LOFAR

Derek McKay-Bukowski

with thanks to LOFAR-UK, SEPnet, ASTRON, Sodankylä Geophysical Observatory, University Oulu, Oxford University, EISCAT Scientific Association, Radboud University Nijmegen, Max-Planck Institut, Onsala Space Observatory, Obs. Nançay, RAL & Chilbolton STFC, NERC, and many others.


Photo: RAL Space


Photo: RAL Space


25m dish
LOFAR
100 feet
25 m
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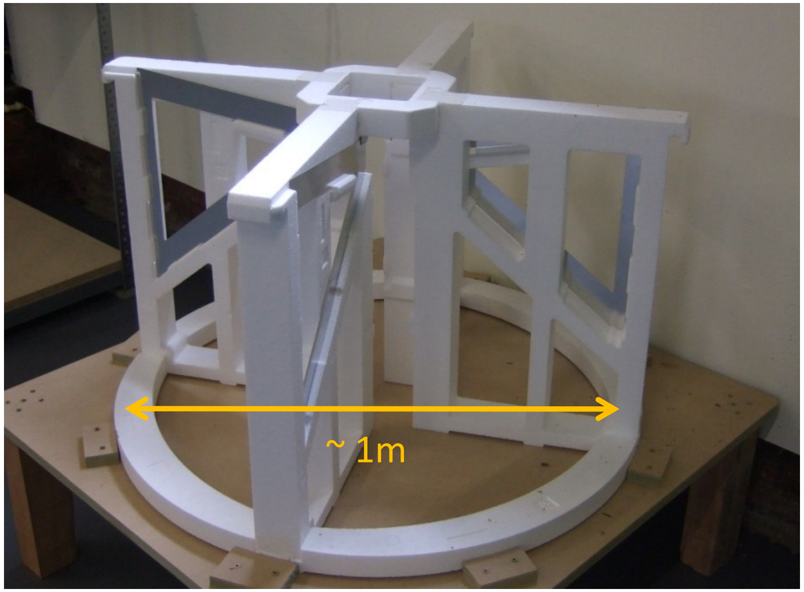
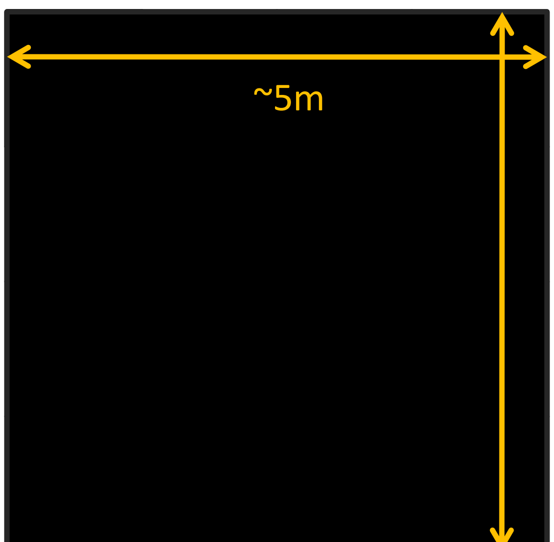
Photo: D. McKay-Bukowski

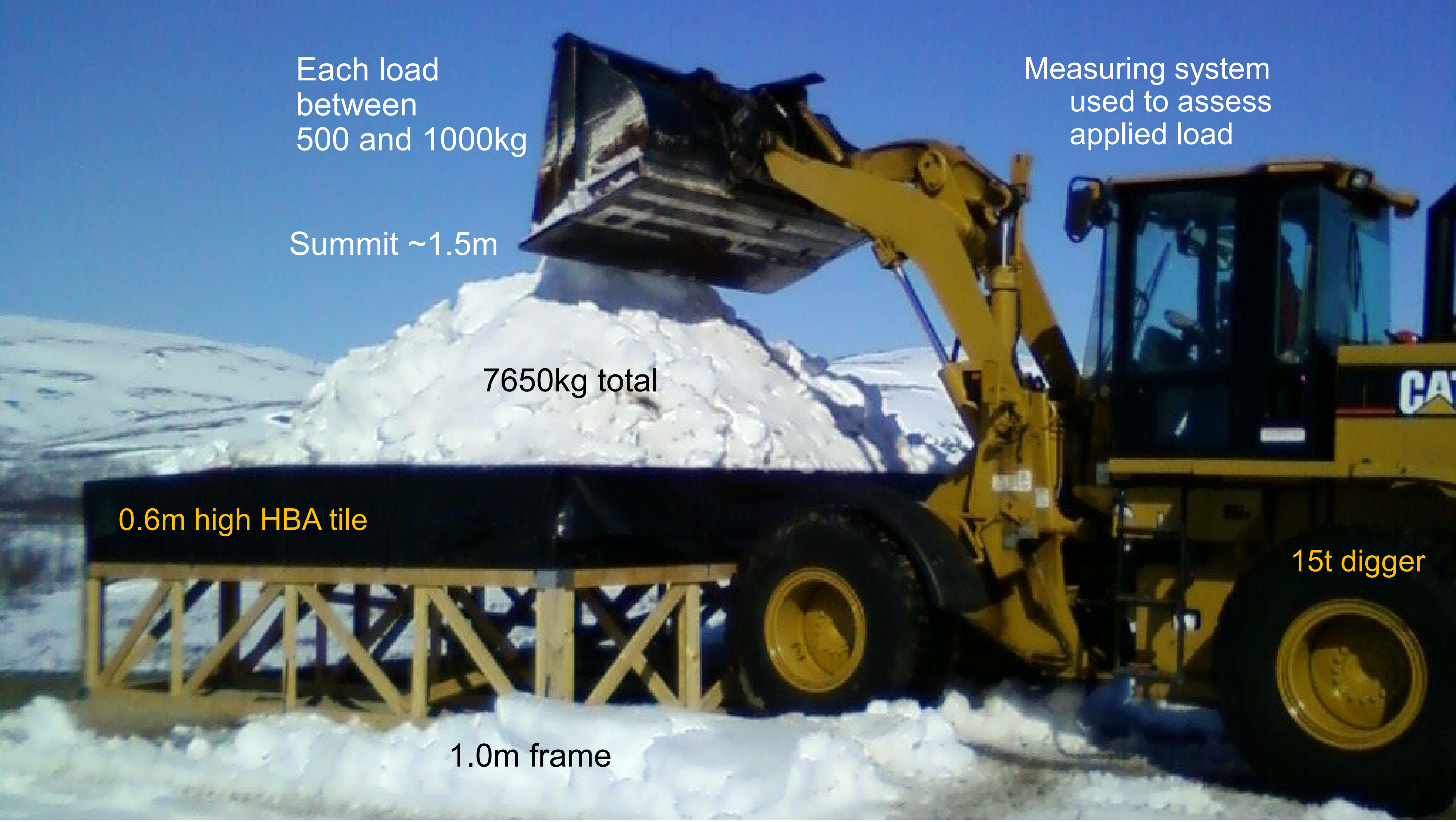
Photo: MPIfR / ASTRON

High-Band Antenna tile (approx. 110-275 MHz)





Photos: ASTRON, RAL Space, SGO



- Snow impact, loading, lateral stresses, etc.
- No structural failures in 2500+ tiles deployed

Photo: Sodankylä Geophysical Observatory, Finland

Photo: D. McKay-Bukowski

Low-Band Antenna aerial (approx. 10-90 MHz)

Photo: RAL Space


Coral Constructors


Photo: C. Tonini

Photo: RAL Space

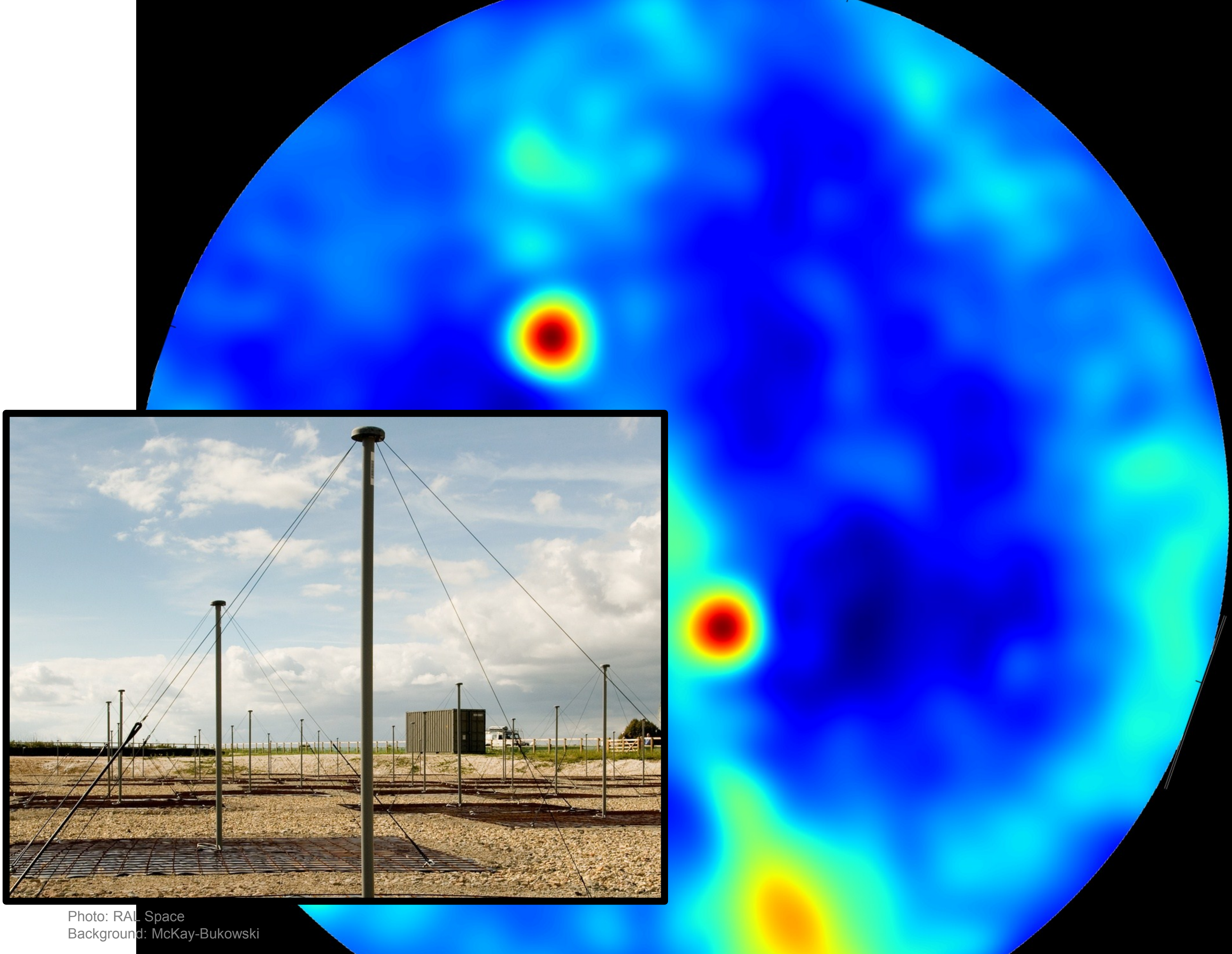


Photo: RAL Space
Background: McKay-Bukowski

Hasn’t this been done before?

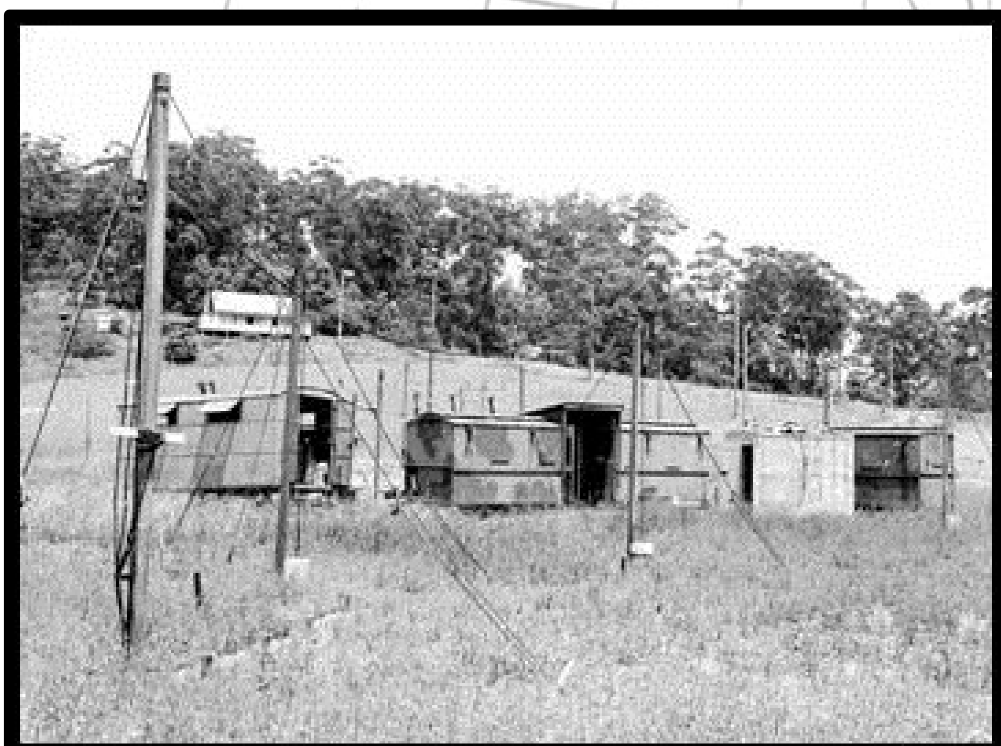
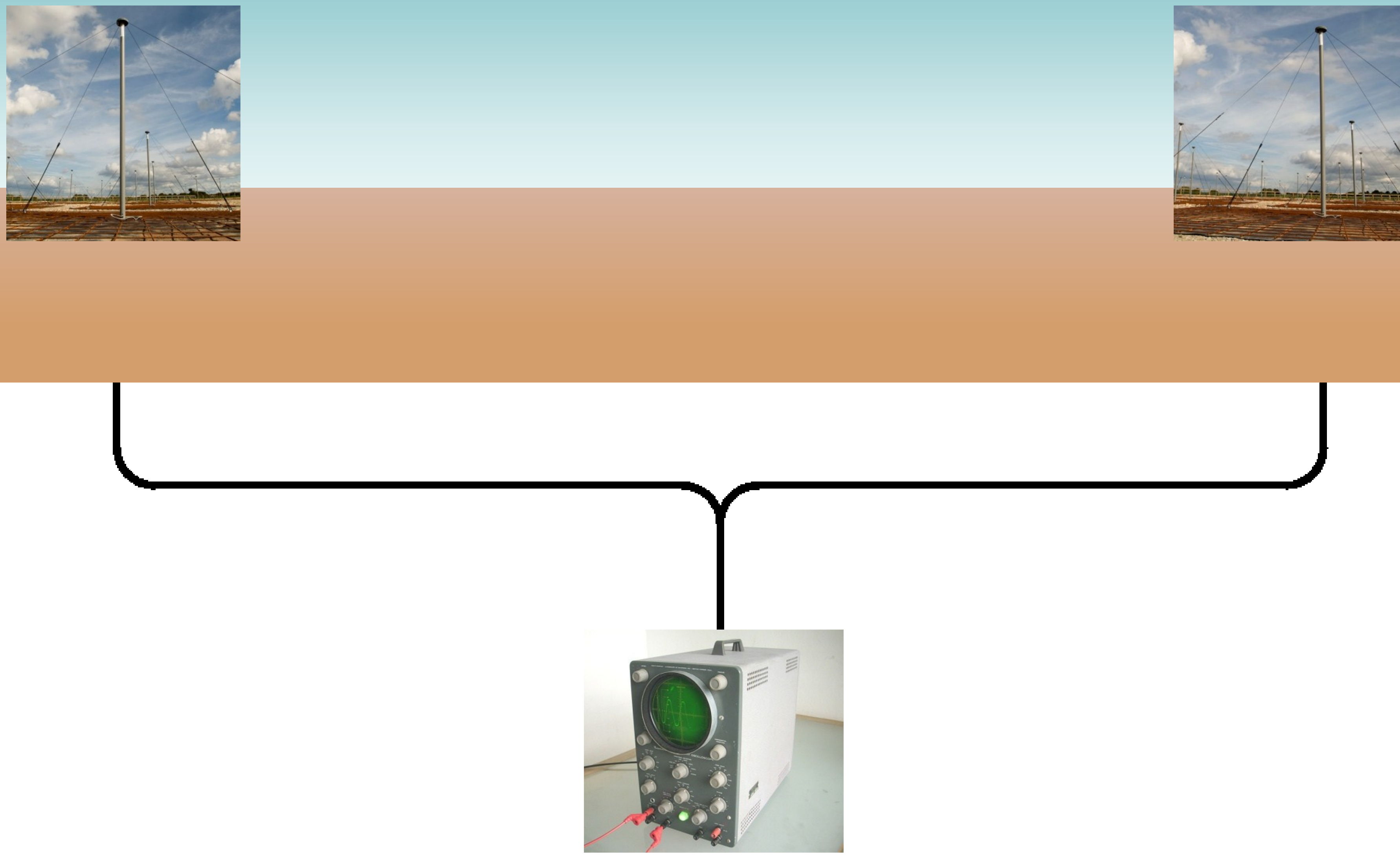
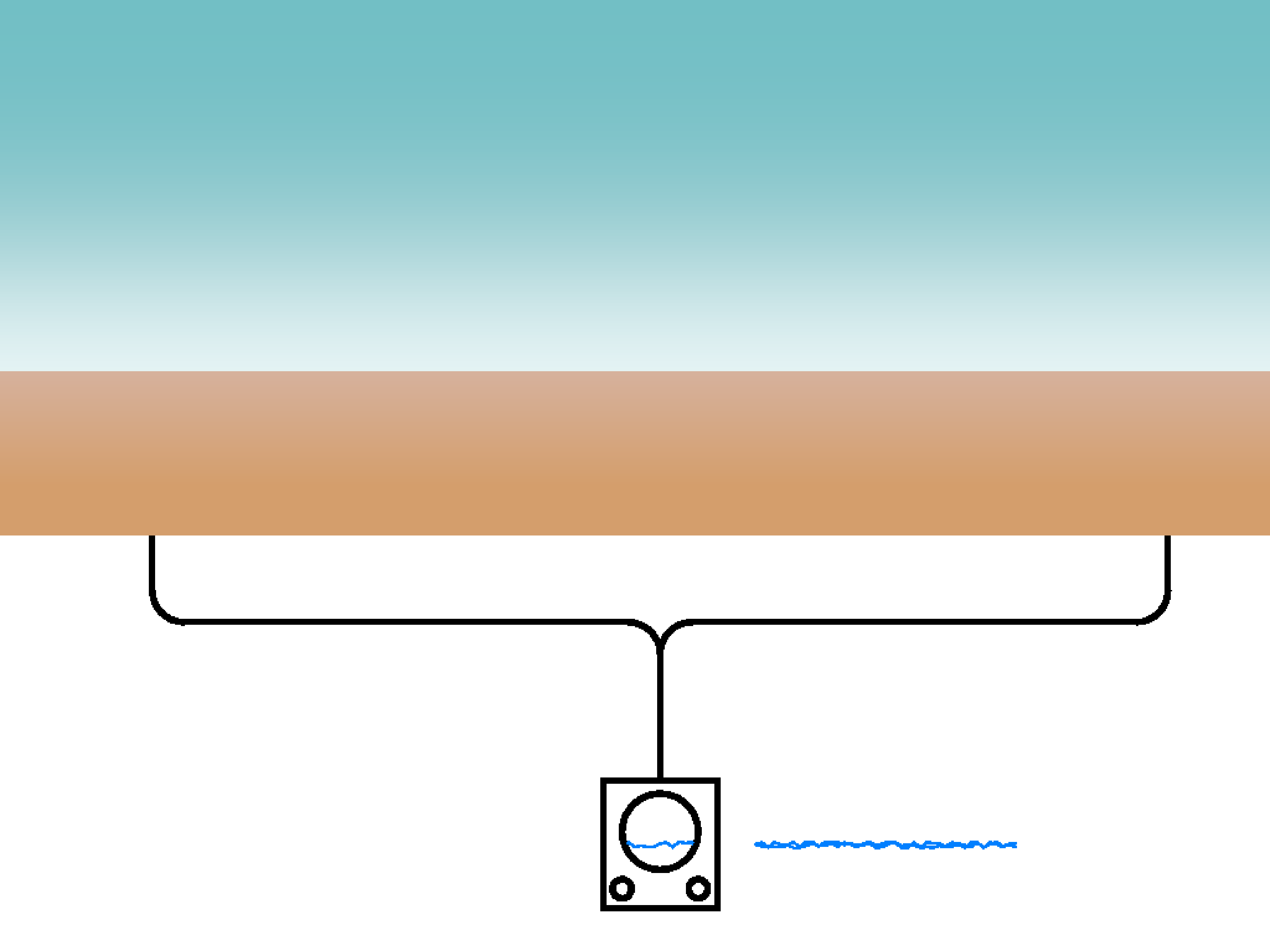
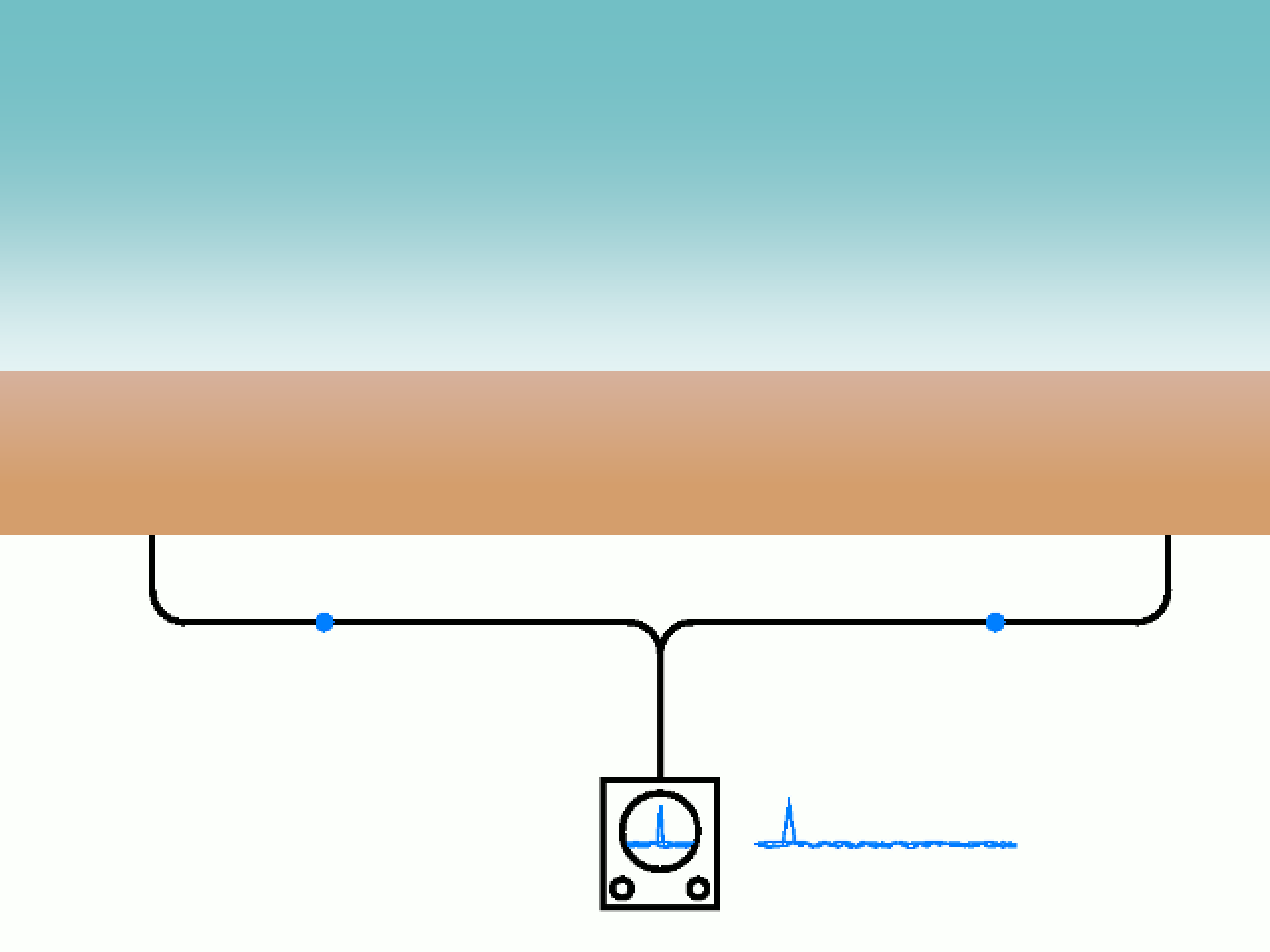


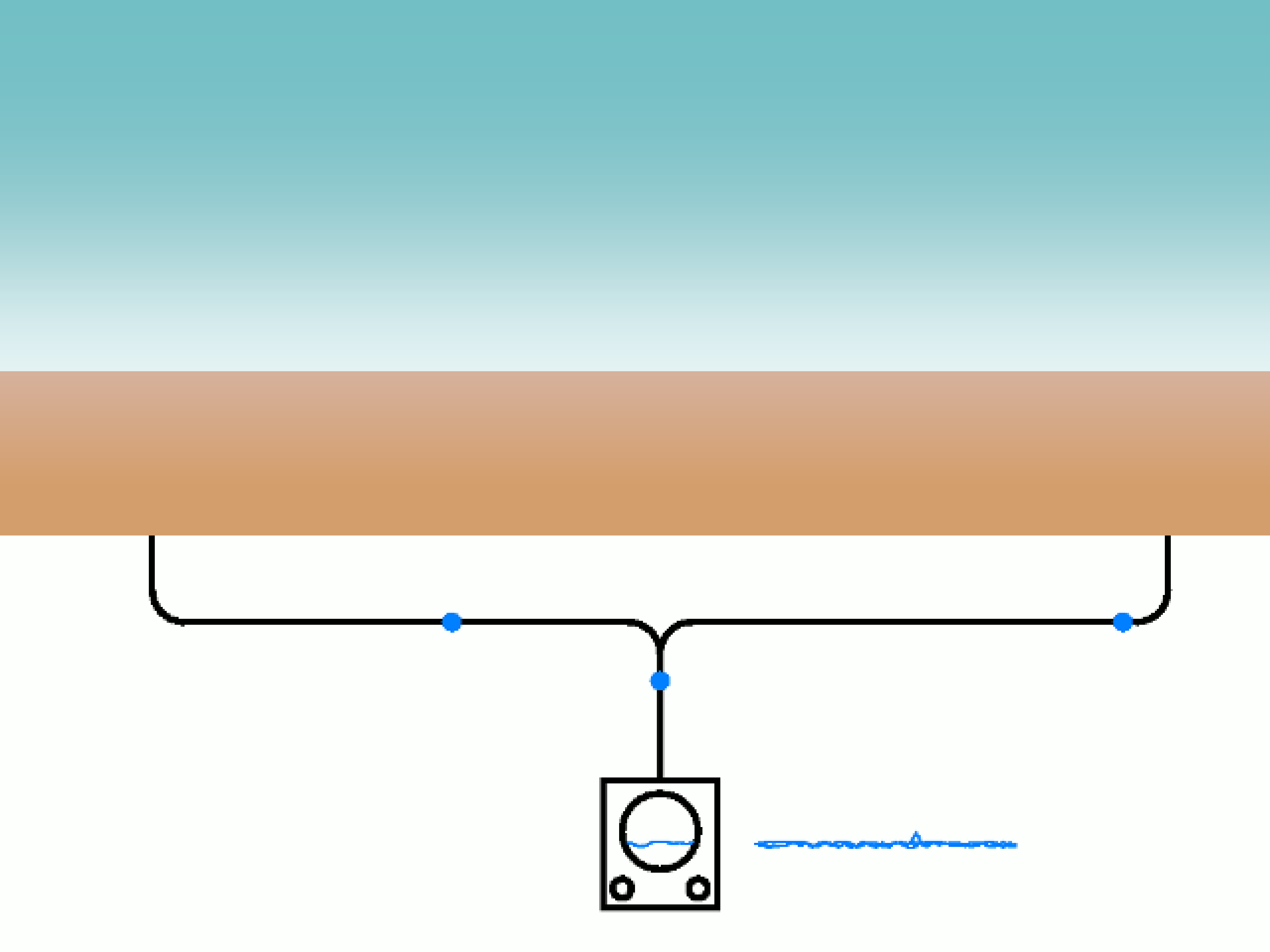
Photo: Orchiston & Slee
Background: *nach* Reber

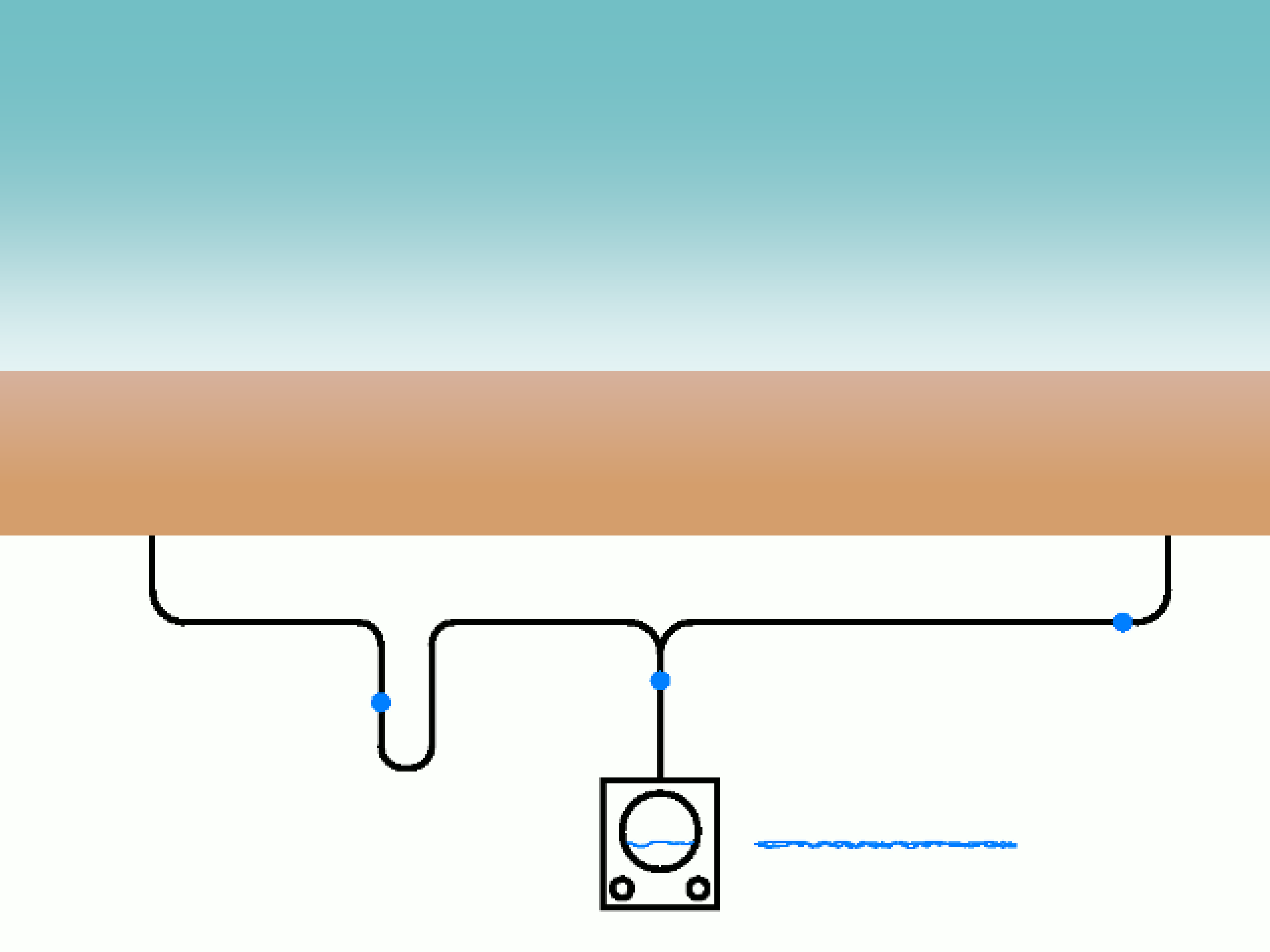
LOFAR station concept

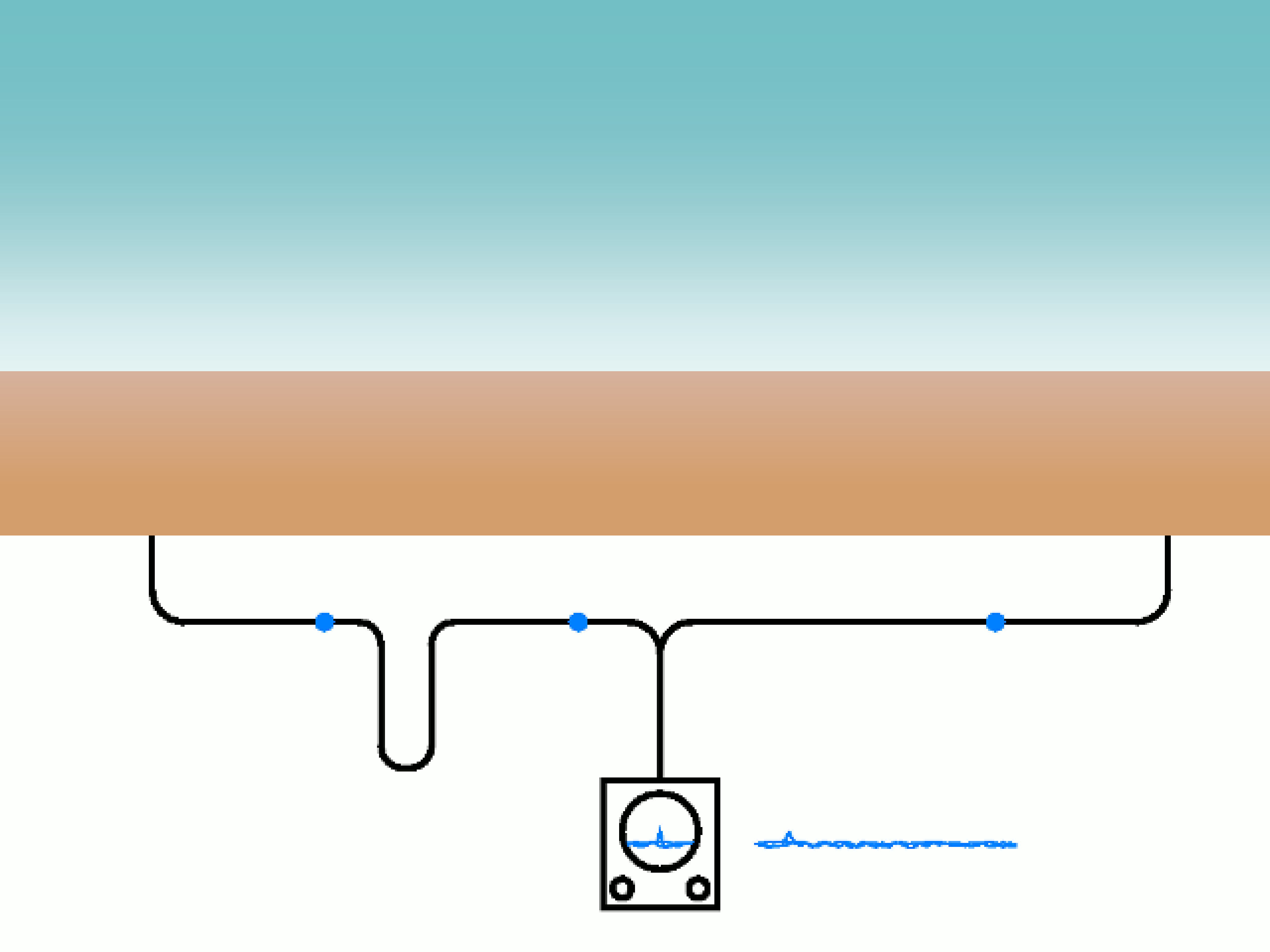



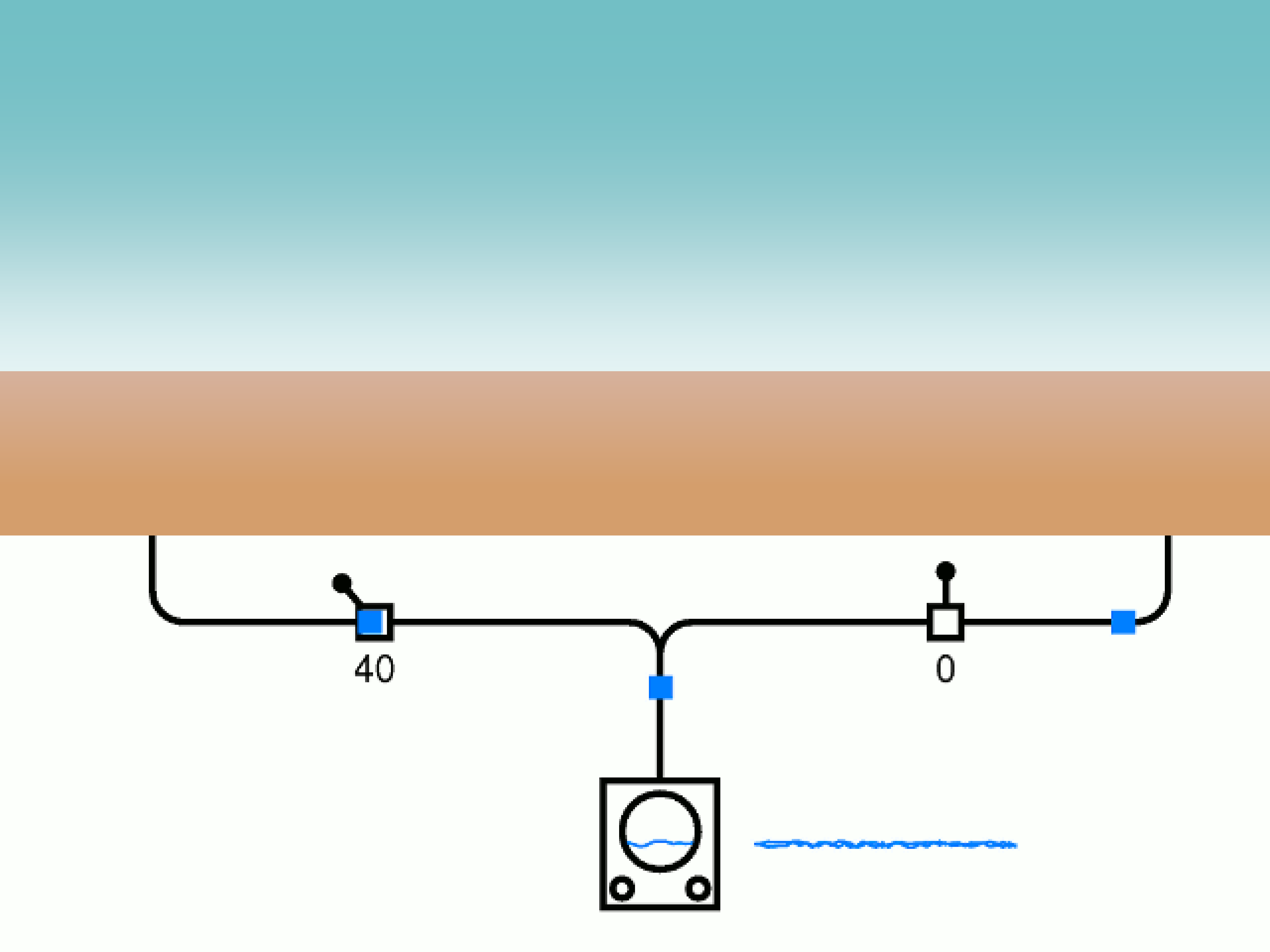


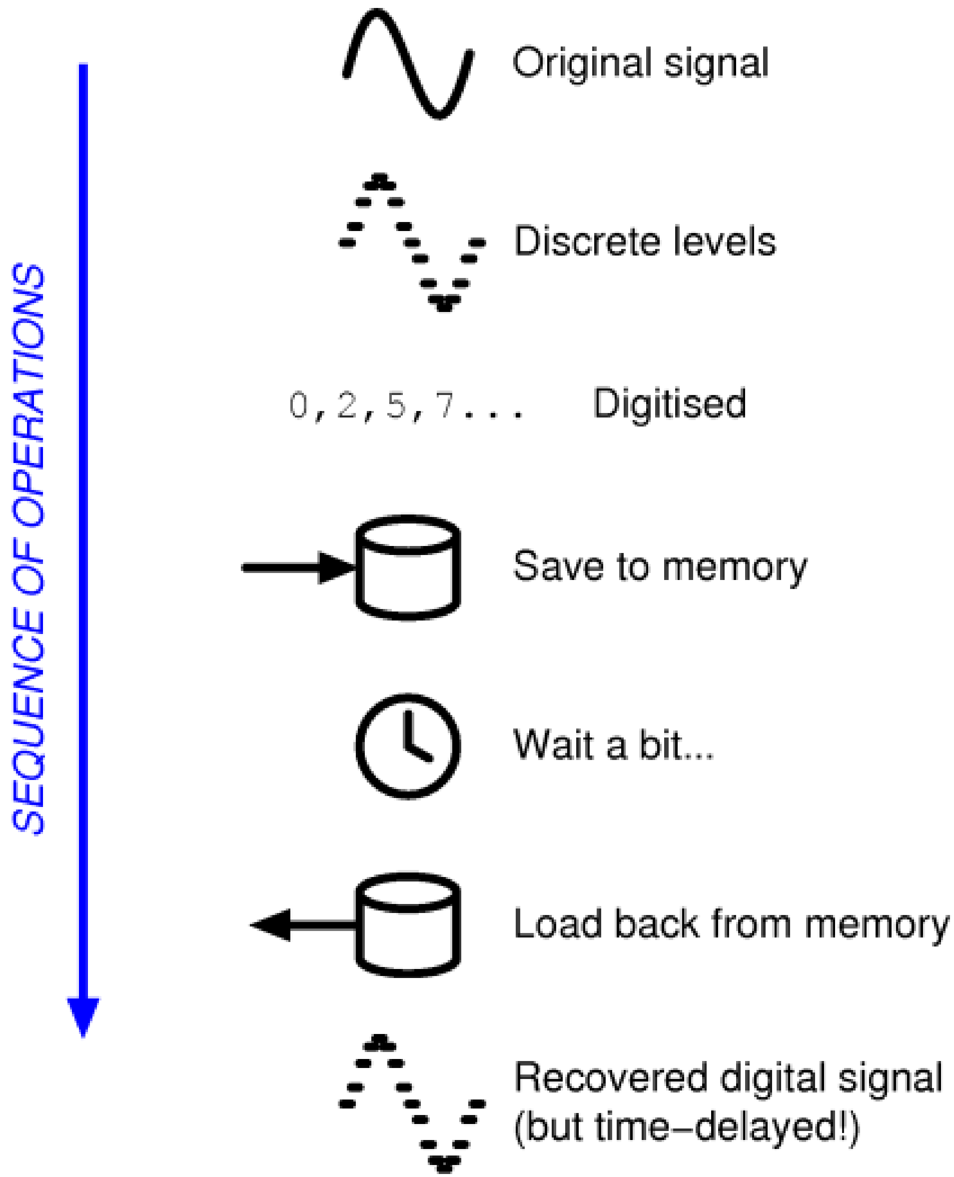









40
0


SEQUENCE OF OPERATIONS
Original signal
Discrete levels
0,2,5,7...
Digitised
Save to memory
Wait a bit...
Load back from memory
Recovered digital signal
(but time−delayed!)

Delay

You change the delays to change where you want to “look”

In a digital system, the signal is delayed in memory

And of course, computer memory is very fast

So you can change where it’s looking...

... very quickly

☺

And that is pretty cool!

Digital

The data are digital

You can make copies of the data

And each copy can have a different delay

Thus, each copy is sensitive to a different direction

That means the telescope can “look” in different directions

☺

And that is also pretty cool!

Interference?

12-bit sampling

High-time resolution

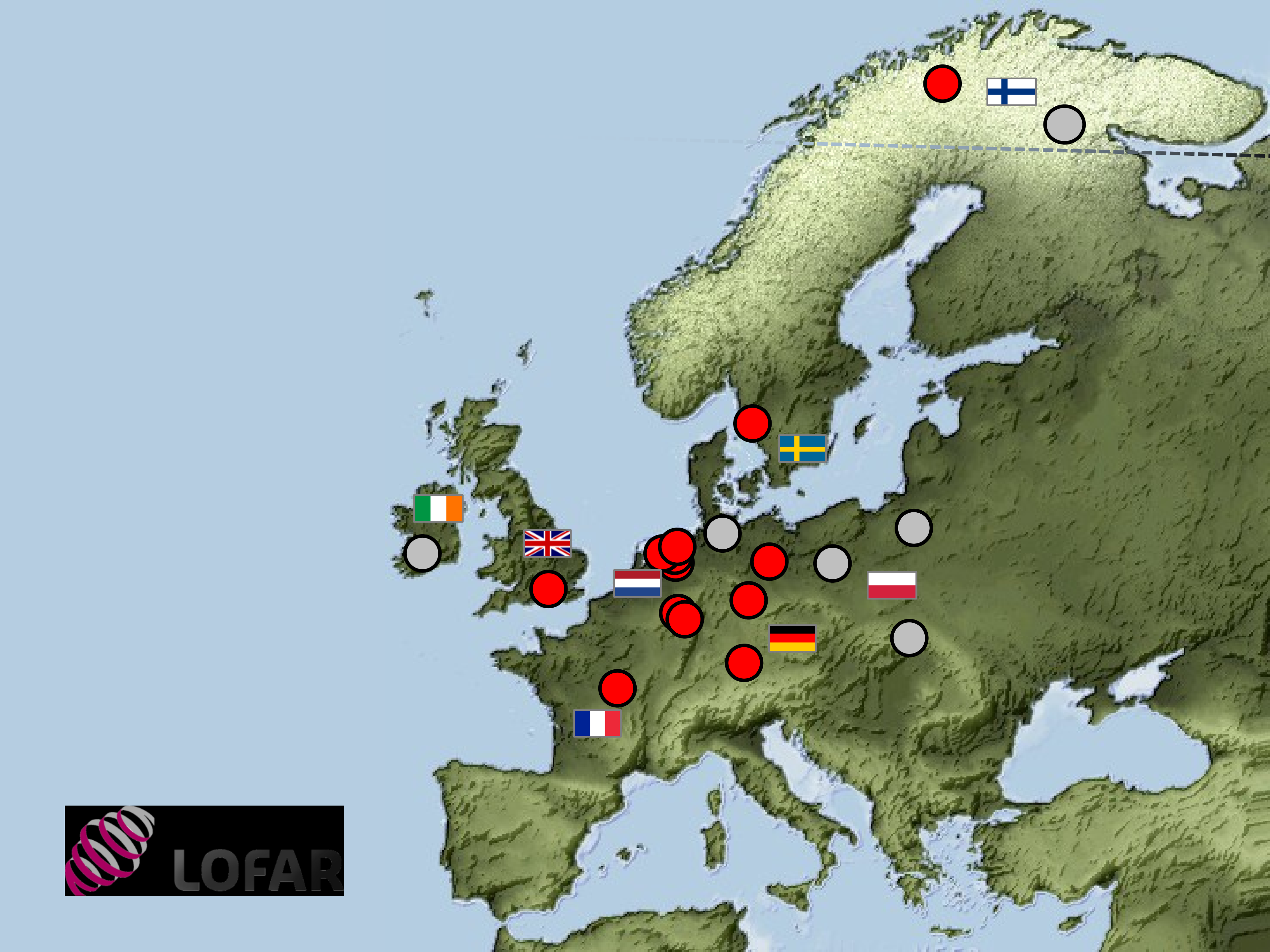
Easily use adaptive nulling

Distributed antennas

☺

Europe is not a problem!

LOFAR network


LOFAR

Superterp, near Exloo, Netherlands

Photo: ASTRON

24 Core station, near Exloo, Netherlands

Photo: ASTRON

12 (+3) Remote stations, this one near Gieten, Netherlands

Photo: ASTRON / Aerofoto Eelde

DE601, Effelsberg, Germany

Photo: Max-Planck-Institut für Radioastronomie

DE602, Unterweilenbach, Germany

Photo: Rainer Hassfurter, Max-Planck Institut für Astrophysik


DE603, Tautenburg, Germany
Photo: Thüringer Landessternwarte Tautenburg

DE604, Potsdam, Germany

Photo: Leibniz-Institut für Astrophysik

DE605, Jülich, Germany

Photo: Forschungszentrum, Jülich

FR606, Nançay, France
Photo: I. Cognard, Station de Radioastronomie de Nançay

SE607, Onsala, Sweden
Photo: Leif Helldner, Onsala Space Observatory


UK608, Chilbolton, United Kingdom
Photo: D. McKay-Bukowski, STFC/SEPnet

Zernikeborg, supercomputing centre

Photo: XPeria2Day

LOFAR International Telescope Control Room, Dwingeloo, Netherlands

Photo: D. McKay-Bukowski, STFC/SEPnet

Network

The data are digital

Using Internet protocols

No tapes, no radio-links...

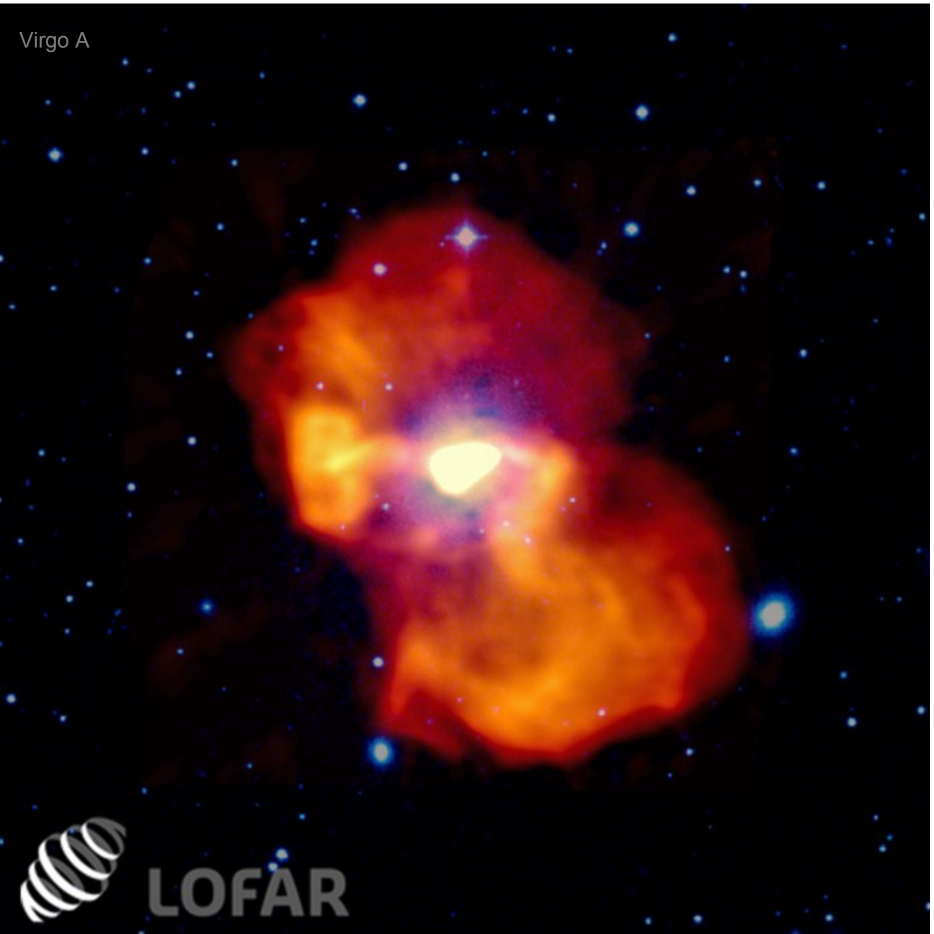
Just commercial networking

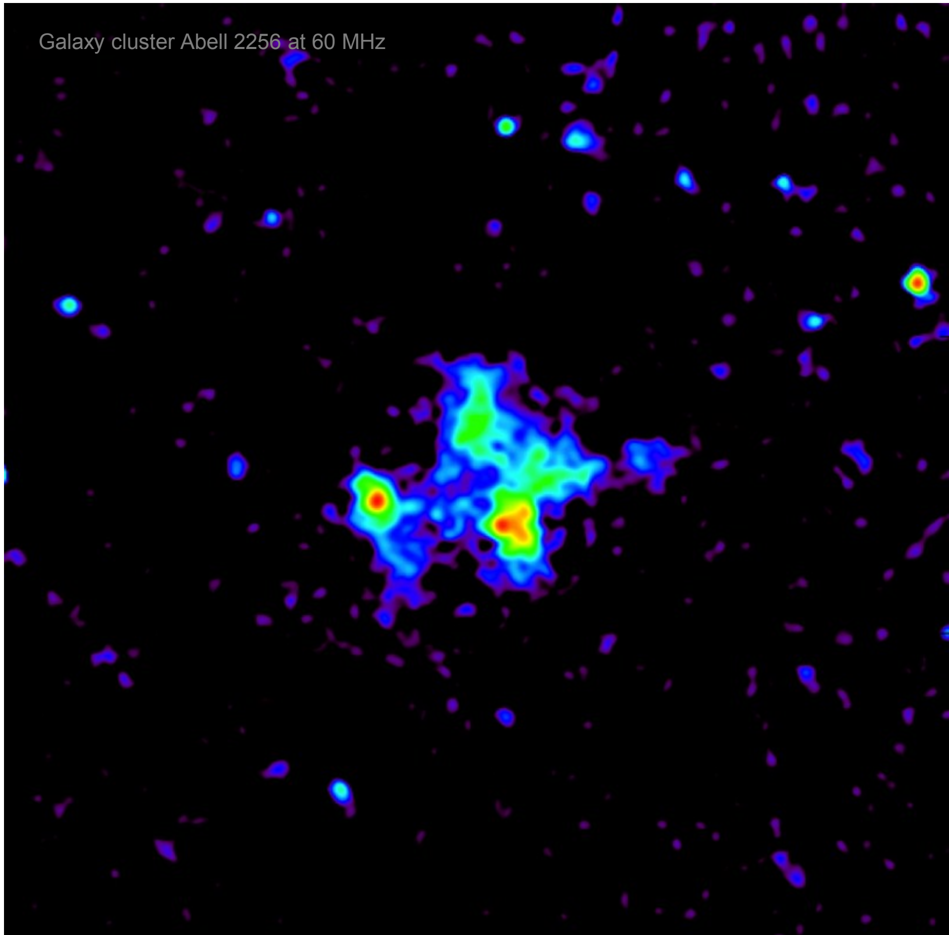
To provide a real-time telescope

☺

And that is pretty cool too!

High-resolution, low-frequency radio astronomy

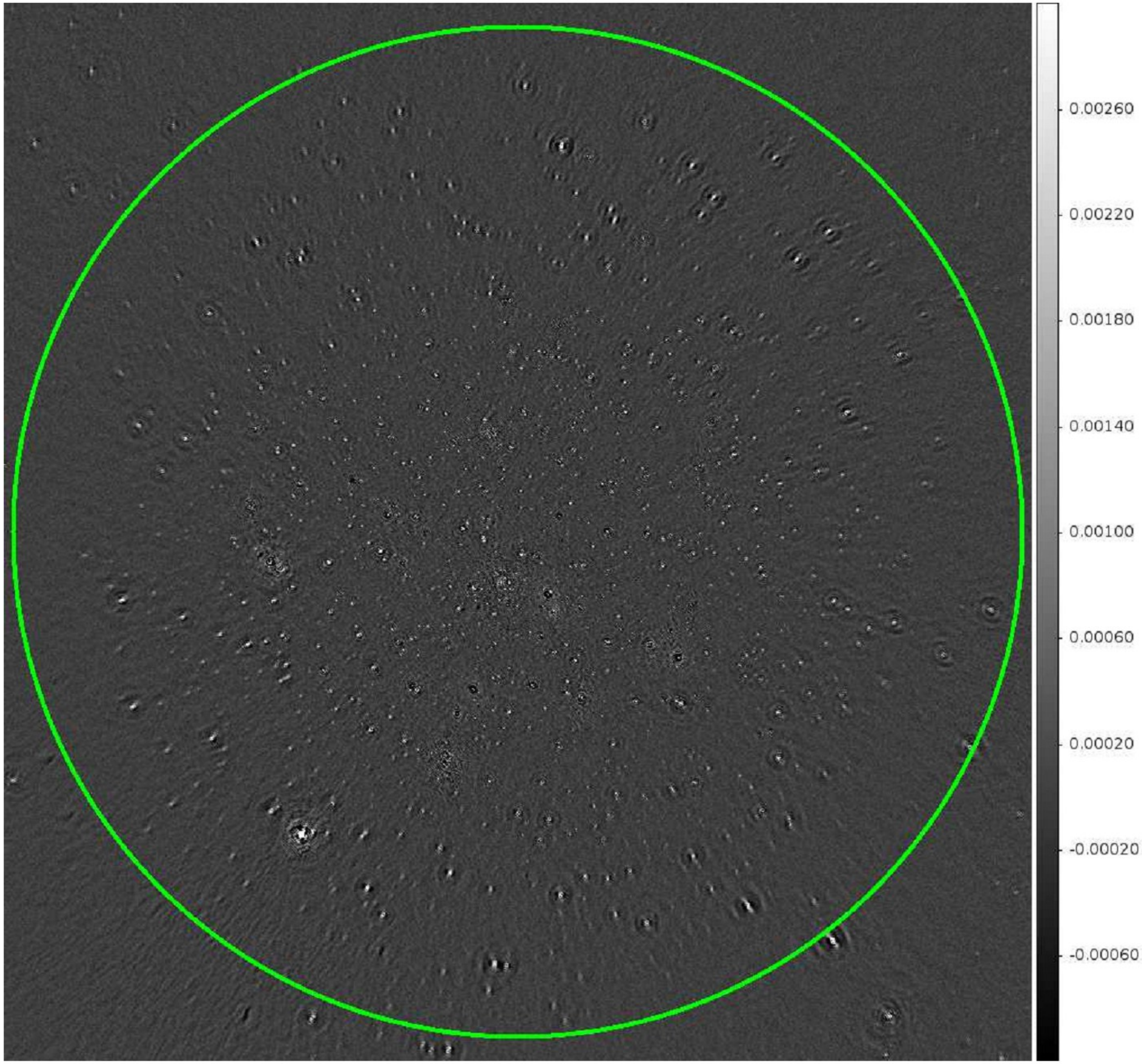




Deep-Imaging

18 hrs
10° FoV
12" PSF
100 µJy

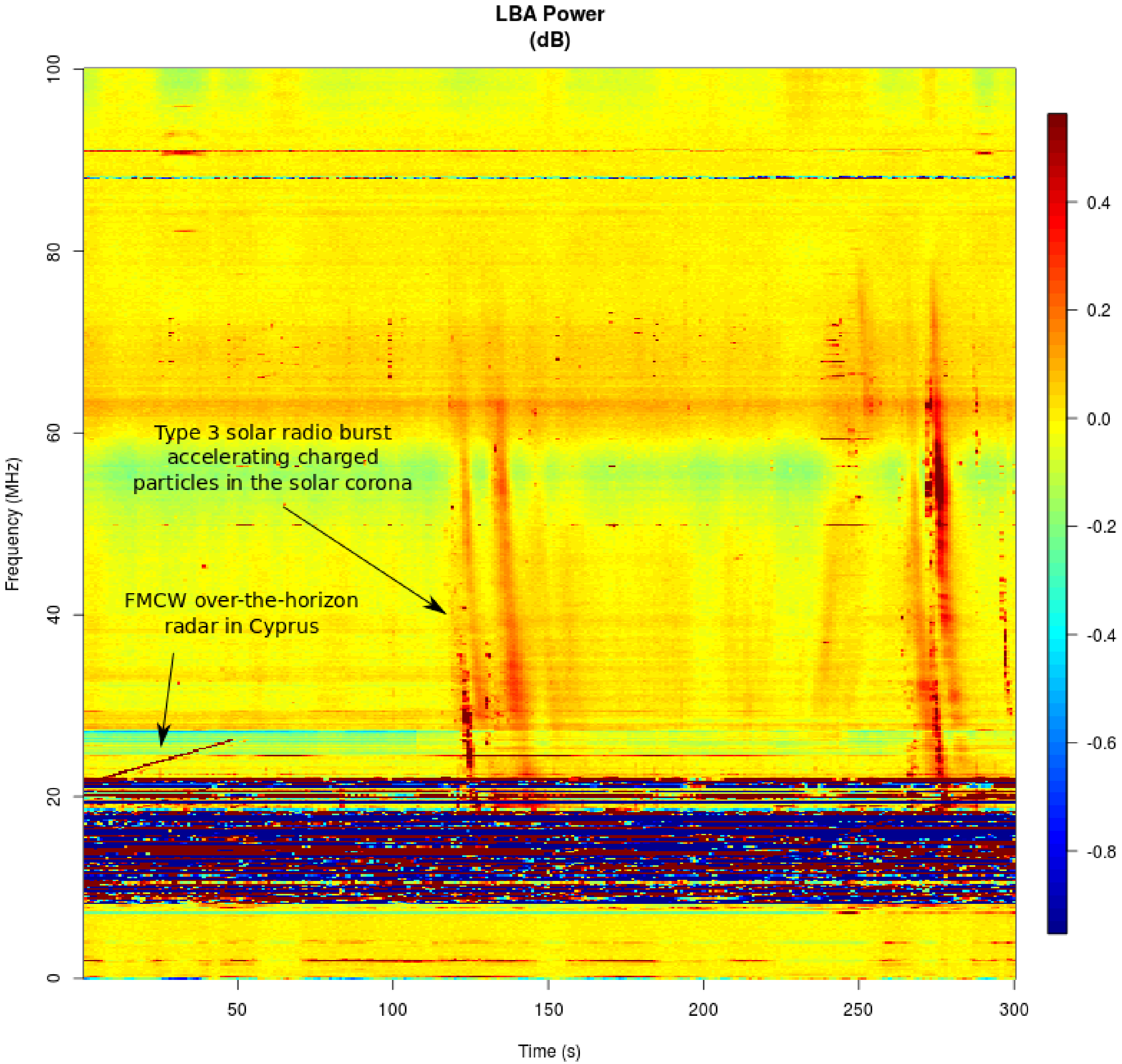
115-163 MHz



Yattawatta, *et al.* 2012

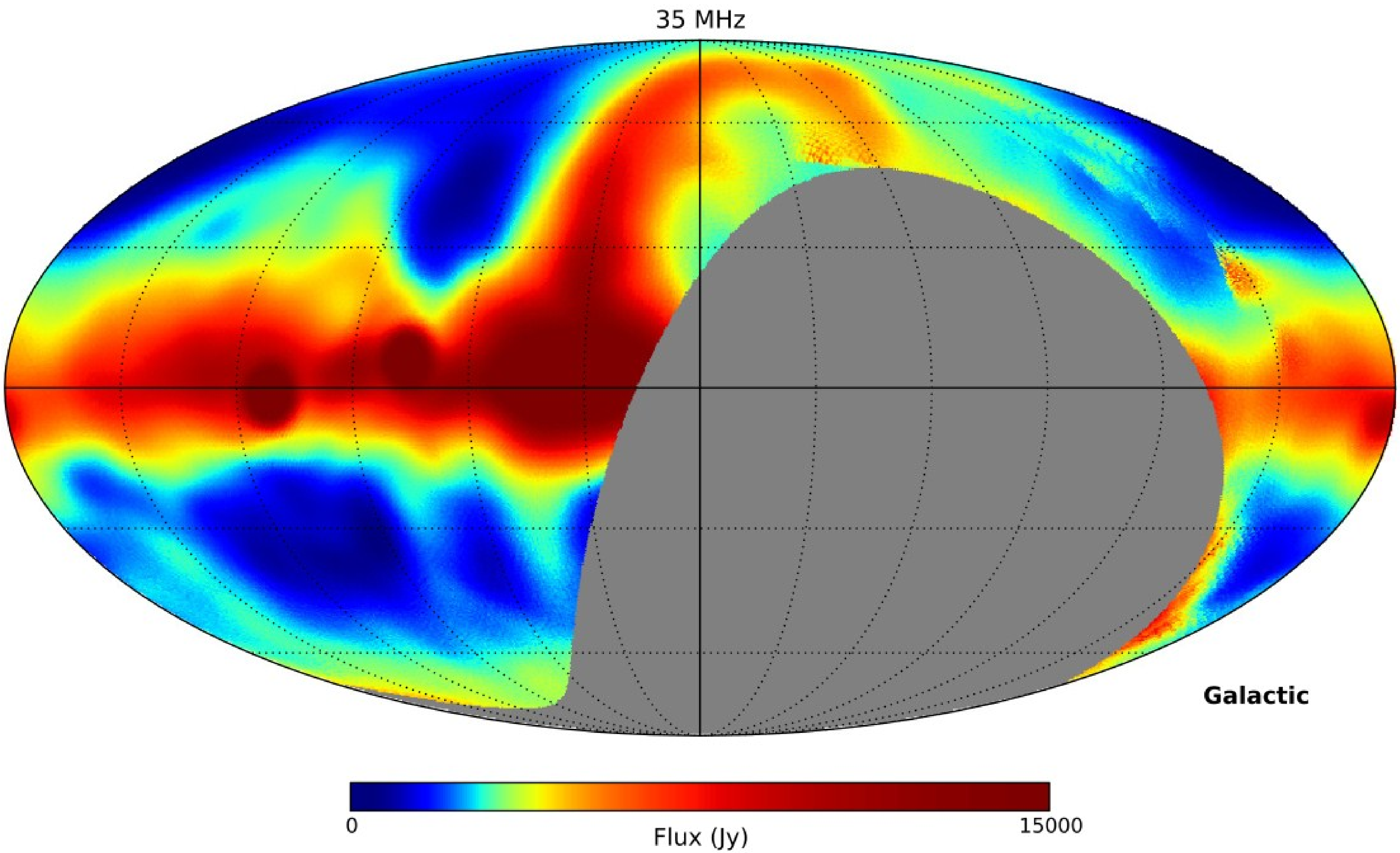
Solar

High
Time-res.
observing



R. Fallows, 2012

Galactic emission



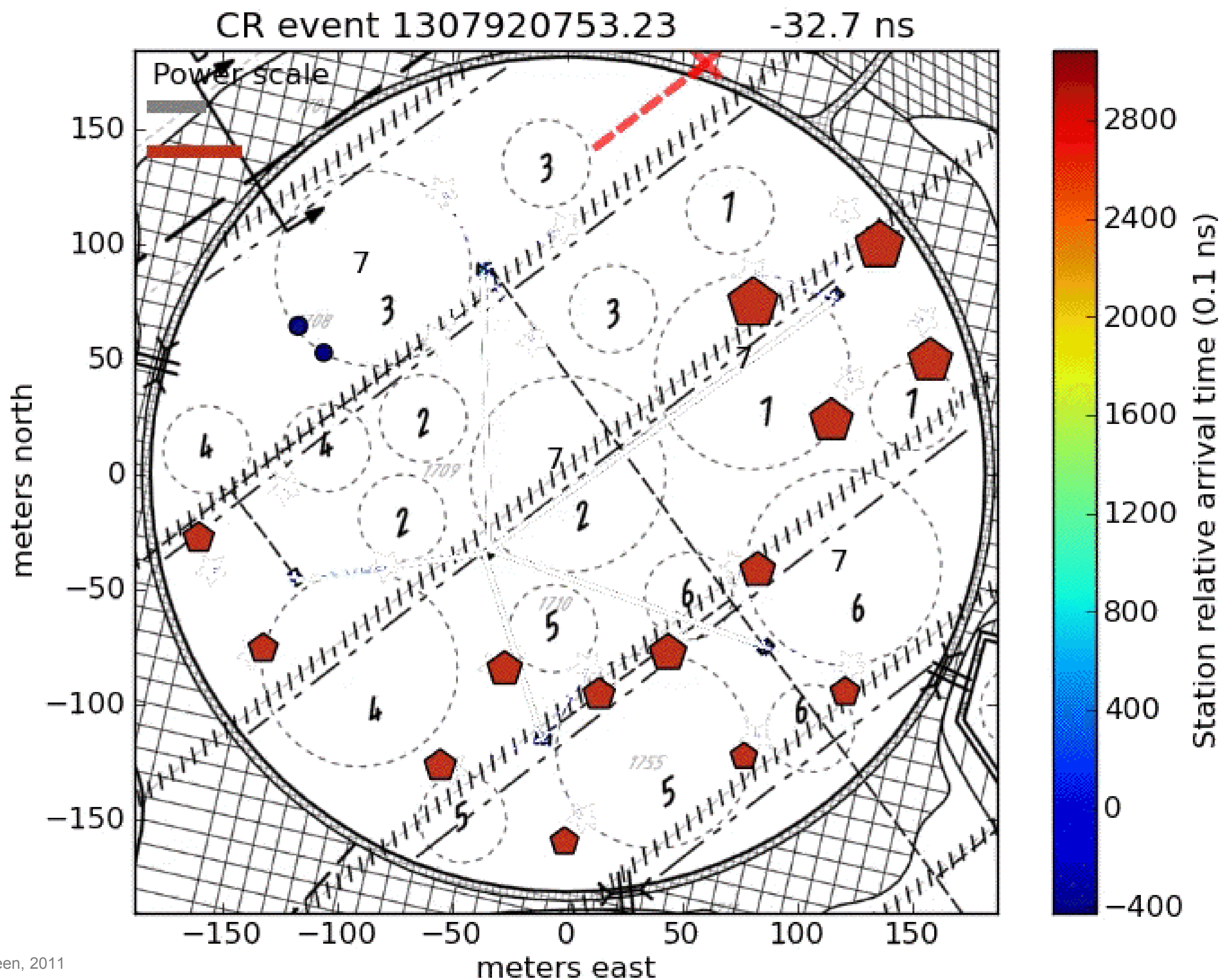
Foster, 2012

Non-astronomical applications

Photo: Läslo Evers, KNMI

Options for non-conventional experiments and instrumentation

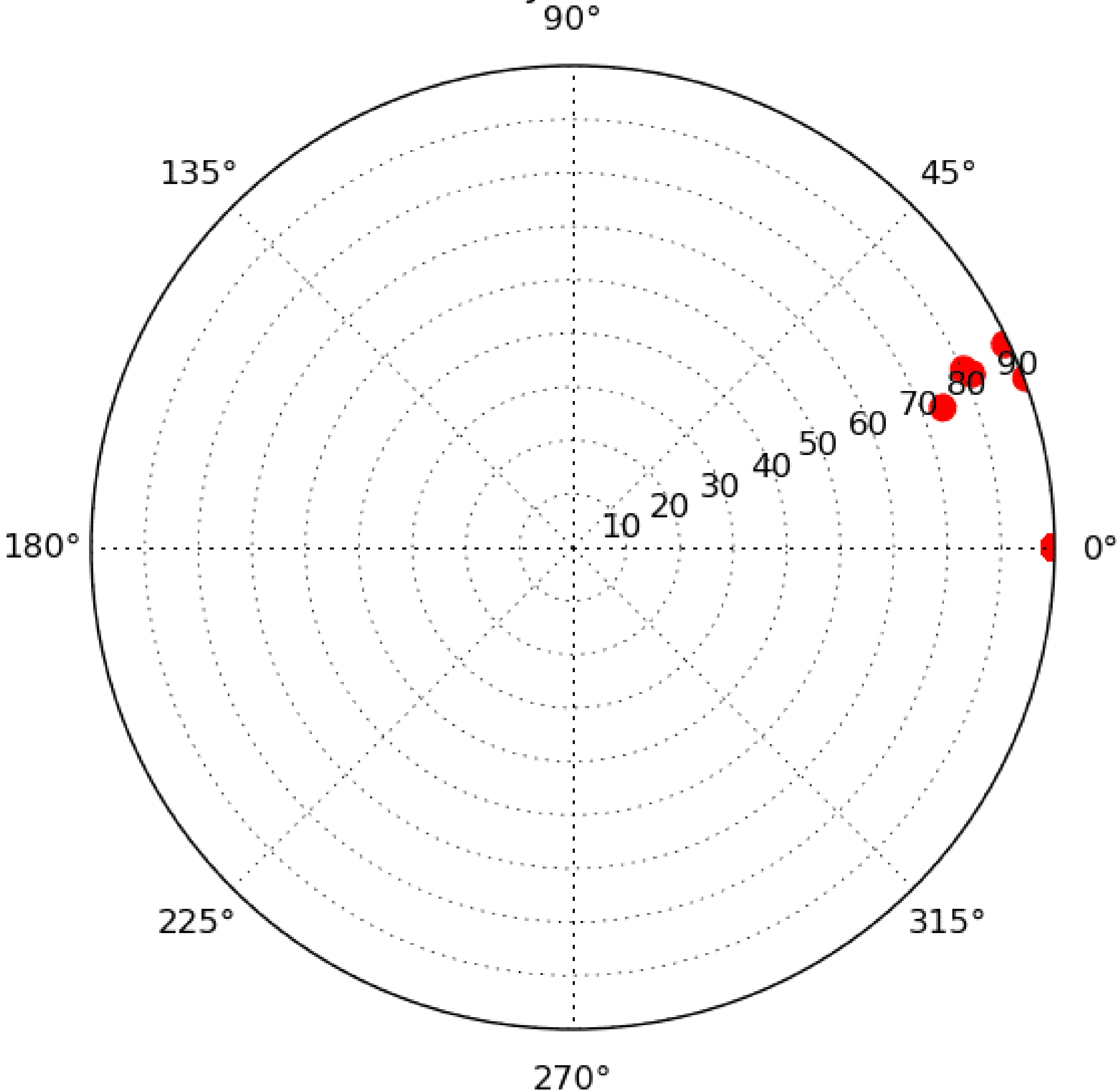
- **Transient detection**
- **Cosmic ray research**
- **Artificial signal detection**
- **Riometry**
- **Rapid all-sky radio cameras**
- **De-dispersion engines**
- **Incoherent scatter radar**
- **LBL-antennas**
- **Infrasound**
- **Seismology**
- **Microbarometry**
- **Distrometry**



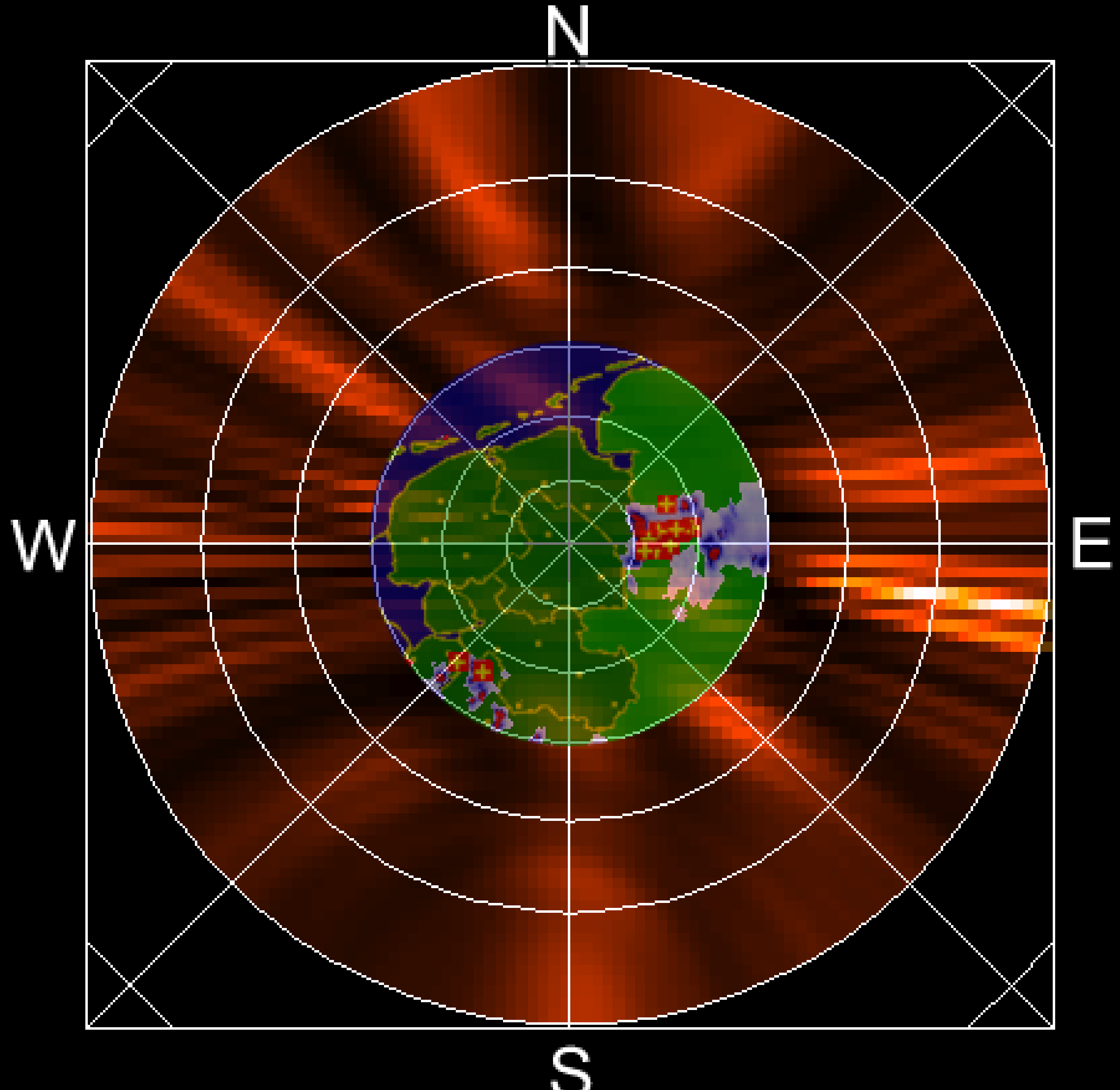
S. ter Veen, 2011

Circles: LOFAR antennas, Pentagons: LORA particle detectors, size denotes signal strength

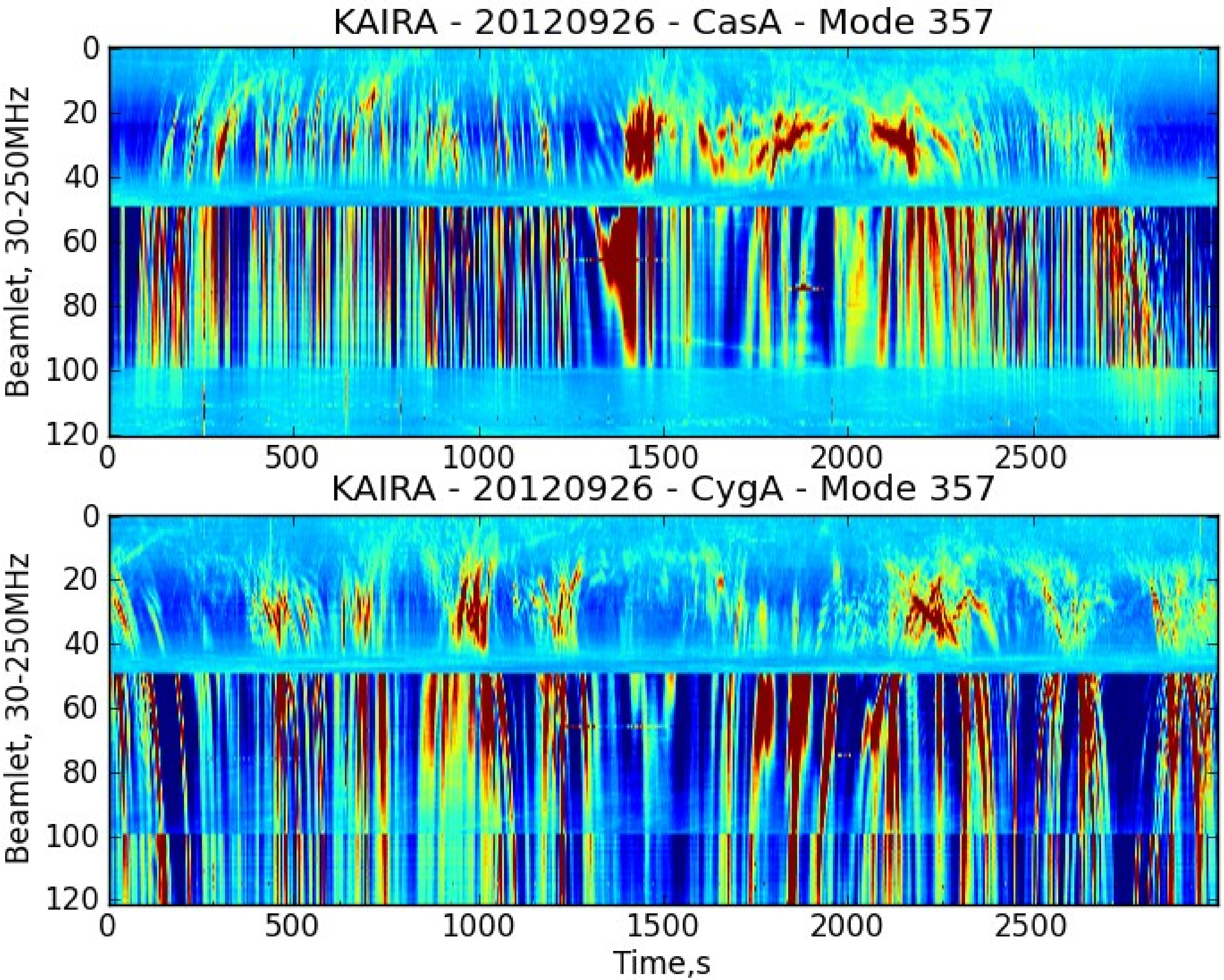
CS021 32ch, Sat Jun 12 14:42:07 2010



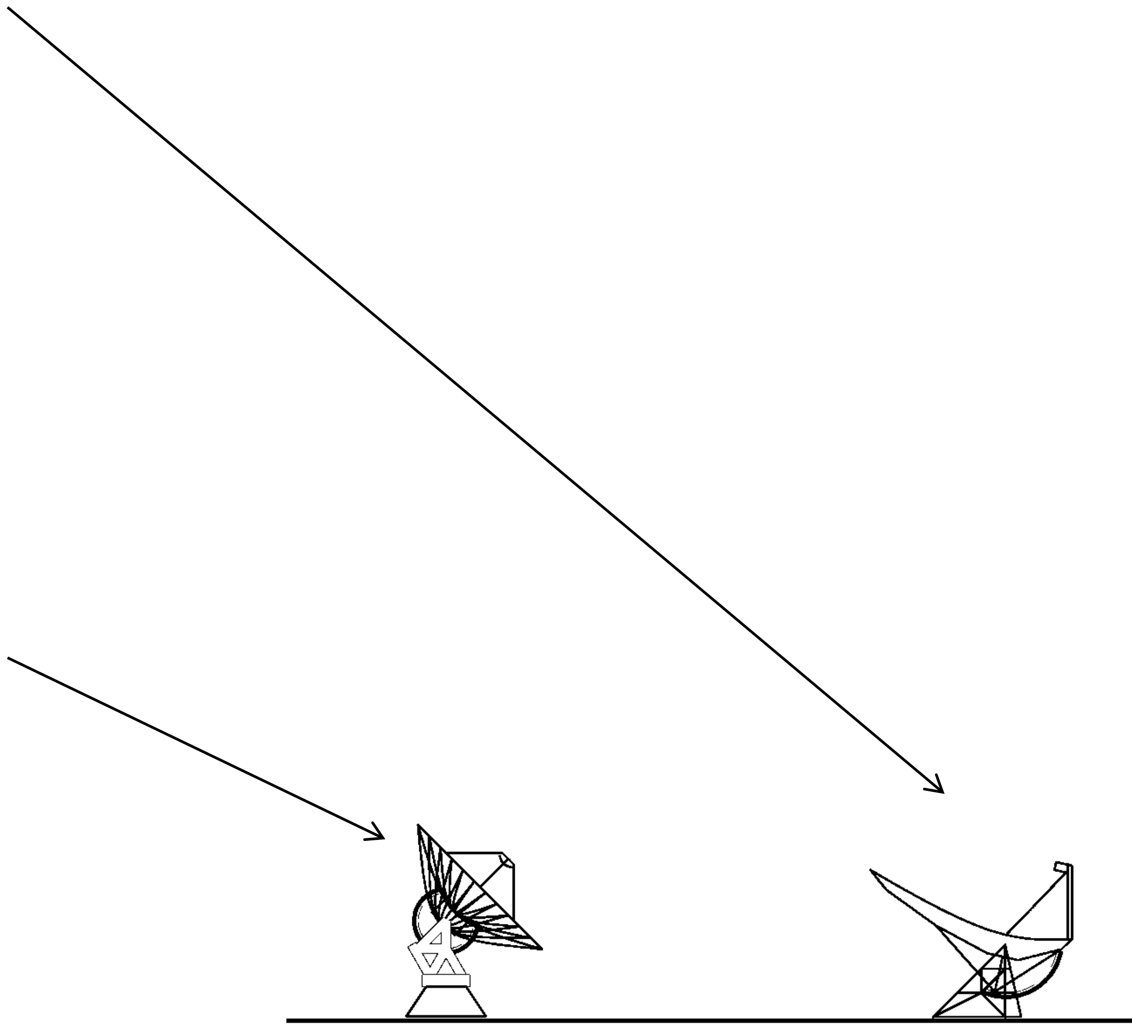
A. Corstanje, 2010



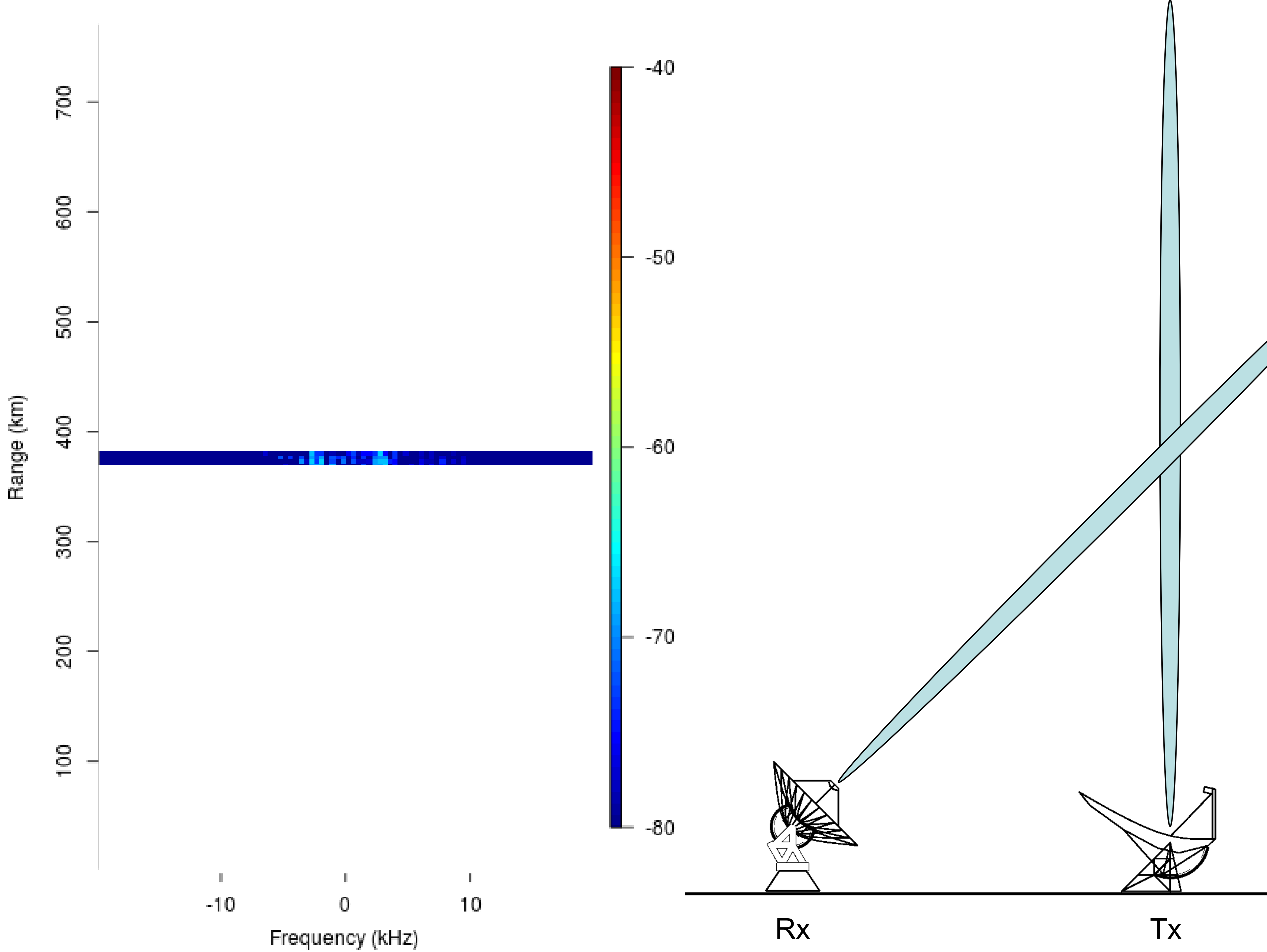
S. ter Veen, 2010



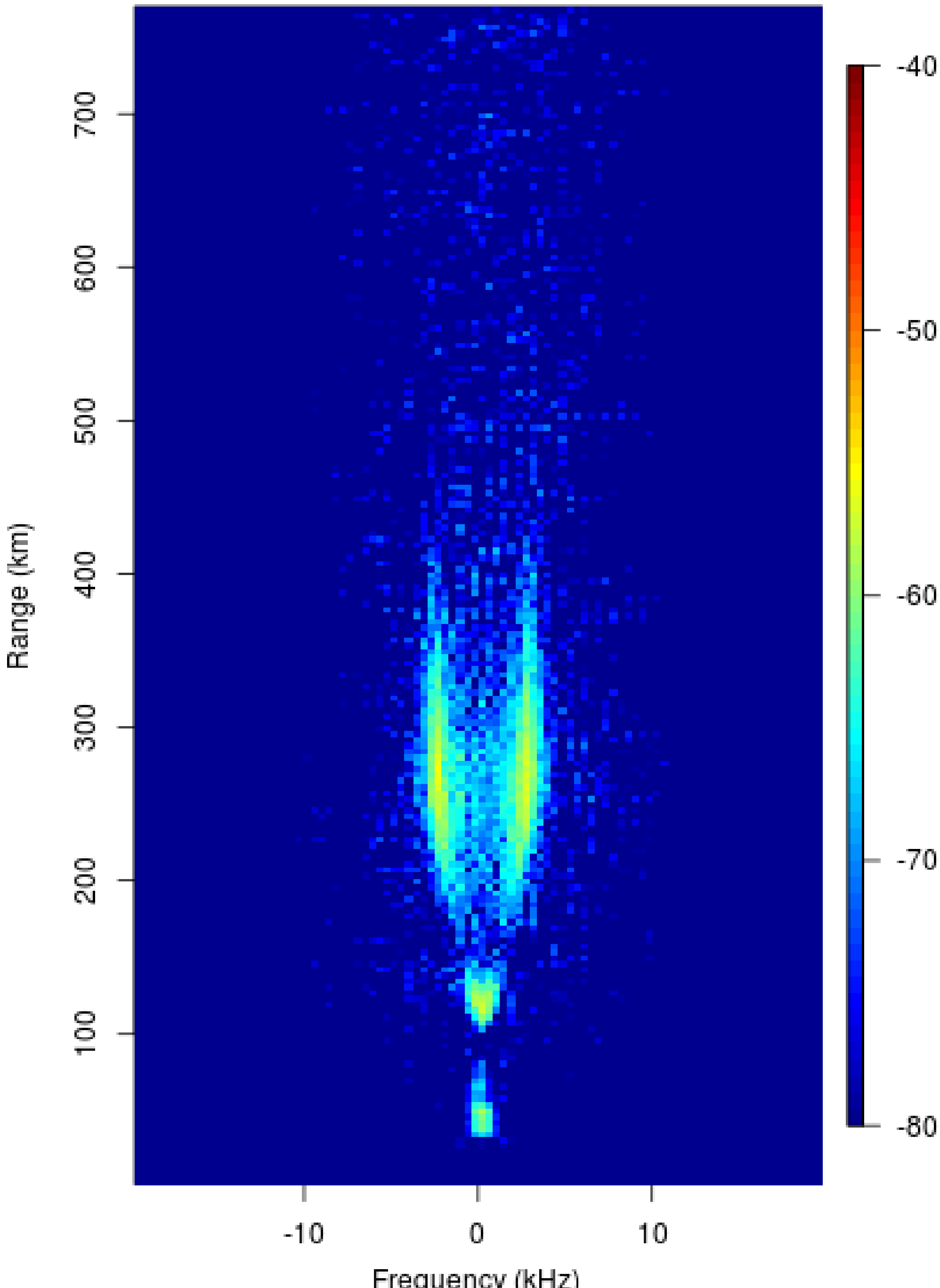
J. Vierinen *et al.*, 2012

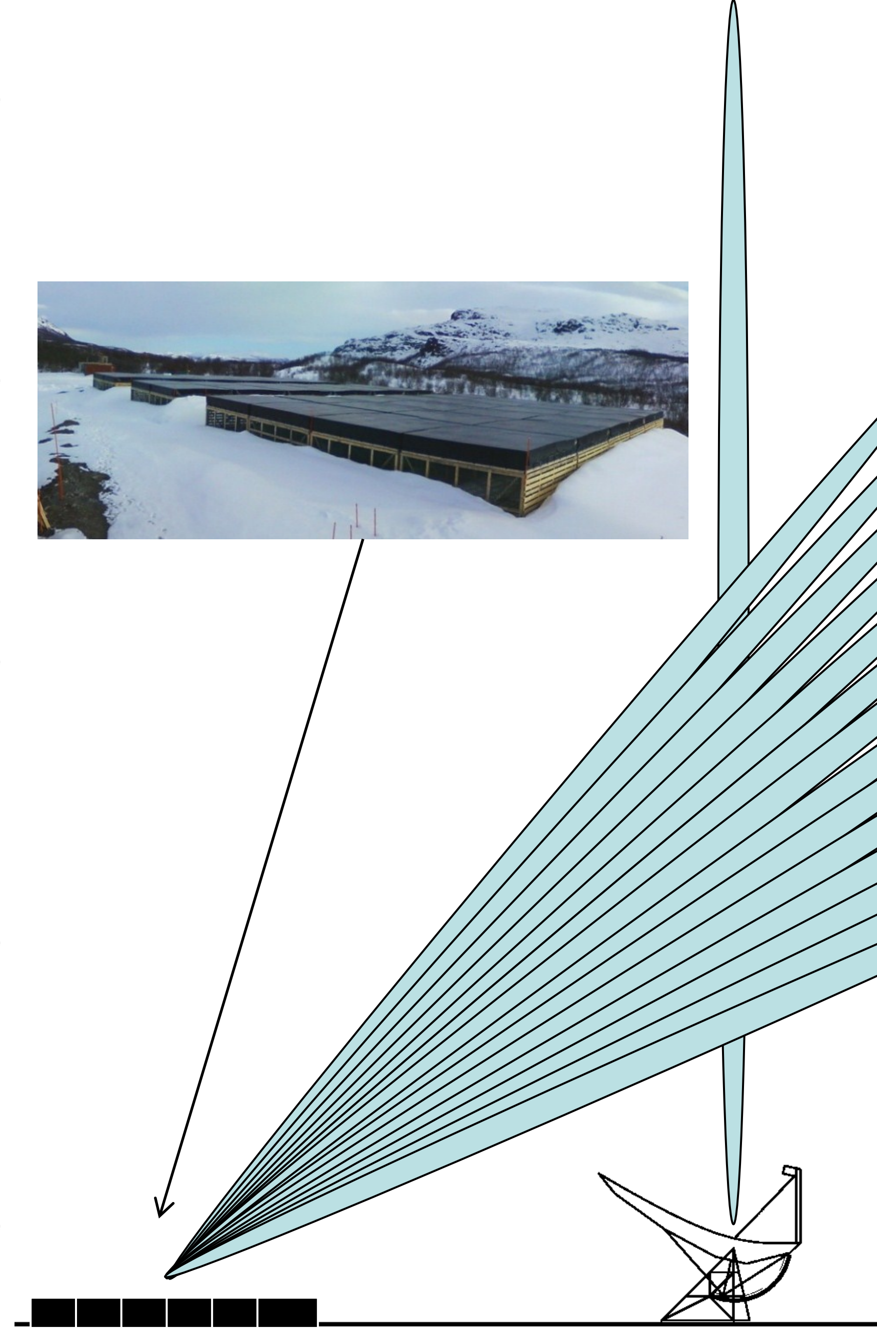


Photos: G. Peacock & D. McKay-Bukowski



Range (km)
700
600
500
400
300
200
100
-10
0
10
Frequency (kHz)
-40
-50
-60
-70
-80
Rx
Tx





Vierinen *et al.*, 2012

Conclusion

- **Rapid-build system** ("flat-pack" concept, production-line efficiency... 0-100% in 6 mths)
- **Accessible** (knowledge base, full documentation, great for student involvement)
- **Low-maintenance** (robust design, no-moving parts, easy on operating costs)
- **Scalable** (multiple-size options, easily expandable, scales and integrates into the full network)
- **Flexible** (allows multiple experiments, simultaneous operation)
- **Common standard** (shared expertise, spare-parts pool, extensively tested)
- **New science area** (low-frequency + high-time resolution = new parameter space)
- **Multi-discipline** (applications to geology, agriculture, atmospherics, space weather, etc.)
- **Internet telescope** (remote access, software-based experiments)

LOFAR exploits developments in computing, networking and digital signal processing, and has opened up vast areas of unexplored scientific parameter space.