A 65μW, 1.9 GHz RF to Digital Baseband Wakeup Receiver for Wireless Sensor Networks

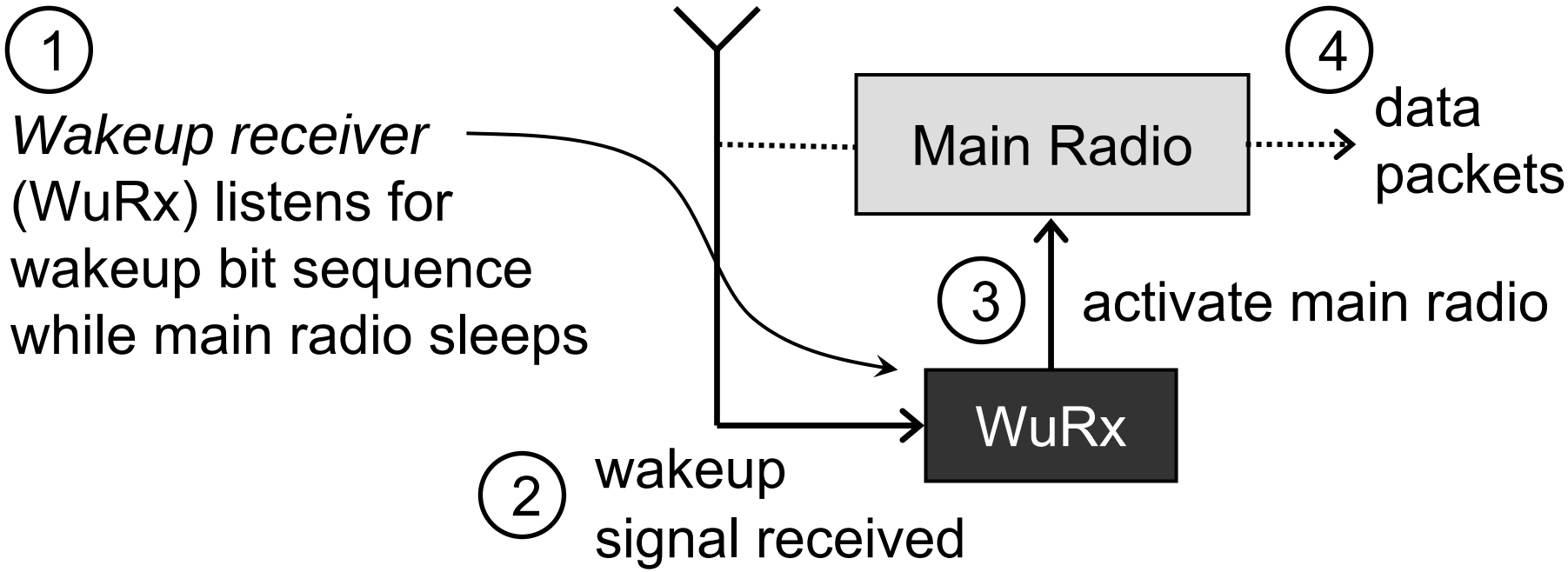
N. Pletcher, S. Gambini, J. Rabaey
pletch@eecs.berkeley.edu

Berkeley Wireless Research Center
Department of EECS
University of California, Berkeley

Outline

- Introduction to wakeup receiver (WuRx)
- Receiver architecture and circuit design
- Measurement results
- Wakeup detection measurements
- Conclusions

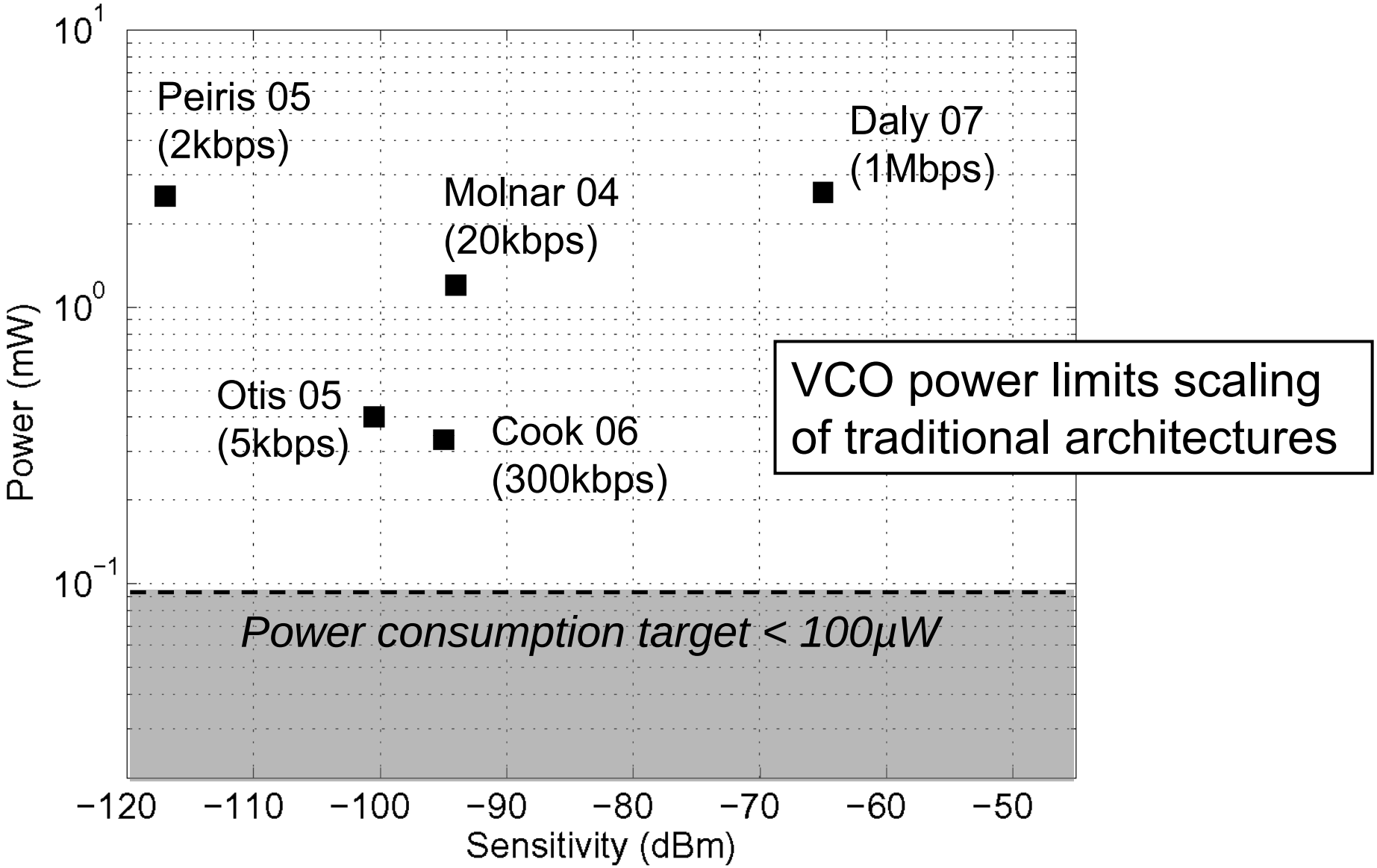
System Architecture with Wakeup



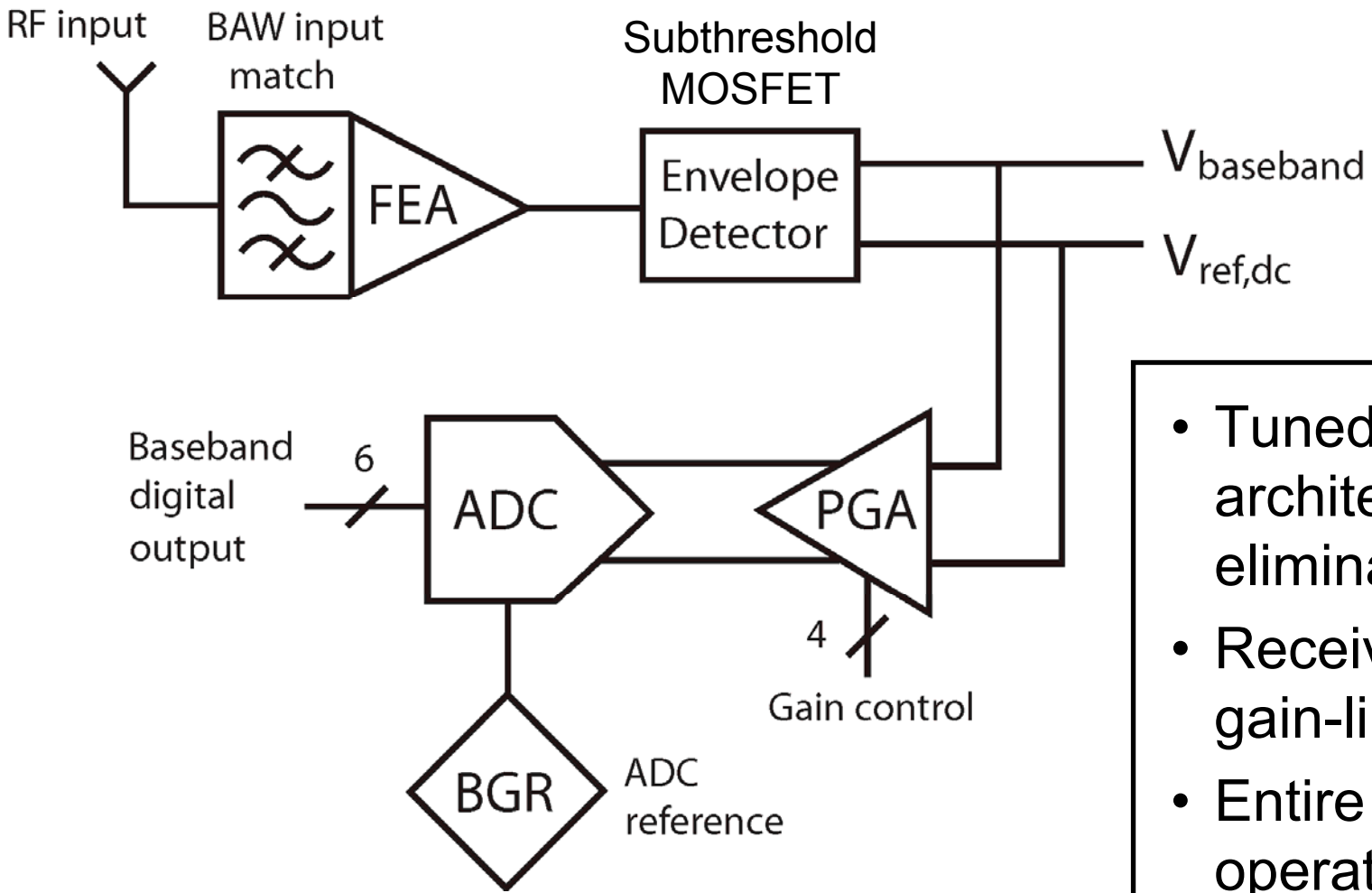
WuRx reduces network latency but requires:

- Ultra-low power (<100μW)
- Complete receiver (RF, baseband, detection, references)

Low Power Receiver Survey

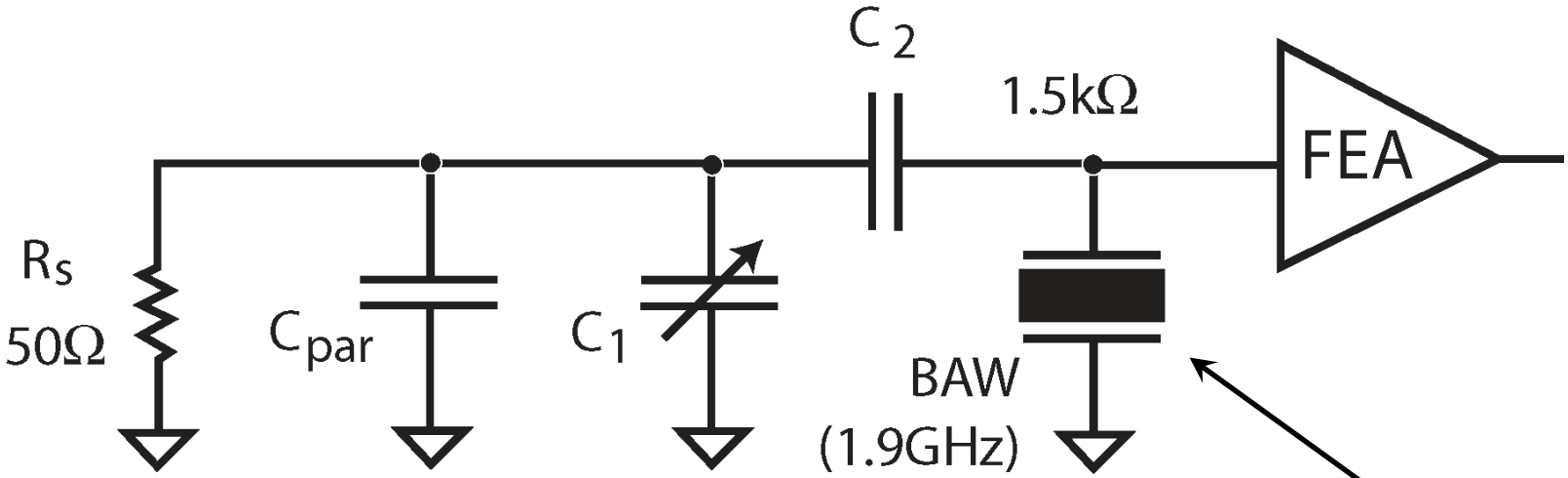


Architecture Overview



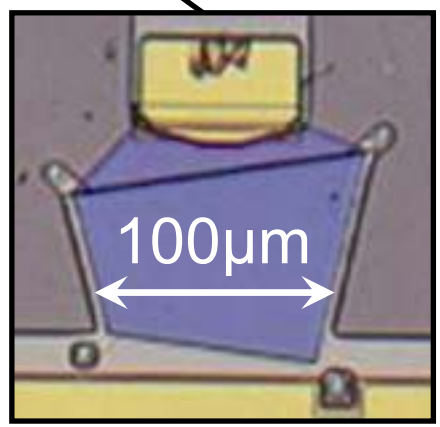
- Tuned RF architecture eliminates VCO
- Receiver is gain-limited
- Entire receiver operates from 0.5V supply

RF-MEMS Matching Network



Advantages:

- RF image/interference filter
- Allows nonlinear downconversion
- Compatible with post-processing or multi-chip package

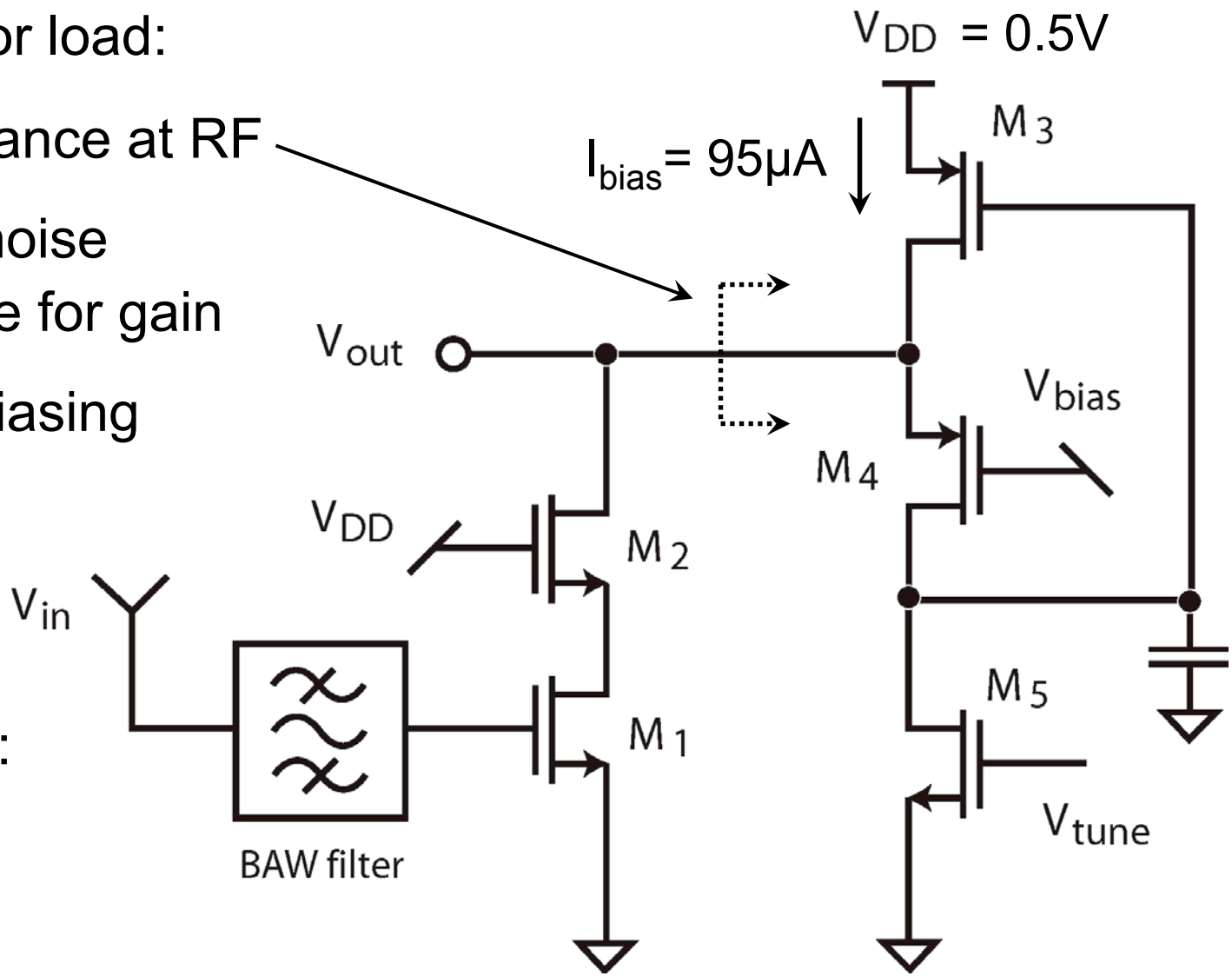


Avago FBAR (BAW)

Frontend Amplifier Design

Active inductor load:

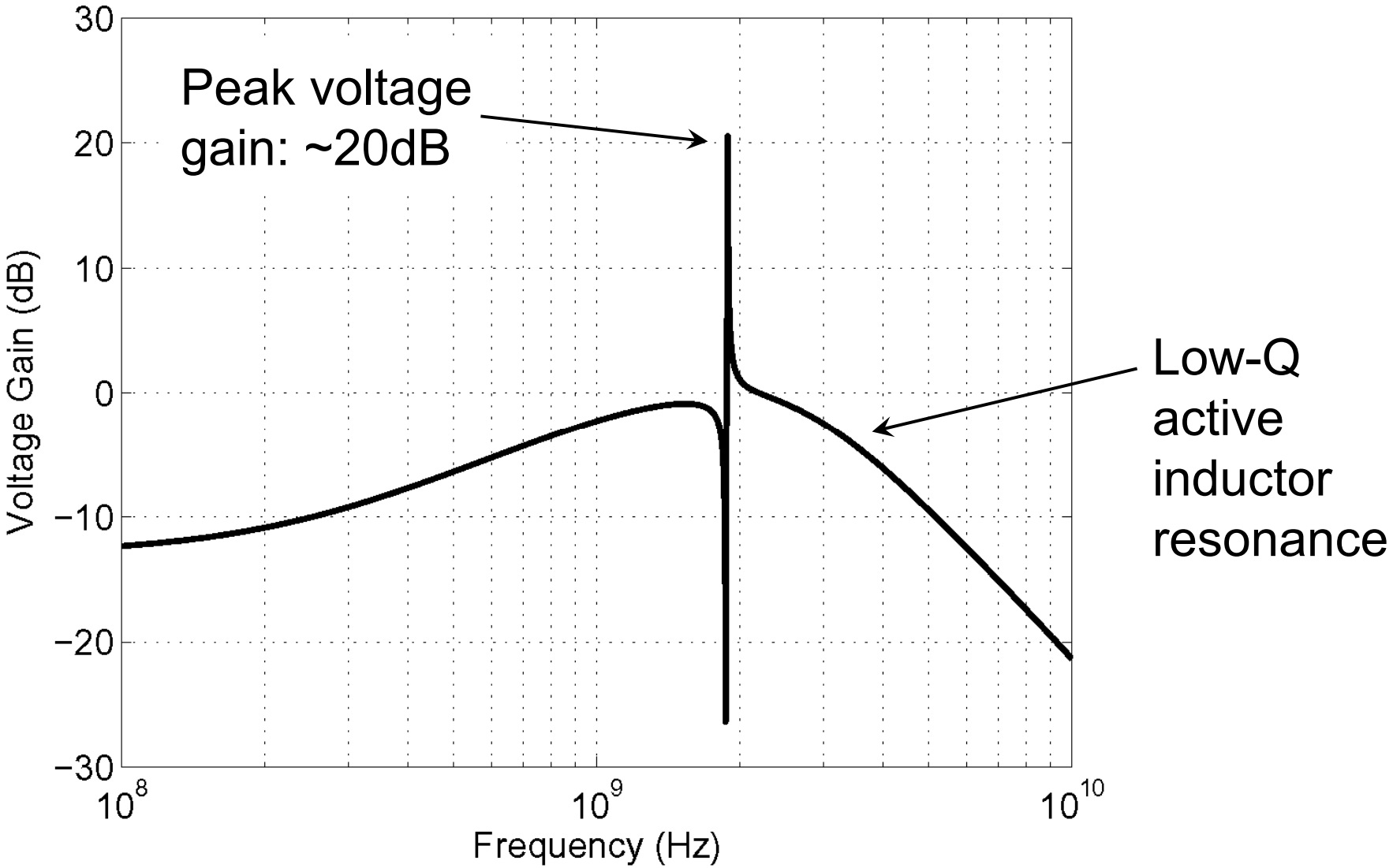
- High impedance at RF
- Trades off noise performance for gain
- Simplifies biasing



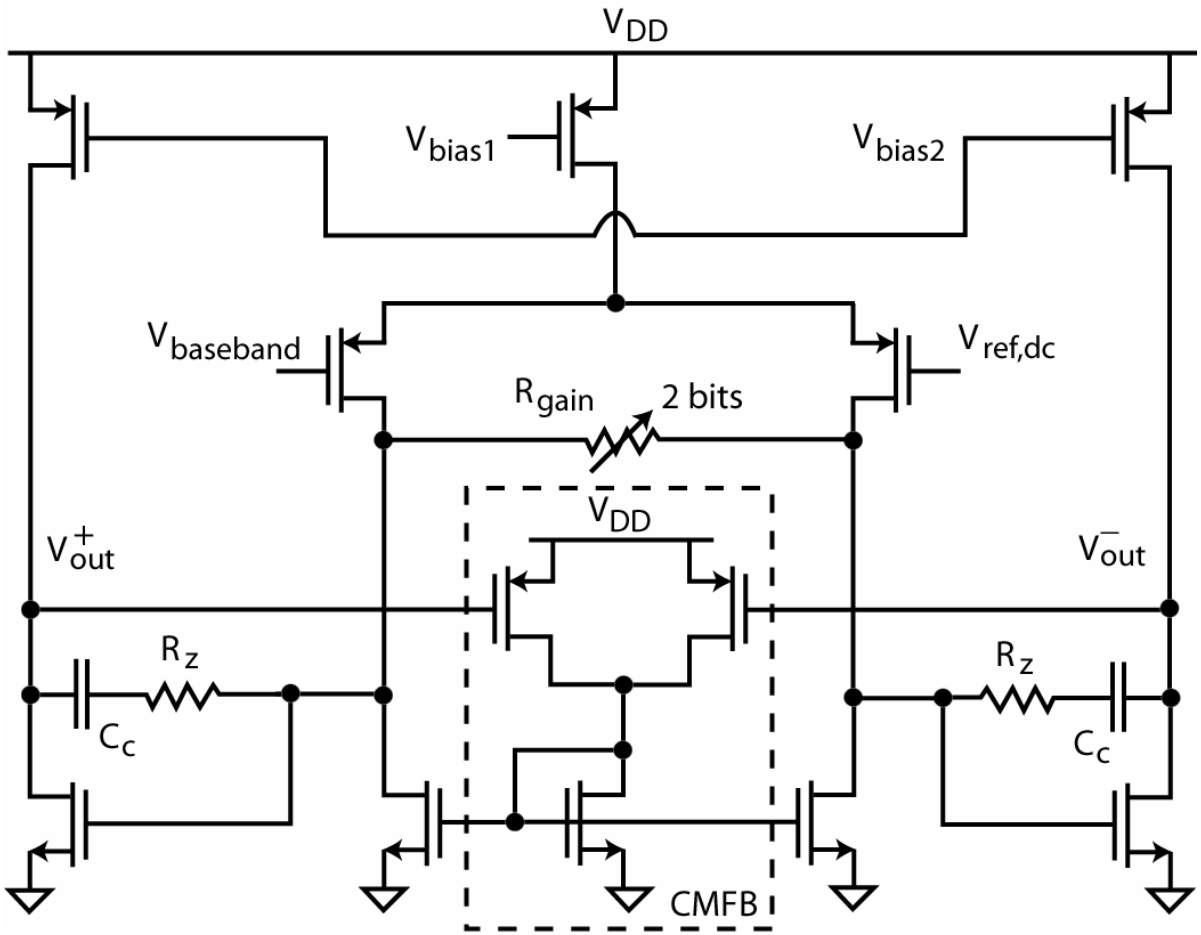
Noise Figure:

7.8dB (sim)
9dB (meas)

Simulated Voltage Gain



Programmable Gain Amplifier



Baseband Gain:

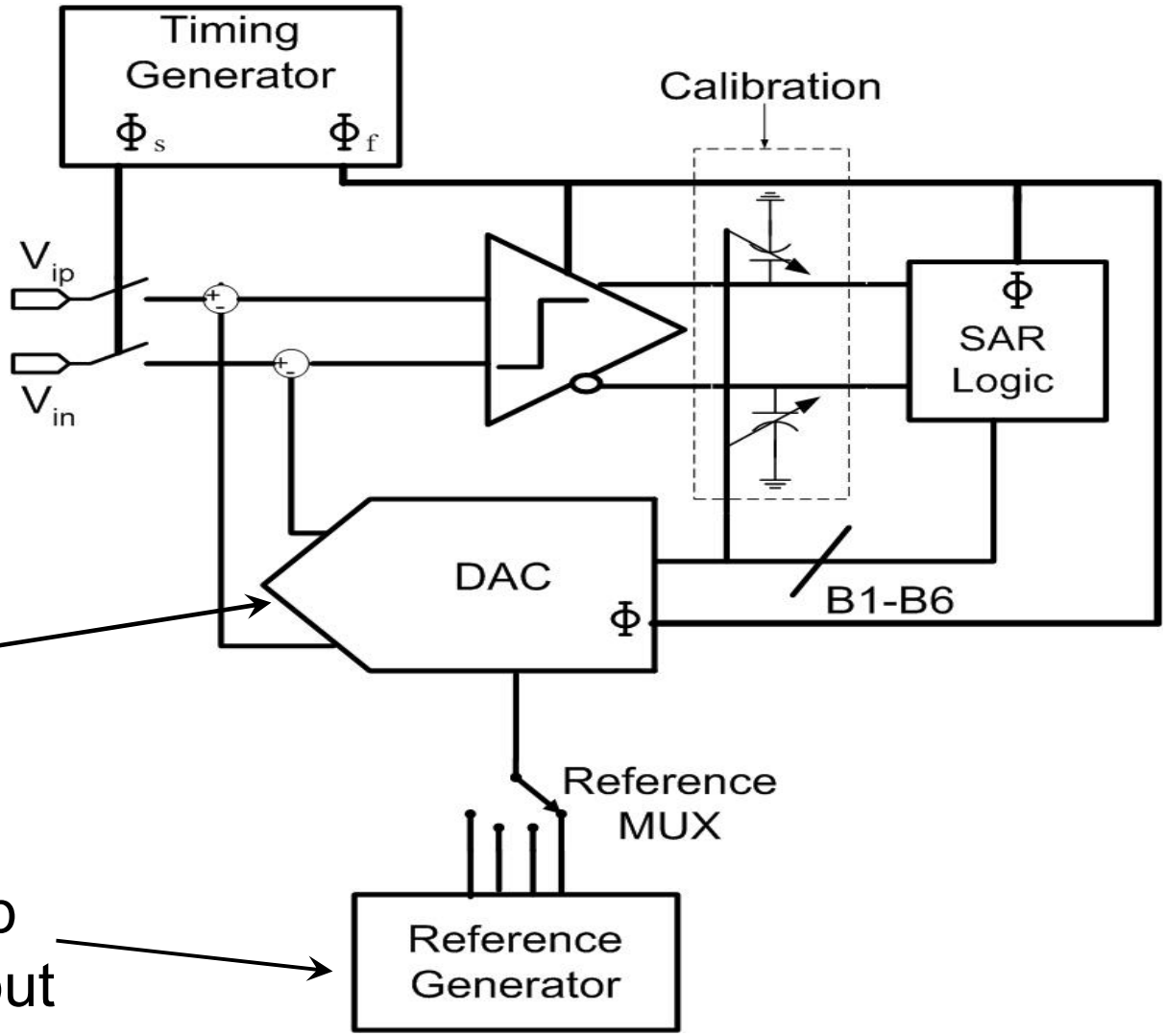
- 2-stage OTA operates at 0.5V
- Gain digitally programmable from 20 to 50dB (10dB steps)
- Power: 2.5μW
- BW_{-3dB} > 150kHz

ADC Design

Supply voltage	0.5 V
Bias current	28 μA
Resolution	6b
Sampling Frequency	1MS/s

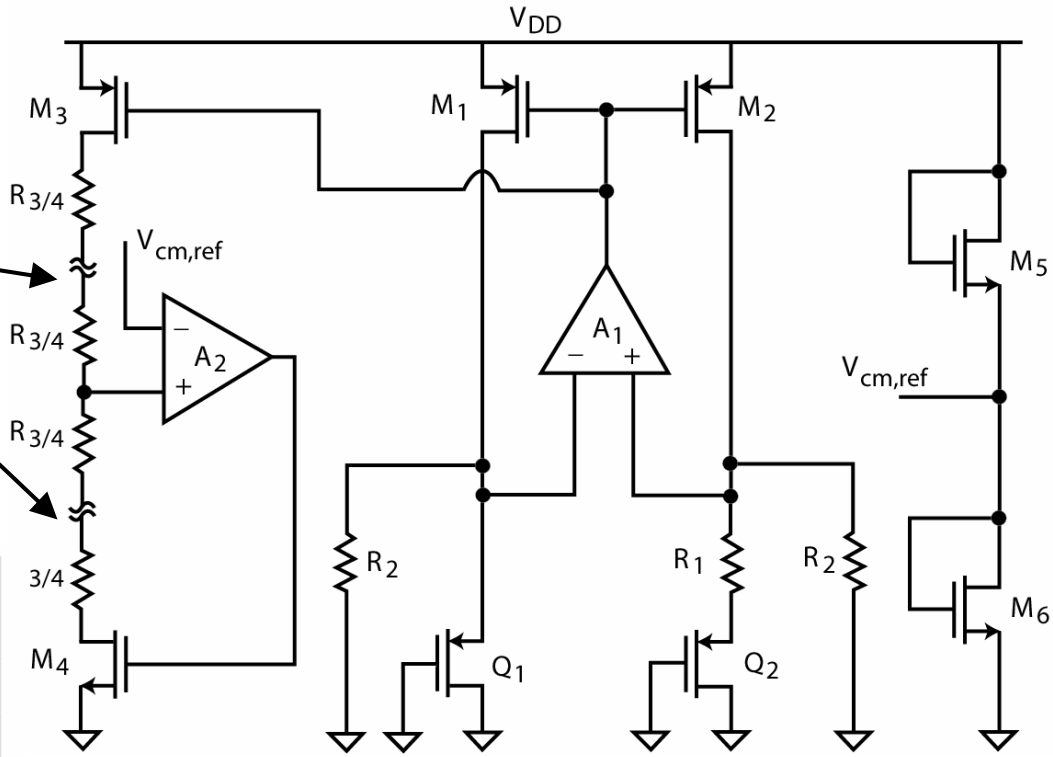
Interlayer metal capacitors minimize loading on PGA

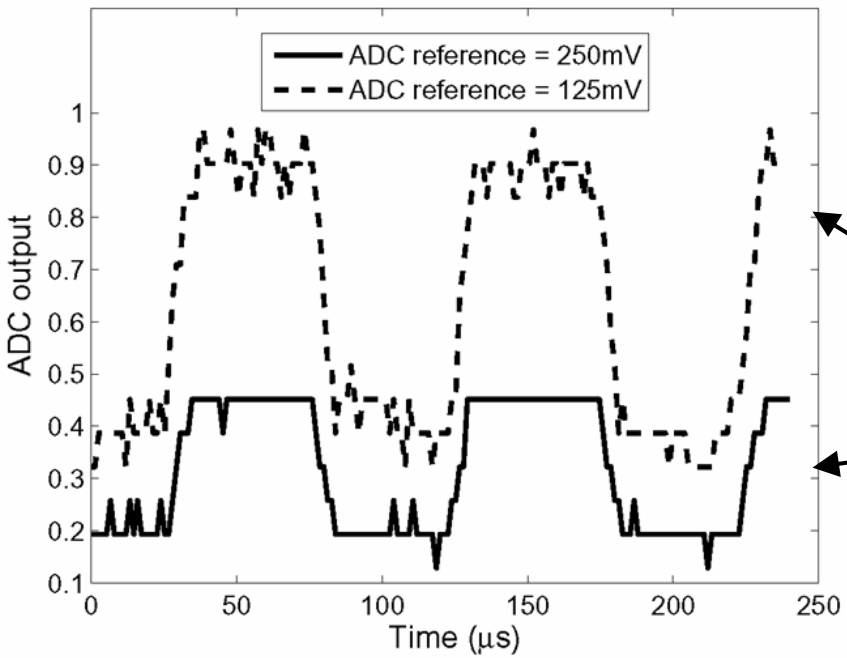
Full CMOS bandgap with adjustable output



Low Voltage ADC Reference

Reference output digitally selected from R-string taps



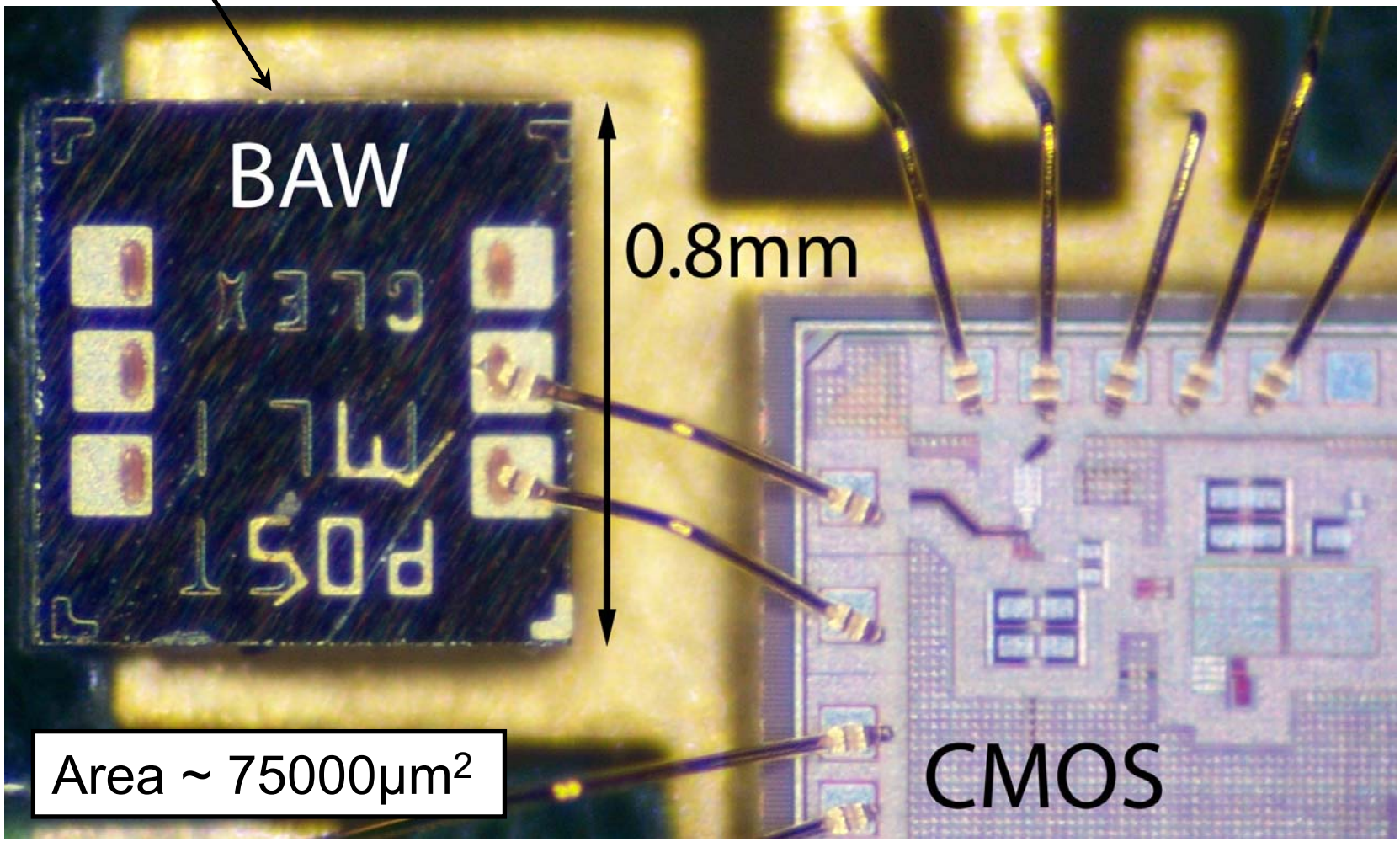


Adjustable reference voltage gives 12dB of variable gain

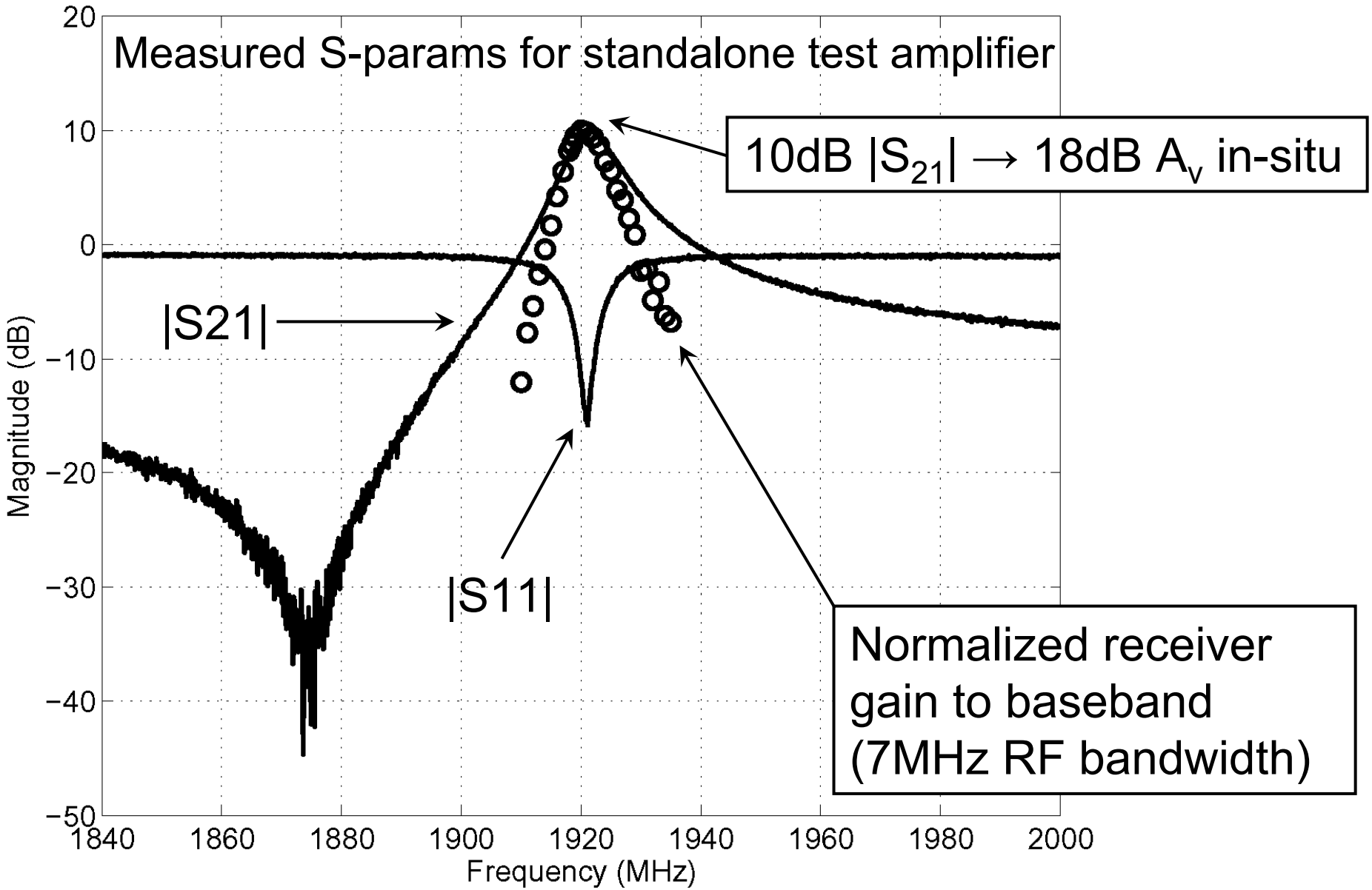
Silicon Prototype

BAW directly bonded to CMOS

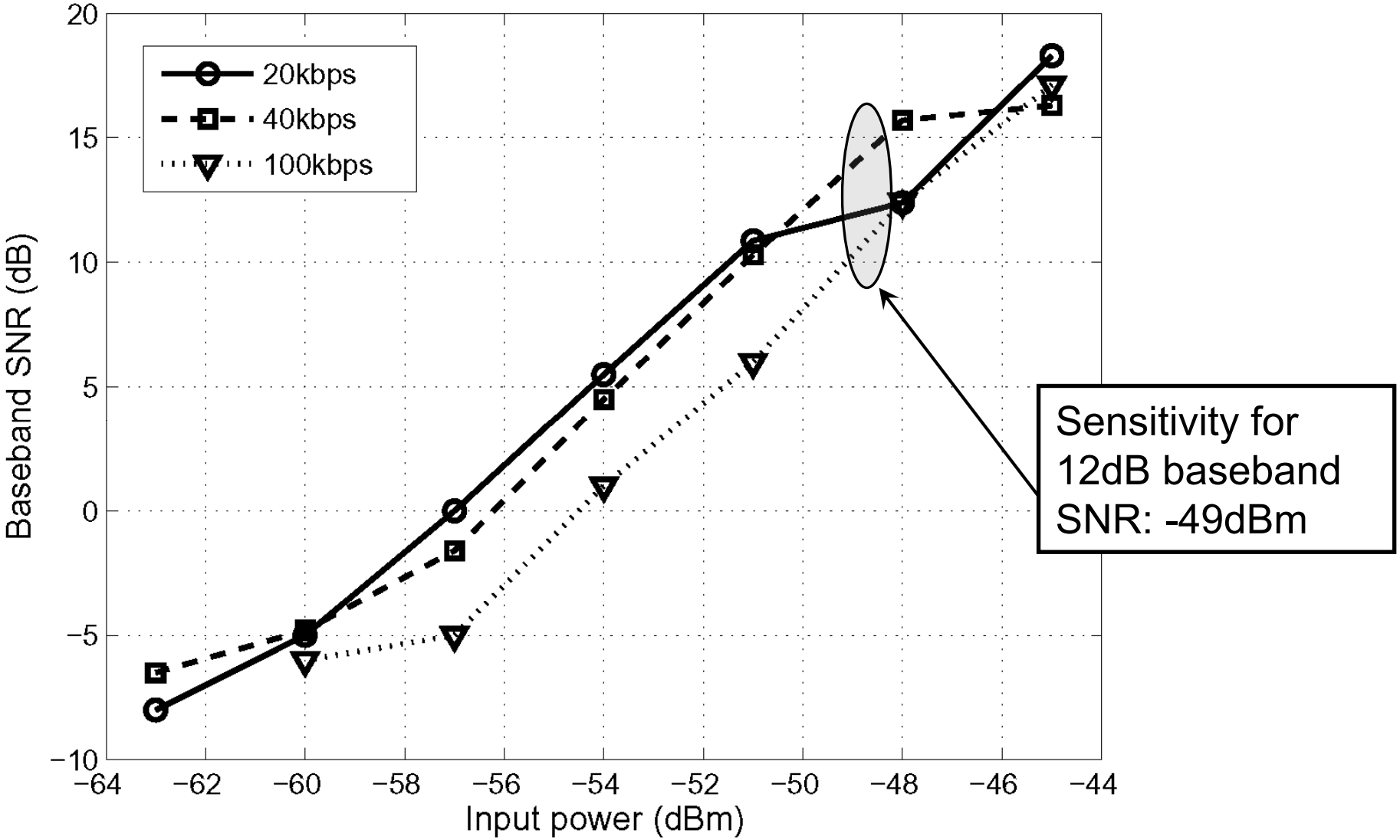
90nm standard CMOS; no on-chip inductors



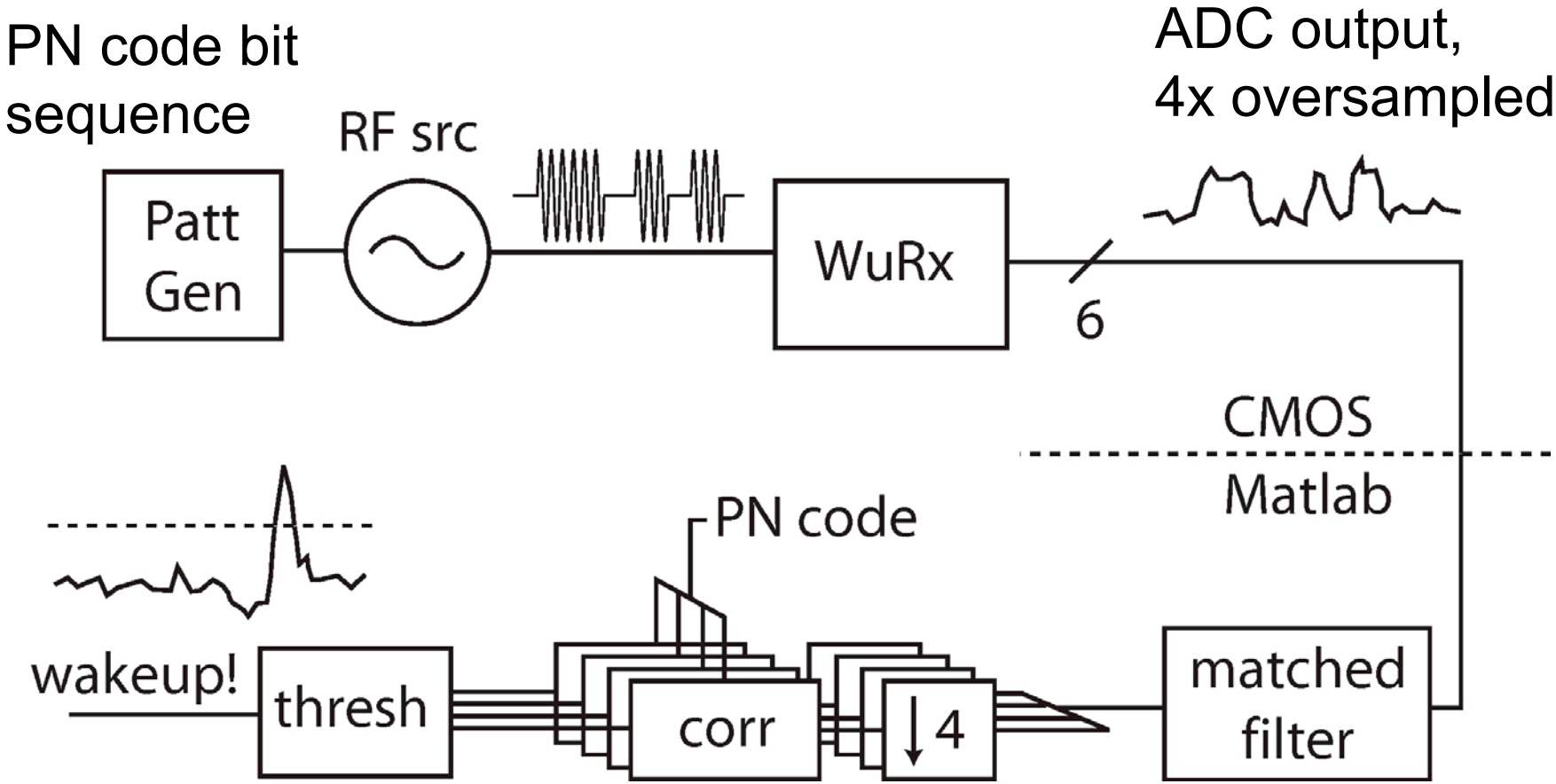
RF Frontend Measurements



Receive Chain Sensitivity



Wakeup Detection Testing



Threshold set for fixed P_{detect} = 90%

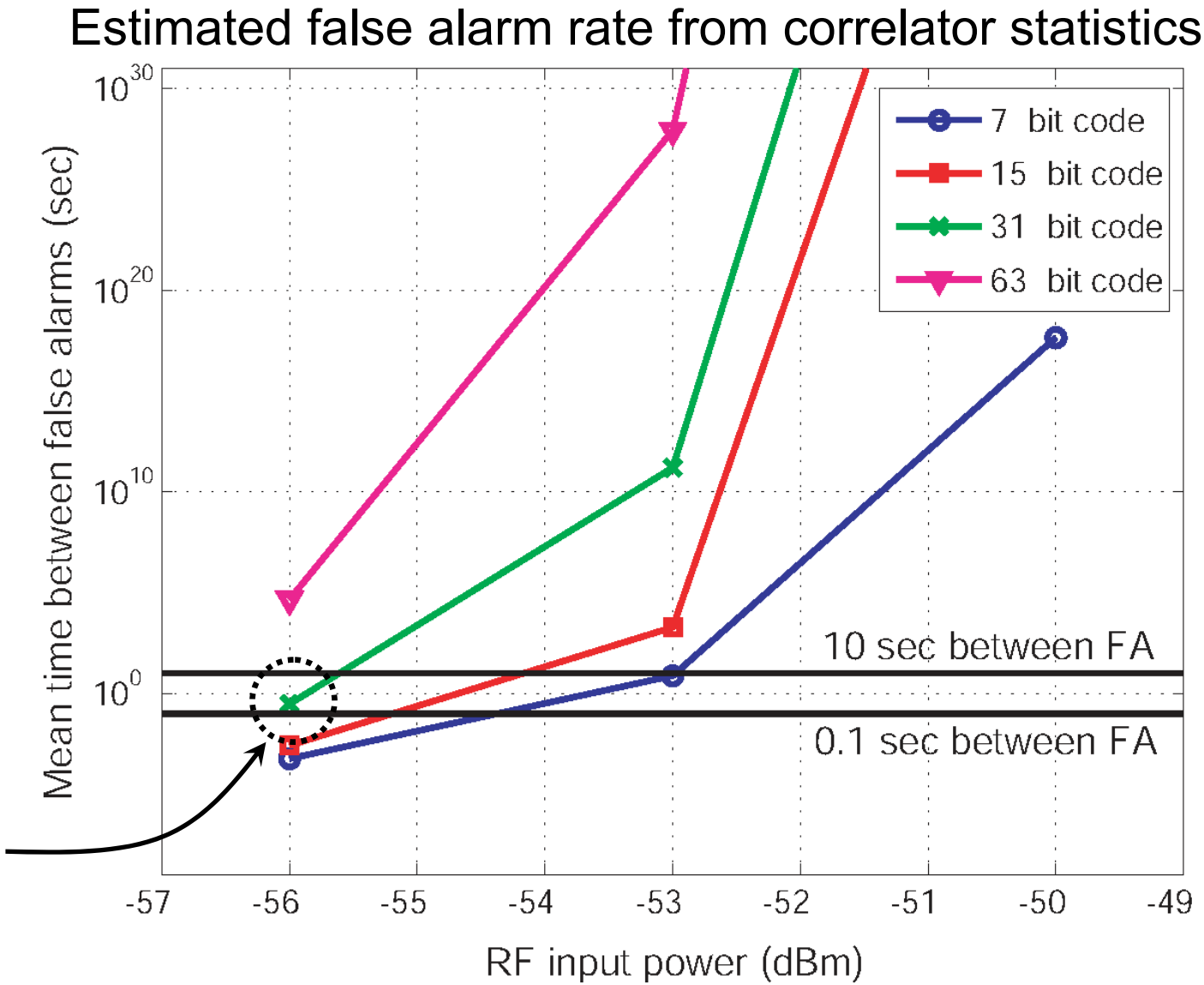
Sensitivity to Wakeup Sequence

Conclusion:

Limited gain from coding due to nonlinear receiver

Example:

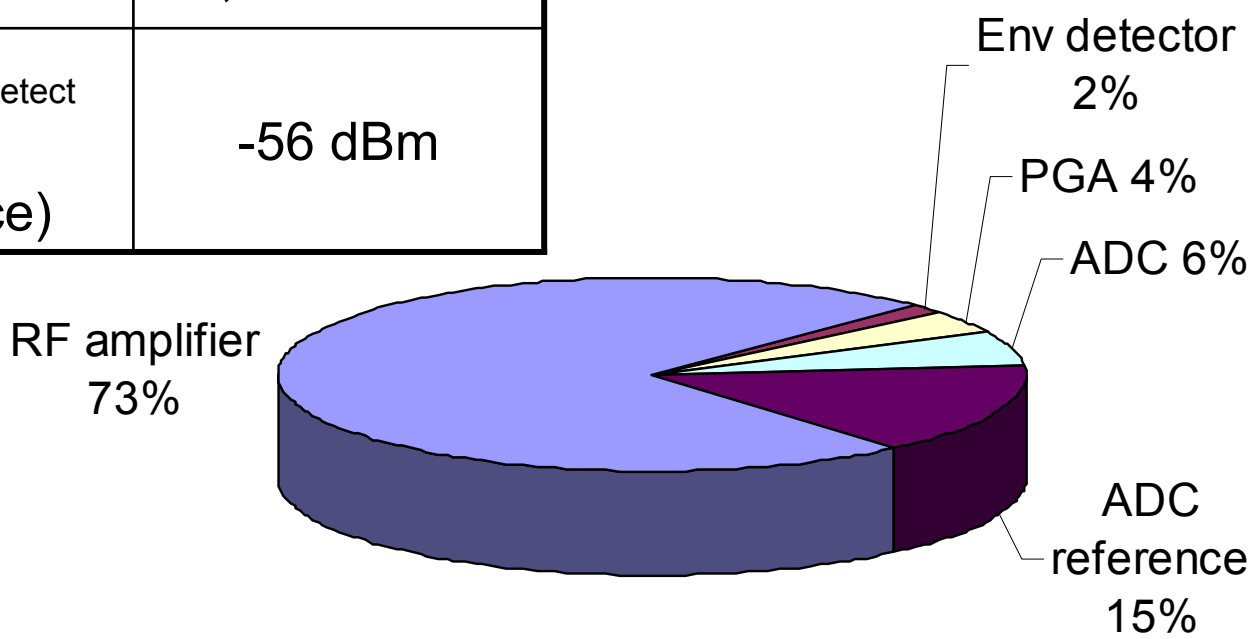
1FA/s for 31b code at -56dBm



WuRx Performance Summary

Global supply voltage	0.5 V
Total power dissipation	65 µW
Nominal/Max datarates	40/100kbps
Overall Receiver -3dB BW	7 MHz
ADC performance	6b, 1MS/s max
Overall sensitivity for P_{detect} of 90% and 1 FA/sec (31-bit wakeup sequence)	-56 dBm

Power consumption breakdown



Conclusion

- WuRx designed specifically for wakeup application where power specification is unusually low (<100 μW)
- Complete receive chain from RF input to digital baseband for 65 μW
- Entire receiver optimized to run from 0.5 V supply

Acknowledgment

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