RF Wireless Power: An Enabling Technology

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Emerging Technology

P2100 Powerharvester®

TX91501 Powercaster®

EDN 2010 Hot 100

P2110 Powerharvester®

P2110 Powerharvester®

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 company founded in 2003

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

Enabling products that eliminate Batteries & Battery Maintenance

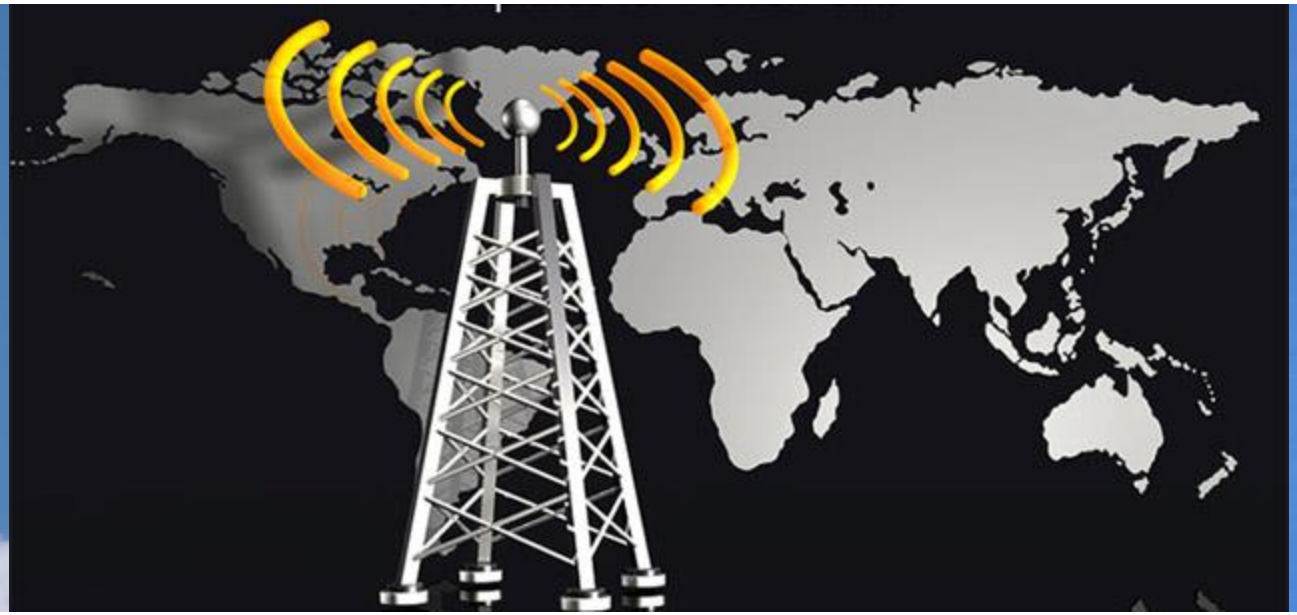
- Products address existing and future markets
  - RF wireless power harvesting ICs and modules
  - RF wireless power transmitters
- Full suite of leading-edge, FCC approved products
- Products sold by numerous distributors (TED)
- Significant opportunities for OEM integration of wireless technology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

Introduction to RF Wireless Power

RF Energy is Everywhere







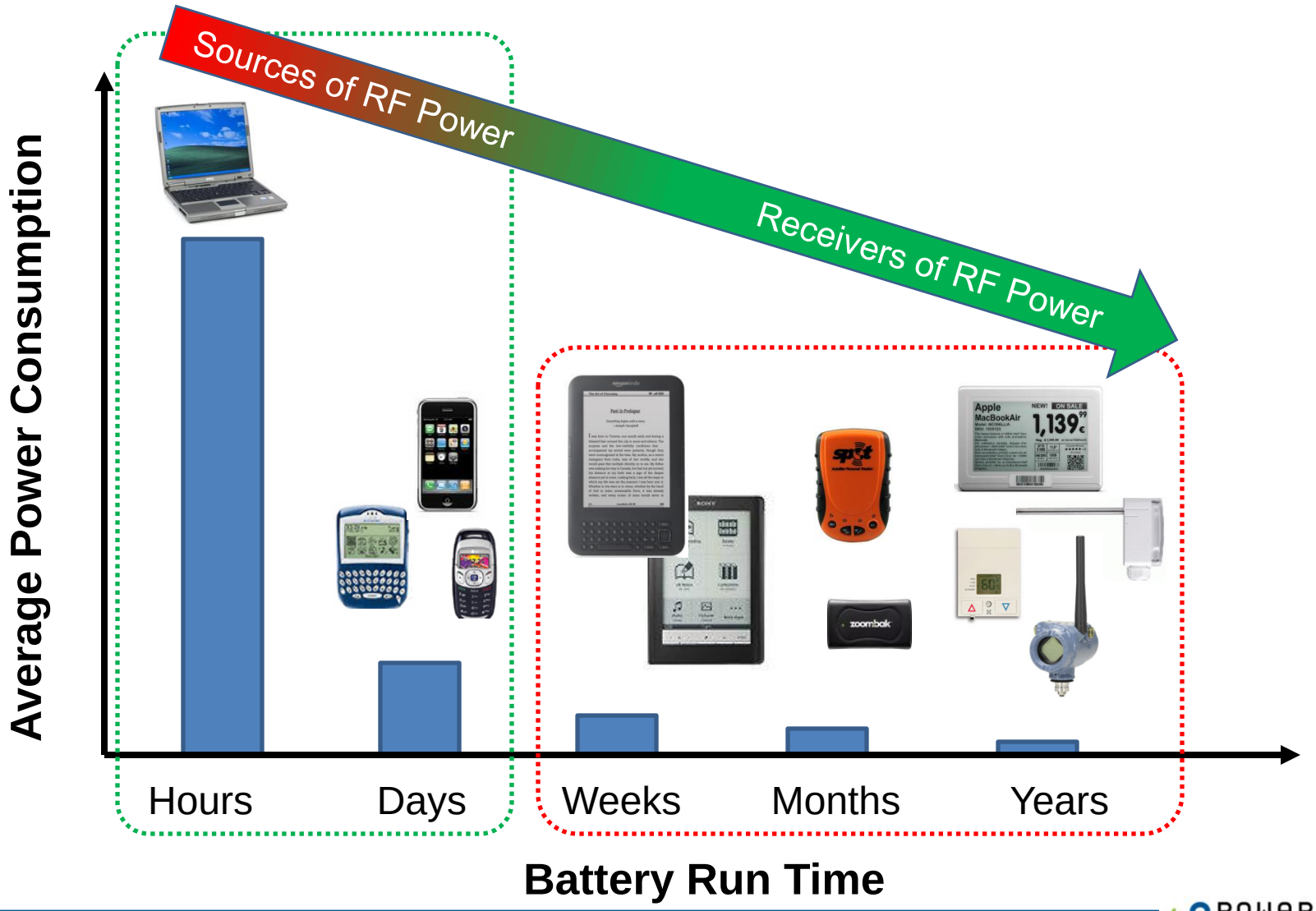

RF Power Sources

Intentional

Anticipated

Unknown

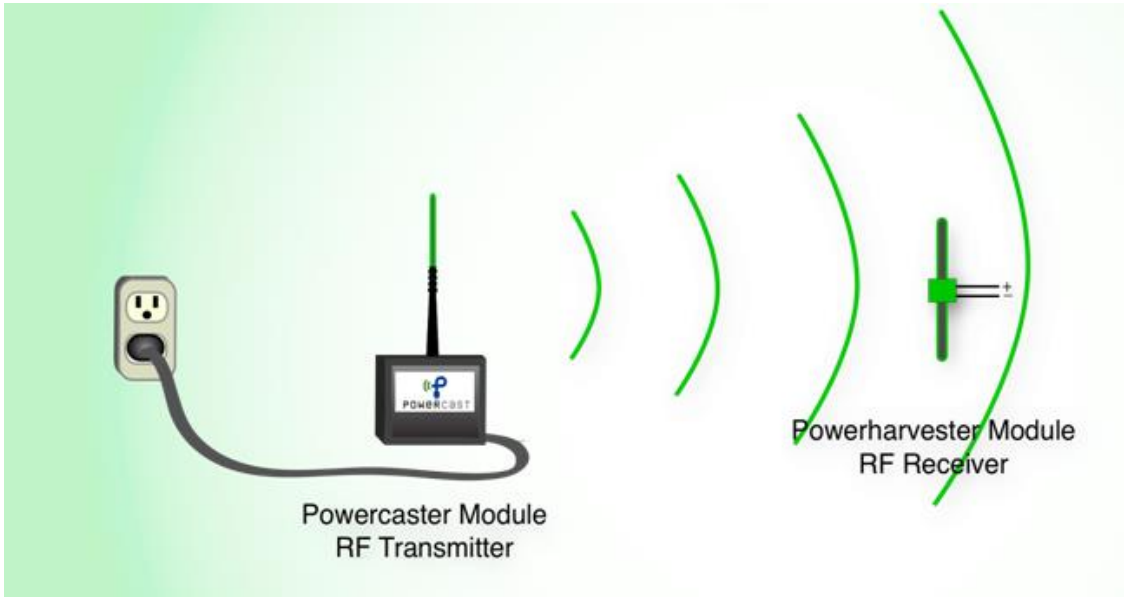
Power Profiles and Target Devices



RF Wireless Power Overview

Intentionally broadcast Radio Frequency (RF) provides wireless power over distance

- 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

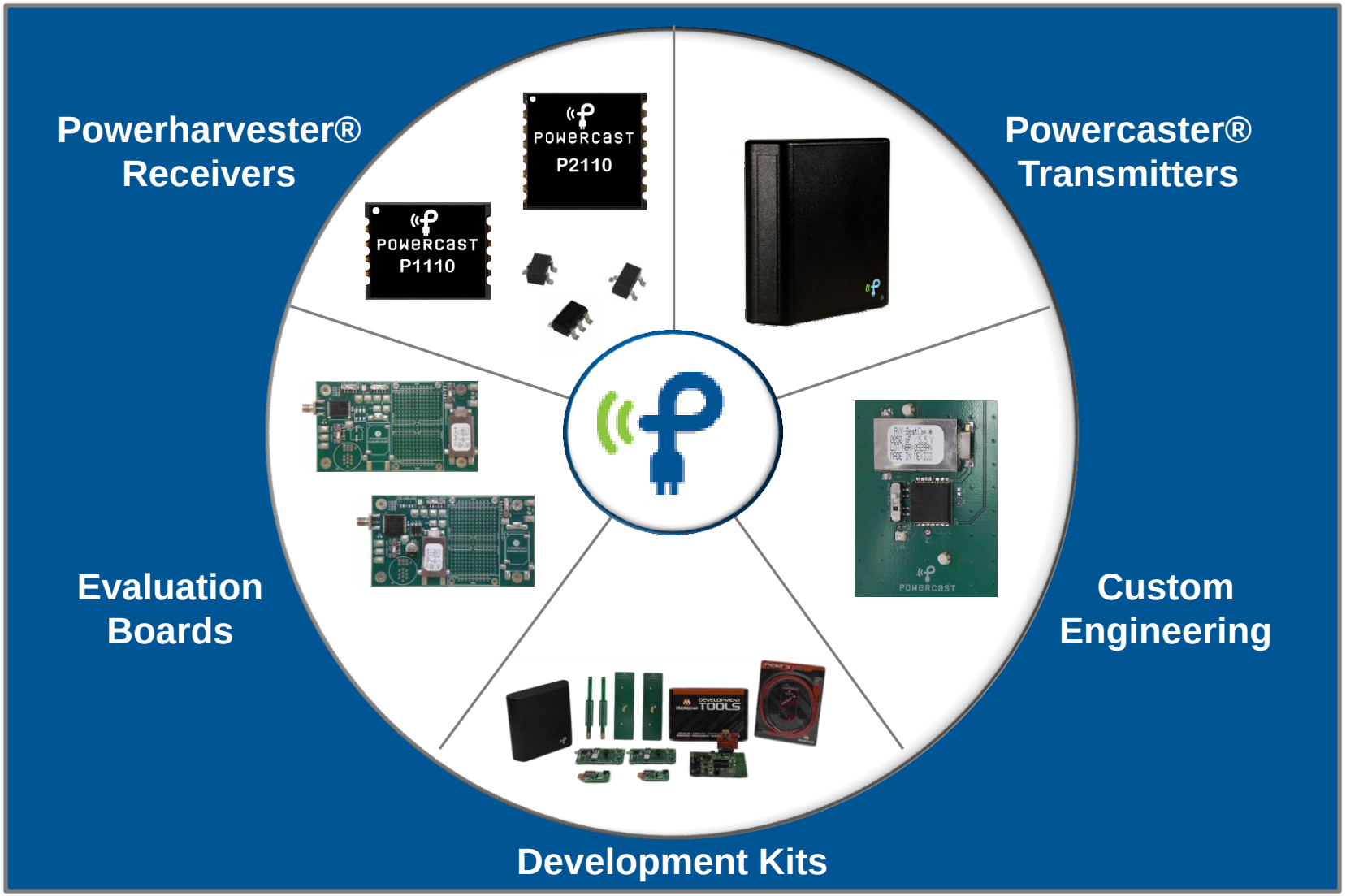
$$P_R = P_T \frac{G_T(\theta_T,\phi_T)G_R(\theta_R,\phi_R)\lambda^2}{(4\pi r)^2}(1-|\Gamma_T|^2)(1-|\Gamma_R|^2)|\hat{\mathbf{p}}_T \cdot \hat{\mathbf{p}}_R|^2$$

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® 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

RoHS

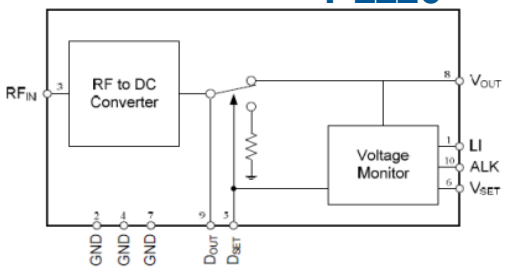
Reference Designs Available (Others available on request):

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

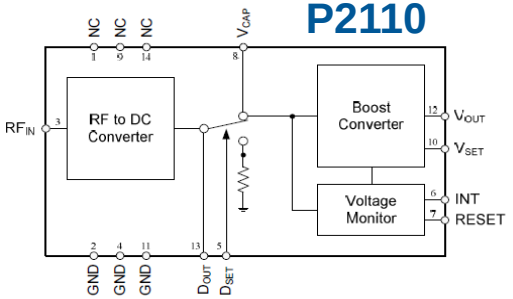
Powerharvester® Modules

- 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



P2110



P1110 Architecture

Continuous Power Output

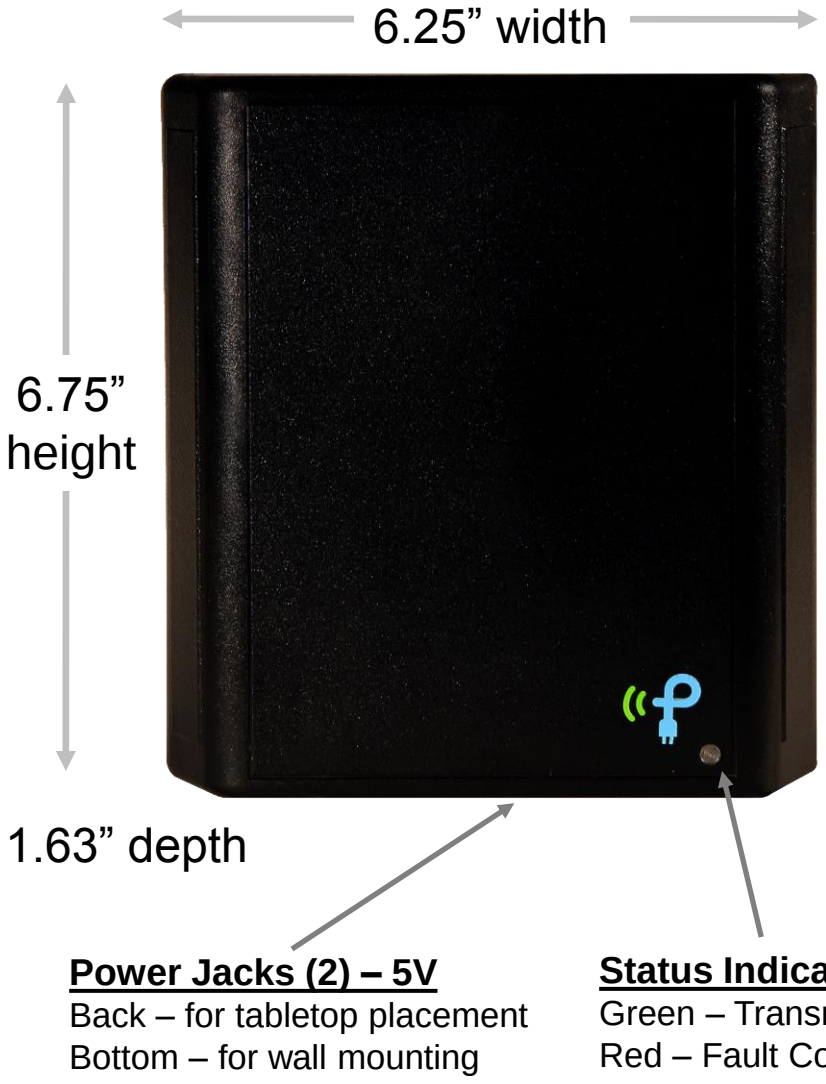
- RF range: -5.0dBm to 20dBm
- Output voltage: 1.8V to 4.2V (configurable)
- Range of 3 meters or more

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**

Lifetime Power® Development Kit

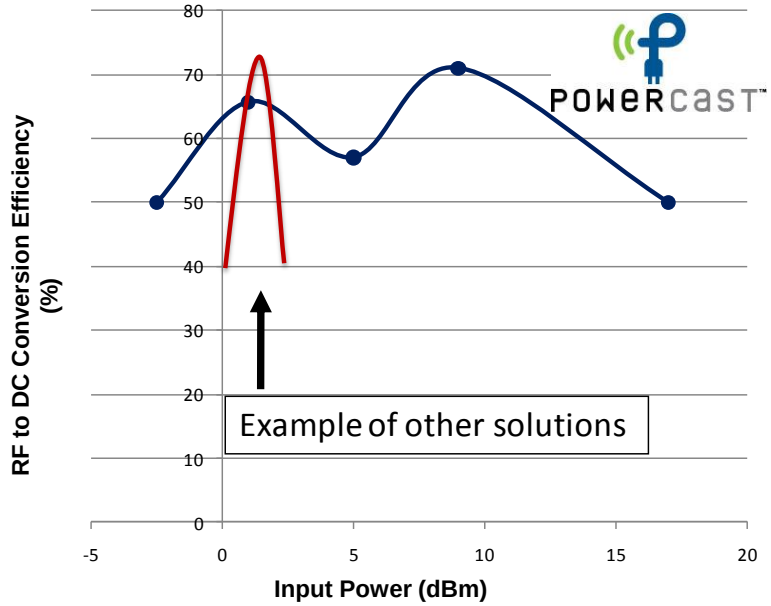
P2110-EVAL-01

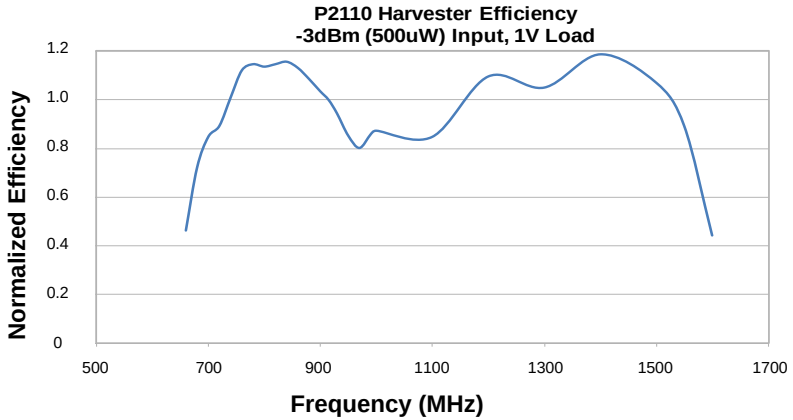
- **Complete system for battery-free wireless applications**
  - Jointly developed with Microchip Technology
  - Designed for wireless sensing applications using MiWi protocol
    - RF Transmitter (TX91501-3W-ID)
    - Two P2110 Evaluation Boards (P2110-EVB)
    - Two 6dBi Directional Antennas (PA-915-01)
    - 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





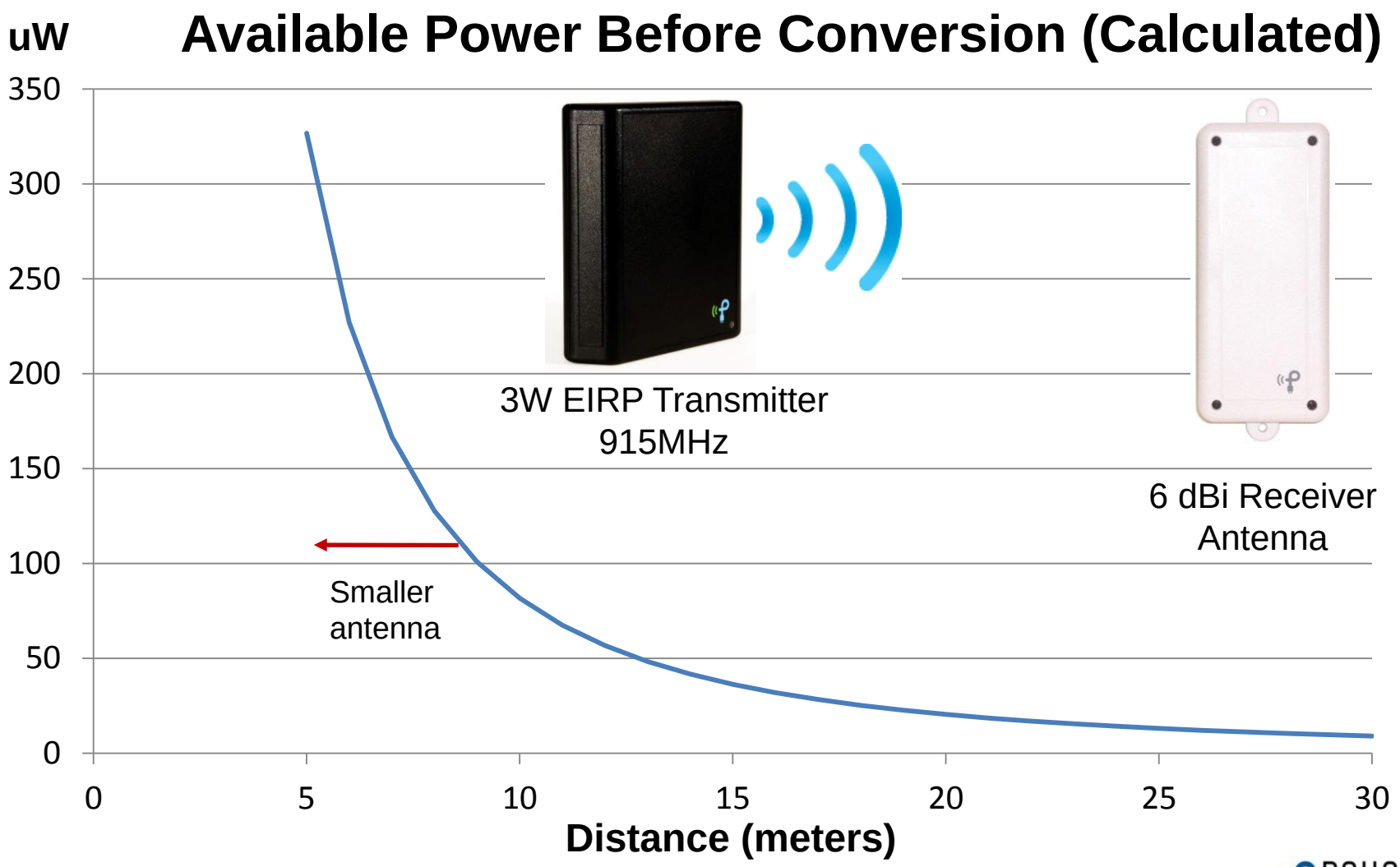
915MHz Link Budget Analysis

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi R)^2}$$

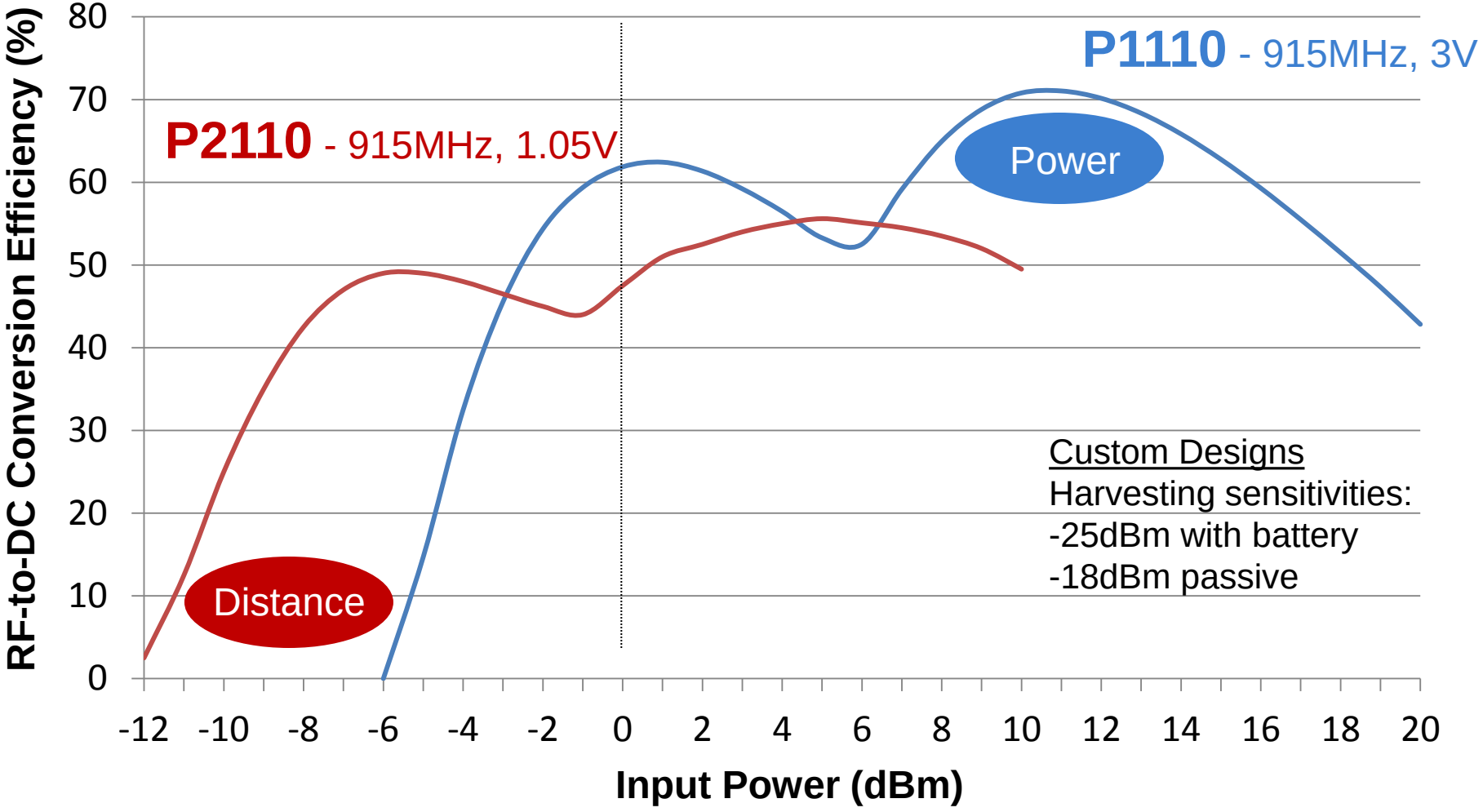
Parameter	Gain/Loss	Total
Transmitted Power (From amplifier) - P_T	27dBm (0.5W)	
Transmitter Antenna Gain - G_T	8.34dBi	
EIRP ($P_T G_T$)		**35.34dBm** **3.4W**
Path Loss (Distance dependent) – $\lambda^2/(4\pi R)^2$		
1m	-31.68dB	
5m	-45.65dB	
10m	-51.68dB	
12m	**-53.25dB**	
Receiver Antenna Gain -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

*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.

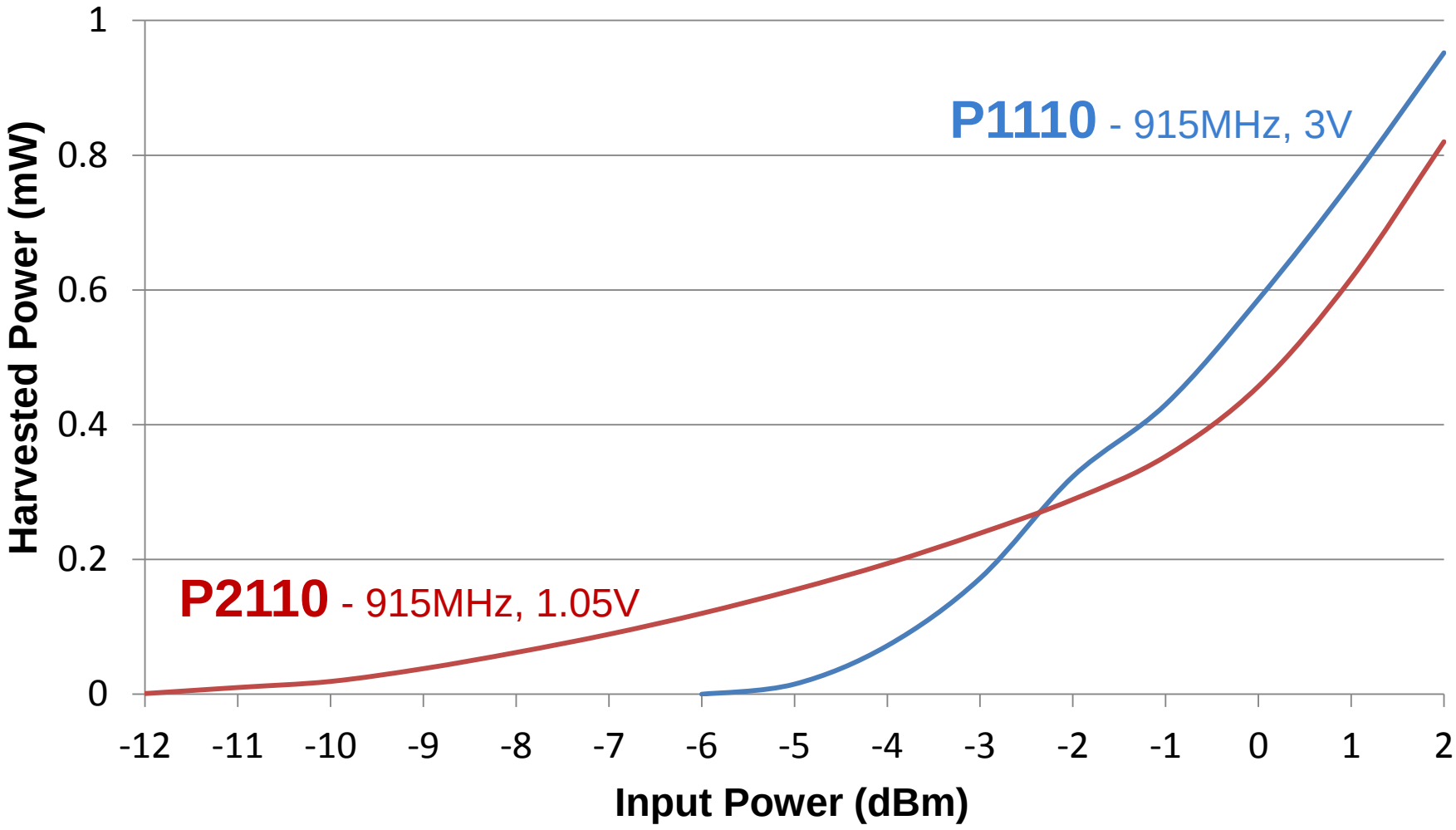
Available Power at 915MHz



Powerharvester® Performance Comparison



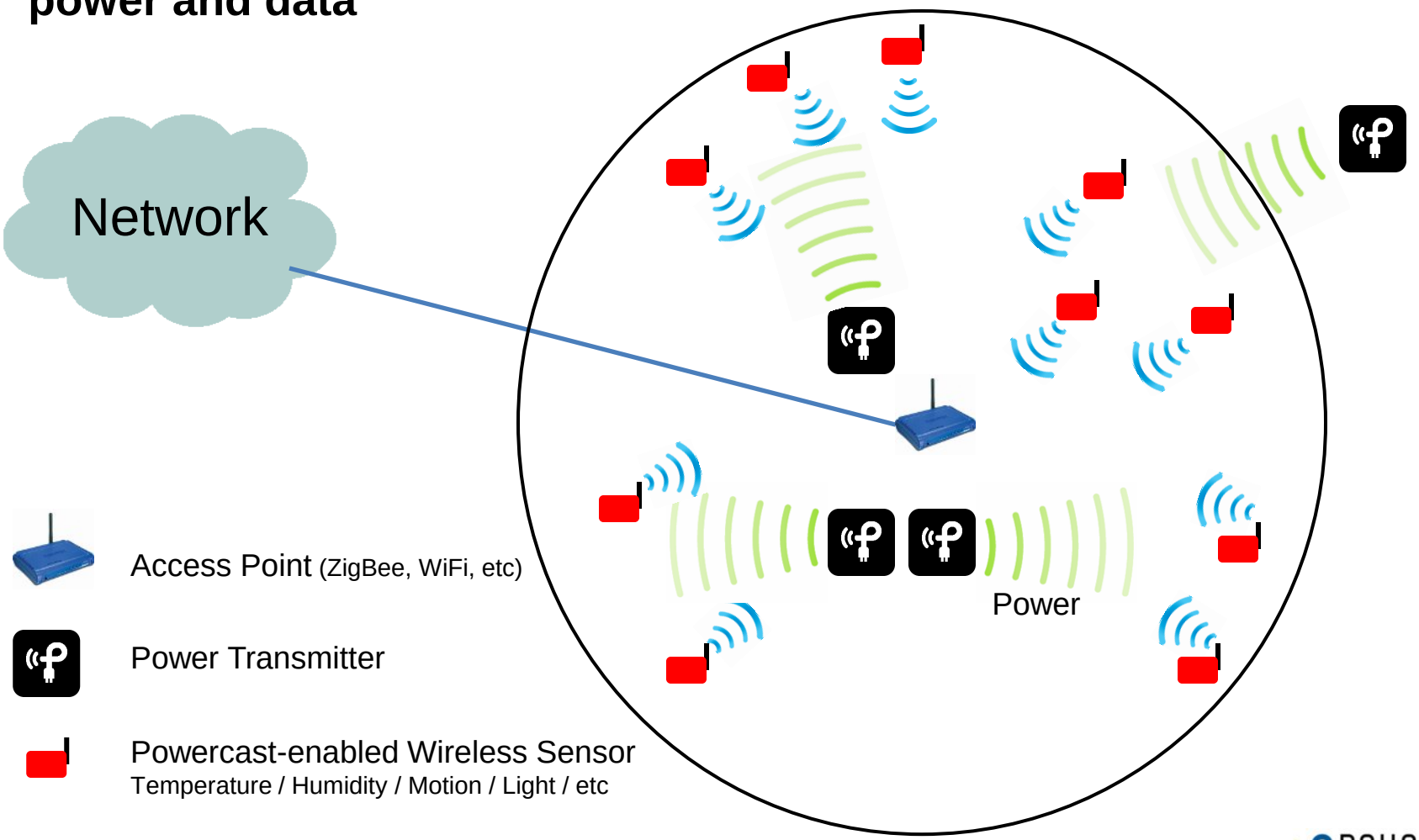
Harvested Power at 915MHz



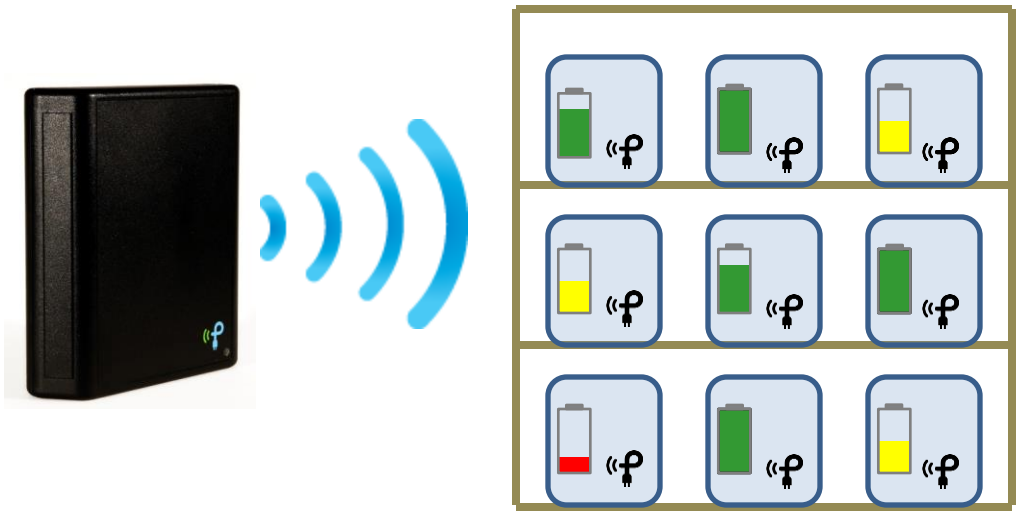
Applications of RF Wireless Power

Application: Wireless Power Network for Sensors

- **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

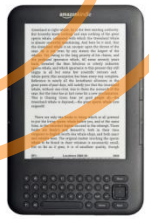
Suitable for low-usage items or longer charge times (+6 hours)

Computer peripherals

Hearing Aids

Headsets

Body-Worn Devices



Tracking Devices

Other Devices

Consumer-oriented transmitter

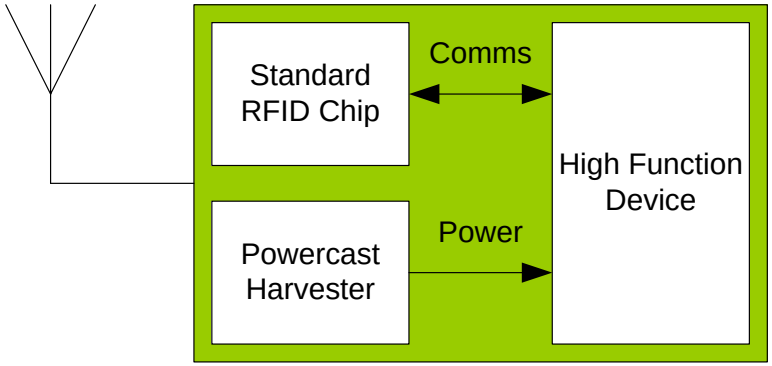
Low-transmit power, Low-cost, USB powered

Application: High-Function RFID Tags

UHF RFID Reader

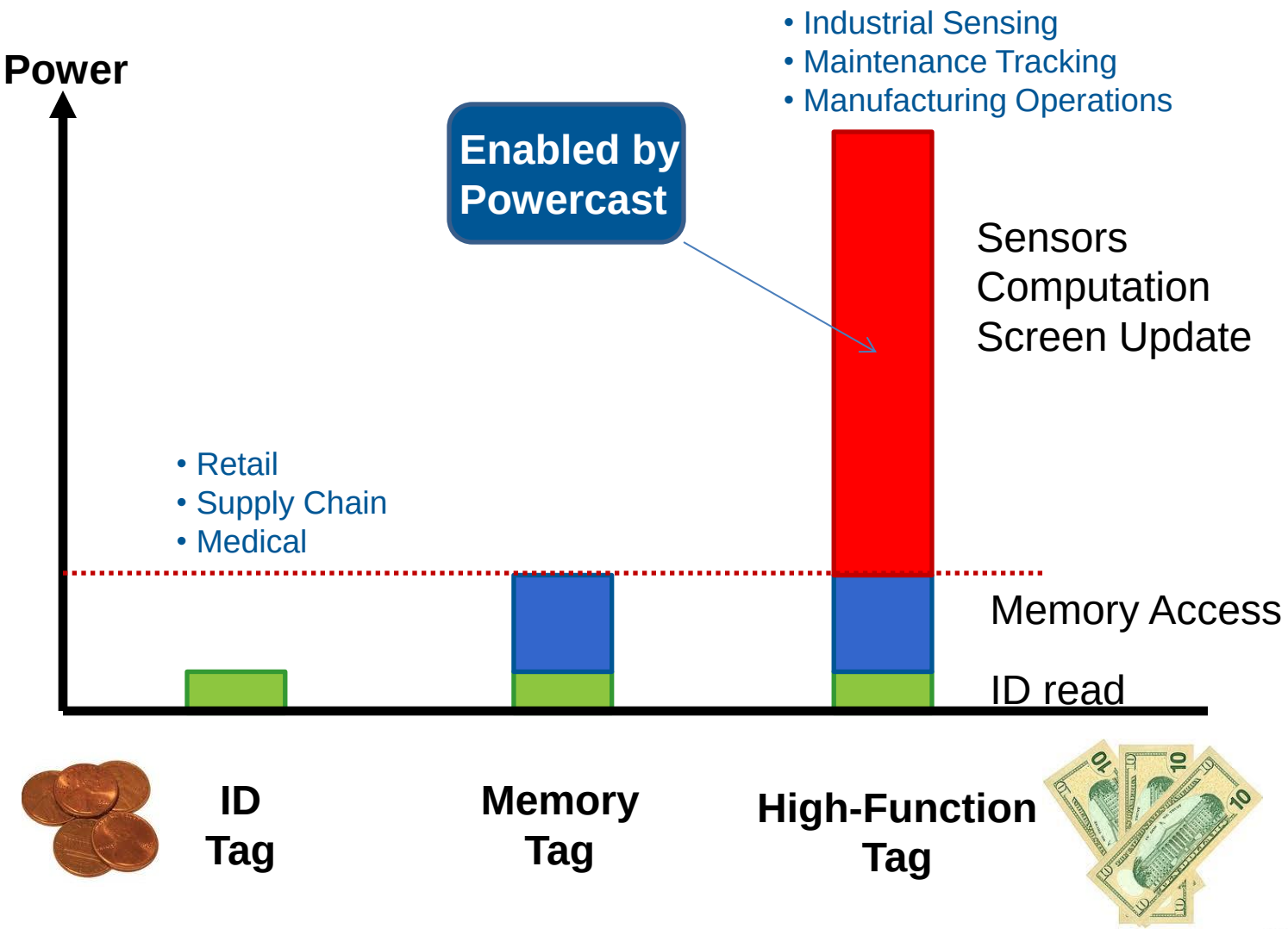
Up to 12 meters

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



Powercast provides >10X the power vs. traditional RFID

RFID Tag Power Requirements



Demonstrations – EPC C1G2 RFID Tags

Temperature & Indication

- **Range: 12 meters**
- **Read/Write capable**
- **Temp Range: -40 to 85C**
- **±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

RF-Power Market Growth

- **As the cost and size of RF-power solutions decrease, opportunities to address additional high-volume markets will increase significantly**

Smart Cards

Novelty Lighting

Consumer Electronics

Battery Packs

Automation Sensors

GPS/RTLS Tracking Tags

Medical Devices

Supply Chain

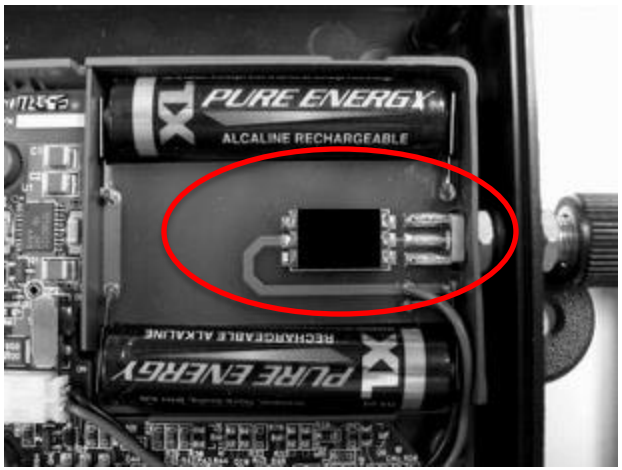
Specific Examples of Implementations

Example: Wireless Sensor Battery Recharging

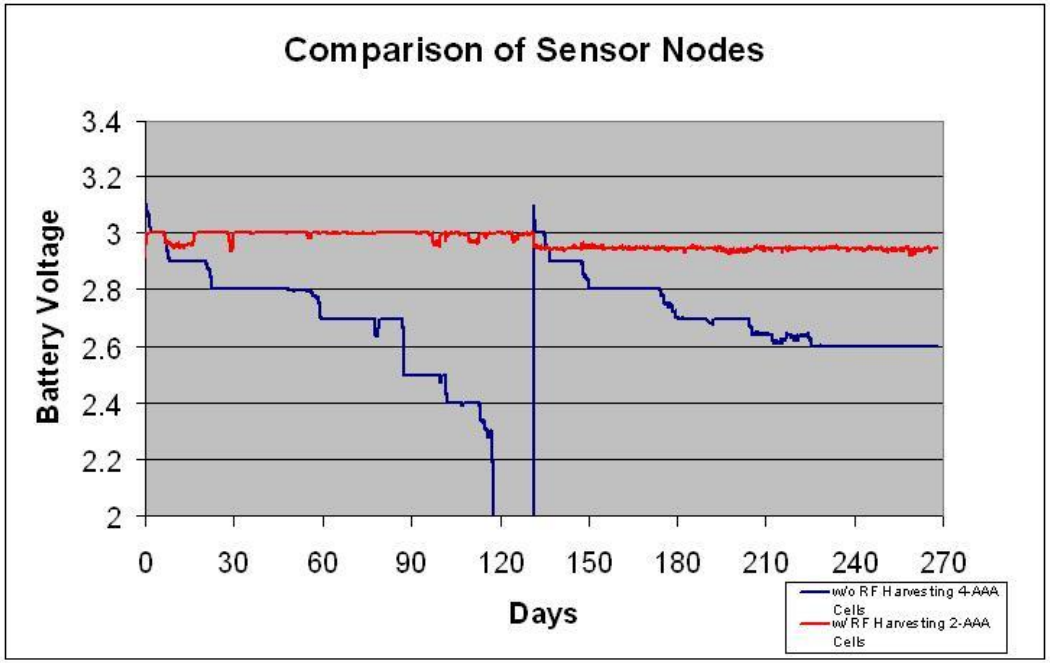
Pittsburgh Zoo Penguin Exhibit:
Sensitive environment, high value assets, very limited access

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



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

- **Passive Temperature**

- **Passive Acceleration**

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

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**
  - http://www.powercastco.com/documentation/
- **Wireless power calculator (Excel)**
  - http://www.powercastco.com/power-calculator/
- **Videos and Presentations**
  - http://www.youtube.com/powercastco
  - http://www.slideshare.net/powercast

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Thank You

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