Wireless data transfer with mm-waves for future tracking detectors

Daniel Pelikan

Uppsala University

14-16 May 2014

Author(s): PELIKAN, Daniel[1] ; BRENNER, Richard[1]; DANCILA, Dragos[2]; GUSTAFSSON, Leif[1] ; BINGEFORS, Nils[1]

[1] Uppsala University, Department of Physics and Astronomy

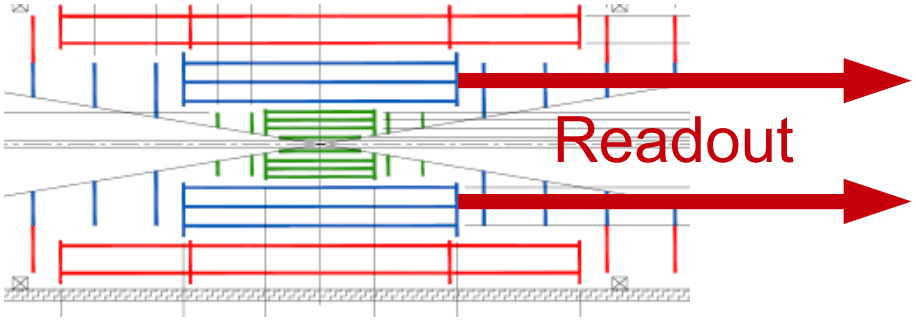
[2] Uppsala University, Department of Engineering Sciences

Introduction

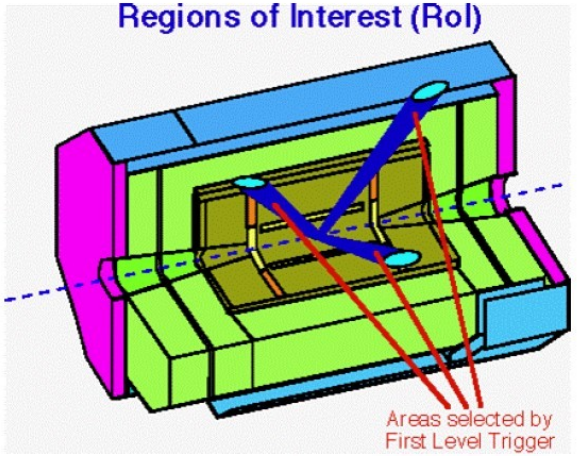
- Why wireless in the track triggers
- 60 GHz technology
- What can we do with it?
- Design of antennas
- Passive data transfer through a tracker.
- Outlook

Why wireless in the track trigger

- The current readout is not optimal to build a track trigger.

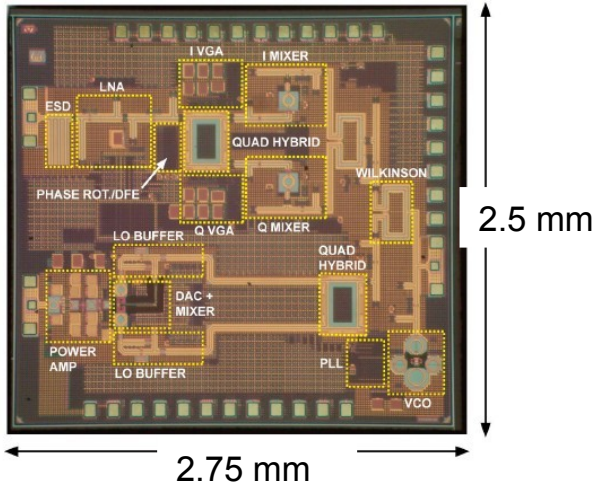


Axial tracker readout resulting in long paths, long latency etc.



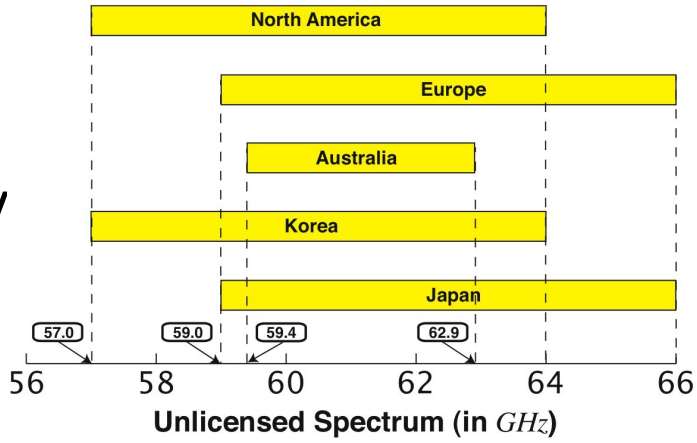
Physics events are triggered in RoI that are conical regions radial from the interaction point in Φ and η.

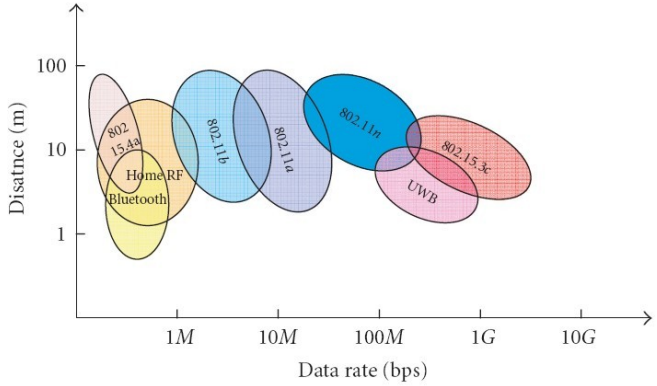
- **How can wireless technology help to solve the problem?**
  - Radial data transfer gets possible.
    - No cables and connectors needed for data transfer.
  - Small and low mass components.
  - Low power and cost.
  - High bandwidth >5 Gbits/s.



60 GHz technology

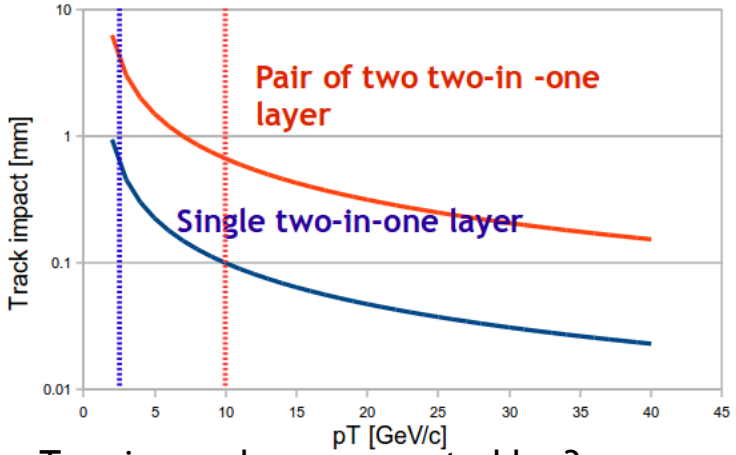
- mm waves
  - Small structures
- Up to 7 GHz unlicensed frequency spectrum.
  - Enormous bandwidth for data transfer.
- Fast developing technology.
  - First implementations are commercially available.
  - A lot of products are expected in the consumer marked, wireless uncompressed video connections...



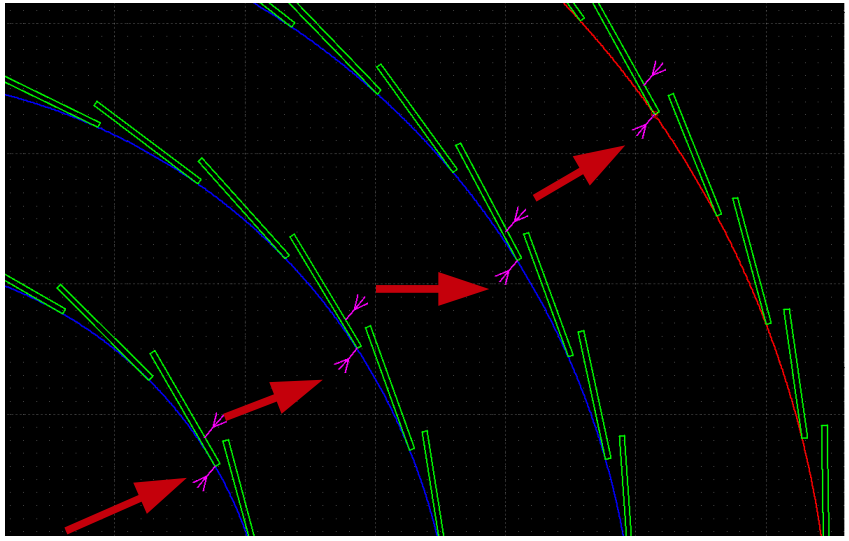


What can we do with it?

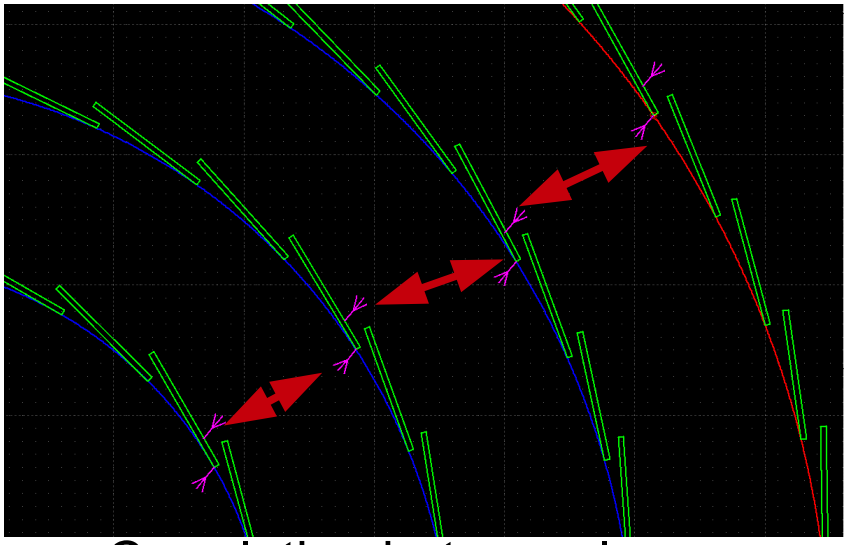
- Build up radial data transfer links.
  - Low latency.
- Different frequencies per layer can be used.
  - 60 GHz does not penetrate through the silicon.
- Pre analysis already on the layer.
  - Use multiple layers correlation to reduce fakes.



Two-in-one layer separated by 3 mm
→ pT cut on a few GeV possible in ATLAS.
Two two-in-one layer separated by 20cm
→ pT cut ~10 GeV possible



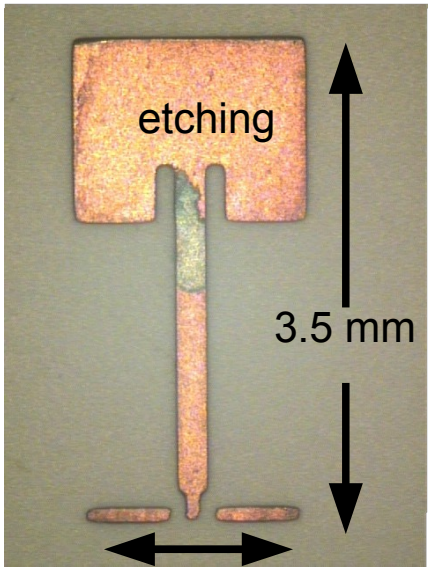
Radial readout



Correlation between layers

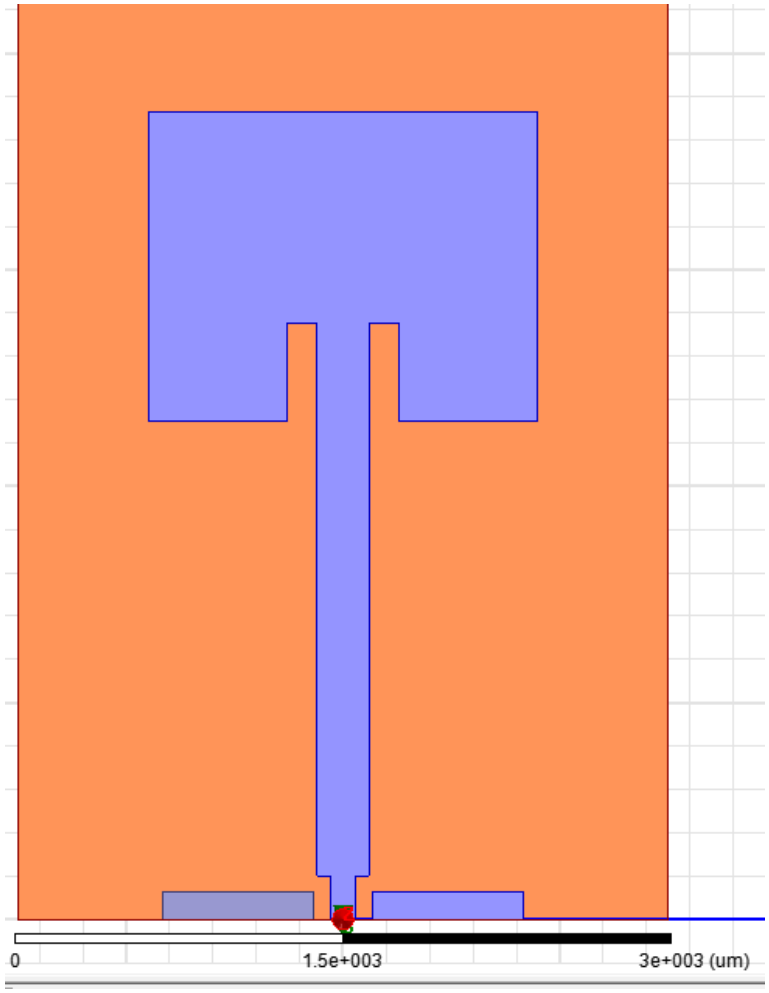
Antenna design

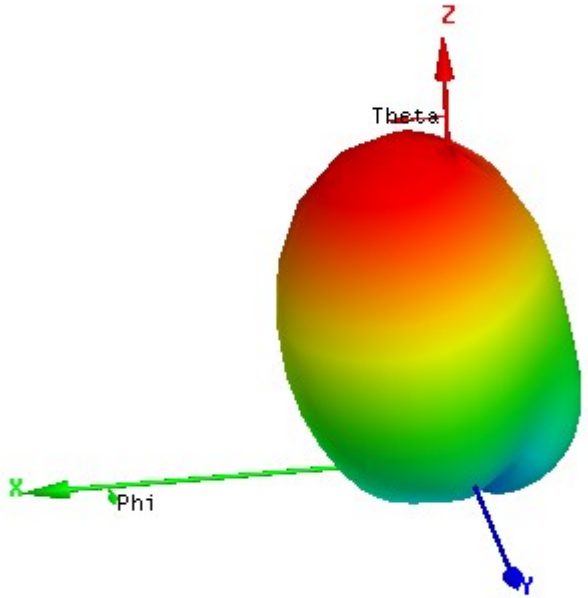
- We have started to design and produce patch antennas.
  - Single and antenna arrays.
  - Can be produced on PCB material.
    - Etching and milling.
    - Rogers, DuPont PCB material
  - Very small structure sizes.



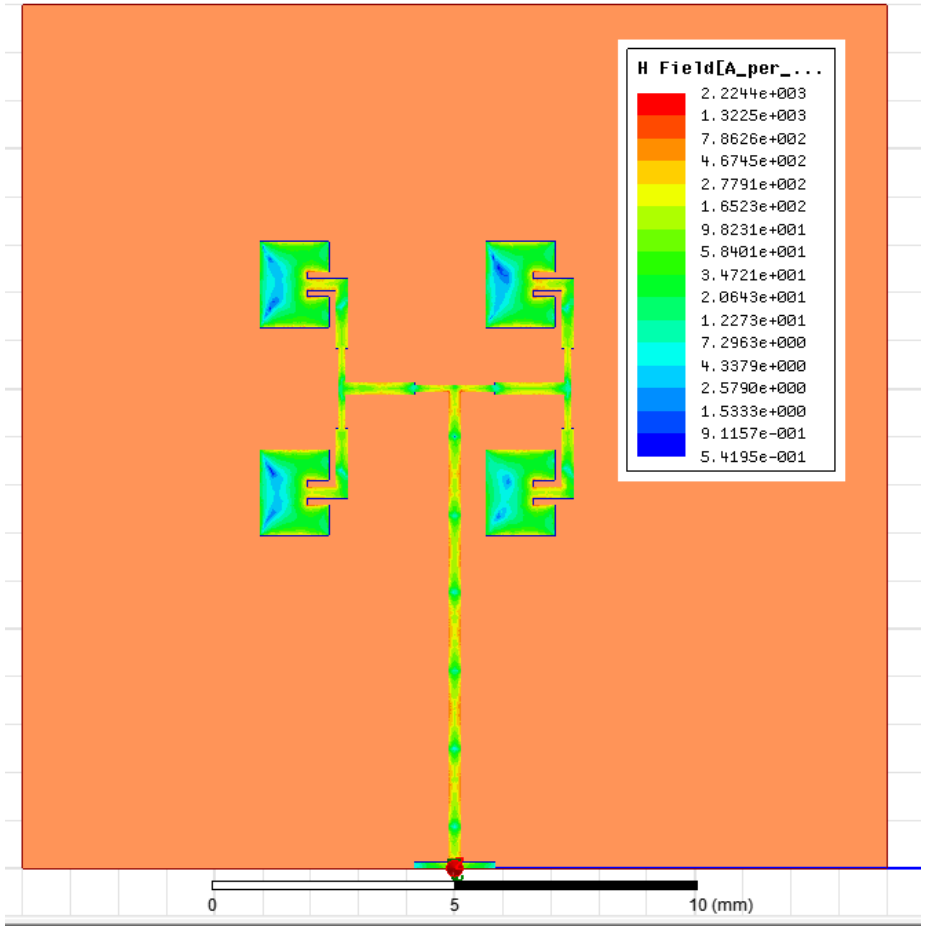
Antenna design - simulation

- Single patch

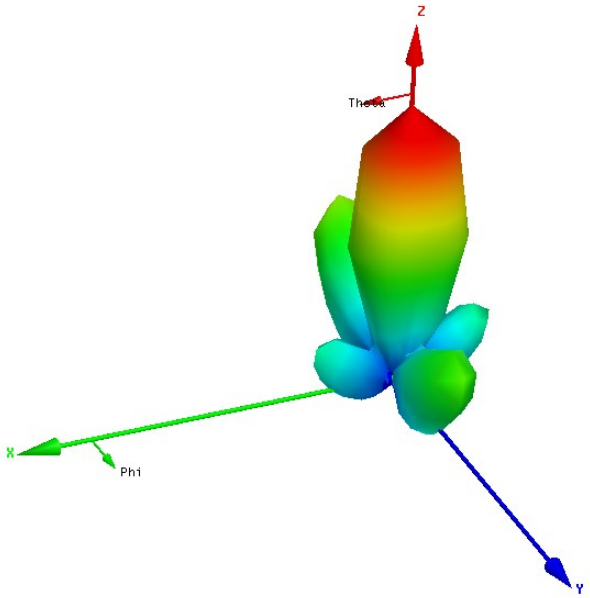




Antenna design - simulation



- Designs for multi patch antennas.
  - 4 Patch design.
  - Higher gain and focus.



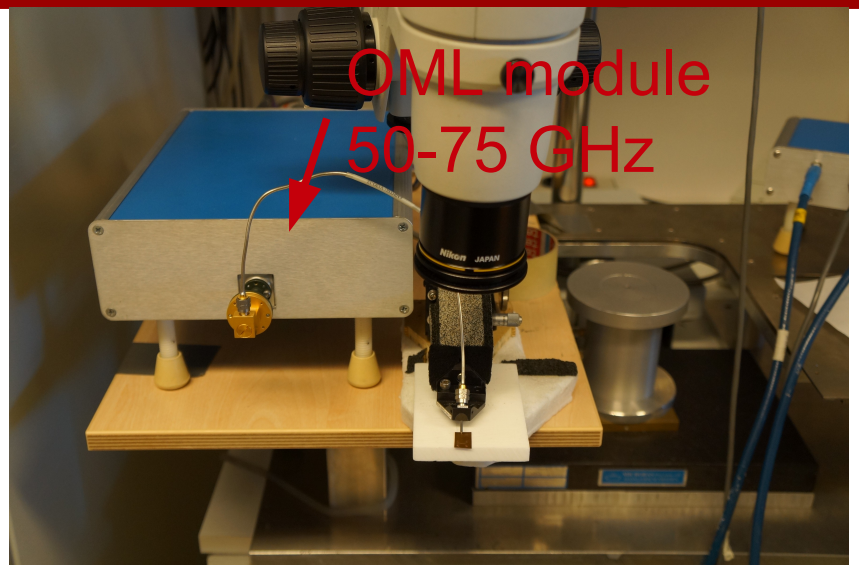
S-parameters

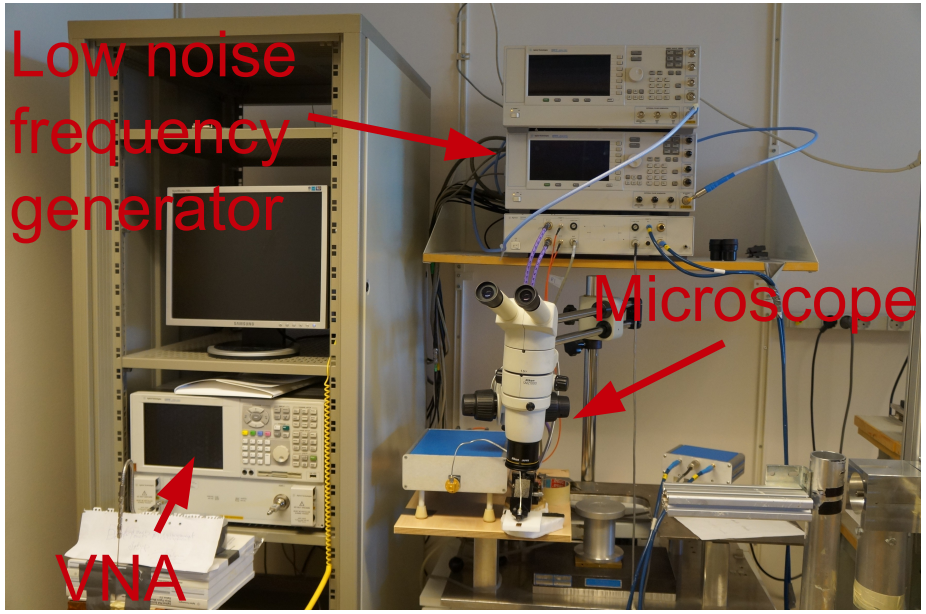
- **S-parameters**:
  - Describe the input-output relationship between ports in an electrical system.
  - Ex.:, 2 ports (Port 1 and Port 2), then S12 represents the power transferred from Port 2 to Port 1.
  - Having a transmitter with an antenna connected:
    - S11 is the reflected power Port 1 is trying to deliver to antenna 1.
    - 0dB all power is reflected
    - - 30dB and below almost no power is reflected

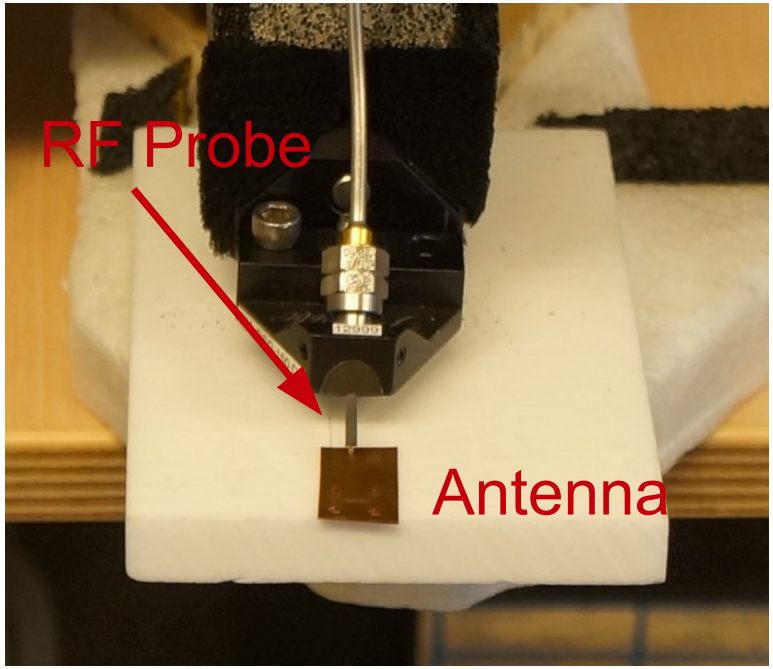
      → good matching
  - Frequency depending variable.

Antenna design Simulation vs Real

- Agilent Technology Signal Generator and Vector Network Analyser

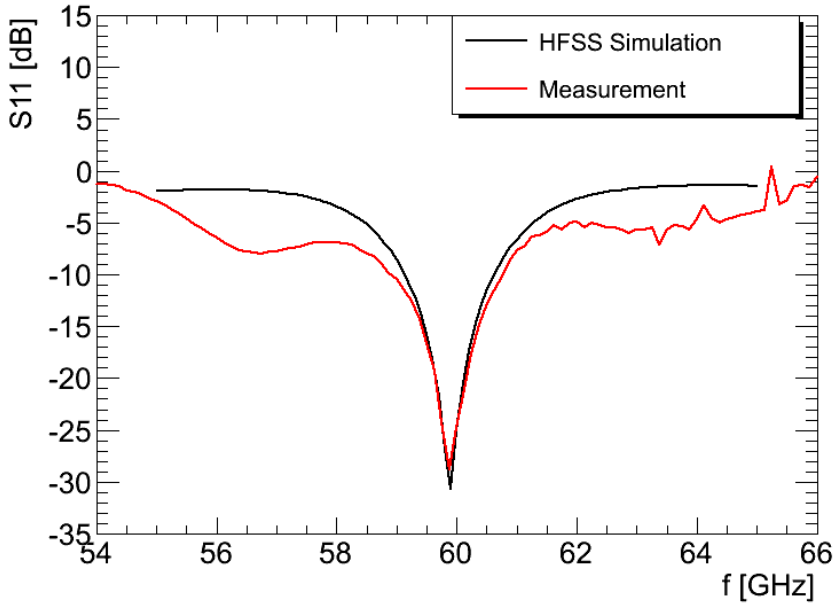




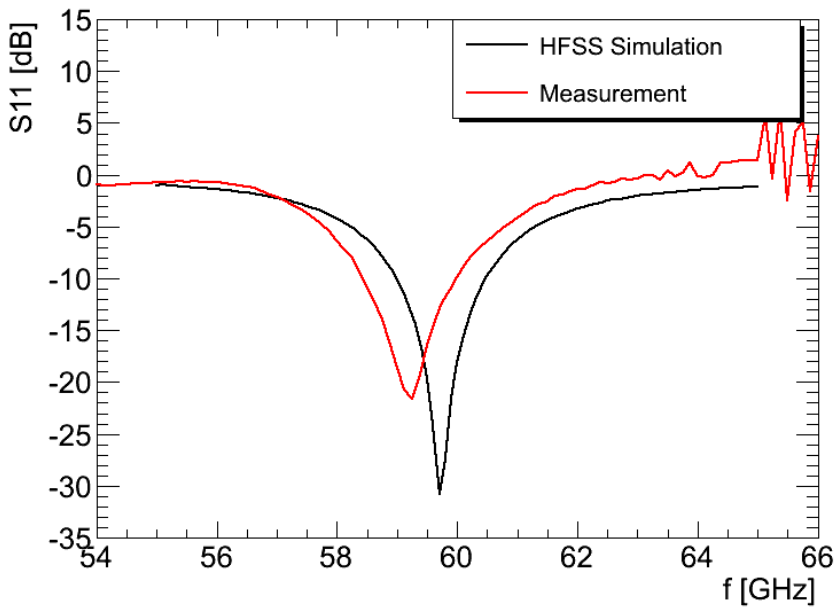


Antenna design Simulation vs Real

- Compare simulation with a manufactured antenna.
  - This gives feedback how good simulation matches reality.
  - Etched antennas were used (PCB etching process).
    - 4 Patch antenna array: very good agreement with simulation.
    - 1 Patch antenna: a shift of ~500MHz.
      - This is good result and shows that antenna production is feasible.



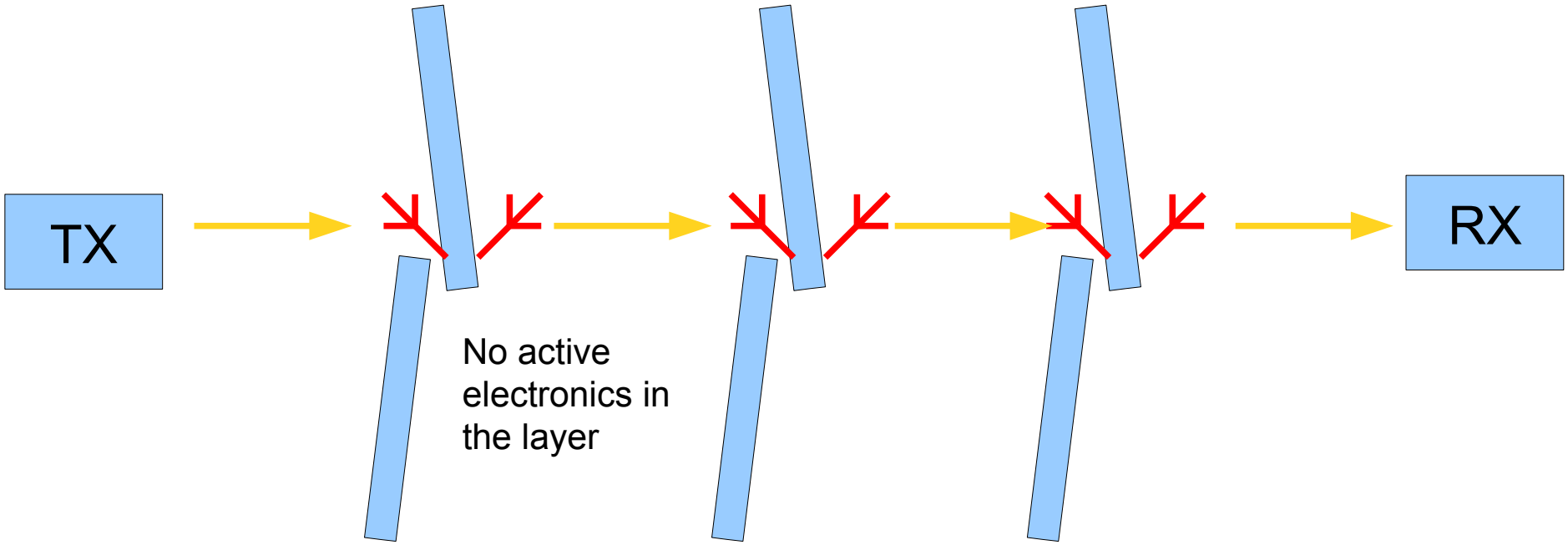
4 Patch design



single patch design

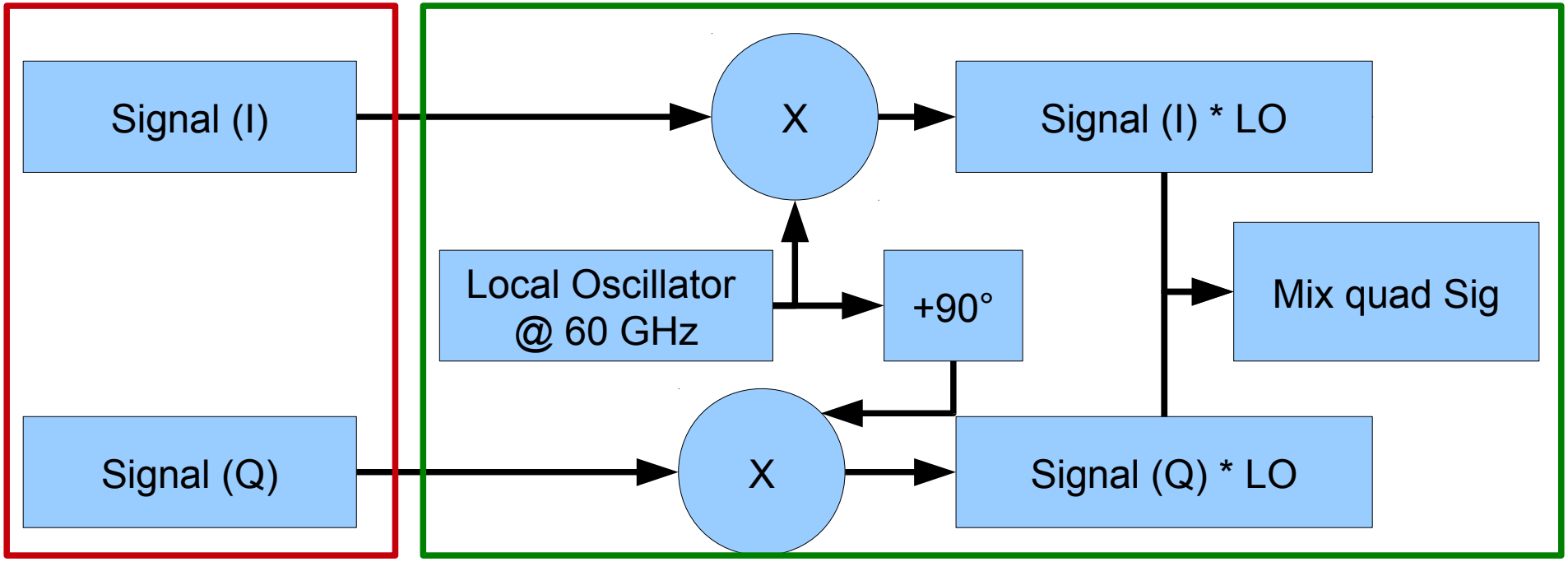
Passive data transfer through layers

- The amount of electronics could be reduced significantly if one could radiate through detector layers.
  - No active hardware would be needed as a repeater.
- Simple approach:
  - One receiver antenna on one side and a transmitter antenna on the other side.
  - Antennas are connected by a micro strip, no active electronics.



Generation of the test frequency

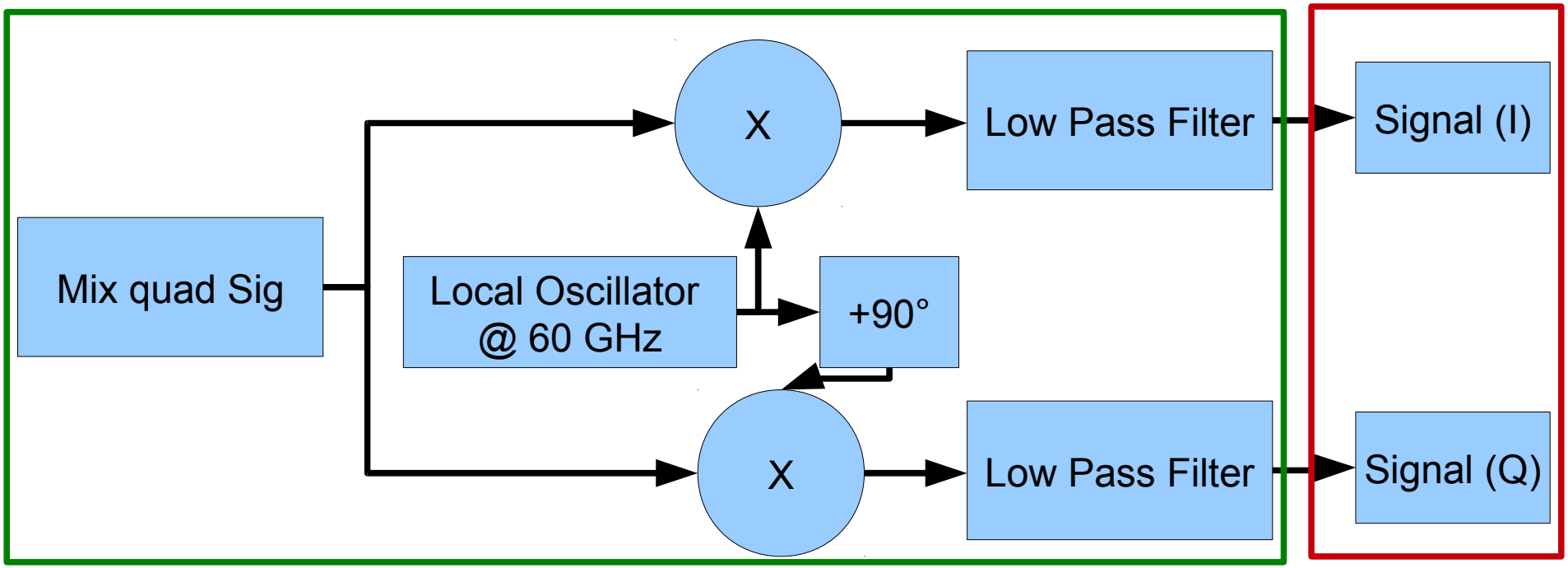
Up conversion (TX)



- I and Q part of the signal is mixed with the frequency of the Local Oscillator (LO)
  - Modulates the baseband on the carrier frequency (60 GHz ± baseband)
- The mixed I and Q part is summed and send through the antenna.

Receiving of the test frequency

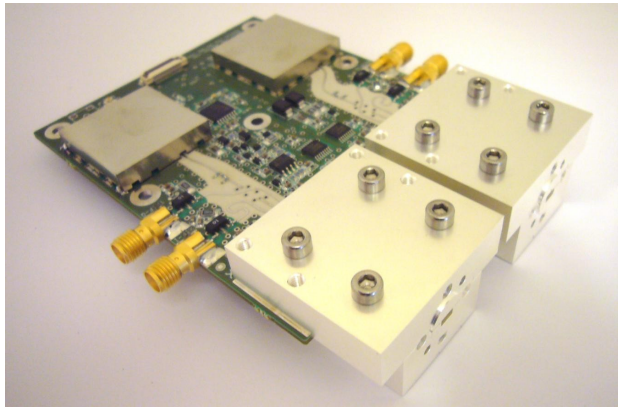
Down conversion (RX)

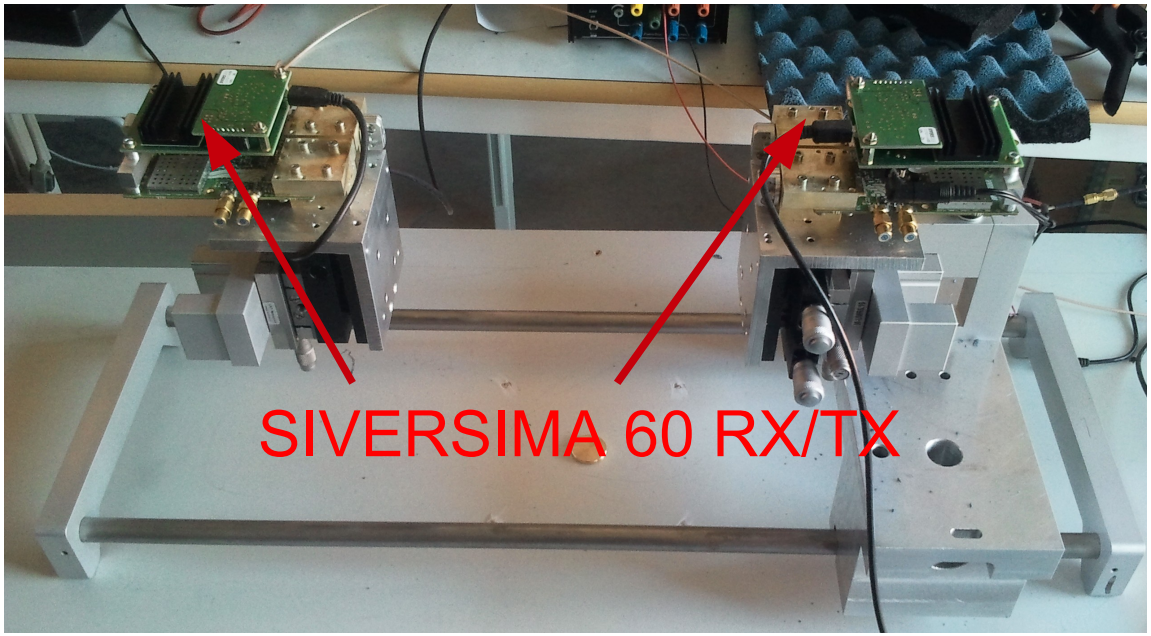


- Received signal is mixed with 60GHz carrier frequency.
  - (60 GHz ± baseband) ± 60 GHz
- With the low pass filter the baseband is extracted.

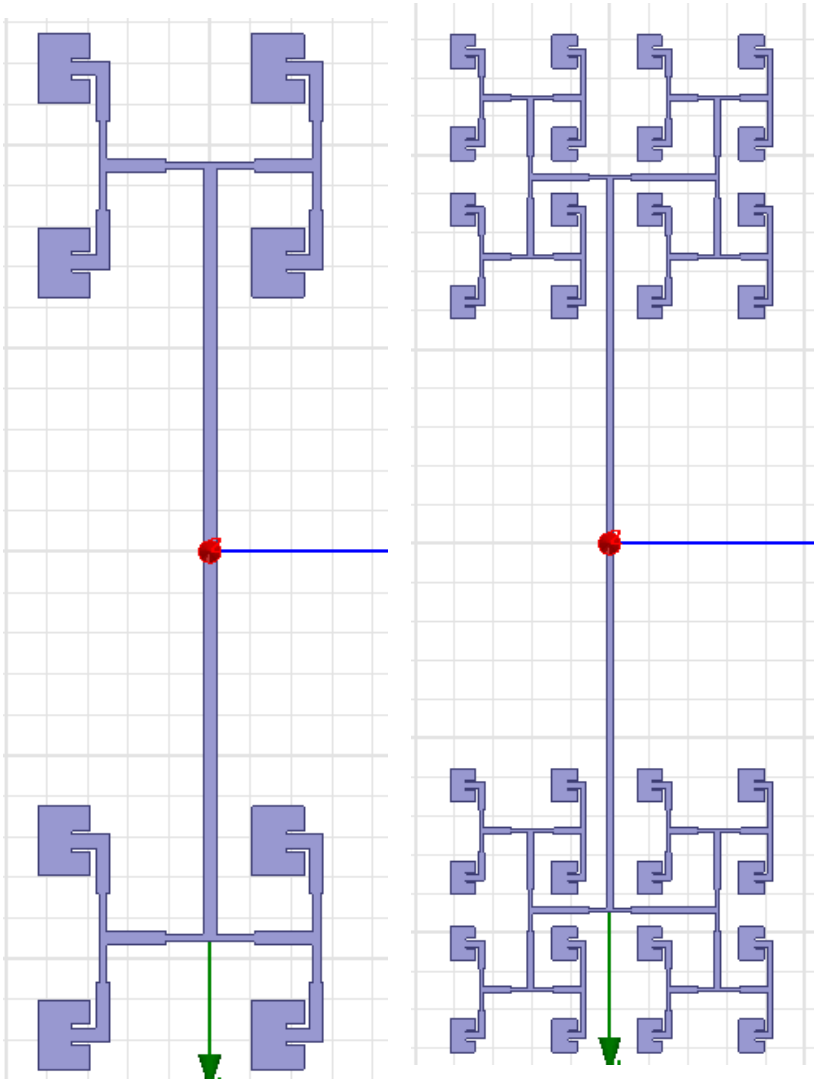
Passive data transfer through layers

- The test setup
  - SIVERSIMA 60 GHz up down converter cards.
    - Duplex card RX and TX.
    - I and Q separately available.
    - Connected horn antennas.



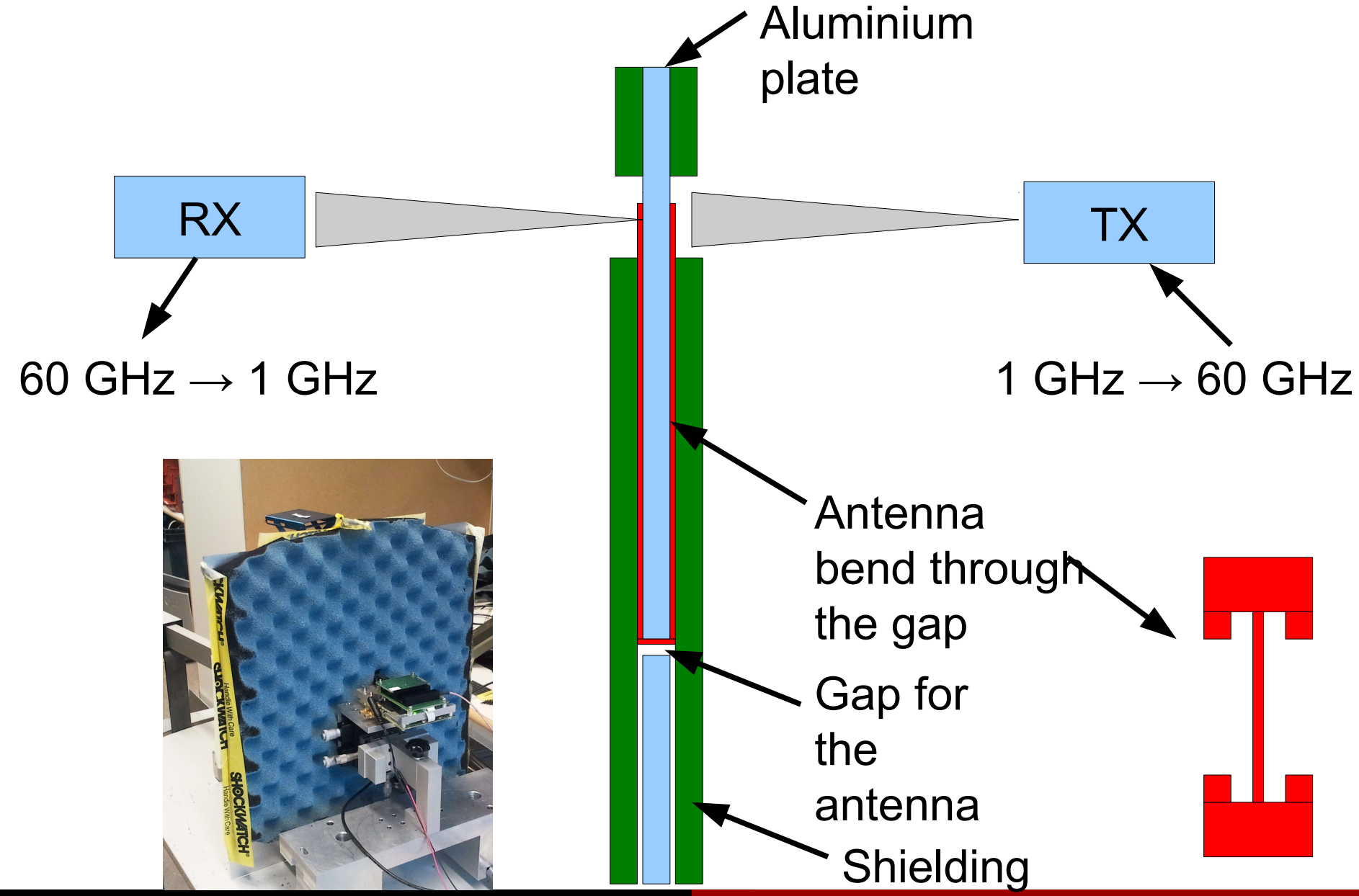


Passive data transfer through layers

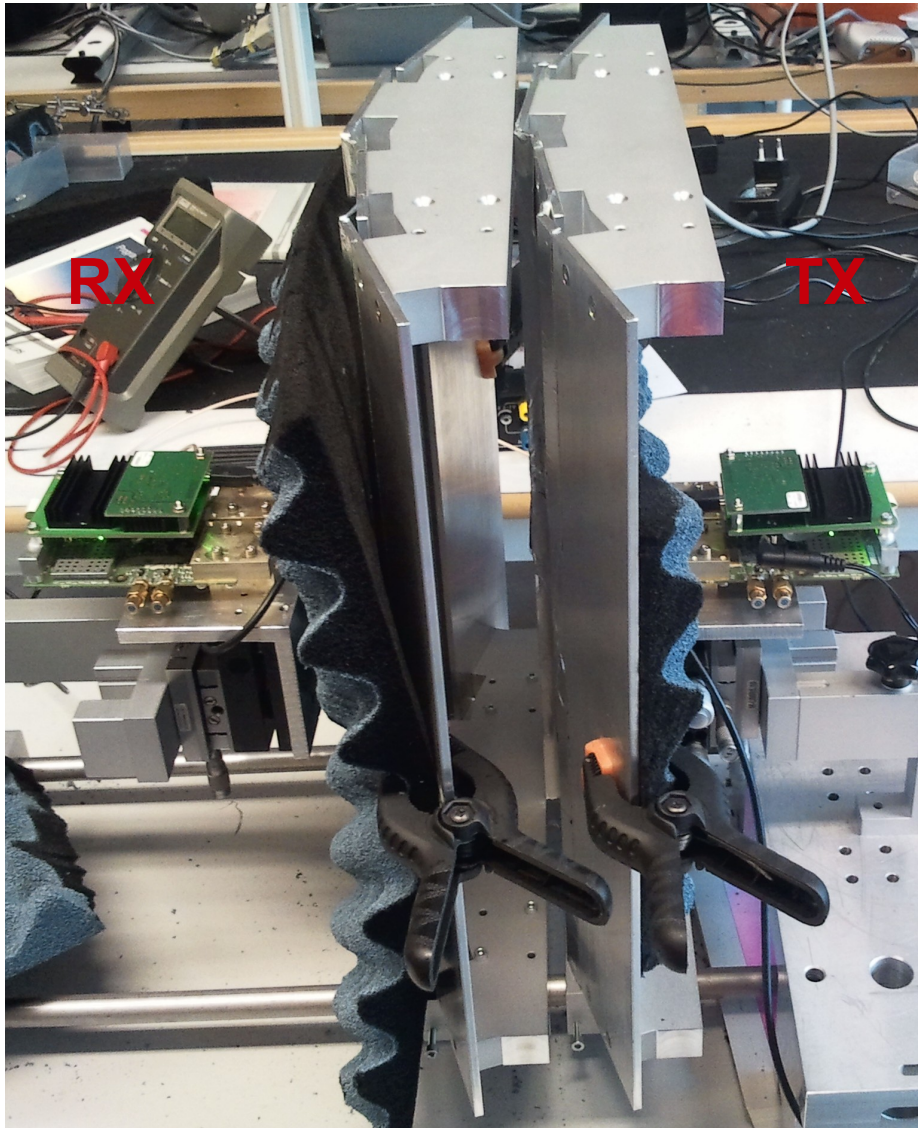


- 1, 4 and 16 Patch design.
  - Patches are connected by micro strip transformations (needed for imp. matching).
  - Antenna arrays are connected by a micro strip.

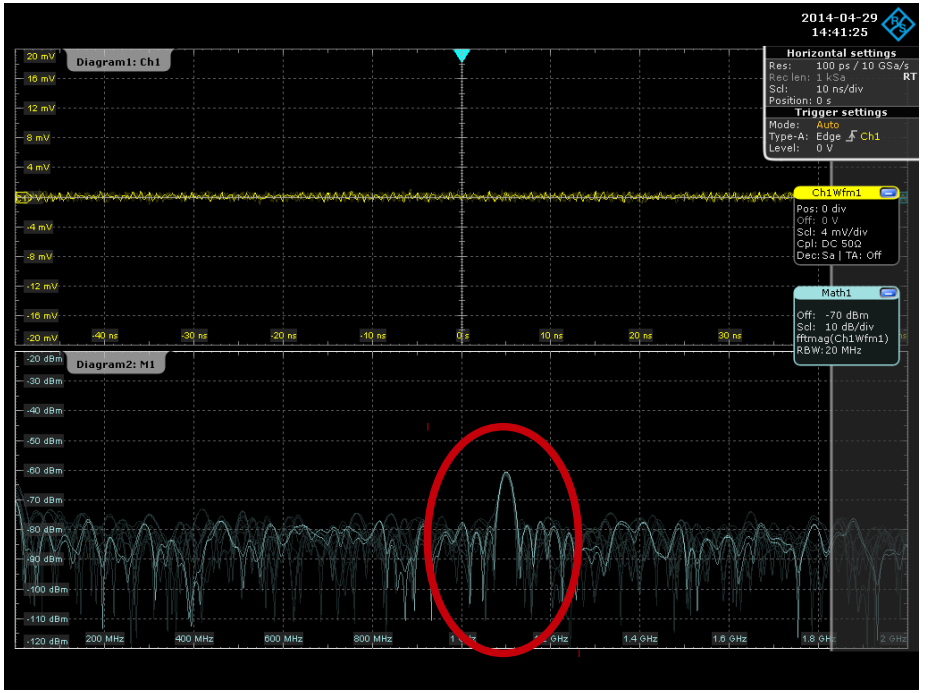
Passive data transfer through layers



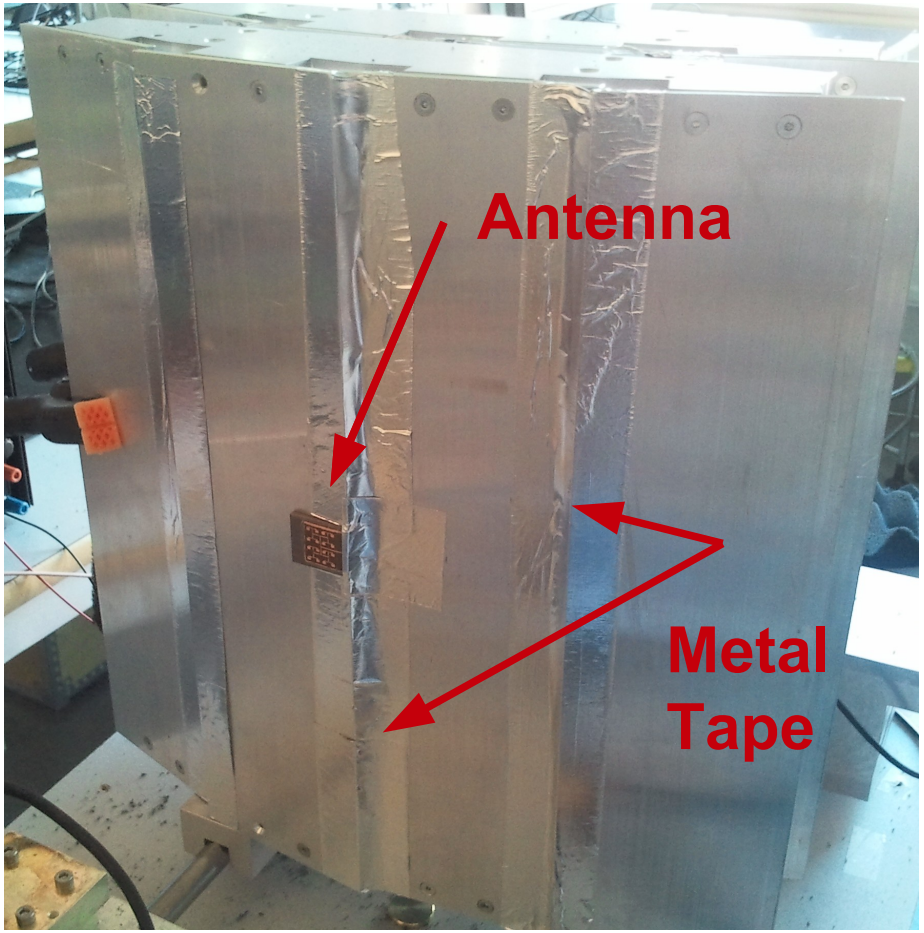
Passive data transfer through layers

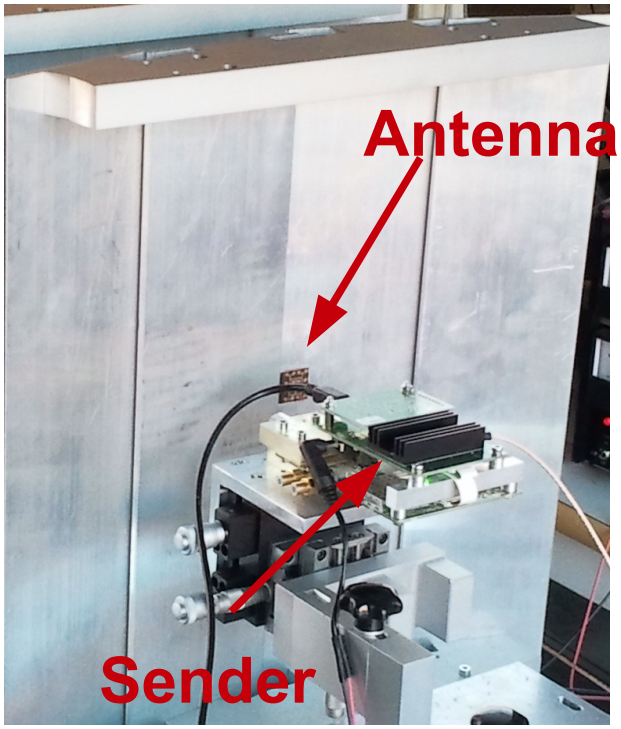


- Two setup
  - Aluminium Plate with small gap to bring though the antenna.
    - Gap is closed by metal tape.
  - Aluminium detector model.
    - 2 detector layers.
- **We are coming trough both setup with just the passive antennas**

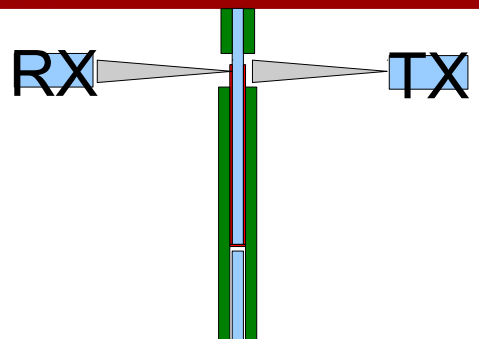


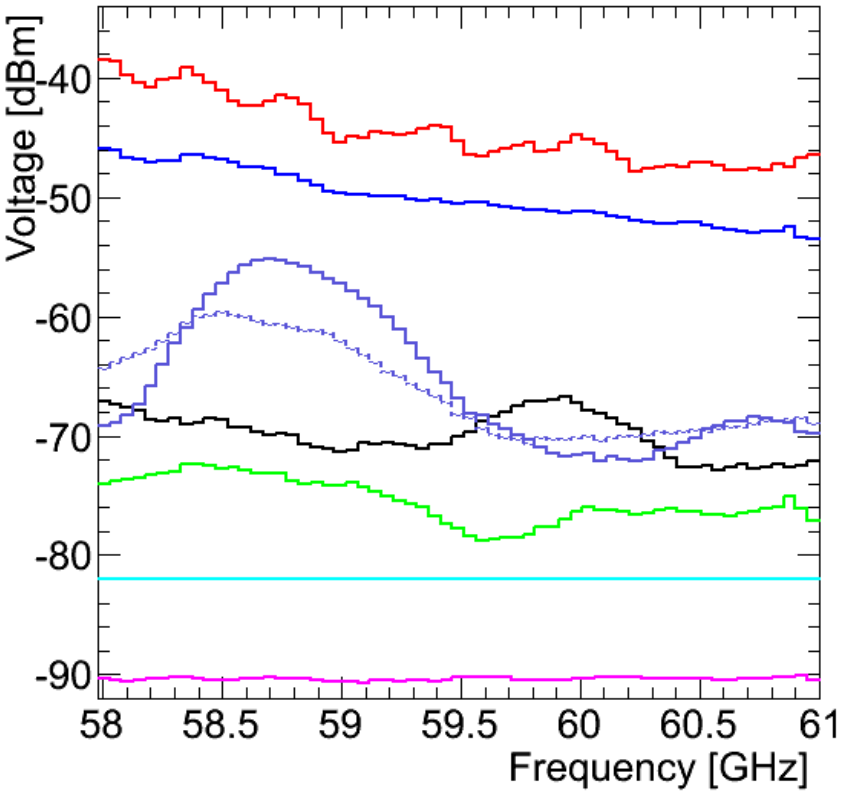
Passive data transfer through layers





Testing the passive antennas

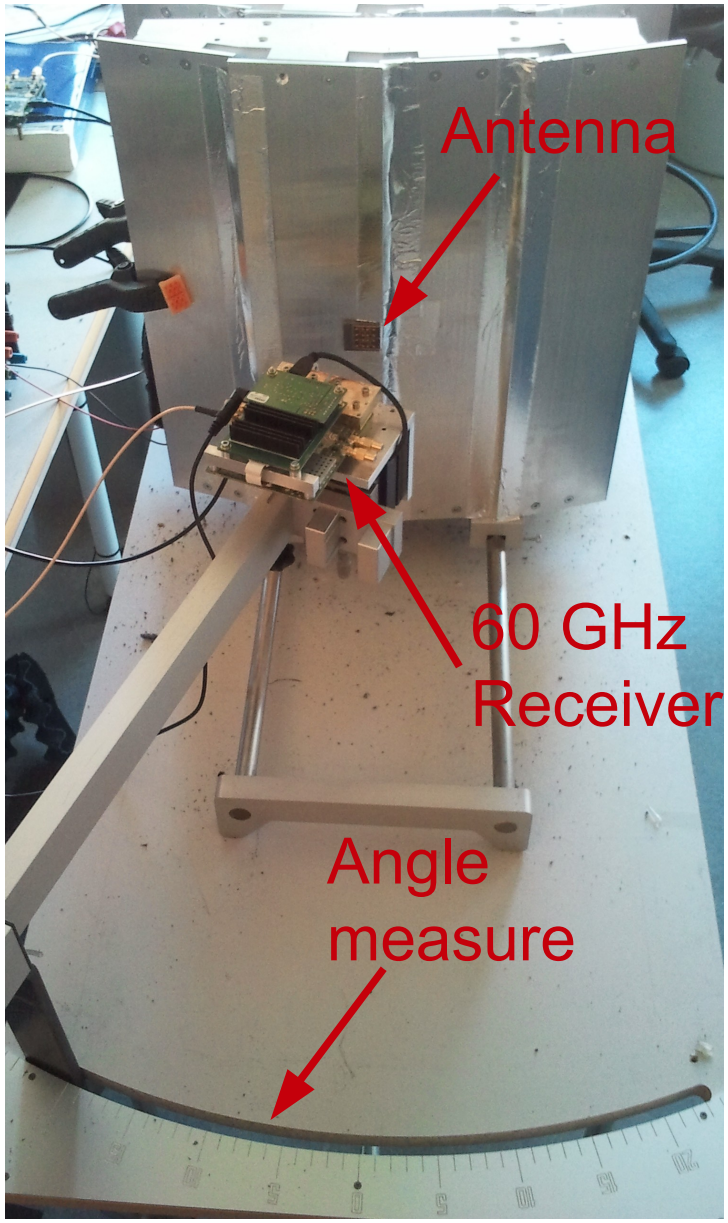




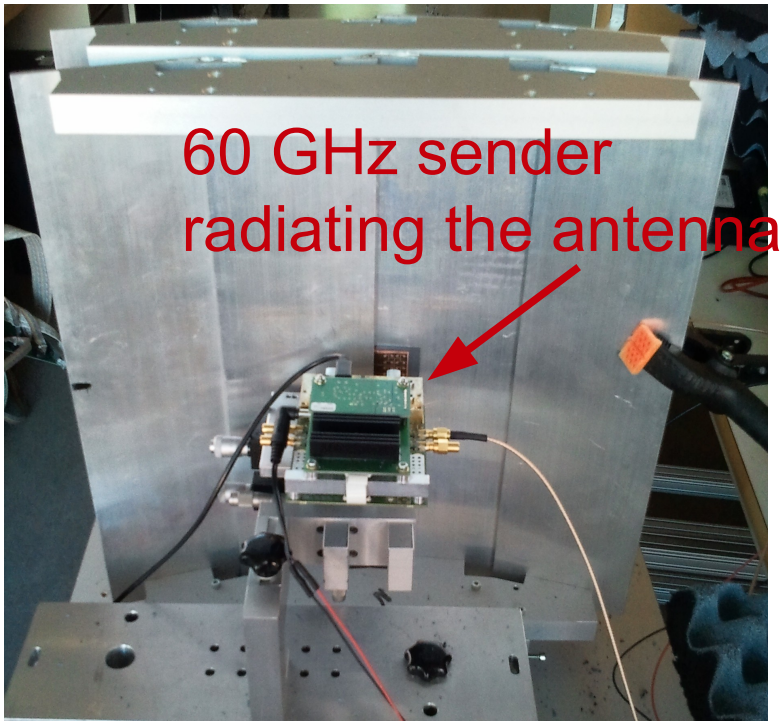
- Different Antennas were tested.
  - 1, 4, 16 patch
- The maximum throughput through the antenna was measured at different frequencies.
- A clear dependence on the amount of patches can be seen.
  - As well as a slight frequency dependence.

Horn-Horn 9.5cm distance
Horn-Horn 35cm distance
16 Patch (Antenna 1)
16 Patch (Antenna 2)
4 Patch
1 Patch
Cutoff
Background

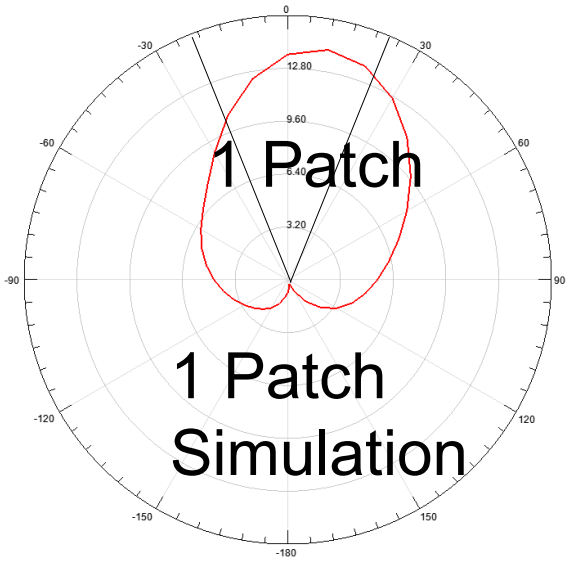
Testing the passive antennas

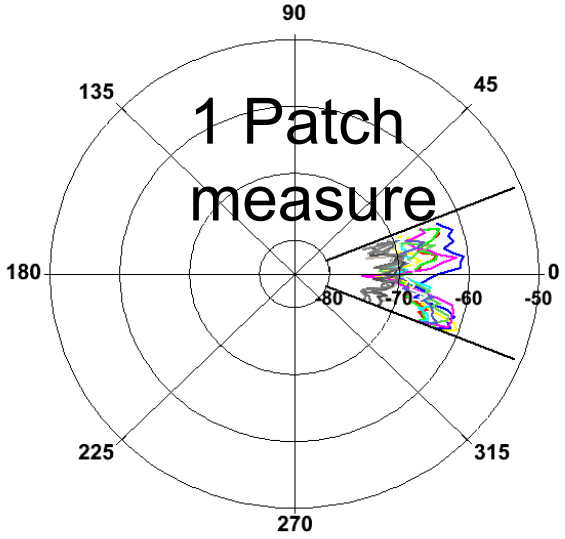


- Angular dependence measure.



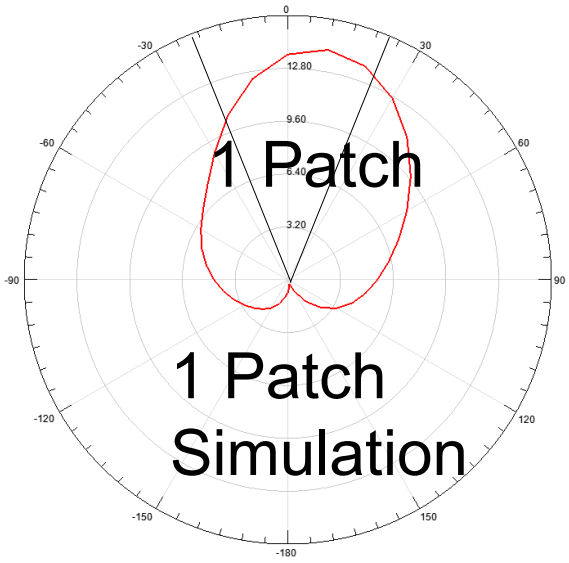
Testing the passive antennas

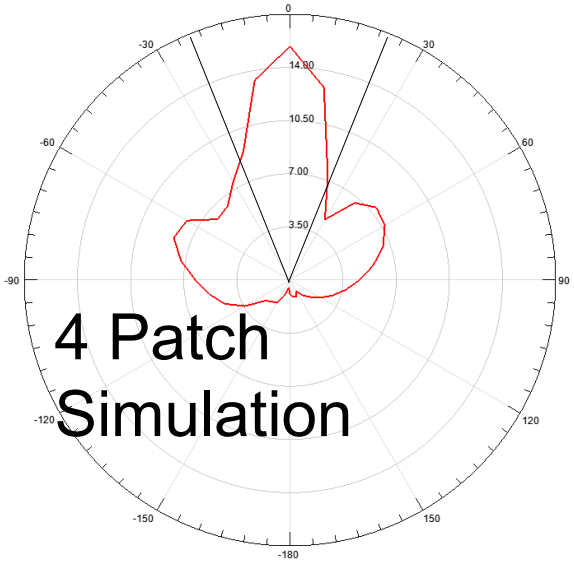


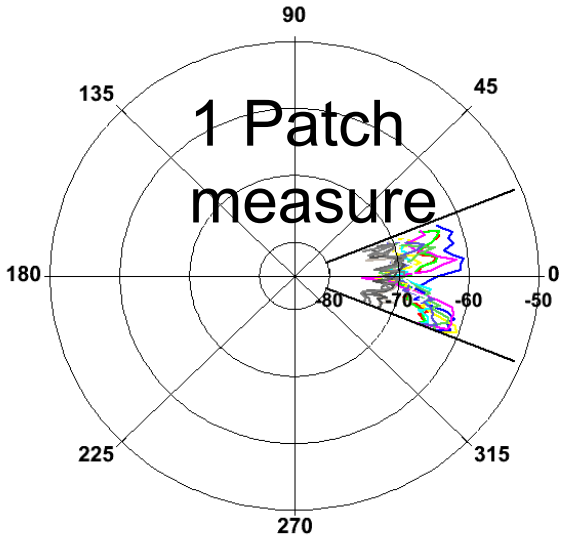


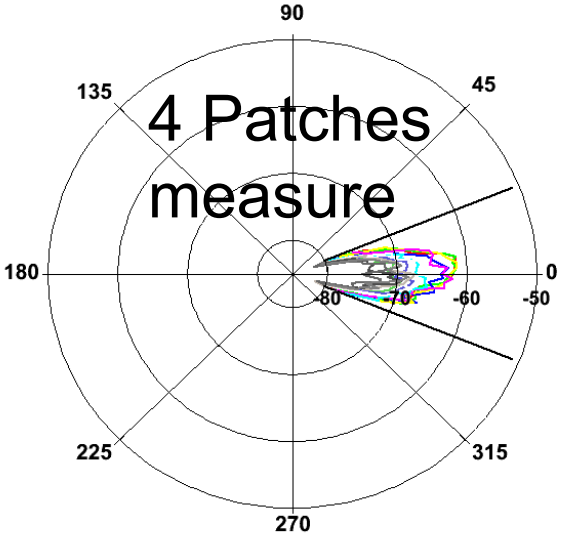
- The angular dependence of the antennas was tested measuring the transmitted power through one layer under different angles -22° to 22°.
- The more patches the more focus and gain we get.

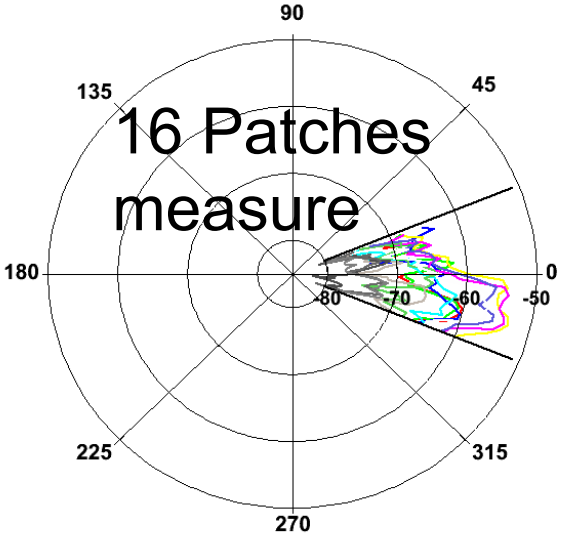
Testing the passive antennas











Outlook

- Next steps:
  - Connect antennas with a wave guide, coax adapter to a transmitter cards.
    - In order to test point to point connection.
  - Develop further the signal generation.
    - FPGA based signal modulation.
  - Start to test Bit Error Rate measurements.

Conclusion

- Wireless data transfer inside a detector system would open up a lot of new possibilities.
  - A key ingredient for a fast track trigger.
- The fabrication of small antennas for 60 GHz has been demonstrated.
- A transfer of signal through a detector model at 60 GHz has been demonstrated using passive antennas.
- Different antenna designs have been studied.
  - A design of high gain focussing antennas is possible.