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Witricity: A Novel Concept of Power Transfer

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Abstract:—Can we imagine the life without electrical wires? From now onwards answer to this question is "Yes". The method proposed in the present paper called "Witricity "will facilitate to Transfer power without using wires. The efficient midrange power can be transmitted to any device which uses that range of power by the technique used in this Witricity concept. When two magnetically Resonating objects at "Strongly coupled" regime tend to exchange energy efficiently by the transfer of power in the non-radiating fields. This is the basic principle involved in it. By taking two coils having same magnetic resonance and one is coupled to source and other is coupled to Device. So that the energy transfer is efficient even the air gap between them is high. Now a days there is a Rapid development of autonomous electronics like Laptops, Cell-phones, House-hold robots and all the above devices typically rely on chemical energy storage(Battery) .As they are becoming daily needs to present generation, Wireless energy transfer would be useful for many applications as above as they need midrange energy.

Keywords:—About five key words in alphabetical order, separated by comma

I. INTRODUCTION

Now day's electricity has become a cup of life. A moment without electricity makes your thinking go dry. The major source of conventional form of electricity is through wires. The continuous research and development has brought forward a major breakthrough, which provides electricity without the medium of wires. This wonder baby is called Witricity. There are certain small but very useful discoveries made in history, which changed the world for ever, Newton's gravitational law, Watt's steam engine, Thomson's bulb and many more. But a renaissance occurred with the invention of Electromagnetic Waves by Maxwell. Sir Jagdish Chandra Bose successfully generated electromagnetic waves having wavelength in the range of 5mm to 25 mm. Thereafter an Italian scientist named Marconi succeeded in transmitting electromagnetic waves up to a distance of several miles. And with this there started a new era called WIRELESS TECHNOLOGY. Today, as we can see the word 'wireless' is common in day – to – day life. Wireless communication has made the world smaller. Almost each and everything is wireless or cordless. Cordless mouse, cordless keyboard, satellite communication, mobiles, cordless microphones and headphones, wireless internet service i.e. WIFI, etc. And these have definitely increased the standard of living. In fact it dates back to the 19th century, when Nikola Tesla used conduction based systems instead of resonance magnetic fields to transfer wireless power. As it is in Radioactive mode, most of the Power was wasted and has less efficiency. Further, in 2005, Dave Gerding coined the term **Witricity** which is being used by the MIT researchers and today's world.[1]

1.1 What is WiTricity?

WiTricity is nothing but wireless electricity. Transmission of electrical energy from one object to another without the use of wires is called as WiTricity. WiTricity will ensure that the cell phones, laptops, iPods and other power hungry devices get charged on their own, eliminating the need of plugging them in. WiTricity technology *is* transferring electric energy or power over distance without wires. with the basics of electricity and magnetism, and work our way up to the WiTricity technology. Even better, because of WiTricity some of the devices won't enquire batteries to operate. No, this concept of wireless electricity is not new. In fact it dates back to the 19th century, when Nikola Tesla used conduction-based systems instead of resonance magnetic fields to transfer wireless power. Further, in 2005, Dave Gerding coined the term WiTricity which is being used by the MIT researchers today. Moreover, we all are aware of the use of electromagnetic radiation (radio waves) which is quite well known for wireless transfer of information. In addition, lasers have also been used to transmit energy without wires. However, radio waves are not feasible for power transmissions because the nature of the radiation is such that it spreads across the place, resulting into a large amount of radiations being wasted. And in the case of lasers, apart from requirement of uninterrupted line of sight (obstacles hinders the transmission process), it is also very dangerous.[5]

1.2 Need of Witricity

Now a days there is a Rapid development of autonomous electronics like *Laptops*, *Cell-phones*, *House-hold robots* and all those devices typically relay on chemical energy storage(Battery) As they are becoming daily needs to present generation, Wireless energy transfer would be useful for many applications as above and they need midrange energy.

Fig1: Wireless energy transfer

1.3 WiTricity Technology is Different than Traditional Magnetic Induction

At first glance, WiTricity technology for power transfer appears to be traditional magnetic induction, such as is used in power transformers, where conductive coils transmit power to each other wirelessly, over very short distances. In a transformer, an electric current running in a sending coil induces another current in a receiving coil .The two coils must be very close together, and may even overlap, but the coils do not make direct electrical contact with each other. However, the efficiency of the power exchange in traditional magnetic induction systems drops by orders of magnitude when the distance between the coils becomes larger than their sizes The power exchange efficiency of some induction systems is improved by utilizing resonant circuits. These so-called *resonantly enhanced induction* techniques are used in certain medical implants and high-frequency RFIDs for example. WiTricity founding technical team was the first to discover that by specially designing the magnetic resonators, one could achieve *strong coupling* and highly efficient energy exchange over distances much larger than the size of the resonator coils, distances very large compared to traditional schemes.

Fig2: An electric tooth brush uses traditional magnetic induction to recharge its batteries

II. THE BASIC IDEA OF TRANSFORMING ELECTRICITY TO WITRICITY

2.1 Electricity:

The flow of electrons (current) through a conductor (like a wire), or charges through the atmosphere (like lightning). A convenient way for energy to get from one place to another!

2.2 Magnetism:

A fundamental force of nature, which causes certain types of materials to attract or repel each other. Permanent magnets, like the ones on your refrigerator and the earth's magnetic field, are examples of objects having constant magnetic fields. Oscillating magnetic fields vary with time, and can be generated by alternating current (AC) flowing on a wire. The strength, direction, and extent of magnetic fields are often represented and visualized by drawings of the magnetic field lines.

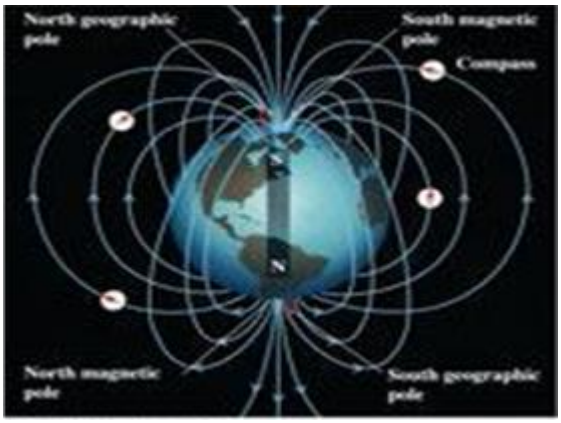


Fig3:An illustration representing the earth's magnetic field

2.3 Electromagnetism:

A term for the interdependence of time-varying electric and magnetic fields. For example, it turns out that an oscillating magnetic field produces an electric field and an oscillating electric field produces a magnetic field.

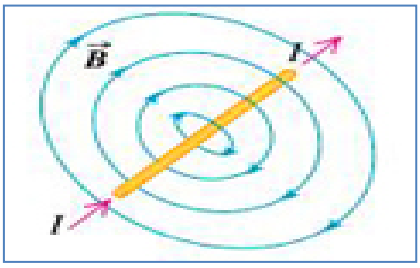


Fig 4: Fundamentals of Magnetic Field

As electric current, I, flows in a wire, it gives rise to a magnetic field, B, which wraps around the wire. When the current reverses direction, the magnetic field also reverses its direction.

2.4 Magnetic Induction:

A loop or coil of conductive material like copper, carrying an alternating current (AC), is a very efficient structure for generating or capturing a magnetic field. If a conductive loop is connected to an AC power source, it will generate an oscillating magnetic field in the vicinity of the loop. A second conducting loop, brought close enough to the first, may "capture" some portion of that oscillating magnetic field, which in turn, generates or induces an electric current in the second coil. The current generated in the second coil may be used to power devices. This type of electrical power transfer from one loop or coil to another is well known and referred to as magnetic induction. Some common examples of devices based on magnetic induction are electric transformers and electric generators.[6]

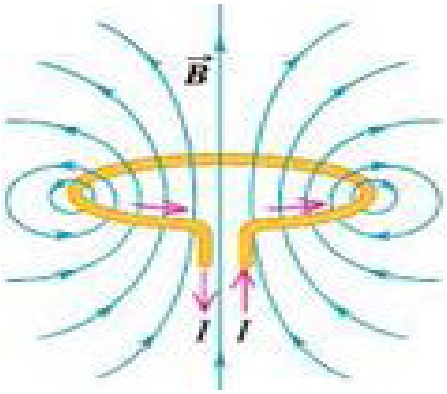


Fig 5: The blue lines represent the magnetic field that is created when current flows through a coil. When the current reverses direction, the magnetic field also

2.5 Energy/Power Coupling:

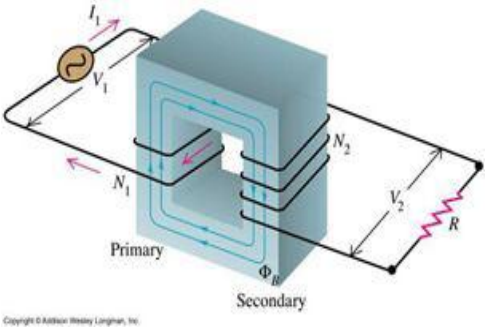


Fig 6: Magnetic Induction

An electric transformer is a device that uses magnetic induction to transfer energy from its primary winding to its secondary winding, without the windings being connected to each other. It is used to "transform" AC current at one voltage to AC current at a different voltage. Energy coupling occurs when an energy source has a means of transferring energy to another object. One simple example is a locomotive pulling a train car— the mechanical coupling between the two enables the locomotive to pull the train, and overcome the forces of friction and inertia that keep the train still—and, the train moves. Magnetic coupling occurs when the magnetic field of one object interacts with a second object and induces an electric current in or on that object. In this way, electric energy can be transferred from a power source to a powered device. In contrast to the example of mechanical coupling given for the train, magnetic coupling does not require any physical contact between the object generating the energy and the object receiving or capturing that energy.[1]

2.6 Witricity Technology

Witricity power sources and capture devices are specially designed magnetic resonators that efficiently transfer power over large distances via the magnetic near-field. These proprietary source and device designs and the electronic systems that control them support efficient energy transfer over distances that are many times the size of the sources/devices themselves.

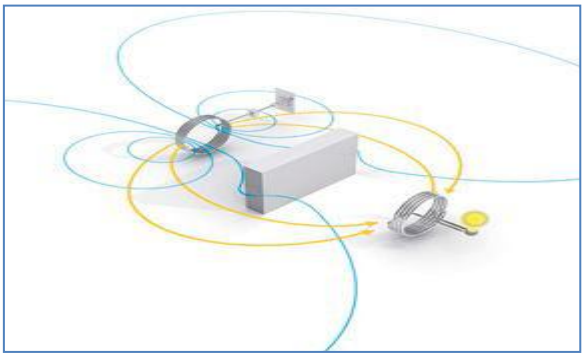


Fig 7: Witricity Power Source

The WiTricity power source, left, is connected to AC power. The blue lines represent the magnetic near field induced by the power source. The yellow lines represent the flow of energy from the source to the Witricity capture coil, which is shown powering a light bulb. Note that this diagram also shows how the magnetic field (blue lines) can wrap around a conductive obstacle between the power source and the capture device.

III. PRINCIPLE & EXPERIMENTAL DESIGN

3.1 Basic principle:

"Witricity" is nothing but the short name of "Wireless Electricity". The basic concept behind this is Magnetic Resonance. Two resonant objects of the same resonant frequency tend to exchange energy efficiently, while dissipating relatively little energy in extraneous off-resonant objects. In systems of coupled resonances, there is often a general "Strongly Coupled" regime of operation. If one can operate in that regime in a given system, the energy transfer is expected to be very efficient. Midrange power transfer implemented in this way can be nearly omni directional and efficient, irrespective of the geometry of the surrounding space, with low interference and losses into environmental objects. The above considerations apply irrespective of the physical nature of the resonances.

Magnetic resonances are particularly suitable for everyday applications because most of the common materials do not interact with Magnetic Fields, so interactions with Environmental objects are suppressed even further. We were able to identify the strongly coupled regime in the system of two coupled magnetic resonances by exploring Non-radiative (near-field) magnetic resonant induction at Megahertz frequencies.[2]

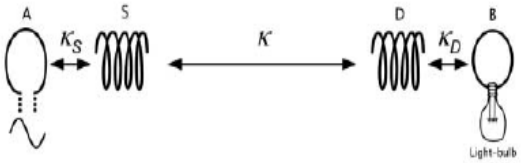
3.2 Experimental Design:

Experimental scheme consists of two Self-resonant coils. One coil (source coil) is coupled inductively to an oscillating circuit; the other (device coil) is coupled inductively to a resistive load. Self-resonant coils rely on the interplay between distributed inductance and distributed capacitance to achieve resonance.

The coils are made of an electrically conducting wire of total length 'l' and cross-sectional radius 'a', wound into a helix of 'n' turns, radius 'r', and height 'h'. There is no exact solution for a finite helix in the literature, and even in the case of infinitely long coils, the solutions rely on assumptions that are inadequate for this system. So here the method implemented is simple Quasi-static model to find the parameters. Those are in Electro Magnetic equations.

$$L = \frac{\mu_0}{4\pi |I_0|^2} \iint d\mathbf{r} d\mathbf{r}' \frac{\mathbf{J}(\mathbf{r}) \cdot \mathbf{J}(\mathbf{r}')}{|\mathbf{r} - \mathbf{r}'|}$$

$$\frac{1}{C} = \frac{1}{4\pi\varepsilon_0 |q_0|^2} \iint d\mathbf{r} d\mathbf{r}' \frac{\rho(\mathbf{r})\rho(\mathbf{r}')}{|\mathbf{r} - \mathbf{r}'|}$$



3.3 Range and Rate of Coupling:

The range and rate of the proposed wireless energy-transfer scheme are the first subjects of examination, without considering yet energy drainage from the system for use into work. An appropriate analytical framework for modeling this resonant energy-exchange is that of the well-known Coupled-Mode Theory (CMT) .Here, the field of the system of two resonant objects 1 and 2 is approximated by **$F(r,t)=a_1(t)F_1(r)+a_2(t)F_2(r)$**, here $F_{1,2}(r)$ are the modes of 1 and 2 alone, and then the field amplitudes $a_1(t)$ and $a_2(t)$. The lower order representation of the system is given by:

$$\frac{da_1}{dt} = -i(\omega_1 - i\Gamma_1)a_1 + i\kappa a_2$$

$$\frac{da_2}{dt} = -i(\omega_2 - i\Gamma_2)a_2 + i\kappa a_1$$

Where $\omega_{1,2}$ are the individual frequencies, $\Gamma_{1,2}$ are the Resonance widths (Decay rates) due to the objects' intrinsic (absorption, radiation etc.) losses, and '**κ'** is the coupling coefficient. The above equation show that at exact resonance ($\omega_1=\omega_2$ and $\Gamma_1=\Gamma_2$), the normal modes of the combined system are split by 2κ. The energy exchange between the two objects takes place in time Pi/κ and is nearly perfect, apart for losses, which are minimal when the coupling rate is much faster than all loss rates ($\kappa >> \Gamma_{1,2}$). It is exactly this ratio {κ /sqrt ($\Gamma_{1,2}$)} shows that, it will set as figure-of-merit for any system under consideration for wireless energy-transfer, along with the distance over which this ratio can be achieved. The desired optimal regime {κ/sqrt ($\Gamma_{1,2}$)>>1} is called "Strong-Coupling" regime. There is No change in Energy, up to κ/Γ>>1 is true.

Consequently, this energy-transfer application requires resonant modes of High Quality factor, Q=ω/2Γ for low (slow) intrinsic-loss rates Γ, so we used here the non-lossy near field. Furthermore, strong (fast) coupling rate κ is required over distances larger than the characteristic sizes of the objects, and therefore, since the extent of the near-field into the air surrounding a finite-sized resonant object is set typically by the wavelength, this mid-range non-radiative coupling can only be achieved using resonant objects of Sub-wavelength size. Such sub-wavelength (λ/r) resonances can often be accompanied with a high radiation-Q, so this will typically be the appropriate choice for the possibly-mobile resonant device-object.[1]

3.4 Parameters For Designing and Simulation:

The coupled mode theory plays a vital role in solving the lower order equations of the system. Using perturbation technique of

$x(t)=A\cos(\omega\ 0t)+ B\sin(\omega\ 0t)$

The solution of this equation is by including decay rate due to loss Γ0 is

$X(t)=C\exp(-i\ \omega\ 0t)\exp(-t/\ \Gamma 0)$

By considering all energy inputs and outputs we can conclude that at resonance condition decay loss by source and device is Γ= ω/2Q. The ratio κ/Γ is proportional to the Quality factor i.e. proportional to the power developed and inversely proportional to decay rate due to loss. so if κ/Γ is high the power output is high.

The simulation process is going on in the above way such that to prove in strongly coupled mode at sub-wavelength (λ/r) resonances by considering the following process.

Consider two loops at distance D between their centers, radius r1 and r2 of conducting wire with circular cross-section of radius 'a' and diameter 'd'.via a dielectric of relative permittivity ε and everything surrounded by air. To calculate the RLC

parameters used the method called Finite-Element Frequency-Domain (FEFD) simulations (for Maxwell's equations solving purpose).

The wire has inductance L, the plates have capacitance C and then the system has a resonant mode, where the nature of the resonance lies in the periodic exchange of energy from the electric field inside the capacitor, due to the voltage across it and due to the current in the wire. The energy released is Magnetic energy. Losses in this resonant system consist of ohmic loss, Rabs inside the wire and radiative loss, Rrad into free space. μ0, ε0 are the magnetic permeability, electric permittivity and impedance of free space and σ is the conductivity of the conductor. By the calculations of FEFD, we found

$\kappa = \omega M/2*\sqrt{(L1L2)}$

$L=\mu 0r[\ln(8r/a)]$

$C=\varepsilon 0\varepsilon a/D$

$\eta=\sqrt{(\mu 0/ \varepsilon 0)}$

where M is the mutual inductance of the two loops and it is dependent on r1, r2,D.

$M=\{(Pi/2)* \mu 0* (r1r2)^2\}/D^3$

$Rabs\approx \{(Pi/6)\eta r/a\}$

$Rrad\approx\{(Pi/6)\eta r/ \lambda \}$

$Qabs\approx\omega L/ Rabs$

$Qrad\approx \omega L/ Rrad$

And taking copper wires so that it is having ε=10 other considerations in **COMSOL software** and **Acoustics Module Tool**, designed the system as

3.5 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.

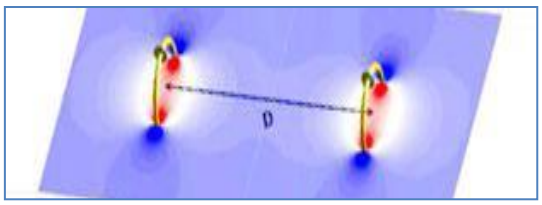


Fig 8: Energy Exchange

3.6 Simulation model using Resonant magnetic coupling:-

Two idealized resonant magnetic coils, shown in yellow. The blue and red color bands illustrate their magnetic fields. The coupling of their respective magnetic fields is indicated by the connection of the color bands.

Simulation Performance:-

The results and performance given with and Without the External object in between the coils.

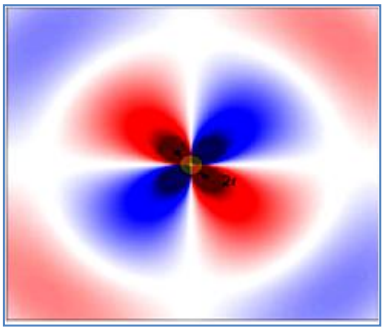


Fig 9: Energy Exchange (With external object)

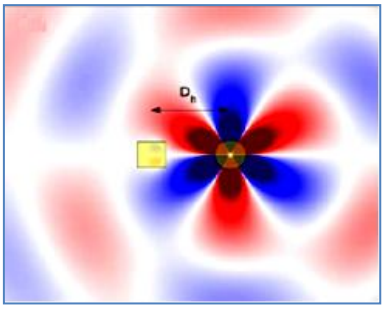
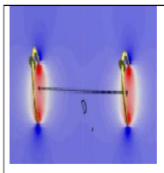


Fig 10: Energy Exchange (Without external object)

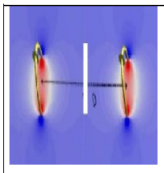
Results without Extraneous objects:



Two loops	D/r	Qrad	Q=ω/2Γ	ω/2κ	κ/ Γ
R=30cm,a=2cm, ε=10,d=4mm,Qabs=4886.	3	30729	4216	63.7	68.7
	5	29577	4194	248	17.8

Fig 11: Results without Extraneous objects-I

If we include a man having muscles of electric permittivity ε=49+16i so that observed the results that only decay is some what raised but got the required κ/ Γ ratio.



Two loops	D/r	Qrad	Q=ω/2Γ	ω/2κ	κ/ Γ
R=30cm,a=2cm, ε=49+16i, d=4mm,Qabs=4886.	3	30729	4136	62.6	67.4
	5	29577	4106	235	17.6

Fig 12: Results without Extraneous objects-I

IV. PERFORMANCE OF DESIGN

4.1 Advantages of design:

There are so many advantages with this Witricity concept, some of those are:

- ❖ Unaffected by the day night cycle, weather or seasons.
- ❖ This is an eco friendly.
- ❖ It is a boon for the devices which use midrange power.

Limitations of design:-

- ❖ The resonance condition should be satisfied, if any medium error is there possibility of power transfer.
- ❖ If there is any possibility of Very Strong ferromagnetic material presence, then there may be a possibility of low power transfer due to radiation.

Parametric conclusions for design:

Wireless Electricity concept is a boon for devices which uses midrange energy. The Power transfer is explained with the help of Magnetic resonance and Coupled mode theory. By the above paper we can concludes the below points.

1) The optimal regime of efficient power transfer is strongly coupled regime.
2) High κ/Γ ratio gives high power output. If no change in κ/Γ ration no chance in power transfer.
3) Designed the parameters with FEFD method and simulated for the κ/Γ ratio changes with and without the external objects and concluded that there is no large variation in κ/Γ ratio.

V. FEATURES AND BENEFITS

5.1 Benefits:

WiTricity technology will make your products:

More Convenient:

- ❖ No manual recharging or changing batteries.
- ❖ Eliminate unsightly, unwieldy and costly power cords.

More Reliable:

- ❖ Never run out of battery power.
- ❖ Reduce product failure rates by fixing the 'weakest link': flexing wiring and mechanical interconnects.

More Environmentally Friendly:

- ❖ Reduce use of disposable batteries.
- ❖ Use efficient electric 'grid power' directly instead of inefficient battery charging.

5.2 Features:

Highly Resonant Strong Coupling Provides High Efficiency Over Distance:-

WiTricity mode of wireless power transfer is highly efficient over distances ranging from centimeters to several meters. Efficiency may be defined as the amount of usable electrical energy that is available to the device being powered, divided by the amount of energy that is drawn by the WiTricity source. In many applications, efficiency can exceed 90%. And WiTricity sources only transfer energy when it is needed. When a WiTricity powered device no longer needs to capture additional energy, the WiTricity power source will automatically reduce its power consumption to a power saving "idle" state.

Energy Transfer via Magnetic Near Field Can Penetrate and Wrap Around Obstacles:-

The magnetic near field has several properties that make it an excellent means of transferring energy in a typical consumer, commercial, or industrial environment. Most common building and furnishing materials, such as wood, gypsum wall board, plastics, textiles, glass, brick, and concrete are essentially "transparent" to magnetic fields—enabling WiTricity

technology to efficiently transfer power through them. In addition, the magnetic near field has the ability to "wrap around" many metallic obstacles that might otherwise block the magnetic fields. WiTricity applications engineering team will work with you to address the materials and environmental factors that may influence wireless energy transfer in your application.

VI. APPLICATIONS

WiTricity wireless power transfer technology can be applied in a wide variety of applications and environments. The ability of our technology to transfer power safely, efficiently, and over distance can improve products by making them more convenient, reliable, and environmentally friendly. WiTricity technology can be used to provide:

- **Automatic Wireless Power Charging**

When all the power a device needs is provided wirelessly, and no batteries are required. This mode is for a device that is always used within range of its WiTricity power source.

When a device with rechargeable batteries charges itself while still in use or at rest, without requiring a power cord or battery replacement. This mode is for a mobile device that may be used both in and out of range of its WiTricity *power* source.

- **Consumer Electronics**
  - ❖ Automatic wireless charging of mobile electronics (phones, laptops, game controllers, etc.) in home, car, office, Wi-Fi hotspots… while devices are in use and mobile.
  - ❖ Direct wireless powering of stationary devices (flat screen TV's, digital picture frames, home theater accessories, wireless loud speakers, etc.) … eliminating expensive custom wiring, unsightly cables and "wall-wart" power supplies.
  - ❖ Direct wireless powering of desktop PC peripherals: wireless mouse, keyboard, printer, speakers, display, etc… eliminating disposable batteries and awkward cabling.

- **Industrial**
  - ❖ Direct wireless power and communication interconnections across rotating and moving "joints" (robots, packaging machinery, assembly machinery, machine tools) … eliminating costly and failure-prone wiring.
  - ❖ Direct wireless power and communication interconnections at points of use in harsh environments (drilling, mining, underwater, etc.) … where it is impractical or impossible to run wires.
  - ❖ Direct wireless power for wireless sensors and actuators, eliminating the need for expensive power wiring or battery replacement and disposal..

- **Transportation:-**
  - ❖ Automatic wireless charging for existing electric vehicle classes: golf carts, industrial vehicles.
  - ❖ Automatic wireless charging for future hybrid and all-electric passenger and commercial vehicles, at home, in parking garages, at fleet depots, and at remote kiosks.
  - ❖ Direct wireless power interconnections to replace costly vehicle wiring harnesses and slip rings.

- **Other Applications:-**
  - ❖ Direct wireless power interconnections and automatic wireless charging for implantable medical devices (ventricular assist devices, pacemaker, defibrillator, etc.).
  - ❖ Automatic wireless charging and for high tech military systems (battery powered mobile devices, covert sensors, unmanned mobile robots and aircraft, etc.).
  - ❖ Direct wireless powering and automatic wireless charging of smart cards.
  - ❖ Direct wireless powering and automatic wireless charging of consumer appliances, mobile robots, etc.

VII. SAFETY AND FUTURE SCOPE

7.1 Is WiTricity technology safe?

Non-Radiative Energy Transfer is Safe for People and Animals:-

WiTricity technology is a non-radiative mode of energy transfer, relying instead on the magnetic near field. Magnetic fields interact very weakly with biological organisms—people and animals—and are scientifically regarded to be safe. Professor Sir John Pendry of Imperial College London, a world renowned physicist, explains: "The body really responds strongly to electric fields, which is why you can cook a chicken in a microwave. But it doesn't respond to magnetic fields. As far as we know the body has almost zero response to magnetic fields in terms of the amount of power it absorbs."

Evidence of the safety of magnetic fields is illustrated by the widespread acceptance and safety of household magnetic induction cook tops. Through proprietary design of the WiTricity source, electric fields are almost completely contained within the source. This design results in levels of electric and magnetic fields which fall well within regulatory guidelines. Thus WiTricity technology doesn't give rise to radio frequency emissions that interfere with other electronic devices, and is not a source of electric and magnetic field levels that pose a risk to people or

animals. Limits for human exposure to magnetic fields are set by regulatory bodies such as the FCC, ICNIRP, and are based on broad scientific and medical consensus. WiTricity technology is being developed to be fully compliant with applicable regulations regarding magnetic fields and electromagnetic radiation.

7.2 Future scope of WiTricity

MIT's Witricity is only 40 to 45% efficient and according to Soljacic, they have to be twice as efficient to compete with the traditional chemical batteries. The team's next aim is to get a robotic vacuum or a laptop working, charging devices placed anywhere in the room and even robots on factory floors. The researchers are also currently working on the health issues related to this concept and have said that in another three to five years time, they will come up with a Witricity system for commercial use. Witricity, if successful will definitely change the way we live. Imagine cell phones, laptops, digital camera's getting self charged! Wow! Let's hope the researchers will be able to come up with the commercial system soon. Till then, we wait in anticipation! Human beings or other objects placed between the transmitter and receiver do not hinder the transmission of power. However, does magnetic coupling or resonance coupling have any harmful effects on humans? MIT's researchers are quite confident that WiTricity's 'coupling resonance' is safe for humans. They say that the magnetic fields tend to interact very weakly with the biological tissues of the body, and so are not prone to cause any damage to any living beings.

VIII. CONCLUSION

This provides mid-range **non-radiative** energy transfer scheme based on **strongly-coupled** resonances. Even very simple design have promising performance and provides better efficiency with respect to distance. As a powerful concept, it could enable a wide range of applications. We can call WiTricity as future technology of Electricity transmission for power consumer.

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