Wireless readout

MULTI-GIGABIT WIRELESS DATA TRANSFER FOR TRACKER READOUT SYSTEMS

H.K. Soltveit, A. Schöning, S. Dittmeier, D. Wiedner

TIPP14 Amsterdam 03-06-14

OUTLINE

- Motivation
- Features of the 60GHz band
- Proposed Readout Concept
- Applied Technology
- 60 GHz Transceiver Chip
- Performance from Simulations
- Summary and Outlook

MOTIVATION

ATLAS Silicon Microstrip Tracker upgrade would requier:

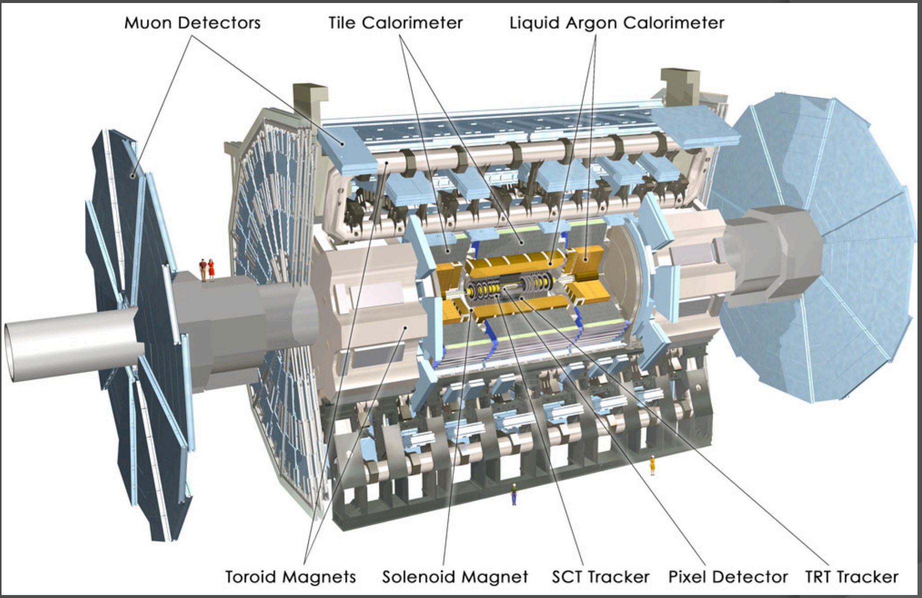
- Bandwidht of 100 Tb/s
- 20 000 links at 5 Gb/s

without increasing the

- Material budget
- Power consumption
- Space for services

and in addition

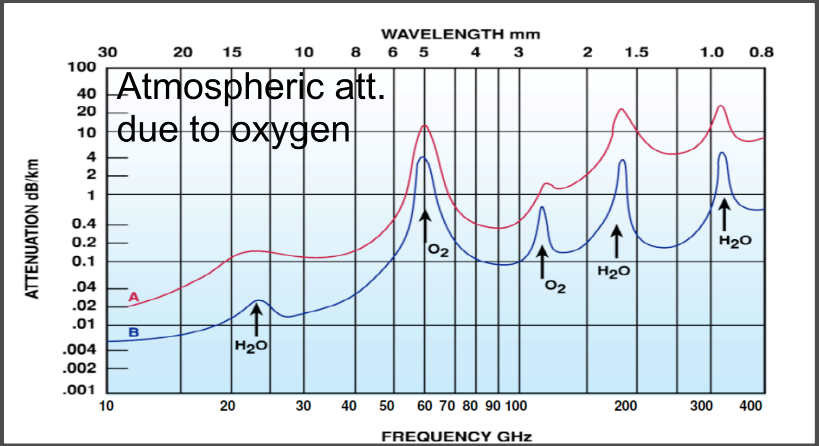
- Contribute to the fast trigger decision



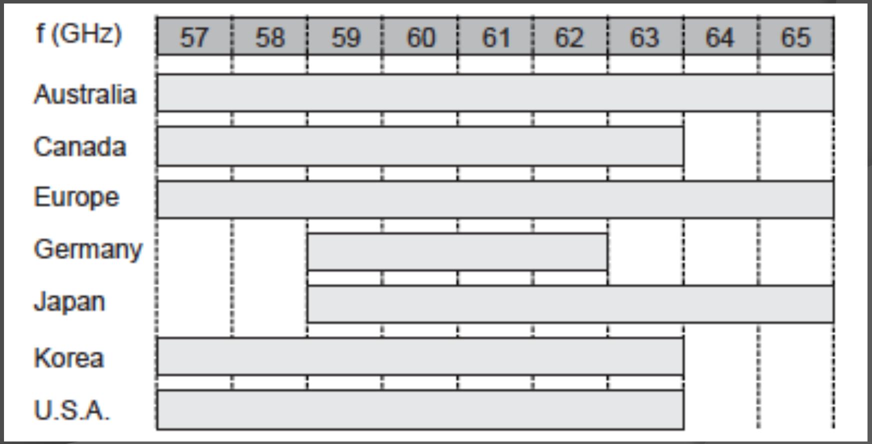
Approach: Wireless Data Transfer using the 60 GHz band

Features of the 60 GHz band

- Unlicensed Spectrum: 4-9 GHz bandwidth available world-wide
- Mostly unused: Low interference probability
- Security: Attenuation through walls/silicon
  - Reuse of frequency
- Can send Gigabits/s of data over short distance (0-100m)
- High frequency: Small form factor
- High transmit power: 40 dBm EIRP (Effective Isotropic Radiated Power)
- Placement: High flexibility



Available frequency band around the world.

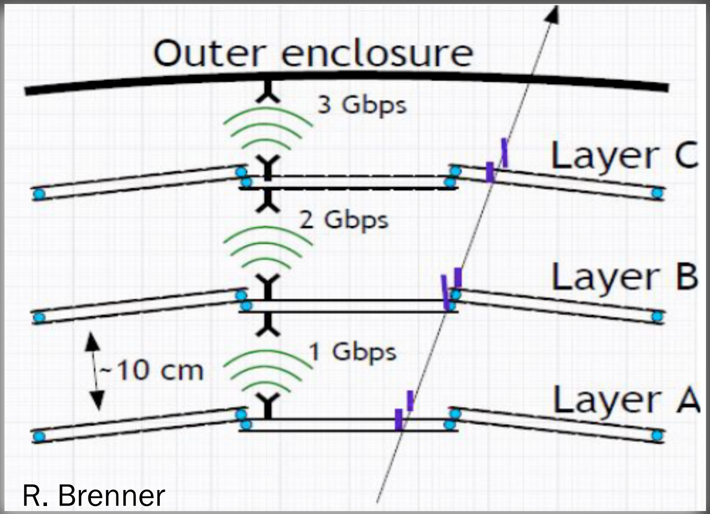


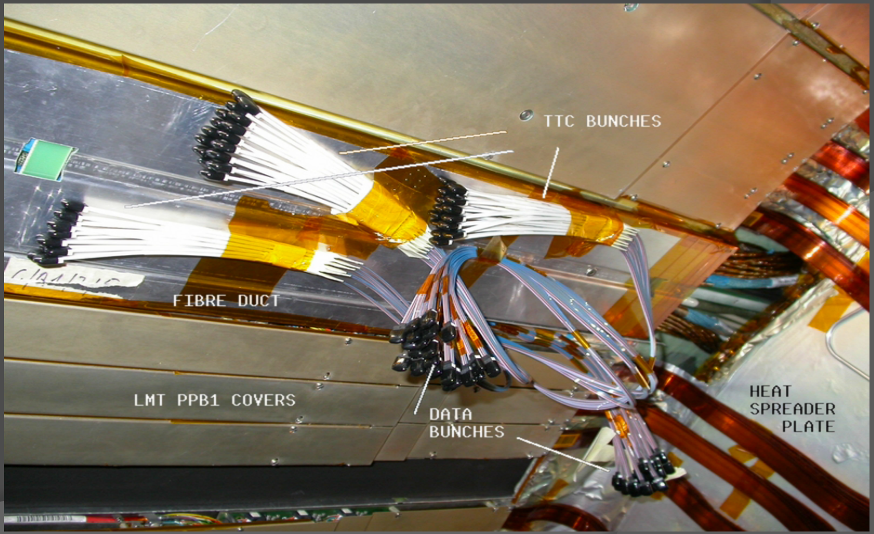
Proposed Readout Concept

- Today the data are readout perpendicular to the particle path.
- Approach: Readout radially by sending the data through the layer(s) by wire/ via connection, with an antenna on both sides.

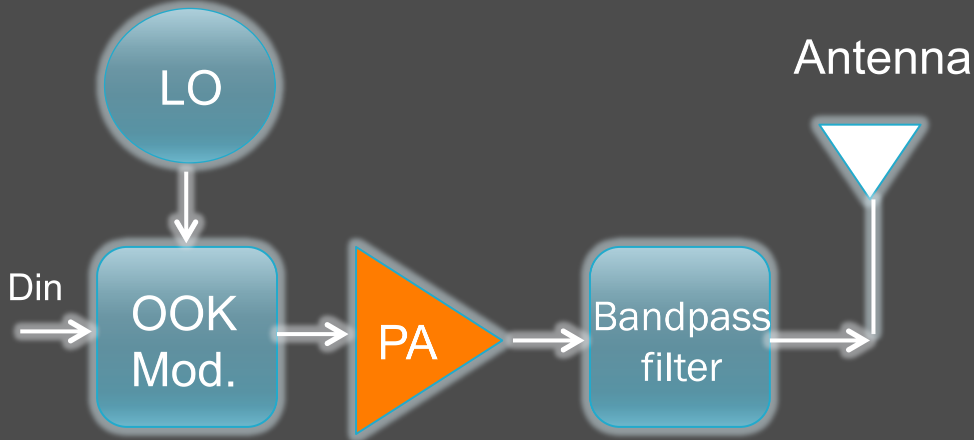
Readout path along particle path
Helps Track Trigger

Less cables and Connectors
Reduce Material Budget





60 GHz Transceiver Chip

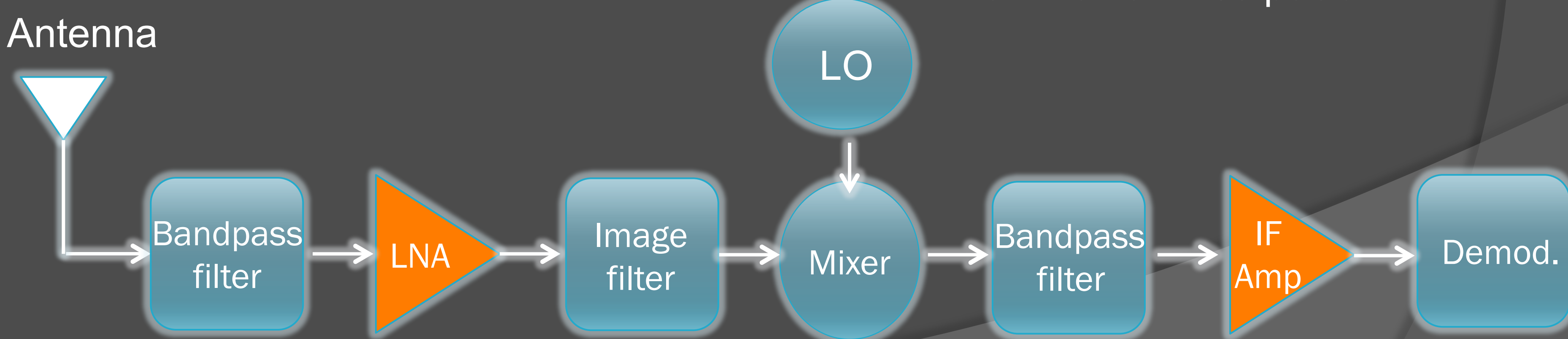


Transmitter:

- Deliver necessary output power
- High power efficiency
- High gain and stability

Receiver:

- Need Low Noise Amplifier (LNA)
- Balance gain, linearity and NF
- Low Power Dissipation



System Specifications

System SNR_{min} is determined by the Bit-Error-Rate (BER) of a given Modulation scheme.

For OOK: $BER = 10^{-12} \rightarrow SNR_{min} \approx 17dB$

$$Noisefloor = -174dBm + 10\log_{10}(9G) = -75\ dBm$$

NF_{tot} chosen to be 9 dB

$$S_{RX} = \text{Noisefloor} + SNR_{min} + NF_{tot} = -49\ \text{dBm}$$

Minimum power level that the system can detect producing an acceptable signal to noise ratio at the output.

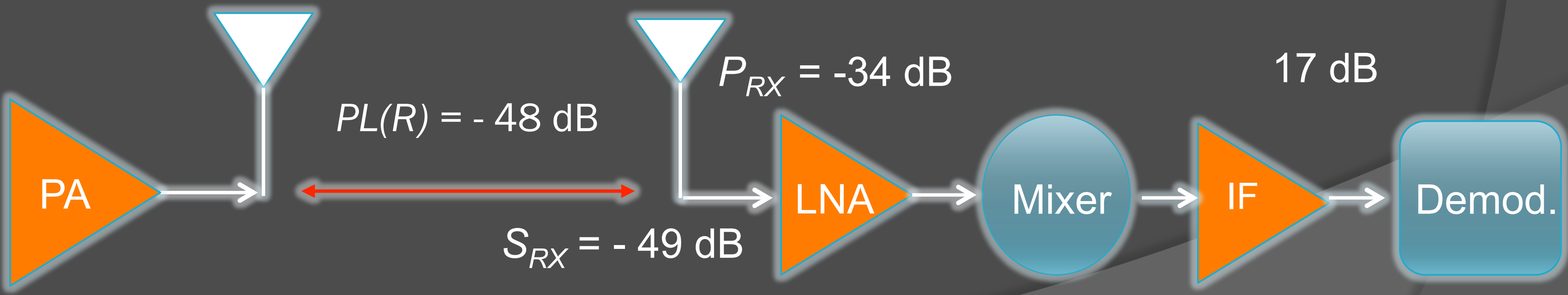
Specifications	Value
Frequency band	57-66 GHz
Bandwidth	**9 GHz**
Data Rate	**4.5 Gbps**
Modulation	OOK
Minimum sensitivity $S_{rx(min)}$	- 49 dBm
Bit Error Rate (BER)	10^{-12}
Target Power consumption	**250 mW**
Transmission Range	10 cm (1m)

Link-Budget

$$P_{RX} = P_{TX} + G_{TX} + G_{RX} - L_{TX} - PL(R) - L_{RX} - FM$$

P_{RX} = RX Power (dBm)
P_{TX} = TX Power (5 dBm)
G_{TX} = Transmitter antenna gain (10 dBi)
G_{RX} = Receiver antenna gain (10 dBi)
L_{TX} = Transmitter losses (4 dB)
L_{RX} = Receiver losses (4 dB)
FM = Fading Margin (3 dBm)
$PL(R)$ = Free space loss@1 m(10 cm)= 68 (48 dB)

System operating margin: 15 dB



SiGe-HBT BiCMOS-8HP

- 130 nm Lithography based SiGe Bi-CMOS
- Advanced SiGe NPNs, We=120 nm, ft=200 GHz, BVceo=1.8V
- 130 nm CMOS FETs 1.5/2.5V

- High integration level

- Millimeter Wave Passives Elements
  - Resistors, Varactors, MOS and MIM caps, Inductors, Transmission-lines, Metal inductors, Coplanar Waveguide inductors and Microstrip Inductors

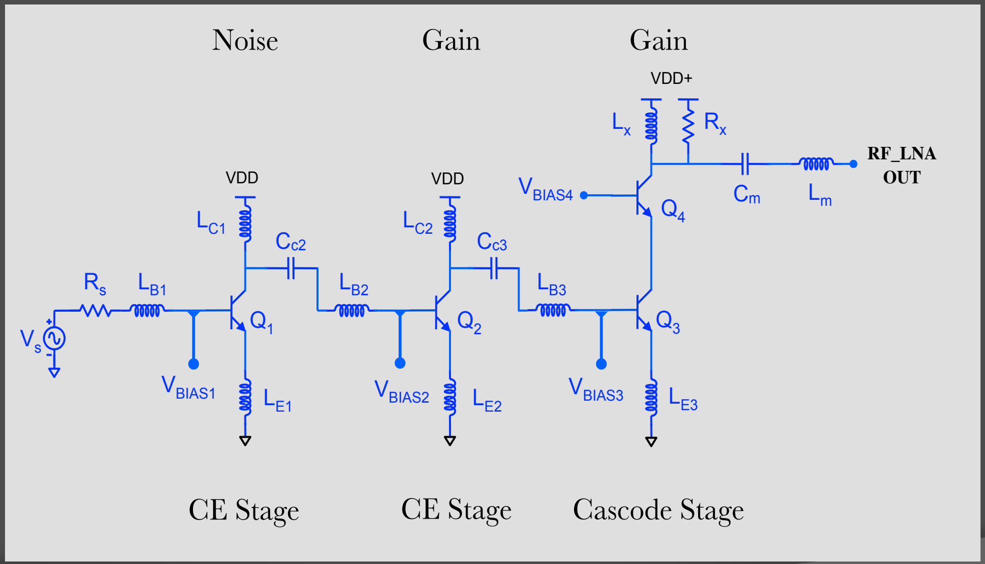
Low Noise Amplifier (LNA)

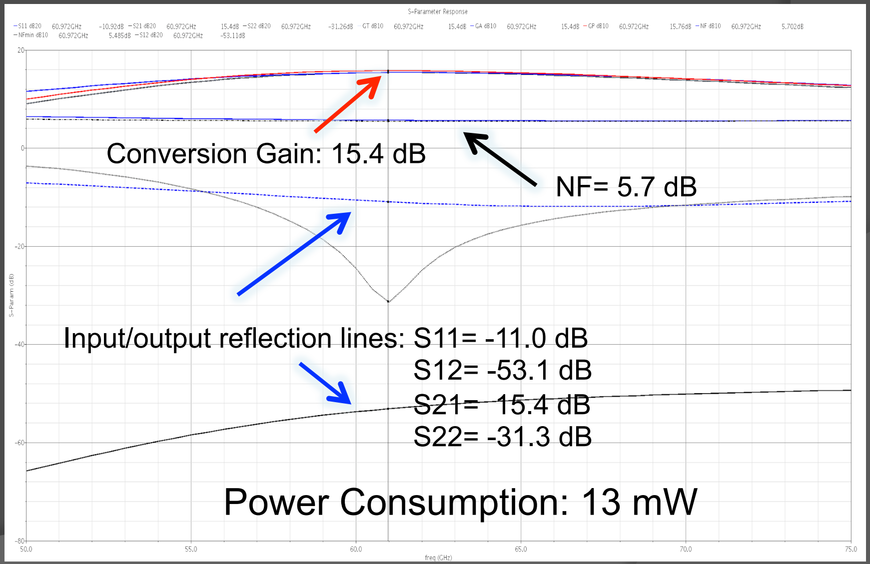
- Sets the lower limit of the system
- Optimized for NF and Gain

$$NF_{IN} = NF_1 + \frac{NF_2 - 1}{G_1} + \frac{NF_3 - 1}{G_1 G_2} + \frac{NF_4 - 1}{G_1 G_2 G_3} + ... + \frac{NF_n - 1}{G_1 G_2 ... G_{n-1}}$$

- Matching of input and output
- Isolation between input and output

S-Parameter Respons, all @ 61 GHz

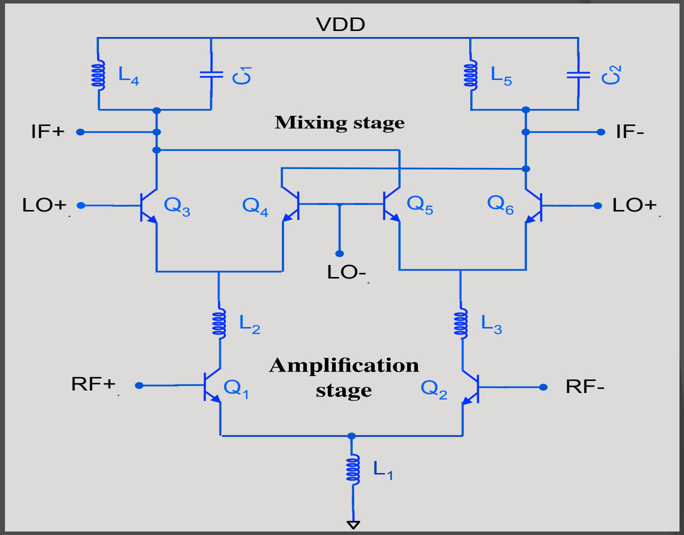


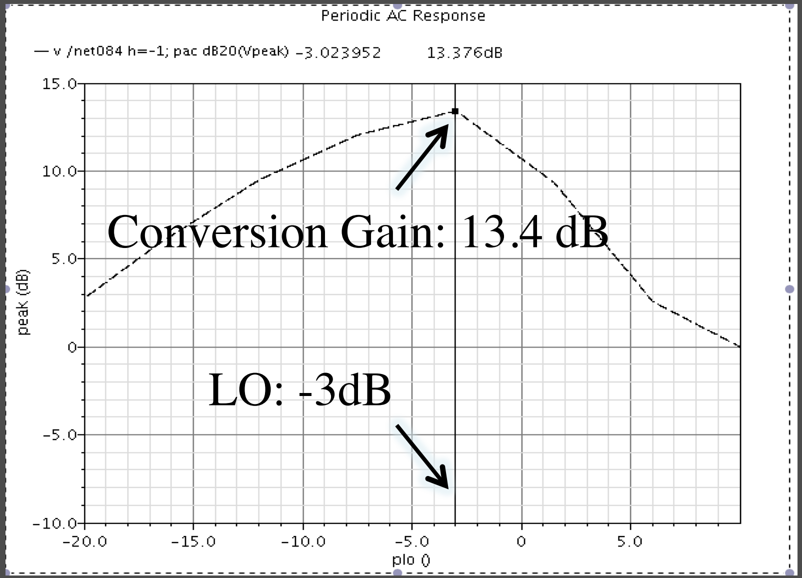


Double Balanced Mixer

Gilbert Cell structure

- Very good Isolation
- Harmonic suppression
- Immune to LO/RF feedthrough noise
- Differential structure
- Integrated on-chip





Noise: 9.5 dB
Power consumption: 7 mW
P1dB: -19 dB
RF-L0: -150 dB
RF-IF: - 90 dB
LO-IF: -100 dB
LO-RF: - 82 dB

On-Off Keying Modulation

Modulation: OOK

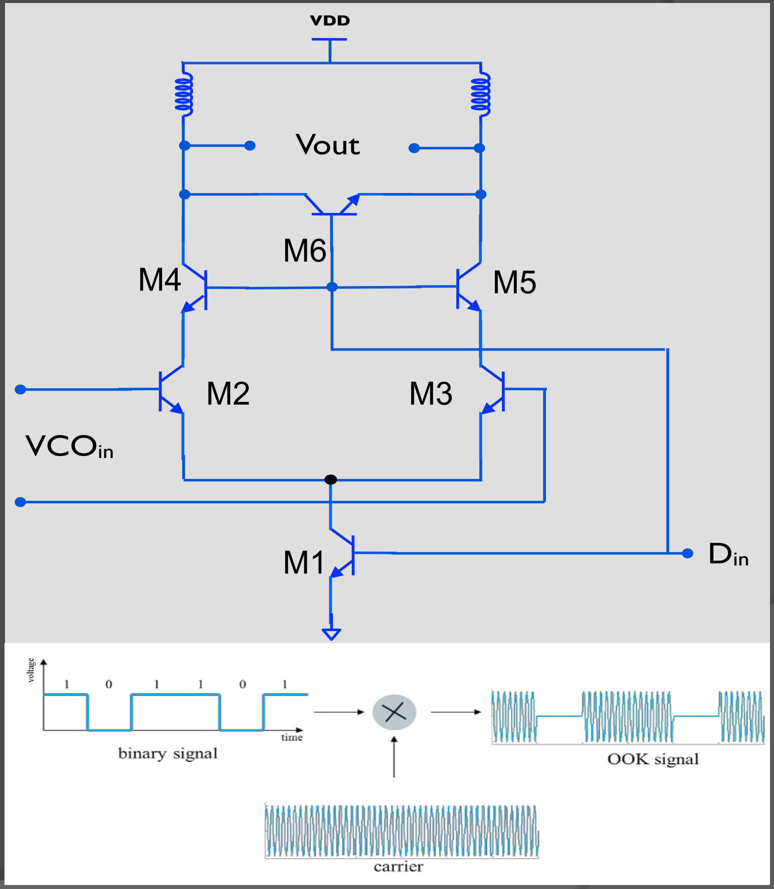
- System bandwidth
- Efficiency
- Power Efficiency
- Sensitivity
- Complexity

Low spectral efficiency: 0.5 bps/Hz

But

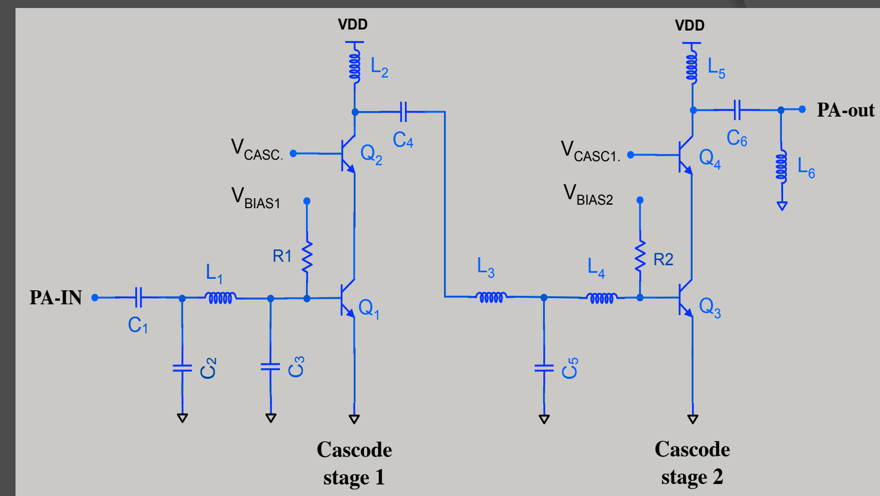
- Non-coherent demodulation
- Simple implementation
- Little power consumption

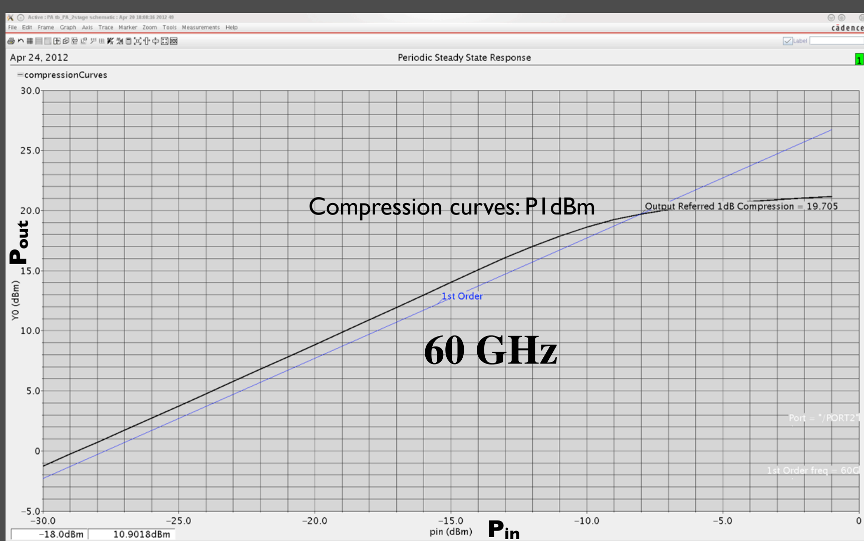
OOK scheme



Power Amplifier (PA)

- Operation class AB
- Provide the required power level
- Drive the antenna





Compression Point: 20 dBm
Reverse Isolation: - 65 dB
Power added efficiency: 20 %
Power consumption: 150 mW

Preliminary Power Estimate

• Low Noise Amplifier:	13 mW
• Gilbert Mixer:	7 mW
• Local Oscillator:	20 mW
• Intermediate Amplifier:	10 mW
• Modulation Scheme:	20 mW
• Demodulation Scheme:	20 mW
• Power Amplifier:	150 mW

Power Consumption: 240 mW

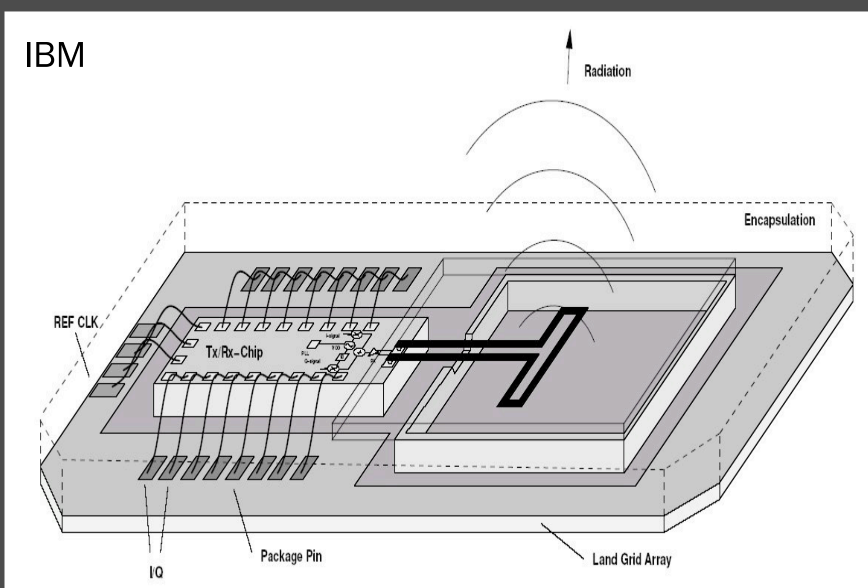
Summary and Outlook

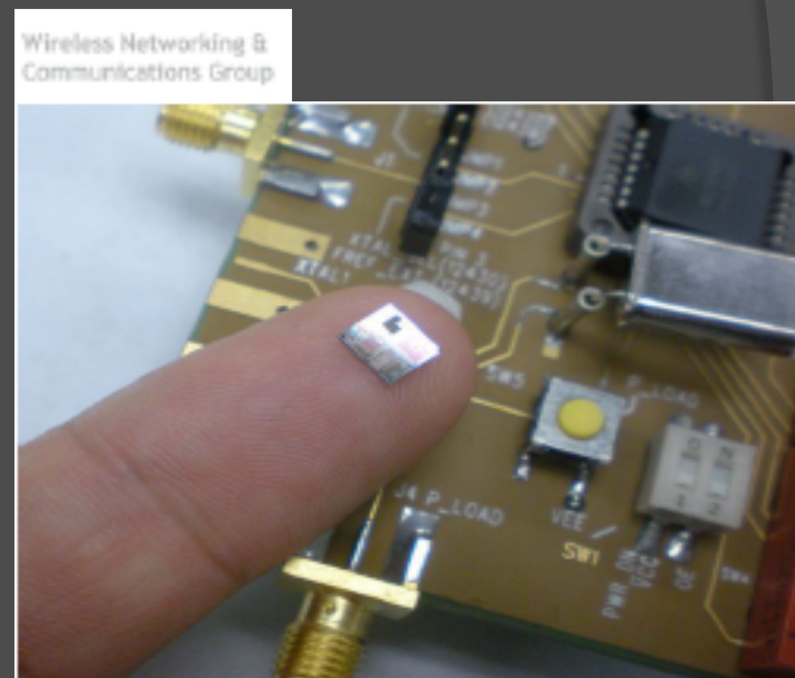
- Potential wireless Readout scheme for the inner tracker proposed
  - Has the bandwidth required for real time readout for fast trigger data
- Focused on the 60 GHz band due to its huge amount of bandwidth
- Performance of key blocks shown from simulations
- Integrate all individual blocks to a fully integrated Transceiver
- Determine efficient and low-cost antenna solution
- Forseen submission 4rd quarter of 2014

BACKUP SLIDES

On-chip Antenna

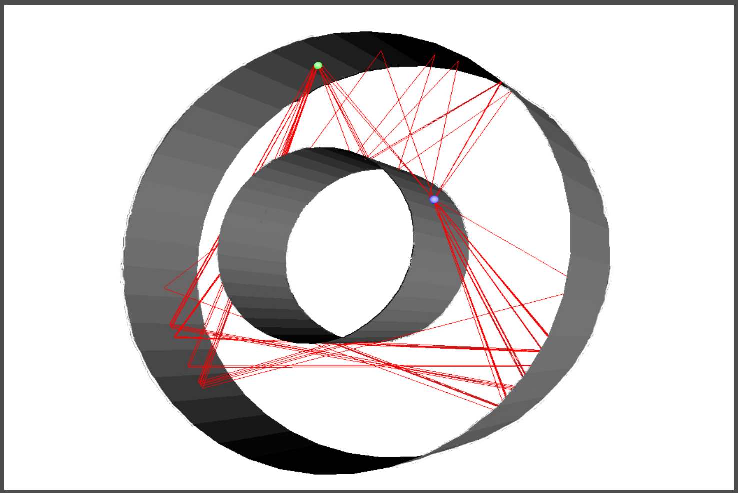
- Millimeter-Wave signals have small wavelengths at 60 GHz (5mm)
- Possible to integrate receive and transmit antenna(s) on chip.
- Multiple metal layers on ICs available
- Can be used to fabricate mm-wave antennas.
- Eliminate cable/connectors loss





Crosstalk evaluation

- Simulations show that reflections will introduce crosstalk



To decrease crosstalk:

- Shielding: Graphite foam
- Use antenna with high directivity
- Polarisation
- Frequency channeling