International
Centre for
Radio
Astronomy
Research

Feasibility Study for Solar-powered SKA-low Front-end

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ICRAR/ Curtin

AAVP Conference 2011
Dwingeloo, 12-16 Dec 2011

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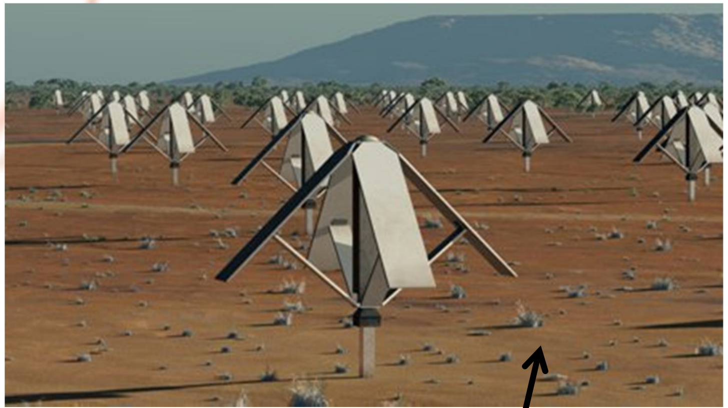
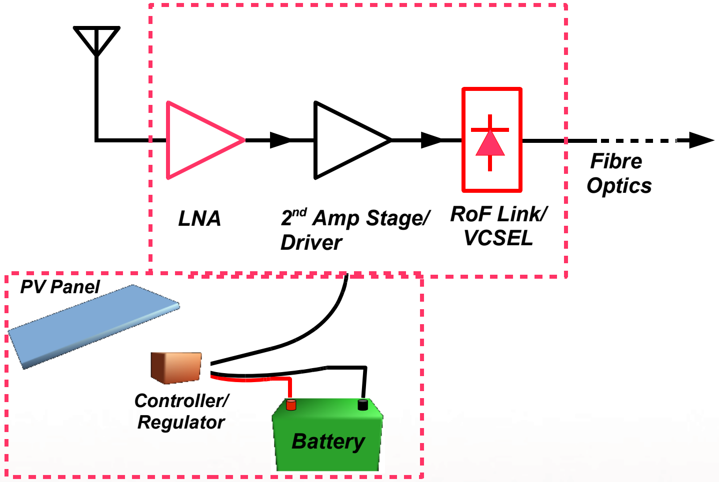
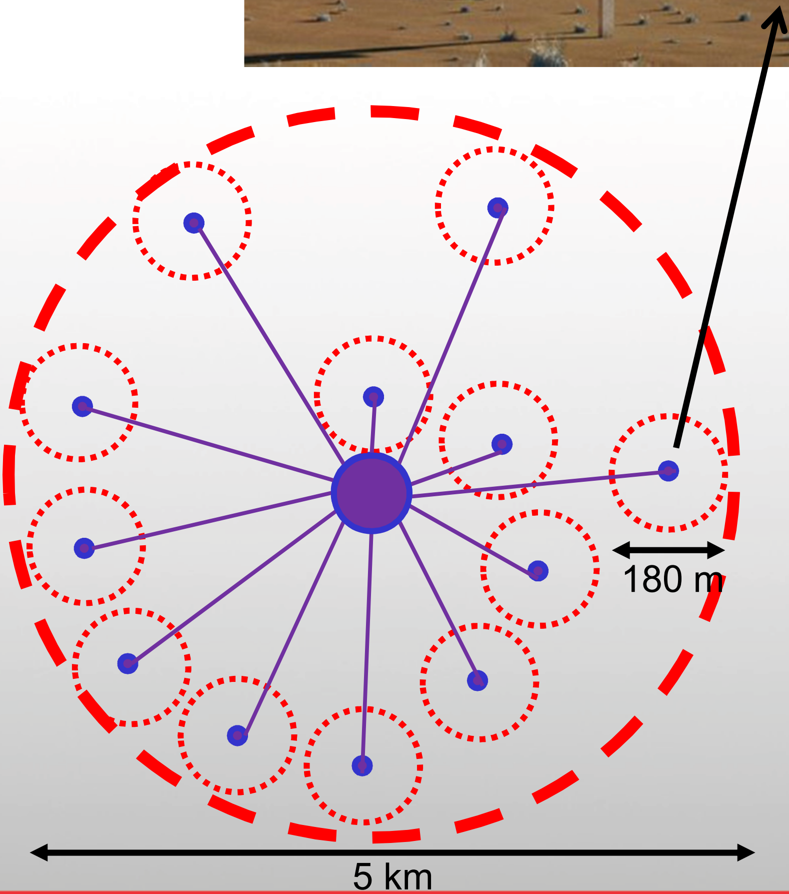
SKA-low Front-end: Introduction

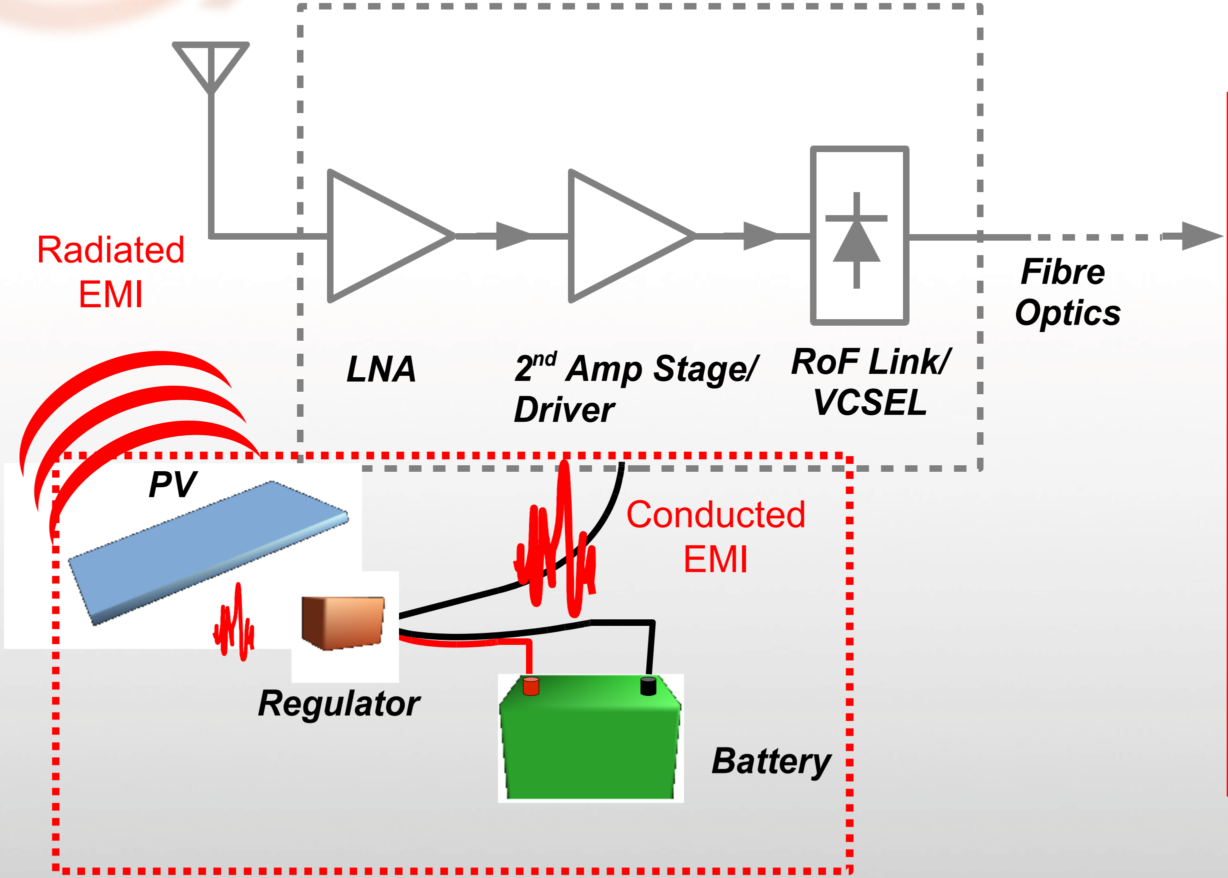






- **SKA-Low:**
  - 70 MHz – 450 MHz
- **Development & evaluation activities at ICRAR:**
  - Low noise amplifier (LNA)
  - Analog optical link (AOL)
  - Power supply:
    - Feasibility study
    - System requirements
    - Prototyping
    - EMI evaluations

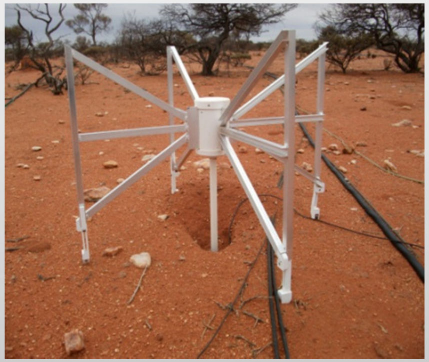
Solar Power for SKA-low Front-end: Why



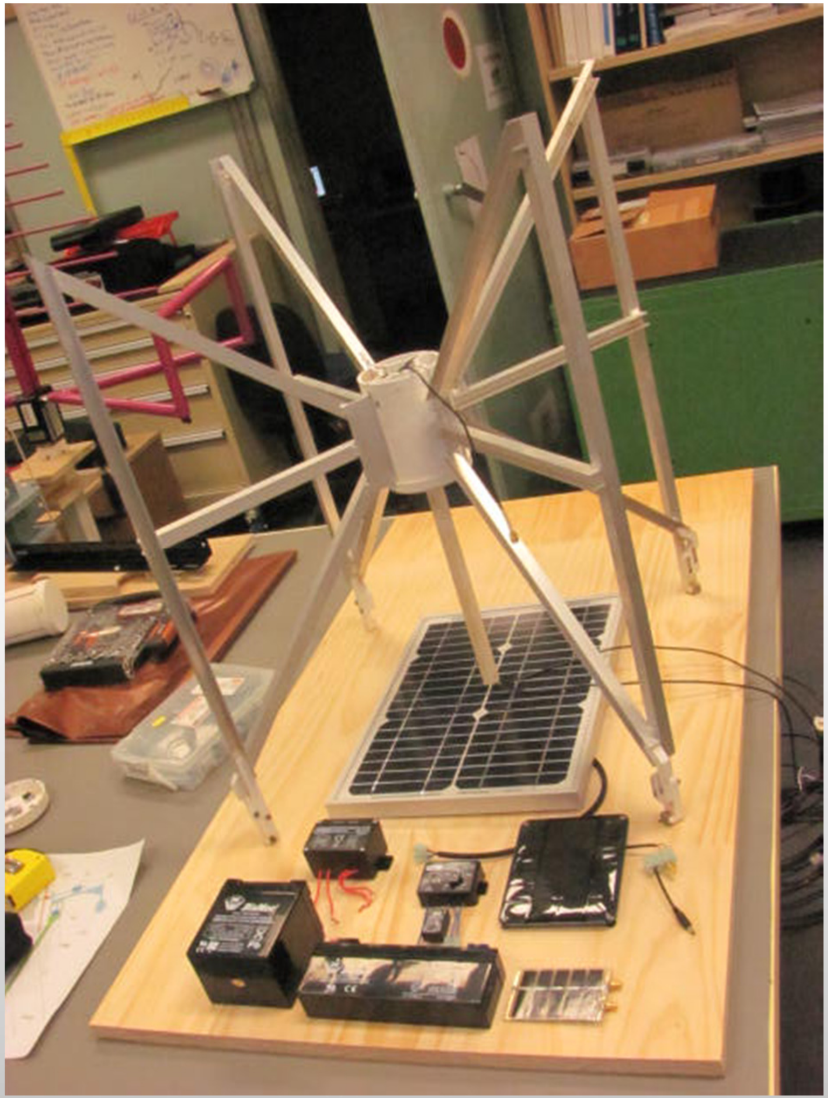
- On-site on antenna
- Free energy
- SKA sites ideal
- Galvanic isolation
- Considerations:
  - Site irradiation
  - Power budget
  - EMI emissions:
    - Conducted
    - Radiated

Case Study: MWA-based Front-end

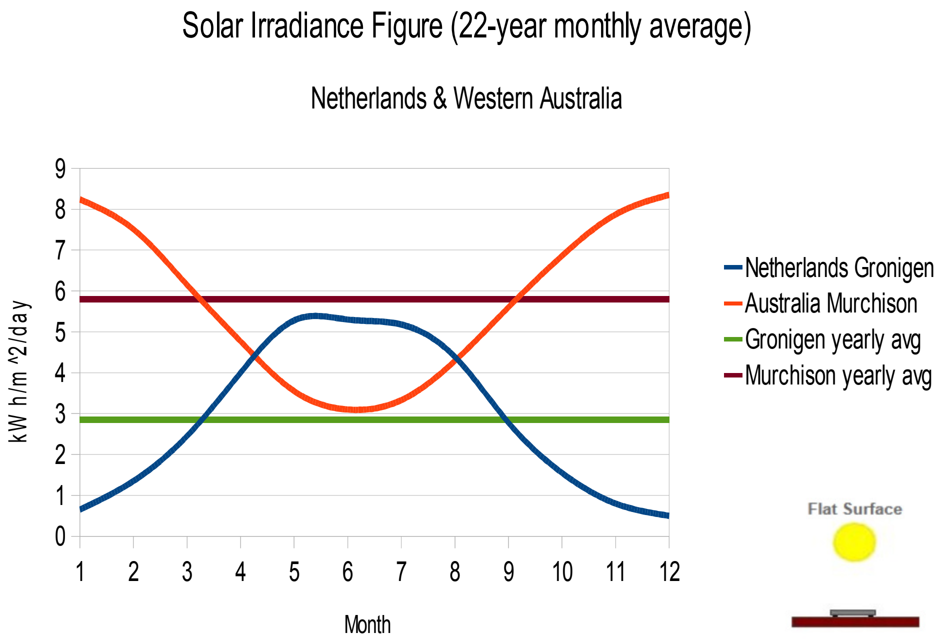
- LNA board draws 450mW
- Power budget = 1W
- Providing supply for 24 hr
- No long-term energy back-up
- Panel flat on ground (no tilt)
- Evaluate COTS

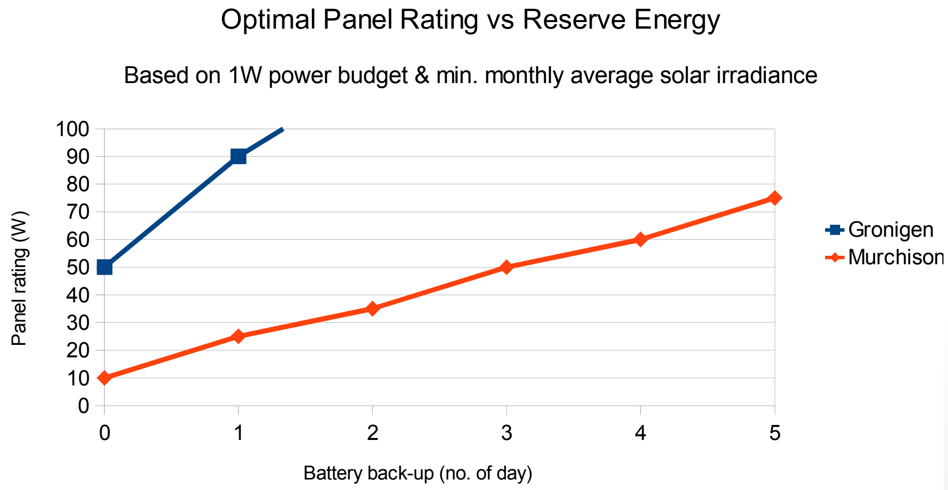


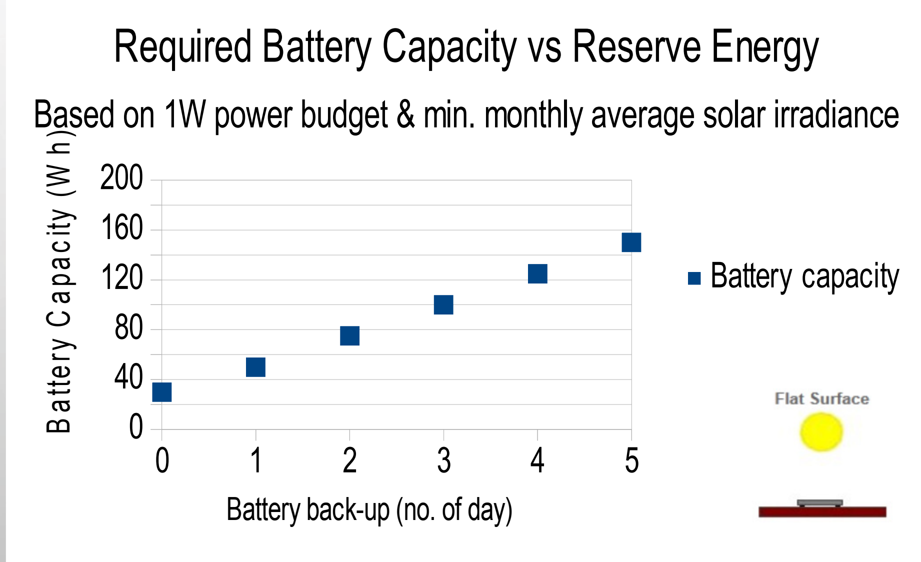
Courtesy: MWA website



Solar Irradiation Comparison: PV System Requirements



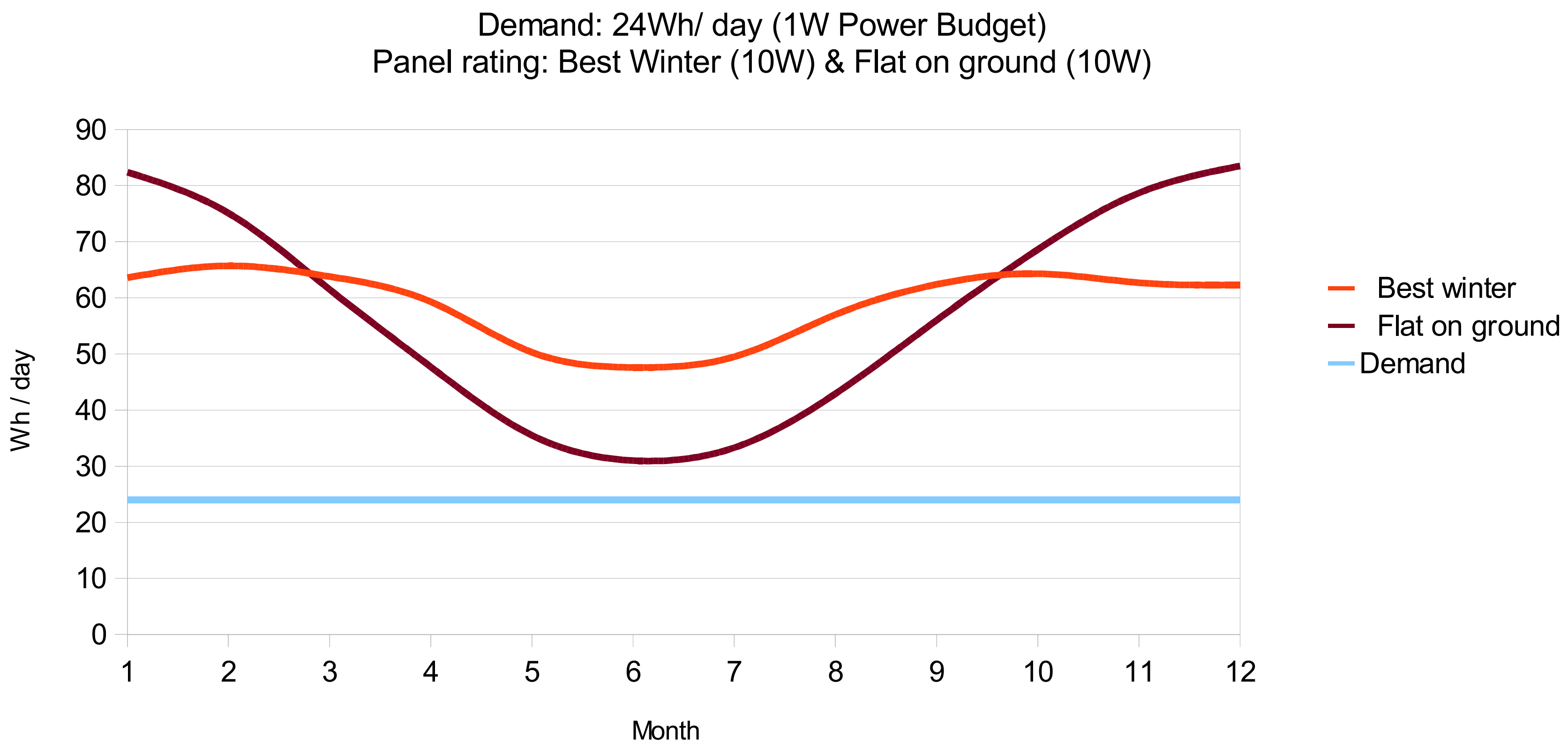




1. **Meet power demand during winter.**
2. **<u>Min monthly avg.</u> at both SKA sites = <u>yearly avg.</u> in Netherlands.**
3. **50W (Netherlands) → 10W (Australia).**
4. **Solar power feasible for SKA-low energy generation.**
5. **Battery capacity requirement independent of location.**

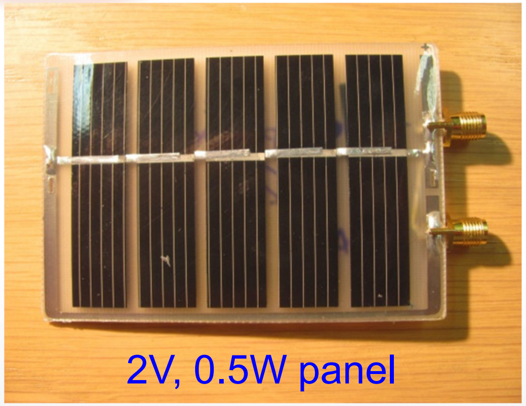
Energy Production Comparison: Panel Tilted vs Flat

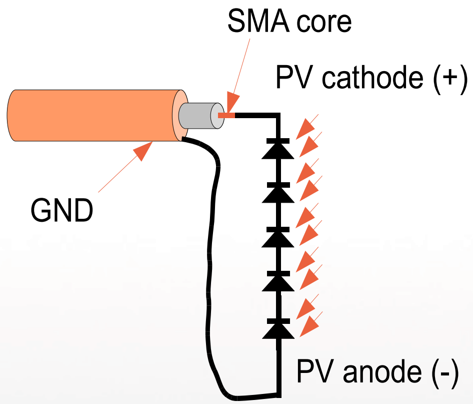
Energy produced (Wh/day) using different configurations at SKA site in Australia

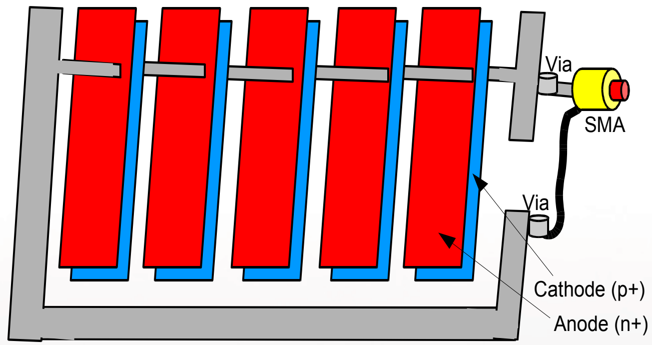


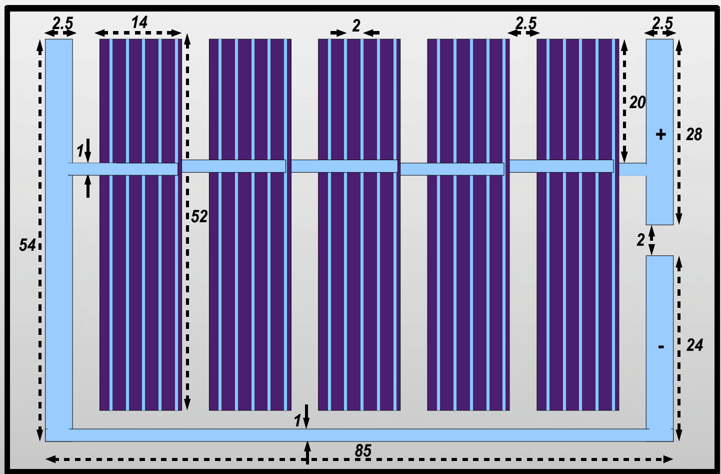
- **10W solar panel for 1W power budget (MWA-case study)**
  → based on 10% efficiency, smaller panel if using high efficient panel
- **Tilting may reduce the required panel rating**

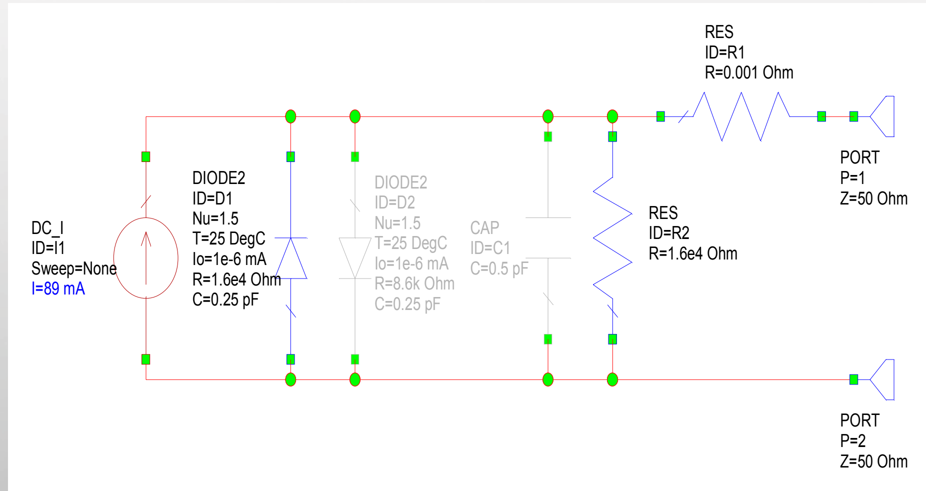
Case Study:
Typical Solar Panel EM Simulation



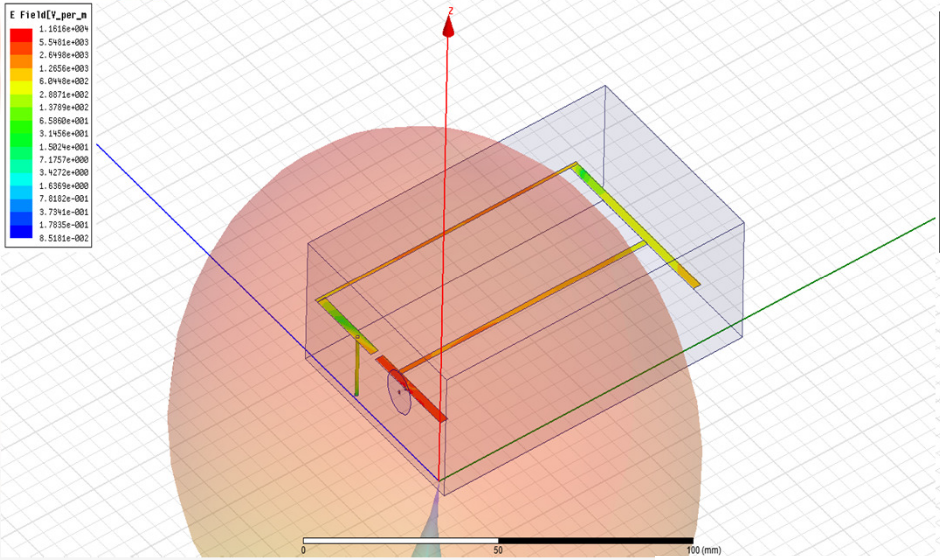


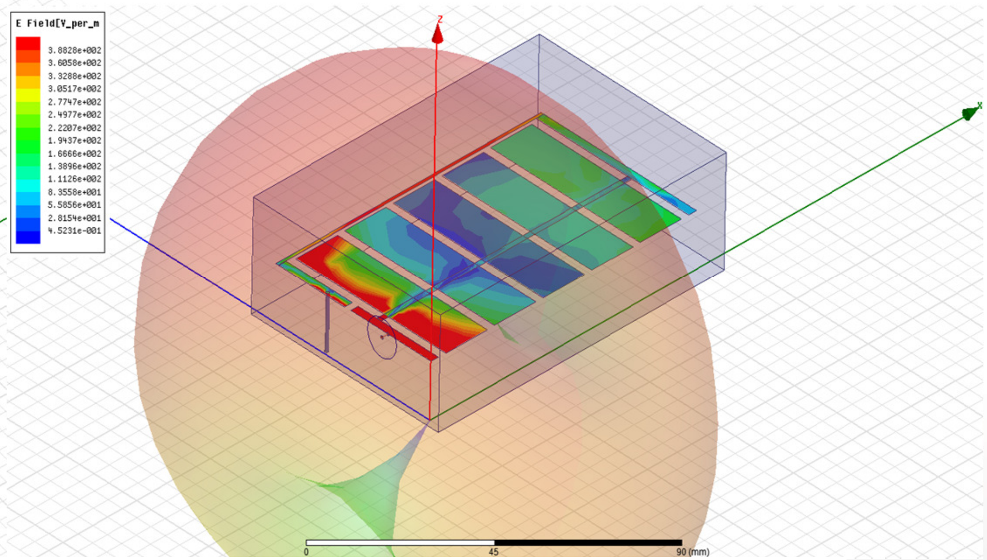


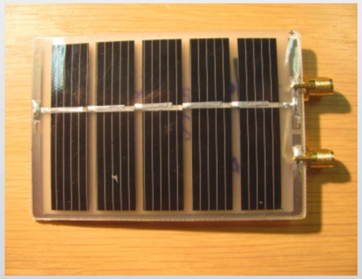


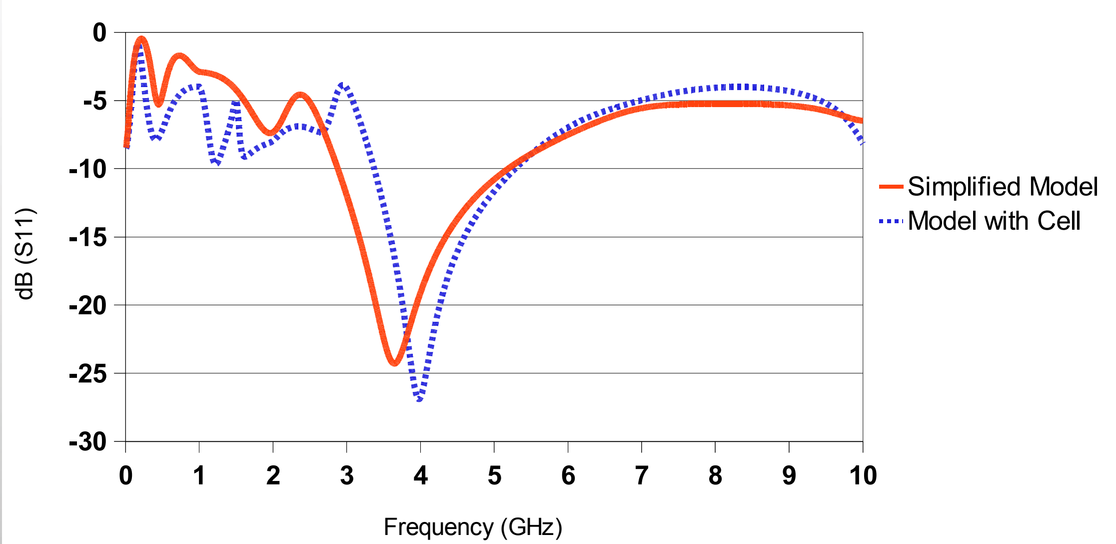


Case Study: Solar Panel EM Simulation (HFSS)



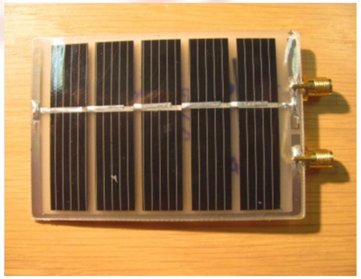


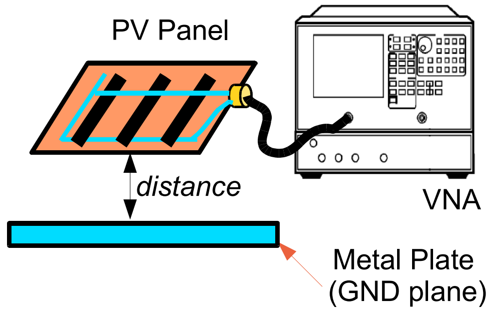


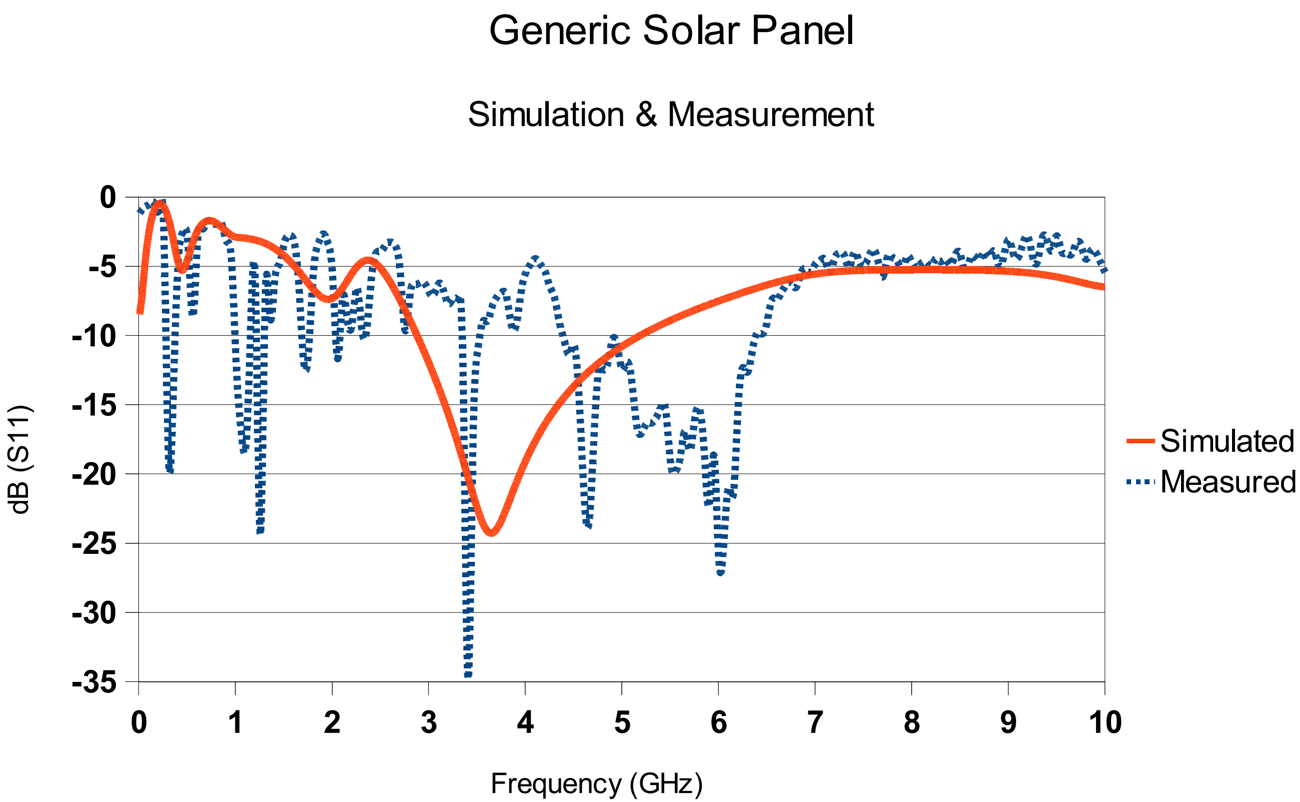


Electrical connector tracks on the PV panel → radiating structure!

Case Study:
Solar Panel Simulation vs Measurement

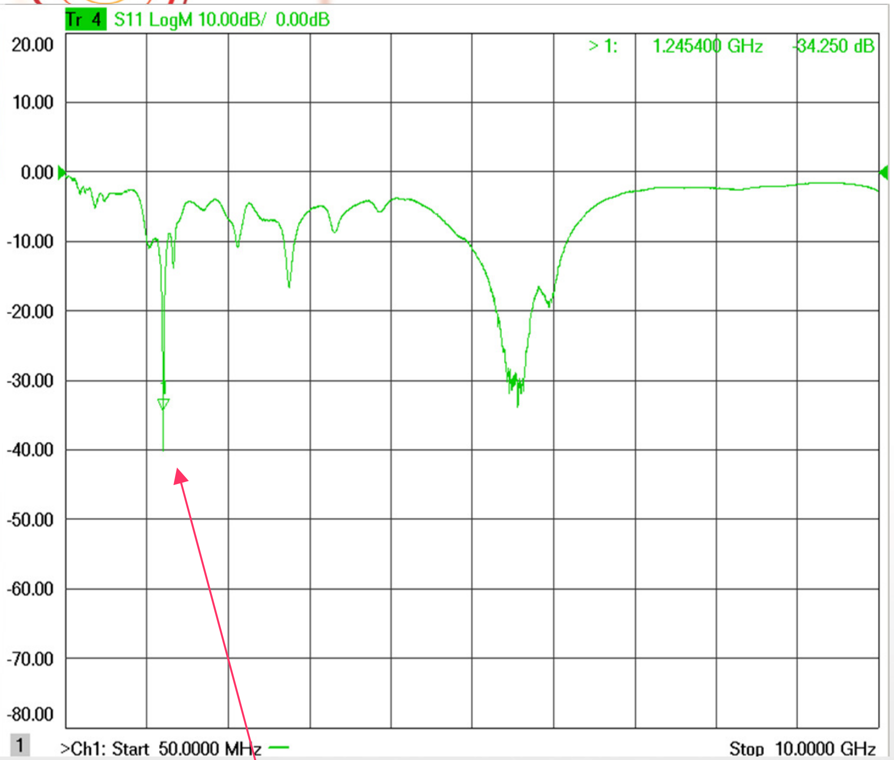


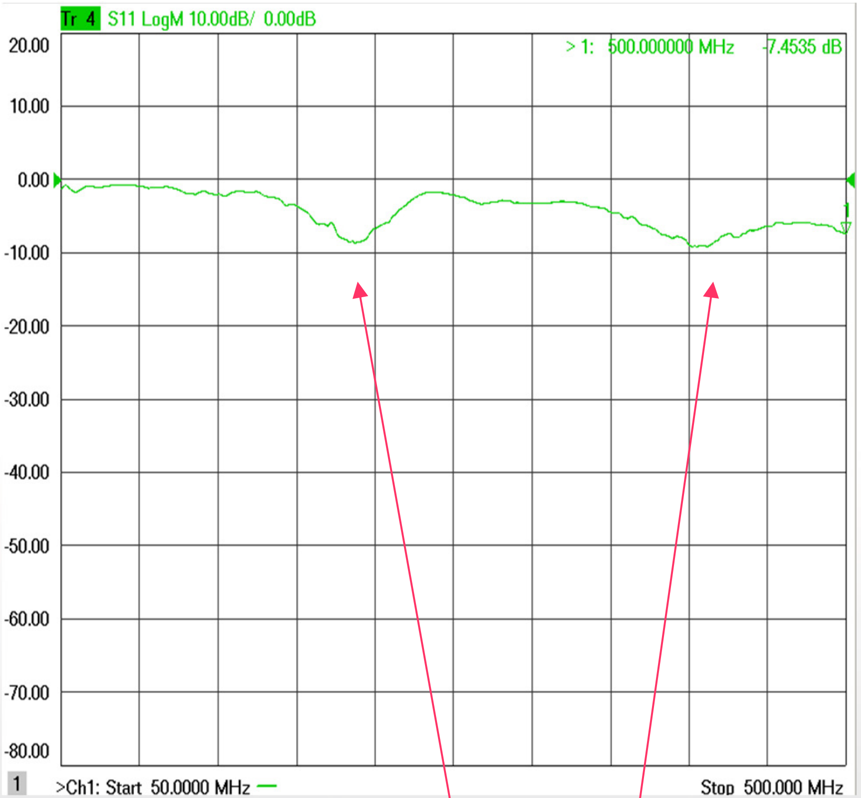




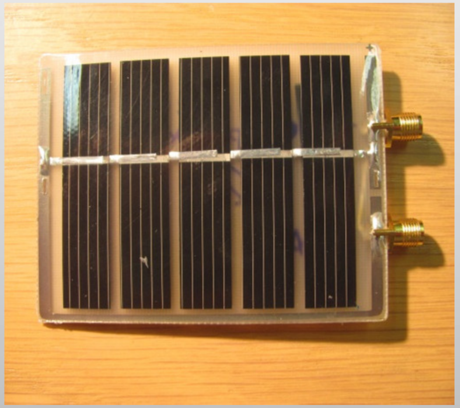
Relatively good agreement between simulated & measured results.

Solar Panel Evaluation: Generic





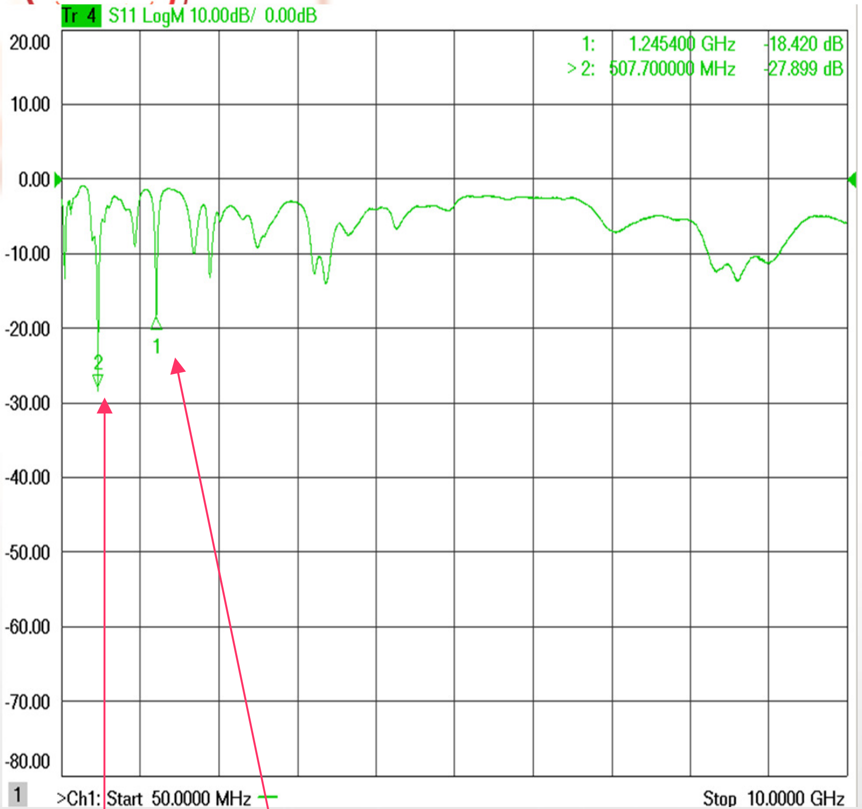
Deep notch at 1.25GHz

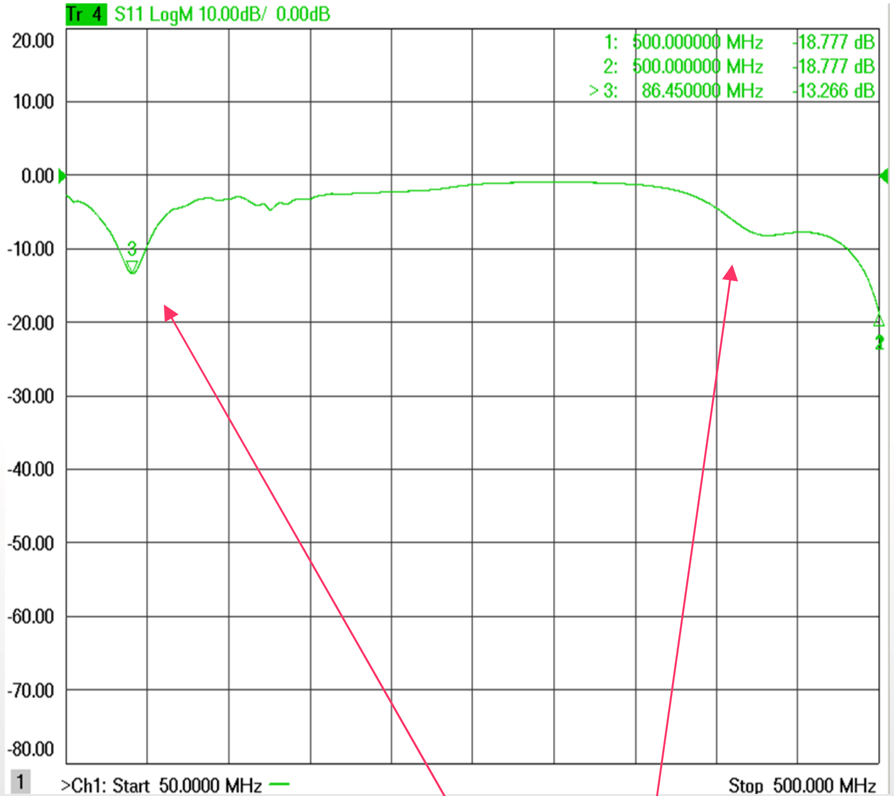


>5dB S11 at 150MHz & 400-500MHz

0.25W, 2V Panel

Solar Panel Evaluation: Voltaic





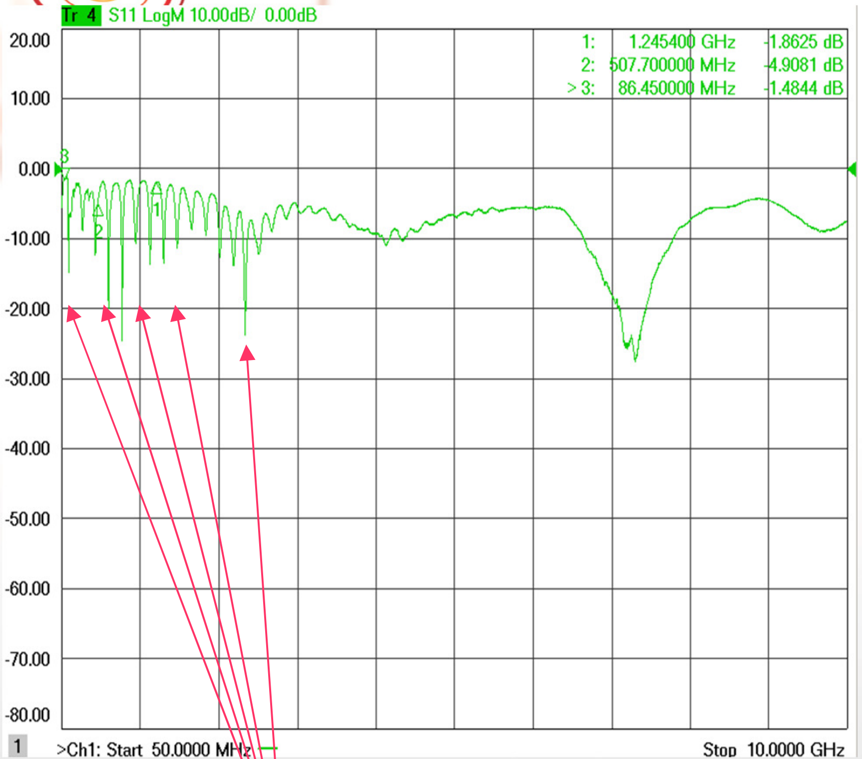
Deep notch at 1.25GHz

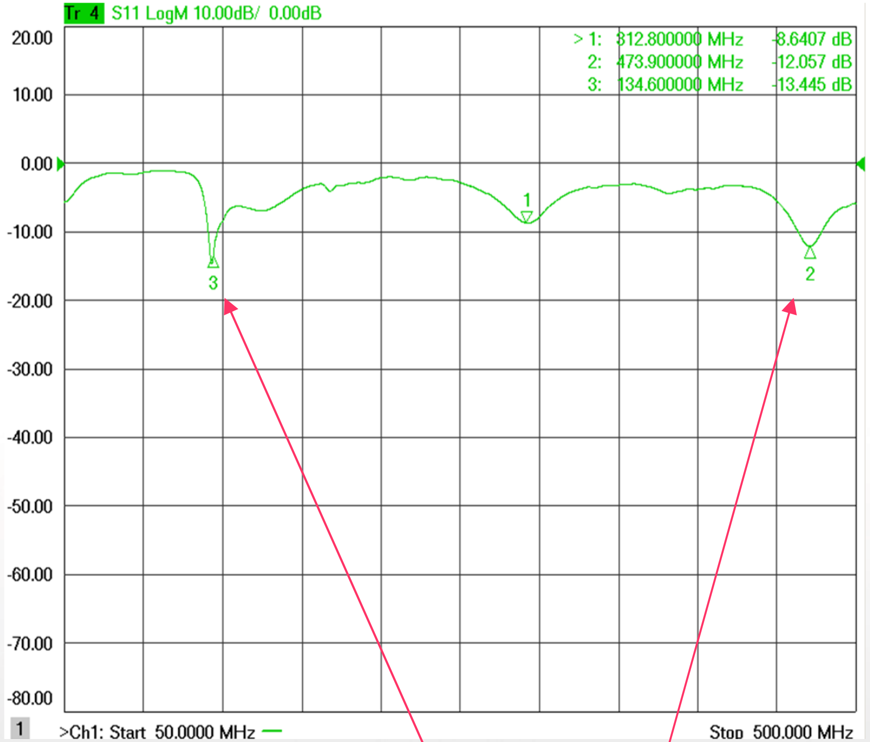
~10dB S11 at 80MHz & 400-500MHz

Deep notch at 500MHz

2W, 5V Panel

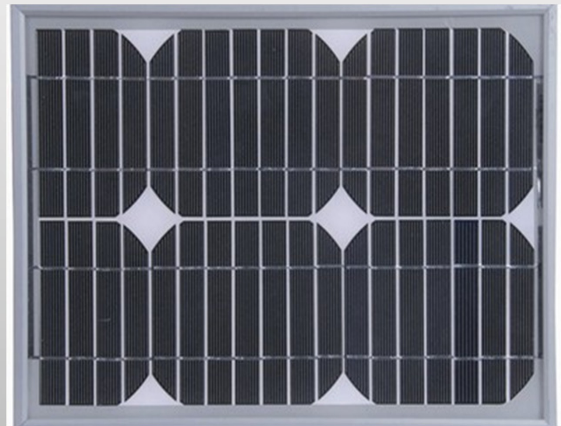
Panel Evaluation: PowerTech





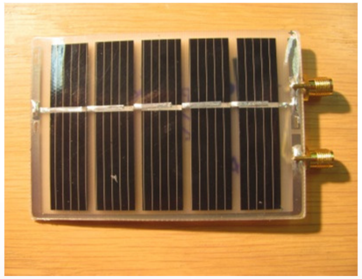
Notches at various frequencies

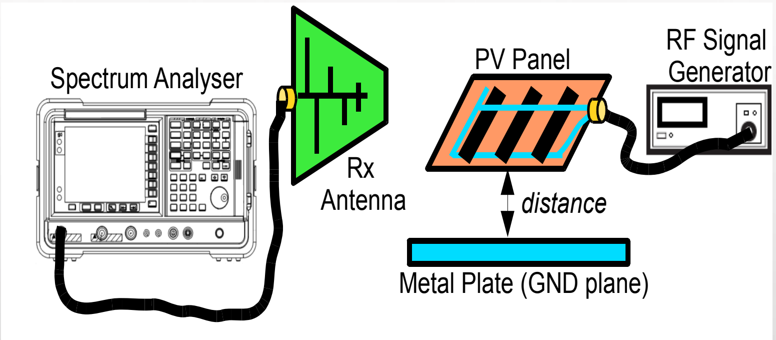
~10dB S11 at 130MHz & 470MHz

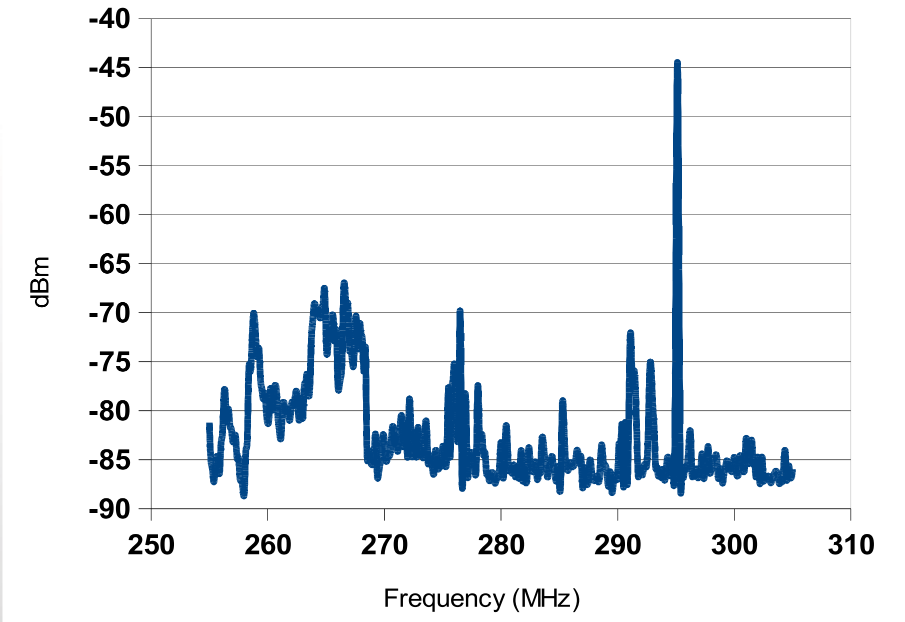


10W, 12V Panel

Case Study:
Solar Panel Radiated EMI Measurement

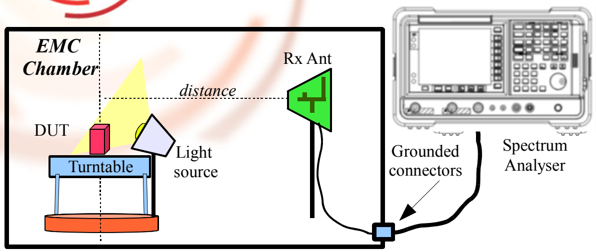




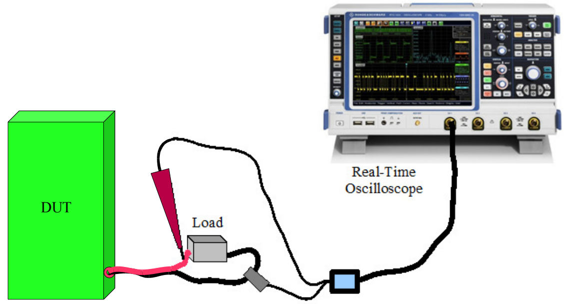


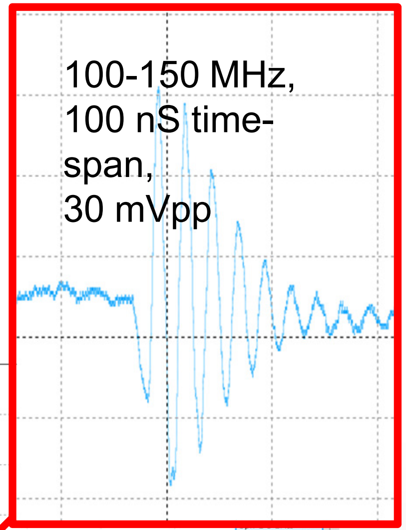
- PV panel → Could potentially radiate EMI emission!
- Metallic objects nearby interact with the panel
- Grounding (distance and conductivity) has some influence

Regulator (DC Converter) EMC Evaluation: Radiated & Conducted Emission



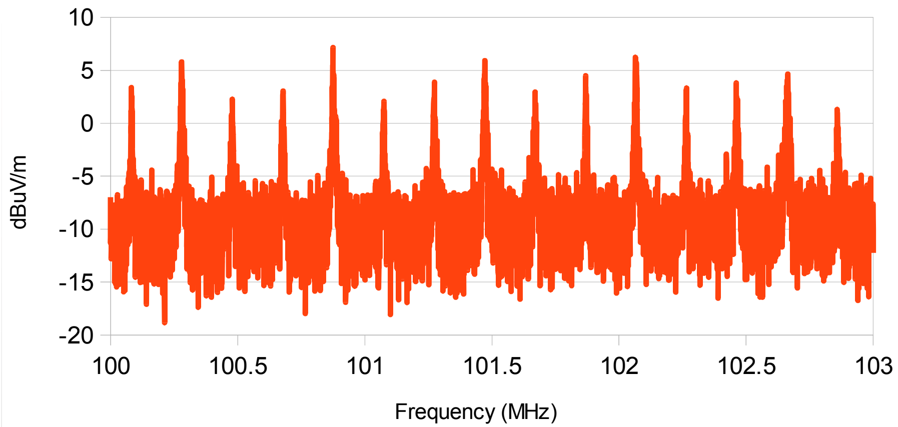
EMI Measurement





Noise from regulator:
1. Ripple (low)
2. Switch noise (high-frequency)

Field strength, 1kHz RBW Voltaic



1. EMI emissions → noise & harmonics at SKA-low band

2. EMI emission could be augmented:
- Metallic object near PV module
- Power cable connection

3. Reduce noise with filters & selection of components → custom made regulator

Conclusion

- **Potential of PV solar module for SKA-low**
  - Galvanic isolation (with radio-over-fibre).
  - Suitability at both SKA sites (irradiation).
  - Custom DC regulator design.
- **Practical Aspects:**
  - Battery/ energy storage life-time

    "LFP ($LiFePO_4$) battery promising"

    → 80% capacity up to 2,000 cycles (5x lead-acid).

    → Price: USD 40¢/ Wh (2011).
  - Dust accumulation on panel.
  - Optimum placement of panel:
    - Best winter performance (tilt)
    - Integrated with the antenna (SKA-low)?
  - Collaboration with solar industry.

Updates on Noise Parameter Measurement & ESD Evaluations:

- **Noise parameter measurements:**
  - Using ASTRON Maury tuners, down to 70MHz!
  - SiGe BJT has higher noise figure compared to GaAs FET.
  - Not for 300-450MHz, but possible for lower band (less than 250MHz).
- **ESD evaluations:**
  - Adopting JEDEC JS-001-2011 (device) & IEC 61000-4-2 (system).
  - Performance degradation of GaAs and BJT without internal protection → exposure to 200V Human Body Model (HBM).
  - SiGe BJTs & MMIC LNA with internal protection are robust.
  - ESD diodes, TVS diodes, surge protectors may not be sufficient against >500V HBM ESD events.