Design Considerations for RF Energy Harvesting Devices

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Overview

• RF energy is generally very low
  – Direct-power at close range to a transmitter
  – Energy accumulation for longer range

• Simple battery-recharge possible

• System level approach needed for optimal implementation
Key System Elements

- Harvester
- Antenna
- Storage
- MCU
- Sensors
- Radio
- Comm. Protocol
System Parameters

- **Operation**
  - continuous vs. intermittent
- **RF power source**
  - distance, power, frequency
- **Receiving antenna**
  - size, performance (gain)
- **Operating voltage**
- **Energy Storage**
- **Sensors** (active, passive)
Key RF Harvesting Characteristics

• Peak Efficiency
• Efficiency Range
• Frequency Range
• Sensitivity
• Output Voltage
• Performance Consistency
• Implementation Scalability
What makes an RF harvester efficient?

- **RF Matching**
  - Harvester is non-linear
- **Proper loading (DC match)**
  - Generally requires a specific discrete or emulated resistance
- **Correct frequency**

Deviation results in significantly reduced efficiency.
RF Matching Techniques

Rectenna (Rectifying Antenna)
- No matching network, No matching loss (assuming lossless antenna dielectric)
- Difficult to measure diode complex impedance
- Requires specialized antenna design

Standard Impedance (Powercast)
- Matched to 50Ω, Negligible matching loss
- No special RF equipment required
- Works with standard antennas
DC Matching Techniques

• Maximum Power Point Tracking (MPPT)
  – Used in many other harvesting technologies
  – Requires monitoring of the DC operating point
  – Requires a voltage converter
  – Uses power (some designs require battery)

• Powercast technology
  – Automatically adjusts to AC and DC operating point
  – No voltage converter required for harvesting
  – Uses no power
**DC Matching Technique - MPPT**

**Challenge**
- Narrow operating band for each load

**Solution: Max. Power Point Tracking**
- Used by other harvesting technologies
- Active monitoring of the operating point

**Drawback**
- Available RF energy is already low
- Active MPPT consumes power
P1110 Powerharvester™ Receiver
915 MHz, 3V Load

Efficiency (%)

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Input Power (dBm)

- Wide operating range
- Automatically maximizes efficiency
- Uses no power
Simplifying RF Design

Custom Design

Data

Power

Drop-In Modules
Battery-Free Sensor Module

Designed for Low-Power RF Harvesting

Module Components & Features

- **Powercast P2110 Powerharvester™ Receiver**
- **MCU:** Microchip PIC24 XLP
- **Radio module:** Microchip MRF24 (802.15.4)
- **System power:** 3.3V
- **Capacitor:** 50mF (as low as 3300uF)
- **Discrete sensors:** Temp, Humidity, Light
- **Wireless protocol:** MiWi™ P2P
System Operation

- Accumulate energy in capacitor
- Power MCU upon reaching charge threshold
- Power and read sensors
- Measure RSSI
- Format data packet
- Transmit data packet (broadcast-only)
- Turn off power (go dormant)

Components only powered when needed
Sensor Module System Voltage

Regulated Output Voltage

3.3V

0V

Sensor Inactive

"Zero Stand-By" Power

Power Output

Capacitor Voltage

V_{\text{MAX}}

V_{\text{MIN}}

Sensor Active

V_{\text{max}} = 1.25V

V_{\text{min}} = 1.05V

RESET
P2110 Powerharvester™ Receiver

Pin Configuration

Functional Block Diagram

Measured at 1.2V charge on capacitor

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Receiving Antenna

- 915 MHz center frequency
- Directional Pattern
  (122° horizontal, 68° vertical)
- Gain = 6.1 dBi
- FR4 material

Antenna included with Powercast evaluation boards
Powercaster™ Transmitter

- 915 MHz center freq.
- DSSS modulation
- 4 Watts EIRP
- Directional Antenna

6.25” width
6.75” height
1.63” depth
Complete Demo System

Power Transmitter 915 MHz
Sensor Modules 2.4 GHz
Data Receiver MRF24J40MA

nanoWatt XLP 16-bit

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Battery-Free Sensor Module Performance

4W EIRP Power Transmitter
Patch RX Antenna G = 6.1dBi

Time between Packets (s)

Distance (ft)
Conclusion

• Optimal performance results from system design that focuses on minimizing power.

• Every component must be selected based on power consumption.

• Wireless protocol must also be implemented to minimize power consumption.

• Reduction in power consumption and operating voltages will increase range and expand applications.
Questions

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