A 94-GHz Receiver for Imaging Radar
(Memphis project A8)

Dixian Zhao

Advisor: Prof. John R. Long

March 4, 2010

Outline

- Introduction
- LNA Design
  - Design challenges
  - Singled-ended neutralized LNA
  - Differential LNA with input balun
- Mixer Design
- Conclusion

Microwave imaging

- Applications: security, logistics inspection & product quality control
  - range: 3-5 m
  - resolution: 1-5 cm
- W-band (75-110 GHz)
  - cm resolution (R=c/2B)



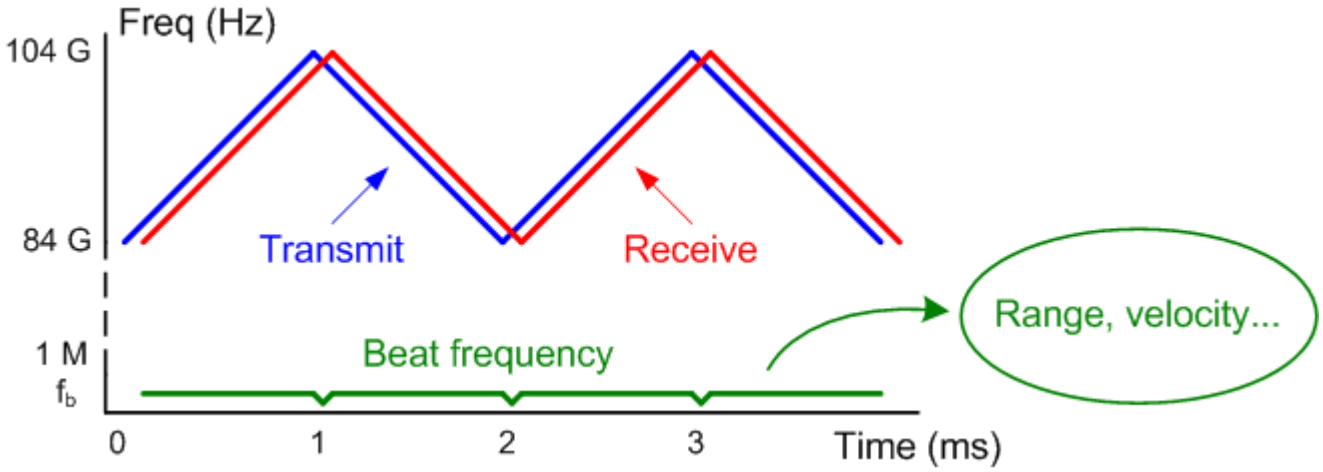
optical image



mm-wave (94GHz) image

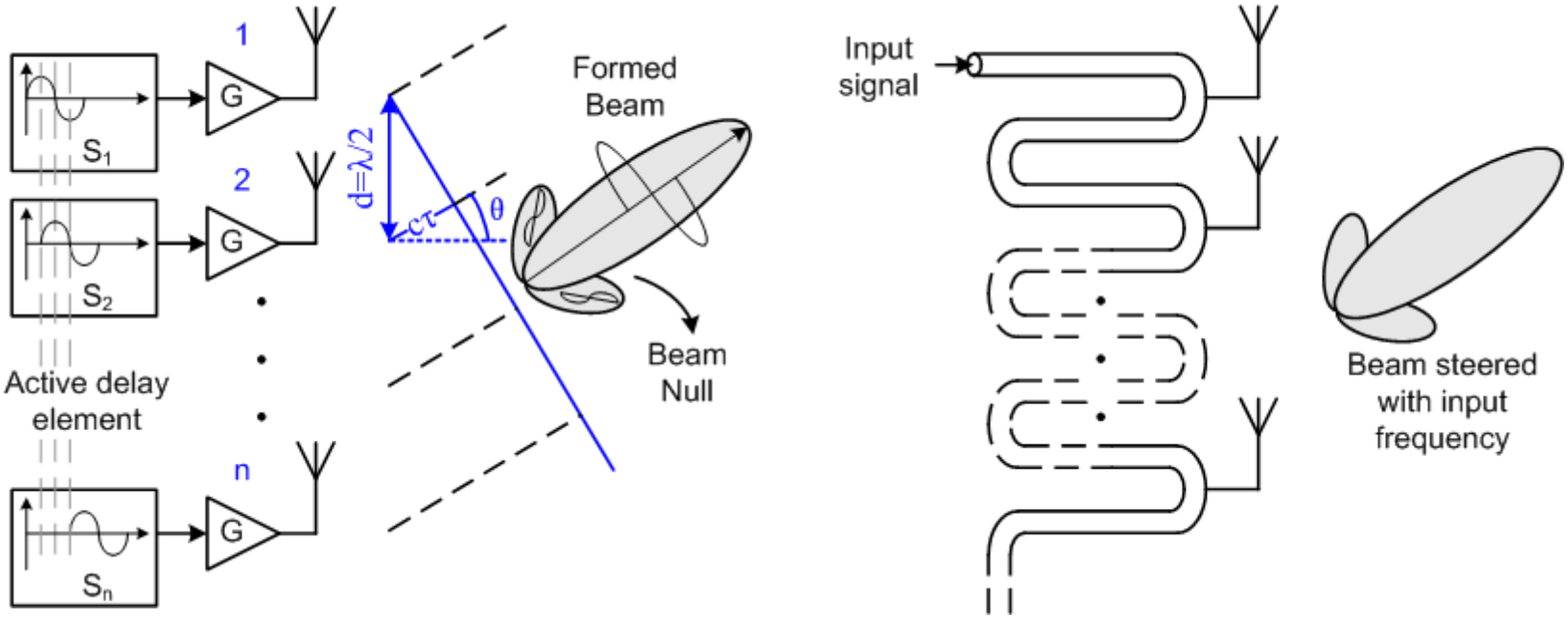
FMCW modulation

- ✓ Lower peak transmit power
- ✓ Reduce the noise bandwidth
- ✓ Relax the speed requirements on the data acquisition
- × Isolation between transmit & receive path
- × System complexity (FMCW signal generation)

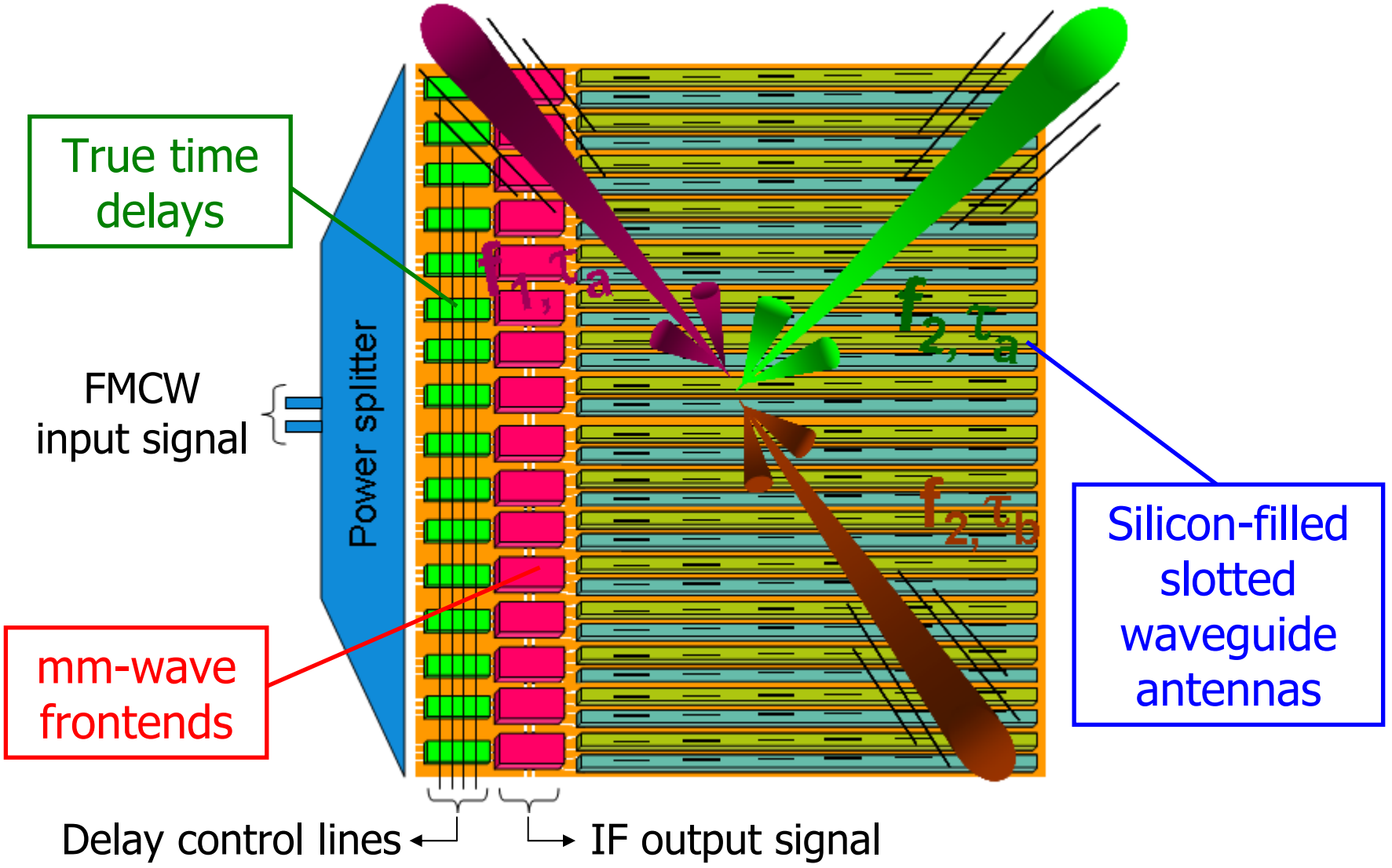


Beamforming

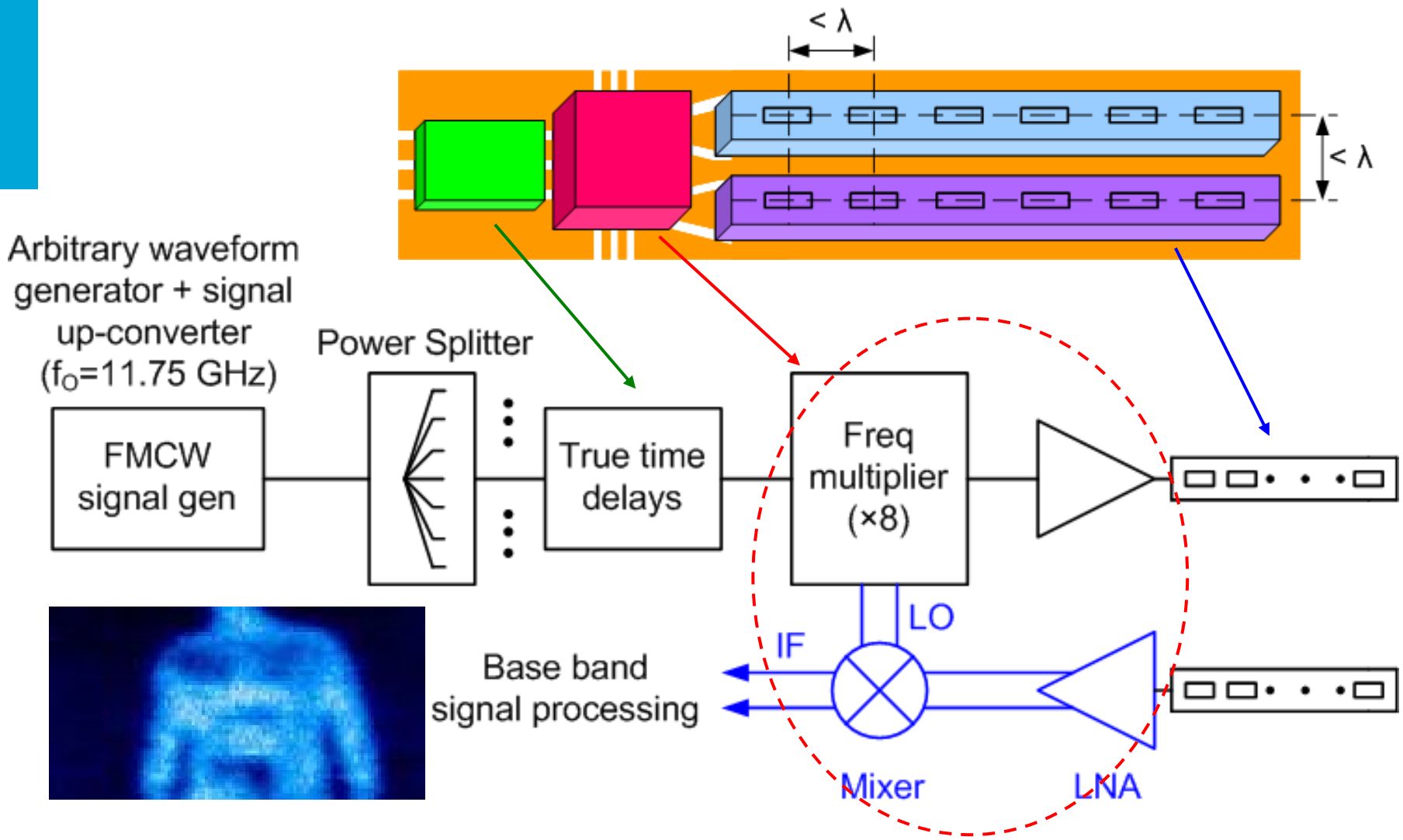
- Planar array: each path has its own hardware with delay element
- Frequency scanning array
- Two-dimensional beamforming
  - For a N×N array, hardware complexity reduced from N^2 to N.



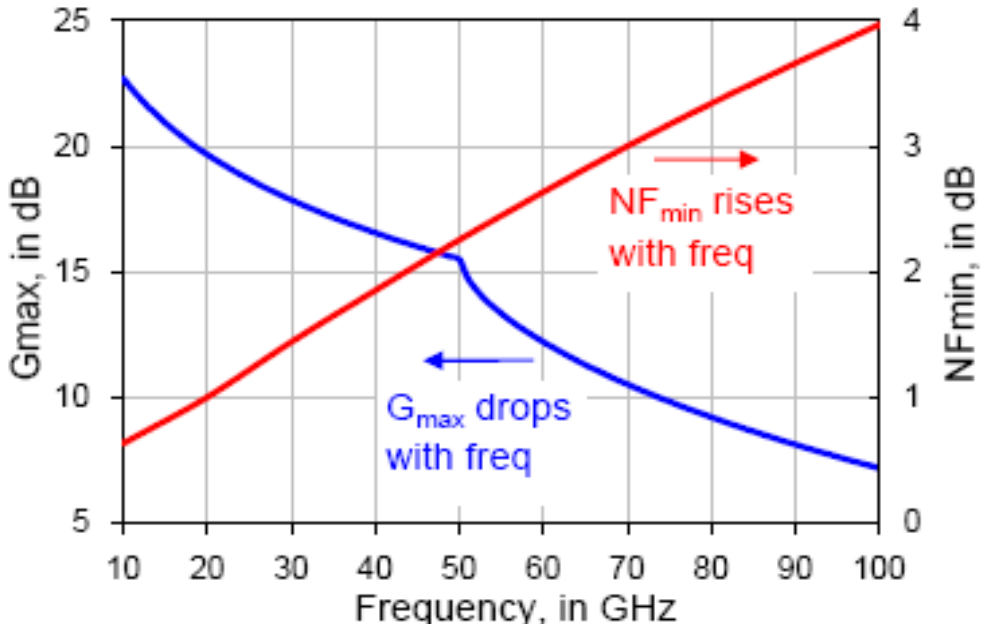
System Architecture



Single channel implementation



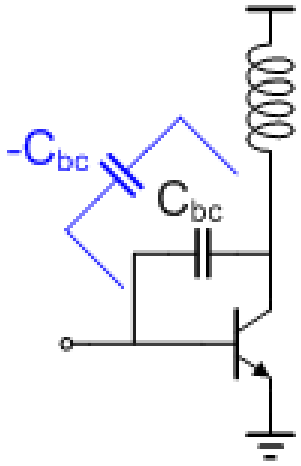
Design Challenges



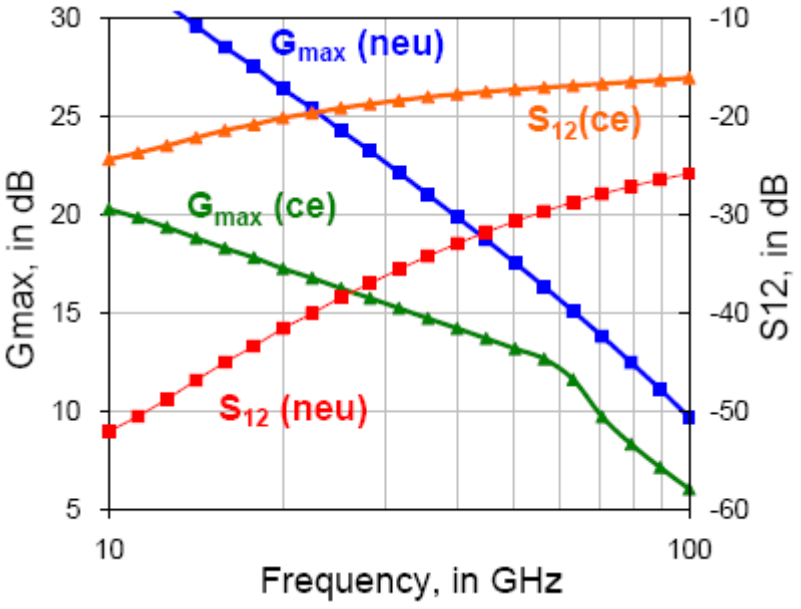
6-um HBTs biased at 11-mA for Gmax & 2-mA for NFmin.

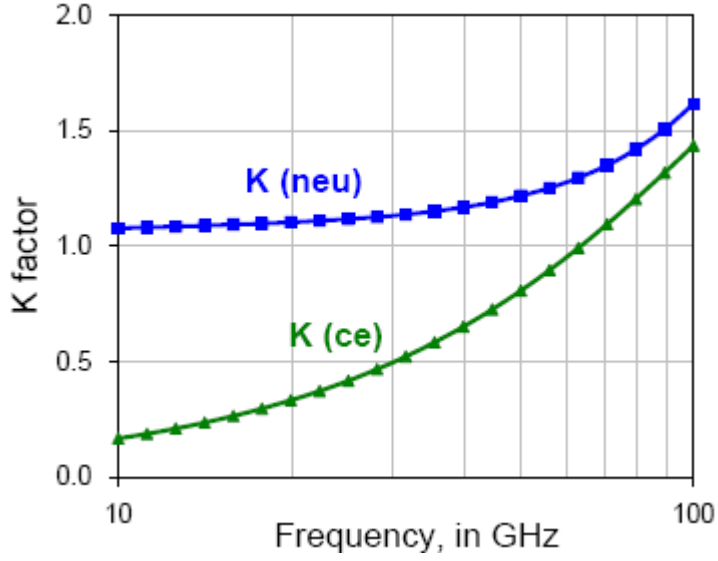
- NF_{min} = 3.85 dB (94-GHz)
- G_{max} = 7.5 dB (94-GHz)
  - not biased for NF_{min}
  - less margin for design optimization
- Conventional design method
  - conjugate match
  - high loss passives
  - large area

Neutralization

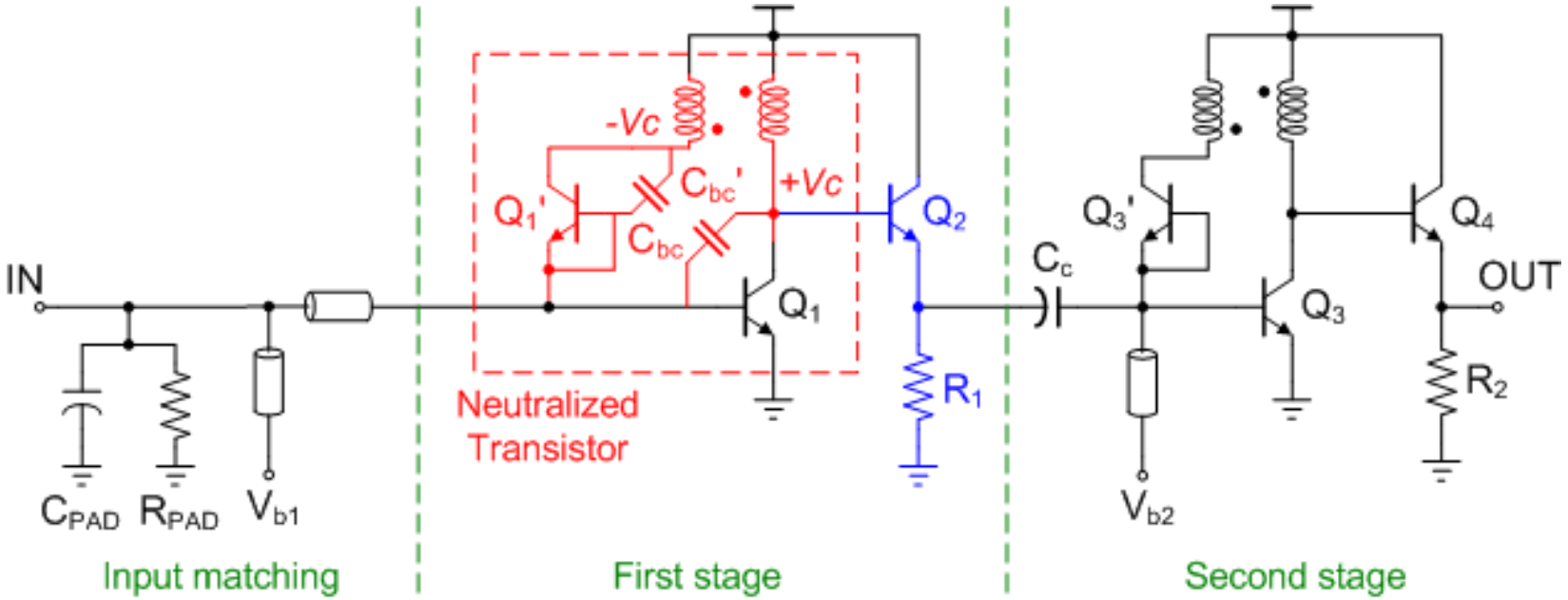


- Increase G_{max}
- Increase terminal impedance
- Improve stability
- Improve reverse isolation



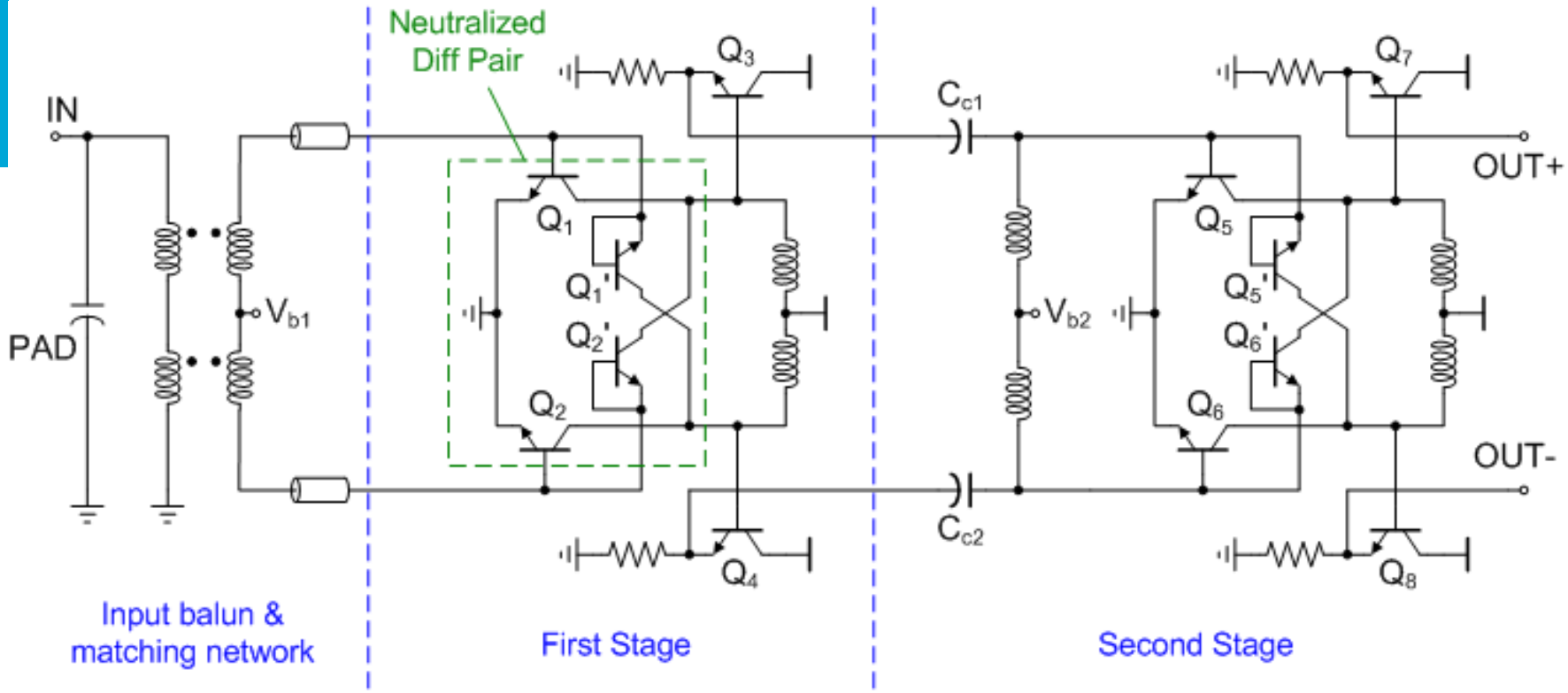


Single-ended neutralized LNA



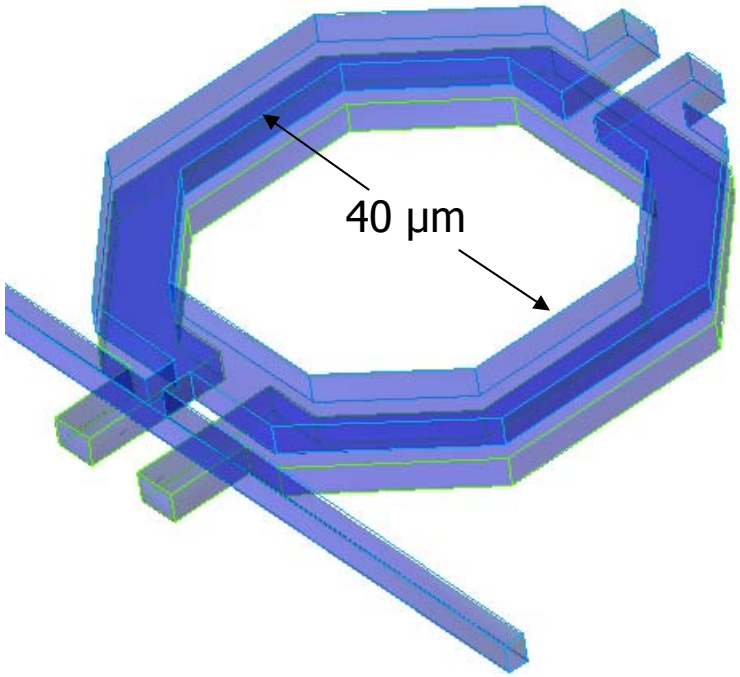
- Transformer-based neutralization technique
- Common-collector stage provides the required load
- Device size selected to simplify input match
- 20 dB gain, 6.5 dB NF & 15 GHz bandwidth

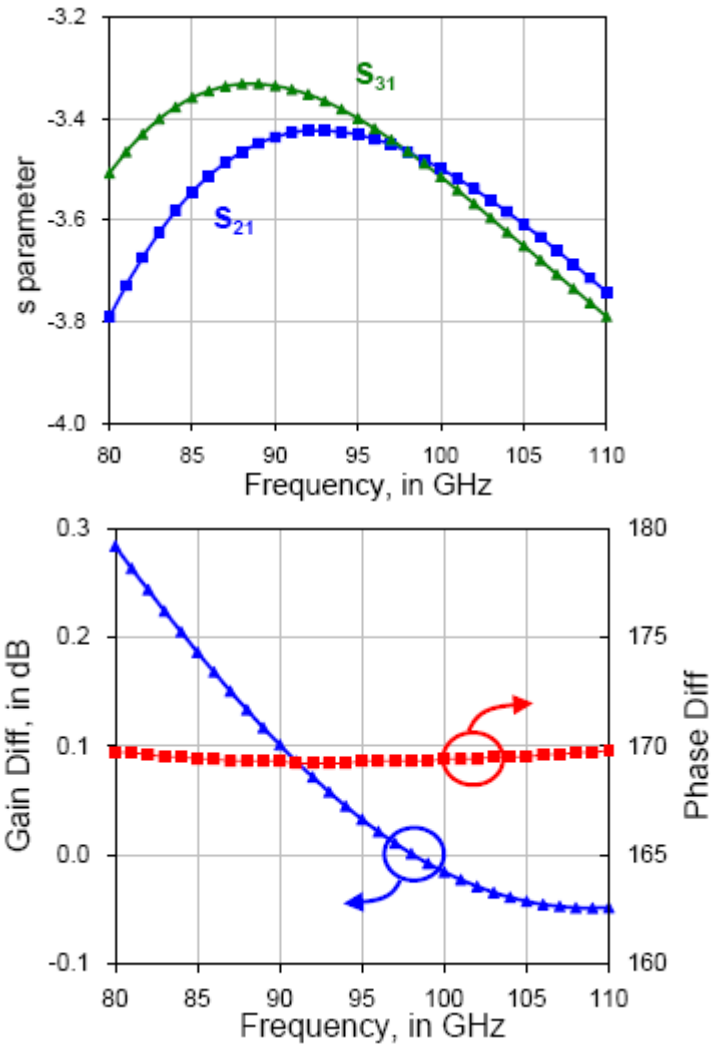
Differential LNA with input balun



- Transformer-based passive balun
- Cross-connected neutralization transistors
- 23-dB gain, 6.3-dB NF & 21-GHz Bandwidth

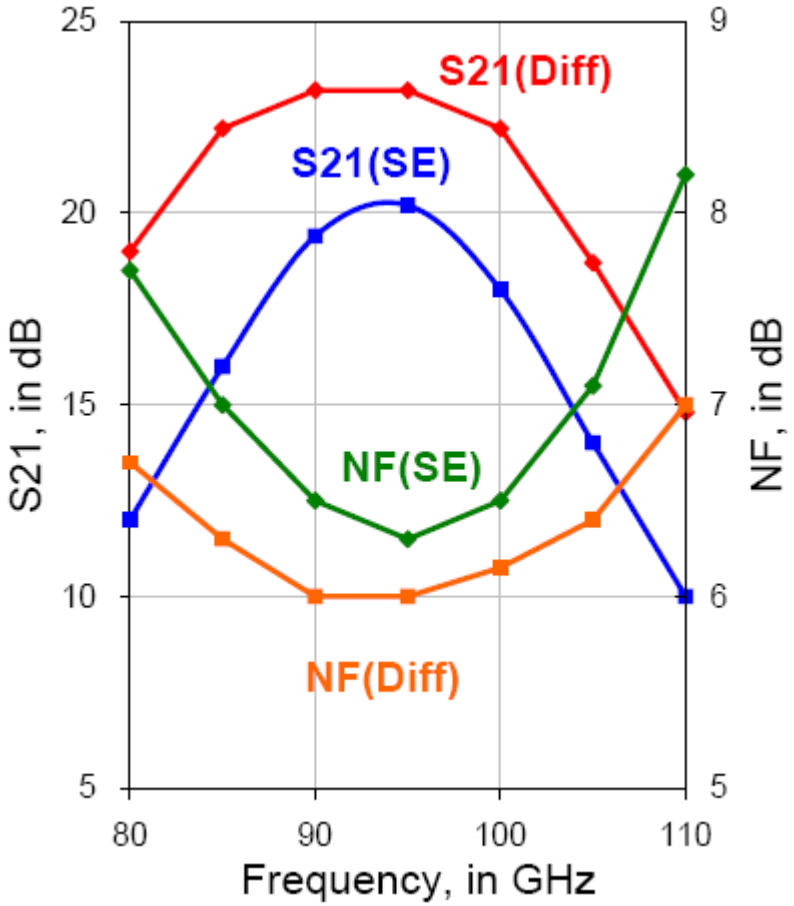
Transformer-based passive balun





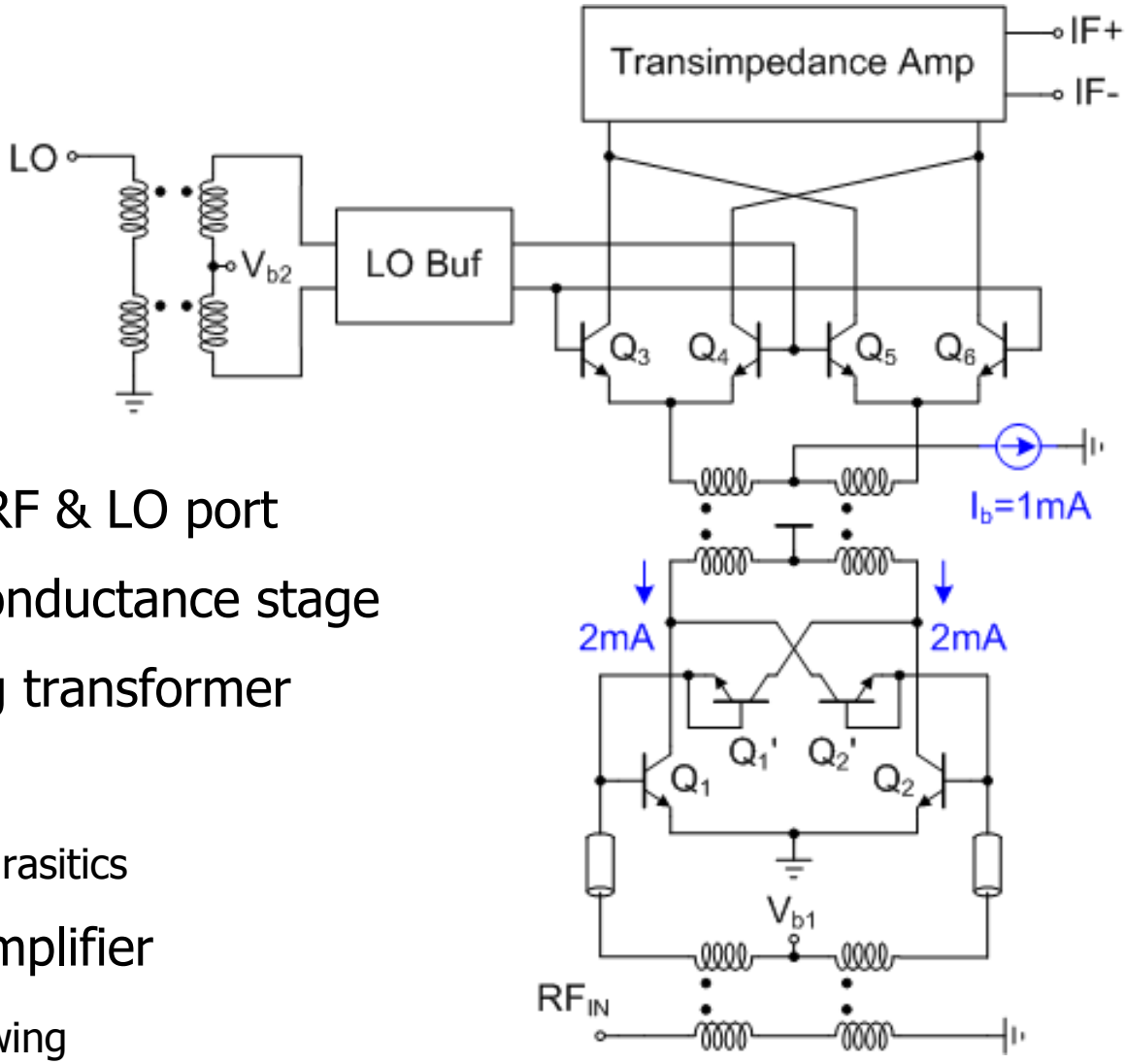
- Convert single-ended to differential
- Match RF port to 50 Ohm

LNA performance (post-layout)



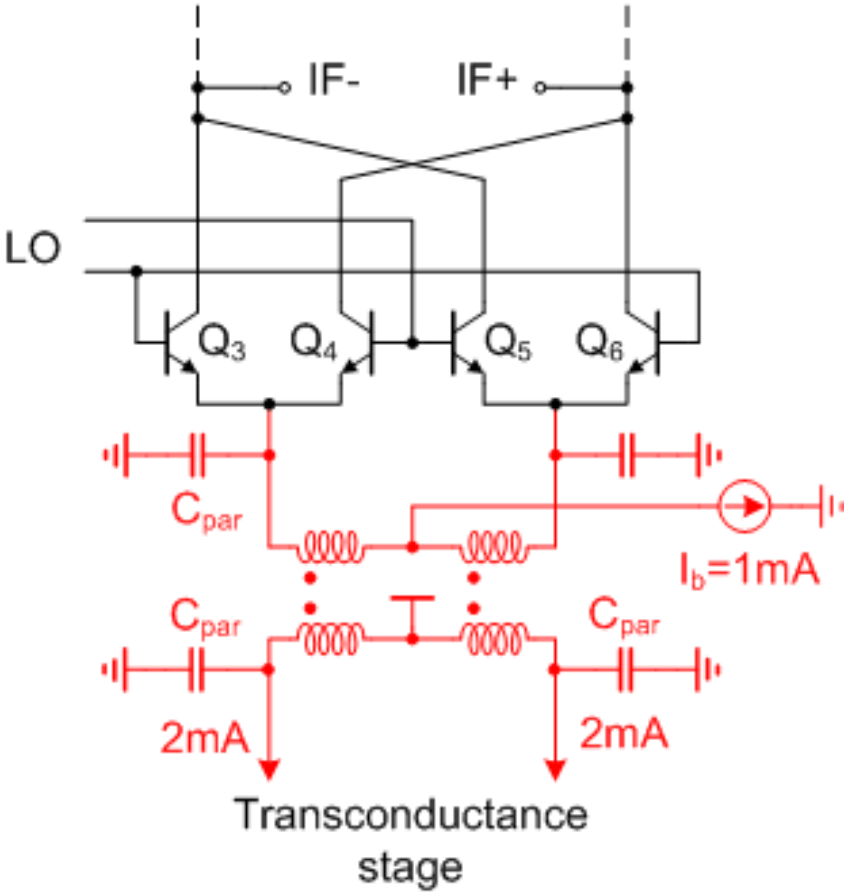
	Single-Ended	Differential
S21 (dB)	20	23
BW_{RF} (GHz)	15	21
NF (dB)	6.3	6.0
S11 (dB)	< 10	< 10
S12 (dB)	< -60	< -60

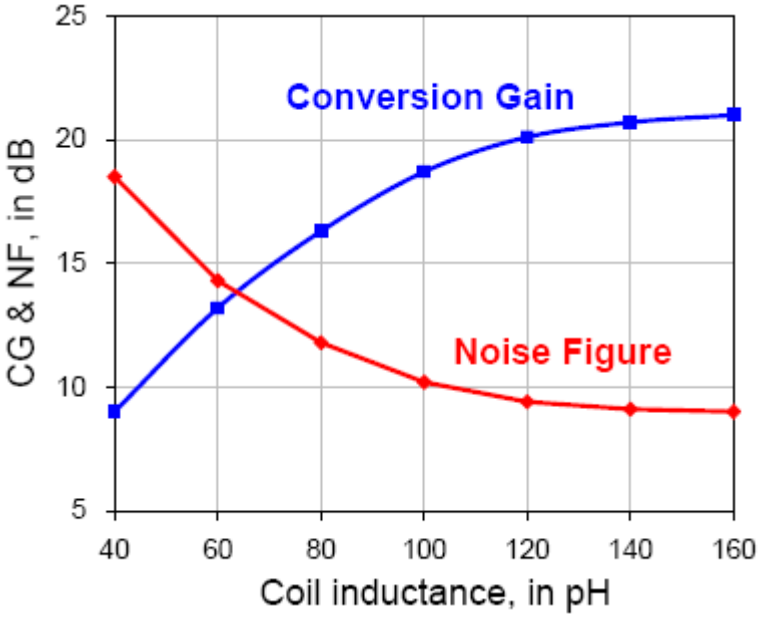
Double-balanced Mixer



- On-chip balun for RF & LO port
- Neutralized transconductance stage
- Interstage coupling transformer
  - separate biasing
  - resonate out the parasitics
- Transimpedance amplifier
  - suppress voltage swing

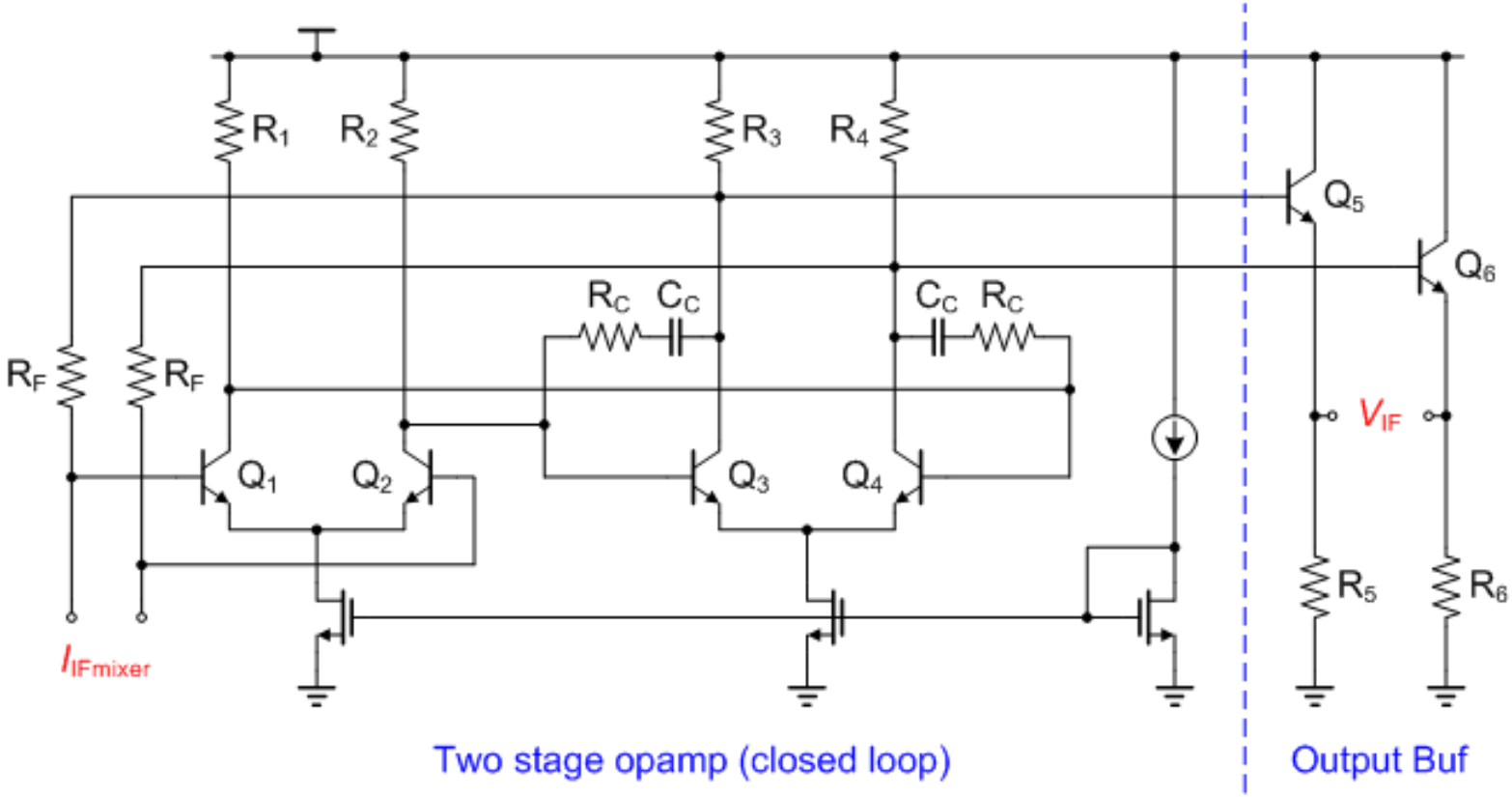
Interstage coupling transformer





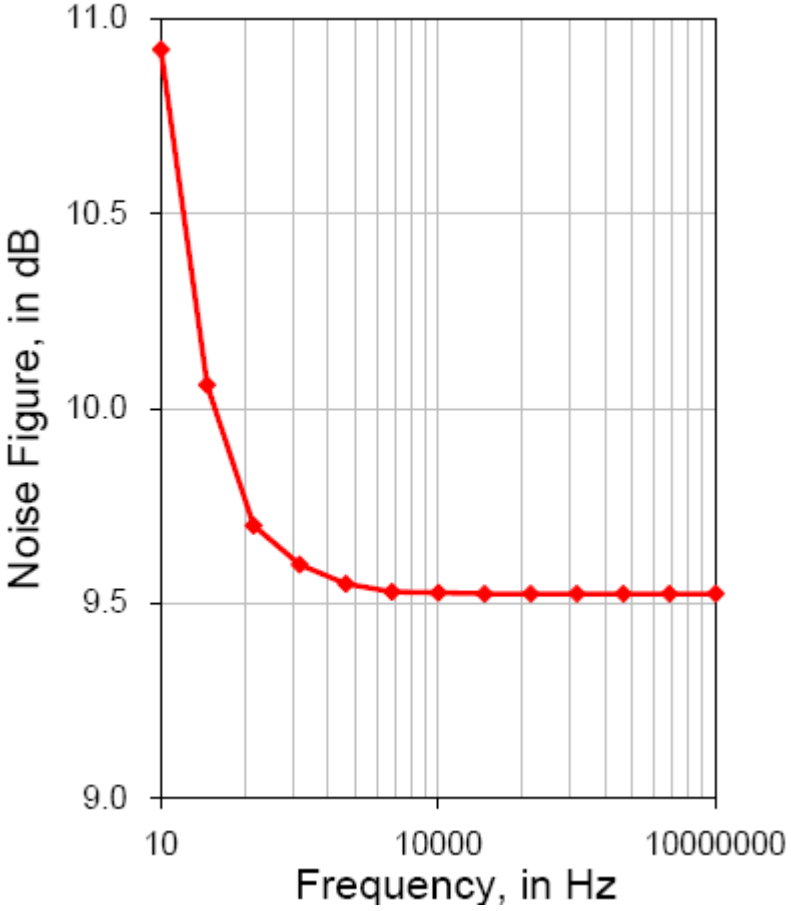
- Improve conversion gain
- Filter out-of-band noise
- Reject undesired harmonics
- Reduce supply voltage

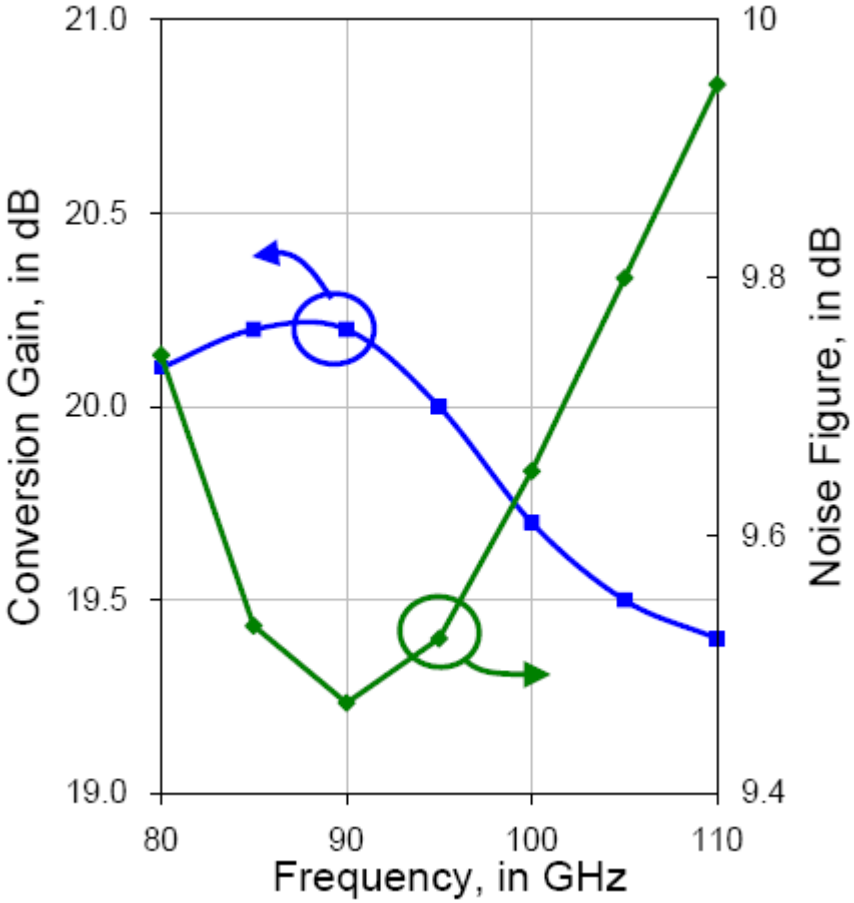
Transimpedance Amplifier



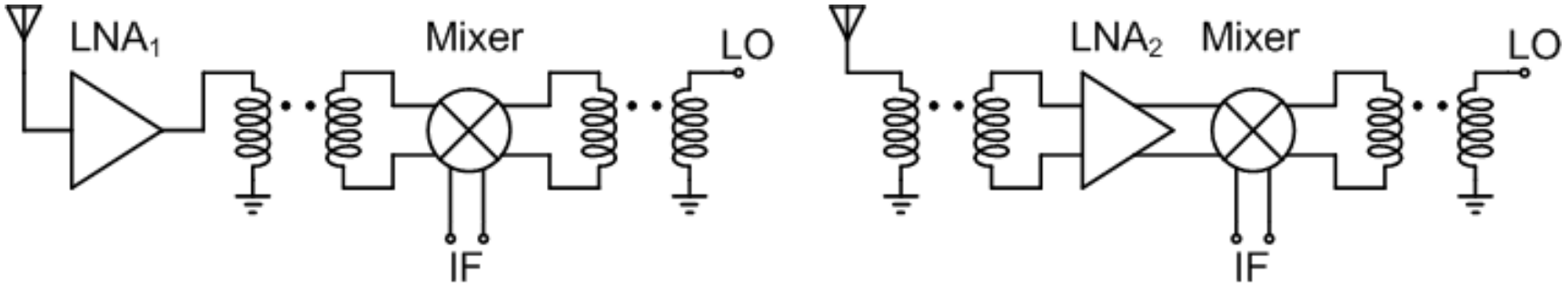
- P+ unsilicided active (diffusion) resistor for low 1/f noise
- Output buffer included for measurement purposes

Mixer performance (post-layout)





Receiver Performance



	Receiver (left)	Receiver (right)
Supply Voltage	1.5 V	1.5 V
Conversion Gain	39 dB	42 dB
Noise Figure (SSB)	9.5 dB	9.2 dB
RF Bandwidth	15 GHz	21 GHz
Power Consumption	22.5 mW	31.5 mW
Chip Area	0.6×0.7 mm^2	0.6×0.8 mm^2
Technology	0.13-um SiGe BiCMOS	

Conclusion

- Neutralization technique improves power gain, stability and reverse isolation, which extends the transistor operating range.
- Transformer-based balun, interstage coupler can be extensively used in mm-wave circuits.
- Receiver with 40-dB gain, 6-dB NF and 20-GHz BW is designed at W-band, which permits the imaging radar has the detection resolution better than 1-cm.

Thank you for your attention!