Aalto University
School of Electrical Engineering

Feasibility study for a nanosatellite-based instrument for in-situ measurements of radio noise

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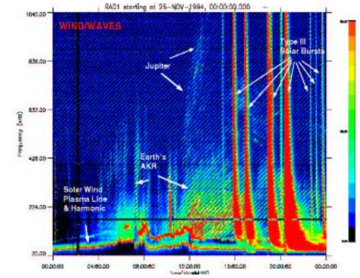
Contents

<u>Our goal</u>: ***To measure the radio emission at ~ 0.1-10 MHz at Low Earth Orbit (~500 km) with a cubesat***

<u>I Science</u>: Why important, What do we expect to observe?

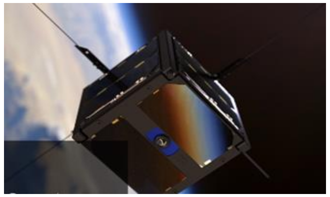
- Natural sources
- Artificial sources



Takahashi 2003b

<u>II Technology</u>: How to measure and when?

- Cubesat
- Radio instrument: wideband and narrowband measurements



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Challenge: Noise makes the science and communication difficult

The altitude (~500 km) and frequency range (LF-HF) is the "worst of both worlds":

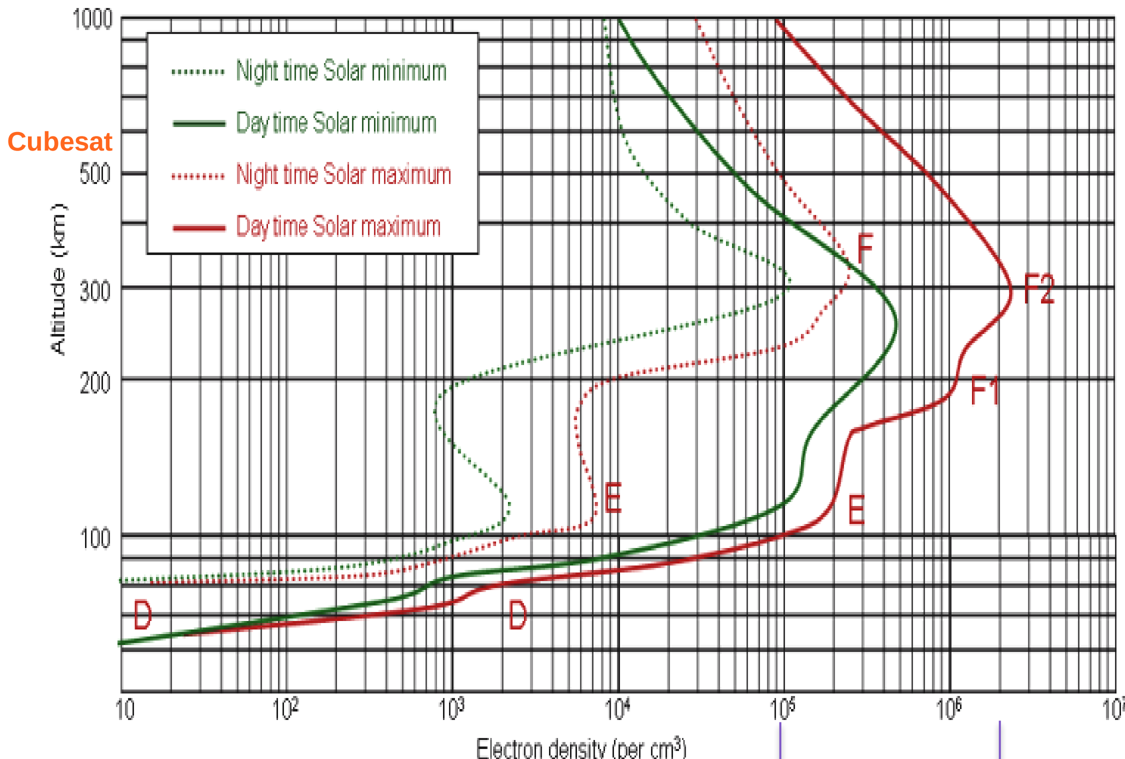
- **Scientific measurements are hindered by man-made noise**
- **Natural noise makes practical applications such as communications difficult**

Why do we want to measure? Interesting area both in science and telecommunication.

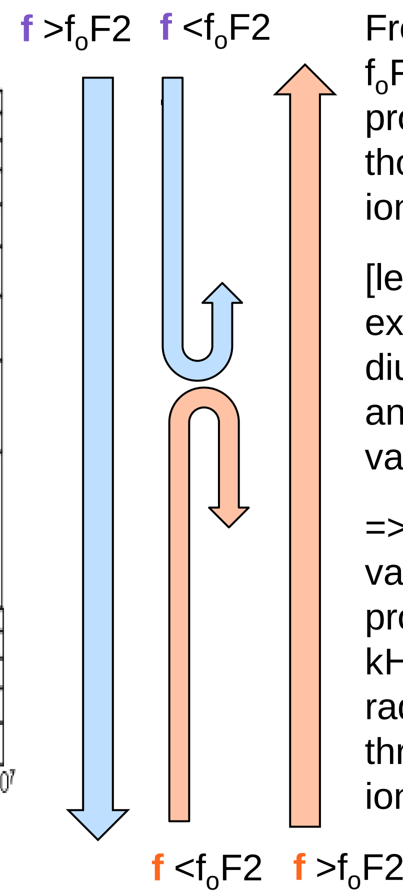
A low-budget cubesat enables measurements which would be very expensive otherwise.

Propagation from the ground to the space and vice versa: Ionosphere

http://sidstation.loudet.org/ionosphere-en.xhtml



f_oF2 (~ $9\sqrt{n[cm^{-3}]}$) kHz 300 kHz 900 kHz 3 MHz 13 MHz



Frequencies below f_oF2 do not propagate thorough the ionosphere.

[left] ionosphere exhibits substantial diurnal, seasonal and solar cycle variations

=> Strong variations on the propagation of 100 kHz – few MHz radio signals through the ionosphere

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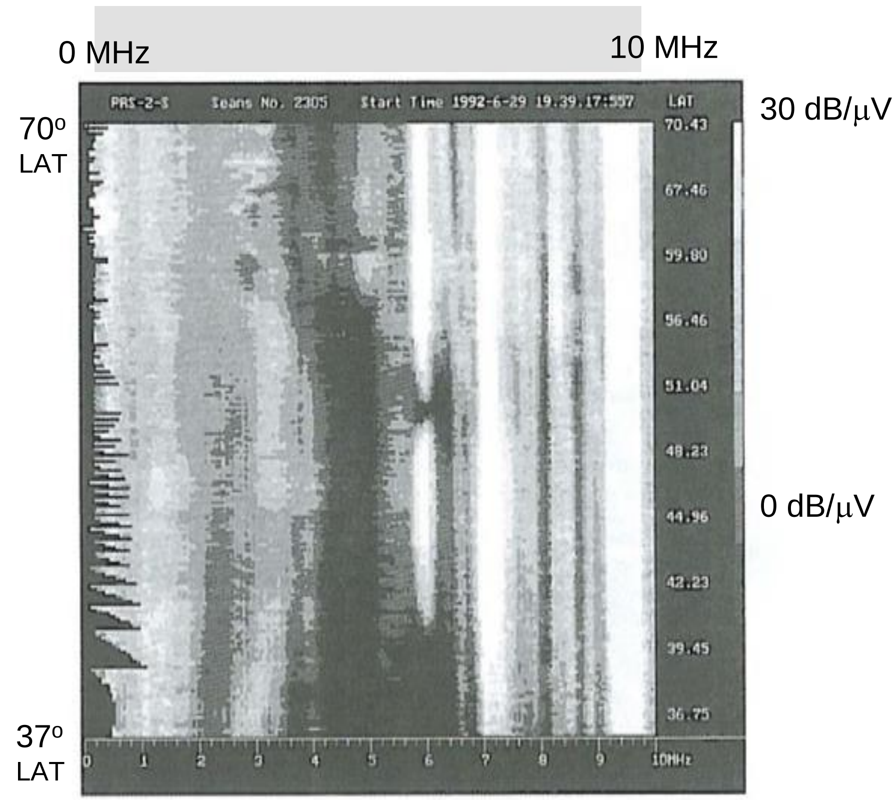
Complex RF environment

- **Extremely complex mix of artificial and natural noise**

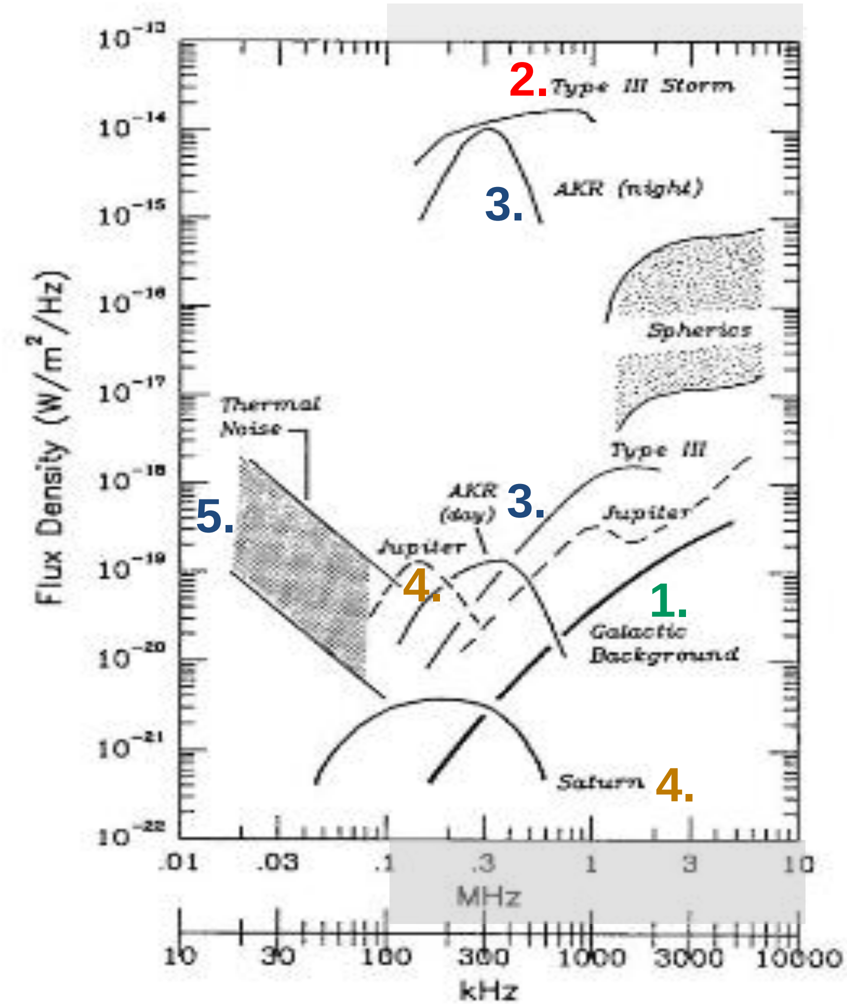
  at Low Earth Orbit (LEO: 160 km-2000 km) & LF to HF range

- **Number of *in situ* measurements is very limited**



Rothkaehl and Klos, 1996

i) Natural emissions: Summary



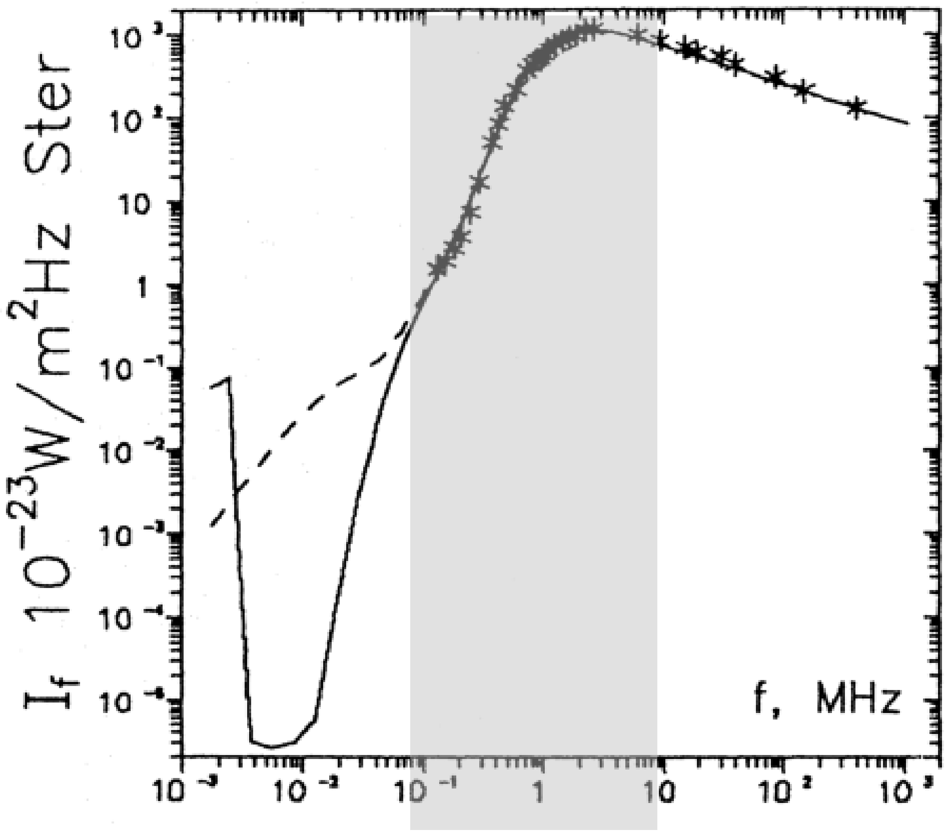
Sources:

1. Galactic background
2. Solar storm (Type III)
3. Auroral kilometric radiation *(AKR)*
4. Giant magnetized planets
5. Lightning *(Atmospheric noise)*

Known phenomena include AKR, auroral hiss, MF-burst, roar, whistler, saucer, chorus…

[left] Overview flux spectra of the principal sources of noise in the terrestrial environment below 10 MHz, from [Desch 1990]

i) Natural emissions (1/5): galactic noise



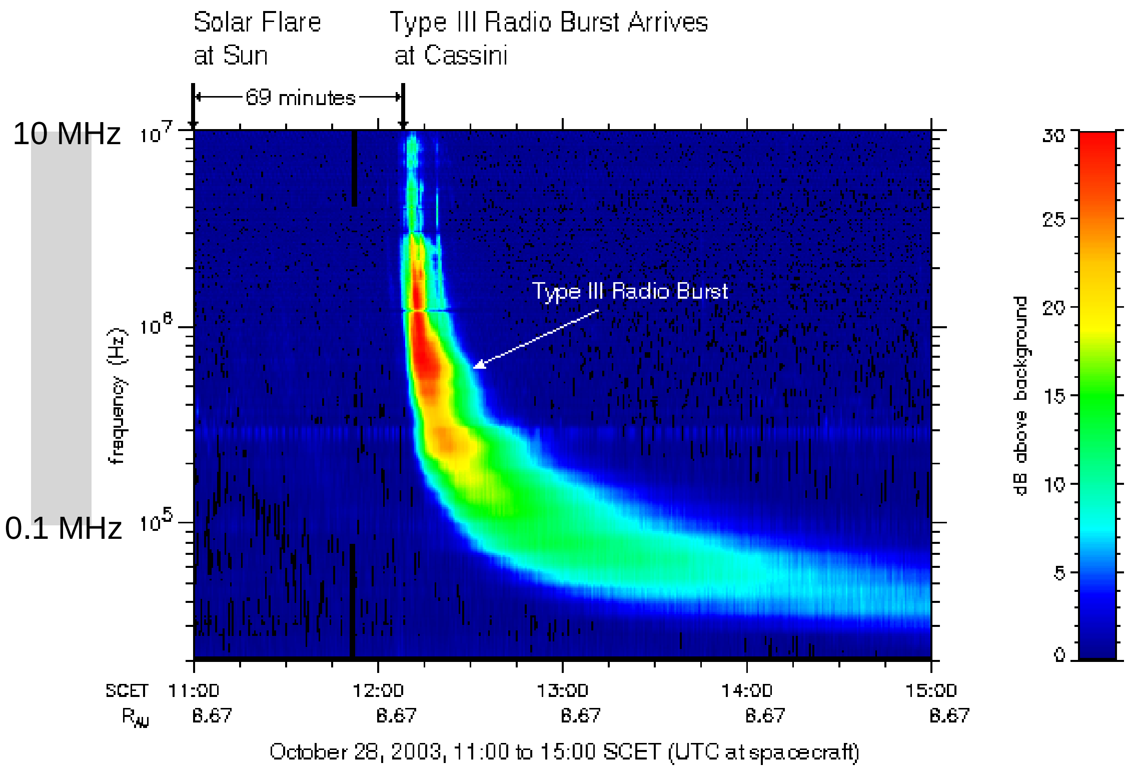
Fleishman and Tokarev (1995)

Between 100 kHz and 100 MHz, the background intensity is of the order of 10^{-23} to 10^{-20} W/m^2 Hz Ster (= 10^{-10} to 10^{-6} V/m/Hz/ster)

Intensity integrated over the whole sky: 10^{-9} to 10^{-5} V/m/Hz

i) Natural emissions (2/5): Solar storms

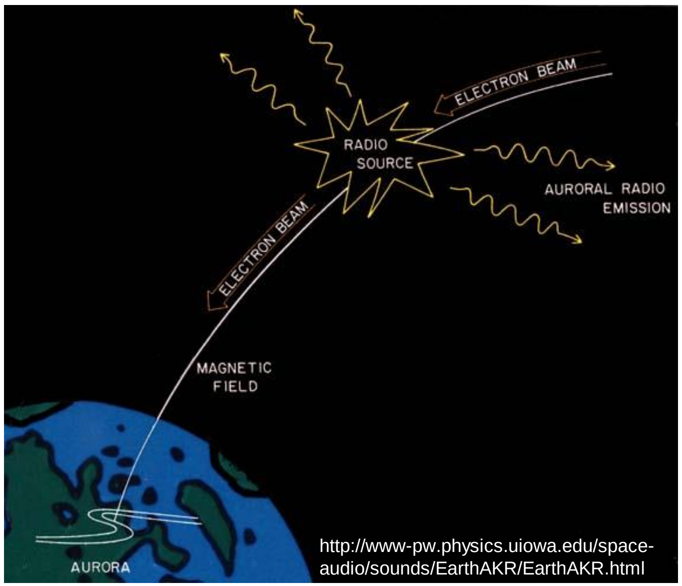
- Measurements at space



Type III radio burst are produced by energetic electrons.

[left] Radio burst seen at CASSINI near Jupiter. From http://www-pw.physics.uiowa.edu/space-audio/typeIII.html Intensity is relative to the galactic background.

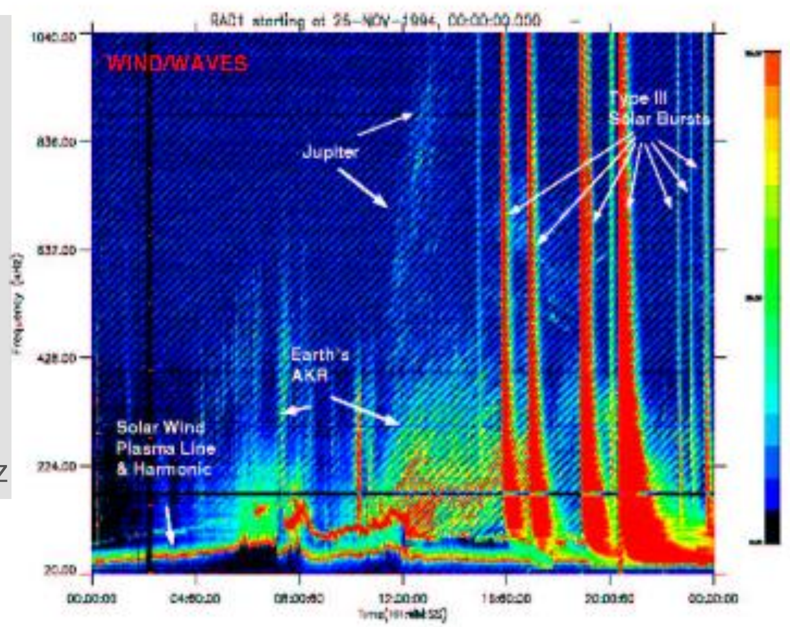
i) Natural emissions (3&4/5): Auroral kilometric radiation and giant planets



1.04 MHz

0.224 MHz

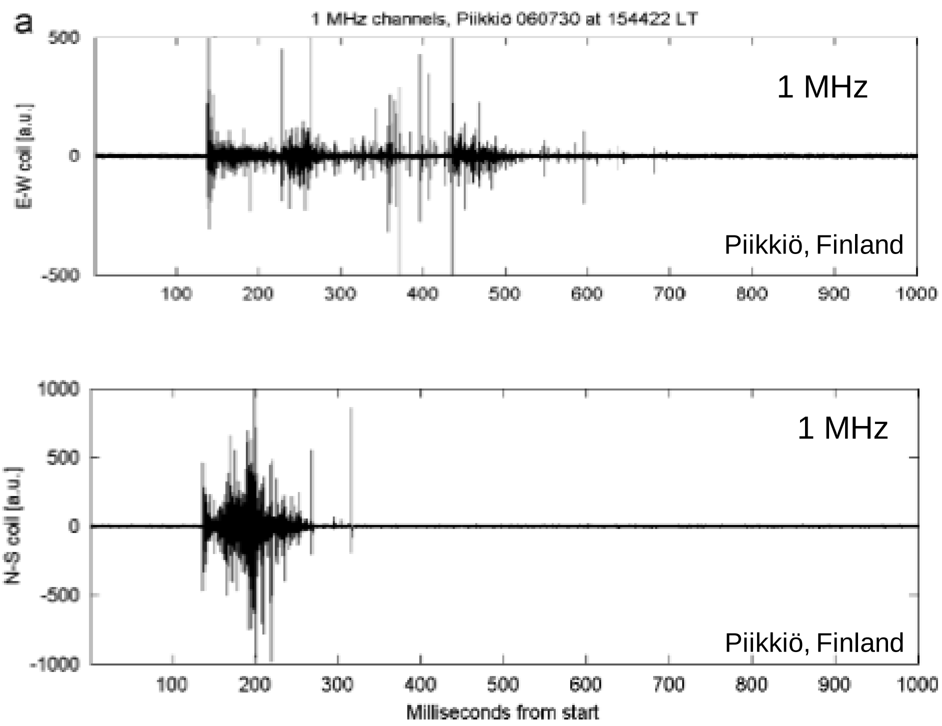
20 kHz



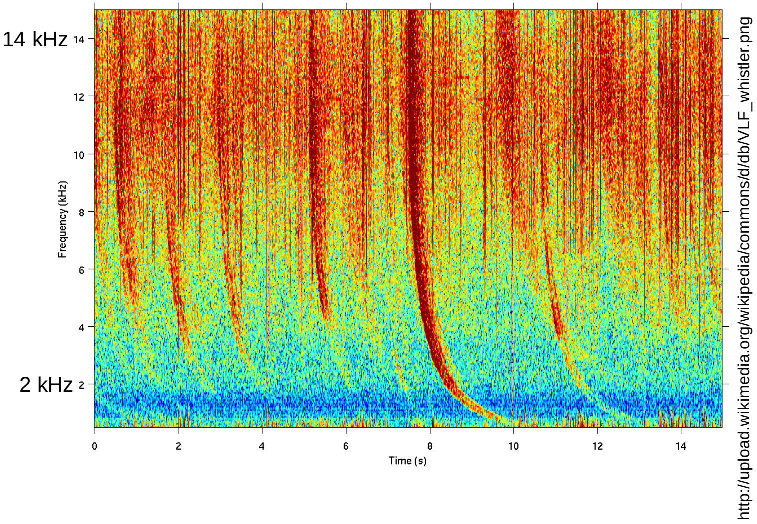
Electromagnetic Auroral kilometric radiation (AKR) emission at ~ 100 - 500 kHz is produced by energetic electrons at ~ 3000 - 20000 km

Multiple radio processes observed by WIND/WAVES instrument. [Takahashi 2003b]

i) Natural emissions (5/5): Lightning



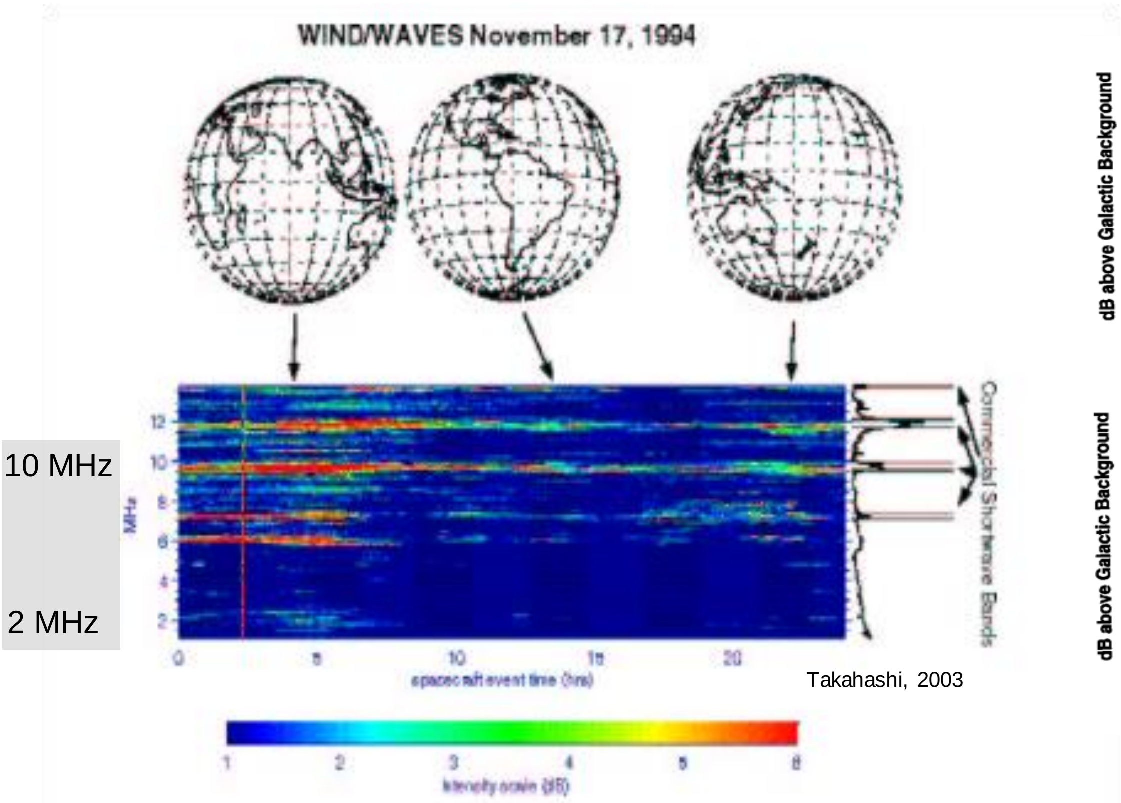
Mäkelä and Porjo



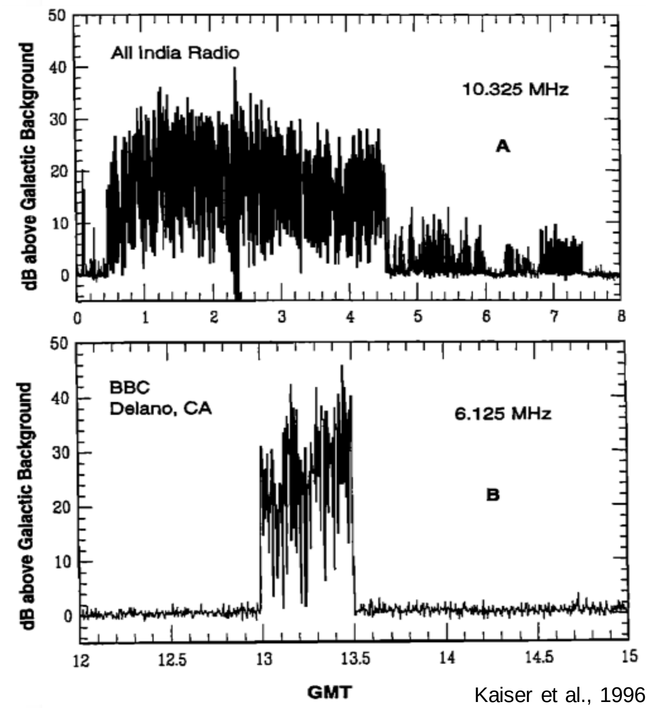
Several whistler signals as received at Palmer Station, Antarctica.

1 MHz lightning signals recorded at ground at Piikkiö, Finland

ii) Artificial emission



Takahashi, 2003

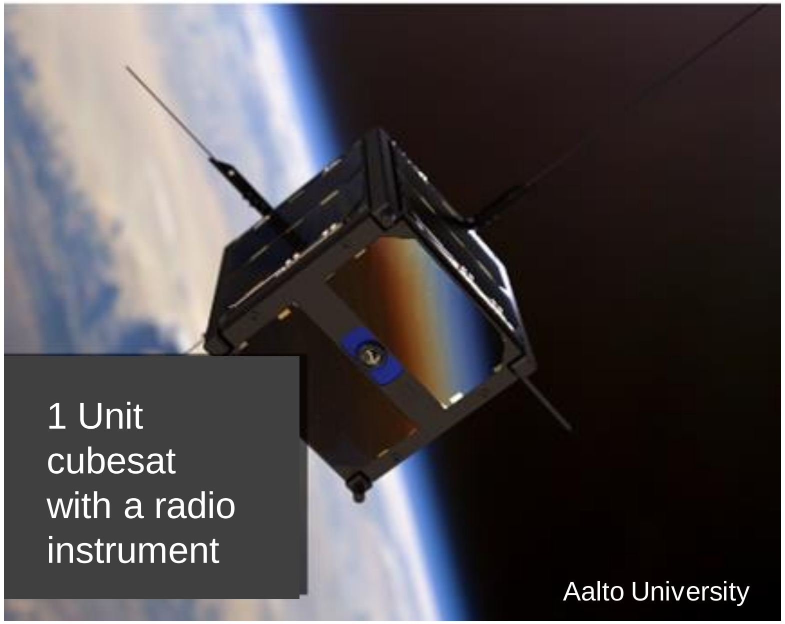


Kaiser et al., 1996

Man-made radio transmission seen by WIND/WAVES instrument at 32 R_E
Sources could be inferred indirectly.

II Technology

Consept: Cubesat with a radio instrument



Cubesat:
- 1 Unit (10x10x10 cm), ~ 1 kg
- 2 Unit (2 x 10x10x10 cm), ~ 2 kg

Concept:
- Radio instrument for a cubsat build at Aalto University
- Science objectivies
- Educational purposes: How to design, build and operate a spacecraft and its payload

Radio instrument: Science objectives

Two main scientific goals: to generate

1. **a global map of the <u>artificial</u> RFI level** at different locations at Earth
   - Demonstrate the feasibility of identifying individual artificial sources

2. **local *in-situ* maps of the <u>natural</u> RF environment,** especially in the auroral zone and ionosphere

   => possible a new method for ionospheric sounding via low-cost nanosatellites (e.g. f_0F2 altitude)

Radio instrument:Technical requirements

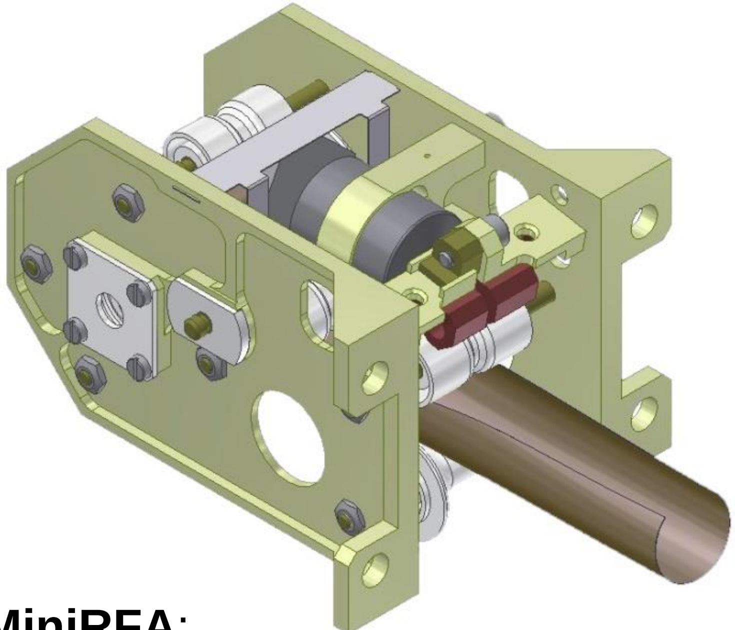
Two measurement modes:

1) Broadband measurement to track the **general level of radio-frequency interference**
2) Narrowband detection to scan **individual interference sources**
   - *9 kHz bandwidth (to identify/monitor individual artificial terrestrial sources)*
   - *3 kHz sampling rate (to identify voice or Morse transmissions)*

Hardware and payload:

- Must fit in a 1-2 U cubesat => small size

Two possible architectures



MiniRFA:
- 30x45x55 mm
- 1 m antenna
- mass budget 740 g

Space Research Centre of the Polish Academy of Sciences

1) Radio Frequency Analyzer (RFA) - type of instrument
   - wideband
   - designed for nanosatellites
   - would need further size reduction

2) Based on terrestrial automotive AM radio chip (unproven technology)

Summary

Noisy radio environment due to artificial and natural sources

Problem caused by the noise:

- Man-made noise disturbances scientific measurements
- Natural noise interference practical communication applications

We will to measure **RF environment** at **LEO** in the **LF to HF** range

Measurement concept**:**

- Low-cost **cubesat** with a miniature radio instrument
- Planned launch for the cubesat: **2017**

Status now: feasibility study is ongoing

THANK YOU