Sensors Expo 2011

RF Energy Harvesting: Theory to Deployment

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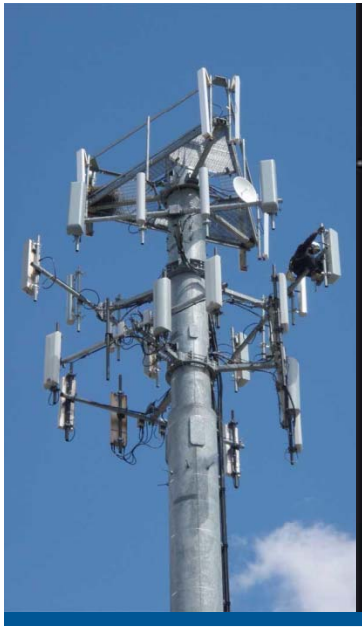
Powercast Corporation

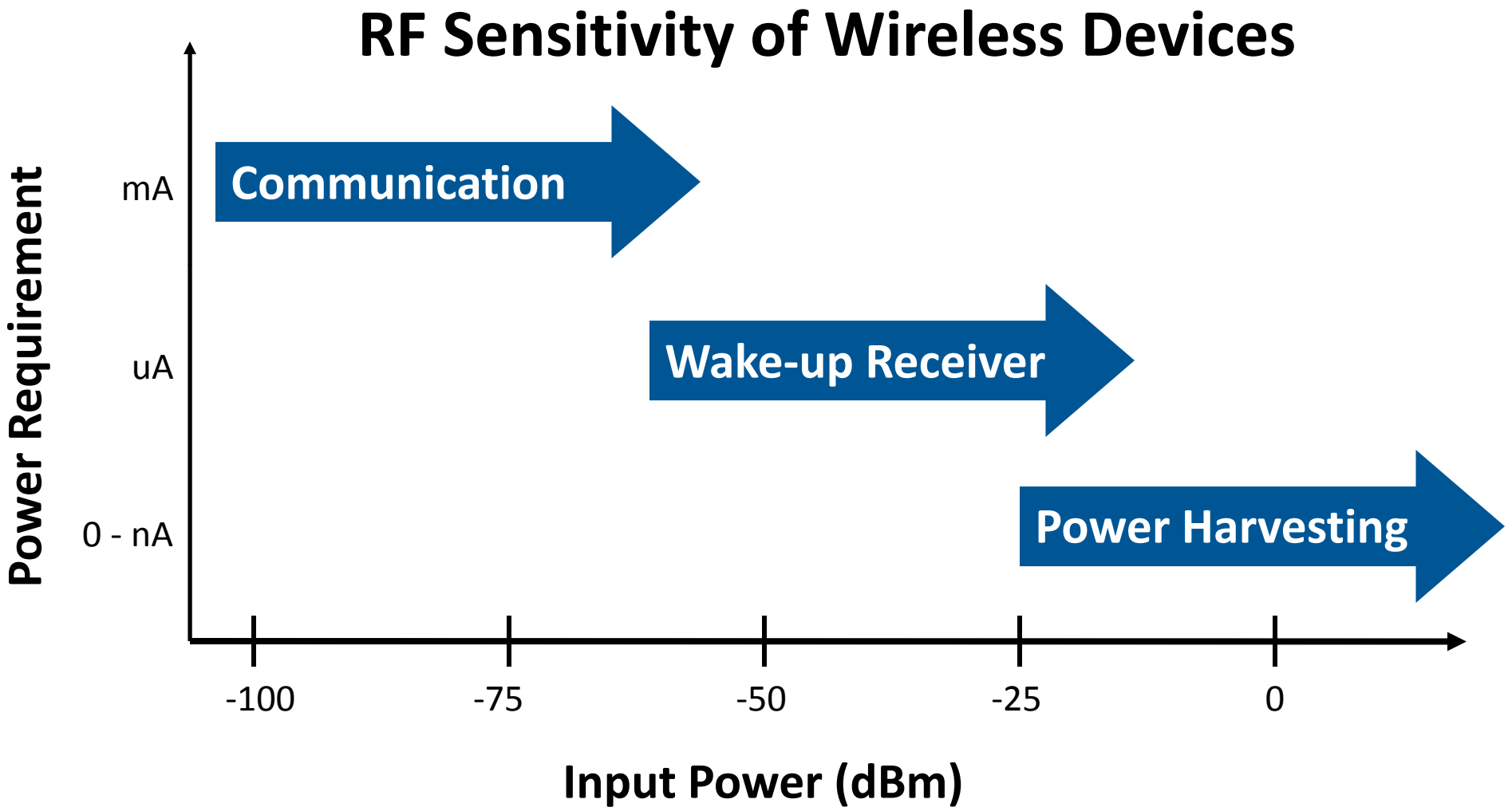
RF Energy is Everywhere




Billions of transmitters globally



Perspective: Communication vs. Power



RF Power Sources

Intentional

Anticipated

Unknown

Ambient

Theory: Calculating Power Transfer

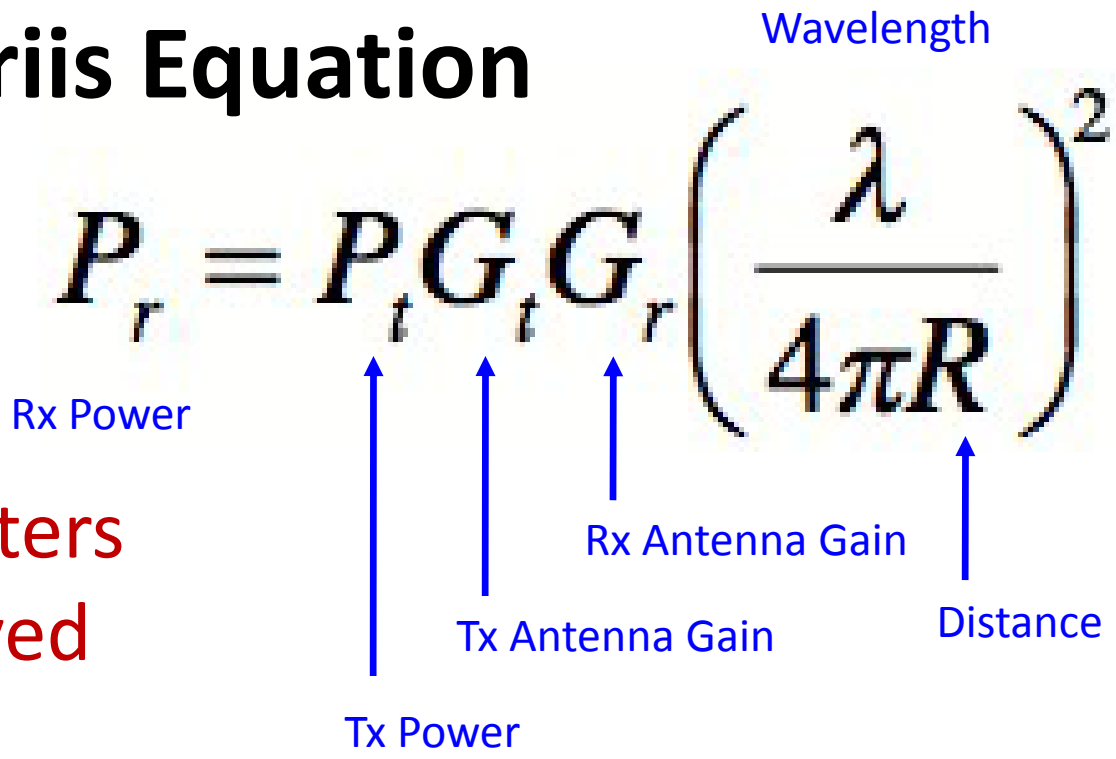
Power Determined by Friis Equation

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

P_R – received power
P_T – transmit power
$G_R(\theta_R,\phi_R)$ – angular dependent receiver gain
$G_T(\theta_T,\phi_T)$ – angular dependent transmitter gain
Γ_T – transmitter reflection coefficent
Γ_R – receiver reflection coefficent
$\hat{\mathbf{p}}_T$ – transmitter polarization vector
$\hat{\mathbf{p}}_R$ – receiver polarization vector
r – distance between the transmitter and receiver
λ – wavelength

Theory: Calculating Power Transfer

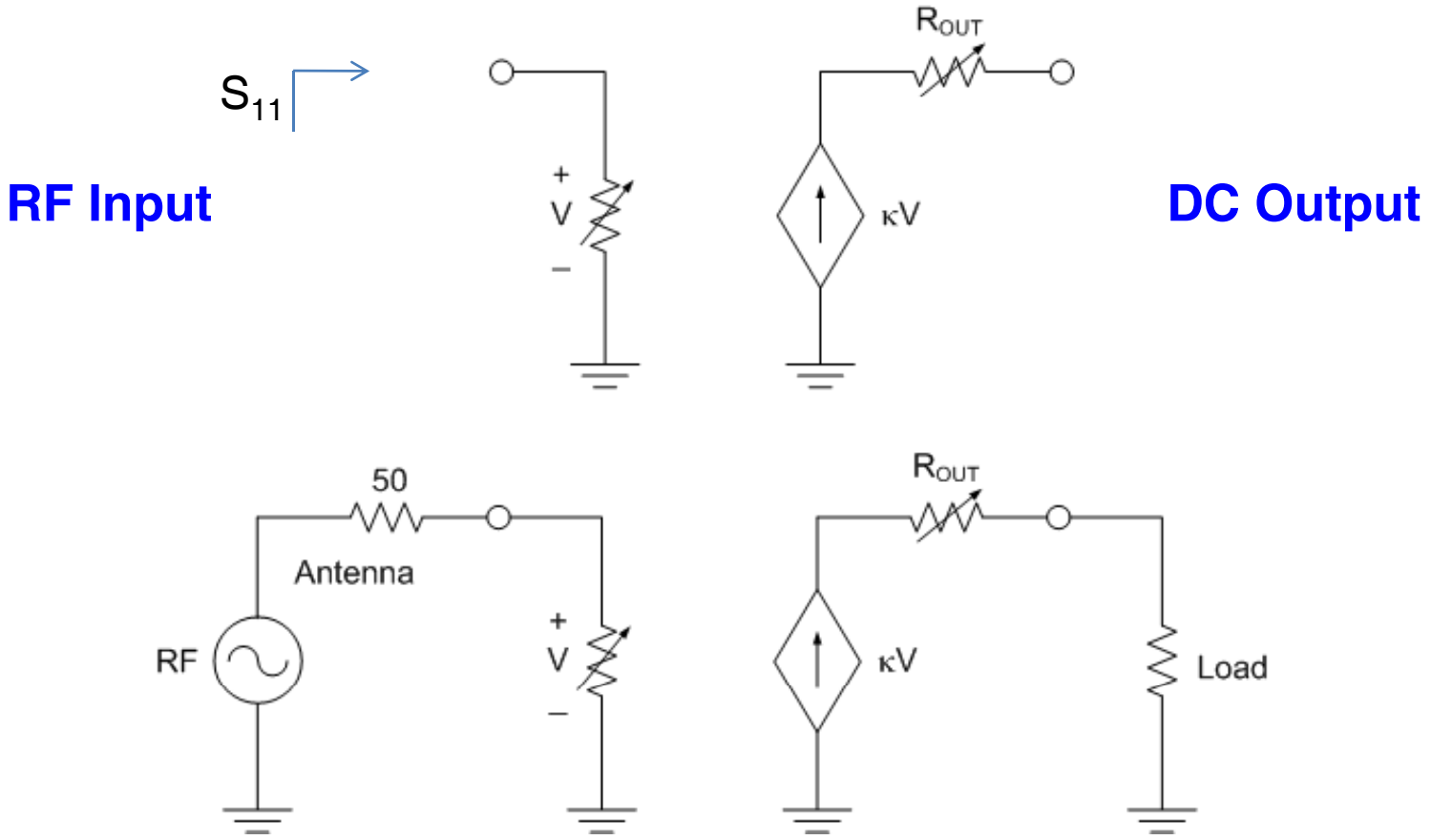
Simplified Friis Equation



Multiple parameters determine received power

Wireless Power Calculator
http://www.powercastco.com/wireless-power-calculator.xls

Theory: Simplistic Circuit Model



Key RF Harvesting Characteristics

- Peak Efficiency
- Efficiency Range
- Frequency Range
- Sensitivity
- Output Voltage

Application scalability increased by having wide performance range for all parameters.

What makes a harvester efficient?

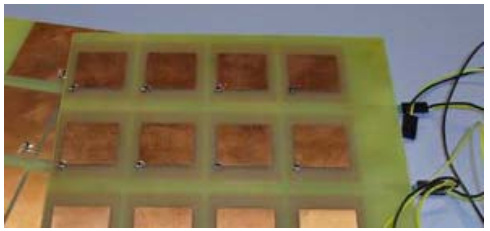
- Proper RF Matching
  - Harvester is non-linear
- Proper loading (DC matching)
  - Generally requires a specific discrete or emulated resistance
- Correct frequency

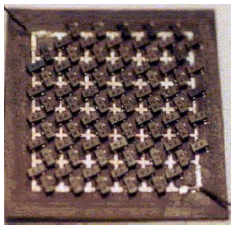
Efficiency declines rapidly when conditions not met.

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 for each application…does not scale across applications





Standard Impedance

- Matched to 50Ω, Negligible matching loss
- No special RF equipment required
- Works with standard antenna designs

Loading (DC Matching) Techniques

Maximum Power Point Tracking (MPPT)

- Used with other harvesting technologies
- Requires monitoring of the DC operating point
- Requires a voltage converter
- Uses power (active)

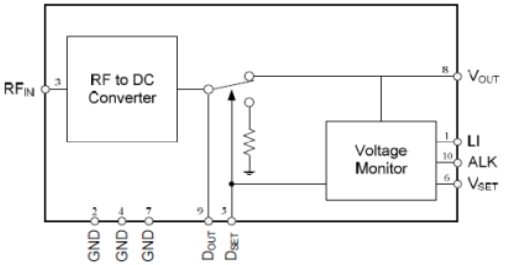
Automatic Load Matching

- Automatically adjusts to AC and DC operating point
  (Powercast technology accomplishes this in the RF domain)
- No voltage converter required for harvesting
- Uses no power (passive)

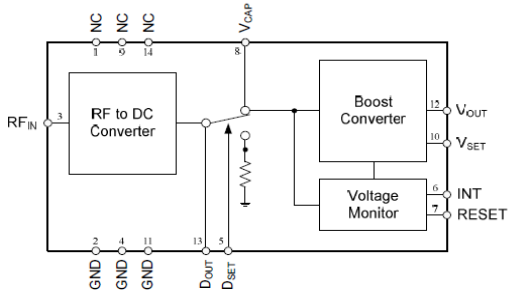
Powerharvester® Receivers

- Convert RF input to DC current
- Provide power management
- Frequency range: 850-950MHz
- RSSI and Data output
- Designed for standard 50Ω antennas

P1110



P2110



P1110

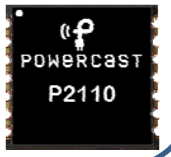
Continuous Power Output

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

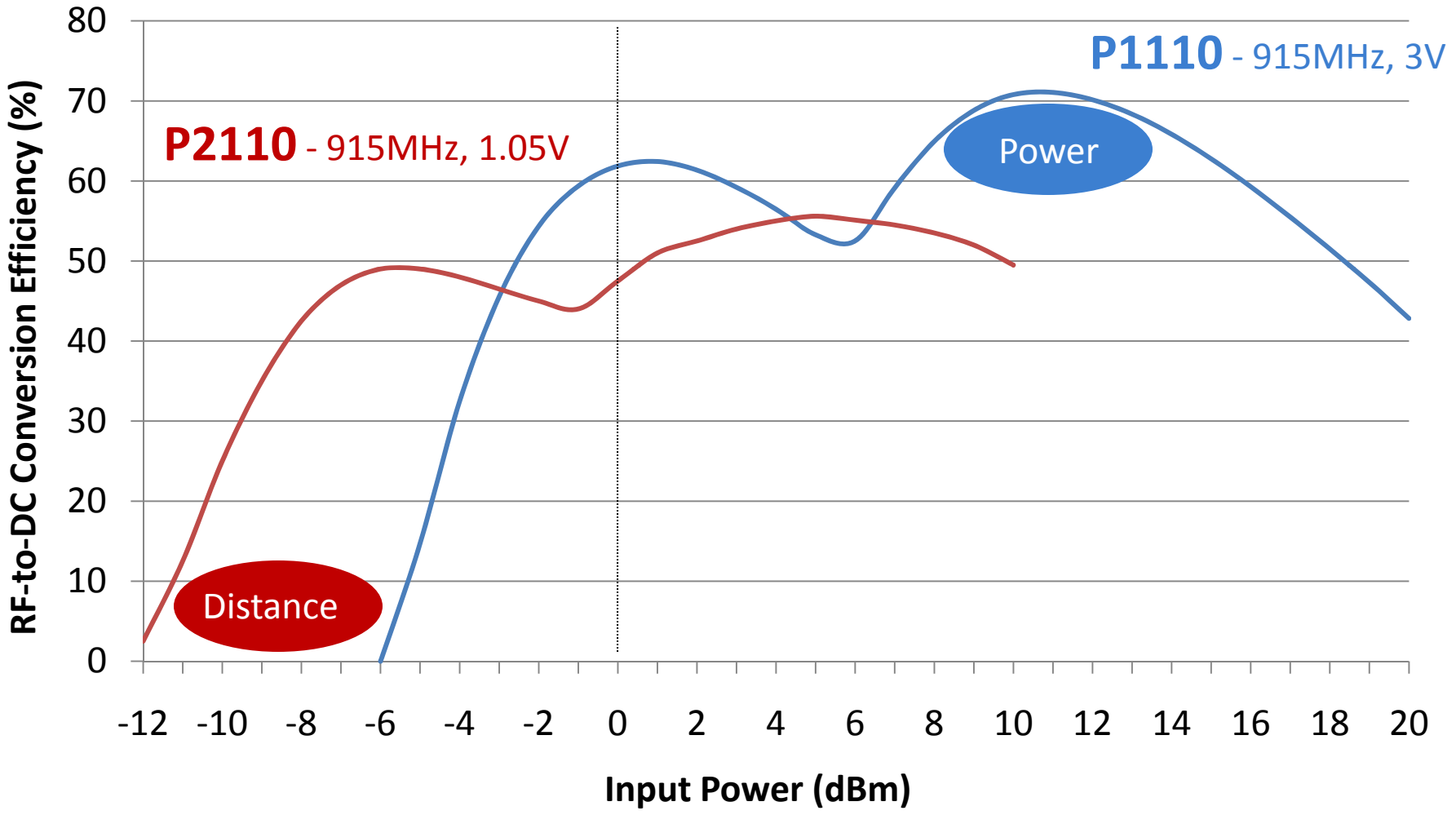
P2110

Pulsed Power Output

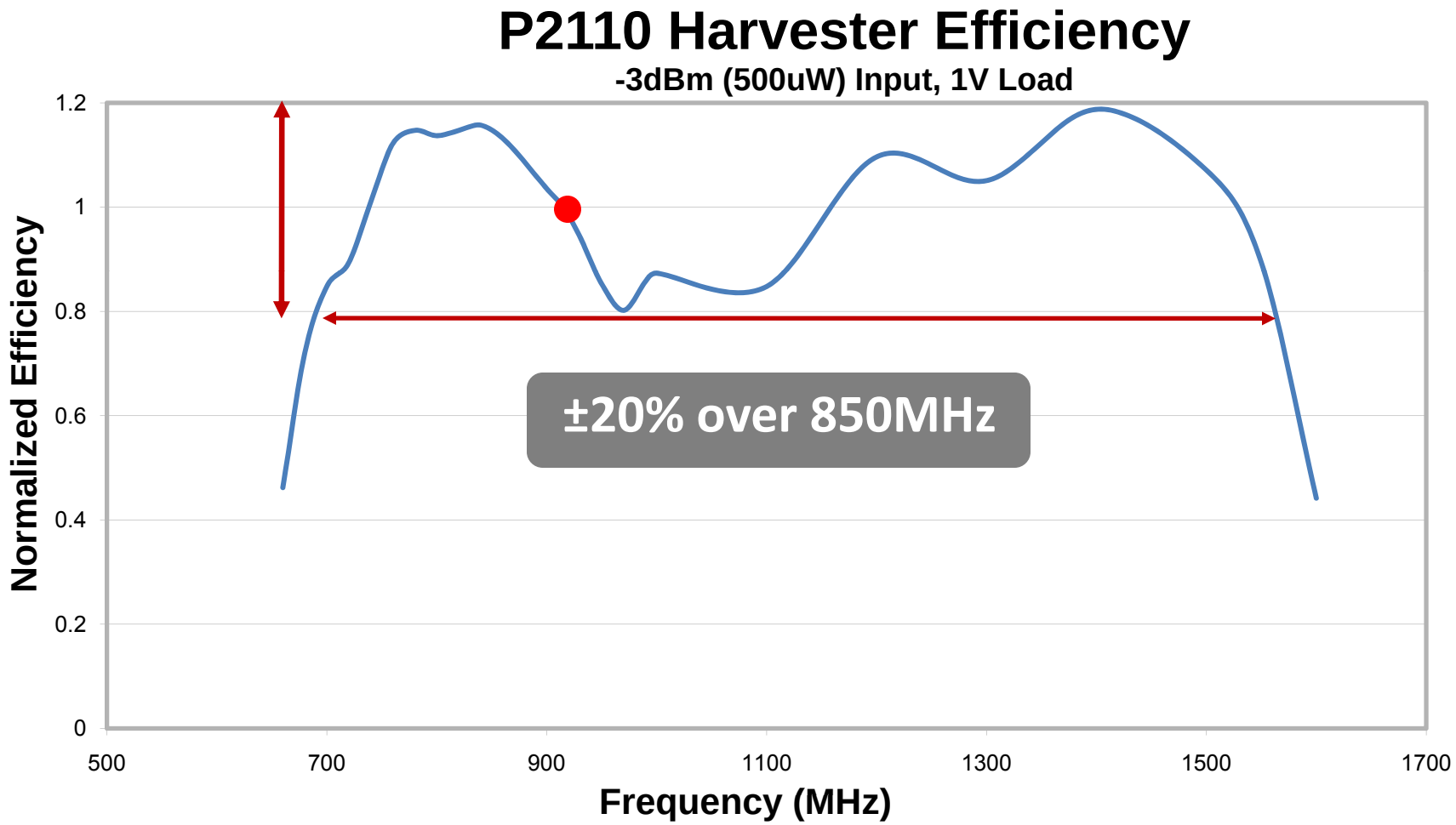
- RF range: -11.5dBm to 15dBm
- Output voltage: 1.8V to 5.25V (configurable and regulated)
- Range of at least 10 meters



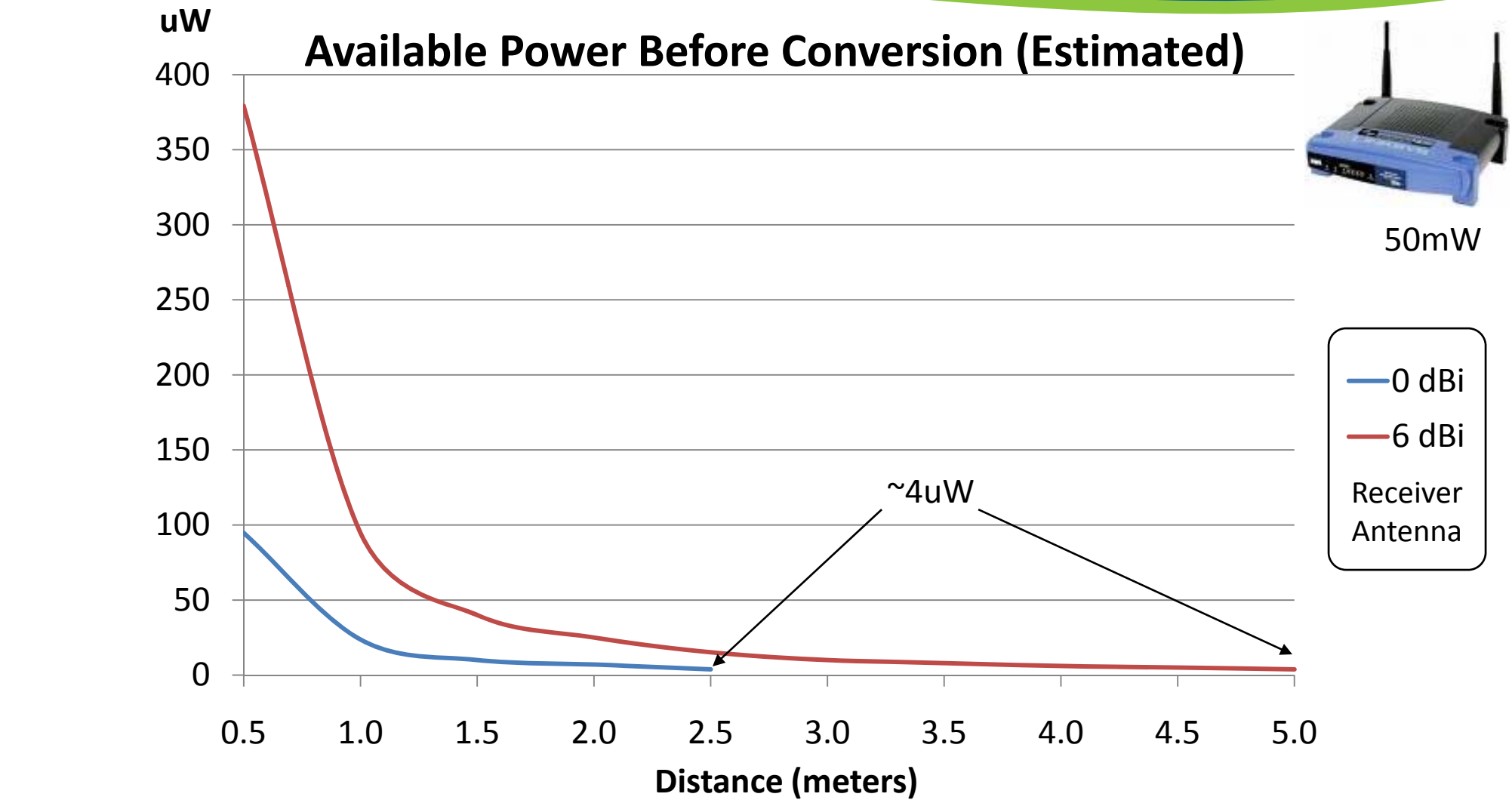
Powerharvester® Efficiency Maintained Over Wide Range of Input Power



Bandwidth Increases with Received Power

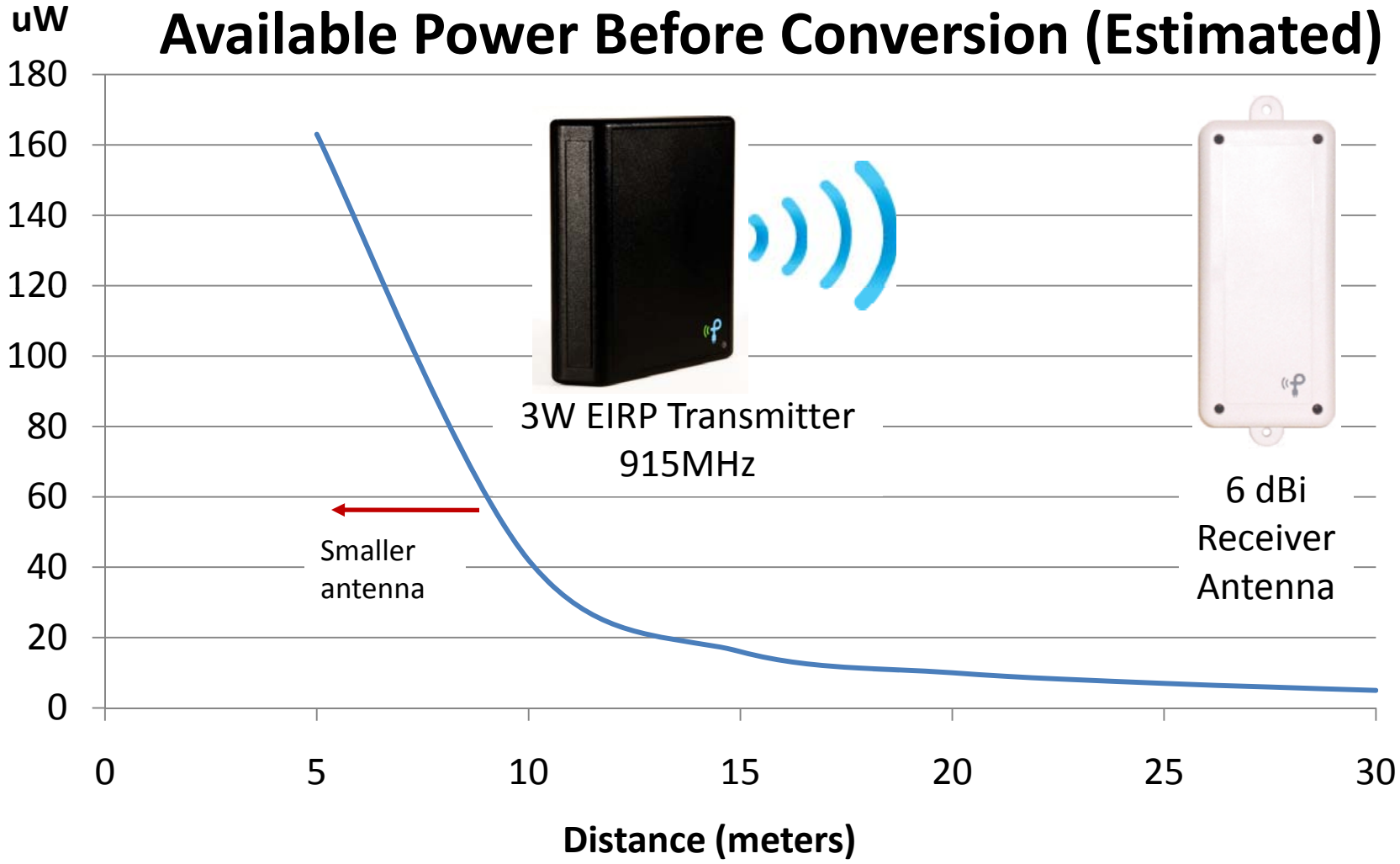


Ambient Wi-Fi Power



50mW

Intentional Transmitter Power



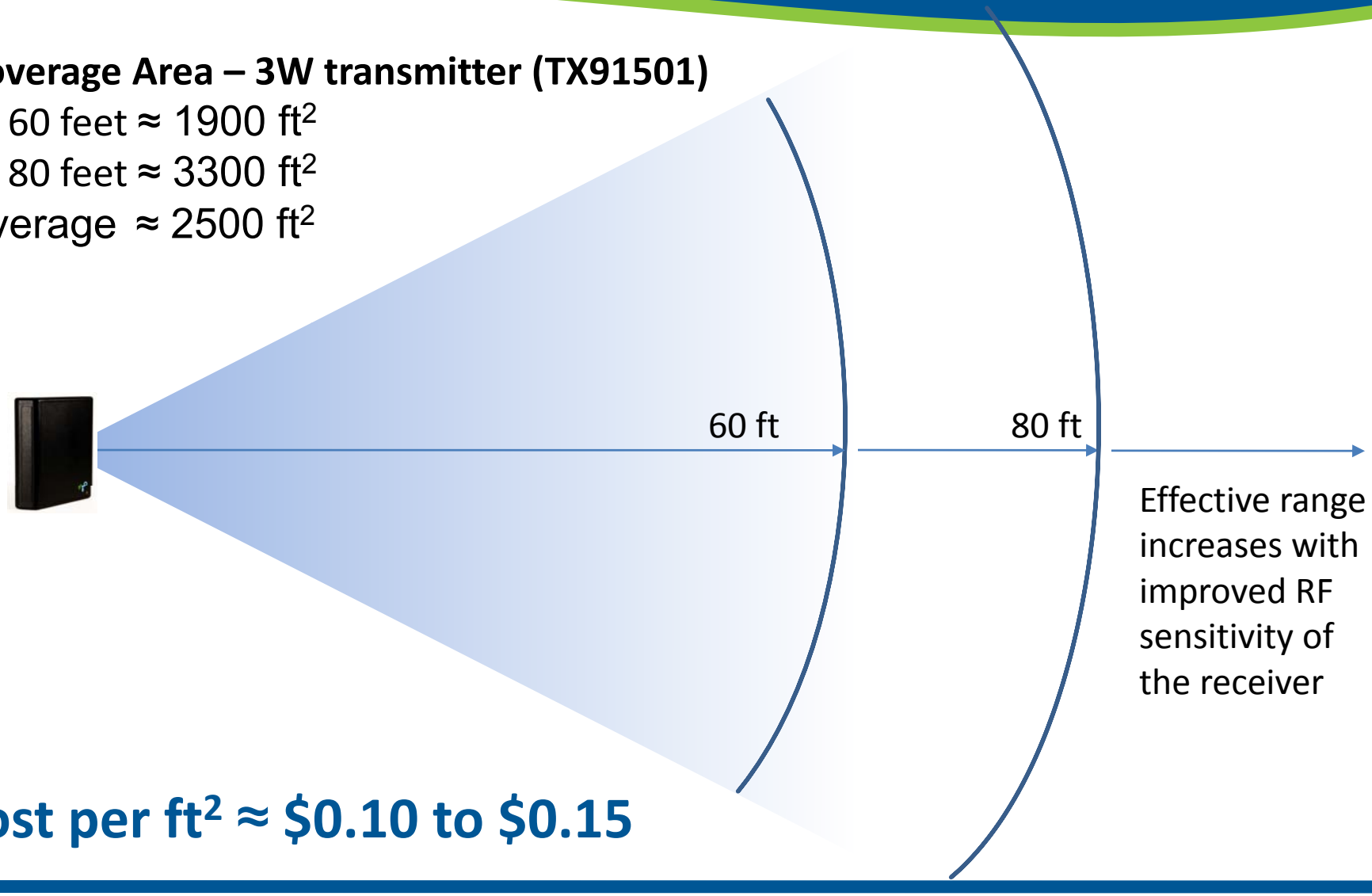
Intentional Transmitter Coverage

Coverage Area – 3W transmitter (TX91501)

@ 60 feet ≈ 1900 ft^2

@ 80 feet ≈ 3300 ft^2

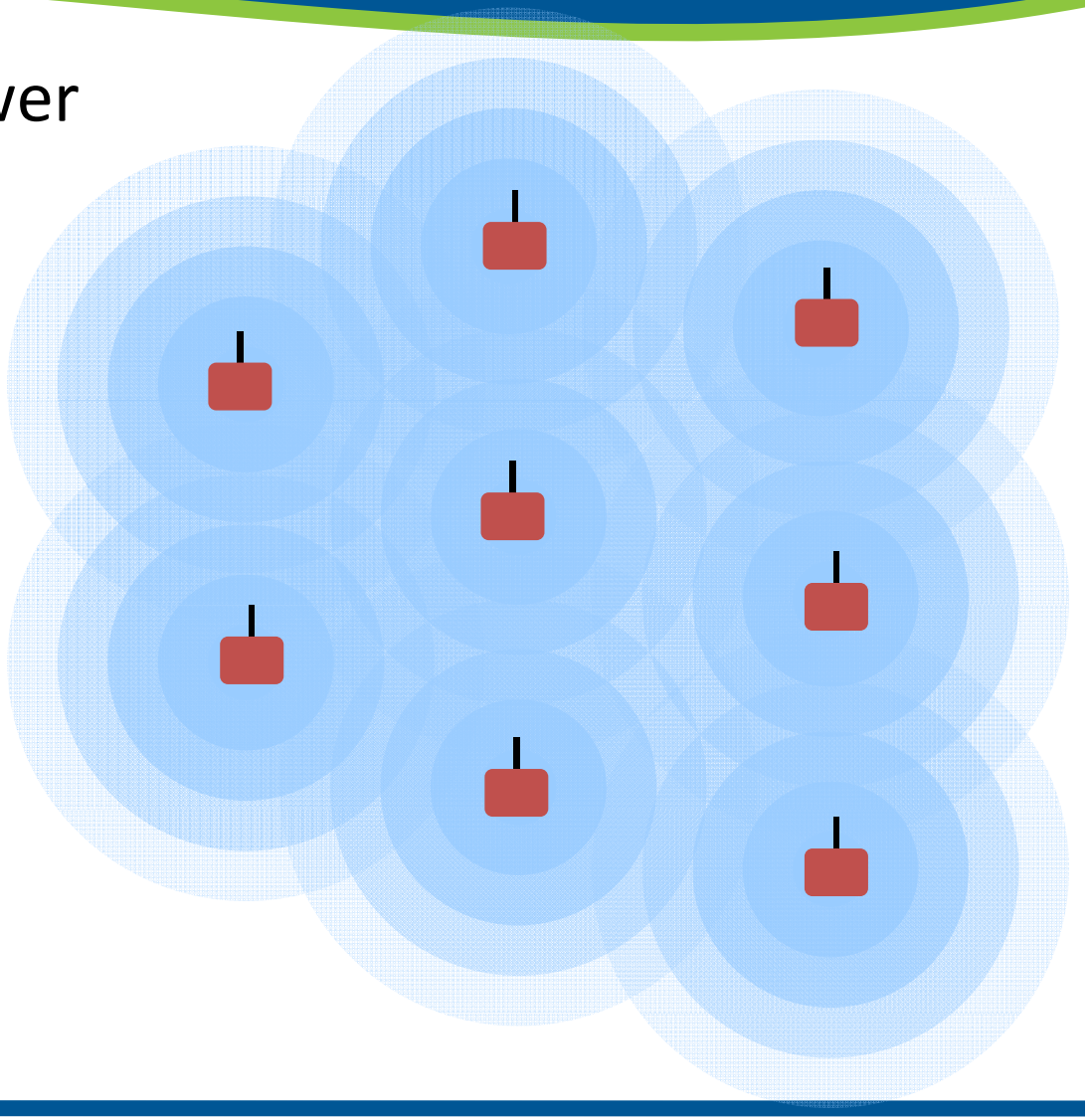
Average ≈ 2500 ft^2



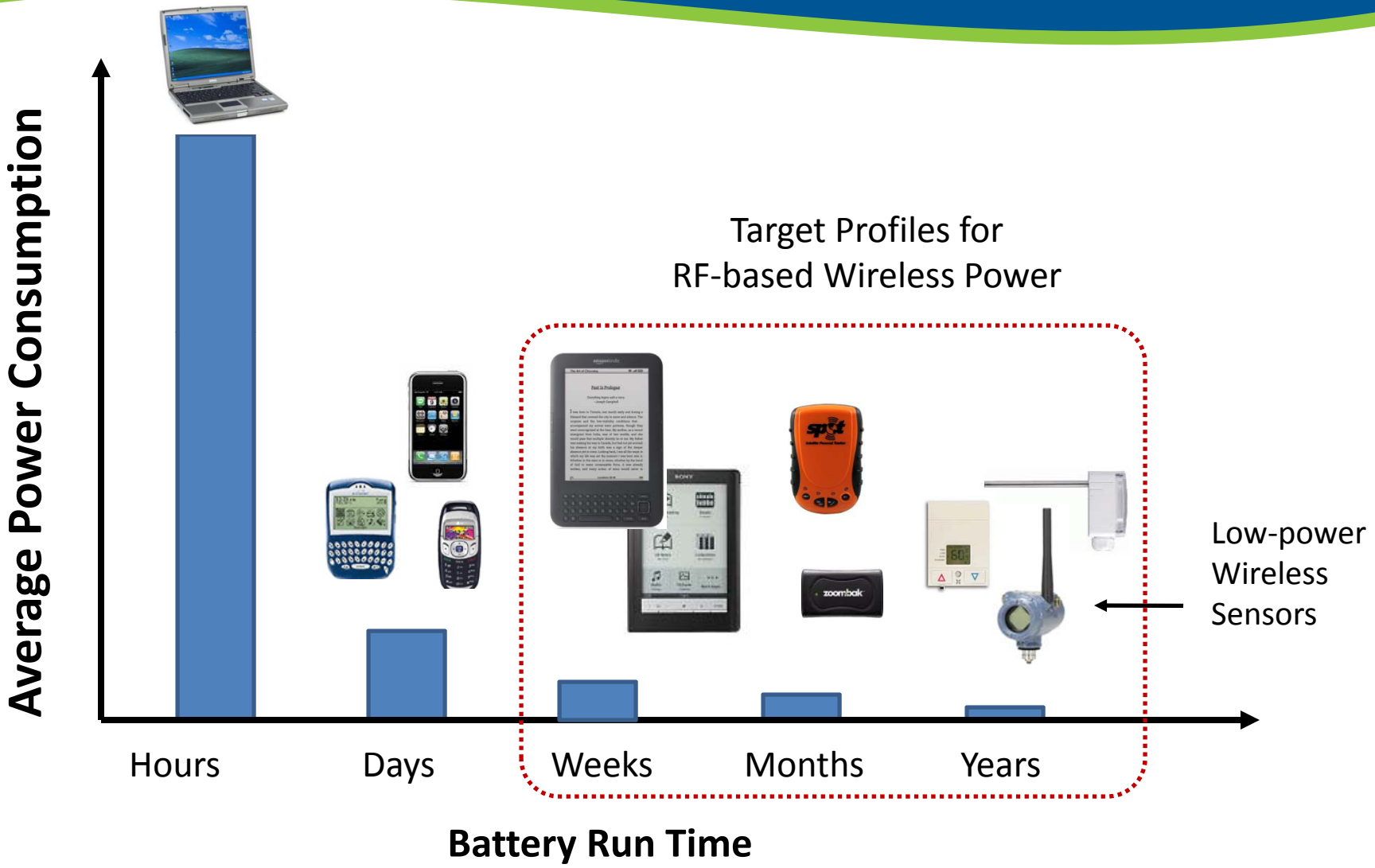
Cost per ft^2 ≈ $0.10 to $0.15

Wireless Power Distribution is Similar to Cellular Model

- Distributed / Lower Power
- Any to Any Coverage
- Inherent Redundancy
- Enables Mobility



Practical Devices for RF Charging



RF-Powered Wireless Sensor System

Powercaster® Transmitter

One-to-Many
Power Source

915 MHz

TX91501

RF-Powered Wireless Sensors

2.4 GHz

Temperature
Humidity
(WSN-1001)

Light

Diff. Pressure

Battery-less Sensors

Building Automation System Gateway

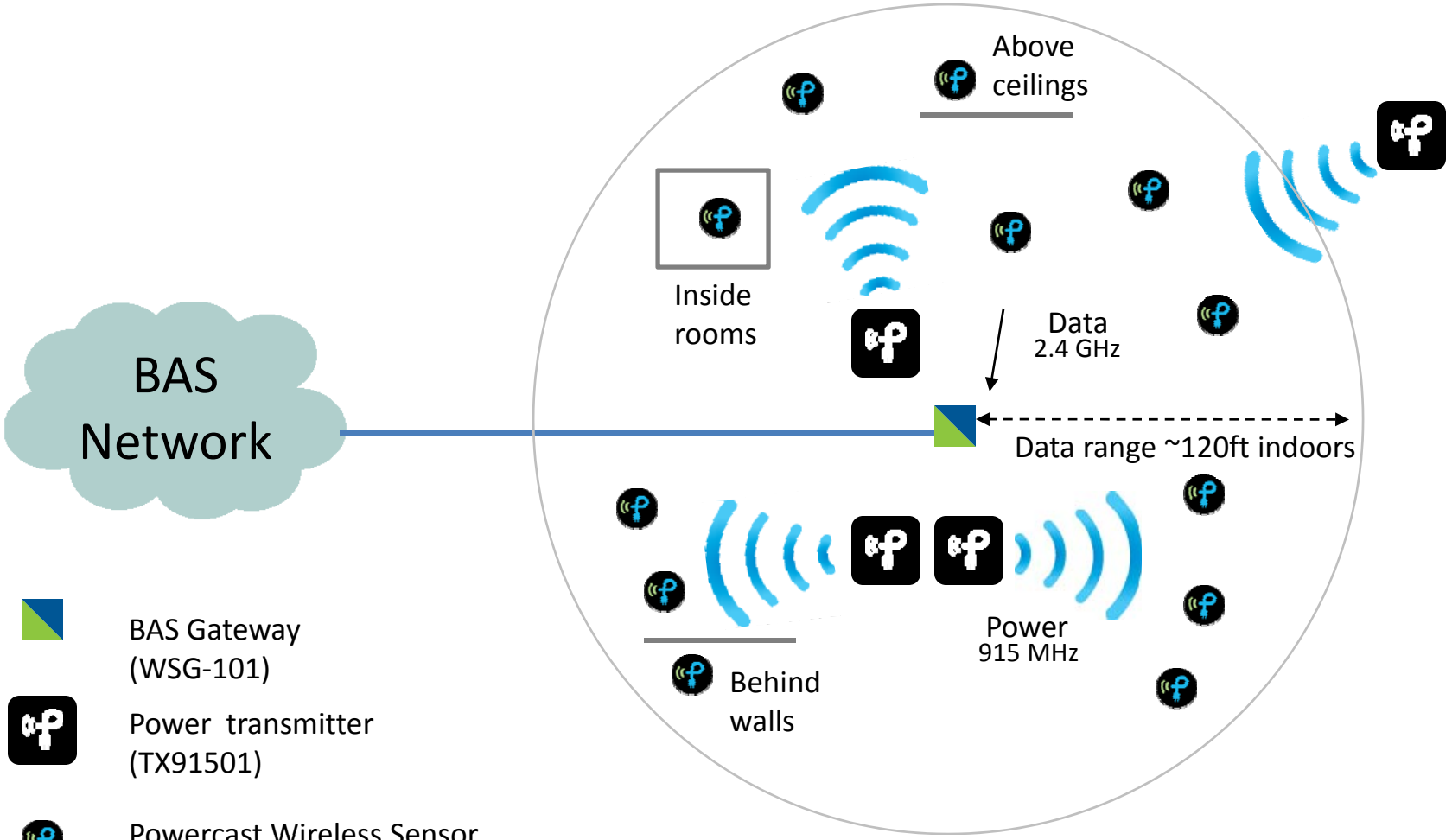
BAS

Ethernet or Serial

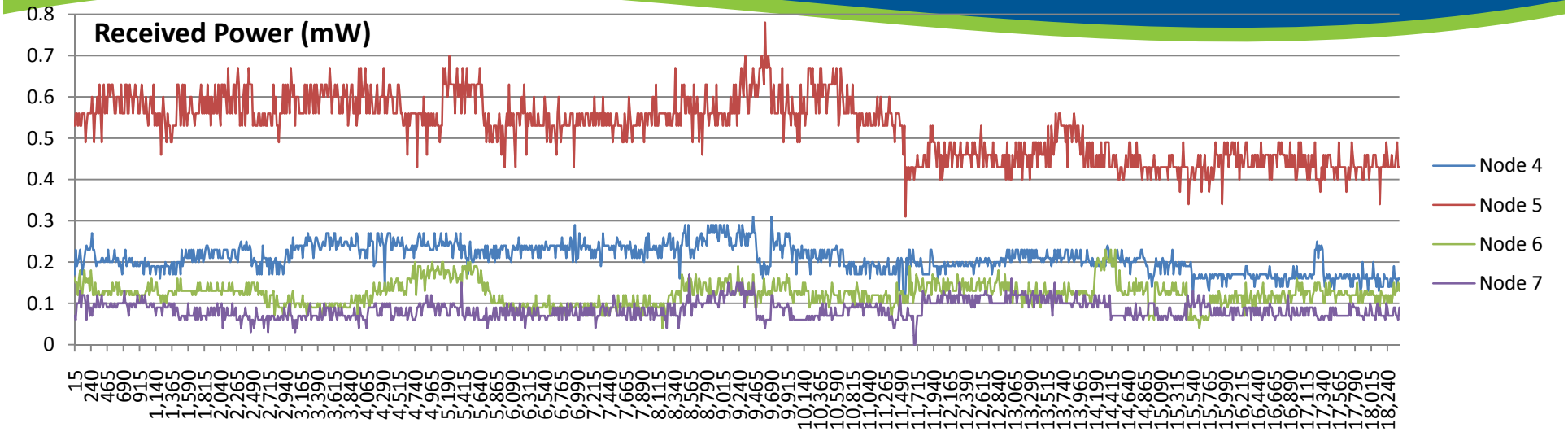
WSG-101

Wireless Access Point
(for up to 100 devices)

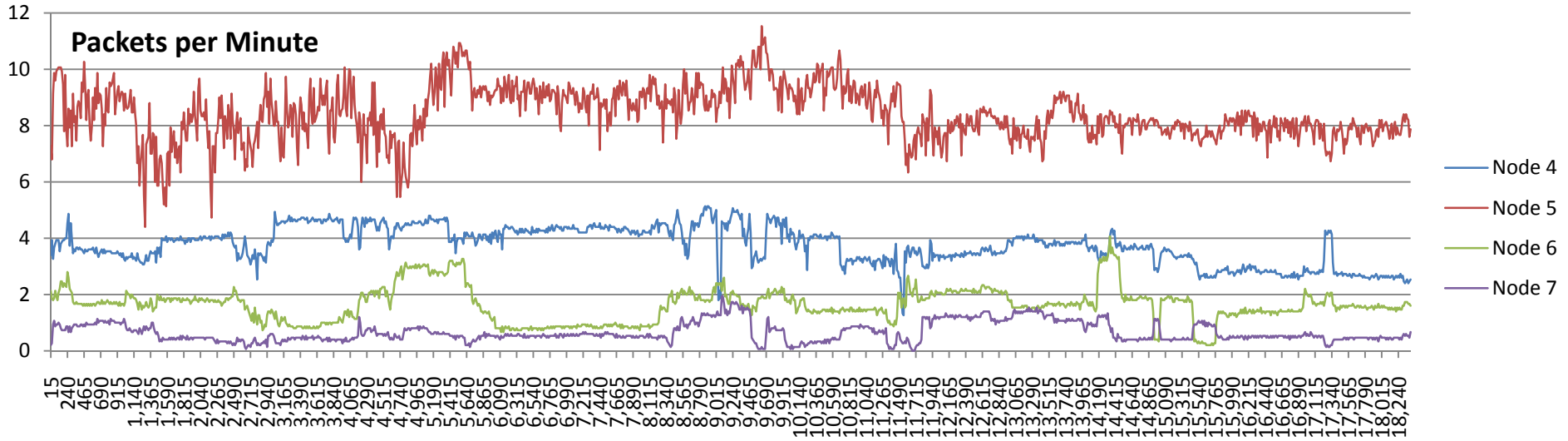
System Deployment Example



Deployment: Data Center Trial



Data samples: 15 minute intervals over 13 days



Future: Smartphone "Power App"

Battery-less
PAN device

IR

RF (ISM band)

Power Solution:
- Universal
- Mobile
- On-demand

Smartphone

Phone-based Remote Control

Phone-based Wireless Power

Demo at http://www.youtube.com/powercastco

Summary

- RF energy harvesting / wireless power is a practical and deployable solution.
- Most of today's applications require dedicated power transmitters
- Power network increases range and improves performance
- RF harvesting technology is tracking with ability to store the energy

Questions

Thank You!

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Emerging Technology

P2100 Powerharvester®

TX91501 Powercaster®

P2110 Powerharvester®

P2110 Powerharvester®