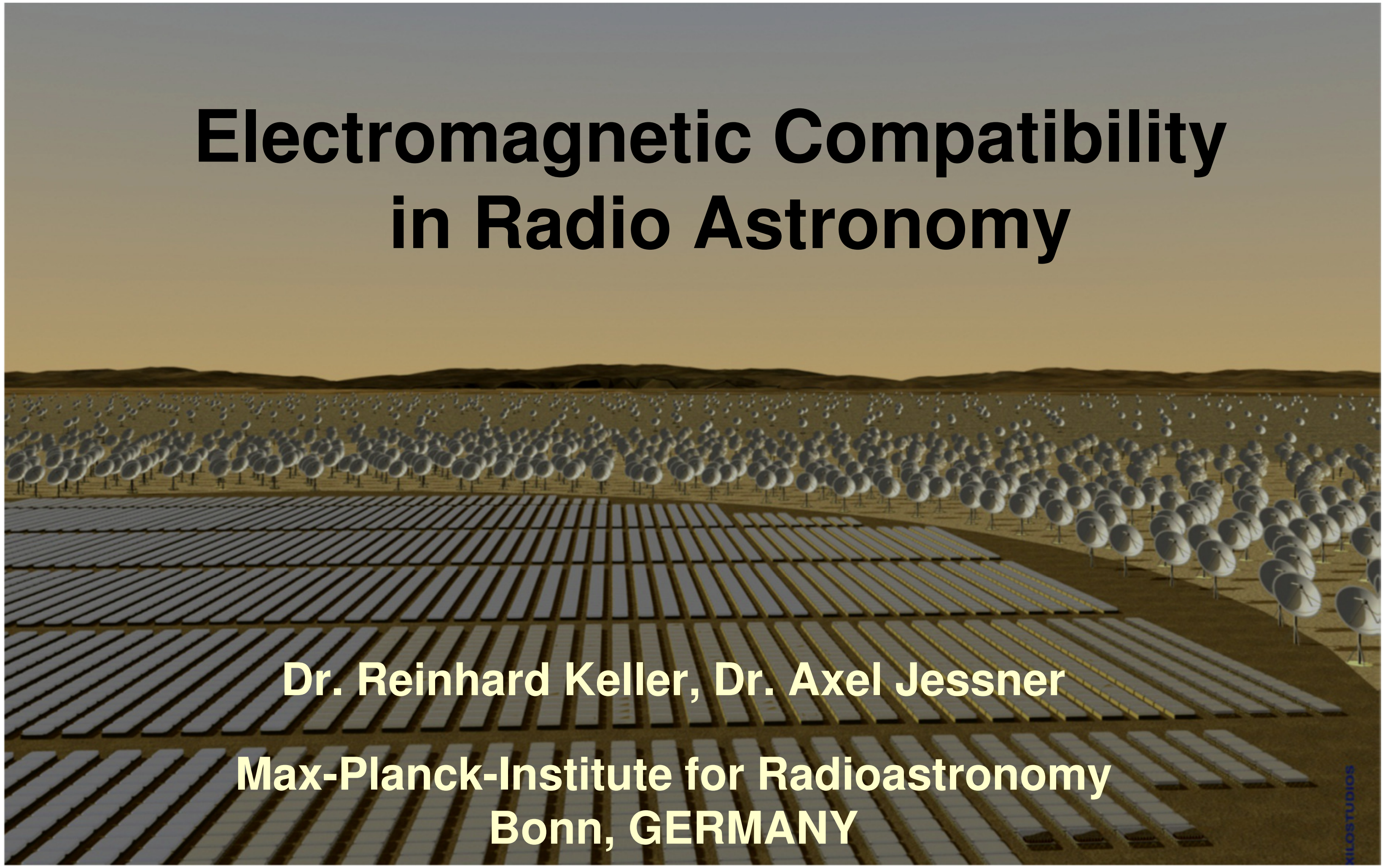

Electromagnetic Compatibility in Radio Astronomy

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Content

- What is EMC?
- Motivation for MPIfR
- EMC in the radio astronomy context.
- Optimization components towards EMC.

MAX-PLANCK-GESELLSCHAFT
Max-Planck-Institut
für Radioastronomie

Problem: Electro Magnetic Compatibility EMC

- „The goal of EMC is the correct operation, in the same electromagnetic environment, of different equipment which use electromagnetic phenomena, and the avoidance of any interference effects. ." (Source: Wikipedia)

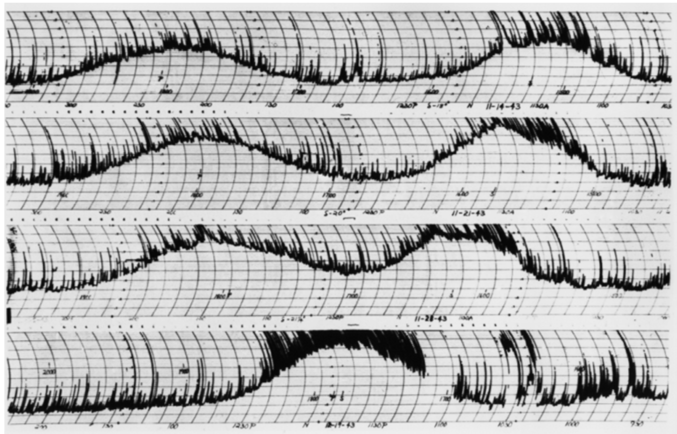
Regulations for

- Industry products:
  EN55011
  VDE 0878-1
- Radioastronomy:
  ITU- R RA 769-2

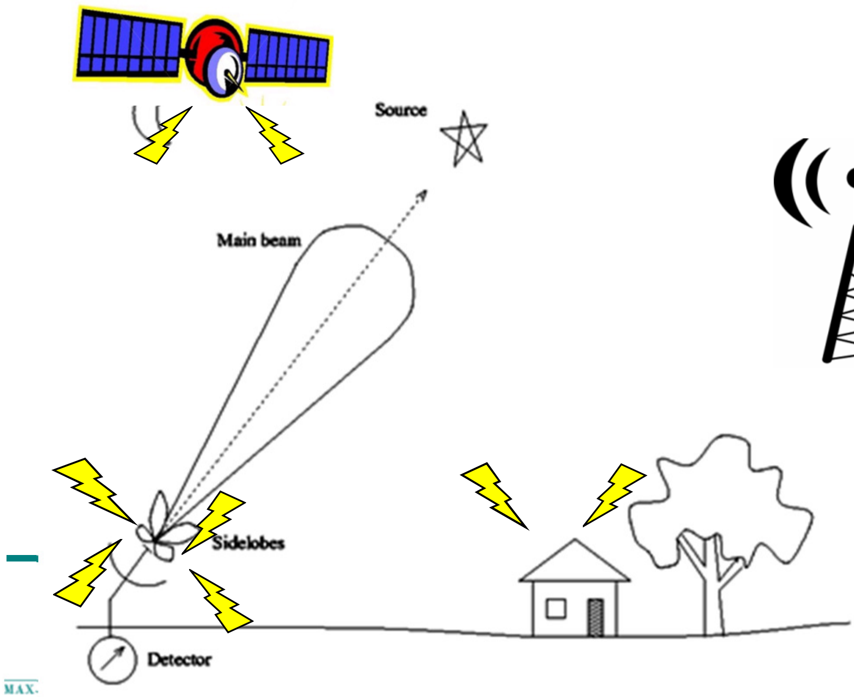
Source: left: Dr. Hj. Biener / right: RP online

Radio Interference in Radio Astronomy

Radio interference is a radio signal of ***human origin*** which is detected in a radio astronomical observation



(Jim Cohen, 2005)

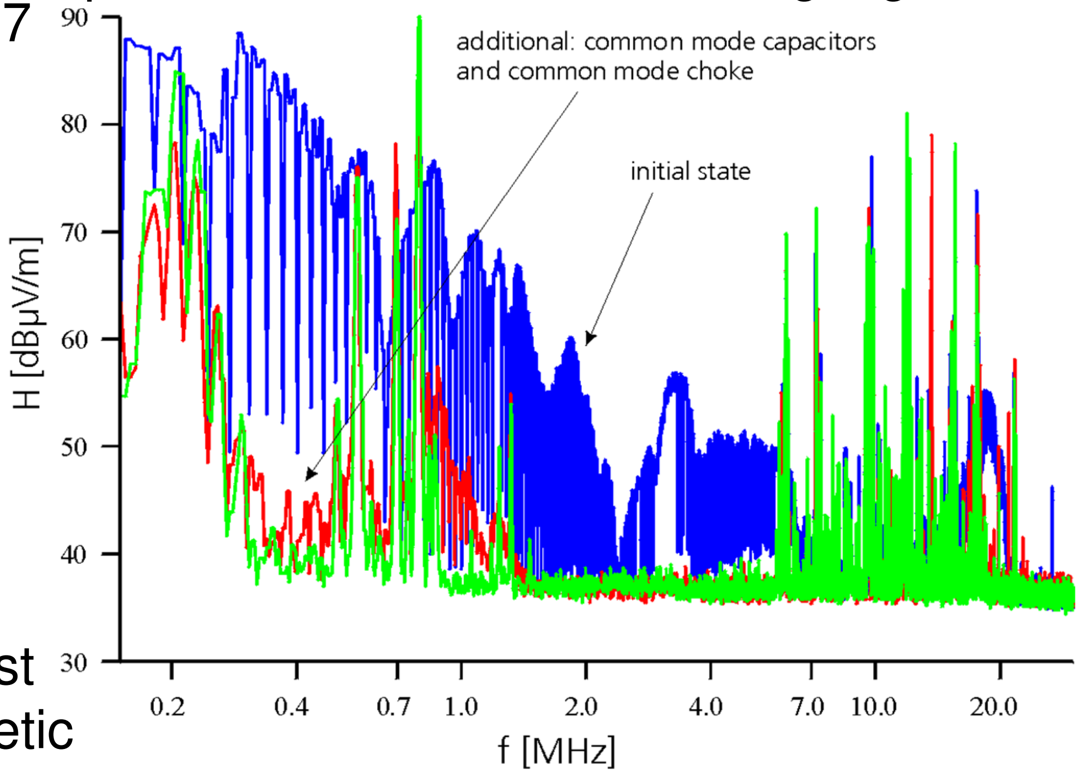


external:
TV, Radar, Satellites, aircraft
Data Processing, Electronics

internal:
oscillations, intermods, harmonics, receiver noise

EMC of PV Components at FhG/ISE

- Untersuchung der elektromagnetischen Eigenschaften des Solar-generators in netzgekoppelten photovoltaischen Stromversorgungs-anlagen, BMBF 1994 – 1997



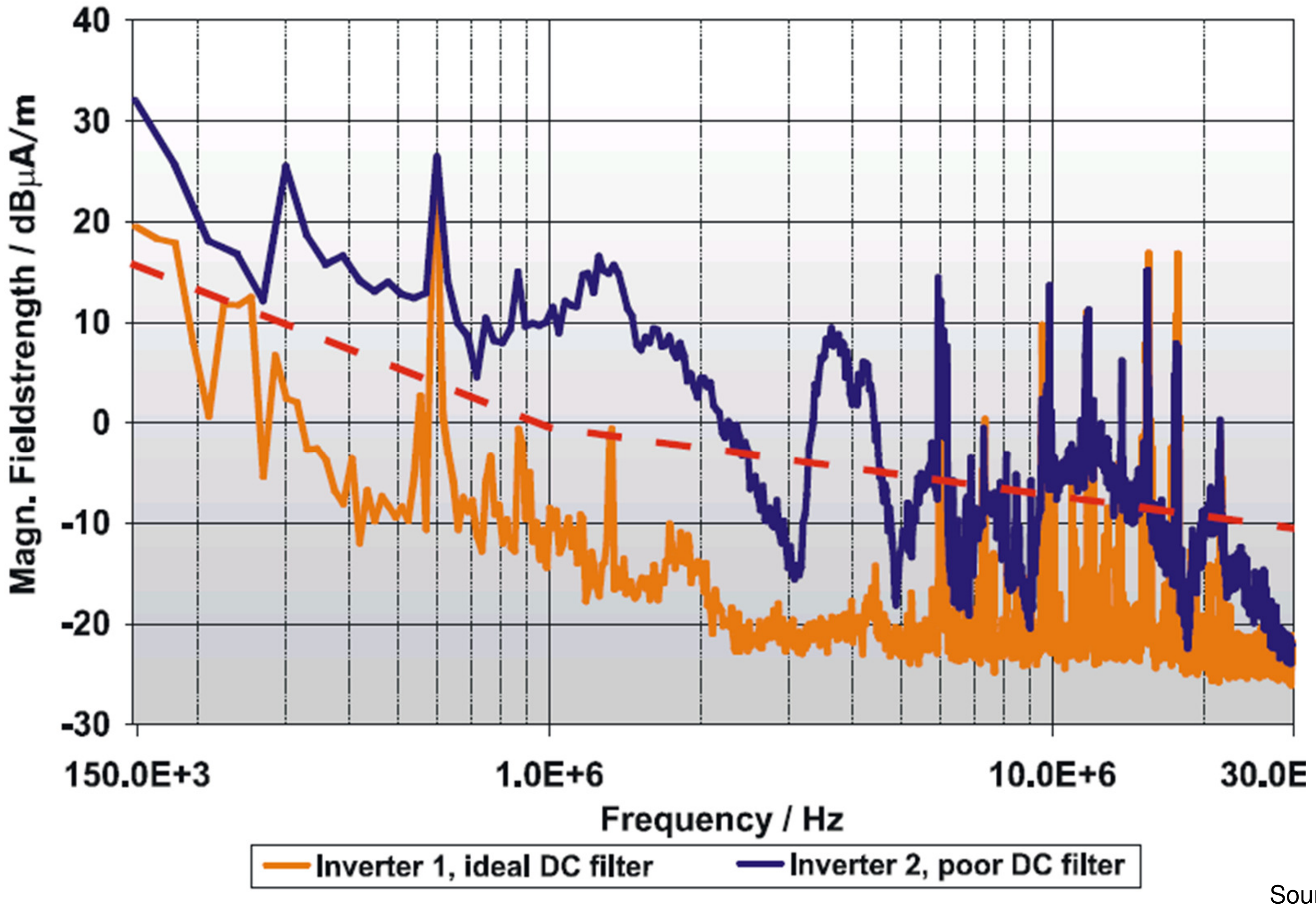
Green: Noise floor
Blue: unmodified power inverter
Red: EMC optimized power inverter

Source: FhG/ISE

- Development of standard test procedures for electromagnetic interference tests and evaluations on photovoltaic components and plants, EC, 1998 – 2000

EMC policy

- EMC compliance by filtering



Source: FhG/ISE

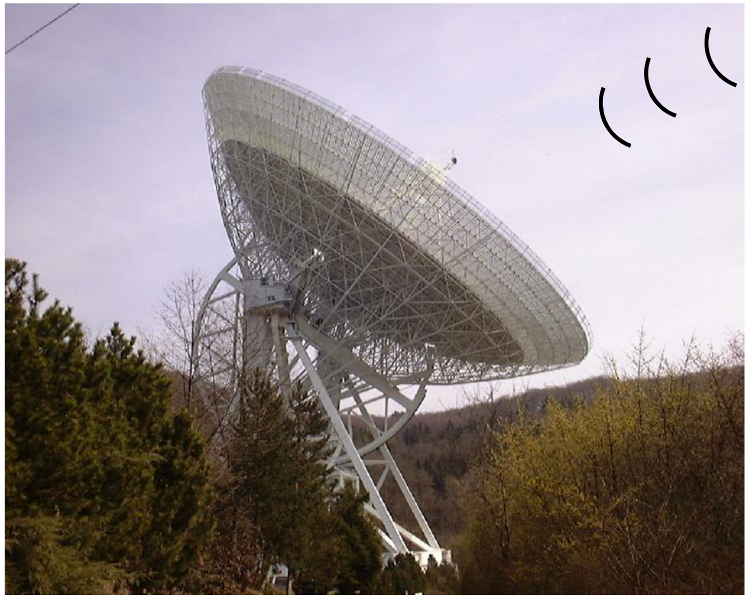
Motivation

Max-Planck-Institut for Radioastronomy & EMC

- Long (and bad) experience with Radio Frequency Interference (RFI)
- Measurement equipment and experience for RFI
- Extremely sensitive astronomical instruments
- Telescopes as test beds for EMC measurements
- Electromagnetic compatibility of all SKA equipment

Performance Requirements of Radioastronomy

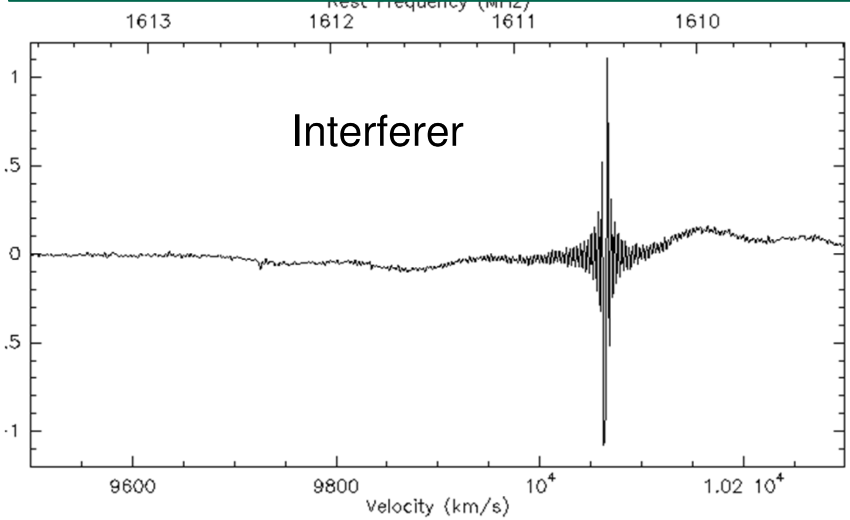
I.E.: Mobile phone on the moon
- * Distance abt. 400.000 km
- * Power 2 Watt

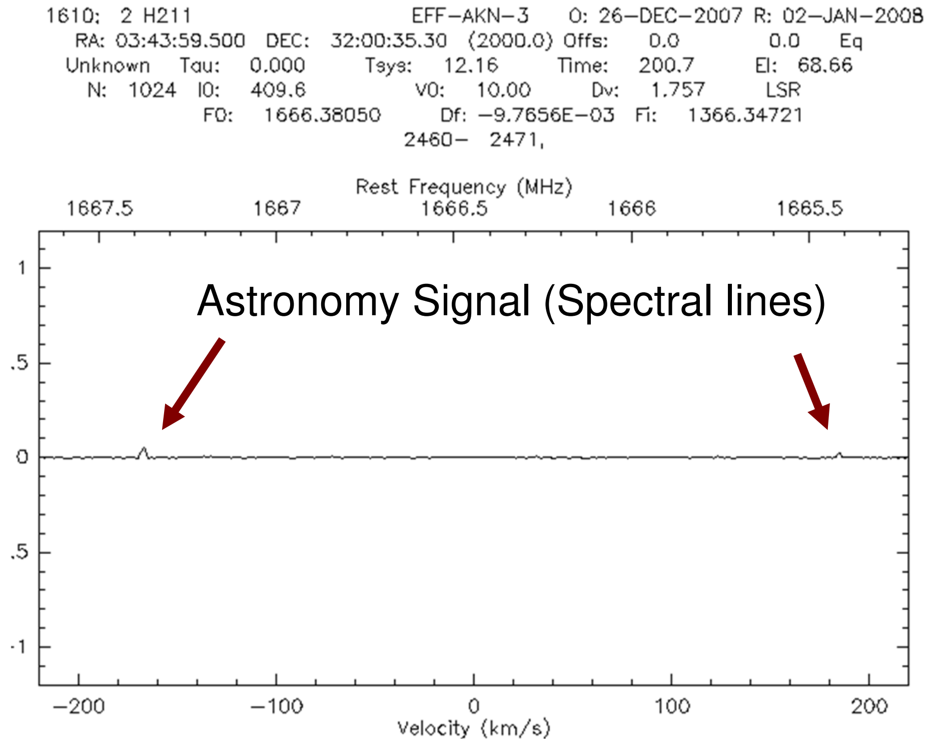


→ one of the strongest radio sources at the sky for the 100m radio telescope Effelsberg

Signal / Noise

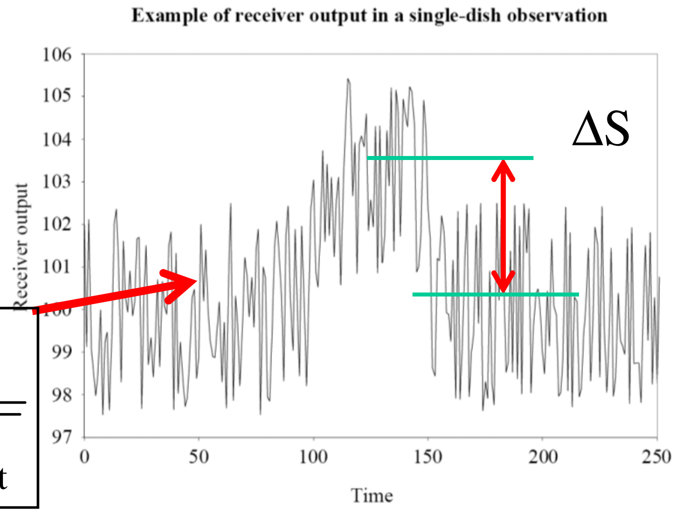
From IRIDIUM Satellite **1500 km** distance:
7th order intermod product: e.i.r.p. **1mW**
Main carrier: e.i.r.p. **12.5 W**





How is it done ?

Typical radio astronomical signals (‚cosmic noise‘) are detected as an addition to receiver and sky noise power



The sensitivity is the precision of a noise power measurement.

It can be much smaller than the system noise itself!

$$\Delta S_{\nu} = \frac{2 \cdot k \cdot T_{sys}}{\varepsilon_{ant} A_{ant}} \frac{1}{\sqrt{\Delta\nu \cdot t_{int}}}$$

$\sqrt{N_{samples}}$ **= number of independent power measurements**

$$\frac{\Delta S}{N} \approx -40\,\text{dB}$$

Large antennas d=100m

Cryogenic receivers

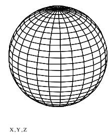
Antenna Gain is different for Astronomy and for RFI

Main beam

Effelsberg 21cm:

$$0.54\cdot\pi\cdot(50\cdot m)^2 = 4.241\cdot10^3 \cdot m^2$$

$$G_{beam} = \frac{A_{eff}}{A_{iso}} = \frac{\eta\cdot A_{geo}}{\left(\frac{\lambda^2}{4\cdot\pi}\right)}$$



isotropic antenna:

$$\frac{(21\cdot cm)^2}{4\cdot\pi} = 3.509\cdot10^{-3} \cdot m^2$$

$$G_{beam} = 1.209\cdot10^6 \qquad 10\cdot\log\left(G_{beam}\right) = 60.823 \text{ dBi}$$

Off-beam gain: G=32-25log (ϕ) dBi for 1° <ϕ<47.8°

ITU-R S. 1428 G= -10 dBi for 47.8 <ϕ<180°

Average Antenna gain for RFI is G_{rfi} ~ 1 or 0 dBi (isotropic antenna)

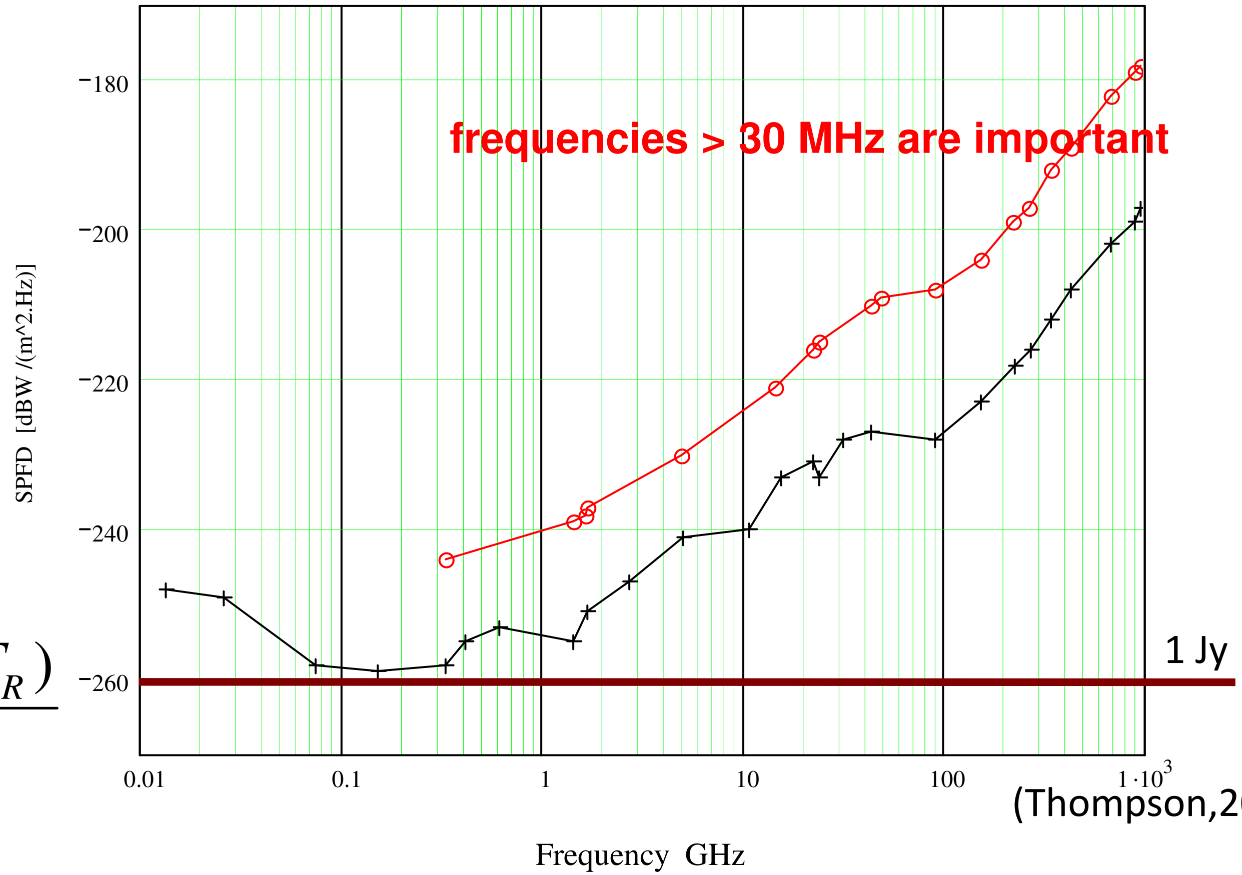
Radio Regulations:
Detrimental thresholds for total power observations

ITU-R RA 769

I/N =0.1

$$S_H = \frac{0.4\pi k f^2 (T_A + T_R)}{c^2 \sqrt{\Delta f \tau}}$$

Signal averaged over τ = 2000 s and bandwidths of several MHz



(Thompson,2005)

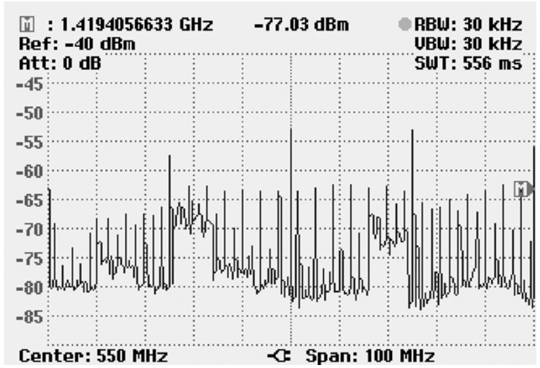
black, continuum; red, spectral line

RA Handbook Fig. 4.1 (p. 36)

Thresholds are defined for the location of the radio telescope !

Radiated Emission Limits for Industrial Devices

CISPR-11 Group 1 Class A
EN 61800-3, Cat. 4 : I>400 A or U > 1000 V



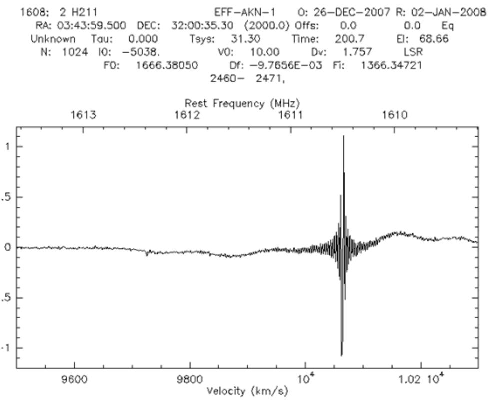
- for frequencies below 230 MHz :

  30 dBµV/m, 120 kHz measurement bandwidth

- for frequencies above 230 MHz:

  37 dBµV/m, 1 MHz Measurement bandwidth

Distance = 10m, with **quasi-peak detector**



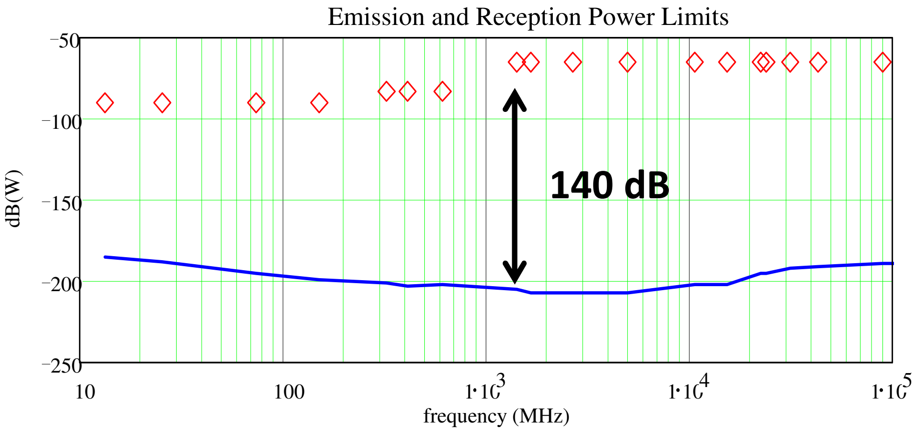
- for frequencies above 1 GHz:

  not defined for all types of equipment!

Limits defined for the interfererer !

Spectrum occupation undefined!

Industrial Equipment Interference and Radio Astronomy

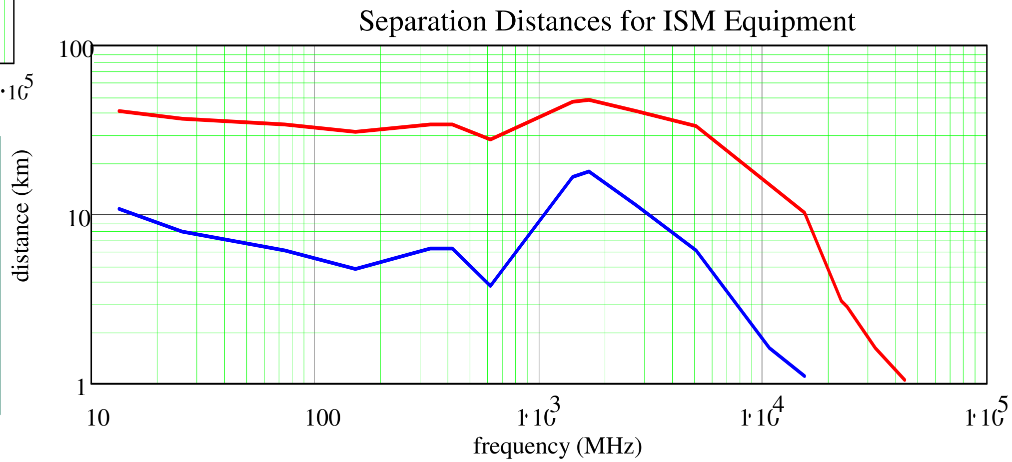


The ITU report SM-1081 describes

A. Protection requirements of radio astronomy as in **ITU-R RA. 769**,

B. limits for industrial equipment as given by **CISPR-11. (EN 550011)**

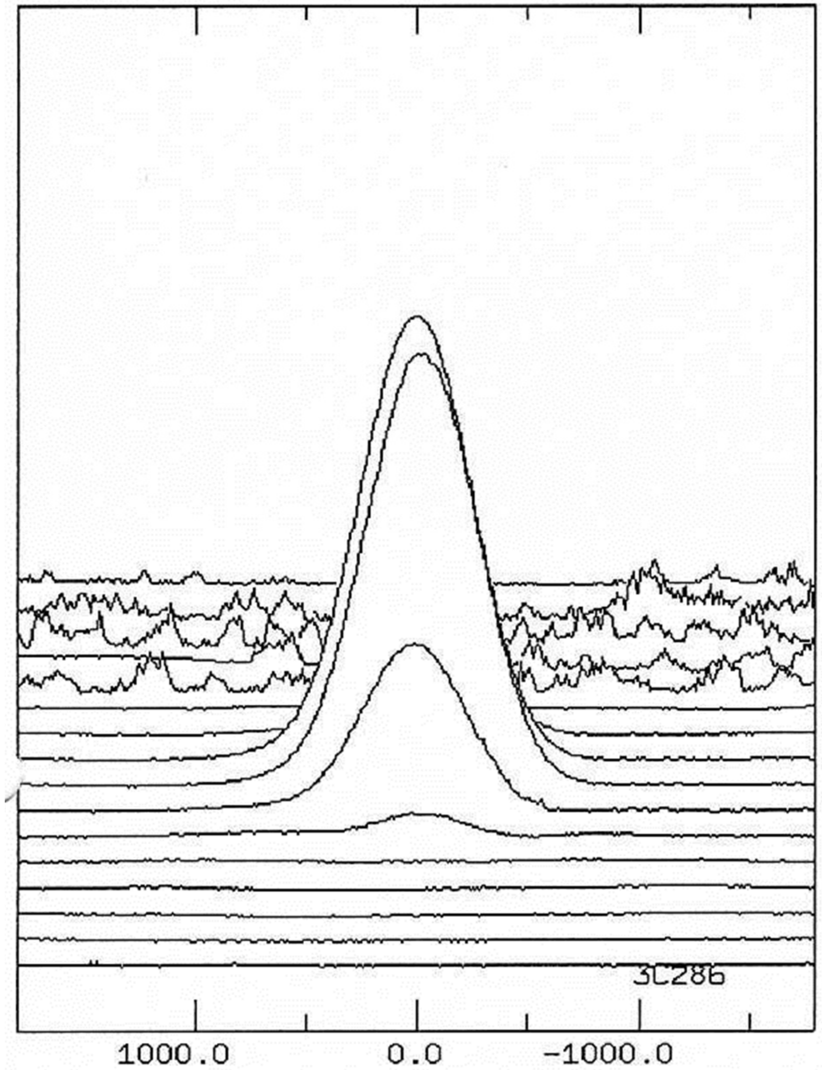
Industrial equipment emissions on the level of these limits require free-space separation distances of **several 10 km** from telescopes in order to fulfil the ITU-R RA. 769 protection requirements!



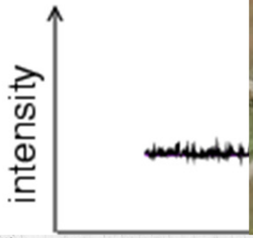
The **standards set for ISM equipment need to be made consistent** with those of the ITU-R RA. 769 for the bands listed in footnotes 5.340 and 5.149 of the RR .

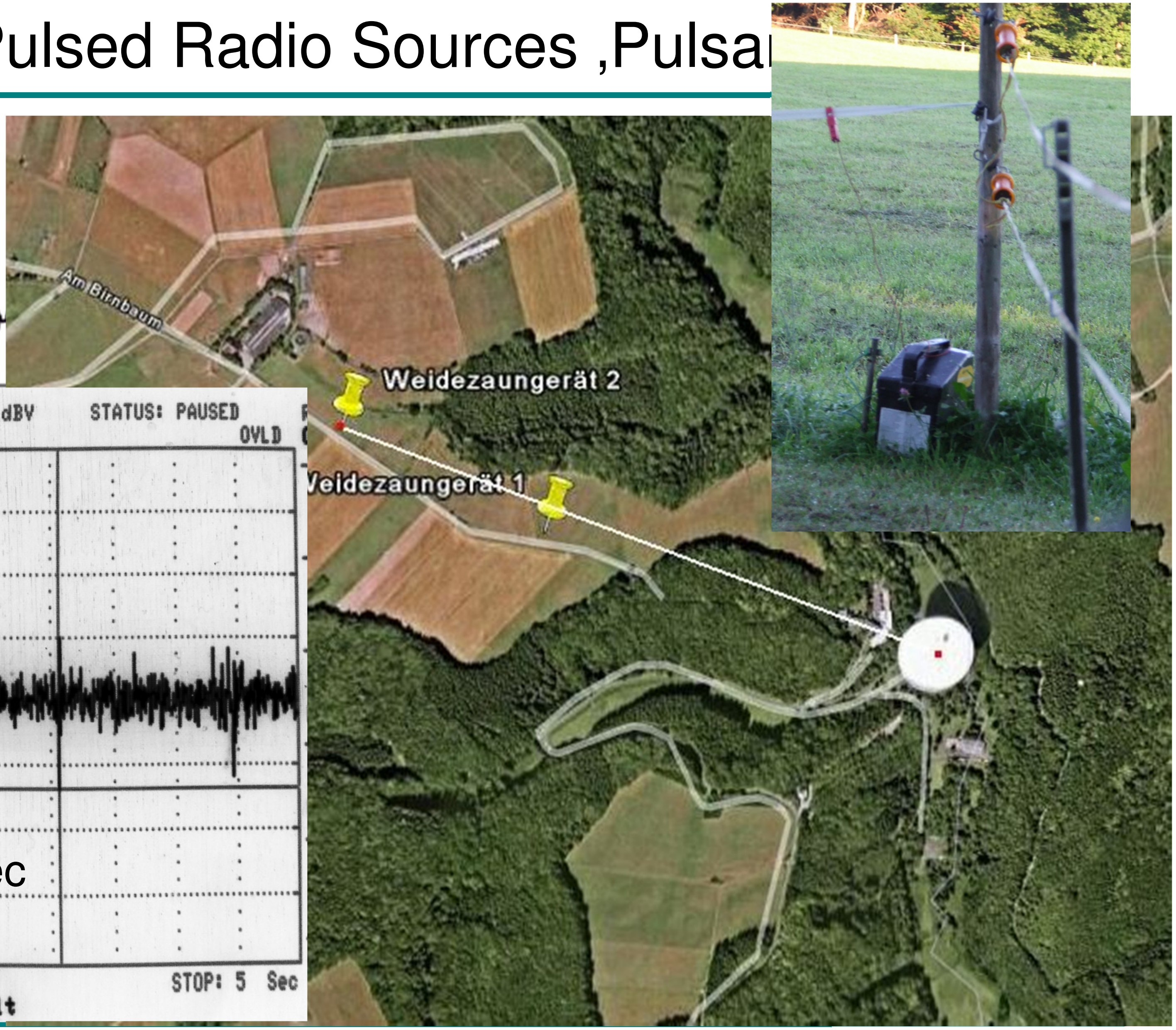
A very difficult task as it concerns all manufactured equipment:
From cattle fences over digital electronics to wind power generators!

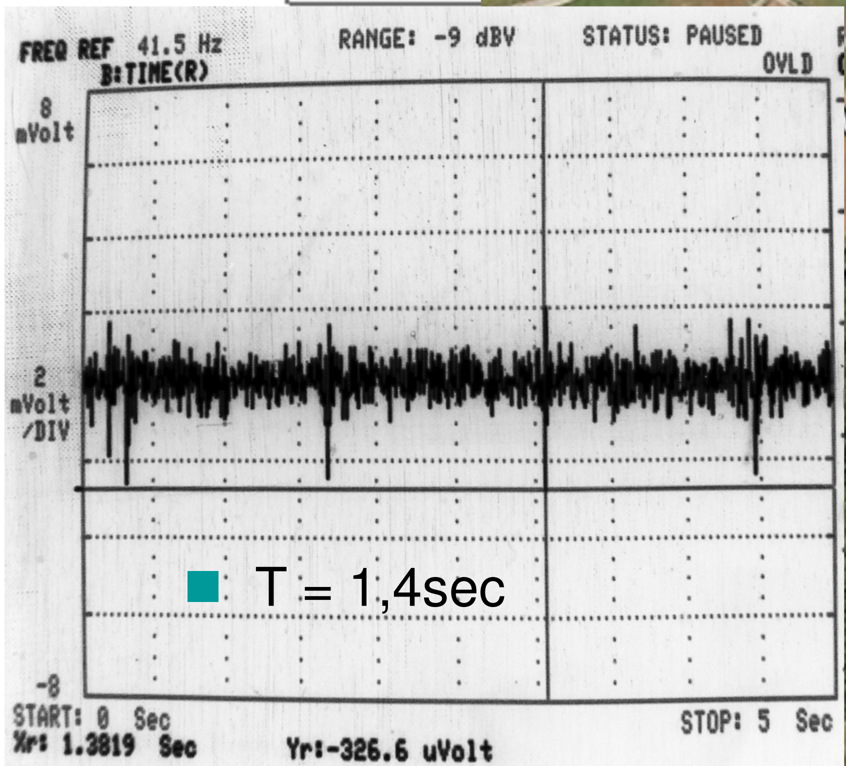
RFI in Radioastronomy



Pulsed Radio Sources ‚Pulsa







- T = 1,4sec

Generic Case: Impact assessment procedure

1. Calculate the effective path loss $\mathbf{L_b(f)}$ from the telescope to the site for each frequency band using the methods of ITU-R P.452-12.

2. If the antenna cannot point at the structure, then calculate the maximum side-lobe gain $\mathbf{G_{max}(f)}$ **=** 32 - 25log($\mathbf{f}_{min}$). If the antenna can point at the structure, then use the full main beam gain of the antenna.

3. ITU-R RA. 769 gives a table of reception limits of continuum input power ΔP_H (table 1, column 7) for each radio astronomical frequency. Any emission from devices at the planning site must be kept below the limit of

$$\Delta P_{site} = \Delta P_H + L_b(f) - G_{max}(f) - 10 \log(N_{dev})$$

(The effect is additive for N_{dev} similar devices at the same site)

4. Repeat for all relevant frequencies to **estimate site emission limits**

5. **Their difference to actual emissions is the additional EMC design requirement. High frequencies (> 1 GHz) and spectrum coverage must be taken into account.**

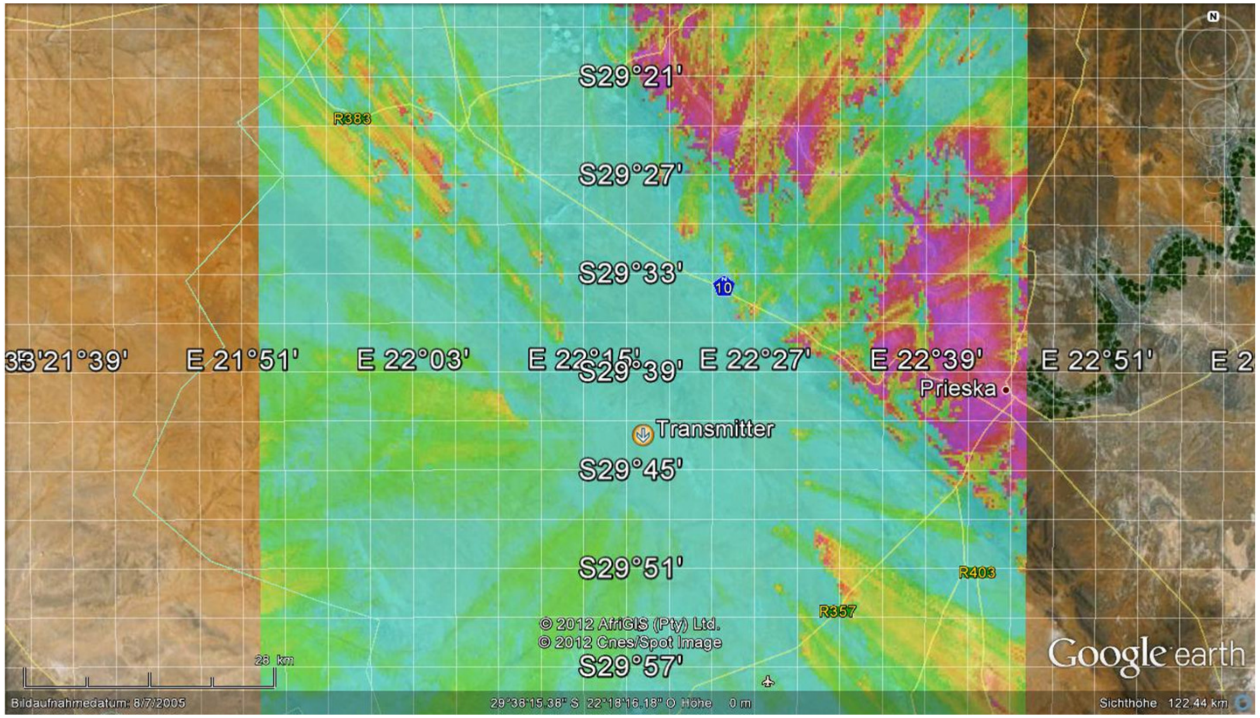
Attenuation Map for 610 MHz at a SKA Remote Site

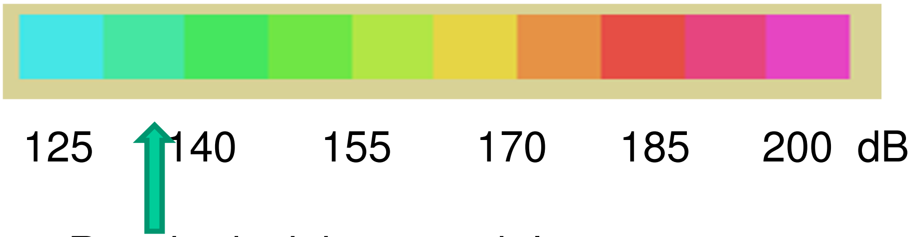
Calculated with ‚Pathprofile' (M. Willis)

Height of emission 5 m

Antenna height 10 m

30 km

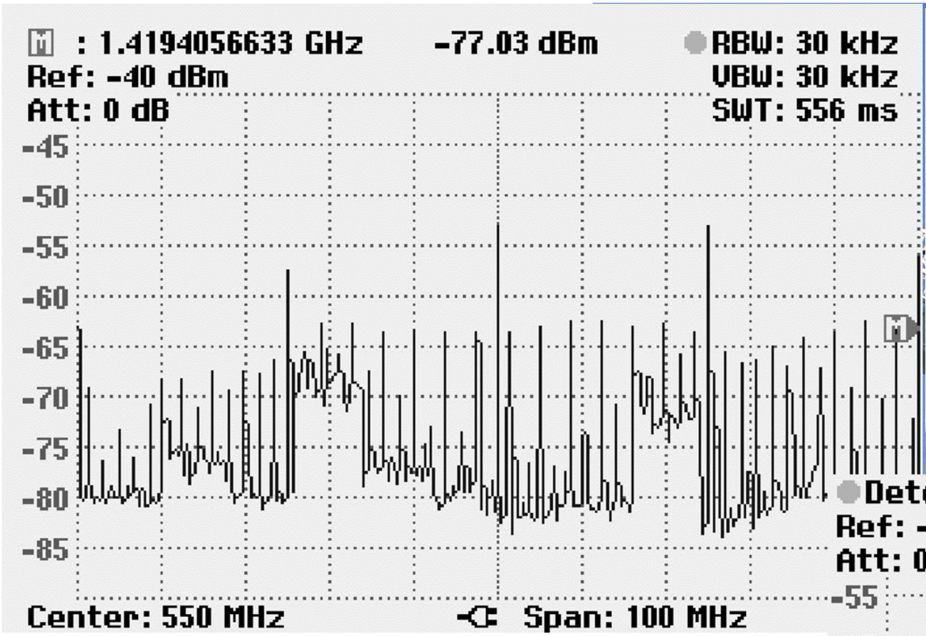


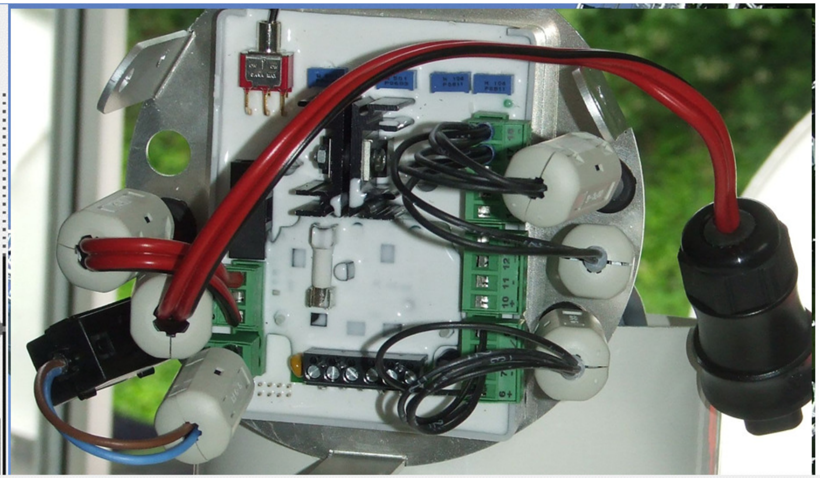


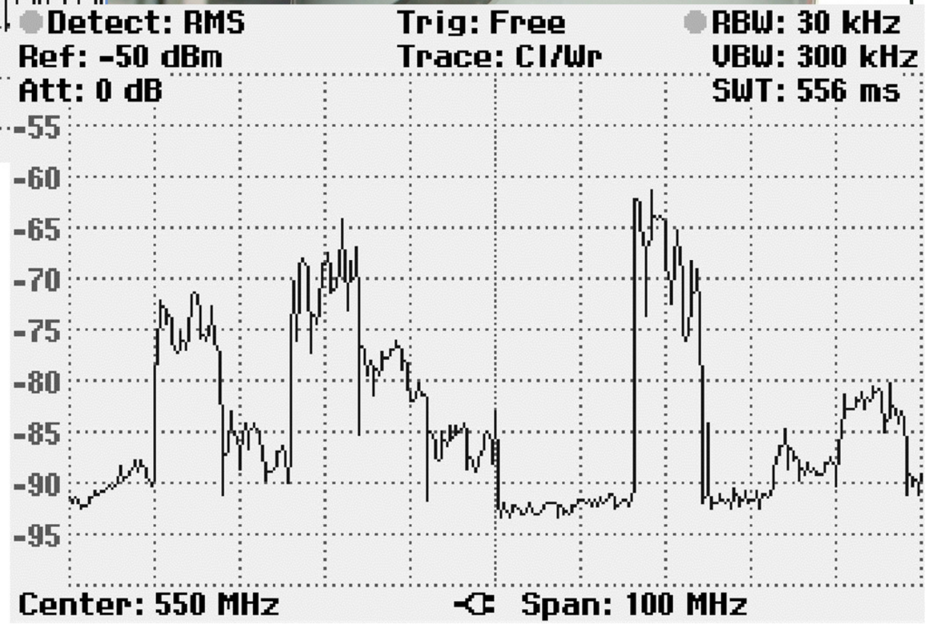
Emission limit in blue region:
>>20 dB below CISPR-11

Required minimum path loss

EMC of a Solar Lamp



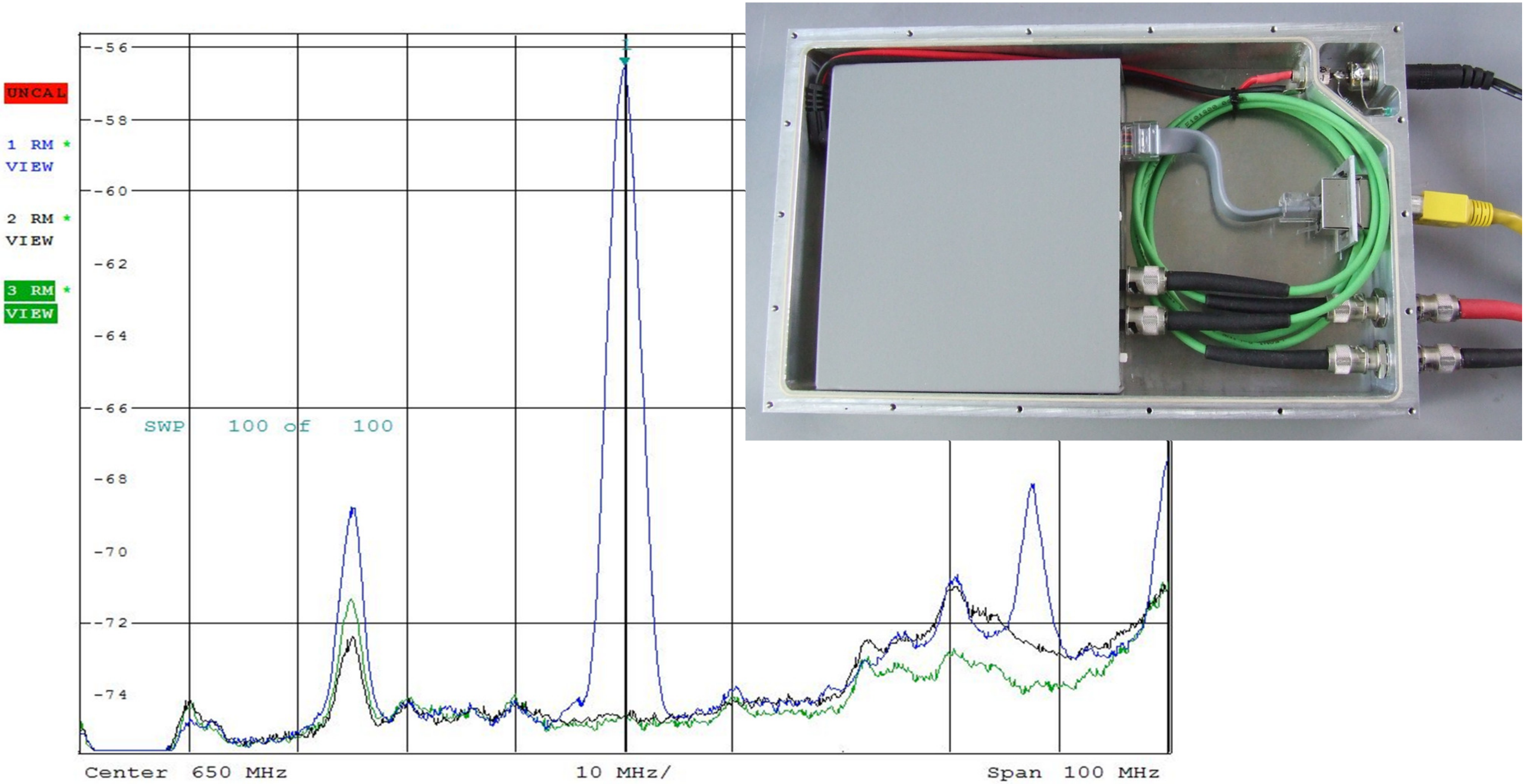




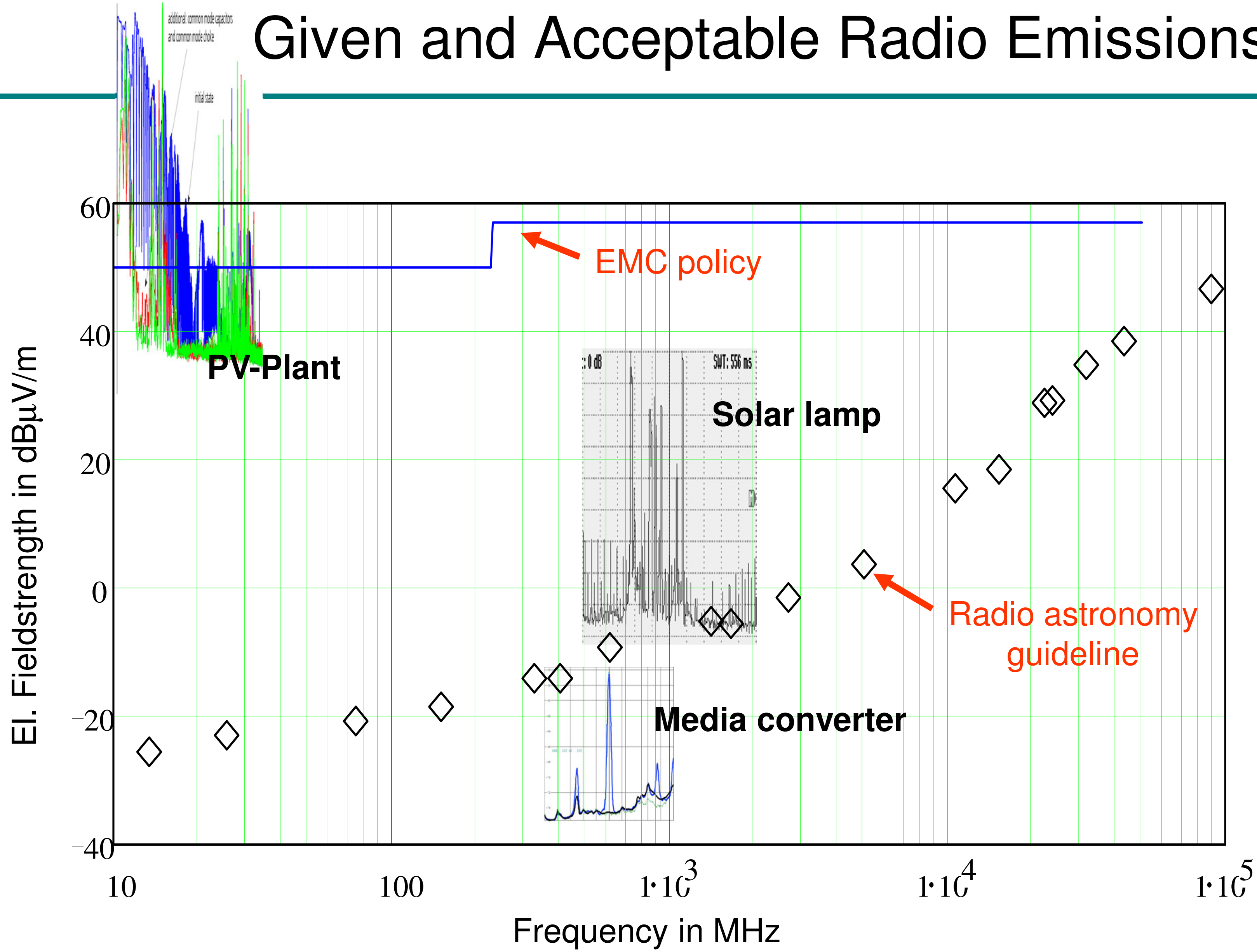
- Radiation of the shelf
- Radiation with shielding and filtering
  - TV channels!

Ethernet Media Converter 100BaseT / Optical fibre

- Strong interferers, i.e. 650MHz — blue line
- In house shielding case with EMC filters — green line



Given and Acceptable Radio Emissions



Summary

- **EMC with Radio Astronomy is a serious problem.**
- **Frequencies above 30 MHz are important**
- **Interferer (CISPR) and victim (ITU-R RA 769) standards are not harmonised**
- **For compatibility assessments, the emissions from the interferer and their spectral characteristics must be well known (better than CISPR).**
- **Spatial separation of a few km is insufficient on its own: minimum coupling losses (MCL) > 135 dB**
- **Case by case compatibility analysis and taylored EMC measures are required**
- **Verify by sensitive measurements!**

Conclusion

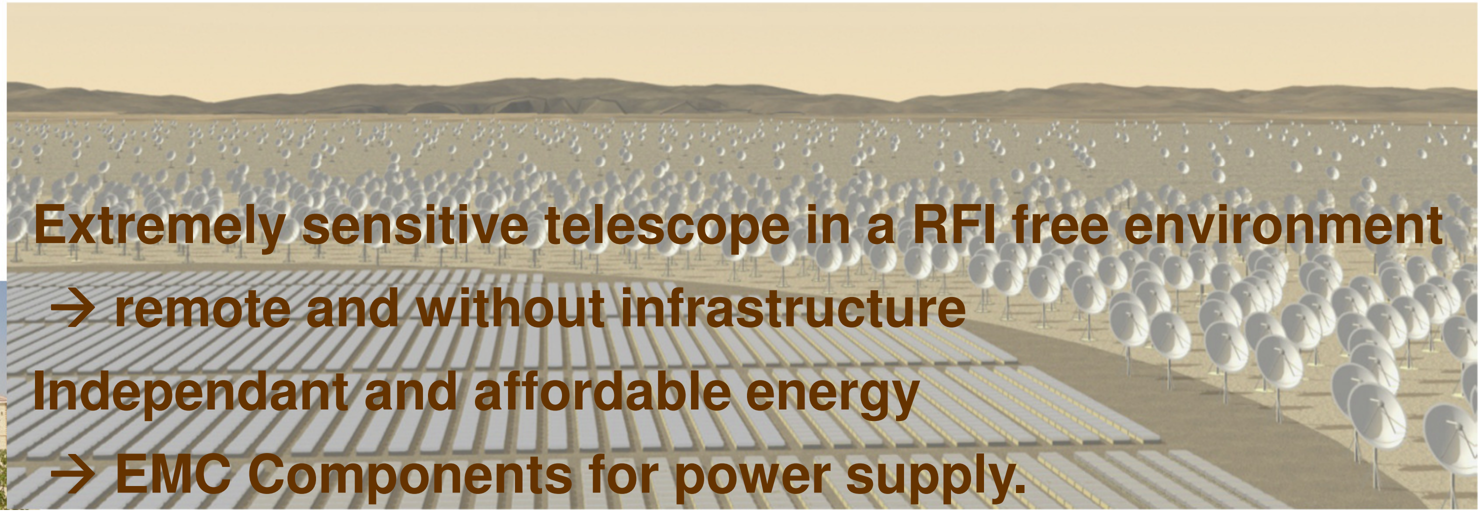
We have:

Expertise in EMC theory and measurement techniques,

EMC-test bed (100m, LOFAR, ASKAP) for monitoring

Leadership in RFI mitigation

Strong partners



We need:

Extremely sensitive telescope in a RFI free environment

→ remote and without infrastructure

Independant and affordable energy

→ EMC Components for power supply.


Thank you for your attention!