A Dual-Band CMOS Receiver for IEEE 802.11n WLAN

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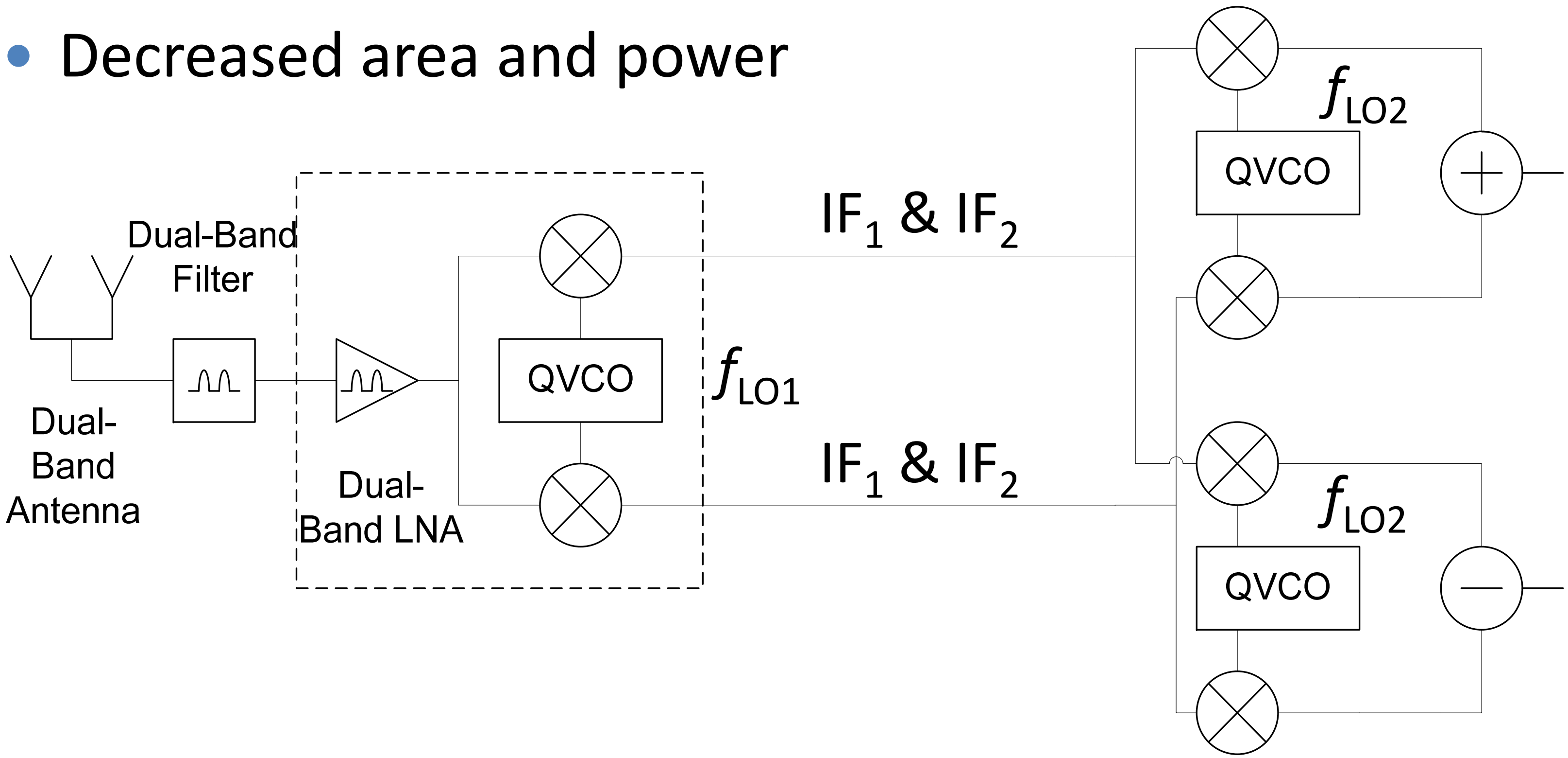
Motivation – IEEE 802.11n

- IEEE 802.11/Wi-Fi is the standard for fast wireless communication
- IEEE 802.11g
  - 54 Mbps theoretical bit rate
  - 2.4 GHz band
- IEEE 802.11n
  - 600 Mbps theoretical bit rate
  - 2.4 & 5 GHz bands

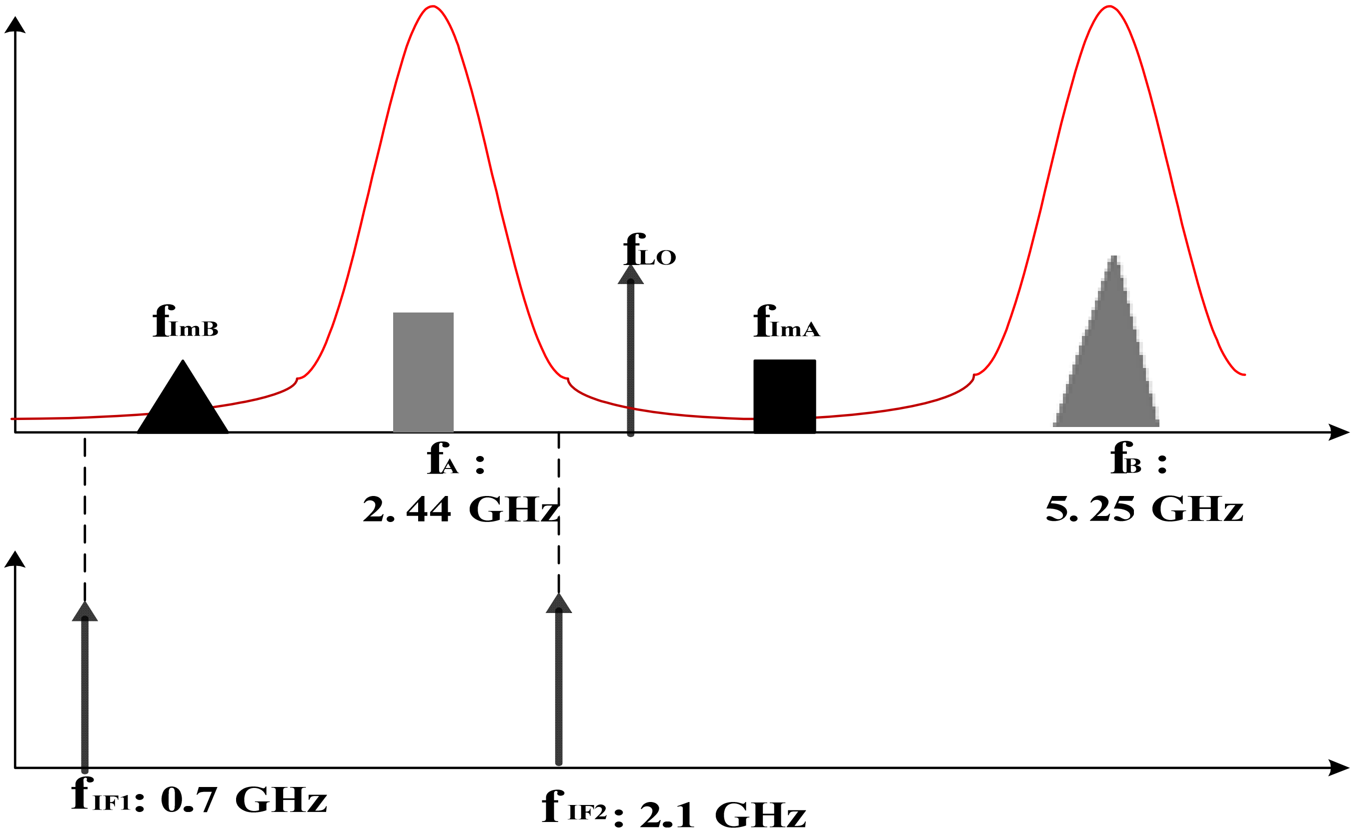
System Architecture

- Differential, Concurrent, Dual-band, & Image Rejection
- Antenna, filter, and LNA provide high attenuation at image frequency
- Decreased area and power



Architecture Image Rejection

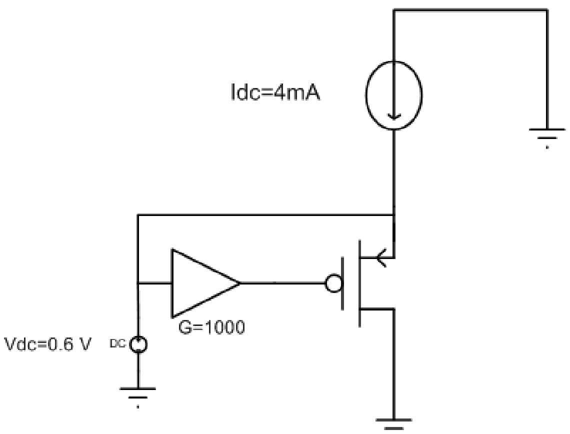
- LO frequency is carefully selected such that the image frequency is in the region of attenuation for frequency selective components



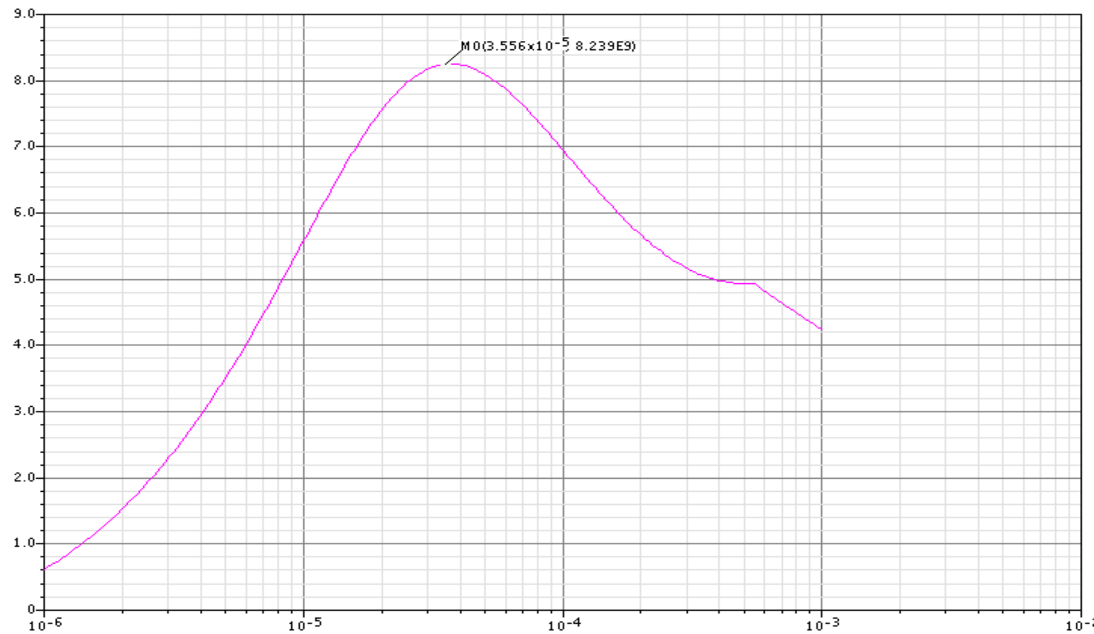
Dual Band LNA – Transistor Sizing

- Fixed I_d and V_{ds}, so fixed P_{DC}

$$I_d = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{gs}-V_{th})^2 \qquad g_m = \mu C_{ox}\frac{W}{L}(V_{gs}-V_{th}) \qquad f_t = \frac{1}{2\pi C_{gs}}$$



g_m*f_t vs. W

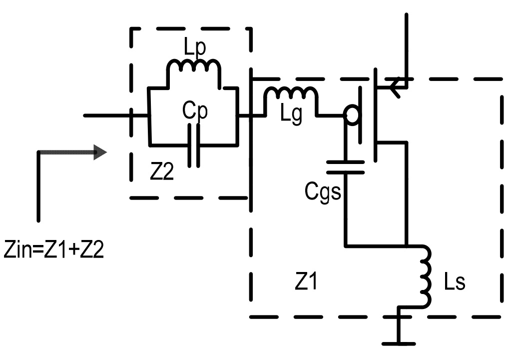


Dual Band LNA - Dual Band Matching

Input Matching

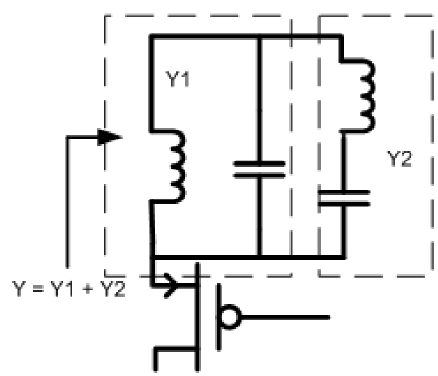
$$\mathrm{Im}(Z_1(\omega_1)+Z_2(\omega_1))=0$$
$$\mathrm{Im}(Z_1(\omega_2)+Z_2(\omega_2))=0$$

$$\frac{g_m \cdot L}{C_{gs}} = 50\Omega$$

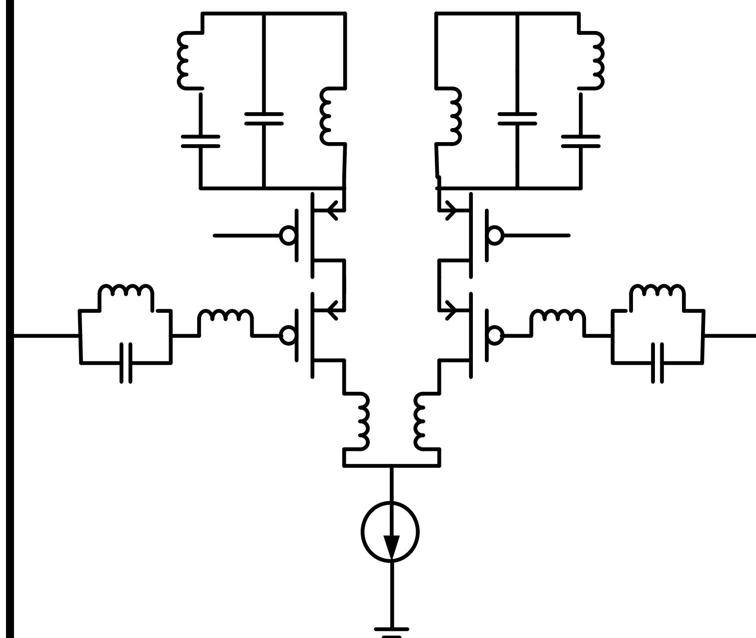


Output Matching

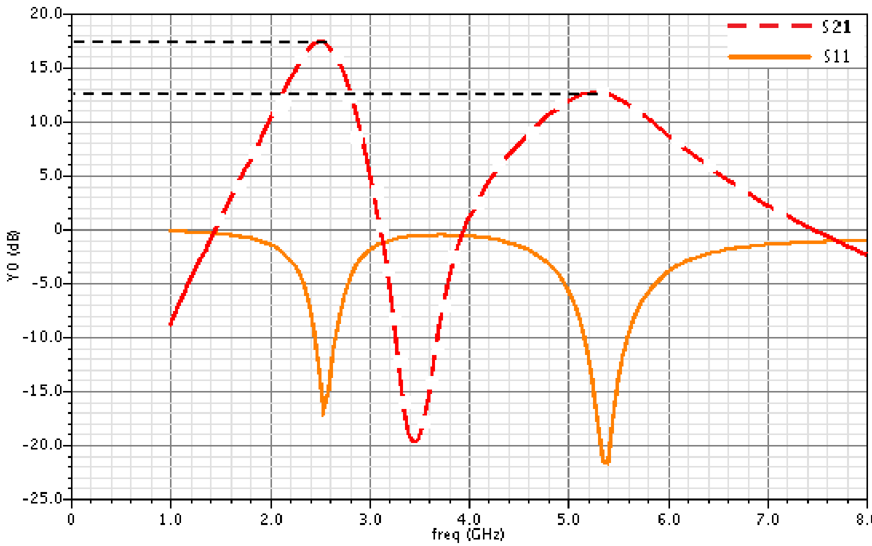
$$\mathrm{Im}(Y_1(\omega_1)+Y_2(\omega_1))=0$$
$$\mathrm{Im}(Y_1(\omega_2)+Y_2(\omega_2))=0$$

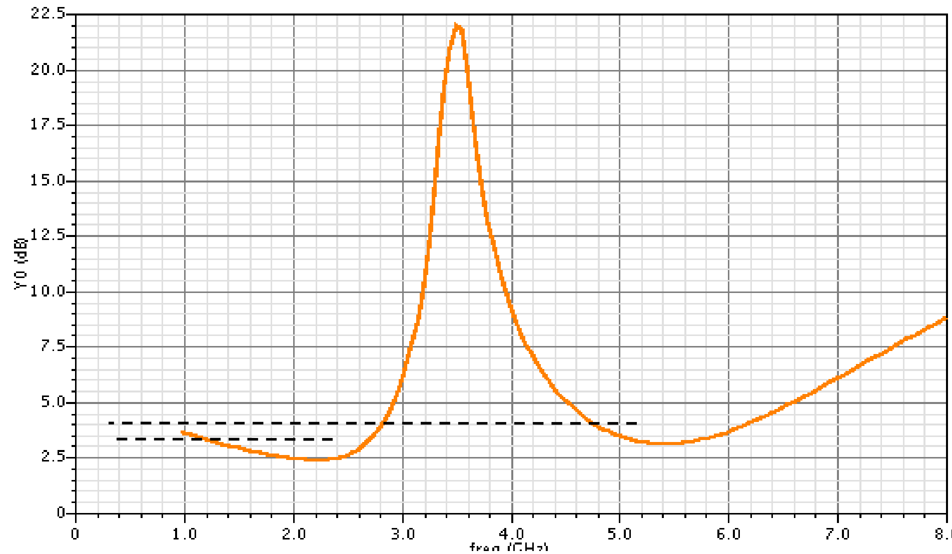


Final Design



LNA – Simulation Results

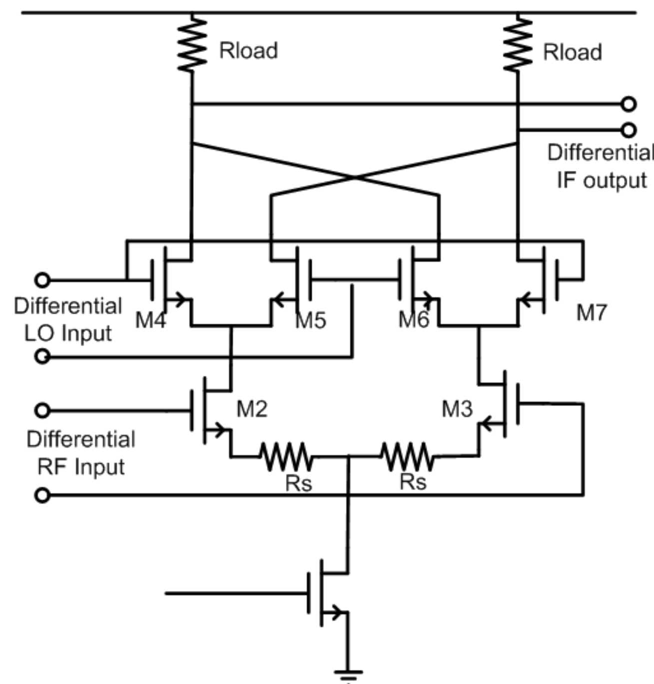




LNA Parameters	2.4 GHz	5.2 GHz
Gain (dB)	17.3	13
NF (dB)	2.5	3
S_{11} (dB)	<-9	<-11
IIP3(dBm)	-6	-3
IP1dB (dBm)	-13.5	-12.9
Quiescent Power (mW)	10.1	10.1

Mixer Architecture

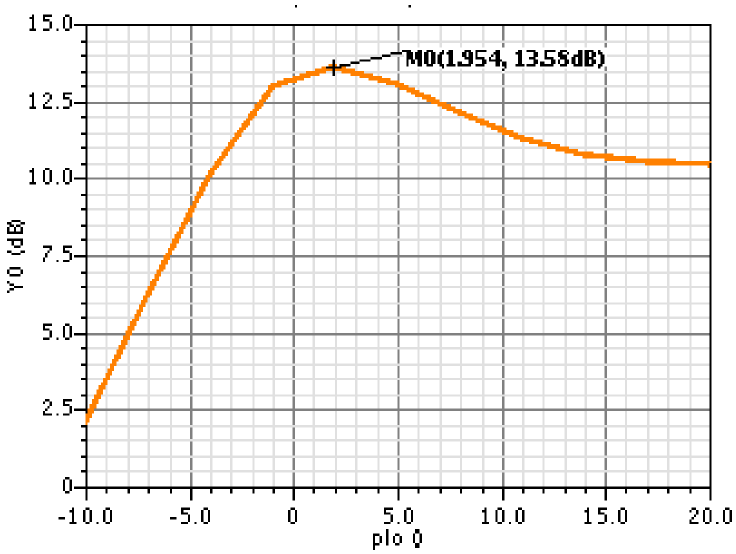
- Differential RF & LO inputs for improved linearity
- M4- M7
  - Multiplication function
- M2, M3, R_{load} carefully sized
  - Conversion gain, $G_C = \frac{V_{IF}}{V_{RF}} = \frac{2}{\pi} g_{m2} R_{load}$
  - Power Consumption



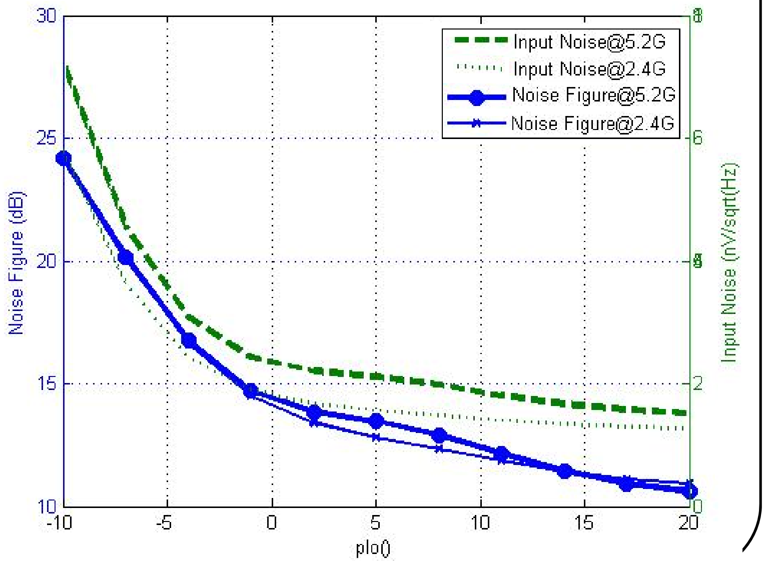
Mixer Architecture

Mixer - Simulation Results

- Conversion gain vs. P_{LO}

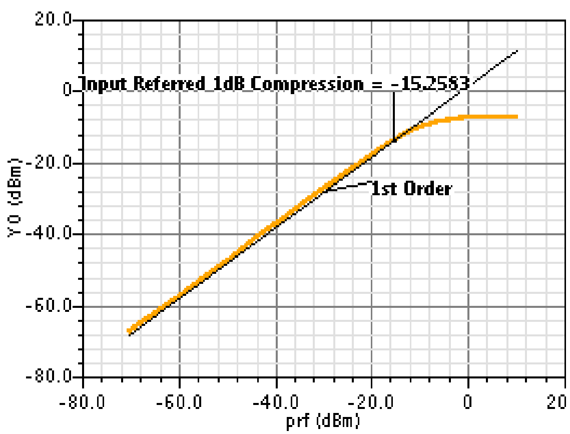


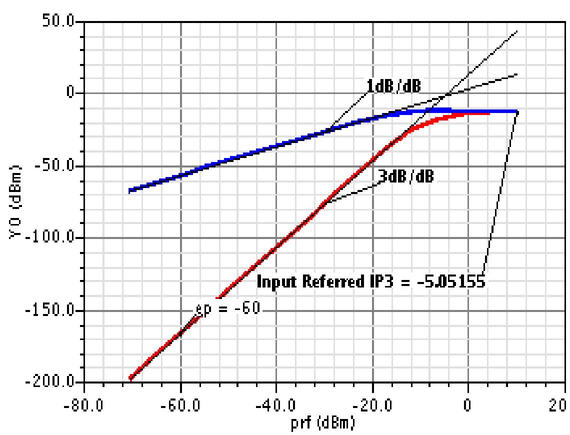
- Noise figure and input referred noise vs. P_{LO}
  - indicates good noise performance.



Mixer - Results Summary

- 1dB Compression point and IIP3 vs. P_{RF} demonstrates the mixer's good linearity



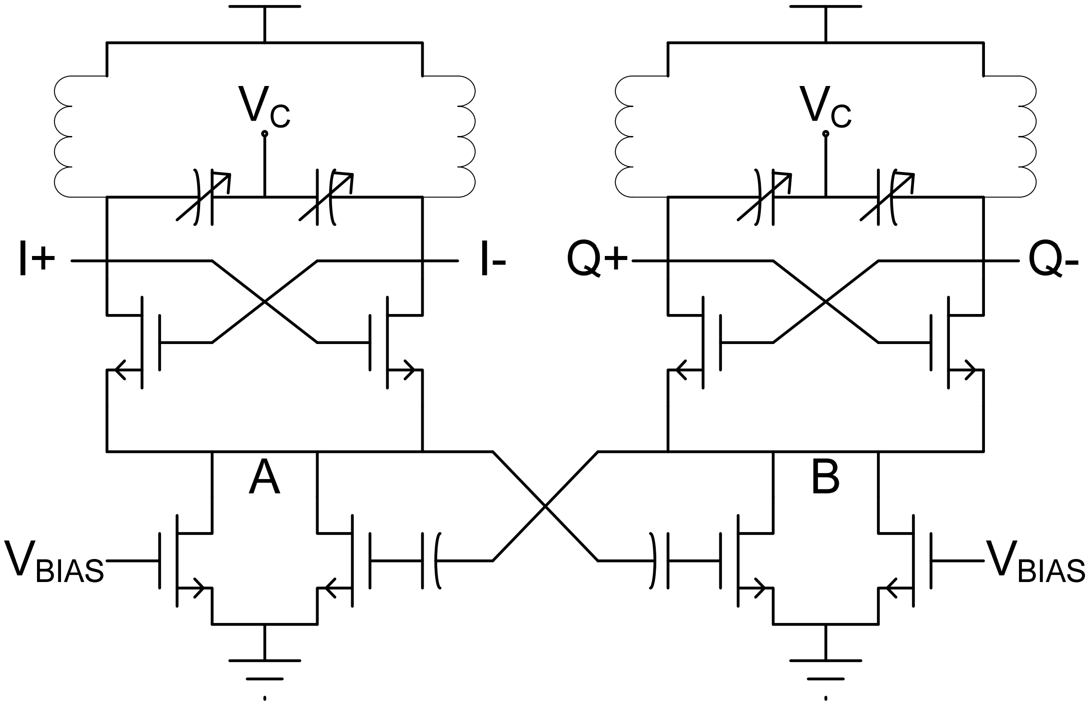


Mixer Parameters	
Gain (dB)	13.59
Quiescent Power (mW)	2.40
THD (dB)	-62.17
SSB NF (dB)	10.70
Input Referred Noise (nV/√Hz)	2.43
Isolation RF to IF (dB)	91.80
Isolation RF to LO (dB)	100.0
Isolation LO to RF (dB)	87.70
Isolation LO to IF (dB)	91.90
IIP3 (dBm)	-5.89
P1dB (dBm)	-15.95

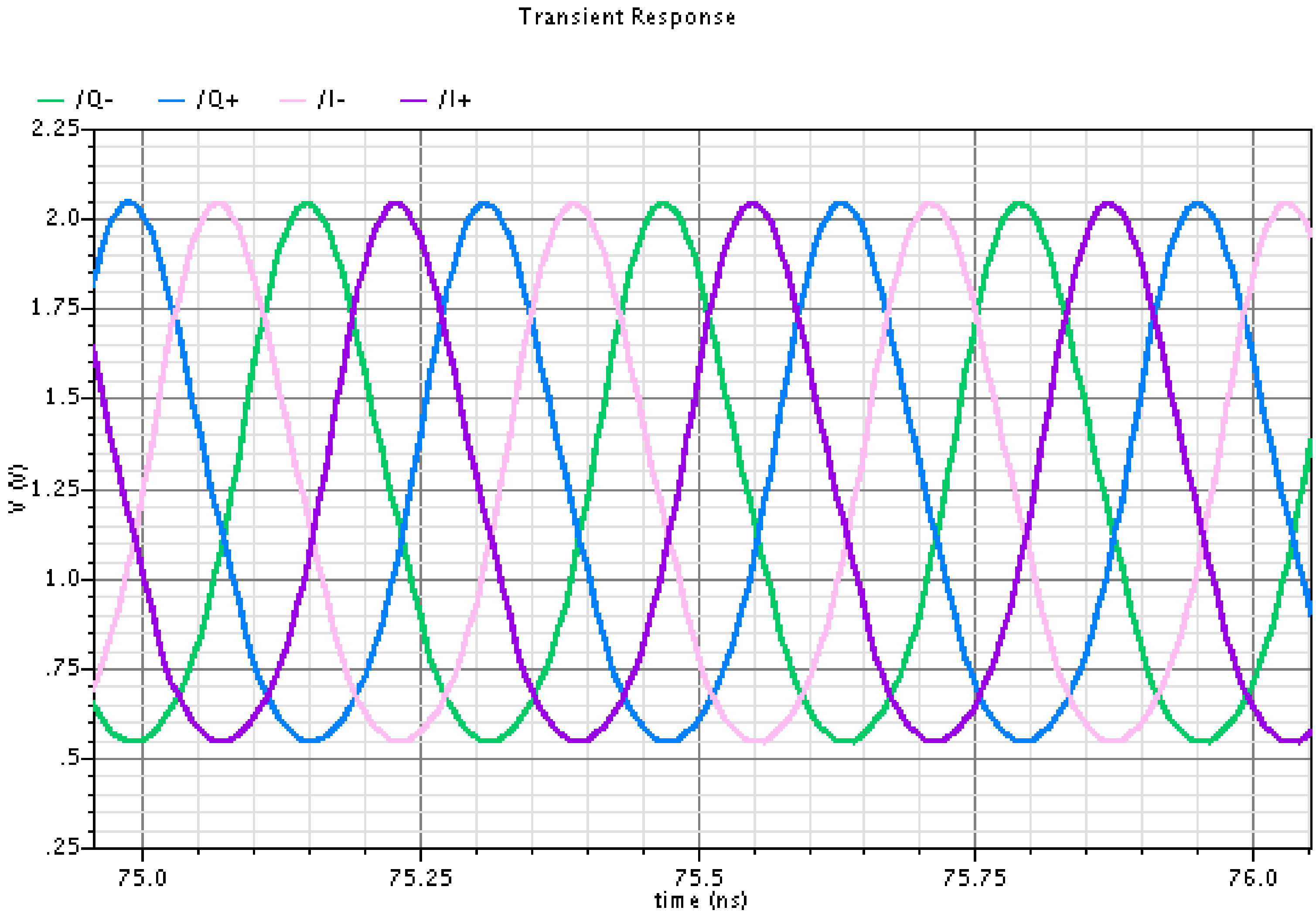
Quadrature Voltage Controlled Oscillator

- Provides differential quadrature outputs
- Composed of two super-harmonic coupled LC oscillators

f_{LO}	3.14 GHz
V_{ppk}	1.4 V
Power	5 mW
Tuning	16 %
Phase Noise	105 dBc/Hz @ 1 MHz

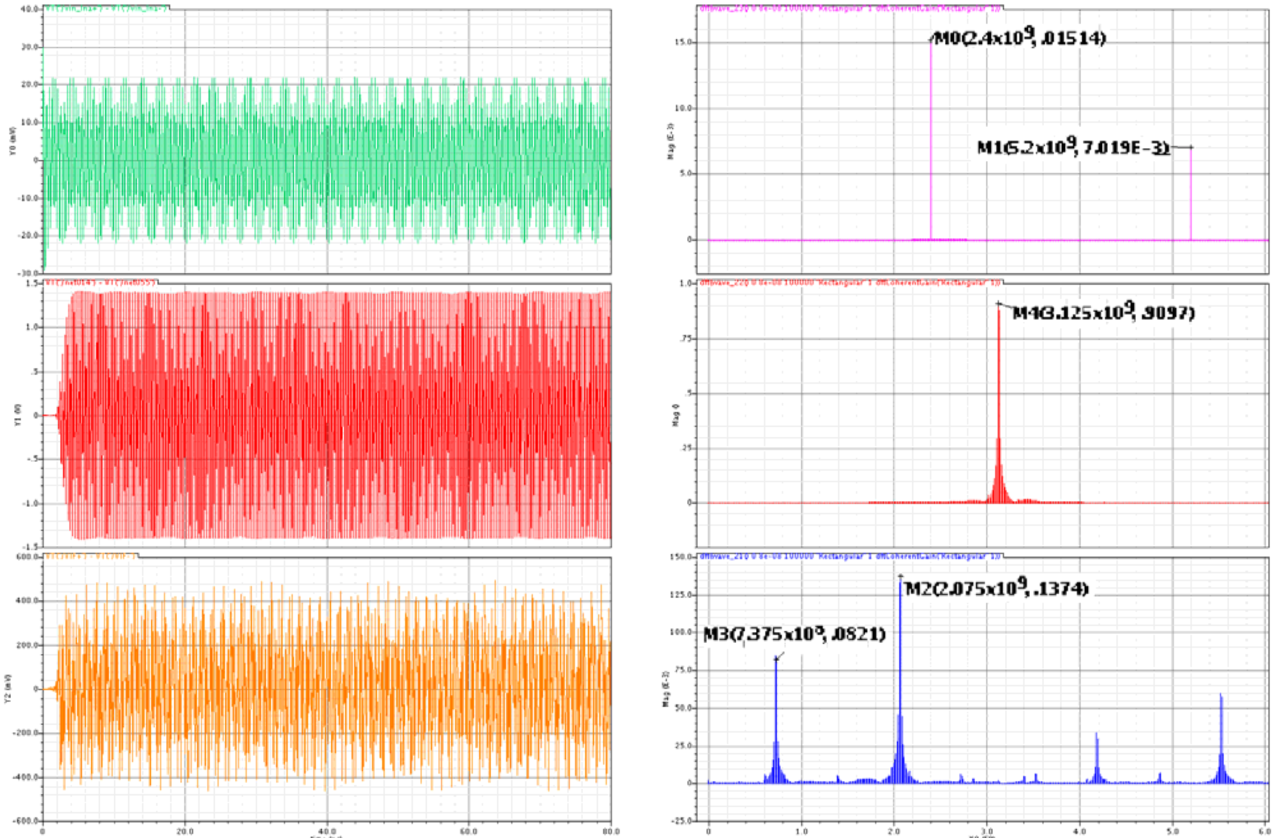


QVCO Output Waveform



System Performance

- RF
- LO
- IF



2.4 GHz

5.2 GHz

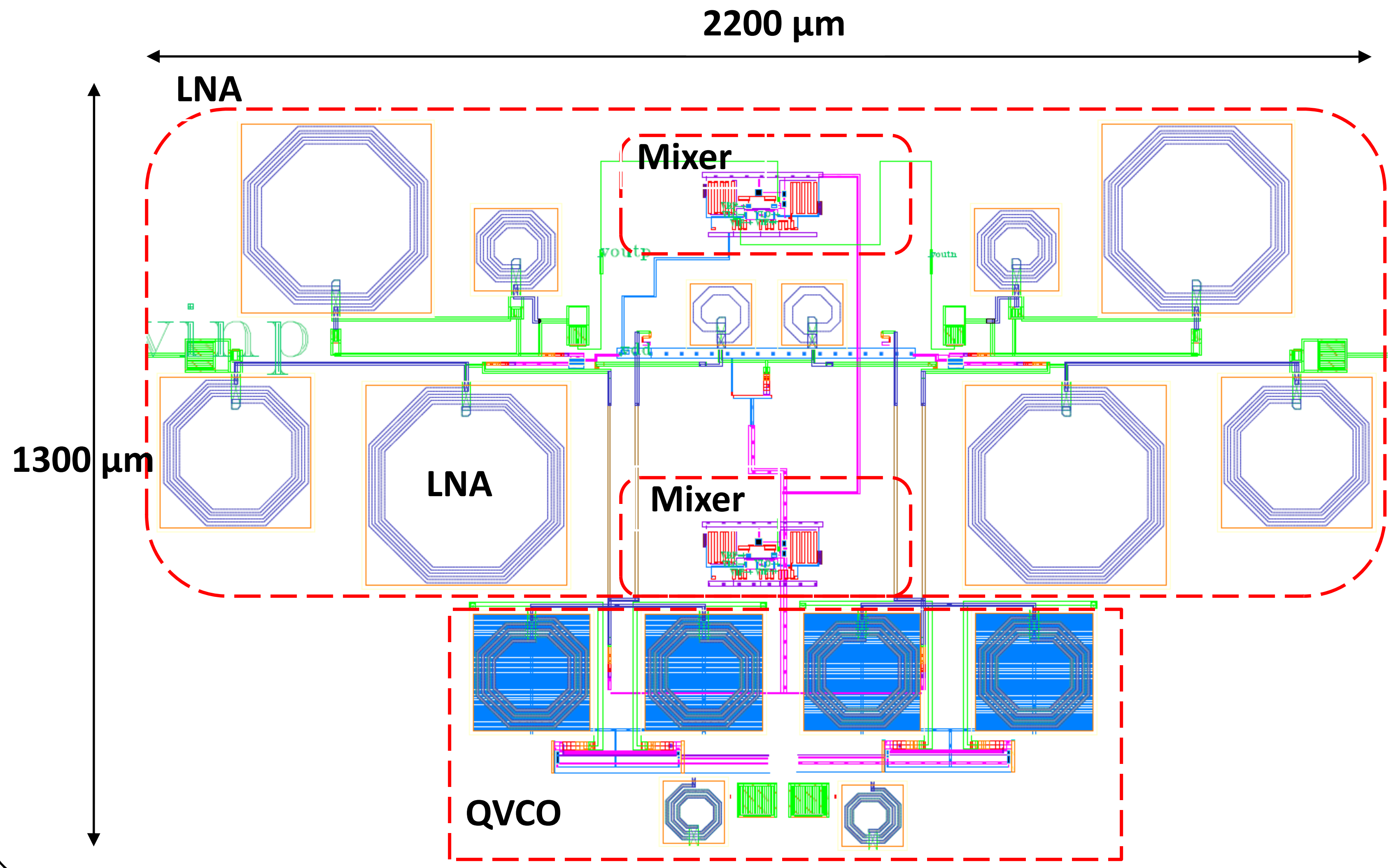
3.125 GHz

0.73 GHz

2.075 GHz

Parameters	2.4 GHz	5.2 GHz
Frequency Band	2.4 - 2.4835 GHz	5.15 – 5.35 GHz
Gain (dB)	26.1	31.91
Quiescent Power (mW)	17.44	17.44

Layout



Summary

- Designed the front end of an 802.11n receiver
- Differential & concurrent receiver architecture
- Performs image rejection through attenuation
- Designed a dual-band LNA, mixer, and QVCO
- Demonstrated a 2.4 & 5 GHz dual-band receiver front-end using the IBM 0.13 µm process with good results
- Design can be further improved for minimum power consumption or noise figure.

Acknowledgements

- Professor Wentzloff for his assistance with this project
- The students in the class for their collaboration in this course

Questions