# WIRELESS POWER TRANSMISSION

Submitted in partial fulfillment of the Degree of

Bachelor of Technology

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# ABSTRACT

The idea of **Wireless Power Transmission** was given by Nicola Tesla as he was keenly interested in lighting the world from his AC generation and transports the power without wire worldwide. Wireless power transmission (WPT) is a very useful technology in near future and can be very much effective. There are two kinds of WPT technologies: near field technique and far field technique. Near field-technique uses inductive coupling, resonance inductive coupling and air ionization. Far-field techniques can be achieved through microwave power transmission and LASER power transmission. However, the efficiency is low as of now and researchers have progressed less in this field to materialize the commercial technology and still in different areas of world researches are still going on over WPT. Thus, we have covered the possible ways to harness the power without wires from many research carried out so far and we have used ferrite rod which increased the efficiency of the output. The advantages, disadvantages, biological impacts and its applications are presented along with all the work done by us and the output.

# CERTIFICATE

This is to certify that project report entitled **"WIRELESS POWER TRANSMISSION",** submitted by **Mr. Ankit Kumar**, **Mr. Kush Dhingra** & **Mr. Kuldeep Singh** in partial fulfillment for the award of degree of Bachelor of Technology in Electronics and Communication Engineering to JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY, Waknaghat, Solan(Hp) has beesn carried under my supervision.

**Mr. Kaushlendar Kumar Pandey**

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We are grateful to Prof. SV Bhooshan, Head of the Department of Electronics and Communication Engineering, for permitting us to make use of the facilities available in the department to carry out the project successfully. Last but not the least we express our sincere thanks to all our teachers and friends who have patiently extended all sorts of help for accomplishing this undertaking.

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# LIST OF ABBREVIATIONS

**Table 1.** List of Abbreviation

| Sl. No. | Terms | Descriptions |
|---|---|---|
| 1 | WPT | Wireless Power Transfer |
| 2 | IEEE | Institute of Electrical and Electronics Engineers |
| 3 | MPT | Microwave Power Transfer |
| 4 | NASA | National Aeronautics and Space Administration |
| 5 | OEM | Original Equipment Manufacturer |
| 6 | RIC | Resonance Inductive Coupling |

# 1. INTRODUCTION

There have been great discoveries in wireless transmission after the invention of Electromagnetic Waves by Maxwell. Since then wireless have made the world small and fast.

Wireless power transmission is the transmission of electrical energy from a power source to an electrical load without interconnecting wires. This Wireless Transmission is useful in cases where interconnecting wires are inconvenient, hazardous, expensive or impossible. With wireless power, the efficiency is the more significant parameter. A large part of the energy sent out by the generating plant must be optimally received at the end.

In our present system where we use wires as the transmission media, it is not always efficient. There are power losses mainly due to transmission and distribution. This mainly accounts for transmission losses from power plant generator to the consumers. The resistance of the wires used in electrical grid distribution accounts for almost 26-30% of the energy generated. Thus our present system in electrical distribution is only 70-74% efficient. Besides the heavy energy losses more resources, infrastructures, manpower, and expenditure involved makes present technique of wired transmission not an all-time business but to find other alternate state – of – technology to transmit and distribute electricity efficiently and economically.

We have already seen an immense growth in the field of wireless transmission which is capable of transmitting energy from one source to the distance destinations. Therefore, wireless transmission of electrical power should be possible. In fact this noble concept was far foreseen by the "Father of Wireless" Nicola Tesla based on Tesla Theory, which would transmit the electrical energy across a large distance and receive it at the destination with negligible losses. There have been series of researches and experiments performed to take this very technology into reality. There are number of technologies that would be possibly used as a means to felicitate the electrical power transmission without wires. This wireless power transmission can be broadly understood in two fundamental categories: far field transmission and near field transmission.

Though the criticism was faced by the Father of this noble concept Tesla for its biological impact, but there could have been safety mode for the same. Since the world is already gridded with wires, lighting the globe would be a great challenge to lose all the present royalties but it will be a great bless ever in the face of humanity.

# 2. WIRELESS TECHNOLOGY: THE BESICS

Wireless power transmission involves the transferring of electrical energy or power over the distance without wires. Thus the basic technology lies on the concept on electricity, magnetism and electromagnetism.

## 2.1 Components

### 2.1.1 Ferrite Rod

In electronics, a ferrite core is a type of magnetic core made of ferriteon which the windings of electric transformers and other wound components such as inductors are formed. It is used for its properties of high magnetic permeability coupled with low electrical conductivity (which helps prevent eddy currents).It is used to attract maximum field lines and let them pass through the coil. Ferrites are ceramic compounds of the transition metals with oxygen, which are ferrimagnetic but nonconductive. Ferrites that are used in transformer or electromagnetic corescontain iron oxides combined with Ni, Zn, and manganese compounds. They have a low coercivity and are called "soft ferrities" to distinguish them from "hard ferrities", which have a high coercivity and are used to make ferrite magnets. high resistivity prevents eddy currents in the core, another source of energy loss. The most common soft ferrites are:

1. Manganese-zinc ferrite ($\mathbf{Mn_aZn_{(1-a)}Fe_2O_4}$).

   MnZn have higher permeability and saturation levels than NiZn.
2. Nickel-zinc ferrite ($\mathbf{Ni_aZn_{(1-a)}Fe_2O_4}$).

   NiZn ferrites exhibit higher resistivity than MnZn, and are therefore more suitable for frequencies above 1 MHz.

**Figure 1.** Ferrite rod

## 2.1.2 Function Generator

A function generator is usually a piece of electronic test equipment or software used to generate different types of electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced by the function generator are the sine, square, triangular and sawtooth shapes. It used to generate different waves with different frequencies and different voltages and with different amplitudes.

Simple function generators usually generate triangular waveform whose frequency can be controlled smoothly as well as in steps. This triangular wave is used as the basis for all of its other outputs. The triangular wave is generated by repeatedly charging and discharging a capacitor from a constant current source. This produces a linearly ascending or descending voltage ramp. As the output voltage reaches upper and lower limits, the charging and discharging is reversed using a comparator, producing the linear triangle wave. By varying the current and the size of the capacitor, different frequencies may be obtained.

**Figure 2.** Frequency generator

## 2.1.3 Oscilloscope

Oscilloscopes are used to observe the change of an electrical signal over time, such that voltage and time describe a shape which is continuously graphed against a calibrated scale. The observed waveform can be analyzed for such properties as amplitude, frequency, rise time, time interval, distortion and others. Modern digital instruments may calculate and display these properties directly. Originally, calculation of these values required manually measuring the waveform against the scales built into the screen of the instrument.

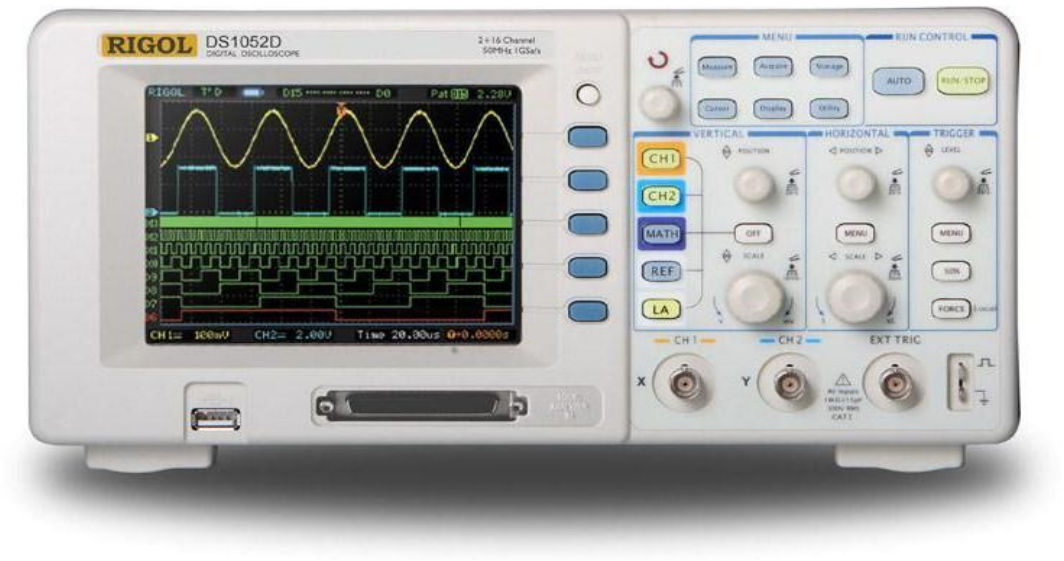



**Figure 3.** Oscilloscope

### 2.1.4 Capacitor

An electronic component that stores an electric charge and releases it when required. It comes in a huge variety of sizes and types for use in regulating power as well as for conditioning, smoothing and isolating signals. Capacitors are made from many different materials, and virtually every electrical and electronic system uses them.

There are many different kinds of capacitors available from very small capacitor beads used in resonance circuits to large power factor correction capacitors, but they all do the same thing, they store charge.

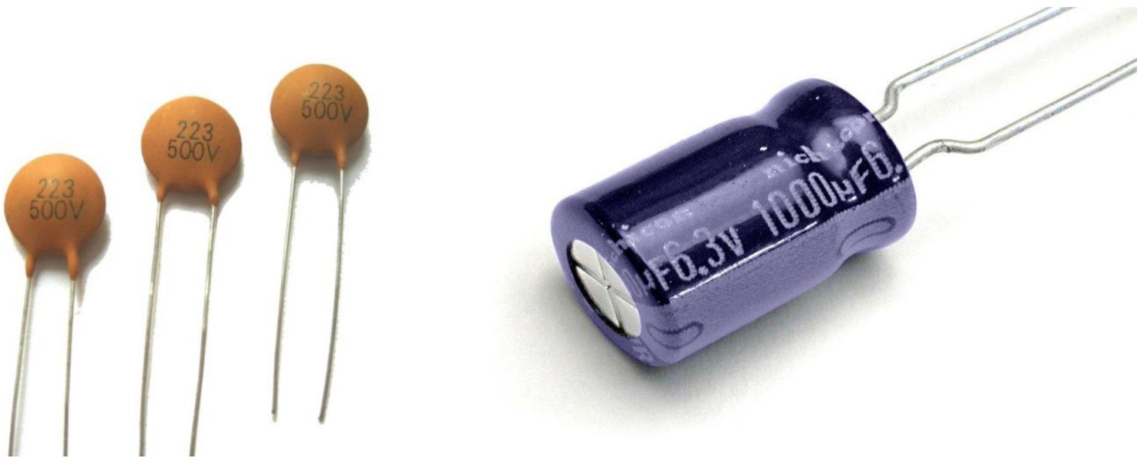



**Figure 4.** Capacitors

### 2.1.5 Resistor

A resistor is an electrical component that limits or regulates the flow of electrical current in an electronic circuit. Resistors can also be used to provide a specific voltage for an active device such as a transistor. All other factors being equal, in a direct-current (DC) circuit, the current through a resistor is inversely proportional to its resistance, and directly proportional to the voltage across it. This is the well-known Ohm's Law. In alternating-current (AC) circuits, this rule also applies as long as the resistor does not contain inductance or capacitance.
Resistors are usually added to circuits where they complement active components like op-amps, microcontrollers, and other integrated circuits. Commonly resistors are used to limit current, divide voltages, and pull-up I/O lines.

They are passive components, meaning they only consume power.

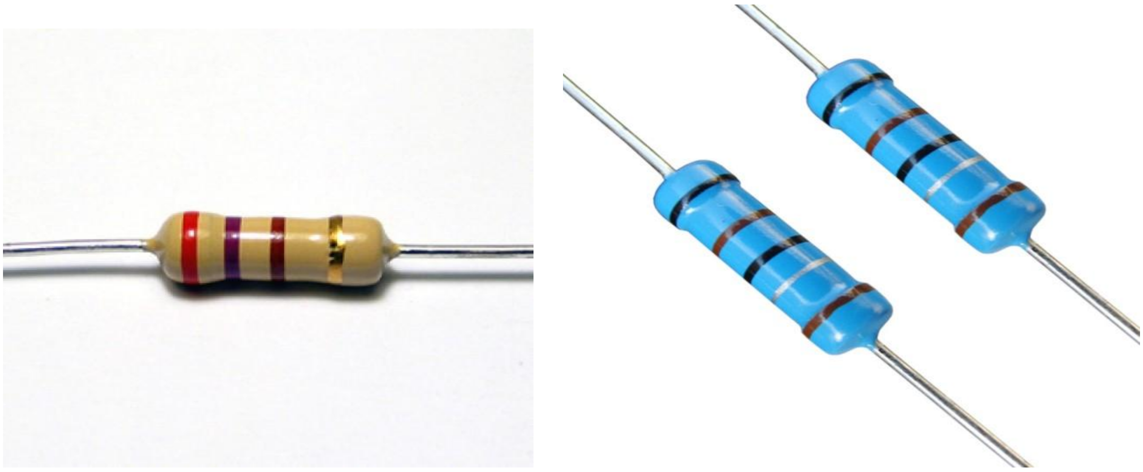


**Figure 5.** Resistor

### 2.1.6 Transformer

Electrical power transformer is a static device which transforms electrical energy from one circuit to another without any direct electrical connection and with the help of mutual induction between two windings. It transforms power from one circuit to another without changing its frequency but may be in different voltage level. Transformer is a static machine that is used to transfer power from one circuit to another without changing frequencies.

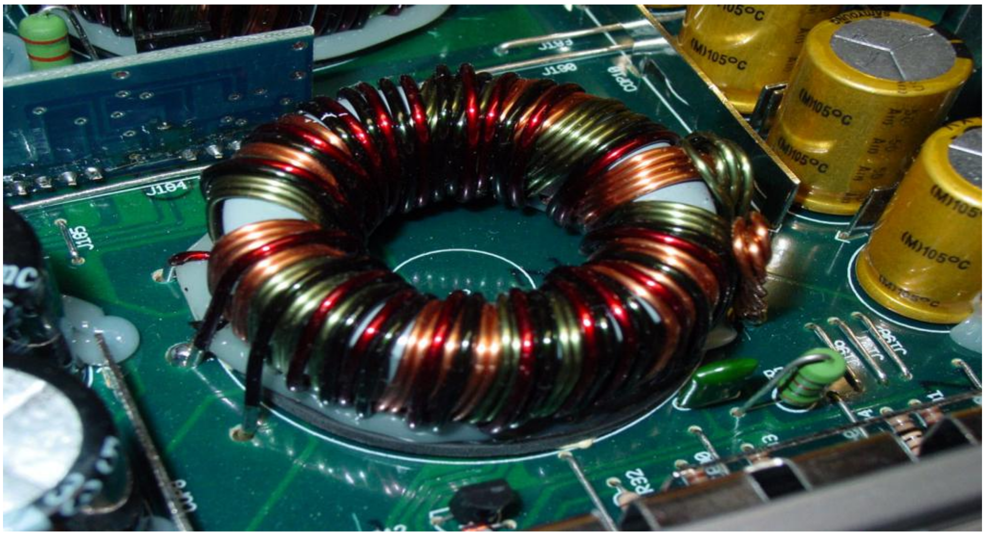



**Figure 6.** Transformer

### 2.1.7 Auto Transformer

An autotransformer is a transformer that uses a common winding for both the primary and secondary windings. Essentially an inductor with a center-tap, an autotransformer is often used in power-supply boost-converter applications to achieve a higher output voltage, while limiting the peak flyback voltage seen by the power switch.

In **Auto Transformer**, one single winding is used as primary winding as well as secondary winding. But in two windings transformer two different windings are used for primary and secondary purpose.It is a type of electrical transformer having single winding shared by primary and secondary coil.


**Figure 7.** Autotransformer

## 2.2 Electricity

The flow of electrons (current) through a conductor (a wire), or charges though the atmosphere (like lightening).

**Electric Charge**: a property of some subatomic particles which determines their electromagnetic interactions. Electrically charged matter is influenced by, and produces, electromagnetic fields.

**Electric field :** an especially simple type of electromagnetic field produced by an electric charge even when it is not moving (i.e., there is no electric current). The electric field produces a force on other charges in its vicinity.

**Electric potential:** the capacity of an electric field to do work on an electric charge, typically measured in volts.

**Electric current**: a movement or flow of electrically charged particles, typically measured in amperes.

**Electromagnets:** Moving charges produce a magnetic field. Electrical currents generate magnetic fields, and changing magnetic fields generate electrical currents.

$$\mathbf{I = V / R}$$

$$R = \rho \cdot \frac{l}{A}$$

| | |
|---|---|
| R=Resistance | Ω |
| ρ=Specific resistance | Ω×m |
| $l$ =Double length of the cable | m |
| $A$=Cross section area | mm |

## 2.3 Magnetism

It is a fundamental force of nature, which causes certain types of material to attract or repel each other. Permanent magnets like in our refrigerator and the earth's magnetic field are example of objects having constant magnetic fields.

Oscillating magnetic fields vary in respect to time, which can be used to generate alternating current (AC). The strength, direction and extend of magnetic fields are visualized by drawing of magnetic field lines as in the figure 8.

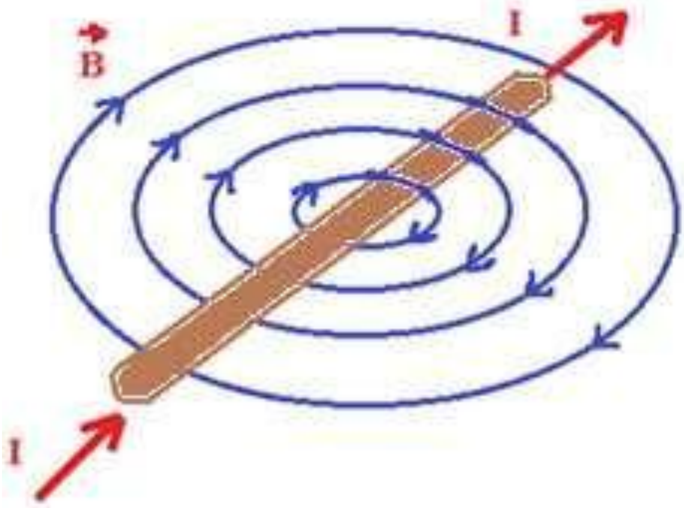



**Figure 8.** Current I flow in the circuit it generates magnetic fields

### Magnetic force

Magnetic fields exert a force on particles in the field, called the Lorentz force. The motion of electrically charged particles gives rise to magnetism. The magnetic force acting on a single electric charge depends on the size of the charge, its speed, and the strengths of the electric and magnetic field.

## 2.4 Electromagnetism

Electromagnetism is the study of the electromagnetic force which is a type of physical interaction that occurs between electrically charged particles. The electromagnetic force usually shows electromagnetic fields, such as electric fields, magnetic fields and light. The electromagnetic force is one of the four fundamental interactions in nature. The other three fundamental interactions are the strong interaction, the weak interaction, and gravitation. It is a term for the interdependence of time-varying electric and magnetic fields. The oscillating magnetic field produces a magnetic and electric field**.**

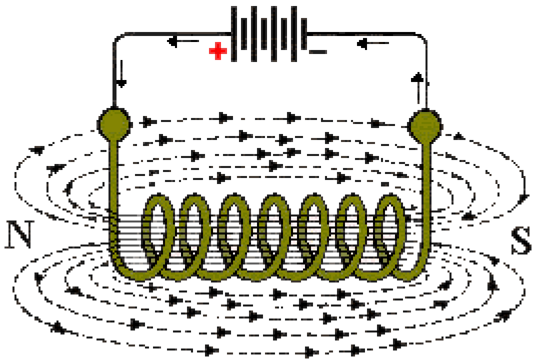



**Figure 9**. Electromagnetism

## 2.5 Magnetic Induction

If a conductive loop is connected to an AC power source, it will generate an oscillating magnetic field in and around the loop. If a second conducting loop is brought near enough, it will capture portion of that oscillating magnetic field, which in turn generates or induces an electric current in the second coil. Thus the electrical power transfer from one loop or coil to another is known as magnetic induction.

Examples of such phenomenon are used in electric transformer and electric generators. This concept is covered by the laws of electromagnetic induction by Faraday. Where he states that whenever there is change in magnetic flux linking with the coil an emf is induced in the coil. And the magnitude of the same is equal to the product of number of turns of the coil and the rate of change of flux.

The law of physics describing the process of electromagnetic induction is known as Faraday's law of induction and the most widespread version of this law states that the induced electromotive force in any closed circuit is equal to the rate of changeof the magnetic flux enclosed by the circuit.

$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$

Where

$\mathcal{E}$ = electromotive force (EMF) and

$\Phi_B$ = magnetic flux

$$N = \frac{120\,f}{P}$$

Where $N$ = Synchronous speed

$f$ = Frequency

$P$ = Number of poles

## 2.6 Energy/Power Coupling

This phenomenon occurs when one device is able to transfer energy to another deice.

Magnetic coupling occurs when one object's magnetic field is able to induce an electric current to the other devices on its vicinity.

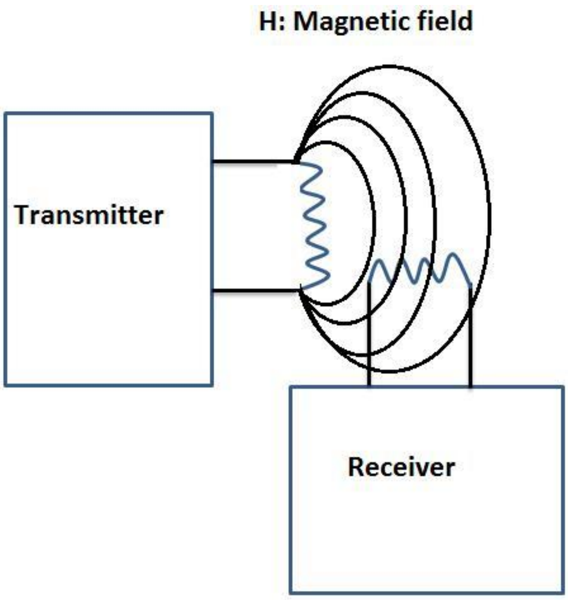



**Figure 10**. Magnetic Coupling

## 2.7 Resonance

Resonance is the phenomenon in which magnetic systems that possesses both magnetic moments and angular momentum. It is the natural frequency at which energy can most efficiently be added to an oscillating system. It exists in most of the physical systems. When the resonant frequency is found it vibrates with higher energy.

## 2.8 Resonance Magnetic Coupling

Resonance between source and load coils is achieved with lumped capacitors terminating the coils. A circuit model is developed to describe the system with a single receiver, and extended to describe the system with two receivers. when there is energy exchange between two objects through their varying magnetic fields. But the resonant coupling occurs when the natural frequencies of the two becomes approximately equal.

# 3.CONTRIBUTIONS

## 3.1 Nikola Tesla

Nikola Tesla, who is seen by mostly American as the "Father of Wireless", is also credited for his remarkable AC generation became the first person to conceive the idea of wireless power transmission and successfully demonstrated the transmission of electricity without wires as early as 1891. In 1893 Tesla won to illuminate the World Columbian Exposition in Chicago, where he demonstrated the success of illuminating the vacuum tubes bulbs without using wires. Tesla constructed the Wardebclyffe tower as shown below in figure 5, for wireless power transmission of electrical power rather than telegraphy. Tesla conducted his experiments in Colorado Spring in 1899. He was also able power the 200 (50W) incandescent lamps at 25 miles from the power hour source.

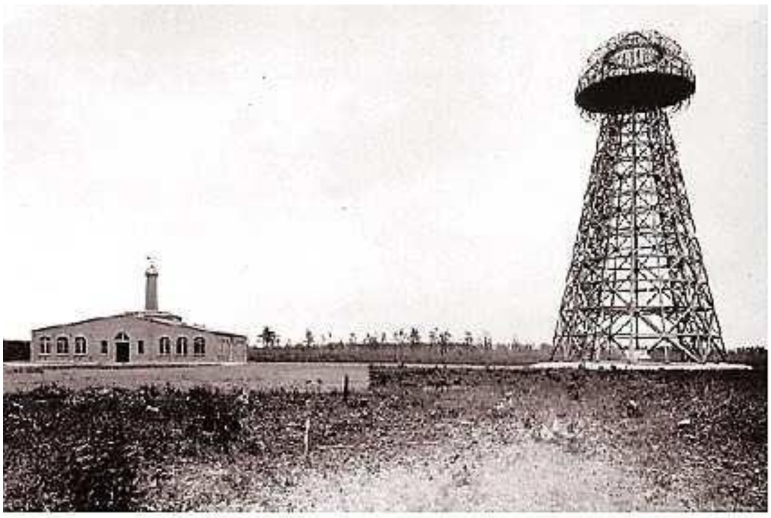


**Figure 11.** Tesla's Wardebclyffe Tower for Wireless Power Transmission

## 3.2 William C. Brown

William C. Brown is credited for modern research and father of microwave power transmission. In 1961 he published his first paper proposing microwave energy for power transmission. In early 1960s Brown invented rectenna which directly convert microwave to DC current and in 1964 he successfully demonstrated a microwave-powered model helicopter that received all the power needed for the flight from a microwave beam at 2.45 GHz. Figure 12 **shows Brown's schematic diagram for microwave power transmission.**

In 1982, Brown along with James F. Trimer (NASA) modified the previous rectenna to thin and light one which led to the development of Stationary High Altitude Relay Platform (SHARP) field. The purpose of this was to develop aircraft that would maintain a circular trajectory above a microwave antenna for relaying communication from various ground terminals.

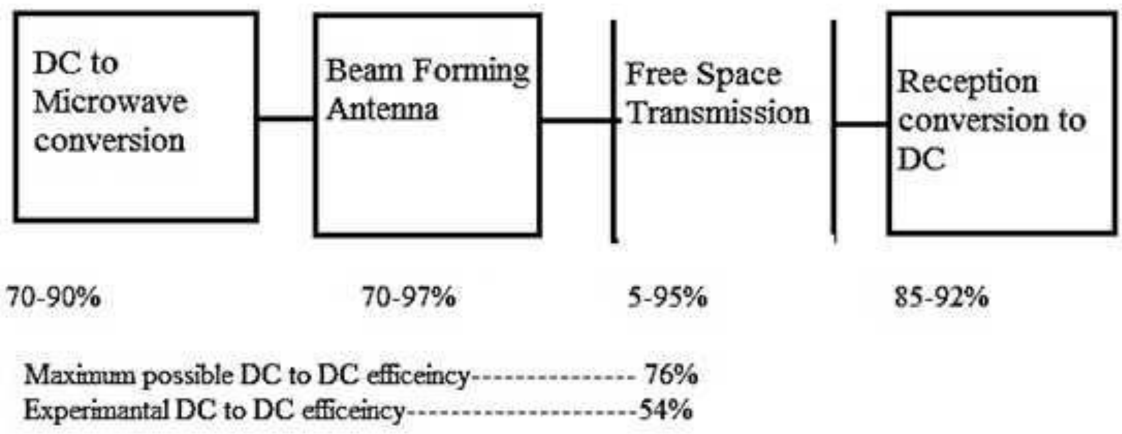



**Figure 12.** Schematic Diagram of element of beam MPT

## 3.3 Prof. Marin Soljacic

A physics research group led by Prof. Marin Soljacic at the Massachusetts Institute of Technology (MIT) demonstrated wireless powering of 60W light bulb with 40% efficiency at 2m (7ft) distance using two 6ocm –diameter coils in 2007. They used resonant induction to transmit power wirelessly. The group is also working to improve the technology.

This came as a chance when Prof. Soljacic's phone beeped in the kitchen letting him know that he forgot to charge. Soon after the success of the experiment the term for the technology was given as WiTricity and to carry out this technology forward from the MIT laboratories, WiTricity Corp. was launched.

# 4. WIRELESS POWER TRANSMISSION: TYPE

## 4.1 Near Field Techniques

### 4.1.1 Inductive Coupling

Two devices are said to be mutually inductively coupled or magnetically coupled when they are configured such that change in current though one wire induces a voltage across the ends of the other wire by electromagnetic induction. This is due to the mutual inductance. Transformer is an example of inductive coupling. Inductive coupling is preferred because of its comfortable, less use of wires and shock proof.

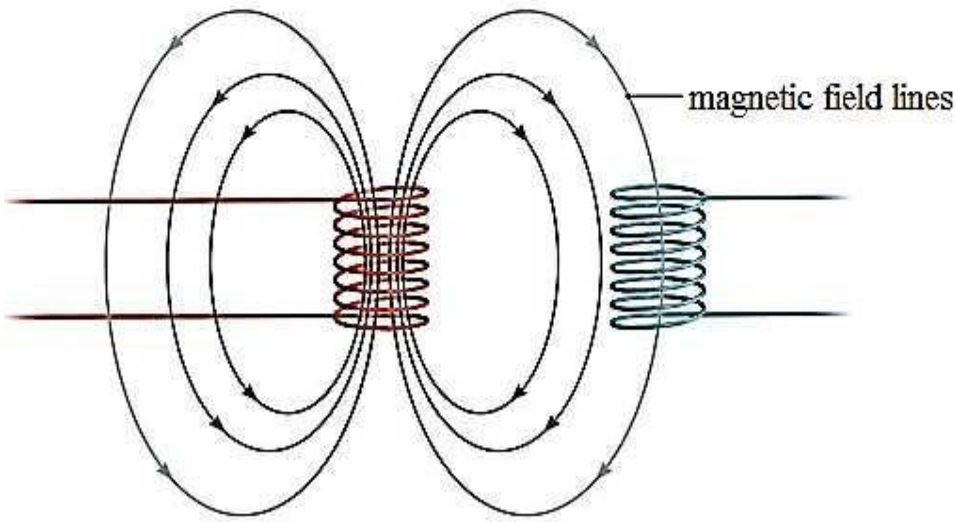



**Figure 13**. Inductive coupling

### 4.1.2 Resonance Inductive Coupling(RIC)

RIC is the combination of both inductive coupling and resonance. Using the concept of resonance it makes the two objects to interact each other very strongly.

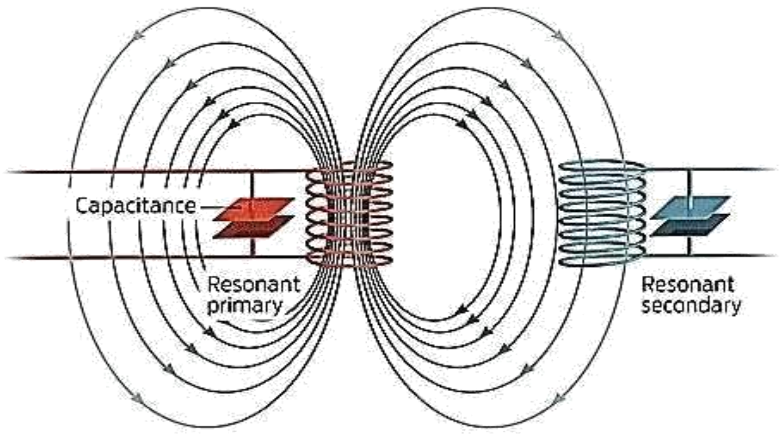



**Figure 14.** Concept of Resonance Inductive Coupling

Inductance induces current in the circuit. As seen in the figure 14, the coil provides the inductance. The capacitor is connected in parallel to the coil. Energy will be shifting back and forth between magnetic field surrounding the coil and electric field around the capacitor. Here the radiation loss will be negligible.

MIT's research group led by Prof. Saljacic used this concept to light the bulb at 2m distance.

They used helical shaped coil instead of capacitor

**Comparison between RIC and Inductive Coupling**

1. RIC is high efficient
2. RIC has greater range than inductive coupling
3. RIC is directional when compared to inductive coupling
4. RIC can be one- to- many whereas inductive coupling is one-to-one
5. Device using RIC technique is highly portable.

### 4.1.3 Air ionization

The concept here is the ionization of air due to field produced. This technique in exist in nature but there is hardly any feasibility of its implementation because it needs high field like 2.11 MV/m. Several experiments are on the way. Richard E. Vollrath, a California inventor has developed an ingenious sand-storm generator, which sends blasts of dust-laden air through copper tubes, generating electricity which can be stored in sphere and used later. Example of this technique is seen in nature lightning.

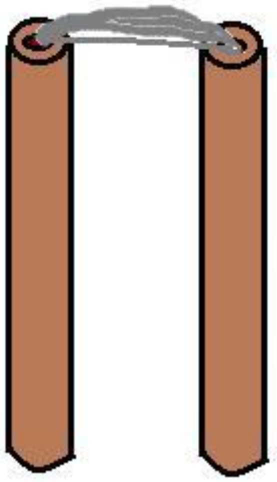


**Figure 15.** Air ionization between two wires due to high field

### 4.1.4 Advantage and Disadvantage of Near Field Techniques

**Table 2.** Advantage and disadvantage of Near Field Technique

| Advantage | Disadvantage |
|---|---|
| No Wires | Distance Constraint |
| No e-waste | Field strength sometime unsafe |
| Need foe battery is eliminated | Initial cost is high |
| Efficient energy transfer | High frequency signal must be supplied |
| Maintenance cost is less | Air ionization technique is not feasible |

## 4.2 Far-Field Energy Transfer Techniques

Far Field Energy Transfer technique is mainly dependent on radiative techniques. Here wave are either broadcasted in the form of narrow beam transmission of radio, or light waves. This is solely for high power transfer. Tesla already gave the concept to the world on his paper: **"Truly Wireless"** long time by late 1980s. He constructed large Wardenclyffe Tower to mainly transfer the energy for large distance.

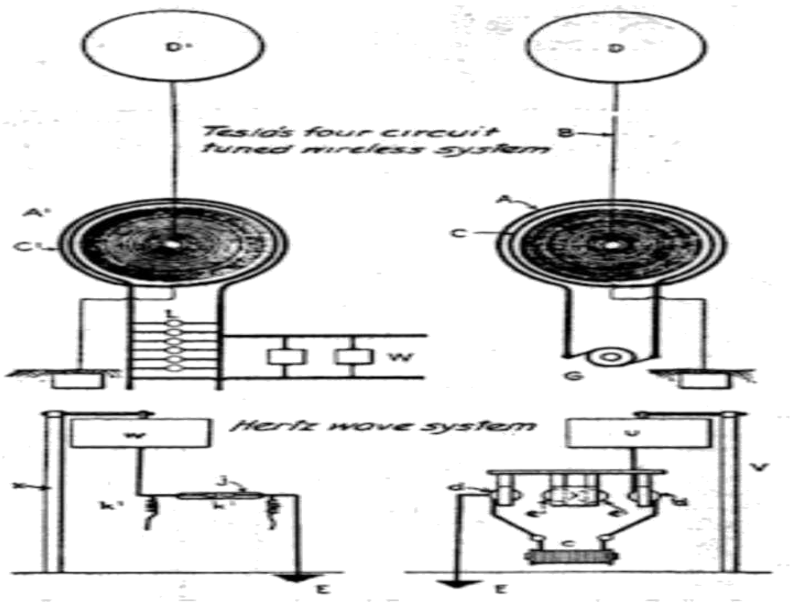



**Figure 16**. The basics for system for the wireless transmission of electrical power

**There are basically two methods for WPT: the microwave power transmission and the power transmission using LASER.**

### 4.2.1 Microwave Power Transmission (MPT)

This technique involves the conversion of energy into microwave and then transfers the wave through the rectenna (rectifier and antenna) from the transmitter and received at the receiver which will be converted into the conventional electrical power.

The steps involved are:

1. Conversion of electrical energy to microwave energy
2. Receiving microwave energy using Rectenna
3. Conversion of microwave energy to electrical energy

William C. Brown, then the leading authority on wireless power transmission technology showed the power transmission through free space by microwave. He said that the primary components include microwave source, a transmitting antenna, and receiving antenna. The basics blocks of elements in wireless power transmission is shown in figure.

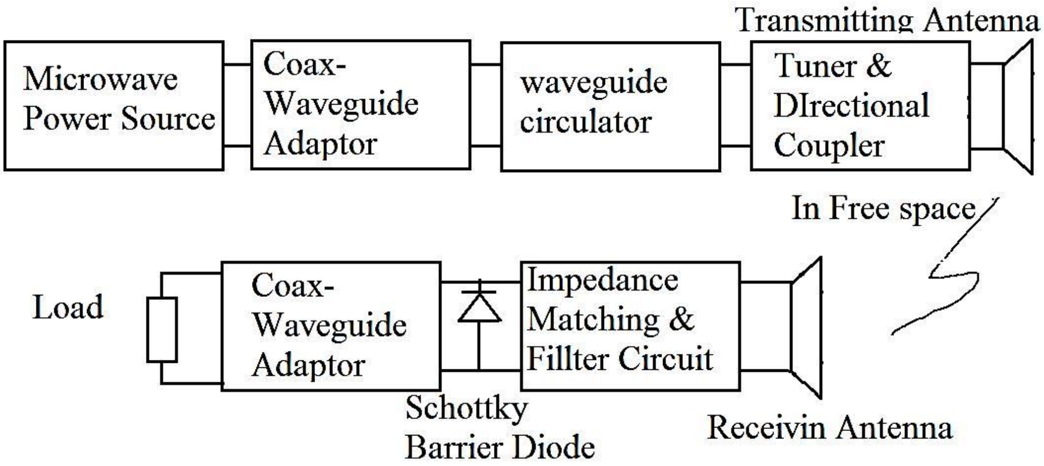



**Figure 17**.Functional Block Diagram of Wireless Power Transmission System

In the transmission side, the microwave power source generates microwave power and the output power is controlled by the electronic control circuits. The wave guide ferrite circulator which protects the microwave power source from reflected power is connected with the microwave power source through the Coax-waveguide adaptor. The tuner matches the impedance between the transmitting antenna and the microwave source. The attenuated signals will be then separated based on the direction of signal propagation by directional coupler. The transmitting antenna radiates the power uniformly through free space to the antenna.

In the receiver, an antenna receives the transmitted power and converts the microwave in DC power. The impedance matching circuit and filter is provided to set the output impedance of a signal source equal to the rectifying circuit. The rectifying circuit consists of Schottky barrier diodes which convert the received microwave power into DC power.

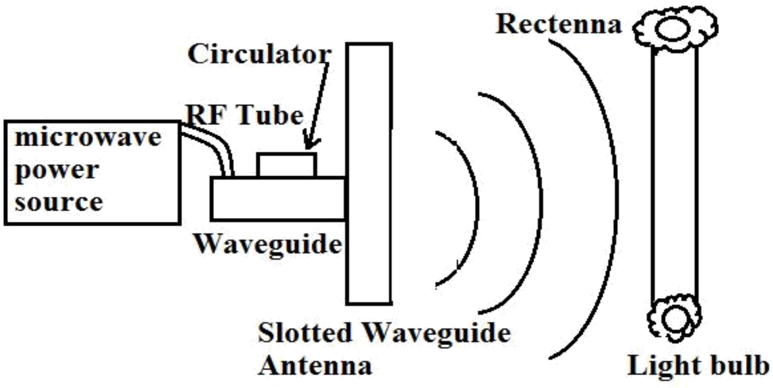



**Figure 18**. Microwave Power Transmission

For the wireless power transmission on the surface of the earth, a limited range of transmission frequencies are availably suitable. Due to atmospheric attenuation and absorption frequencies above 6 GHz, it is not efficient. The frequencies below 2 GHz require excessively large apertures for transmission and reception. Therefore, the suitable ranges of frequencies are in the range of 2GHz to 6 GHz. Efficient transmissions requires that the beams have Gaussion power density. Transmission efficiency for Gaussian beams is related to the aperture sizes of the transmitting and receiving antennas by.

Followings are the components required for generating frequencies of transmitting the power:

**(a) Microwave Generator**

Microwave transmitting devices are classified as Microwave Vacuum Tubes (magnetron, klystron, travelling wave tube), and microwave power module (MPM) and Semiconductor Microwave transmitters (GaAs MESFET, GaN, pHEM, SiC MESFET, AlGaN/GaN HFET, and InGaAs). The microwave transmitter often uses 2.45 GHz or 5.8 GHz of ISM band. The other frequencies are 8.5 GHz, 10GHz and 35 GHz. The highest efficiency over 90% is achieved at 2.45 GHz.

**(b) Transmitting Antenna**

The slotted wave guide antenna as shown in the above figure 14, micro-strip antenna and parabolic dish antenna are the most used amongst the others. The slotted waveguide antenna is considered to be ideal with the efficiency greater than 95% and high power handling capacity.

**(c) Rectenna**

The name rectenna comes from William C. Brown (Raytheon) in the early 1960s [13]. It is the term given to the combination of rectifying diode and antenna. The rectenna is passive element and consists of antenna, rectifying circuit with a low pass filter between the antennas and rectifying diode. The antenna used may be dipole, Yagi-Uda, micro-strip or parabolic dish antenna. The patch dipole antenna is best with highest efficiency.

### 4.2.2 LASER Technology

The LASER Technology is another efficient way of wireless power transmission. It uses the same possibility as microwave wireless transmission but here energy emission is of high frequency and is coherent. Research organisations like NASA, ENTECH, and UAH have been working on this project as a means to transmit power wirelessly. The other great advantage of

LASER power transmission is the aperture collection efficiency which is that antenna can be made small sized as these are the colliminated beams.

LASER transmission does not get dispersed for long distance but it gets attenuated when it propagates though atmosphere. During the design the receiver used can be simple like photovoltaic cell. Due to the simplicity in its construction it is cost efficient than he microwave power transmission. Developing photovoltaic cells which are capable of efficiently converting the multiple sun intensity coherent monochromatic light in to electricity have been under the belt of many researchers and scientist. Maximum efficiency for photovoltaic cell with monochromatic light has been achieved at a wavelength that is just short of cutoff wavelength for the semiconductor.

**Application of LASER in SPS**

Solar Power Satellite (SPS) is stationed in the geostationary orbit containing lots of photo cells. The solar energy trapped by this can be transmitted to earth Rectenna as a LASER beam. At the receiver this is converted back to electrical energy.

### 4.2.3 Comparison between LASER and MPT

The size of the antenna can be reduced by using LASER. LASER has high attenuation losses, interference and gets diffracted by atmospheric particles. Conversion of waves is found to be inefficient.But to overcome this difficulties, the LASER system will have to be provided with ground energy storage capacity or multiple sites located sufficiently far apart such that one site could be available all times.

Microwave faces interference and the safety is the biggest concern. Another biggest concern is the FRIED BIRD effect.

### 4.2.4 Advantages and disadvantages of Far Field Energy Transfer

**Table 3**. Advantage and Disadvantage of Far Field Techniques

| ADVANTAGES | DISADVANTAGES |
|---|---|
| Efficient<br>Easy and simple<br>Grids, substations are eliminated<br>Low maintenance cost<br>Reach remote places<br>NO theft of power<br>Shock free environment<br>More effective when the transmitting and receiving points are along a line-of-sight<br>Can reach the places which are remote | Radiative<br>Needs line -of-sight<br>Initial cost is high<br>When LASERs are used,<br>Conversion is inefficient<br>Absorption loss is high<br>When microwaves are used,<br>Interference may arise |

# 5. MEASUREMENTS AND FIGURES

## 5.1 Experiment at 22 v pp at 3 MHz frequency

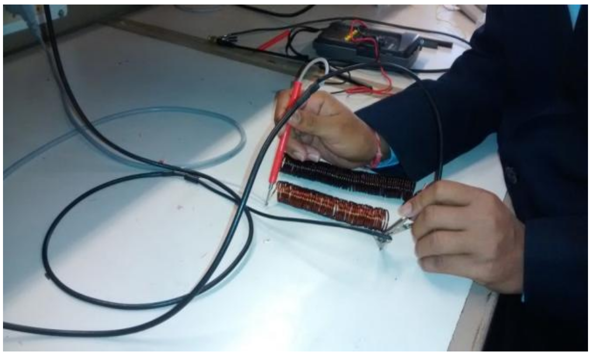
We made two coils by using copper wires, first is primary coil having inductance 8.4 uH, resistance 46 mΩ and diameter of 2.5 cm, second is secondary coil having inductance 7.4uH, resistance 24 mΩ and same diameter of 2.5 cm also. Both coils are 15 cm long in length. When we apply the voltage supply by function generator of 22 volts peak to peak at the frequency of 3MHz, Then we measured the outputs at various distances with ferrite rod and without ferrite rod, which are shown in the following table.

**Table 4.** Experiment at 22 v pp at 3 MHz frequency

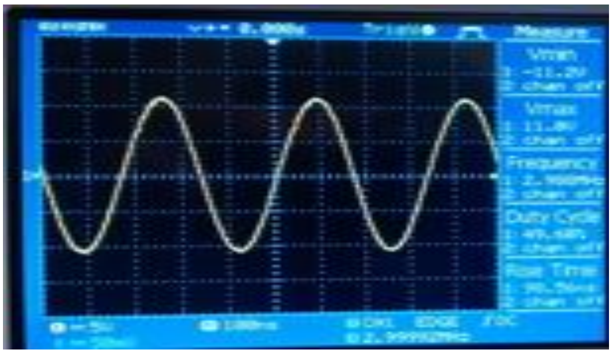
| **Diameter =2.5cm** | | | | | | | **Frequency =3MHz** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Primary Coil** | | | **Secondary Coil** | | | | | | |
| **Vin (p-p)** | **L (uH)** | **R (mΩ)** | **L (uH)** | **R (mΩ)** | **S(cm)** | **V1(mV)** | **V2(mV)** | **n1%** | **n2%** |
| | | | | | **3** | **100** | **224** | **0.12** | **6.22** |
| **22 V** | **8.4** | **46** | **7.4** | **24** | **5** | **60** | **130** | **0.10** | **3.01** |
| | | | | | **7** | **29** | **58** | **0.72** | **2.1** |

Where,V1 and V2 are the output voltages at secondary coil without and with ferrite rod.

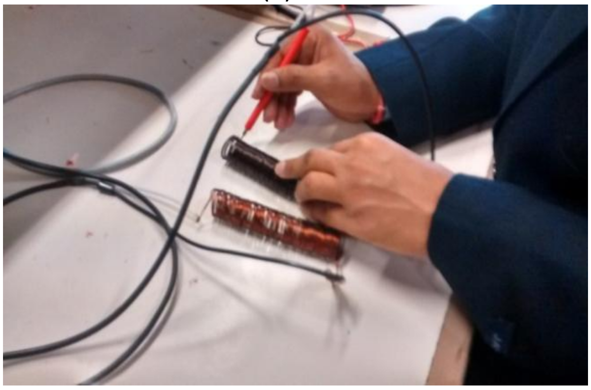
In the very first we set the input waveform in the oscilloscope and then connect the input with the primary coil, as shown in the fig.(a) and the input waveform across the primary coil is shown in the fig.(b). Make connects of secondary coil with the multimeter and oscilloscope. Now took measurments for the various distances without ferrite rod as shown in figure (c) and (d).After that, took the measurements for same distances with the ferrite rod as shown in the figure (e) and (f). All the mathematical data are shown in the above table.



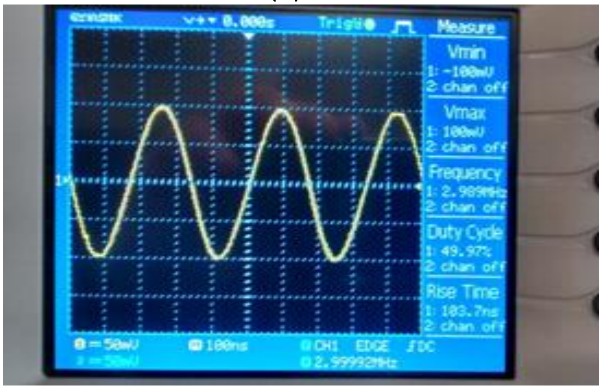
(a)



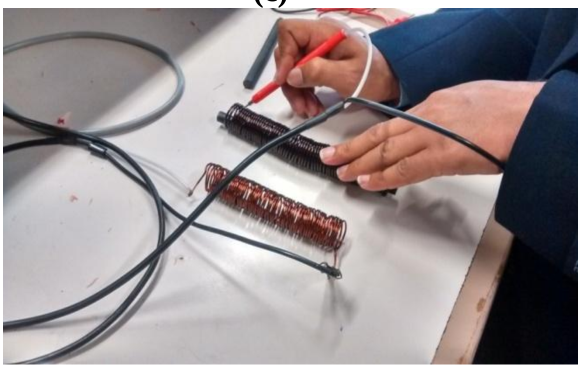
(b)



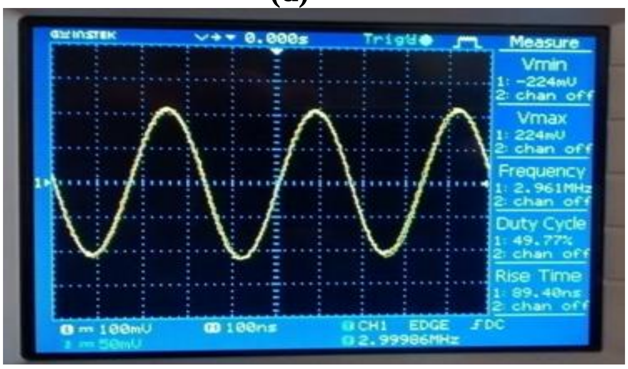
**(c)**




**(d)**



**(e)**




**(f)**

**Figure 19.** (a) Input power supply and (b) Waveform at primary coil, (c) Output voltage and (d) Waveform at secondary coil without ferrite rod, (e) The output voltage and (f) Waveform at secondary coil with ferrite rod.

## 5.2 Experiment by using auto-transformer with and without ferrite rod

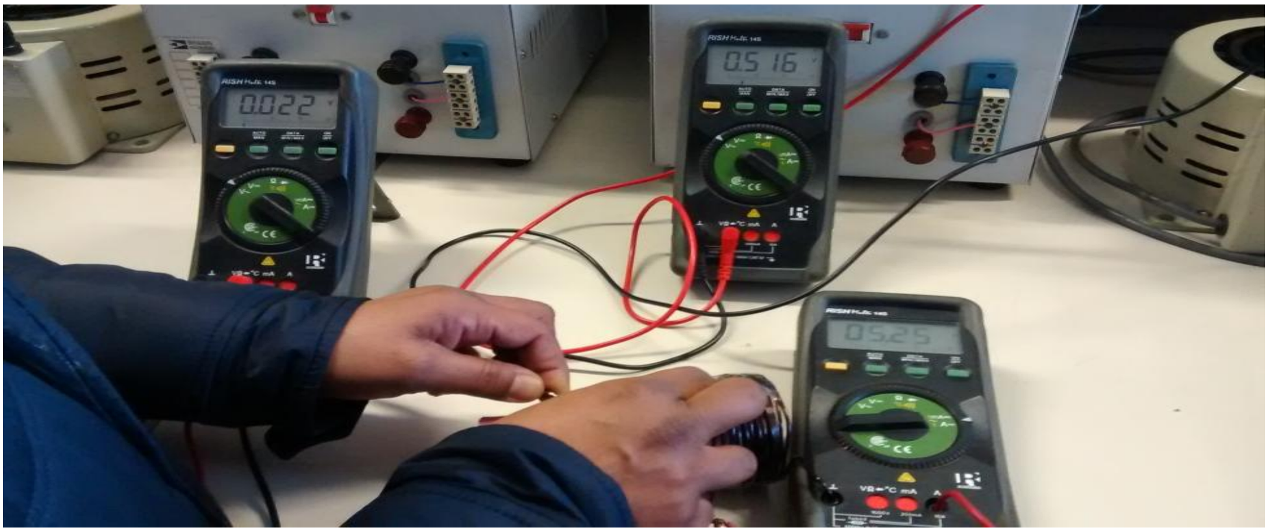
In the above experiment we did not get good efficiency, So make some changes, and make two coils of different diameters, different lengths and different turns having different diameter of copper wires.

Because we have a frequency generator of maximum limit of input voltage 22 V peak-to-peak, that is why we can't increase the input voltage more than 22 V. For overcome this problem we go to the auto transformer in which we can increase the input voltage supply up to 150 V. But we can't increase the frequency more than 50 Hz in the auto-transformer that's why we set the frequency of 50 Hz. The primary coil have resistance of 13 mΩ, Inductance of 29.5 uH and the diameter of 6.3 cm. In the other hand, Secondary coil have resistance of 38.95 Ω, inductance of 700 uH and the diameter of 2.5 cm. We varied the input voltage supply and measured the outputs at the various distances with and without ferrite rod, Which are shown in the following table.

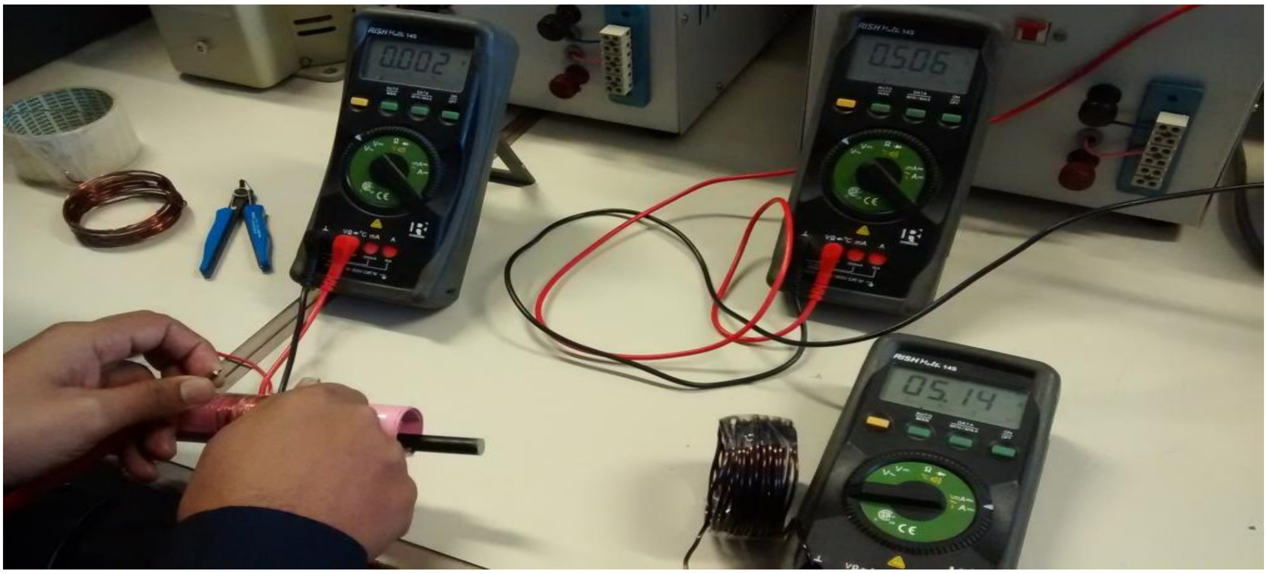
**Table 5. Output measurement by using auto-transformer with and without ferrite rod**

| Primary Coil | | | | | Secondary Coil | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter=6.3cm | | | | | Diameter=2.5cm | | | | | | |
| L (uH) | R (mΩ) | F (Hz) | V(v) | I (amp) | L (uH) | R (Ω) | S (cm) | V1 (mv) | V2 (mv) | n1% | n2% |
| 29.5 | 13 | 50 | 0.516 | 5.25 | 700 | 38.95 | 10 | 50 | 150 | 11.66 | 14.3 |
| | | | 0.721 | 6.8 | | | 15 | 23 | 80 | 9.25 | 11.58 |
| | | | 0.830 | 7.9 | | | 18 | 11 | 20 | 5.84 | 8.98 |

In this experiment we connect the primary coil with the auto-transformer and with the multimeter and give the supply to the auto-transformer. Make connections of secondary coil with the another ac multimeter. Now measured the output values at various input voltages and distances without ferrite rod as shown in fig.(a). Do the procedure with the ferrite rod as shown in fig.(b). The mathematical datas are shown in the above table.




**(a)**




**(b)**

**Figure 20. Measurements (a) Without ferrite rod, (b) With ferrite rod.**

## 5.3 Measurements with tank circuit

In the above experiment, Because of we can't increase the frequency of input power supply more than 50 Hz, Which is required to transmit the electrical power energy for long distance.

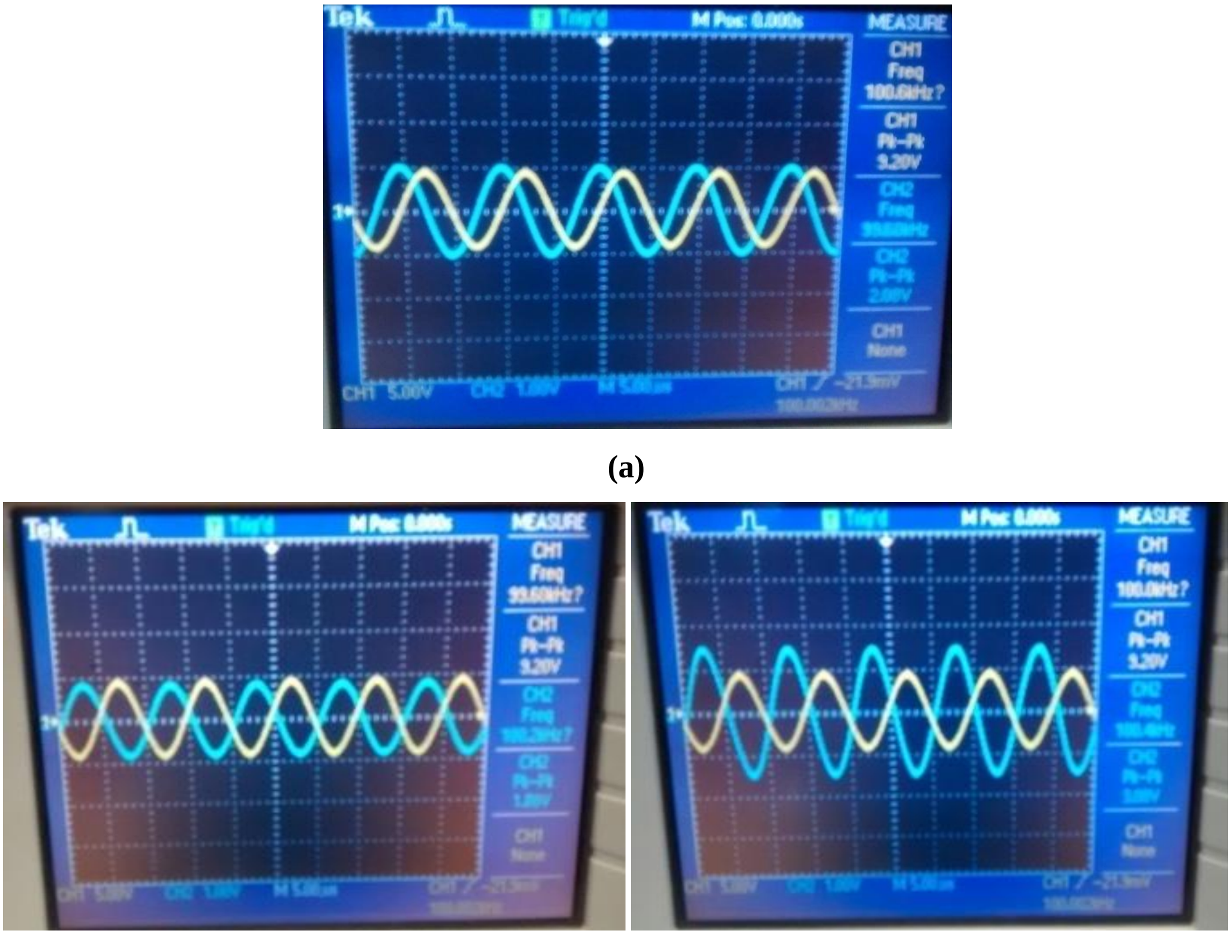
We did not get good efficiency. To increase the distance and improve the efficiency we go to resonance concept between sender and receiver ends. We made tank circuit at the sender and receiver end and set the values of inductor, capacitor and resistors for making the resonance at both sender and receiver ends.

We set the whole setup with the bread board, function generator and oscilloscope and connected the sender end by the probes and wires. Now, set frequency of 100 KHz in function generator and measured the output values at various distances, Which are shown in the following table.

**Table 6.** Measurements with tank circuit

<table>
<tr><th colspan="4">Primary Coil</th><th colspan="5">Secondary Coil</th></tr>
<tr><th>L(mH)</th><th>R(mΩ)</th><th>C(uF)</th><th>F(kHz)</th><th>L(uH)</th><th colspan="2">R(Ω)</th><th>C(uF)</th><th>F(kHz)</th></tr>
<tr><td>29.5</td><td>13</td><td>0.1</td><td>100</td><td>700</td><td colspan="2">38.95</td><td>3.63</td><td>100</td></tr>
<tr><td colspan="4" rowspan="5">Vin=10v(p-p)</td><td>S(cm)</td><td>V1(v)</td><td>V2(v)</td><td>n1%</td><td>n2%</td></tr>
<tr><td>7.5</td><td>3.04</td><td>5.40</td><td>21.97</td><td>79.28</td></tr>
<tr><td>25</td><td>1.80</td><td>2.8</td><td>17.98</td><td>51.42</td></tr>
<tr><td>37.5</td><td>440m</td><td>800m</td><td>13.16</td><td>17.72</td></tr>
<tr><td>45</td><td>45m</td><td>380m</td><td>12.81</td><td>9.91</td></tr>
</table>

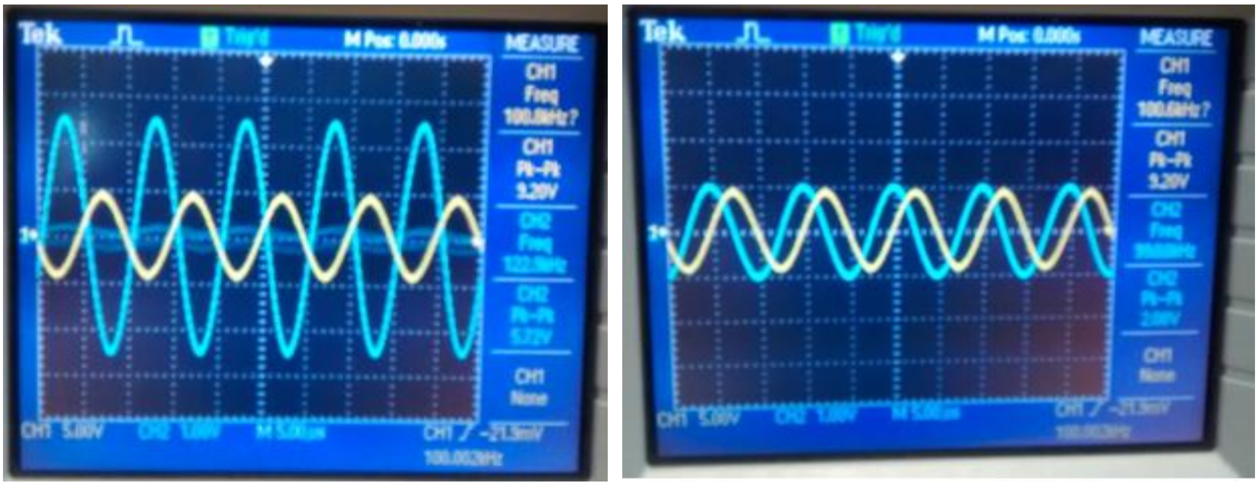
In the very first we connect a tank circuit parallel with primary and secondary coil and both coil with the oscilloscope by using probes. Now generate a input signal having voltage 10 V peak–to-peak and frequency of 100 MHz in the oscilloscope and give it to the primary coil as an input, which is shown in the fig.(a). At the receiver end took the measurements for various distances without ferrite rod as shown in fig.(b) & (c) and with ferrite rod as shown in fig.(d) & (e).




**(a)**

**(b)** **(c)**

**Figure 21.** (a)Input supply, (b)&(c) outputs without ferrite rod




**(a)** **(b)**

**Figure 22.** (a) & (b) are Output waveform with ferrite rod.

# 6. MERIT, DEMERIT AND CHALLENGES OF WPT

## 6.1 Merits

The WPT would eliminate the high-tension power transmission line cables, towers and substation, which are seen as not very efficient way of energy transmission. This will easily lead to the global scale connectivity of power system. Thus the cost of transmitting and receiving the energy becomes less expensive thereby reducing the tariff rate. Since here we do not use cable, electricity would be reached to any places irrespective of the geographical situations. Loss of power through transmission is negligible thus this method is more efficient. The natural hazards like earthquake, landslides, flood and others cannot cut the power as long as the WPT system operates thereby reliability is more compared to the wired transmission of energy. The power failure due to short circuit, fault in the cable lines would never occur. The e-waste that is produces would be drastically reduced thus it becomes more environment friendly. The space occupancy by the infrastructures like power house, dam, substations and transmission grid lines will be eliminated. The receiver can be embedded to any electrical devices and appliances that it need not use battery. The portability of the electrical devices increases.

## 6.2 Demerits

Initial cost is very high for its practical implementation. Since microwave is used interference is high. Even if LASE is used the conversion is difficult, suffers attenuation losses and is diffracted by atmospheric particles. The major concern remains the safety of the waves it emits: the biological impacts. But the safety studies has been taken that its radiation level would be never higher than the dose received while opening the microwave oven door, meaning it is slightly higher than the emissions created by cellular telephones. Thus the public exposure of WPT fields would be below existing safety guidelines (ANSI/IEEE exposure standards). Since the energy is freely in the air energy theft will occur.

## 6.3 Challenges

To sustain the constant power level, there are few challenges for WPT. This is due to the electromagnetic wave scatters freely in space as it propagates, which causes the efficiency to be much lower: leaving some energy left unused or transferred unused. But using multiple antennae arrays will be able to solve the problem.

Other major challenges that are in front for the success of WPT is the outer space transmission system in its design. This system for WPT uses massive solar panels to **collect the Sun'**s rays and sends that energy to the Earth through microwaves. The concerns that some environmentalists are placing is the depletion of ozone layer by the radiation. But this technology is young and many researches are underway to incorporate the shortcomings.

Since the world is lit by wires and every electrical device is fed with wires, it will be biggest challenge to implement the WPT technology. There should be complete revolution in the electrical world for manufacturing and designing. Still the safety of the microwaves remains a question for the public. Some of the countries which depend on electrical energy for the economy like our country Bhutan: it will be a heavy blow. This was the main reason that Tesla failed to convince then the sponsors and entrepreneurs of his time to carry out his project.

## 6.4 Safety measures

Many thinks that WPT is not safe and fear its impact in human health and environment, but as per the IEEE standard, but the safety studies has been taken that its radiation level would be never higher than the dose received while opening the microwave oven door, meaning it is slightly higher than the emissions created by cellular telephones . Thus the public exposure of WPT fields would be below existing safety guidelines (ANSI/IEEE exposure standards).

# 6. APPLICATIONS

The WPT has a great variety of applications and environments ranging from small devices to the big industries and machines. Thus application can be broadly used in two ways: direct wireless power and energy to be used in other purposes.

In Direct Wireless Power (DWP) the need of the electrical energy of the devices can be fed directly by embedding receiver on those devices from the OEM (Original Equipment Manufacturer). Thus by using DWP our devices never runs out of battery, become more reliable, convenient and environment friendly.

Since the waves can be received from any part of the globe our world will never dream in darkness. Geographical terrors will not restrict the energy flow. This technology can also be used to automatically recharge the electric vehicles, space crafts and satellites.

The industries can use the wireless energy for any purpose. Their reliability in inefficient wired energy can be eliminated.

In this phase WPT will have great application in outer space solar panels. Using the outer space solar panels to collect the sun’s energy, solar powered satellites will be able to beam the energy back to Earth. This will drastically reduce our dependence on conventional fuels and it will certainly solve the energy crisis.

# CONCLUSION

The Wireless Power Transmission is noble technology in principle put forward by Nikola Tesla. WPT has the potential to change the face of this planet with its implementation with the revolution starting from electronics to the satellites. Ranging from charging the handset to changing the effect of global warming WPT has the answer. The microwave power transmission would replace the conventional inefficient technology. It will reduce the dependence on the fossil fuels and other petroleum products that directly leads to the global warming.

Currently the technology is progress and the researchers are trying their best to overcomed the challenges. Though the practical implementation are limited at this stage due to lack of knowledge and technology, and limited frequency ranges yet the studies are on and there can be alternative to the Earth's burden of other harmful techniques.

Currently wireless power transfer is the most marketable and sustainable alternative to fossil fuel power plants.

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