Compact Solar Cell
Ultra-Wideband Dipole Antenna

Mina Danesh*, John R. Long
High-Frequency Electronics Research Lab

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Outline

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  • Antenna radiation patterns
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Motivation

Solar energy harvesting for autonomous wireless transceivers

**Applications**
(outdoor & indoor environments)
- Wireless sensor networks
- Wireless body-area networks
- Space applications
- Active RFID
- Asset & people tracking
- Positioning

- Higher integration: combined DC and RF energy source
- Size reduction
- Overall cost reduction

**System-in-Package**

- Sensor
- Radio transceiver
- Power management
- Energy storage
- Solar antenna

**Smart System Integration**
UWB transceiver specifications

UWB antenna requirements

• Transceiver specifications:
  • Frequency band: 3.1 – 10.6 GHz
  • Low-power consumption: < 10 mW (peak power)
  • Differential circuits directly integrated to antenna
  • Compact package
  • Outdoor applications
  • For impulse-radio or FM UWB modulations
  • Low duty-cycling (< 10%), average power in µW or nW

• Antenna requirements:
  • Frequency bandwidth: 3.1-10.6 GHz
  • Efficiency > 50%
  • Gain: ~ 0 dBi
  • Radiation pattern: omnidirectional
Dimes solar cell technology

Thin-film amorphous silicon cells

- Amorphous hydrogenated silicon p-i-n junction
- Asahi glass with TCO (SnO₂)
- 10% efficiency attained

Front view

Cross-section

Back view

4 x 4 mm² Back contacts
Front contacts
UWB dipole antenna topology

- Broadband planar fat dipole antenna
- 1.5 mm FR-4 substrate

HFSS simulation model
Solar dipole antenna fabrication

1. DC connections for RF decoupling on substrate backplane
2. Solar cells in series or parallel DC connection
Solant dipole antenna (enhanced layout)

1. 0.4 mm FR-4 substrate
2. Symmetric layout
Solar cell DC characteristics

2 x 2 cm² solar cells

- Current density = 13 mA / cm²
- Solar cell efficiency = 6.3%

- Real environment: variable current source
- Fixed voltage supply needed → use DC/DC converter or regulator

\[ \text{Isc} = 35 \text{ mA} \]

\[ \text{Imp} \approx 30 \text{ mA} \]

\[ \text{Pmp}_1 = 16.8 \text{ mW} \]

\[ \text{Pmp}_2 = 17.4 \text{ mW} \]

\[ \text{Vmp} = 0.57 \text{ V} \]

\[ \text{Voc} = 0.85 \text{ V} \]
Solar dipole DC power management unit

Outdoors - in direct sunlight 5pm

Solar cells in parallel DC connection to maximize current

1. Supercapacitor charges with maximum available solar cells current
2. Once supercapacitor is fully charged, solar cells deliver minimum current to sustain DC-DC converter

Solar Energy Harvesting Power Management Solution for Outdoor Applications

Solar cell 1
Boost DC-DC converter
MPPT circuit
Supercapacitor
Buck DC-DC converter
LDO_1
LDO_2

0.2 V to 0.8 V
Vstart = 0.5 V, < 10 mA
2 V to 4.5 V
1.8 V
1.2 V
0.7 V
EN

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Solar antenna RF performances

RF input reflection coefficient

1. Initial design of solant without DC connections
2. Copper-only version of solant → Copper antenna was not optimized for input matching

Input mismatch:
1. DC interconnects (~2-6 GHz)
2. Coax cable + SMA connector

Coax cable length de-embedding
Solar antenna RF performances
Input impedances

Backside DC connections affect signal reflections at the input port
Solar antenna RF performances

Total Field Radiation Patterns

- 4 GHz
- 7.5 GHz
- 10 GHz

Copper-only dipole

Solar dipole
(prototype 1)

Solar dipole
(prototype 2)
Solar antenna RF performances

Surface currents comparisons

4 GHz
Copper-only dipole
Solar dipole (prototype 1)
Solar dipole (prototype 2)
7.5 GHz
10 GHz

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Solar antenna RF performances

Antenna Maximum Gain & Efficiency

- Compact Solar Cell
- Ultra-Wideband Dipole Antenna

**Graph:**

- **X-axis:** Frequency (GHz)
- **Y-axis**:
  - Left: Maximum antenna gain (dB)
  - Right: Antenna radiation efficiency (%)

**Graph Details:**

- Line colors and styles:
  - Copper dipole: Blue dashed line
  - Solant dipole+DC: Red solid line
  - Solant dipole: Green dotted line

- Frequency range: 3 GHz to 11 GHz
Conclusions

Planar Dipole Solar Antenna

- Amorphous silicon solar cell as a dipole antenna
- DC source and RF radiator/receiver for low-power UWB transceiver applications
- Solar antenna (solant) directly integrated with other circuitry (power management and RF front-end)
- Solant behavior comparable to copper-only antenna
- Radiation patterns change and losses increase:
  1. Solar cell stack-up (adjacent contacts)
  2. Material characteristics
  3. DC interconnections
- Further system integration design under way
- Overall RP measurements planned
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For more information on the project:

Website: www.minadanesh.com
Email: mina.danesh@ieee.org

“Small-area Solar Antenna for Low-Power UWB Transceivers” (EuCap 2010)