Conditions for LOFAR radio telescope and wind farm co-existence

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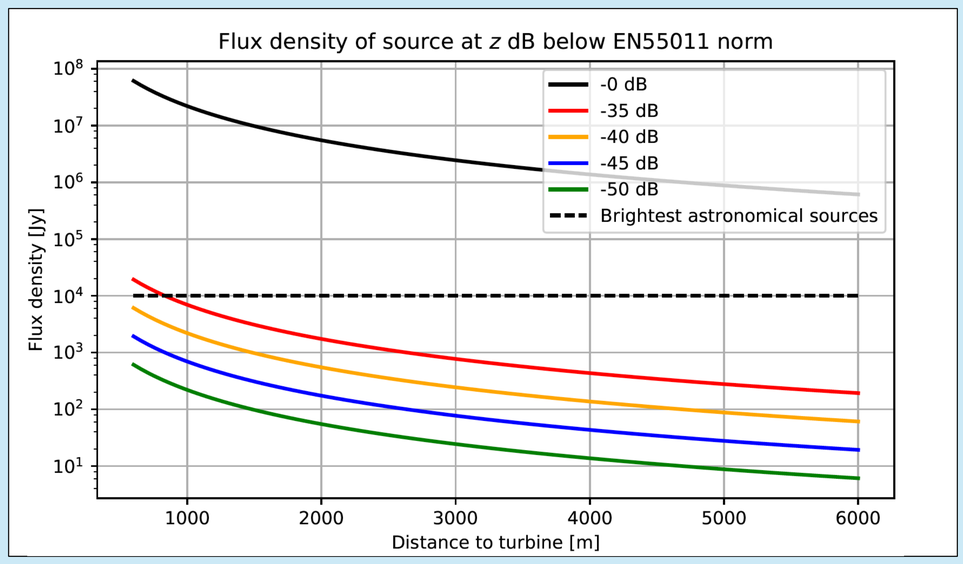
LOFAR

Core area: 3,456 phased array antennas on 4 km^2 area

Total: 6,336 antennas
Antennas grouped in 52 'stations'

Imaging by using radio interferometry
Transient research by using tied-array beams

Windfarm challenge



Plans for 45, ~240 m tall wind turbines near LOFAR core (~4-10 km from Superterp), max. 3.9 GW

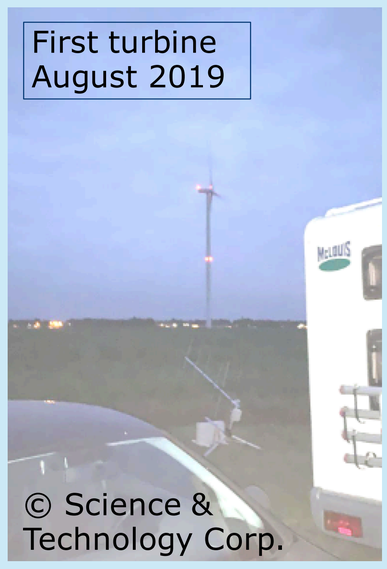
Covenant requiring radio-quiet wind turbines

Covenant

EM interference reduction
< 35 dB:
35 dB < improvement < 40 dB
40 dB < improvement < 50 dB
improvement 50 dB

Consequence
No permission to operate
56–62 12 h idle
Reduced idle time to be negotiated
No restrictions

- ASTRON must find 7 dB additional improvement in signal processing
- Agentschap Telecom establishes method to measure improvement
- In case of conflict: binding arbitration

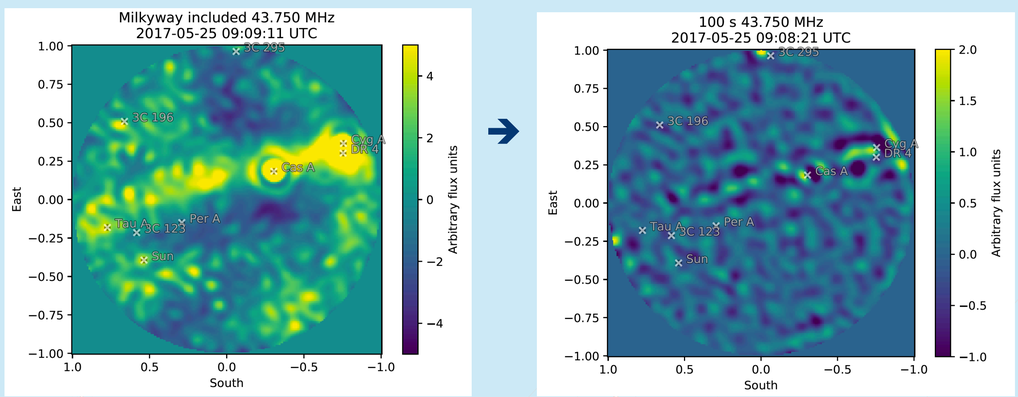


Measurement approach

- Use imaging radio interferometer plus cal source to measure below ambient noise levels
- Use near-field visibility models:

$$V_{ij} = \sum_{k=1}^{K} I_k e^{2\pi i \nu (\vec{u}_{ij} \cdot \vec{l}_k)/c} \rightarrow V_{ij} = \sum_{s=1}^{S} \sqrt{I_{si} I_{sj}} e^{2\pi i \nu (\|\vec{r}_{sj}\| - \|\vec{r}_{si}\|)/c}$$

- Sensitivity determined by ability to subtract astronomical sources and unrelated interference



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Field measurements

Test set-up verification done using drones, to check system parameters such as

- integration time and number of antennas
- source and interference subtraction capability

Measurements on-going

- biconic transmit antenna mounted on 100 m tower near turbine
- LOFAR stations in near-field imaging mode

Paper in preparation