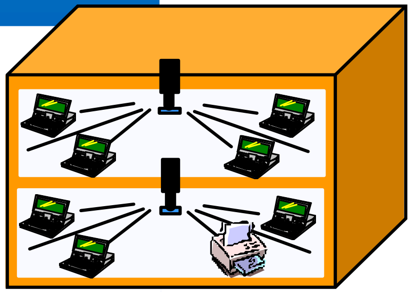
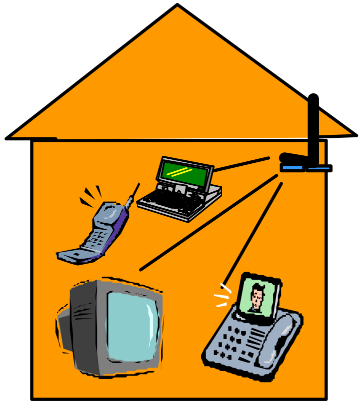
Broadband Wireless Communication

The world is going wireless !



Enterprise WLAN



Wireless home gateway

Wireless personal network

- Wireless LANs experience a growing success in enterprises.
- Wireless home gateways are the missing piece in fast internet and video access.
- Wireless personal networks will open new service opportunities

Wireless Requirements

- ▷ **Cost < 10$**
- ▷ **Power consumption < 100 mW**
- ▷ **Network capacity > 100 Mbps**
- ▷ **Range > 50 m**

⇨ **IMEC's Mission: "To enable low cost and low power integrated solutions for the next generation broadband communication networks"**

Long term strategy executed in a phased approach

phase 1

enterprise WLAN

OFDM

phase 2

home gateway with extended range and capacity

Turbo coding
SDMA
QoS MAC
5 GHz FE SIP

phase 3

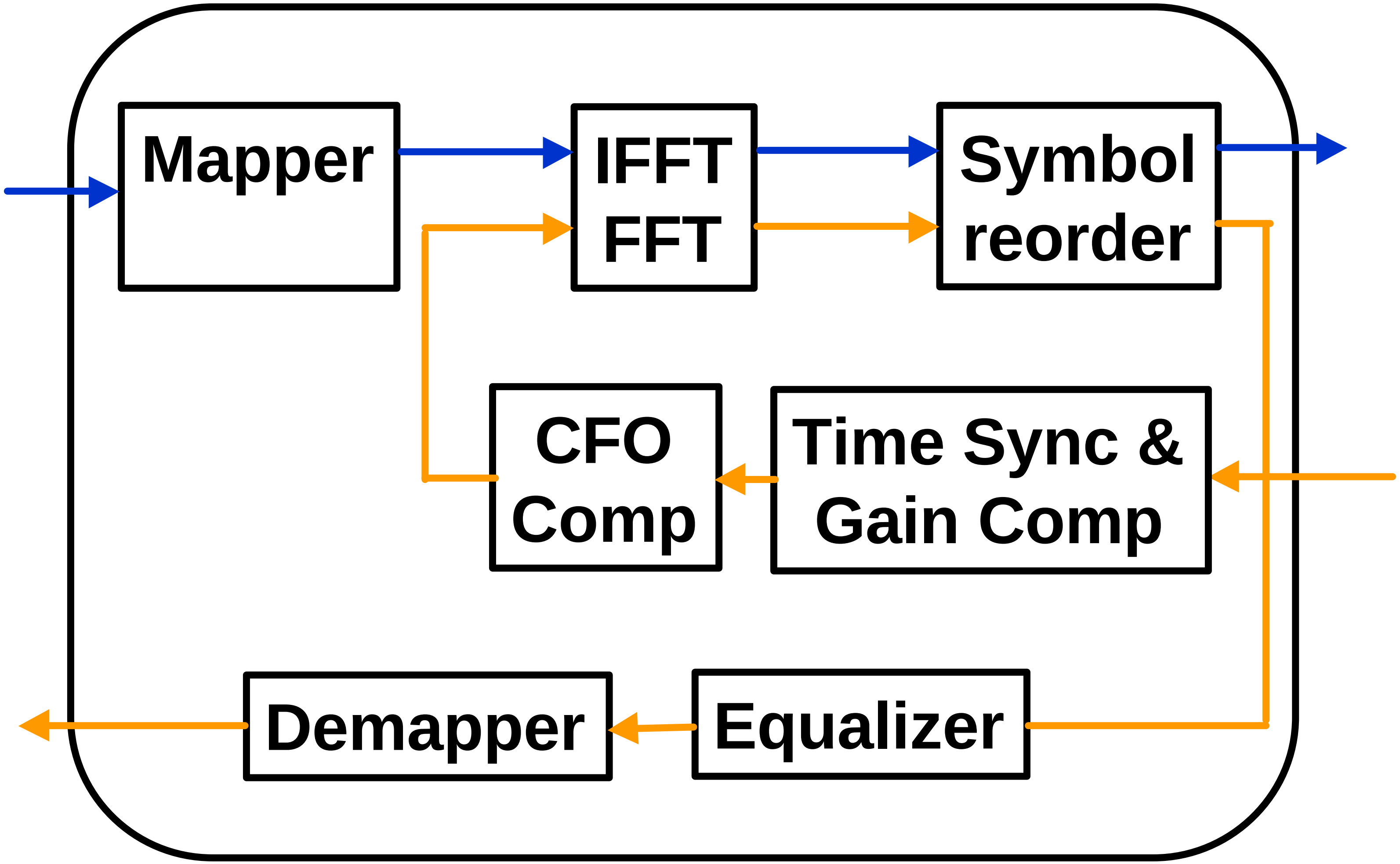
high datarate terminals

MIMO

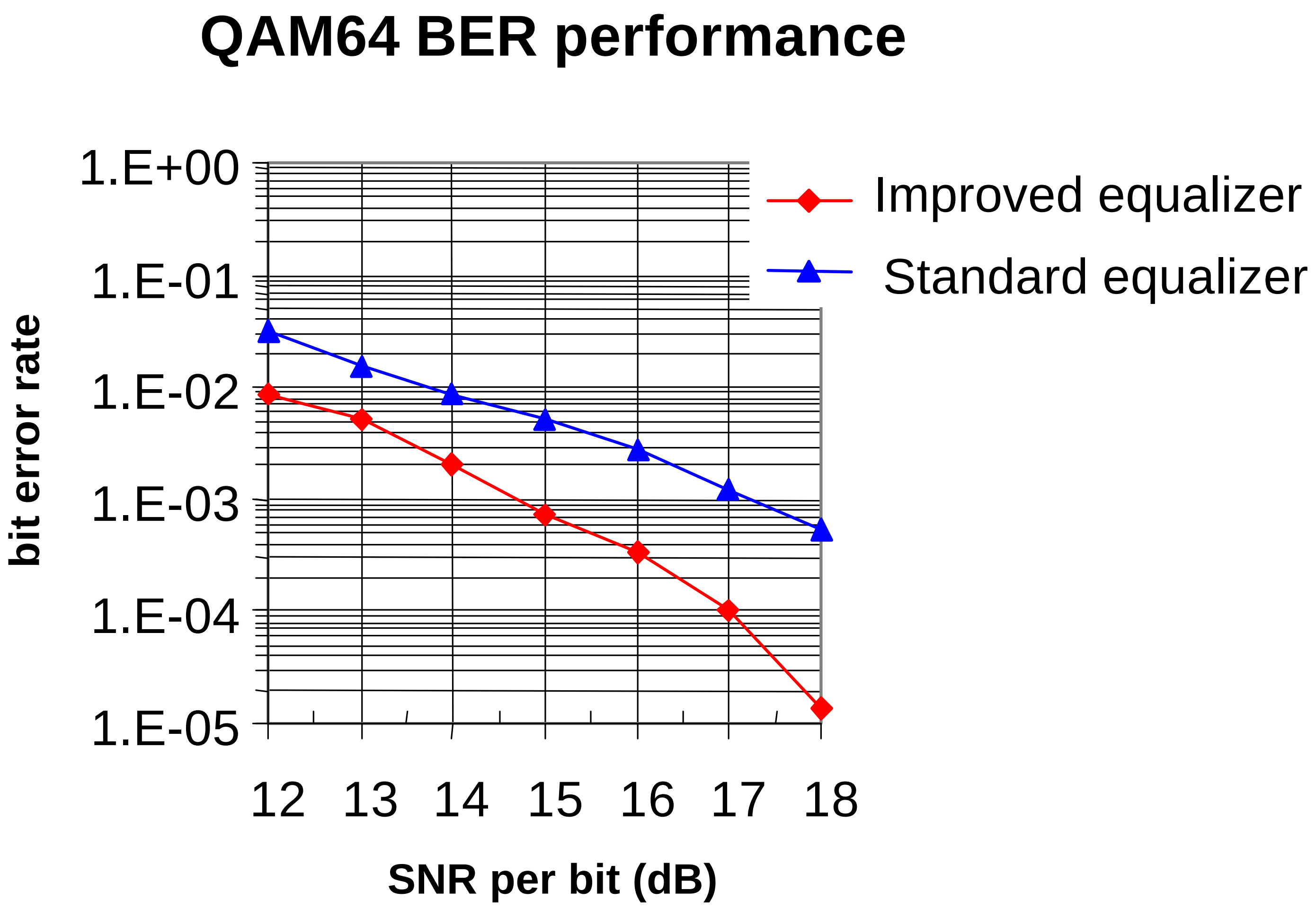
personal area network

Scalability
SIP

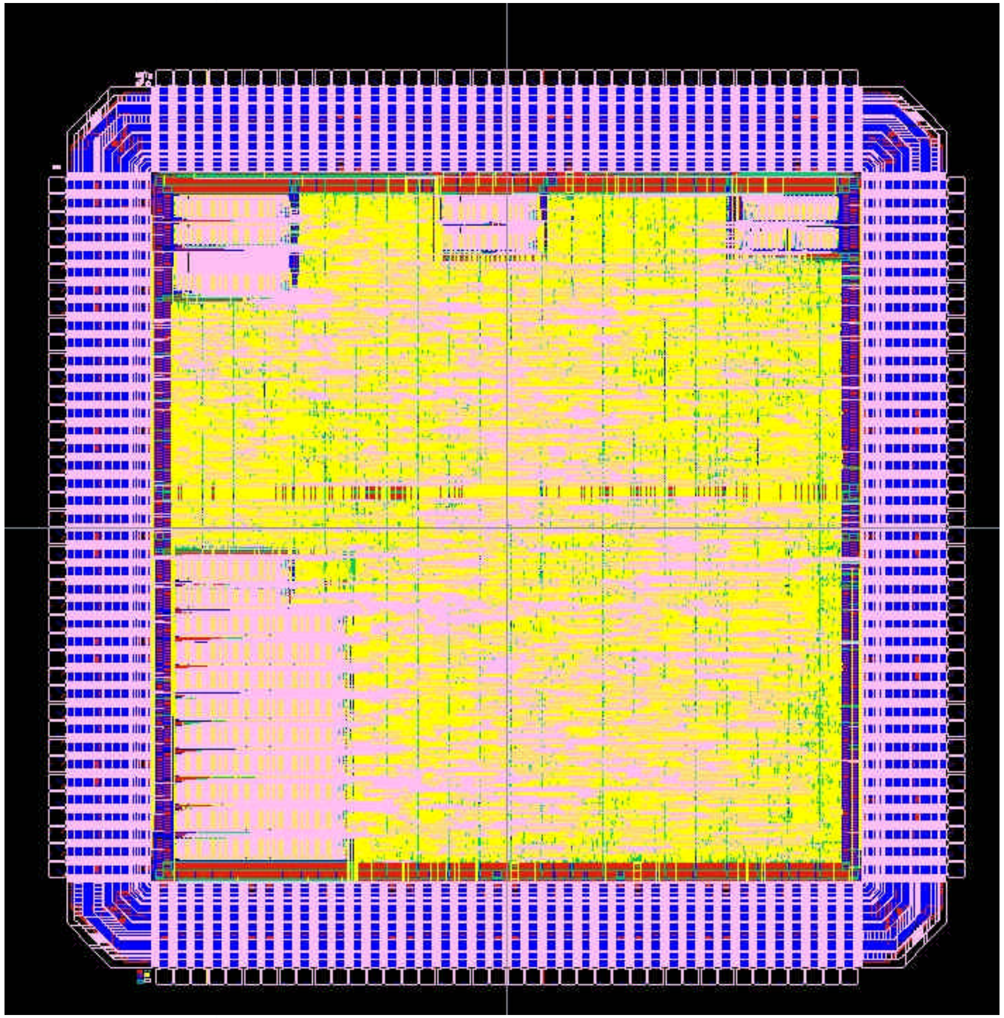
OFDM Modem Architecture



Improved equalizer for better performance with QAM

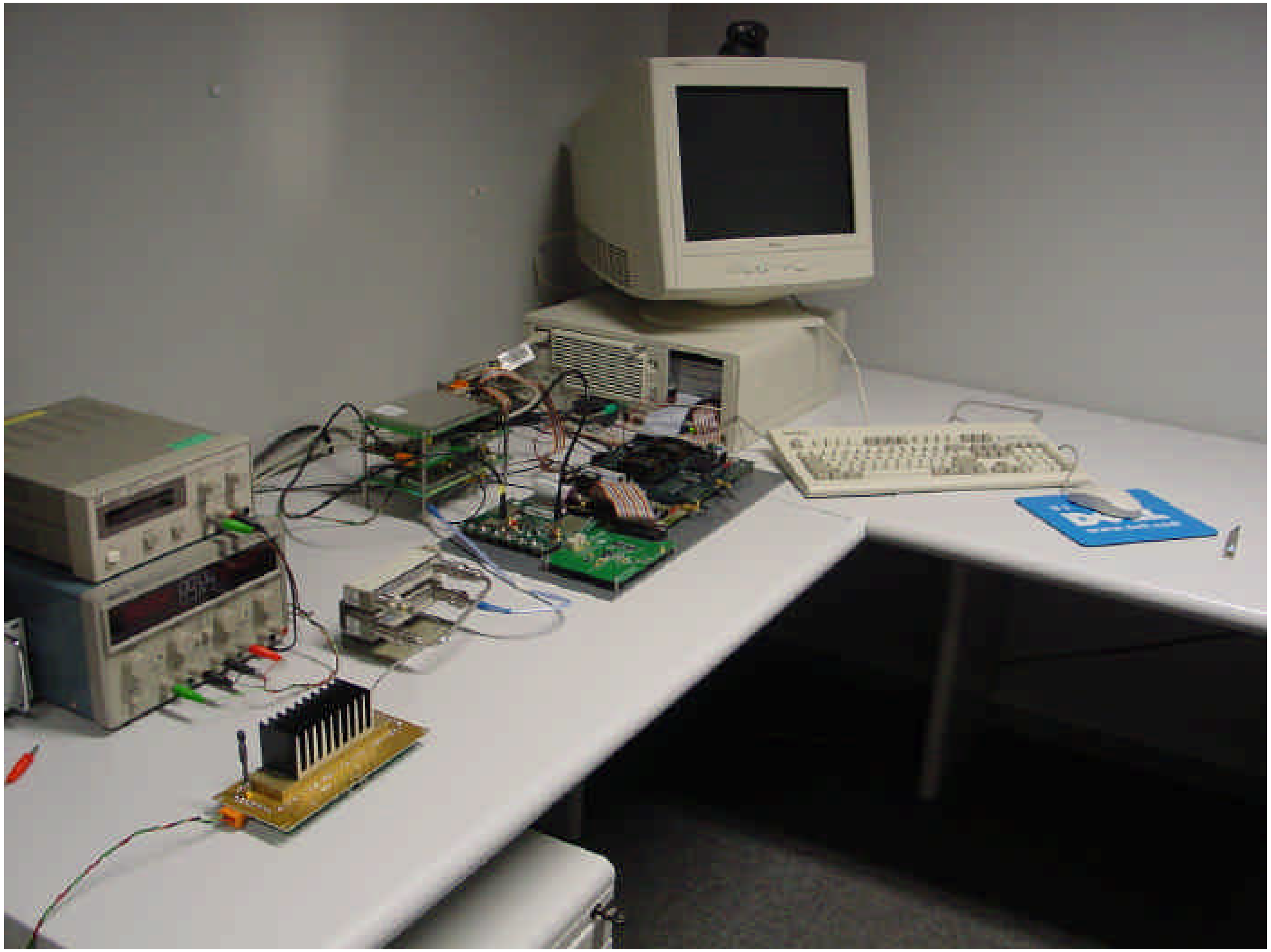


Second generation OFDM Modem



- 0.18m CMOS 5LM
- 20MHz
- 160 PQFP
- 431 kgates
- 19 RAMs
- 20.8mm2
- Ptx = 199mW
- Prx = 212mW

Wireless set-up at 5.2 GHz



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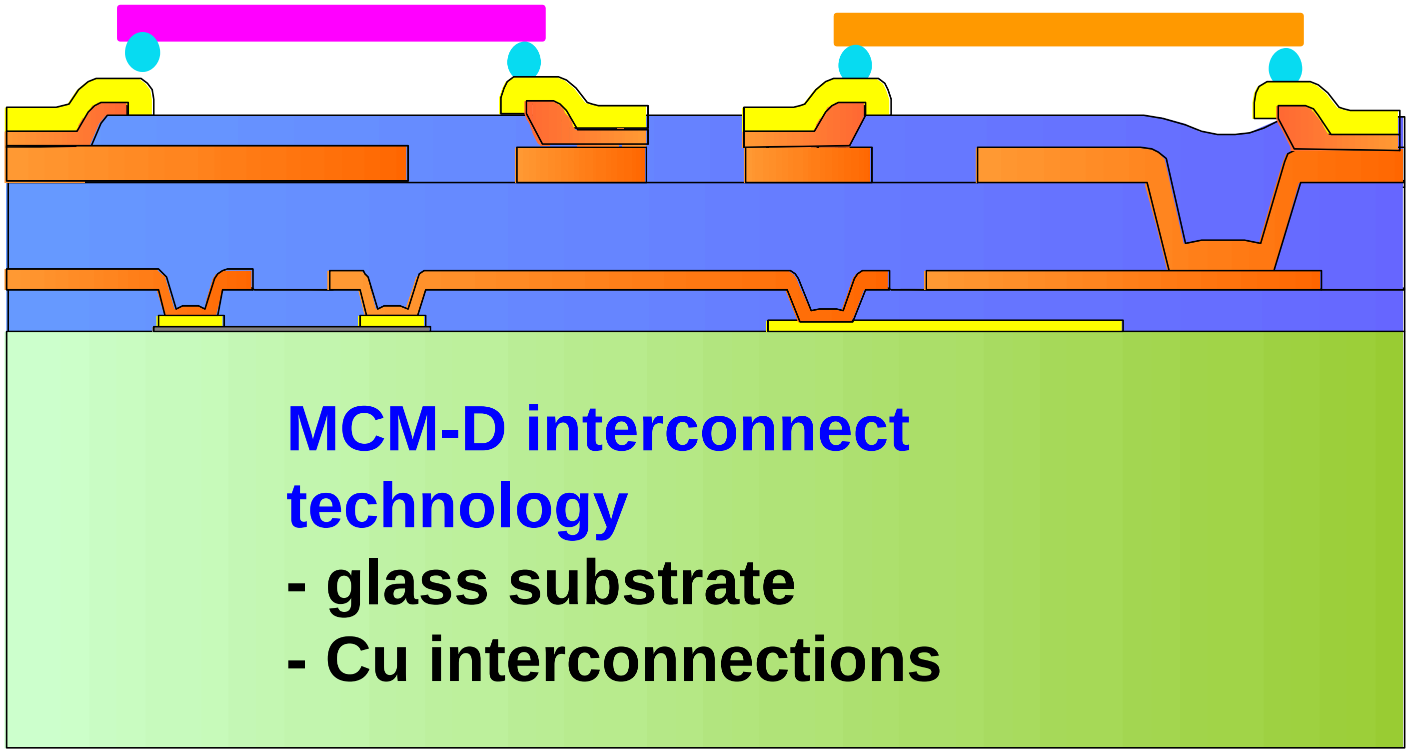
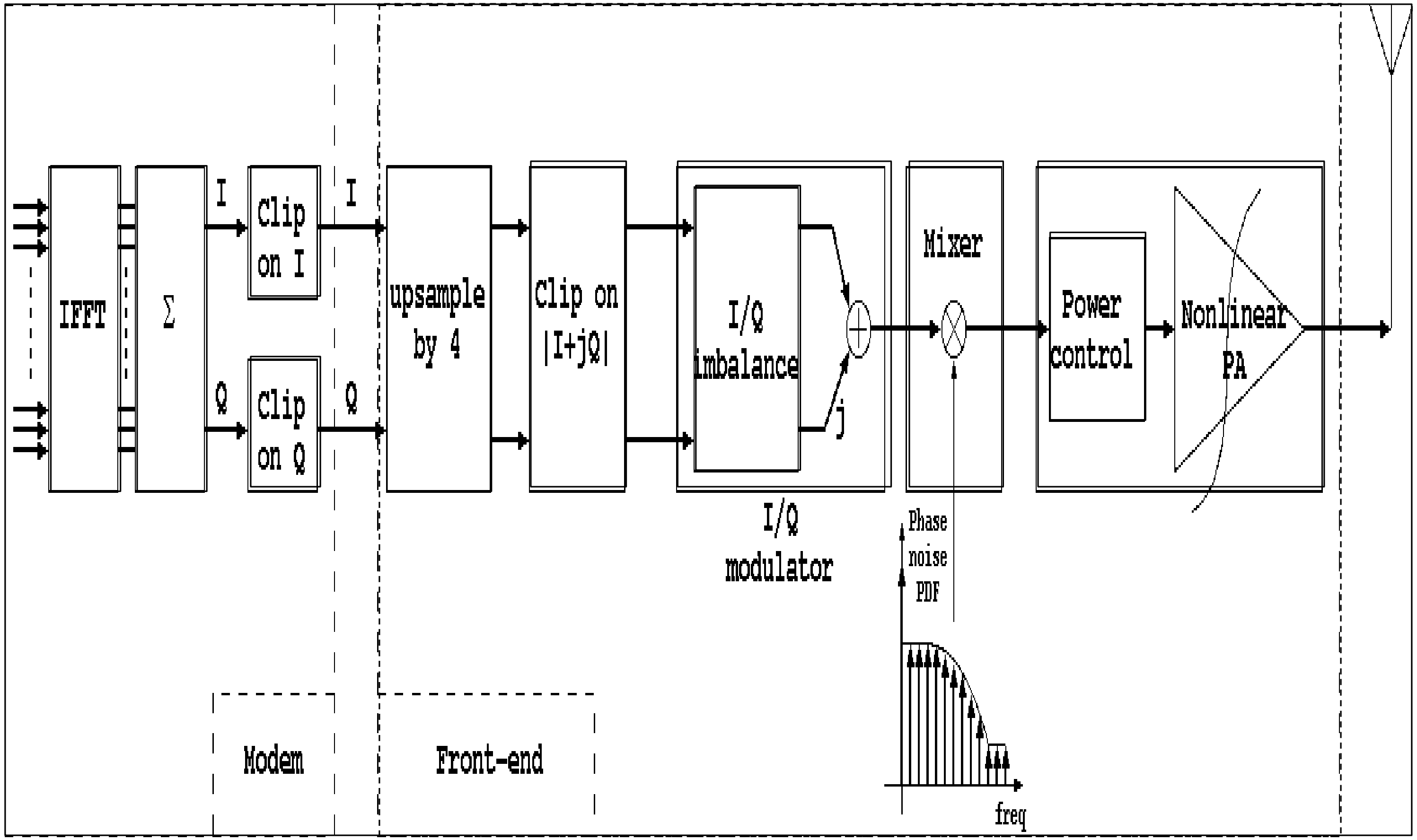
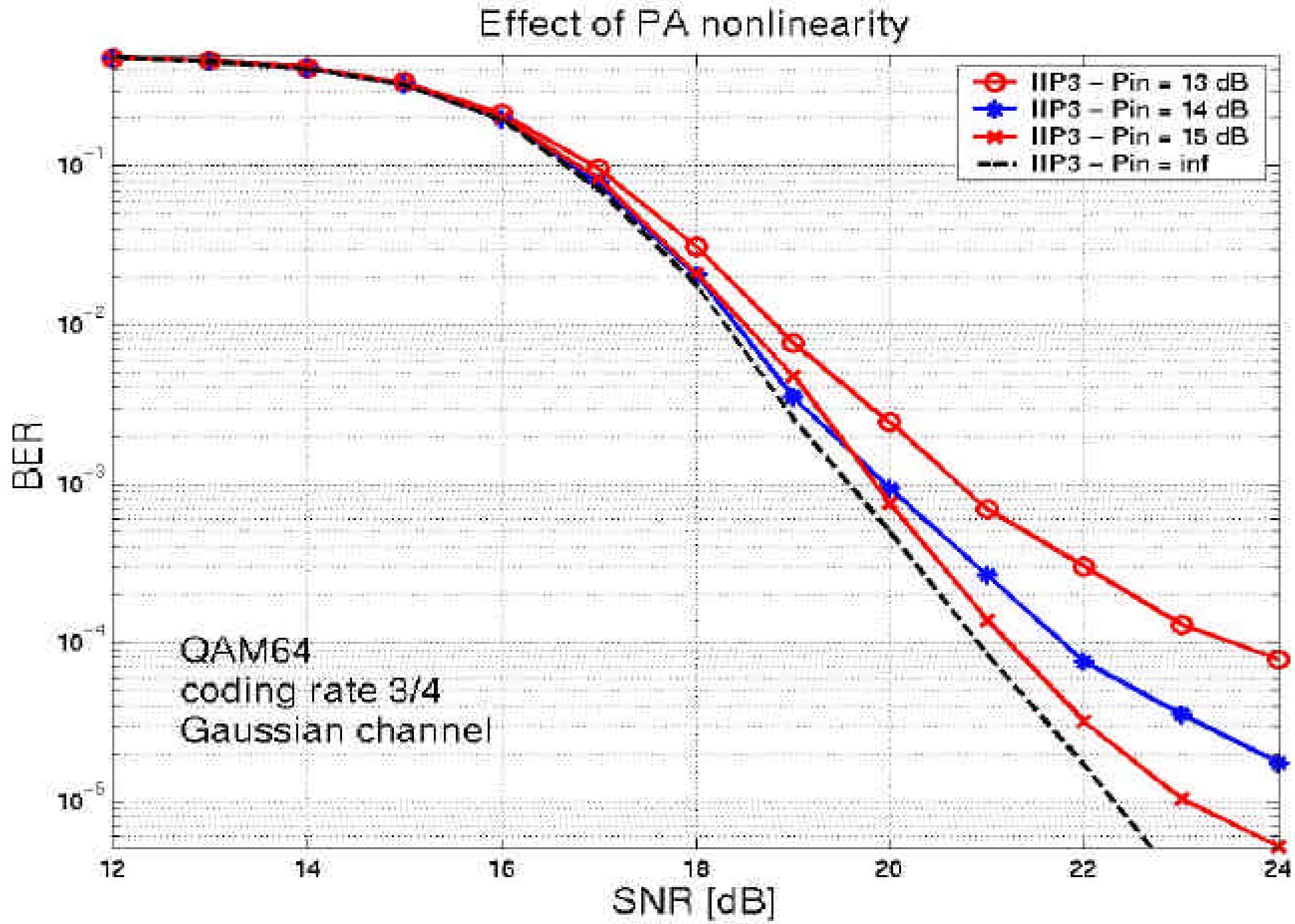
IMEC's solution: WLAN-in-a-package



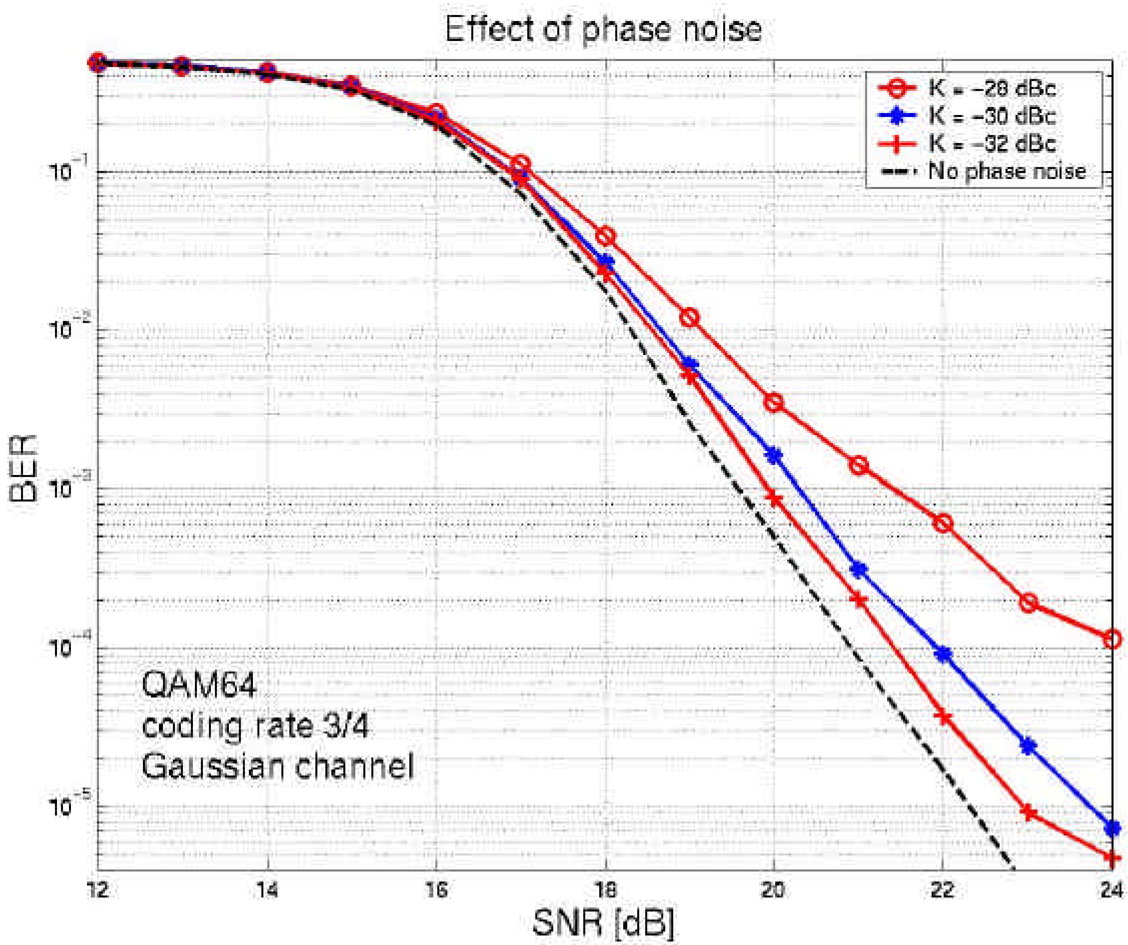
System model includes 4 most important front-end impairments



PA can be operated with only 15 dB back-off (IIP3 - Pin)



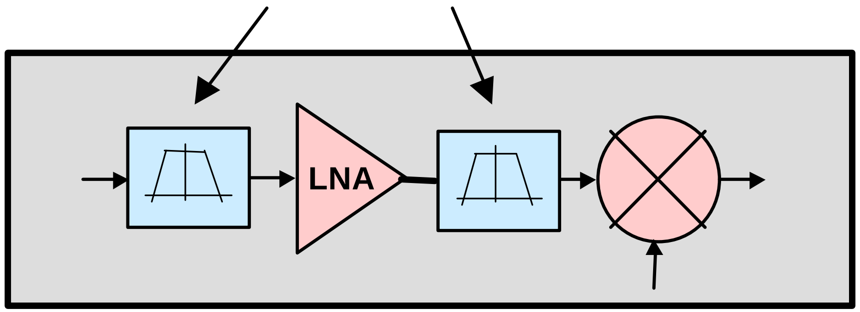
Phase noise must be K<-32dBc for a Lorentzian model



Demonstrator: Single-package 5 GHz receiver RF module

5 GHz WLAN

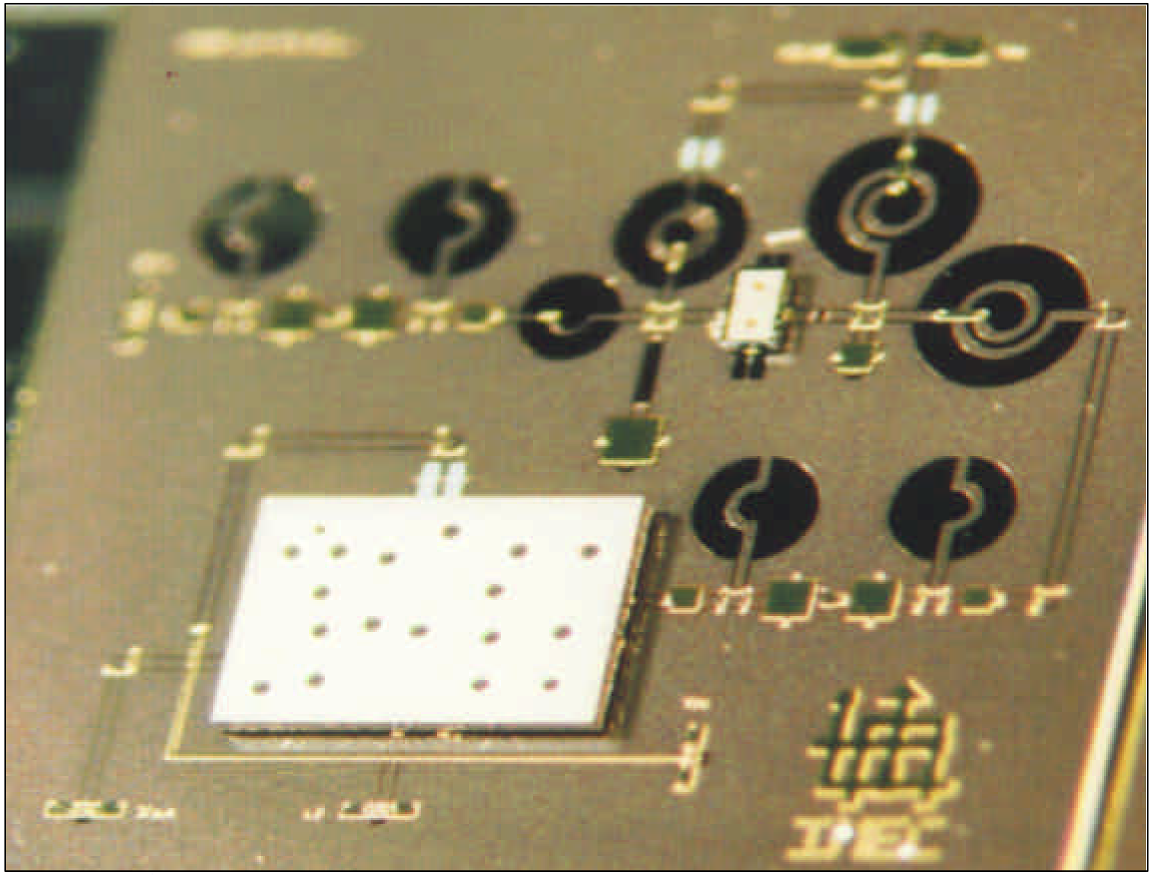
Two 5 GHz MCM Bandpass Filters



LNA with bare die pHEMT transistor (EC2612)

GaAs (pHEMT) bare die downconversion mixer (TGC1411)

Single-package 5 GHz receiver RF module



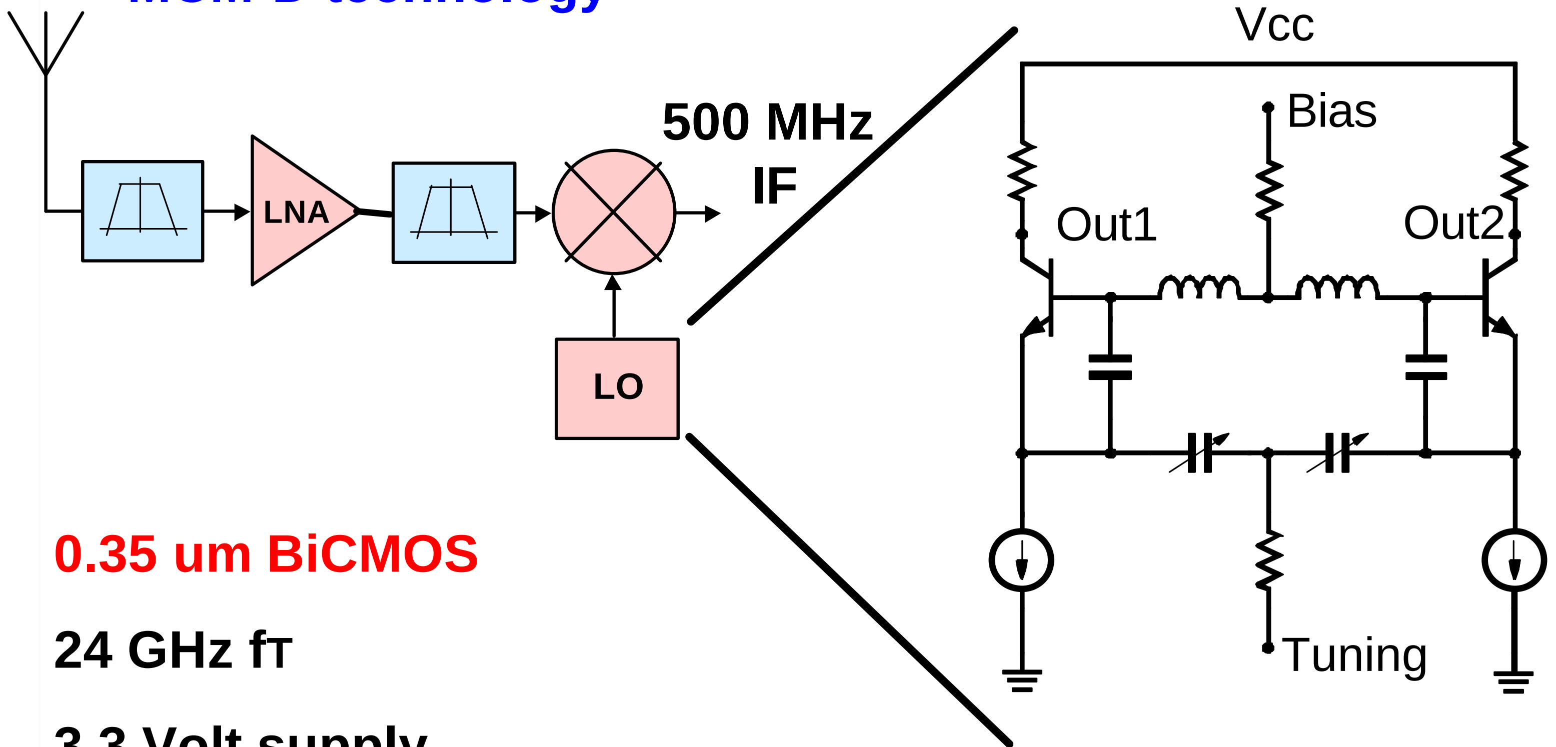
Mixer:
conv. gain: 15 dB
power: 25 mA @ 3V

BPF-LNA-BPF-mixer:
gain: 22.4 dB
NF: 7.8 dB
P_{-1dB}: -25 dBm (input)
size: 6.5 x 7 mm^2

Co-Design of ASIC and MCM allows optimal trade-offs

Chip-package co-design trade-offs in VCO design

MCM-D technology

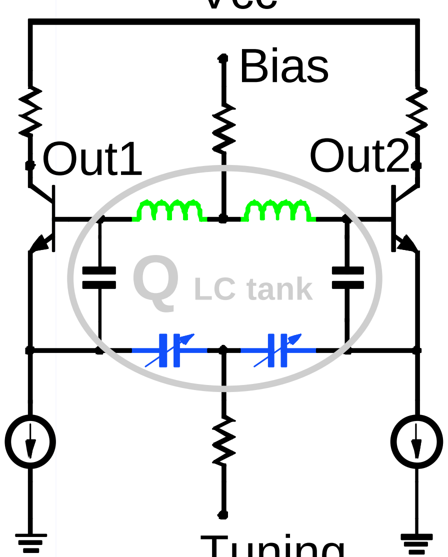


0.35 um BiCMOS

24 GHz fT

3.3 Volt supply

Better VCO performance with high-Q MCM passives



3 versions with constant output power

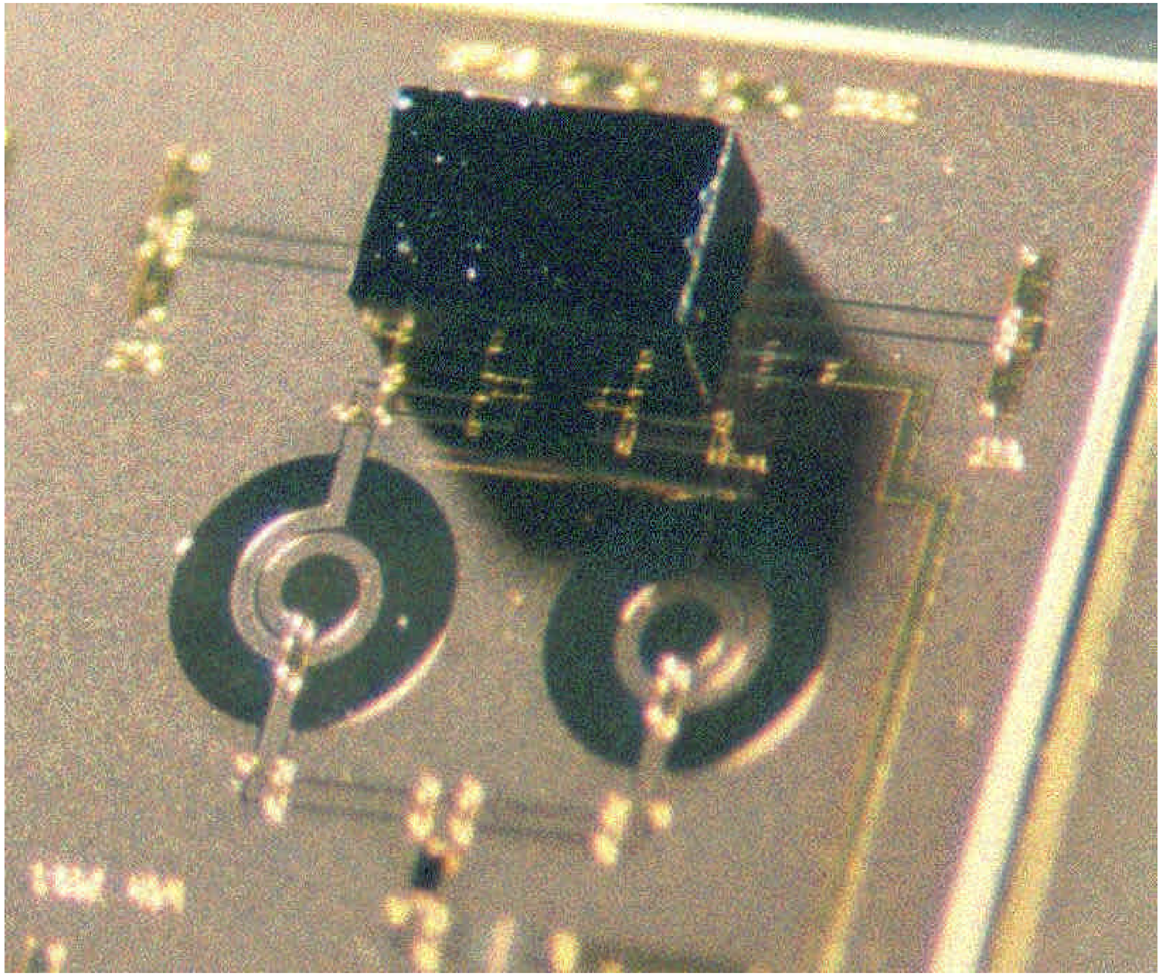
inductors	varactors	phase noise (dBc/Hz @ 100 kHz)	Power (mW)	FOM
on-chip Q=5.5	on-chip Q=17	-86	17.8	167
MCM Q=50	on-chip Q=17	-90	9.5	173.7
MCM Q=50	off-chip Q=40	-92	7.9	176.5

(simulated results)

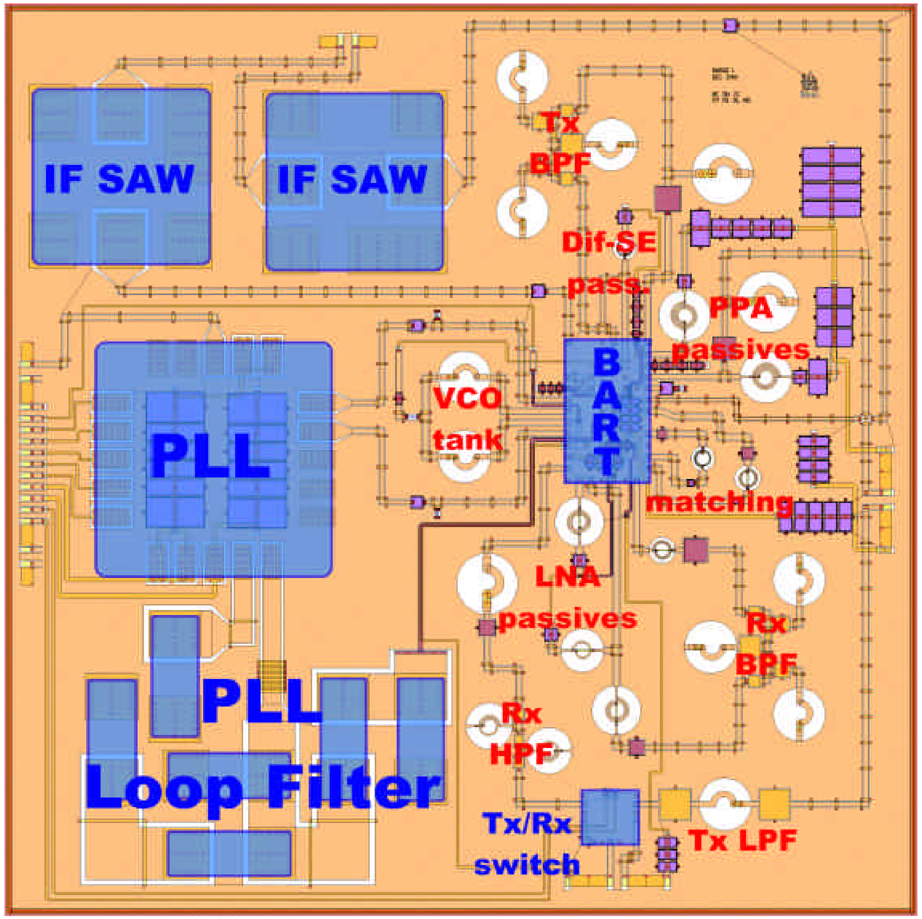
$$S_{\Phi} \propto \frac{1}{Q^2} \cdot \left(\frac{f_{osc}}{f_m}\right)^2 \cdot \frac{2kT \cdot F}{P_S}$$

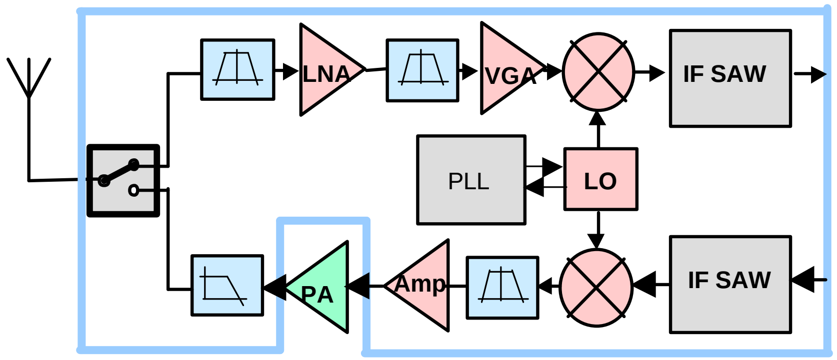
$$FOM = 10 \log \left[\left(\frac{f_0}{\Delta f}\right)^2 \frac{1}{L(\Delta f) P_{dc}} \right]$$

4.7 GHz VCO with MCM-D inductors



Complete RF Transceiver in a single package





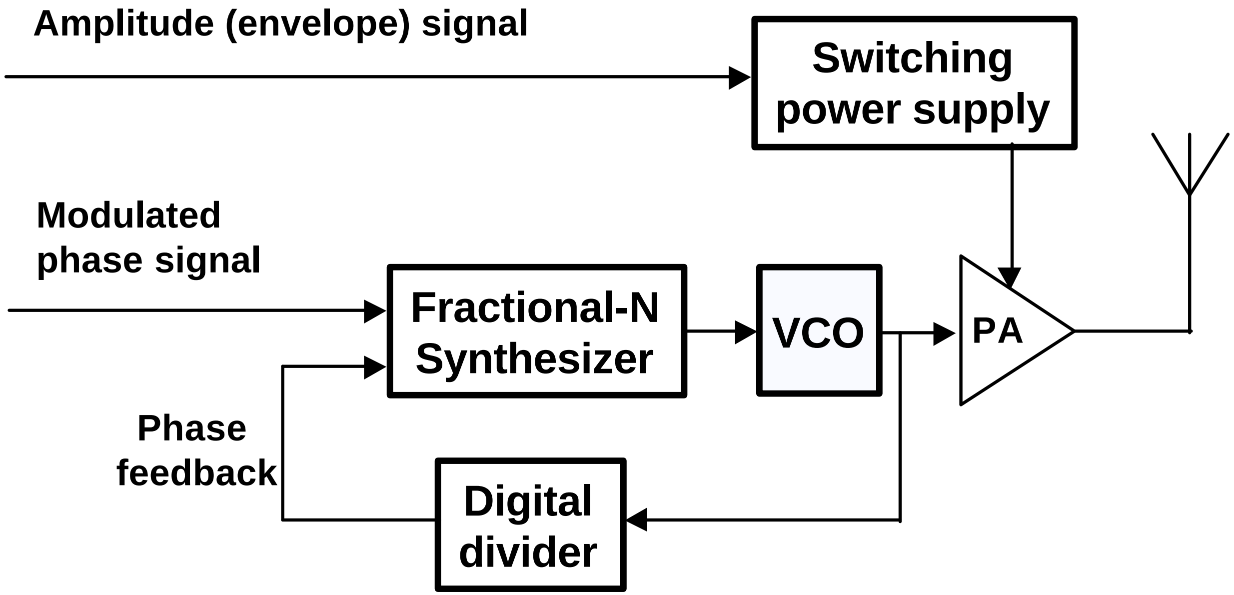
Size:
16 x 16 mm2

Next step: from antenna to DC in a single package

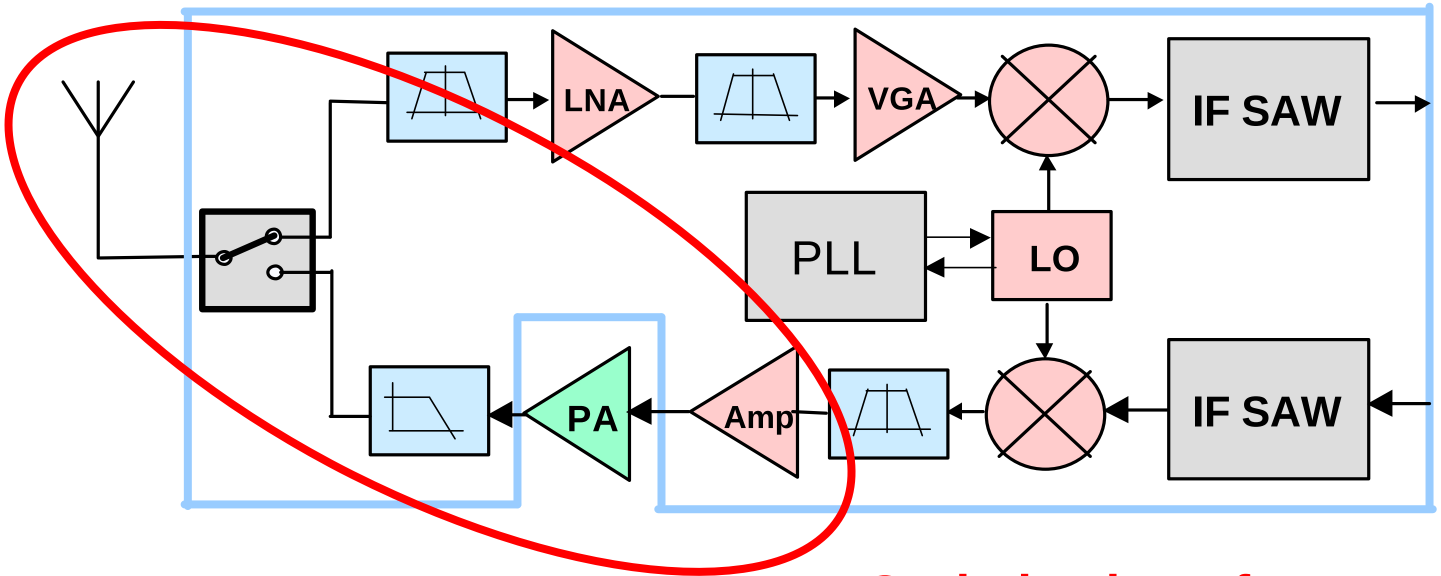
- ▷ Direct downconversion
- ▷ Polar upconversion
- ▷ power amp in the package
- ▷ eventually, antenna in the package

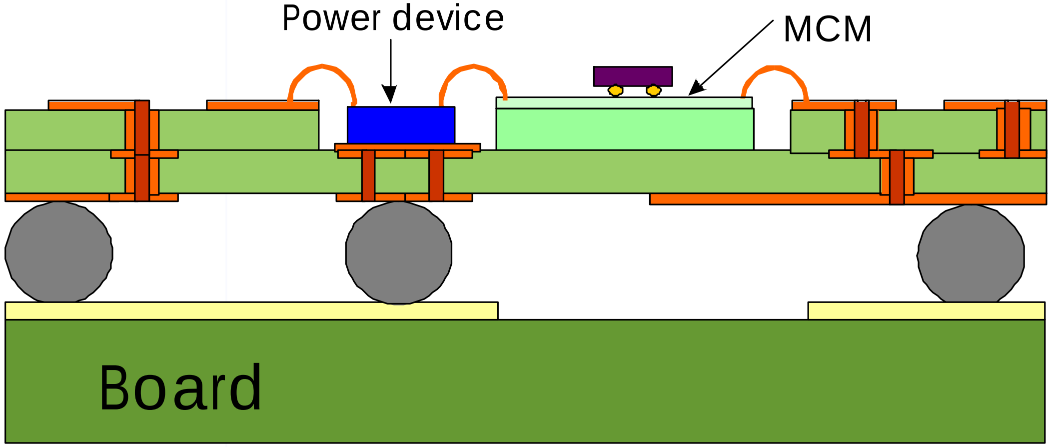
Transmitter architecture exploration

Polar upconversion



Single-package implementation and demonstration





Optimization of power amplifier chain

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OFDM

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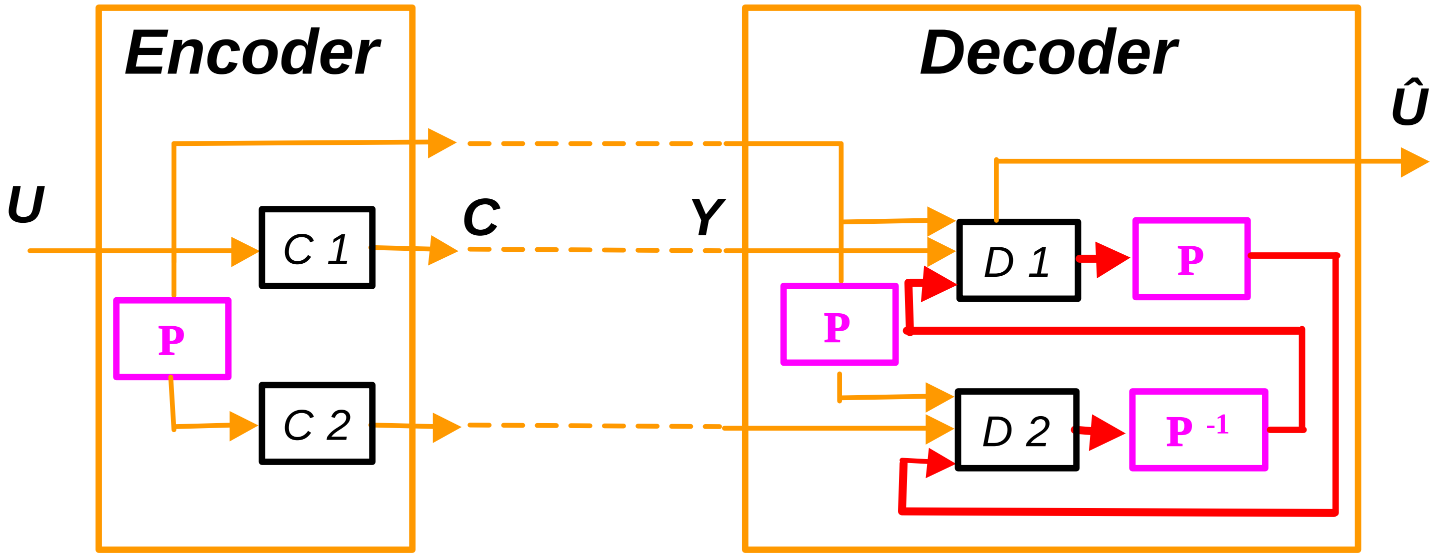
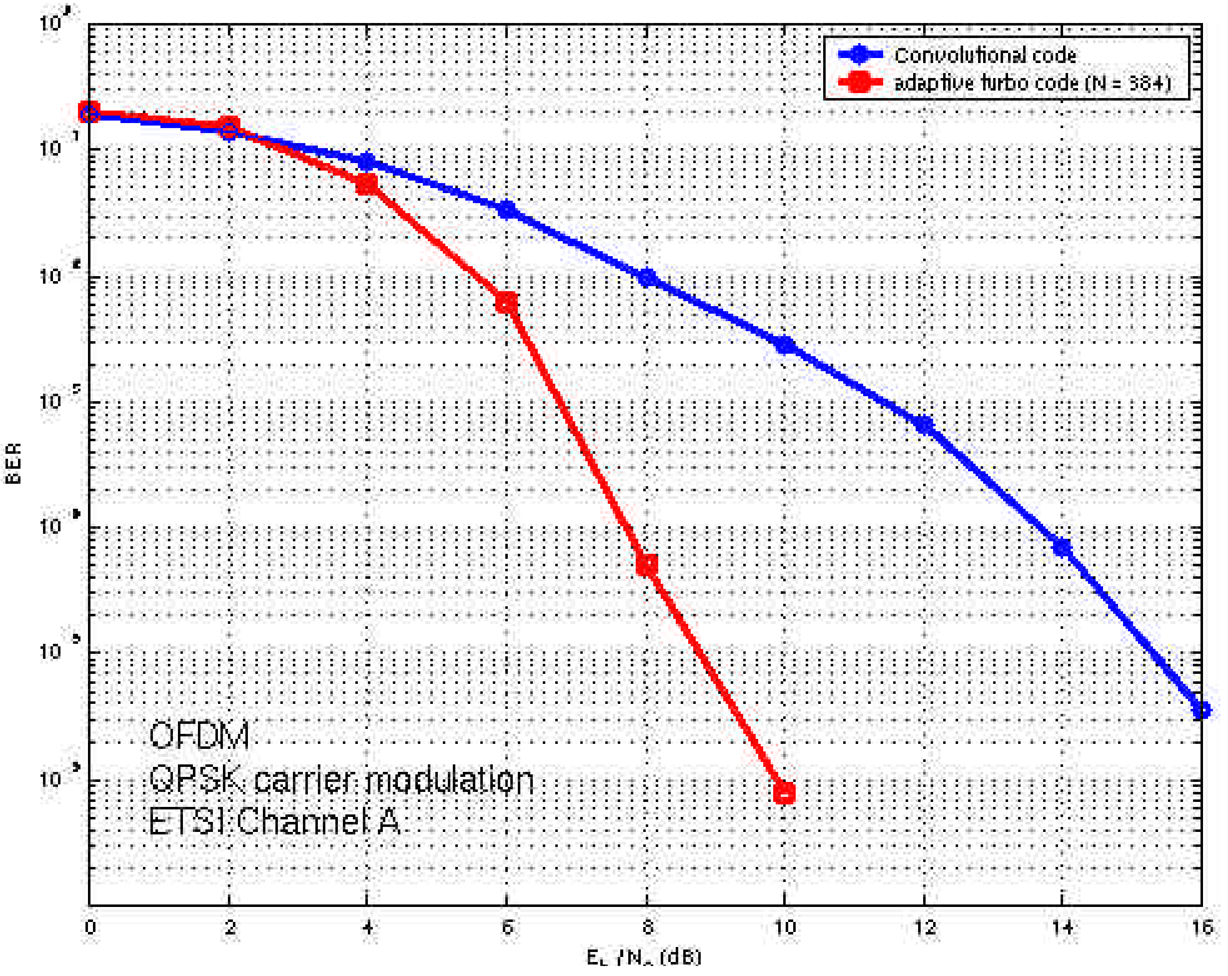
Turbo Decoding Scheme

- **Iterative decoding:** *D1* ® *D2* ® *D1* ® *D2* ® ...
- **A decoder module (*D*) for each encoder (*C*)**
- **Increasingly good solution:**

  closer to maximum likelihood decoding



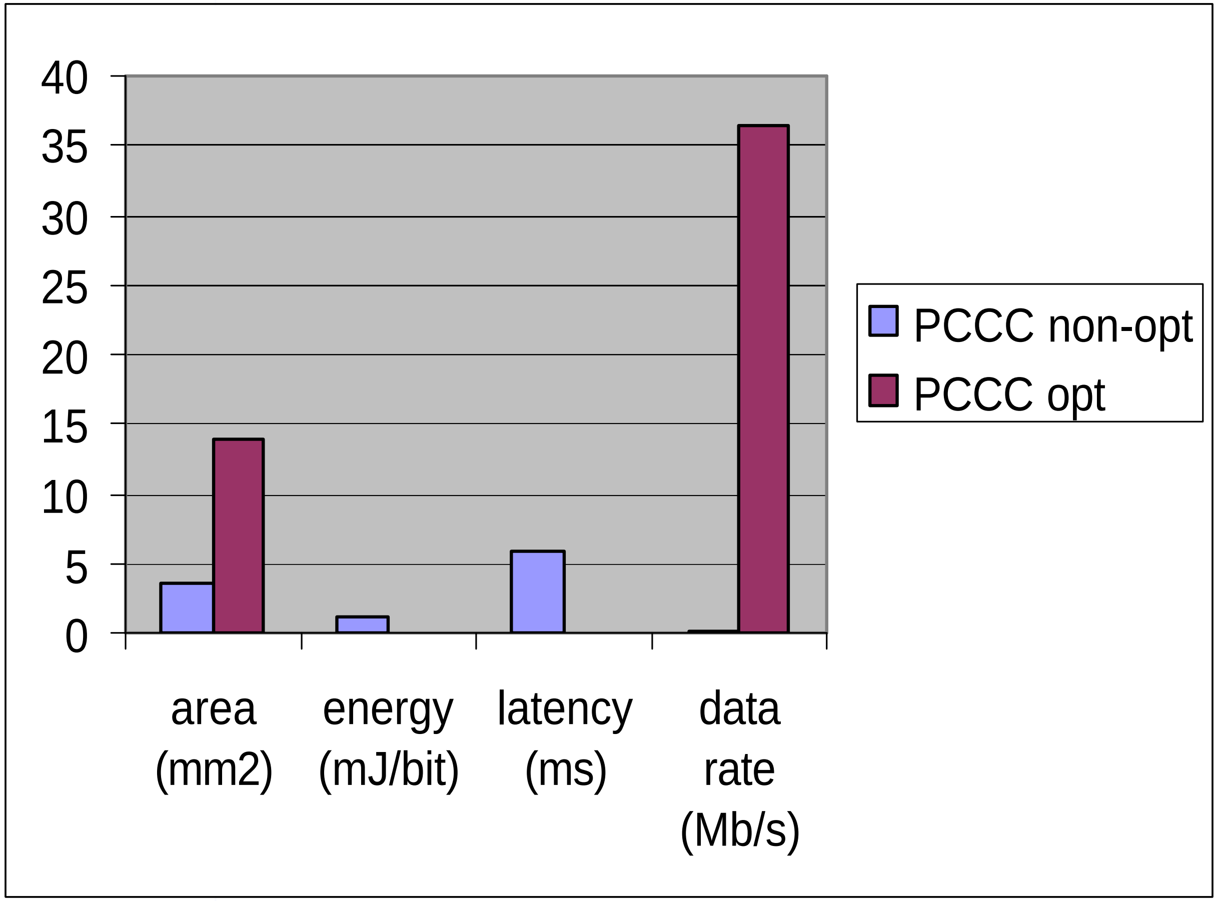
Turbo coding significantly improves performance



BER

Eb/No (dB)

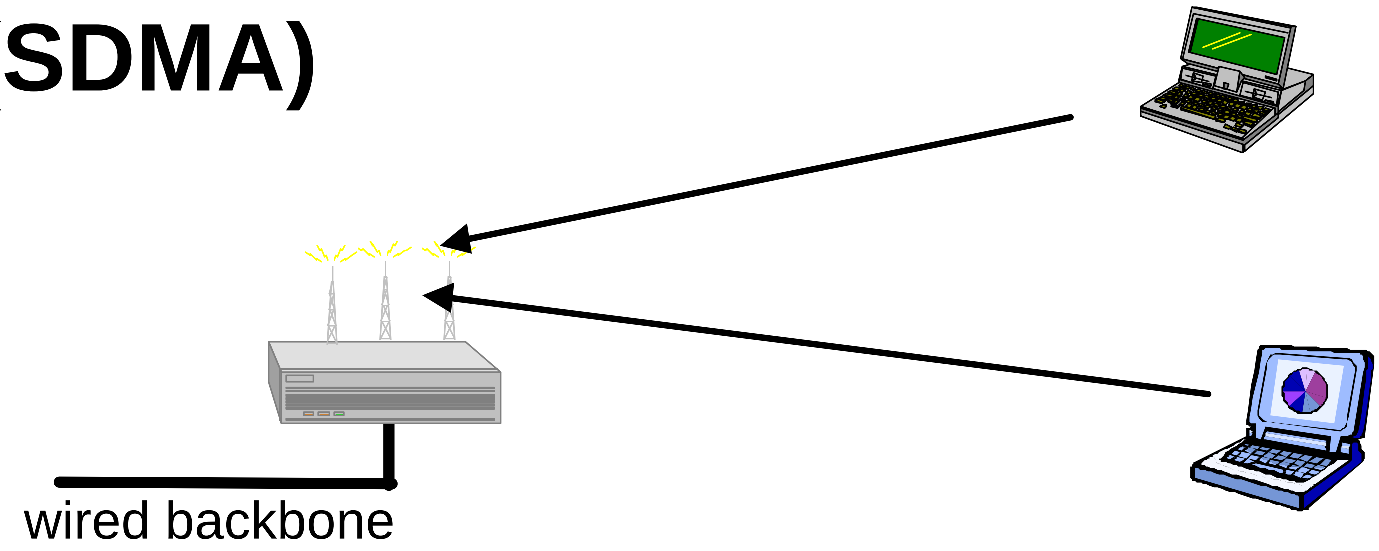
Systematic memory optimizations reduce power consumption



*3.9 /20.9 /568 *323

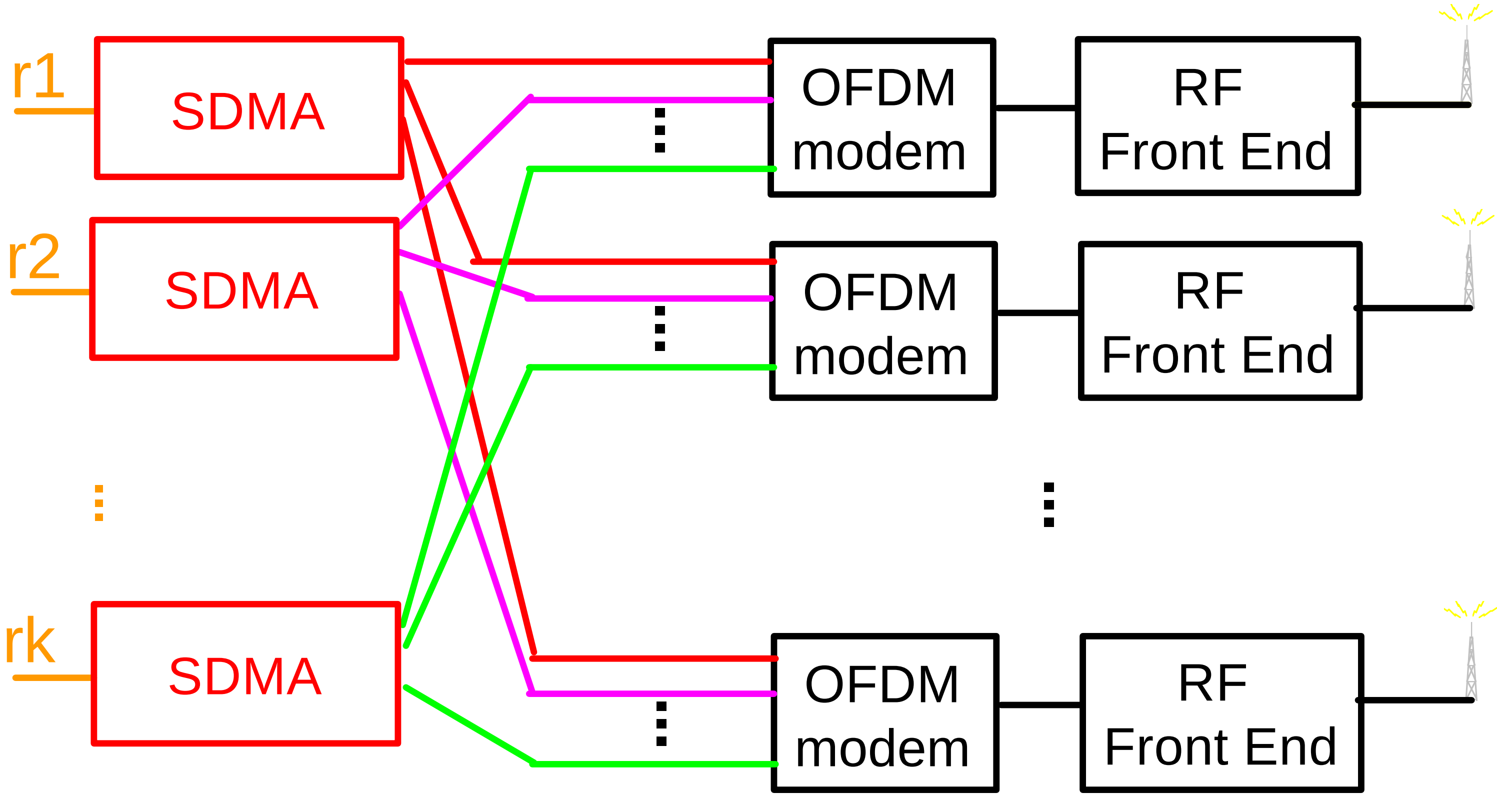
- ▷ **Systematic optimization improves:**
  - **power**
  - **decoding delay**
  - **data rate**
- ▷ **At the cost of area**

Spatial Division Multiple Access (SDMA)

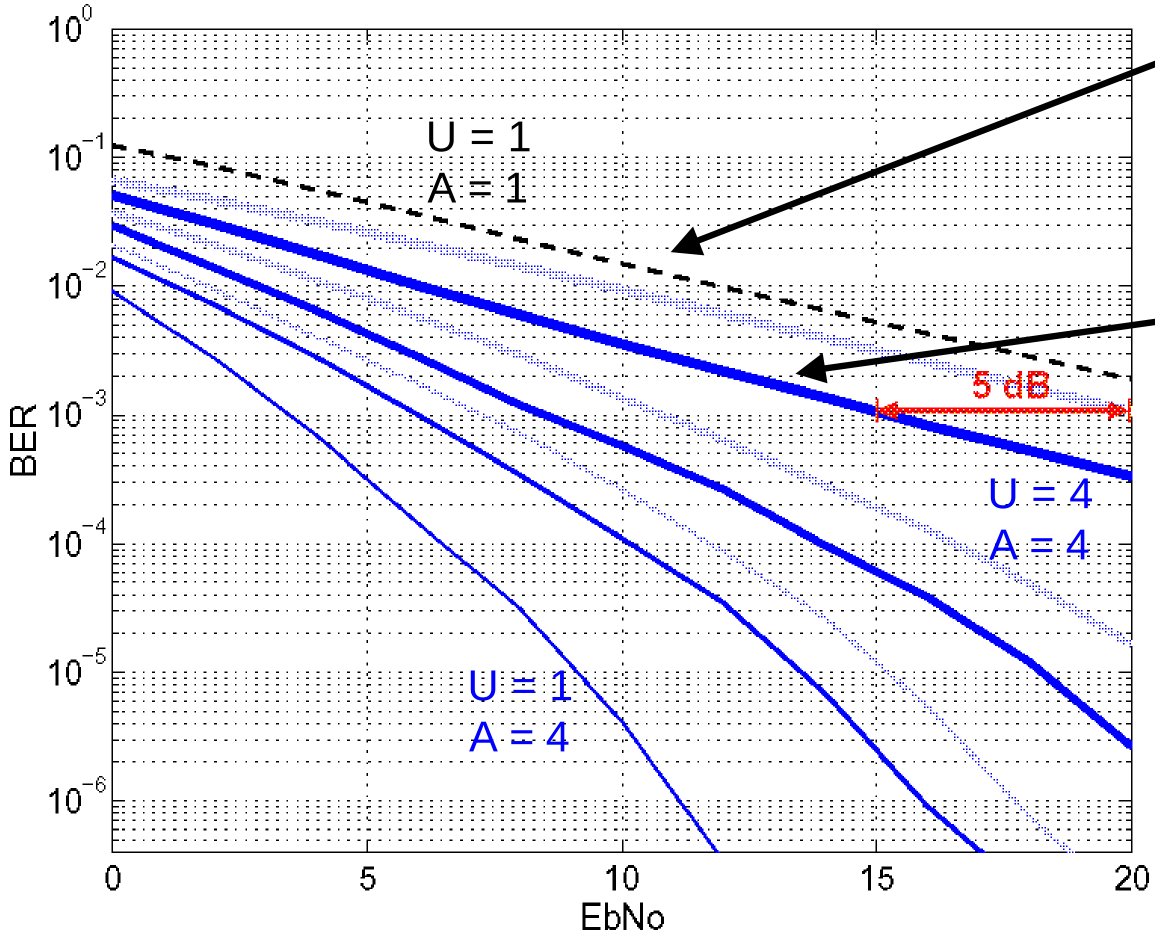


- Improves bandwidth efficiency. System capacity increases with number of antennas
- By exploiting spatial diversity
- Antenna array processing at basestation for Tx and Rx
- OFDM reduces the complexity of baseband SDMA processing

OFDM / SDMA Architecture with Per-carrier Processing

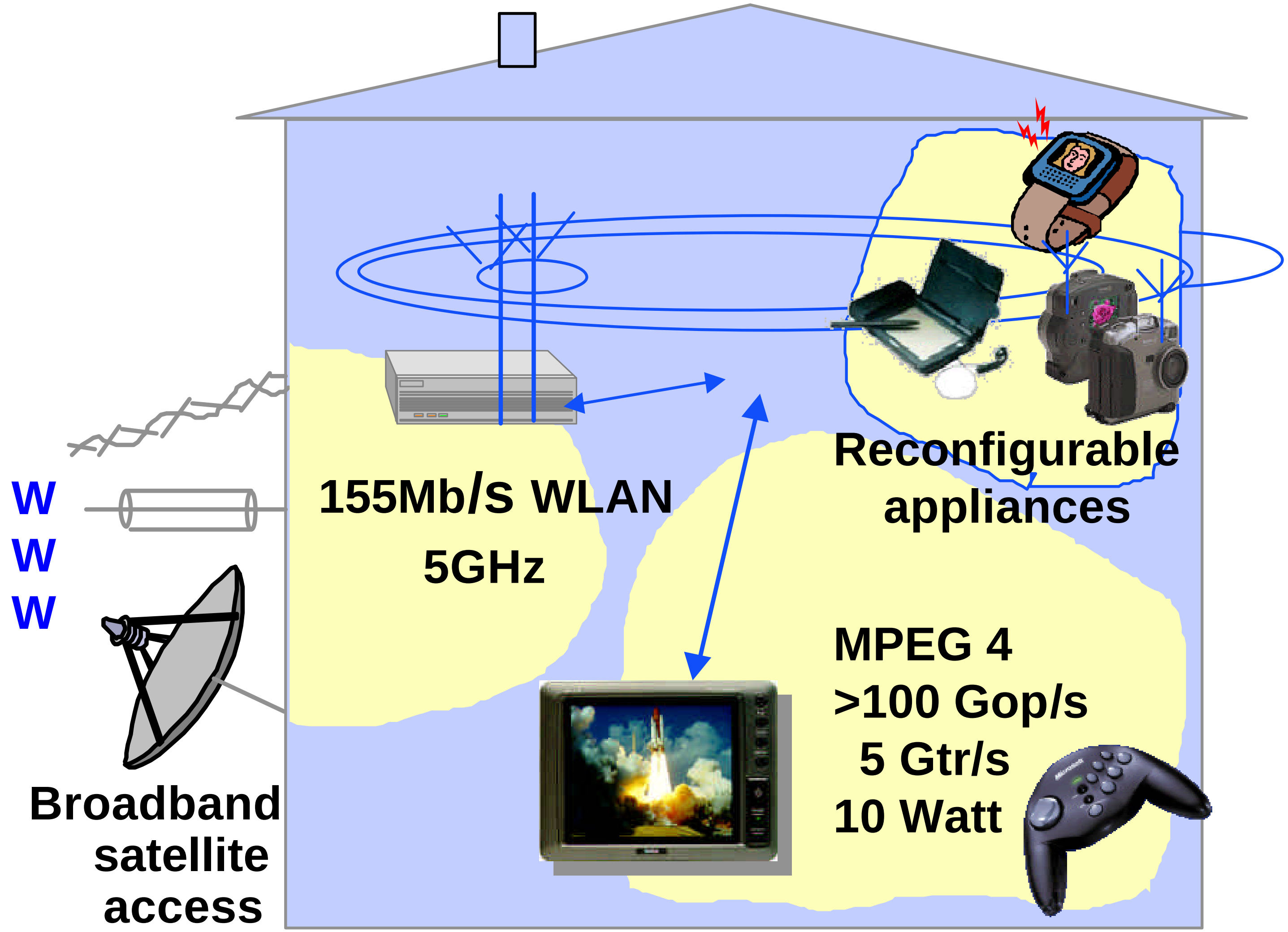


OFDM/SDMA Multiplies Network Capacity



- 1 user
  @ 25 Mbps
  1 antenna
- 4 users
  @ 25 Mbps
  4 antennas
- Same bandwidth !
- Better performances !

Multimedia home gateway requires a QoS MAC

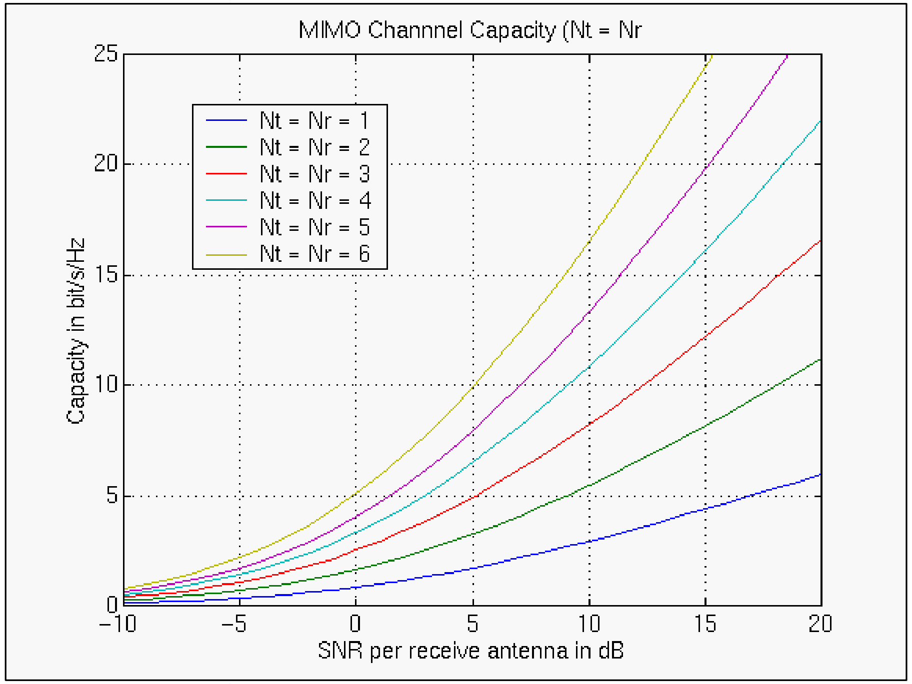


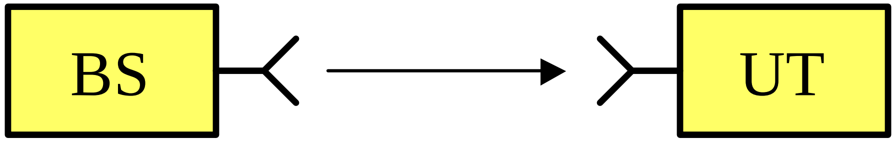
Long term strategy executed in a phased approach

phase 1	phase 2	phase 3
enterprise WLAN	home gateway with extended range and capacity	high datarate terminals
		MIMO
		personal area network
OFDM	Turbo coding SDMA QoS MAC 5 GHz FE SIP	Scalability SIP

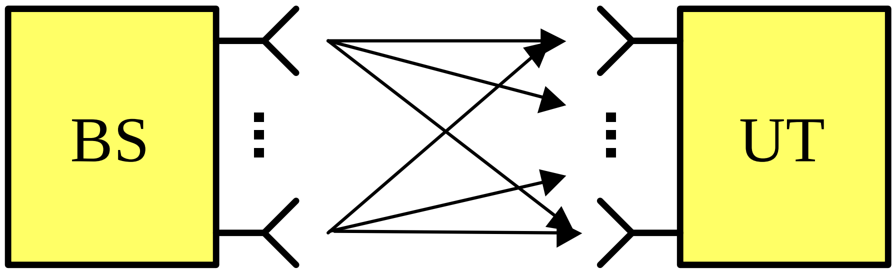
Wireless Personal Network enables new applications

Multiple Antennas : Scalability of Link Capacity





1 channel

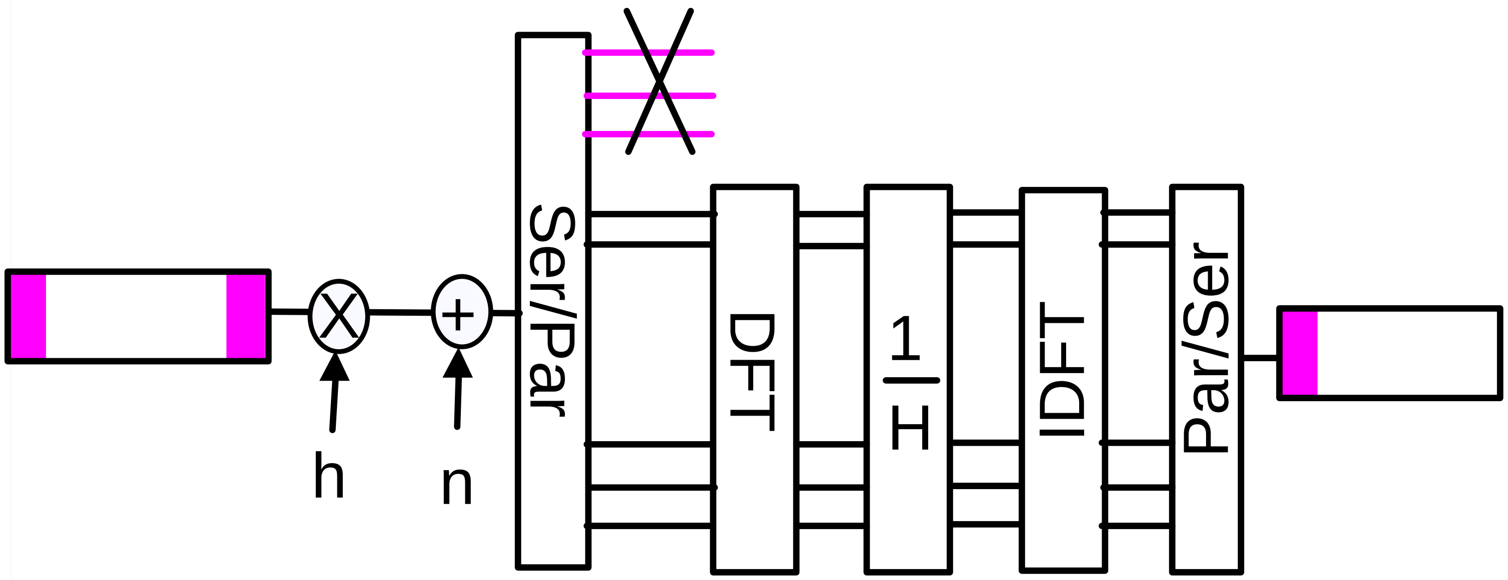


n_T x n_R channels

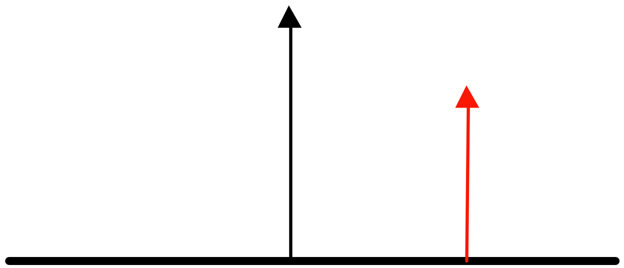
Total Transmitted power is the same

Link Capacity x n

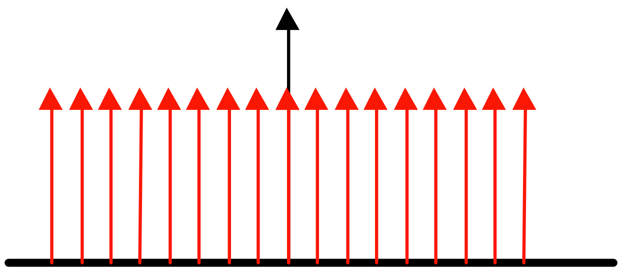
SC-CP offers OFDM performance with low PAPR



Scalability with Hybrid OFDM

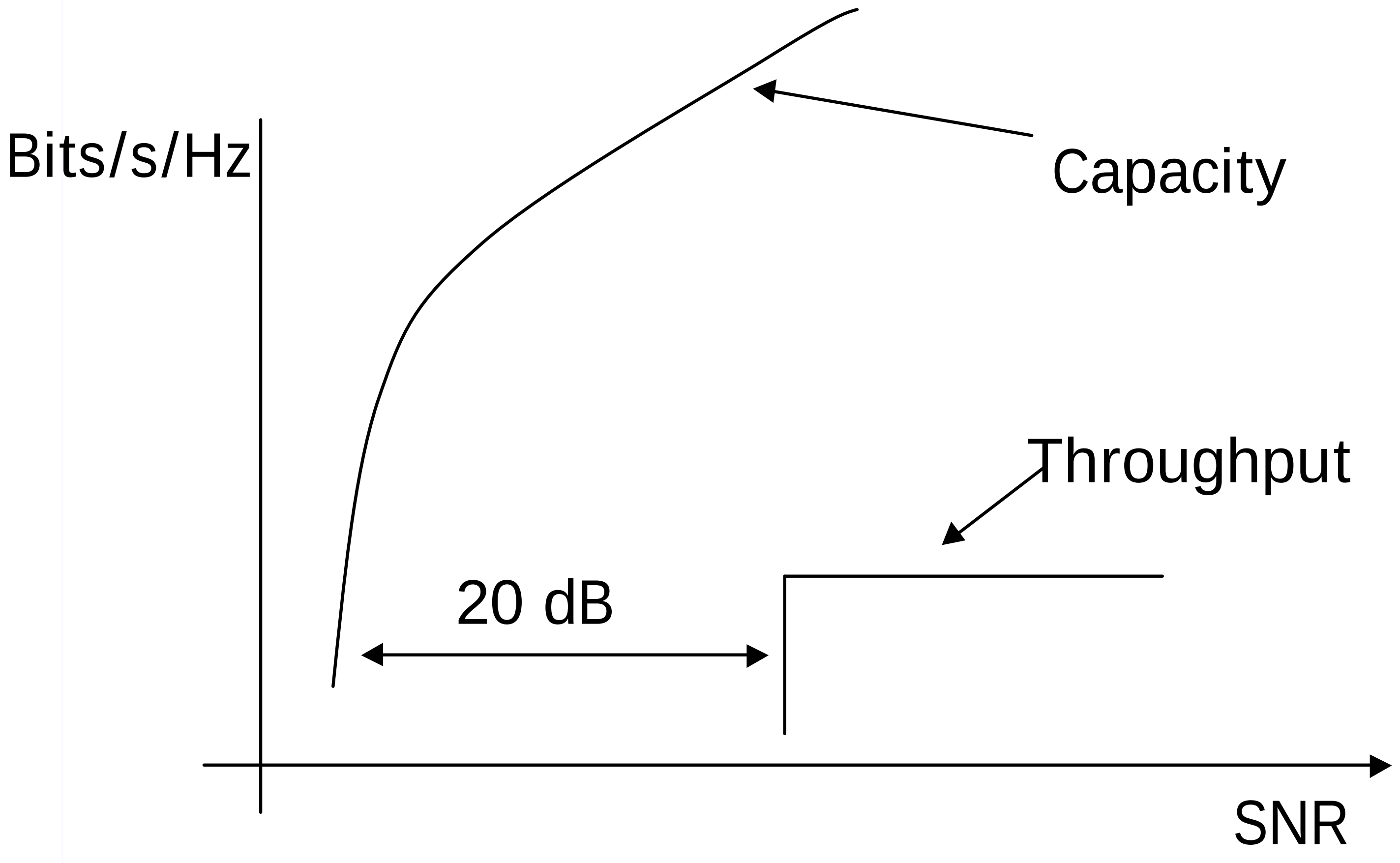


Small and
Low cost

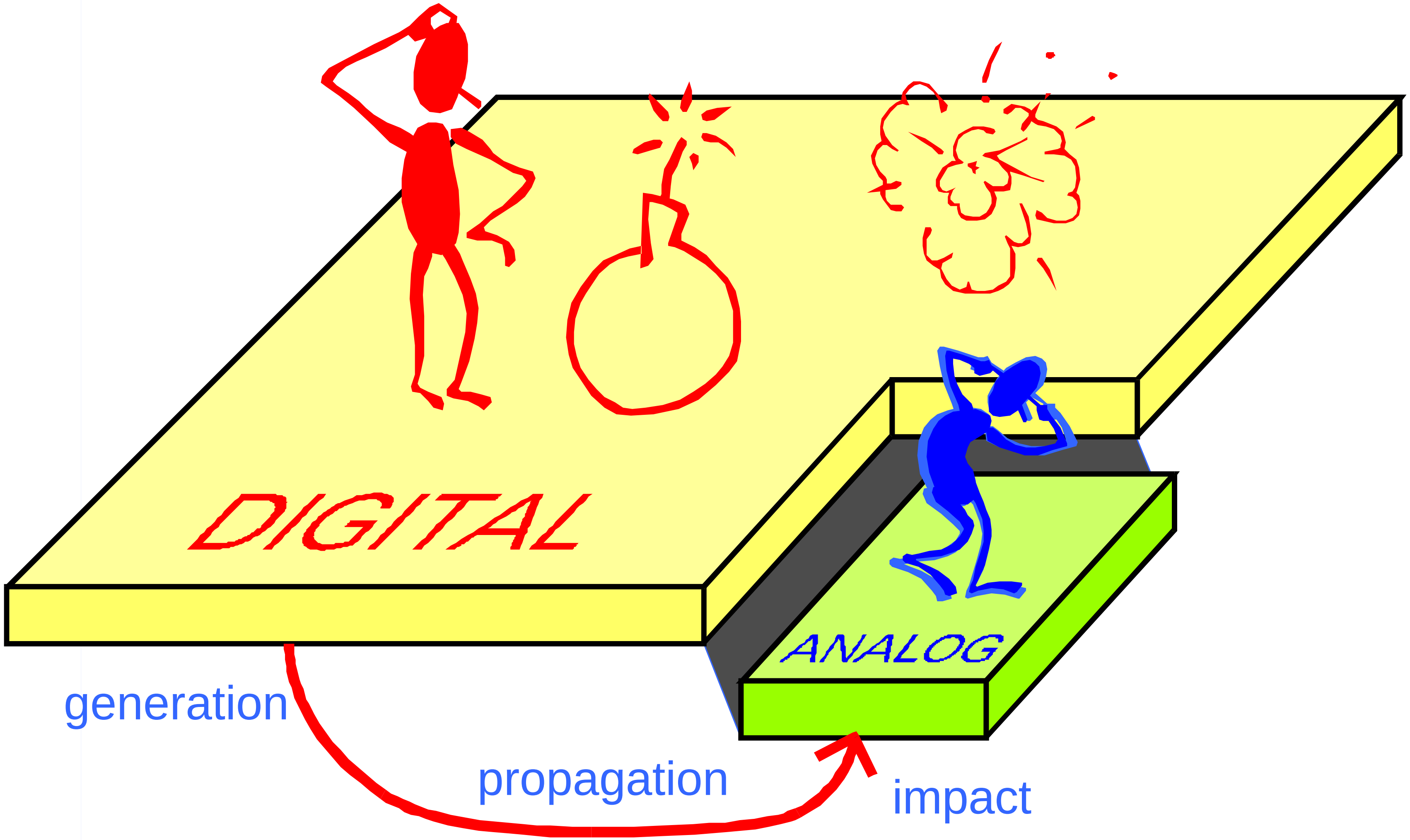


Rich and
fancy

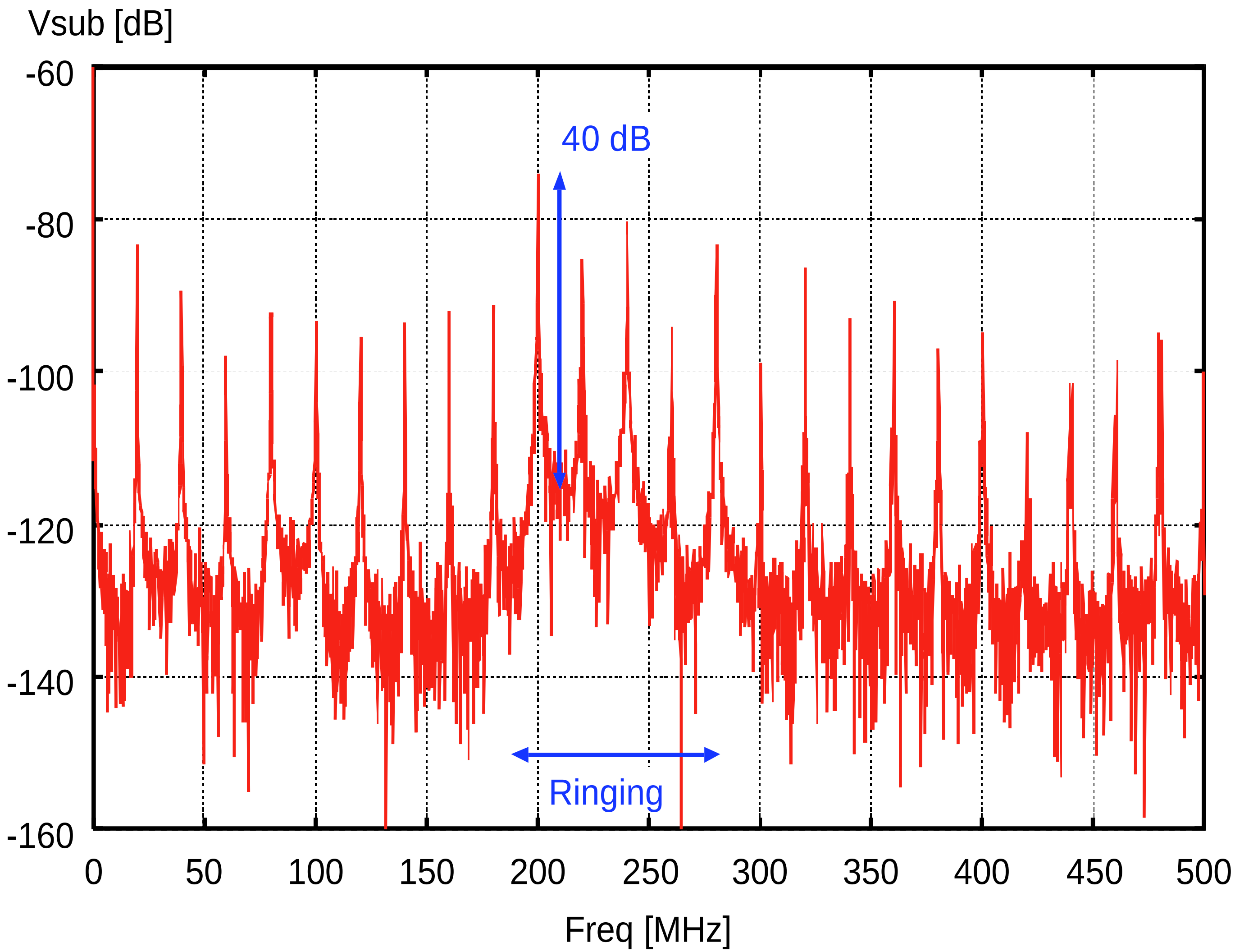
Capacity search : link adaptation to avoid fading margin



Substrate noise coupling is a problem for integrated radio's

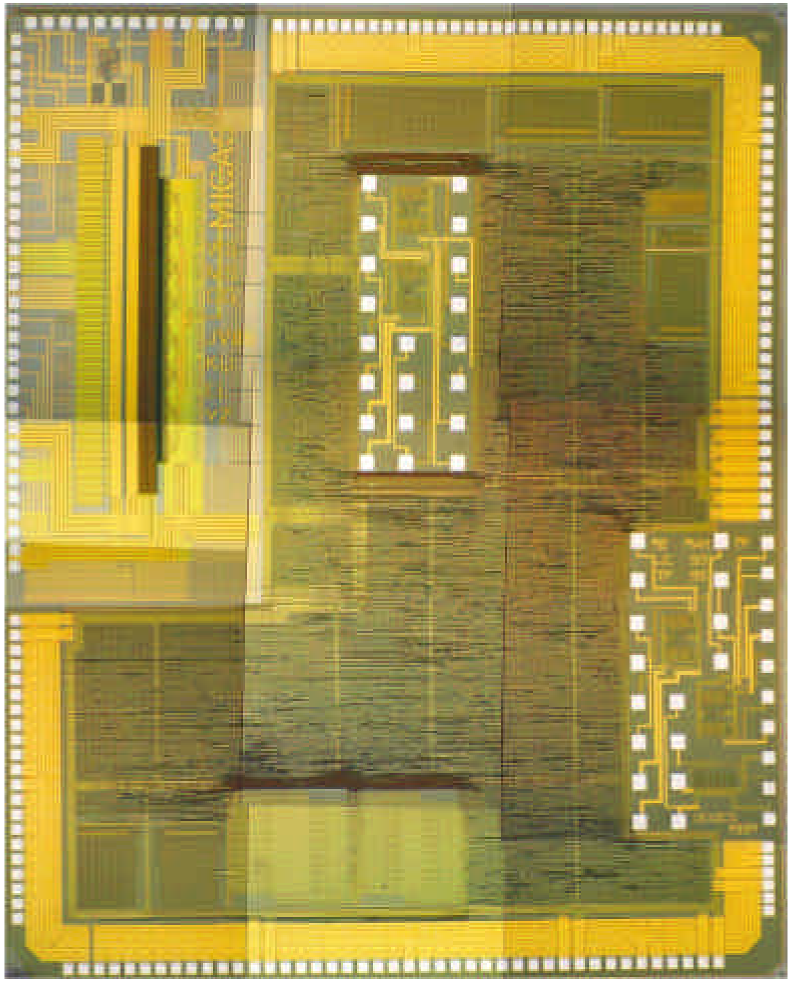


Substrate noise spectral peaks 40 dB larger than noise floor



Applying the analysis to the WLAN OFDM baseband chip

- Mixed-signal IC in 0.35 um digital CMOS
- embedded 8-bit ADC
- digital up/down-converter and complex filter
- WLAN modem
- noise sensors



Our Goals

▷ **Mid term goals:**

- **demonstrate a high performance wireless home gateway: turbo coding, SDMA, QoS MAC.**
- **Demonstrate an integrated 5GHz front-end.**

▷ **Long term goals:**

- **single-package radio for personal area networks.**
- **High datarate multi-antenna terminals.**