



# **OBSERVATION OF LIGHTNING-INDUCED SIGNALS ON THE SUMMIT OF LA GRANDE MONTAGNE: PART 2 – INTERFEROMETRY AND VLF MEASUREMENTS**

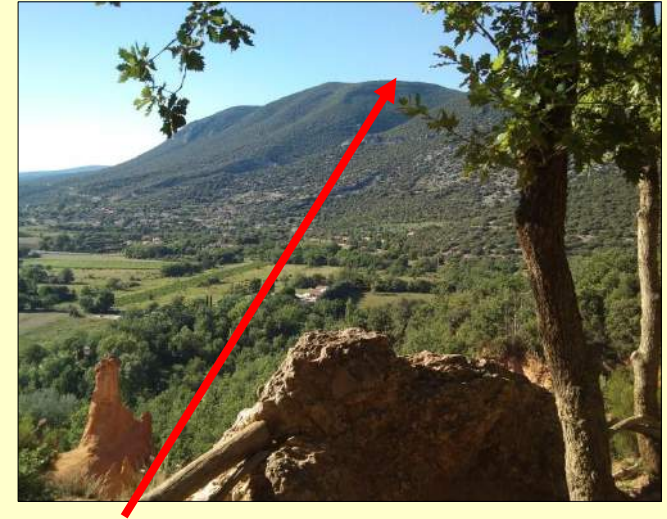
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**Luděk UHLÍŘ<sup>1</sup> Radek LÁN<sup>1</sup>**

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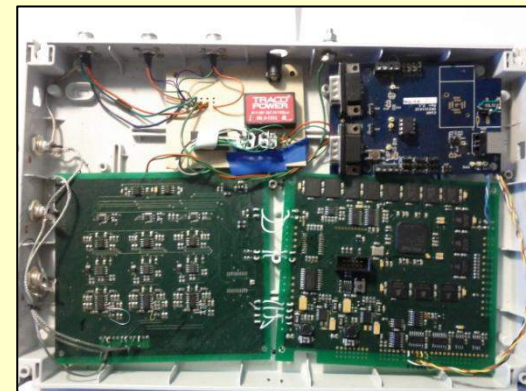
# VLF INSTRUMENTATION



Two perpendicular magnetic loops and an electric spherical sensor connected to a ground-based version of the **ELMAVAN** analyzer (RESONANCE spacecraft mission) [200 Hz – 20 kHz]

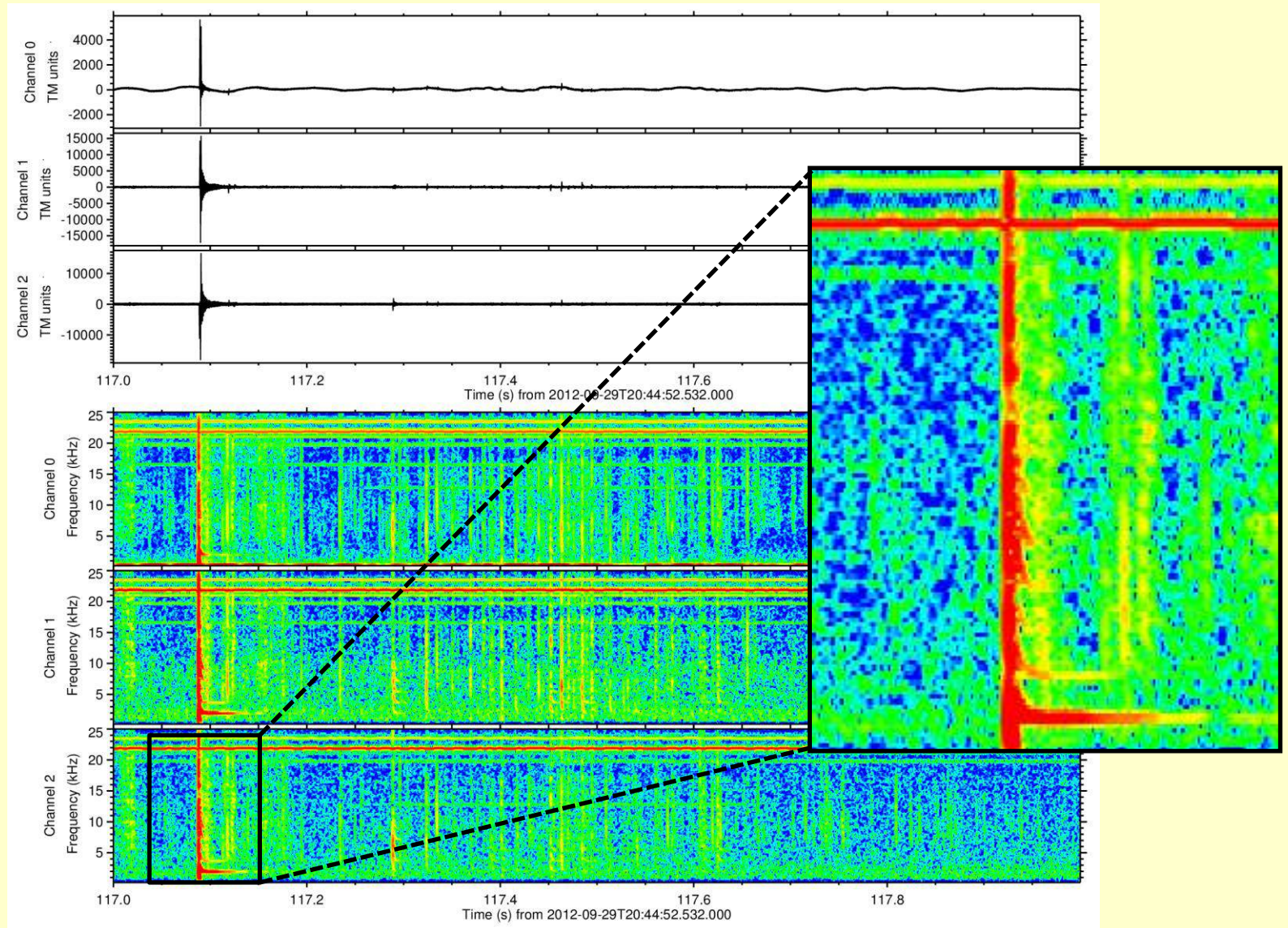


*La Grande Montagne*  
(1028 m, 43.9410N, 5.4836E)

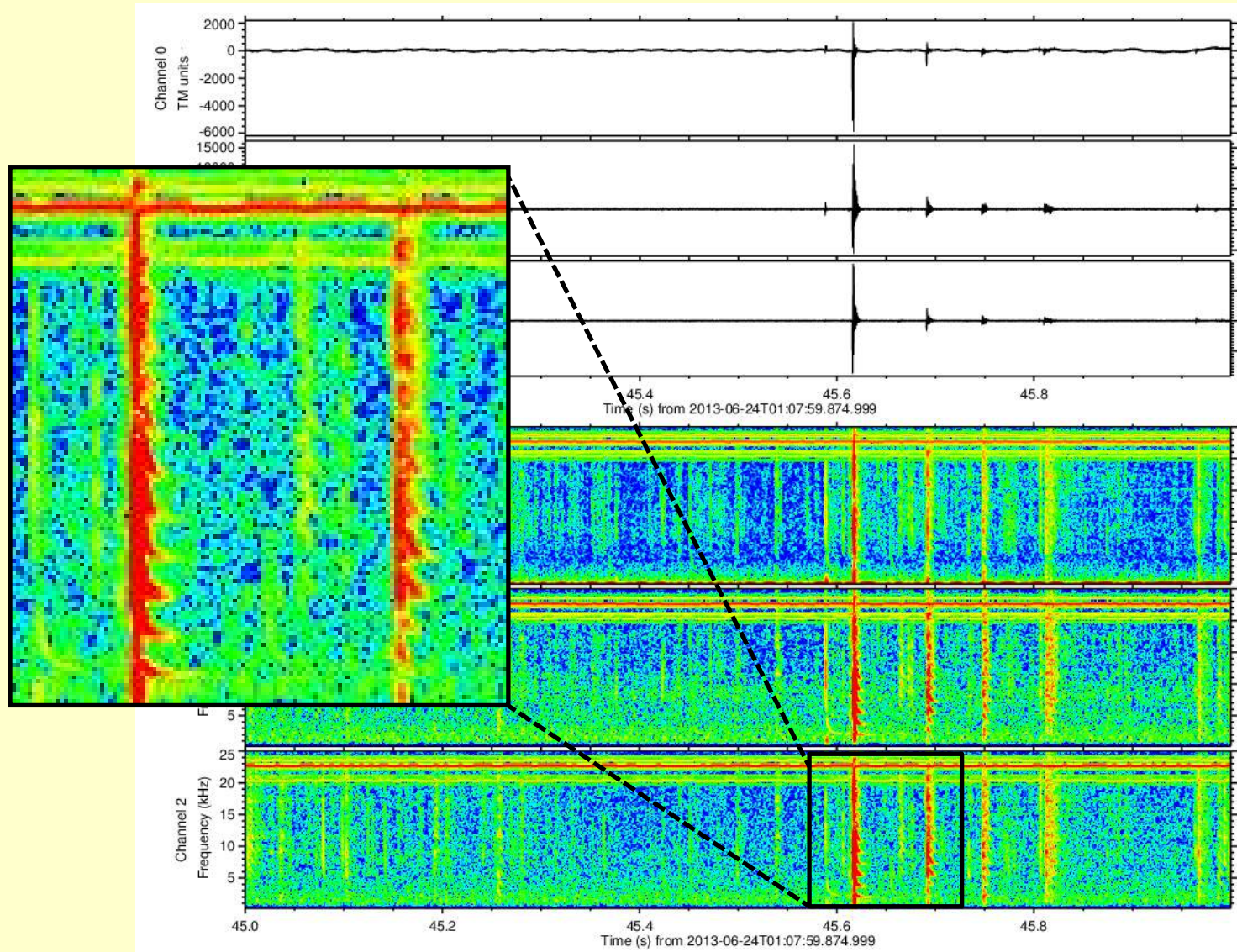


8/2012 – 9/7/2013

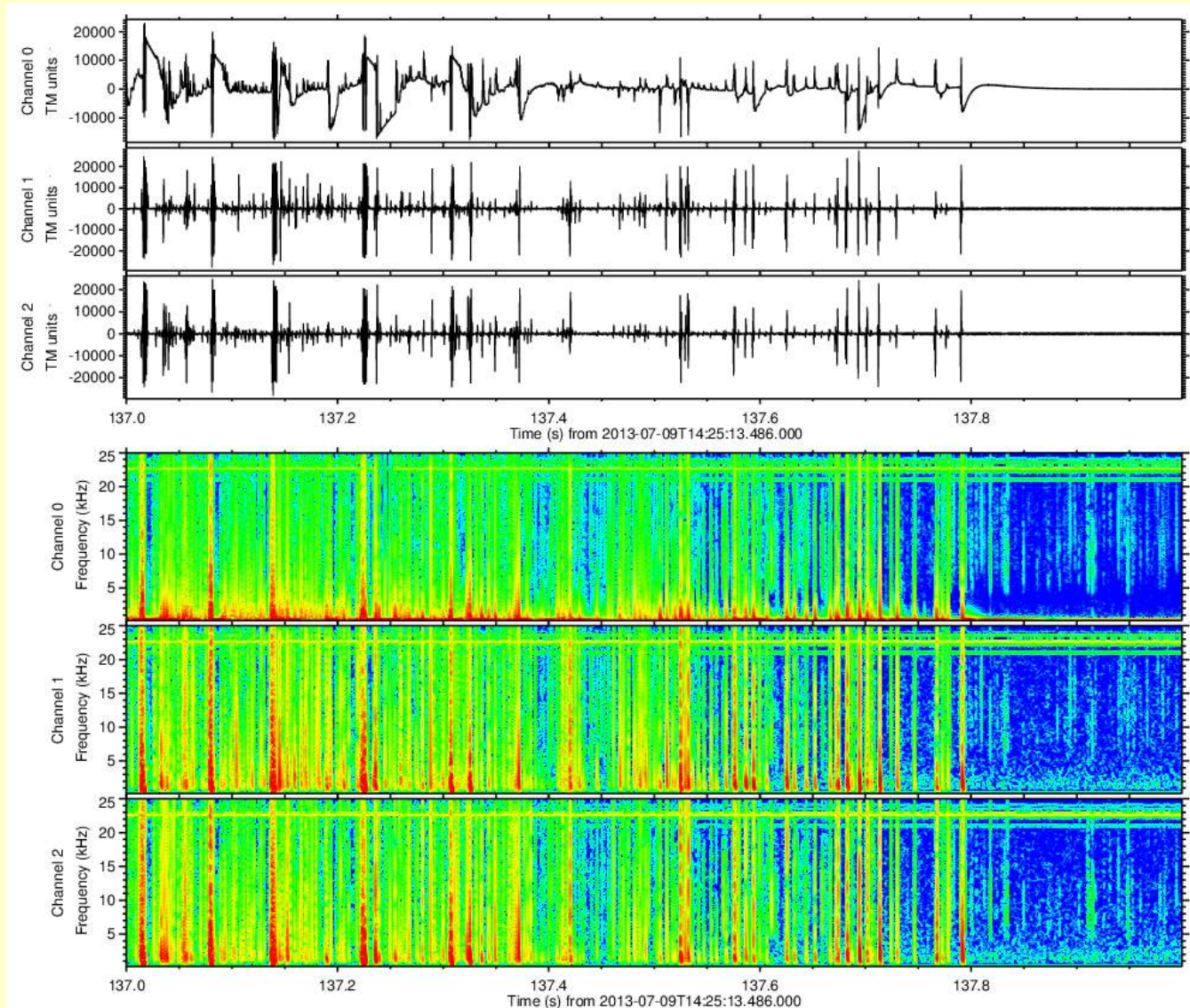
# VLF OBSERVATION OF DISTANT LIGHTNING



# VLF OBSERVATION OF DISTANT LIGHTNING



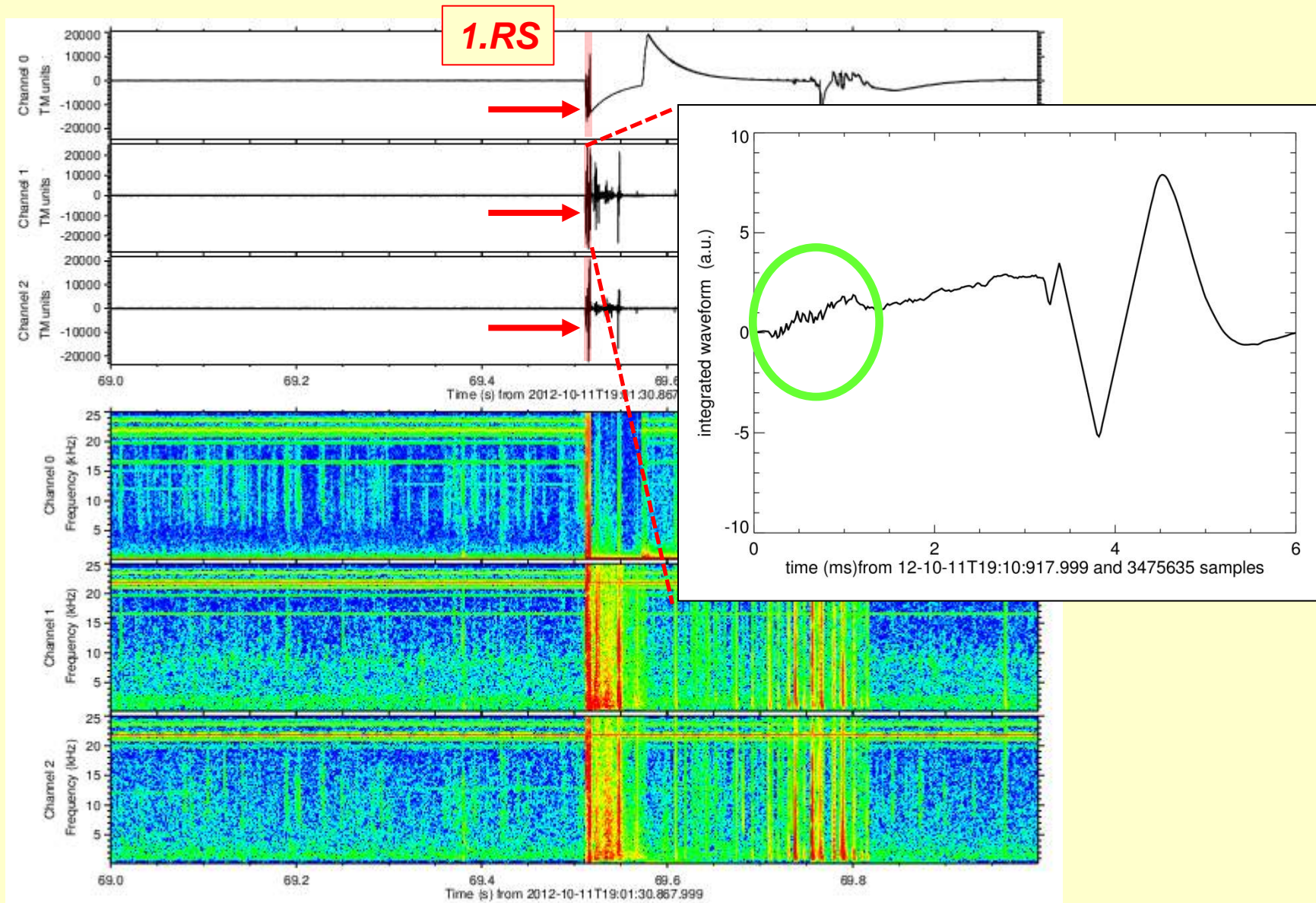
# VLF OBSERVATION OF CLOSE LIGHTNING



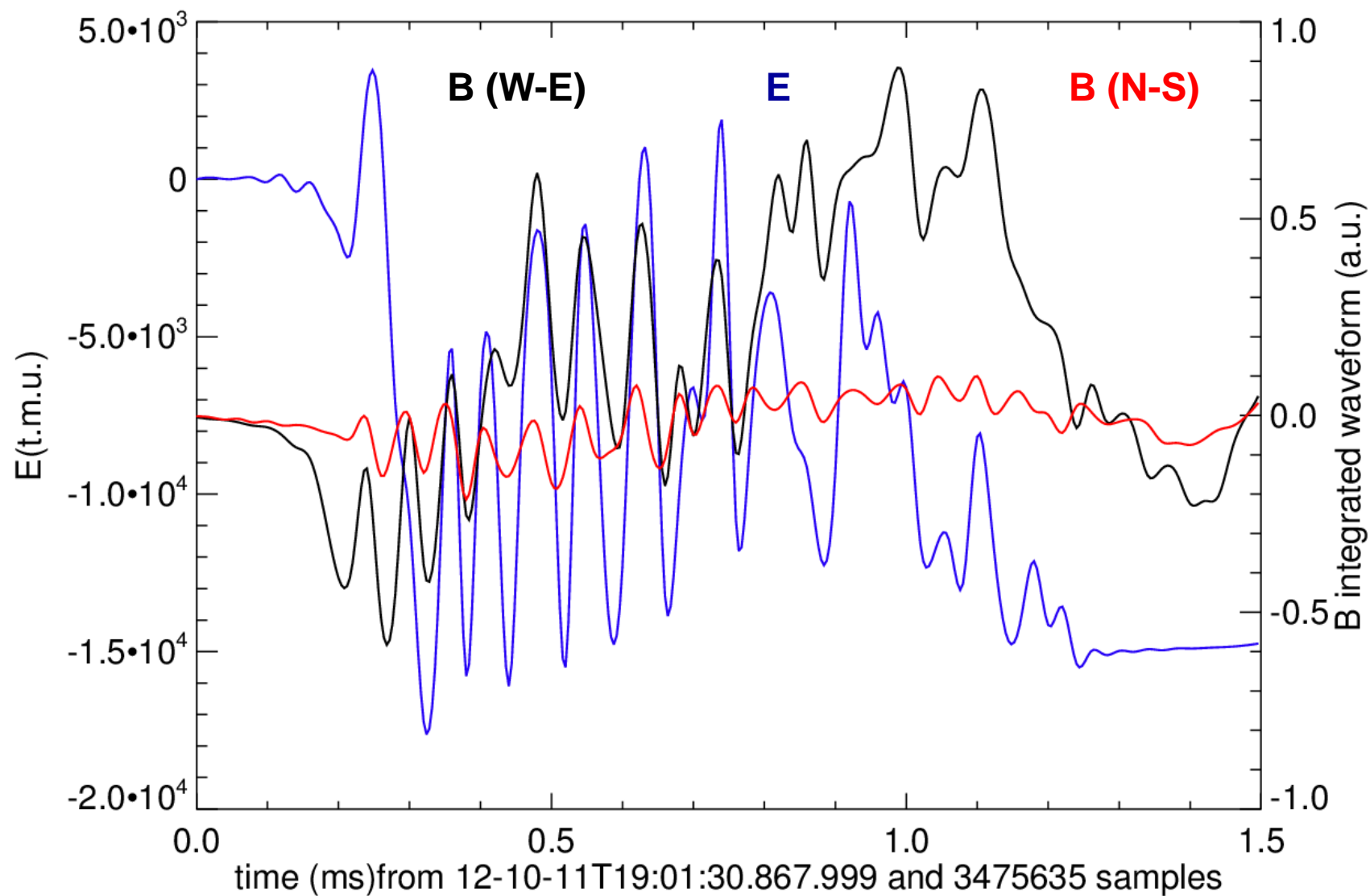
*last  
record*



# PRE-STROKE PULSE ACTIVITY



# PRE-STROKE PULSE SEQUENCE IN THE VLF RANGE

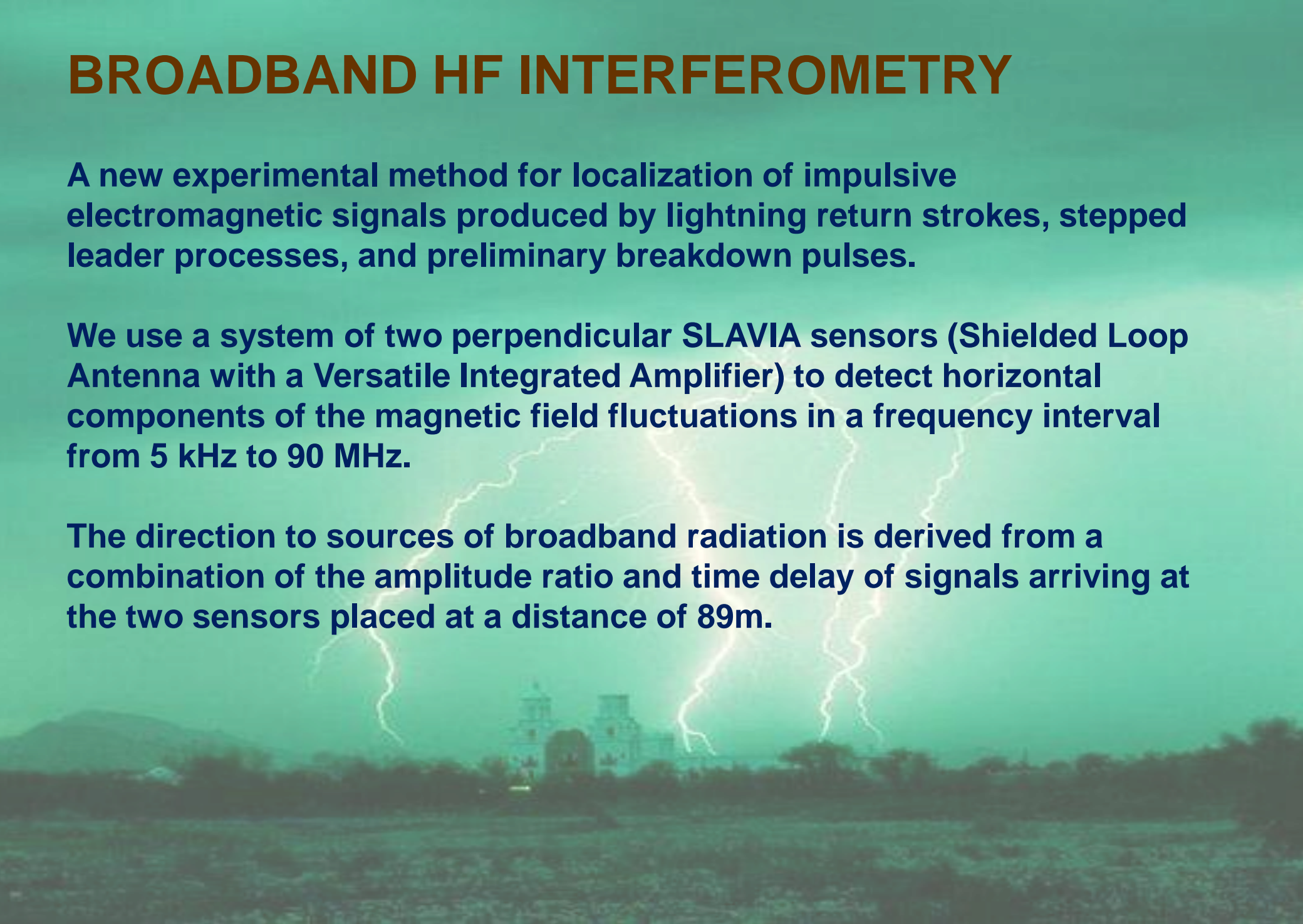


# BROADBAND HF INTERFEROMETRY

A new experimental method for localization of impulsive electromagnetic signals produced by lightning return strokes, stepped leader processes, and preliminary breakdown pulses.

We use a system of two perpendicular SLAVIA sensors (Shielded Loop Antenna with a Versatile Integrated Amplifier) to detect horizontal components of the magnetic field fluctuations in a frequency interval from 5 kHz to 90 MHz.

The direction to sources of broadband radiation is derived from a combination of the amplitude ratio and time delay of signals arriving at the two sensors placed at a distance of 89m.







Initial  
configuration

3-26  
September  
2013

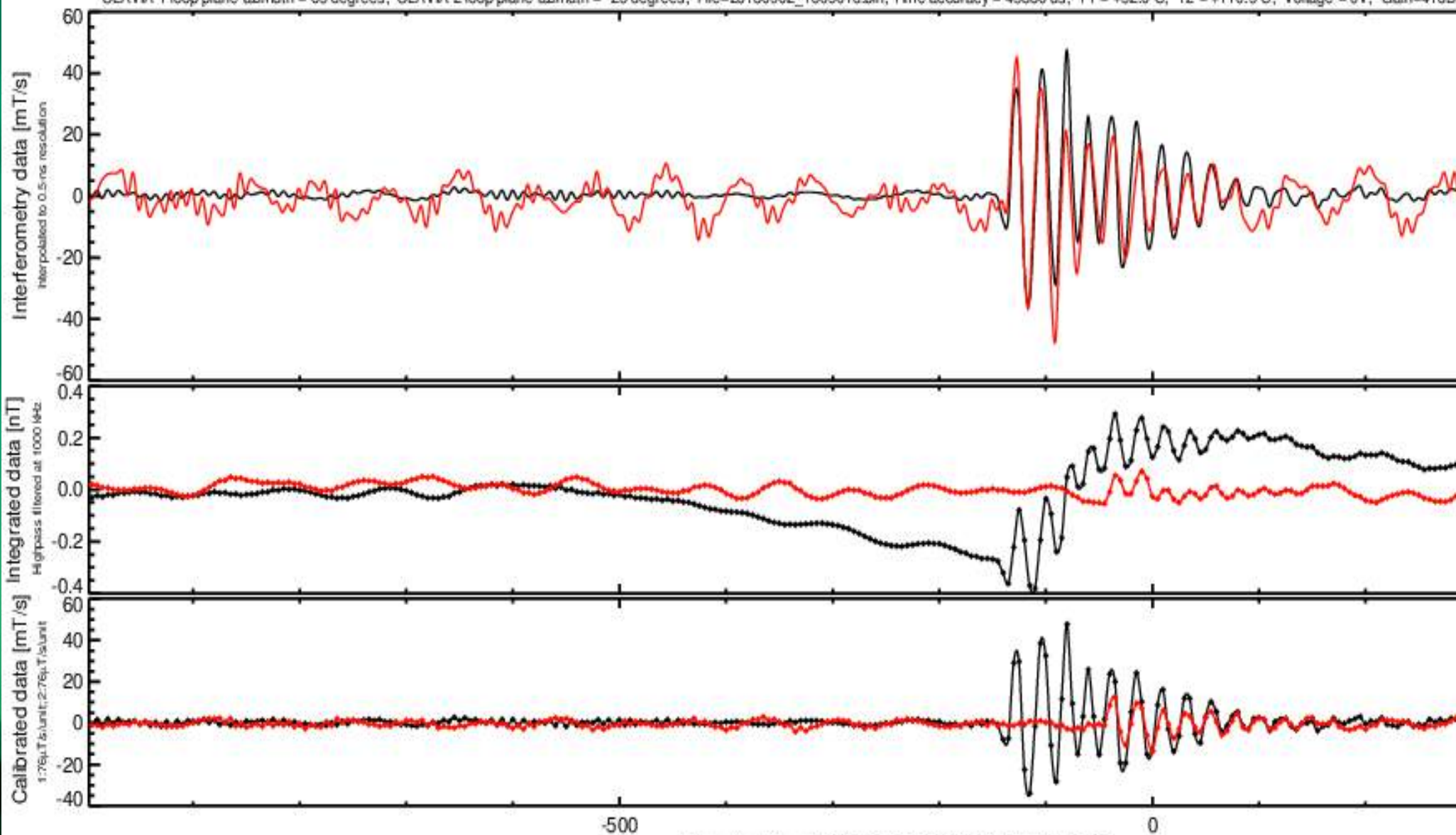
Two perp  
antennas

29.4 m  
baseline



INTERFEROMETRY: SLAVIA 1 (black) - SLAVIA 2 (red, lagged and scaled), Baseline = 29.4m, Azim<sub>1,2</sub> = -25°, Scale<sub>2</sub> = 3.47, Lag<sub>2</sub> = 100 ns

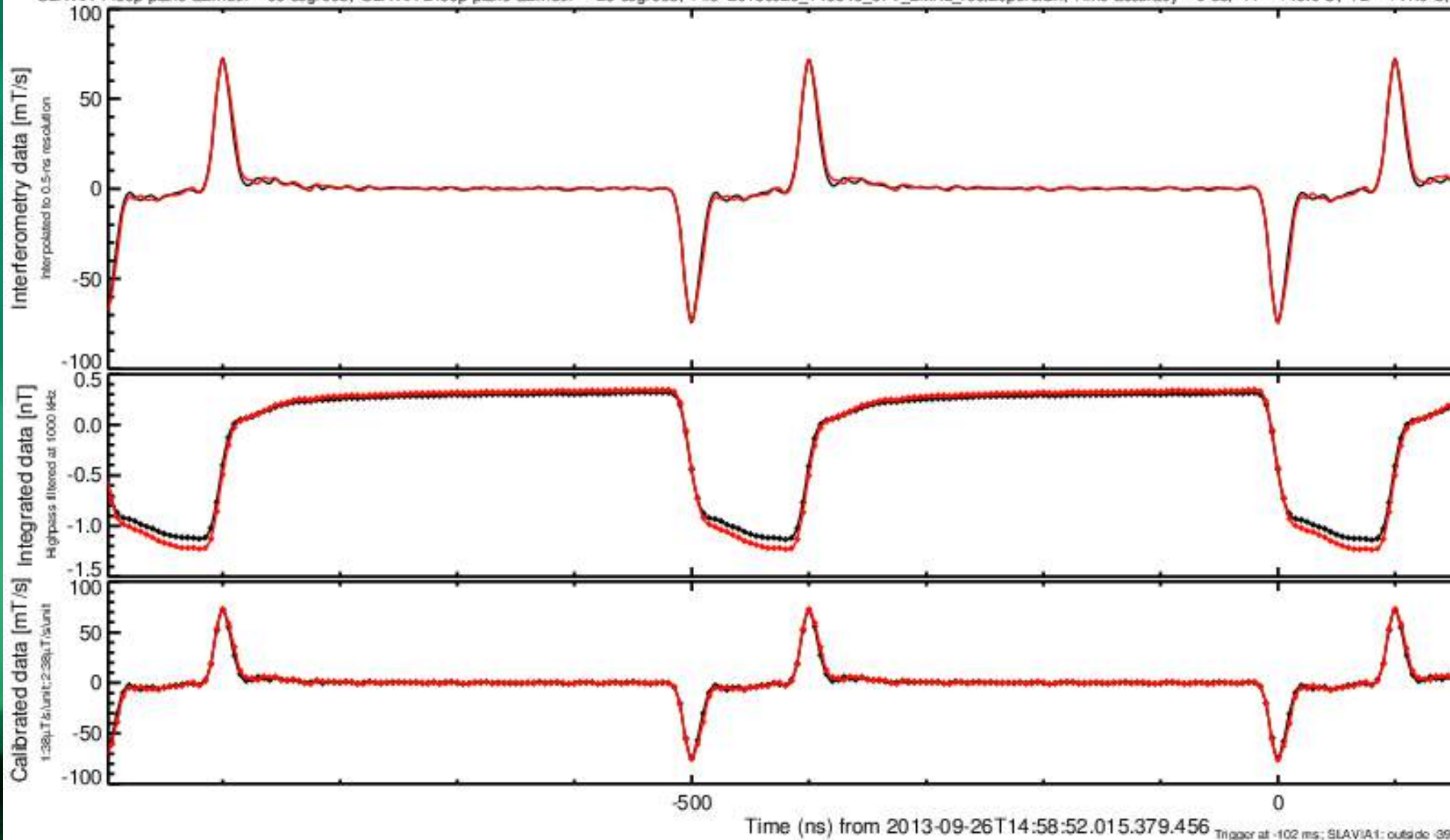
SLAVIA 1 loop plane azimuth = 65 degrees, SLAVIA 2 loop plane azimuth = -25 degrees, File=20130902\_180501d.bin, Time accuracy = 45330 us, T1 = +52.0 C, T2 = +110.5 C, Voltage = 0V, Gain=41dB



Time (ns) from 2013-09-02T18:05:06.864.273.408 Trigger at -48 ms; SLAVIA1: outside -9.38 and 9.38 mT/s; SLAVIA

# INTERFEROMETRY: SLAVIA 1 (black) - SLAVIA 2 (red, lagged and scaled), Baseline = 29.4m, Azim<sub>1,2</sub> = -

SLAVIA 1 loop plane azimuth = 65 degrees, SLAVIA 2 loop plane azimuth = -25 degrees, File=20130926\_145848\_57V\_2MHz\_rect20perc.bin, Time accuracy = 0 us, T1 = +45.0 C, T2 = +41.0 C,



Actual configuration

Since 26 September 2013

Two perp antennas

89m baseline



# Broadband electromagnetic measurement of lightning discharges

Live online data recorded by the [Institute of Atmospheric Physics, Prague, Czech Republic](#) in collaboration with [Laboratoire Souterrain a Bas-Bruit, Rustrel, France](#). The thunderstorm activity is continuously monitored in a favorable electromagnetic environment on the summit of La Grande Montagne (1028 m, 43.9410N, 5.4836E), Plateau d'Albion. These measurements are prepared as a ground-based counterpart of instrumentation which is being developed by the Institute of Atmospheric Physics for the [TARANIS](#) spacecraft.

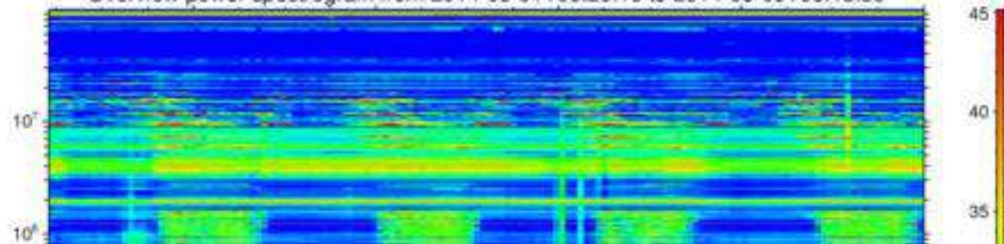
- [List of recorded data](#)
- [Data form](#)
- [Data archive](#)
- [Weather in Rustrel](#)
- [Lightning Detection](#)



The SLAVIA sensors (Shielded Loop Antenna with a Versatile Integrated Amplifier) detect horizontal component magnetic field fluctuations in a frequency interval from 5 kHz to 90 MHz. The loop surface is  $0.23 \text{ m}^2$ , the maximum gain is 47 dB. The maximum sensitivity of the recording system is  $6 \text{ nT/s}/\sqrt{\text{Hz}}$ , corresponding to  $1 \text{ fT}/\sqrt{\text{Hz}}$  at 1 MHz.

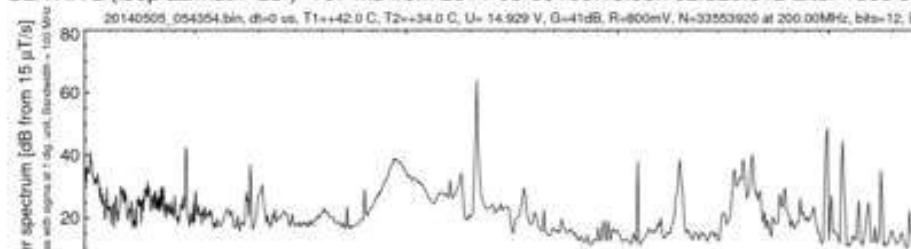
## 1. Overview of four days of measurements (time is given in UTC):

Overview power spectrogram from 2014-05-01T06:25:16 to 2014-05-05T06:13:55



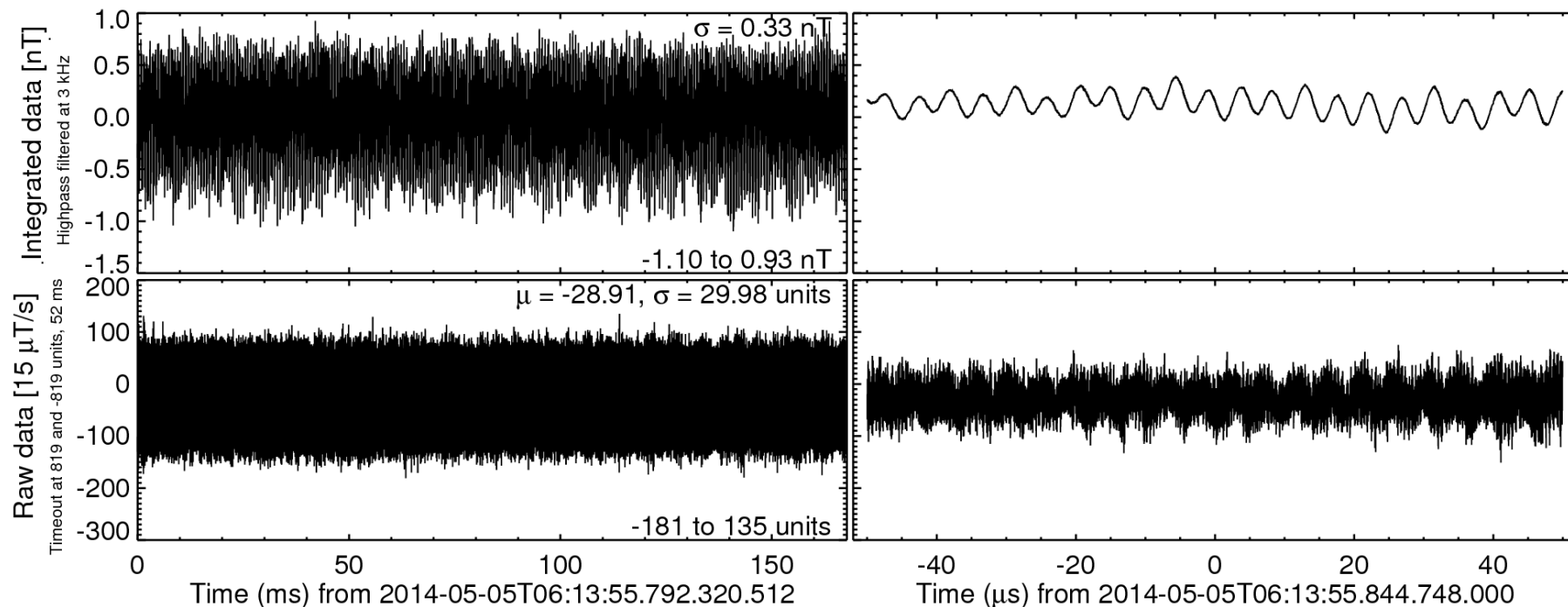
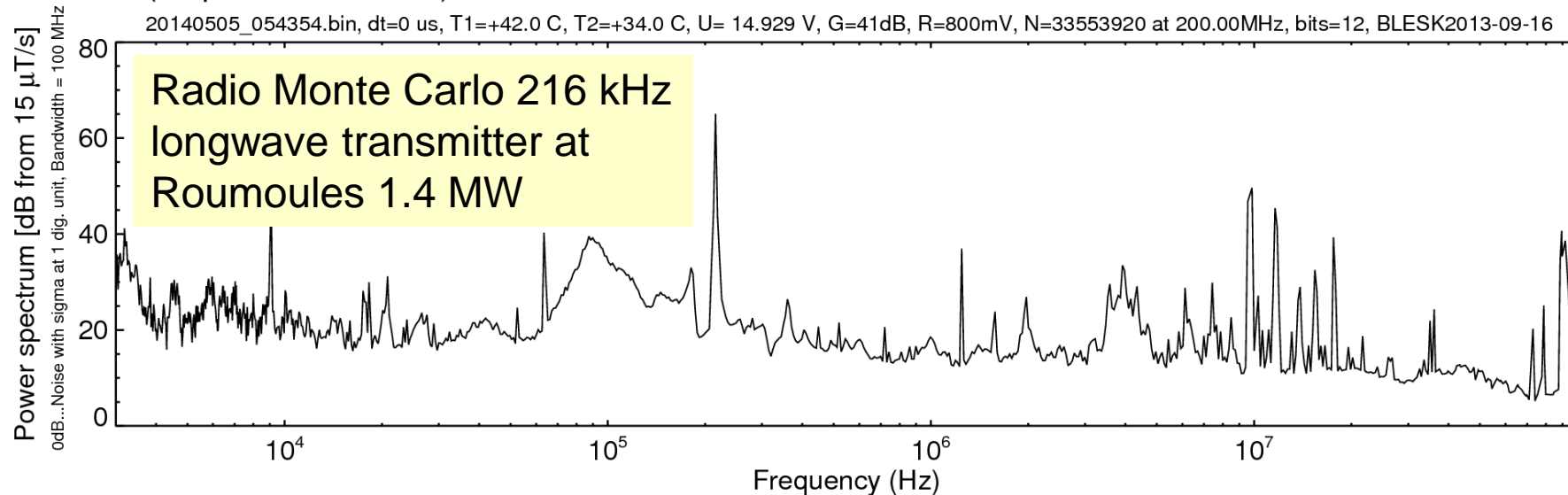
## 2. Latest broadband waveform snapshot:

SLAVIA 2 (loop azimuth -25°) 167 ms from 2014-05-05T06:13:55.792.320.512 after 1800 s



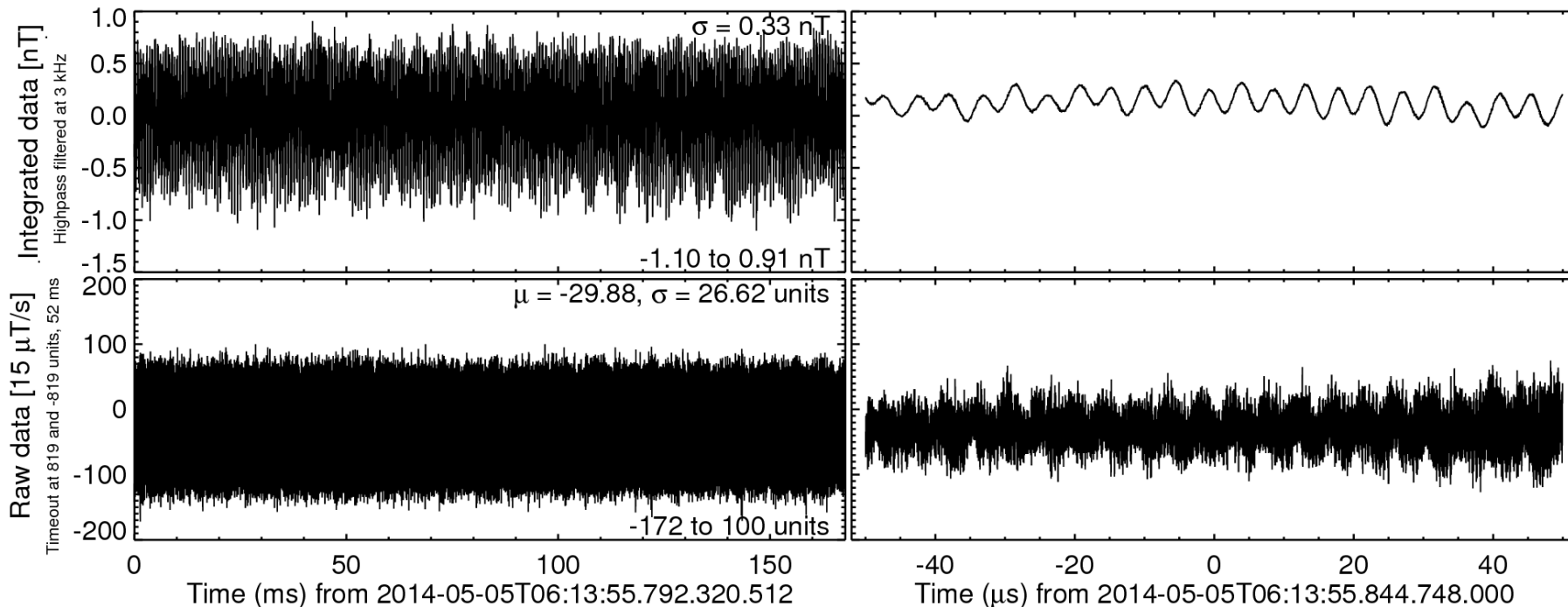
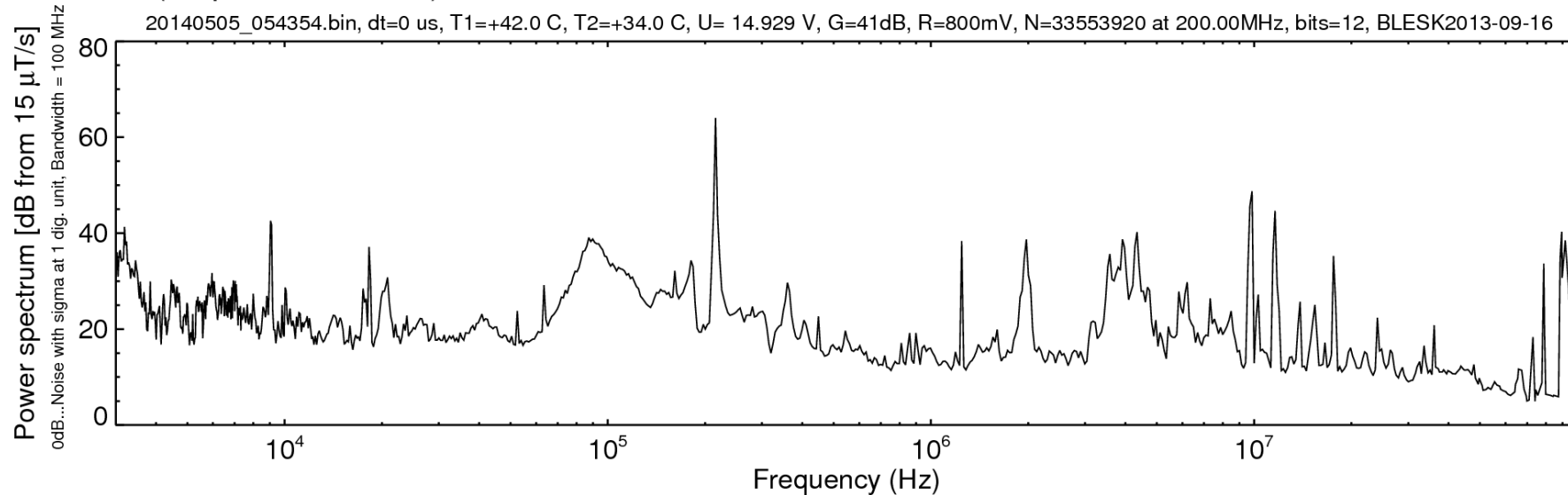
# SLAVIA 1 (loop azimuth $-115^\circ$ ) 167 ms from 2014-05-05T06:13:55.792.320.512 after 1800 secs SURVEY

20140505\_054354.bin, dt=0 us, T1=+42.0 C, T2=+34.0 C, U= 14.929 V, G=41dB, R=800mV, N=33553920 at 200.00MHz, bits=12, BLESK2013-09-16



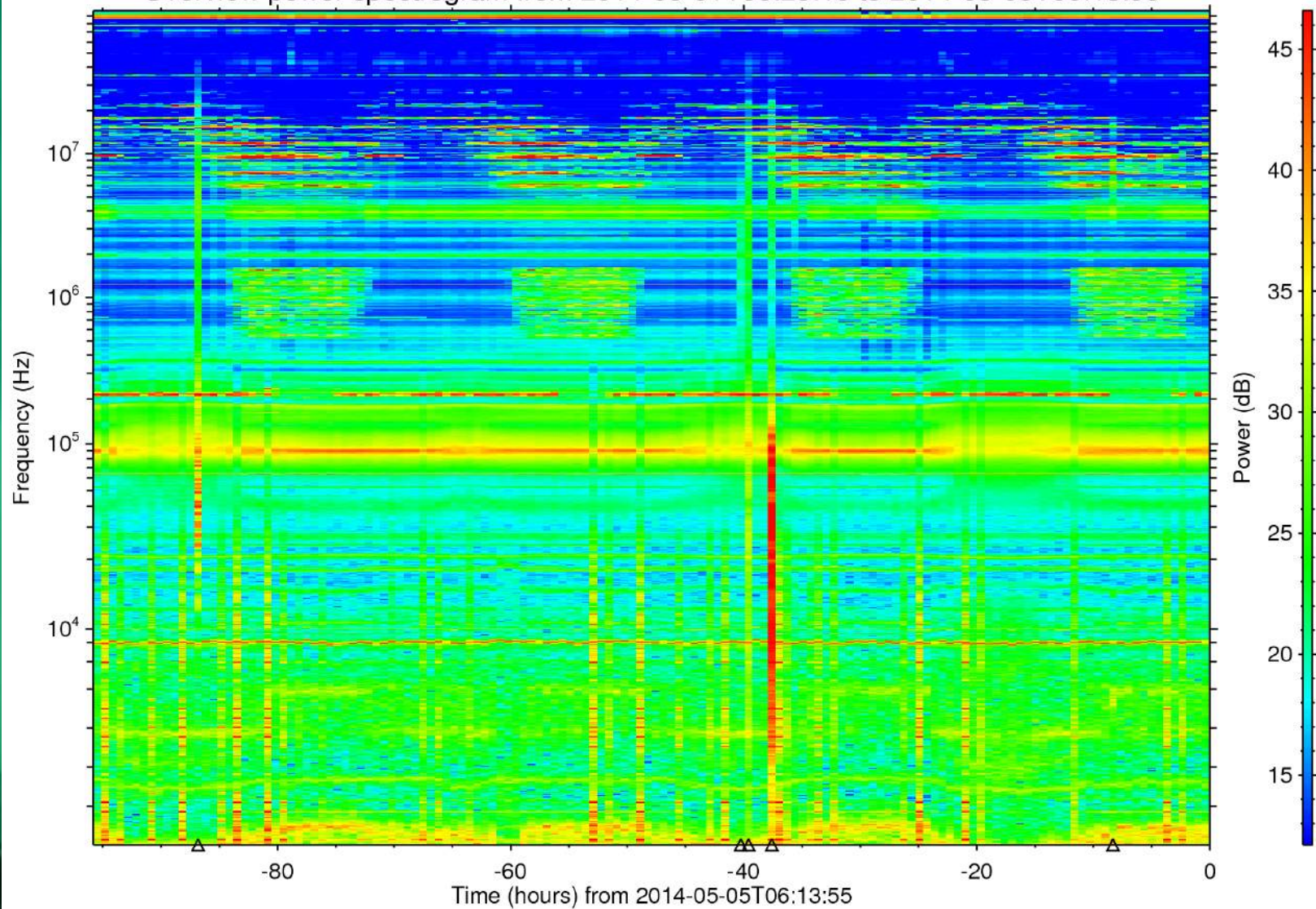
# SLAVIA 2 (loop azimuth $-25^\circ$ ) 167 ms from 2014-05-05T06:13:55.792.320.512 after 1800 secs SURVEY

20140505\_054354.bin, dt=0 us, T1=+42.0 C, T2=+34.0 C, U= 14.929 V, G=41dB, R=800mV, N=33553920 at 200.00MHz, bits=12, BLESK2013-09-16

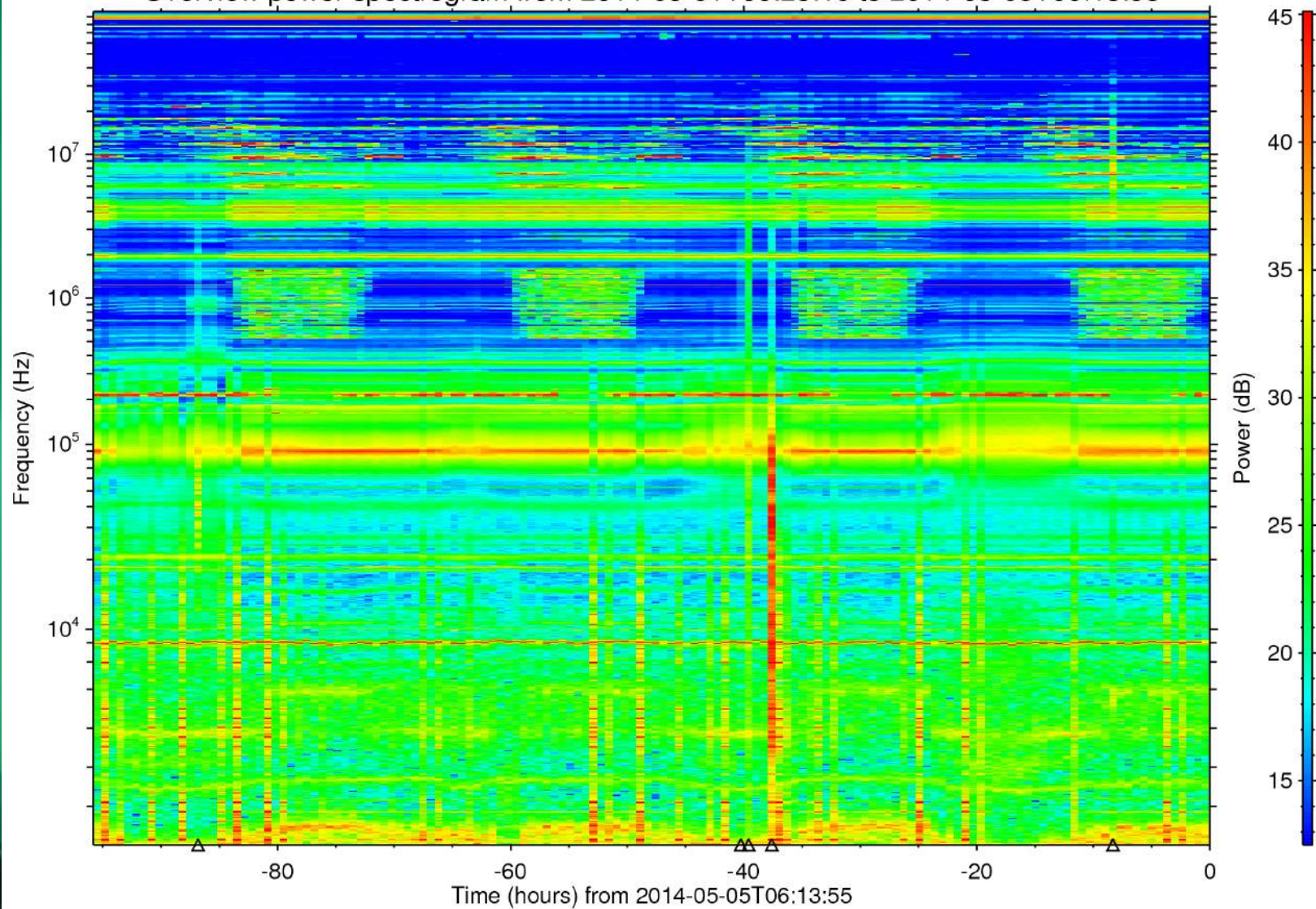


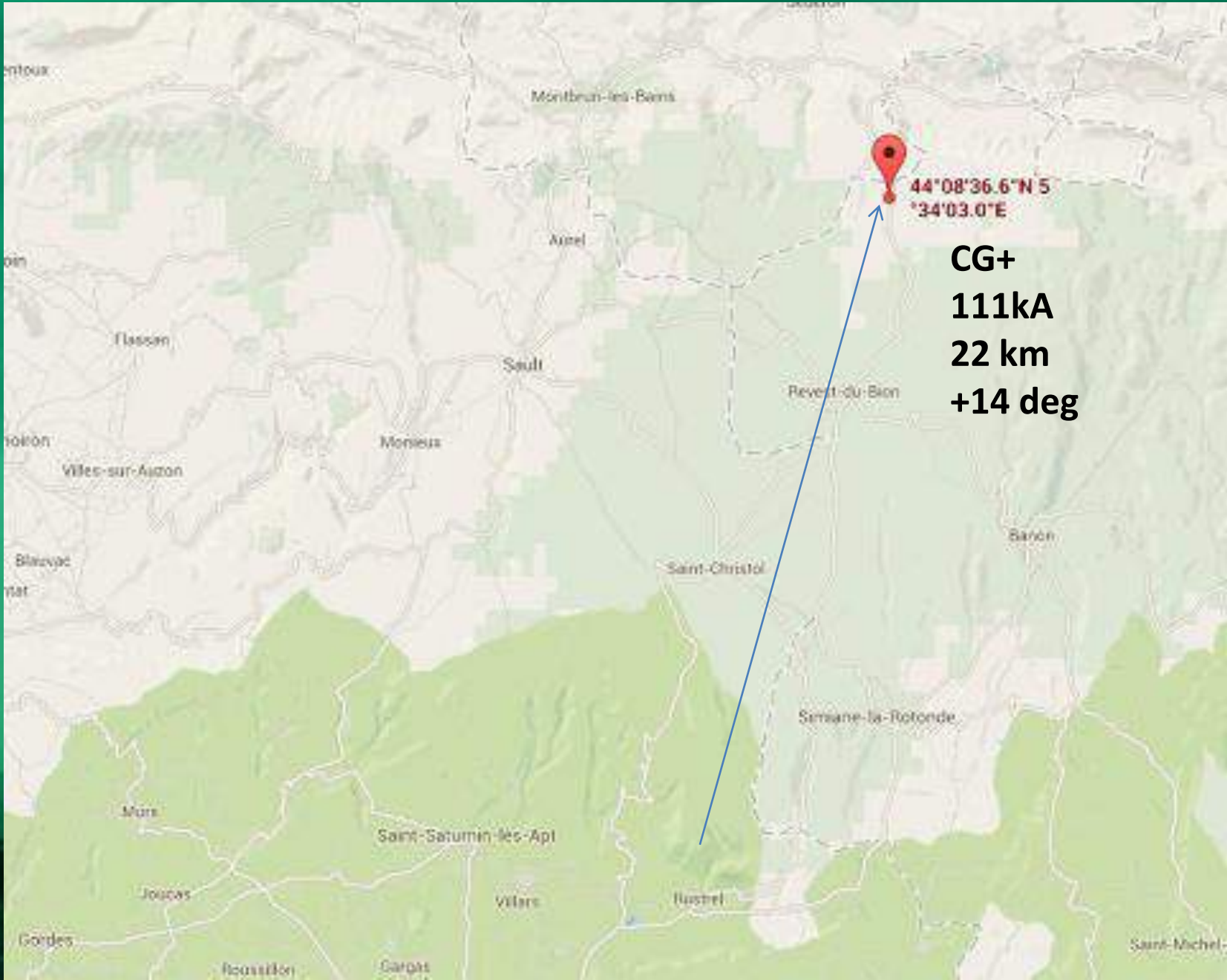


Overview power spectrogram from 2014-05-01T06:25:16 to 2014-05-05T06:13:55



Overview power spectrogram from 2014-05-01T06:25:16 to 2014-05-05T06:13:55



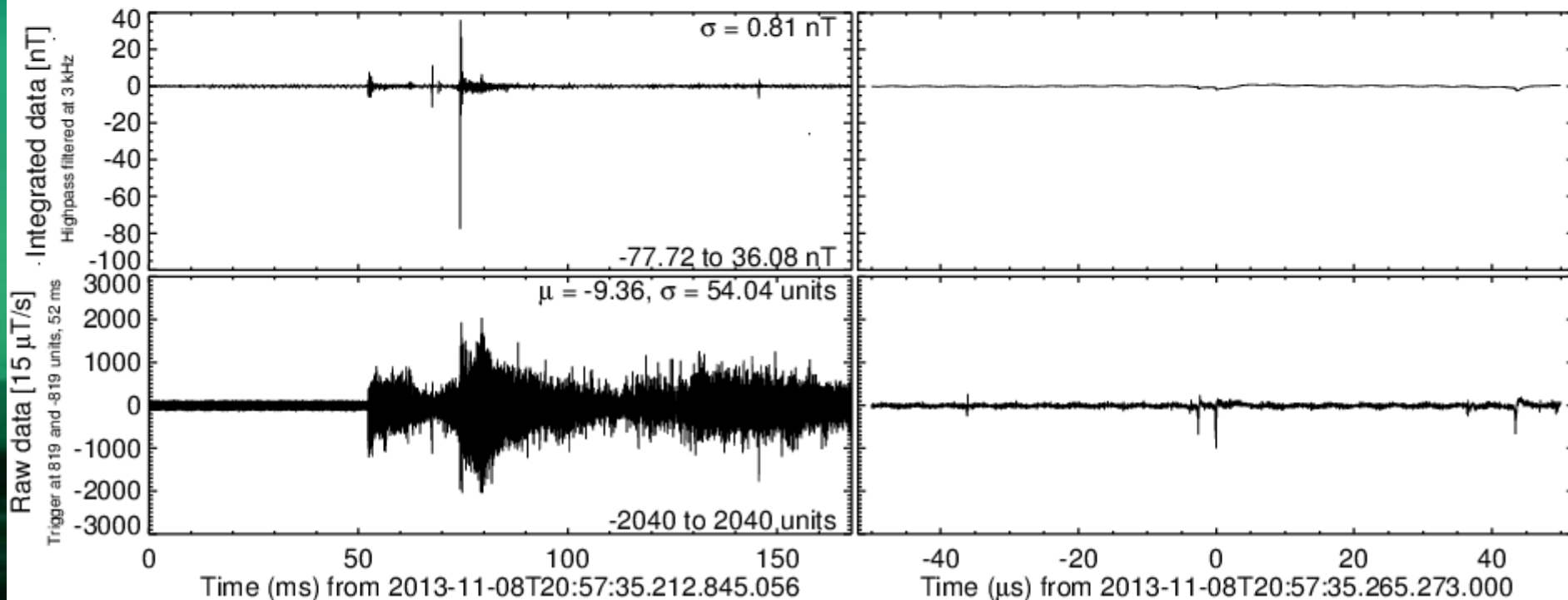
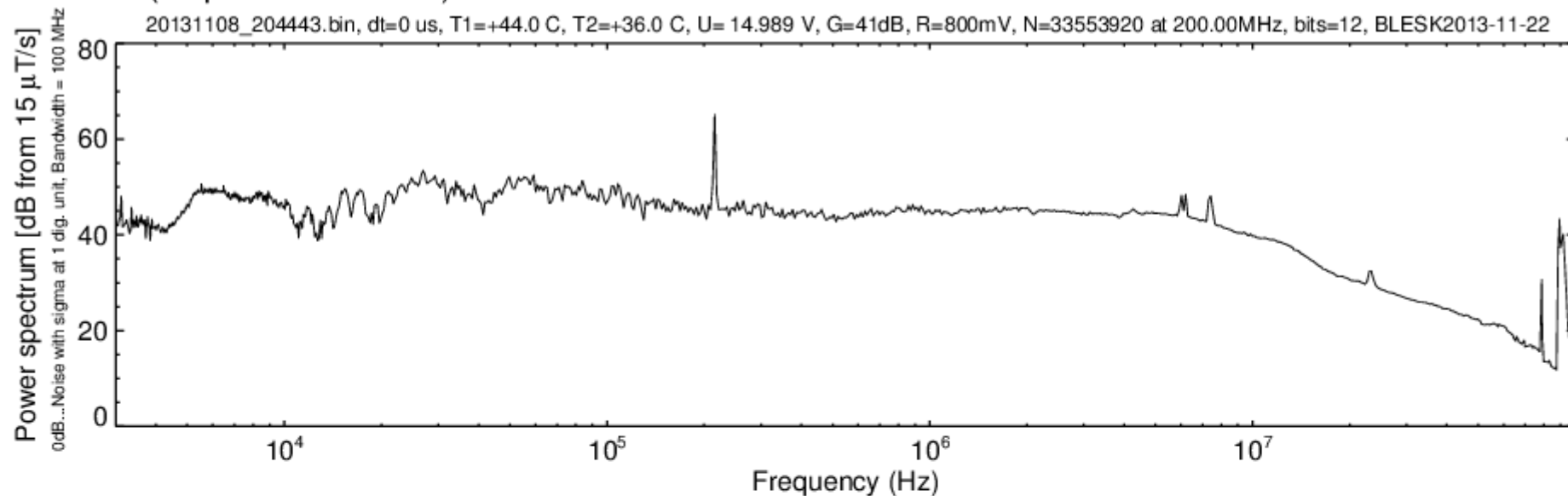


44°08'36.6"N 5°34'03.0"E

**CG+**  
**111kA**  
**22 km**  
**+14 deg**

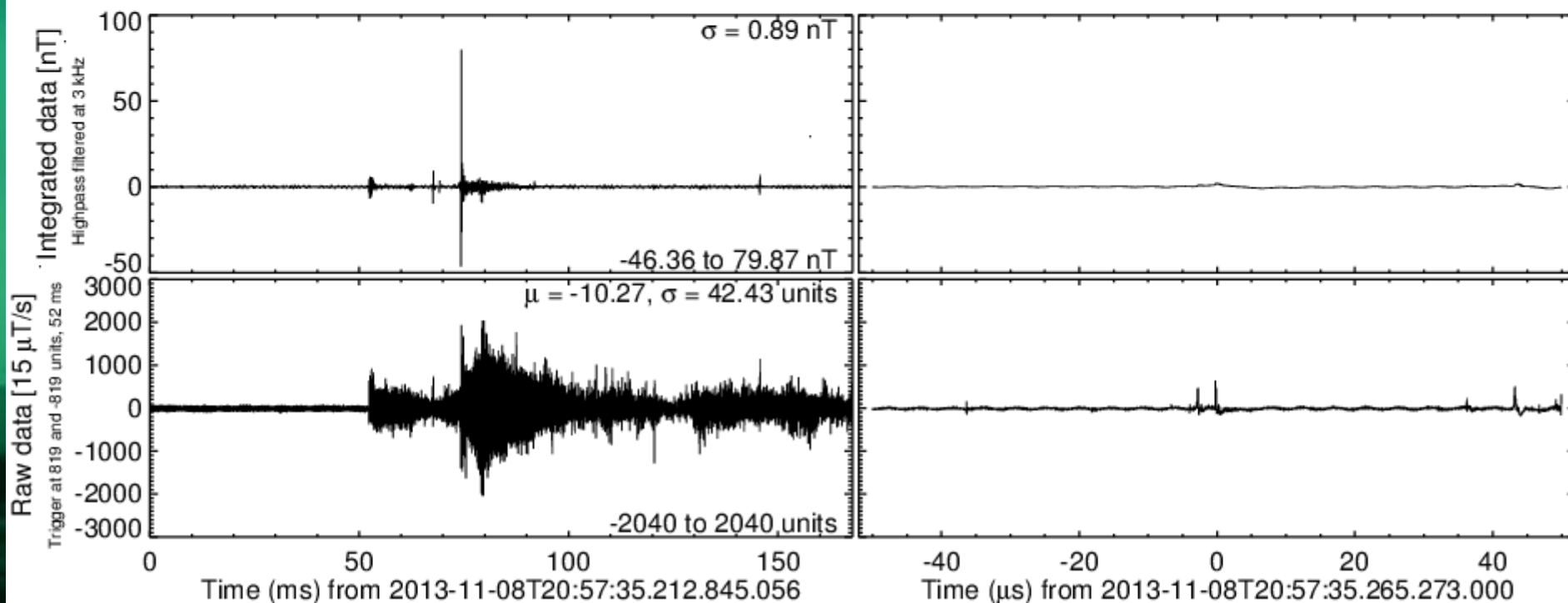
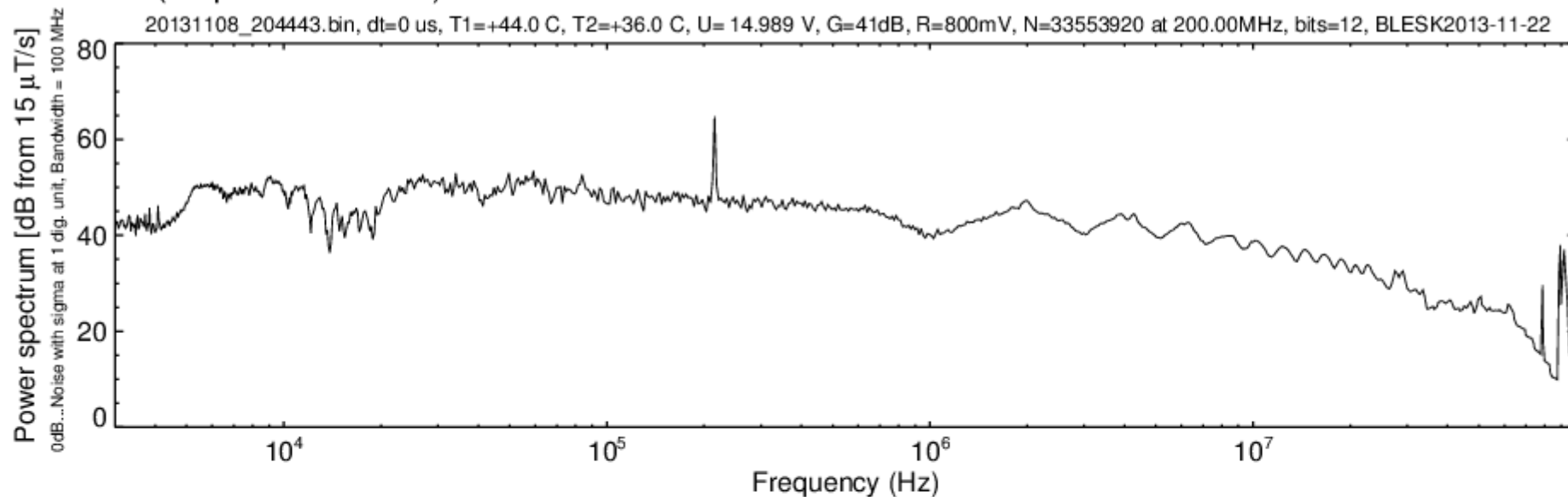
# SLAVIA 1 (loop azimuth $-115^\circ$ ) 167 ms from 2013-11-08T20:57:35.212.845.056 after 771 secs TRIGGER

20131108\_204443.bin, dt=0 us, T1=+44.0 C, T2=+36.0 C, U= 14.989 V, G=41dB, R=800mV, N=33553920 at 200.00MHz, bits=12, BLESK2013-11-22

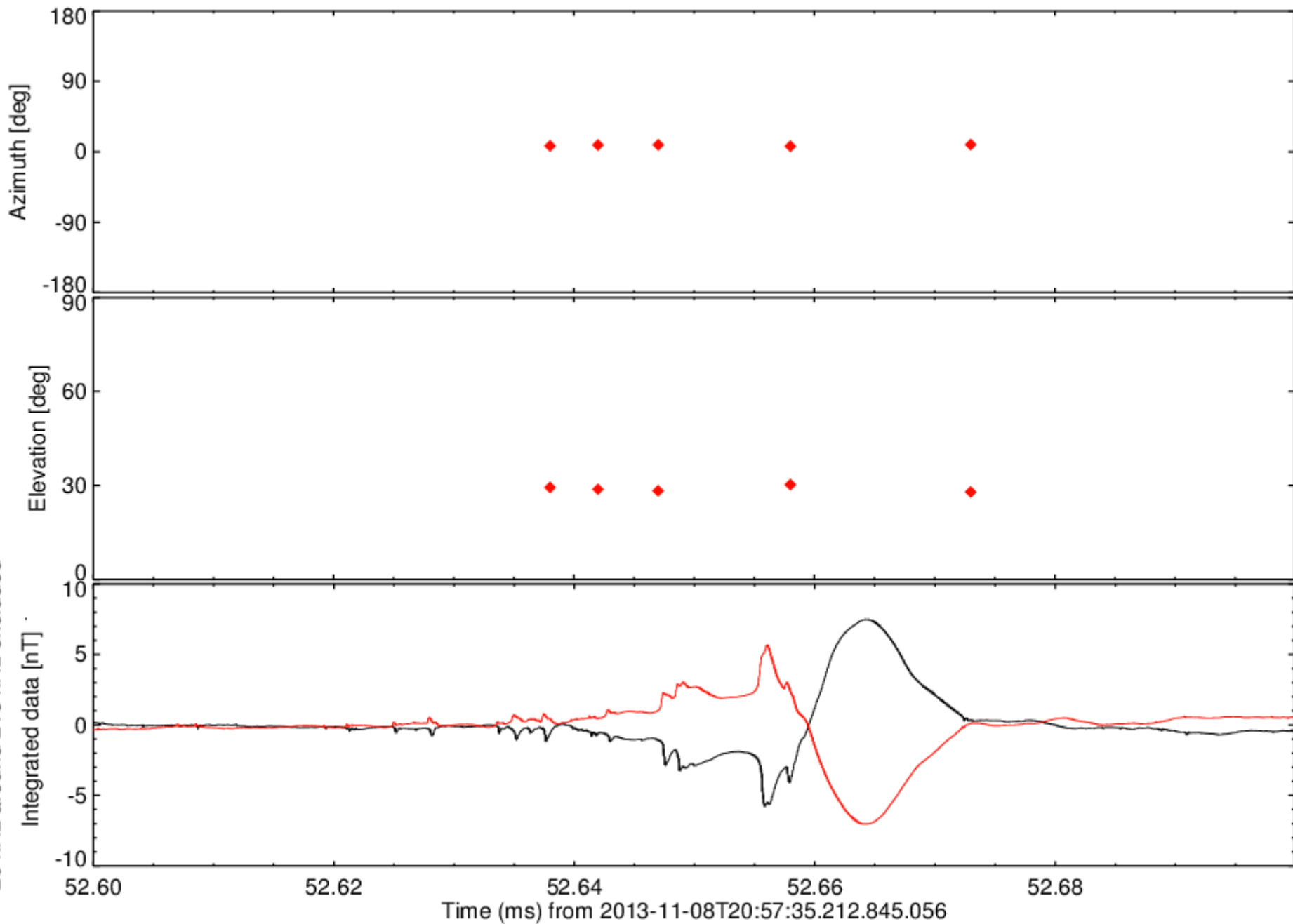


SLAVIA 2 (loop azimuth  $-25^\circ$ ) 167 ms from 2013-11-08T20:57:35.212.845.056 after 771 secs TRIGGER

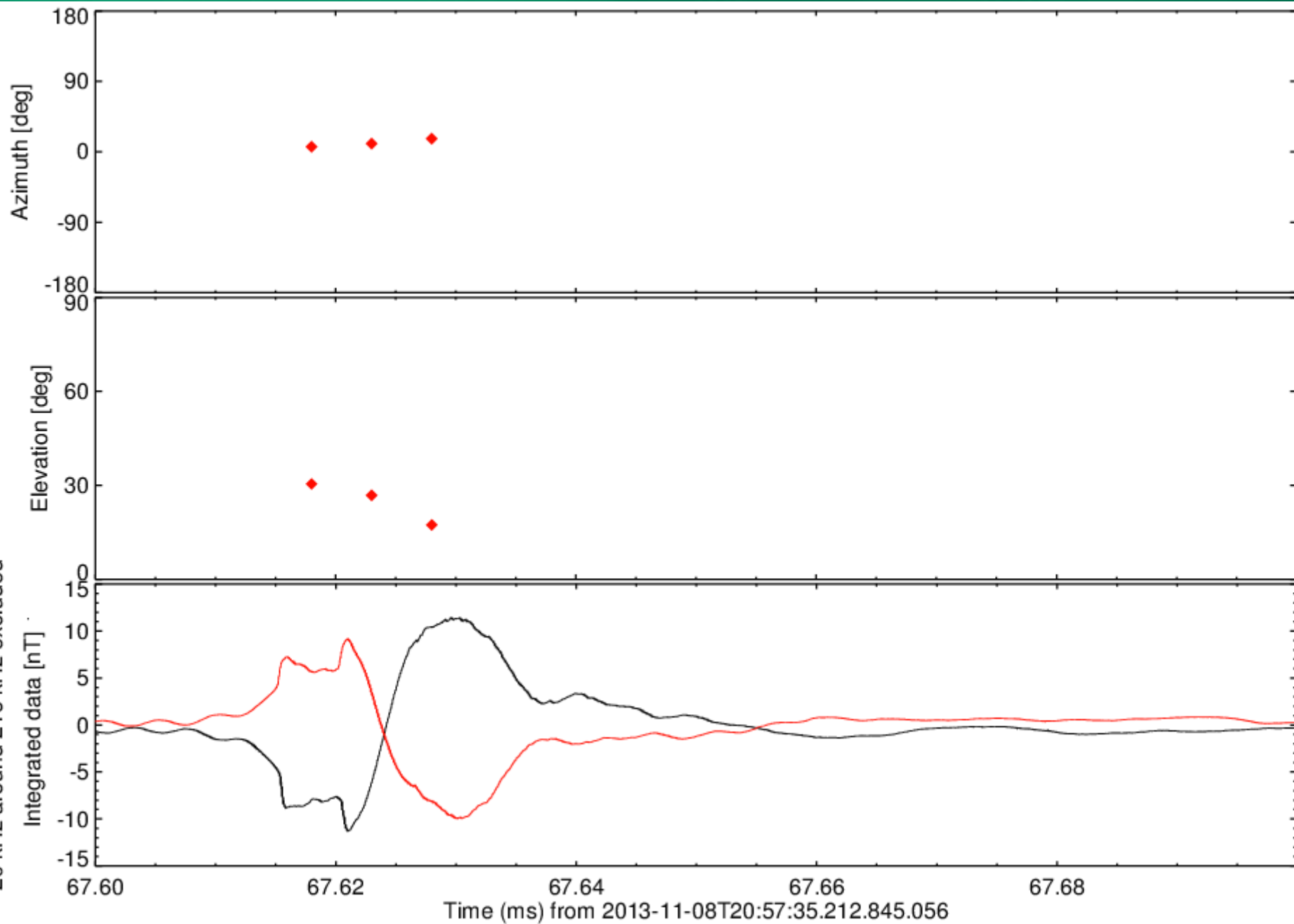
20131108\_204443.bin, dt=0 us, T1=+44.0 C, T2=+36.0 C, U= 14.989 V, G=41dB, R=800mV, N=33553920 at 200.00MHz, bits=12, BLESK2013-11-22



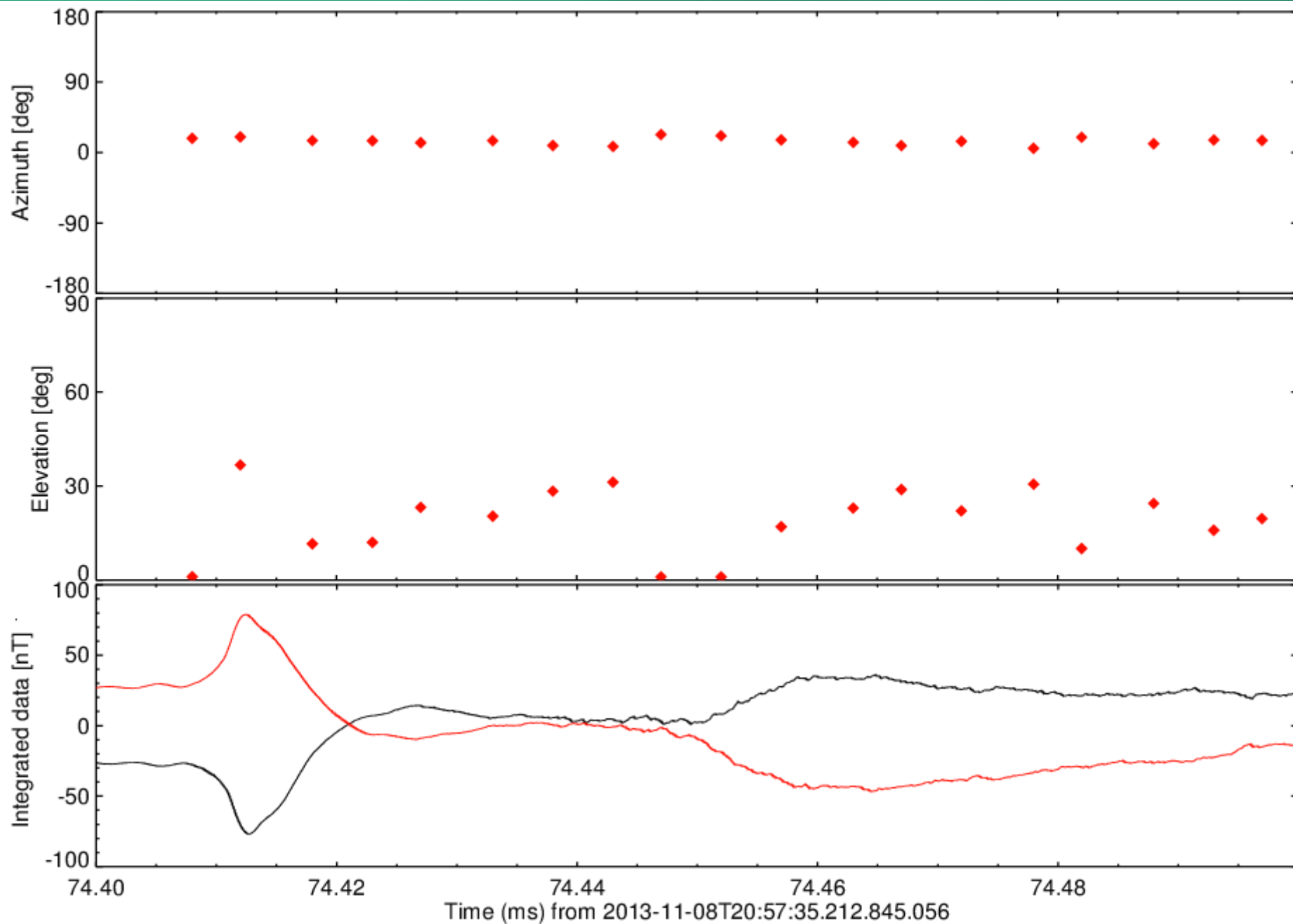
20 kHz around 216 kHz excluded



20 kHz around 216 kHz excluded



20 kHz around 216 kHz excluded





# CONCLUSIONS

**Analysis of VLF and HF electromagnetic signals radiated by in-cloud discharges is a useful tool for looking inside the thundercloud**

**The broadband interferometry method allows us to estimate the movement of irradiative sources of the pulses in the pulse sequences using a new antenna system**

**The ground-based measurements will complete the satellite measurements after the launch of the TARANIS spacecraft**