IR-UWB Receiver RF Front End

Low Noise Amplifier

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- Introduction
- LNA Chosen Topology
- Simulated Output Results Using TSMC13RF Design Kit
- Process Corners Simulation
- Design Migration to LF15RF Design Kit
- Deviation in Performance Between the Two Design Kits
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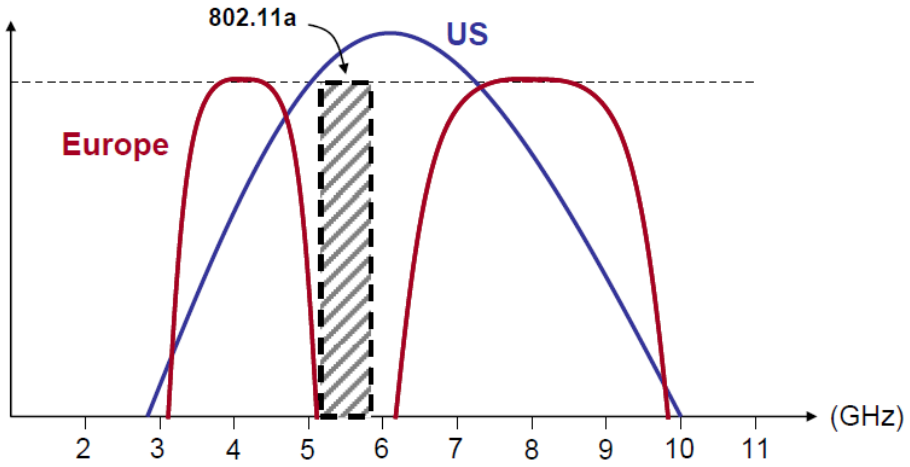
Introduction

- It is required to design an UWB-LNA for a 3.1 GHz to 5.3 GHz range
- Why 3.1 GHz to 5.3 GHz range ?

P400 Module

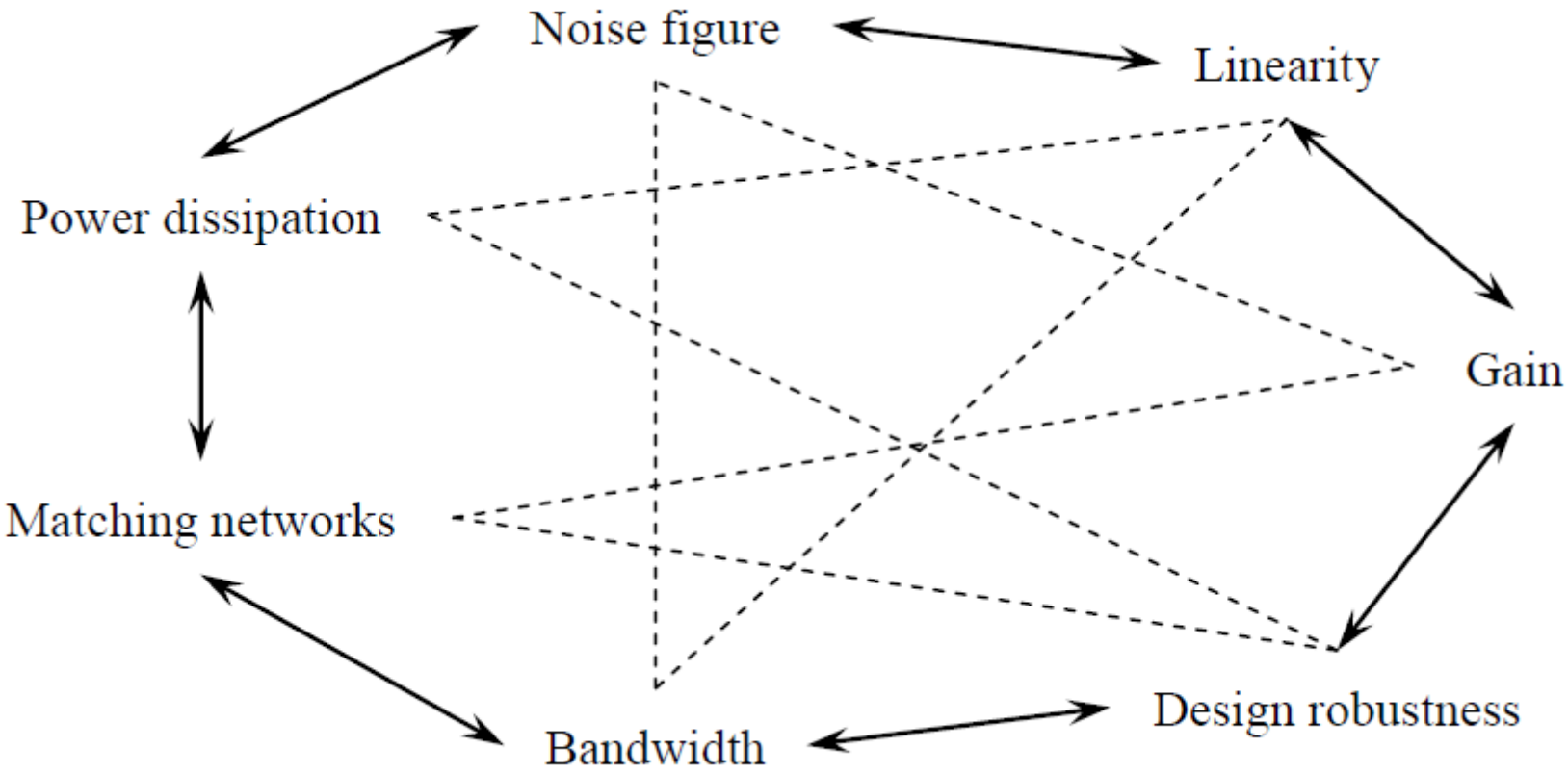


EU and US Standard

- Comparison between LNA basic topologies

Topology	Advantages	Disadvantages
Resistive termination	Good input matching (Wideband)	Huge NF and low gain
Common gate	Good input matching (Wideband)	Large NF and low gain
Resistive feedback	Good input matching (Wideband)	Operation at low frequencies, low gain and stability issues
Common source with inductive degeneration	Good narrow band matching, small noise figure at resonance frequency	Large area due to inductor L_g It can be off chip but this will increase the cost

- LNA design problem



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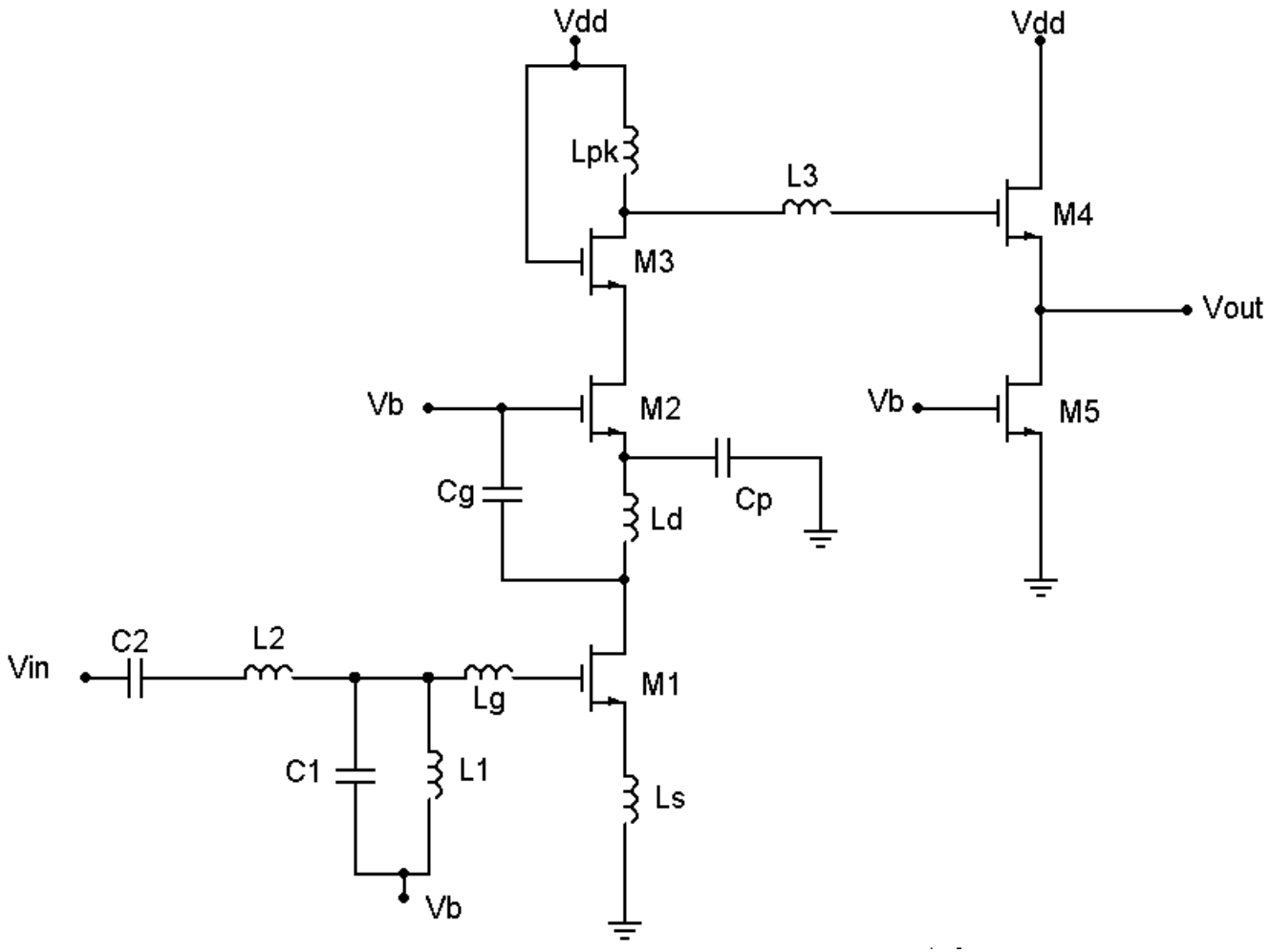
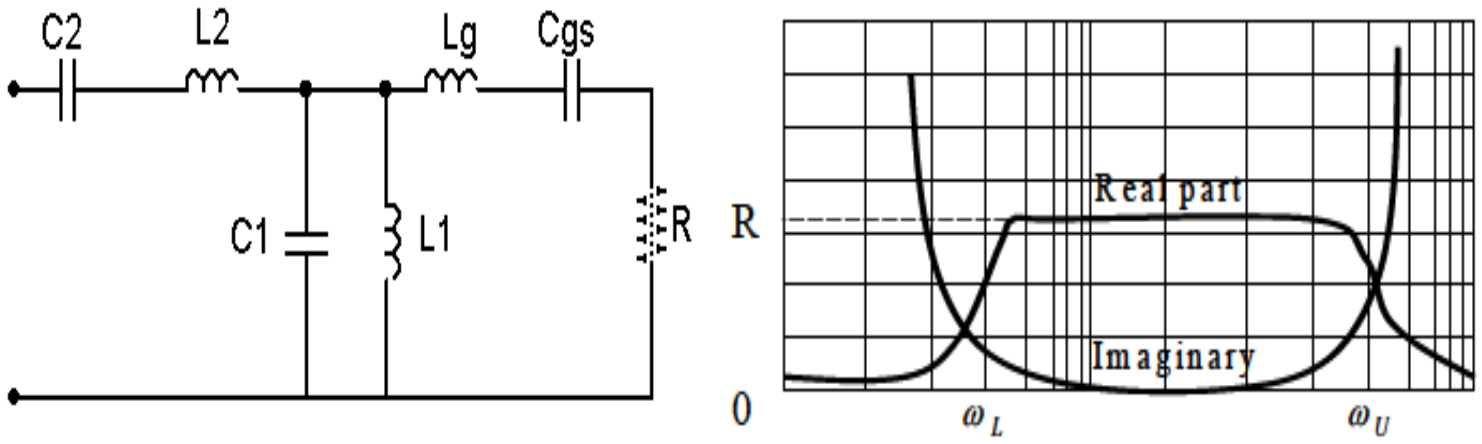
- The chosen topology is the UWB-LNA with current-reuse technique



- The input matching network



$$Z_{in} = sL_2 + \frac{1}{sC_2} + (sL_1 \| \frac{1}{sC_1} \| Z_g)$$

$$Z_g = \frac{1}{sC_{gs1}} + s(L_s + L_g) + \frac{g_{m1}L_s}{C_{gs1}}$$

$$\omega_L \approx \frac{R}{L_1} \approx \frac{1}{RC_2}$$

$$\omega_U \approx \frac{R}{L_2} \approx \frac{1}{RC_1}$$

- The noise figure at the inductive degeneration part is given by:

$$NF = 1 + g_{m1} R_s \gamma \left(\frac{\omega_o}{\omega_\tau} \right)^2$$

Where ω_o is the resonance frequency:

$$\omega_o = \frac{1}{(L_g + L_s) C_{gs}}$$

The resonance frequency is 4 GHz at the center of the bandwidth

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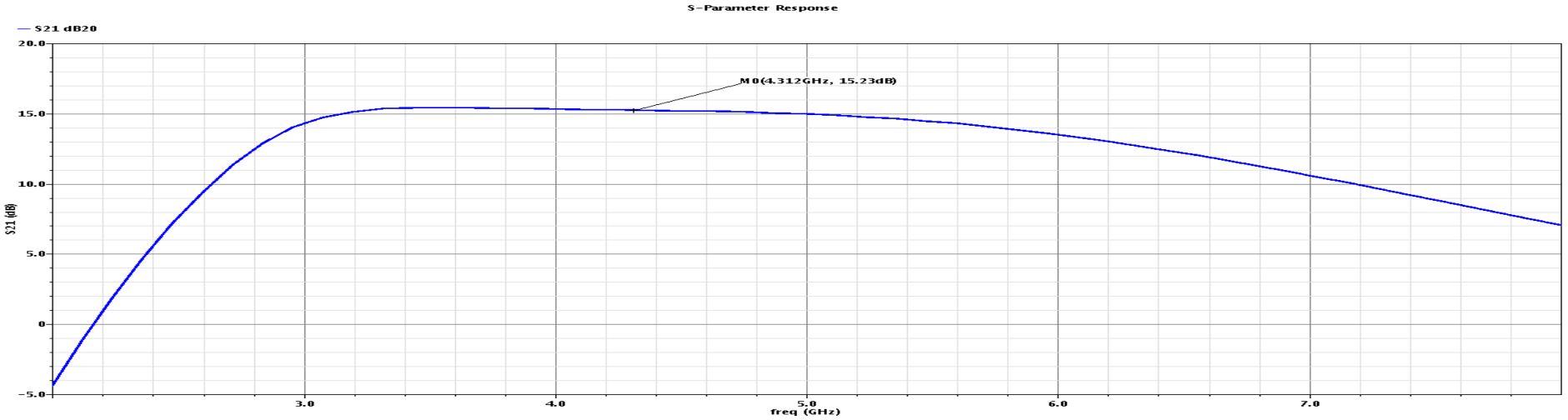
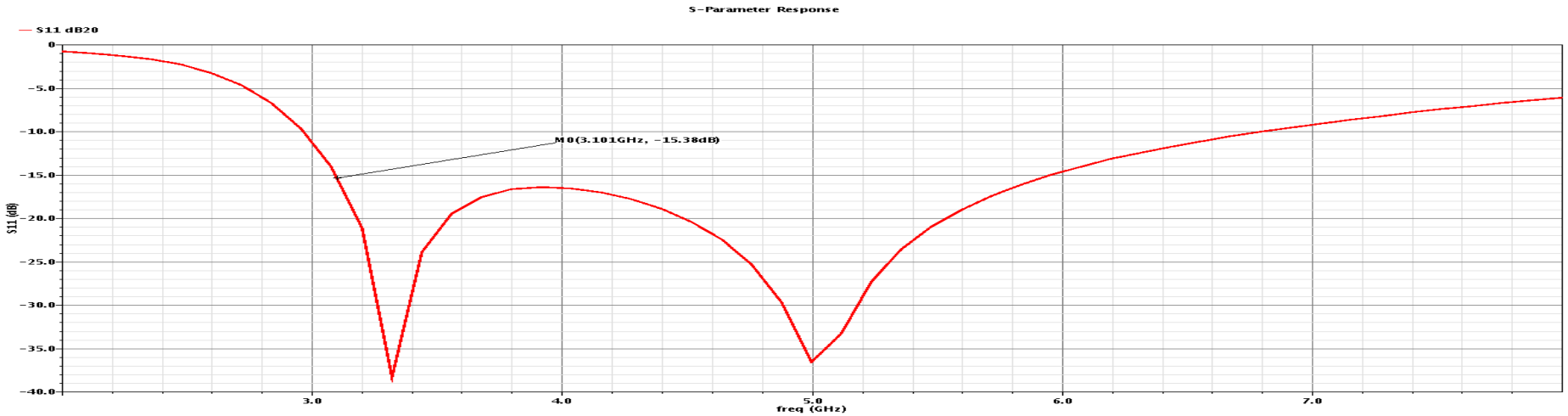
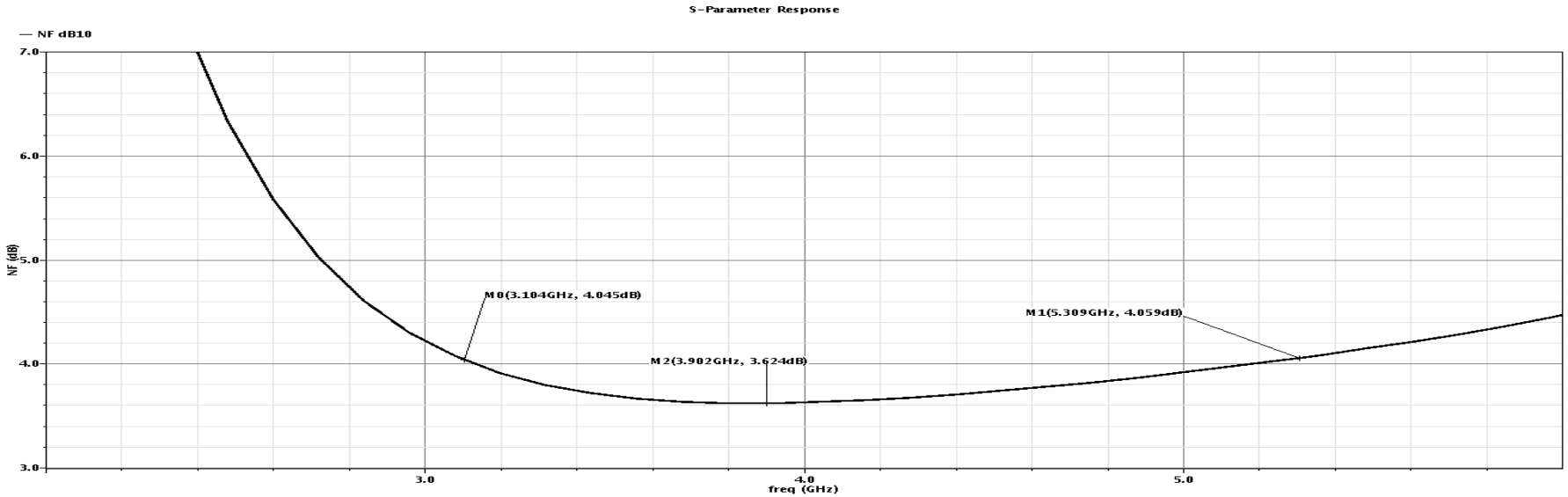
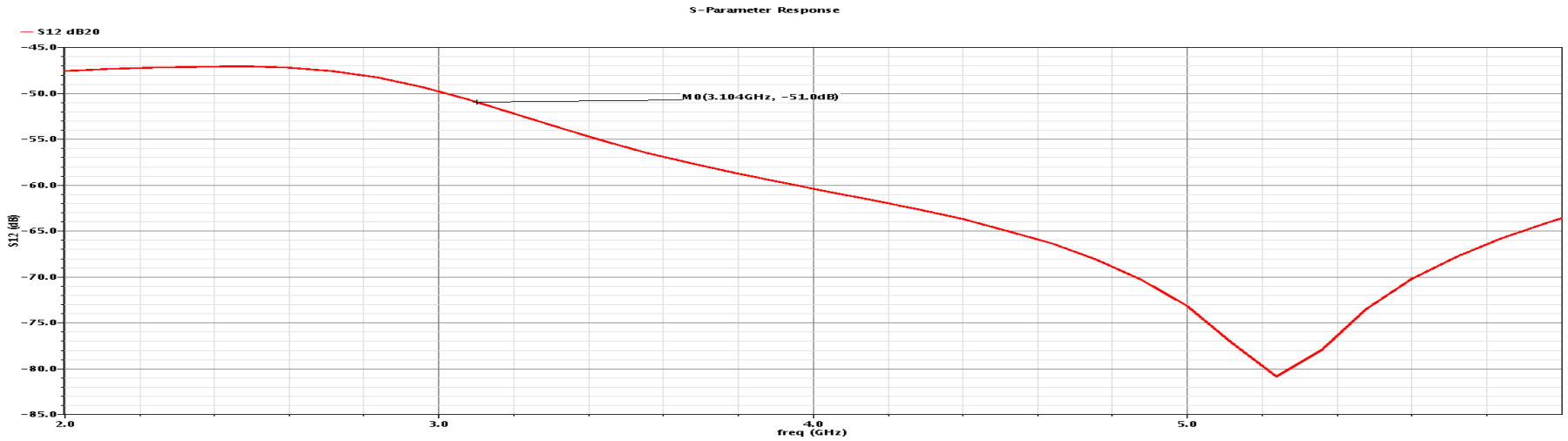
- The reflection coefficient S_{11} and the gain S_{21}





- The noise figure NF and the reverse isolation S_{12}





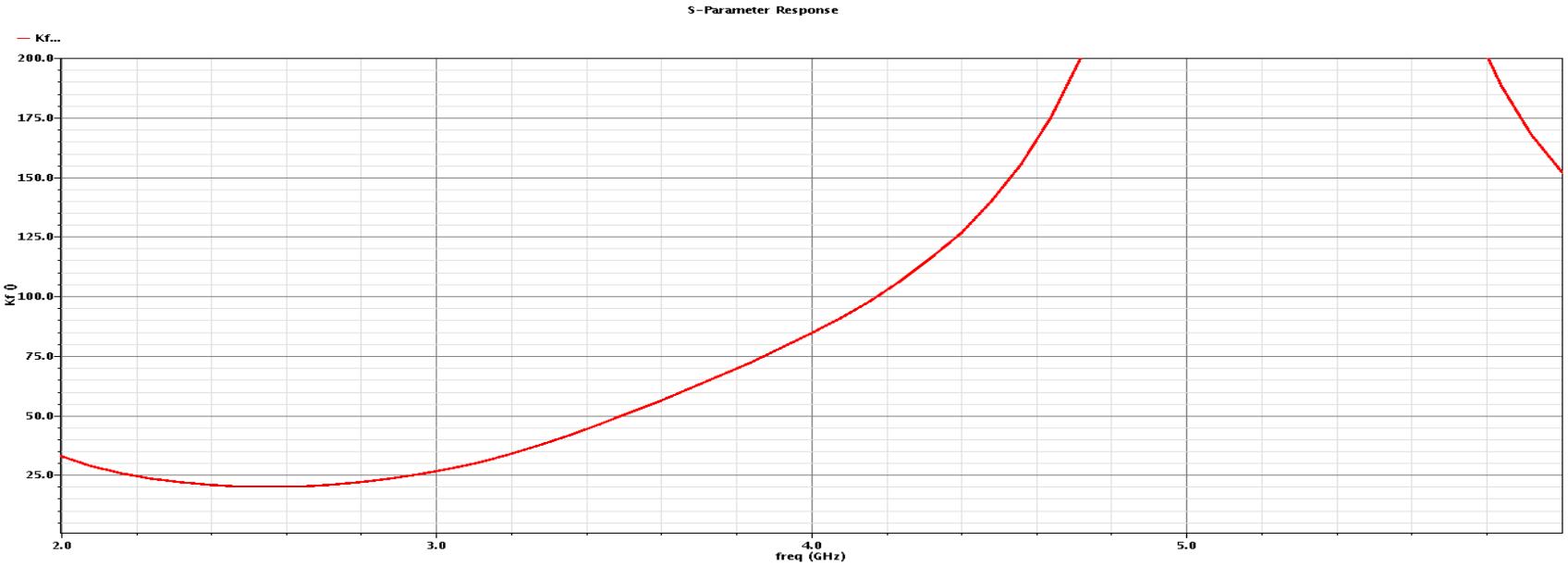
- For unconditional stability of the LNA

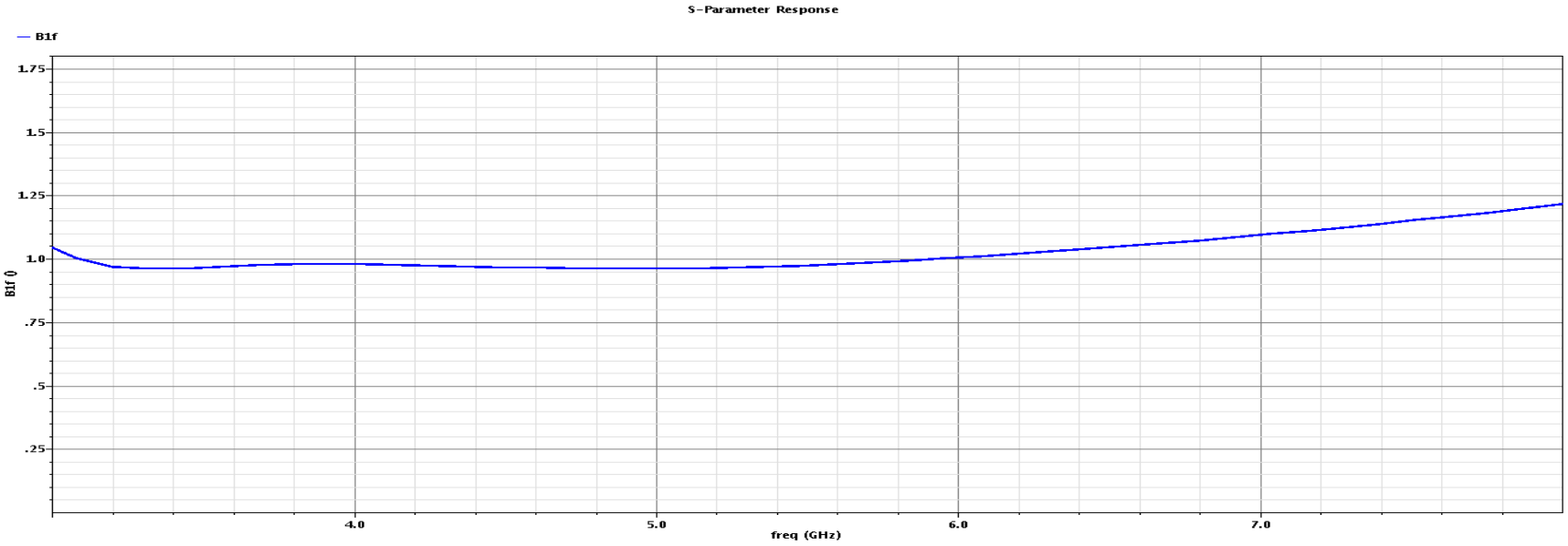
$$K_f = \frac{1+\left|\Delta\right|^2-\left|S_{11}\right|^2-\left|S_{22}\right|^2}{2\left|S_{11}\right|\left|S_{12}\right|} > 1$$

$$\Delta = S_{11}S_{22} - S_{12}S_{21}$$

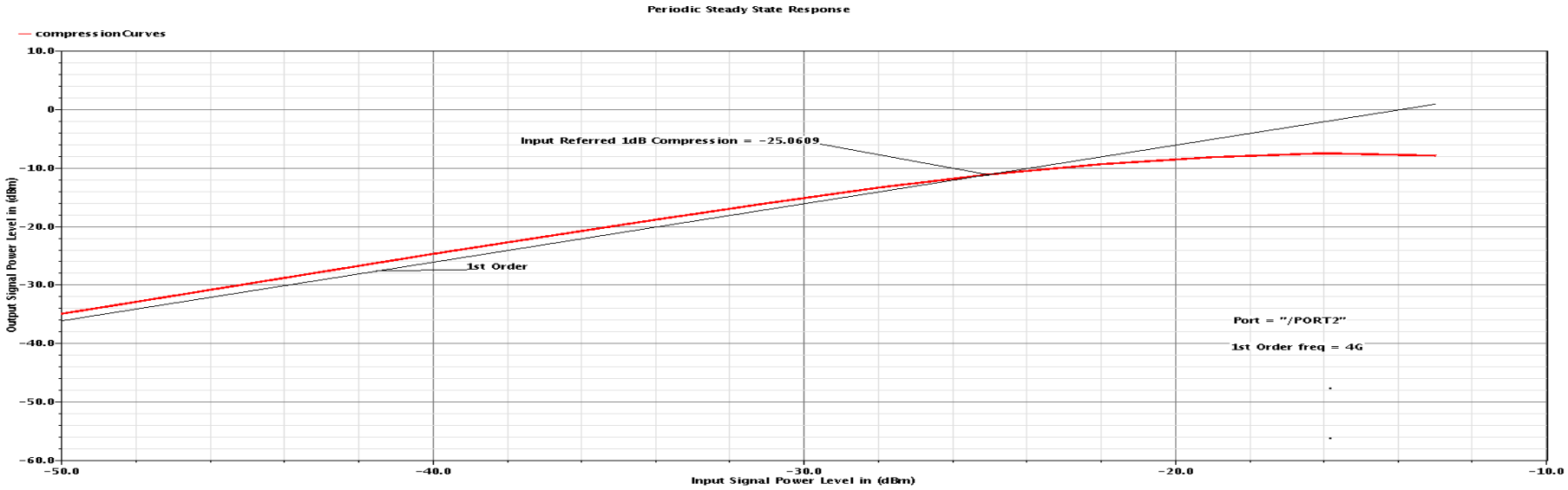
$$B_{1f} = 1+\left|S_{11}\right|^2-\left|S_{22}\right|^2-2\left|\Delta\right|^2 > 0$$

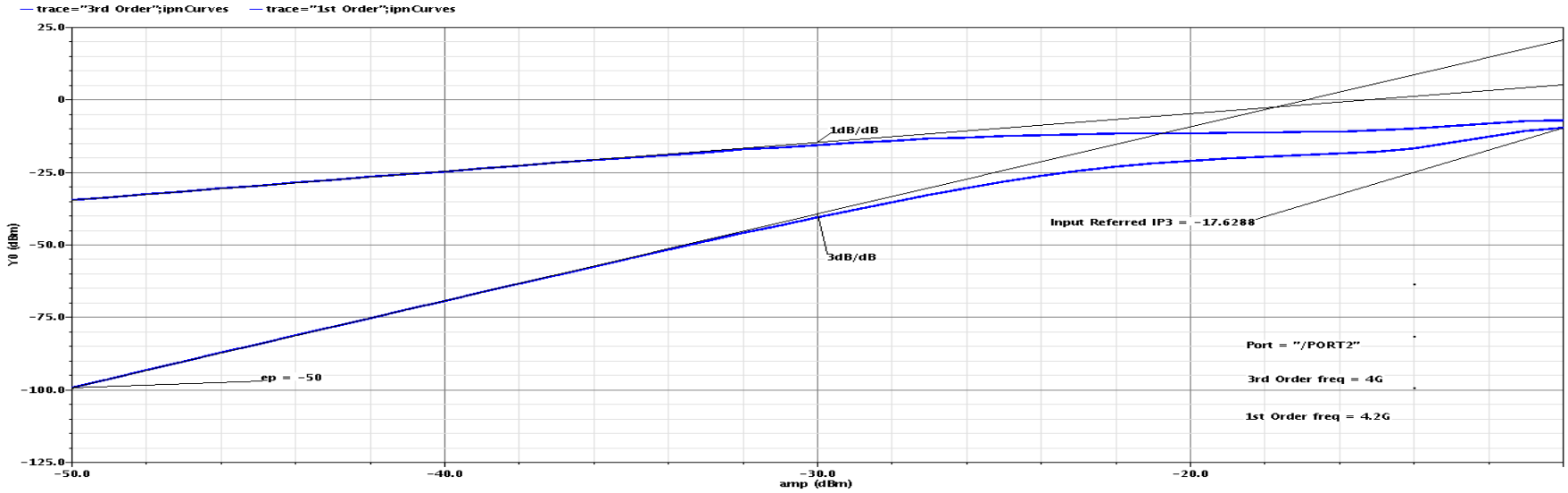
Where Kf is the stability factor and B1f is alternative stability factor


S-Parameter Response
Kf...
200.0
175.0
150.0
125.0
100.0
75.0
50.0
25.0
Kf ()
2.0
3.0
4.0
5.0
freq (GHz)


S-Parameter Response
B1f
1.75
1.5
1.25
1.0
.75
.5
.25
B1f ()
4.0
5.0
6.0
7.0
freq (GHz)

- LNA large signal analysis





- Summary of the achieved results

Parameter	Specifications	Achieved
Bandwidth	3.1 GHz to 5.3GHz	3.1 GHz to 5.3GHz
Input Reflection Coefficient (S_{11})	< -10 dB	-15 dB
Noise Figure (NF)	< 4dB	4 dB
Gain (S_{21})	14 dB to16 dB	15 dB
Reverse isolation (S_{12})	Lowest possible	< -51 dB
Power	Lowest possible	3.2 mW
IIP_3	> -15 dBm	-17 dB
FOM	-	5.1

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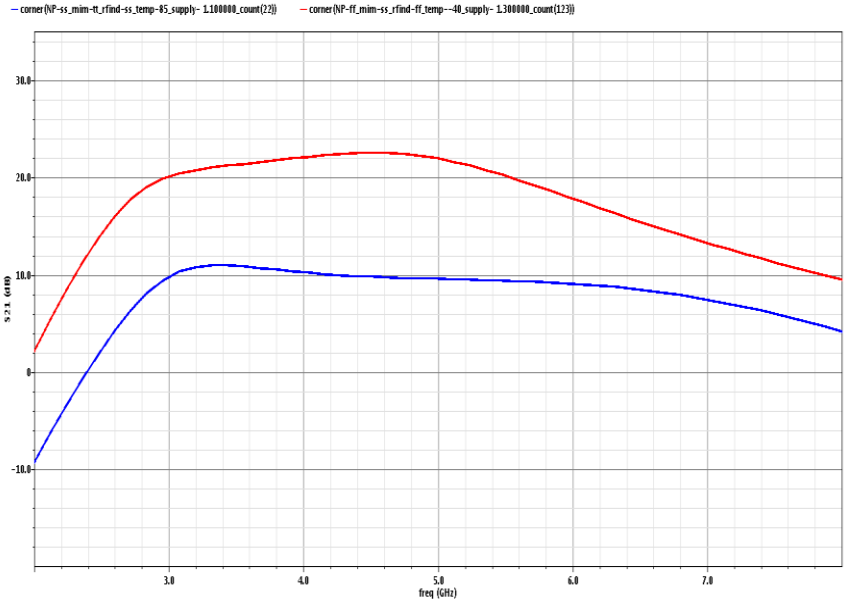
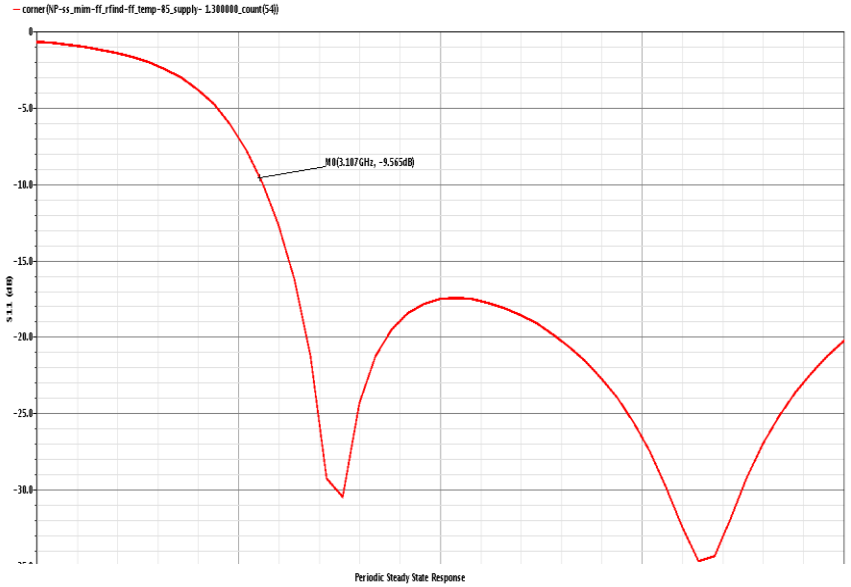
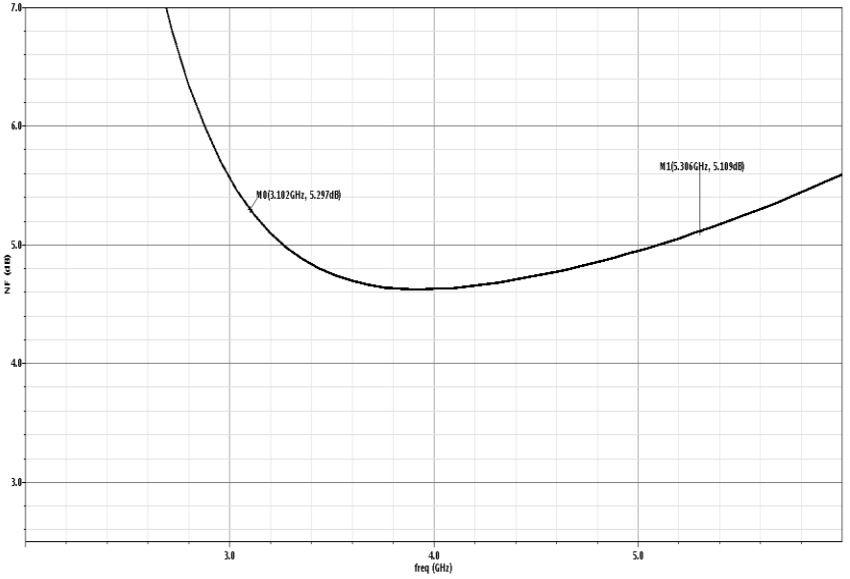
Process Corners Simulation

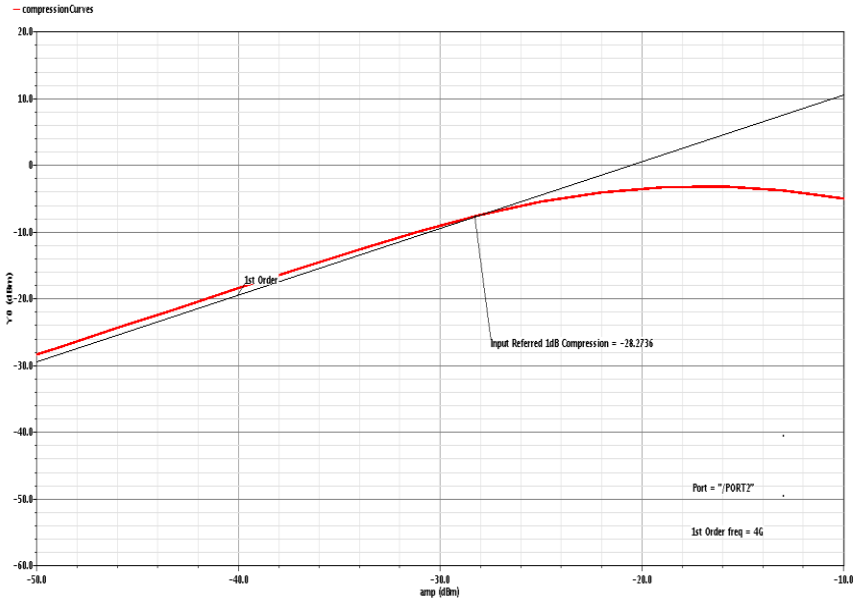
- The models used for the NMOSFETS are BSIM3V3 models provided by the fab
- All models used for the capacitors and inductors are provided by the fab
- Simulations are done by running an Ocean script across all corners
- The temperatures are taken to be -40°C and 85°C
- The supply voltage varies +-10%

- Worst case process corners









- The achieved results from running process corners simulations

Parameter	Worst case corner
Bandwidth	3.1 GHz to 5.3GHz
Input Reflection Coefficient (S_{11})	-9.5 dB
Noise Figure (NF)	5.2 dB
Gain (S_{21})	Varies from 10 dB to 21 dB
Reverse isolation (S_{12})	< -47
IIP_3	-18 dBm

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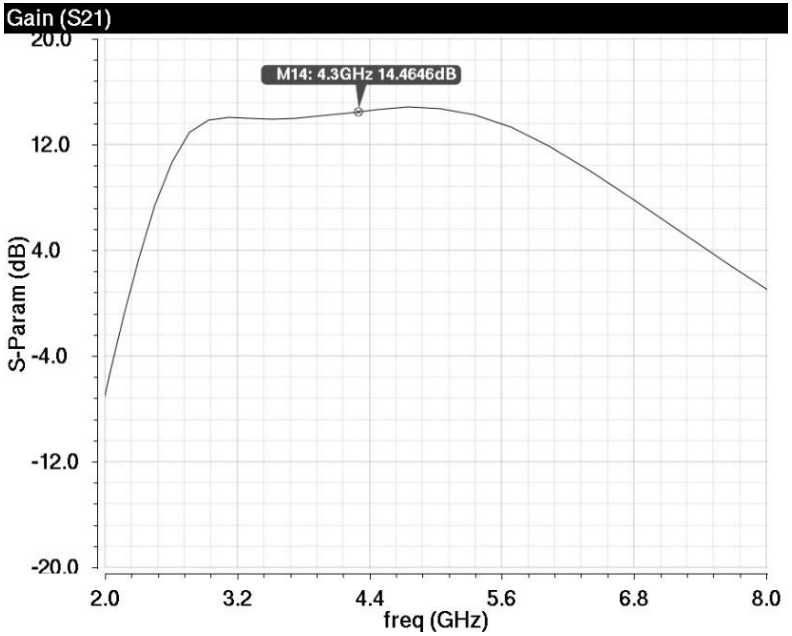
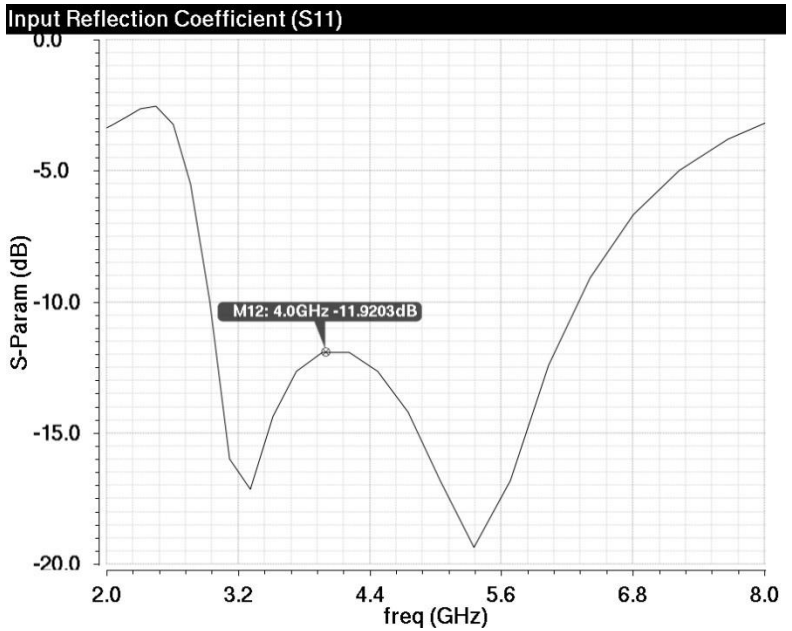
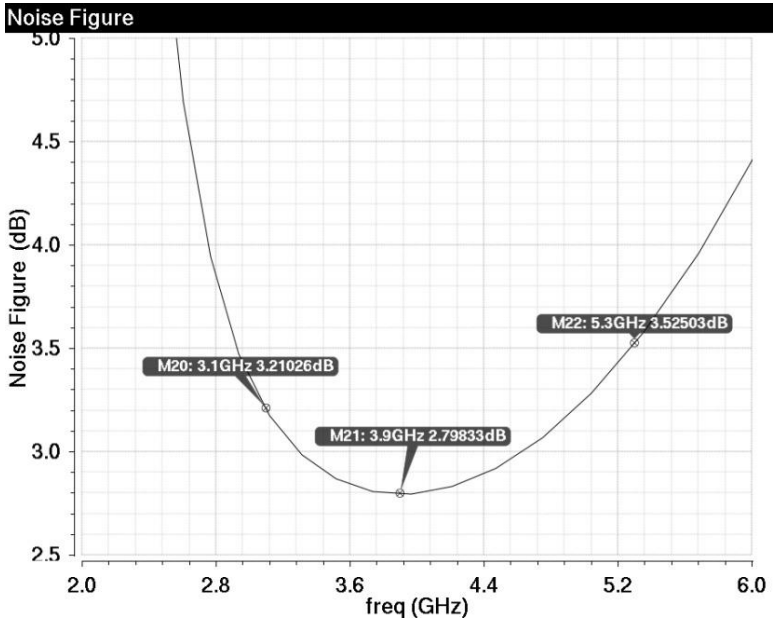
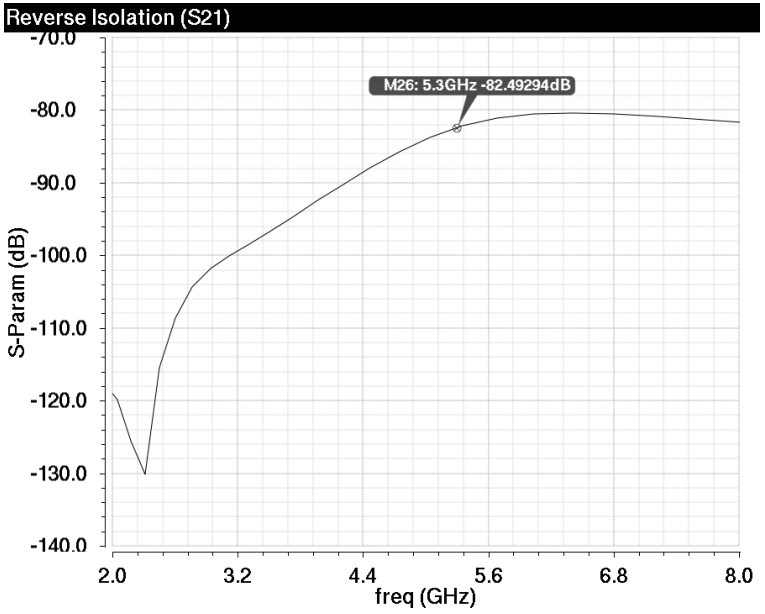
Design Migration to LF15RF Design Kit

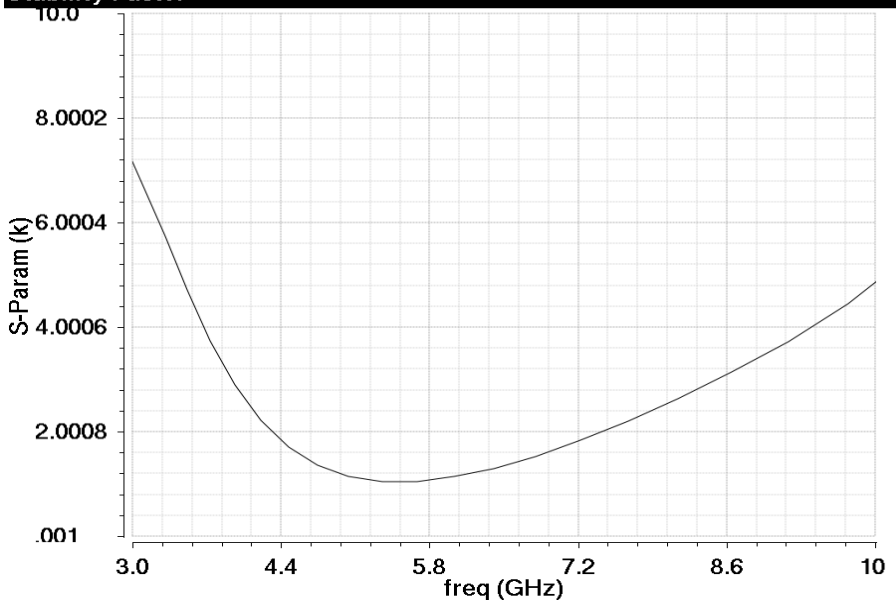




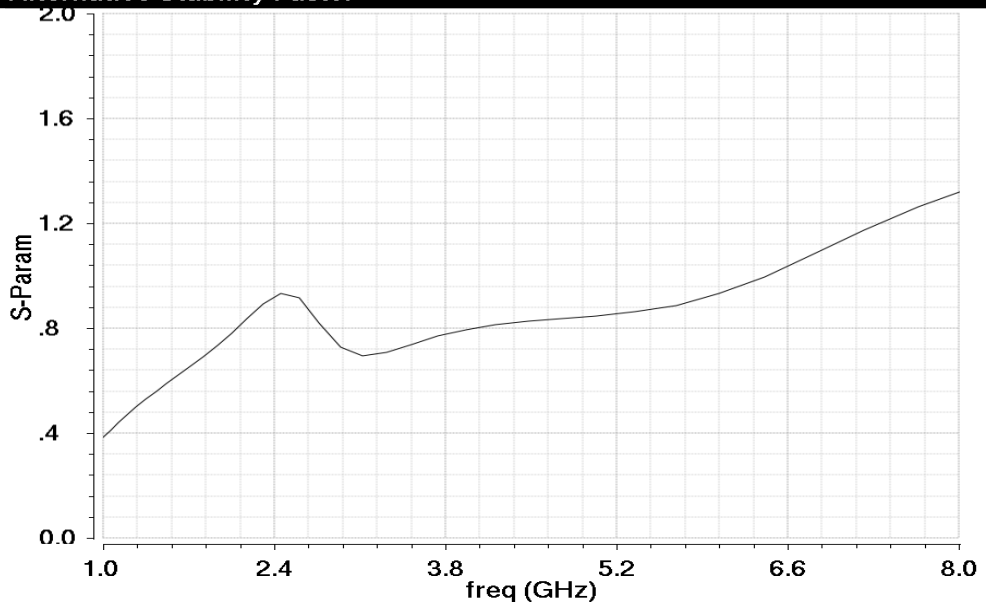




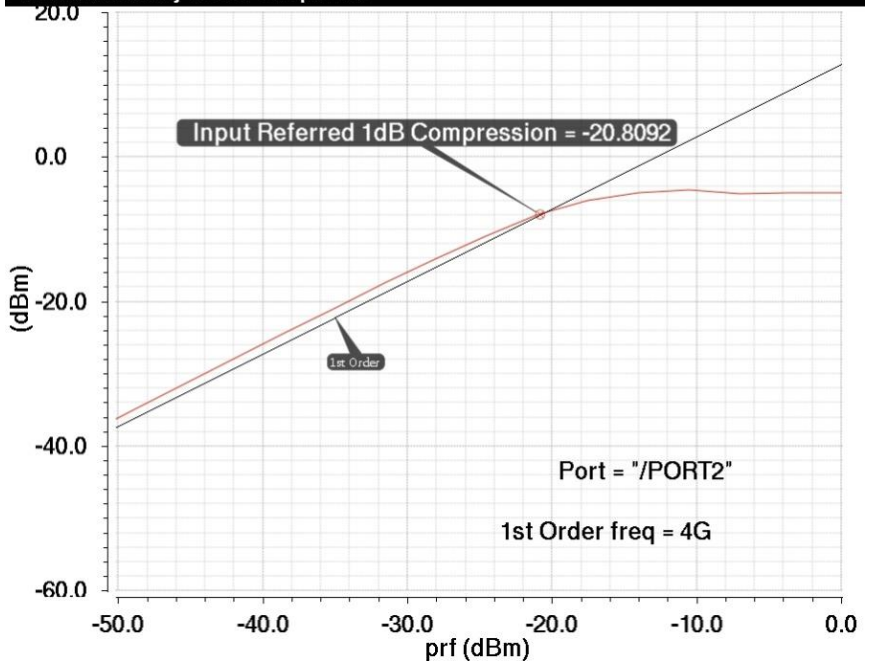
Stability Factor



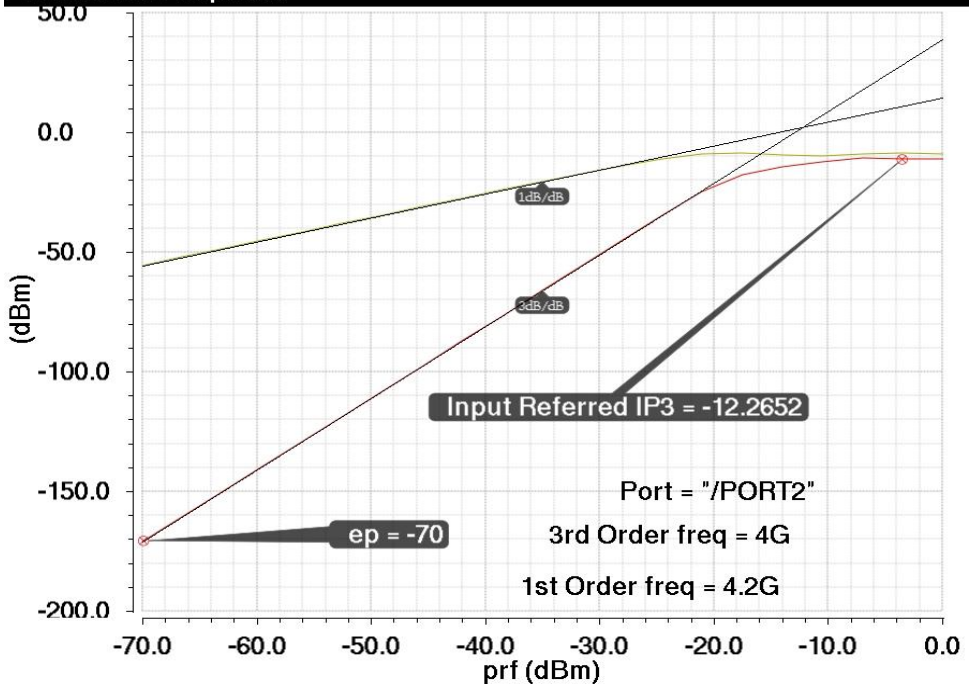
Alternative Stability Factor



Periodic Steady State Response



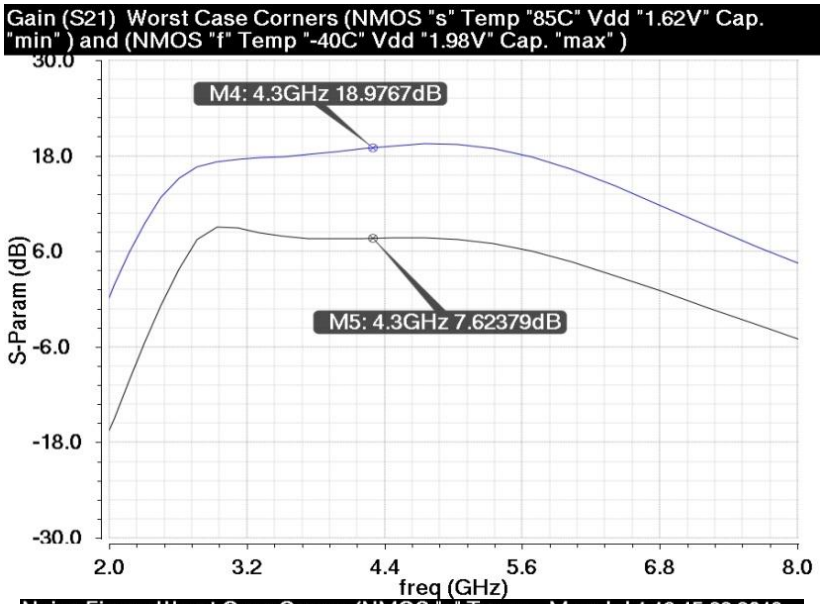
Periodic AC Response

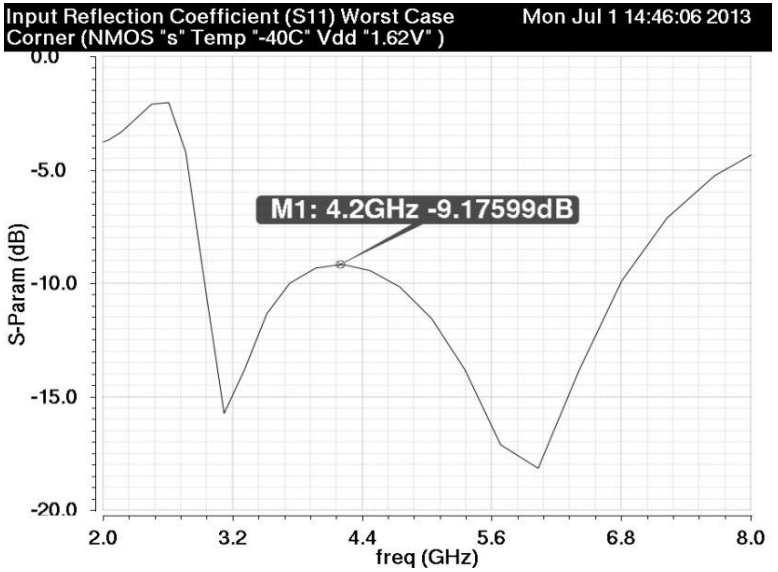


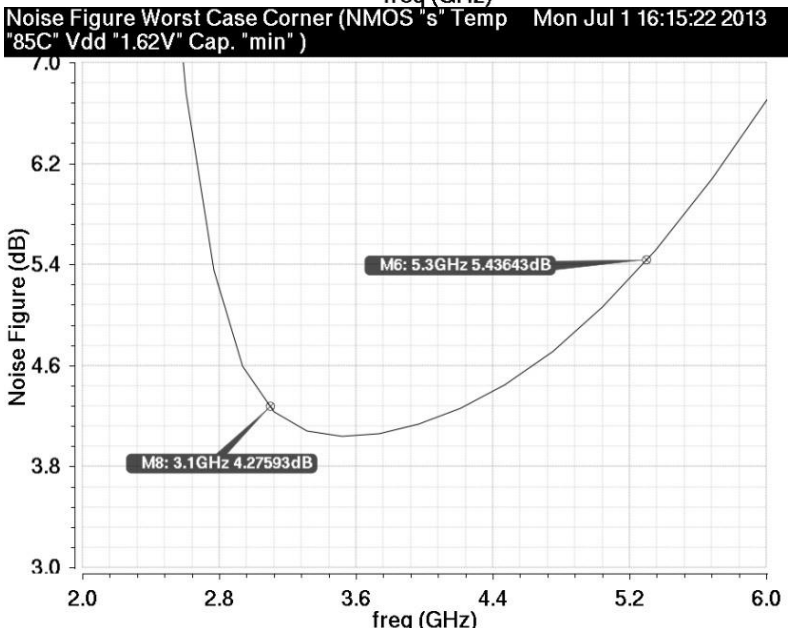
- Summary of the achieved results

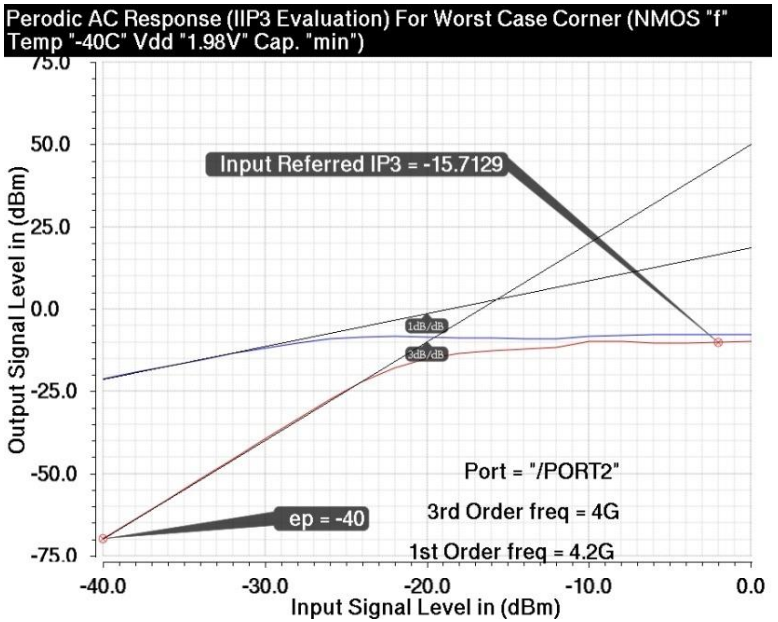
Parameter	Specifications	Achieved
Bandwidth	3.1 GHz to 5.3GHz	3.1 GHz to 5.3GHz
Input Reflection Coefficient (S_{11})	< -10 dB	-12 dB
Noise Figure (NF)	< 4dB	3.5 dB
Gain (S_{21})	14 dB to16 dB	14.5 dB
Reverse isolation (S_{12})	Lowest possible	< -82 dB
Power	Lowest possible	6.12 mW
IIP_3	> -15 dBm	-12 dB
FOM	-	2.51

- Worst case process corners









- The achieved results from running process corners simulations.

Parameter	Worst case corner
Bandwidth	3.1 GHz to 5.3GHz
Input Reflection Coefficient (S_{11})	-9.2 dB
Noise Figure (NF)	5.4 dB
Gain (S_{21})	Varies from 7.6 dB to 19 dB
Reverse isolation (S_{12})	< -79
IIP_3	-15.7 dBm

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Deviation in Performance Between the Two Design Kits

Point of comparison	TSMC13RF	LF15RF
Power consumption	Low due to low supply voltage 1.2V	High due to high supply voltage 1.8V
Linearity	Less linearity	High linearity
Noise Figure	Higher due to the low quality factor of the inductors at high frequency	Low due to the high quality factor of the inductors at high frequency

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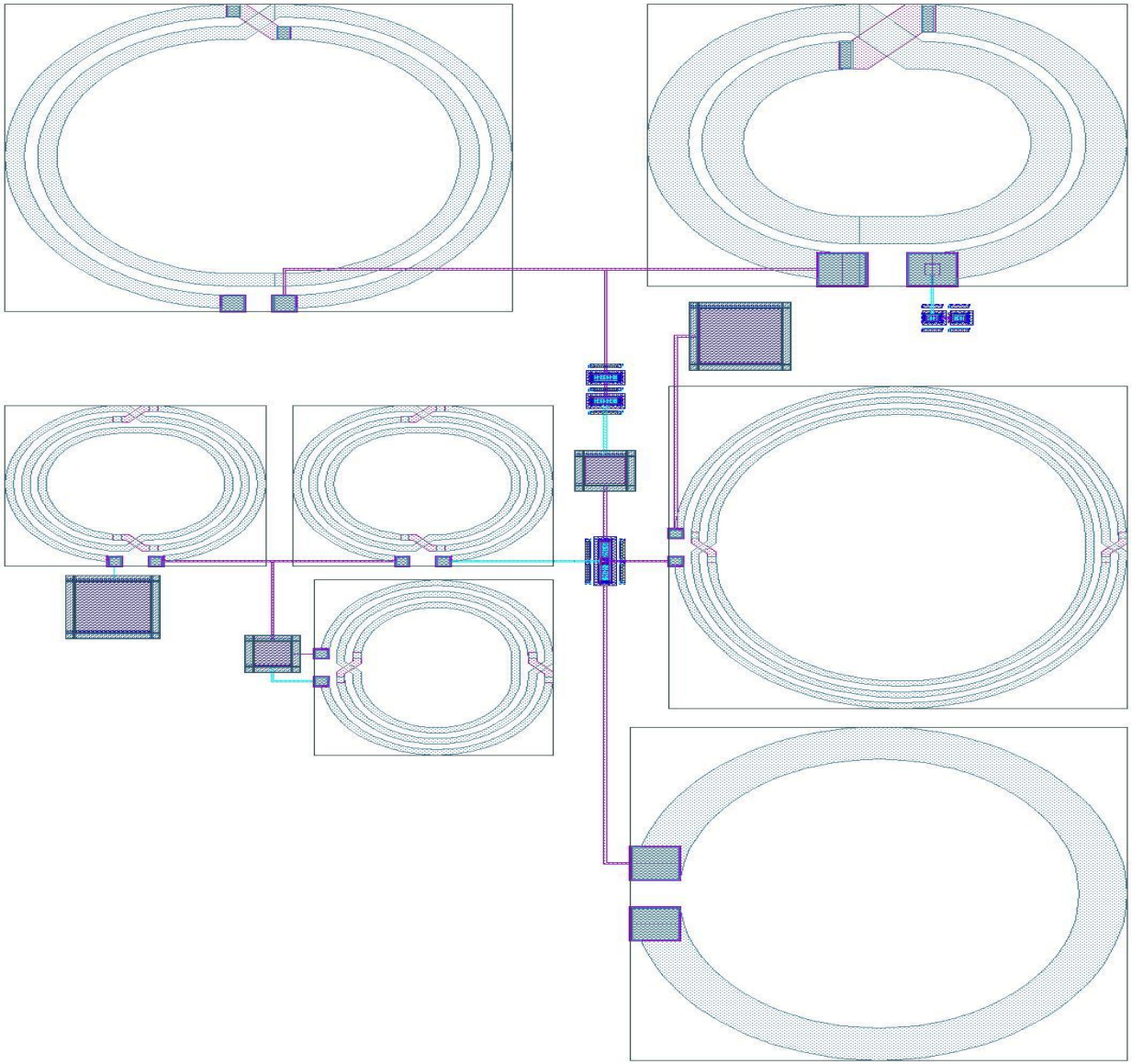
Layout