Fully Integrated Solar Panel Slot Antennas for Small Satellites

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Deployed dipole antennas, Helical antennas, Microstrip pat antennas

Alternative approach: Integrated solar panel antennas
- Conformal, does not take extra space
- Safe, no deployed mechanism

Different types of solar panel antennas
- Antennas integrated on top of solar panel
- Antennas placed under the solar cells (patch, slot)
- Slot antennas placed around the solar cells
Considerations

- Antennas should not block solar array
- Should not occupy additional surface area
- Easy to design and mass produce
- Safe
- Flexible in design (location, pattern, polarization)

Solutions: Solar Panel Antennas
1. Transparent solar cell antennas
2. Integrated slot antennas
There are gaps existing between solar cells.
Why don’t we fit antennas to these gap? 😊
How? – Slot antennas!

Feasibility of Integrated Solar Panel Slot Antennas
Cavity Backed Slot Antennas

- Realistic considerations.
- Isolating the antenna from the electronics inside.
- Radiation in one plane.
- Flexibility of choosing cavity substrate.
**Starting Point: Single Slot Antenna**

- **Feed Design**
  - Slot
  - Probe feed
  - CPW feed
  - Microstrip line

- **Prototype Antenna**
Circular Polarization (CP)

- **What is Circular Polarization?**
  1. Two orthogonal linear field components.
  2. Same magnitude.
  3. 90 degree phase difference.

- **Why Circular Polarization?**
  Simplify the ground station receiver design.

- **How to Design Circularly Polarized Slot Antennas?**
  An Axial ratio of $1.25e^{j85}$ was obtained.
Dual Band Antenna

- **Design**
  1. The idea depends on mutual coupling
  2. Matching was performed by adjusting the position of the feed line

- **Advantages**
  One antenna can perform the role of two
Prototype Solar Panel Antennas

- Prototype a fully integrated solar panel antenna that is ready to use for near future small satellite missions
- Characterize antenna performance considering the realistic circuit board layout, feed geometry, solar cell connections, and solar cells
- Determine the solar cell performance in the presence of antennas
Two substrates, three layers.

Polyimide as substrates:
- Relative Permittivity: 4.3
- Relative Permeability: 1.0
- Dielectric loss tangent: 0.004
- Substrate thickness: 1.54 mm
- Low expansion coefficient

SMA connectors were used to feed the antenna.

The walls of the antenna was shorted using conductive epoxy from Creative Material.
Layer Information

The layers of the printed circuit board

Antenna and Solar cells Layers

Feed Layer

Ground Layer
Measurement Setup
Circular Polarization Antenna

- Center frequency: 2.6 GHz.
- Ground plane size: 155×96 mm².
- The antenna was designed as LHCP.
- Directivity: 7 dB.
- Radiation Efficiency: 54%.
Measurements Vs Simulations:

- S-11 Parameter
- Radiation Patterns
Dual Band Antenna

- Operating frequencies: 2.1 and 2.9 GHz.
- Ground plane size: 198×96 mm²
- Directivity: 8 dB
- Radiation Efficiency: 54 %
Dual Band Antenna

Measurements Vs Simulations:

- S-11 Parameter
- Radiation Patterns
Solar Cells Integration

Circular Polarization

Linear Polarization
Solar Cells Integration

- Simulation
- Measurements Co-pol (no solar cells)
- Measurements Co-pol (solar cells)
- Measurements Cross-pol (no solar cells)
- Measurements Cross-pol (solar cells)
Two Elements Linearly Polarized Antenna

- Center frequency: 2.2 GHz
- Ground plane size: 155×96 mm²
- Directivity: 6.5 dB
Two Elements Linearly Polarized Antenna

Measurements Vs Simulations:
- S-11 Parameter
- Radiation Patterns
The measurements were taken in a sunny clear day
The results were more than satisfying
The measured solar cells efficiency was 30 %
Three integrated solar panel slot antennas at S band are prototyped on printed circuit boards.

The substrate has a relative higher loss that reduces the antenna efficiency, but is cost friendly and practical.

Both RF tests and solar cell tests show great results and prove that the antenna solution is very promising.

There are some shifts in antenna performance comparing with simulations, but most of them are explainable and can be improved.

A close collaboration with SDL is scheduled to prototype the final fully integrated solar panel antennas and test fly with real mission in the near future.