LOFAR: Low Frequency Array

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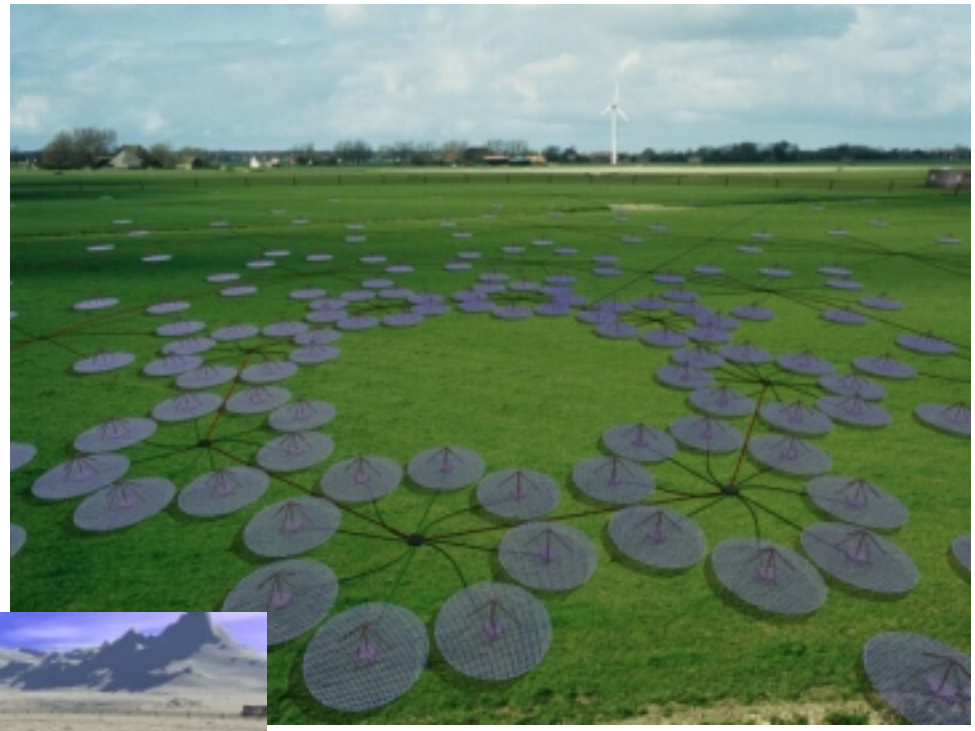


Participating Institutes:

- ASTRON (Dwingeloo)
- Naval Research Laboratory (Washington DC)
- MIT Haystack Observatory

LOFAR Aims

- **Innovative Science**
  - Epoch of Reionization
  - Sky Surveys (Galactic and Extragalactic)
  - Solar and Ionospheric Science
  - Transient Events
  - others ... (see http://www.astron.nl/lofar)

- **Testbed for Square Kilometre Array technology**

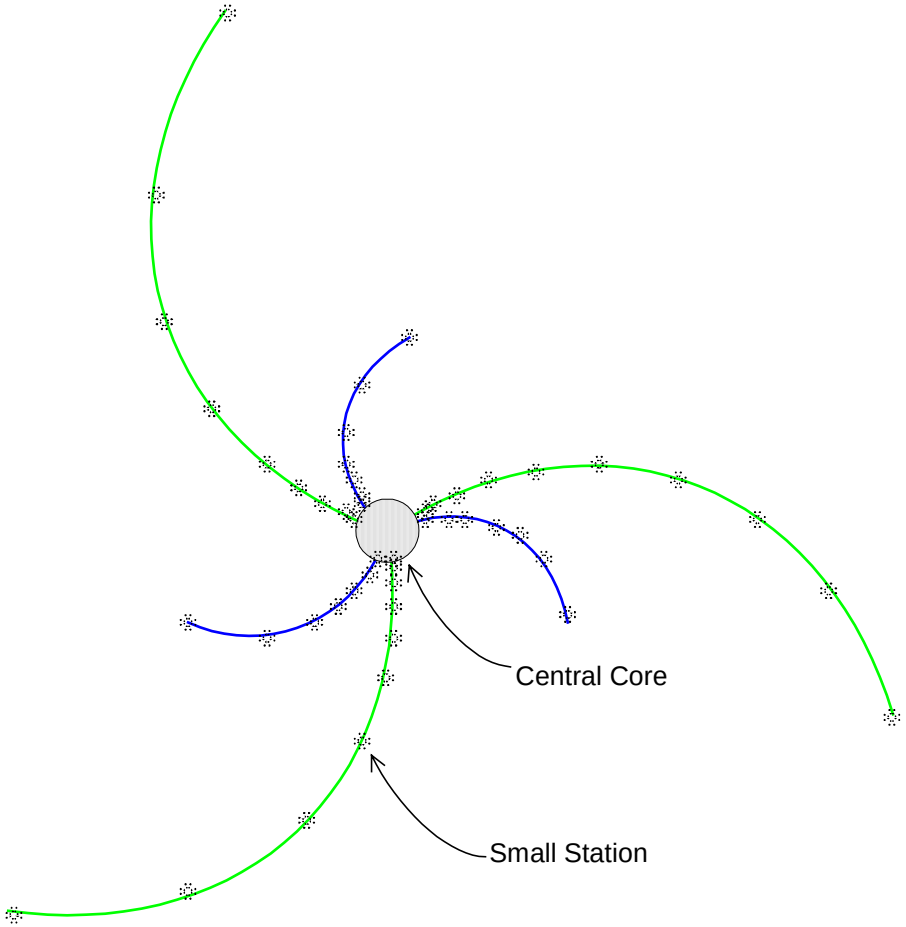
Basic LOFAR Concept

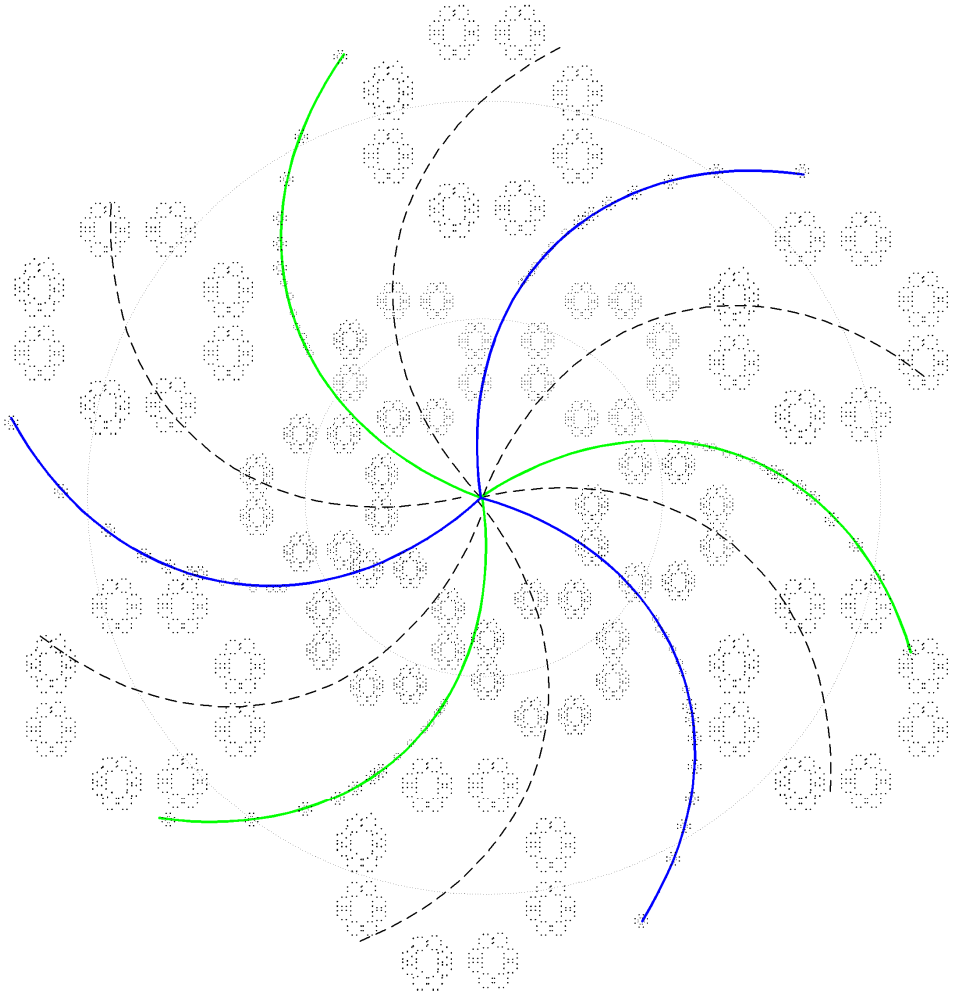
- Frequency Range: 10-90 MHz and 110-220 MHz
- High-frequency: 4x4 grid with RFBF
- A/D conversion at antenna level (65 MS/s, 14 bit)
- Antennas combined into clusters (n~10)
- Multiple Clusters form a Station
- Number of Stations (60-180)

Basic LOFAR Concept (2)

- Approximately Scale-Free radial distribution (multi-arm log-spiral)
  - 25% within r~1 km
  - 50% within r~6 km
  - 75% within r~40 km
  - 100% within r~200 km
- Remote stations: Beamforming at cluster level
- Central region (inner few km) – dipole signals sent to central facility for all beamforming

Configuration (example)



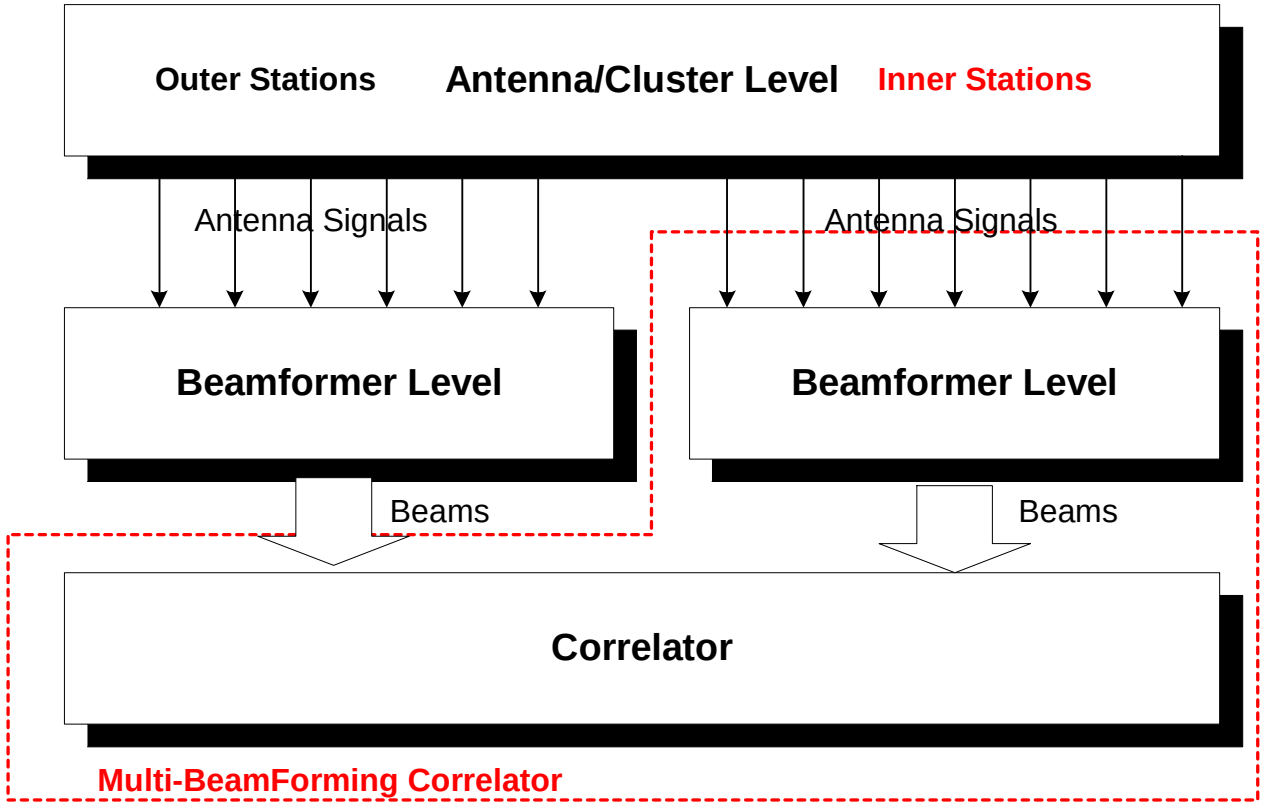


Basic LOFAR Concept (3)

- At central site:
  - Multi-Beamforming Correlator
  - Selfcal Processing Pipeline
  - Dedicated Processing (e.g. pulsars, transients, radar)

Multi-Beam Forming Correlator

- Reconfigurable, i.e. exchange:
  - Number of Beams
  - Processed Bandwidth
- Use off-the-shelf components
- FX correlator architecture



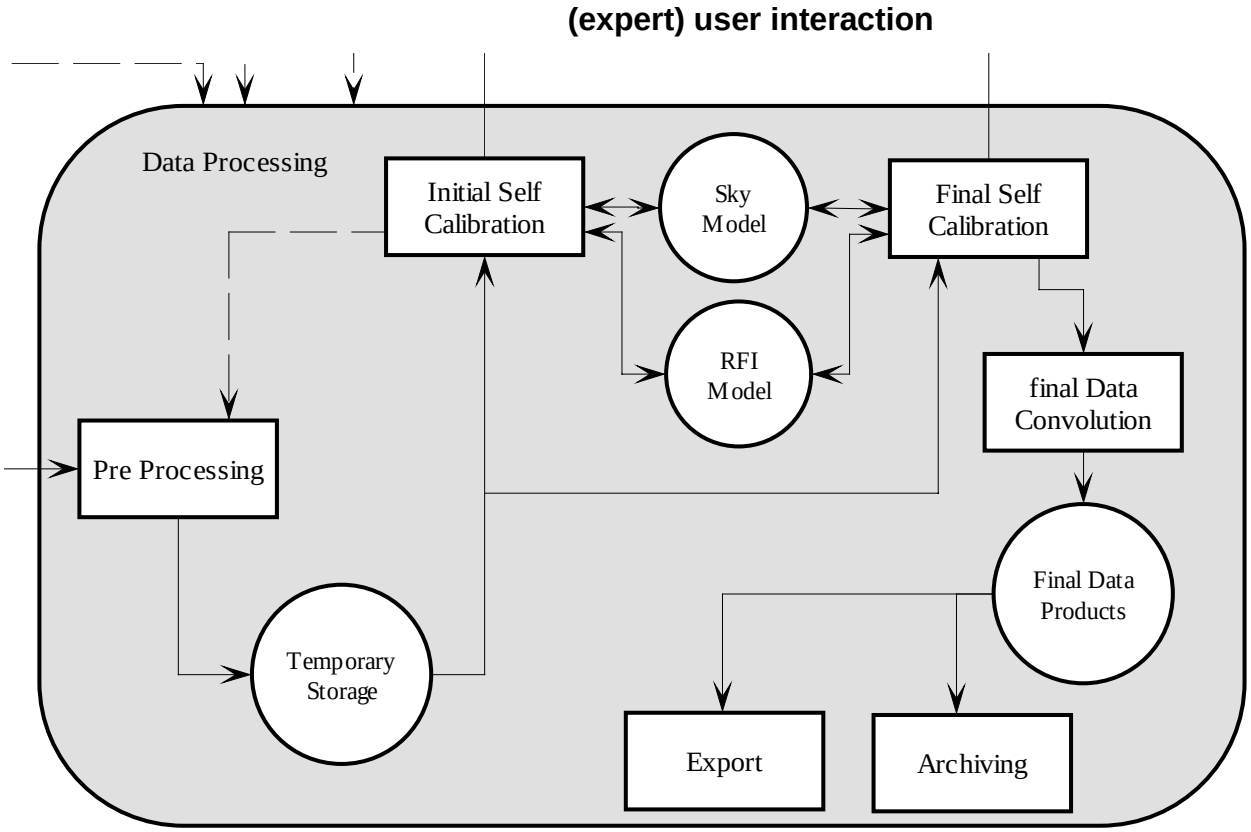
Data Processing Pipeline

Data Rates

- WSRT (2000): ~10 MB/s (160 MHz)
- LOFAR (2006): 500 GB/s (per beam)

Map Making

- now : expansion of data
- LOFAR: data compression



Part of LOFAR Functional Diagram

Main Points of Synergy with SKA

- **Configuration Studies**
  - Antennas, clusters and stations
  - Scale-free distributions
- **Dynamic Range**
  - Bright sources
  - Sidelobe confusion
- **RFI Mitigation**
  - Nulling (BF)
  - Spectral techniques

Additional Topics

- Signal Processing Pipeline
- Data transport (fibres, timing)
- Remote access to data and processing
- Multi-beam operations

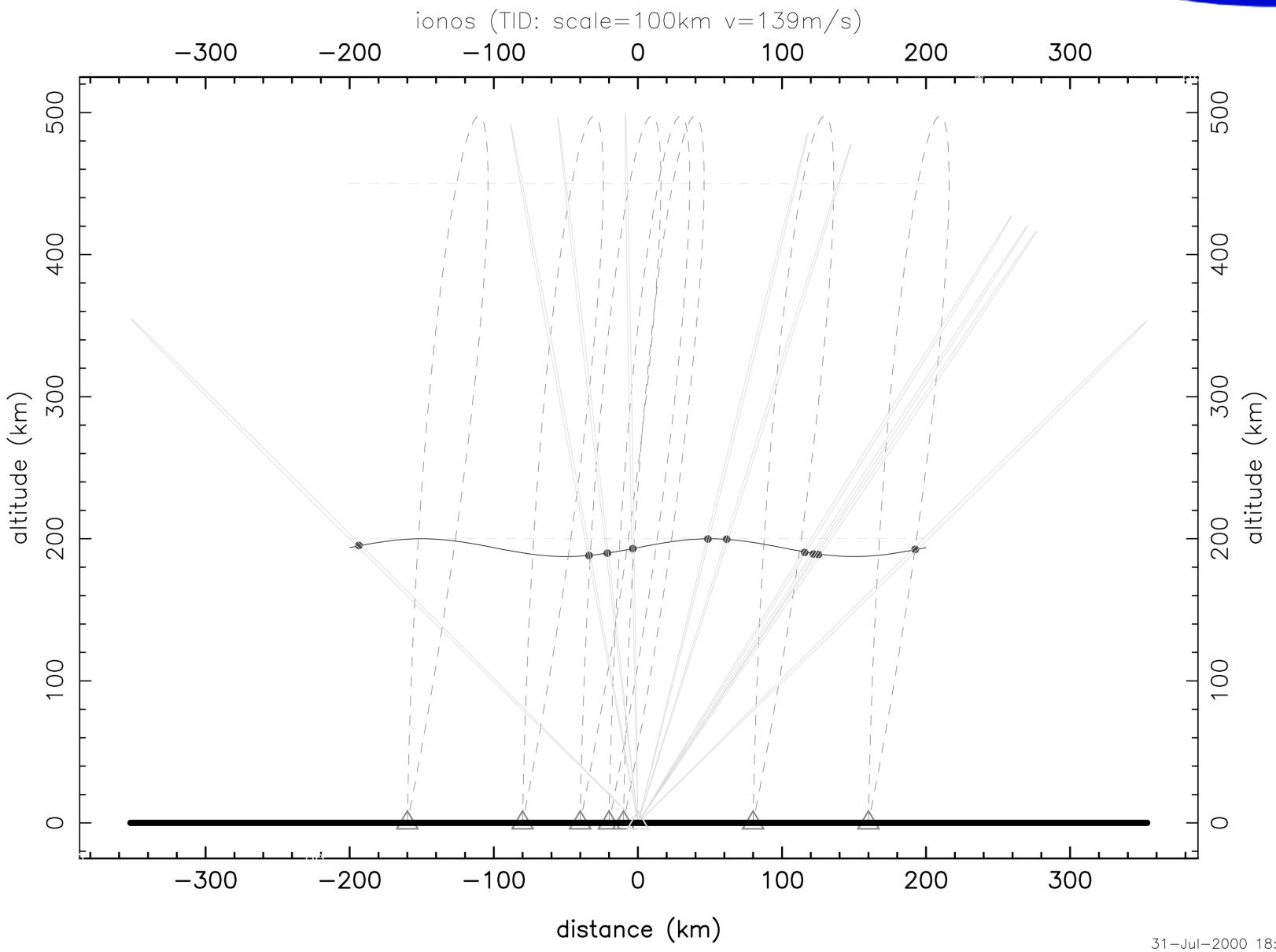
Calibration and the Ionosphere

Need high dynamic range to reach (sky) noise levels

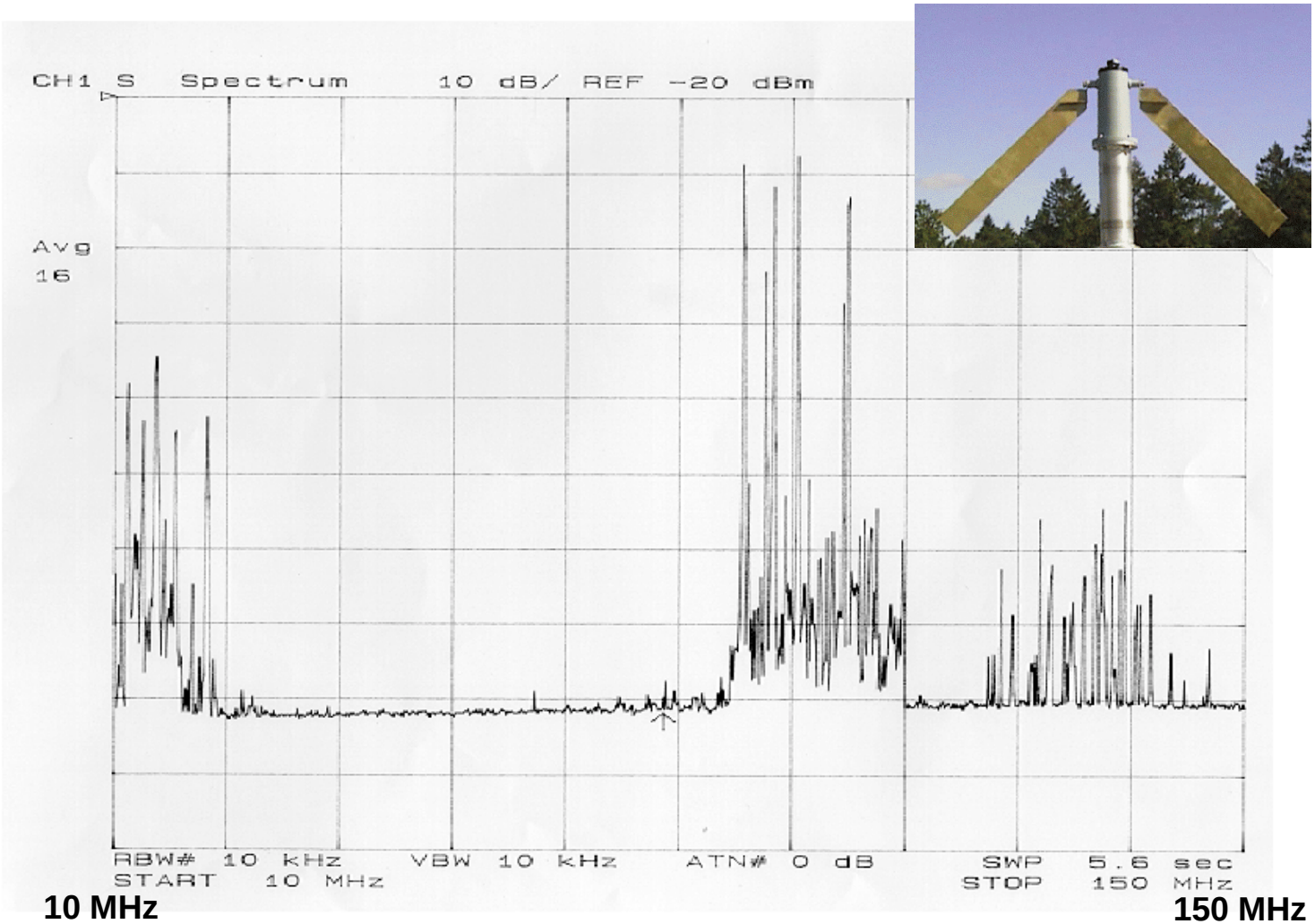
- Fully subtract the bright sources
  - Characterize ionospheric (phase)
  - Characterize individual beamshapes (amplitude)
- Avoid side-lobe confusion by faint sources
  - Full uv-coverage needed

- **Approach:**
  - Sufficient sensitivity per baseline
  - Large central station (“compact core”) with many smaller remote stations

Characterizing the Ionosphere



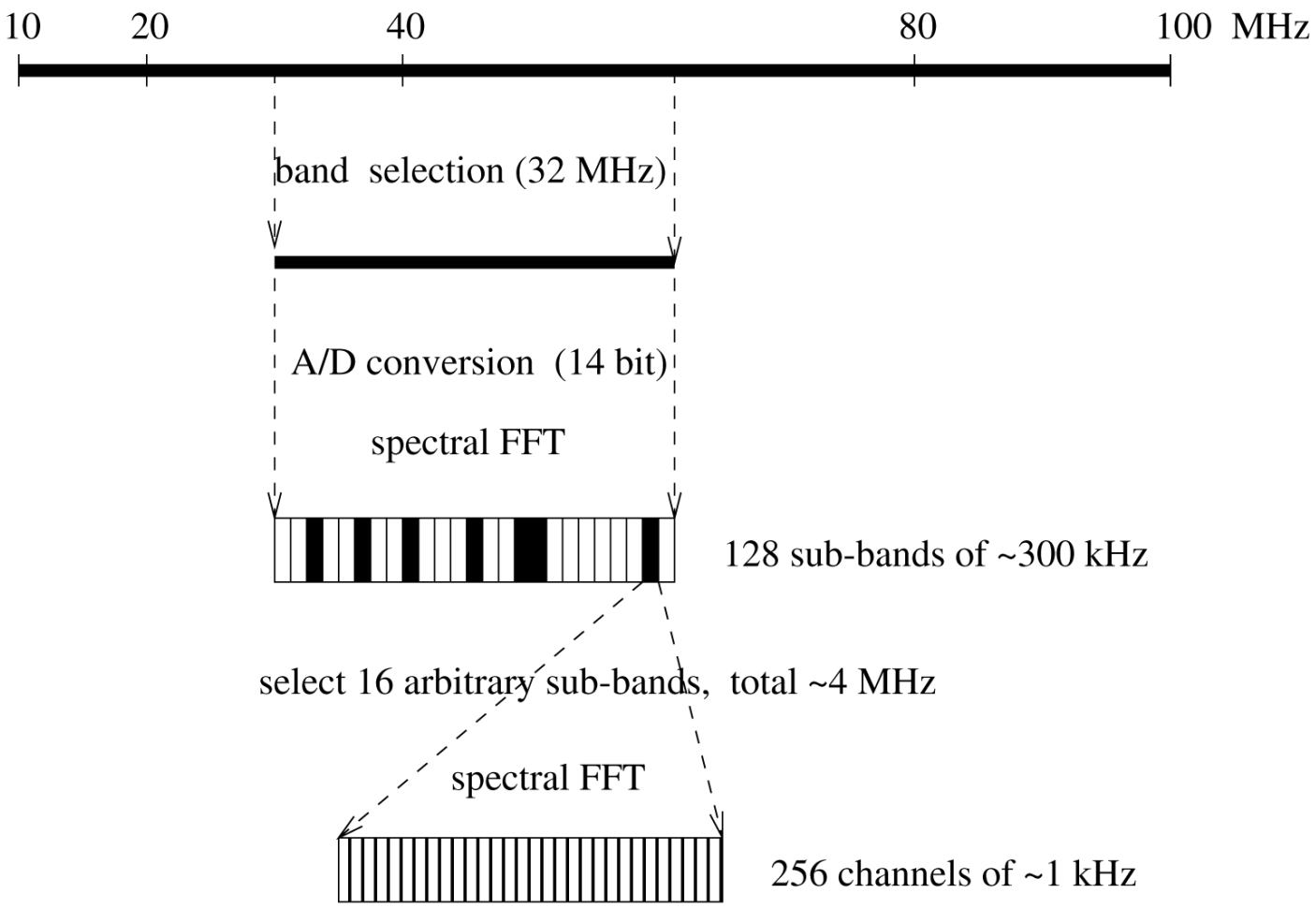
RFI Characterization



10 MHz

150 MHz

RFI Mitigation



into 2D spatial FFT of cluster beamformer

LOFAR Performance

- Number of receptors: 13,500 (each type)
- A_{eff}=380,000 m^2 at 20 MHz (50%)
- A_{eff}=95,000 m^2 at 160 MHz (50%; compound)

- Imaging Sensitivity
  - 2.2 mJy (ν=20 MHz, 4^h, $\Delta\nu$=4 MHz)
  - 32 μJy (ν=160 MHz, 4^h, $\Delta\nu$=4 MHz)

LOFAR Observing Modes

- Survey Mode
- Dedicated Observations
- Special Observational Modes
  - pulsars
  - transient events
  - radar (CME's, ionosphere)

- **Q**: Can Special Modes run on "reconfigured" MBFC?

Further Information

- LOFAR Web Site:
  - http://www.astron.nl/lofar
- Posters at this meeting:
  - RFI monitoring for LOFAR – Boonstra, Bregman & Mohamoud
  - LOFAR System Design Summary + Calibration
- People at this meeting:
  - Jaap Bregman, Jan Noordam, Bart Smolders, Harvey Butcher, Arnold van Ardenne - ASTRON
  - Colin Lonsdale – MIT Haystack