Wireless Power Transmission using ISM Band RF Energy Harvesting a Review Paper

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Abstract— At present wireless technology is being used for various applications, reason behind using this technology is that in this technology there is no need of wires for transmission, which reduces the losses occurring in transmission using wires and hence increases the degree of power transmission. Right now we are able to transmit data from one place to another place by using the wireless communication technology, but still there are so many problems which we face during the transmission of power by using of this technique. In this paper, the comparative analysis between existing wireless power transmission technique in terms of inductive, conductive and electromagnetic is presented. There are lots of applications where we need wireless power transmission such as WSN network based controlling unit etc. In this paper we have presented some research issue which can be treted like a future research objective in area of wireless power transmission.

Keywords — *Conduction, Induction, IPT, WPT, WSN, Remotely.*

1. Introduction

The discussion of wireless power transmission as an alternative to transmission line power distribution started in the late 19th century. Both Heinrich Hertz and Nicolai Tesla theorized the possibility of wireless power transmission. Tesla demonstrated it in 1899 by powering fluorescent lamps 25 miles away from the power source without using wires[]. Despite the novelty of Tesla's demonstration and his personal efforts to commercialize wireless power transmission, he soon ran out of funding because it was much expensive to lay copper than to build the equipment necessary to transmit power through radio waves.

"In 1982, Brown (Raytheon) and James F. Trimer (NASA) announced the development of a thin-film plastic rectenna using printed-circuit technology that weighed only one-tenth as much as any previous rectenna". This new, lighter weight rectenna led to the development of the Stationary High Altitude Relay Platform (SHARP). The purpose of the sharp program, as its name suggests, was to develop unmanned aircraft that would maintain a circular trajectory above a microwave antenna field for the purpose of relaying communications from various ground terminals. No commercial development past the prototype stage has been funded.

Despite these advances, wireless power transmission has not been adopted for commercial use except for the pacemakers and electric toothbrush rechargers. However, research are going on many promising applications which may be suitable for wireless power transmission. Fig. 1.1 shows the Sharp system.

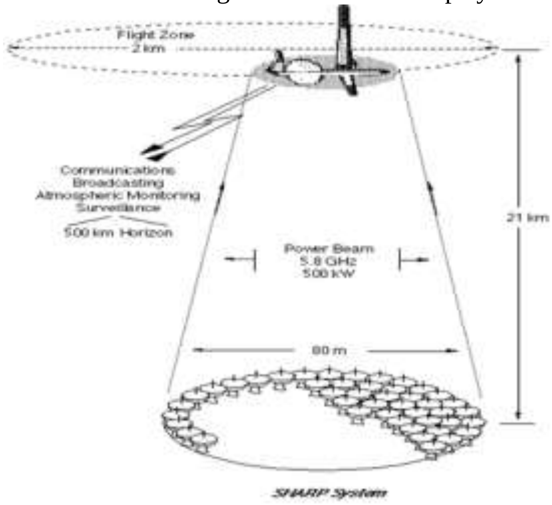

Fig. 1.1 Sharp System

As we know there are two types of power transmission :

- Wire power Transmission
- Wireless power Transmission

The driving force behind system design is the overall system efficiency. Current research on transmission based on the use of microwaves as the frequency range. It is known that efficiency of 54% is currently attainable and 76% is possible using present technology for microwave power transmission. Lower frequency waves would be hard to direct because of their large wavelengths. For transmission efficiency the waves must be focused so that all the energy transmitted by the source is incident on the wave collection device. There are a lot of practical experiences with directional propagation of microwaves from the communications industry. Higher frequencies are also impractical because of the high cost of transmitters and the relative low efficiency of presently used optical and infrared devices. It should be noted that, in this paper the term "low efficiency" is related to the efficiency of energy transfer, not intelligence transfer. The fact that there is a lot of practical experience with microwave technology also makes it cheaper to produce instruments associated with microwave transmission and reception.

Wireless power transmission is further divided into three sub parts, these are:

- Electromagnetic Power Transmission
- Induction Power Transmission
- Magnetic Power Transmission

Each sub part can be further categorized into there sub parts:

- Microwave
- Laser
- Capacitive
- Resonant
- Inductive

This division of wireless power transmission system is show in fig. 1.2, this figure give the details about the classification of WPT system

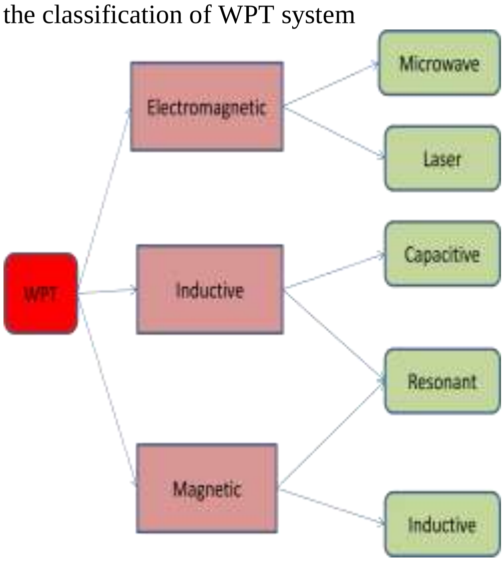

Fig.1.2 Division of wireless power transmission

In this paper, a brief introduction of all the exsisting techniques, used for the wireless power transmisiion is already discussed. Wireless transmission is useful to power electrical devices in cases where interconnecting wires are inconvenient, hazardous or connections are impossible to be made. For example the life of WSN is its node which consists of several device controllers, memory, sensors/actuators,

1.1 **Area where WPT is required:**

Due to the relatively low cost and high efficiency of power line transmission, wireless power transmission is only alternative under two general circumstances: 1) In order to transport necessary power over an impossible or impractical barrier for wires or 2) Rapid deployment of assets for disaster recovery or military operations that could be aided by wireless power transmission more than by local generators. For these reasons most of the researches are focused on those applications that can solve these problems.

Solar Power Satellites (SPS)

The most widely documented area of research is being done with the goal of putting solar power generating satellites into space and transmitting power to Earth stations. The idea was first proposed in 1968 and all of the experiments thus far have only been carried out in terrestrial laboratories.
The SPS satellites would be put in high earth orbit at geosynchronous locations. The high orbit would allow them to receive light 99% of the year. A large rectenna array facility will be built on the Earth to collect the incoming microwaves. In order to maintain a good lock on the rectenna the satellite will need to be built with a retro directive transmitter which locks on to a pilot beam emanated from the ground station.
Since most of the research is done in the 2.4 GHz to 5.8 GHz range there are some spectrum regulatory issues to deal with. Also since the retro directive antenna system is unproven. There is the health concern that the microwave beam could veer off target and microwave some unsuspecting family. However, a Japanese government agency is planning to send up 10 to 100 kW low earth orbit satellite to prove its feasibility.

Inductive Charging

A wide range of research has been devoted to charging low power portable devices such as cell phones via inductive coupling .Palm Inc. (which is now acquired by HP) was the first company to introduce inductive charging for cell phones. The user would place the phone on a wireless charging pad and the phone would charge as if it was charged via a cable. In this type of charging magnets are used to align the receiver with the transmitter in order to ensure that a high coupling coefficient is achieved. No information is available on the topology of the internal circuitry used. One can assume that the charger is capable of delivering up to 5W since the phone can be charged also from a USB connection which has a maximum power of 5 W.

Planetary Exploration

An IPT can be deployed in remote, dangerous and inhabitable environments to provide power to a swarm of autonomous ground and air vehicles that perform miscellaneous tasks. For instance the system can be used on Mars to provide power to a swarm of rotor drones or robots that are performing scientific tasks. Power supplies could be sent regularly to the planet at reduced costs. Since the entire system including the rotor drones and the robots can be autonomous, minimum or no human interaction should be involved, therefore reducing the maintenance requirements is essential in this case. A major issue that leads to an increase in maintenance requirements is the use of electrical connections. The tear and wear due to the forces and pressures that result from docking operations as well as erosion and oxidation can increase the contacts' resistances and can significantly affect the amount of current that they can carry. Therefore, replacing contacts with a contactless or a wireless power transfer system can eliminate these maintenance requirements and can significantly increase the service life of the system.

Wireless Sensor Networks

The deployment of sensors to monitor and record physical and environmental conditions in spacious areas might cause difficulties in providing power to them. In many cases having long power cables or batteries that need replacement is not feasible. A remote controlled vehicle could be sent to those sensors recharging their batteries wirelessly. A drone could be sent to a remote location to recharge the batteries of underground and over ground sensors.

Grid Monitoring

Remote controlled drones provide a low cost, effective and safe method for routine health monitoring of overhead power transmission lines and towers. An onboard camera records and streams video which is then assessed by engineers and technicians to report for faults and maintenance requirements. The capacity of the battery packs installed on such drones limit their flying and operating time to 15-20 minutes. This requires the drones to return and recharge or replace their battery packs. Consequently, the range of operation, monitoring and surveillance capability of theses drones are reduced.

1.2 Wireless Power Transfer Systems

The history of wireless power transmission dates back to the late 19th century with the prediction that power could be transmitted from one point to another in free space by Maxwell in his "Treatise on Electricity and Magnetism". Heinrich Rudolf Hertz performed experimental validation of Maxwell's equation which was a monumental step in the direction. However, Nikola Tesla's experiments are often considered as being some of the most serious demonstrations of the capability of transferring power wirelessly even with his failed attempts to send power to space [6].

Classification of wireless power transfer systems

Wireless power transfer systems can be classified into different types depending on various factors. On the basis of the distance from the radiating source, the characteristics of the EM fields change and so are the methods for achieving wireless power transfer. They can be categorized as:
1. Near field
2. Mid field
3. Far field

In case of near field radiation, the boundary between the regions is restricted to one wavelength. In the transition zone, the boundary between the regions is between one to two wavelengths of electromagnetic radiation. In case of far field, the distance between the radiating source and the receiver is more than twice the wavelength of the radiation.

Based on the mode of coupling between the transmitter and the receiver, wireless power transfer techniques can be classified into the following:
1. Electromagnetic induction (Resonant Inductive Power Transfer)
2. Electrostatic induction (Resonant Capacitive Power Transfer)
3. Far field transfer techniques (Laser and Microwave Power Transfer)

1.2.1. Electromagnetic induction

Electromagnetic Inductive Power Transfer (IPT) is a popular technique of transferring power wirelessly over a short range. This technique of transferring power derives its capability from the two fundamental laws of physics: Ampere's law and Faraday's law. The functioning of such IPT systems is based on the changing magnetic field that is created due to alternating currents through a primary that induce a voltage onto a secondary coupled by means of air. In order to improve the efficiency of power transfer, resonant mode coupling of the coils is established by means of capacitive compensation. This technique is one of the most popular for wireless power transfer and has found vast applications including powering consumer devices, biomedical implants, electric mobility, material handling systems, lighting applications and contactless underwater power delivery among many others.

1.2.2. Electrostatic induction

Capacitive Power Transfer (CPT) is a novel technique used to transfer power wirelessly between the two electrodes of a capacitor assembly [6]. It is based on the fact that when high frequency ac voltage source is applied to the plates of the capacitor that are placed close to each other, electric fields are formed and displacement current maintains the current continuity. Thus, in this case the energy carrier media is the electric field and hence the dual of IPT. Some of the features that CPT has compared to IPT are [6]:

1. Energy transfer can still continue even on the introduction of a metal barrier as it would result in a structure consisting of two capacitors in series.
2. Most electric fields are confined within the gap between the capacitors and hence EMI radiated and power losses are low.
3. The requirement for bulky and expensive coils doesn't exist and hence, the circuit can be made small.

In every WPT system there is need of Transceivers and battery. The transceiver can operate in four states, i.e. 1) Transmit 2) Receive 3) Idle and 4) Sleep. The major energy problem of a transmitter of a node is its receiving in idle state, as in this state it is always being ready to receive, consuming great amount of power.

However, the battery has a very short lifetime and moreover in some deployments, owing to sensor location, battery replacement may be both practically and economically infeasible or may involve significant resists to human life. That is why energy harvesting for WSN in replacement of battery is the only and unique solution. In wireless power transfer, a transmitter device connected to a power source, such as the mains power line, transmits power by electromagnetic fields across an intervening space to one or more receiver devices, where it is converted back to electric power and utilized. In communication the goal is the transmission of information, so the amount of power reaching the receiver is unimportant as long as it is enough that the signal to noise ratio is high enough that the information can be received intelligibly. In wireless communication technologies, generally, only tiny amounts of power reach the receiver. By contrast, in wireless power, the amount of power received is the important thing, so the efficiency (fraction of transmitted power that is received) is the more significant parameter.

2. LITERATURE REVIEW

2.1 HISTORY

The literature review of WPT technologies will include the theoretical background and system concept. There are three basic methodologies to achieve wireless power transmission. They are longitudinal acoustic compression wave, inductive resonance coupling and electromagnetic propagation coupling. WPT by longitudinal acoustic compression wave was discontinued, therefore only a brief description is available as follows. The inductive resonance coupling and electromagnetic propagation coupling are modern methodology to achieve wireless power transmission. Both technologies will be described in detail latter.

In 1826 André-Marie Ampère developed Ampère's circuital law showing that electric current produces a magnetic field. Michael Faraday developed Faraday's law of induction in 1831, describing the electromagnetic force induced in a conductor by a time-varying magnetic flux. In 1862 James Clerk Maxwell synthesized these and other observations, experiments and equations of electricity, magnetism and optics into a consistent theory, deriving Maxwell's equations. This set of partial differential equations forms the basis for modern electro magnetics, including the wireless transmission of electrical energy[9] . The capital cost for particle implementation of WPT seems very high WPT may cause interference with present communication systems. Biological Impacts Common beliefs fear the effect of microwave radiation. But the studies proven that the microwave radiation level would be never higher than the dose received while opening the microwave oven door, meaning it slightly higher.

2.2Tesla's experiment

Tesla demonstrated wireless power transmission in a lecture at Columbia College, New York, in 1891. The two metal sheets are connected to his Tesla coil oscillator, which applies a high radio frequency oscillating voltage. The oscillating electric field between the sheets ionizes the low pressure gas in the two long Geissler tubes he is holding, causing them to glow by fluorescence, similar to neon lights. Experiment in resonant inductive transfer by Tesla at Colorado Springs 1899. The coil is in resonance with Tesla's magnifying transmitter nearby, powering the light bulb at bottom (right side) Tesla's unsuccessful Wardenclyffe power station. Inventor Nikola Tesla performed the first experiments in wireless power transmission at the turn of the 20th century, and may have done more to popularize the idea than any other individual. In the period 1891 to 1904 he experimented with transmitting power by inductive and capacitive coupling using spark-excited radio frequency resonant transformers, now called Tesla coils, which generated high AC voltages. With these he was able to transmit power for short distances without wires. In demonstrations before the American Institute of Electrical Engineers and at the 1893 Columbian Exposition in Chicago he lit light bulbs from across a stage. He found he could increase the distance by using a receiving LC circuit tuned to resonance with the transmitter's LC circuit. using resonant inductive coupling. At his Colorado Springs laboratory during 1899–1900, by using voltages of the order of 10 megavolts generated by an enormous coil, he was able to light three incandescent lamps at a distance of about one hundred feet. The resonant inductive coupling which Tesla pioneered is now a familiar technology used throughout electronics and is currently being widely applied to short-range wireless power systems.[1] Here we presents some of the research on this area.

Energy harvesting:

Energy harvesting In the context of wireless power, energy harvesting, also called power harvesting or energy scavenging, is the conversion of ambient energy from the environment to electric power, mainly to power small autonomous wireless electronic devices.[6] The ambient energy may come from stray electric or magnetic fields or radio waves from nearby electrical equipment, light, thermal energy (heat), or kinetic energy such as vibration or motion of the device. Although, the efficiency of conversion is usually low and the power gathered often of minuscule (miliwatts or microwatts). This new technology is being developed to eliminate the need for battery replacement or charging of such wireless devices, allowing them to operate completely autonomously. Fig. 1.3 Shows energy harvesting system .

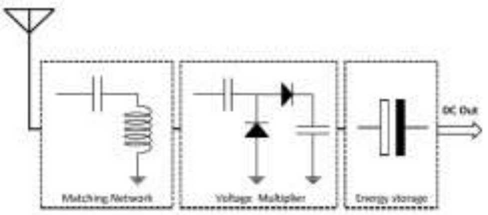

Fig. 1.3 Energy Harvesting System

Kavuri 2012[11] presents an optimization of the voltage doubler stages in an energy conversion module for Radio Frequency (RF) energy harvesting system at 900 MHz band. The function of the energy conversion module is to convert the (RF) signals into direct-current (DC) voltage at the given frequency band to power the low power devices/circuits. The de- sign is based on the Villard voltage doublers circuit. A 7 stage Schottky diode voltage doublers circuit is designed, modeled, simulated, fabricated and tested in this work.

Gianfranco[12]presntes an idea according to that designing, measuring and testing an antenna and rectifier circuit (RECTENNA) optimized for incoming signals of low power density. The rectenna is used to harvest electric energy from the RF signals that have been radiated by communication and broadcasting systems at ISM band centered in 2.45 GHz. Venkateswara 2013[13] present the concept of transmitting power without using wires i.e., transmitting power as microwaves from one place to another is in order to reduce the cost, transmission and distribution losses. This concept is known as Microwave Power transmission (MPT). They also discussed the technological developments in Wireless Power Transmission (WPT).

Allen [14] presents a design and experimental implementation of a power harvesting met materials. There proposed design is working in the frecquency of 900MHz.

Tamal[15] presents a simulated and designed 1,7 & 9-stage voltage multipliers which led to the final statements that :1) Higher voltage can be achieved by increasing the number of circuit stages; and 2) Voltage gain decreases with increasing number of stages. Zahriladha[16] presents an overview and the progress achieved in RF energy harvesting, which involves the integration of antenna with rectifying circuit. Different combinations of antenna and rectifier topologies yield diverse results. Therefore, this study is expected to give an indication on the appropriate techniques to develop an efficient RF energy harvesting system.

Nahida[15] presents an optimization of the voltage doublers stages in an energy conversion module for Radio Frequency (RF) energy harvesting system at 950 MHz band is presented. Two 10 stage voltage multipliers were designed and the Agilent diode HSMS-2850 and HSMS-2822 were compared, Agilent’s HSMS-286x family of DC biased detector diodes have been designed and optimized for use from 915 MHz to 5.8 GHz.

Prusayon[16]presents a twofold contribution. First, they propose a dual-stage energy harvesting circuit composed of a seven-stage and ten-stage design, the former being more receptive in the low input power regions, while the latter is more suitable for higher power range. TARIS [19] presents a guideline to design and optimize a RF energy harvester operating in ISM Band at 902 MHz. The circuit is implemented on a standard FR4 board with commercially available off-the-shelf devices. The topology of the impedance transformation block is selected to reduce the losses which improves the overall performances of the system.

1.3. Problems In Previous Research:

Wireless power transmission is new and progressive area, as we are living in the era of wireless communication. So there is need of wireless power transmission system. But previous existing wireless power transmission is have some limitations are problem. According to previous coil based magnetic induction is very dangerous for human life. But still with some good efficiency & modification there is some PAD based charger is available which is based on magnetic induction. But those charger have the limitation of distance. Now for complete wireless power transmission is under research area. Some researchers are present there model which is based on WPT (wireless power transmission) but those approach are having the issue with distance, efficient power generation, radiation issue & costing issue

1.4. Future Scope on WPT:

As we already see there are lots of issues associated with presently existing approaches. So in this section we represents the future objectives those objectives are followings:

- **Try to make sufficient amount of Distance.**
- **Try to make sufficient amount of Voltage.**
- **Try to make sufficient amount of Current.**
- **Try to reduce the costing of the design.**

7.Conclusion

As we already see different techniques of wireless power transmission. Right now commercially there is PAD based charger is available which is act like wireless power transmitter but still that approach is not having sufficient distance. The concept of wireless power transmission offers greater possibilities for transmitting power with negligible losses. In the long run, this could reduce our society's dependence on batteries, which are currently heavy and expensive. In this paper we try to perform a comparative study on the previous existing wireless power transmission approach and according to our study we can say there islots of future scope is which will reduce the current issue of WPT.

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