Development of self-trigger algorithms for radio detection of air-showers

Oleg Fedorov

June, 2020

Motivation

The detection of the air-showers radio emission is the promising technique for studies of UHE cosmic rays, gamma rays and neutrinos.
Advantages:

- Almost full duty cycle
- Simple and cost-effective
- Sensitive to the energy and shower maximum

Disadvantage:

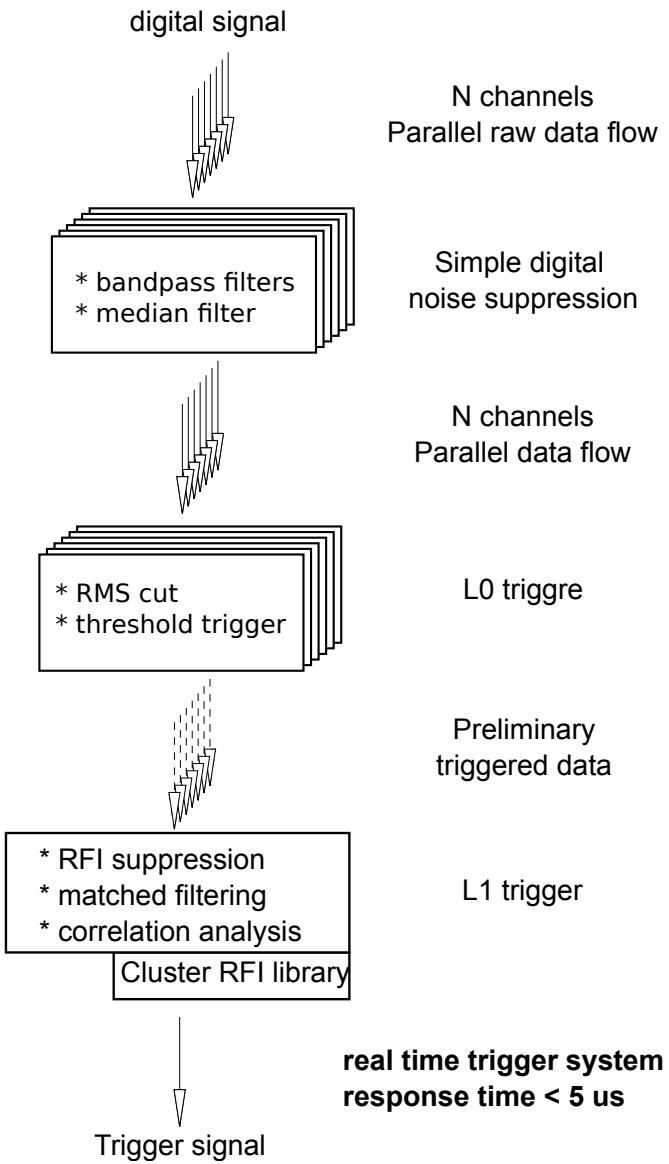
- Low signal-to-noise ratios (SNR) and many transient background (RFI)

Trigger implementation complexity

- 1 GB/s (or more) raw data from each station
- EAS pulses are short and low-intensity
- A lot of RFI

Requires a smart trigger generation mechanism and an advanced noise reduction system. The first step is studying background noise and develop noise reduction algorithms.

Trigger design

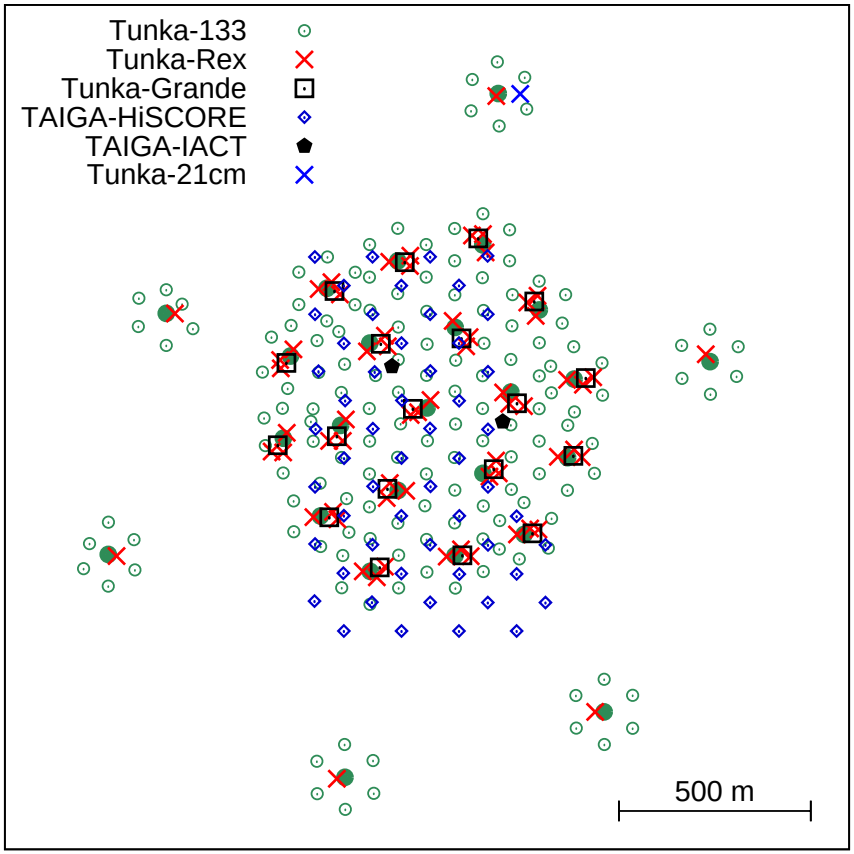


Multi-Level Realtime Trigger System

- Channel level
  - Digital bandpass and median filters
- Station level (L0)
  - Threshold trigger
  - Pairwise channel analysis
  - False triggers suppression
- Cluster level (L1)
  - Match pattern
  - Suppression of known RFI
  - Restriction on direction
  - EAS signal search

Response time < 5 μs
On-chip built system

Tunka-Rex and TRVO



Tunka-Rex

- 63 antenna station
- Operation period 2012 - 2019
- Triggered by Tunka-133 and Tunka-Grande

Tunka-Rex Virtual Observatory (TRVO)

- 100M traces
- Trace length – 5120 ns / 1024 samples
- Sample resolution – 5 ns

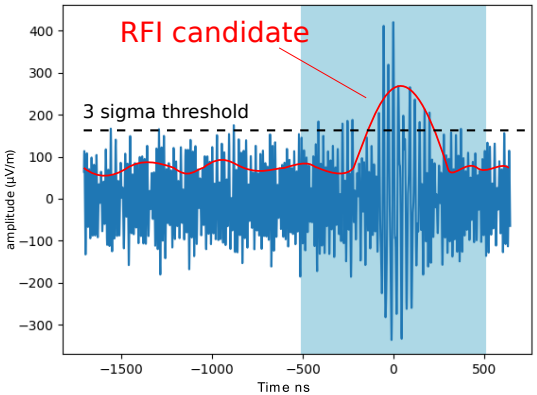
Tunka-Rex

data + software

astroparticle.online

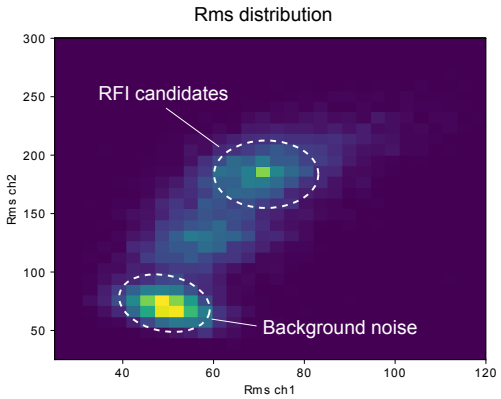
RFI searching method

Station data
(2 channels)



* Calculating RMS in sliding window.

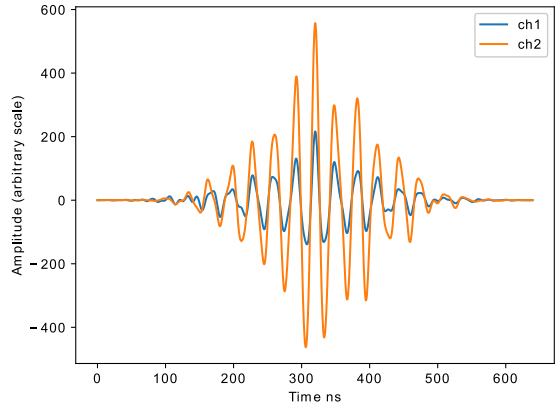
* 3 sigma detection threshold



* Building a channel-to-channel distribution of RFI candidates RMS responses

* Finding cores of distribution

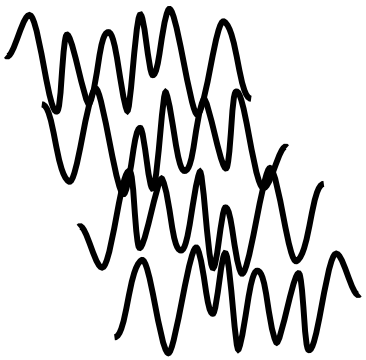
RFI template

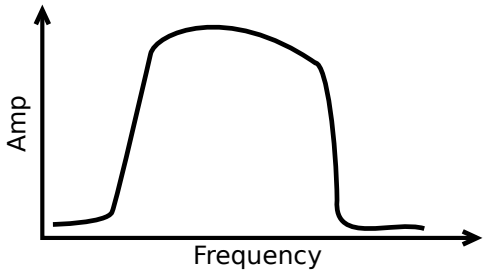


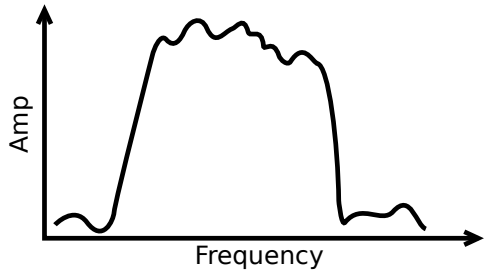
* Averaging RFI candidates

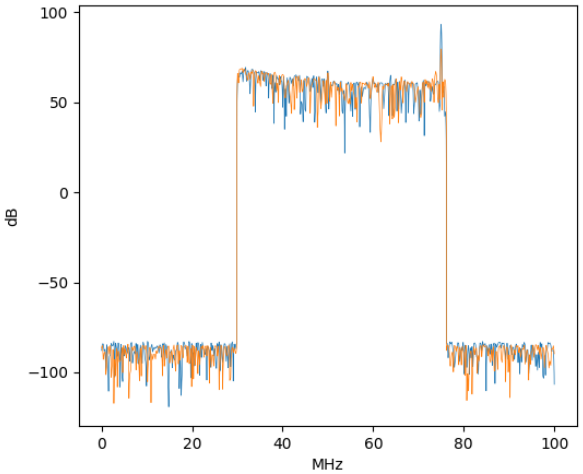
Noise generator

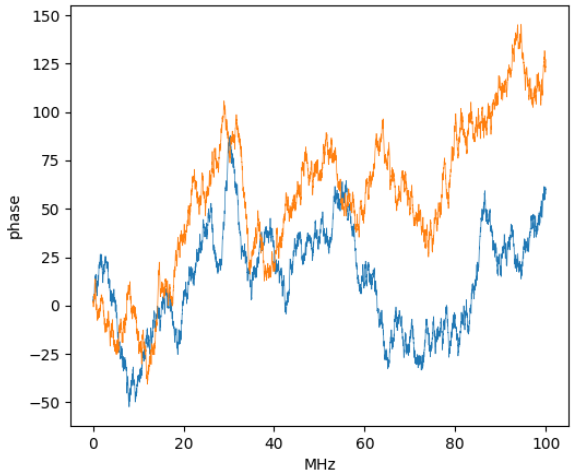
Set of traces from TRVO → Mean Spectrum → Randomized mean Spectrum → Generated Trace

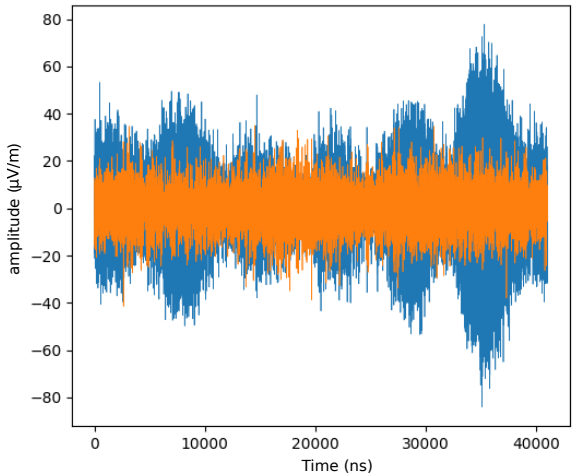






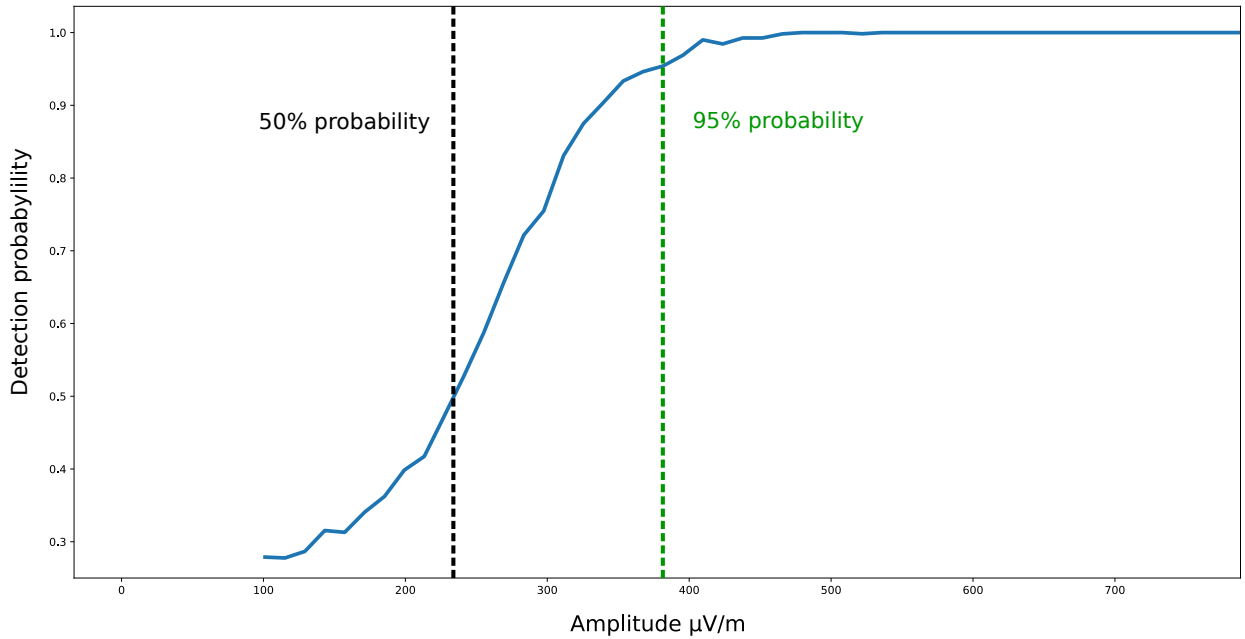






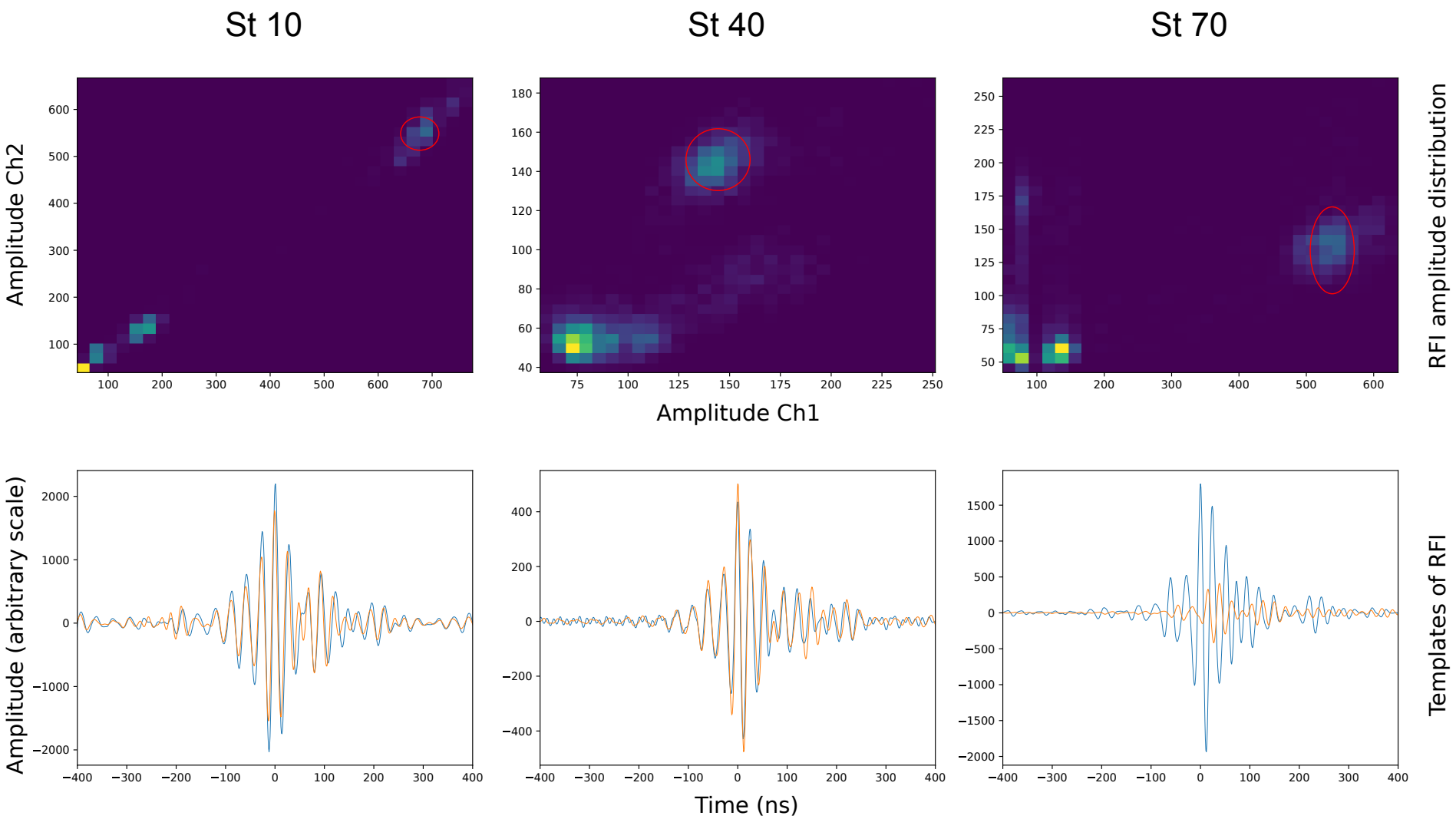
Preliminary evaluation of L0 trigger

- Matched filtering using EAS template
- 4 sigma trigger amplitude cut
- ~ 250 kHz trigger rate
- 50/95% detection efficiency for amplitudes $\sim 230/380\ \mu V/m$



Conclusion and future plans

- Improvement and tuning L0 trigger algorithms
- Development L1 trigger
- Tunka-Rex RFI library


St 10
St 40
St 70
Amplitude Ch2
Amplitude Ch1
RFI amplitude distribution
Amplitude (arbitrary scale)
Time (ns)
Templates of RFI