A 6.75 – 7.25 GHz Pulse Position Modulation Ultra-Wideband Receiver Front End

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Outline

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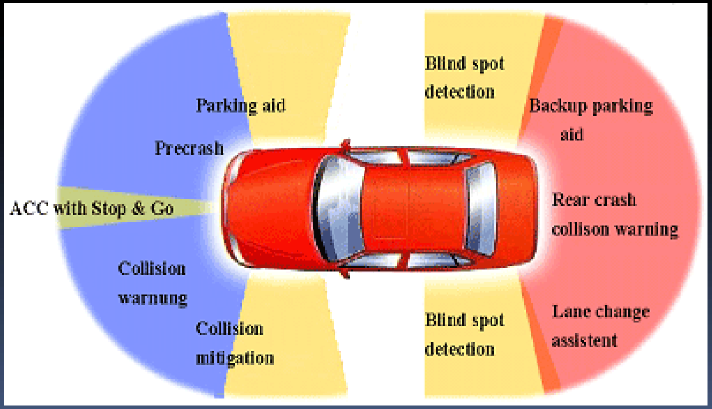
Motivation

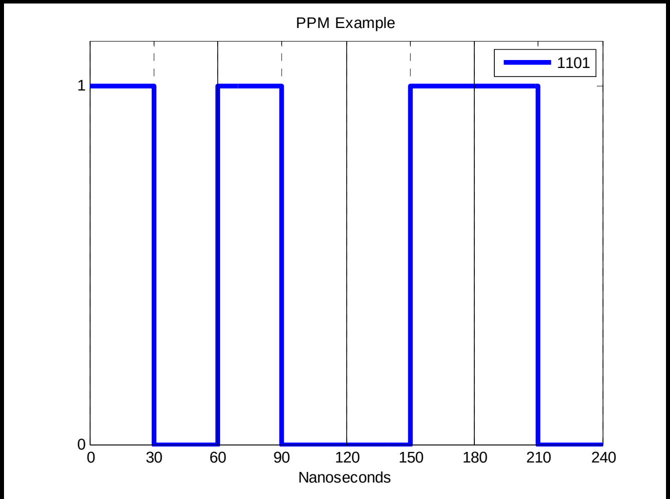
- UWB Communication, WPAN/WLAN
- High Speed/Short Range
- Higher end of UWB band
  - Available in most countries, not just U.S.A.

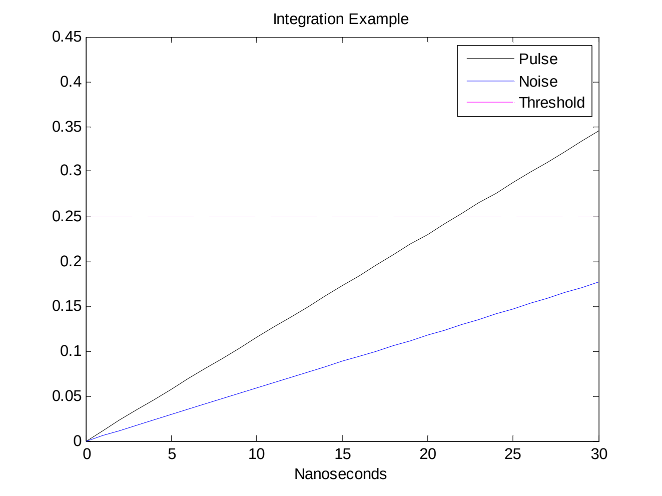


Images taken from [8] and [9]

Pulse Position Modulation

- Energy detection
  - 2 integration time windows
  - Threshold detection
- Advantages
  - Low Power
  - Low Complexity
- Disadvantages
  - Low Data Rate
  - Sensitive to channel noise





Bandwidth Reduction

- Non-Coherent Energy Detection
  - An optimal Receiver Bandwidth Exists
- Slight degradation in system performance provides:
  - Hardware benefits
  - Low power consumption
  - Better input matching
  - Reduced adjacent channel interference.

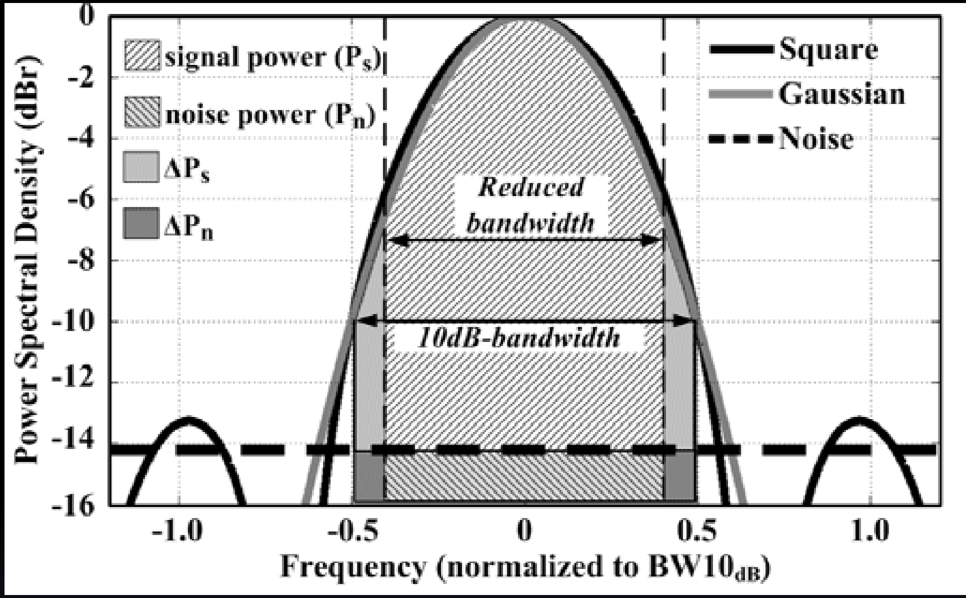
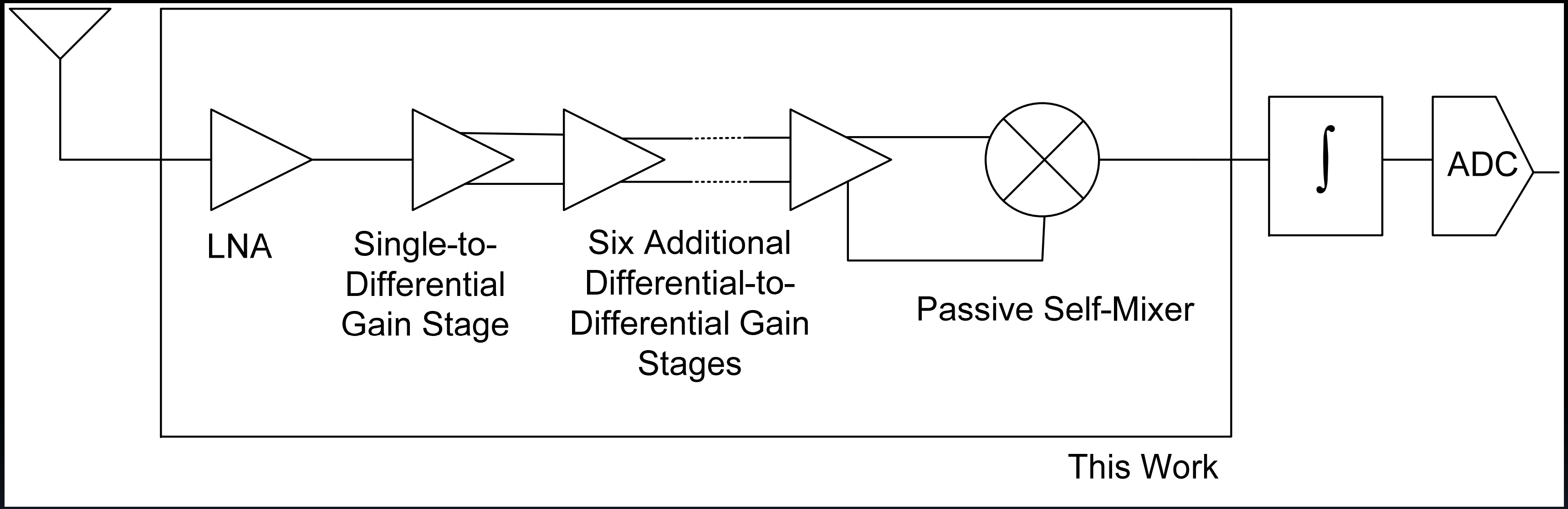


Image taken from [2]

Design Specifications

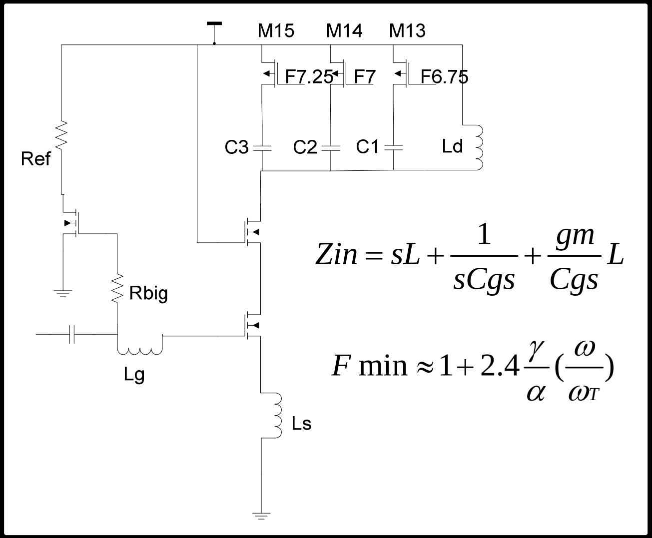
Parameter	Desired
Process	0.13 µm CMOS
Data Rate	16.67 Mbit/s
Supply	1.2 V
Channel Δf	250 MHz
fc Subbands	6.75, 7, and 7.25 GHz
Gain	> 40 dB
NF	< 10 dB
S11	< -10 dB
Power	< 40 mW
Distance	10 m

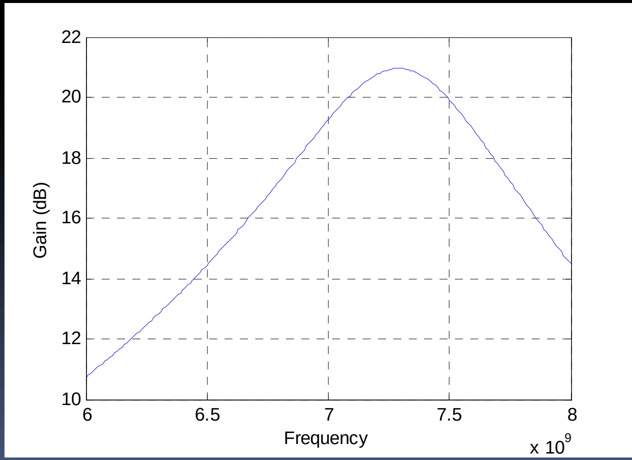
System Overview

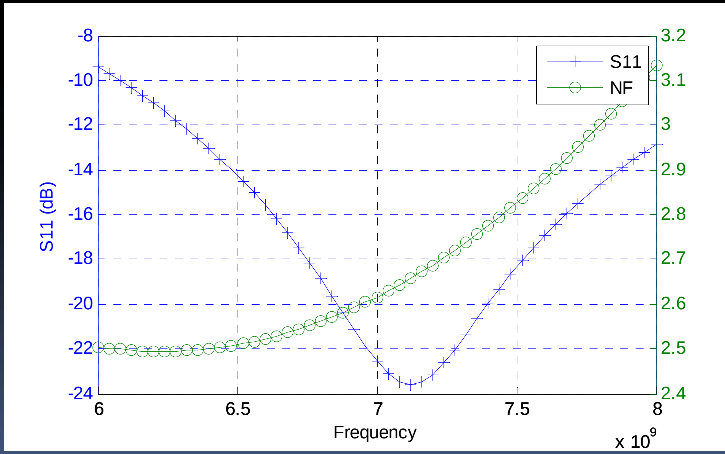


Low Noise Amplifier

- Input Referred P1dB
  - -4.4 dBm
- IIP3
  - 8.5 dBm

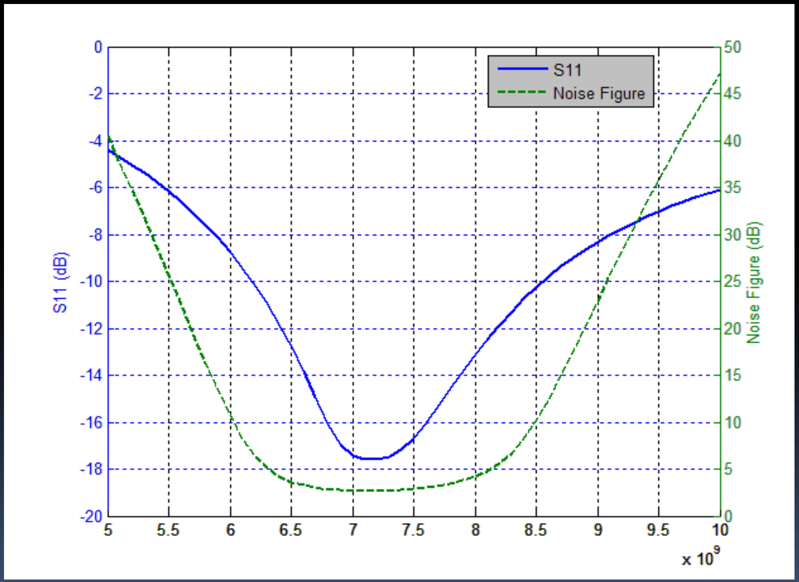






Low Noise Amplifier

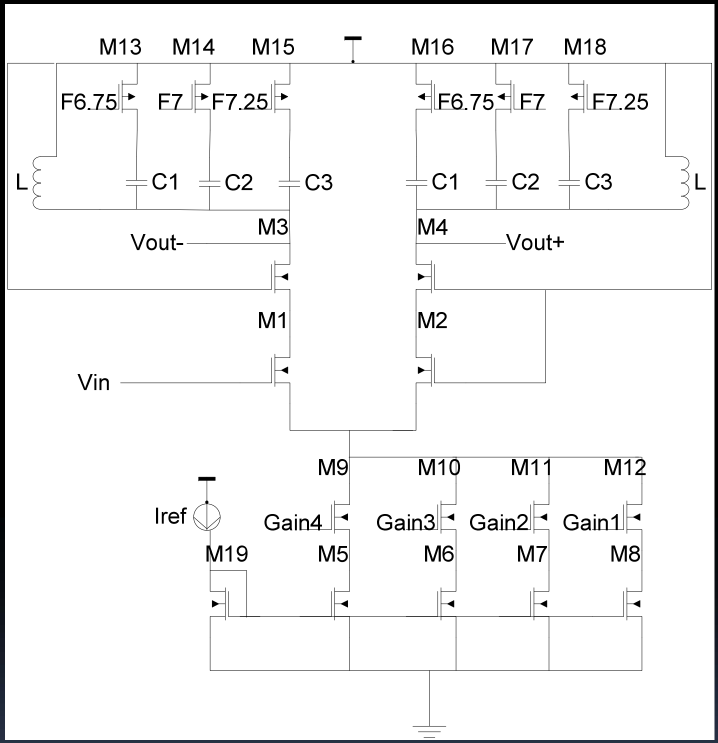
- Overall NF < 2.6 dB
- Overall Return Loss > 15 dB



Noise Figure and S11

Controllable Gain Stages

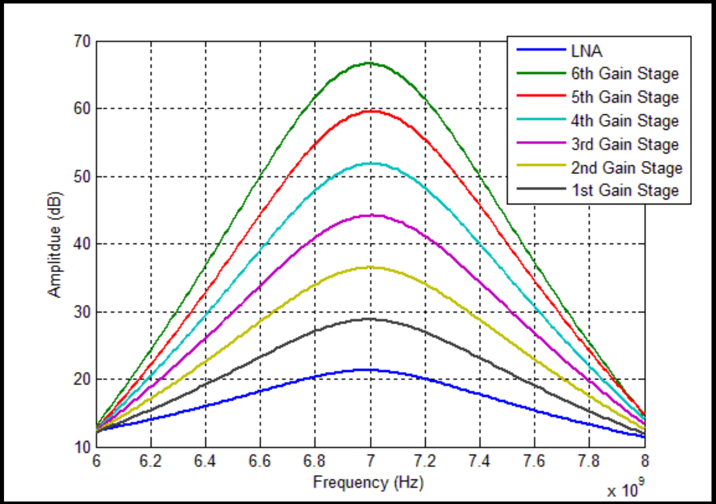
- Design Strategy
  - Simple diff amp with LC tank load
  - Used gm/W vs. I/W plots to optimize between power, gain, and noise figure
  - Added cascode to increase isolation between stages
  - Single-to-differential conversion done in 1st stage



First gain stage with switchable gain and f_0

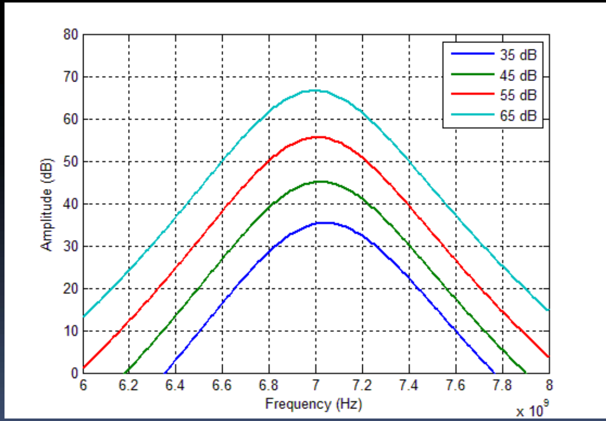
Controllable Gain Stages

- Switchable load on all stages
  - Need for high overall Q
  - Optimize switch sizing

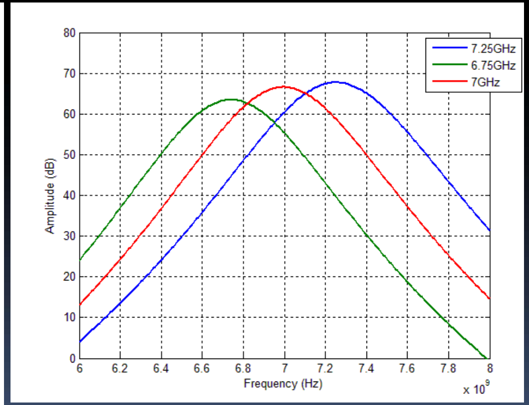


Overall Gains

- Switchable gain on first stage only
  - Switching affects f_0
  - First stage relatively wideband



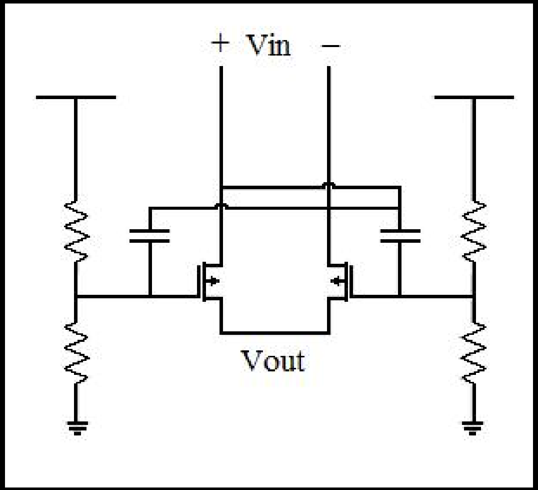
Proper Functionality of Gain Control

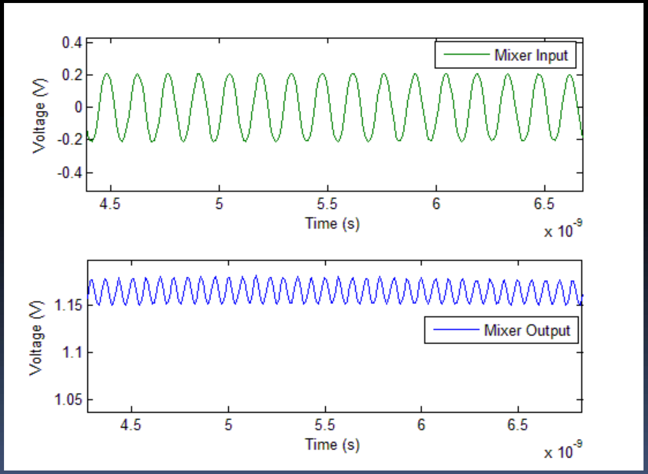


Proper Functionality of Channel Selection

Self-Mixer

- Voltage Controlled Resistance.
- Biased near Vth
  - Achieves best swing of resistance
- Passive
  - Very Low Power
  - High NF and Conversion Loss
- Differential to Single-Ended Output





Self-Mixer Input and Output

Results

- We can now find the approximate range for Non-coherent PPM with BER of 10^{-3} [1]

$$\frac{E_b}{N_0} = 17dB$$

$$SNR_{out} = \frac{E_b}{N_0} - 10\log(BW) + 10\log(R) \approx 4.45dB$$

$$P_r = \frac{P_t G^2 \lambda^2}{(4\pi R)^2}$$

f(GHz):	7
λ(m):	0.042857
G(dB):	0
Pt (dBm):	-17.32
R(m):	5.75
Path Loss(dB):	-64.5371
PRx (dBm):	-81.8571

*Signal powers given in dBm

Antenna	
Gain:	0
PRx:	-81.8571

LNA	
Gain:	21.4
NF:	2.6
NFCas:	2.6
GCas:	21.4
Pout:	-60.4571

Gain Stages	
Gain:	45.3
NF:	10
NFCas:	2.752883
GCas:	66.7
Pout:	-15.1571

Mixer	
CL:	25.6
NF:	25.6
NFCas:	2.753062
GCas:	41.1
Pout:	-40.7571

T (K)	300
B (GHz)	0.3
k	1.38E-23
Ni (dBm)	-89.06
Te	265.4932518
No (dBm)	-45.20
SNRout (dB)	4.45

Results

Parameter	This Work	Desired	Li, Xia, Huang	Fred Lee Thesis
Process	0.13 µm CMOS	0.13 µm CMOS	0.13 µm CMOS	90nm CMOS
Data Rate	16.67 Mbit/s	16.67 Mbit/s	-	16.67 Mbit/s
Supply	1.2 V	1.2 V	1.2 V	0.65 V
Die Size	0.869 mm x 3.83 mm	-	1.1 mm x 1.5 mm	1mm x 2.2mm
Channel Δf	300 MHz	250 MHz	> 250 MHz	500 MHz
fc Subbands	6.75, 7, and 7.25 GHz	6.75, 7, and 7.25 GHz	3.4, 3.9, and 4.4 GHz	3.4, 3.9, and 4.4 GHz
Gain	40 dB	> 40 dB	22 dB	40 dB
NF	2.6 dB	< 10 dB	3.3 - 4 dB	8.6 dB
S11	< -15dB	< -10 dB	< -10 dB	-
Power	34.4 mW	< 40 mW	21.6 mW	-
Distance	6m	10 m	-	7m

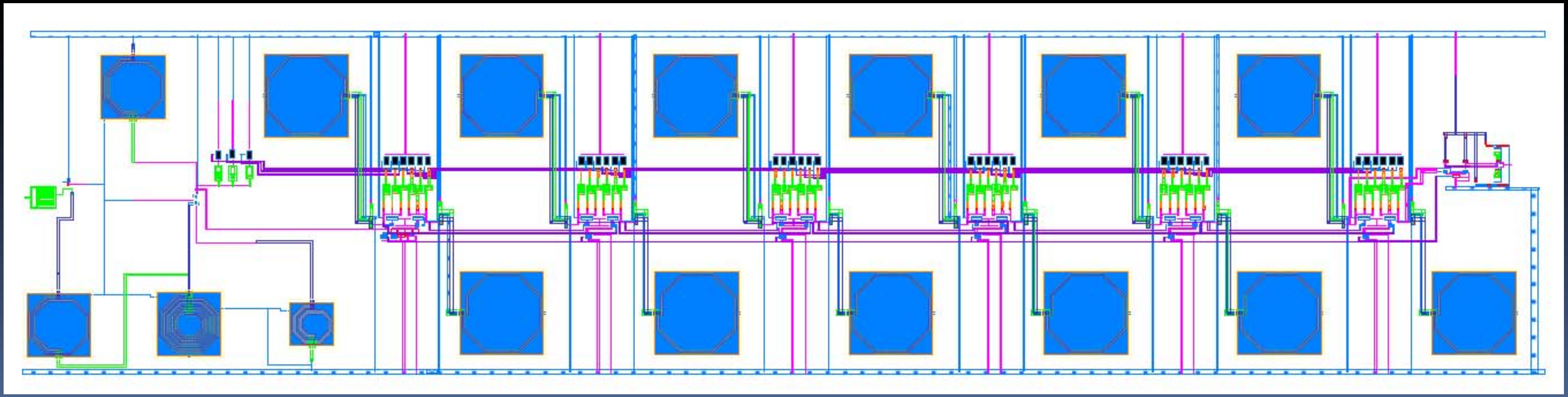
Layout

- 0.869 mm x 3.83 mm
- Inductors spaced 1 diameter apart to reduce coupling

LNA

Controllable Gain Stages

Buffer and Self-Mixer



Design Challenges

- Upper Band Channel Selection
  - High Q, Narrow Bandwidth
- Center Frequency Tuning
- Channel and Gain Switches
- Mixer Characterization
- Die Size

Conclusions

- Specifications reasonably met or exceeded
  - Very low noise figure
  - Good input matching, gain, and BW
- Large die size
- Future Work
  - Differential Inductors
  - Higher order filters
    - Fewer Gain Stages

Questions

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References

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