Space Weather Introductory Course

March 2023
Brussels, Belgium

SWIC

Radio Astronomy & Space Weather

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Additional help from the ROB Technical Service colleagues

Solar-Terrestrial Centre of Excellence

Solar Influences Data analysis Center

Royal Observatory of Belgium

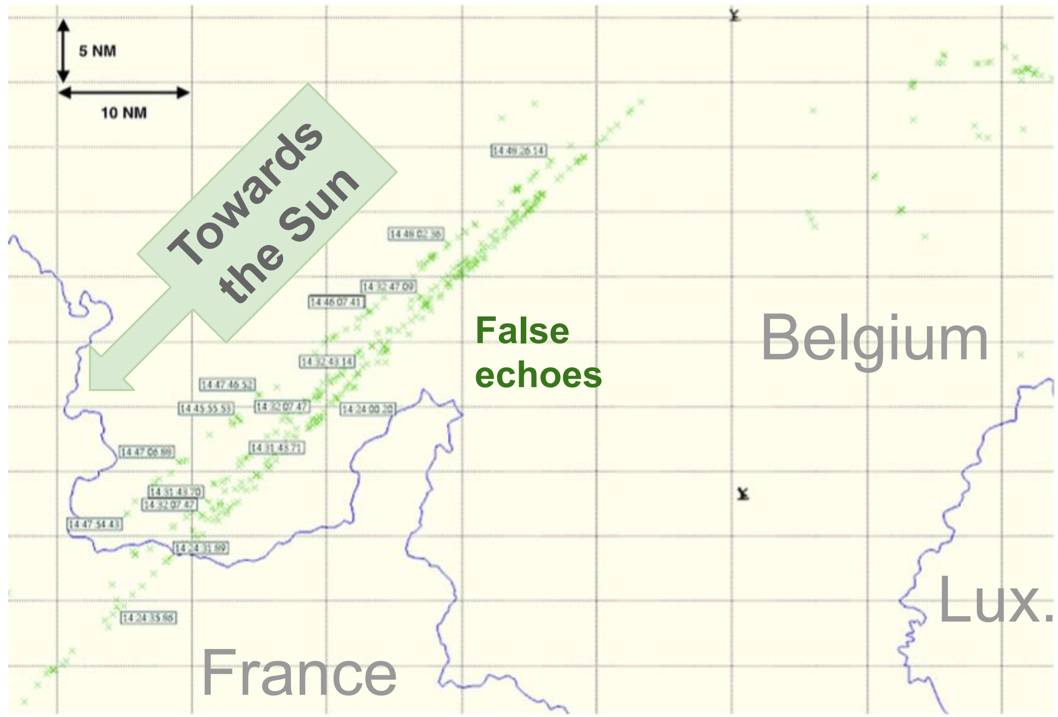
Belgian Science Policy Office
belspo

November 4th, 2015

Aeronautical navigation disturbances

Belgocontrol reported issues with a secondary A/C radar during two periods of time:

- 14:19:23–14:33:35 UT
- 14:45:52–14:49:18 UT



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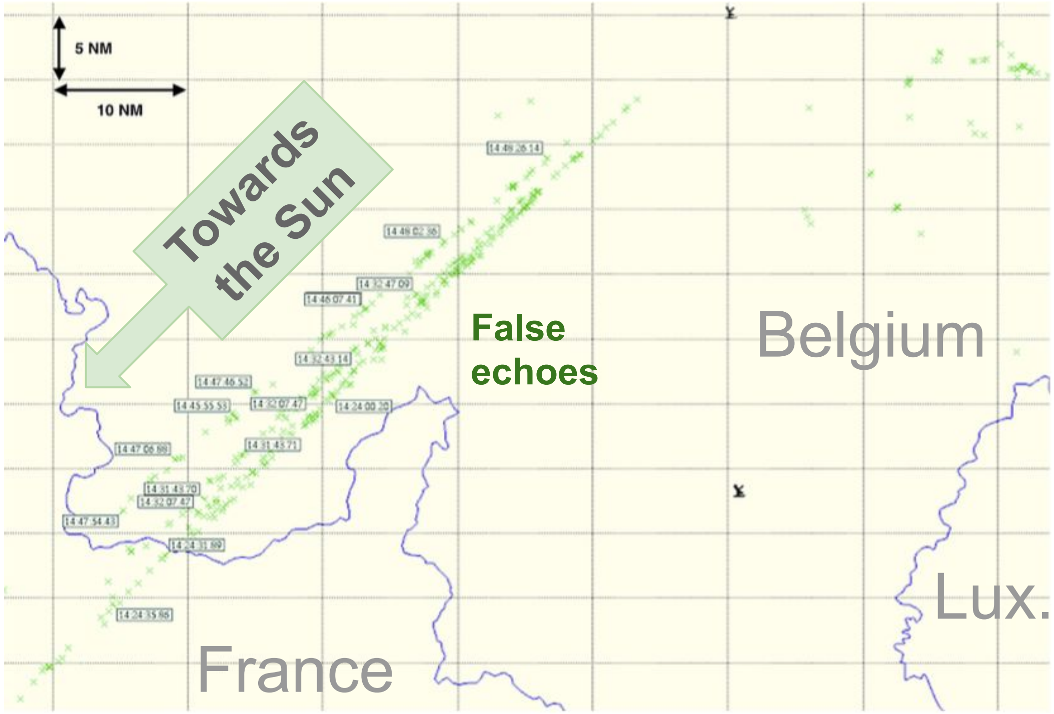

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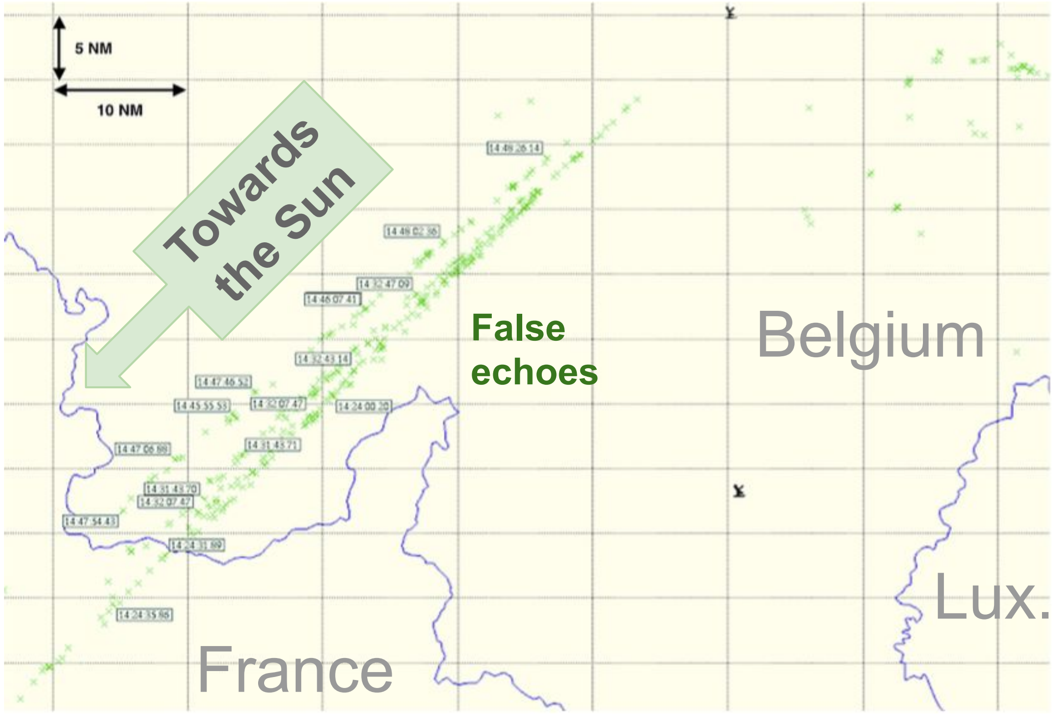

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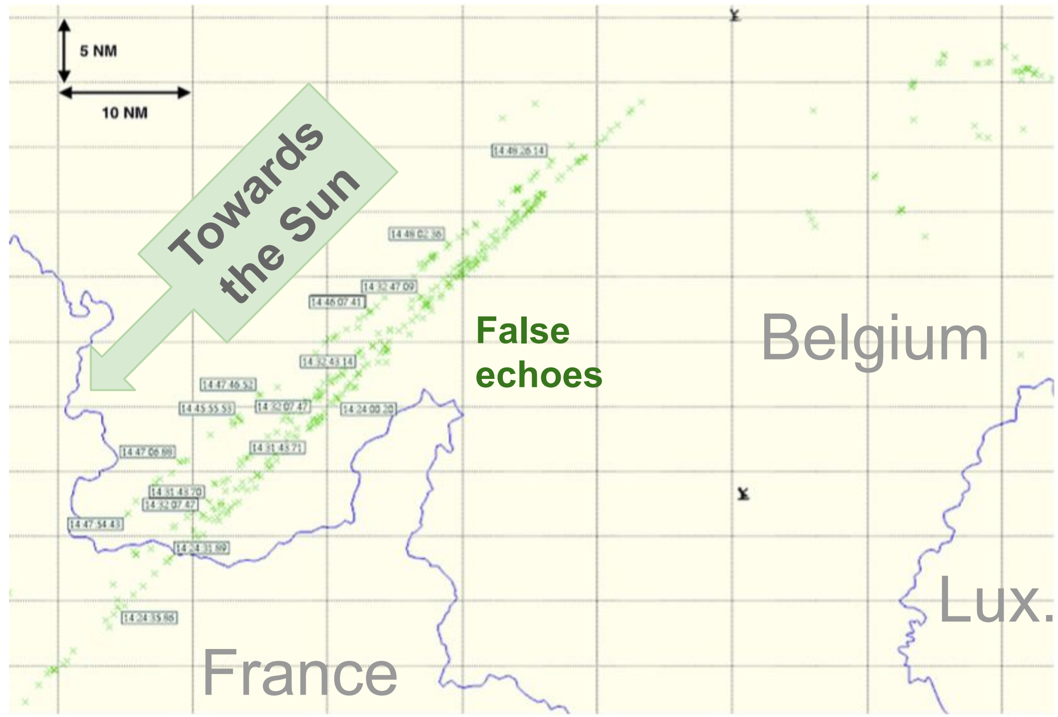

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- ~ 14:47–14:50 UT

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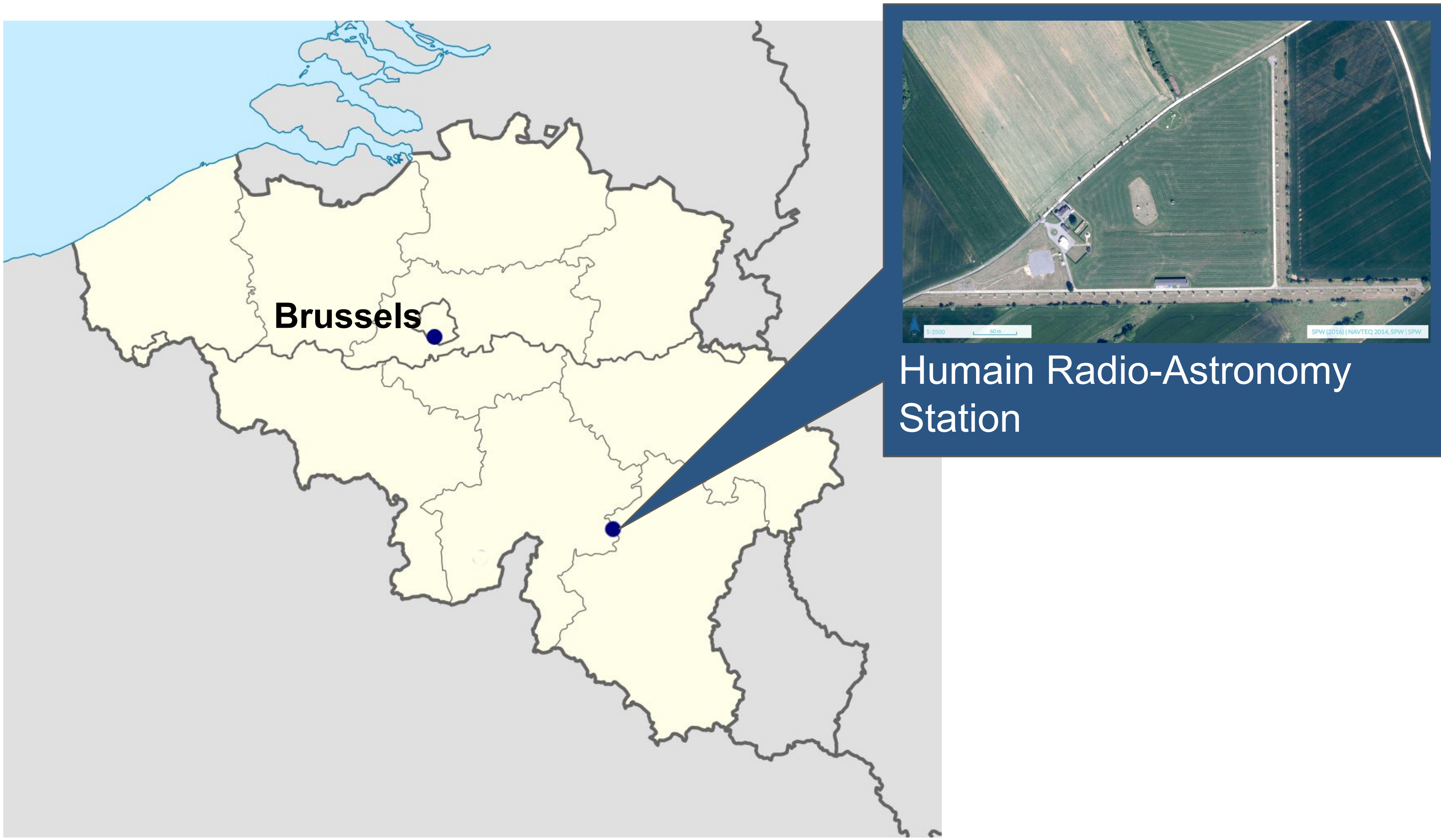
Greenland: issues in landing at Thule above 4000 ft with a conflicting report between an ILS localizer and the autopilot (~14:49 UT)

Humain Radio-Astronomy Station

Solar Radio Observations from Belgium



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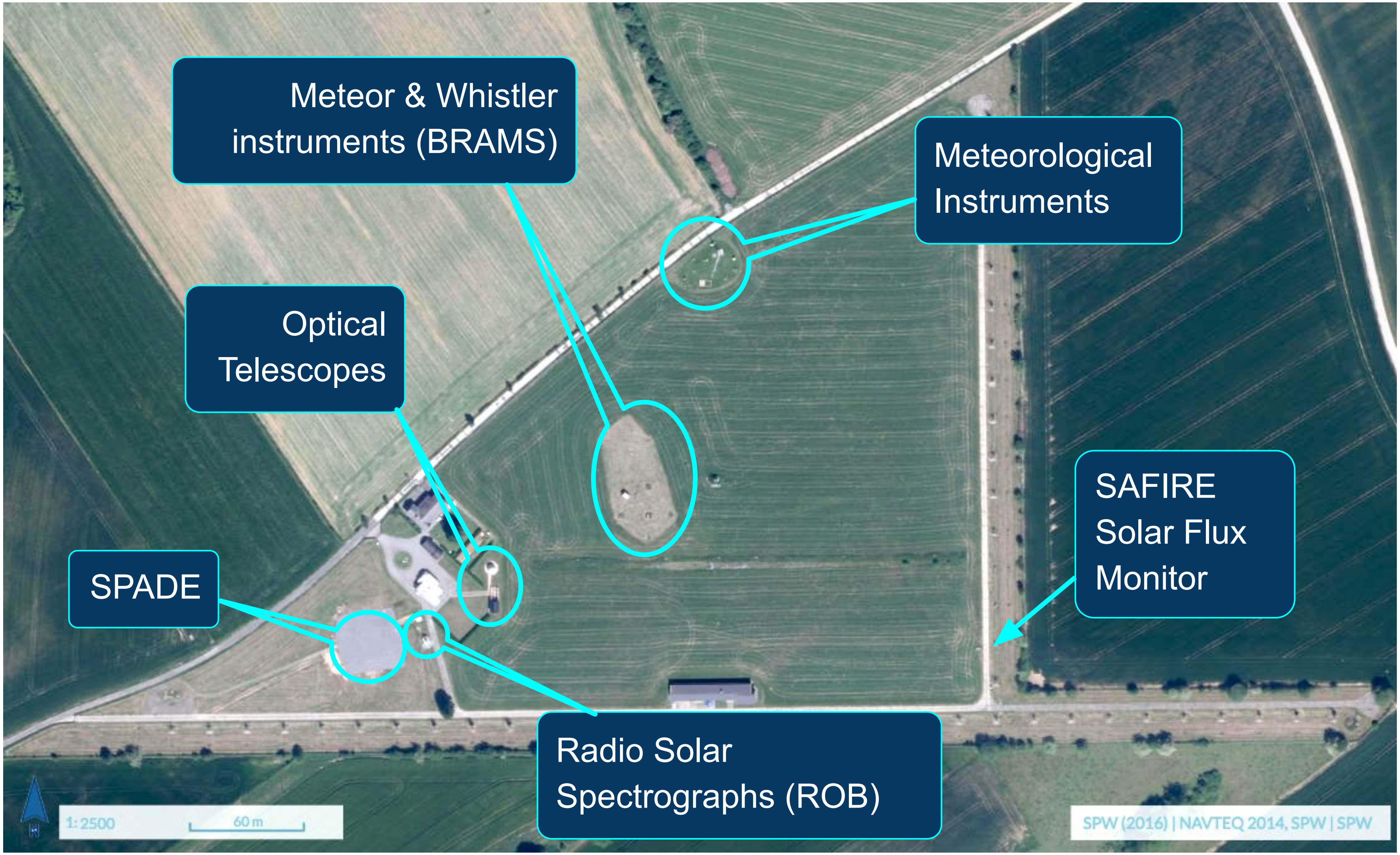

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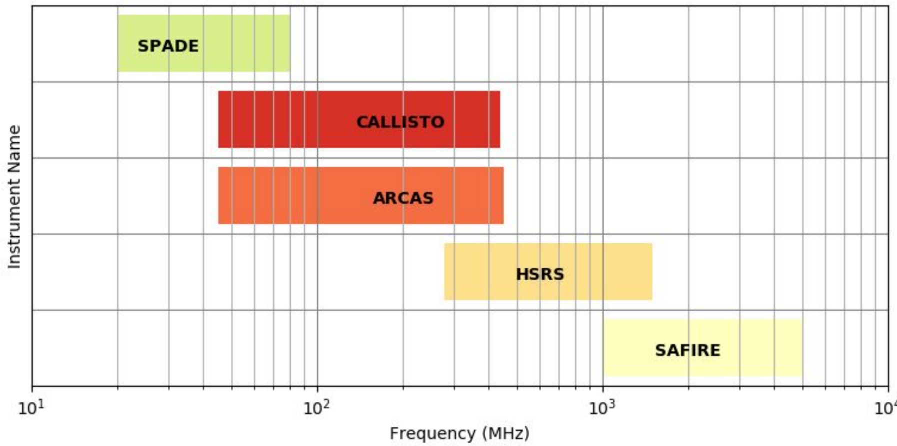
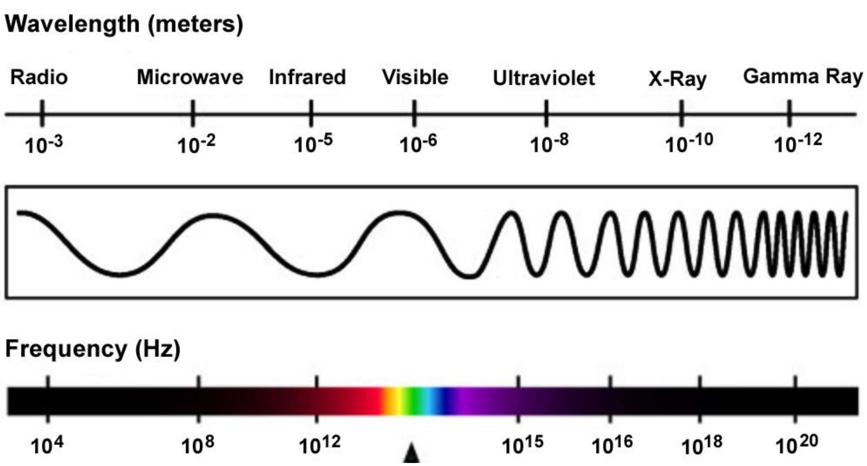




Radio Telescopes
Instrumentation

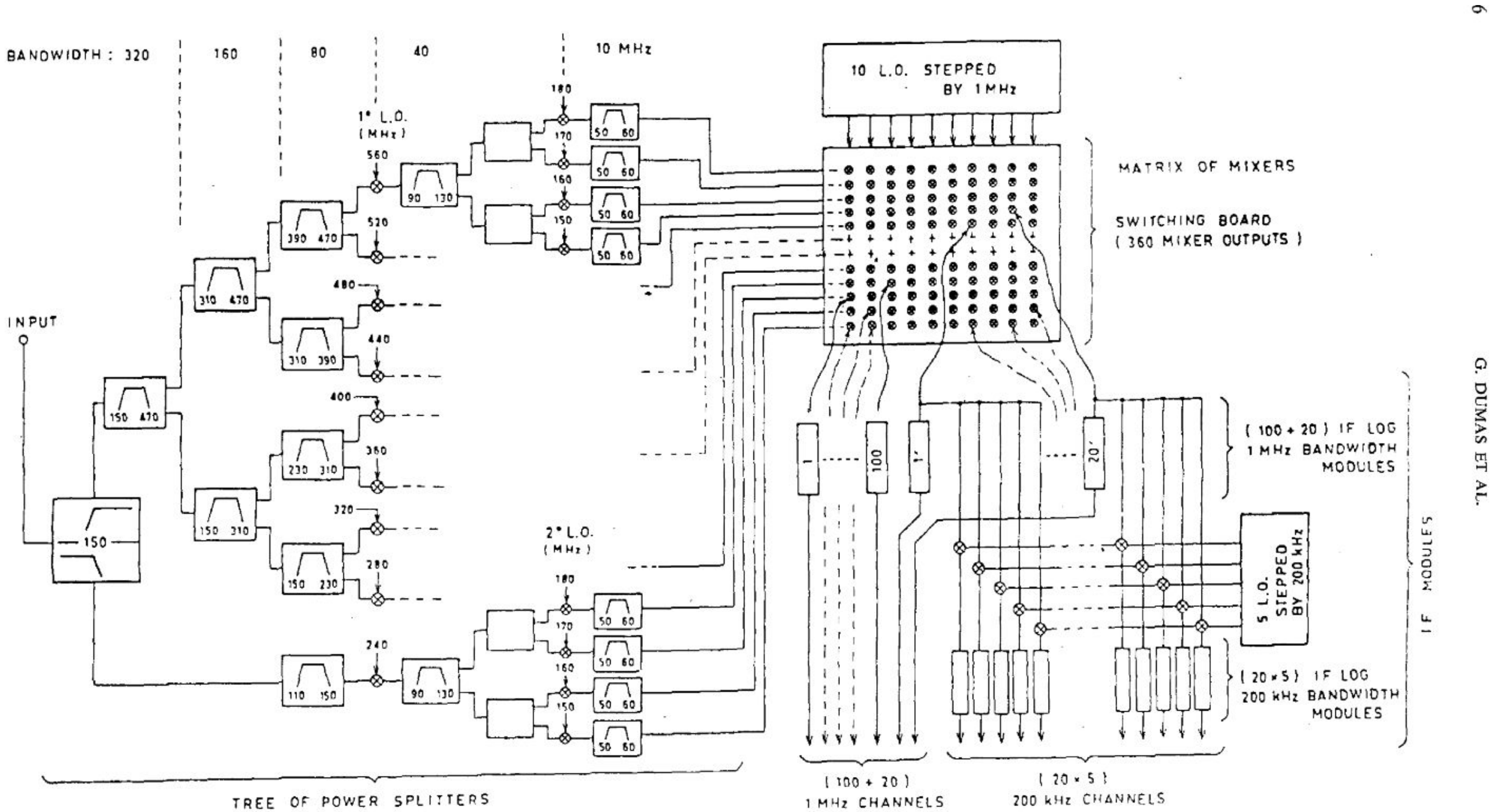
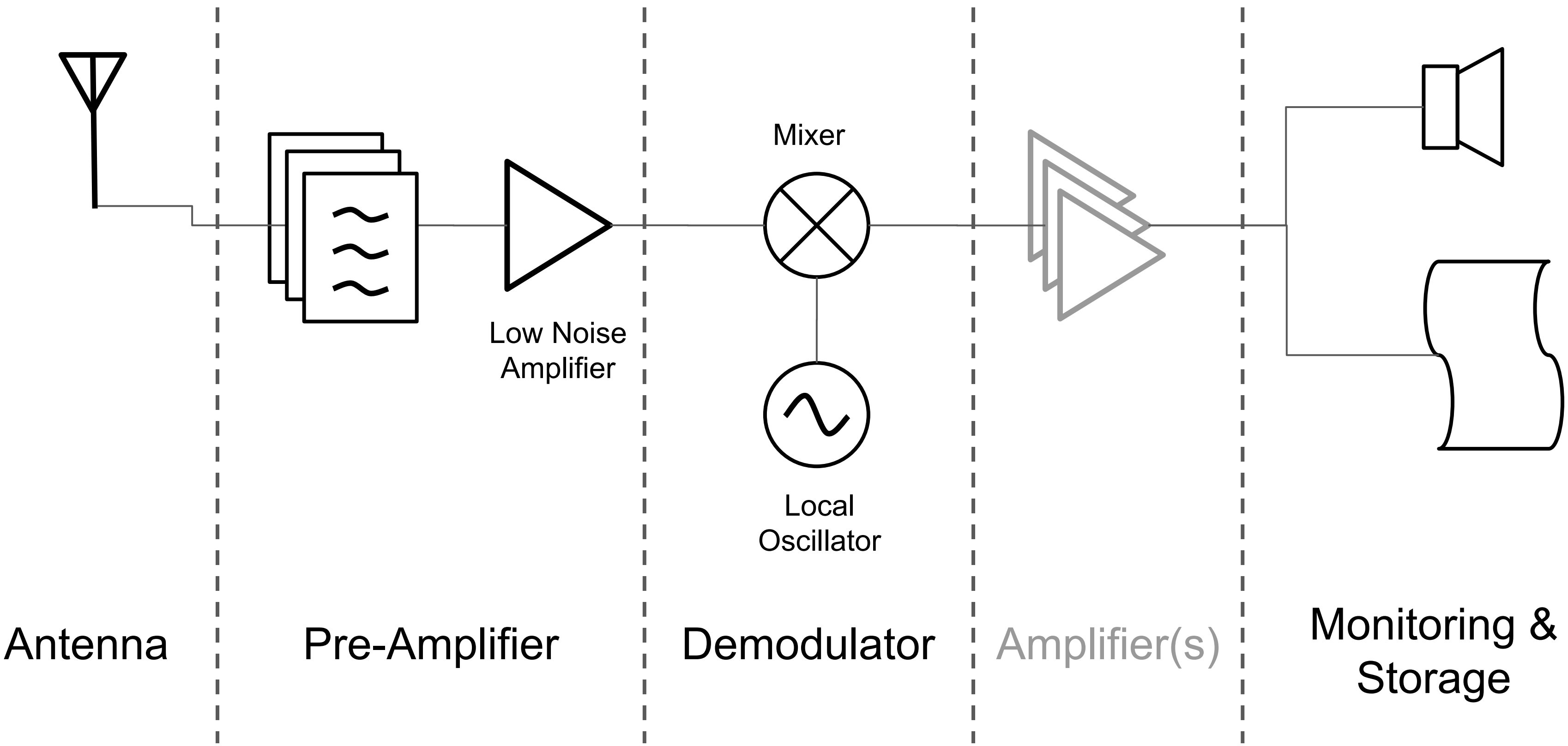


Fig. 1. Spectrograph receiver block diagram.

Dumas et al, 1982

Radio Telescopes

Instrumentation



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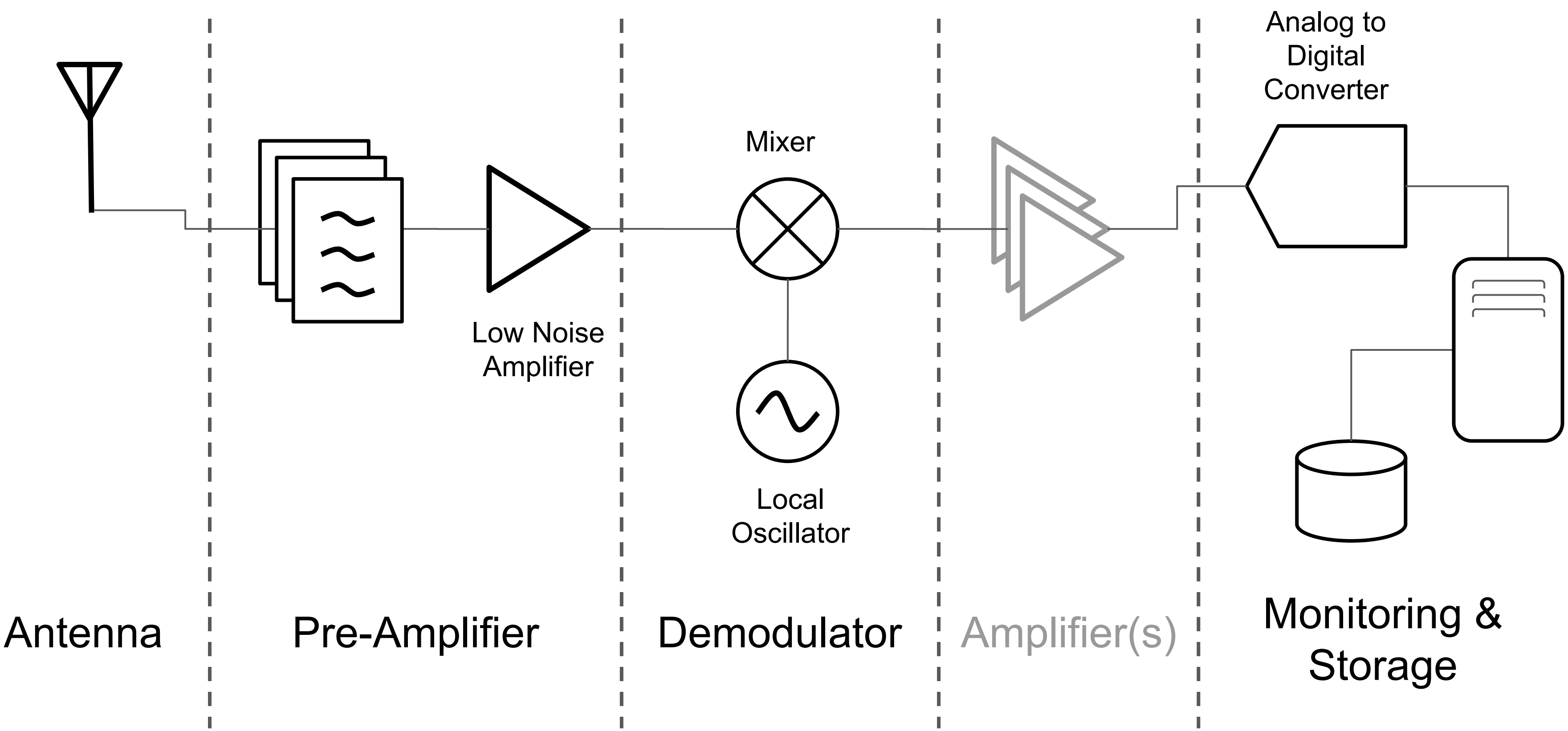

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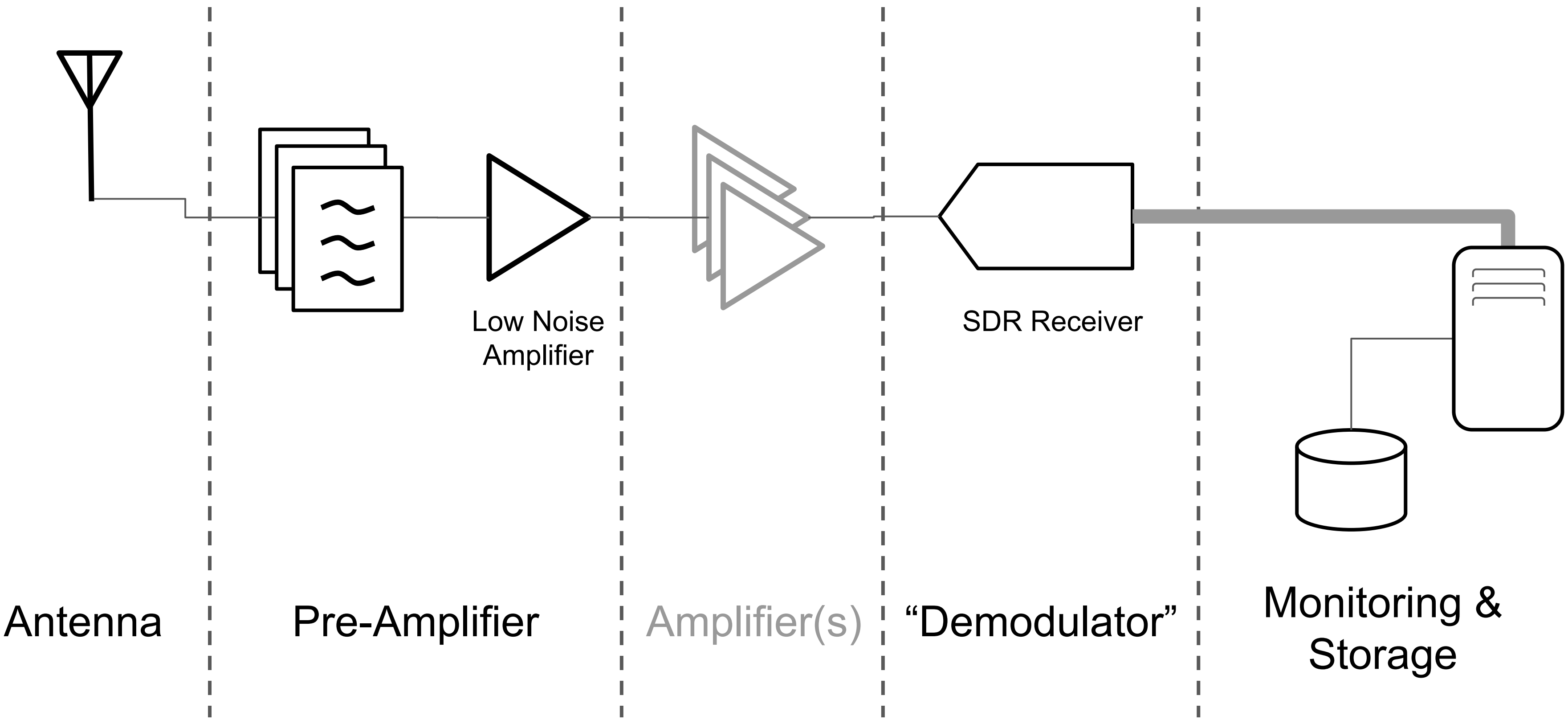

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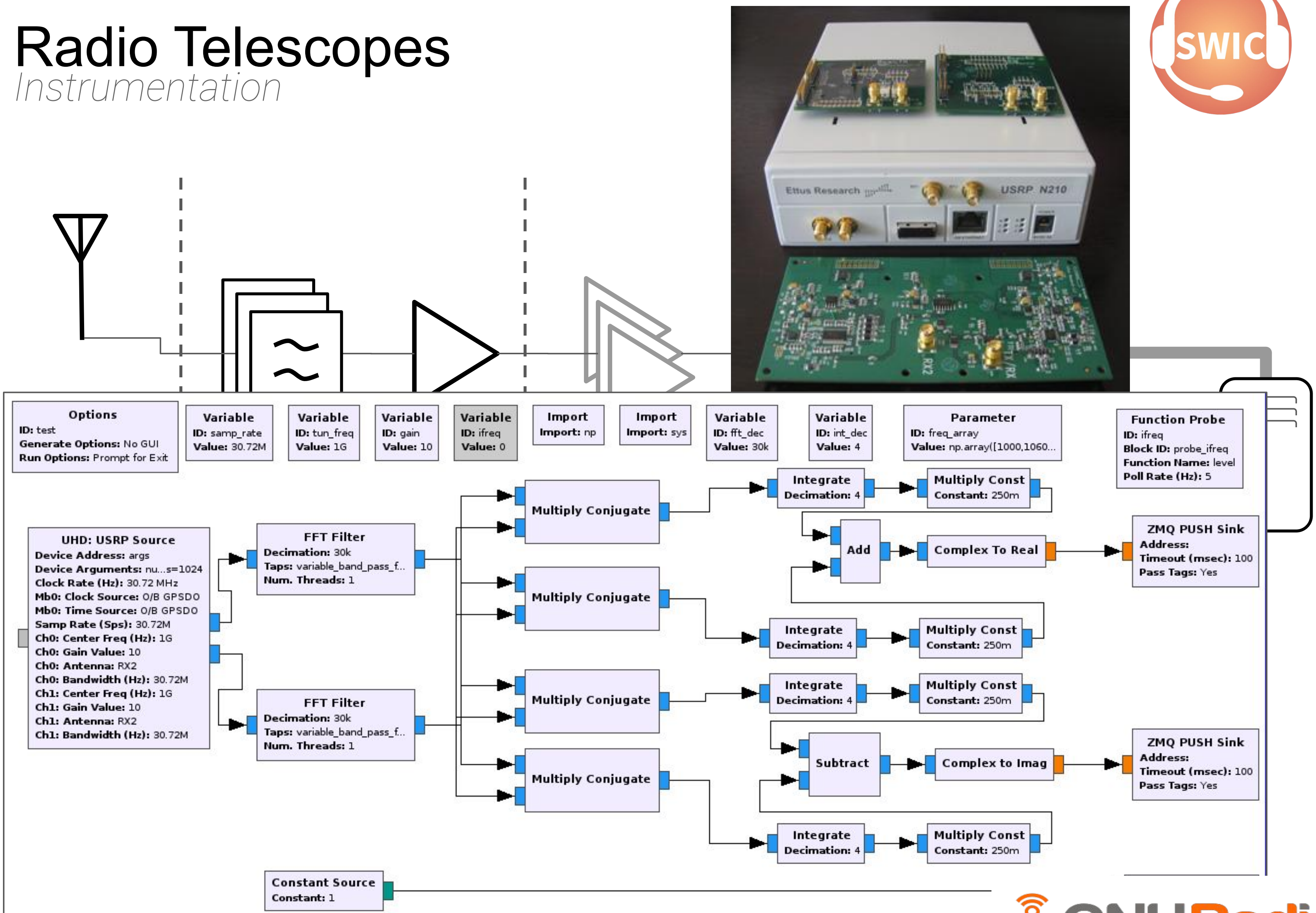
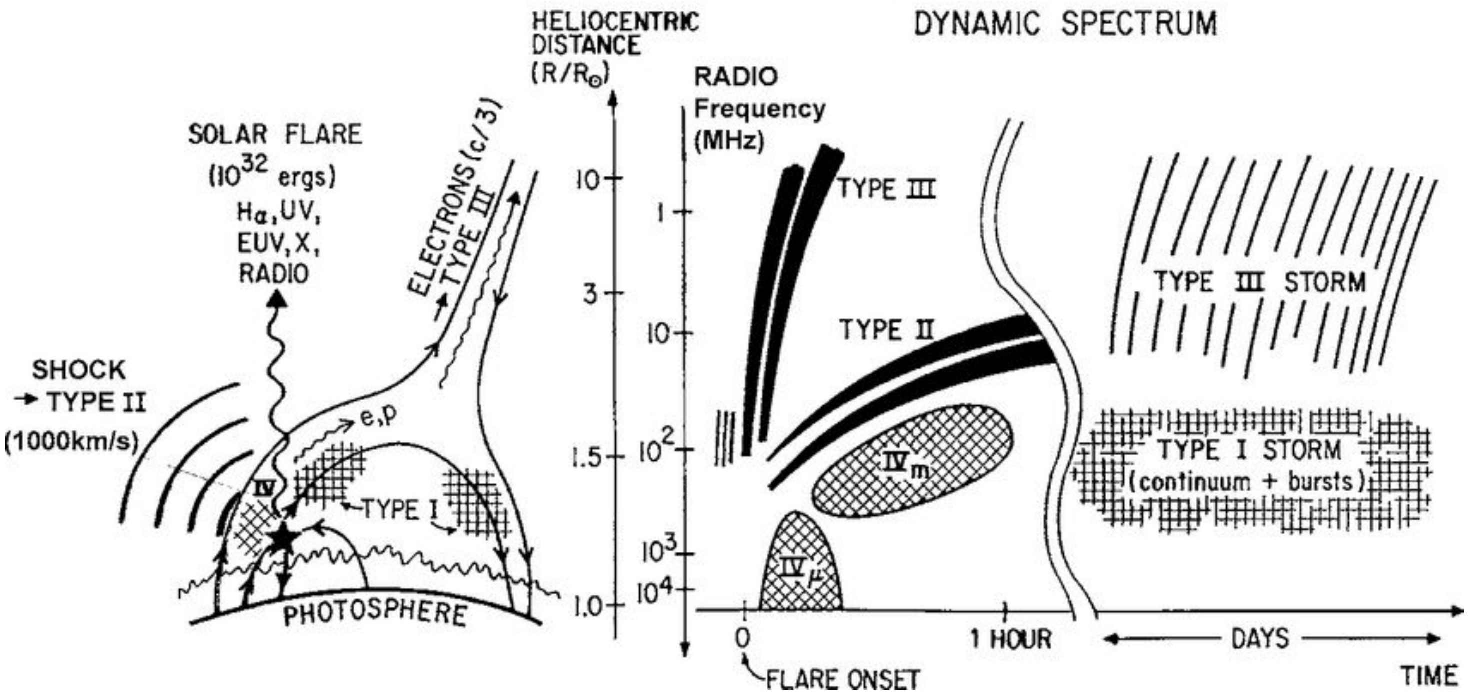


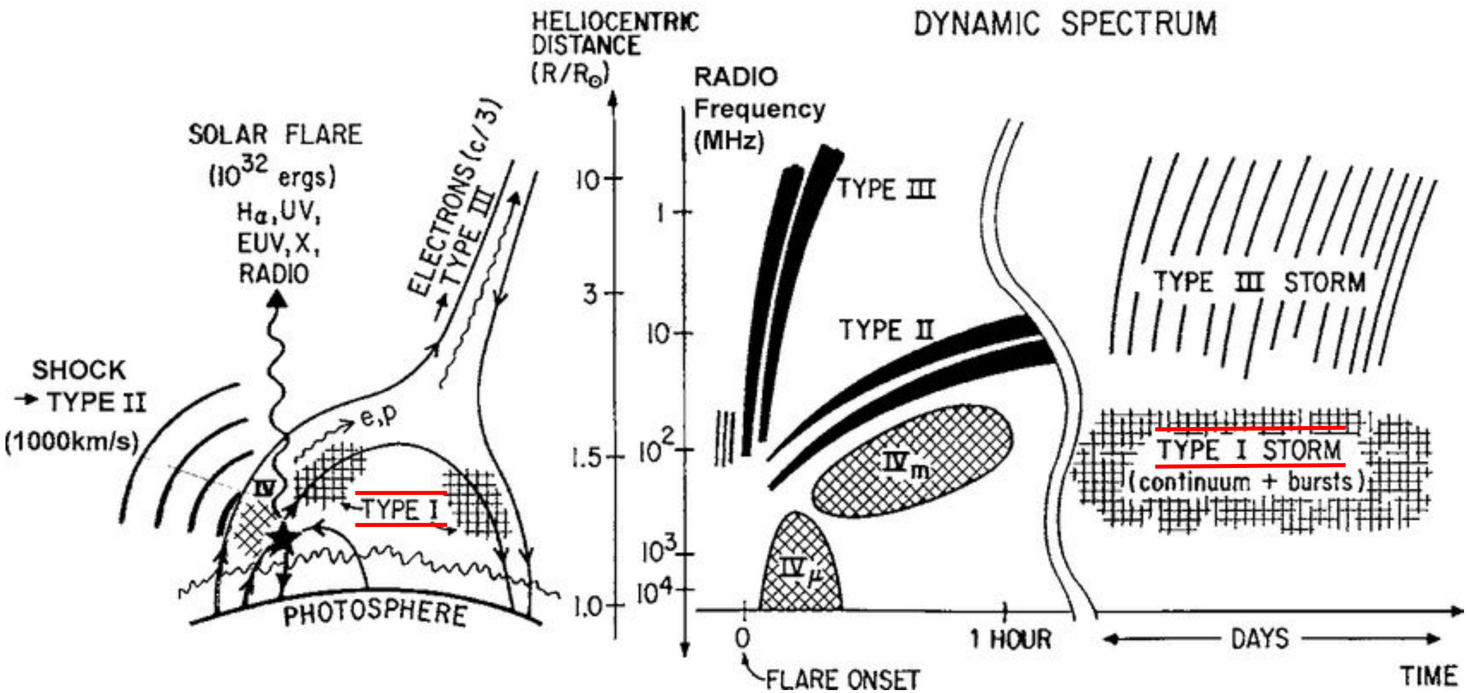
Radio Telescopes
Observing solar radio bursts



- Radio bursts are emitted by **accelerated electrons**
- Emission frequency depends on local density
- Each type has a recognizable signature in the *dynamic spectrum*
- The differences among them depend on their emission mechanism and the coronal structures where they are produced

Solar Radio Bursts

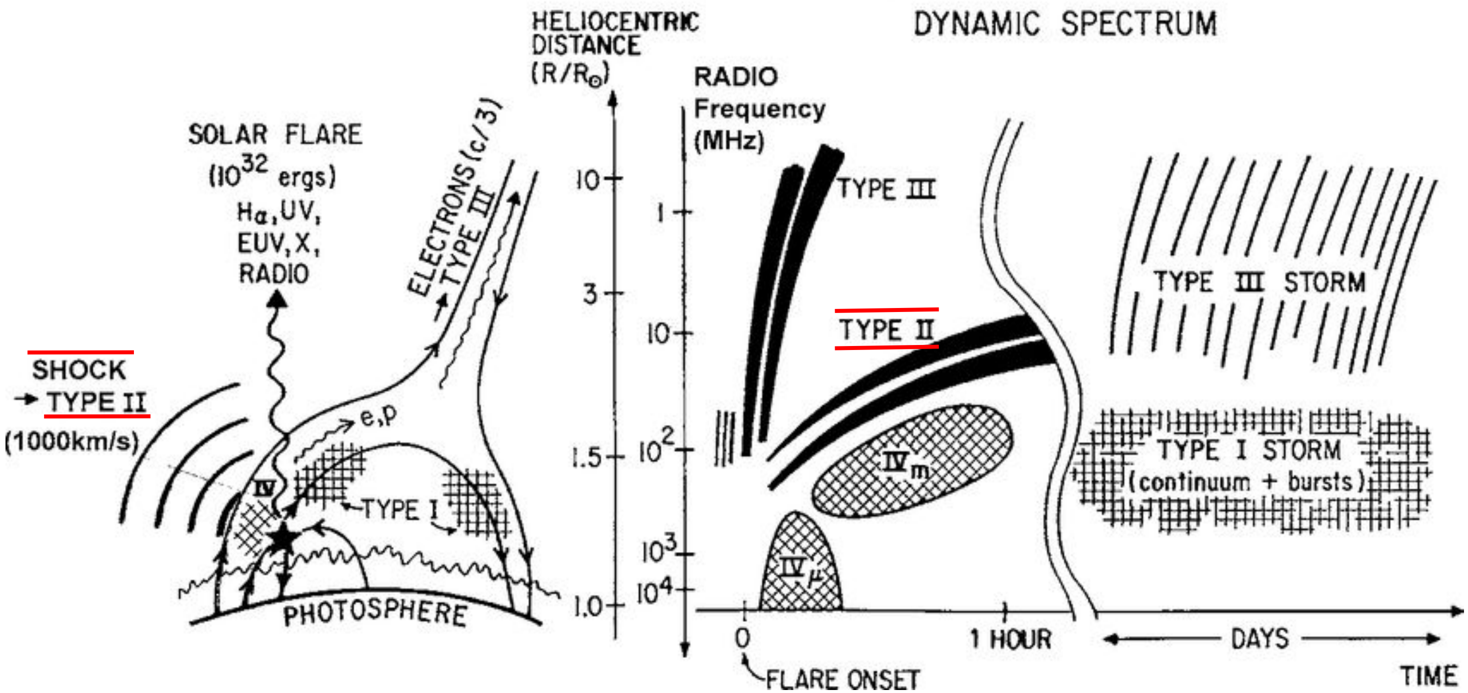
Type I



- *Noise storms* producing Type I bursts are attributed to closed loop systems
- Storms are the only non-thermal emissions at metric wavelengths that are relatively permanent near the active regions

Solar Radio Bursts

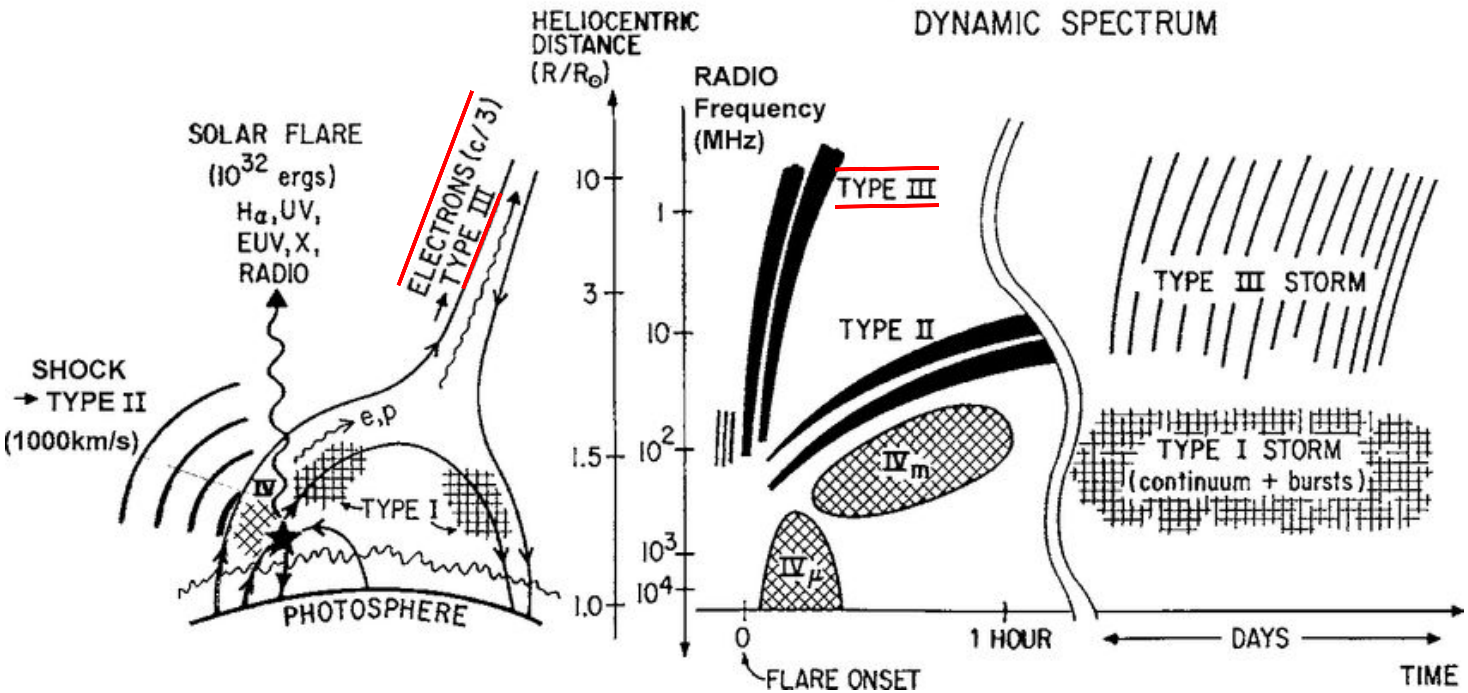
Type II



- Generally attributed to fast electrons accelerated by the CME-driven shock wave
- Type II drift rate and selected coronal electron density model can provide an estimate of the shock wave speed

Solar Radio Bursts

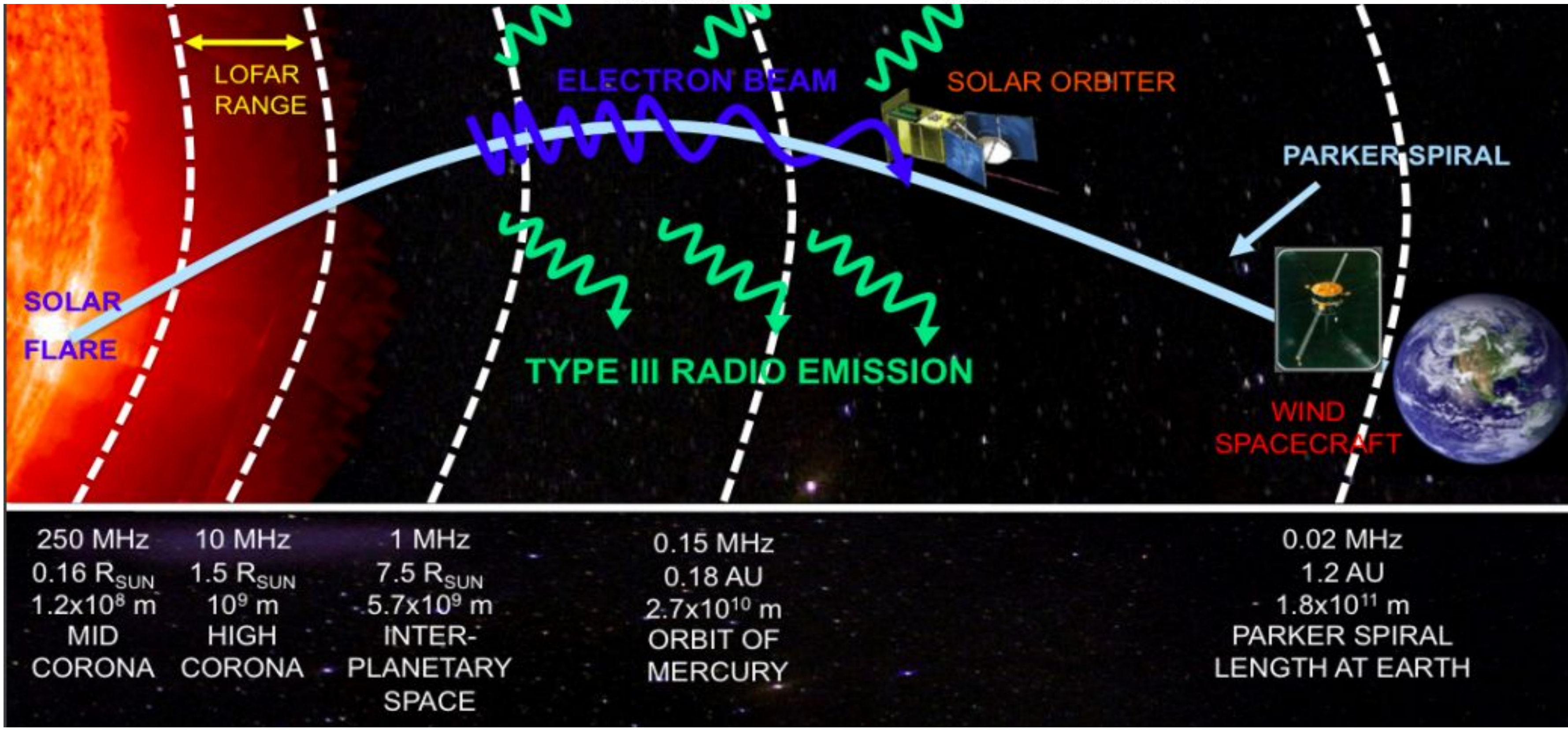
Type III



- Type III burst is created by an electron beam through plasma emission
- The radio emission tracks the electron beam as it travels through the decreasing plasma density of the solar corona and solar wind

Solar Radio Bursts

Type III

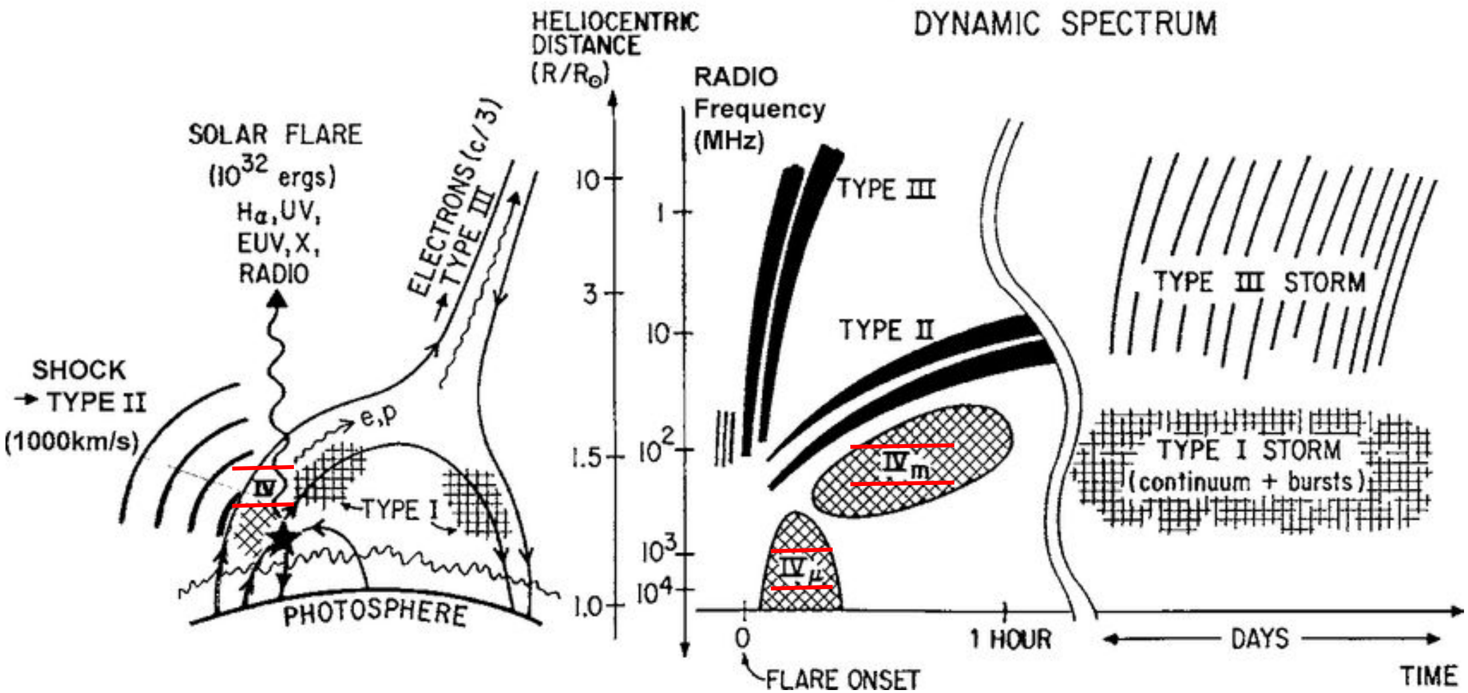


Source: H. Reid

- The radio emission tracks the electron beam as it travels through the decreasing plasma density of the solar corona and solar wind

Solar Radio Bursts

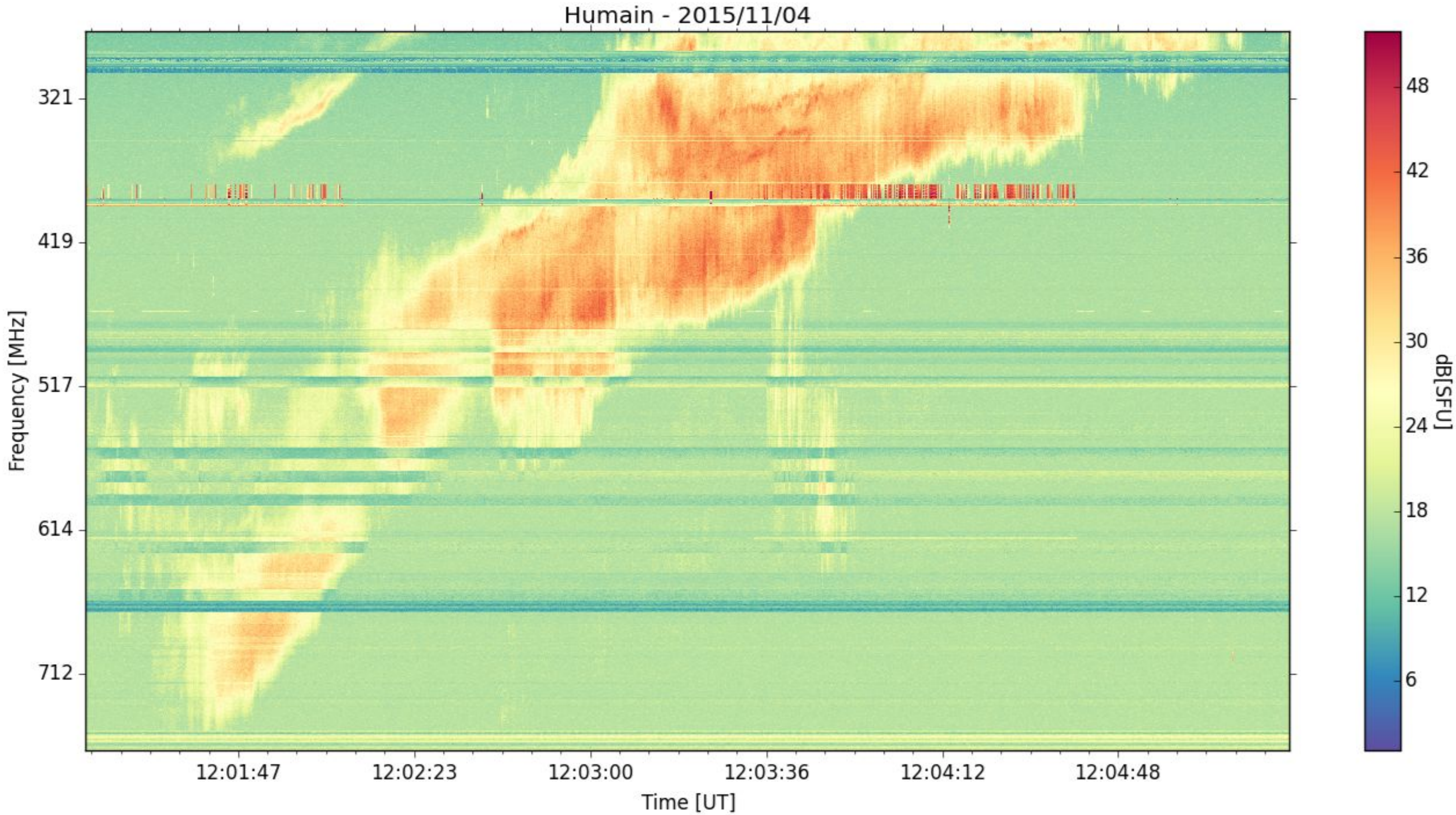
Type IV



- Type IV bursts (stationary or moving) are common in large/explosive flares
- Due to plasma or *gyrosynchroton* emission
- Cause: electron populations trapped in eruptive flux ropes and post-flare loops

November 4th, 2015

Observations at Humain Radio-Astronomy Station



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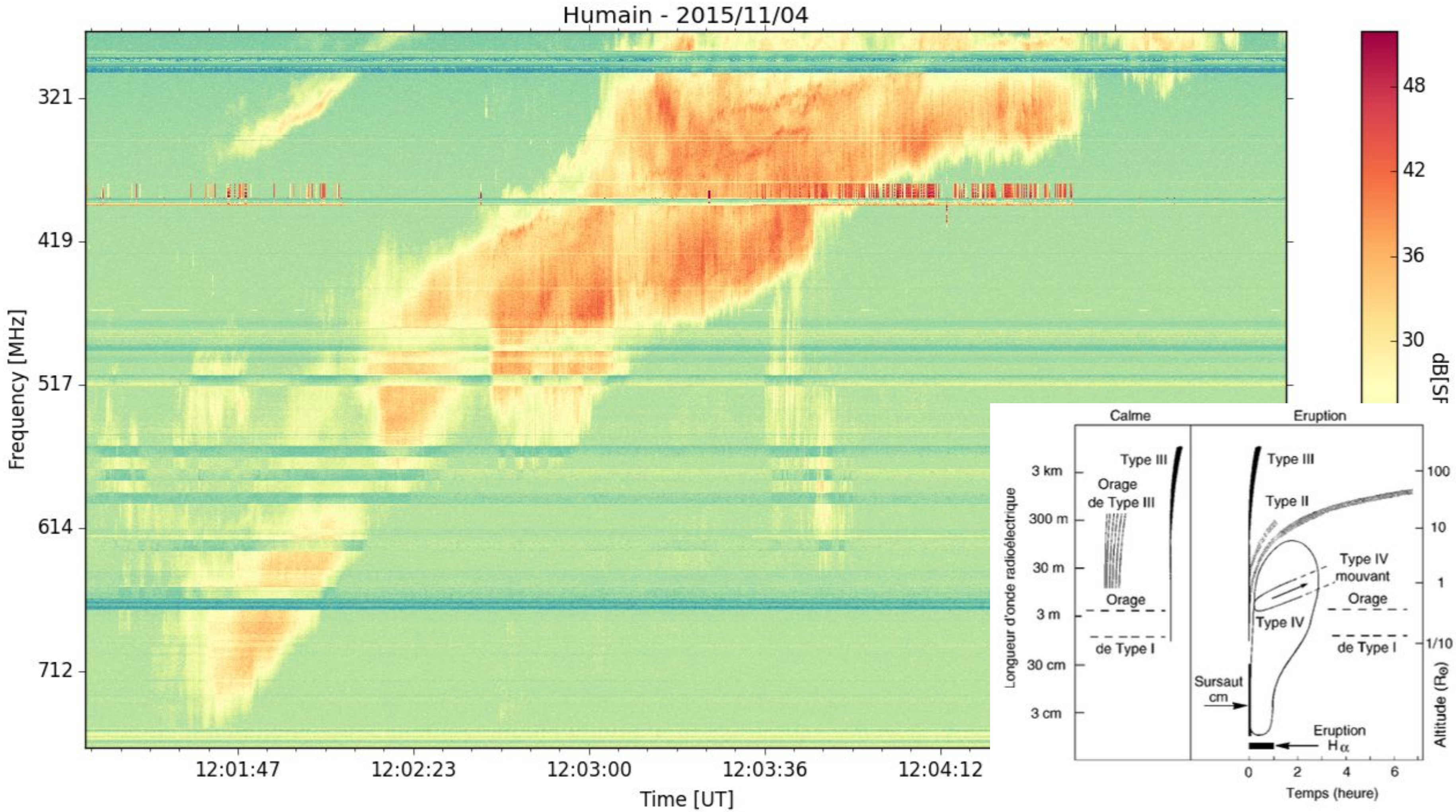

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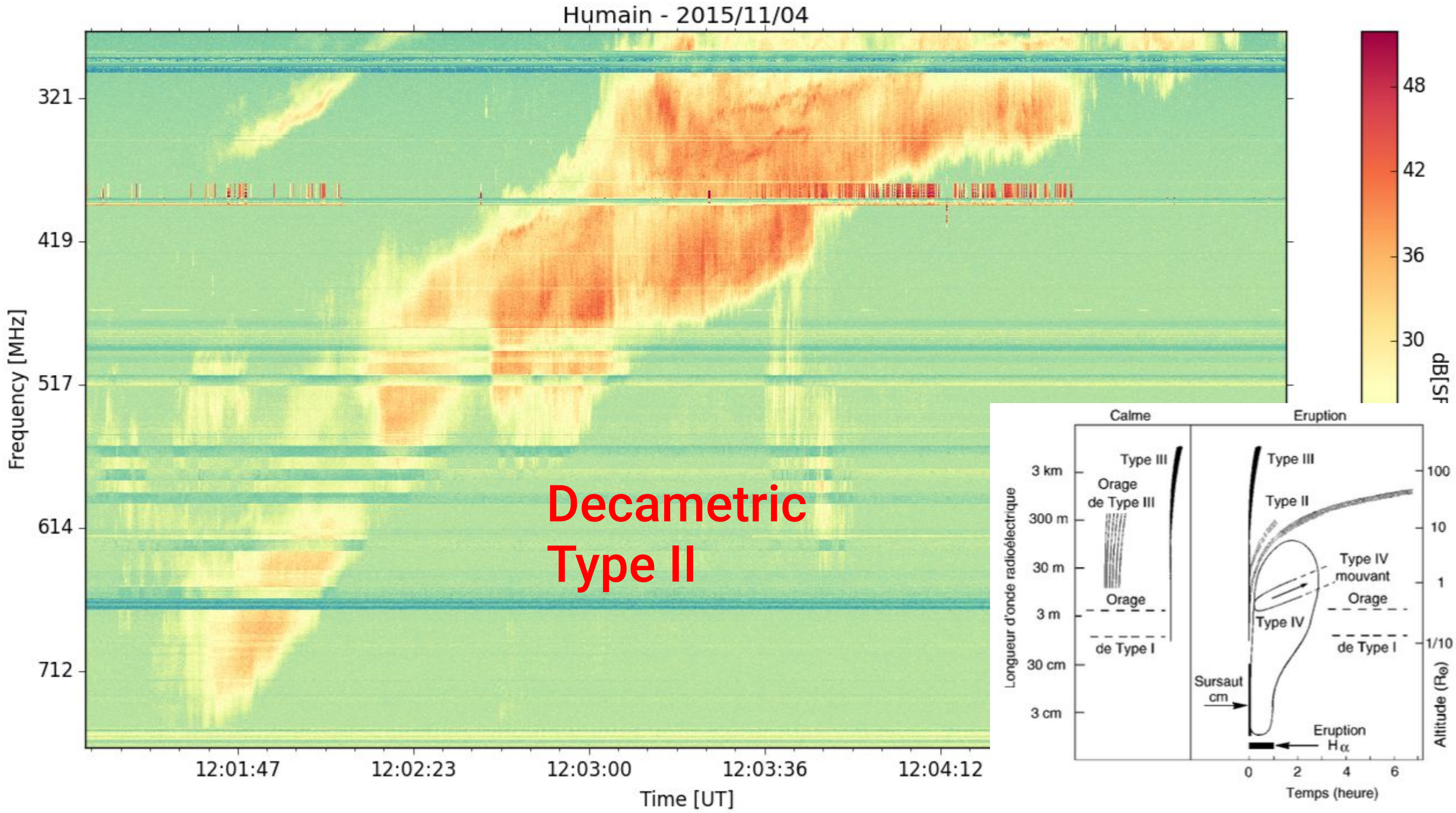

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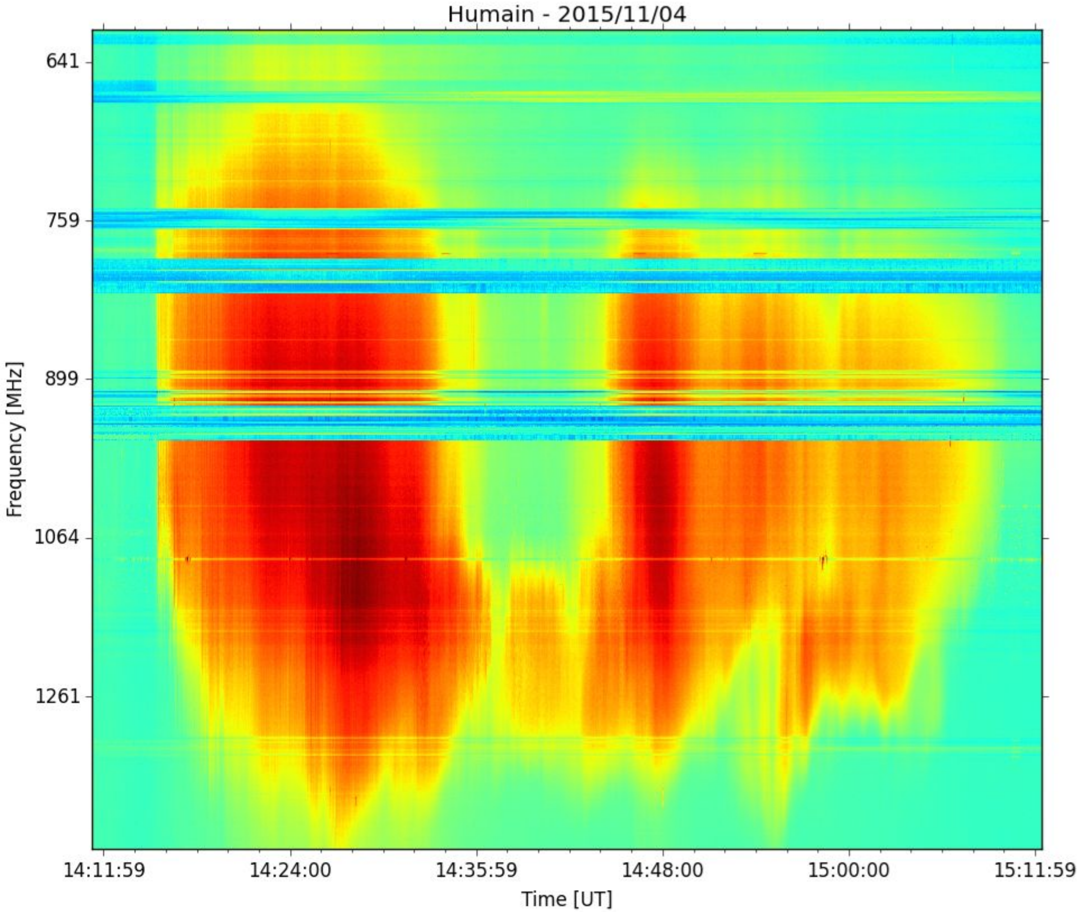
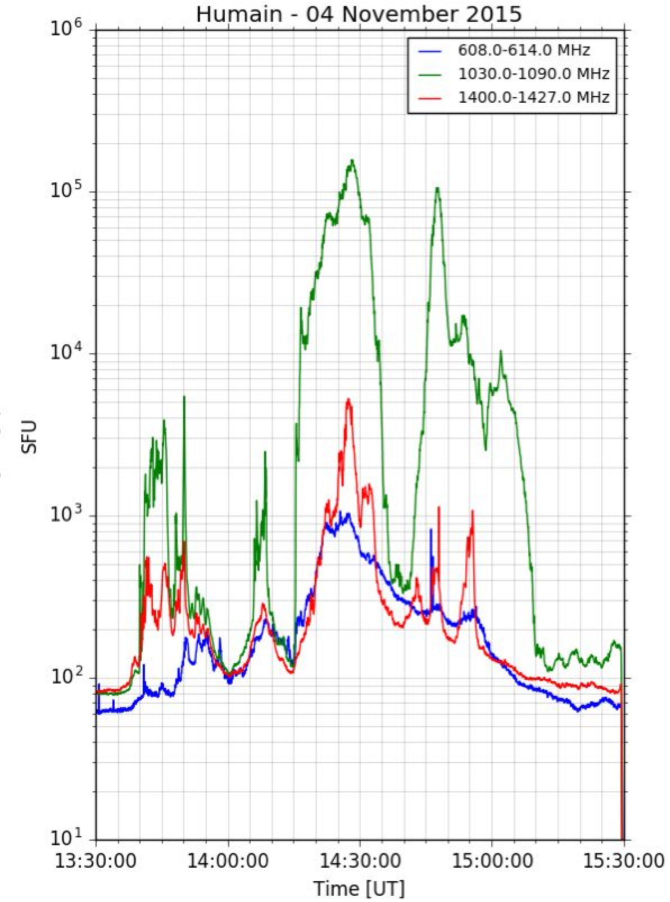
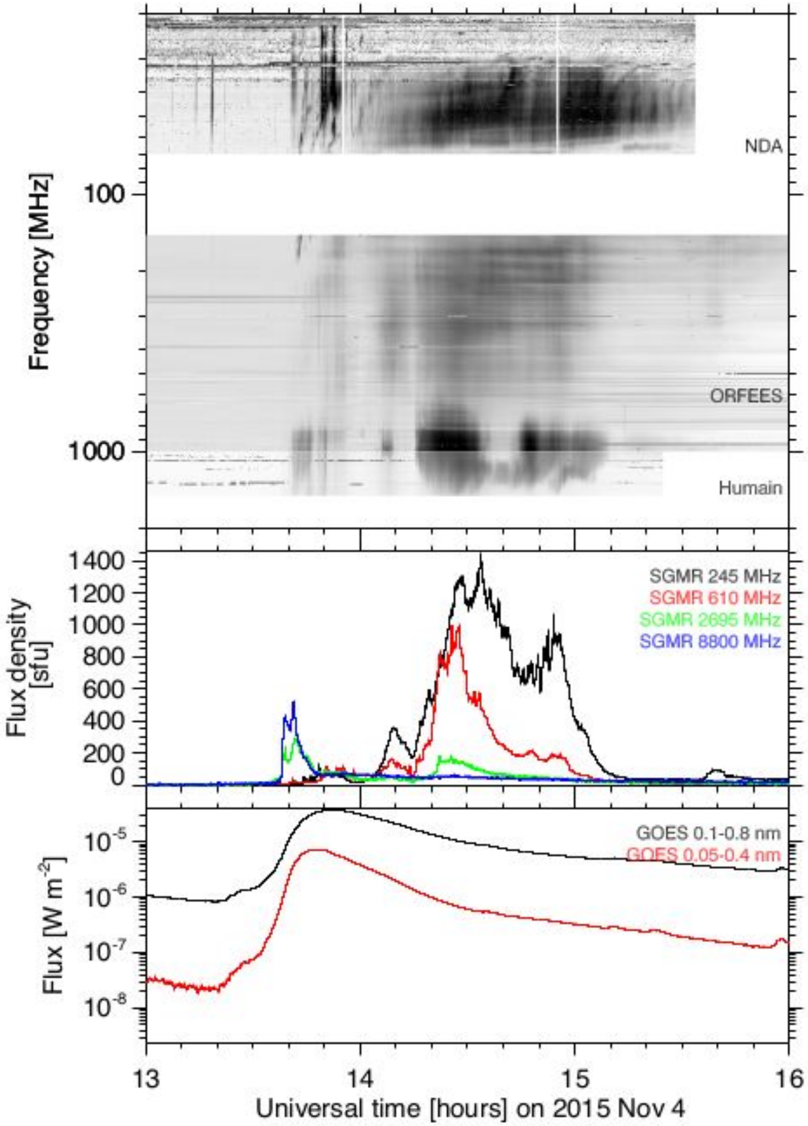
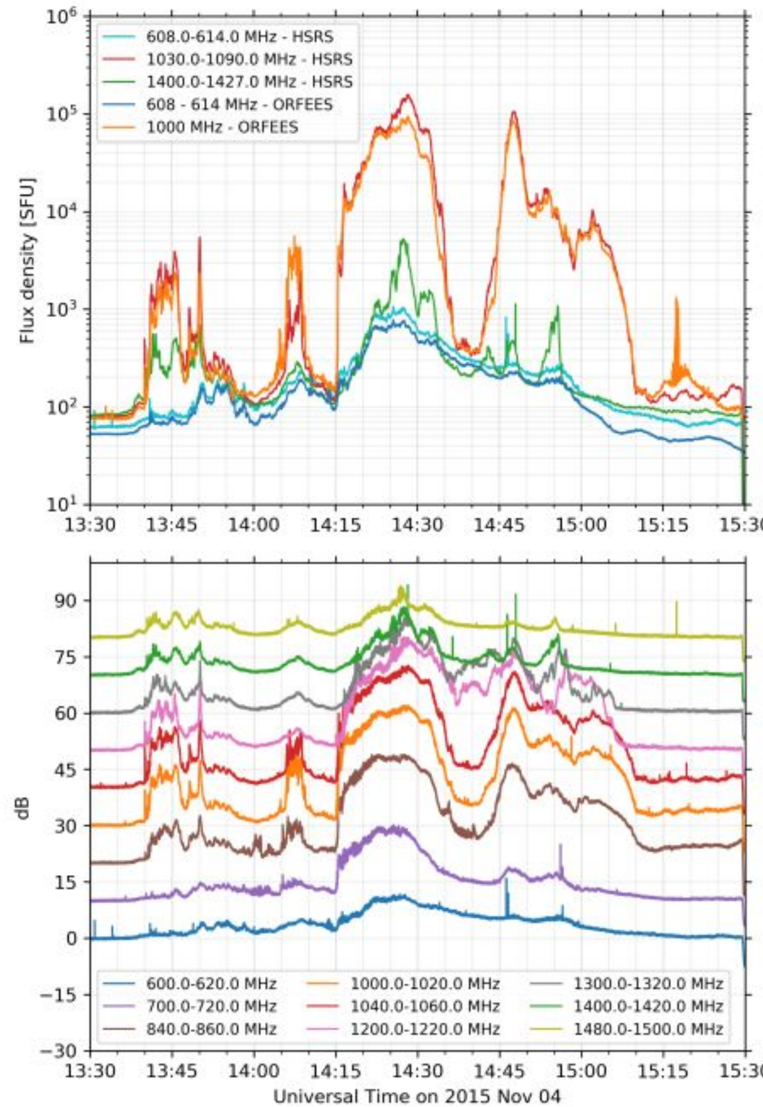




November 4th, 2015

Combined observations (Humain + Nançay)





Source: C. Marqué et al, 2018

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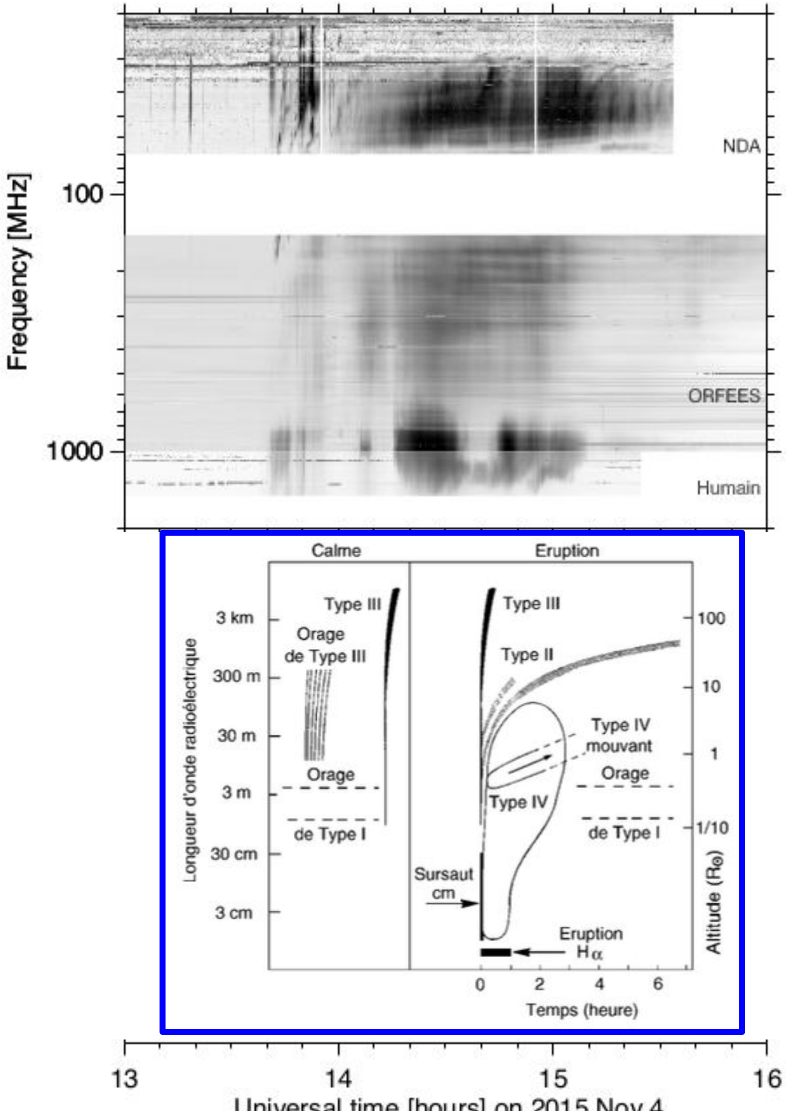

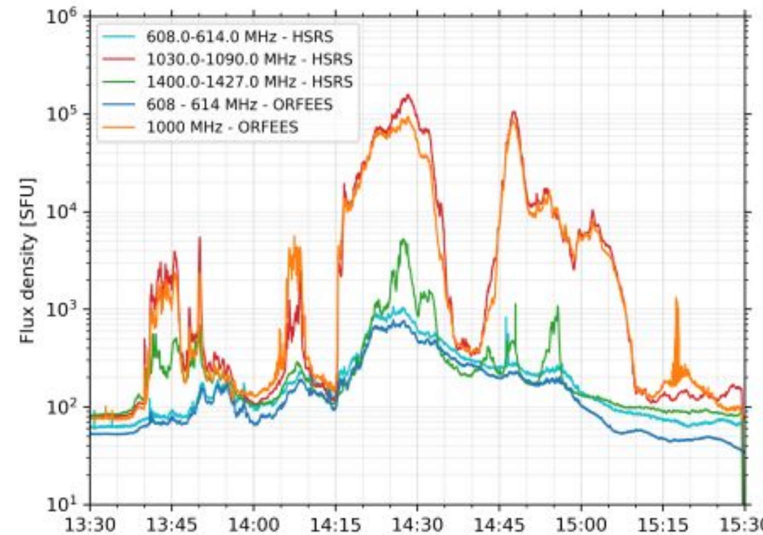

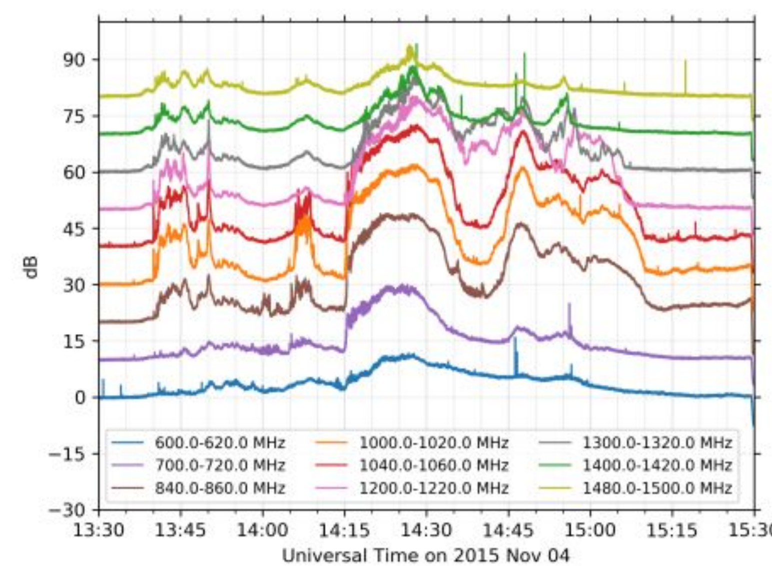

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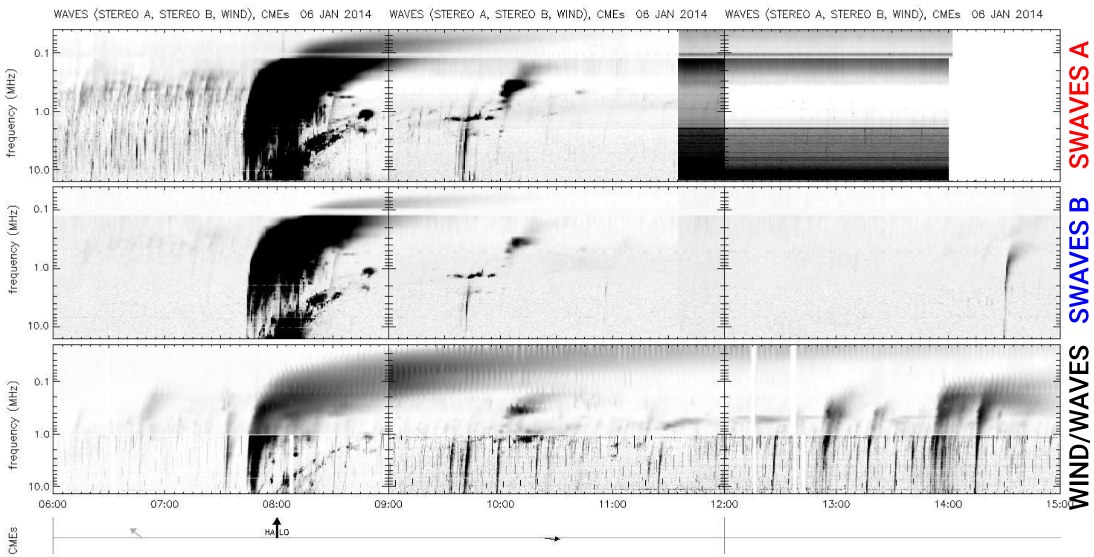
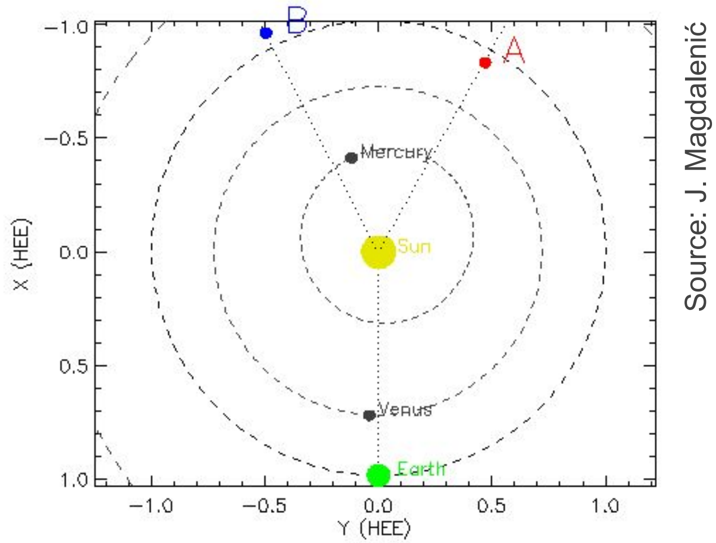
Radio Sun & Space Weather

Analysis of data





<u>Observed</u>:

1. interplanetary type II & type III bursts
2. intensity of the radio emission different for different spacecraft:
   - Strongest emission SWAVES A,
   - Type III bursts intensity stronger for SWAVES A than for SWAVES B?!

<u>Deduced</u>:

1. Flare & fast and wide CME,
2. Direction of the CME propagation between SWAVES A & SWAVES B?!
   ↳More towards SWAVES A.
3. Back side event? Strongly southward propagating or west solar limb event?!
4. CME-driven interplanetary shock wave

Radio Sun & Space Weather

Some tips for forecasters

- When eruptions are observed in optics, radio or X-rays, it is possible to “predict” the potential arrival of solar protons and -to some extent- their intensity and even the temporal profile

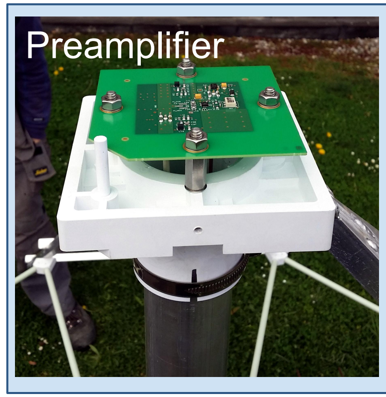
- These parameters are statistically related to the importance of the eruption and its position on the solar disk

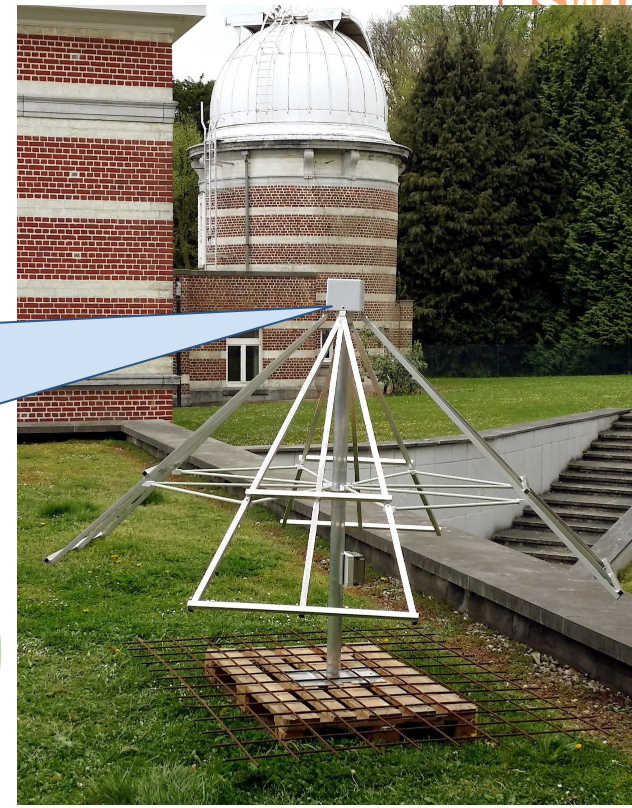
- Radio observations are very useful for the space weather forecasting purposes because they bring a number of indications on the characteristics of the associated flare/CME event & associated shock wave.

Radio Telescopes

Basic element antennas

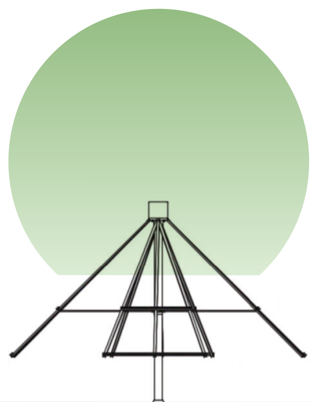
Station de Radioastronomie de Nançay





Antenna Pattern

G_{max} = 0.8 dBi

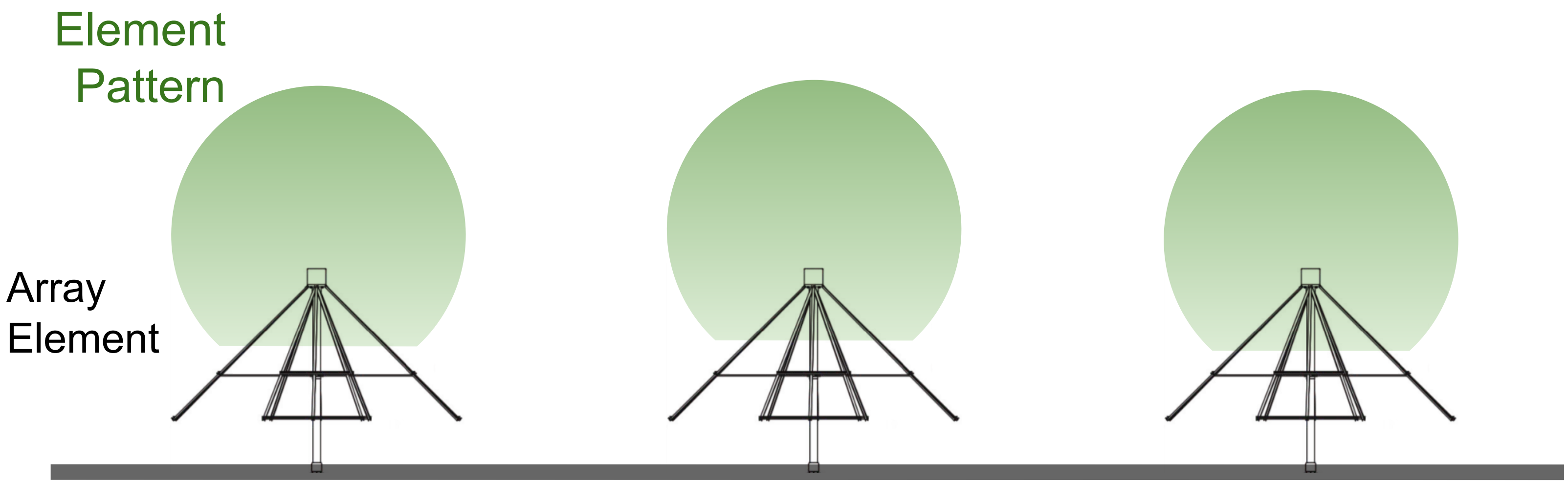


NENUFAR Project Antenna

- Cross *thick inverse vee*
- Additional conductive grid underneath
- Dual polarisation available

Beamforming technique

Principle



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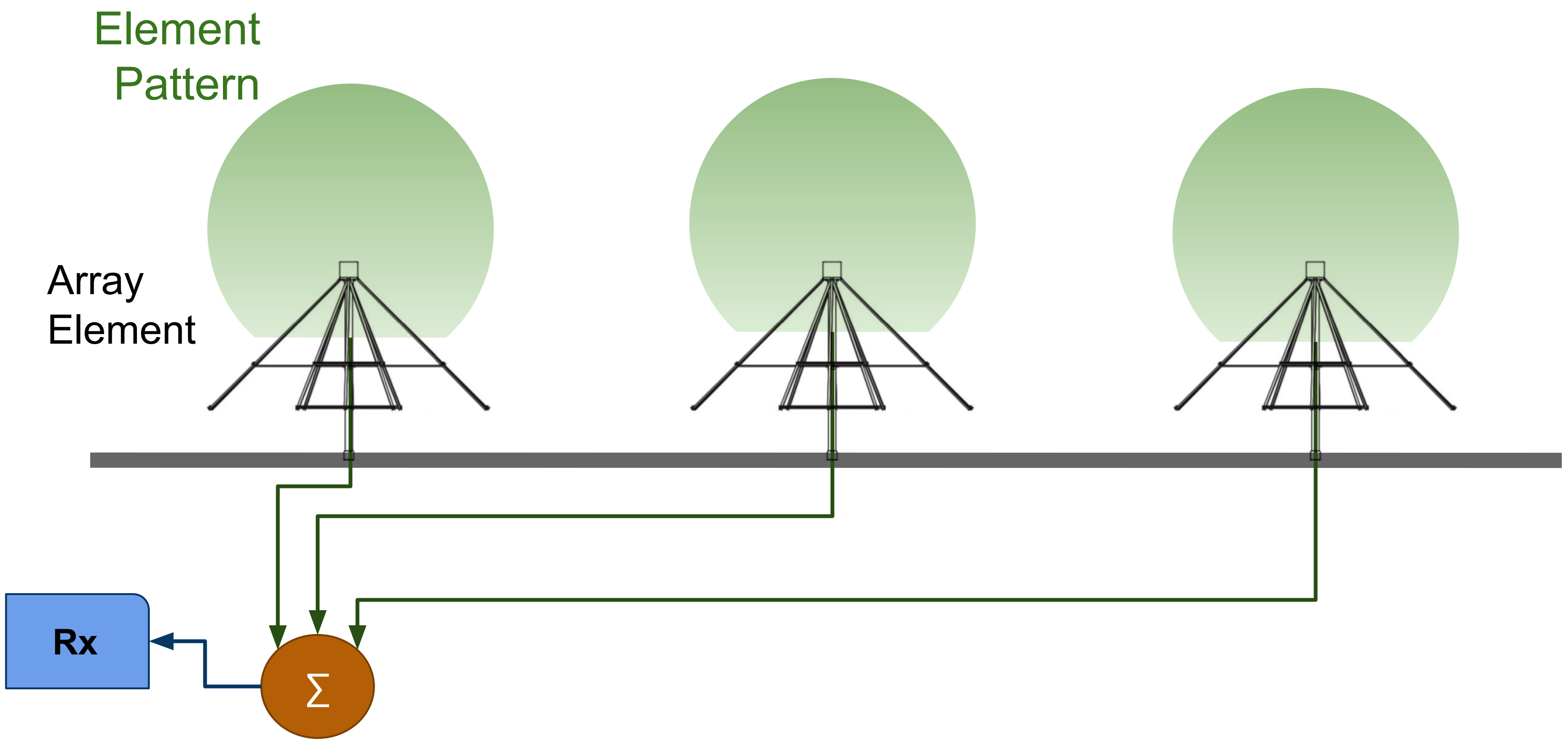

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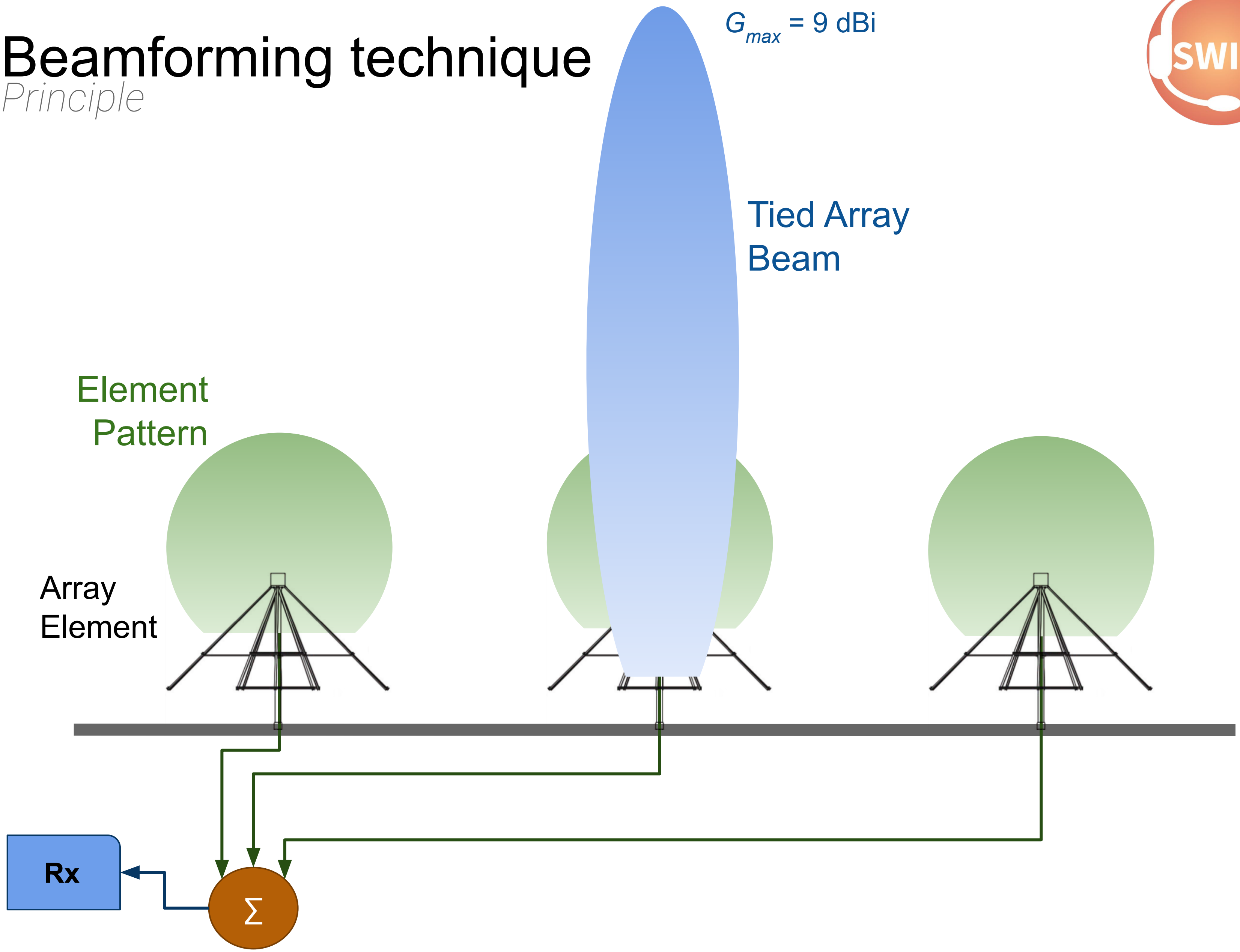

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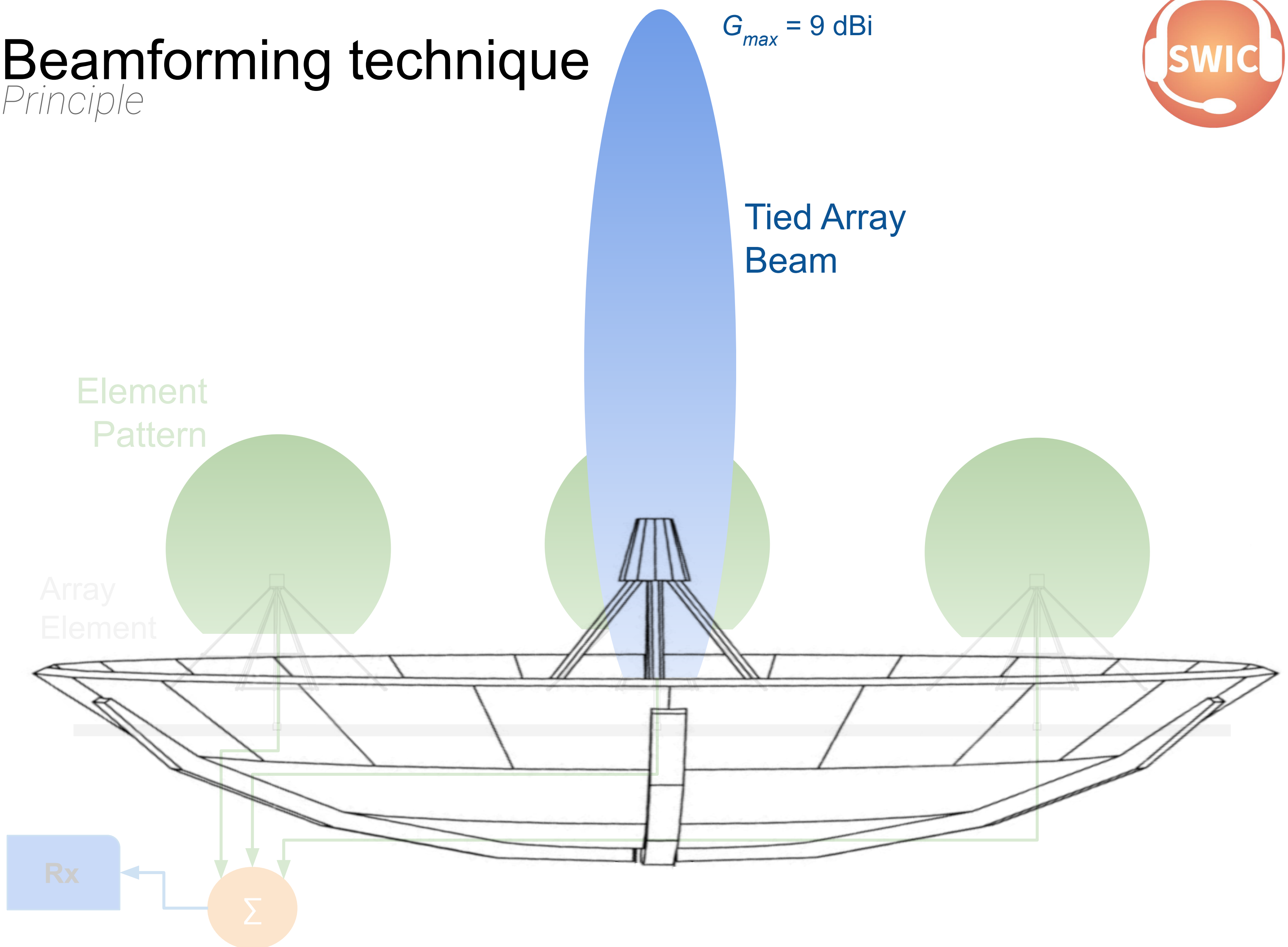

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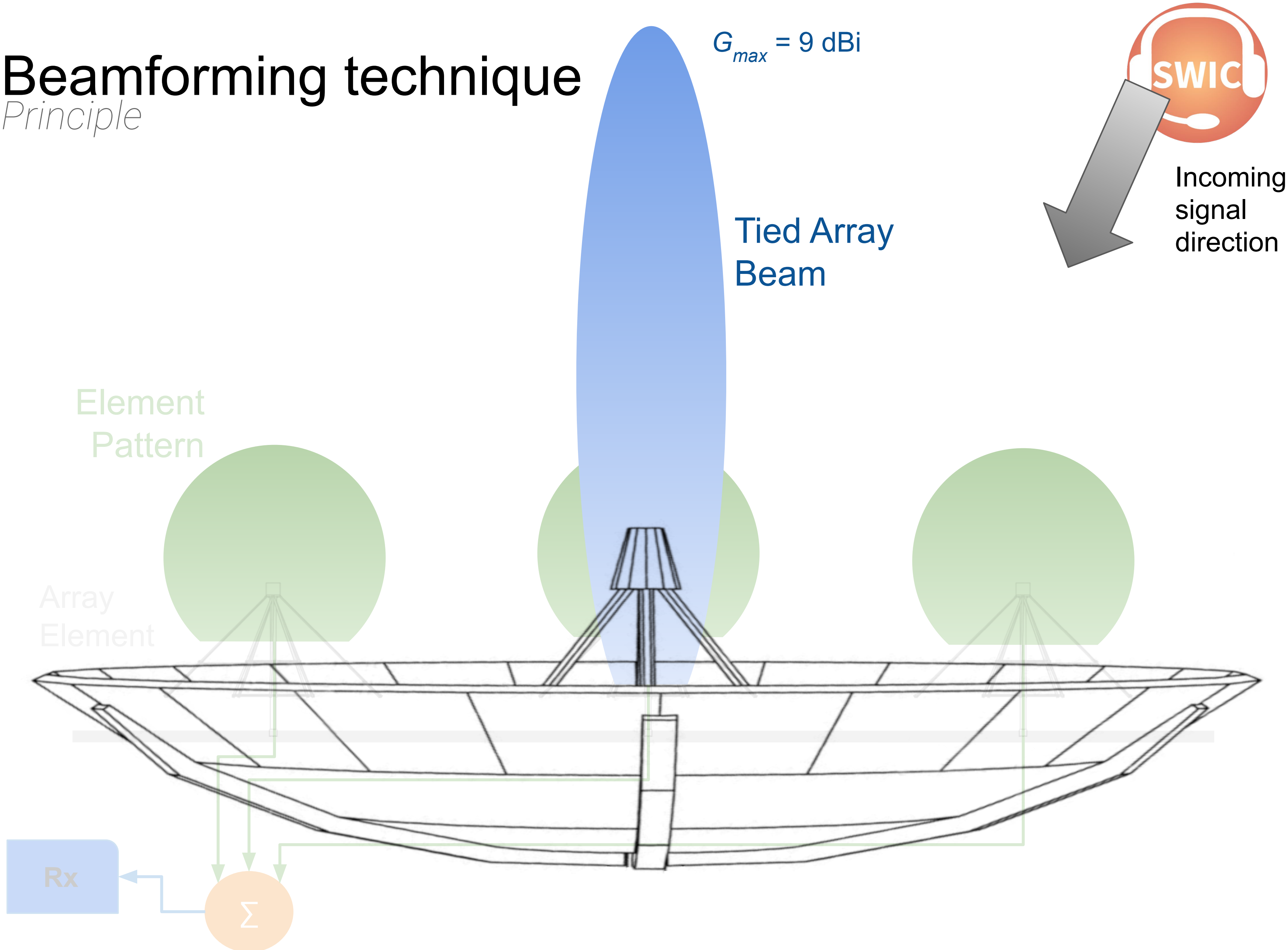

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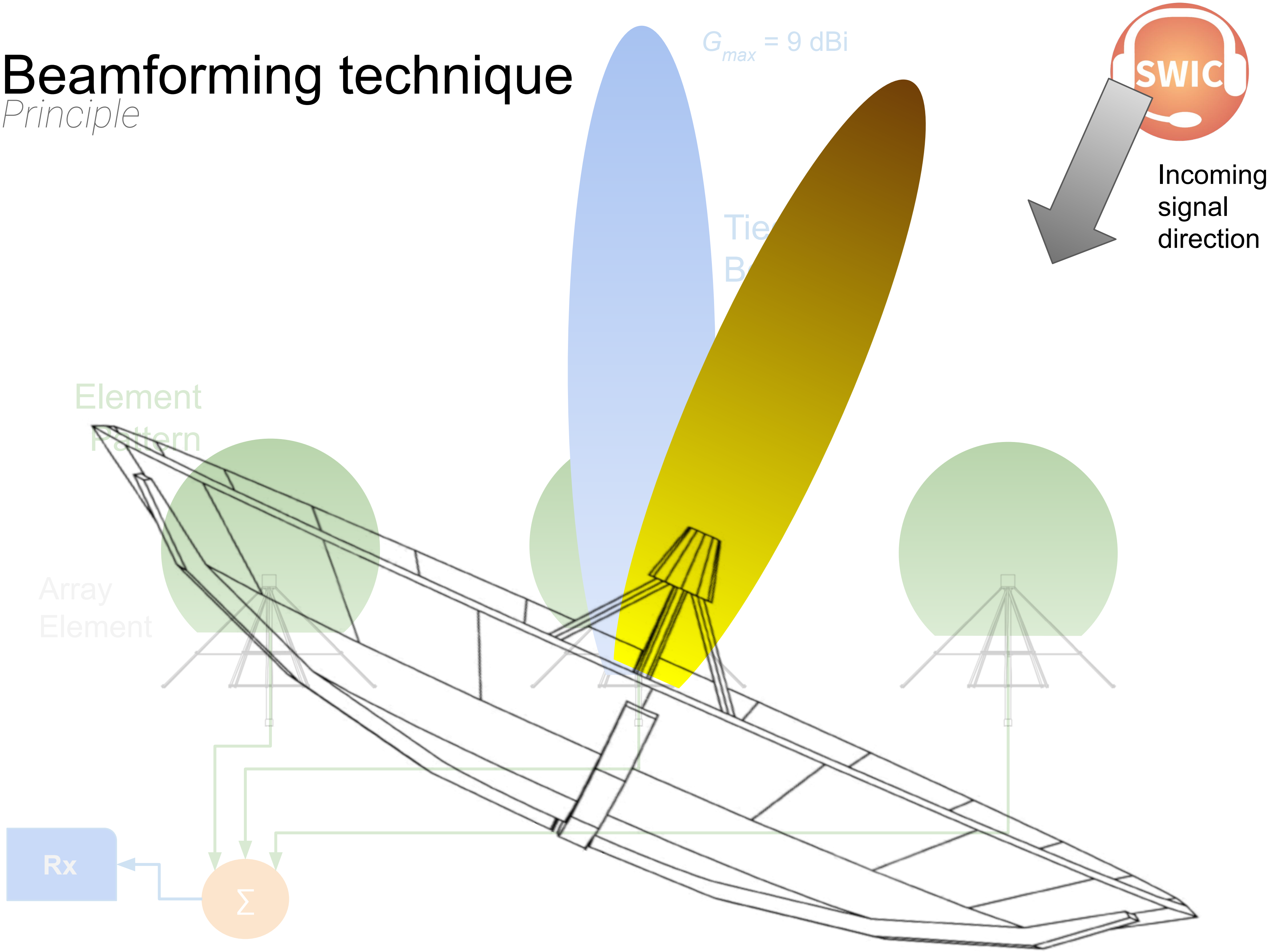

Beamforming technique

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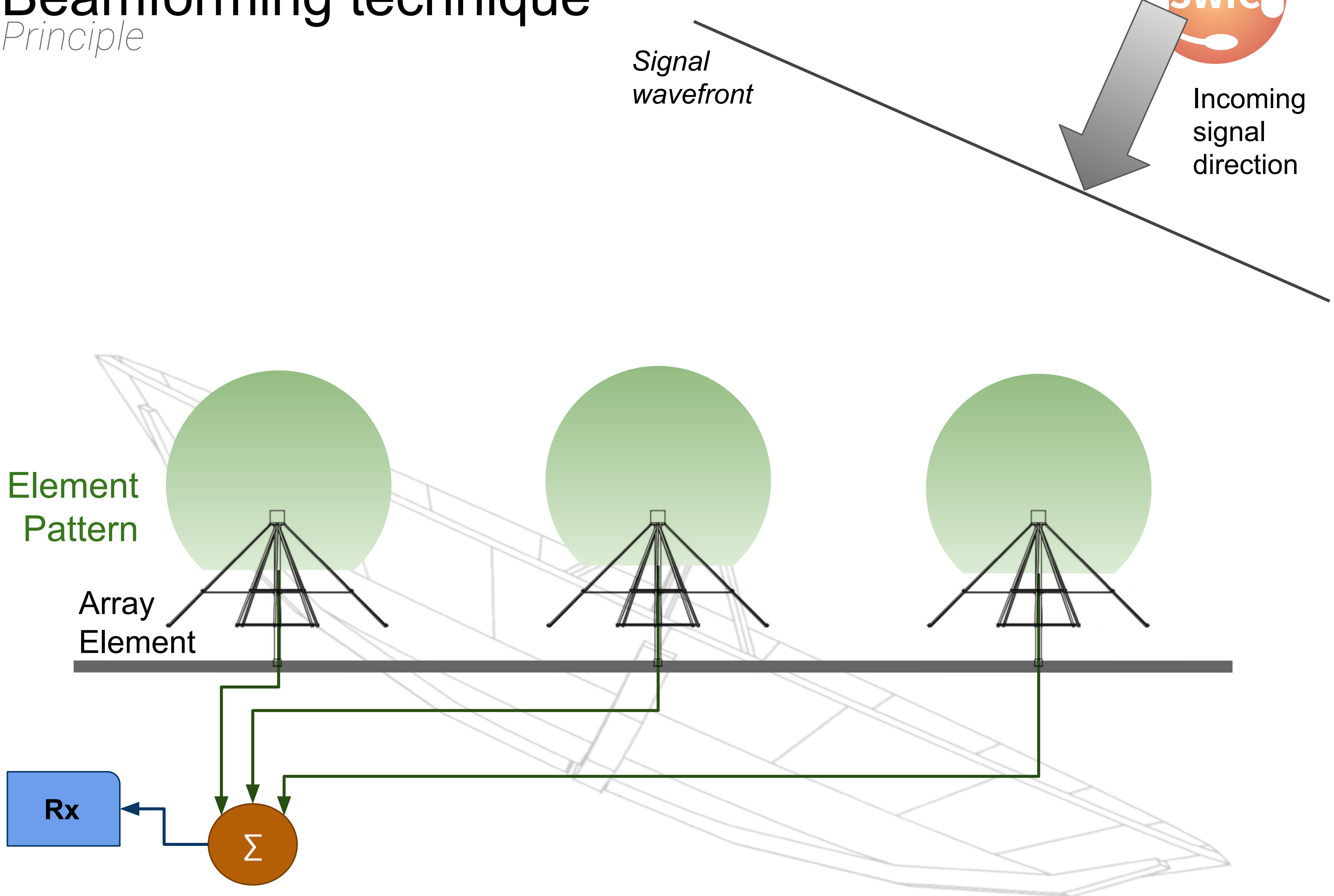
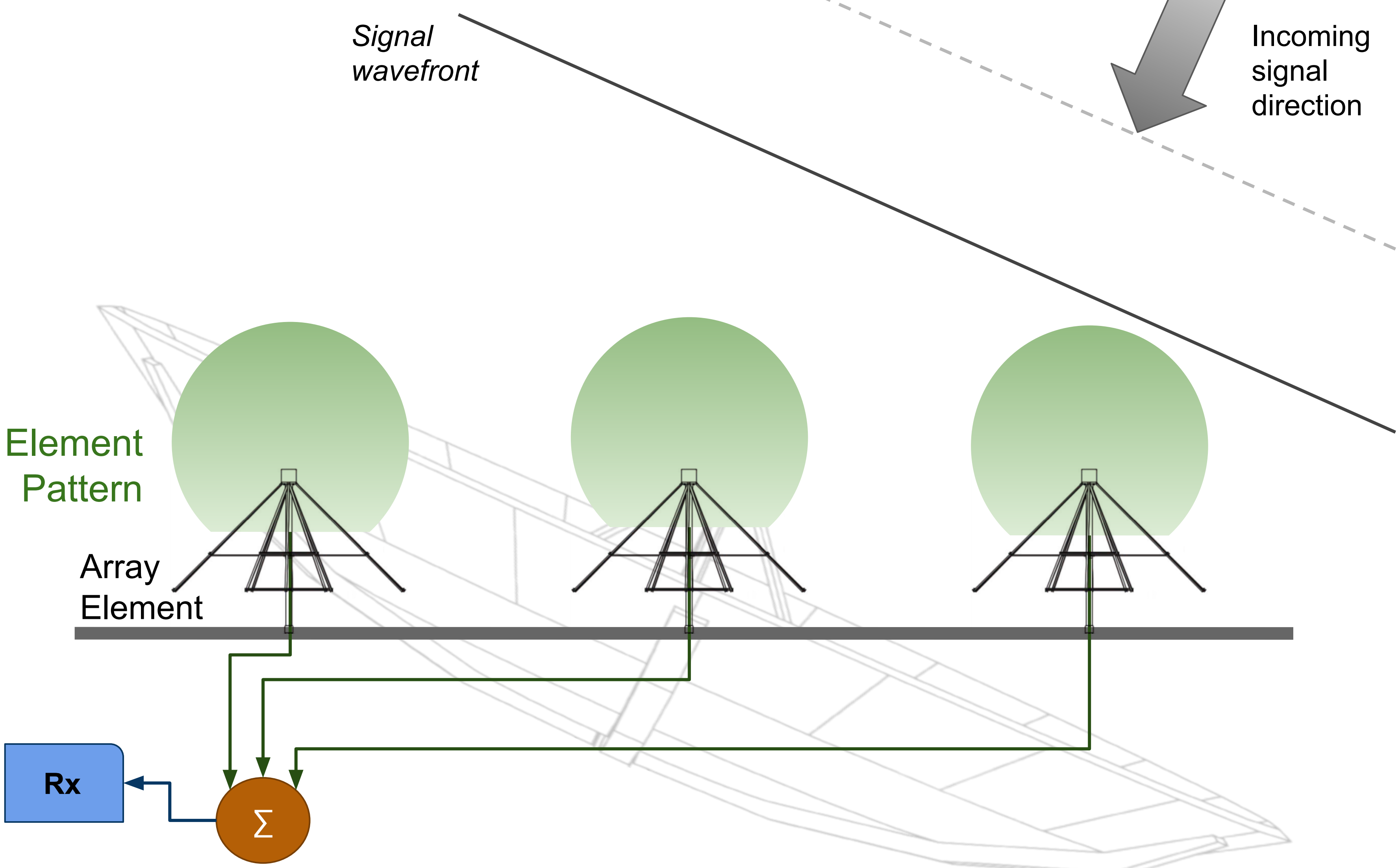


Beam-forming technique

Principle



Beamforming technique

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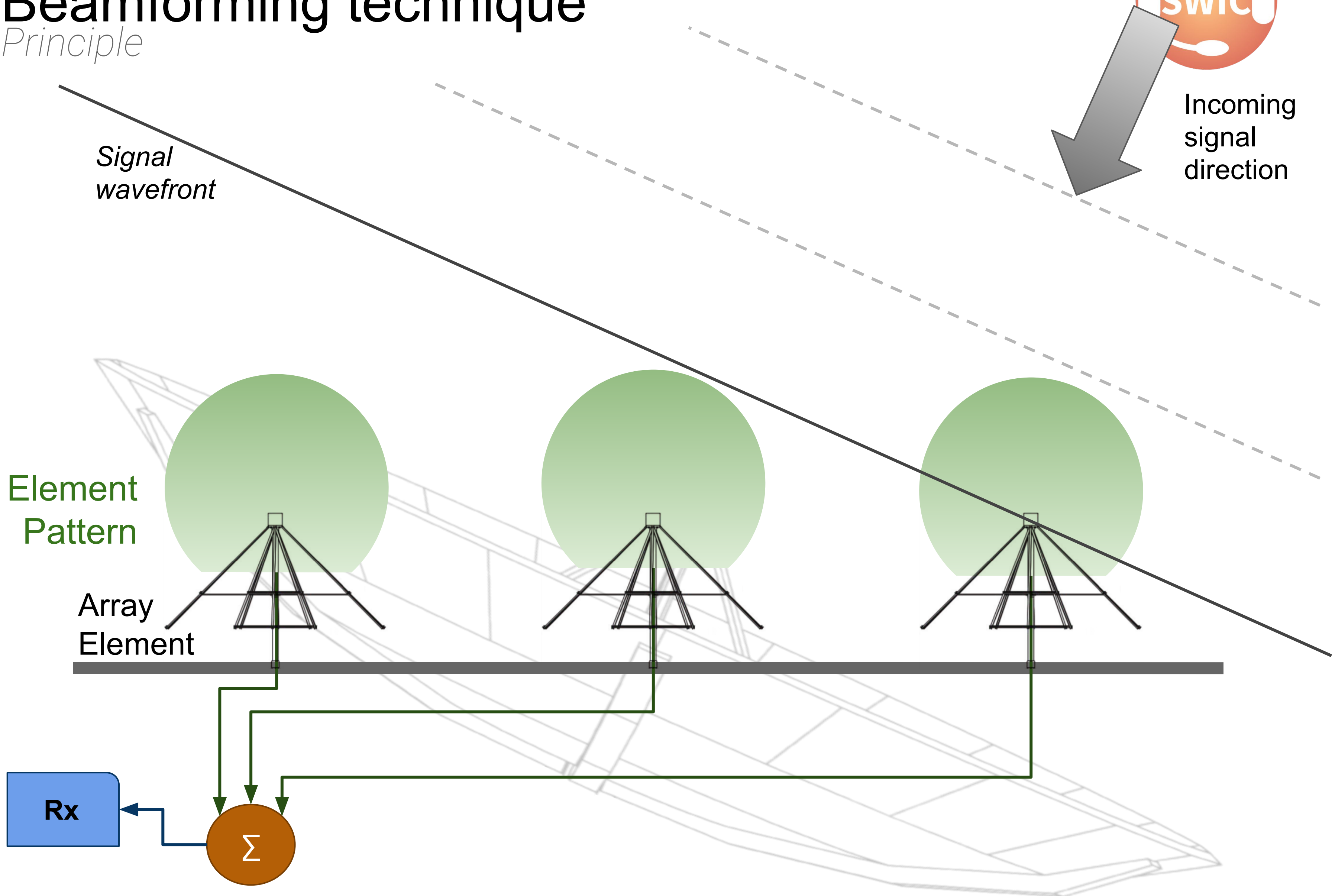

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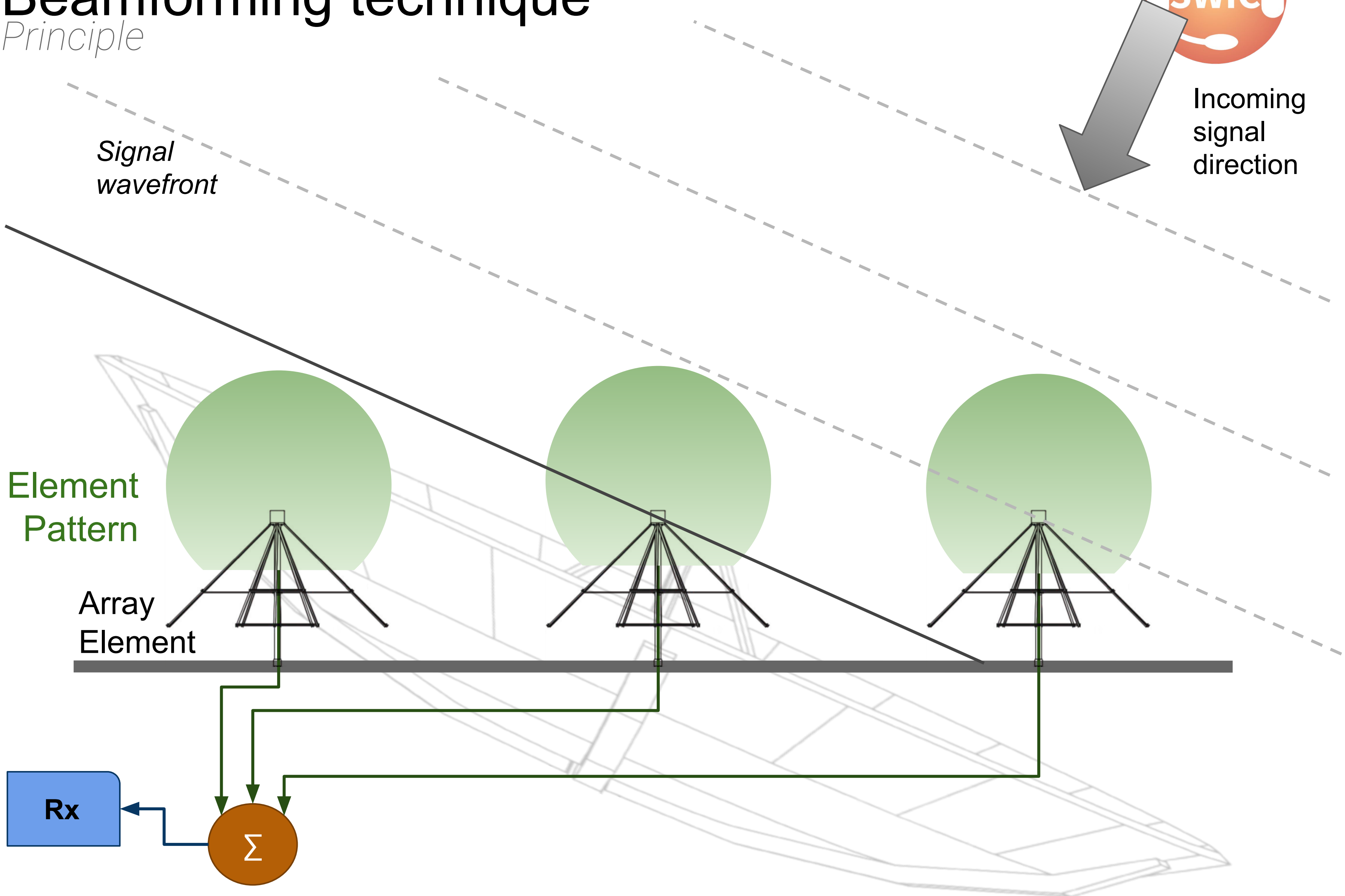

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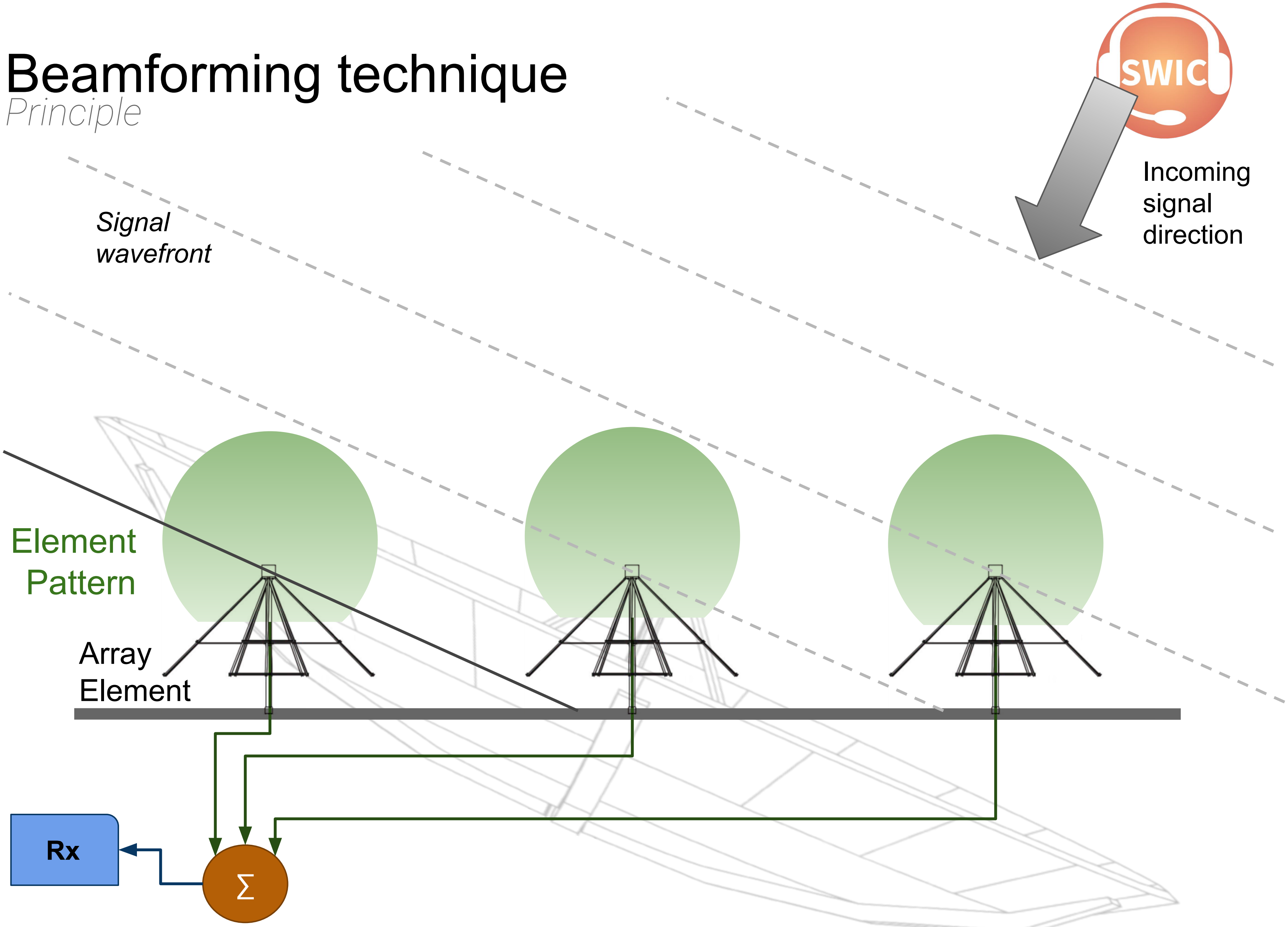

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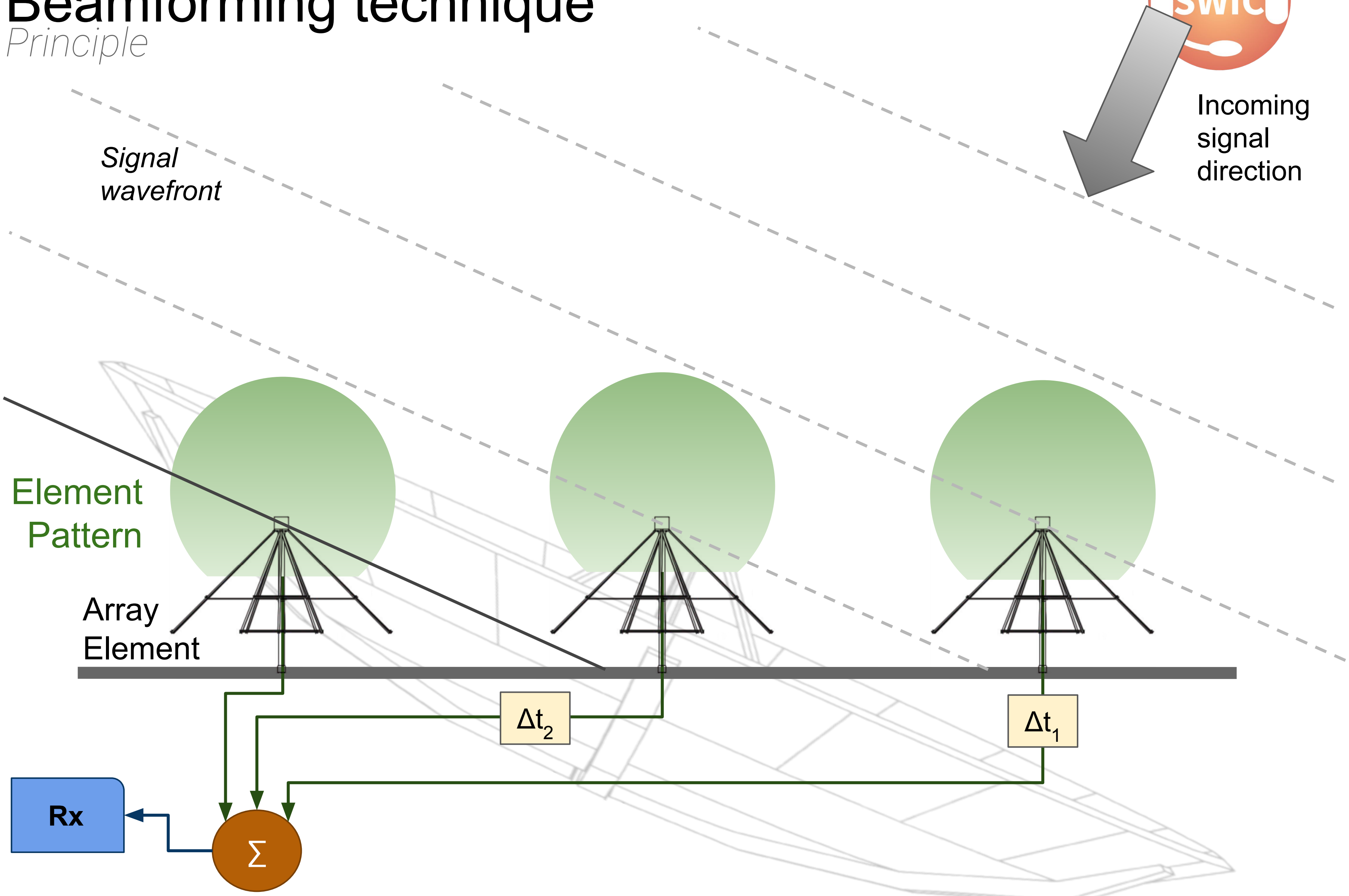

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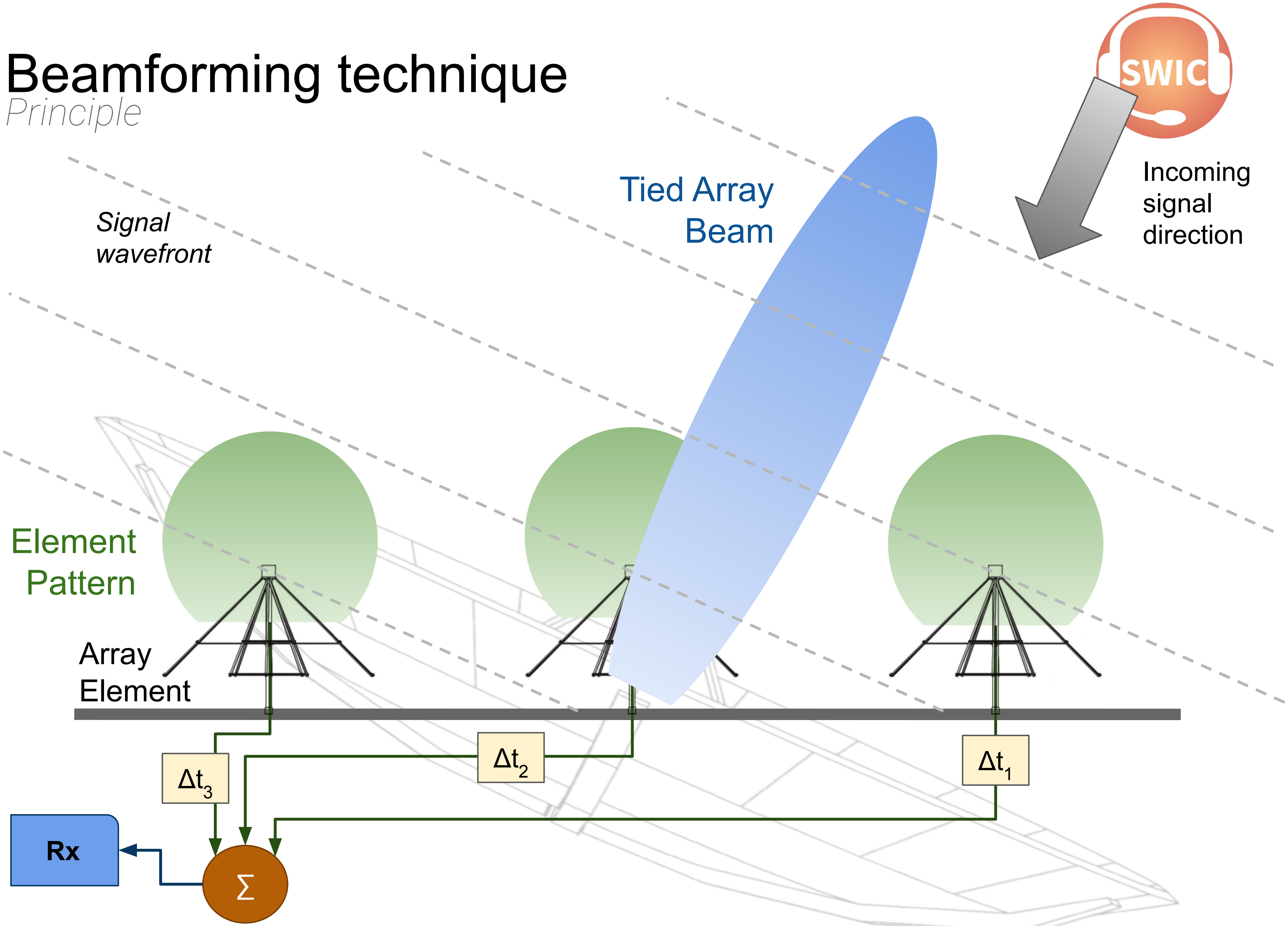

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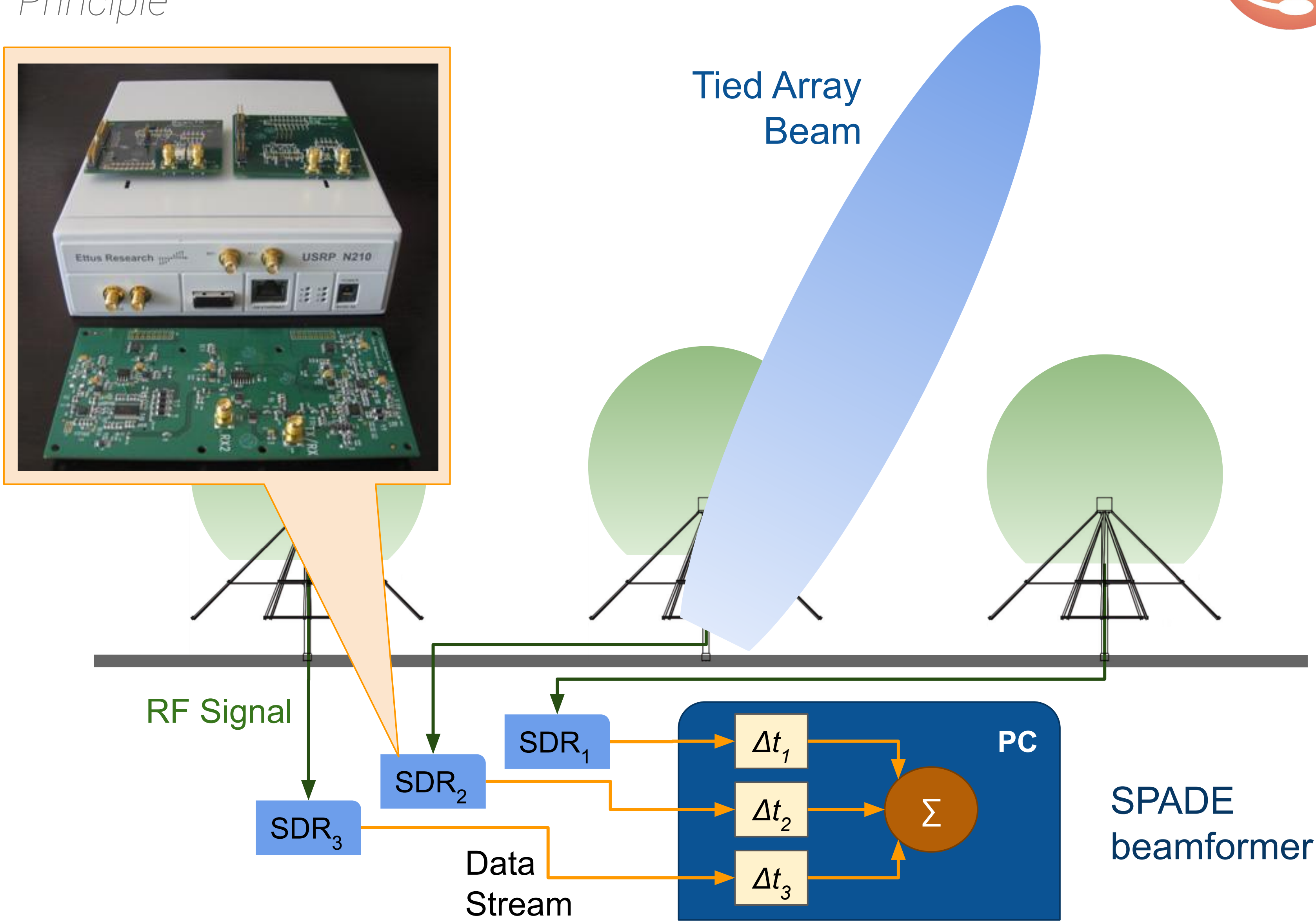
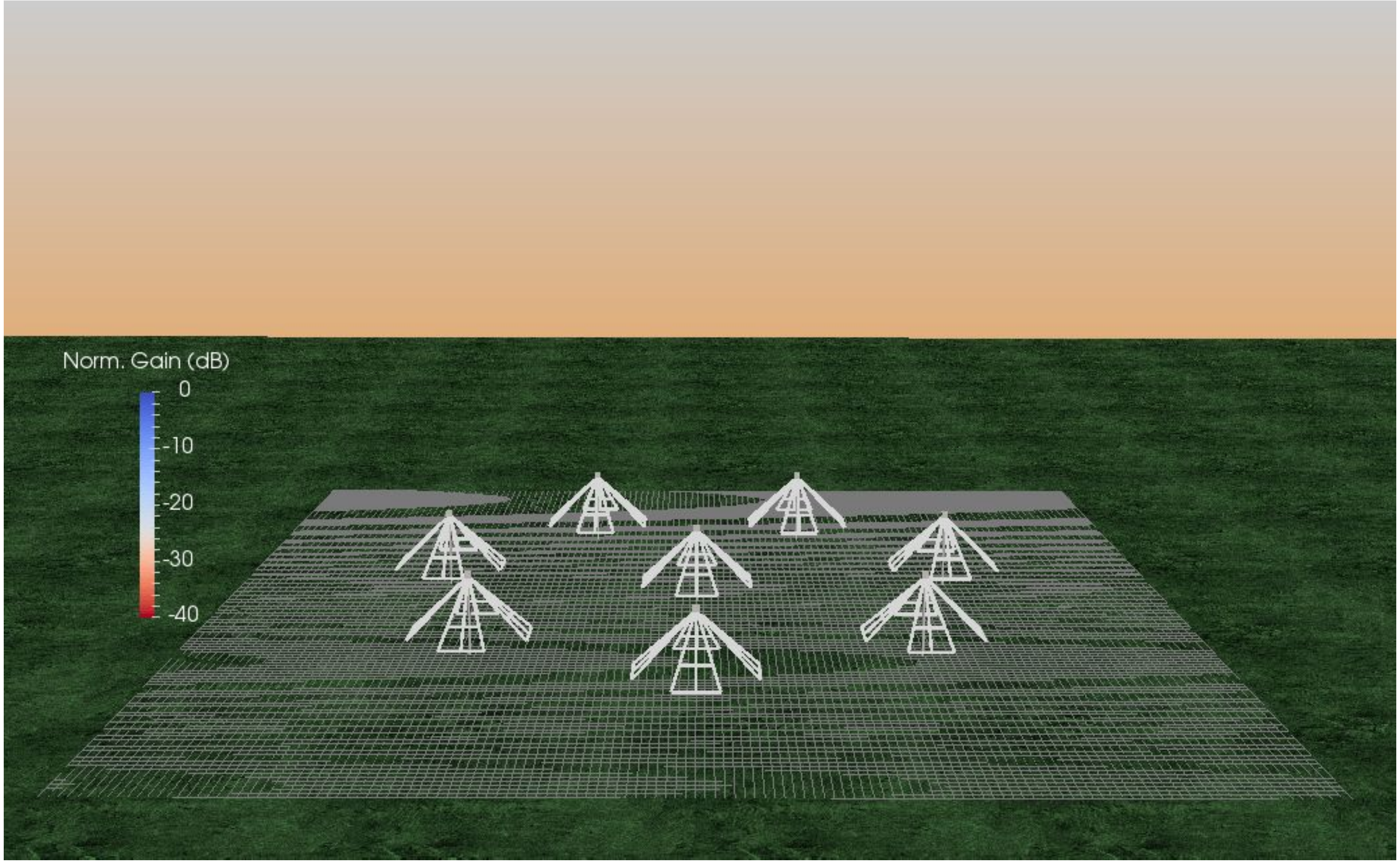


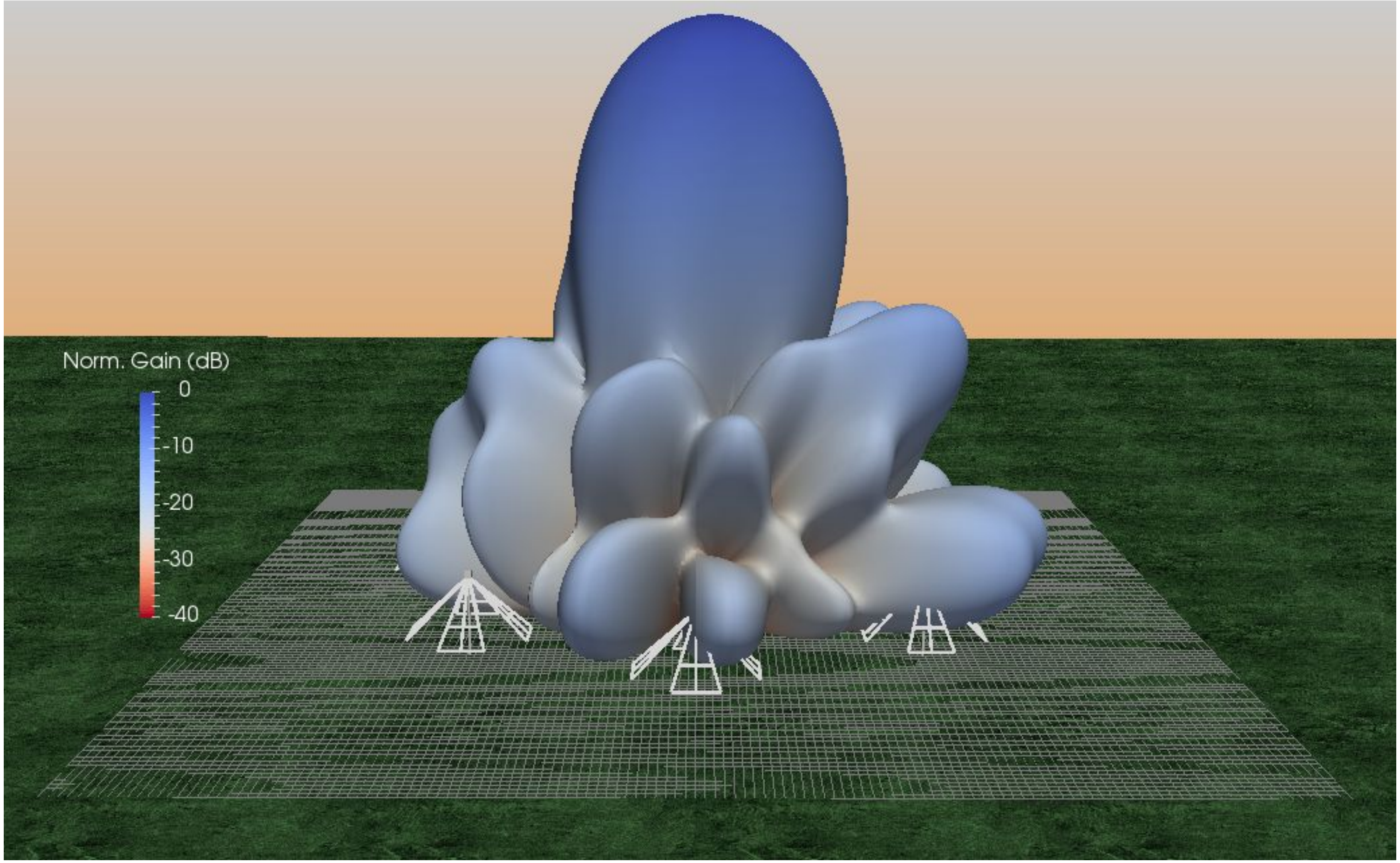
Building SPADE
Array Configuration



The layout of the array must provide a symmetric beam with low sidelobe levels

Building SPADE

Array Configuration



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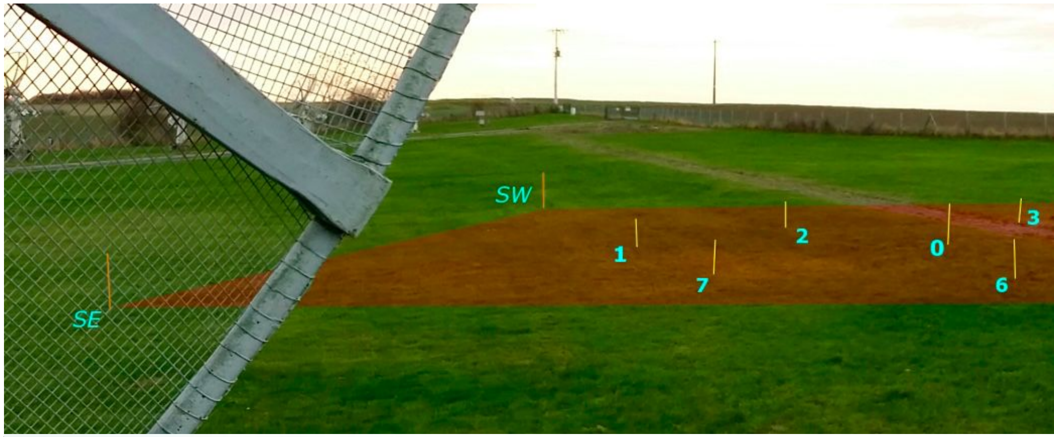
Building SPADE

Terrain preparation

Building SPADE
Terrain preparation



Building SPADE

Terrain preparation

Building SPADE
Terrain preparation

Building SPADE
Array Field

Building SPADE

Array Field

Building SPADE

Array Field

~~First Light~~ (not quite yet)

... but maybe it is the last appointment with the obstetrician!

Radio Telescopes

Observing solar radio bursts

- Radio bursts are emitted by **accelerated electrons**
- The differences among them depend on their emission mechanism and the coronal structures where they are produced
- Each type has a recognizable signature in the *dynamic spectrum*
- Emission frequency depends on local density