ASTRON

LOFAR

Netherlands Institute for Radio Astronomy

RFI (Windmill & Solar farms)

ILT-TO face to face meeting, Amsterdam
6 & 7 November 2019

Menno Norden

Outline Talk

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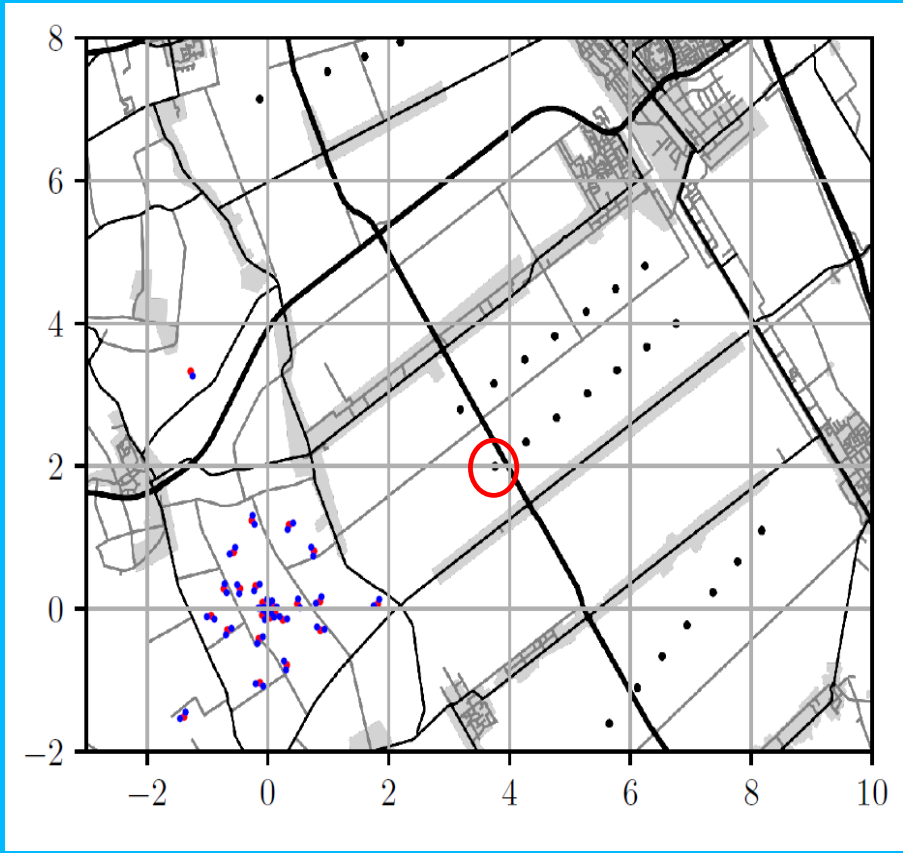
- Status of Windmill project
- Various solar farms around core and remote stations

WTG status



WTG status

- First NORDEX N131/3.9 MW prototype WTG including infrastructure (a few million Euro)
- Build completely from scratch with all possible EMC measures
  - Very good emc engineers/ consultants
  - German university support
- Goal is a level of 35 dB below CISPR-11.

  (50dBuV/m @ 10 meter distance at 100 meter height in 120 kHz BW (average) in the 30-240MHz frequency band)
- When pass, the other 44 WTG could be build.
- NORDEX EMC-Dossier under NDA (+190 pages)
  - Assessment of EMI classes
  - A – probably no problem (conventional lamp)
  - B – might be a problem (control cabinet)
  - C - for sure could be a problem (inverter)

  For type B and C they have done EMC emission measurements in test labs.
  The EMI should be below a certain level including some safety margin.
  When a component failed the test, mitigation measures where taken and re-measured.

- This systematic approach gives better isolation of the systems and easier to improve.

WTG status

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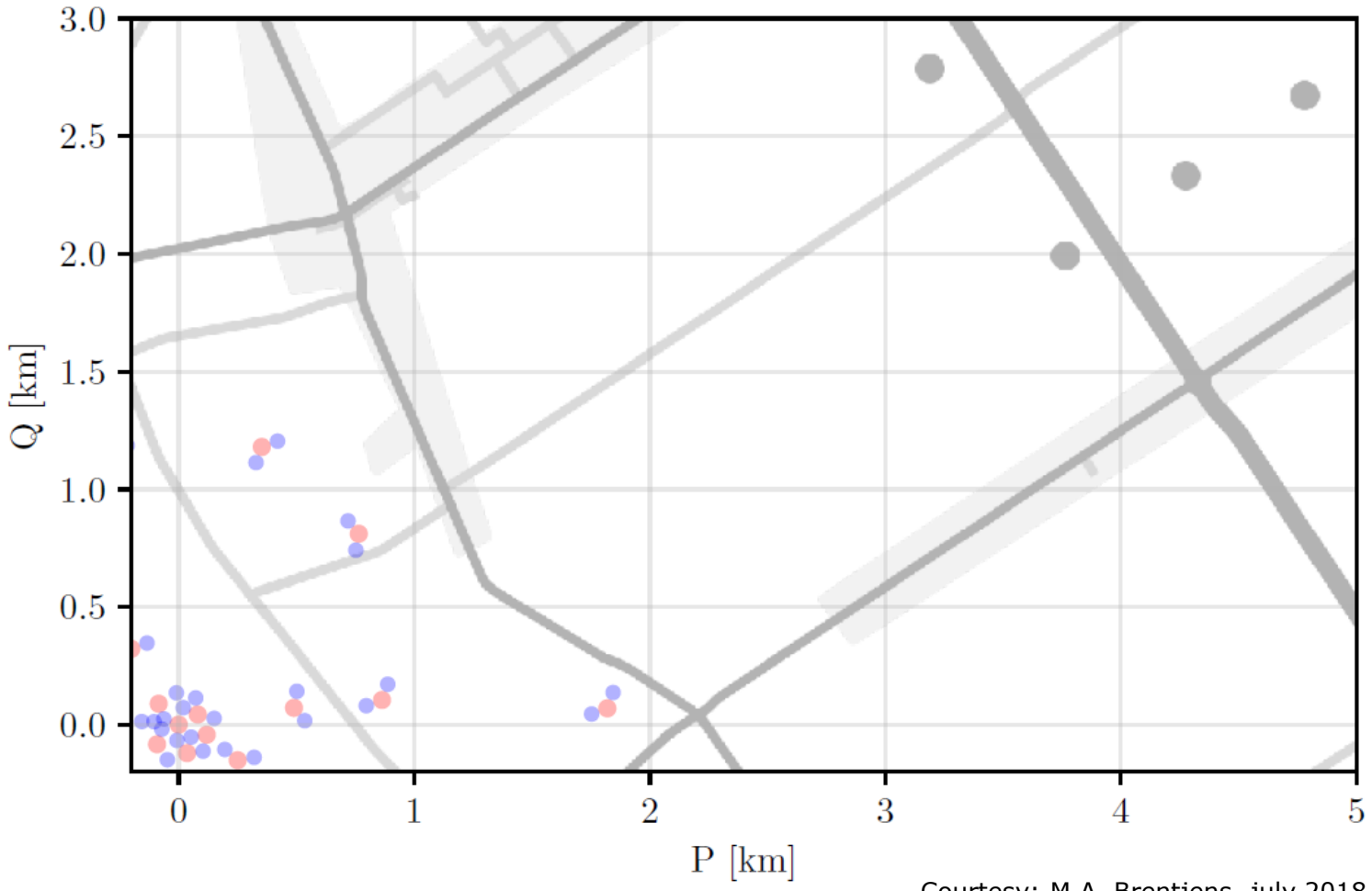
- Several test observations have been executed (Astron, AT, S&T)
  - Check the duration of battery lifetime
  - Remote switching of 0 and -35 dB level
  - Different comb frequencies (100kHz, 1MHz)
  - Test the dedicated LOFAR observing mode
  - Parallel processing of the recorded data (long queue)
  - External company S&T has to post process and image the data
- Reference transmitter places at 100 meter height crane!
  - Both LBA and HBA test observations
- Official measurement campaign first two weeks of September 2019
  - Measurements in a few subbands in LBA and HBA
  - Same subbands are used by reference signal from transmitter
  - WTG and reference transmitter are special isolated by a few hundred meter
  - 0 dB level 1 or 2 seconds is sufficient, for -35 dB you have to integrate minutes
  - Also you need to flag RFI and subtract strong radio sources (A-team,..)
  - The residual power of the strong sources at the location of the windmill should be sufficient low to detect the windmill RFI at -35 dB level with sufficient S/N

WTG status

- The WTG is measured in three different modes
  - Operational mode
  - Minimum mode
  - Completely switched off

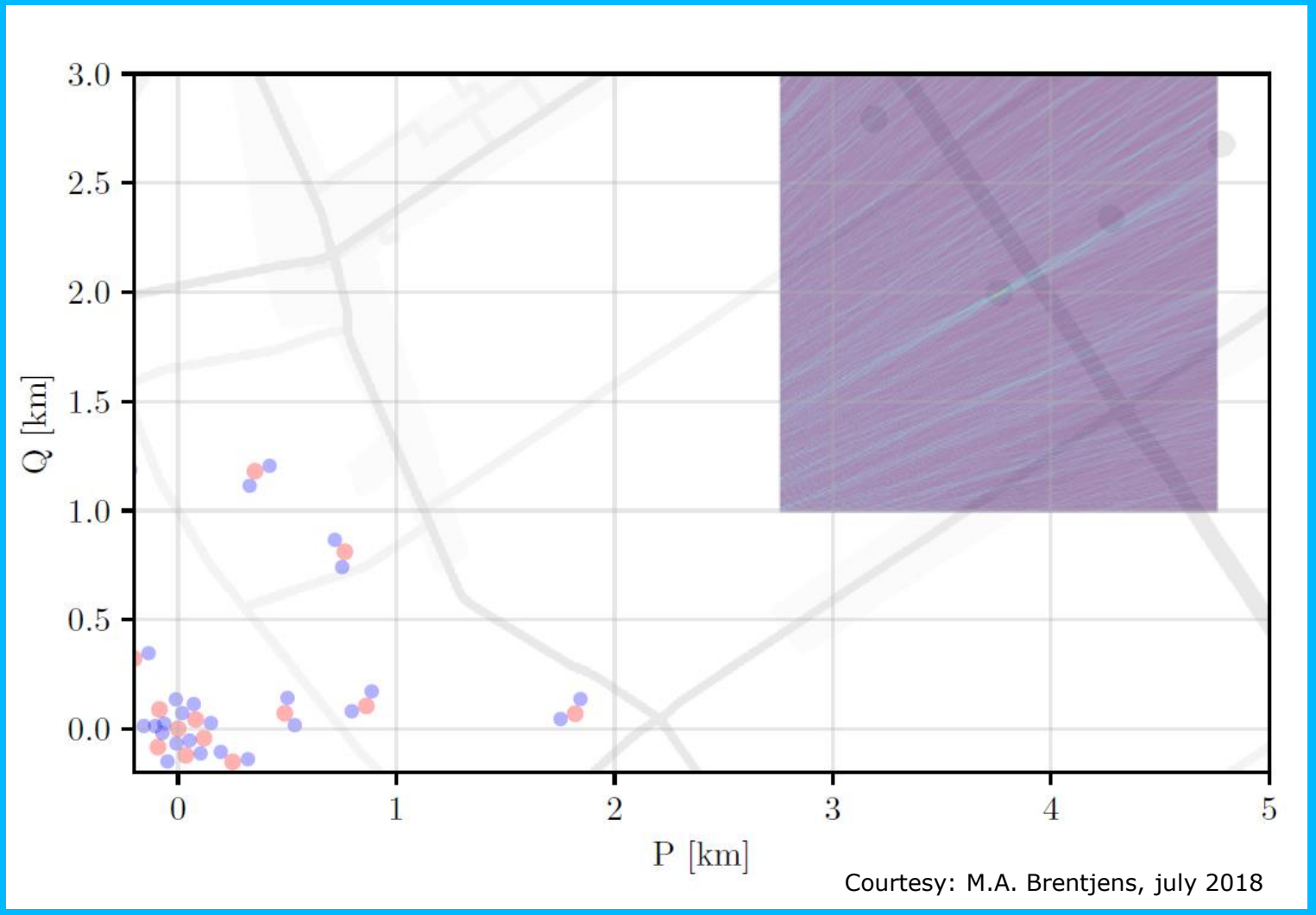
- We expected final results before end of the year.
- When less than 35 dB reduction, modifications are needed and new measurement campaign.
- When more than 35 dB reduction, they can start building the rest.
- The 50 dB reduction is difficult or impossible to measure with LOFAR.

WTG status



Courtesy: M.A. Brentjens, july 2018

WTG status



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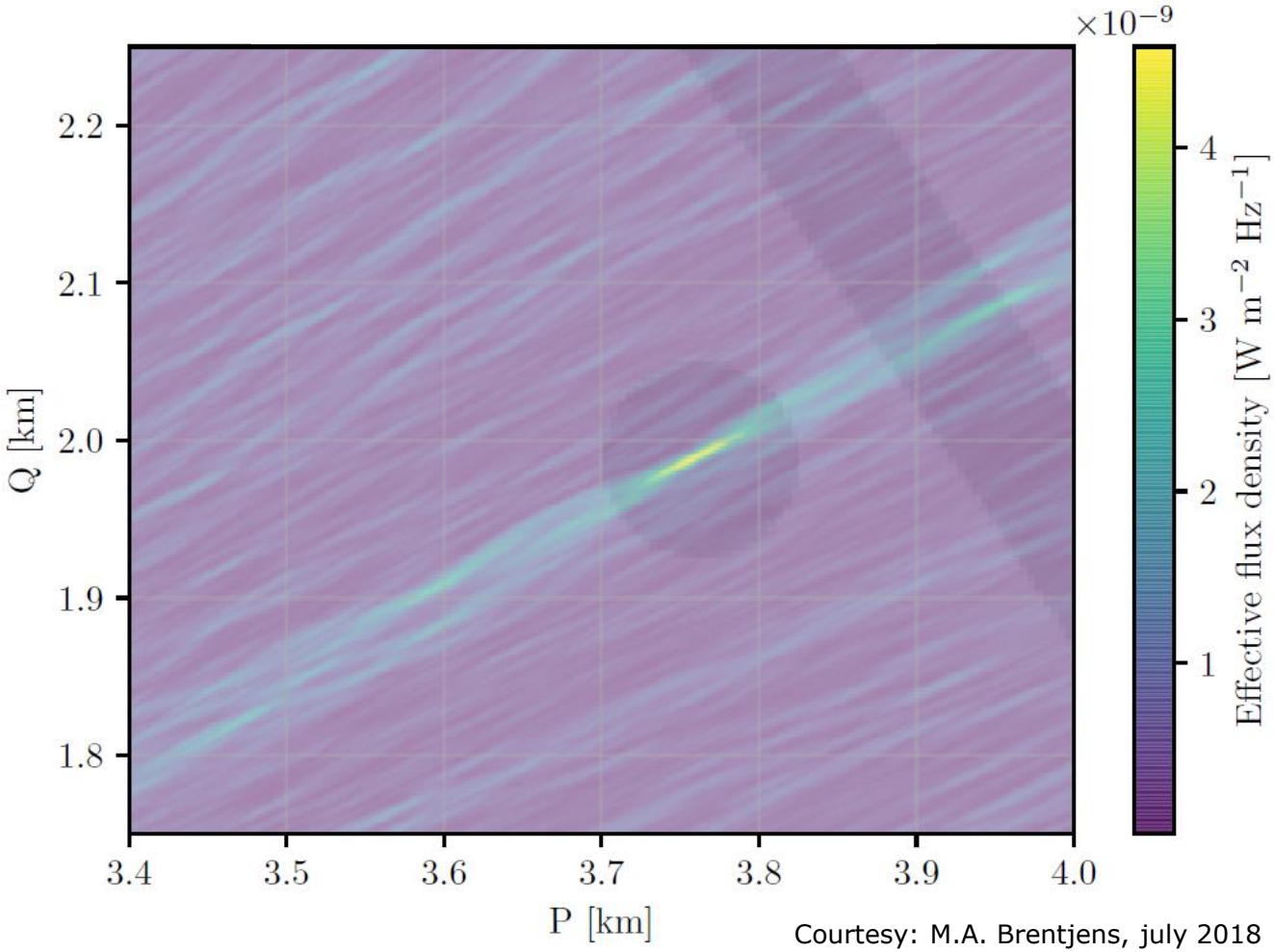

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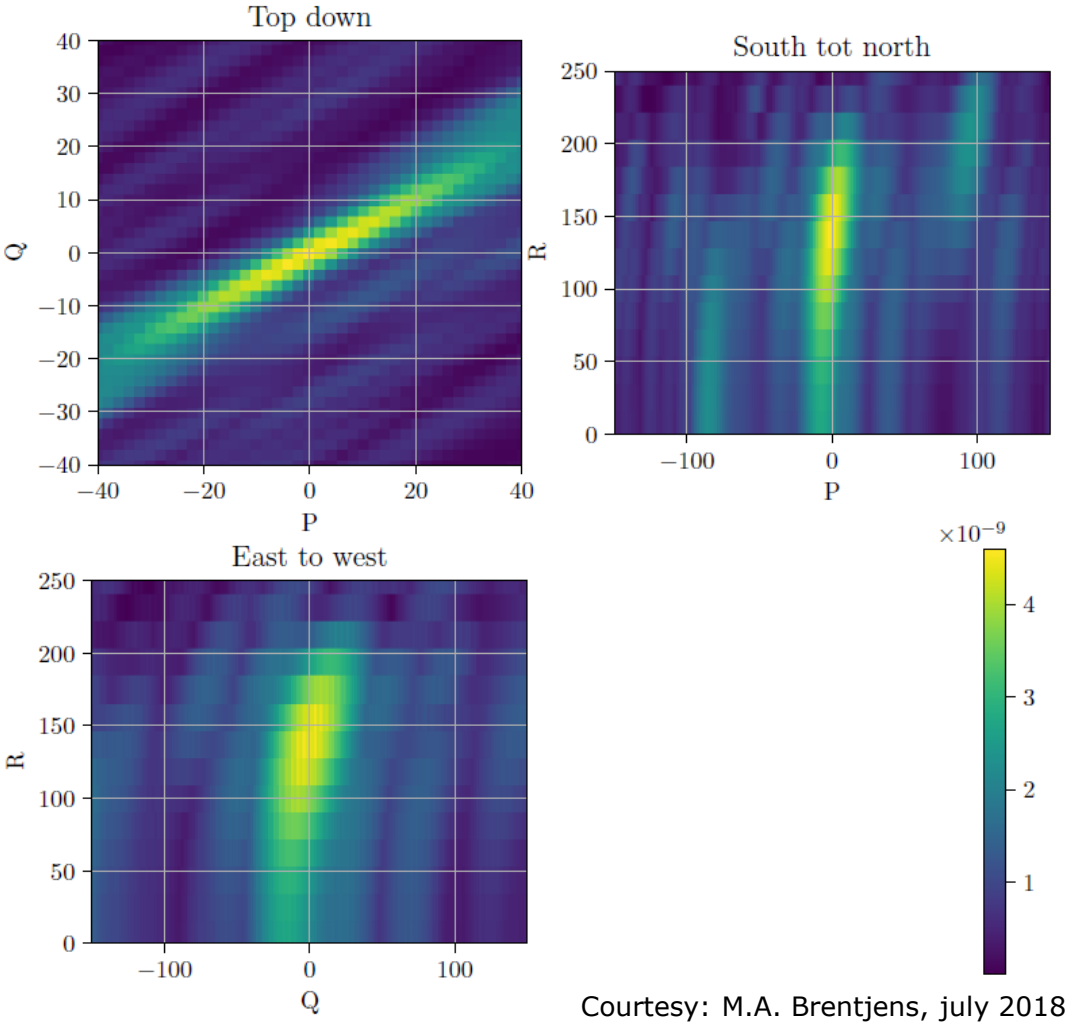
WTG status



Courtesy: M.A. Brentjens, july 2018

Conditions for LOFAR radio telescope and wind farm co-existence

M.A. Brentjens[1], E. van Maanen[2], P. Bolli[3], M.J. Norden[1], B.A. Witvliet[4], G. Virone[5], F. Paonessa[5], A.J. Boonstra[1]

[1] Netherlands Institute for Radio Astronomy, ASTRON, NL, [2] Radiocommunications Agency Netherlands, NL, [3] INAF - Arcetri Astrophysical Observatory Florence, IT, [4] Centre for Space, Atmospheric Oceanic Science, University of Bath, UK, [5] CNR-IEIIT, IT

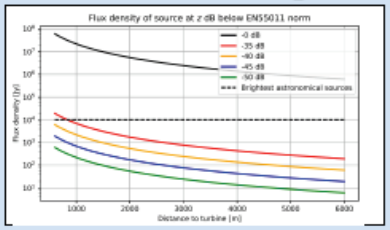
LOFAR

Core area: 3,456 phased array antennas on 4 km² 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	Consequence
< 35 dB:	No permission to operate
35 dB < improvement < 40 dB	56–62 12 h idle
40 dB < improvement < 50 dB	Reduced idle time to be negotiated
improvement 50 dB	No restrictions

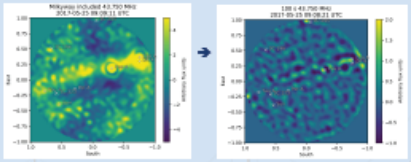
- ASTRON must find 7 dB additional improvement in signal processing
- Agentschap Telecom establishes method to measure improvement
- In case of conflict: binding arbitration

Measurement approach

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

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

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



Sky images © Science & Technology Corp.

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

ASTRON NWO Agentschap Telecom UNIVERSITY OF BATH IEIIT INAF

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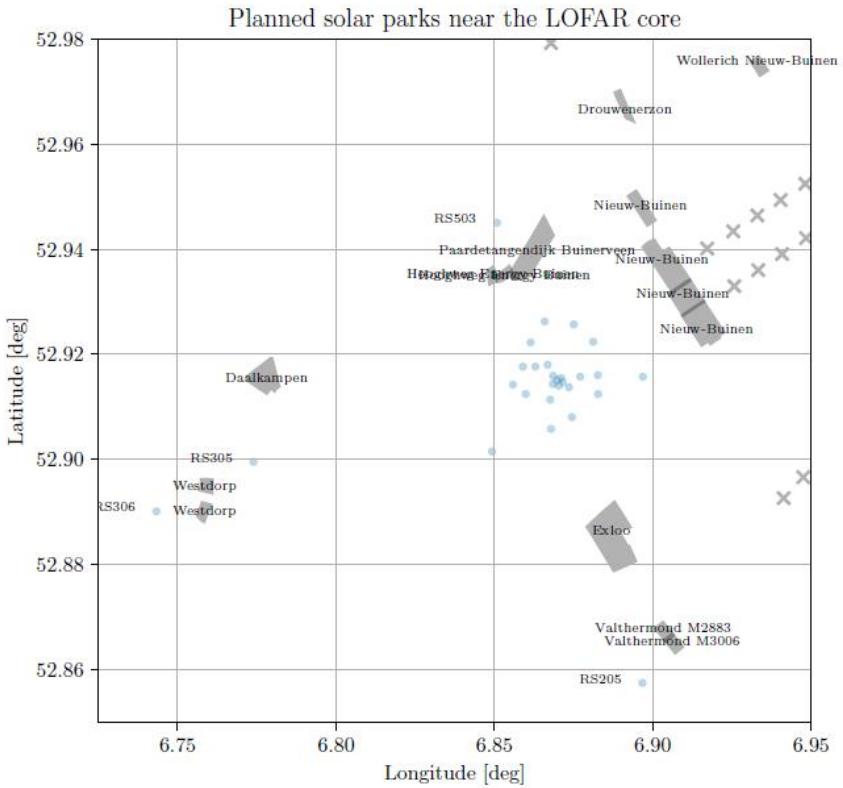
Poster @ RFI 2019

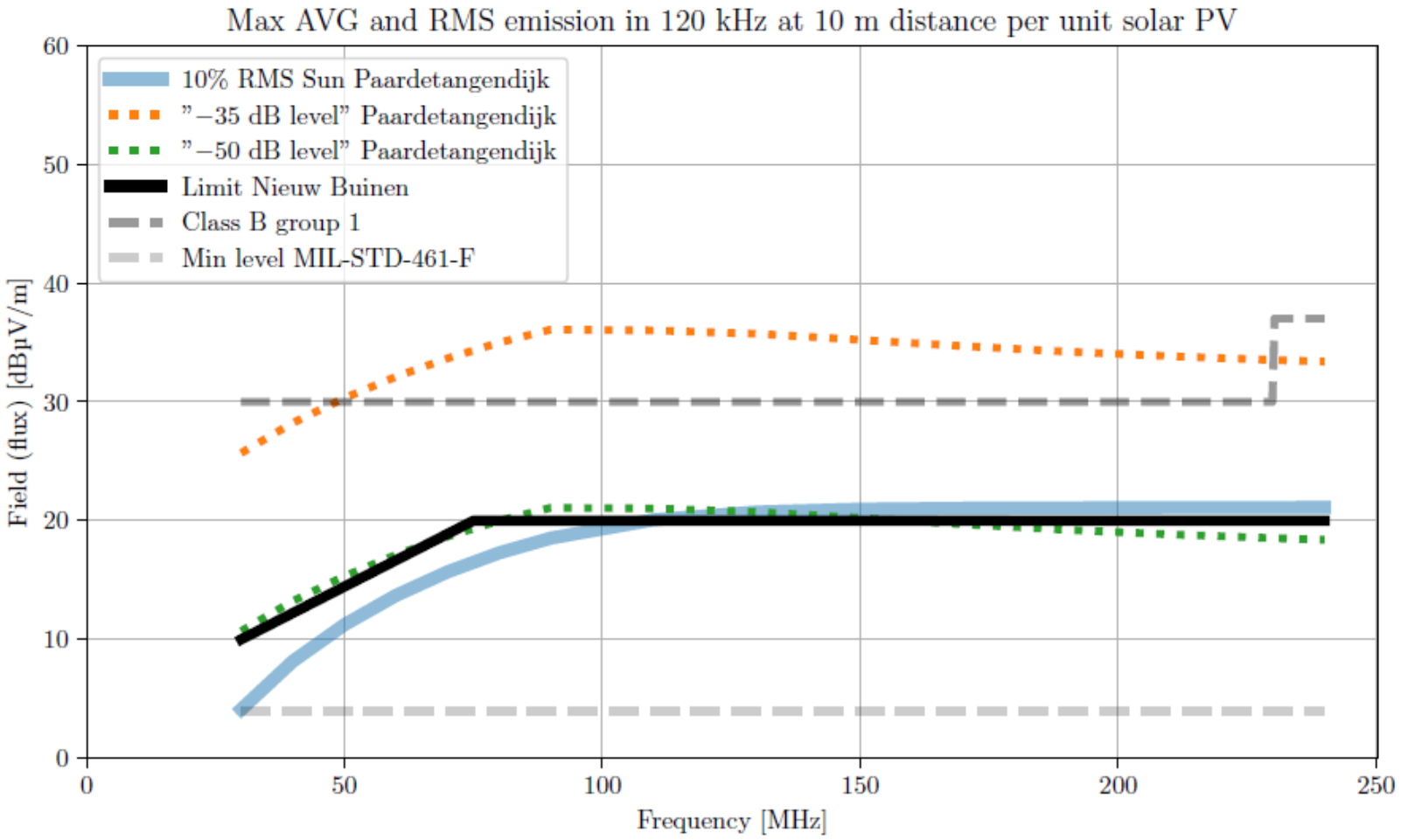
Toulouse, France
September 23-26

Solar plant emission

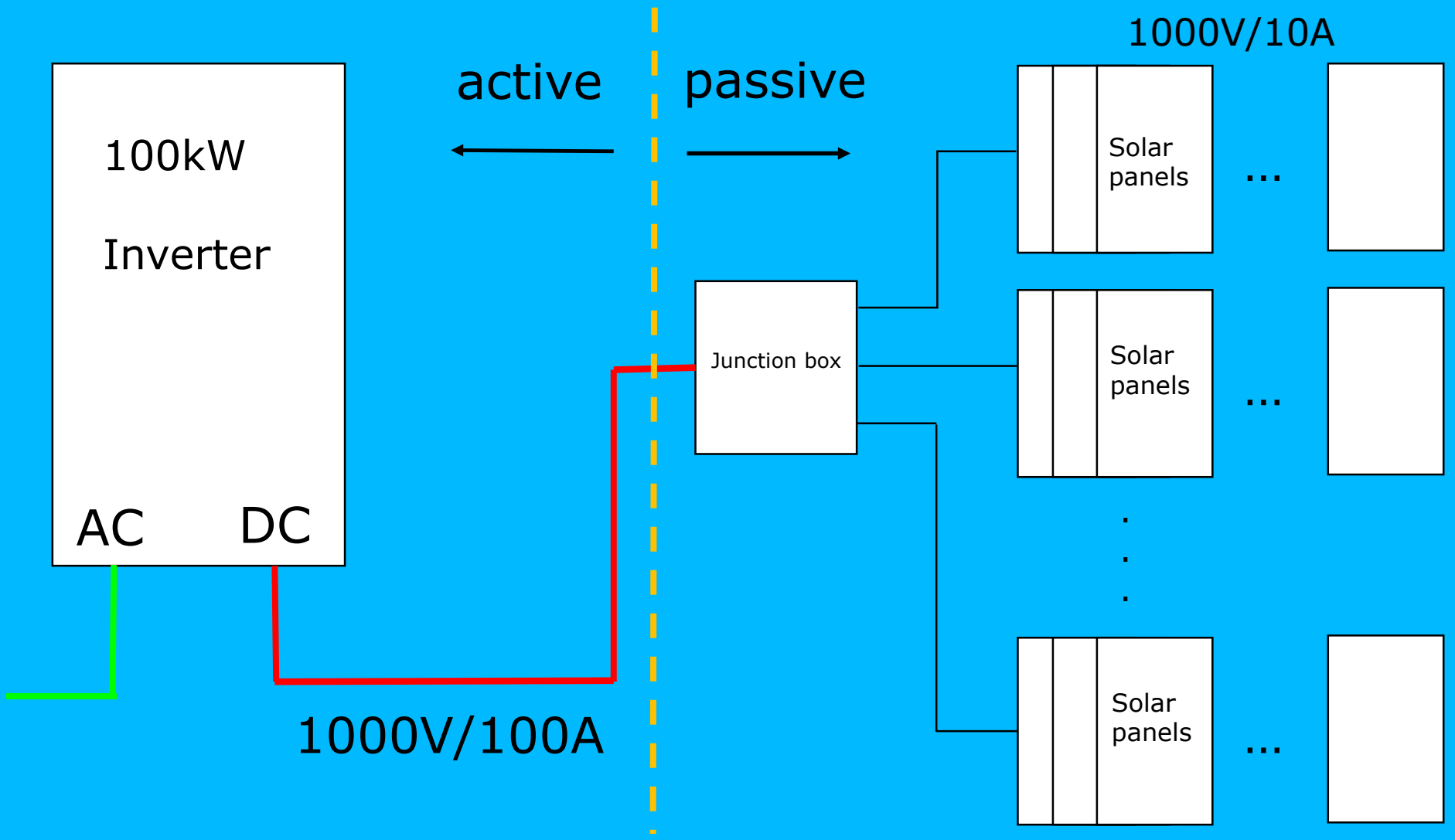


2 - 100 MW installations (total 250 MW around core)

Solar plant emission



100kW PV unit



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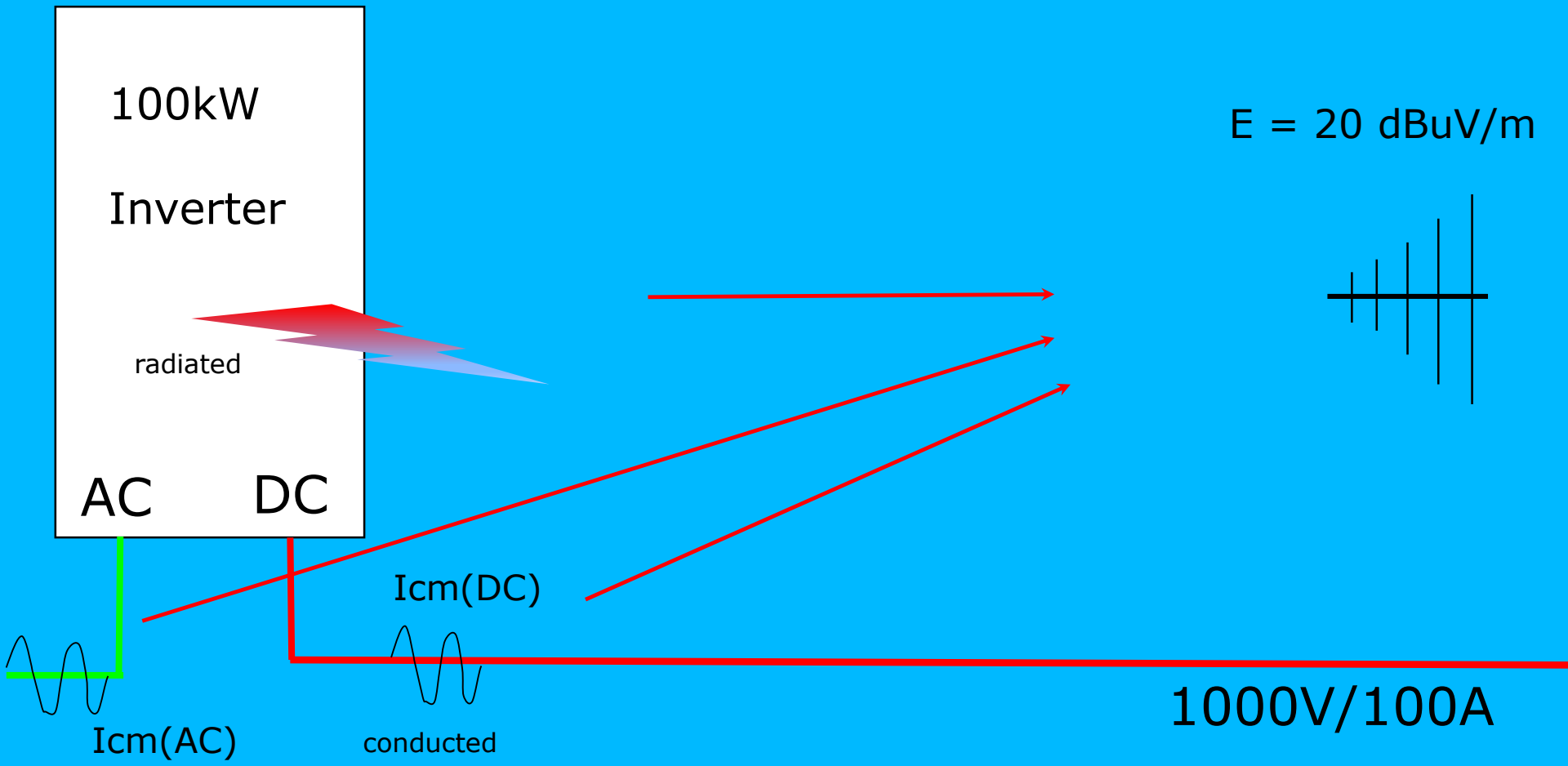
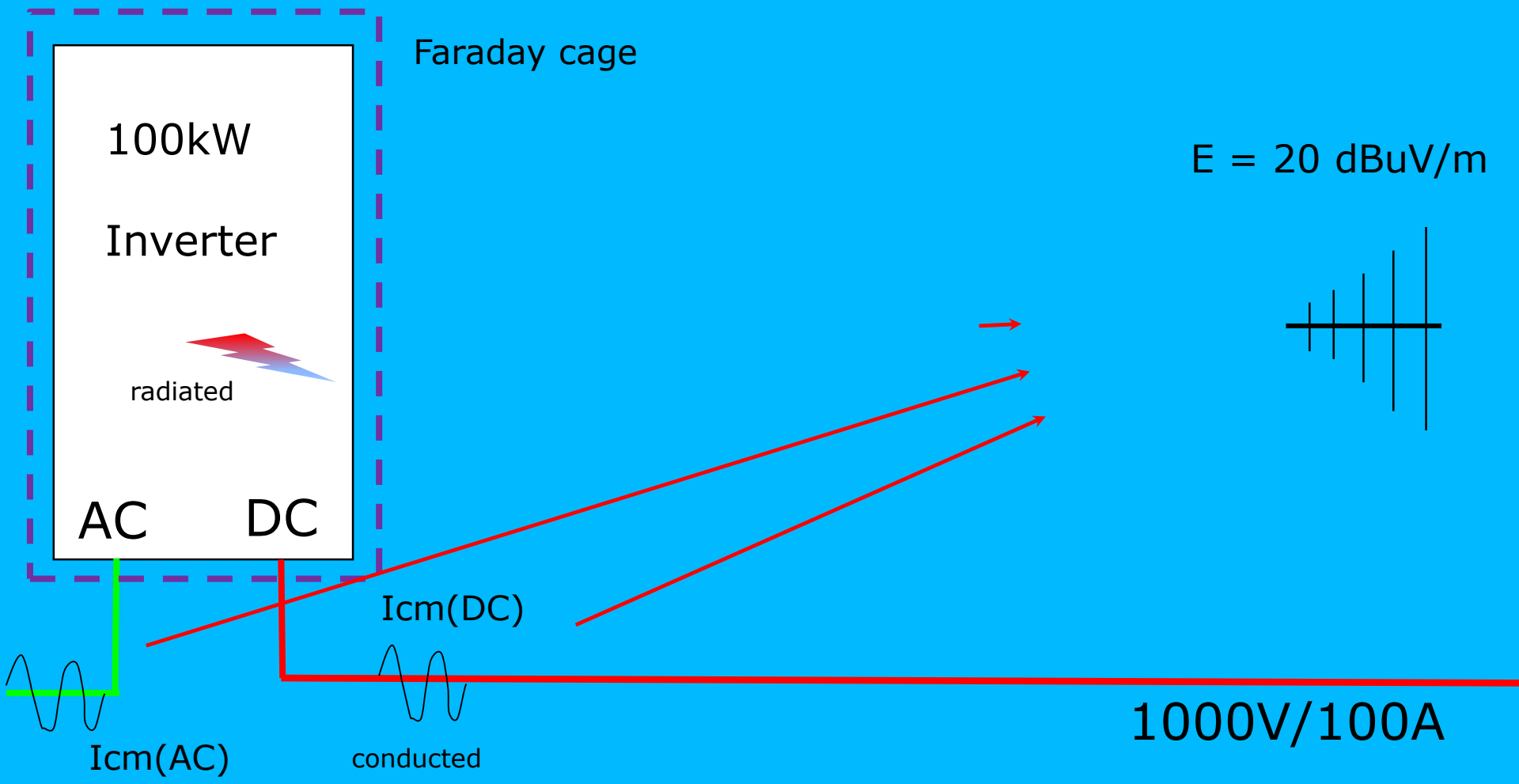
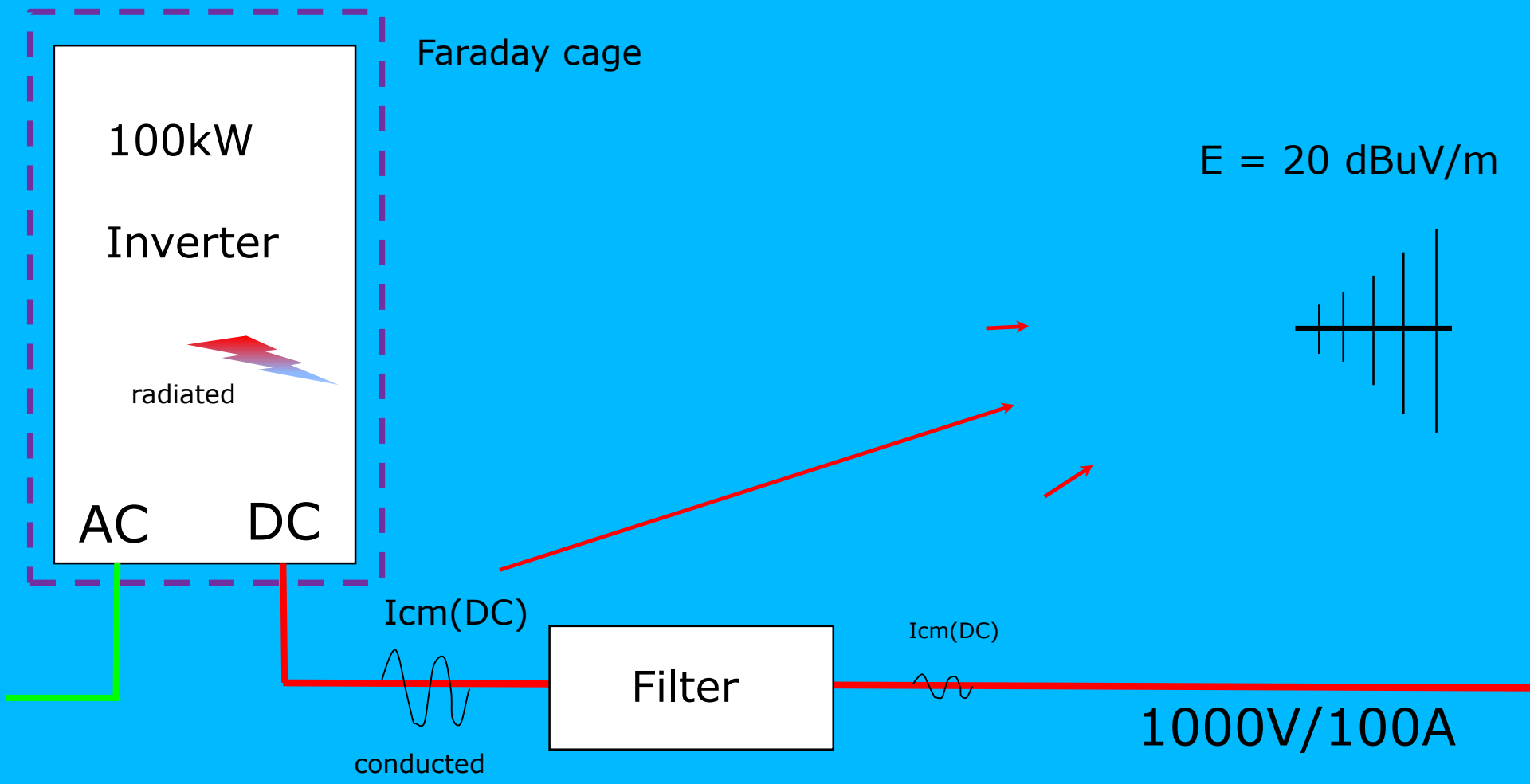


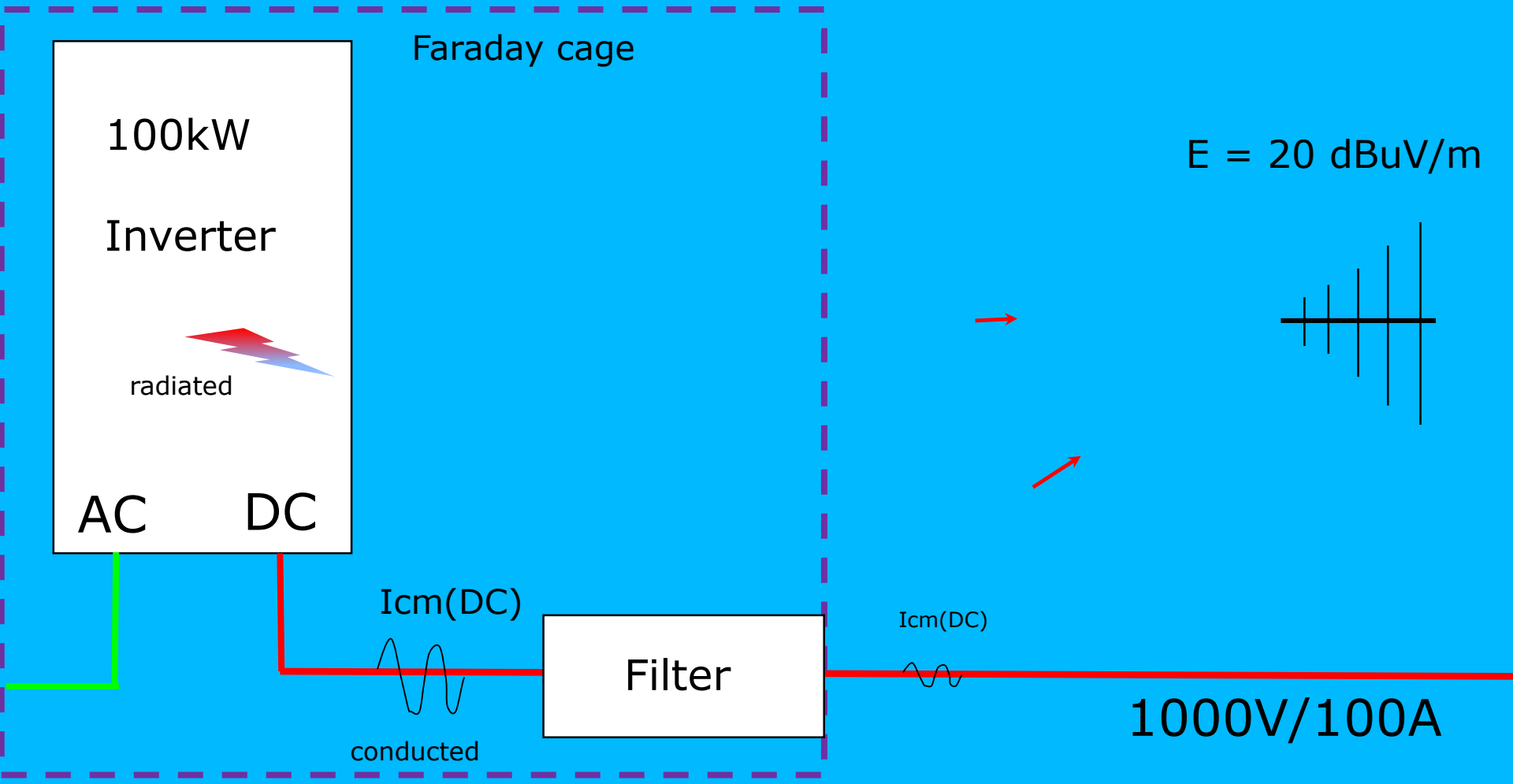
100kW PV unit



100kW PV unit



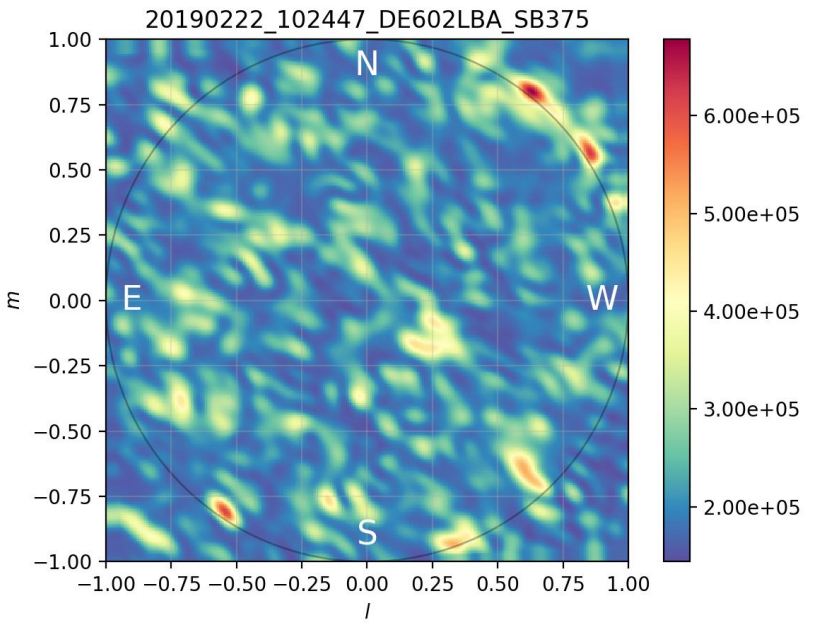
100kW PV unit



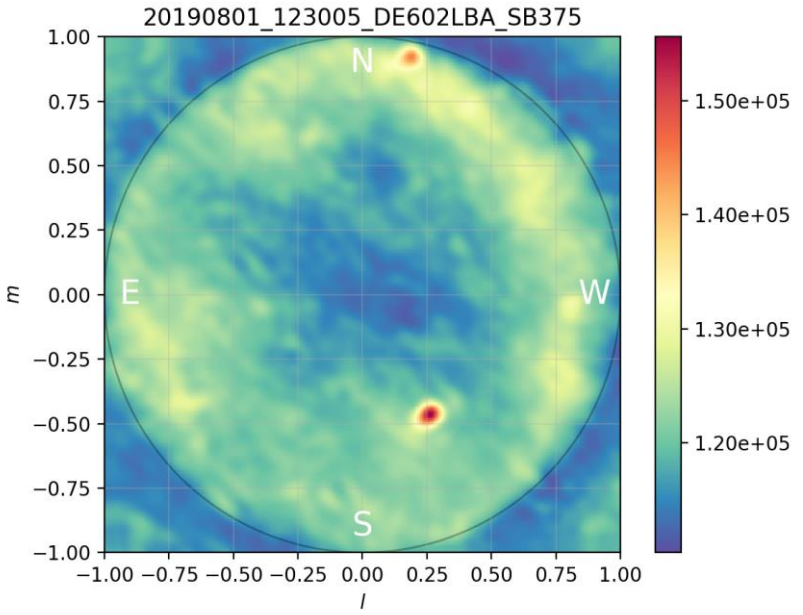
Faraday cage examples

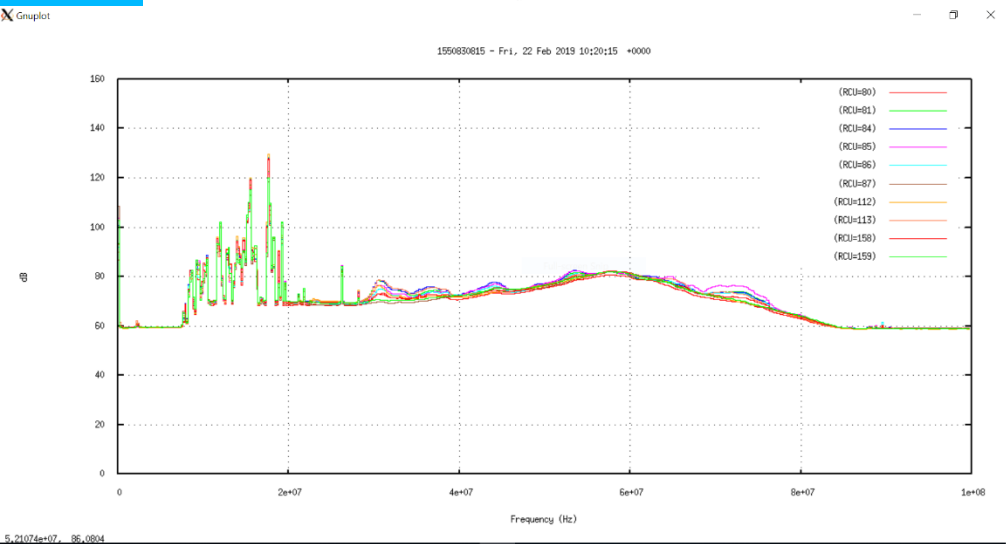
Faraday cage result

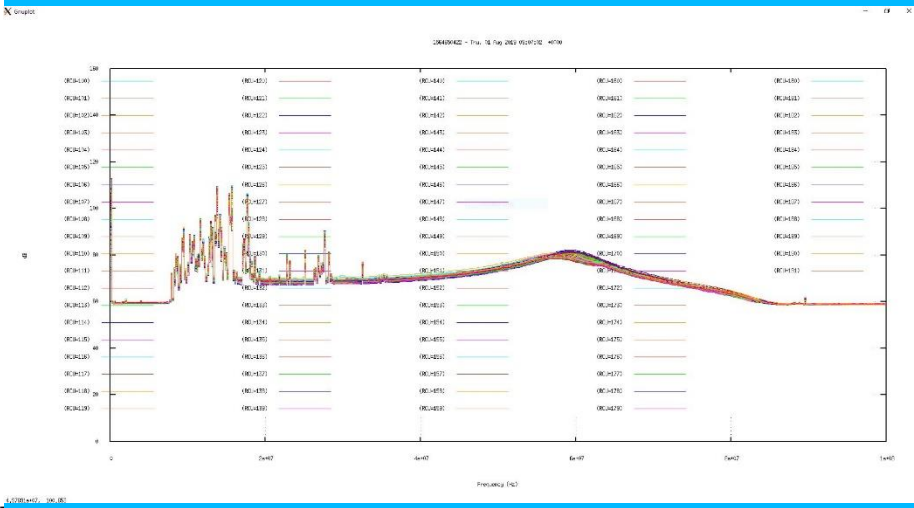
before



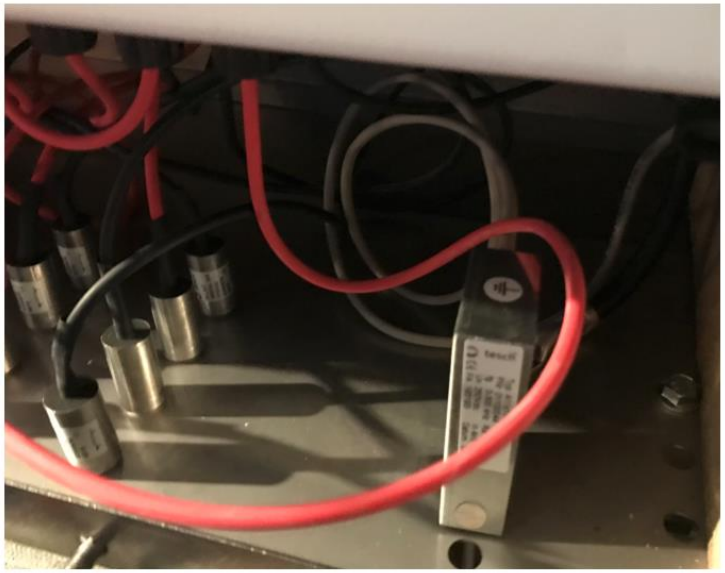
after



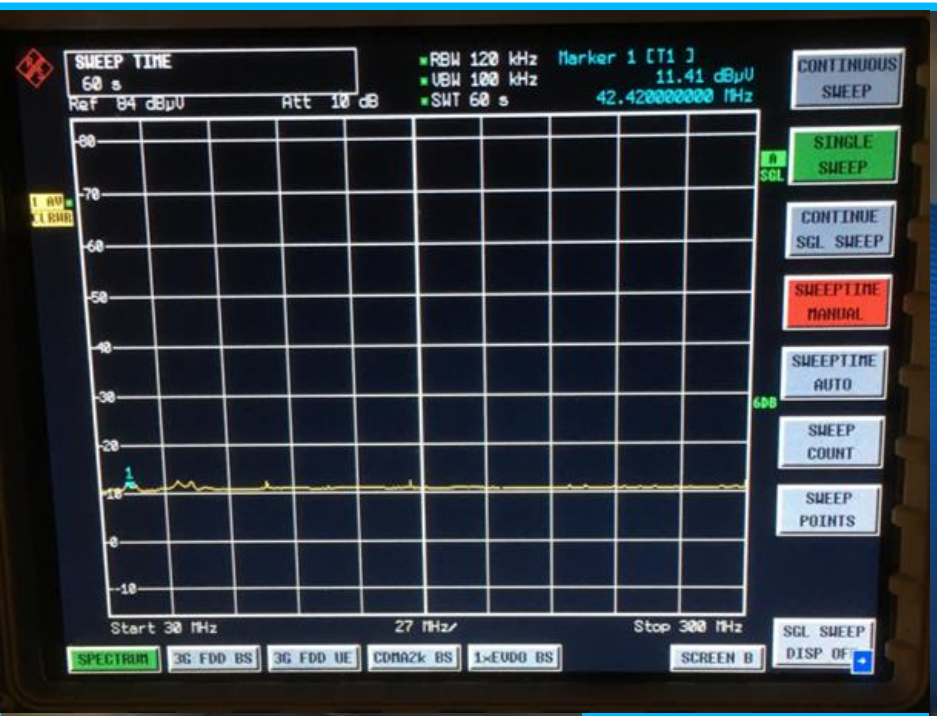




Implementation example



Measurement 30&31 Sept 2019



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Conclusions/Remarks

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- The total radiated PV unit emission should stay below the covenant limit.
- Both radiated and conducted emission need to be considered.
- Also Cameras, LED equipment, controller EMI should low.
- The common mode current should be as low as possible on the AC/DC cables.
- The loop area of the cables should be as small as possible. Shielding or use the construction to reduce emission.
- A faraday cage can reduce the radiated emission (look out for slits!). No longer than 0.2m (preferably smaller).
- Create a technical construction file with all technical details and measurements (before/after).