Towards a Fully Integrated, Multi-Purpose Radio Front-End for Wireless 100 Gb/s

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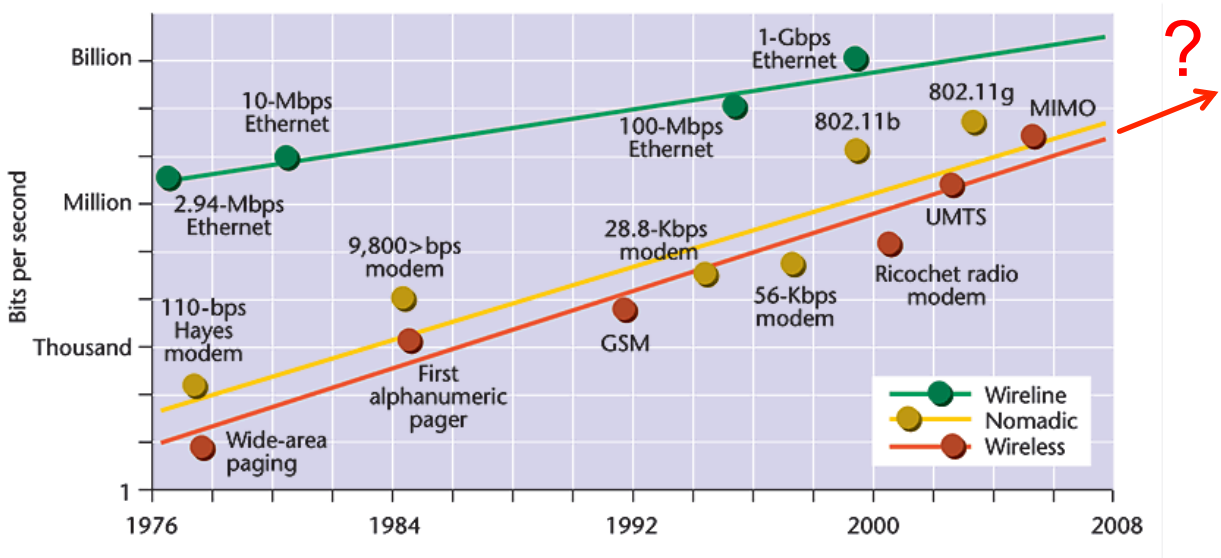
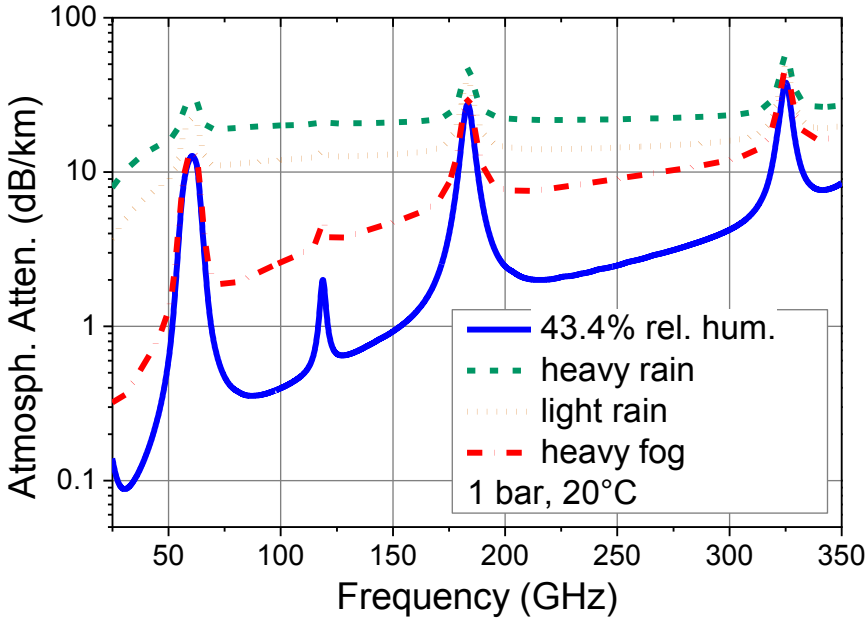
Motivation



[SC04] Steven Cherry, „Edholm's Law of Bandwidth", IEEE Spectrum, July 2004

Why 200-300GHz?



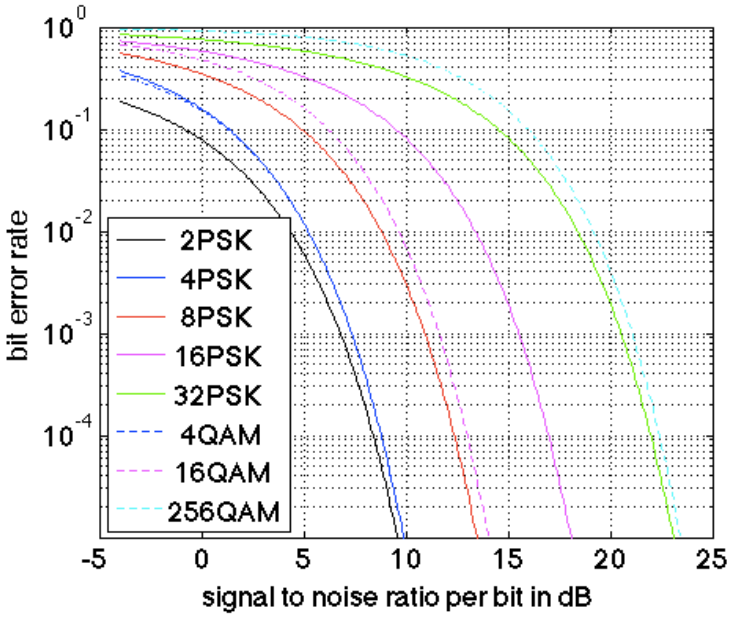
How Can We Achieve 100 Gigabit Wireless?

Option 1 at 61.5GHz:

- 2^20 QAM with BW=5GHz
- BER=10^{-3} at SNR=**53,3dB**

Option 2 at 275GHz:

- 4 PSK with BW=50GHz
- BER=10^{-3} at SNR=**7.33dB**



[] John G. Proakis, "Digital Communications", 4th edition, McGraw-Hill", 2001

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$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi r} \right)^2$$

Advantages/Disadvantages at 61.5GHz:

- **10dB** less noise power due to smaller bandwidth
- **13dB** more receive power due to link budget
- Turbo coding etc. to reduce required SNR at 61.5GHz
- Much higher computing power required at 61.5GHz -> much higher power consumption

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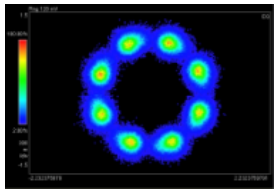
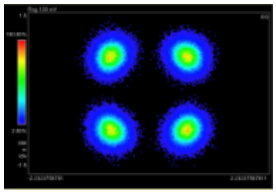
Multi-Gigabit Wireless Data Transmission

- Experiments at KIT in May 2013
- MMIC based Receiver and Transmitter
- Fraunhofer IAF 35nm mHEMT techn.
- LNA, PA, Mixer, Frequency multiplier
- RF frequency range 200 – 280 GHz
- NF < 12 dB
- Pout: -6 to -4 dBm
- Modules mounted in RPG HATPRO
- Cassegrain antenna with 55 dBi gain
- 1.1 km wireless transmission



6 Gbaud (18 Gbit/s)
EVM 18.5%
BER ~ $1x10^{-3}$



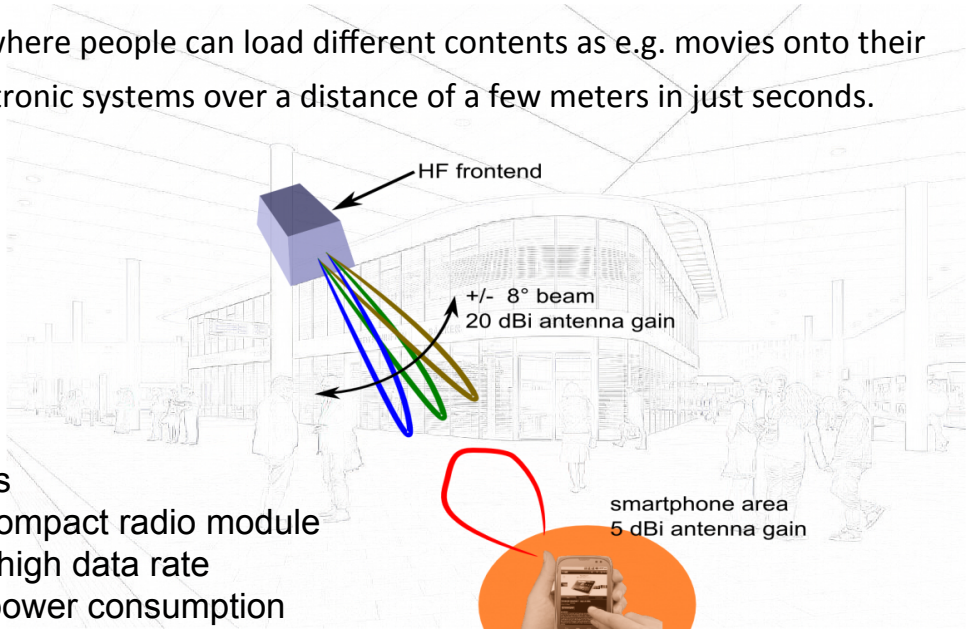
12 Gbaud (24 Gbit/s)
EVM 22.7%
BER < $1x10^{-5}$

What Comes Next?

- Can we do 100GBit/s wireless
  - highly integrated?
  - in silicon?
  - low power?
  - Low cost?

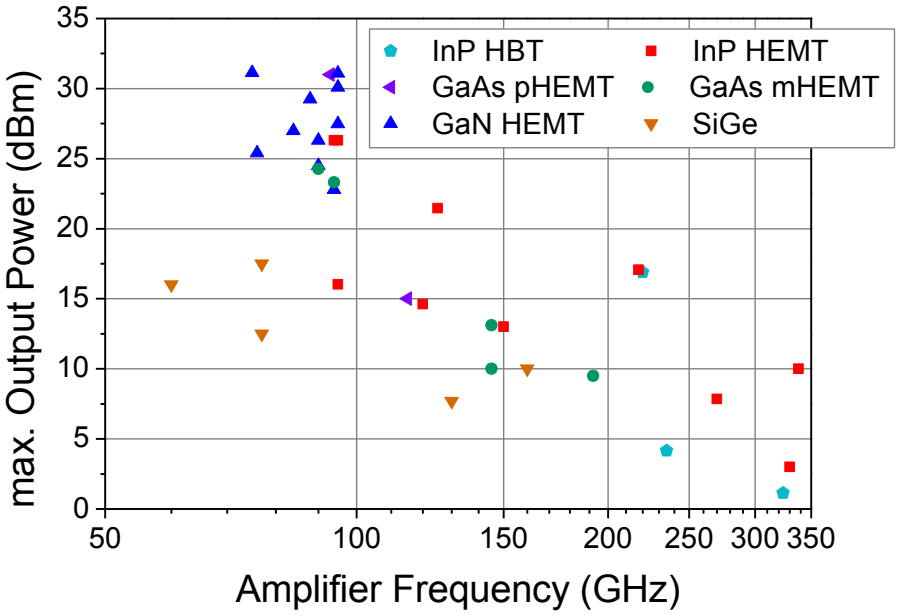
Possible Application

- Data kiosk where people can load different contents as e.g. movies onto their mobile electronic systems over a distance of a few meters in just seconds.

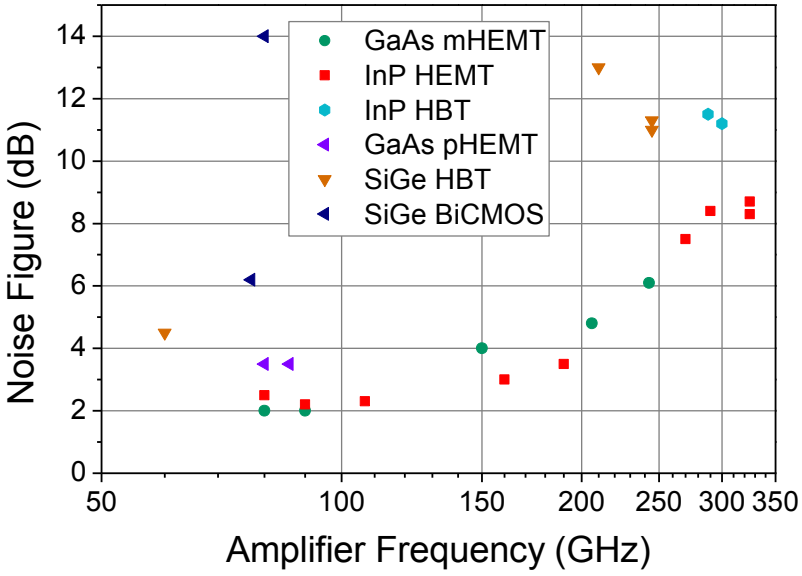


This requires
- an ultra-compact radio module
- with very high data rate
- And low power consumption

Technology Capabilities 1



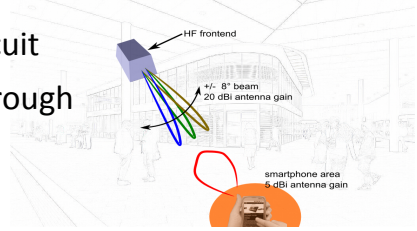
Technology Capabilities 2



Link Budget Considerations

data rate in Gbit/s	100	100	100	100	100
center frequency in GHz	61,5	275	275	275	275
modulation	2^20 QAM	4 PSK	4 PSK	4 PSK	4 PSK
number of channels	1	1	1	1	4
bandwidth per channel in GHz	5	50	50	50	12,5
SNR required for BER<10^-3 in dB	53,26	7,33	7,33	7,33	7,33
output power per channel in dBm	16	6	6	6	6
noise figure in dB	6	12	12	12	12
minimum required receive power in dBm	-17,58	-47,51	-47,51	-47,51	-53,53
Tx antenna gain in dBi	10	0	10	25	25
Rx antenna gain in dBi	10	0	10	25	5
margin / implementation loss in dB	10	10	10	10	10
maximum path loss in dB	43,58	43,51	63,51	93,51	79,53
achievable range in m	0,058598	0,012999	0,129994	4,110759	0,822152

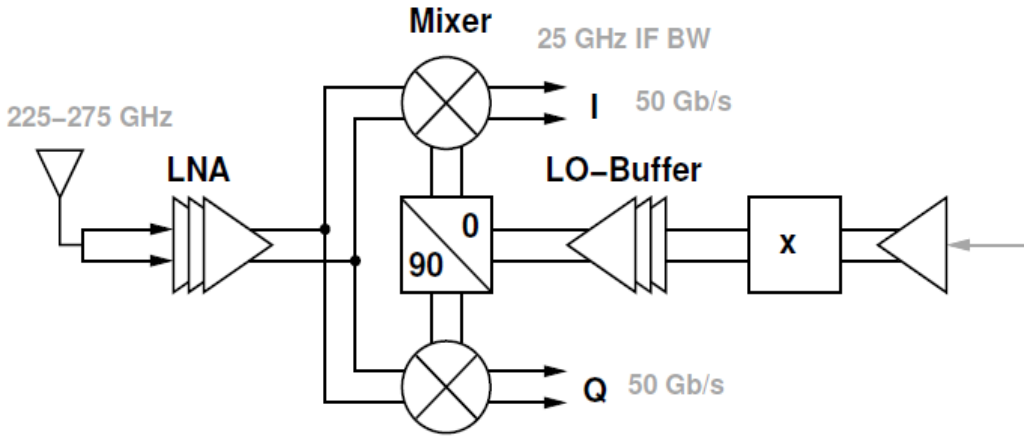
- Either new semiconductor technologies or new circuit and system concepts are required to get a breakthrough in wireless communication above 200 GHz



Major RF Challenges

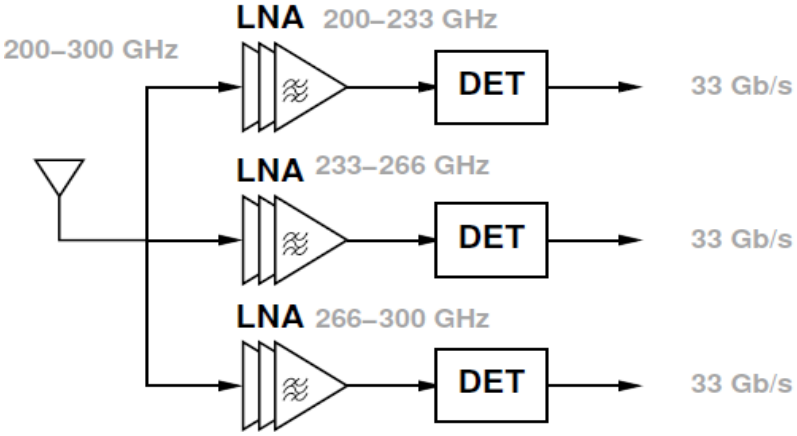
- Low-cost, silicon based, surface-mount RF front-end modules enabling 100Gbps wireless short-range communication
- Wideband millimeter wave circuit architectures based on silicon process technologies above 200GHz
- Ultra-compact surface-mount radio modules with package integrated antenna arrays
- New multi-antenna front-end concepts based on silicon process technologies for high-speed data transmission

Standard Circuit Approach



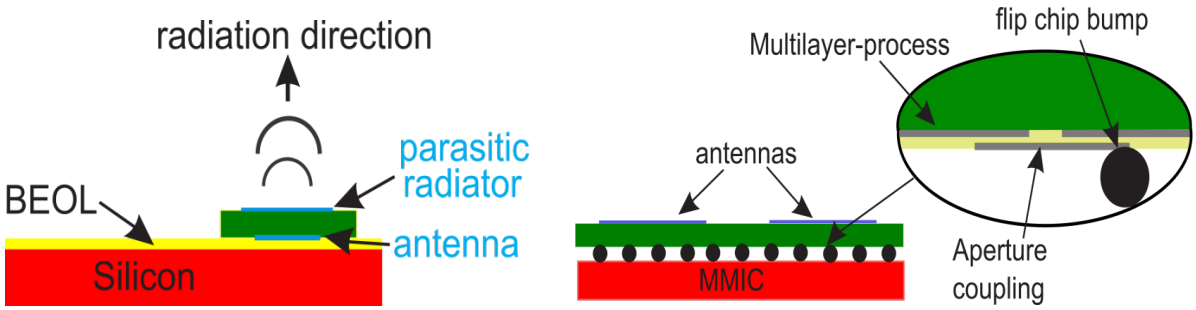
- wideband I/Q radios with spectral efficiencies of 2-3 bit/s/Hz at 250 GHz – up-scaling of working circuits from lower frequencies

Advanced Circuit Approach



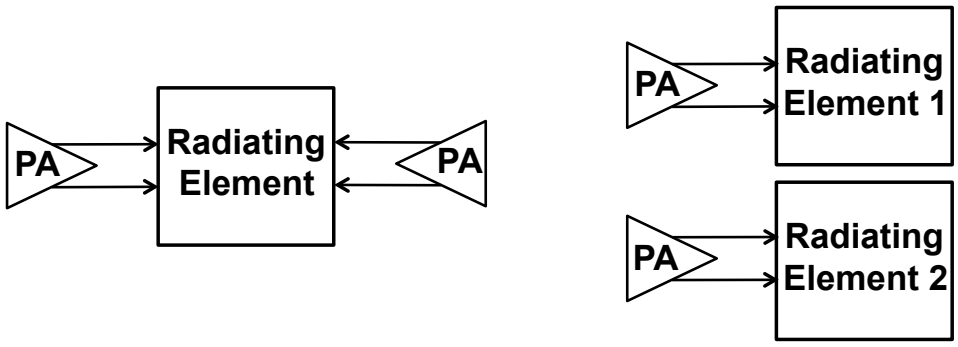
- ASK modulator/de-modulators for multi-channel transceivers – multi-channel transceiver architectures with lower spectral efficiency

Packaging/Antenna Options



- Standard on-chip antennas only offer low efficiency and small band-width due to technological restrictions. Off-chip antennas require a reliable broadband interconnect
- Novel structures e.g. using backside etching or additional thin-film layers might help
- Frequency ↑ → interconnect losses ↑ & antenna size ↓ → on-chip antennas

Options for Circuit/Antenna Integration



- effective combinations of several parallel amplifiers with a single radiating element or with a very compact antenna array – power combining in air

Conclusions

Ultra-high data rate communication at above 200GHz might be possible based on highly integrated Si-based modules

Key for realization are:

- Complete RF front-end on a single chip
- Integrated antennas in a low-cost SMD package
- New concepts for silicon circuits / systems above 200 GHz
- Novel circuit / antenna integration techniques

Beat the link budget!