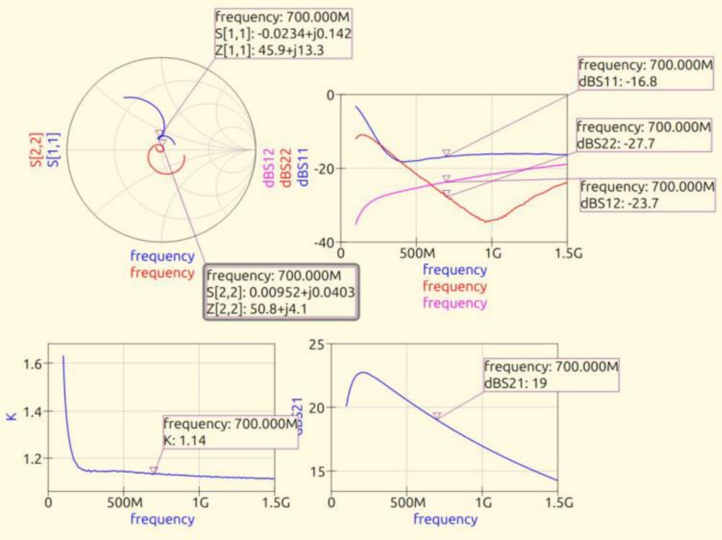


Number of freq. points: 1011
Found resonance near : 1.015 GHz
S11(dB) at resonance : -27.30 dB
Offset from design (MHz) : 14.90 MHz

Lab 5 Stand-Alone Amplifier Findings

- Using the TAMP-72LN+ S-parameter file in QUCS, we see:
  - S11 (input reflection), S12(isolation), S21 (gain), S22 (output reflection).
  - K-factor > 1, indicating unconditional stability over ~400-700MHz.
  - Gain ~19dB at 700MHz, closely matching datasheet (about 18.7dB)
- No external biasing needed: module has internal bias/matching; just supply 5V.
- Minor deviations from datasheet due to simulation vs real conditions, but overall close



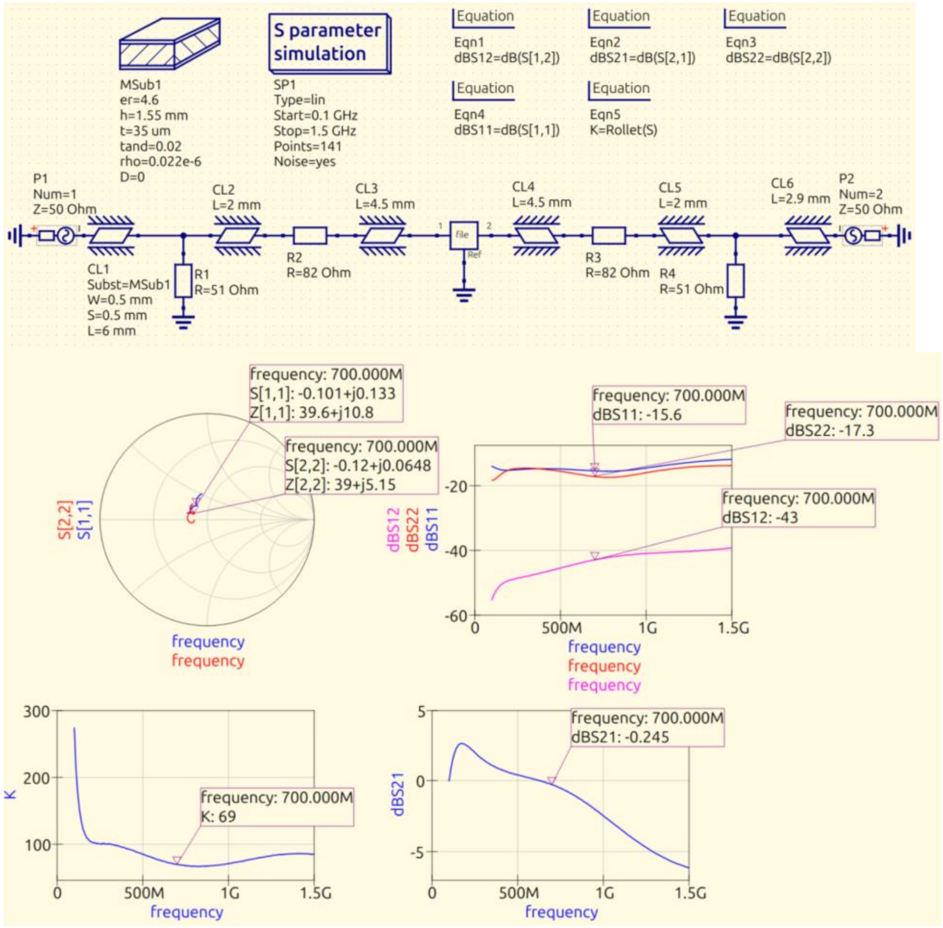


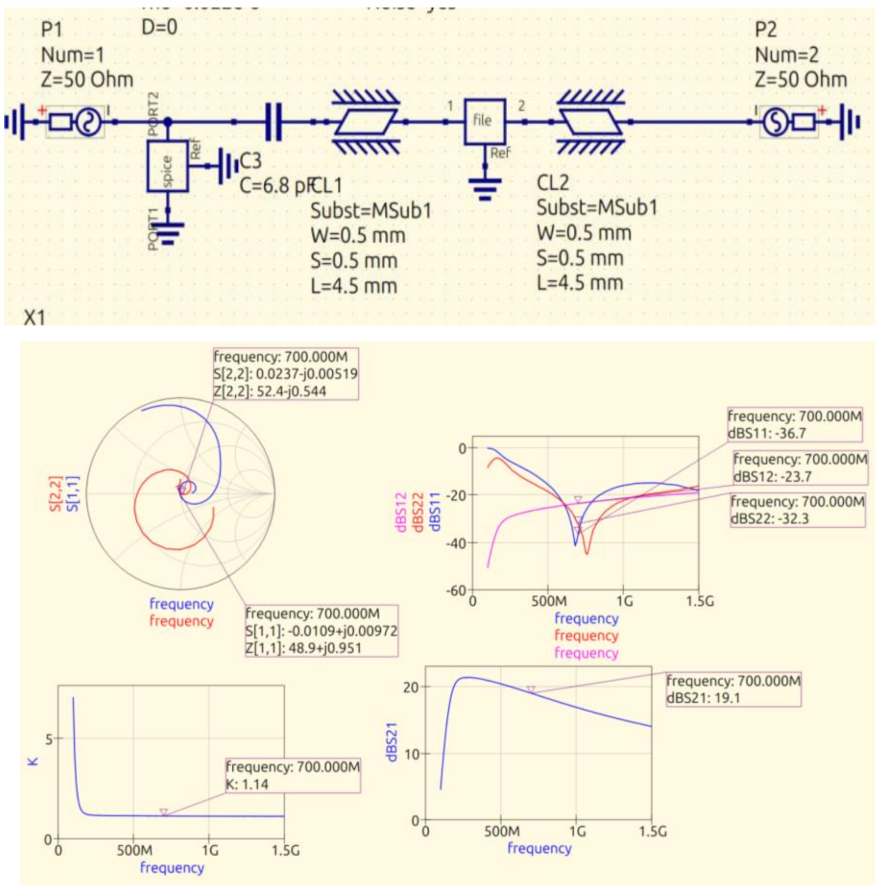
Original Board with Resistors:

- S21 drops significantly (19 dB -> near 0dB) because added load the amplifier
- Input (S11) and output (S22) reflections worsen from nearly 50 ohms to ~39 ohms, leading to mismatches.
- K-factor becomes very high (~69) due to extra damping, ensuring stability but sacrificing gain.
- Co-planar grounded spaces between components alter the line impedance.

Redesigned Board (Removing Resistors, Adding LC Matching):

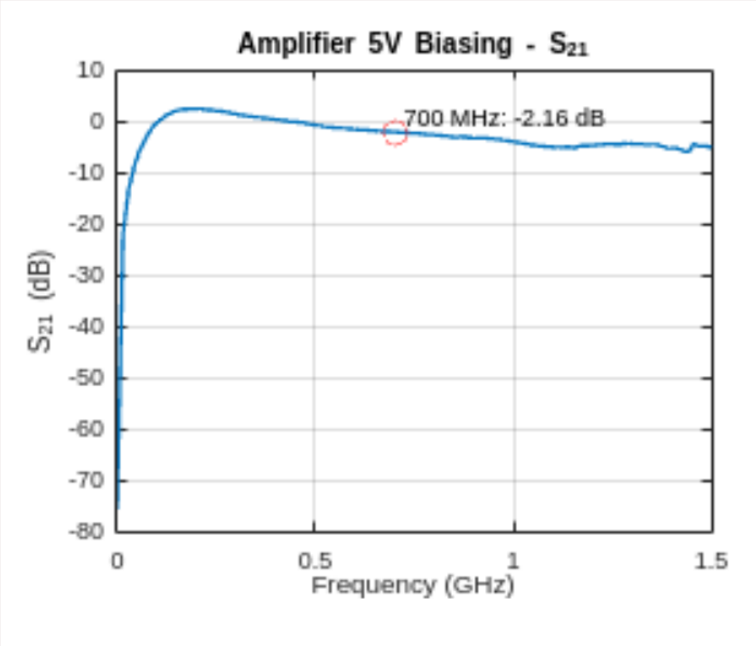
- Restore ~19dB gain at 700 MHz (close to the stand-alone amplifier's performance).
- S11 and S22 improve (near 50 ohms) by adjusting the coplanar spacing and using shunt/series LC elements.
- Highlights that the original layout had ~39 ohms trace impedance (needed ~0.11 mm spacing for 50 ohms).
- Achieves stable operation (K>1), matching typical stand-alone amplifier specs.


S parameter simulation
MSub1
er=4.6
h=1.55 mm
t=35 um
tand=0.02
rho=0.022e-6
D=0
SP1
Type=lin
Start=0.1 GHz
Stop=1.5 GHz
Points=141
Noise=yes
Equation
Eqn1
dBS12=dB(S[1,2])
Equation
Eqn2
dBS21=dB(S[2,1])
Equation
Eqn3
dBS22=dB(S[2,2])
Equation
Eqn4
dBS11=dB(S[1,1])
Equation
Eqn5
K=Rollet(S)
P1
Num=1
Z=50 Ohm
CL1
Subst=MSub1
W=0.5 mm
S=0.5 mm
L=6 mm
CL2
L=2 mm
R1
R=51 Ohm
R2
R=82 Ohm
CL3
L=4.5 mm
file
Ref
CL4
L=4.5 mm
R3
R=82 Ohm
CL5
L=2 mm
R4
R=51 Ohm
CL6
L=2.9 mm
P2
Num=2
Z=50 Ohm
frequency: 700.000M
S[1,1]: -0.101+j0.133
Z[1,1]: 39.6+j10.8
frequency: 700.000M
S[2,2]: -0.12+j0.0648
Z[2,2]: 39+j5.15
S[2,2]
S[1,1]
frequency
frequency
frequency: 700.000M
dBS11: -15.6
frequency: 700.000M
dBS22: -17.3
frequency: 700.000M
dBS12: -43
dBS12
dBS22
dBS11
frequency
frequency
frequency
K
frequency: 700.000M
K: 69
frequency
dBS21
frequency: 700.000M
dBS21: -0.245
frequency


D=0
P1
Num=1
Z=50 Ohm
PORT2
spice
PORT1
Ref
C3
C=6.8 pF
CL1
Subst=MSub1
W=0.5 mm
S=0.5 mm
L=4.5 mm
file
Ref
CL2
Subst=MSub1
W=0.5 mm
S=0.5 mm
L=4.5 mm
P2
Num=2
Z=50 Ohm
X1
frequency: 700.000M
S[2,2]: 0.0237-j0.00519
Z[2,2]: 52.4-j0.544
S[2,2]
S[1,1]
frequency
frequency
frequency: 700.000M
S[1,1]: -0.0109+j0.00972
Z[1,1]: 48.9+j0.951
frequency: 700.000M
dBS11: -36.7
frequency: 700.000M
dBS12: -23.7
frequency: 700.000M
dBS22: -32.3
dBS12
dBS22
dBS11
frequency
frequency
frequency
K
frequency: 700.000M
K: 1.14
frequency
dBS21
frequency: 700.000M
dBS21: 19.1
frequency

Measurement Results & Comparisons

- **Key S-Parameter Values at 700 MHz:**
  - **No Bias:** S11=-16.49dB, S21 = -29.10 dB (amplifier is off -> large attenuation), S12 = -29.74 dB, S22 = -12.80 dB.
  - **5V Bias:** S11 = -11.42 dB, S21 = -2.16 dB, S12 = -44.70 dB, S22 = -11.94 dB.
  - **1.4V Bias:** S11 = -11.37 dB, S21 = -5.01 dB, S12 = -42.79 dB, S22 = -11.58 dB



Observed gain (~ -2 dB) is much lower than the ~19 dB from simulation. Resistor pads and measurement factors (connector/cable losses, NanoVNA range limits, different LC components) heavily reduce net gain. S11 and S22 also differ because real PCB parasitics are not perfectly accounted for in simulation.

Explanations & Analysis

1. **Resistor Attenuation (80 ohm + 50 ohm):** Around 9.8dB input pad to avoid VNA compression.
2. **Extra Bias Resistor for 1.4V:** ~180 ohm in series ((5V – 1.4V)/0.02A=180 ohm).
3. **NanoVNA Power vs. Amplifier Limits:** NanoVNA ~0 dBm output; amplifier can handle ~+27 dBm. Well within limits.
4. **Input/Output Power Calculation:**
   - Input to amp ~0 dBm – 9.8 dB = -9.8 dBm.
   - Amp gain ~19dB -> ~+9.2 dBm at amplifier output.
   - Another ~9.8 dB pad on output -> final ~-0.6 dBm to the VNA.

The End, Thanks for Listening