RF Wireless Power: An Enabling Technology

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Charles Greene, Ph.D.
Chief Technical Officer
Agenda

- Introduction to Powercast Corporation
- Overview of RF Wireless Power
- Powercast Products
- Performance Data
- Applications of RF Wireless Power
- Specific Examples of Implementations
Powercast Overview

RF Wireless Power
compny founded in 2003

• Privately held company
• Located in Pittsburgh, PA, USA

Enabling products that eliminate Batteries
& Battery Maintenance

- Products address existing and future markets
  - RF wireless power harvesting ICs and modules
  - RF wireless power transmitters
- Full suite of leading-edge, FCC approved products
- Products sold by numerous distributors (TED)
- Significant opportunities for OEM integration of wireless technology
- 16 U.S. patents issued and 10 U.S. patent applications (worldwide filings)
Introduction to RF Wireless Power
RF Energy is Everywhere
RF Power Sources

- **Intentional**
  - Examples: Equipment, smartphones, wireless routers

- **Anticipated**
  - Examples: Future technologies, wireless networks

- **Unknown**
  - Examples: Untested or unrecorded emissions
Power Profiles and Target Devices

**Average Power Consumption**

- **Sources of RF Power**
- **Receivers of RF Power**

**Battery Run Time**

- **Hours**
- **Days**
- **Weeks**
- **Months**
- **Years**
RF Wireless Power Overview

- Inches to over 100 feet depending on application
- Power from microwatts (µW) up to milliwatts (mW)

Controllable by Design

- Power Level
- Frequency
- Transmit Antenna Gain
- Receive Antenna Gain
- Number of Transmitters
- Distance
- Device Duty Cycle
- System Cost

\[ P_R = P_T \frac{G_T(\Theta_T, \Phi_T)G_R(\Theta_R, \Phi_R)}{(4\pi r)^2}(1-|\Gamma_T|^2)(1-|\Gamma_R|^2)|\hat{P}_T \cdot \hat{P}_R|^2 \]
Market Segment Value Propositions

- **Industrial – Minimizes Operating Costs**
  - Eliminates cost to hard wire or replace batteries – e.g. wireless sensors
  - Eliminates service downtime caused by depleted batteries
  - Reduces battery handling and disposal

- **OEMs – Improved Product Design**
  - Product differentiation – eliminate wires, cables, connectors
  - Sealed devices – less expensive enclosures and manufacturing, waterproof
  - Reliability – improved durability, reduced product failures, eliminate ESD

- **Consumers – Convenience and Usability**
  - Placement flexibility – no charging mats or charging stations
  - Untethered embedded power – eliminate wires, cables, connectors
  - Transparent charging – no user action required
Powercast Products
Full Suite of RF Wireless Power Solutions

- Powerharvester® Receivers
- Powercaster® Transmitters
- Evaluation Boards
- Development Kits
- Custom Engineering
Powerharvester® Chipset

PCC110 – RF to DC Converter

- High conversion efficiency, up to 75%
- Converts low-level RF signals enabling long range applications
- RF operating range: -18dBm to +20dBm
- Frequency range: 10MHz to 6GHz
- Harvests from all modulation types
- Interoperable with numerous RF sources: Powercast TX91501 transmitter, RFID readers, Mobile Phones, Wi-Fi routers, etc.
- SC-70 package

PCC210 – Boost Converter

- High efficiency, up to 95%
- Operation down to 0.4V input
- Capable of 5.5V @ 50mA output
- Resistor settable output voltage
- SOT23-6 package

Reference Designs Available (Others available on request):

- P1110  915MHz high-efficiency continuous powering and recharging
- P2110  915MHz long-range pulsed powering and pulsed recharging
- P2111  P2110 with enhanced sensitivity
- P2120  2.45GHz long-range pulsed powering and pulsed recharging
Powerharvester® Modules

- Modules allow easy deployment – RF in → DC out
- Provide high RF to DC conversion efficiency
- Power microcontrollers, sensors, electronics
- Designed for standard 50Ω antennas
- Support multiple frequency bands: 840-960MHz
- Based on Powercast PCC110 & PCC210 ICs

### P1110 Architecture

**Continuous Power Output**
- RF range: -5.0dBm to 20dBm
- Output voltage: 1.8V to 4.2V (configurable)
- Range of 3 meters or more

### P2110 Architecture

**Pulsed Power Output**
- RF range: -12dBm to 15dBm
- Output voltage: 2V to 5.5V (configurable and regulated)
- Range of 10 meters or more
TX91501 Powercaster® Transmitter

- 915 MHz center frequency
- FCC and IC certified
- RoHS compliant
- DSSS modulation (power)
- ASK modulation (data)
- 1W or 3W EIRP
  - TX91501-1W-ID
  - TX91501-3W-ID
- Integrated antenna with 60° beam pattern
- Data broadcast (factory-set)
- Plug-and-play installation
- Powers virtually unlimited number of Powerharvesters

Dimensions:
- 6.25” width
- 6.75” height
- 1.63” depth

Power Jacks (2) – 5V
- Back – for tabletop placement
- Bottom – for wall mounting

Status Indicator LED
- Green – Transmitting
- Red – Fault Condition
Lifetime Power® Development Kit

P2110-EVAL-01

- Complete system for battery-free wireless applications
  - Jointly developed with Microchip Technology
  - Designed for wireless sensing applications using MiWi protocol
    - RF Transmitter (TX91501-3W-ID)
    - Two P2110 Evaluation Boards (P2110-EVB)
    - Two 6dBi Directional Antennas (PA-915-01)
    - Two 2.5dBi Omni-directional Antennas (DA-915-01)
    - Two Wireless Sensor Boards (WSN-EVAL-01) – Temperature, Humidity, Light Level
    - Microchip 16-bit XLP Development Board
    - Microchip MRF24J40 PICtail/PICtail Plus daughter card
    - Microchip PICkit 3 programmer/debugger
Performance Data
Powercast Technology Advantages

- **High efficiency over a broad range:**
  - Load resistance
  - Input power
  - Recharging current

- **No Maximum Power Point Tracking (MPPT) required**

- **Over 850 MHz operating bandwidth**
  - Essential for ambient energy harvesting
  - Easy scalability for geographic regions using different frequencies

- **Result …**
  - Better performance
  - More power
  - Simplified design-in
## 915MHz Link Budget Analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Gain/Loss</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitted Power (From amplifier) - $P_T$</td>
<td>27dBm (0.5W)</td>
<td></td>
</tr>
<tr>
<td>Transmitter Antenna Gain - $G_T$</td>
<td>8.34dBi</td>
<td></td>
</tr>
<tr>
<td>EIRP ($P_T G_T$)</td>
<td></td>
<td>$35.34$dBm</td>
</tr>
<tr>
<td>Path Loss (Distance dependent) – $\frac{\lambda^2}{(4\pi R)^2}$</td>
<td></td>
<td>$3.4W$</td>
</tr>
<tr>
<td>1m</td>
<td>-31.68dB</td>
<td></td>
</tr>
<tr>
<td>5m</td>
<td>-45.65dB</td>
<td></td>
</tr>
<tr>
<td>10m</td>
<td>-51.68dB</td>
<td></td>
</tr>
<tr>
<td><strong>12m</strong></td>
<td><strong>-53.25dB</strong></td>
<td></td>
</tr>
<tr>
<td>Receiver Antenna Gain - $G_R$</td>
<td>6dBi</td>
<td></td>
</tr>
<tr>
<td>Received Power - $P_R$</td>
<td></td>
<td>-11.91dBm</td>
</tr>
<tr>
<td>RF to DC Converter</td>
<td>-5.2dB (30%)</td>
<td></td>
</tr>
<tr>
<td>Usable Power*</td>
<td></td>
<td>-17.11dBm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19.45uW</td>
</tr>
</tbody>
</table>

*Using the Powercast P2110, this energy is continuously stored in a capacitor and provided to the load intermittently. The energy is stored at approximately 1V and is boosted to a user selectable voltage (2 to 5.5V) at 85% efficiency. The output current can be up to 50mA for a duration set by the capacitor value.
Available Power at 915MHz

Available Power Before Conversion (Calculated)

- **uW**
  - 350
  - 300
  - 250
  - 200
  - 150
  - 100
  - 50
  - 0

- **Distance (meters)**
  - 0
  - 5
  - 10
  - 15
  - 20
  - 25
  - 30

- **3W EIRP Transmitter 915MHz**
- **6 dBi Receiver Antenna**

- Smaller antenna
**Powerharvester® Performance Comparison**

**RF-to-DC Conversion Efficiency (%)**

**P1110** - 915MHz, 3V

**P2110** - 915MHz, 1.05V

**Input Power (dBm)**

Custom Designs
Harvesting sensitivities:
- -25dBm with battery
- -18dBm passive

**Distance**

**Power**
Harvested Power at 915MHz

- **P1110** - 915MHz, 3V
- **P2110** - 915MHz, 1.05V

![Graph showing harvested power vs. input power for P1110 and P2110 at 915MHz.](image-url)
Applications of RF Wireless Power
Powercast enables a complete wireless infrastructure for micro-power and data.
Application: Bulk Trickle Charging

- Freedom of placement
- Eliminate wires and connectors
- Automatic/transparent charging
- Multiple battery types/chemistry
Application: Desktop Charging Hot Spot

Suitable for low-usage items or longer charge times (+6 hours)

Computer peripherals
Hearing Aids
Headsets
Body-Worn Devices
Tracking Devices
Other Devices

Consumer-oriented transmitter
Low-transmit power, Low-cost, USB powered
Application: High-Function RFID Tags

- Identification
- Sensing
  - Temperature
  - Vibration
  - Heart Rate
  - Stress/Strain
  - Shock
- Smart Packaging
  - Bi-Stable Display
  - Indications – LED, Audible
- Security
  - Biometrics and Encryption

UHF RFID Reader

Powercast provides >10X the power vs. traditional RFID
RFID Tag Power Requirements

Enabled by Powercast

• Industrial Sensing
• Maintenance Tracking
• Manufacturing Operations

Sensors
Computation
Screen Update

Memory Access
ID read

ID Tag
Memory Tag
High-Function Tag

• Retail
• Supply Chain
• Medical

Power

- Retail
- Supply Chain
- Medical

- Industrial Sensing
- Maintenance Tracking
- Manufacturing Operations
Demonstrations – EPC C1G2 RFID Tags

Temperature & Indication
- Range: 12 meters
- Read/Write capable
- Temp Range: -40 to 85°C
- ±1% Accuracy
- LED Indications
  - Temp update (Green)
  - Find-tag indication (Red)

Visual Bi-Stable Display
- Range: 2-4 meters
- Read/Write capable
- Image sent from Reader
- Image retention without power
RF Wireless Power Markets

- Identification
- Electronic Labeling
- Automation Sensors
- Cold Chain
- Access Control
- Industrial Monitoring
- Structural Monitoring
- Defense
As the cost and size of RF-power solutions decrease, opportunities to address additional high-volume markets will increase significantly.
Specific Examples of Implementations
Example: Wireless Sensor Battery Recharging

Pittsburgh Zoo Penguin Exhibit:
Sensitive environment, high value assets, very limited access

Problem:
Battery replacement every 3-4 months in wireless sensor nodes

Solution:
Powercast RF wireless power system to provide continuous battery charging and perpetual battery life

Battery compartment retrofitted with Powercast RF Harvester

![Comparison of Sensor Nodes](image)
Example: Passive UHF RFID Sensing

- Used in shipping and warehouse applications
- Monitor temperature inside shipments
  - -40 to 85C
- Monitor shock and tilt of packages or totes
  - ±3 g
- Waterproof and flexible packaging
- Customizable graphics
- Packaged in Teslin®
  - Durable synthetic paper that offers easy, high-quality printability, strong adhesion, and thermal/chemical durability
  - Acts like miniature bubble wrap, protecting the embedded RFID inlay and other electronics
  - Independent laboratory studies show lasts two to three times longer than PVC cards
Example: Decorative Lighting

- **Wireless Christmas Tree**
  - Eliminates interconnecting wires
  - Two RF transmitters located inside the tree
  - A passive harvester directly drives each LED, 100 per tree
  - Numerous lighting effects can be achieved via patented modulation techniques

- **Decorative lighting technology being included in other products**
  - Stickers
  - Labels
  - Illuminated product packaging

[www.frontgate.com](http://www.frontgate.com)
Example: Industrial Oven Temperature Monitoring

- **Wyze Temp®HT High Temp Battery-less Probe**
  - Temperature sensing without batteries! (Sensors are powered up by the reader RF energy)
  - Numerous temperature probes can be read simultaneously
  - Perfect for conveyor ovens and rotisseries where tethered probes cannot be used
  - Bakery goods and other foods that go through cooking and cooling zones benefit by real time temperature tracking
  - Product benefits include: continuous cooking operation, no interruption of cook process to measure product temperature, long-term product reliability, improved safety for employees

http://www.matrixpd.com/
Powercast Resources

- **Documentation**

- **Wireless power calculator (Excel)**
  - [http://www.powercastco.com/power-calculator/](http://www.powercastco.com/power-calculator/)

- **Videos and Presentations**
  - [http://www.youtube.com/powercastco](http://www.youtube.com/powercastco)
  - [http://www.slideshare.net/powercast](http://www.slideshare.net/powercast)
Thank You

Charles Greene, Ph.D.
Chief Technical Officer
+1.412.923.4770
cgreene@powercastco.com
Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

Powercast:
DA-915-01  PA-915-01