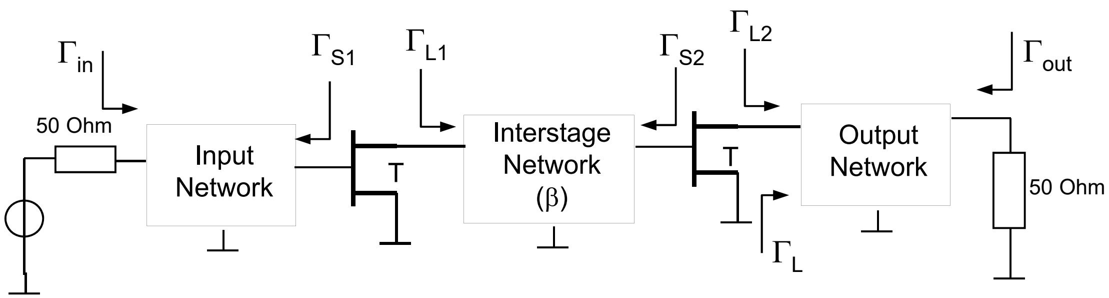
# Design of a multistage amplifier




2 GHz:
$S_{11}$= (.63, 156°)
$S_{21}$= (3.5196, 59°)
$S_{12}$= (0.064, 66°)
$S_{22}$=(0.31, -36°)
$N_{fmin}$= 2 dB
$\Gamma_{opt}$= (0.24, -179°)
$R_{norm}$=0.11

a) Evaluate $G_{S1}$, $G_{S2}$, $G_{L1}$, $G_{L2}$, for maximizing the overall transducer gain $G_{T.}$ Evaluate $G_T$.
b) Compute the overall value of NF
c) Compute $|\Gamma_{in}|$ and $|\Gamma_{out}|$ assuming the input and output networks lossless
d) Synthetize the three networks using single stub for in/out networks and double-stub for inter-stage network
e) Evaluate $IP_3$ of the overall amplifier assuming $P_{1dB}$ of each active device equal to 10 dBm.

a) Evaluate $G_{S1}$, $G_{S2}$, $G_{L1}$, $G_{L2}$, for maximizing the overall transducer gain $G_{T.}$

Using the Smith Chart we get for each device:

**Unconditionally STABLE**

**Stability Coefficient K: 1.1281**

**Optimum Gamma Source (Mag, Phase deg): 0.83274 , -156.5457**

**Optimum Gamma Load (Mag, Phase deg): 0.70415 , 33.8427**

**Maximum Transducer Gain (dB): 15.2275**

We know that in case of unconditionally stable devices, input and output are matched. Moreover the overall Gt is the sum (in dB) of the maximum gain of each stage. Then:

$G_{S1}=G_{S2}=(0.833, -156.5°)$

$G_{L1}=G_{L2}=(0.704, 33.8°)$

$GT=2 \cdot 15.225=30.45$ dB

## b) Compute the overall value of NF

We must compute before the NF of each stage. Being both devices loaded with the same $\Gamma_s$, we have:

$$NF_1 = NF_2 = (NF)_{min} + 4r_n \frac{\left|\Gamma_s - \Gamma_{min}\right|^2}{\left|1+\Gamma_{min}\right|^2 \cdot \left(1-\left|\Gamma_s\right|^2\right)}$$

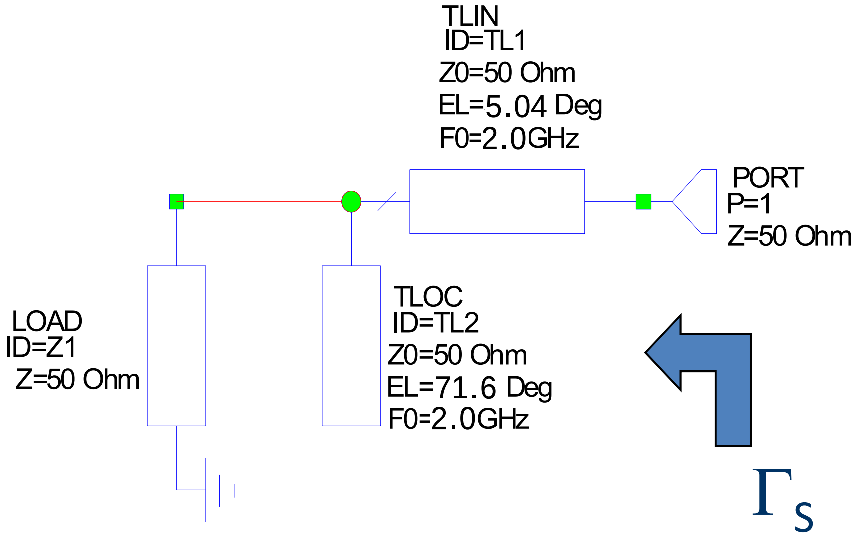
Using the SC we get: $NF_1$=$NF_2$=4.04 dB. The available power gain ($G_{AV}$) of the first stage coincides with $GT_1$ (output matched) then:

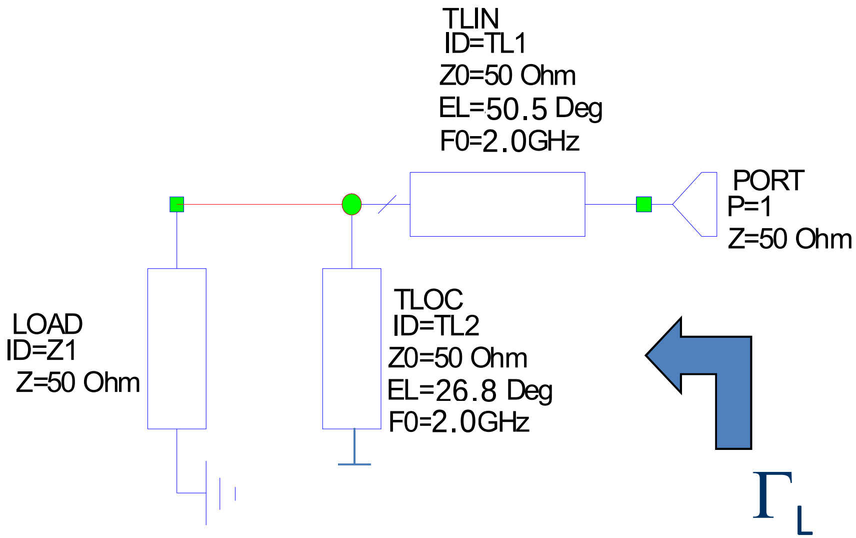
$$\left(NF\right)_{TOT} = NF_1 + \frac{NF_2 - 1}{G_{a1}} = 10^{0.4} + \frac{10^{0.4} - 1}{10^{1.52}} = 2.5575 \rightarrow 4.08 \text{ dB}$$

c) Compute $|\Gamma_{in}|$ and $|\Gamma_{out}|$ assuming the input and output networks lossless

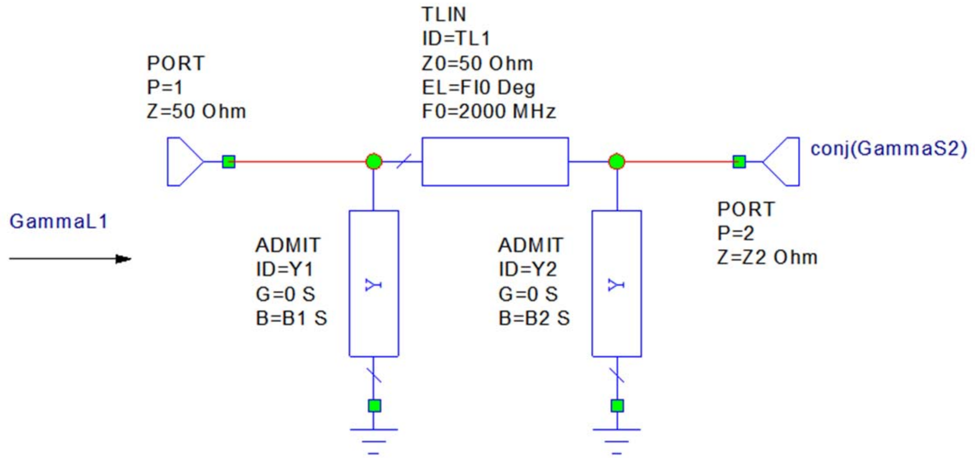
With lossless networks, the matching at the device sections is transferred also at the source and load sections. Then $|\Gamma_{in}|$ and $|\Gamma_{out}|$ are both zero.

d) Synthetize in/out networks using single stub



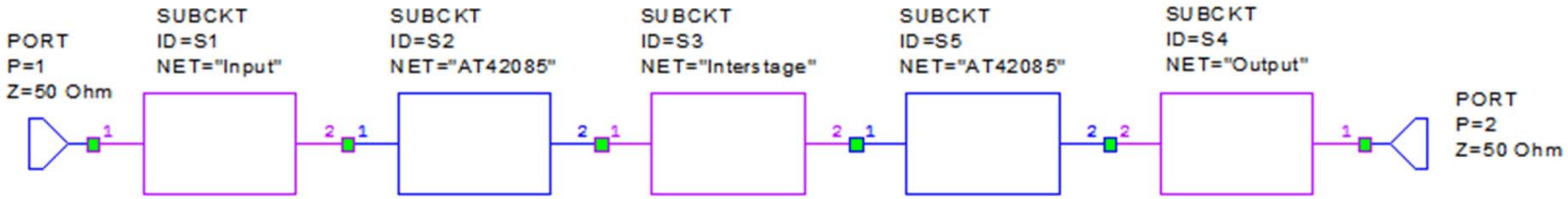



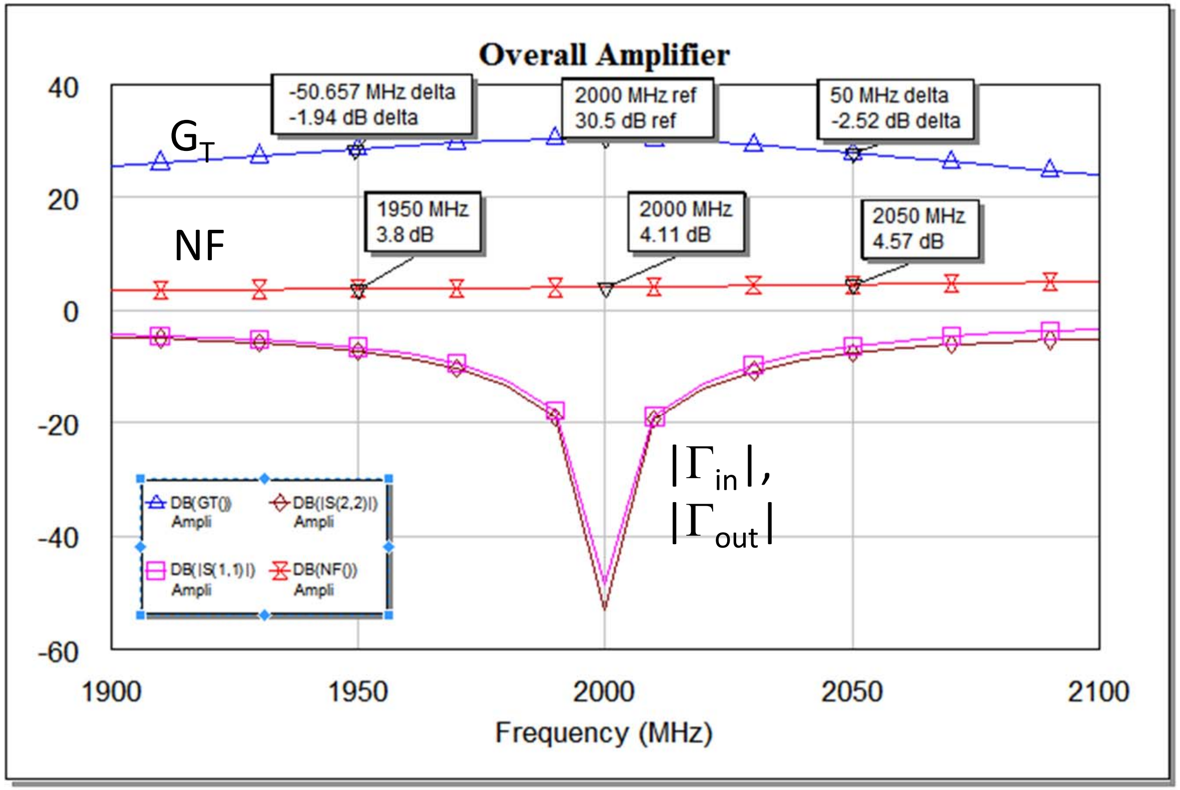
d) Synthetize inter-stage network using double stub




1. Enter (GammaL1)
2. Draw the circle G=const passing for the current point rotated by +270° (toward load)
3. Enter conj(GammaS2) and store
4. Draw the circle G=const passing for the current point
5. Set the current point to the intersection of the two circles
6. B2 is given by imaginary part of Delta Y
7. Increment the phase of current point by -270° (toward source) and store
8. Enter (GammaL1)
9. B1 is given by imaginary part of Delta Y

# Verification with MWOffice



e) Evaluate $IP_3$ of the overall amplifier assuming $P_{1dB}$ of each active device equal to 10 dBm

Assuming 3th order non linearity:
IP3,1=IP3,2=10.63+10=20.6 3dBm → 115.61 mW

$$\left(\frac{1}{IP3}\right)^2 = \left(\frac{1}{G_{T,2} IP3_1}\right)^2 + \left(\frac{1}{IP3_2}\right)^2 = \left(\frac{1}{IP3_1}\right)^2 \left(1 + \frac{1}{G_{T,2}^2}\right)$$

$$IP3 = \frac{IP3_1}{\sqrt{1 + \frac{1}{G_{T,2}^2}}} = \frac{115.61}{1.0005} = 115.55 \rightarrow 20.627 \text{ dBm}$$

Evaluate the overall GT and NF imposing the minimum NF at the 1 stage

NF,min is obtained by imposing $\Gamma_{s1}$=$\Gamma_{opt}$= (0.24, -179°). The output of the first stage is matched by assigning $\Gamma_{L1}$= ($\Gamma_{out,1}$)*=(0.369, 39.64°). The available gain of the first stage is $G_{AV,1}$=12.59 dB.
Note that the inter-stage network transforms also in this case $\Gamma_{in,2}$= ($\Gamma_{s,2}$)* into the new value of $\Gamma_{L1}$.
The overall available gain results $G_{AV}$=12.59+15.23=27.82 dB. This number represents also the overall $G_T$ because the output of the amplifier is matched.

The overall noise figure is given by:

$$(NF)_{TOT} = NF_1 + \frac{NF_2 - 1}{G_{a1}} = 10^{0.2} + \frac{10^{0.4} - 1}{10^{1.259}} = 1.668 \rightarrow 2.22 \text{ dB}$$

Note that the amplifier input is no more matched at 2 GHz