

*Pushing frontiers with the first lady of emerging technologies*

# How is Wireless Power Transmission Going to Affect Our Lives?

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## Abstract

Development of the mobile technologies brought in a wave of mobile devices and made wireless communications a way of life. But these mobile devices still were tethered to the power sources for their energy needs. The emerging Wireless Power Transmission (WPT) is changing all that, and setting mobile devices free from electrical cords. WPT has enabled the transmission of electrical energy from a power source to an electrical load without interconnecting wires. This emerging technologies update discusses various WPT technologies including electromagnetic induction and electromagnetic radiation. This ability to deliver power wirelessly to a remote device has given rise to a variety of ways in which our lives are impacted in a major way. Some technology solutions enabled by WPT are perpetual wireless powering of Wireless Sensor Networks, corrosion monitoring in concrete structures, capsule robots, and endoscopic micro-balls.

## Keywords

*Biomedical implants, Capsule robots, Electromagnetic induction, Electromagnetic radiation, Electronic paper display, MIMO broadcast, Neural bridge, Solar power, Wireless power transmission, Wireless sensor network.*

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## 1. Why Do We Need Wireless Power Transfer?

There are so many places where a power source is needed for many appliances to work, but batteries cannot be there. Examples of such situations include remote underwater locations for temperature and tide sensors, concrete reinforcements for corrosion detectors, or even inside our own body for diagnostic endoscopes, etc.

In such instances, ability to deliver power wirelessly where it is needed becomes an enabler to a much larger impact from countless electrical devices.

Wireless Power Transmission (WPT) is the transmission of electrical energy from a power source to an electrical load without a conductive physical connection or interconnecting wires.

Transmission of power wirelessly is very different from data communication wirelessly.

Radio waves are used to send and receive cell phone, TV, radio, and WiFi data. The radio waves spread in all

directions until they reach the antenna that is tuned to the right frequency. Spreading power in a similar way would be not only inefficient but also dangerous.

Therefore, WPT is done utilizing technologies like inductive coupling. WPT is increasingly being used to make everyday products like cell phones, laptop computers, mobile robots, and electric vehicles, capable of re-charging themselves without ever being plugged in.

WPT enables flat screen TVs hang on the wall without any wires to power source. Medical devices and implants no longer need wires or batteries. Pacemakers do not have to be surgically replenished with batteries every few years.

WT technologies continue to evolve, so they can be safely and efficiently over larger and larger distances and deliver large amount of power.

## 2. What Can We Do with WPT?

Wireless energy transmission applications by WPT technologies will enable a new tetherless truly mobile

connected world:

- Eliminate cords for everything from lamps and laptops to kitchen appliances
- Eliminate the need for surgery to replace batteries for pacemakers inside human bodies
- Eliminate chargers for mobile cell phone and cameras chargers
- Eliminate extra installations needed for new power outlets when installing electrical devices
- Eliminate restrictions of distance and need to place electrical product within a limited cord range to the wall outlet
- Eliminate dangers of tripping posed by dangling power cord
- Electrically powered devices will no longer need recharging
- Highways would continuously recharge electric cars that drive on them

### 3. How Does WPT Work?

Wireless energy transfer (WPT) is an emerging technology that can wirelessly provide perpetual energy supply to wireless networks and wireless devices. WET is achieved by either the “near-field” electromagnetic (EM) induction technology or the “far-field” EM radiation (such as radio) for short- or long-range applications, respectively. There are many ways to transfer low levels of energy including:

- WPT using EM induction
- WPT using EM induction with resonance
- WPT using EM radiation with radio waves
- WPT using EM radiation with Light Amplification by Stimulated Emission of Radiation (laser)

#### 3.1 How Do We Achieve WPT Using EM Induction?

EM induction is the production of an electric current across a conductor when it moves through a magnetic field. Energy transferred by EM induction is magnetic.

EM induction can be used as a means of power transmission wirelessly in WPT.

Faraday’s law states that a changing current in one coil creates an electromotive force (emf), which induces a current in another coil.

This principle of induction is used in electric generators (mechanical to electrical energy conversion) or a motor (electrical to mechanical energy conversion) or transformers (AC to AC conversion).

How can this be used for wireless transmission of power in WPT?

The important point to be noted is that the two coils (source and destination) do not need to be in contact,

but can be a short distance away. Thus, EM induction is used for short distance WPT.

Some examples of WPT using EM induction are recharging mats, pads, or desks that can recharge several devices kept on their surfaces, at once.

#### 3.2 How Do We Enhance EM Induction Based WPT with Resonance?

EM method of WPT is used to charge devices, but can only work for small distances. Hence, WiTricity is used that increases the distance for WPT using EM induction by using resonant coupling between the source and destination coils.

EM induction that is enhanced with resonance is also called WiTricity.

WiTricity is a new technology for transmitting energy wirelessly via resonant coupling in the non-radiative near-field.

How does resonance help?

The sender coils and receiver coils are kept at the same magnetic resonance frequency, and the environment is at non-resonant frequency. Then, the energy losses to the non-resonant environment are small. And most of energy transmitted by source is received by destination.

The source and destination induction coils are similar to antennas.

At short distances, there are no radiation losses.

WiTricity technology allows transferring of electric energy or power over longer distance without wires.

Why does resonance help in the transfer of wireless magnetic energy?

The kind of resonance used in WiTricity is called resonant magnetic coupling.

Magnetic coupling occurs when two objects exchange energy through their varying or oscillating magnetic fields. Resonant coupling occurs when the natural frequencies of the two objects are approximately the same.

WiTricity power transmitter and receiver devices are specially designed magnetic resonators that efficiently transfer power over large distances via the magnetic near-field. The steps are as follows:

- Power source is connected to AC power.
- Magnetic near-field is induced by the power source.
- Energy flows wirelessly from the source to the capture coil.

- This energy in capture coil can power any electrical device.

Wireless energy transferred by EM induction is magnetic, and so is not harmful to humans.

### 3.3 How Do We Achieve WPT Using Radio Wave Transmission?

WPT using radio wave transmission technology converts radio-frequency (RF) signals to DC electrical current. It picks up RF energy from ambient power sources since RF energy is constantly available and coming from WiFi and mobile networks around us. This is called RF-energy harvester.

WPT using radio waves utilizes Rectenna. A Rectenna is a combination of a rectifier (to convert AC to DC power) and an antenna (to receive the EM power), and the rectifying circuit converts it to DC electric power. The amount of power received depends on the size of Rectenna. For portable devices, the size of Rectenna is small, hence WPT using radio waves has a limitation of small amount of power being delivered.

WPT using radio wave transmission is effective for various uses, such as powering of remote sensors. RF sensors are so small that they need to be battery-less. So, by being powered by WPT using RF transmitter, these sensors have controllable, continuous power source.

So, an RF-energy harvester does RF-to-DC conversion for WPT. Thus, it is used for low-power devices such as wireless sensors.

The challenge is that using radio waves dissipates energy in all directions.

### 3.4 How Do We Achieve WPT Using Lasers?

Sunlight is available only during daytime and solar cells have limited efficiency. Hence, there is a need to generate artificial light sources.

A good way to achieve this is through WPT using laser light source, transmitting the laser beam through air, and then using photovoltaic cell receiver convert it into electricity. This electricity can be used to power anything that needs electrical energy.

Using WPT with laser has advantages of ability to transfer over large distances. The limitation is that laser beam needs to be within the line of sight of the photovoltaic cells. Also, lasers are too powerful to be safe.

This method of WPT using laser is called “power beaming” technology. It is being used in military weapons, aerospace applications, and consumer electronics.

### 3.5 What are the Differences between Different WPT Methods?

To summarize, EM induction is a near-field method because distances between transmitter and receiver are smaller as magnetic coupling happens in close proximity.

EM induction with resonance helps bring that to near-field by reducing energy losses to non-resonant environment. Thus, WiTricity, which is EM induction with resonance, has mid-range WPT method.

EM radiation is a far-field WPT method with longer ranges using radio waves and optical devices. The reason being the EM radiation in the far-field can be made to match the shape of the receiving area using high directivity antennas or well-collimated laser beam. This maximum directivity for antennas helps capture the most energy transmitted.

## 4. What Does the Magical World Enabled by WPT Look Like?

WPT enables powering of wireless lamps and any other electrical wireless devices that are coupled to them through AC electric current.

It now enables an environment with a powerful, rapidly alternating electrostatic field. Inside this environment, the electrical device can be moved and put anywhere, and it is powered, no matter where it is put inside that environment and without being electrically connected to anything.

### 4.1 WPT Enables Wireless Sensor Networks for Remote Environment Monitoring

Wireless Sensor Network (WSN) can be used to monitor remote environments.

WSNs can take spatial and temporal measurements of a given set of real-world parameters in remote locations. The sensor nodes monitor the environment and route their sensing data back to the monitoring entity.

WSNs are self-organized wireless *ad hoc* network comprising large number of resource-constrained devices called sensors.

Sensors battery drainage is the main constraint in getting maximum value out of WSN. Traditional WSNs have wireless sensor nodes that have limited battery life, which is a performance bottleneck.

Breakthroughs in WPT can remove such performance bottlenecks by allowing a sensor network remain operational forever.

WPT mobile charging vehicles can now travel inside the

sensor network and charge each sensor node's battery wirelessly. This will provide perpetual endless supply to WSN.

#### 4.2 WPT Enables Remote Corrosion Monitoring of the Concrete Structures

Corrosion process of the steel bar in reinforcing concrete structures causes damages to buildings and endangers life. This corrosion is a series of electrochemical reactions in which energy is released. Thus, monitoring the energy produced during these reactions allows identification of the corrosion status from remote with the following steps:

- Energy is released in the corrosion process
- This energy becomes the power source for the WPT
- The remote destination sensor is activated as a result of this corrosion energy.

Thus, using WPT, there is an automatic alert on the remote hidden damages to the concrete, to the monitors.

#### 4.3 WPT Enables Medical Devices to Navigate in Human Organs

A capsular endoscope is a medical device used for inspection of the large intestine. The endoscope requires a powered motor for backward movement against the automatic direction of movement in the intestine.

The capsular endoscope can be wirelessly powered using WPT as follows:

- The magnetic field can be generated remotely by a wound inductance coil
- Current is passed to the coil through a resonating capacitor remotely.

Thus, using WPT, the EM inductance delivers power wirelessly to the remote medical device inside the body.

#### 4.4 WPT Enables Transcutaneous Wireless Power to Biomedical Implants

Transcutaneous WPT to biomedical implantable devices is needed with high efficiency. Traditional inductive coupling is not efficient enough due to unfavorable coupling conditions in biomedical applications.

- Resonant coupling WPT improvements provide the much needed efficiency for energy transfer method for biomedical implants
- There are two planar resonators: A primary resonator that is connected to a power source and operates outside the body and a secondary resonator that is connected to the implanted device and operates inside the body
- WPT is obtained by magnetic coupling between the two resonators when they are operating at small distances.

Thus, WPT enables transcutaneous wireless power to biomedical implants.

#### 4.5 WPT Enables Electronic Paper Display

The breakthrough of electronic paper display (EPD) using Quick-response Liquid Powder Display (QR-LPD™) technology is happening due to WPT. Flexible EPD, when combined with wireless energy through WPT, and wireless data transfer allows building of extremely thin, light-weight, and flexible smart card that has dot matrix EPD.

#### 4.6 WPT Enables Automatic Charging for Electric Vehicle

WPT based on resonance enables the process of automatically charging Electric Vehicle (EV). Magnetic resonance coupling is a new technology in WPT, which can transfer a large amount of energy with high efficiency in middle distance.

WPT for EV wireless charging systems is achieved by having a transmitting induction coil at the charging station and a receiving induction coil in the vehicle.

- Resonance between the two coils enables efficient charging even when EV is at a distance from the charging station
- To make the two coils resonant, the transmit frequency should be able to adapt to that of the receiver.

Thus, frequency-agile, resonance-based wireless charging systems are being developed. They sense the current in the transmitting coil and adapt the frequency such that resonance and maximum efficiency is maintained.

#### 4.7 WPT Enables Uninterrupted Power Supply for Embedded Devices

There is a need for a reliable long-term energy supply to power embedded sensing and control electronics.

Energy Harvesting Wireless Nodes harvest energy from the environment in order to communicate over a wireless link and can do perpetual operation of a wireless network if they can be perpetually powered wirelessly.

Energy harvesters extract energy from the ambient environment to power hardware. However, there may be environmental conditions in which the harvesting from ambience cannot meet all of the demands of the embedded electronics. This shortfall in uninterrupted supply of harvested energy can be supplemented with the WPT supply of energy. This is called the hybrid model. Using hybrid approach, the energy harvesting



receiver can now be more compact, and the energy supply can be uninterrupted.

#### **4.8 WP Enables Powering of Homes with Space Solar Power**

The solution to the problem of powering homes from space energy consists of having satellite which will transmit power via microwave to a base station on earth. It involves:

- Utilizing solar panel-equipped satellite in space and
- The satellite will wirelessly beam a gigawatt-strong stream of power down to earth and power thousands of homes.

Thus, WPT enables space solar power. The space solar power involves huge satellites (PowerSats) in earth's orbit. WPT enables these PowerSats to gather sunlight, convert it to electricity, and transmit it to earth wirelessly.

Most satellites are powered by solar energy today. Also, by using WPT technologies, we can wirelessly transfer that energy to earth.

#### **4.9 WPT Enables Non-contact Transcutaneous Energy for Heart Pump**

Artificial hearts need power supply. Traditional power supply to artificial heart is provided by wire across skin, which causes frequent infection and friction to the patient.

WPT based on EM induction can be used as transcutaneous energy transmission system to transfer power by non-contact coupling.

Wireless energy transmission efficiency of artificial heart implemented in human body depends on factors like switching frequency, transformer air gap size, etc.

#### **4.10 WPT Enables Capsule Robot's Locomotion Inside Body**

The applications of wireless capsule endoscopes are limited without a wireless power supply. WPT solves that problem by creation of a capsule robot that has power supply delivered wirelessly.

Traditional capsule endoscopes have the disadvantages of passive locomotion, which offers very little control of navigation inside body. The limitation is due to the fact that adding electric motors needs more energy and rising of temperature inside body, which is dangerous. Now, WPT enables new kinds of active capsule endoscopes such as "internal force-static friction capsule robot (capsubot)". These wirelessly powered capsubots can

be controlled better not only by professionals but also by patients.

#### **4.11 WPT Enables Radio Frequency Identification Sensors to Track and Monitor Remotely**

Radio frequency identification (RFID) sensors are used to track and monitor many items. Some food companies are now tracking their delivery trucks using RFID tags on perishable items. Trucks need power transmitter that can both recharge and query RFID-based sensors periodically. Also, when the sensors detect a change in their environments, say a temperature change or a theft, the tags need to relay that data back to the transmitter. This requires active RFID tags that need power. That means that the RF energy would either need to be captured and stored or transmitted continuously. WPT solved this problem by wireless powering of sensors through the strongly coupled magnetic resonance WPT technology. The solution is that WPT with two single resonant loops and two self-resonant helical coils is used, in contrast to the two resonant loops traditionally used in RFID systems.

#### **4.12 WPT Enables Omnidirectional Wireless Endoscopic Micro-ball**

The wireless endoscopic micro-ball is a medical device that is placed inside human body for diagnostic purposes. It captures internal images of gastrointestinal (GI) tracts and saves them into flash memories.

The challenge of powering micro-ball with batteries is that after the micro-ball is excreted from human body, the batteries are exhausted. So, we lose the critical diagnostic information. The solution is to use WPT to wirelessly transmit energy from the image reader to the micro-ball in order to get the stored images.

#### **4.13 WPT Enables Wireless Implantable Microelectronic Neural Bridge**

Microelectronic Neural Bridge (MENB) is a medical device that can be implanted inside human body to treat injury to nerves. MENB helps rebuild the lost neural function of an injured nerve under the control of the signal from the body itself.

The challenge in MENB is to provide the energy wirelessly, without the use of batteries within the implant. WPT solved the problem by providing wireless transcutaneous energy for the implantable MENB.

#### **4.14 WPT Enables Automated Roadway Charging for EVs**

WPT enables inductive charging of electronic devices by

transferring electrical power without physical contact through wiring. Application of WPT technologies is a great way to improve operations with electric cars.

Today's problem is that electrical or even hybrid cars deplete their batteries in long country drives. The issue with electric cars is that they have a limited range of travel, i.e. less than 100 miles. So, one needs to stop at a charging station and let the car charge for several hours.

WPT technologies can provide the solution by putting a wireless charging system in the roadways to overcome this battery limitation. The charging equipment is placed underneath the road surface, in sealed water-proof containers that can withstand weight, with WPT equipment. This way, the moving electric and hybrid vehicles can get the wireless recharging from roadways itself.

#### 4.15 WPT Enables Multiple-input Multiple-output Broadcasting to Simultaneous Wireless Information and Power Transfer

WPT with radio signals enables WPT simultaneously

with data transmission. Radio signals can carry energy as well as information at the same time in the form of a Multiple-input Multiple-output (MIMO) wireless broadcast system. The MIMO system consists of one receiver that harvests energy and another receiver that decodes information separately from the signals sent by a common transmitter.

#### 5. Summary

Electrical and electronic devices can now be placed into areas earlier inaccessible since WPT technologies can now bring power wirelessly to these devices anywhere. This is resulting in technology breakthroughs in areas of medicine such as endoscopy, pacemakers, defibrillator, etc.

In many areas, batteries losing charge can be life threatening. Now that fear of losing charge is put to rest by the environment itself providing the ability to recharge using WPT anywhere, anytime.

The emerging technologies enabled by WPT are impacting our lives in major ways, and a breathtaking future is ours to behold!

#### AUTHOR



**Satwant Kaur** is hailed as the "First Lady of Emerging Technologies™" in Silicon Valley, media, and the industry worldwide. Hundreds of radio shows have broadcast her interview, and her live radio show, "First Lady of Emerging Technologies™," earned thousands of live audience. She has been interviewed by CBS, and her interview was broadcast on hundreds of CBS sites.

Intel published her book entitled "Transitioning Embedded Systems to Intelligent Environments." Currently, she is a Master Solutions Architect at HP. She was the CTO of Emerging Technologies group at TIBCO.

As a senior information technology executive, innovator, patent holder, and author, Dr. Satwant Kaur has more than 20 years of proven success in the emerging technology arena.

Dr. Kaur was a key member of Intel's Architecture Group in the role of Platform Architect. Among her many contributions was the successful introduction of a new, highly profitable strategic retail sales channel initiative. Dr. Kaur also developed innovative platform enhancements resulting in new retail technologies. Her creation, Reduced Interoperability Methodology (awarded patent), has since been adopted by Intel and is currently utilized company-wide. As a result of her strong leadership, technical acumen, and operational improvements, Kaur received Intel's Technology Innovation Award and was subsequently featured in Intel Circuit and Intel IAG Magazine.

As the Director of Development with Symantec, Dr. Kaur was instrumental in the company's provisional business transformation. Hired to facilitate these dramatic changes, she worked closely with international implementation

teams, leading them in the transition strategy. Her accomplishments in this crucial endeavor include reducing R & D expenses by \$14 million and leading the \$10 billion integration of Symantec and VERITAS. In addition to the successful joining of these two industry leaders and a dramatic improvement in bringing the company's product to market, she reduced company expenses by \$20 million.

While being the Chief Architect with Computer Associates, Dr. Kaur was charged with turning around the company's until then unprofitable Allstate relationship. Under her leadership, Computer Associates developed a new help desk facility supporting over 150,000 Allstate representatives. Dr. Kaur was ultimately responsible for the management of 10,000 remote servers. The successful management of this critical relationship resulted in Computer Associates' largest contract, \$200 million annually.

In addition to keynote speaking events such as IEEE, "Weekly segment by Dr. Satwant Kaur, the First Lady of Emerging Technologies™" on "Computers 2 Know" media show (Hall of Fame), Dr. Kaur has been featured on the front cover of "Mobile Development and Design," "Image Source," "Fierce Smart Grid," "Government Security News" magazines and is guest on several media shows, and is a published author. She owns several patents for her innovative work in emerging technology. Dr. Kaur has also served on the Board of Panacea Software and as an Expert Consultant for Thomson Reuters.

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