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A Study on Wireless Power Transmission

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ABSTRACT:
Generally, the power is transmitted through wires. This paper describes an original idea to eradicate the hazardous usage of electrical wires which involve lot of confusion in particularly organizing them. Imagine a future in which wireless power transfer is feasible: cell phones, household robots, mp3 players, laptop computers and other portable electronics capable of charging themselves without ever being plugged in, freeing us from that final, ubiquitous power wire. Some of these devices might not even need their bulky batteries to operate. This paper includes the techniques of transmitting power without using wires with an efficiency of about 95% with non-radiative methods. Due to which it does not affect the environment surrounding. These techniques Includes resonating inductive coupling in sustainable moderate range. In this paper, we present the concept of transmitting power wirelessly to reduce transmission and distribution losses. The wired distribution losses are 70 - 75% efficient. We cannot imagine the world without electric power which is efficient, cost effective and produce minimum losses is of great concern.The coupling consists of an inductor along with a capacitor with its own resonating frequency. In any system of coupled resonators there often exists a so-called “strongly coupled” regime of operation. If one ensures to operate in that regime in a given system, the energy transfer can be very efficient. Another technique includes transfer of power through **microwaves using rectennas**. This is particularly suitable for long range distances ranging kilometers. With this we can avoid the confusion and danger of having long, hazardous and tangled wiring. This paper as a whole gives an effective, high performance techniques which can efficiently transmit the power to the required area varying in distances.

KEY WORDS: Wireless Power, Power Transmission, transmitter, receiver, Resonance, non- radiative energy

INTRODUCTION:

The prediction and evidence of the radio wave in the end of 19th century was start of the wireless power transmission. During the same period of Marchese G. Marconi and Reginald Fessenden who are pioneers of communication via radio waves. **Nikola Tesla** is known as the father of wireless transmission.You may have even had to follow one particular cord through the seemingly impossible snarl to the outlet hoping that the plug you pull will be the right one. This is one of the downfalls of electricity. While it can make people's lives easier, it can add a lot of clutter in the process. For these reasons, scientists have tried to develop methods of **wireless power transmission** that could cut the clutter or lead to clean sources of electricity. Researchers have developed several techniques for moving electricity over long distances without wires. Some exist only as theories or prototypes, but others are already in use.

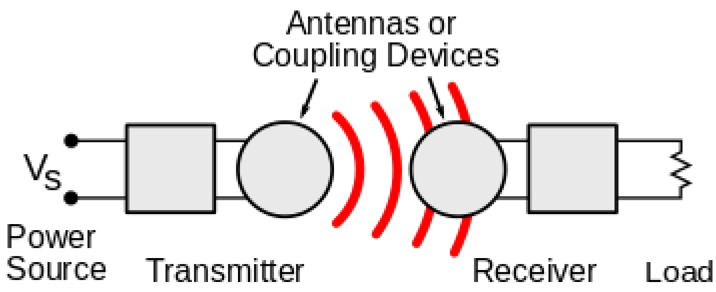


Fig. - Wireless transmission

This paper provides the techniques used for wireless power transmission between the transmitter and receiver. These are: Short range, Moderate range and Long range:

SHORT DISTANCE INDUCTION:

These methods can reach at most a few centimetres The action of an electrical transformer is the simplest instance of wireless energy transfer. The primary and secondary circuits of a transformer are electrically isolated from each other. The transfer of energy takes place by electromagnetic coupling through a process known as mutual induction. (An added benefit is the capability to step the primary voltage either up or down.) The electric toothbrush charger is an example of how this principle can be used. A toothbrush's daily exposure to water makes a traditional plug-in charger potentially dangerous.

Fig. Wireless induction charging

Ordinary electrical connections could also allow water to seep into the toothbrush, damaging its components. Because of this, most toothbrushes recharge through **inductive coupling**. You can use the same principle to recharge several devices at once. For example, the Splash power recharging mat and Edison Electric's Power desk both use coils to create a magnetic field. Electronic devices use corresponding built-in or plug-in receivers to recharge while resting on the mat. These receivers contain compatible coils and the circuitry necessary to deliver electricity to devices' batteries. A Splash power mat uses induction to recharge multiple devices simultaneously.

MODERATE DISTANCE:

RESONANCE AND WIRELESS POWER:

Adaptive Inductive Coupling wireless power transfer technology can be used to charge the electronic objects automatically. The ability of our technology to transfer power safely, efficiently, and over distance can improve products. This principle of wireless electricity works on the principle of using coupled resonant objects for the transference of electricity to objects without the use of any wire.Household devices produce relatively small magnetic fields. For this reason, chargers hold devices at the distance necessary to induce a current, which can only happen if the coils are close together. A larger, stronger field could induce current from farther away, but the process would be xtremely inefficient. Since a magnetic field spreads in all directions, making a larger one would waste a lot of energy. An efficient way to transfer power between coils separated by a few meters is that we could extend the distance between the coils by adding resonance to the equation. A good way to understand resonance is to think of it in terms of sound. An object's physical structure -- like the size and shape of a trumpet -- determines the frequency at which it naturally vibrates. This is its **resonant frequency**. It's easy to get objects to vibrate at their resonant frequency and difficult to get them to vibrate at other frequencies. This is why playing a trumpet can cause a nearby trumpet to begin to vibrate. Both trumpets have the same resonant frequency.Induction can take place a little differently if the electromagnetic fields around the coils resonate at the same frequency. The theory uses a curved coil of wire as an inductor. A **capacitance plate**, which can hold a charge, attaches to each end of the coil. As electricity travels through this coil, the coil begins to resonate. Its resonant frequency is a product of the inductance of the coil and the capacitance of the plates.

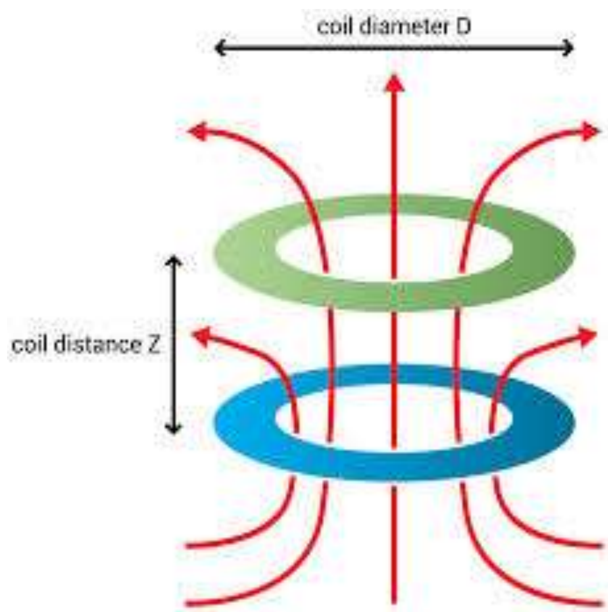
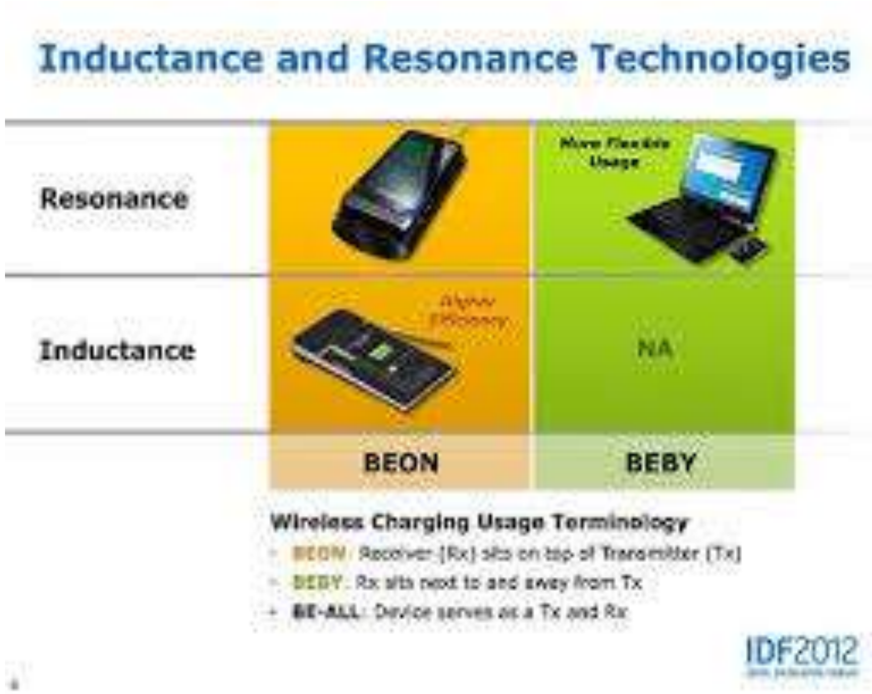


Fig.- inductive Coil

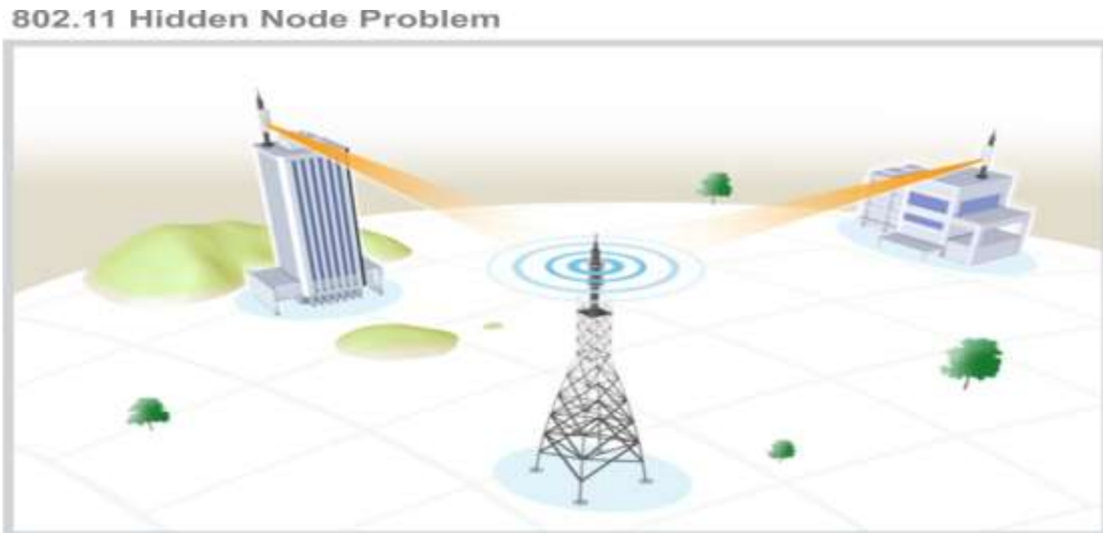
The wireless power project uses a curved coil and capacitive plates.Electricity, traveling along an electromagnetic wave, can **tunnel** from one coil to the other as long as they both have the same resonant frequency. In a short theoretical analysis they demonstrate that by sending electromagnetic waves around in a highly angular waveguide, evanescent waves are produced which carry no energy. An evanscent wave is nearfield standing wave exhibiting exponential decay with distance. If a proper resonant waveguide is brought near the transmitter,the evanescent waves can allow the energy to tunnel (specifically evanescent wave coupling, the electromagnetic equivalent of tunneling to the power drawing waveguide, where they can be rectified into DC power. Since the electromagnetic waves would tunnel, they would not propagate through the air to be absorbed or dissipated, and would not disrupt electronic devices.As long as both coils are out of range of one another, nothing will happen, since the fields around the coils aren't strong enough to affect much around them. Similarly, if the two coils resonate at different frequencies, nothing will happen. But if two resonating coils with the same frequency get within a few meters of each other, streams of energy move from the transmitting coil to the receiving coil. According to the theory, one coil can even send electricity to several receiving coils, as long as they all resonate at the same frequency. The researchers have named this **non-radiative energy transfer** since it involves stationary fields around the coils rather than fields that spread in all directions.



According to the theory, one coil can recharge any device that is in range, as long as the coils have the same resonant frequency."Resonant inductive coupling" has key implications in solving the two main problems associated with non-resonant inductive coupling and electromagnetic radiation, one of which is caused by the other; distance and efficiency. Electromagnetic induction works on the principle of a primary coil generating a predominantly magnetic field and a secondary coil being within that field so a current is induced within its coils. This causes the relatively short range due to the amount of power required to produce an electromagnetic field. Over greater distances the non-resonant induction method is inefficient and wastes much of the transmitted energy just to increase range.This is where the resonance comes in and helps efficiency dramatically by "tunneling" the magnetic field to a receiver coil that resonates at the same frequency. Unlike the multiple-layer secondary of a non-resonant transformer, such receiving coils are single layer solenoids with closely spaced capacitor plates on each end, which in combination allow the coil to be tuned to the transmitter frequency thereby eliminating the wide energy wasting "wave problem" and allowing the energy used to focus in on a specific frequency increasing the range.

LONG-DISTANCE WIRELESS POWER:

Whether or not it incorporates resonance, induction generally sends power over relatively short distances. But some plans for wireless power involve moving electricity over a span of miles. A few proposals even involve sending power to the Earth from space. In the 1980s, Canada's Communications Research Centre created a small airplane that could run off power beamed from the Earth. The unmanned plane, called the Stationary High Altitude Relay Platform (SHARP), was designed as a communications relay. Rather flying from point to point, the SHARP could fly incircles two kilometers in diameter at an altitude of about 13 miles (21 kilometers).Most importantly, the aircraft could fly for months at a time..



Long distance transmission

The secret to the SHARP's long flight time was a large, ground-based microwave transmitter. The SHARP's circular flight path kept it in range of this transmitter. A large, disc-shaped **rectifying antenna**, or **rectenna**, just behind the plane's wings changed the microwave energy from the transmitter into direct-current (DC) electricity. Because of the microwaves' interaction with the rectenna, the SHARP had a constant power supply as long as it was in range of a functioning microwave array.

Rectifying antennae are central to many wireless power transmission theories.They are usually made an array of dipole antennae, which have positive and negative poles. These antennae connect to shottkey diodes. Here's what happens:

1. Microwaves, which are part of the electromagnetic spectrum reach the dipole antennae.
2. The antennae collect the microwave energy and transmit it to the diodes.
3. The diodes act like switches that are open or closed as well as turnstiles that let electrons flow in only one direction. They direct the electrons to the rectenna's circuitry.
4. The circuitry routes the electrons to the parts and systems that need them.

There are many new techniques but we useonly two here:

I)Microwave Generator. The microwave transmitting devices are classified as Microwave Vacuum Tubes (magnetron, klystron) and Microwave Power Module (MPM)) and Semiconductor Microwave transmitters and amplifiers (GaAs MESFET, SiC MESFET, HFET, and InGaAs). Cooker type Magnetron is widely used for experimentation of WPT.

II) Transmitting antenna. The slotted wave guide antenna, micro strip patch antenna, and parabolic dish antenna are the most popular type of transmitting antenna. The slotted waveguide antenna is ideal for power transmission because of its high aperture efficiency (> 95%) and high power handling capability.

II) Rectennas. A rectenna is a rectifying antenna; a special type of antenna that is used to directly convert microwave energy into DC electricity. This concept is discussed in SPS detail.

EFFICIENCY:

The efficiency of wireless power is the ratio between power that reaches the receiver and the power supplied to the transmitter.Researchers successfully demonstrated the ability to power a 60 watt light bulb from a power source that was seven feet (2 meters) away using resonating coils. This kind of setup could power or recharge all the devices in one room. Some modifications would be necessary to send power over long distances, like the length of a building or a city. Power transmission via radio waves can be made more directional, allowing longer distance power beaming, with shorter wavelengths of electromagnetic radiation, typically in the microwave range. A rectenna may be used to convert the microwave energy back into electricity. Rectenna conversion efficiencies exceeding 95% have been realized.Wireless Power Transmission (using microwaves) is well proven. Experiments in the tens of kilowatts have been performed.

NEED FOR WIRELESS POWER TRANSMISSION:

Wireless transmission is employed in cases where instantaneous or continuous energy transfer is needed, but interconnecting **wires are inconvenient, hazardous, or impossible**

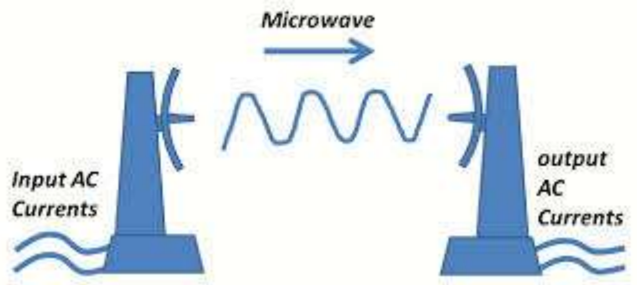
Number of household points receives electricity at the same frequency using single transmitting coil as long as they all are at resonance. So this setup could recharge all the devices in a room at once.

The unmanned planes or robots (where wires cannot be involved viz oceans volcanic mountains etc.) which are run by the wireless power over an area, as they could fly for months at a time, could be used for research as well as a mini satellite.

MICROWAVE:

The principle of the microwave transmission is simple. First, convert electricity to microwaves, then send those microwaves to a receiver stationed somewhere else, and finally convert those microwaves back into electricity. The trick, however, lies in converting electricity to microwaves and vice versa. Microwaves can be generated by the use of a magnetron. A magnetron resonates much like a flute does, except instead of creating sound waves, it produces electromagnetic waves (Woodford). These waves are short radio waves, generally between 1 and 30 cm (Woodford). A magnetron is constructed of a negatively charged cathode (shown in yellow), surrounded by a positively charged anode (shown in red). When the cathode is heated up, electrons are released from it and they make a path for the anode (line 3). However, there is a powerful magnet located underneath the anode, creating a magnetic field parallel to the cathode. Now there is both an electric field from the cathode to the anode, and a magnetic field between the two. Instead of the electron going straight from the cathode to the anode, it is caught in the magnetic field and speeds around in a circle (blue line on picture). These electrons flying by the cavities create a resonance that emits microwave radiation. The microwave radiation is then gathered and sent out by an antenna or satellite dish (the explanation for a magnetron was found on explainthatstuff.com).

Once the electricity has been converted into microwave radiation and has been sent somewhere, it needs to be converted back into electricity for it to be of any use to anyone. This is where the rectenna comes in. The definition given by wisegeek.com for a rectenna is a rectifying antenna, an antenna used to convert microwaves into DC power. It does this through a series of steps. Once the microwave power is received by the individual antenna, it passes through the high frequency rectifying diodes. The diode is then used to convert high frequency power to DC voltage. The electricity is then sent through a low-pass filter before being delivered as the final product of DC power (Karmakar). Rectennas have been created to have efficiency's of 90%, meaning a loss of only 10% (wisegeeks).



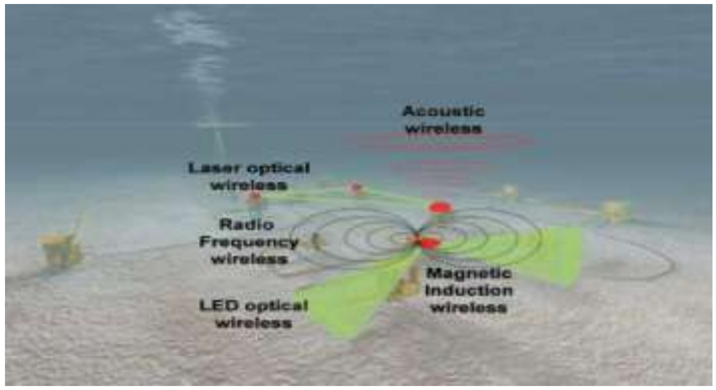
The whole journey of solar energy from space would look something like this. Solar energy is collected by huge solar arrays in space. The solar energy is then converted to microwave radiation and beam it down to a combination rectifier-antenna, called a rectenna, located in an isolated area. The rectenna would convert the microwave energy back to DC (direct current) power (Beam).

Aside from the high costs associated with launching solar panel satellites, another component keeping this idea from fruition is the fear factor that sending microwaves down to Earth has. Many people fear that since an unprotected microwave oven can cause cancer, beaming down microwaves would also do the same thing. Another fear is that anything that crosses through the path of the beam would be fried, be it a hot air balloon or a bird. However, according to Dr. Neville Marzwell, technical manager of the Advanced Concepts & Technology Innovations program at NASA's Jet Propulsion Laboratory, the dangers of being close to the microwave beam would be similar to the dangers of cell phone transmissions, microwave ovens or high-power electrical transmission lines (Beam).

LASERS:

An alternate plan to microwave power transmission would be the use of laser beams. The basic plan would remain essentially the same, with power being collected by solar panels in orbit and then sending energy back down to Earth. Lasers provide an advantage over microwaves in that they do not spread out as much with distance, meaning more of the energy sent is received on target. The main difference between microwave transmission and laser transmission is the wavelength. While microwave transmission uses 2.45 GHz or 5.8 GHz (5 cm, 12cm), laser energy transmission takes advantage of the atmospheric transparency window in the visible or near infrared frequency spectrum (Summerer). Laser energy transmission allows much higher energy densities, a narrower focus of the beam and smaller emission and receiver diameters (Summerer). A smaller receiver diameter means that fewer collector antennas would need to be build.

The use of lasers for transmitting energy has already been proven quite well. The longest distance between emitting and receiving points achieved so far is in the order to hundred kilometers. The largest amount of energy transmitted so far was during an experiment by the US Jet Propulsion Laboratory in 1975, when 30 kW were transmitted from a 26 m diameter parabolic dish to a 1.54 km distant rectenna with 85% efficiency (Summerer). Besides beaming down energy from the heavens, lasers have other uses. Researchers at NASA's Marshall Space Flight Center, Huntsville, Ala., and Dryden Flight Research Center, Edwards, Calif., and the University of Alabama in Huntsville have flight-demonstrated a small-scale aircraft that flies solely by means of propulsive power from an invisible, ground-based infrared laser (Beamed). The demonstration was a key step toward the capability to beam power to an aircraft, allowing it to stay in flight indefinitely — a concept with potential for the scientific community as well as the remote sensing and telecommunications industries (Beamed).



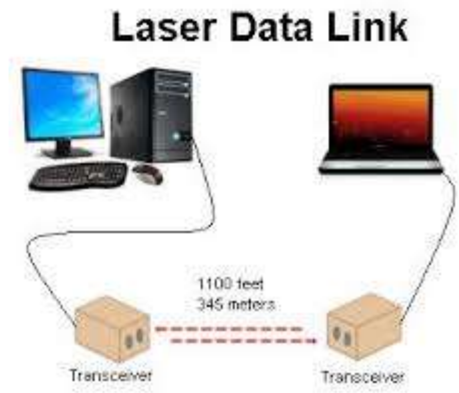
Again, as with microwave transmission of power, there are many fears associated with the transmission of power by lasers. When most people think of a laser beam from space, their first thought is that it's a weapon. And indeed, lasers do have the potential to be used as weapons. One reason the U.S. has not pursued this option as much as it might seem they should is because they have a treaty with Russia that prohibits high powered lasers from space (Beam). However, the risk of a laser transmitting power accidentally wandering across a city and destroying everything in its wake is unlikely. Even still, it is strongly recommended that power beams to Earth be visible (green, for example) so that the general populace can be aware of their steady location when operating (Dickenson). Should a plane fly through the beam on accident, the biggest concern would be that the passengers eyes might be blinded, not that the plane would be zapped up (Dickenson).

WIRELESS ELECTRICITY AT HOME:

Broadcasting electricity for hundreds of miles is just one application of wireless electricity. As the scenario in the introduction showed, another valuable application of wireless electricity would be the charging and powering of everyday household objects, such as phones, computers, TV's, and small kitchen appliances.

Several companies have come up with several different ideas on how to turn this ideal into a reality. Among them are the Powermat, PowerBeam, UBeam, and Witricity. Most of them are taking different approaches to the task of wireless electricity, with varying levels of usefulness.

The Powermat (seen at left) is one of the first wireless chargers to hit the market. When a phone or other such device has been coupled with a Powermat, it only needs to set on the mat to start charging, no plugging in of cords is required. The Powermat uses magnetic induction, the same phenomenon discovered by Michael Faraday decades ago. Electricity in the Powermat creates a rapidly changing magnetic field above the mat, which are converted by receivers in the device into electrical power (Powermat). Despite the Powermat transferring electricity wirelessly, the range between the mat and device must be so small that it is not too much more practical than just plugging the device in. PowerBeam takes a much different approach to the task. PowerBeam uses lasers to transfer electricity in the same way NASA hopes to beam electricity from space, albeit on a smaller scale. Electricity is turned into optical energy (laser) and pointed at the receiver to be turned back into electricity (PowerBeam). While the range of the PowerBeam is considerable more than the Powermat (up to 100 meters), it requires line of sight, meaning you cannot use this technology on a mobile device. Several other approaches to the wireless electricity problem have been made. One of them, UBeam, has a story that is rather unorthodox. 22 year old Meredith Perry is a recent college graduate, and new owner of a company she created, based around a product she invented (Noguchi). Not only does Perry have to worry about the success of her product, she also has to worry about every other aspect of running the business. Her approach to creating wireless electricity is just as unorthodox as her story is. "What happens is, the ultrasound, which vibrates the air, vibrates what's called a piezoelectric transducer," she says. "And what happens is the ultrasound will vibrate the piezocrystals, and the crystals will move back and forth, and that will generate an electrical current" (Noguchi).



In the current race for creating the most practical form of wireless electricity, there appear to be two groups. The first group focuses on distance, and trying to get as much space between sender and receiver as possible. However, this comes at the cost of power. Products such as PowerBeam lack the power to run much more than a lamp, powering a laptop is still a ways off. The other group focuses on getting enough power to devices, but at the cost of distance. The Powermat and other products can power stronger devices, but their wireless range is limited to a few centimeters.

A few proposals even involve sending power to the Earth from space

MERITS:

1. Various methods of transmitting power wirelessly have been known for centuries. Perhaps the best known example is electromagnetic radiation, such as radio waves. While such radiation is excellent for wireless transmission of information, it is not feasible to use it for power transmission. Since radiation spreads in all directions, a
2. vast majority of power would end up being wasted into free space.
3. Wireless Power Transmission system would completely eliminates the existing high-tension power transmission line cables, towers and sub stations between the generating station and consumers and facilitates the interconnection of electrical generation plants on a global scale.
4. It has more freedom of choice of both receiver and transmitters. Even mobile transmitters and receivers can be chosen for the WPT system.
5. The power could be transmitted to the places where the wired transmission is not possible. Loss of transmission is negligible level in the Wireless Power Transmission; therefore, the efficiency of this method is very much higher than the wired transmission.
6. Power is available at the rectenna as long as the WPT is operating. The power failure due to short circuit and fault on cables would never exist in the transmission and power theft would be not possible at all.

DEMERITS:

1. Capital Cost for practical implementation of WPT to be very high.

2. The other disadvantage of the concept is interference of microwave with present communication systems.
3. Common belief fear the effect of microwave radiation.
4. But the studies in this domain repeatedly proves that the microwave 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
5.

APPLICATIONS OF WPT:

1. Generating power by placing satellites with giant solar arrays in Geosynchronous Earth Orbit and transmitting the power as microwaves to the earth known as Solar
1. Power Satellites (SPS) is the largest application of WPT.
2. Moving targets such as fuel free airplanes, fuel free electric vehicles, moving robots and fuel free rockets. The other applications of WPT are Ubiquitous Power
3. Source (or) Wireless Power Source, Wireless sensors and RF Power Adaptive Rectifying Circuits (PARC).
4. Mobility -user device can be moved easily within the wireless range.
5. Neat and easy Installation-since no cable running here and there, just start up the wireless device and you're ready to rumble .

CONCLUSION:

Technological developments in Wireless Power Transmission (WPT), the merits, demerits, applications of WPT are also discussed in this paper. By this we are able to know the
greater possibilities for transmitting power with negligible losses and ease of transmission in the years to come.The crucial advantage of using the non-radiative field lies in the fact that most of the power not picked up by the receiving coil remains bound to the vicinity of the sending unit, instead of being radiated into the environment and lost. Transmitting electricity wirelessly is a new and attractive technology that is turning heads. The purpose of the project is to determine whether this technology would be practical for consumer use without causing any major interferences and maintaining adequate efficiency.With such a design, power transfer for laptop-sized coils are more than sufficient to run a laptop can be transferred over room-sized distances nearly omni-directionally and efficiently, irrespective of the geometry of the surrounding space, even when environmental objects completely obstruct the line-of-sight between the two coils. As long as the laptop is in a room equipped with a source of such wireless power, it would charge automatically, without having to be plugged in. In fact, it would not even need a battery to operate inside of such a room." In the long run, this could reduce our society's dependence on batteries, which are currently heavy and expensive. At the same time for the long range power transmission, power can be sent from source to receivers instantaneously without wires, reducing the cost.

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