ECE 6420: WIRELESS IC DESIGN

Wideband Direct Downconversion Receiver Design

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A. Design Summary:

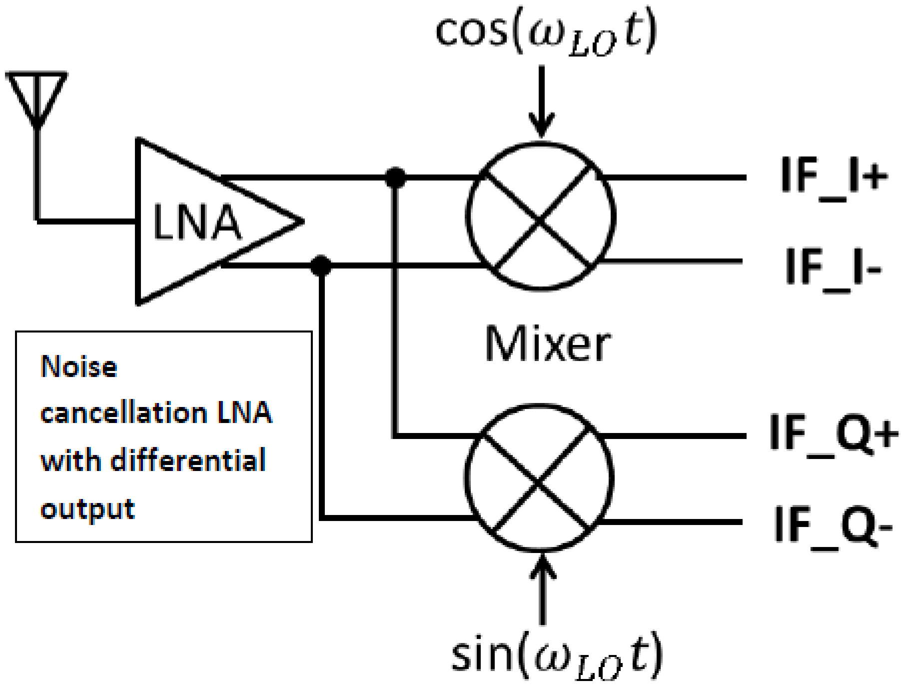

Fig. 1: Receiver Block Diagram

1. **LNA:** A differential LNA with resistive feedback topology has been used for this project. Employing the resistive feedback set up we relax the correlation of the Noise Figure, gain, and BW with the help of resistive current reuse.

2. **Mixer:** Using a Gilbert cell double-balanced active mixer with a negative impedance we were able to significantly boost the conversion gain.

B. Performance Table:

	Target Specifications	Simulated Results
Figure of Merit(FOM)	≥ 287.5	6025.2
VDD	≤ 2.5V	1.4V
Q for inductor	15	15
DC Power Budget	≤ 80 mW	61.32 mW
S11	≤ -10dB	-18.2dB
Bandwidth	2.4 – 5 GHz	5.5 GHz
IF Bandwidth	50 MHz	100 MHz
Peak Conversion Gain	≥ 27 dB	27.859
Noise Figure (DSB)	≤ 5 dB	4.422 dB
P1dB @input	≥ -25dBm	-17.5 dBm
IIP3	≥ -20dBm	-12.489 dBm
Total Inductance	≤ 20nH	8.47nH
Total Capacitance	Unlimited	-

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C. Schematics:

System Level Diagram:

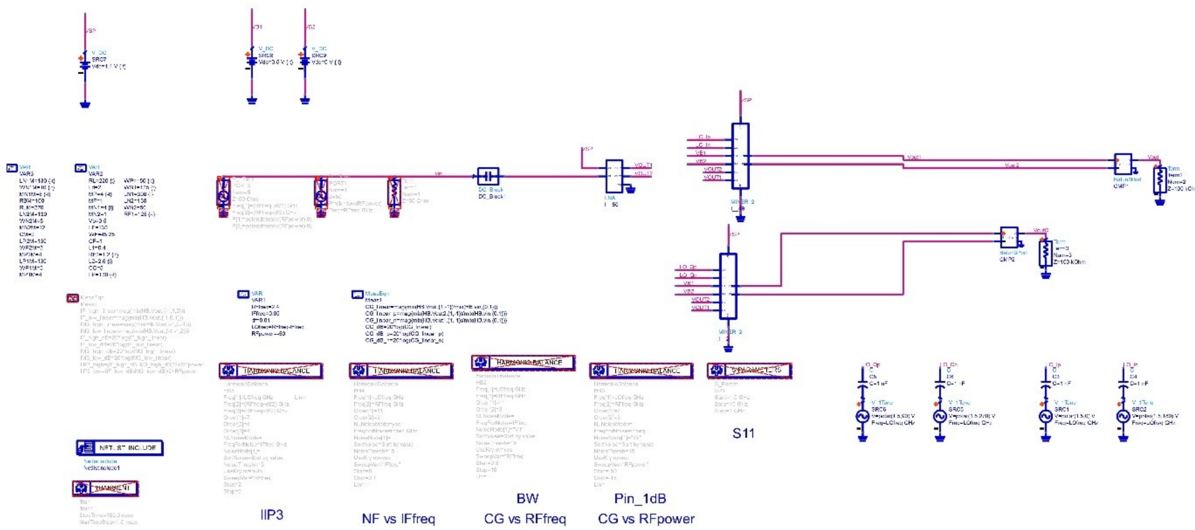

Fig. 1: Complete receiver schematic

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LNA:

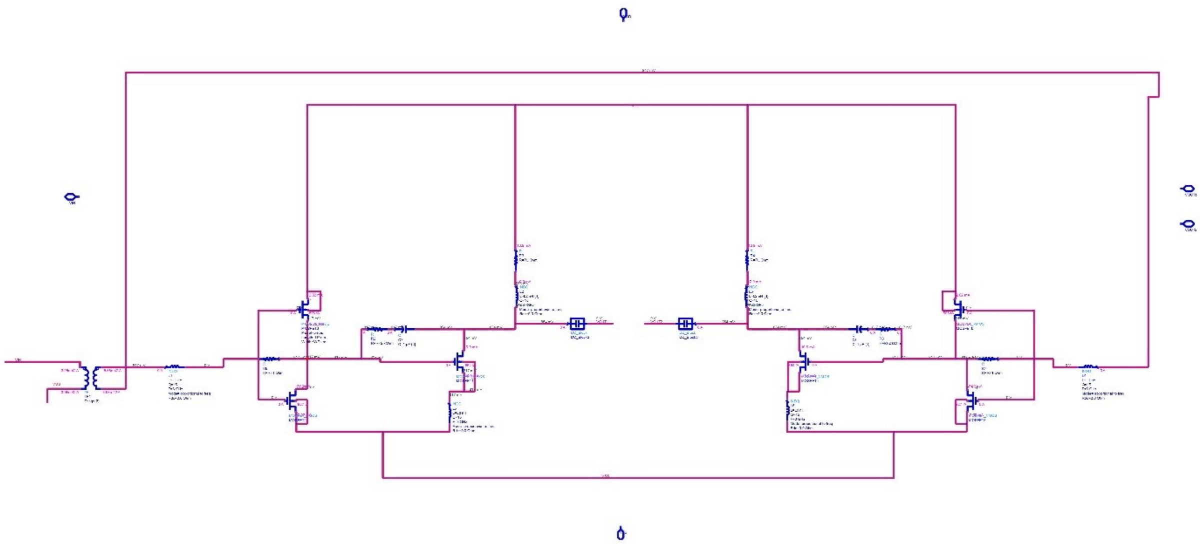

Fig. 2: LNA Schematic

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Mixer:

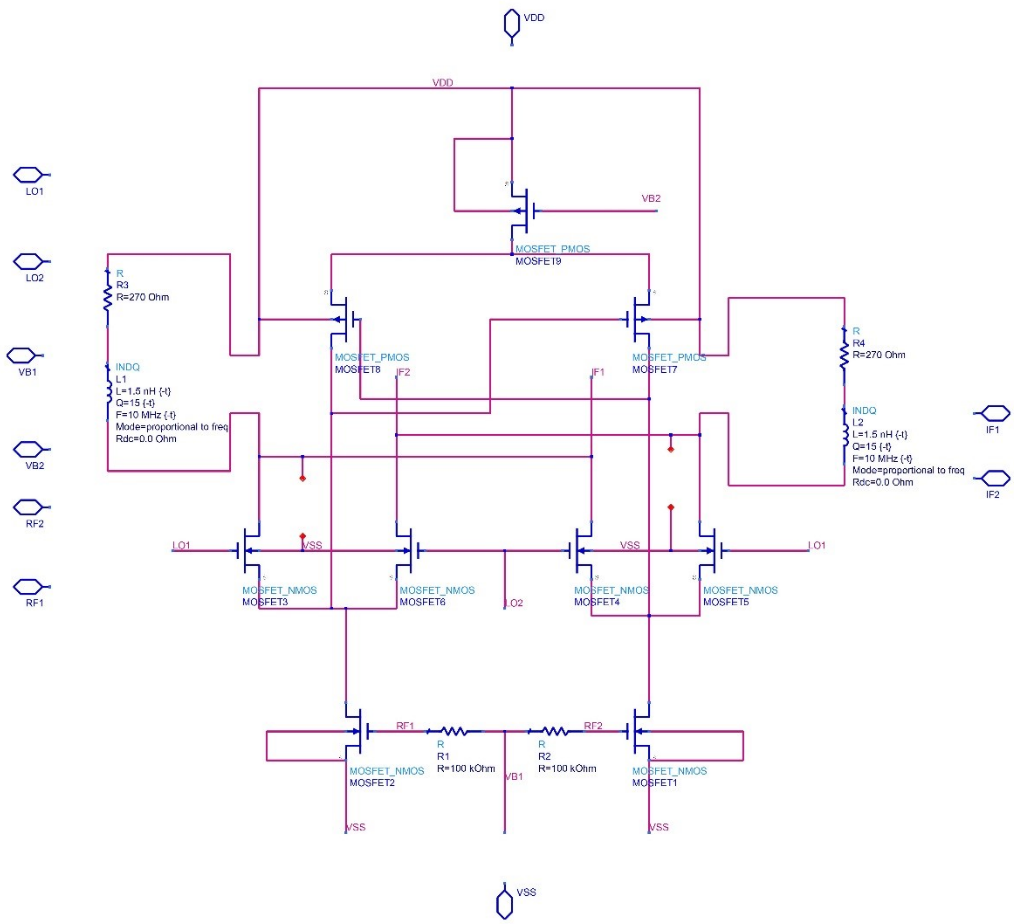

Fig. 3: Mixer schematic

D. Theoretical Analysis:

LNA:

LNA input impedance:

$$\mathrm{Zin} := \frac{R_F}{1 + Av}$$

$$R_F = 1.2\ \mathrm{K}\Omega$$

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LNA gain:

$$Av = (0.5 * g_m * R_F) + (g_{m2}*(R_L + \omega L)$$

$$g_m = gmN + gmP$$

$$gmN = 39.1 \text{ mS}$$

$$gmP = 73.9 \text{ mS}$$

$$Av = 16.15 \text{ dB}$$

LNA Noise figure:

$$NF := 1 + \frac{2}{3} \cdot \frac{1}{g_m \cdot (R_S)^2} + \left[\frac{f}{f_{(T_{Min})}} \right]^2 \cdot \frac{2}{3} \cdot g_m \cdot R_S$$

$$NF = 4.08 \text{ dB}$$

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Mixer: the following equation is the voltage conversion gain of mixer neglecting LO crossing equilibrium and parasitic capacitance effect on gain degradation. The conversion gain is 10.3 dB.

$$A_V = \frac{2}{\pi} g_{m3}(R_L + \omega L)\frac{g_{m1,2}}{\sqrt{\omega^2 {C_P}^2 + {g_{m1,2}}^2}} \approx \frac{2}{\pi} g_{m3}(R_L + \omega L) = 3.27$$
$$= 10.3\ dB$$

$$where\ g_{m3} = 0.019,\ g_{m1,2} = 0.014, R_{load} = 270\ \Omega$$

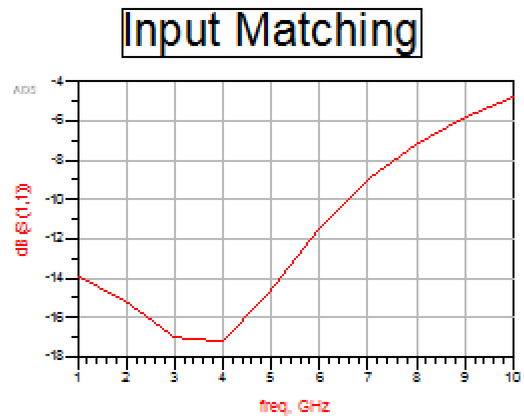
In order to get NF of a mixer, we need to calculate an input-referred noise voltage. Let assume $\gamma = 1$, and the noise effect from the parasitic capacitance at source nodes of M1, M2 is also neglected. Then, the double sideband noise figure of the mixer is 6.15 dB.

$$\overline{V_{n,in}^2} = 2\pi^2 kT(\frac{\gamma}{g_{m3}} + \frac{2}{{g_{m3}}^2 R_L})$$

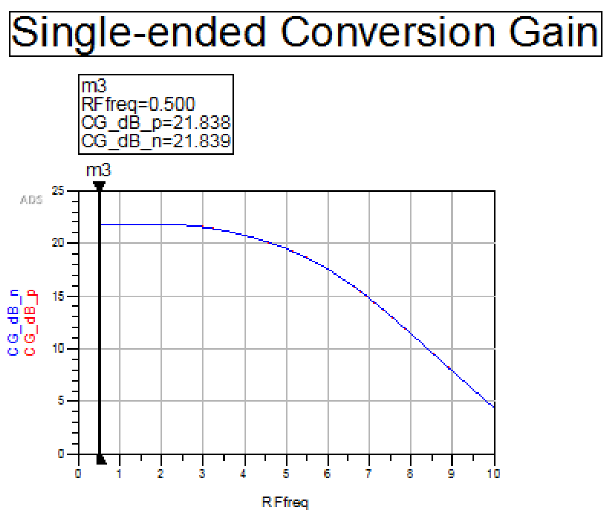
$$NF_{SSB} = 1 + \frac{\overline{V_{n,in}^2}}{4kTR_S} = 1 + \frac{\pi^2}{2R_S}\left(\frac{\gamma}{g_{m3}} + \frac{2}{{g_{m3}}^2 R_L}\right) = 8.22 = 9.15\ dB$$

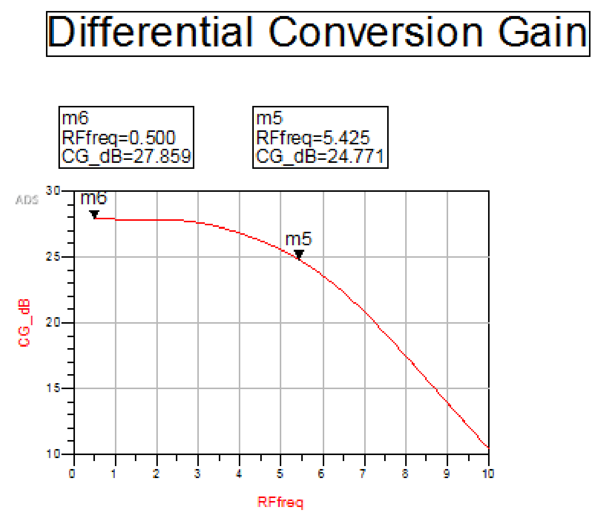
$$NF_{DSB} = NF_{SSB} - 3 = 6.15\ dB$$

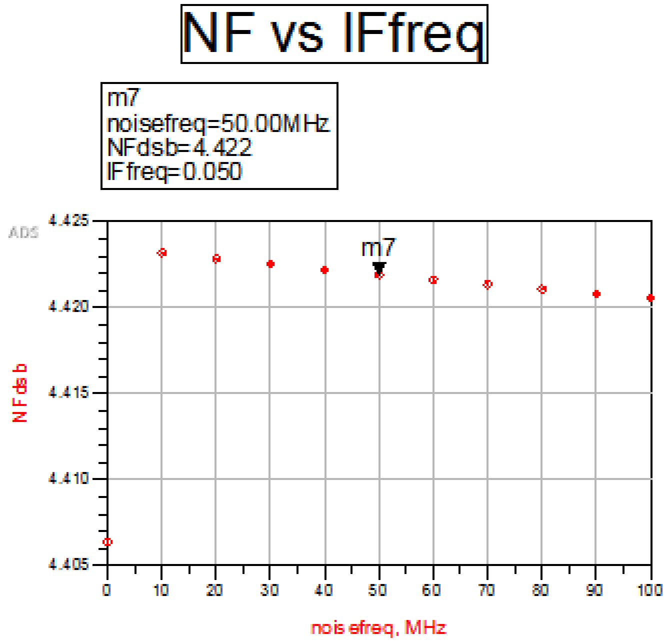
E. Simulation Results:

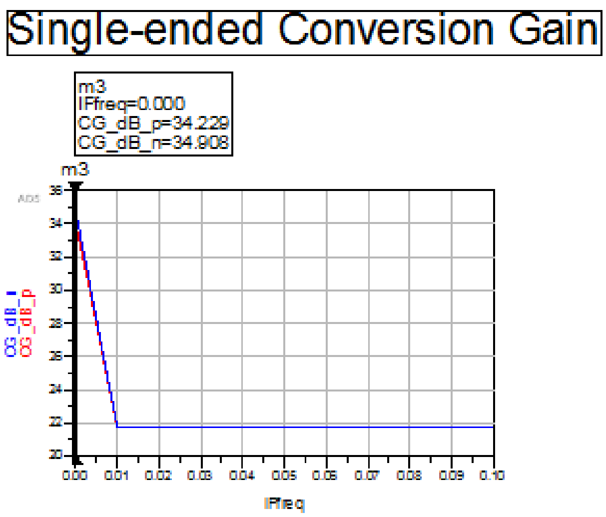


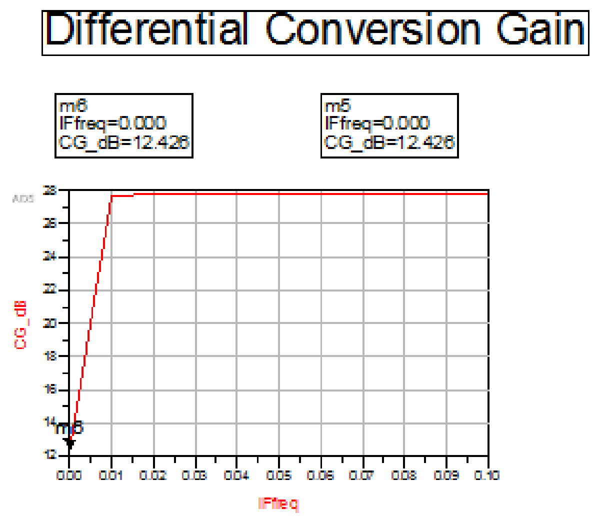
CONVERSION GAIN



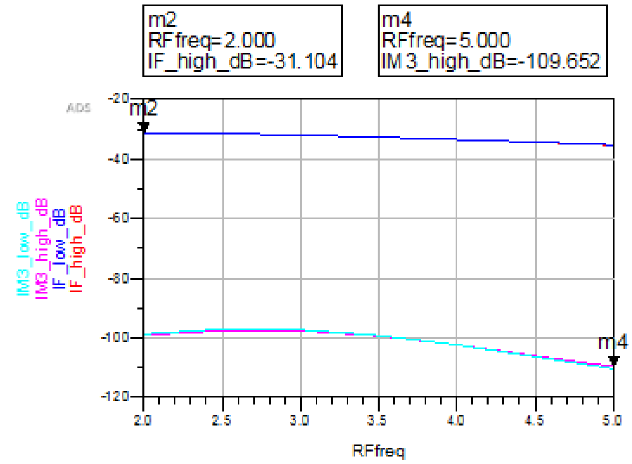



NF vs IFfreq
m7
noisefreq=50.00MHz
NFdsb=4.422
IFfreq=0.050
NFdsb
noisefreq, MHz


Single-ended Conversion Gain
m3
IFfreq=0.000
CG_dB_p=34.229
CG_dB_n=34.908
CG_dB_n
CG_dB_p
IFfreq


Differential Conversion Gain
m6
IFfreq=0.000
CG_dB=12.426
m5
IFfreq=0.000
CG_dB=12.426
CG_dB
IFfreq

IIP3

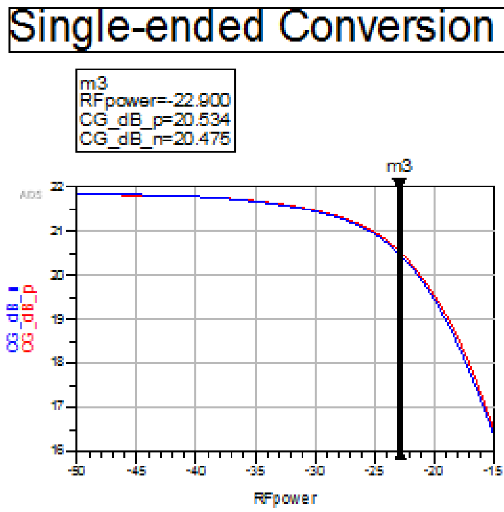


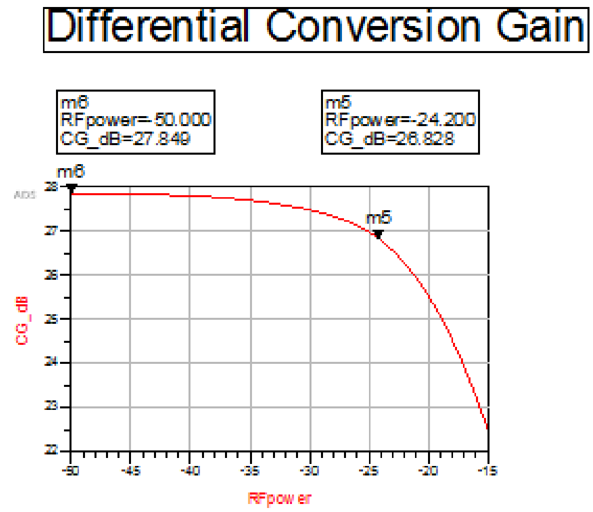
IIP3

RFfreq	IIP3_high	IIP3_low
2.000	-16.040	-16.180
2.500	-16.899	-17.221
3.000	-17.165	-17.335
3.500	-16.672	-16.712
4.000	-15.544	-15.504
4.500	-14.128	-14.005
5.000	-12.832	-12.480

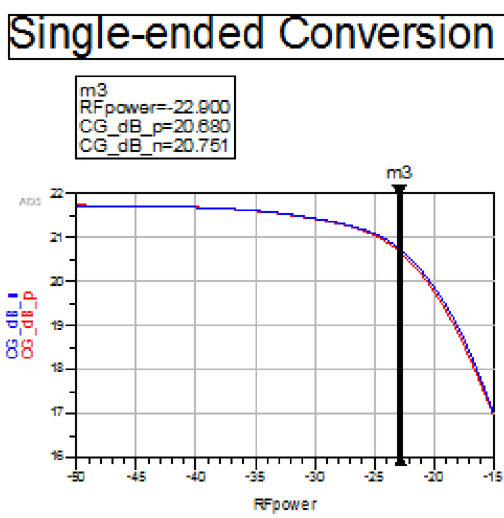
P_1dB Plot

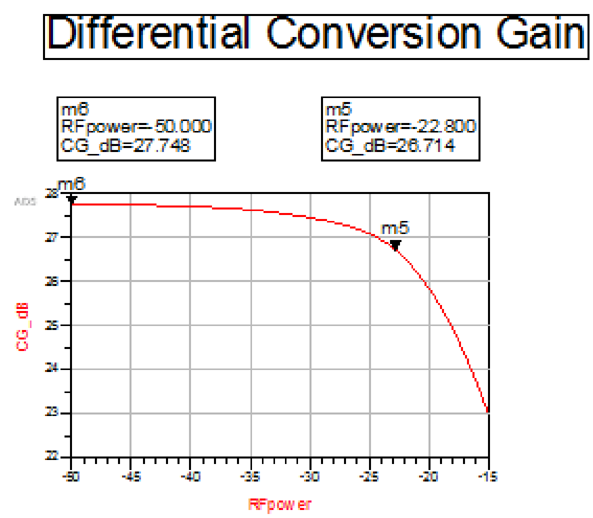
@2.5 Ghz



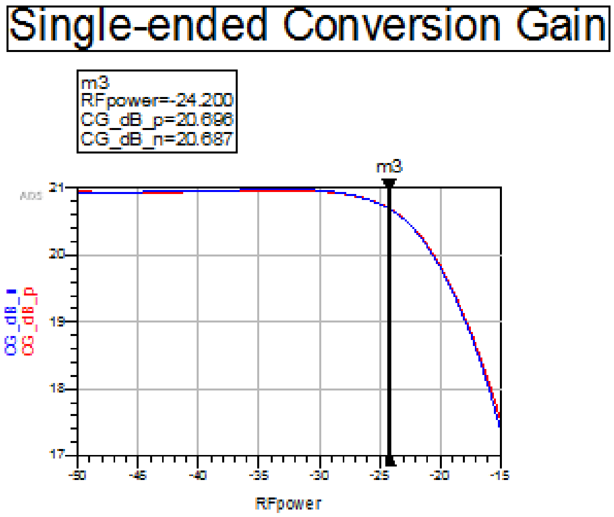


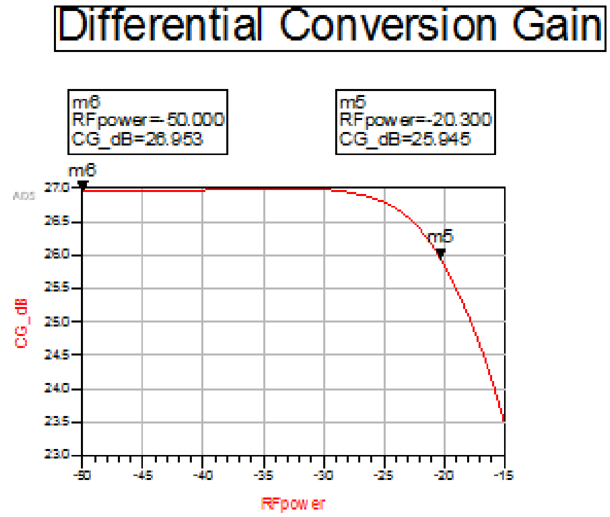
@3 Ghz



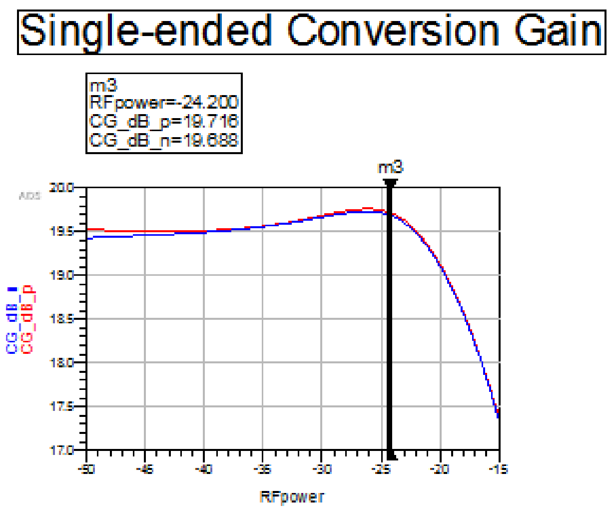


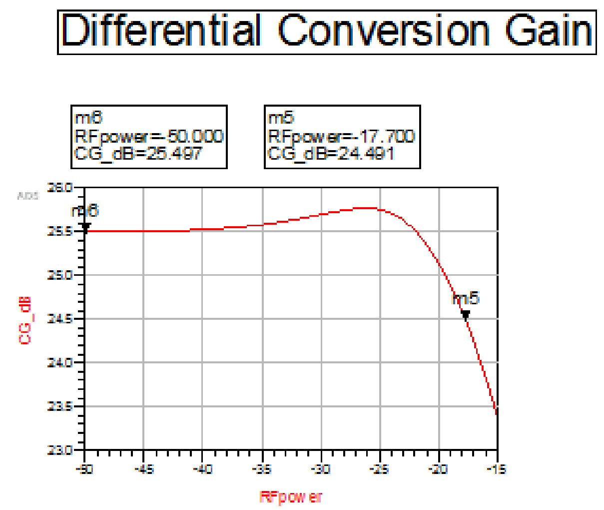
@4 Ghz


Single-ended Conversion Gain
m3
RFpower=-24.200
CG_dB_p=20.696
CG_dB_n=20.687
CG_dB_n
CG_dB_p
RFpower


Differential Conversion Gain
m6
RFpower=-50.000
CG_dB=26.953
m5
RFpower=-20.300
CG_dB=25.945
CG_dB
RFpower

@5 Ghz


Single-ended Conversion Gain
m3
RFpower=-24.200
CG_dB_p=19.716
CG_dB_n=19.688
CG_dB_n
CG_dB_p
RFpower


Differential Conversion Gain
m6
RFpower=-50.000
CG_dB=25.497
m5
RFpower=-17.700
CG_dB=24.491
CG_dB
RFpower