

RF Frontends and Components for Ultra High-Speed Wireless Communications

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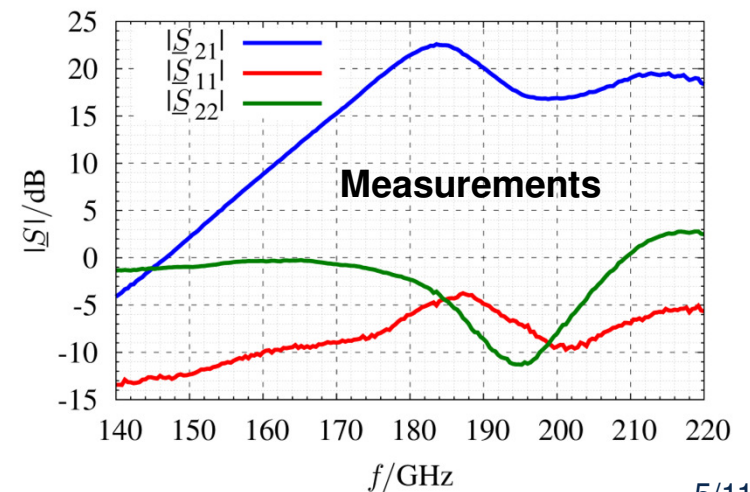
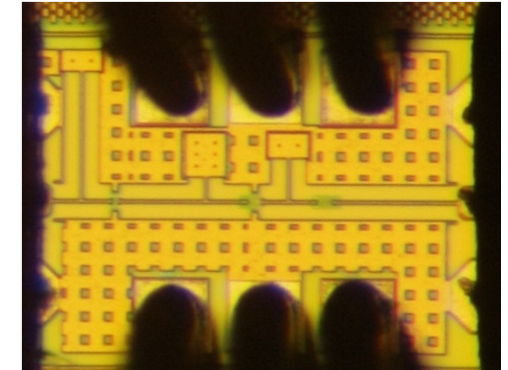
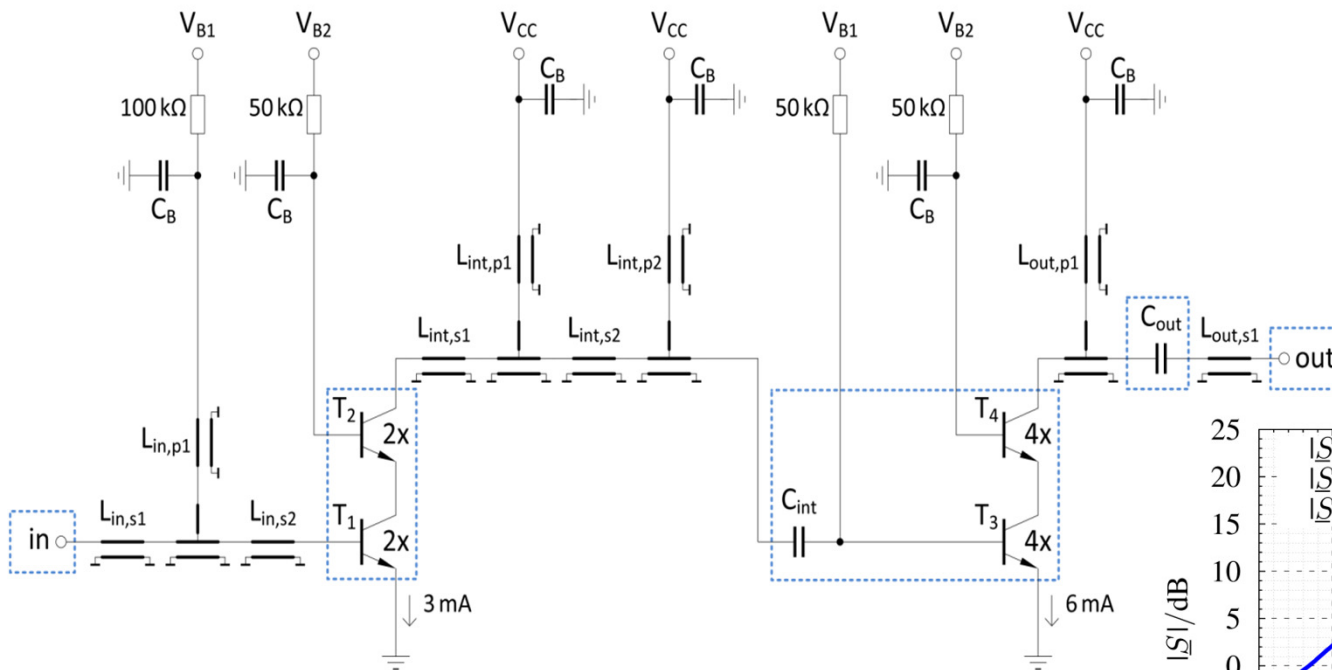
I feel the need the need for speed

Tom Mitchel (Tom Cruise), Movie Top Gun

Statement

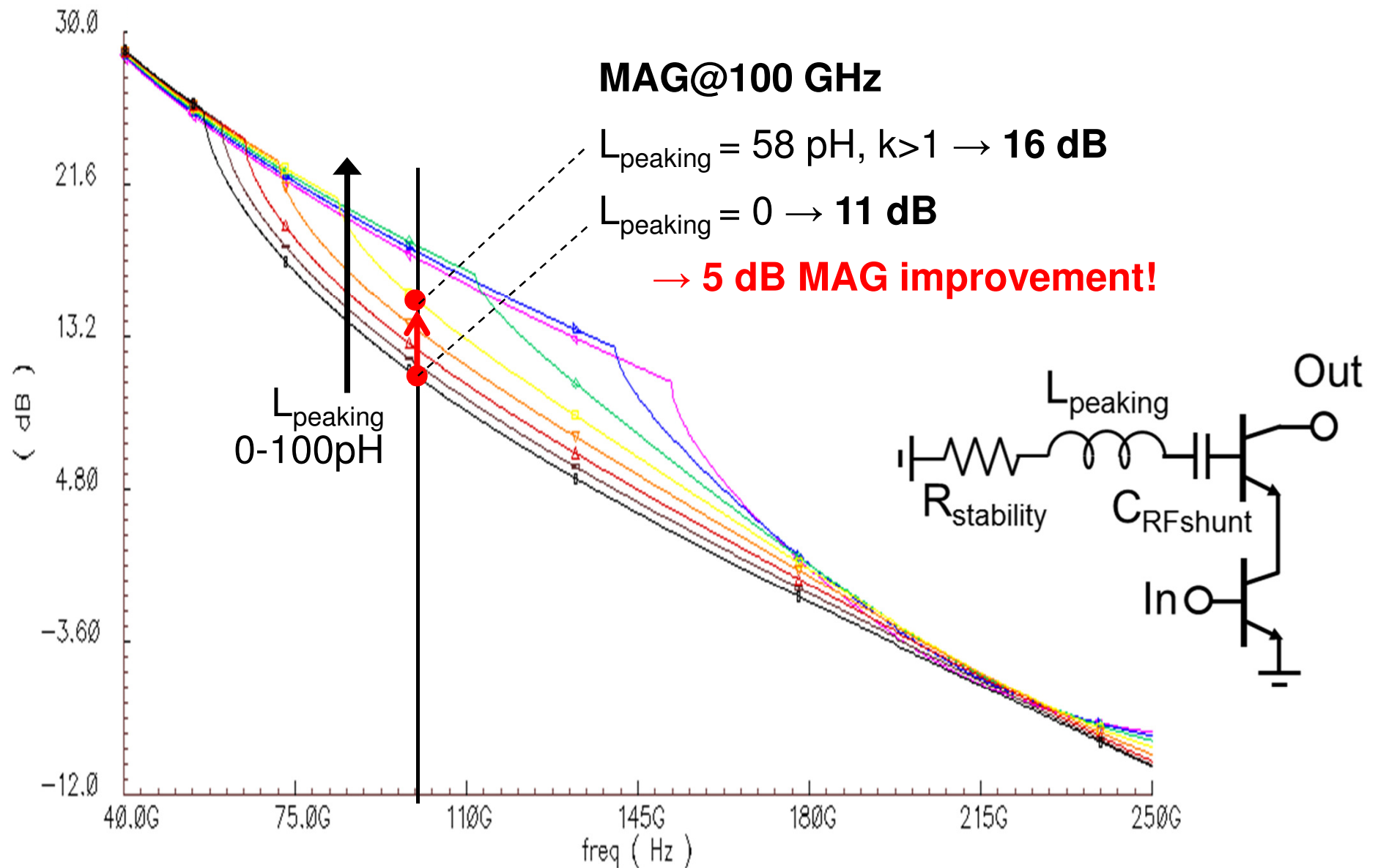
In addition to scaled technologies we need advanced RF circuit architectures to meet demands for future ultra high speed communications

Low-Power High-Gain 160-220 GHz SiGe LNA



Ref.	Technology	f/GHz	BW/GHz	G/dB	P _{DC} /mW	A/mm ²
TUD	130 nm SiGe HBT	205	> 30 (50)	17	22	0.24
[Tess09]	50 nm GaAs mHEMT	200	40	16	24	1.0
[Sch12]	130 nm SiGe HBT	245	10	18	303	0.15

Higher Cascode MAG by Controlled Positive Feedback, e.g. by L_{peaking}

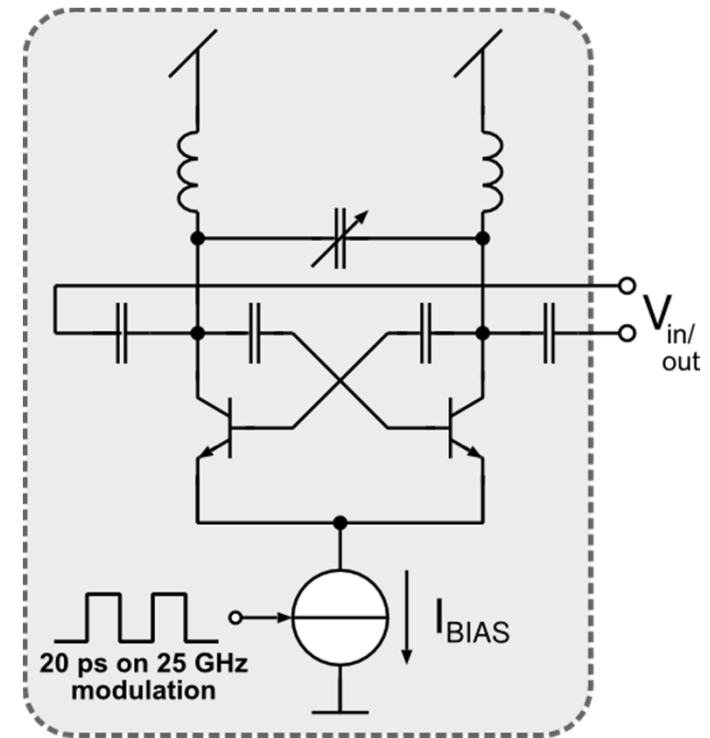


State-of-the-Art Architectures

- $f < f_{\max}/2-4$
- Low “*linear*” gain (8 dB/stage)
- Low SNF

Pulsed Regenerative Sampling

- Up to frequencies close to f_{\max}
- Oscillators need only MAG of 0 dB
- Oscillates *phase coherent* to *incoming signal*
- Strong “*nonlinear*” amplification in oscillator by positive feedback
- $P_{\text{out}} > 40$ dB higher than $P_{\text{in}} \rightarrow$ high SNR
- 16 QAM, 25 GHz modulation \rightarrow 100 Gb/s

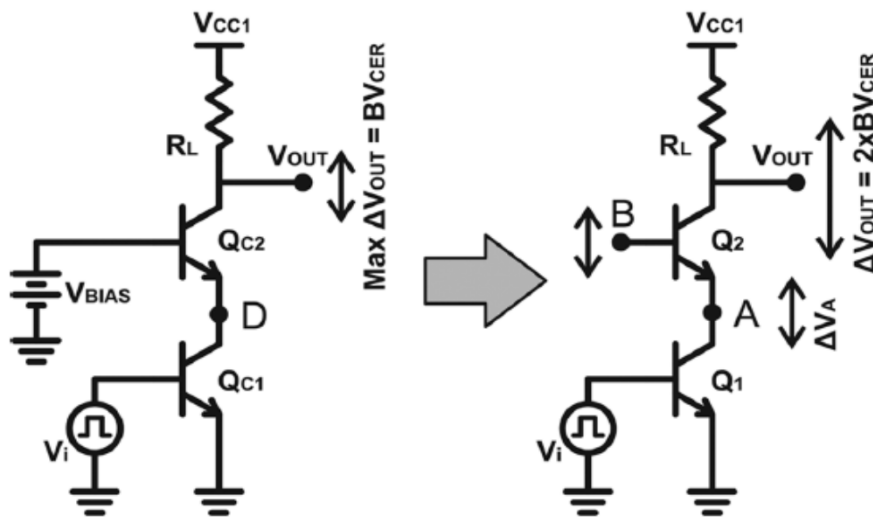


How to Get Enough PA RF Power?

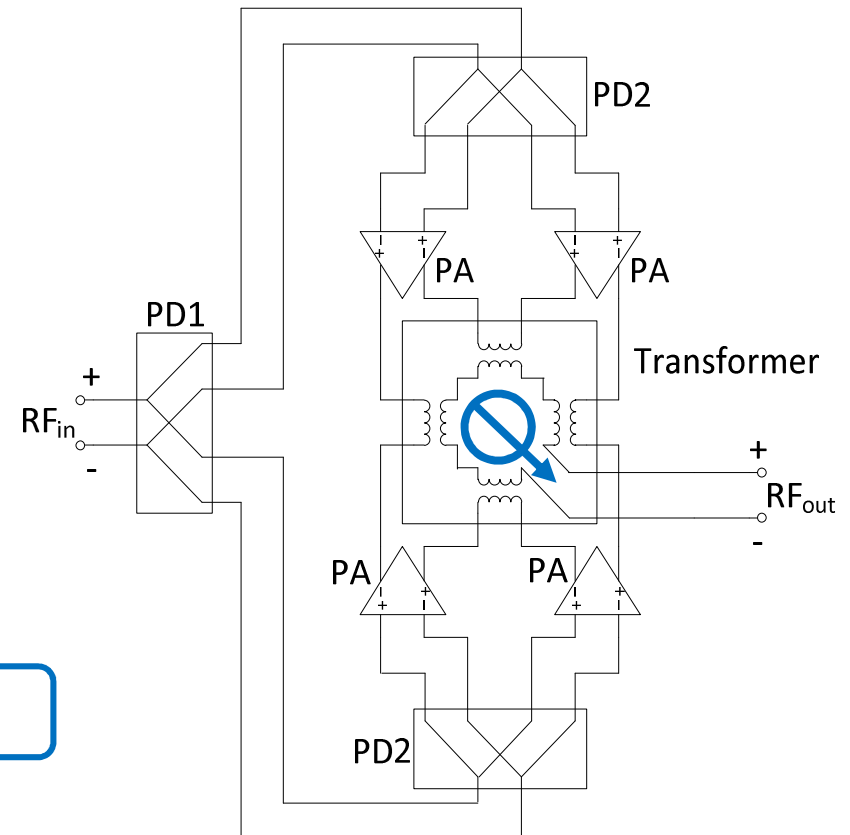
- ☹ Frequency $\uparrow \Rightarrow$ transistor scaling \Rightarrow RF power \downarrow
- ☺ Smart voltage adding

A. Transistor stacking

Real time control at B!

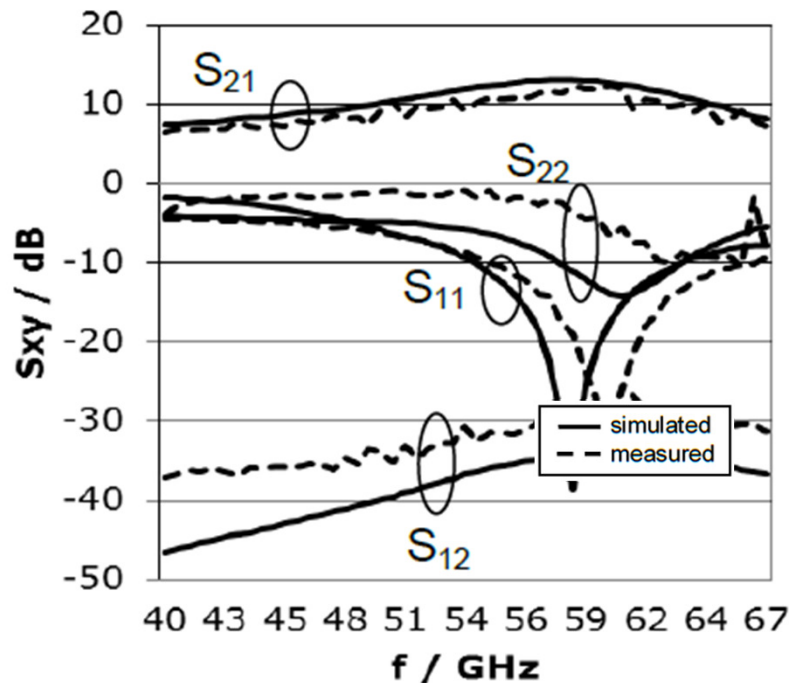


B. integrated n to 1 transformer

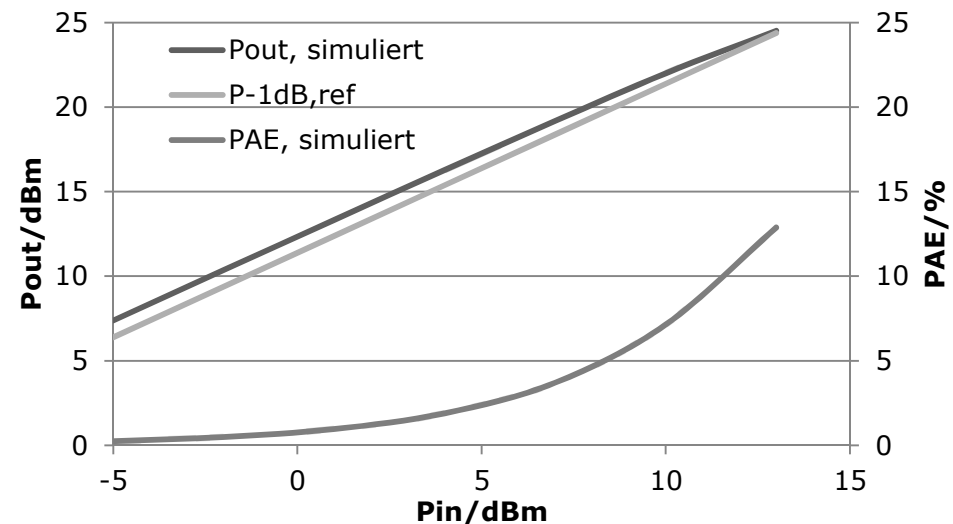


A. + B. \Rightarrow 8 \times RF power!

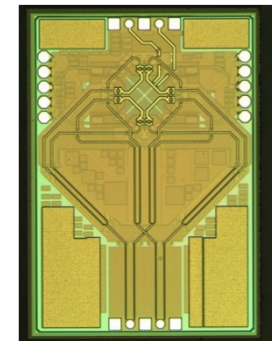
Power Combining PA at 60 GHz in SiGe



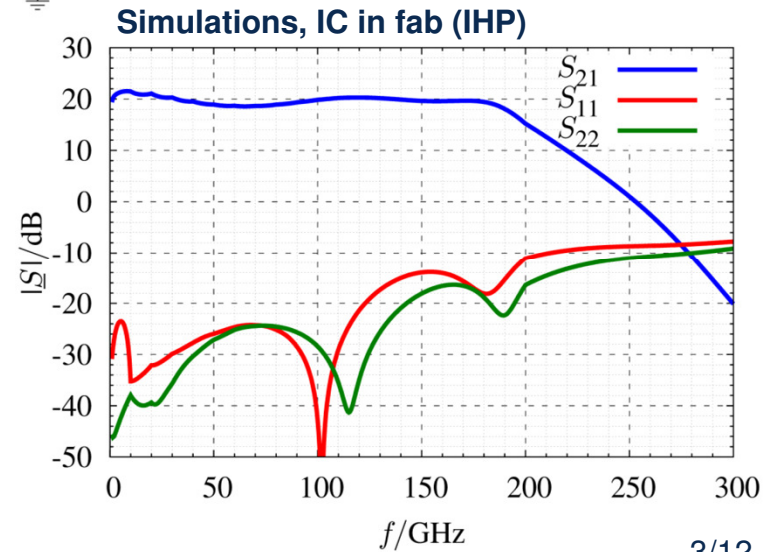
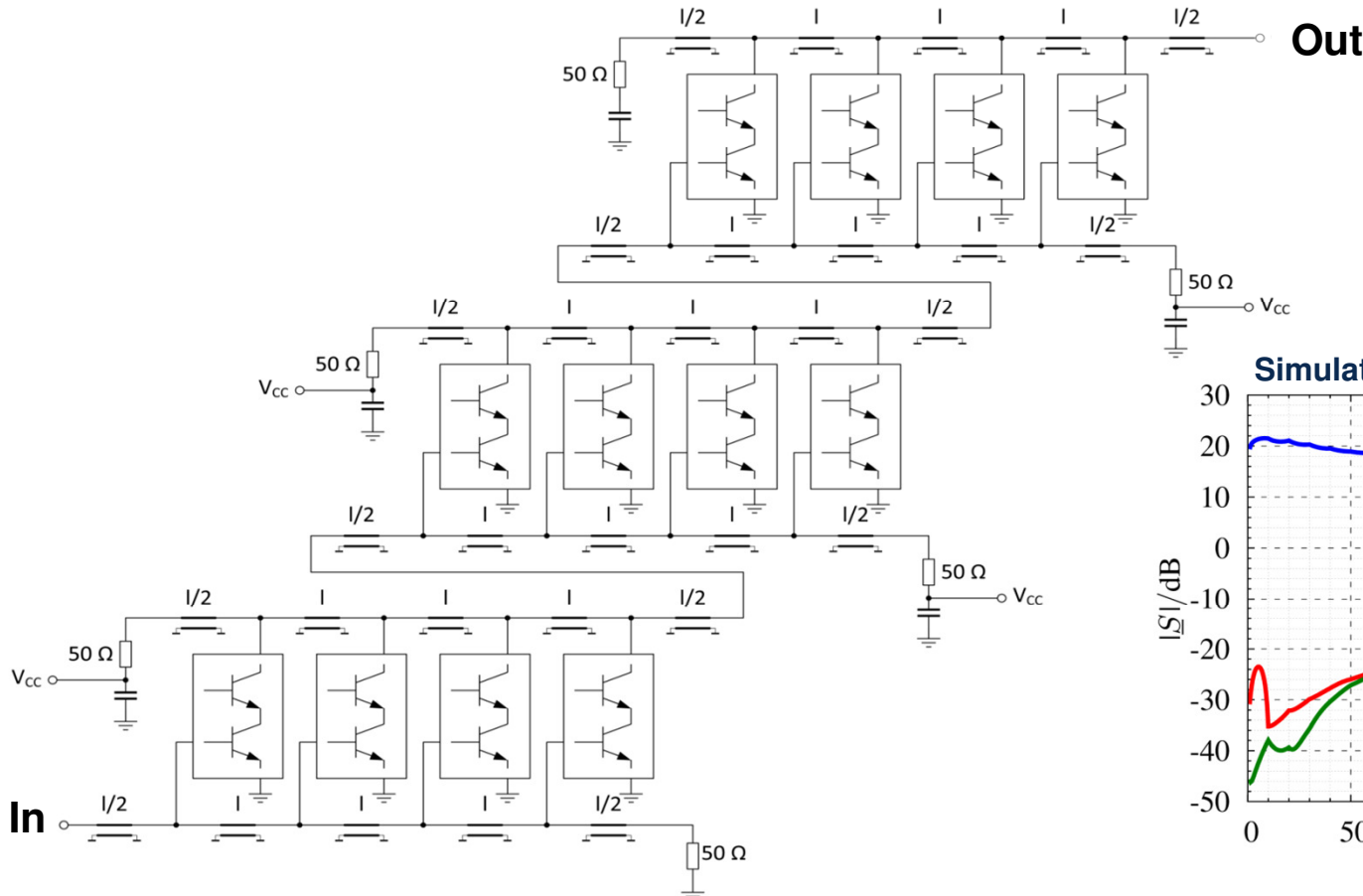
True differential sim. (meas. not possible yet) but verification single ended



Ref.	f/BW [GHz]	P_{1dB} [dBm]	PAE [%] @ $P_{1dB}/peak$	V_{dc} [V]	Technology
TUD	60/12	24.5	> 13	3.3	0.25 μm SiGe
[Pfe07]	62	21	n.a./6.3	4	0.13 μm SiGe
[Wan12]	79	16.4	13/19.2	1	65 nm CMOS
[Dea08]	270	7.7	4/n.a.	1.7	35 nm InP HEMT



SiGe Amplifier with 200 GHz Bandwidth



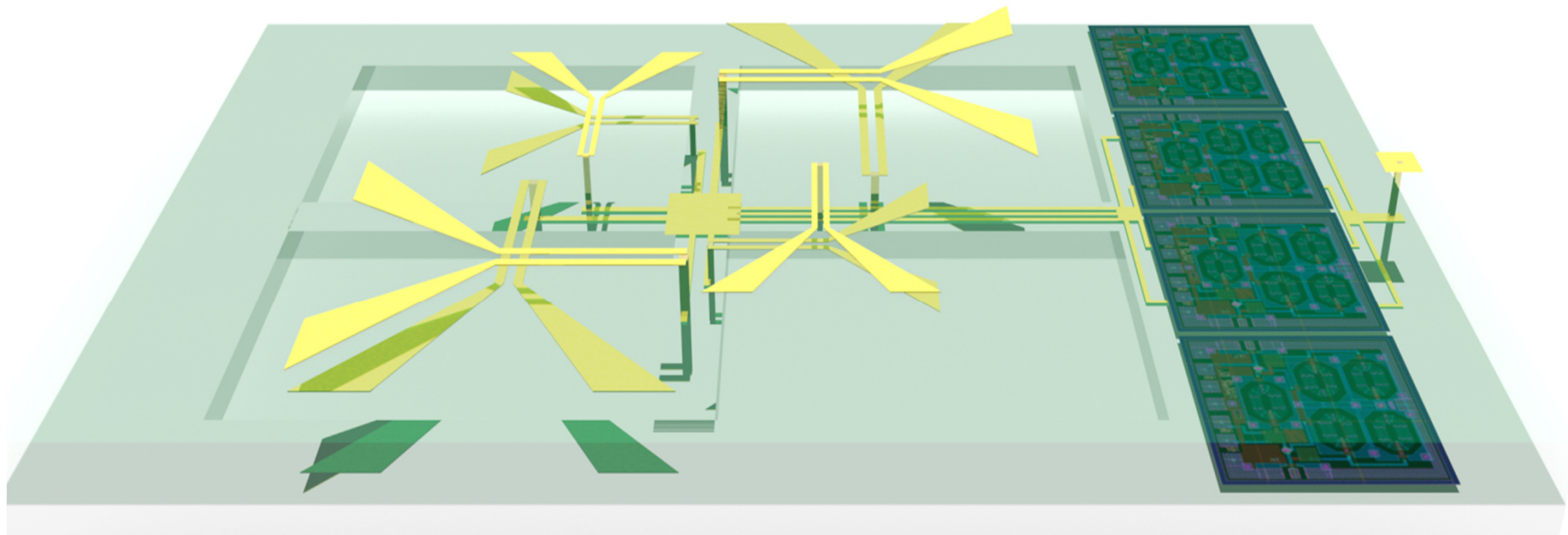
Reference	Technology	Gain/dB	BW/GHz	P_{DC}/mW	A/mm^2
Group Ellinger, sim.	130 nm SiGe	20	190	200	0.6
Niknejad, RFIC12	130 nm SiGe	24	110	248	0.65
Zech, GeMiC12	50 nm GaAs HEMT	11	110	450	1.7

Antennas at Different Metal Levels & Locations and Multiple Combined TWAs

Very large BW

⇒ More signal radiated **upwards** and **lower substrate losses**

Substrate etching lowers losses especially at lower metal levels

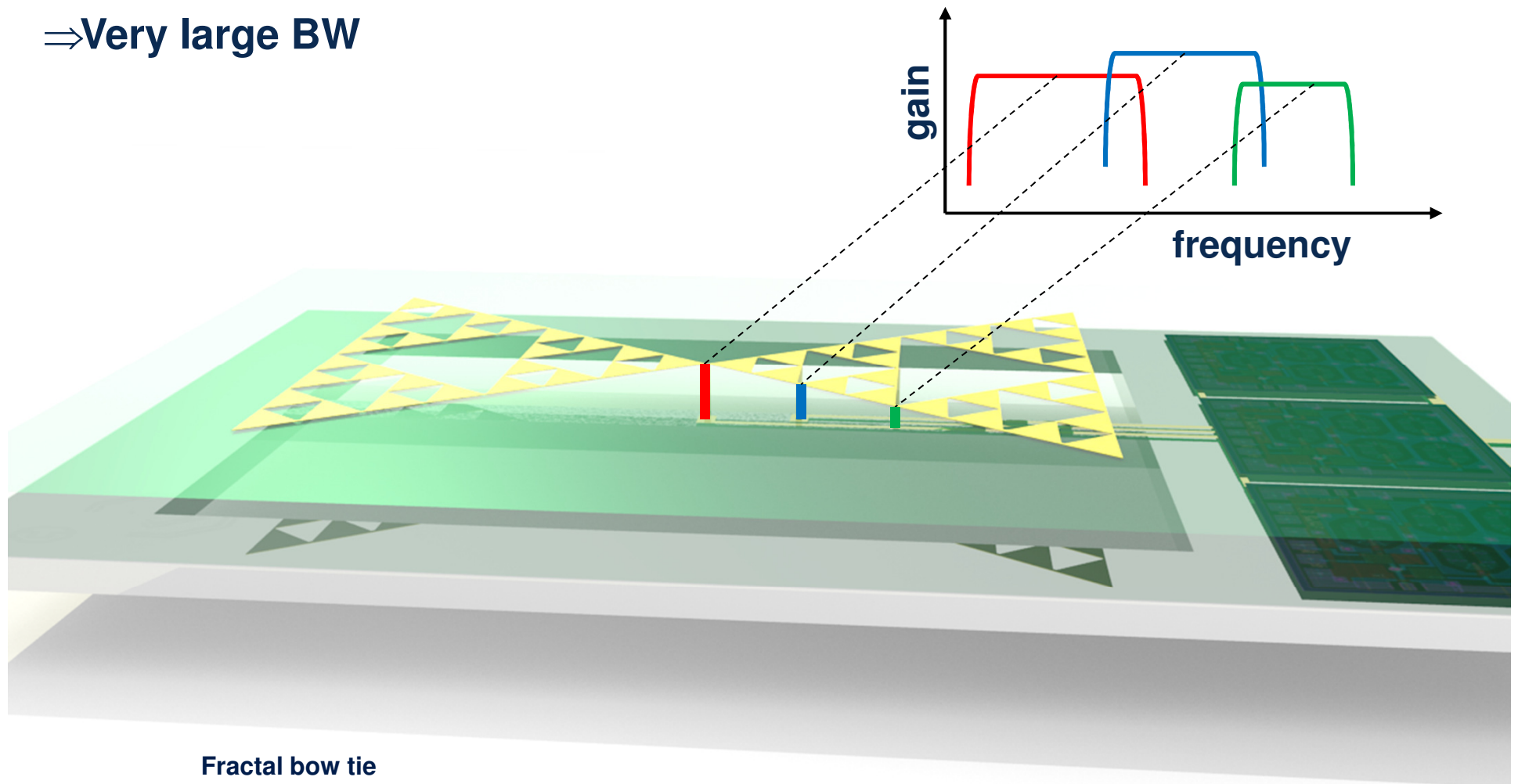


Linear tapered slot

M. Jennings, D. Plettemeier, Multilayer and multi-directional linearly-tapered slot antenna for 300 GHz applications, EuCAP, April 2010

Multiple Antenna Contact Points and Multiple Frequency Scaled Amps

- ⇒ **Different contact points** have **different optimum centre frequencies**
- ⇒ Adding of **multiple bands** by **frequency scaled amplifiers**
- ⇒ **Very large BW**



Multiple Antenna Contact Points and Distributed Adding with one TWA

Antenna feeding points used as transmission line elements for amplifier towards fully distributed system

⇒ **Higher BW**

