

# Broad-band electric field measurements above thunderstorms by the IME-HF instrument prepared for the TARANIS mission

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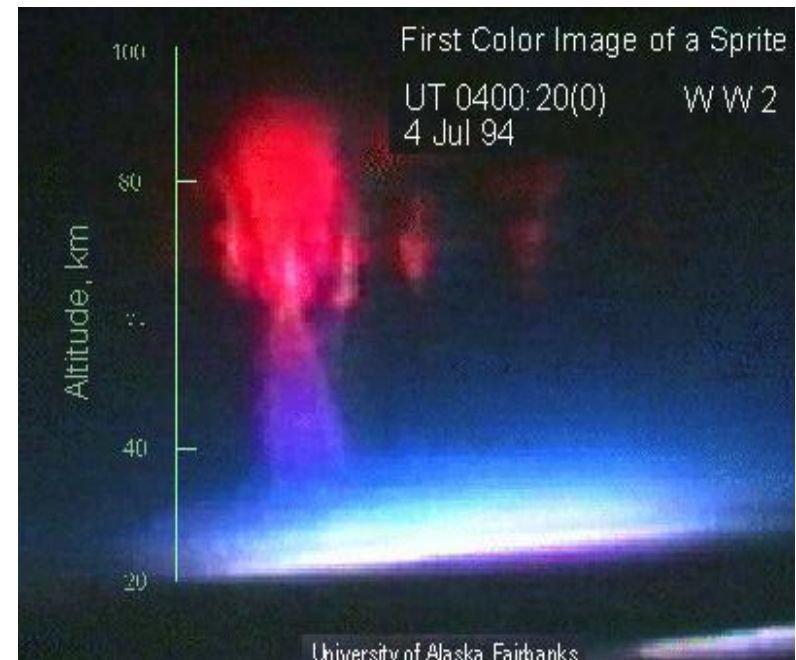
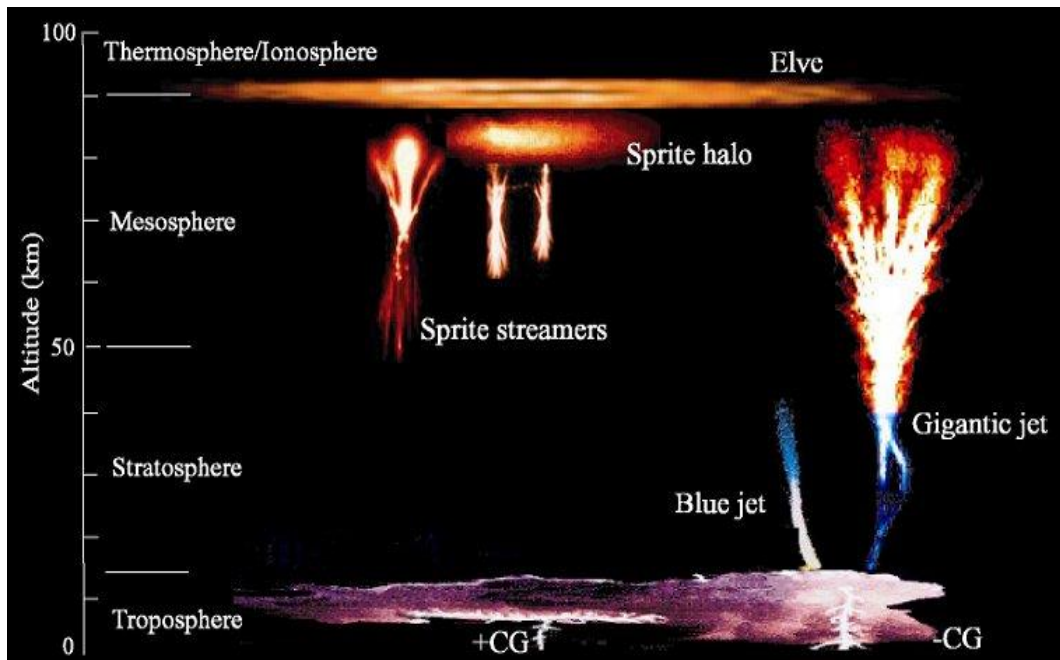
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# TARANIS:

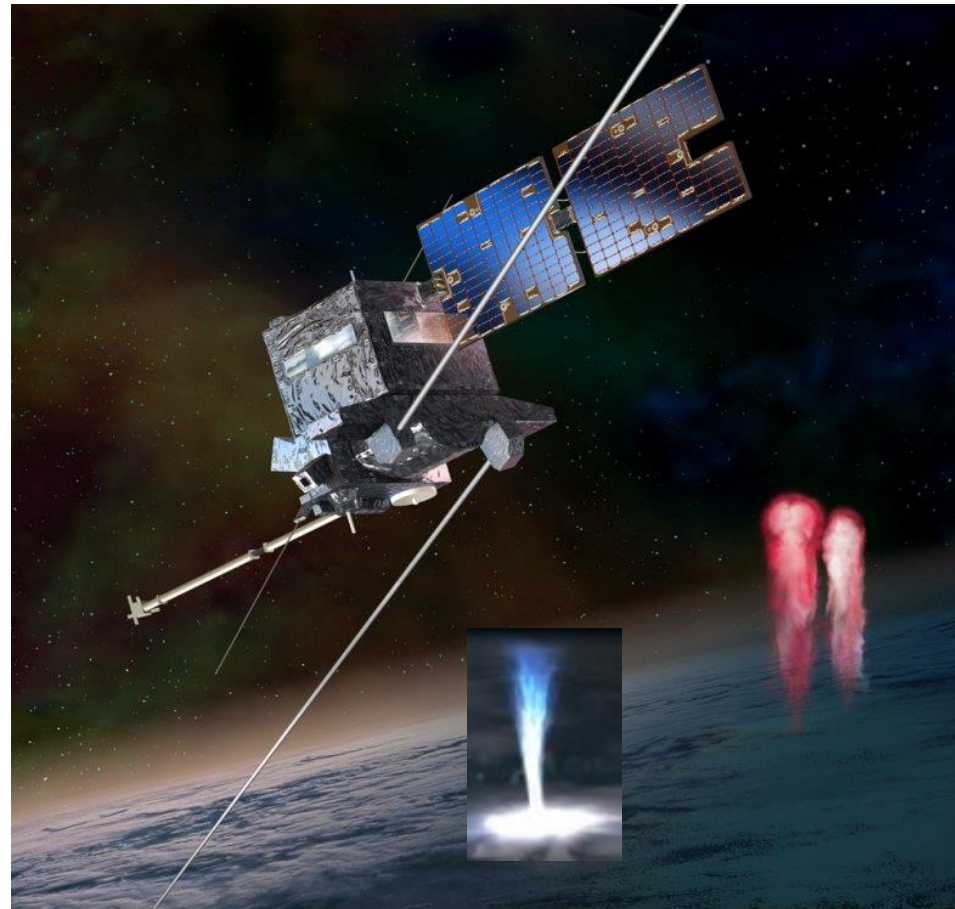
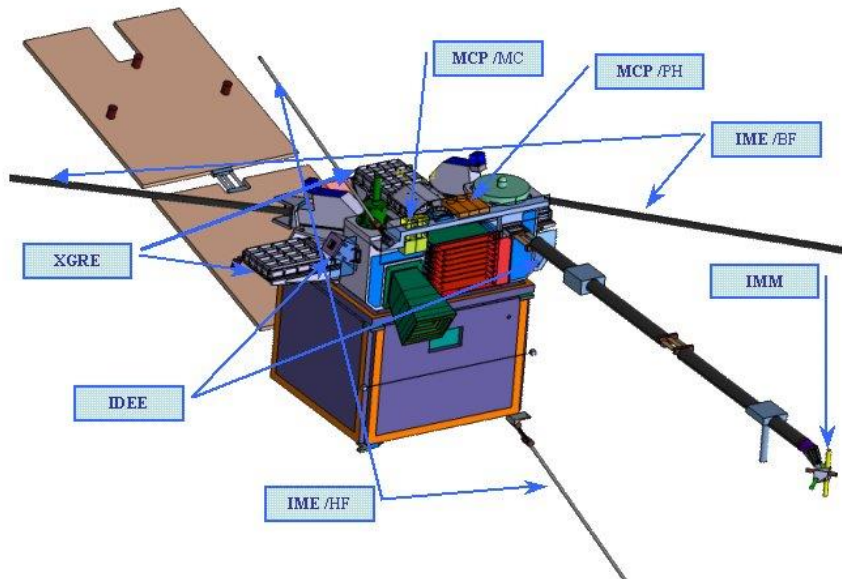
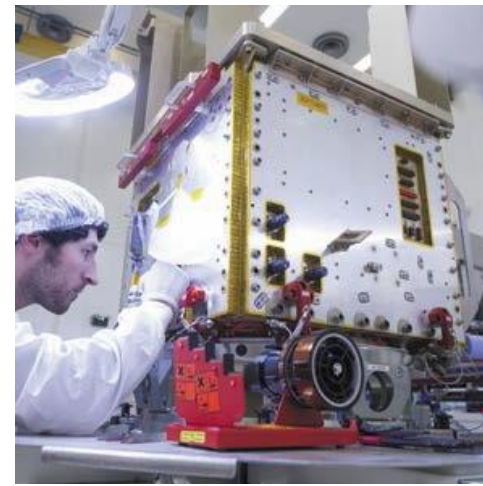
(Tool for the Analysis of Radiation from lightning and Sprites)

- French space agency CNES, launch in August 2020 (?)
- Scientific team lead by J-L. Pincon, LPC2E Orleans: French institutes and universities, international participation (Czechia, Poland, USA).
- Main focus: **Transient luminous phenomena, Terrestrial gamma ray flashes**



# TARANIS

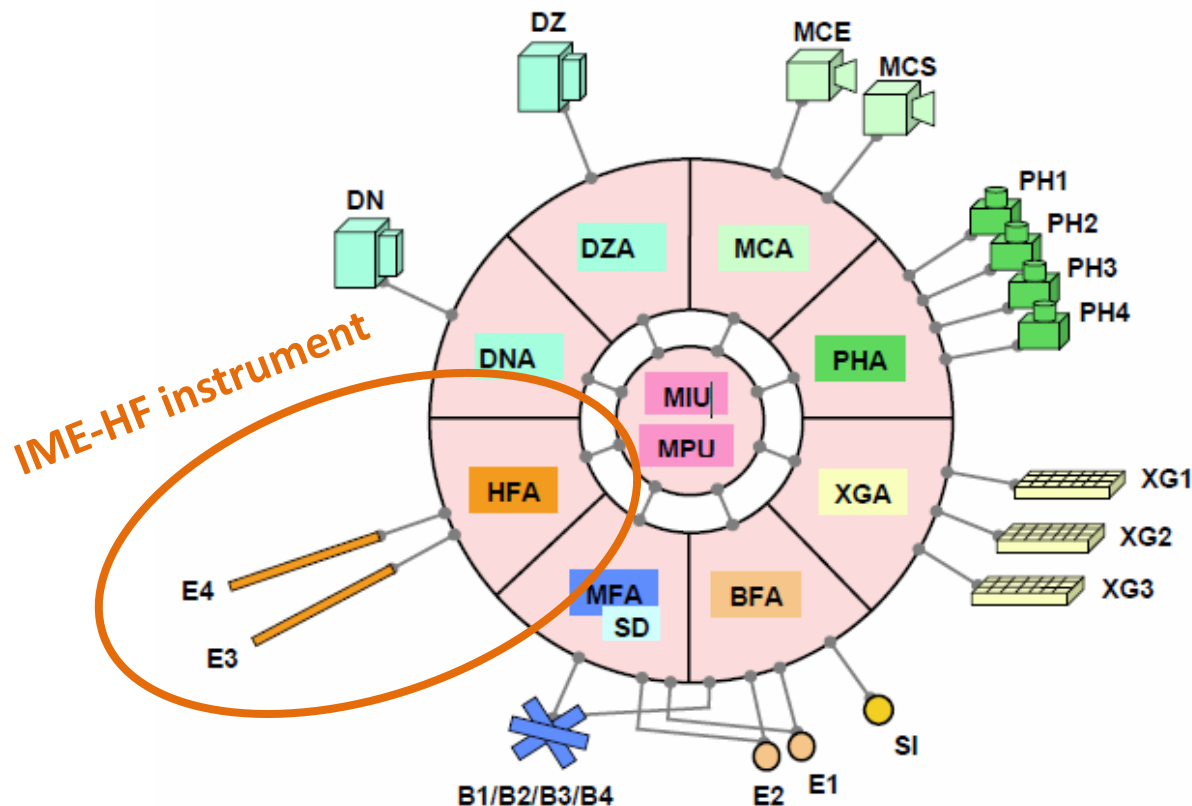
- Sun-synchronous high inclination low-Earth orbit (700 km)
- CNES MYRIDE microsat (the same as DEMETER), 160 kg
- 2-3 yeas of operations are anticipated





# TARANIS

2 microcameras, 4 photometers, 2 detectors of energetic electrons, 3 X-ray detectors, instruments to measure electromagnetic fields in 3 frequency bands, onboard analysis and synchronous triggering





# IME-HF instrument

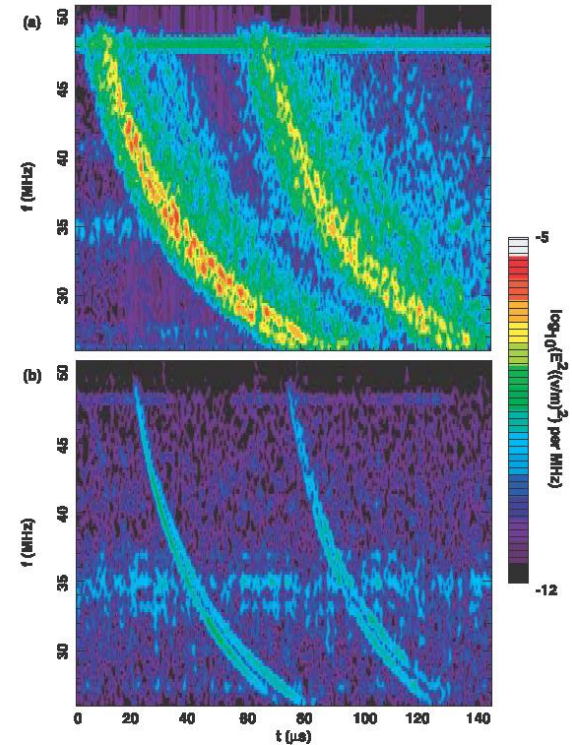
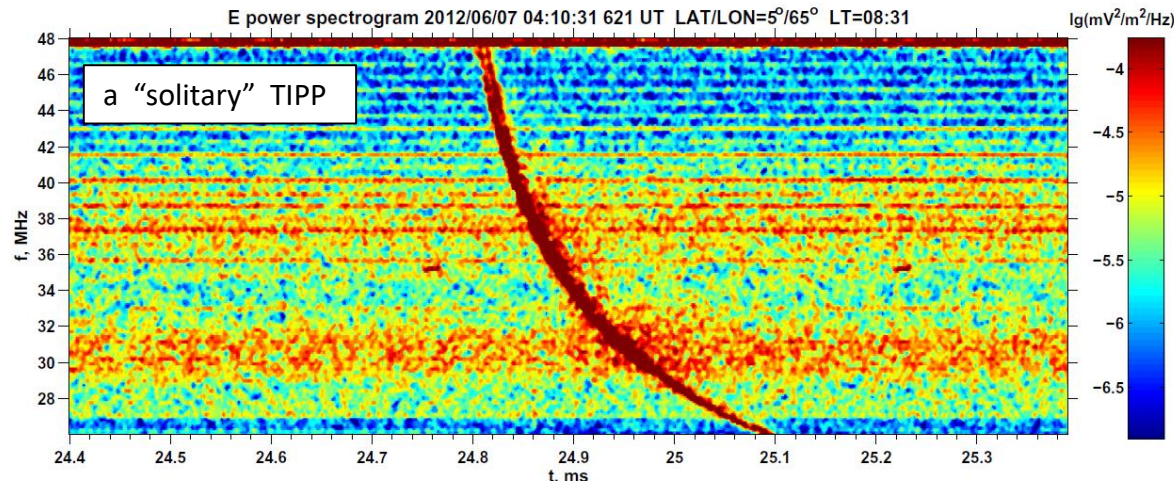
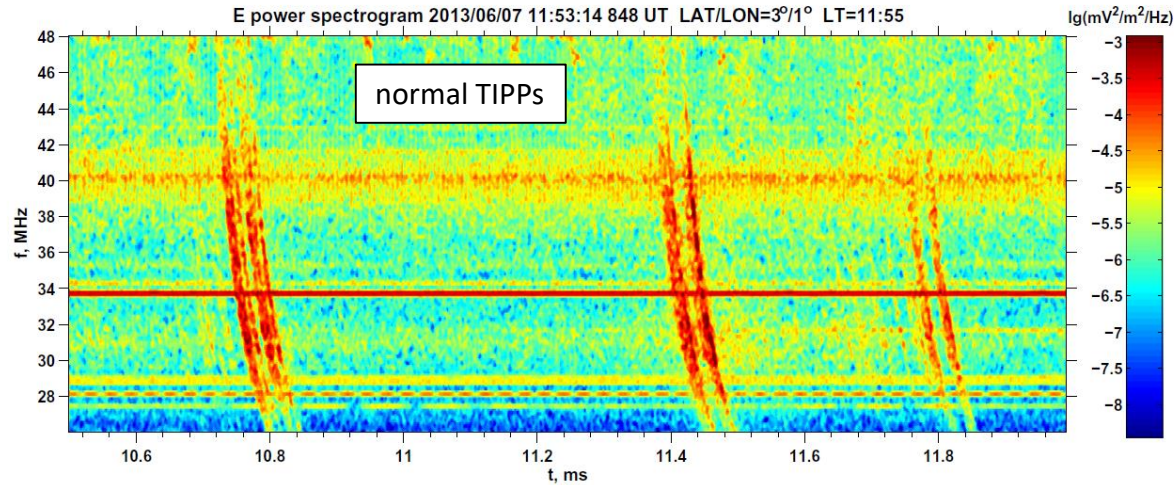
A broad-band (5 kHz – 37 MHz) analyzer intended to study radiation originating in atmospheric lightning discharges and in optical phenomena (Transient Luminous Events) observed between the Earth troposphere and ionosphere.

- Identification of wave signatures associated with transient luminous events and terrestrial gamma-ray flashes
- Characterization of lightning flashes from their HF electromagnetic signatures
- Identification of possible HF electromagnetic or/and electrostatic signatures of precipitated and accelerated particles
- Determination of characteristic frequencies of the medium using natural waves properties
- Global mapping of the natural and artificial waves in the HF frequency range, with an emphasis on the transient events



# Trans-ionospheric pulse pairs (TIPPs)

- pairs of short VHF bursts separated by a few tens of microseconds
- the first burst accompanies an IC discharge (Compact Intracloud Discharge)
- the second burst is a the ground reflection of the first burst



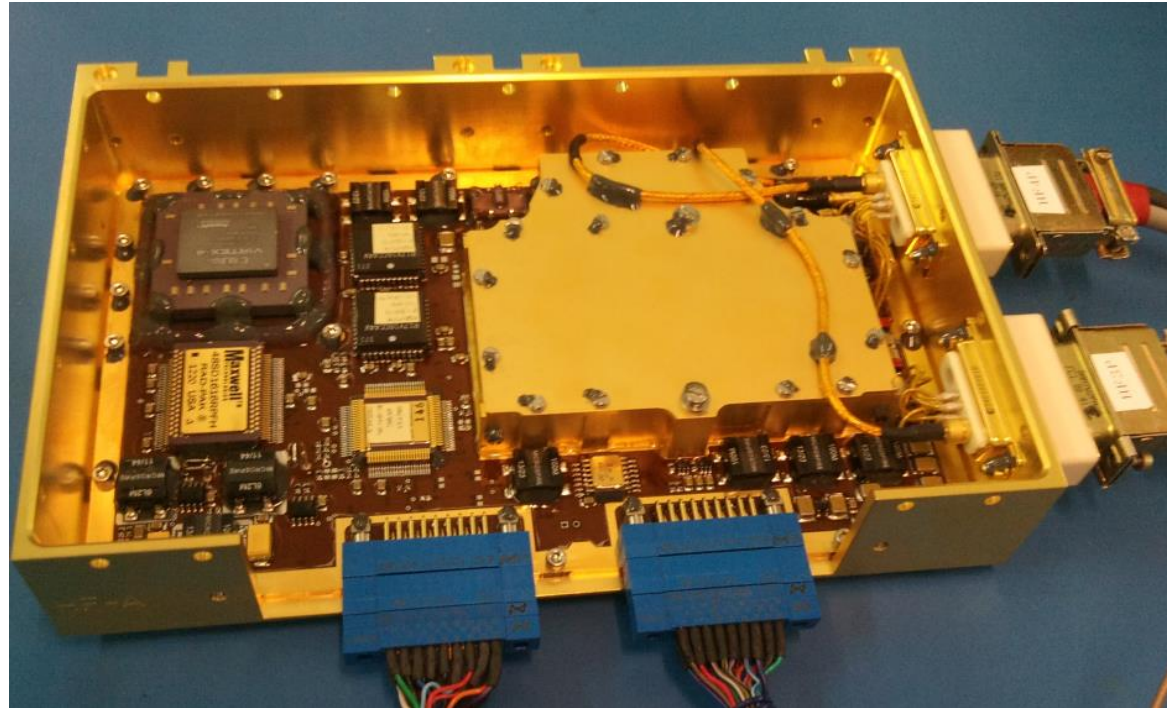
Jacobson and Light, 2003  
(FORTE satellite observation)





# IME-HF Analyser for the TARANIS satellite

- Broadband waveform measurements of the HF electric field between 5 kHz and 37 MHz
- Sampling frequency 80MHz, processing on a VIRTEX4 FPGA
- Onboard data selection algorithm, generation of alert signal
- 128 Mbits event mode data, 40 kbit/s survey mode data
- Power 3.8W
- Mass 470g





# IME-HF Data structure

## Survey data:

- Regular 80 MHz waveform snapshots (12 bit, 17us every 0.8s);
- Averaged filter bank output (12 channels, no gaps, 7.4ms resolution);
- Automatically selected best 80 MHz waveform snapshots (12 bits, 300us every 15s, enough to capture TIPPS and signals from other lightning processes).

## Event data:

- Up to 416 ms of 80-MHz waveforms of internally or externally triggered events, nominally 3 events of 42 ms per half-orbit
- Full resolution 12 us filter bank data, 12 channels, up to 32 events

## Radio waveforms:

- programmable down-converted 16 bit waveforms,
- bandwidths of 5 kHz, 10 kHz, 20 kHz, or 80 kHz





# Flexible Detection Algorithm

## 1. Detection algorithm for transient signals based on filter bank channels

A rank is calculated as a sum of weighted differences between maxima and averages of the RMS values of the twelve bandpass filters.

We can adjust the weight for each band-pass filter, the number of filter-bank samples over which the maximum amplitude is obtained and the interval over which the average values are calculated.

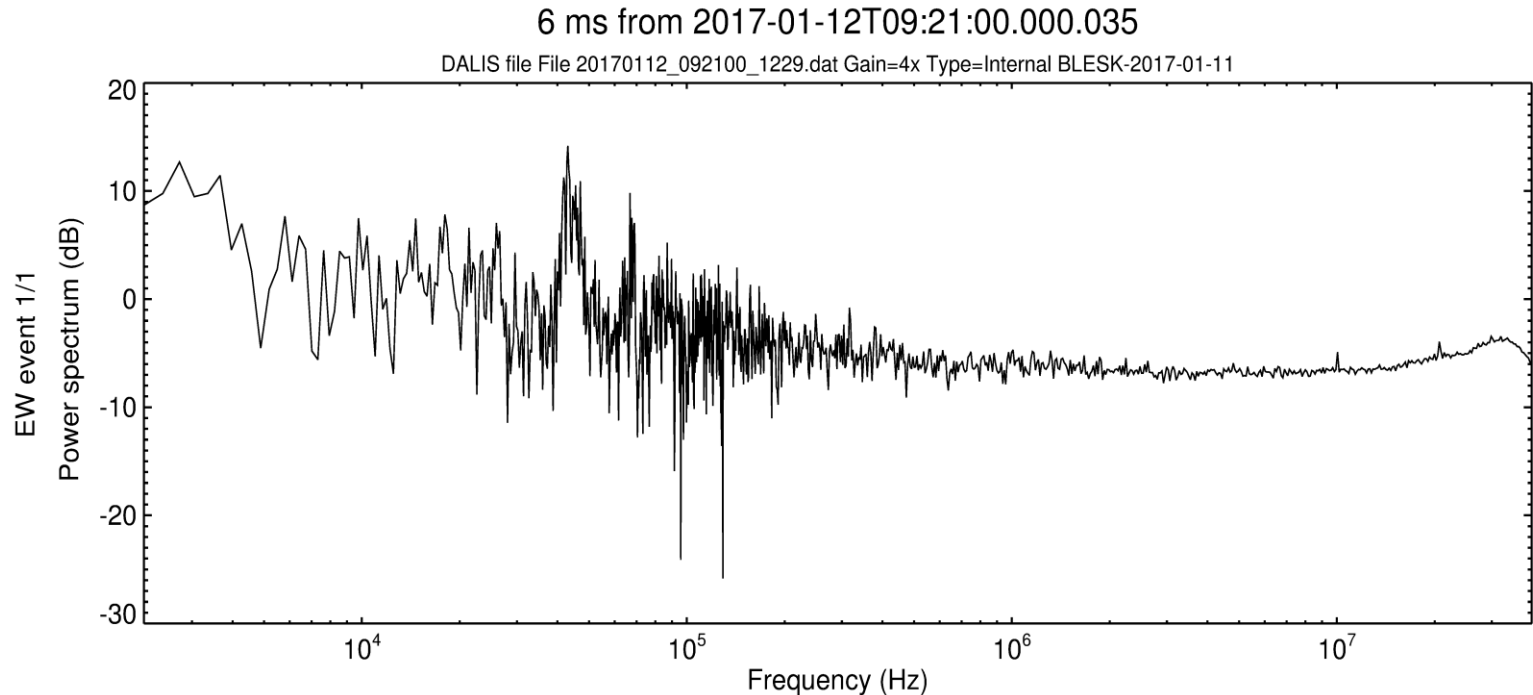
## 2. Detection algorithm for transient signals based on waveform

A simplified rank is calculated as a difference between maximum over a series of waveform samples and its average



# Analyzer sensitivity

Analyzer without sensors, from telemetry data, 2kHz - 40MHz :



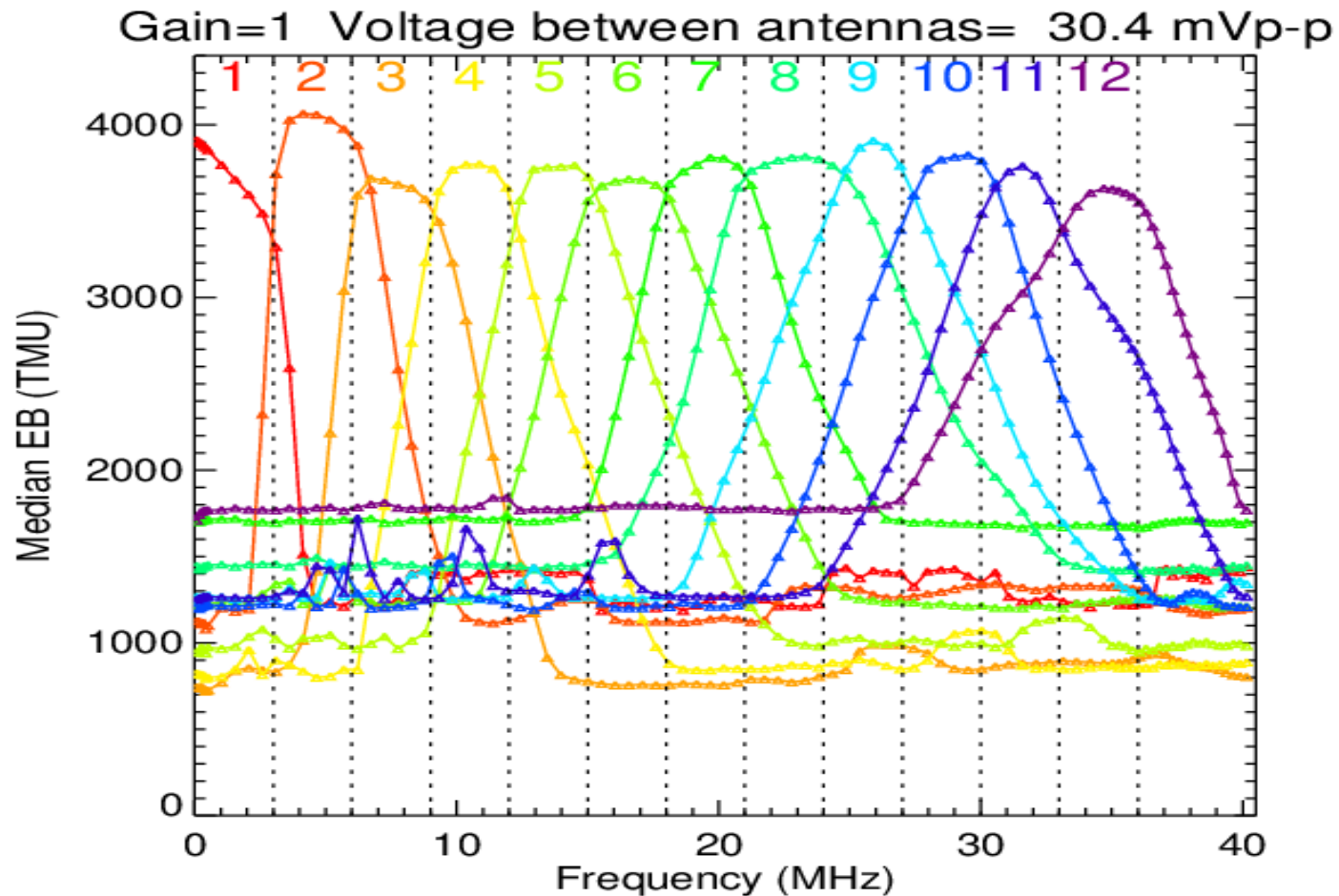
**Gain 4x ... amplitudes from  $12 \mu\text{V}_{\text{pp}} \text{ m}^{-1}$  à  $49 \text{ mV}_{\text{pp}} \text{ m}^{-1}$**

**0 dB corresponds to spectral amplitude  $1.9 \text{ nV m}^{-1} \text{ Hz}^{-1/2}$  ( $L_{\text{eff}}=1\text{m}$ )**

**-5 dB at 1 MHz -> sensitivity  $1.1 \text{ nV m}^{-1} \text{ Hz}^{-1/2}$**



# Filterbank frequency response

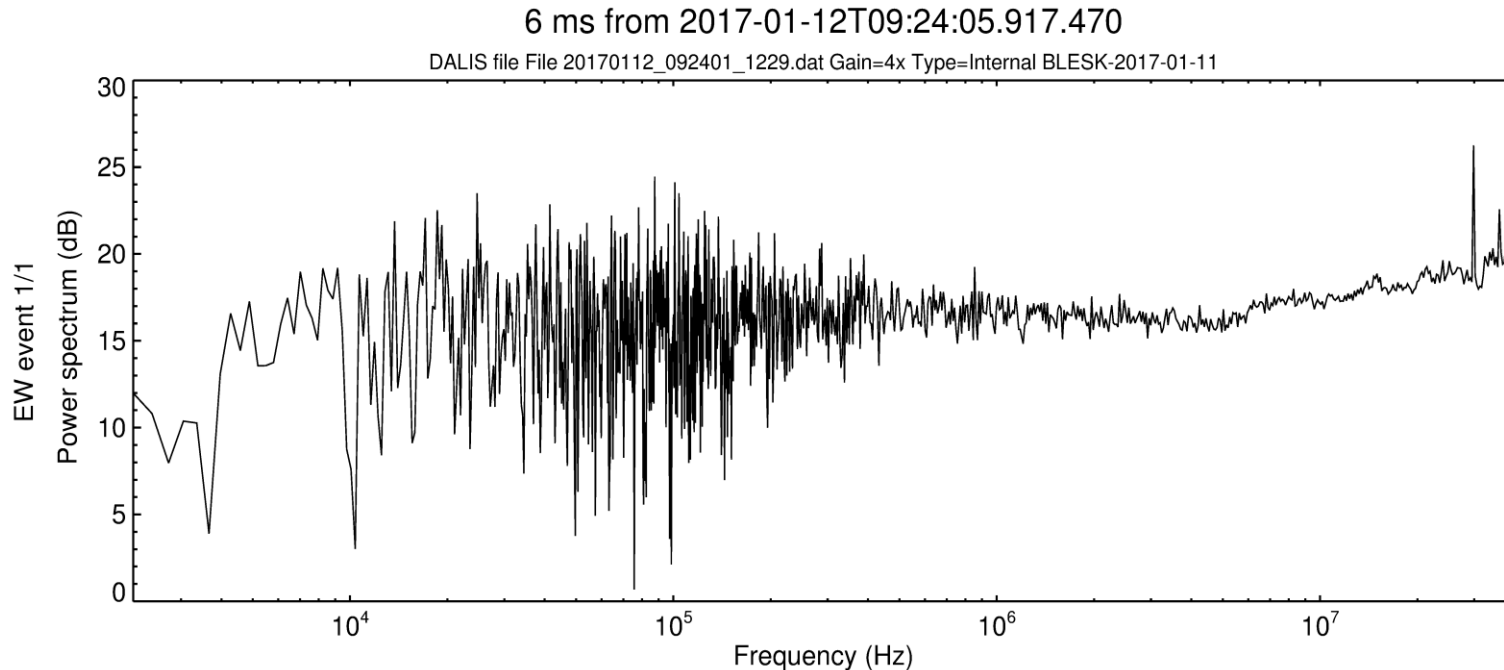






# Instrument sensitivity

Sensors+ analyzer, from telemetry data, 2kHz - 40MHz :



**Gain 4x ... amplitudes from  $12 \mu\text{V}_{\text{pp}} \text{ m}^{-1}$  à  $49 \text{ mV}_{\text{pp}} \text{ m}^{-1}$**

**0 dB corresponds to spectral amplitude  $1.9 \text{ nV m}^{-1} \text{ Hz}^{-1/2}$  ( $L_{\text{eff}}=1\text{m}$ )**

**18 dB at 1 MHz -> sensitivity  $15 \text{ nV m}^{-1} \text{ Hz}^{-1/2}$**

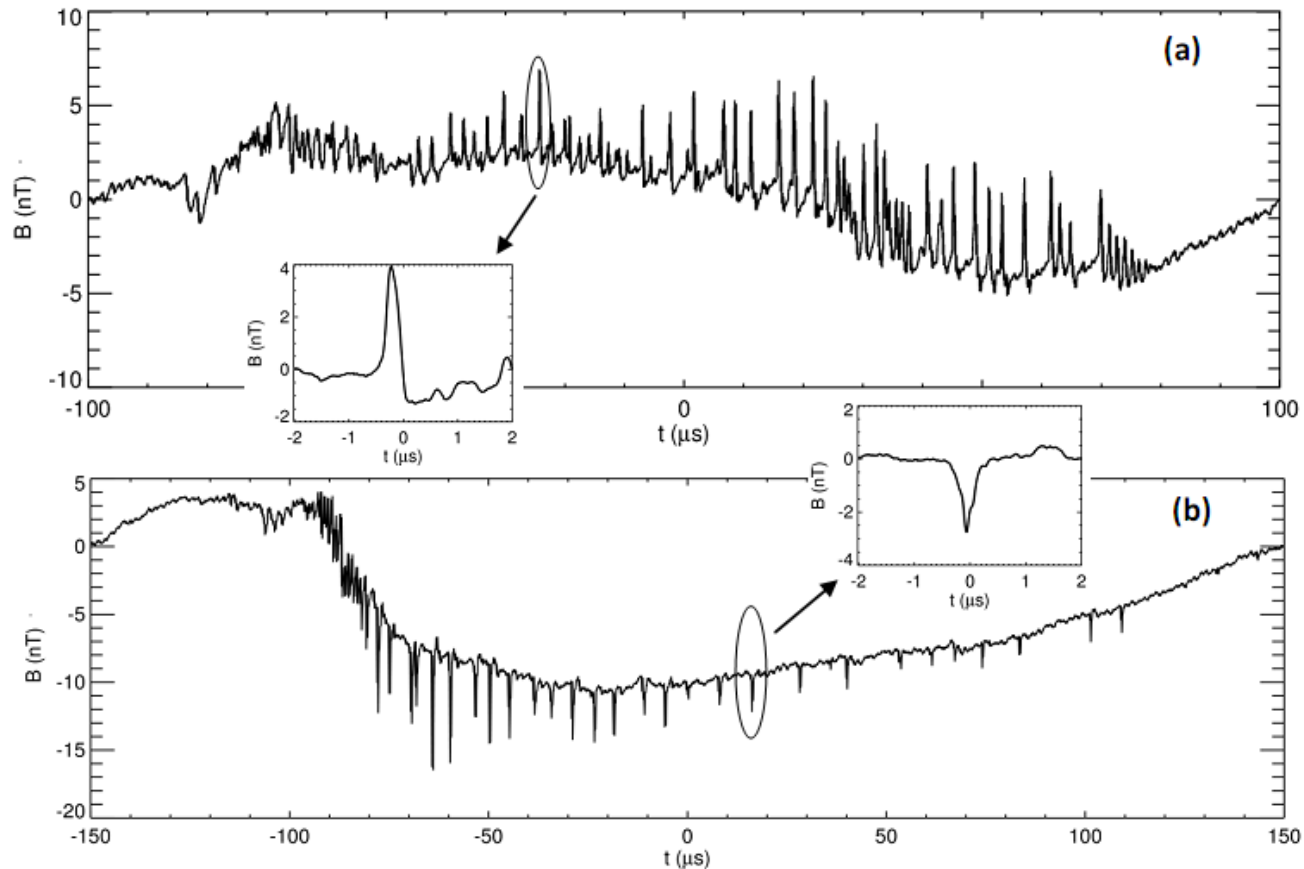
# Ground-based measurements

IME-HF Analyser for the TARANIS satellite is also used in high-resolution ground-based measurements of electric and magnetic fields (using Shielded Loop Antenna with Versatile Integrated Amplifier)

- Measuring station La Grande Montagne, Plateau d'Albion, in cooperation with LSBB Rustrel, France; 4 antenna interferometer, 3-component VLF measurements;
- Measuring station Corsica in cooperation with the Institute of Aerologie, Toulouse, France; with LMA;
- Measuring station Lomnický štít observatory, High Tatras, in cooperation with the IEP SAS, Kosice, Slovakia; with cosmic ray detectors
- Measuring site Mílesovka meteorological observatory, Czechia;
- Measuring site, Ter Wisch, Netherlands; with LOFAR.



# Measurement of inter-stroke pulse sequences

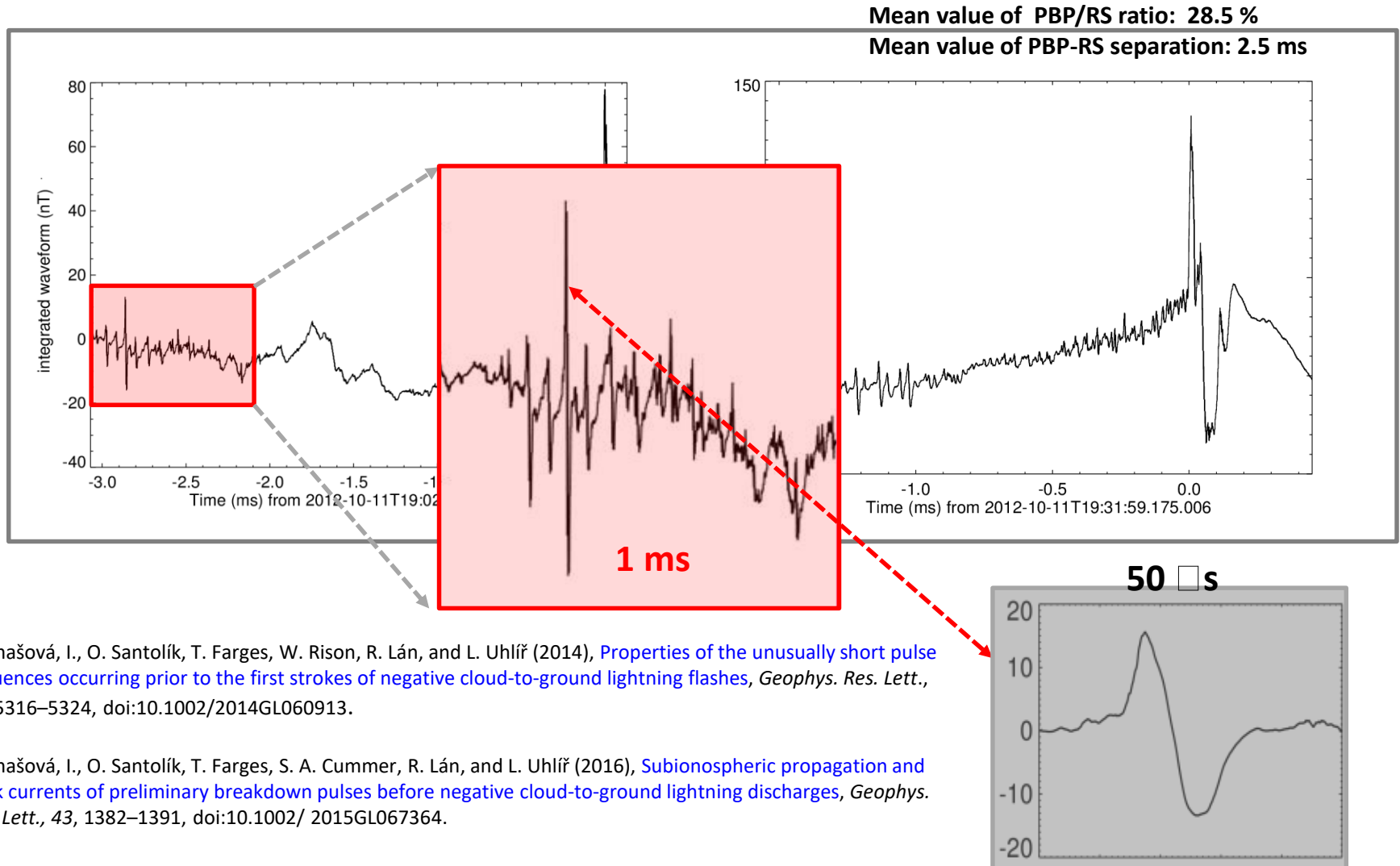


Kolmašová, I., and O. Santolík (2013), [Properties of unipolar magnetic field pulse trains generated by lightning discharges](#), *Geophys. Res. Lett.*, 40, 1637–1641, doi:10.1002/grl.50366.

Kašpar, P., O. Santolík, and I. Kolmašová (2015), [Unipolar and bipolar pulses emitted during the development of lightning flashes](#), *Geophys. Res. Lett.*, 42, 7206–7213, doi:10.1002/2015GL064777.



# Measurement of short pre-stroke pulse sequences

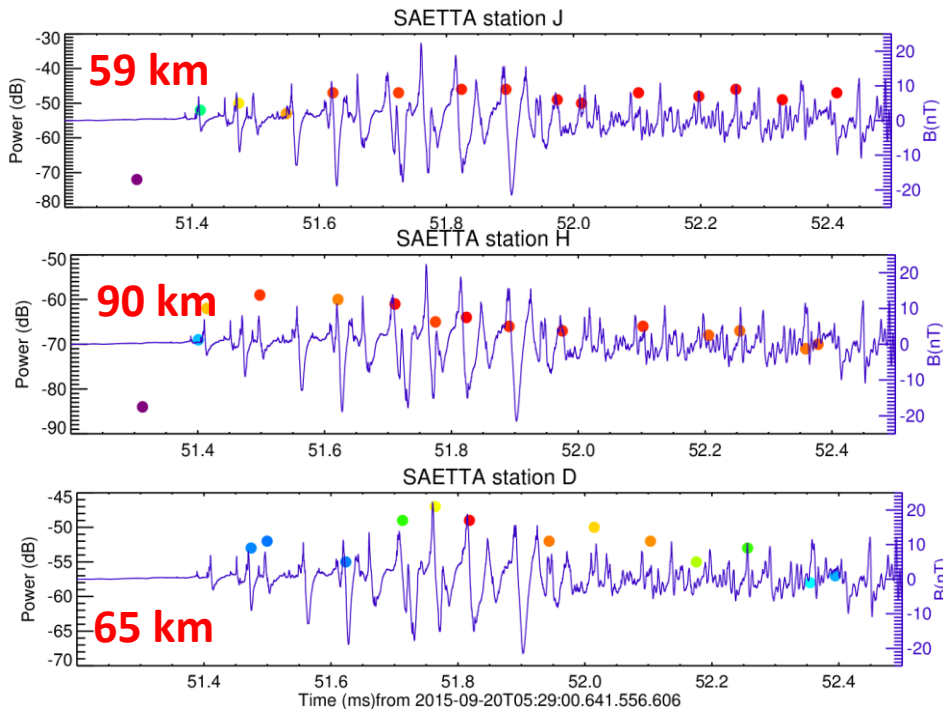
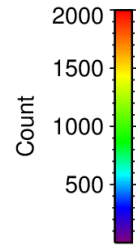
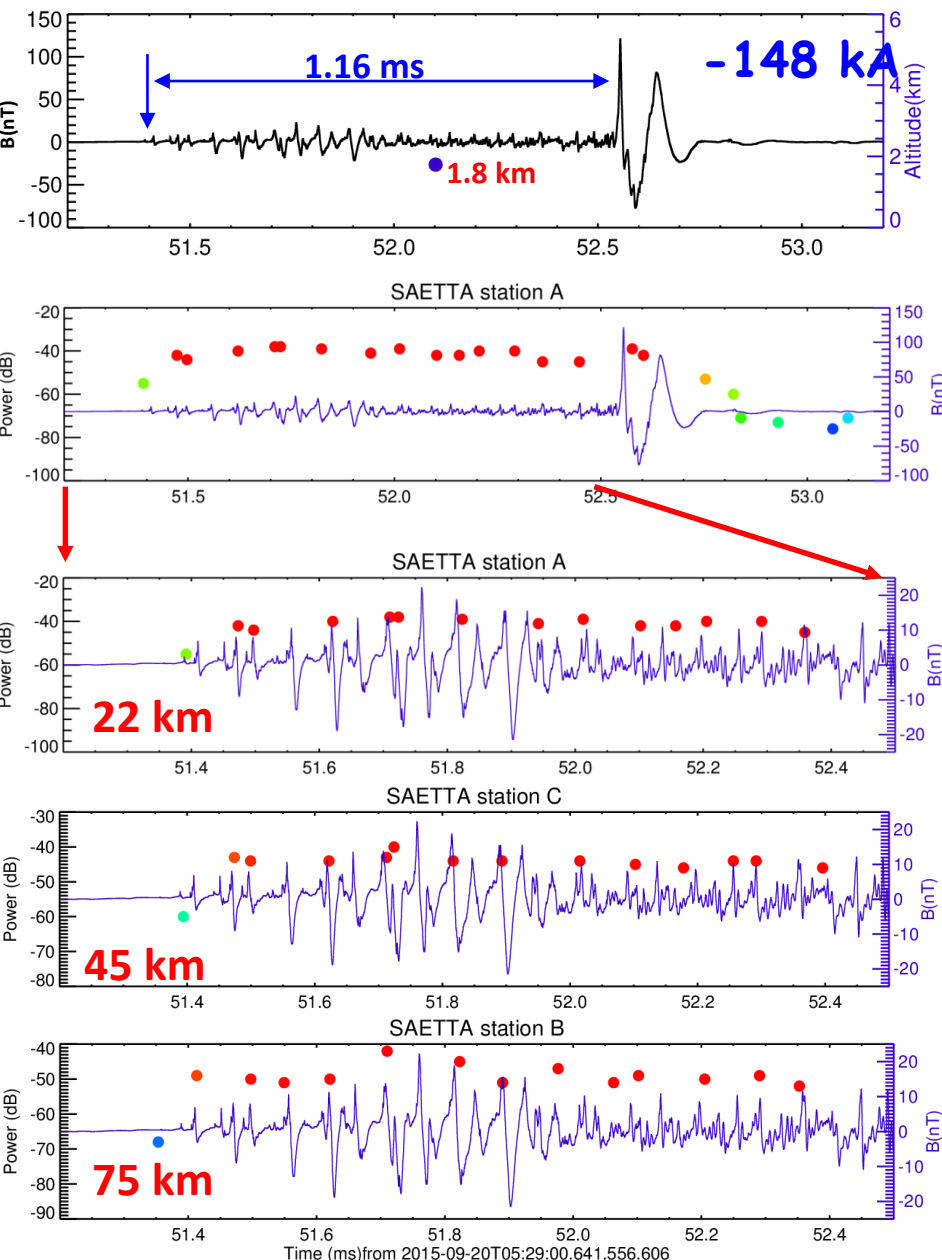


Kolmašová, I., O. Santolík, T. Farges, W. Rison, R. Lán, and L. Uhlíř (2014), [Properties of the unusually short pulse sequences occurring prior to the first strokes of negative cloud-to-ground lightning flashes](#), *Geophys. Res. Lett.*, 41, 5316–5324, doi:10.1002/2014GL060913.

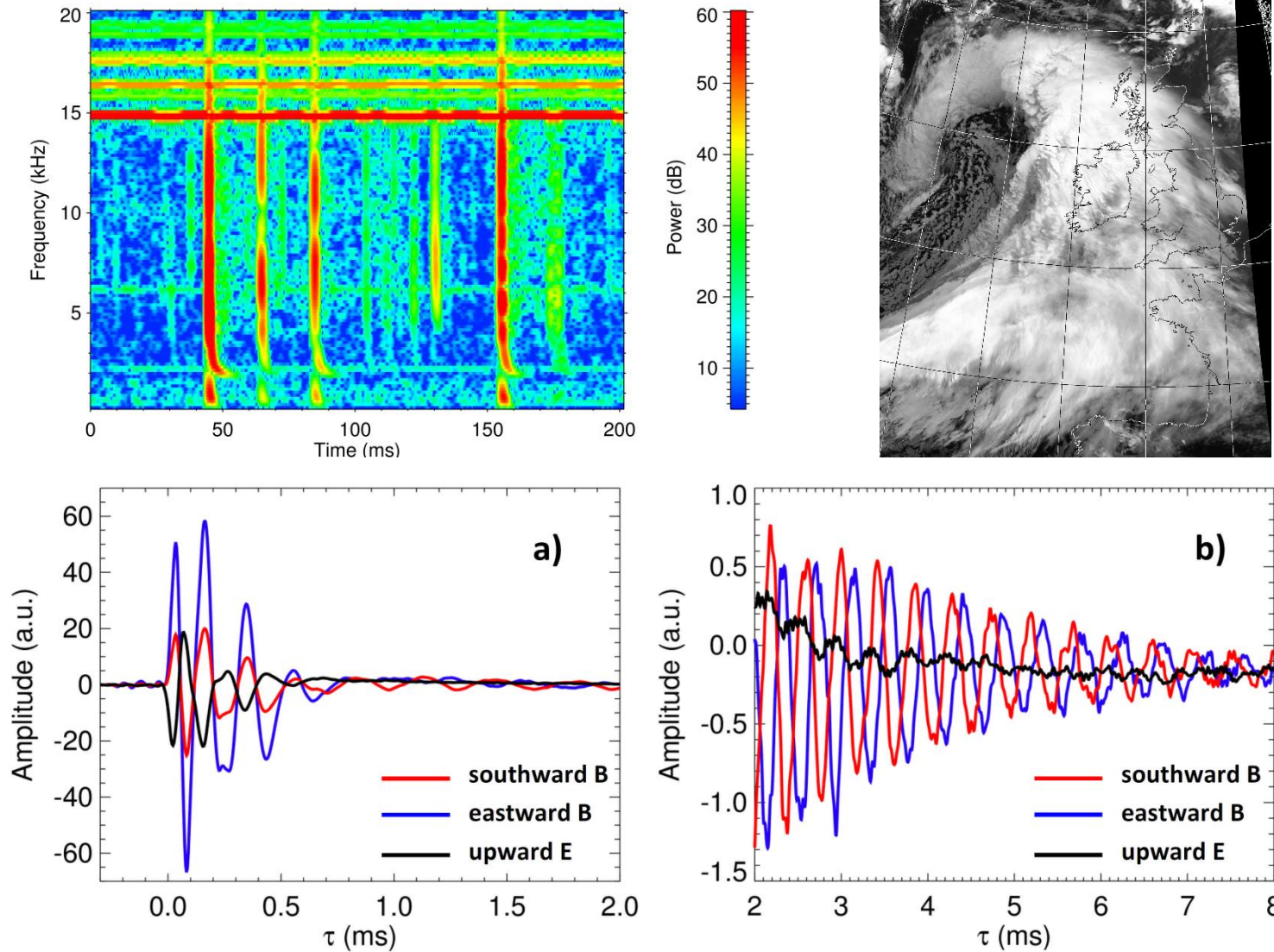
Kolmašová, I., O. Santolík, T. Farges, S. A. Cummer, R. Lán, and L. Uhlíř (2016), [Subionospheric propagation and peak currents of preliminary breakdown pulses before negative cloud-to-ground lightning discharges](#), *Geophys. Res. Lett.*, 43, 1382–1391, doi:10.1002/2015GL067364.

# Broadband measurements x SAETTA

Kolmašová, I., O. Santolík, E. Defer, W. Rison, S. Coquillat, S. Pedeboy, R. Lán, L. Uhlíř, J.-P. Pinty, S. Prieur, V. Pont (2018), [Lightning initiation: Strong pulses of VHF radiation accompany preliminary breakdown](#), Scientific Reports, 8, 1, 3650



# Daytime Tweek Atmospherics



Santolík, O., I. Kolmašová (2017), [Unusual Electromagnetic Signatures of European North Atlantic Winter Thunderstorms](#), Scientific Reports, 7,1, 13948.



# Conclusions

- Broad-band electric field measurements up to 37 MHz have been prepared for the TARANIS spacecraft, waiting for launch;
- Ground based measurements in the same frequency range and at different measurement site in Europe will support the TARANIS mission;
- Examples of recent results of these measurements show a range of subjects from the preliminary breakdown processes, through interstroke pulse sequences, to tweak atmospheric.