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Short communication paper

Microwave Engineering: A Panacea for Wireless Power Transmission

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ABSTRACT: This paper presents the concept of transmitting power wirelessly using microwave. In this paper, magnetron is used for DC to microwave signal conversion after the AC signal has been rectified with the aid of diodes. The rectenna in turn is applied here as a microwave- to- DC converter while inverter is used to transform the DC back AC at the receiver end.

Keywords: Wireless power transmission, rectenna, klystron, magnetron, inverter, microwave
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INTRODUCTION

Microwave is referred to as electromagnetic energy with frequency higher than 1 gigahertz and so, microwave engineering is the study and design of microwave circuits, components and systems. Wireless power transmission through microwave is a fast growing technology in this modern world. Power can be transmitted from one location to another without wires. Thus, power generated at a point as an alternating current (ac) power supply can be converted to direct current (dc) using rectifiers, and then, converted into microwave energy using klystron and magnetron.

A rectenna is used to convert the microwave power back to direct current (DC) power. A rectenna is a passive element with rectifying diodes that operates without an internal power source. It is capable of receiving and rectifying microwave power to DC power. Microwaves are unique among electromagnetic waves in that their wavelength is of the same order of magnitude as the dimensions of the apparatus in which they are used. Microwaves may be propagated along hollow tubes and formed into a sharp beam by means of horns or parabolic reflectors of moderate size.

The wireless energy can be collected by the antenna attached to the rectifying diodes through filters and matching circuit. The rectifying diodes convert the received wireless energy into DC power. The low-pass filter will match the load with the rectifier and block the high order harmonics generated by the diode in order to achieve high energy conversion efficiency which is the most important parameter of such a device.

Related works

According to Brown (1984), Raytheon created the rectifying antenna, also known as the rectenna. This device was made up of a half-wave dipole antenna and a balanced bridge or single semiconductor diode that was positioned above a reflecting plane. After that, a resistive load is attached to the rectenna element's output. The transmitting frequency of 2.45 GHz was widely used because of its advanced and efficient technology base. Also, its location at the centre of an industrial, scientific, and medical (ISM) band and due to its minimal attenuation through the atmosphere even in heavy

rainstorms. The conversion efficiency of the rectenna was increased at this frequency between 1960's to the 1970's. Joshua (1961) published the first paper proposing microwave energy for power transmission, and in 1964 he demonstrated a microwave-powered model helicopter that received all of the power needed for flight from a microwave beam at 2.45 GHz from the 2.4GHz - 2.5GHz frequency band, which is reserved for Industrial, Scientific, and Medical (ISM) applications.
Tesla, (1893), demonstrated the illumination of vacuum bulbs without using wires for power transmission at the World Columbian Exposition in Chicago.

Brown, in 1961 published the first paper proposing microwave energy for power transmission, and in 1964 he demonstrated a microwave-powered model helicopter that received all the power needed for flight from a microwave beam at 2.45 GHz from the range of 2.4GHz – 2.5 GHz frequency band which is reserved for Industrial, Scientific, and Medical (ISM) applications.
Vikash (2011) used resonant induction to wirelessly transmit electricity but was only able to wirelessly power a 60watt bulb for three feet with a 75 percent efficiency. He then experimented with widely spread coils, sending electricity to a coil that was working at 3.6KW but only receiving 800watts at the receiver. As a result, the biggest disadvantage was the amount of energy lost during the process.

METHODOLOGY

This section presents the methodology developed for transmitting ac power wirelessly from one point to another using microwave transmission. Figure 1 shows a block diagram of the wireless power transmission. At the transmission side, the alternating current (ac) source is converted to direct current (dc) using diodes (rectifiers). The rectified dc output is fed to the dc to microwave converter which is made of magnetron and transmission antenna.

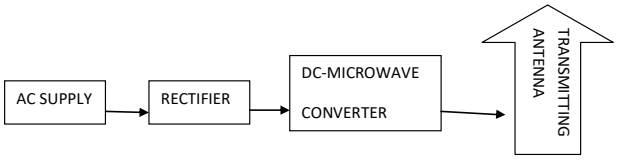

Figure 1: Wireless Power Transmitter Block Diagram.

The ac to dc conversion circuitry is shown in (Figure 2), in this circuit, the ac voltage is fed to the bridge rectifier, during the positive half cycle of the ac, diode D_2 and D_3 conduct since they are forward biased. Similarly, during the negative half cycle of the ac signal, diodes D_1 and D_4 conduct. The rectified output is filtered by the capacitors as shown in the diagram.

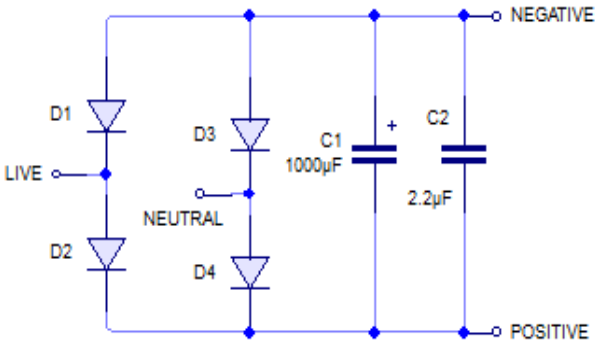

Figure 2: AC to DC Conversion.

In some cases, the ac source is connected to the magnetron through its rectifying circuitry as is the case in (Figure 3), the microwave power source generates microwave power and the output power is controlled by electronic control circuits.

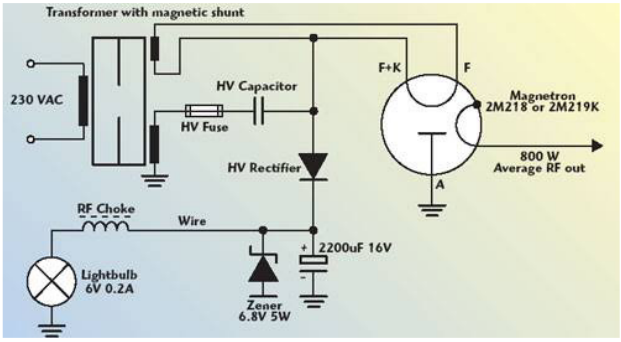

Figure 3: Microwave Transmitter.

The output of the DC – microwave converter is transmitted to the space through the transmitting antenna. The transmitting antenna is the slotted wave guide antenna. This is because it is ideal for power transmission because of its high aperture efficiency (> 95%) and high power handling capability as shown in (Figure 4).

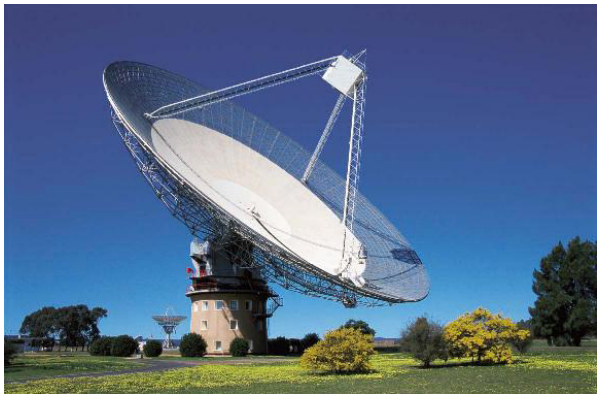

Figure 4: Microwave Antenna.

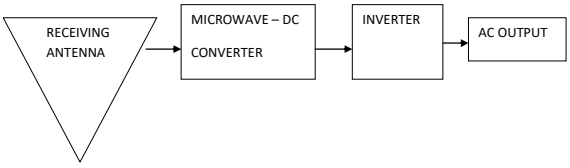

Figure 5: Wireless Power Receiver Section.

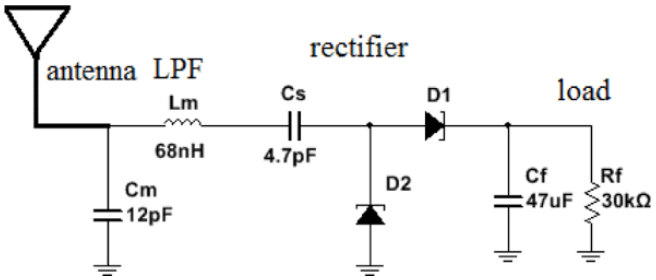

Figure 6: The Rectenna.

Similarly, at the receiving end, the microwave antenna receives the transmitted microwave signal and the signal is converted to direct current DC by the microwave – DC converter. This converted DC output is fed to an inverter, which in turn converts the DC back to AC to be used by the AC electrical appliances as shown in the block diagram of (Figure 5).

The circuit diagram of the rectenna used at the receiver end is shown in (Figure 6). It comprises a microwave antenna, a low pass filter (LPF) and a rectifier. The LPF passes signals with frequency lower than cut off frequency while attenuating signals with frequency higher than the cut off frequency. The dc output can be utilized directly by a dc powered appliance; otherwise the dc output is connected to an inverter which converts it to alternating current (ac).

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. It has more freedom of choice of both receiver and transmitters. The cost of transmission and distribution become less and the cost of electrical energy for the consumer also would be reduced. The power could be transmitted to the places where the wired transmission is not possible. Loss of transmission is at negligible level in the Wireless Power Transmission; therefore, the efficiency of this method is very much higher than the wired transmission.

It is important to state that power transmission through microwave is useful especially, in the river line areas, where it becomes difficult to plant electric poles on water in order to supply power to the next town. Thus, a microwave transmitter can be installed in the power generating town and is transmitted to the receiving town using microwave link. It is also important to note that the effect of microwave radiation can never be higher than the dose received while opening the microwave oven door, so it is not harmful.

The most common transmitters for microwaves are the Travelling Wave Tube (TWT), klystron and magnetron. The TWT is far too expensive and power restrictive making it impractical for the task of power transmission. The klystron has been the DC to microwave converter of choice however it is also somewhat expensive.

But in magnetron, power transmission is more lenient to frequency fluctuations and it is cheap.

Contribution to knowledge

After a systematic design methodology has been carried out, it can be said that the use of magnetron to convert direct current to microwave and the inclusion of an inverter at the receiver to convert dc to ac is a contribution to knowledge. The direct current (dc) generated by the rectenna is converted to alternating current (ac) by the inverter so as to be used for home and industrial appliances.

Conclusion

The importance of wireless power transmission can not be over emphasized. It makes it easier to transmit power from one location to another especially when it might not be convenient to use wires. It makes it easier for a home and an office to share the same power supply over a long distance devoid of flying electrical wires. With microwave power transmission, electricity supply can be transmitted and distributed across oceans to the next city without planting poles and flying wires.

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