Techniques & Results of the LOPES^{STAR} Experiment for Detection of UHECRs by their Radio Emission

Hartmut Gemmeke on behalf of the LOPES collaboration

(LOPES = Lofar prototype experiment system)$^{\text{Self Triggered Array of Radio detectors}}$

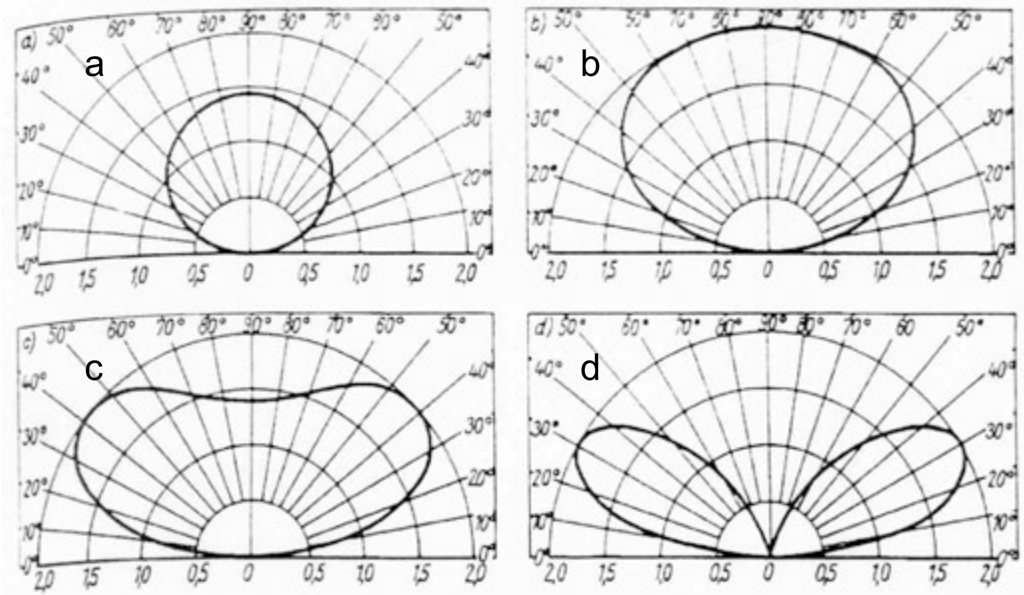
1. **Motivation**
2. **Techniques**
   - **Antennas**
   - **Analogue electronics**
   - **Trigger**
3. **Some results**

Motivation

- Find an antenna
  - Independent from environment
  - Easy to install
  - Low cost for large arrays as Auger
  - Easy to calibrate
- Electronics
  - Low power consumption (< 5W) - power from battery & solar panel
- Self-trigger at each antenna
  to allow
  - Low communication rates
    ⇒ Low power
  - Low random coincidence rate
  - Lower E-threshold

Antennas

Dipole Antenna CODALEMA (Nançay)



a) h =**λ/8**, b) h =**λ/4**, c) h =3**λ/8**, d) h =**λ/2**

Advantage: cheap and simple

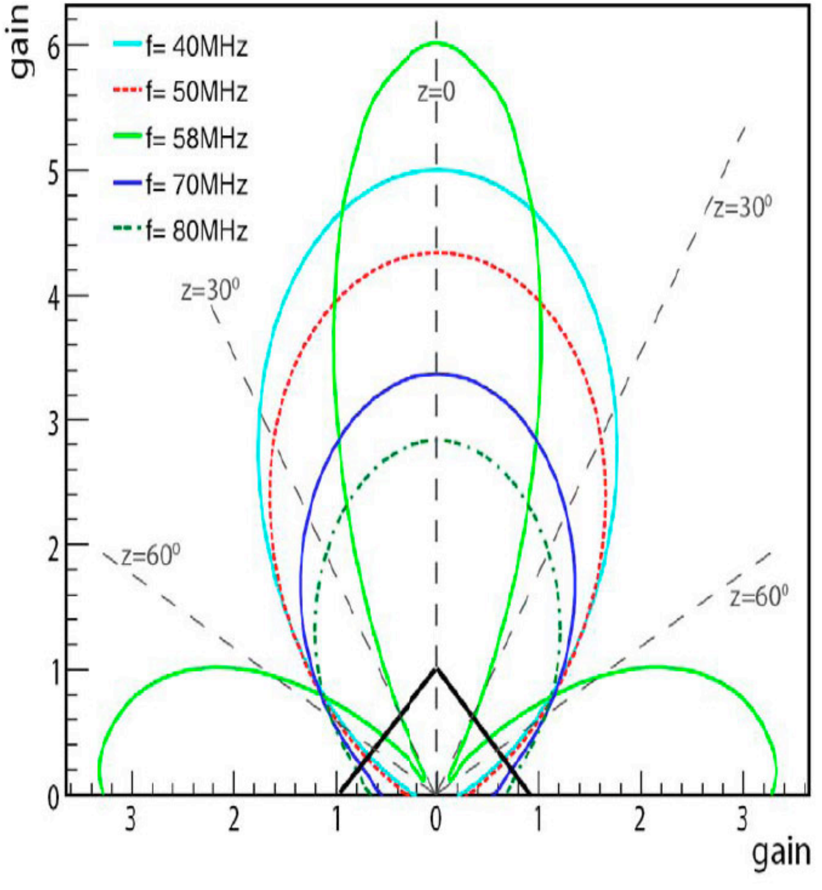
Problems:

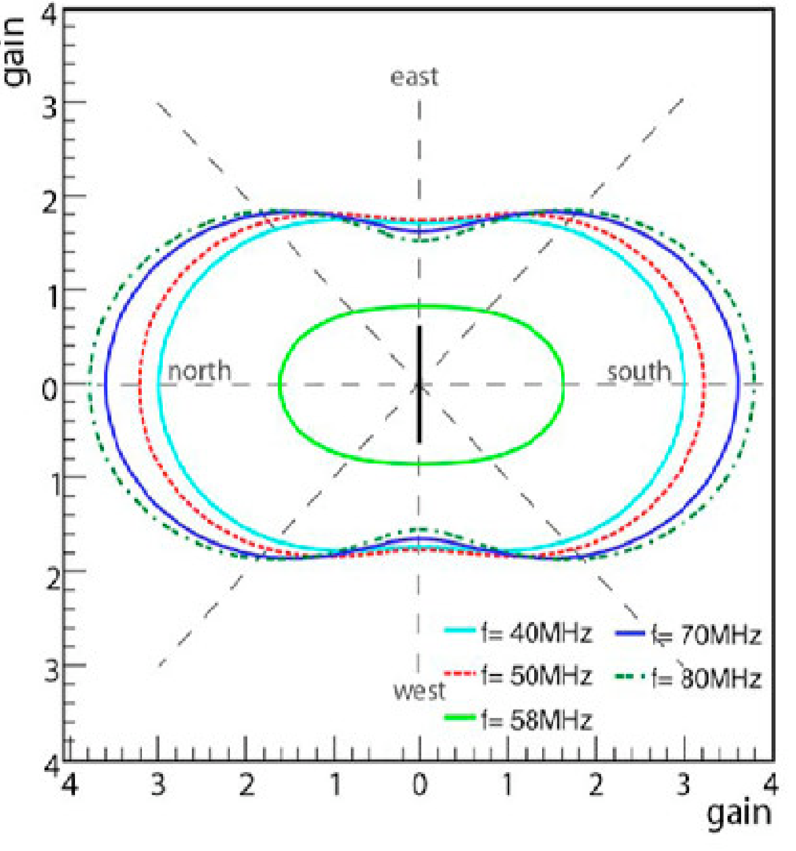
- complex impedance
  - ⇒ Current pre-amp or
  - ⇒ High impedance pre-amp
- Sensitivity dependent from distance **to** and impedance **of ground**

LOPES V-Dipol

Karlsruhe

Resonance behavior (58 MHz) due to the ground plate



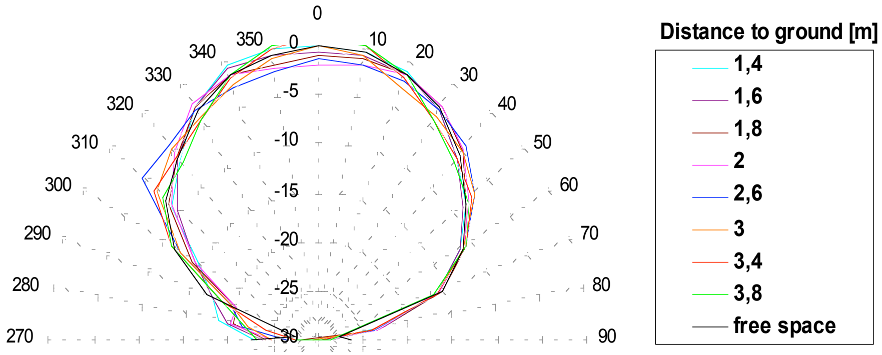


Logarithmic periodic dipole antenna (LPDA)

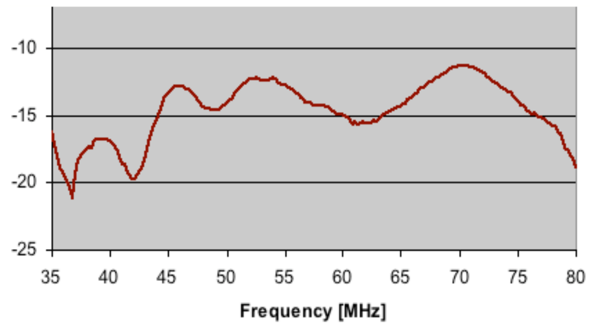
- **LOPES-Star (Karlsruhe)**

PHD O. Krömer

Measured sensitivity as function of elevation angle and different distances from the ground

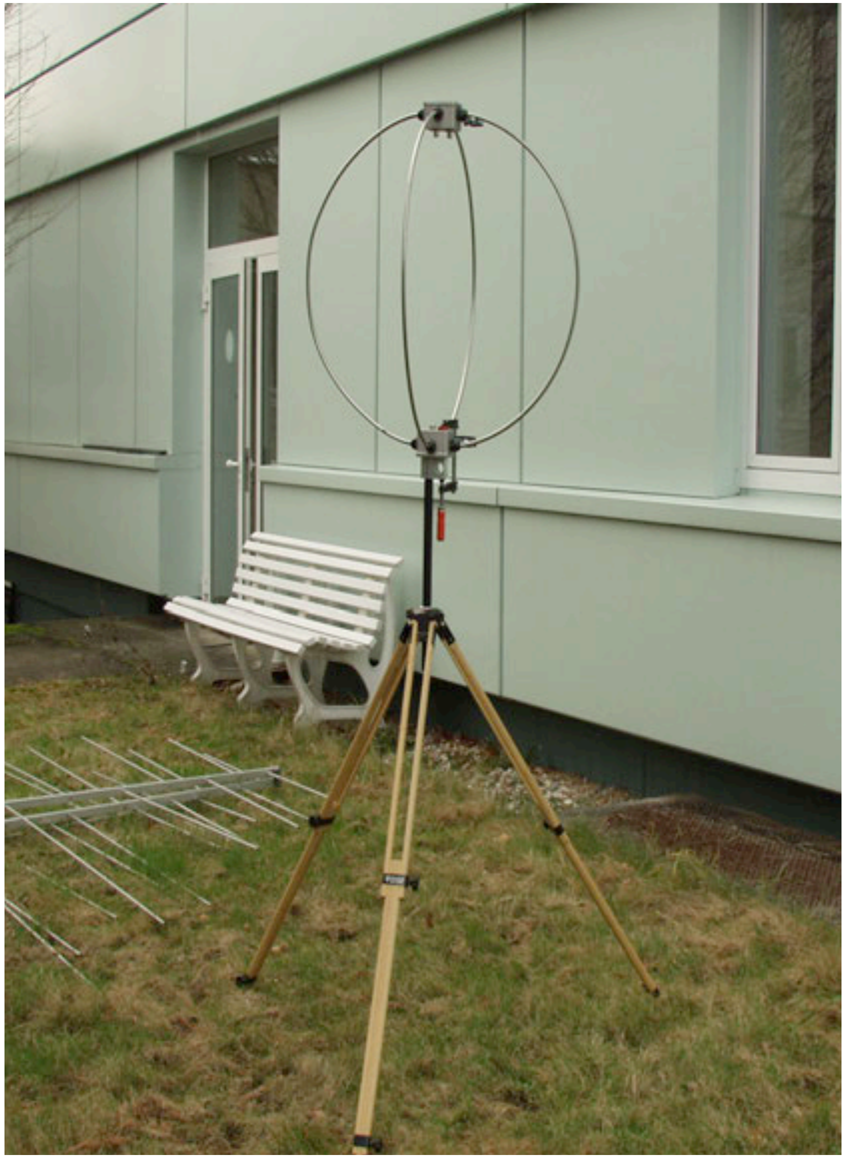


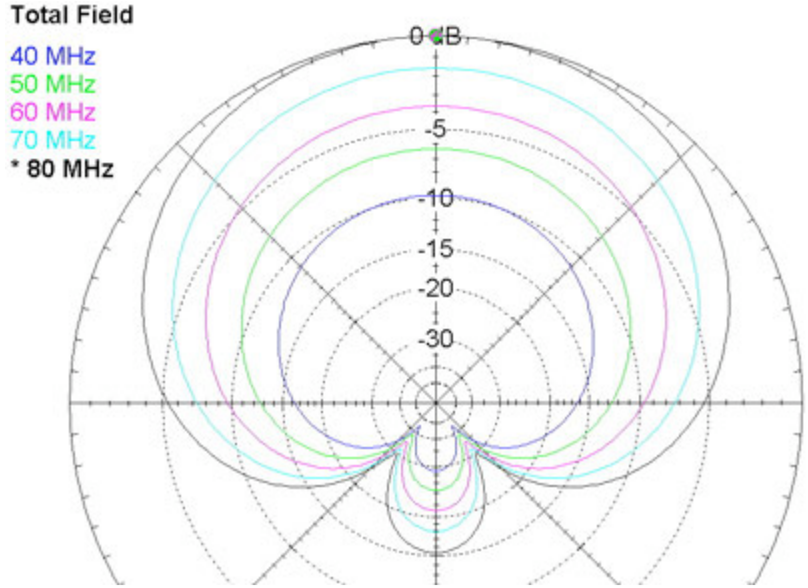
Independent from ground conditions



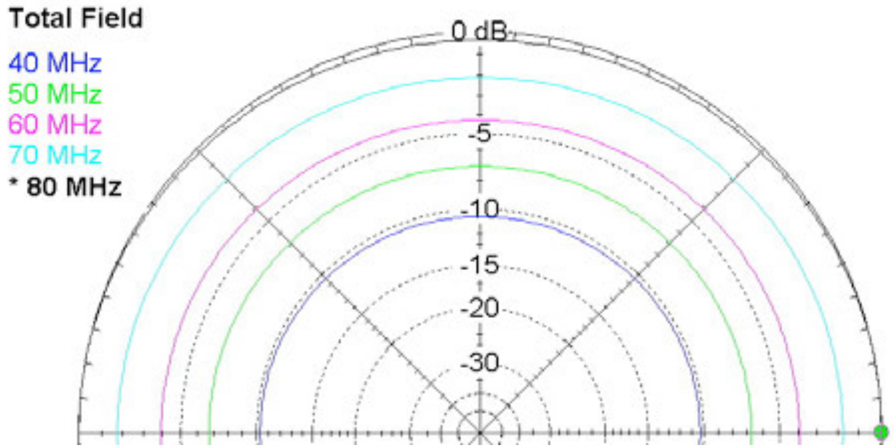
More than 90 % of the received power are reaching the 50 Ω receiver input

Short Loaded Beverage Antenna (SLBA)





Sensitivity as function of Elevation

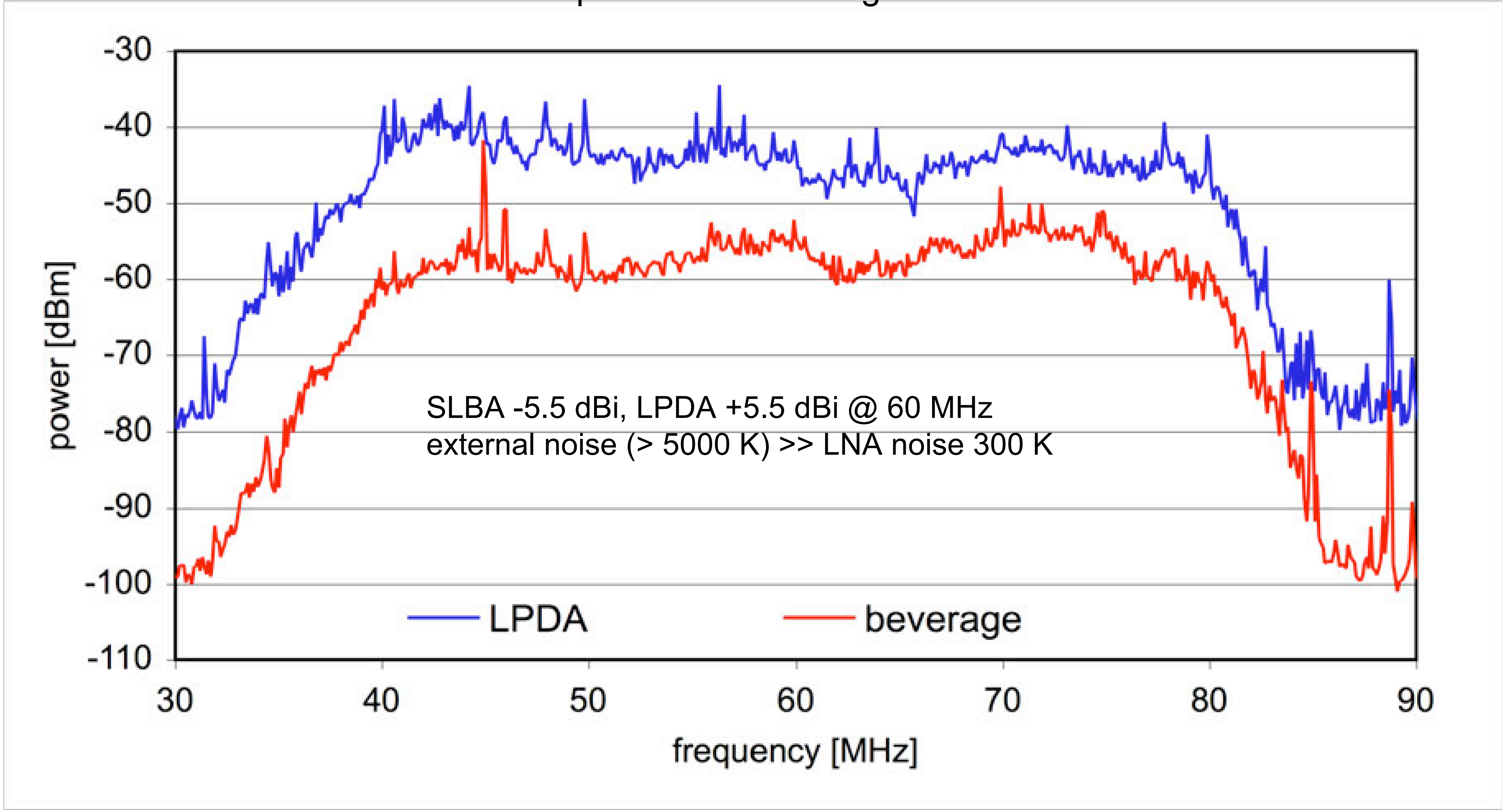


Azimuth distribution at 45° elevation

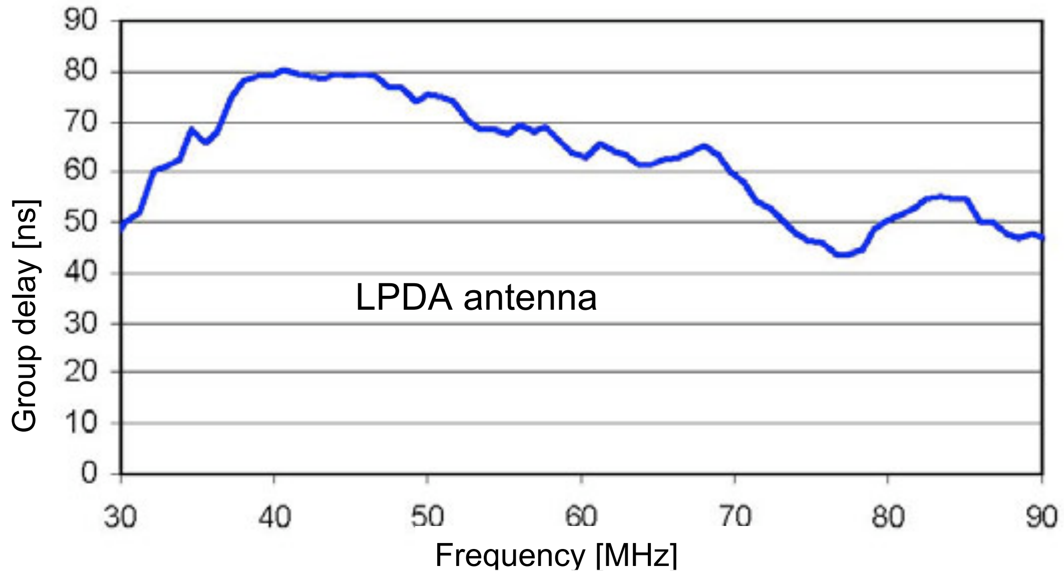
Comparison of SLBA and LPDA

Measured background spectrum at FZK with LPDA and SLBA

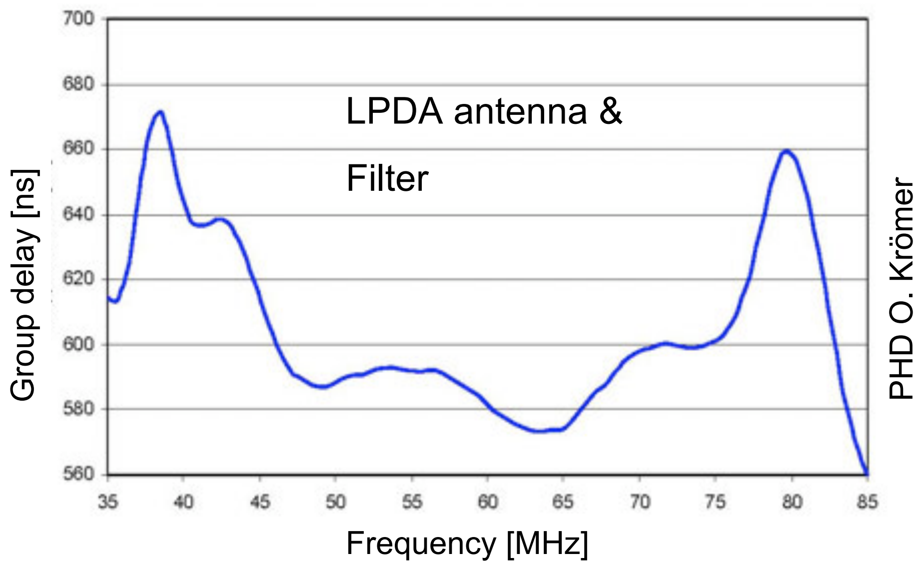
data are taken after LNA and band-pass filter of analogue board



Group delays of LPDA



Δt (40 to 80 MHz) = 35 ns

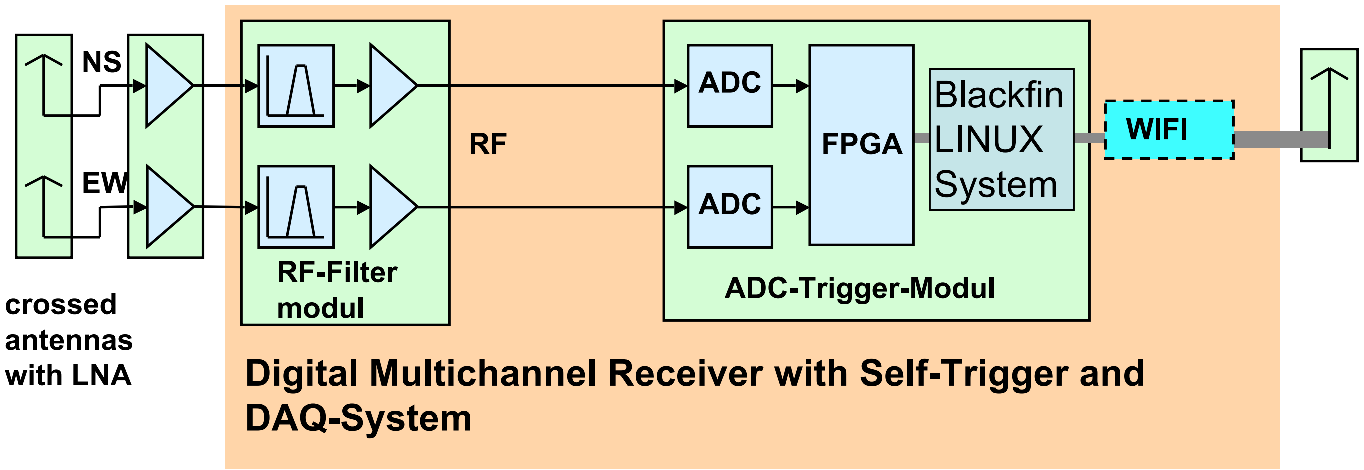


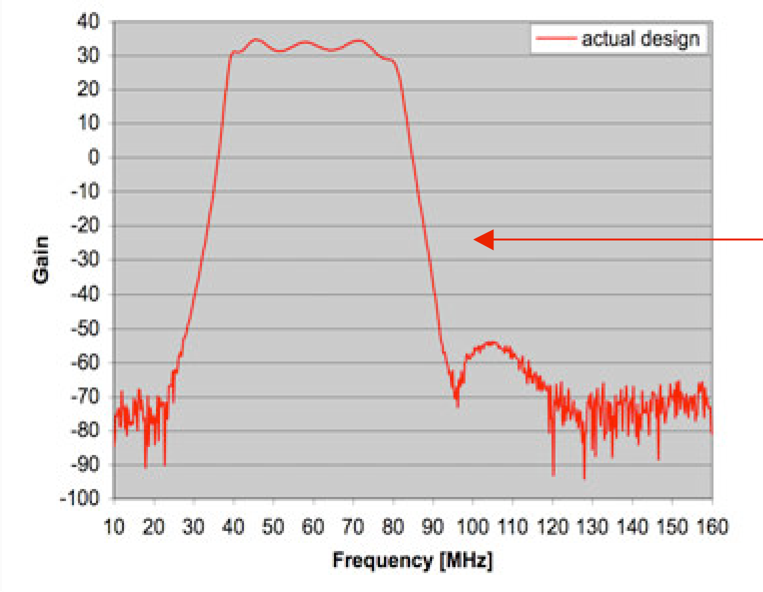
Δt_{max}(40 to 80 MHz) = 80 ns

Has to be considered in the analysis and is **elevation dependent**

Electronics

Receiver Concept





Goals:

Low power consumption < 5 W

Good suppression of FM radio-signals and definition of 2_{nd} Nyquist band 40 - 80 MHz with a passive 32_{nd} order band pass filter

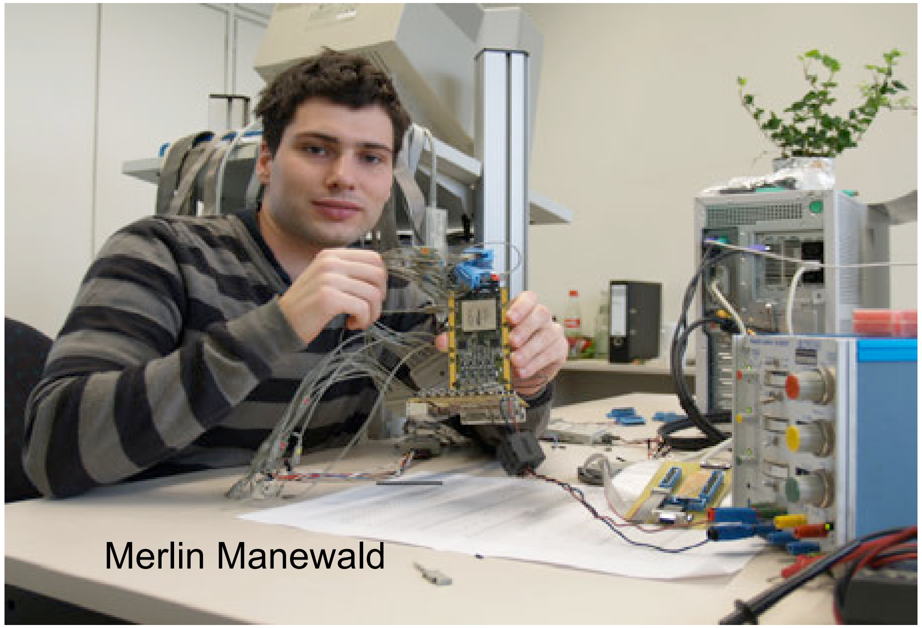
Suppression of radio-signals & transients in the accepted band of 40 - 80 MHz

$\Rightarrow$ trigger

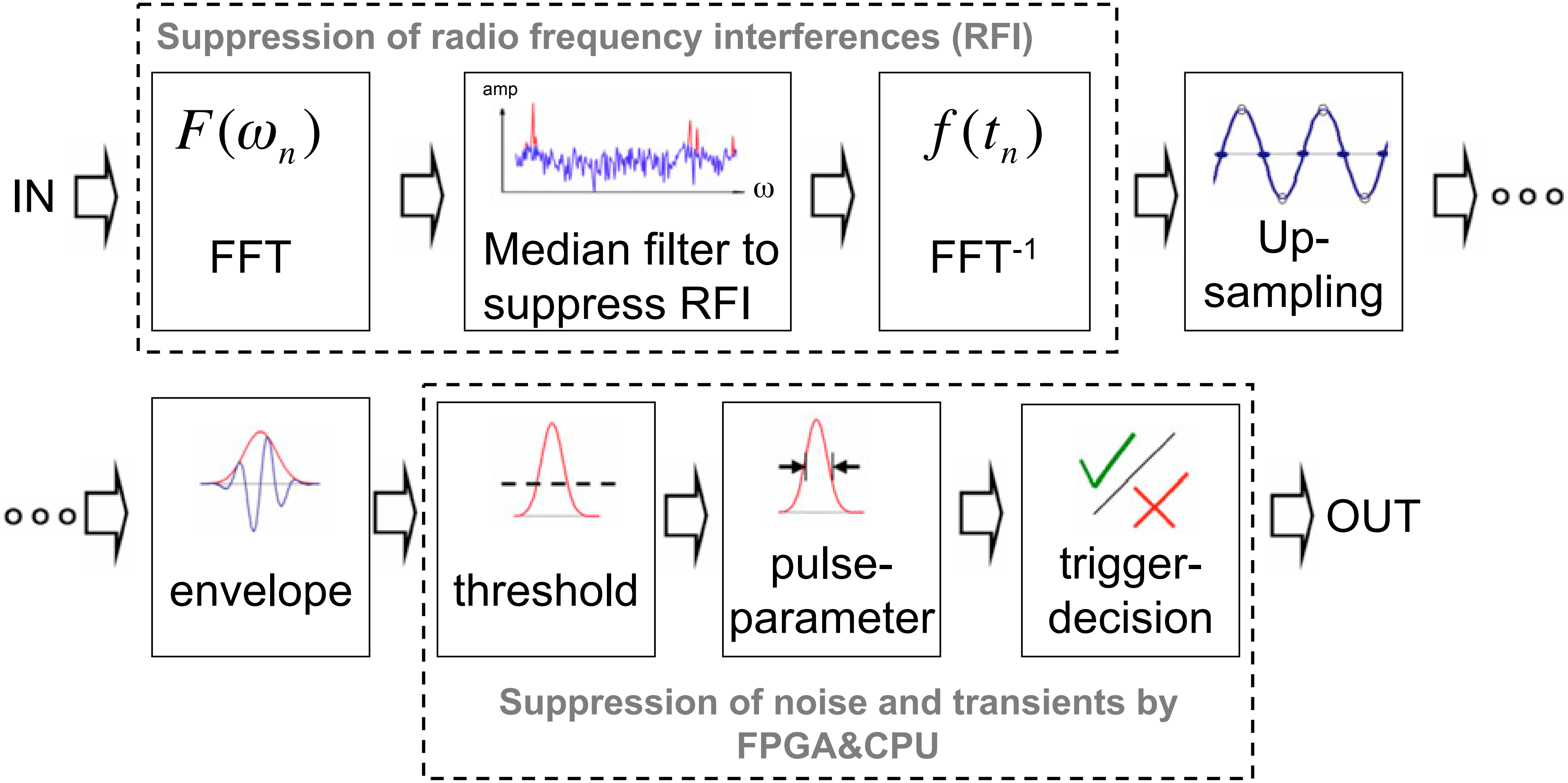
(Self) - Trigger per Antenna

Why?

1. Power-Budget: solar power & battery
2. Communication congestion



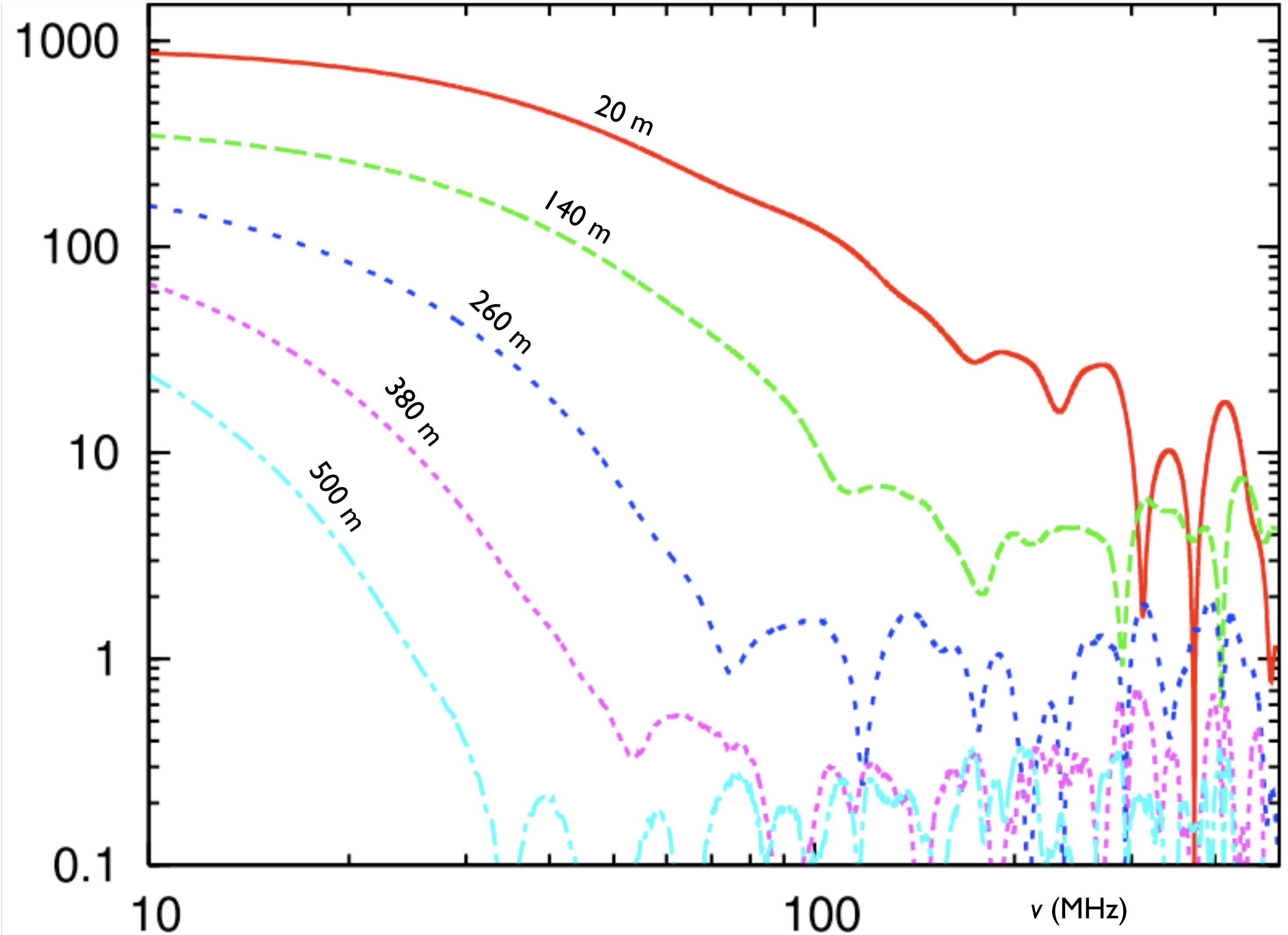
Schematic of Trigger in the FPGA



Is median trigger allowed?

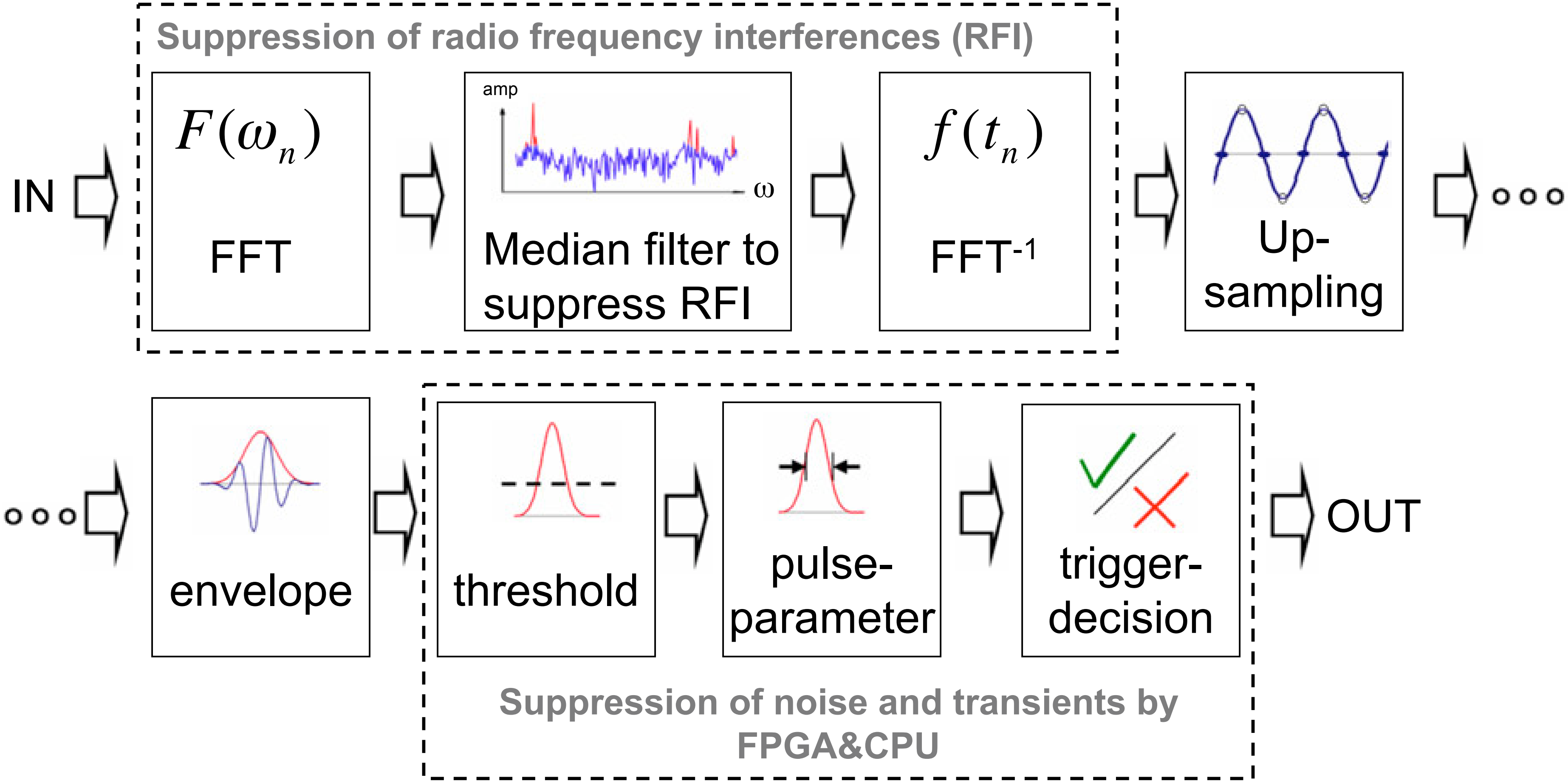
Frequency spectrum of radio signal

Smooth spectrum ⇒ median trigger allowed



Huege et al. (2005)

Schematic of Trigger in FPGA



First version of a complex trigger for radio trigger

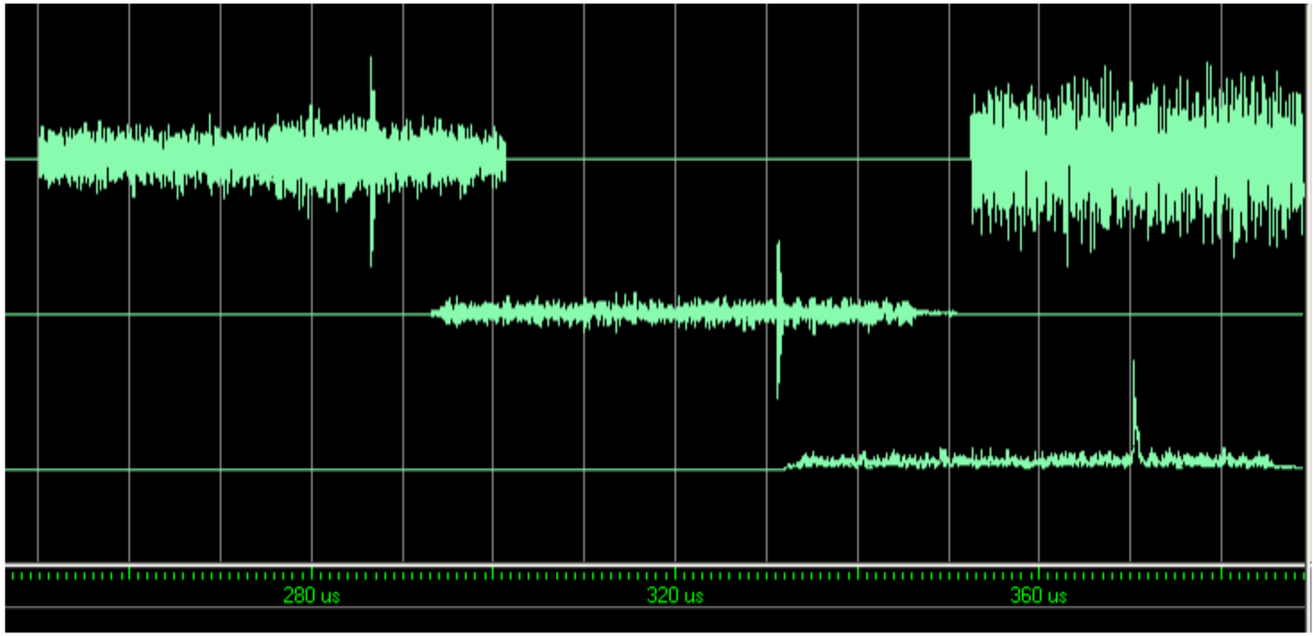
Results

ModelSim results of trigger-simulation

Real raw data

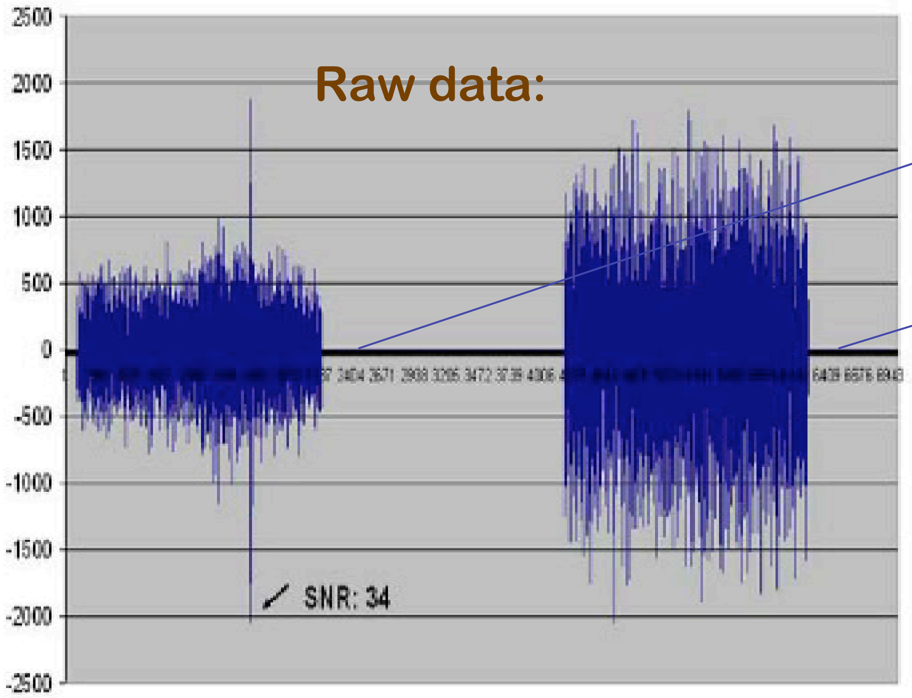
RFI-suppressed

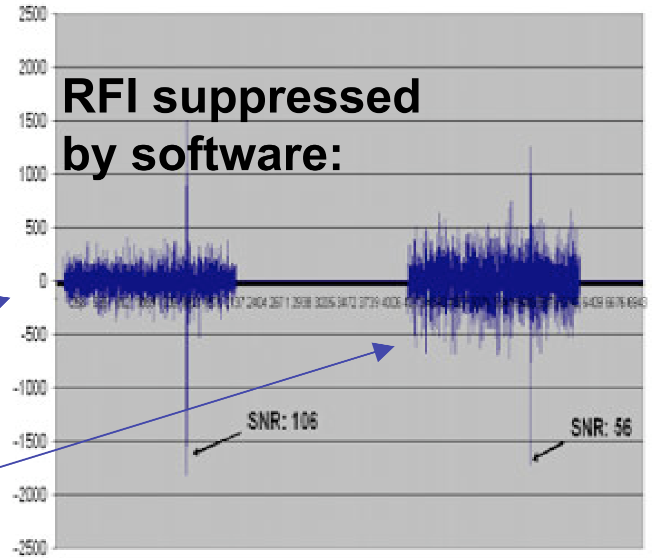
Up-sampled &
envelope

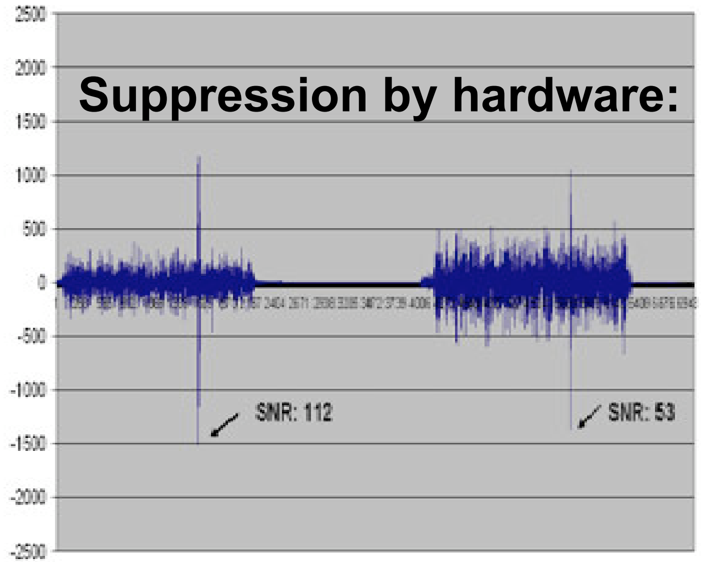


Test of hardware trigger of LOPES^STAR

Improvement by a factor 3







Real shower event,
measured with LOPES^STAR
at FZK

Conclusion

- New **complex** self trigger is possible & running in Ka with a factor 2 to 5 lower threshold **at E > $5{\cdot}10^{17}$ eV**
- Radio signals of cosmic rays are a promising (old/new) detection method **of Ultra High Energy Cosmic Rays**
- **Next step:** Tests at Auger-South site

Thanks