A 5.2 GHz RF-Front end

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OUTLINE

- ***Motivation***
- ***IEEE 802.11a Specs***
- ***Receiver Architecture***
- ***Receiver Design***
- ***Overall performance***
- ***References***

MOTIVATION

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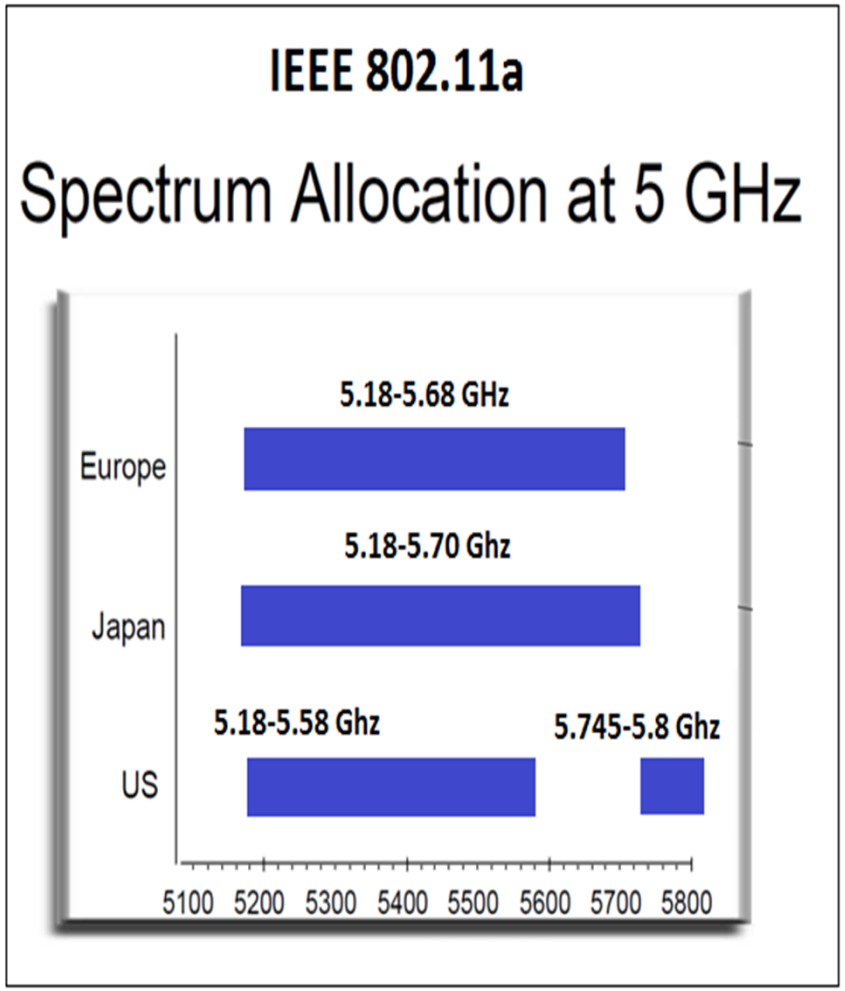
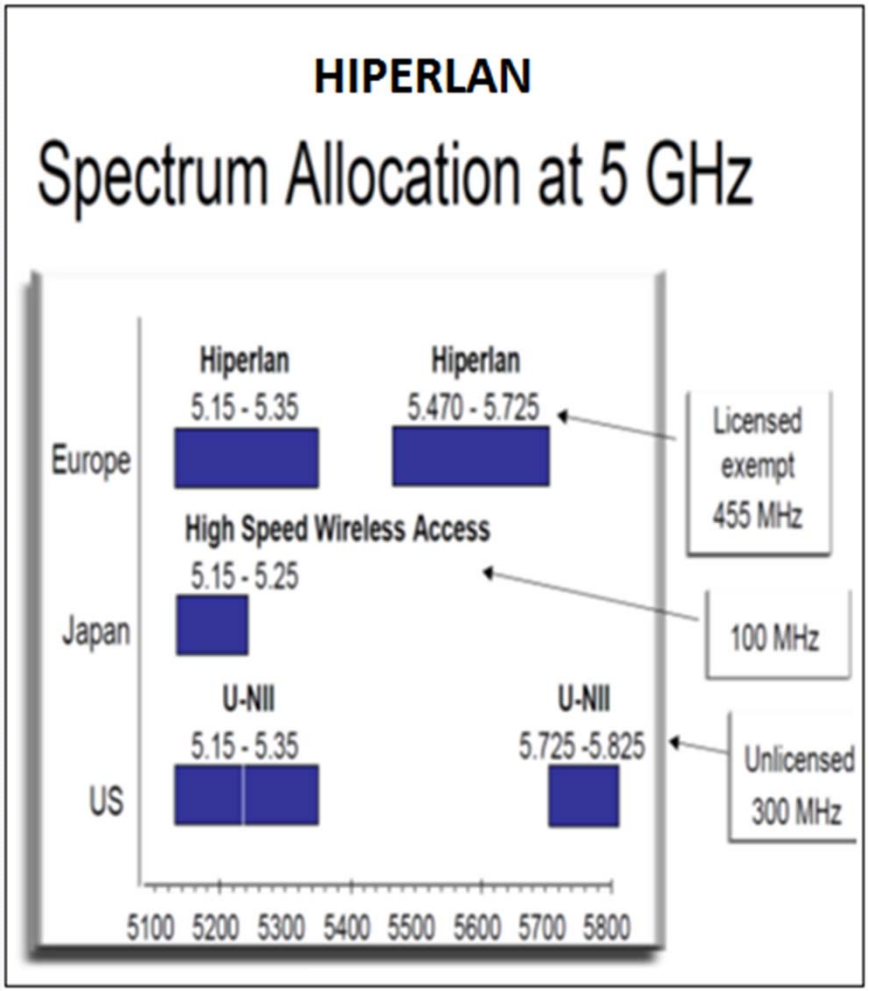
- Why the 5-GHz band?
  - ✓ 100s of MHz of unlicensed spectrum available
  - ✓ free from microwave oven radiations

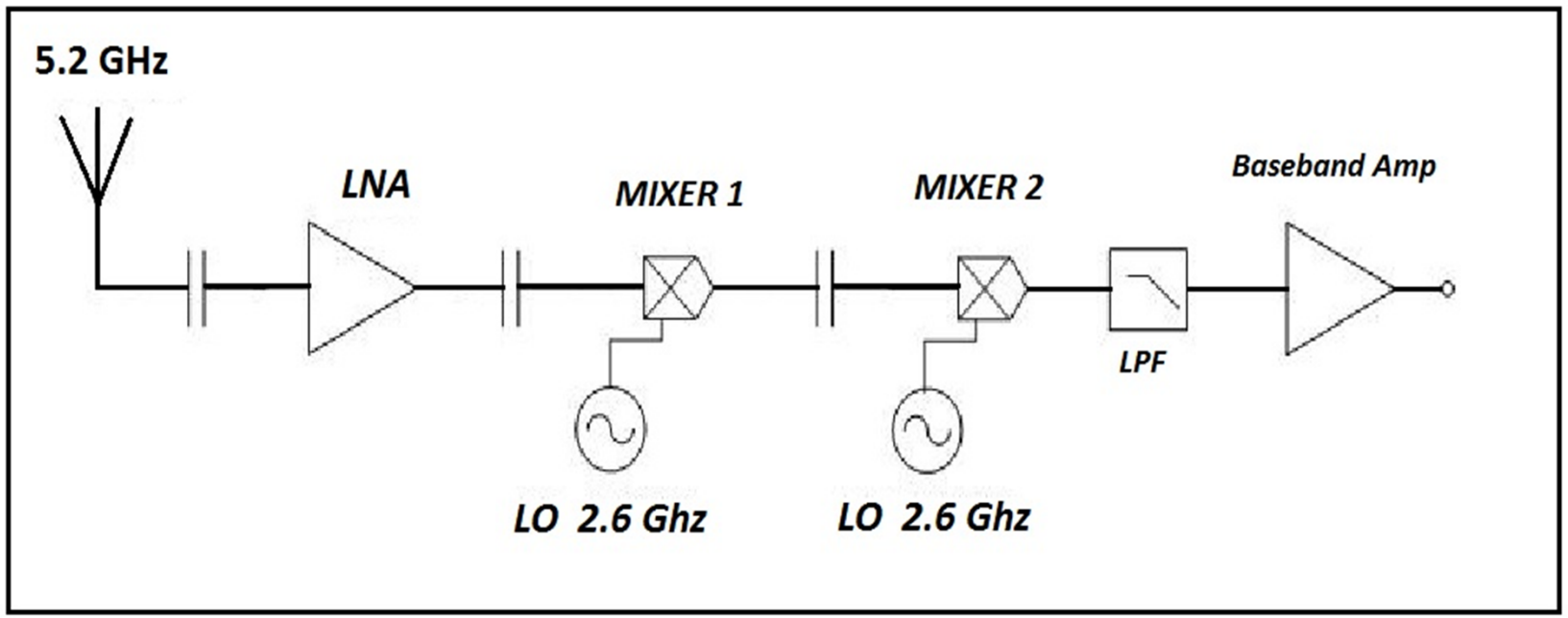
- Application
  - ✓ IEEE 802.11a standard for WLAN
  - ✓ High Performance Radio Local Area Network (HIPERLAN)
  - ✓ For high data rate (upto 54 Mbps), data intensive applications.

IEEE 802.11 A, HIPERLAN





RECEIVER ARCHITECTURE



- RF 5.2 GHz → IF 2.6 GHz → Baseband
- A dual conversion heterodyne architecture

RECEIVER ARCHITECTURE

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+ Frequency synthesizer (not designed) operates at half the i/p frequency => more accurate phase
+ Image band centered at Zero => high image rejection achieved. No explicit Image reject Filter required
+ In contrast to direct conversion receiver, low LO leakage to antenna
— Flicker noise up converted to the first IF
— LO-IF feedthrough of first mixer may desensitize second mixer
— No channel select filtering between two mixers =>high linearity requirement for IF mixer

[5]

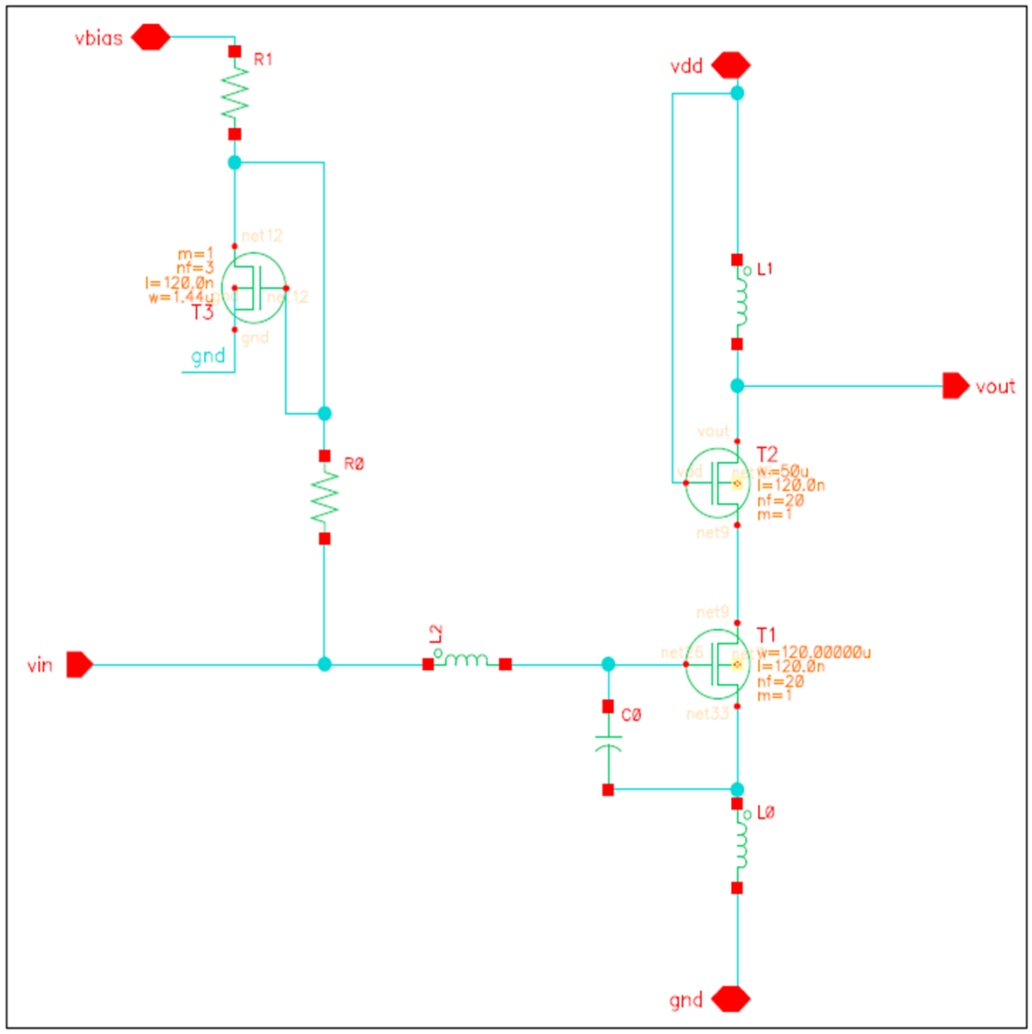
DESIGN CONSIDERATIONS

- *LNA* : Low Noise Figure(NF), High Gain
- *RF Mixer (Mixer 1):* Low NF, Low LO-IF feedthrough, High Gain
- *IF Mixer (Mixer 2):* High linearity, Low NF, Reasonable Gain
- *Base-band Section*: High linearity, Low NF

LNA DESIGN

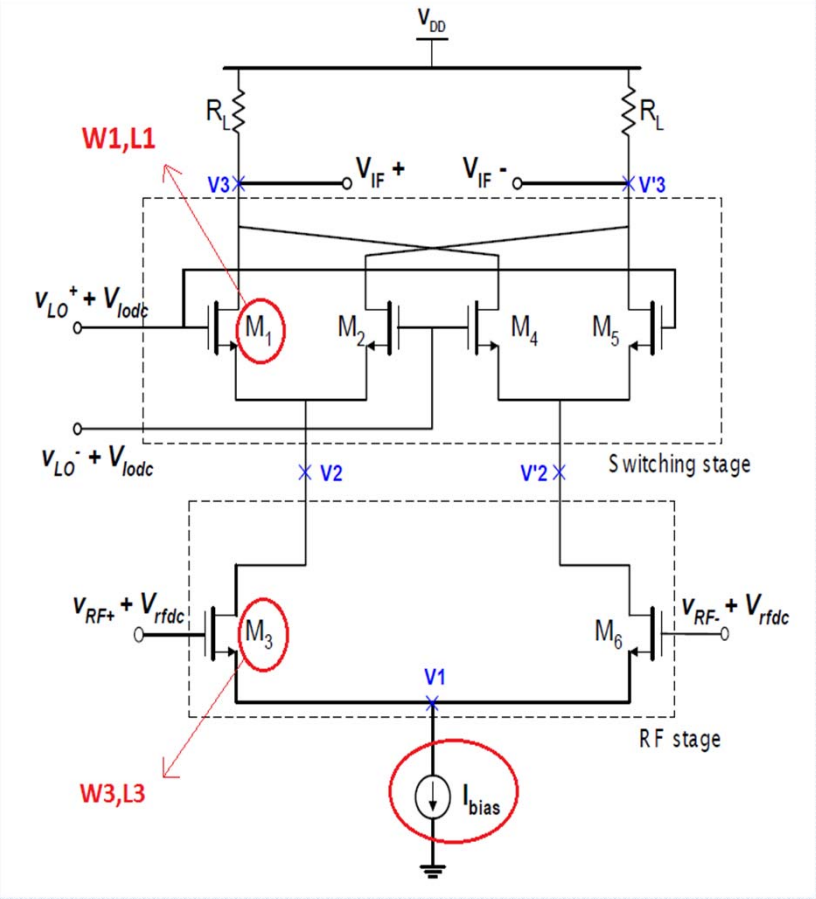
5.2 GHz Cascoded LNA -

LNA Performance	
Gain	29.82 dB
NF	1.58 dB
Power	7.61 mW



RF MIXER DESIGN

- Topology: Double Balanced Gilbert Cell
- Design Variables:
  - *Switching, RF Transistor W,Ls*
  - I_{bias}, R_L
- Initial MATLAB analysis for:
  - *NF, Conversion gain*
  - To choose parameters for optimum performance



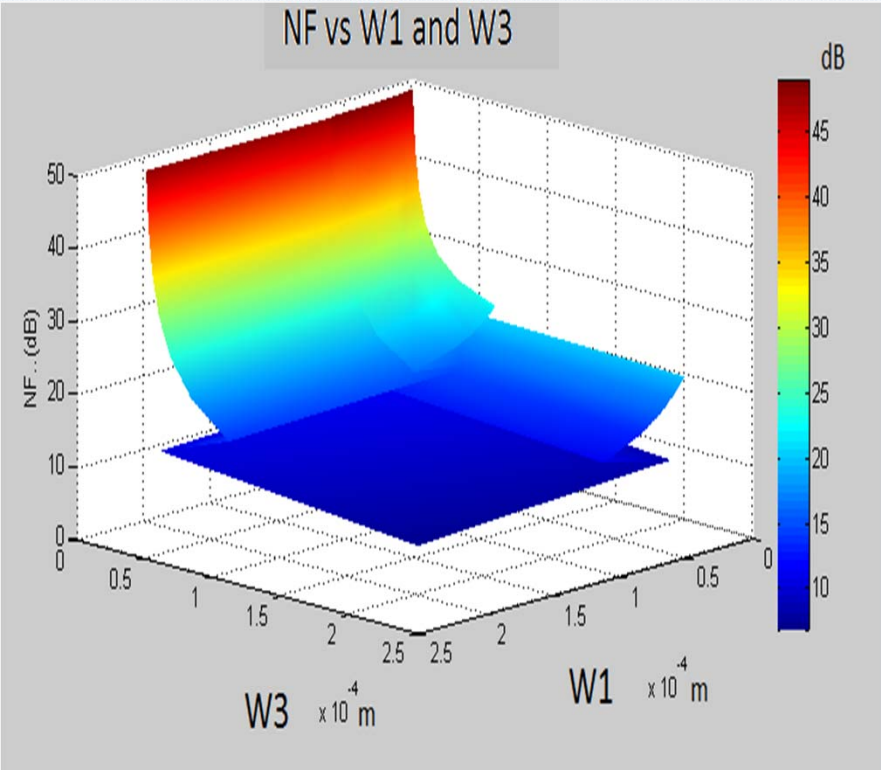
Sample topology

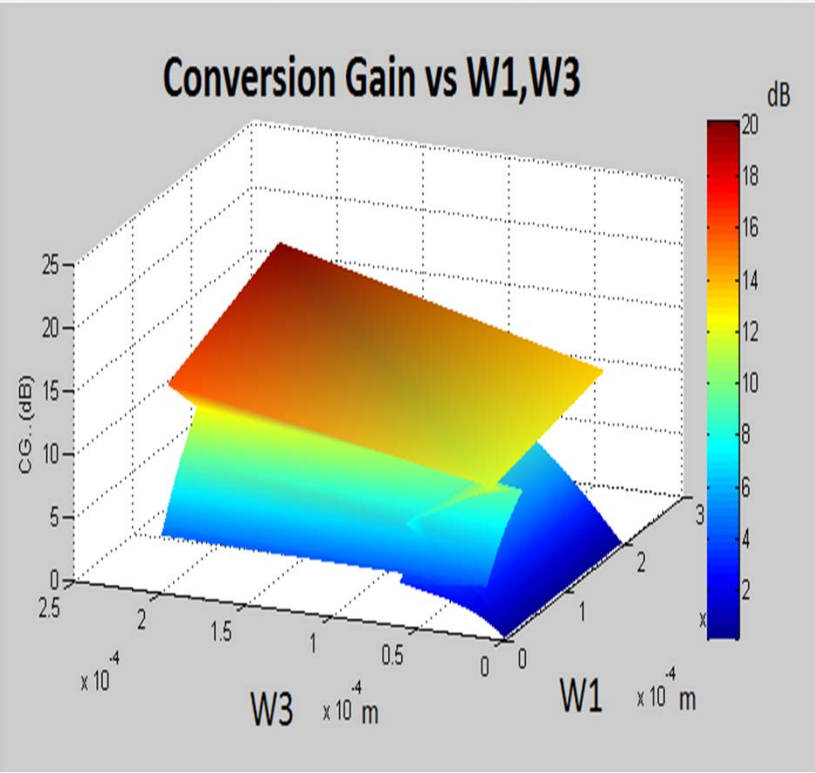
RF MIXER DESIGN : MATLAB

$$NF_{(SSB)} = 10.LOG\left[\frac{\alpha}{c^2} + \frac{2(\gamma_3 + rg_3.g_{m3})\alpha.g_{m3} + \gamma_1\overline{G} + (4r_{g1})\overline{G^2} + \left(\frac{1}{R_L}\right)}{R_S.c^2(g_{m3})^2}\right]$$

$$CG = A_{VRF} \times A_{switch} = -\frac{2}{\pi} g_{m3}.(r_{ds1} // R_L)$$

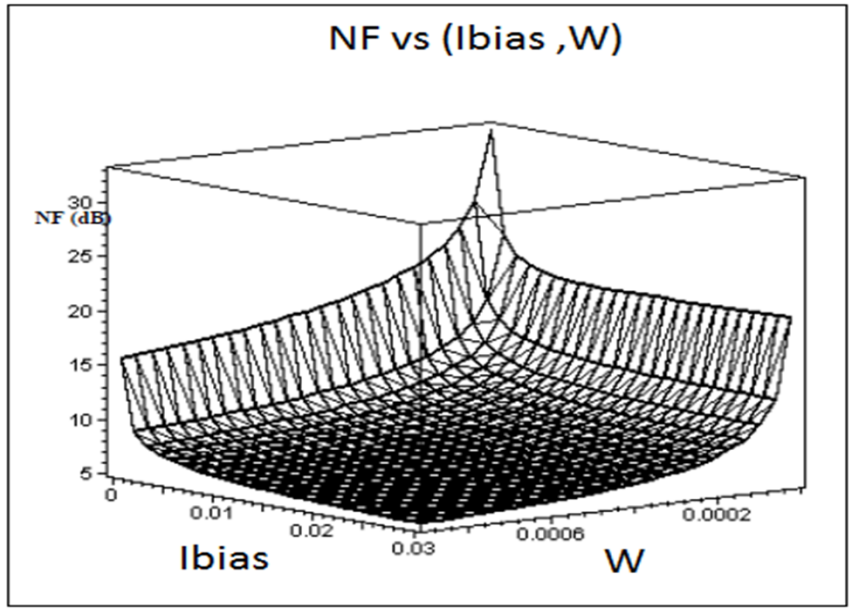
[6]





RF MIXER DESIGN : MATLAB

Variation of NF with Ibias and W:



Ref- S. Douss, F. Touati and M. Loulou," Design Optimization Methodology of CMOS Active Mixers for Multi-Standard Receivers", International Journal of Electrical and Computer Engineering 2:9 2007

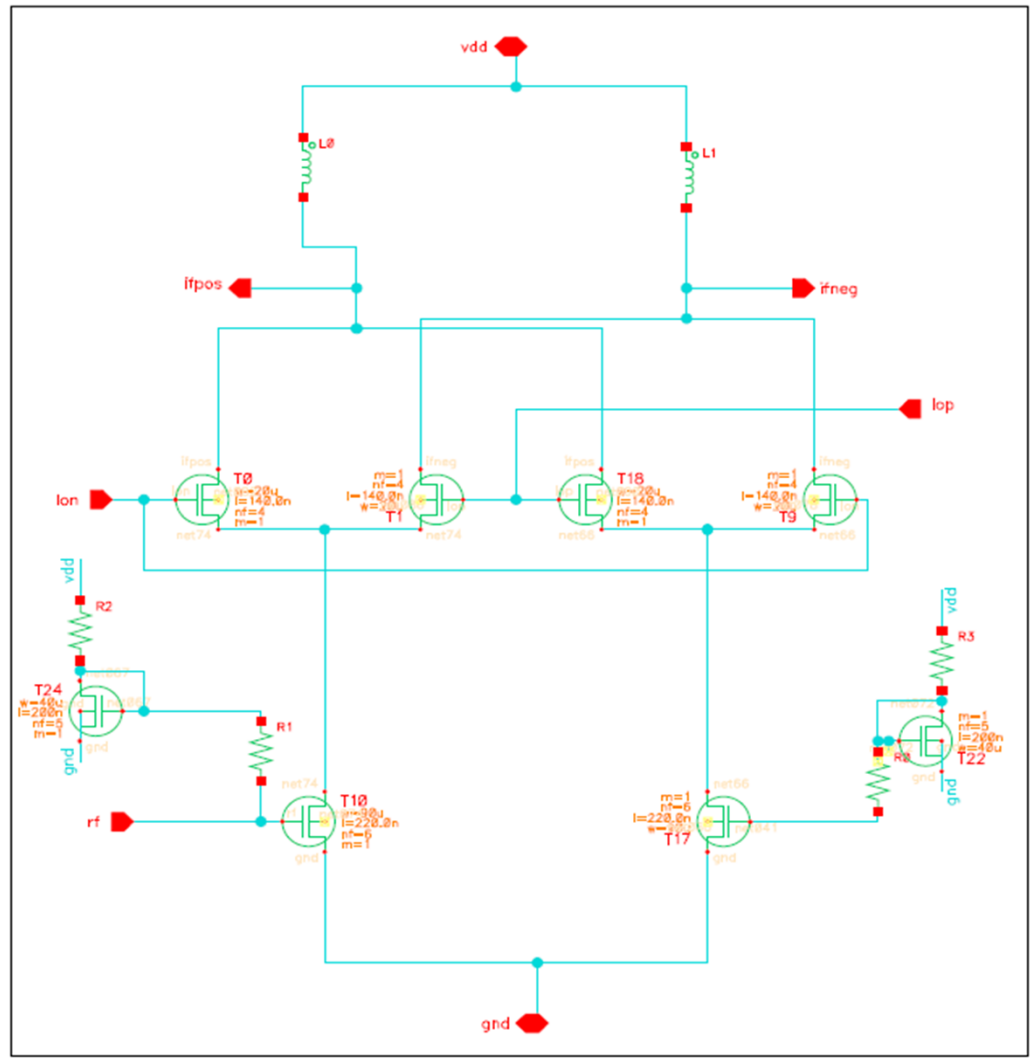
RF MIXER DESIGN

Features:

- High frequency operation => Load = Inductors (rather than resistors)
  - R_p of inductor increases withfrequency
  - Quality Factor, $Q=L\omega/R_p$ is relatively constant.
- Low LO-IF feedthrough

Problem:

- Up-Conversion of Flicker Noise!



RF MIXER DESIGN

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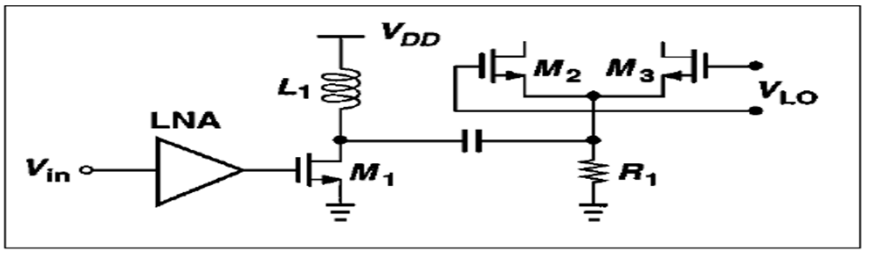
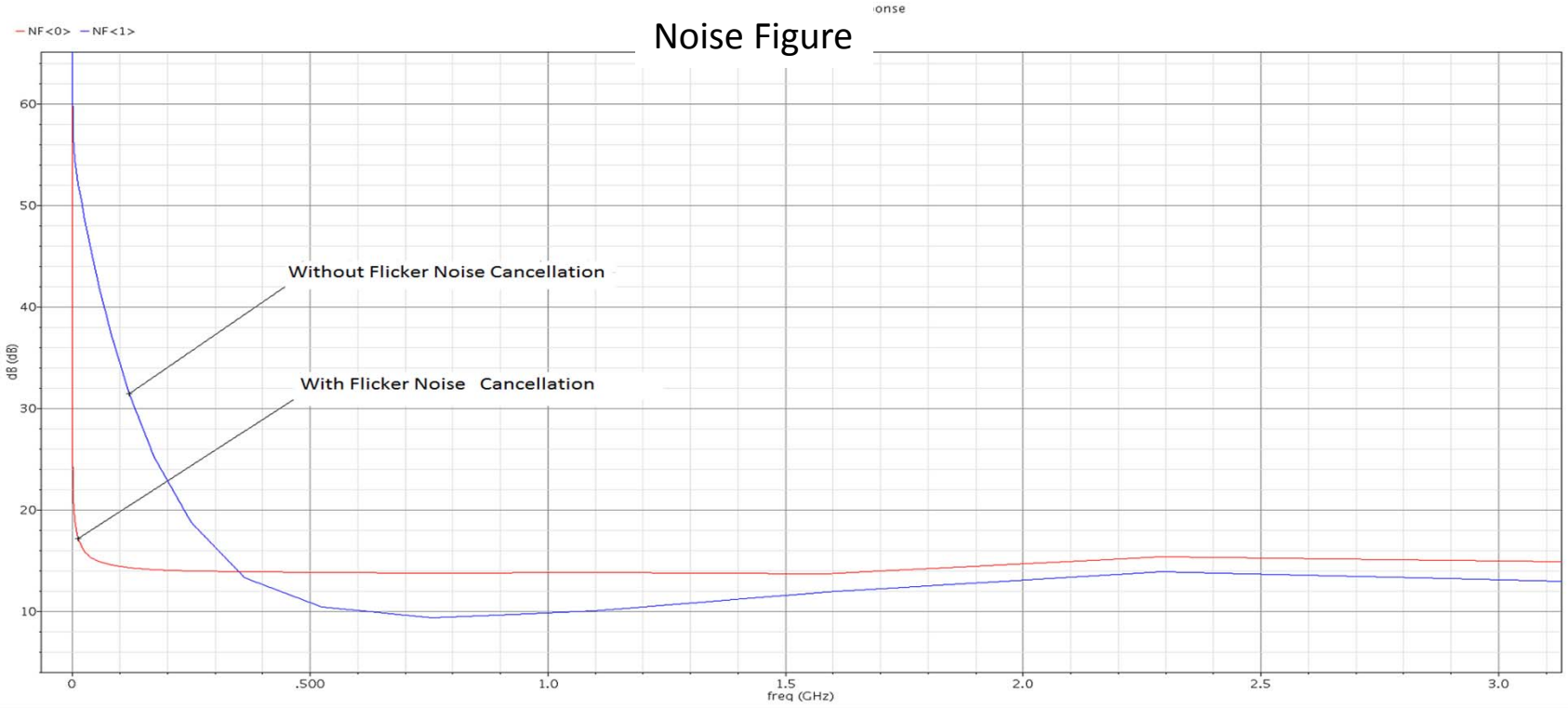
Alternate Topology



Noise Figure

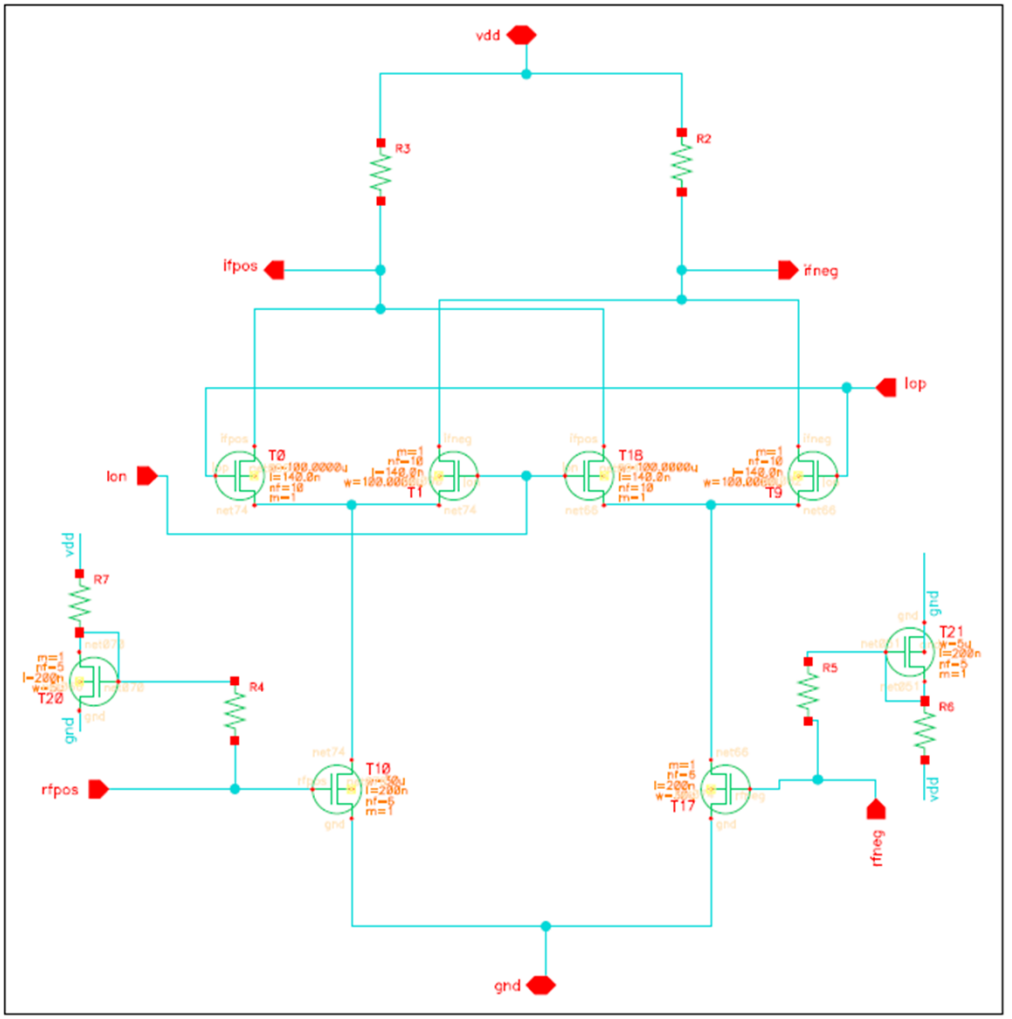


IF MIXER DESIGN

Topology –
Double Balanced Gilbert Cell

Advantages –
- Low LO-IF feed through
- Even harmonic cancellation
- Odd harmonic amplification

Design Requirements –
- High linearity, since no channel selection filter between mixers



IF MIXER DESIGN

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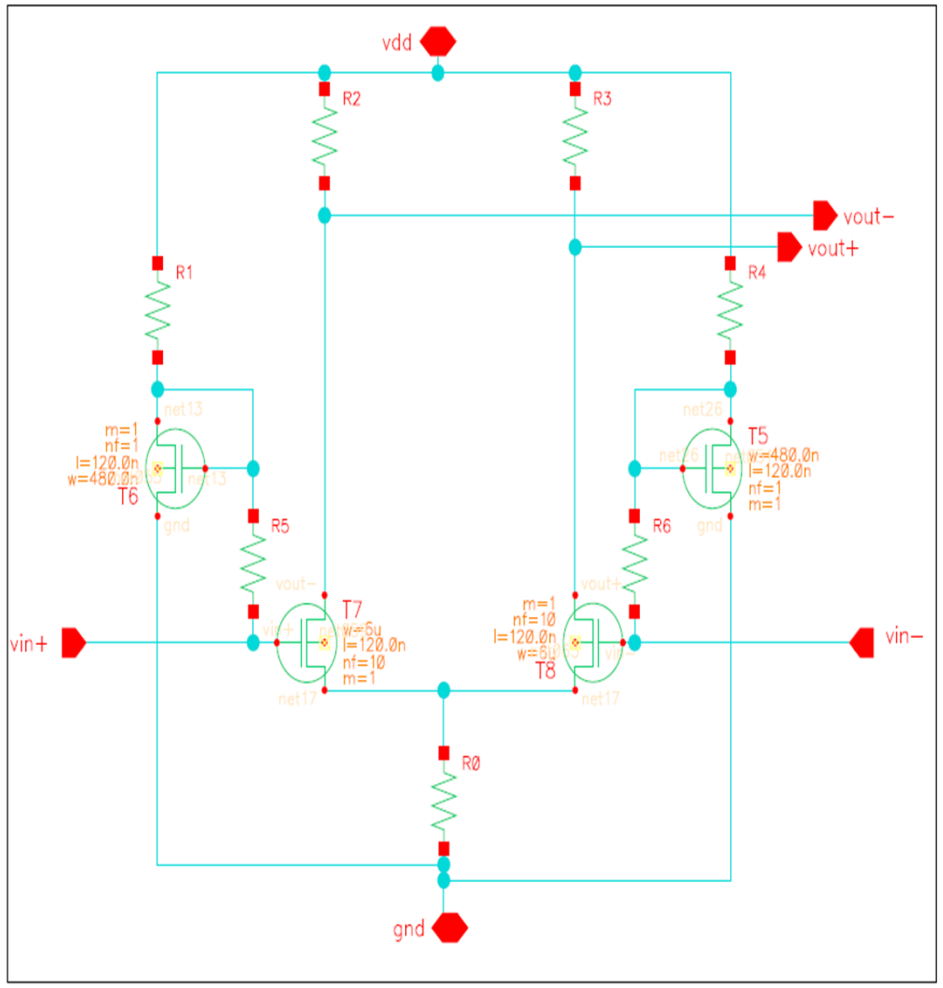
IF Mixer Performance and Benchmarking				
Parameter	[2]	[3]	[4]	**Our Work**
Technology (µm)	0.18	0.5	0.25	**0.13**
Supply Voltage	1.5	2.5	1.8	**1.2**
Conversion Gain (dB)	3.3	3.35	-2.688	**6**
P1 dB (dBm)	-8.98	-8.2	5.075	**-2.9**
IIP3 (dBm)	5.46	2.17	12.81	**5.57**
Noise Figure(dB)	14.87	9.04	13.678	**13.2**
Power consumption(mW)	5.6	10	13.3	**5.04**

BASEBAND SECTION



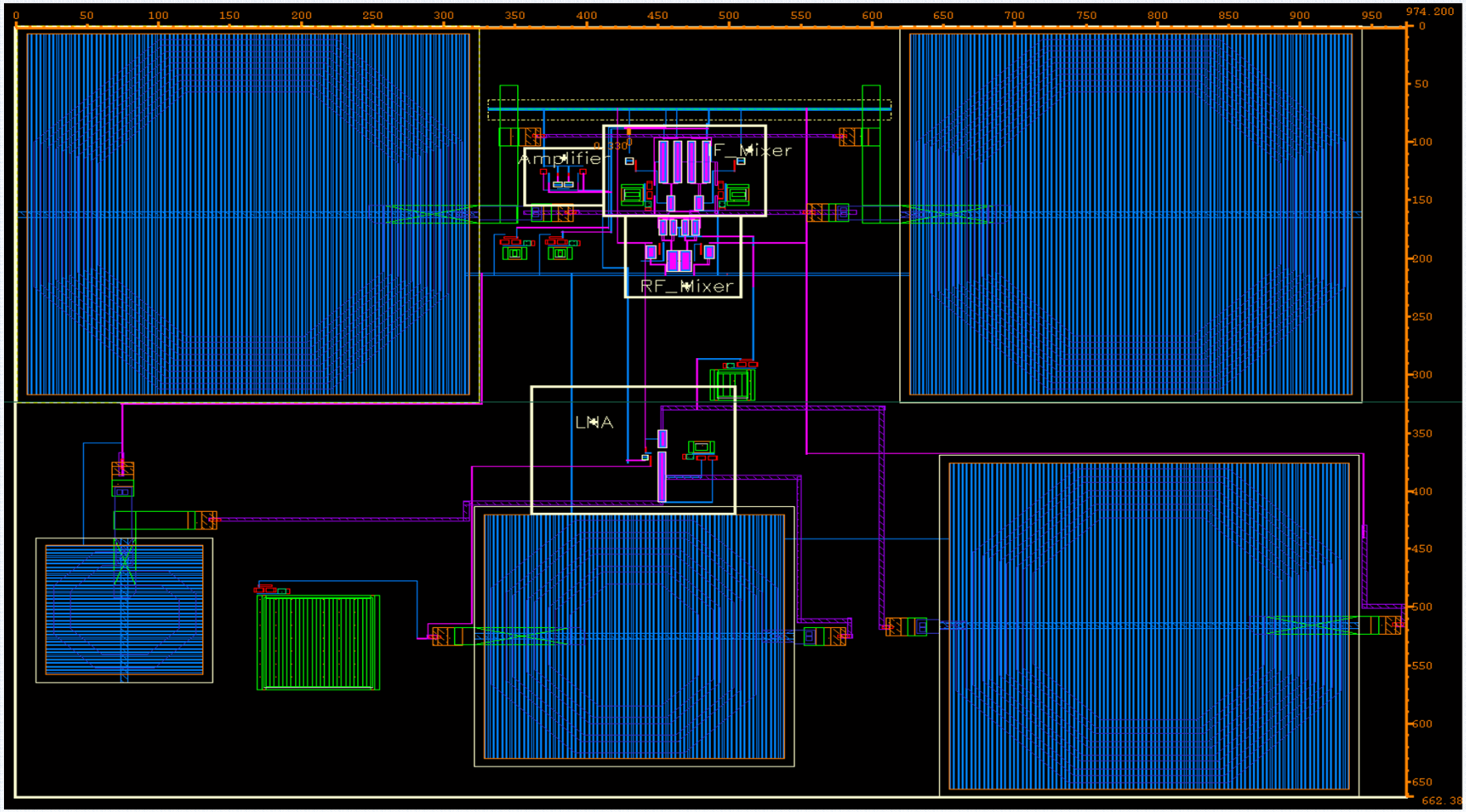
Topology:
Fully differential amplifier

Design Requirements:
- High linearity
- $g_m = 2I_D/(V_{GS}-V_{TH})$
  => tradeoff with gain

Performance	
Gain	3.2 dB
NF	9.2 dB
P1dB	7.54 dBm
Power	0.57 mW

LAYOUT

Area = 0.974 µm x 0.662 µm



OVERALL PERFORMANCE

Parameter	[1] Razavi, B.	Our Work
Technology	0.25 µM CMOS	0.13 µM CMOS
Supply Voltage	2.5 V	1.2 V
Center Frequency	5.2 GHz	5.2 GHz
Noise Figure	6.4 dB	9.83 dB
1- dB Compression	-26.5 dBm	-36.5 dBm
Image Rejection	62 dB	57.1 dB
Voltage Gain	43 dB	35.28 dB
Power dissipation		
LNA	8.75 mW	7.61 mW
RF Mixer	5 mW	7.4 mW
IF Mixer	5 mW	5.04 mW
Baseband Section	5.25 mW	570 µW
Total	29 mW	20.62 mW

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- [2] Hung-Che Wei, Ro-Min Weng, Chih-Lung Hsiao and Kun-Yi Lin, " A 1.5V,2.4Ghz CMOS Mixer With High Linearity", The 2004 IEEE Asia-Pacific Conference Circuit and Systems , Dec 6-9, 2004
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- [4]Kumar Munusamy and Zubaida Yusoff ," A Highly Linear CMOS Down Conversion Double Balanced Mixer", ICSE2006 Proc. 2006, Kuala Lumpur, Malaysia
- [5] B. Razavi, " Design Considerations for Direct-Conversion Receivers IEEE Transactions On Circuits and Systems—II: Analog And Digital Signal Processing, vol. 44, no.6, June 1997
- [6] S. Douss, F. Touati and M. Loulou," Design Optimization Methodology of CMOS Active Mixers for Multi-Standard Receivers", International Journal of Electrical and Computer Engineering 2:9 2007

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QUESTIONS?