A 19-GHz Broadband Amplifier Using a g_m-Boosted Cascode in 0.18-µm CMOS

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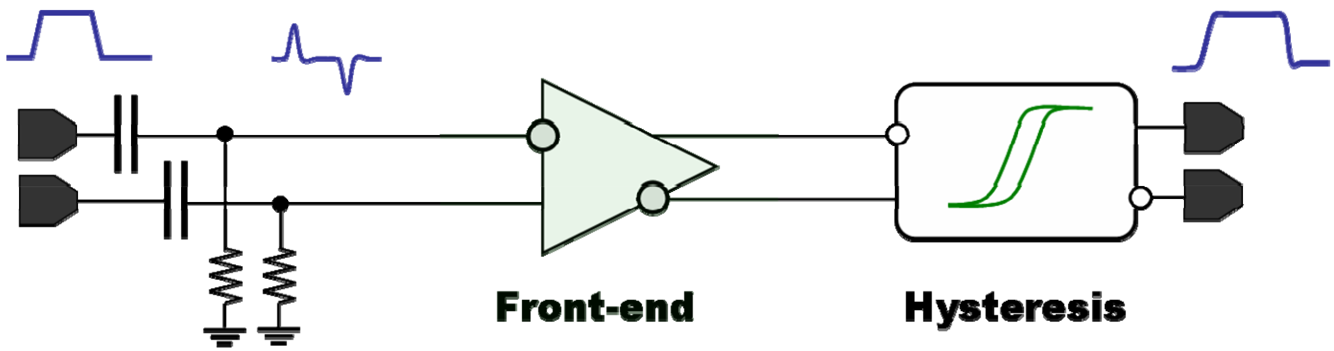
Outline

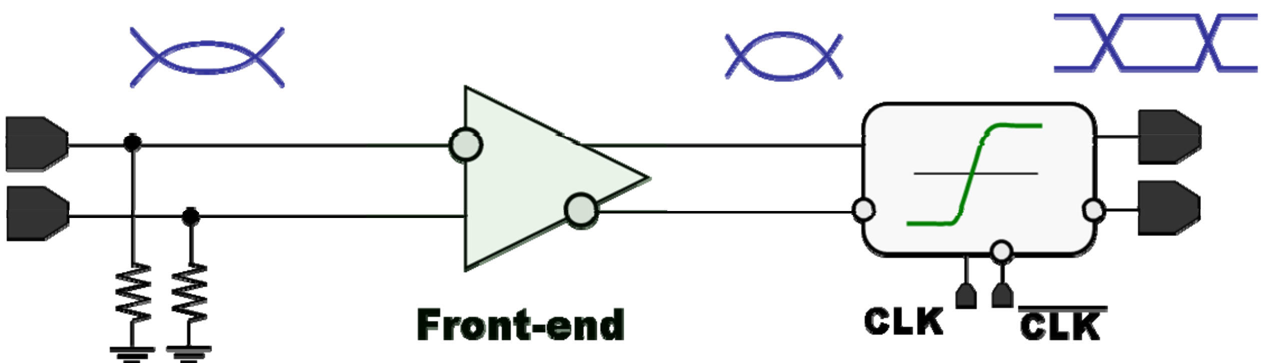
- Applications
- g_m-Boosting for bandwidth enhancement
- Differential pre-amplifier employing passive g_m-boosting
- Full front end amplifier
- Conclusions

Applications

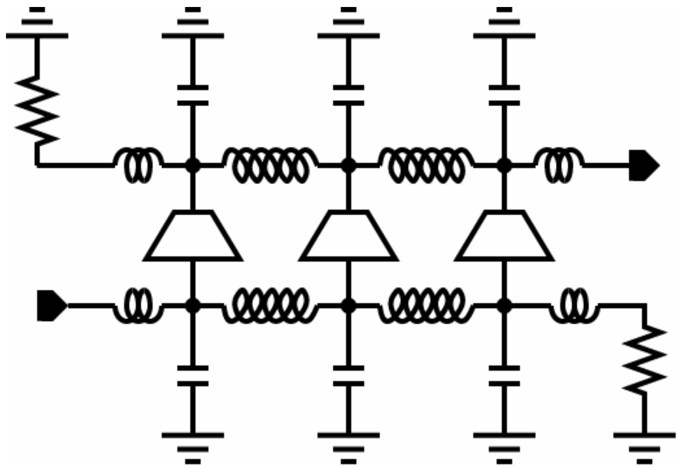
AC-coupled receiver front end:



Serial link receiver front end:

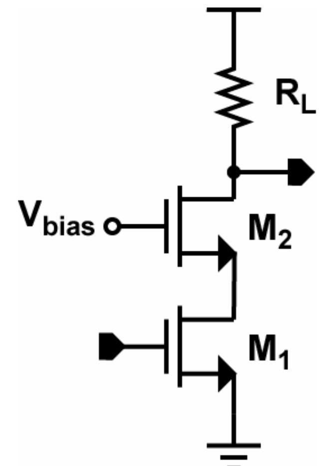


Pre-amp Topology



Distributed Amplifier

- ✓ High bandwidth
- ✖ Large area
- ✖ High power consumption
- ✖ Difficult to achieve constant group delay

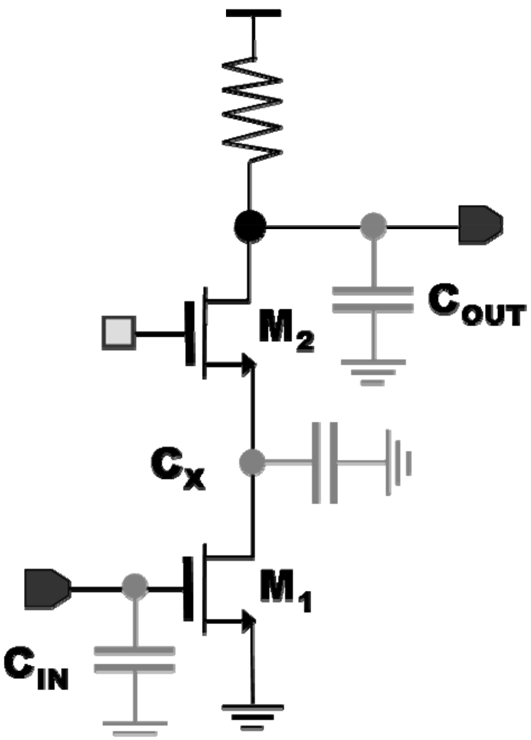


Cascode Amplifier

- ✓ Low power
- ✖ High VDD due to stacked transistors
- ✖ Bandwidth limited by node capacitances

Standard CMOS Cascode

3 time constants of simple cascode:

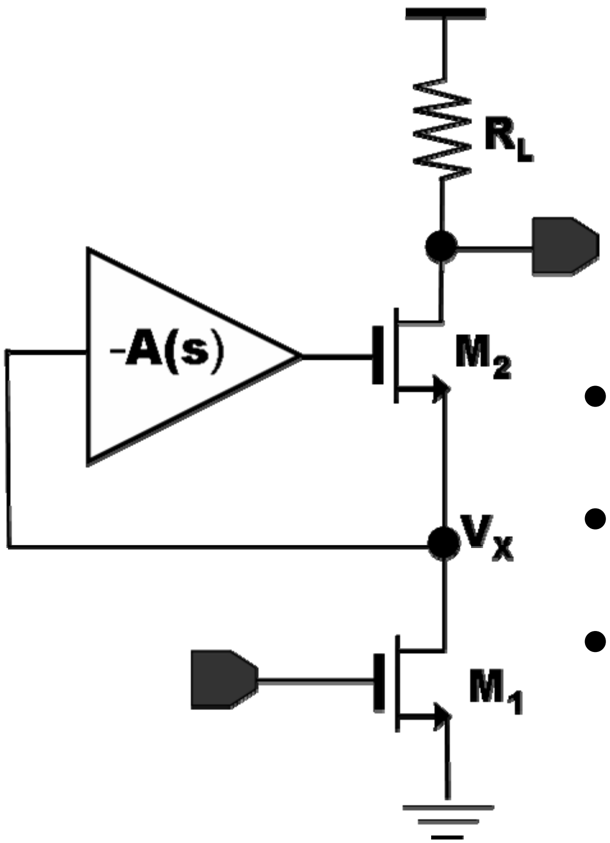


$$\tau_{out} = \left(R_L \| r_0\right) C_{OUT}$$

$$\tau_{cascode} = \frac{C_{GS2} + C_{DB1} + C_{SB2} + 2C_{GD1}}{g_{m2}} = \frac{C_X}{g_{m2}}$$

$$\tau_{input} = R_{in} C_{in}$$

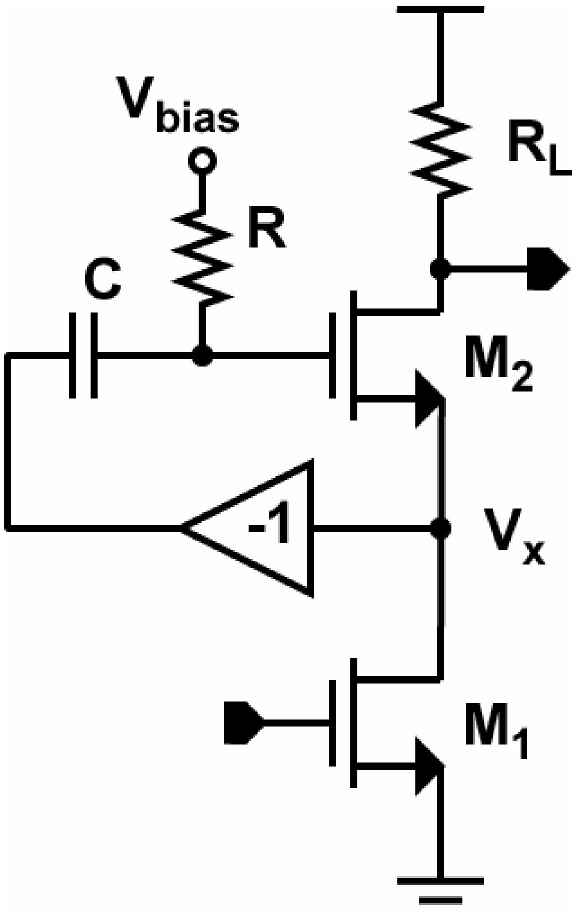
g_m-Boosted Cascode



$$g_{meff} = \left[1 + A(s)\right] g_m$$

- Increases output resistance
- **Reduces time constant at V_X**
- **Ameliorates Miller effect at the input**

g_m-Boosted Cascode



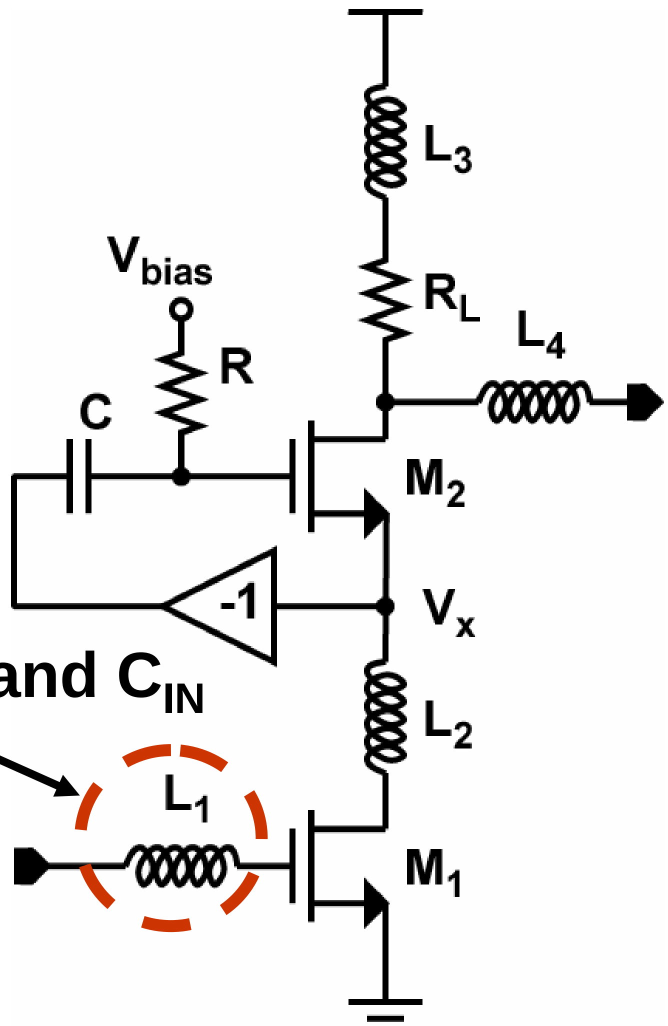
Passive g_m- boosting:

$$g_{meff} = [1 + A(s)]\, g_m$$

$$g_{meff} = g_m \quad \text{for} \; s = 0$$

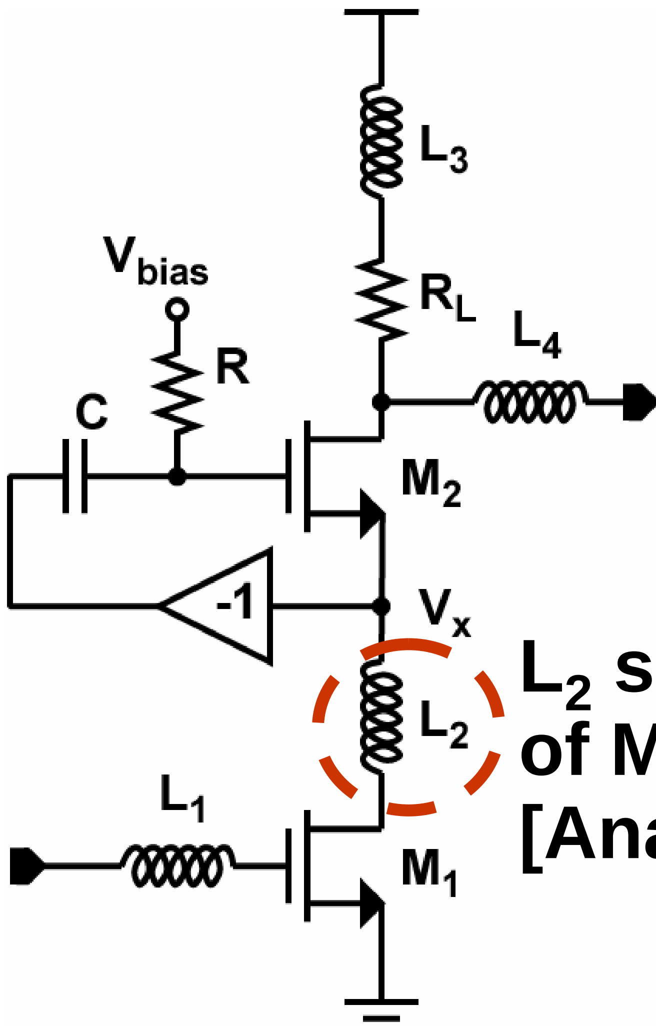
$$g_{meff} = 2g_m \quad \text{for} \; s = \infty$$

g_m-Boosted Cascode



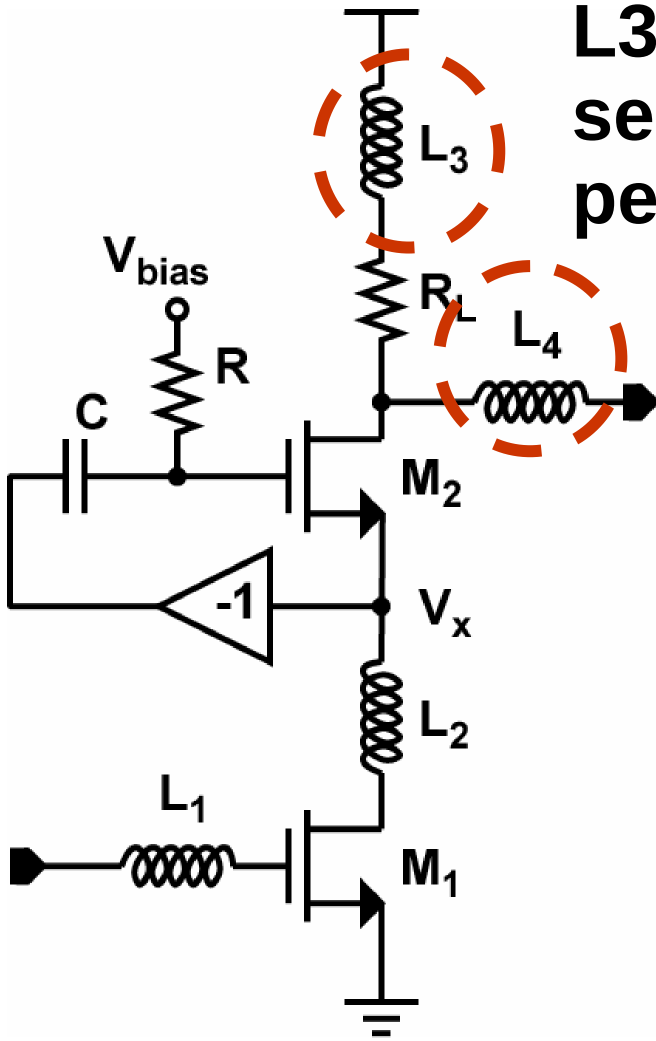
L_1 separates C_{PAD} and C_{IN} [Sackinger'05]

g_m-Boosted Cascode



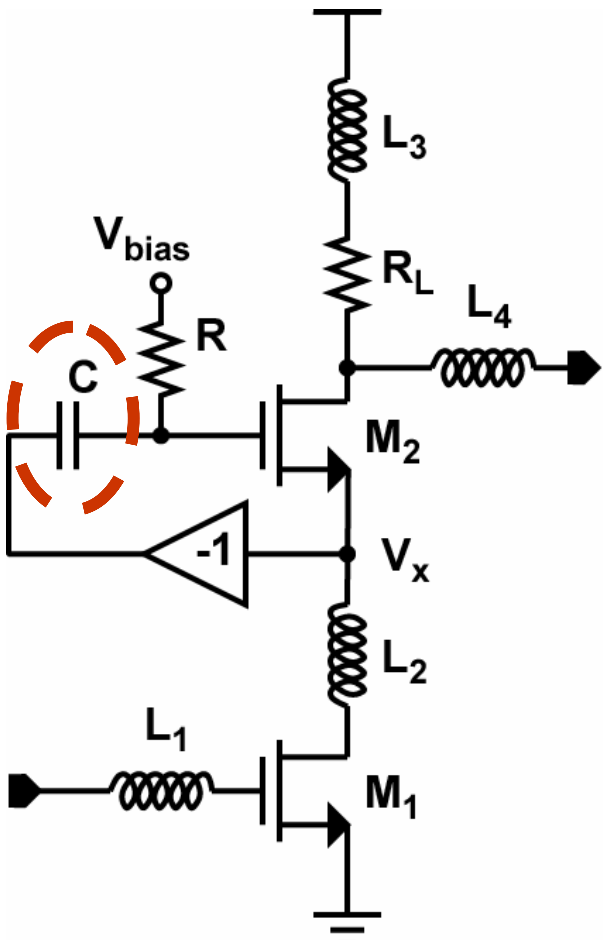
L_2 separates the C_D of M_1 and C_S of M_2 [Analui'04]

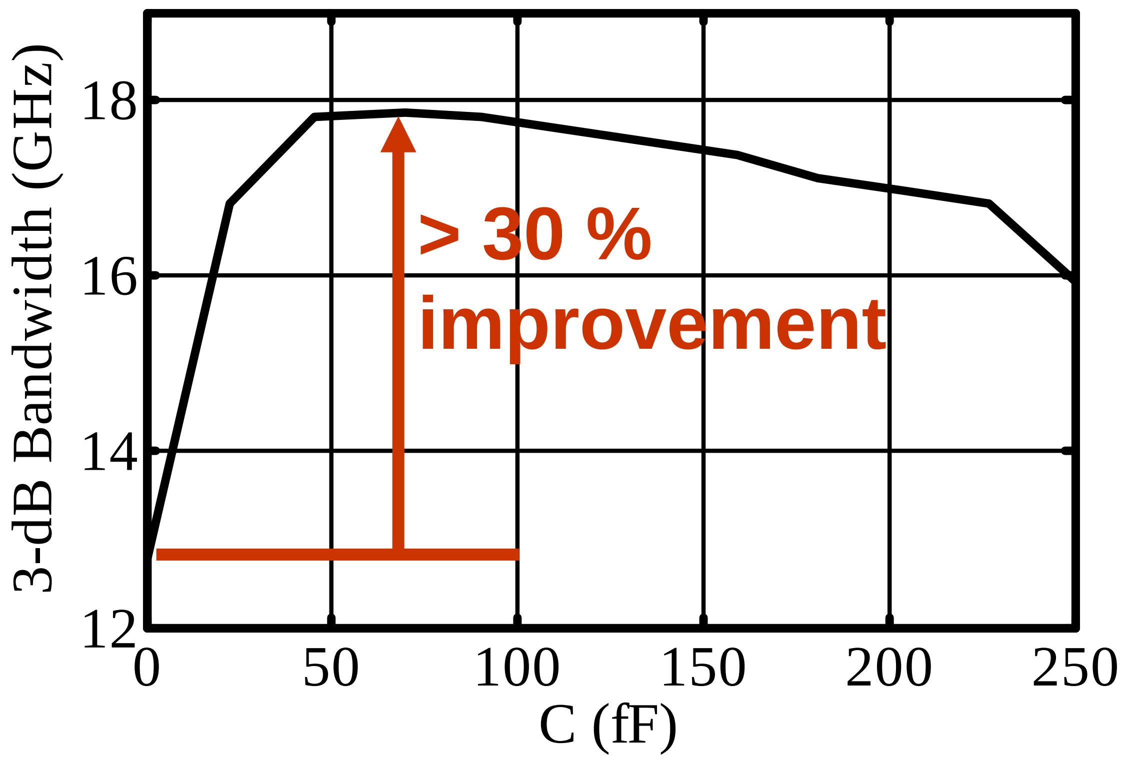
g_m-Boosted Cascode



L3 and L4 provide series and shunt peaking [Lee'04]

g_m-Boosted Cascode

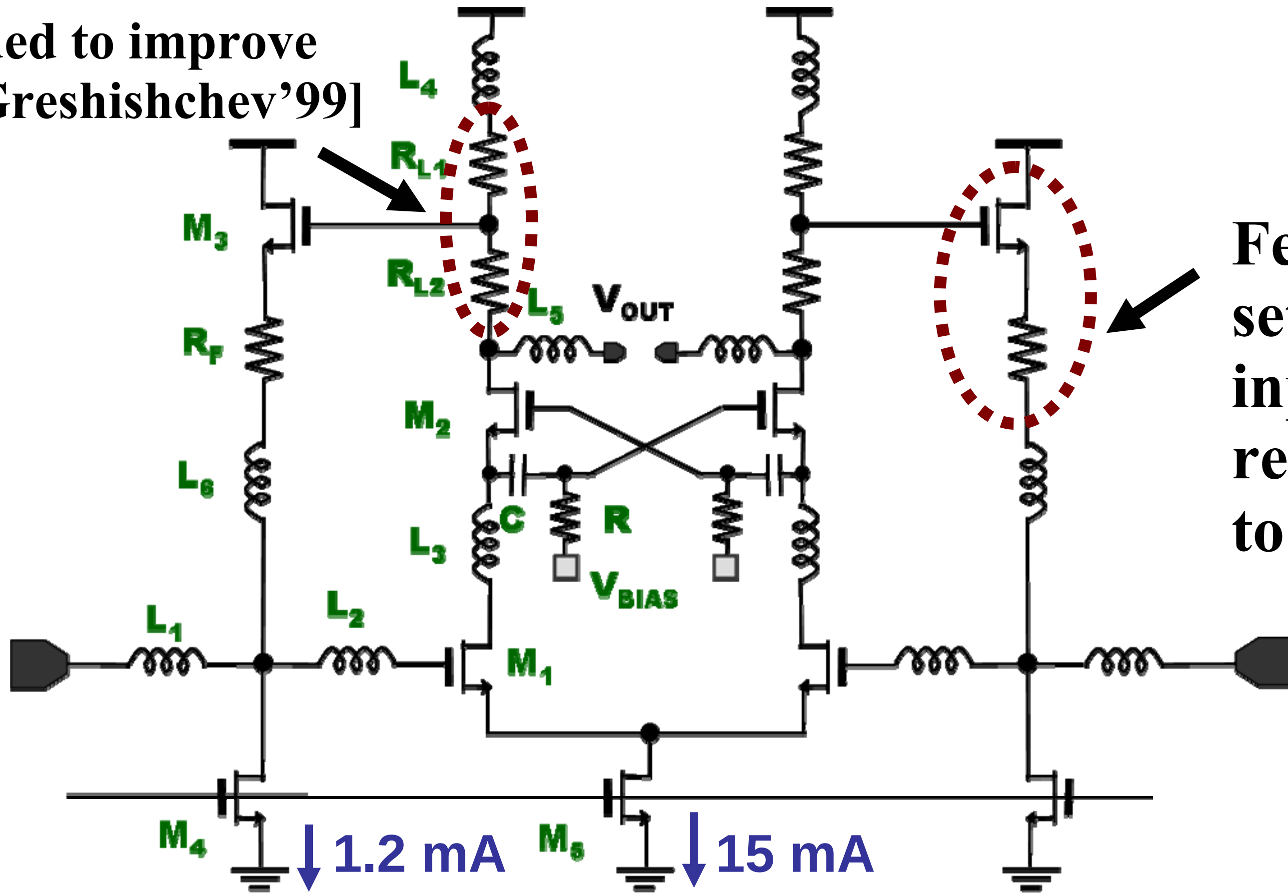




R = 500Ω

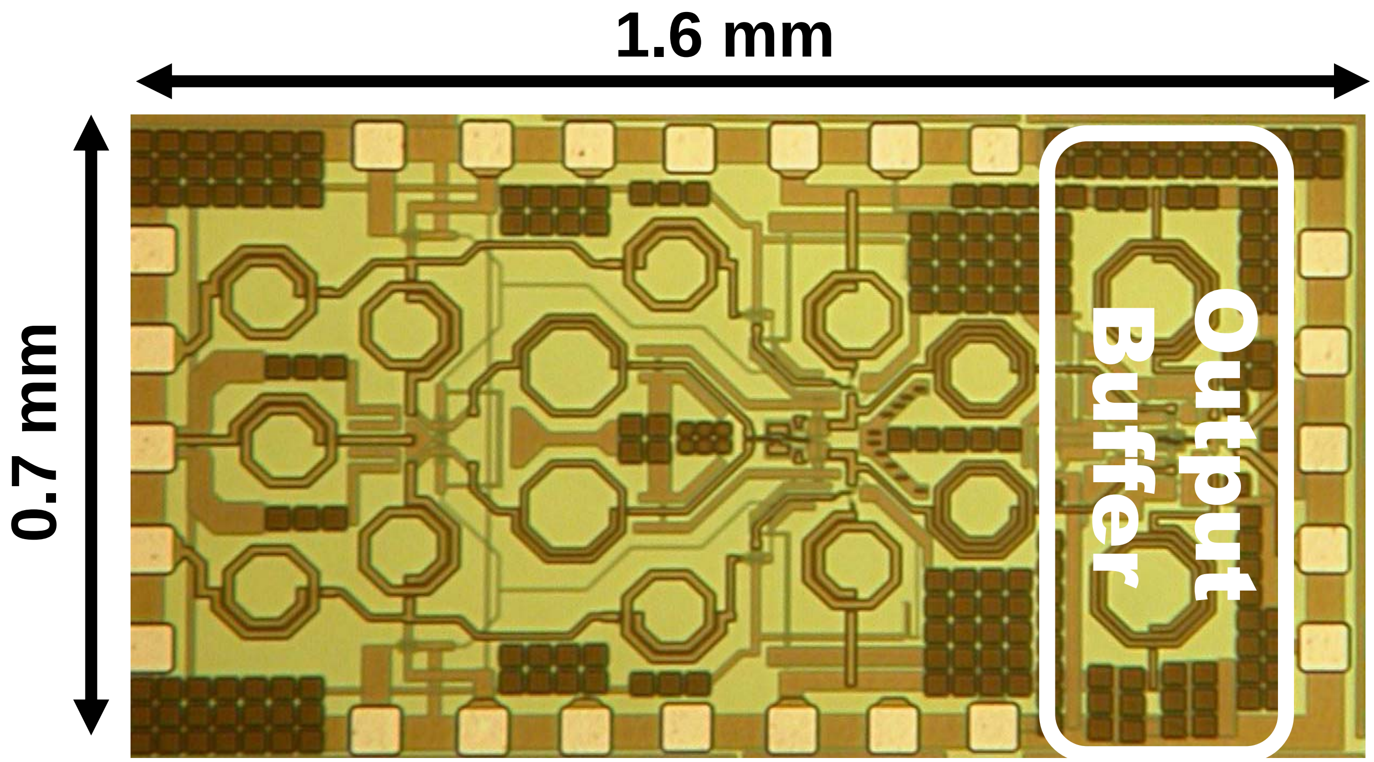
Differential g_m-Boosted Cascode

R_L is divided to improve the BW [Greshishchev'99]

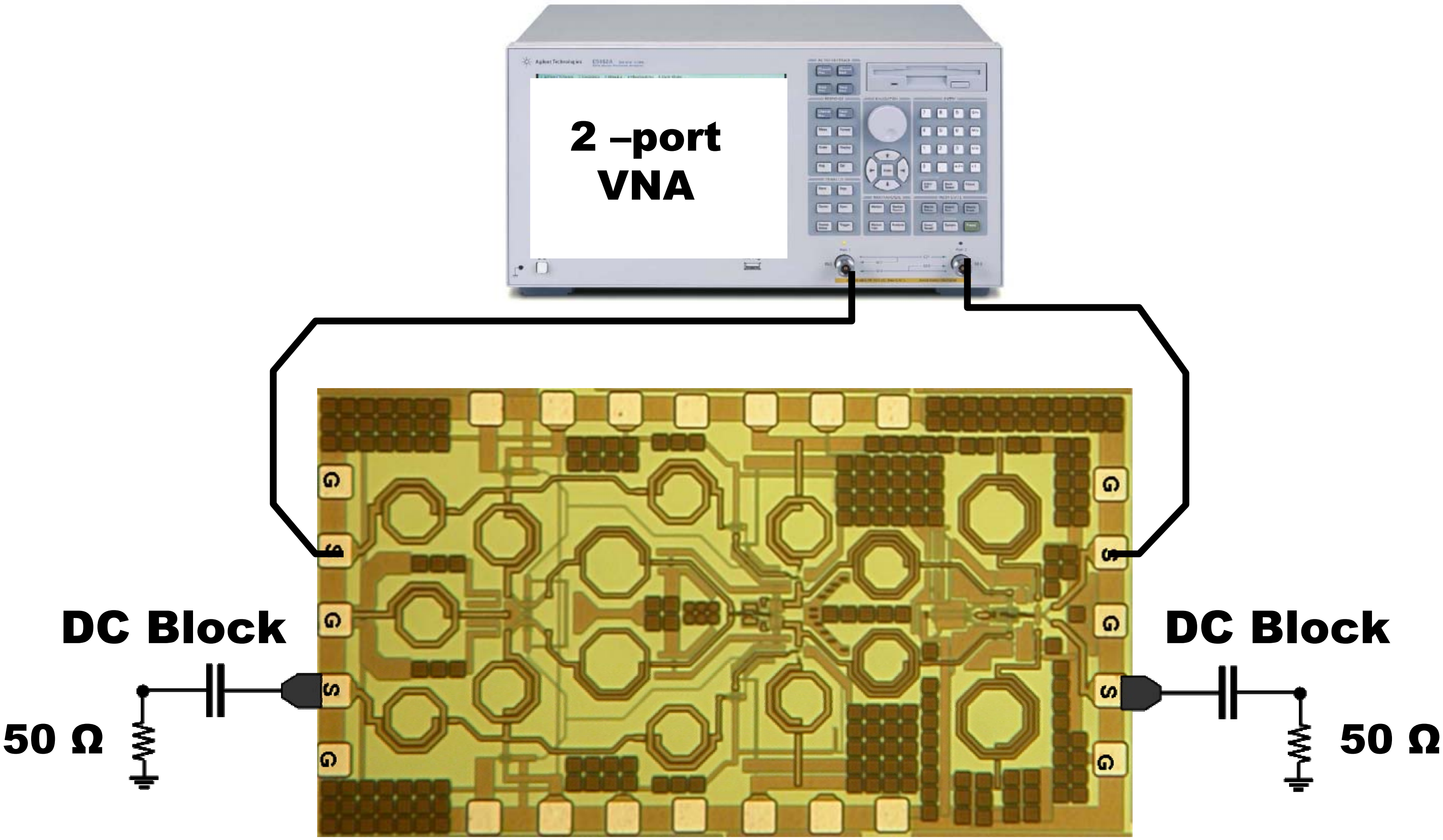


Feedback sets the input resistance to 50 Ω

Differential g_m-Boosted Cascode

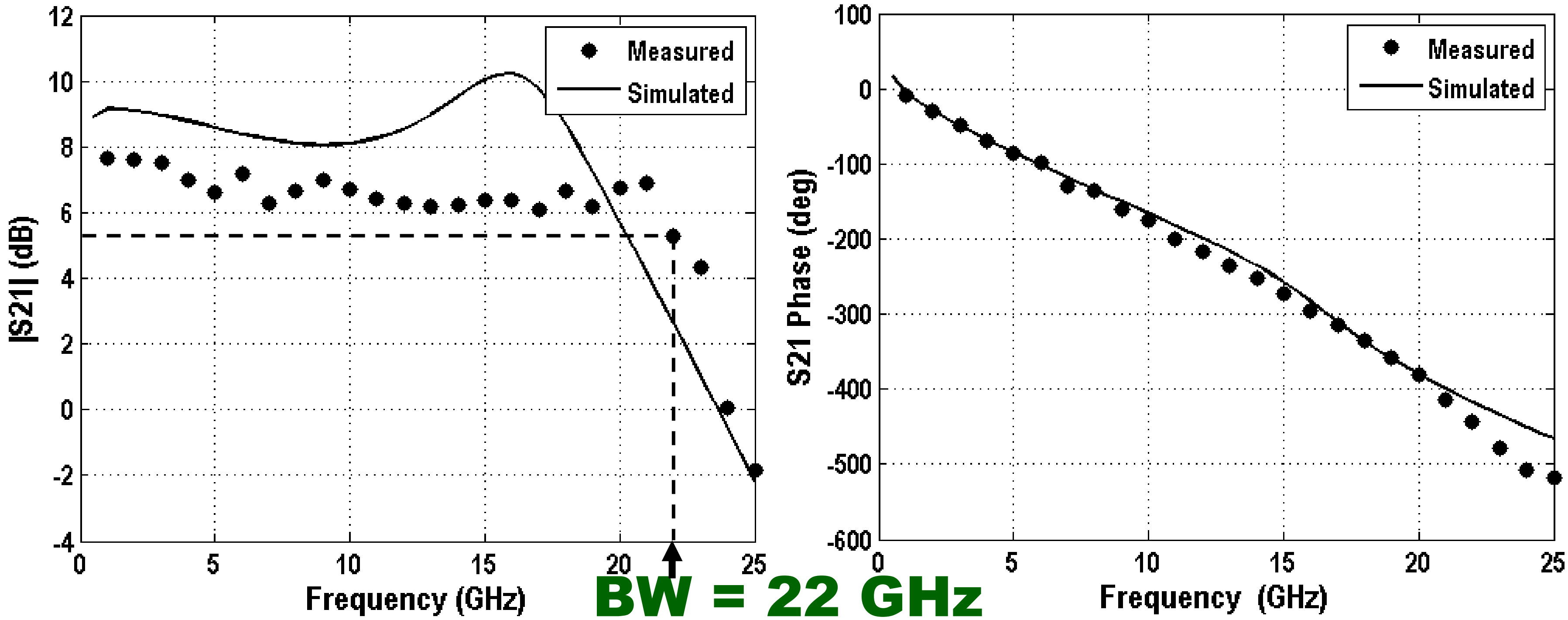


Measurement of g_m-Boosted Pre-amp



Measurement of g_m-Boosted Pre-amp

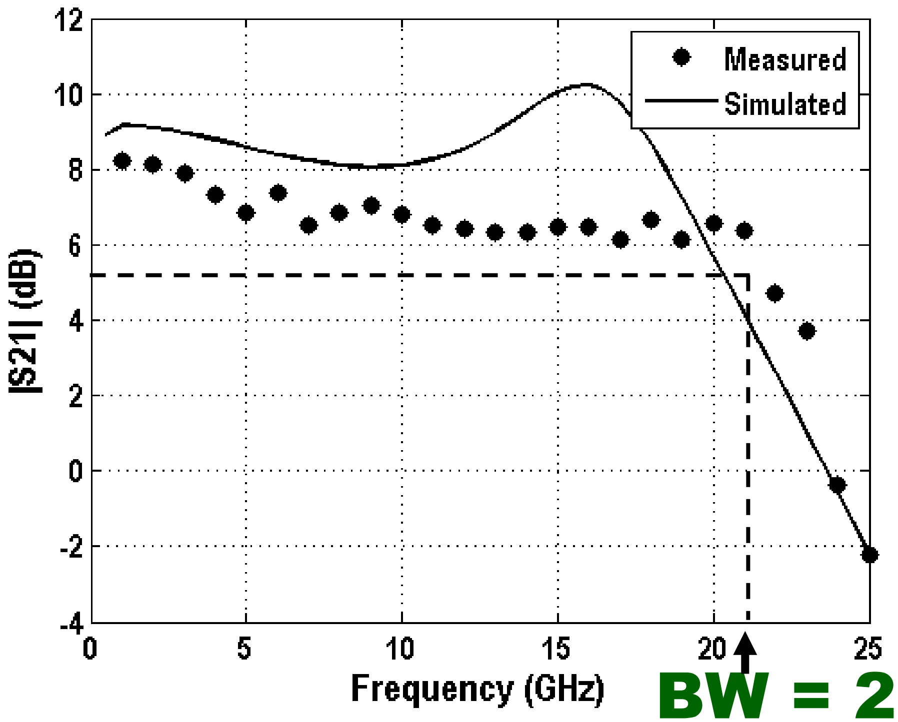
V_{DD} = 2.5 V

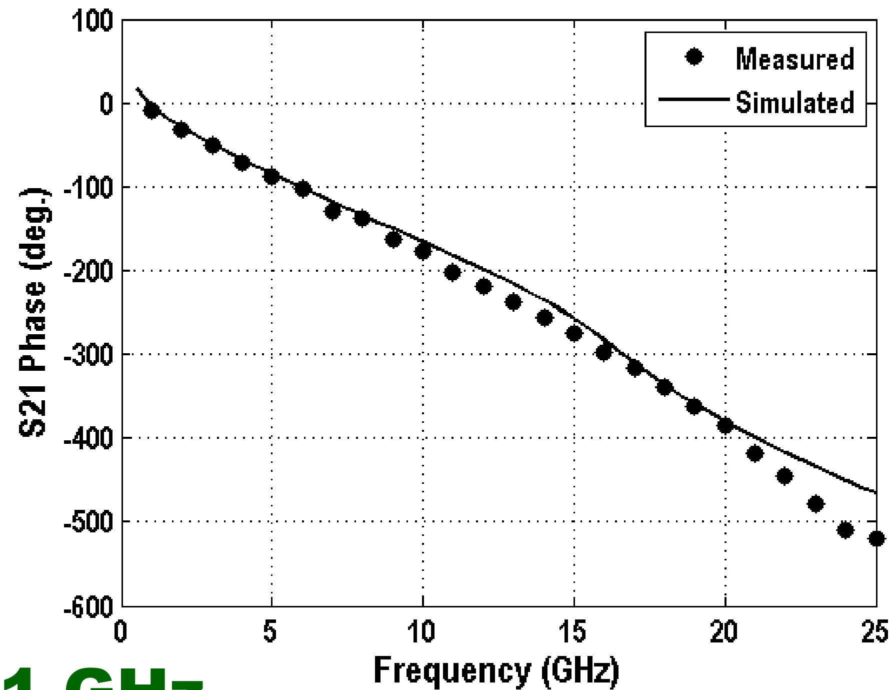


6 dB was added to the S_{21} measured on a 2-port network analyzer

Measurement of g_m-Boosted Pre-amp

V_{DD} = 2.2 V



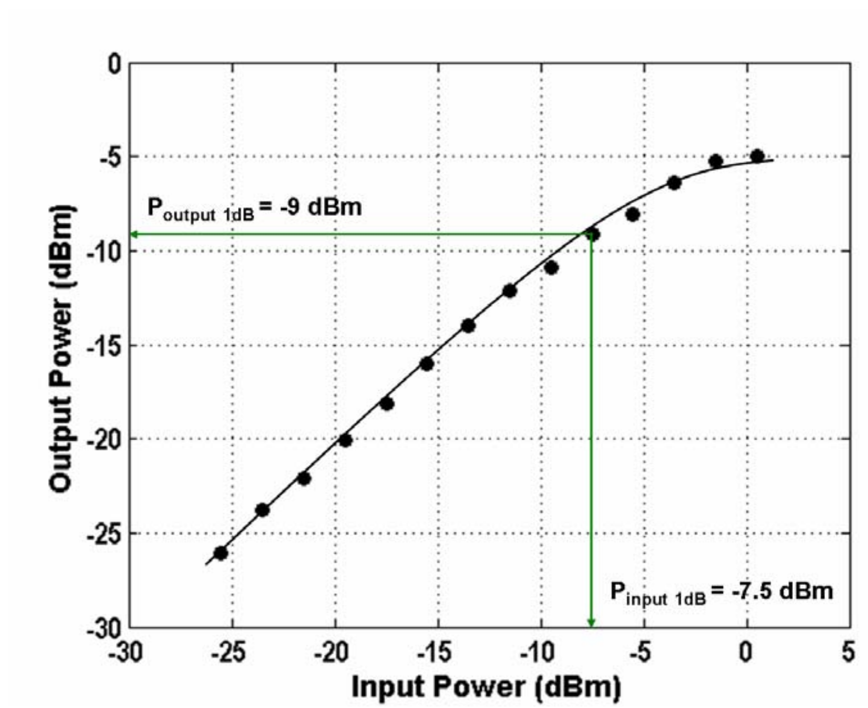


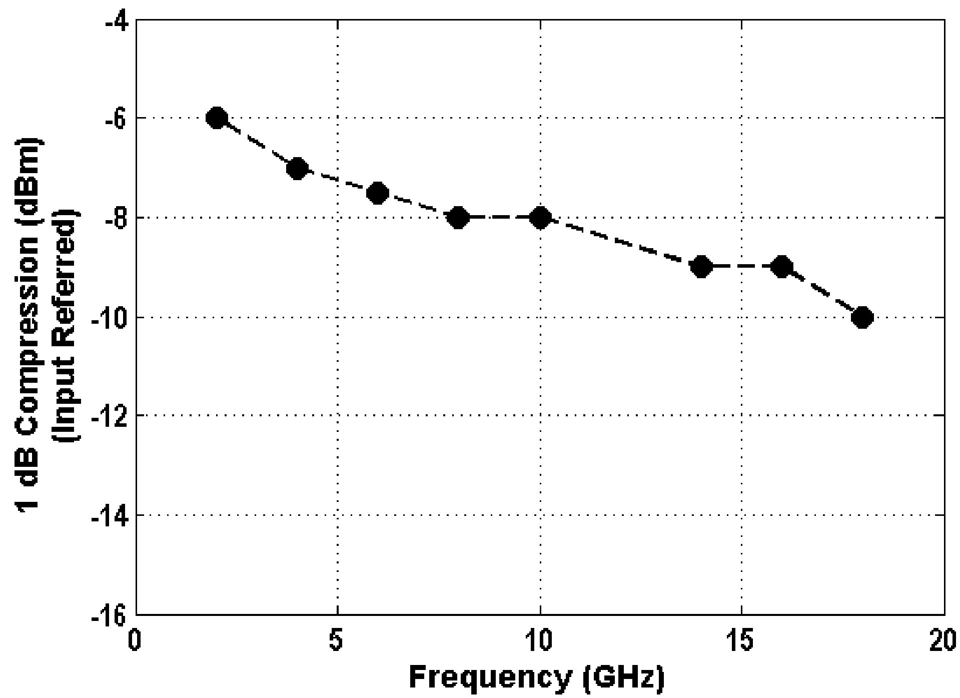
BW = 21 GHz

6 dB was added to the S_{21} measured on a 2-port network analyzer

Measurement of g_m-Boosted Pre-amp

V_{DD} = 2.5 V

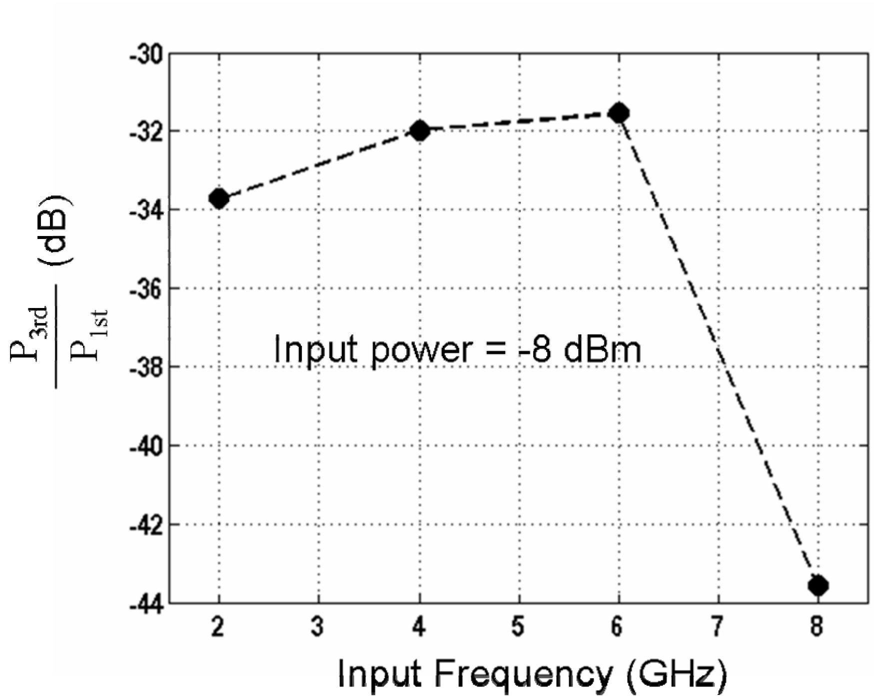


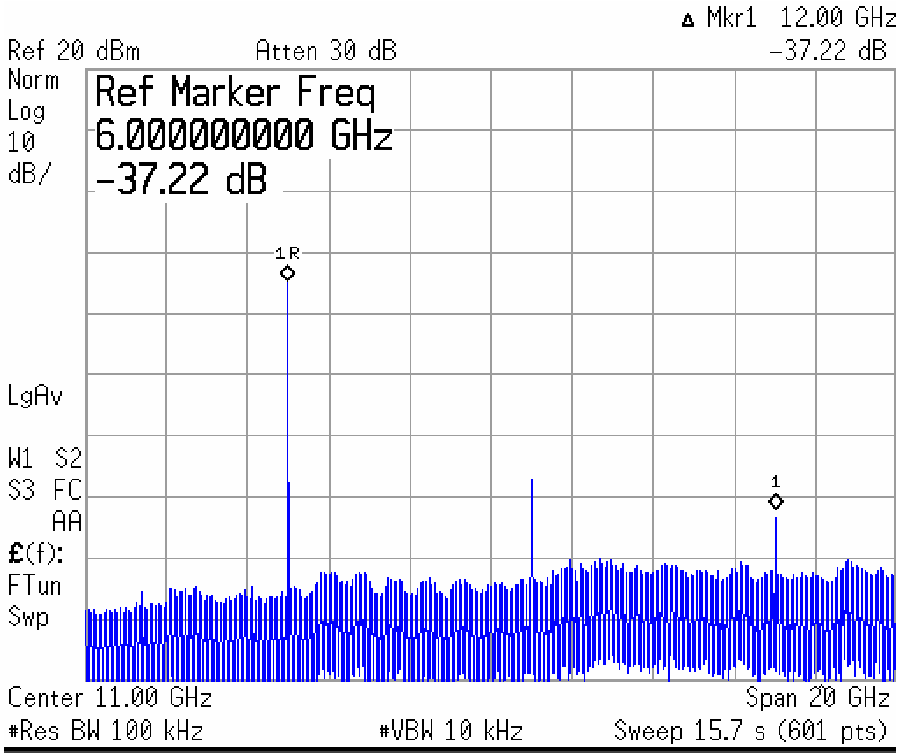


P_{1dB} for 6-GHz input

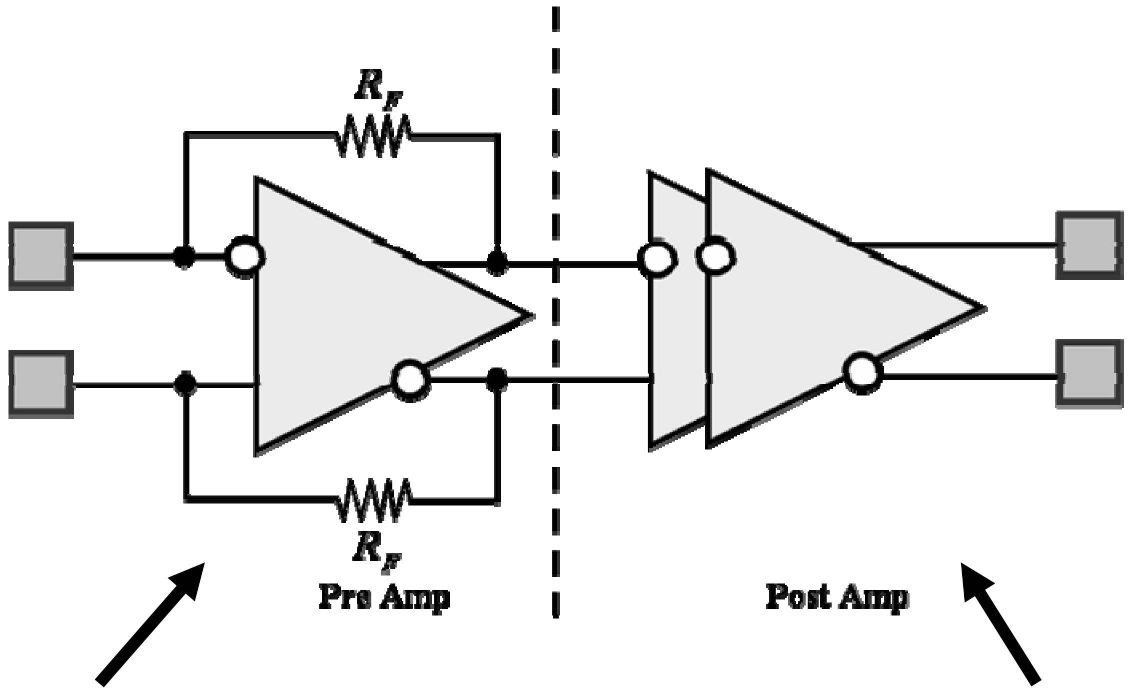
Measurement of g_m-Boosted Pre-amp

V_{DD} = 2.5 V





Full Front End Design

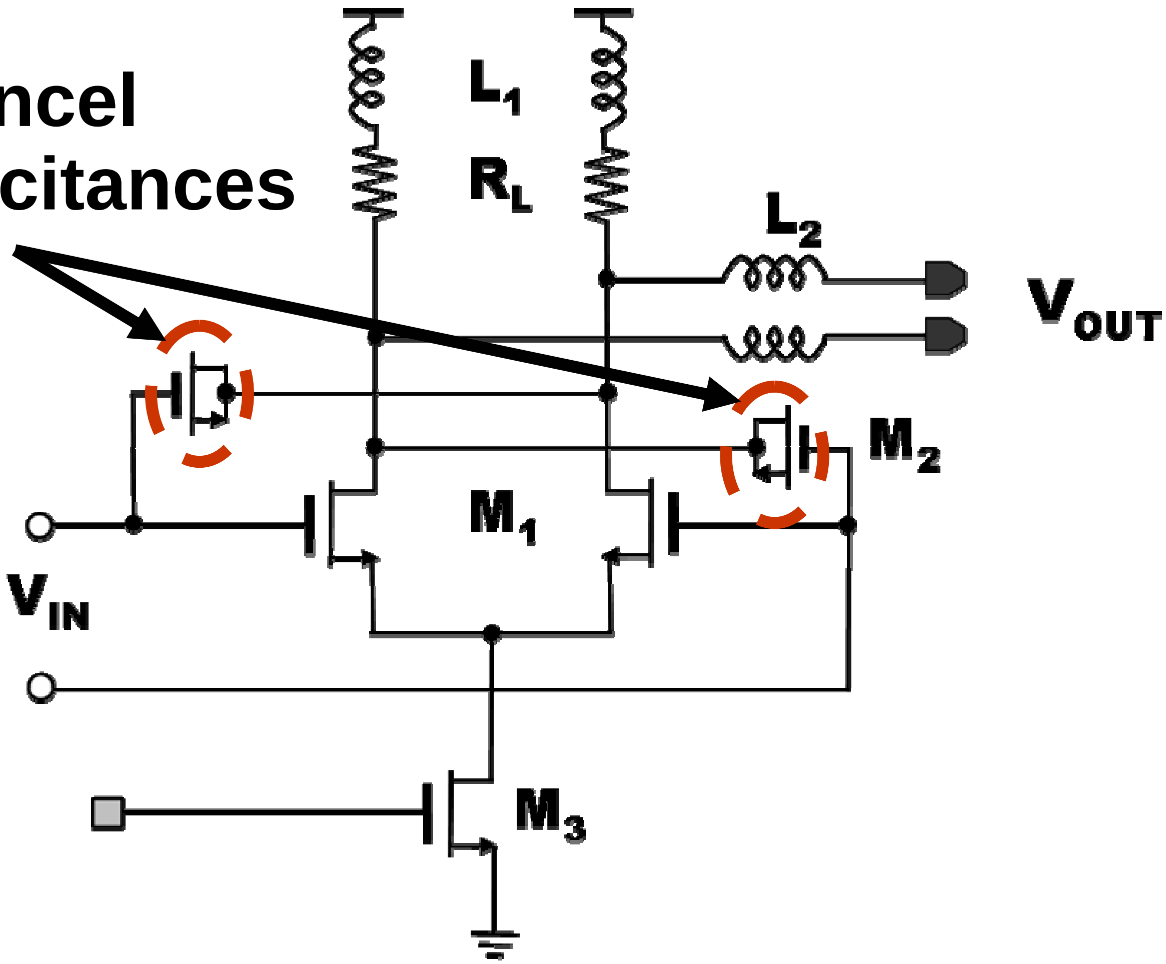


- Bandwidth > 20 GHz
- Constant group delay
- Gain > 6 dB
- 50-Ω Input Matching

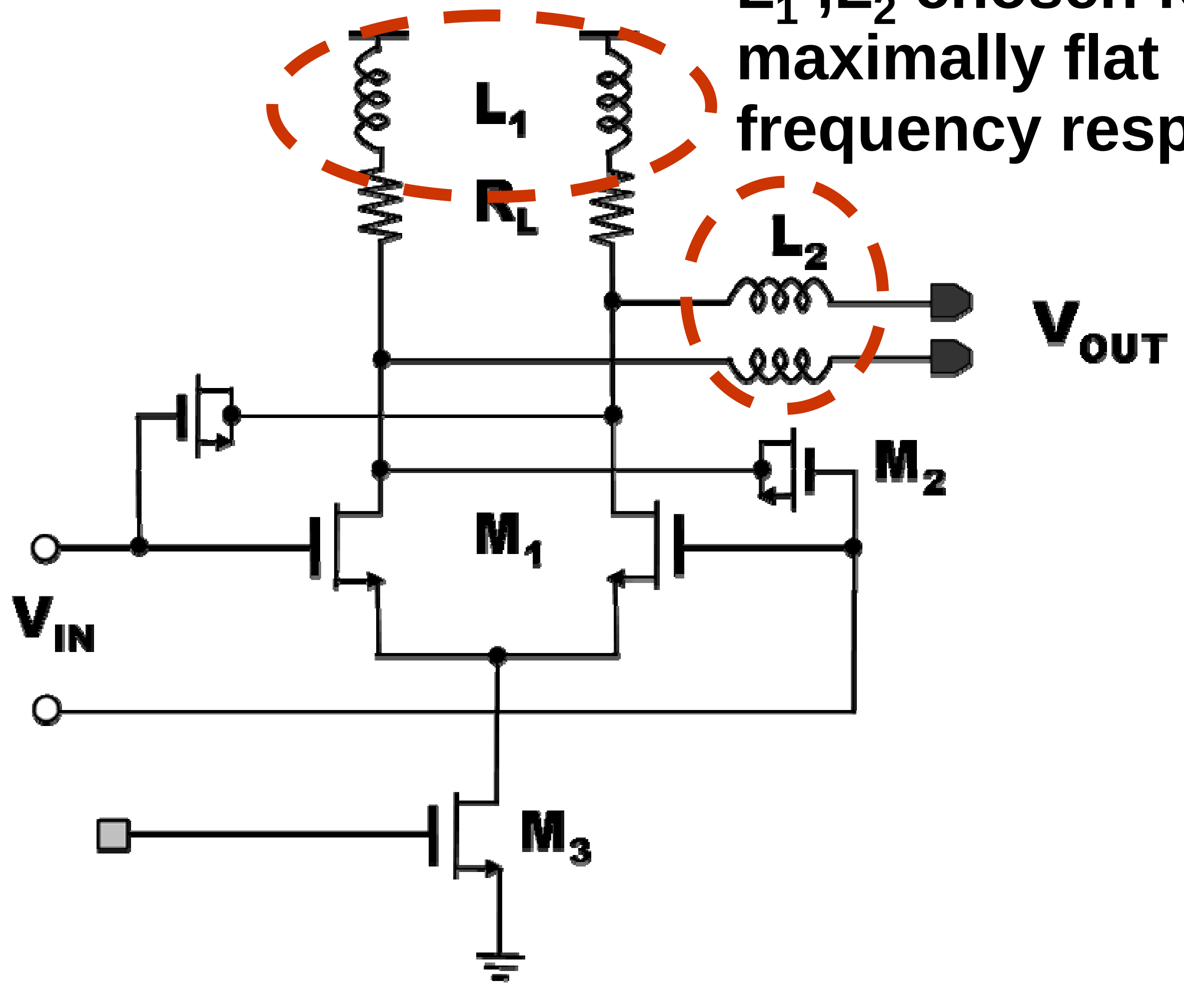
- Bandwidth > 20 GHz
- Constant group delay
- Gain > 4 dB
- 50-Ω output driver

Post-amplifier

Used to cancel Miller capacitances

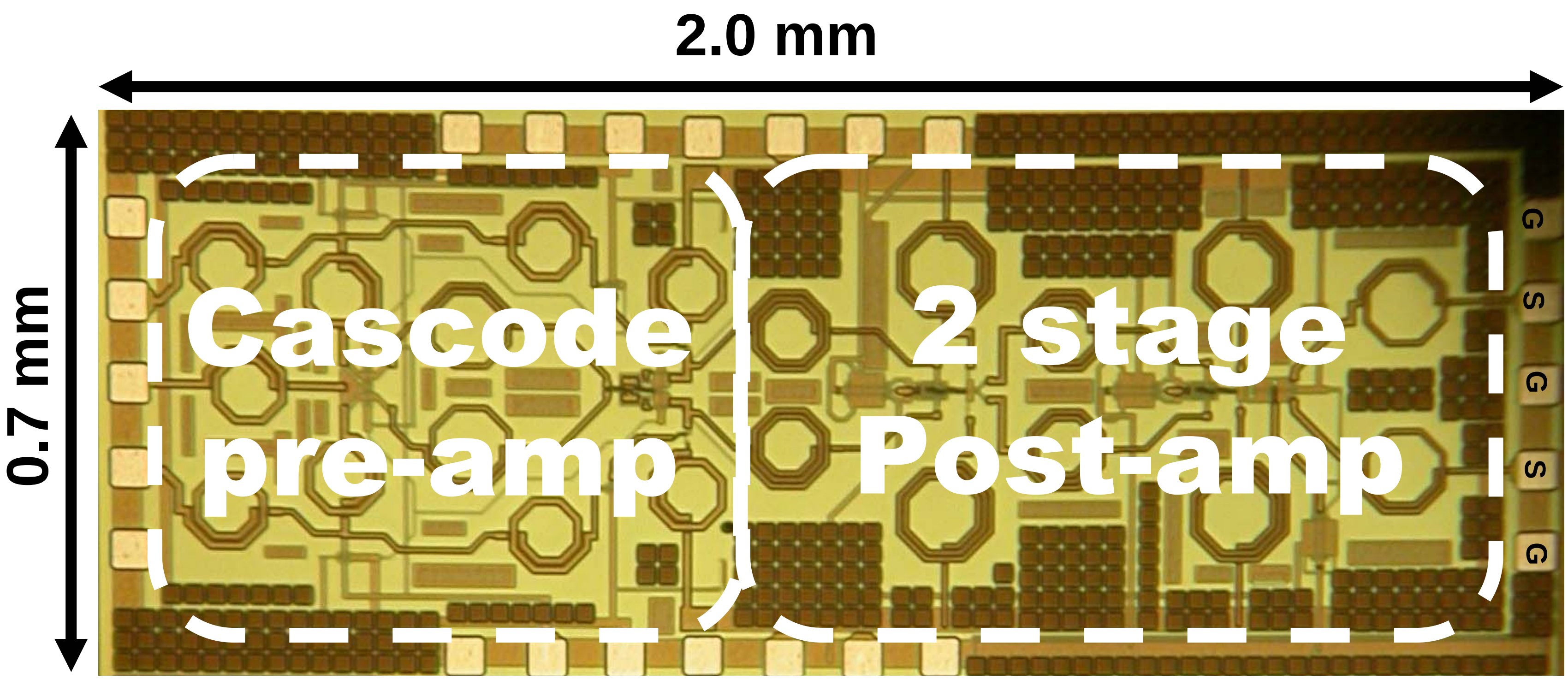


Post-amplifier



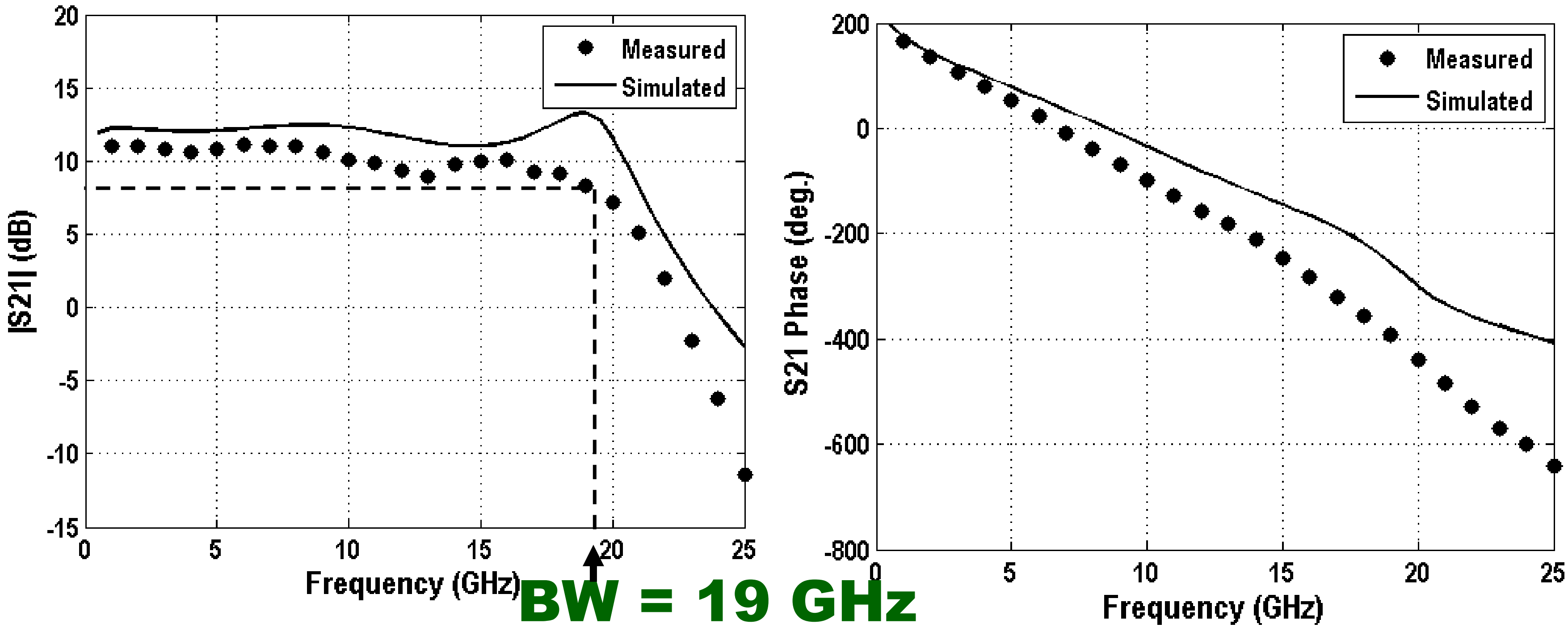
L_1 ,L_2 chosen for maximally flat frequency response

Full Front End



Measurement of Full Front End

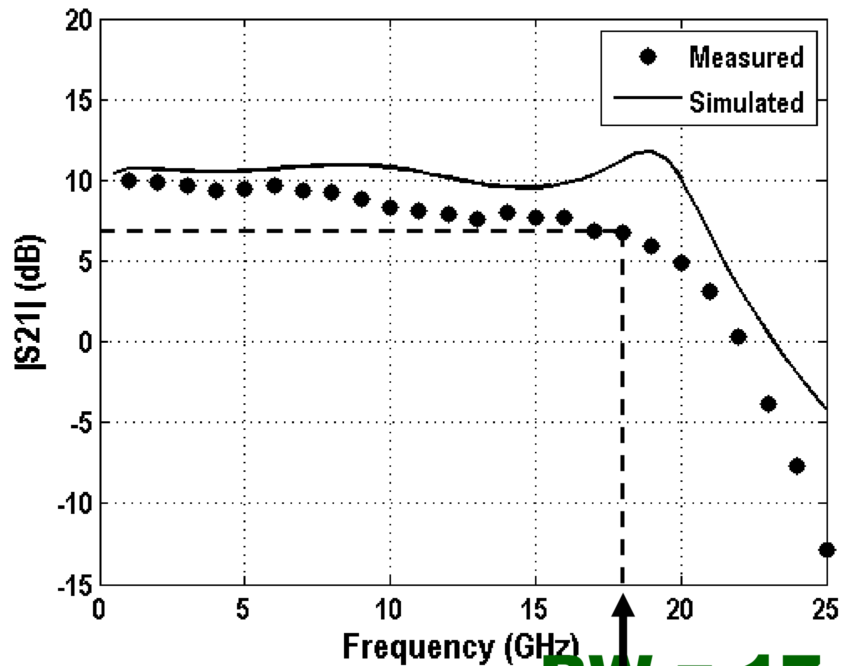
V_{DD} = 2.5 V

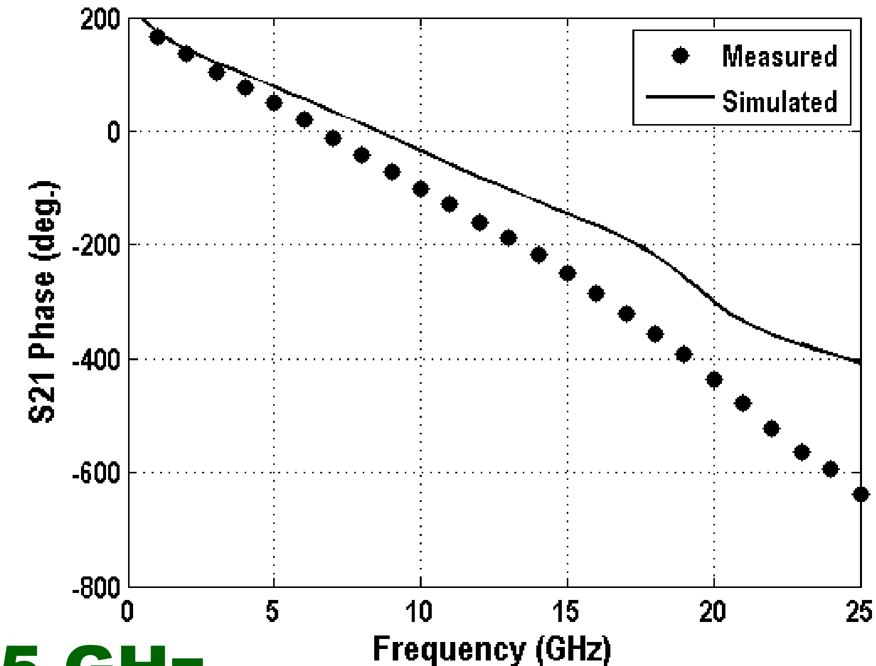


6 dB was added to the S_{21} measured on a 2-port network analyzer

Measurement of Full Front End

V_{DD} = 2.2 V



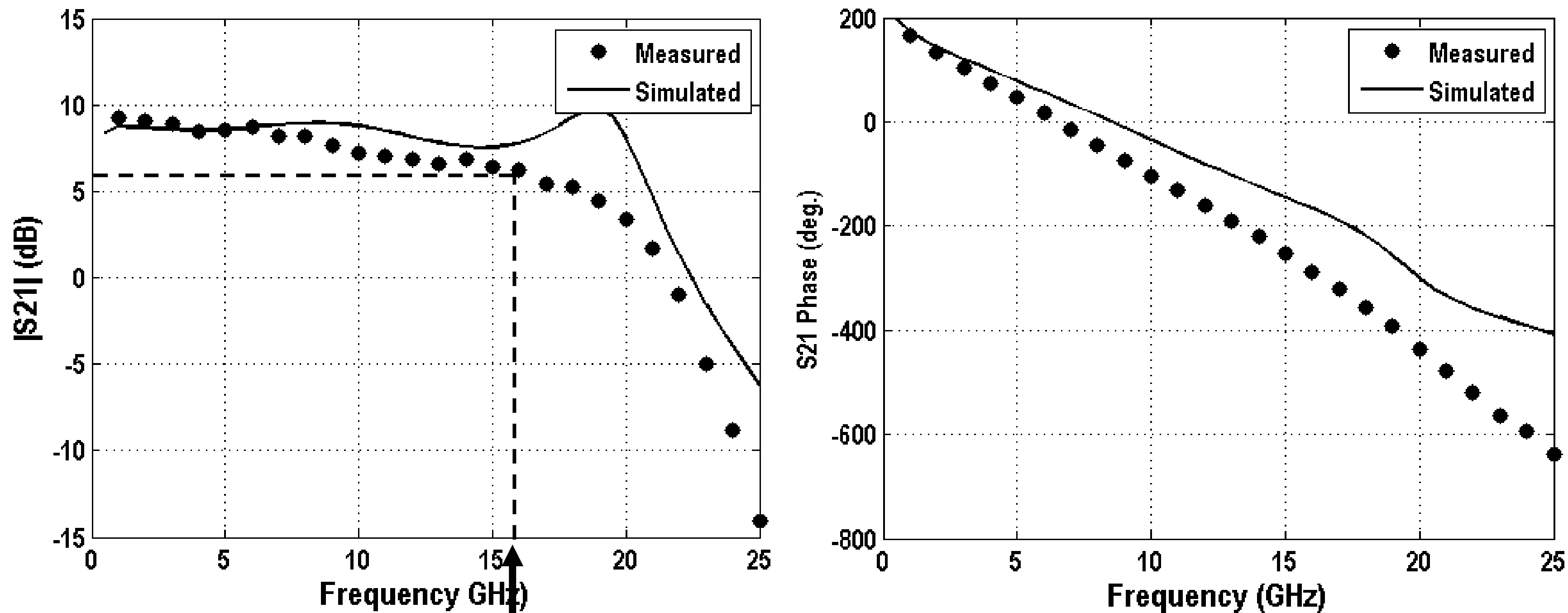


BW = 17.5 GHz

6 dB was added to the S_{21} measured on a 2-port network analyzer

Measurement of Full Front End

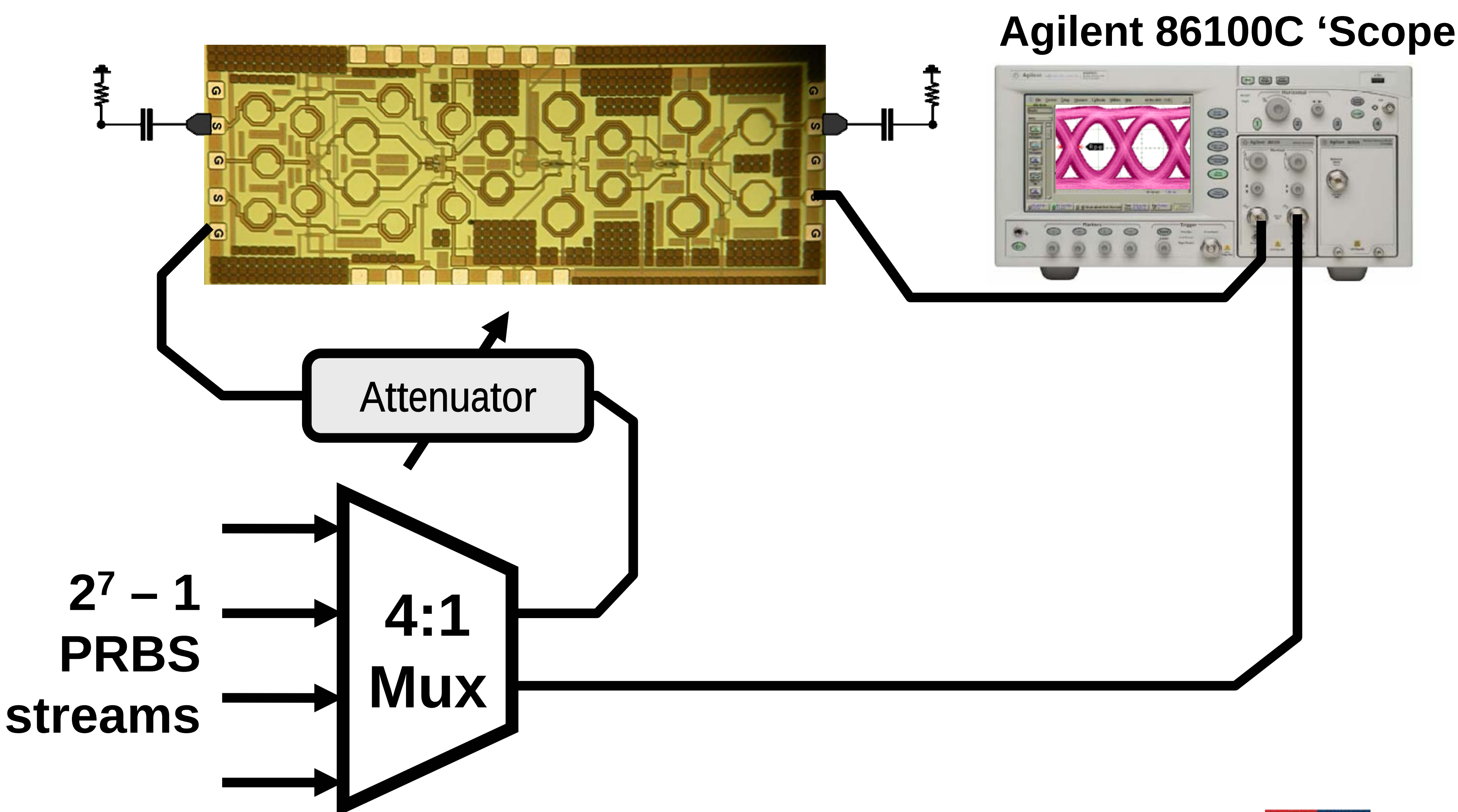
V_{DD} = 2.0 V



BW = 16 GHz

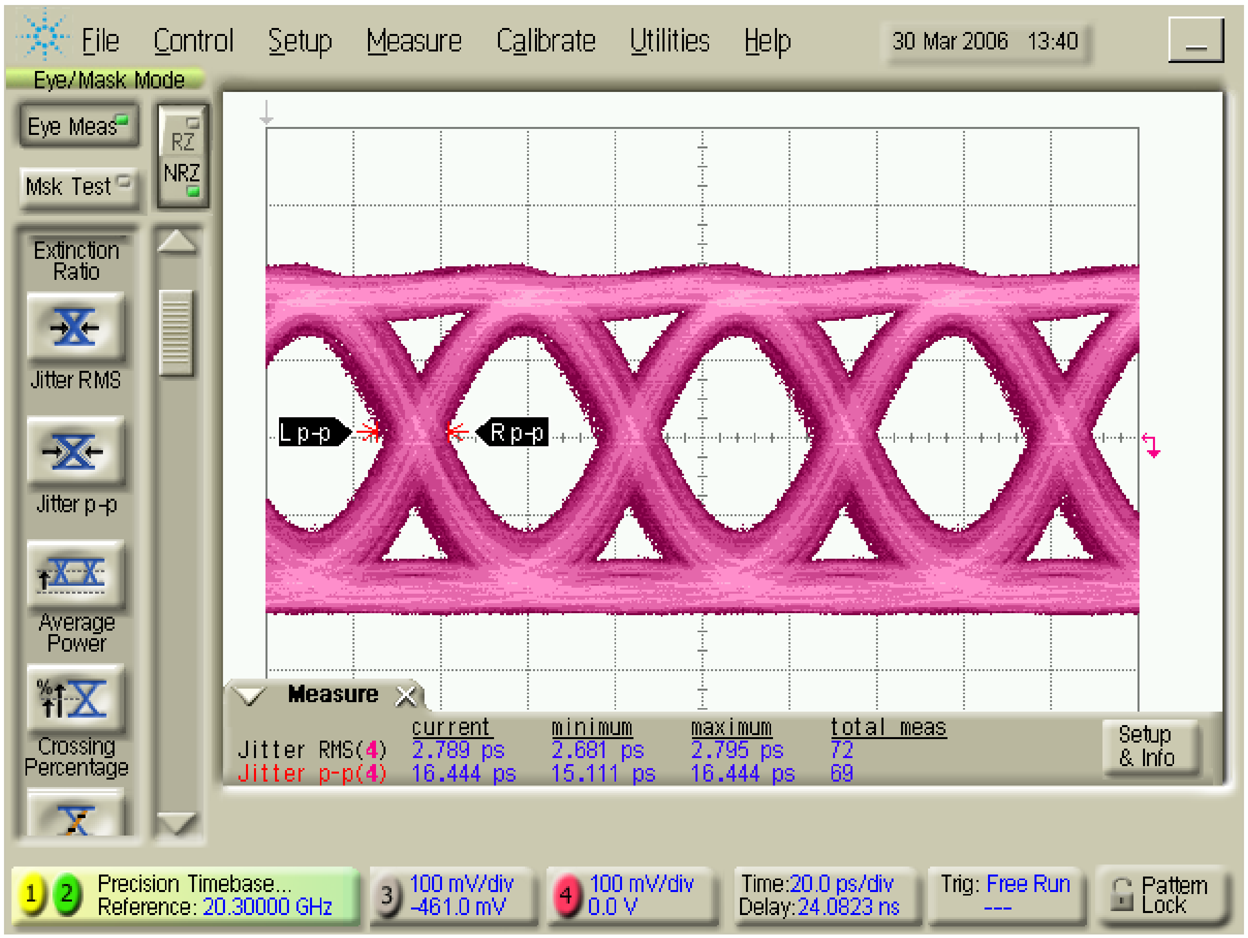
6 dB was added to the S_{21} measured on a 2-port network analyzer

Measurement Setup for Eye Diagrams



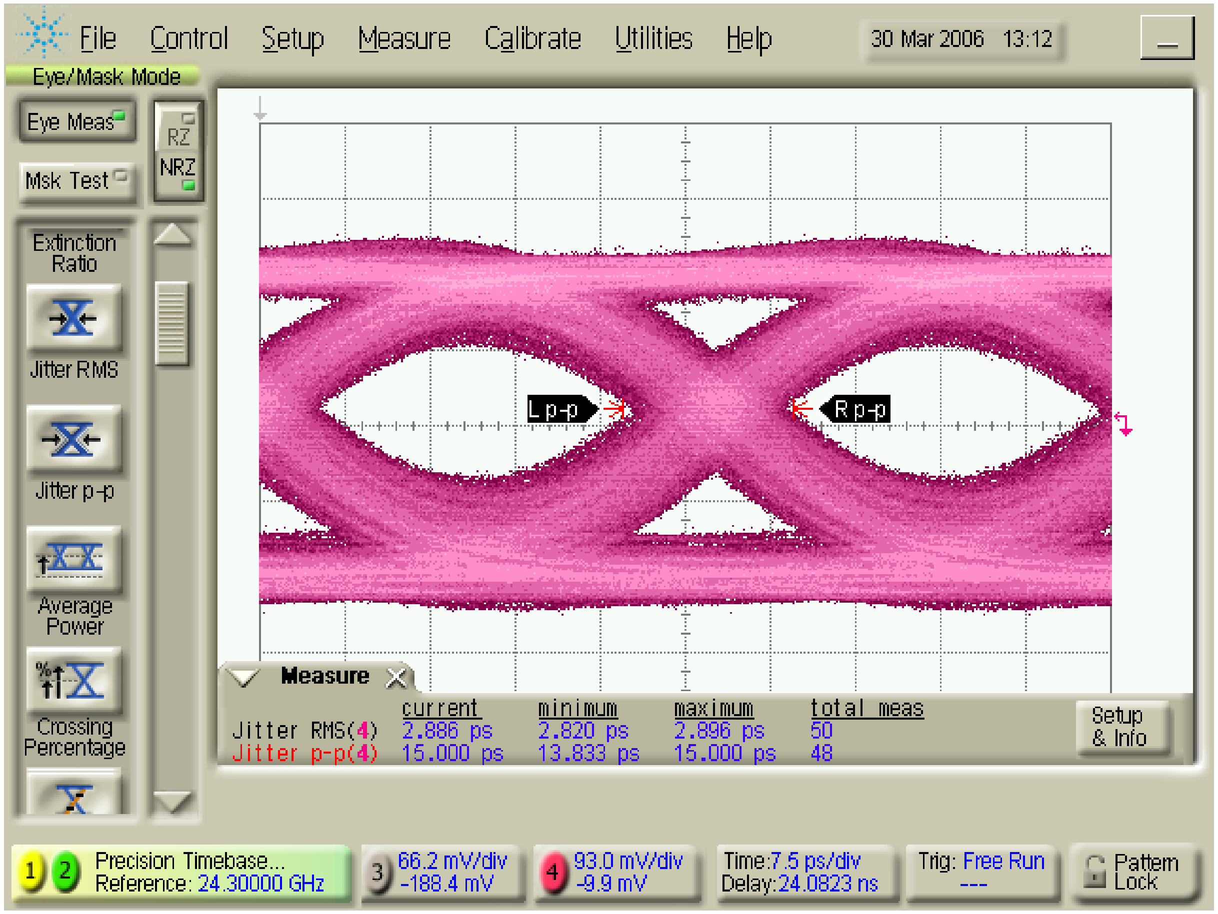
Eye Diagram Measurements

20 Gb/s, 270 mVpp input amplitude



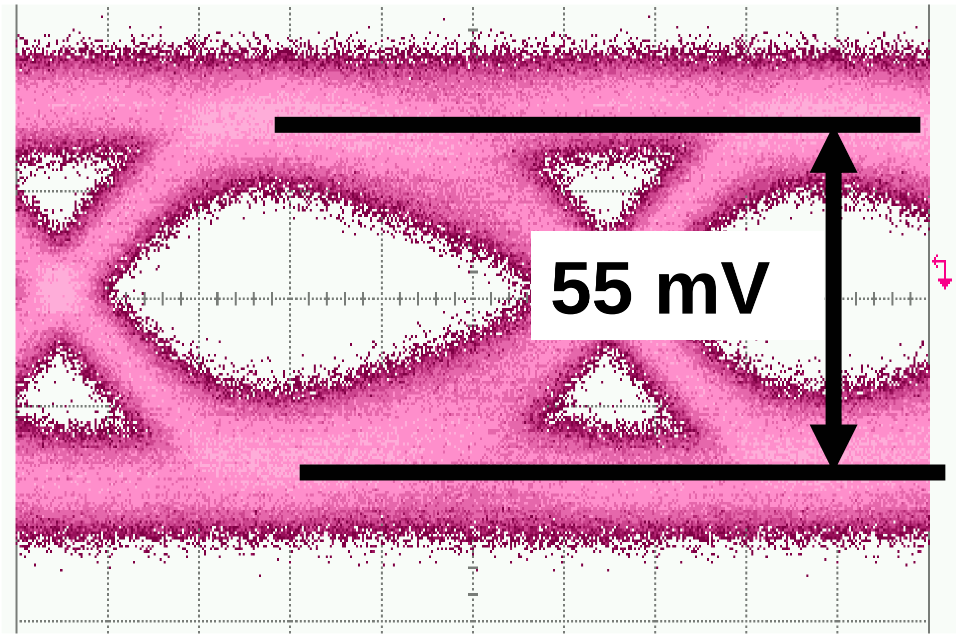
Eye Diagram Measurements

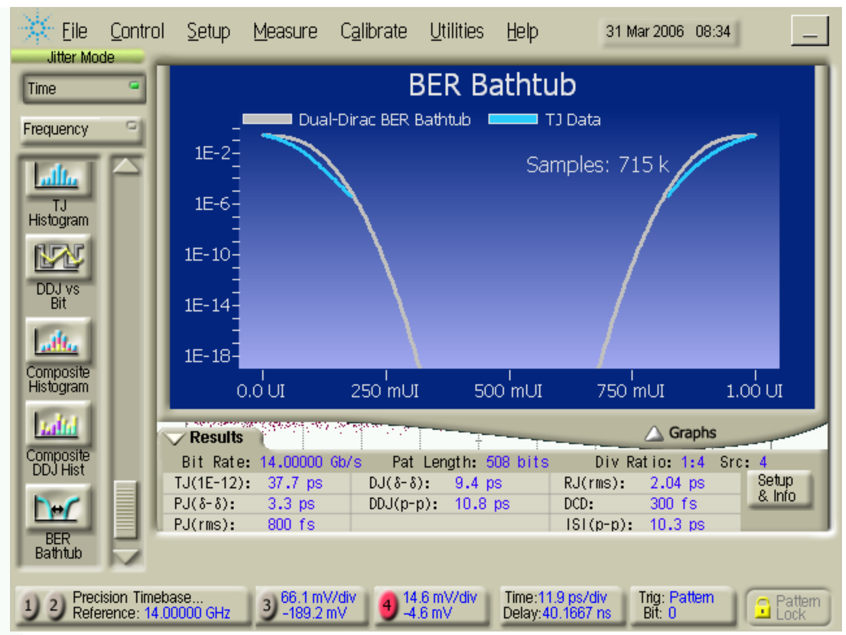
24 Gb/s, 270 mVpp input amplitude



Sensitivity Testing

14 Gb/s, 27 mVpp input amplitude





Summary

	This work	Analui'04	Bevilacqua'04
CMOS Technology	0.18 μm	0.18 μm	0.18 μm
Single ended (SE) or Differential (Diff)	Diff.	SE	SE
3 dB bandwidth (GHz)	19	9.2	7
DC $\|S_{21}\|$ (dB)	11	—	9.3
DC $\|Z_{21}\|$ (dBΩ)	52	54	—
Sensitivity (μW)	3.6 @ 14Gb/s	15.8 @ 10Gb/s	—
Input referred P_{1dB} (dBm)	-7.5 @ 6 GHz	—	—
P_{3rd}/P_{1st} (dB)	-31.8 @ 6 GHz	—	—
Power (mW)	111	137	9
Supply Voltage (V)	2.5	2.5	1.8
Area (mm^2)	1.4	.64	1.1

Conclusions

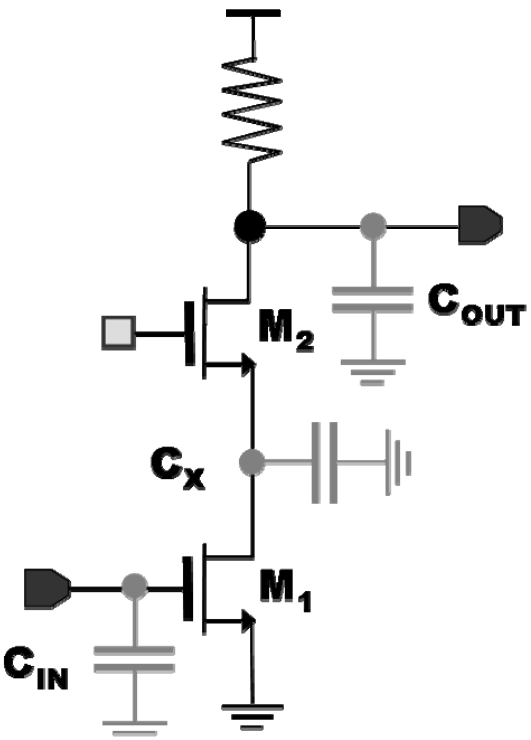
- Passive g_m-boosting
  - ✓ Improves the time constant at cascode node
  - ✓ Reduces Miller effect at the input node
  - ✓ Does not reduce DC gain
  - ✓ Does not introduce peaking
  - ✓ No additional power consumption
- Pre-amplifier (only) achieves BW of 22 GHz in 0.18-μm CMOS
- Front end (pre-amp + post-amp) gain > 10 dB is achieved with BW of 19 GHz

Acknowledgements

- Shahriar Shahramian
- Canadian Microelectronics Corporation
- Intel Corporation

Extras

Standard CMOS Cascode



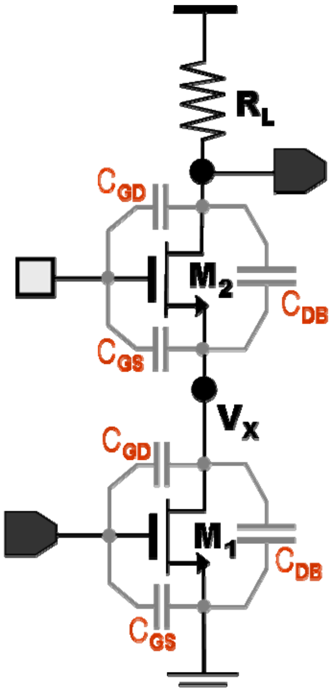
For example, assuming R_{in} = 50 Ω, R_L = 150 Ω, M1 & M2 are 20 x 2 μm, I_D = 7.5 mA, C_{PAD} = 70 fF, and C_L = 40 fF:

$$\tau_{out} = 15pS$$

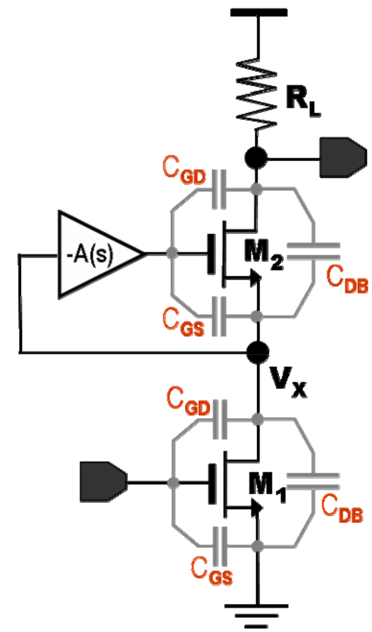
$$\tau_{cascode} = 12pS$$

$$\tau_{input} = 9pS$$

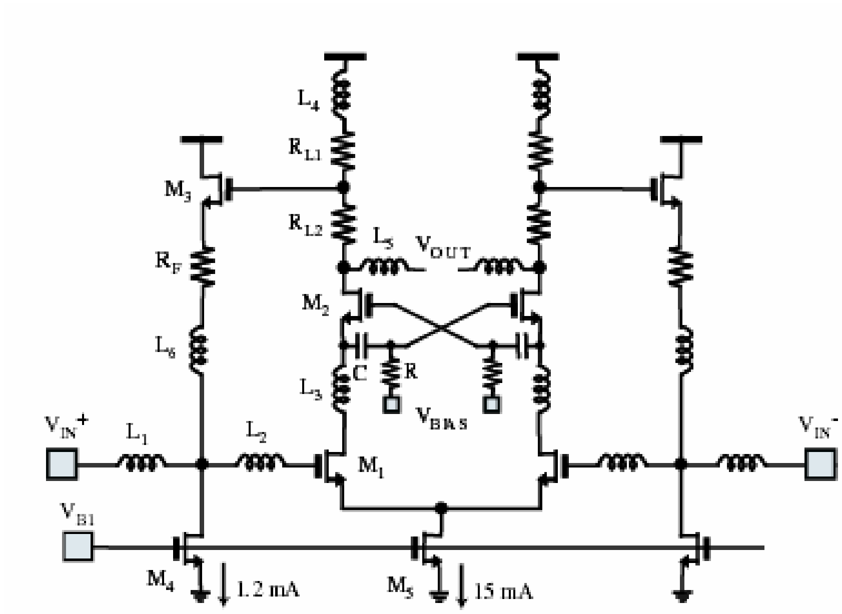
Time Constants of g_m-boosted Cascode



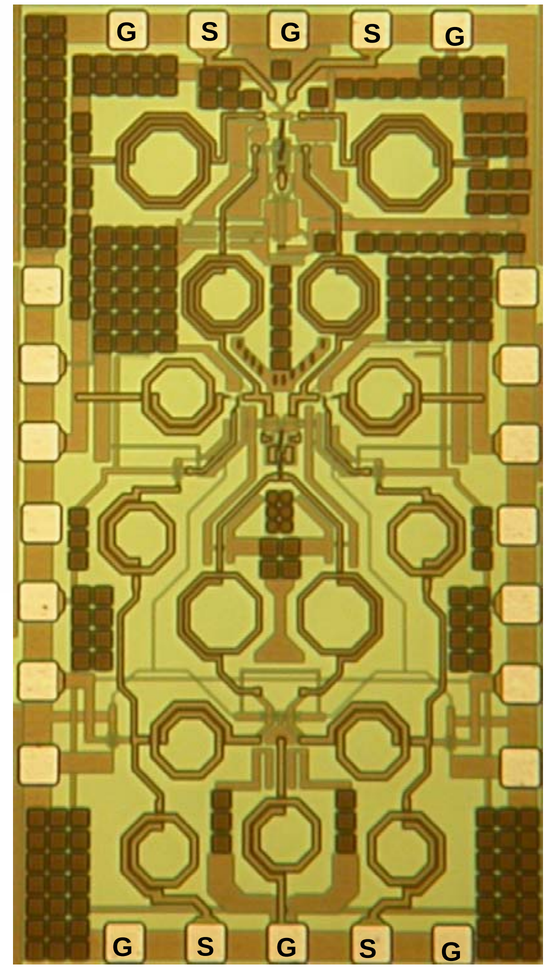
	Standard Cascode	g_m-boosted Cascode
DC Gain	$g_{m1}R_L$	$g_{m1}R_L$
τ_{Input}	$R_S[C_{GS} + 2C_{GD}]$	$R_S[C_{GS} + 1.5C_{GD}]$
$\tau_{CASCODE}$	$\frac{C_{Tot} + 2C_{GD}}{g_{m2}}$	$\frac{.5C_{Tot} + 1.5C_{GD}}{g_{m2}}$
τ_{OUTPUT}	$R_L[C_{GD} + C_{db} + C_L]$	$R_L[C_{GD} + C_{db} + C_L]$



Differential g_m-boosted Cascode



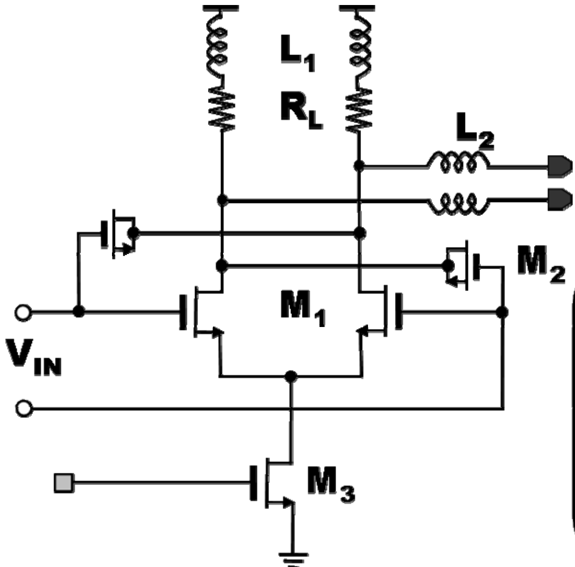
- M_1=20X2um
- M_2=20X2um
- M_3=8X 2um
- M_4=7X 2um
- M_5=120X2um
- R_F=70 -ohm
- R_{L1}=100-ohm
- R_{L2}=50 -ohm
- L_1=200 pH
- L_2=100 pH
- L_3=200 pH
- L_4=200 pH
- L_5=800 pH
- L_6=200 pH
- C=70 fF
- R=500 -ohm



g_m boosting :

- ✓ **Improves Input time constant**
- ✓ **Improves the time constant @ cascode node**
- ✓ **Do not reduce DC Gain**
- ✓ **No additional DC power consumption**

Post Amplifier Implementation



1st Amp	2nd Amp
M_1= 20 X 2 um	M_1= 20 X 2 um
M_2= 4 X 2 um	M_2= 4 X 2 um
M_3= 120 X 2 um	M_3= 120 X 2 um
L_1= 900 pH	L_1= 900 pH
L_2= 800 pH	L_2= 400 pH
R_L= 100-ohm	R_L= 50-ohm