ISSN 2229-5518

Underground Microwave Power Transmission

A.Rajesh kumar, R.Hariharan

Abstract— This paper proposes the concept of underground microwave power transmission using wave guides. The main aim of this proposal paper is to overcome the drawbacks of existing microwave power transmission methods. Thereby losses are minimized and efficiency is increased. The wireless power transmission (WPT) stands one among the top 10 trending research areas in the development of everyday science and technology. Among several methods of WPT, MICROWAVE POWER TRANSMISSION (MPT) is more efficient method when compared with others. In this paper, the method of underground MPT is explained with block diagram. Each element of block diagram is mentioned in detailed. The merits, demerits and impacts on living things are also discussed.

Keywords: wireless power transmission, electromagnetic spectrum, microwave power transmission, wave guides, magnetron, rectenna,schottky diode

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1 INTRODUCTION

The technology of wireless power transmission came into existence in 19th century. Nikola tesla designed wardenclyffe tower on which a ball shaped coil is placed and resonated at 150 KHz [1]. James C. Maxwell found radio waves by mathematical model, which plays a major role in communication system. Wiring system has its own drawbacks such as losses and faults in transmission lines by short circuit, low insulation resistance, low mechanical strength. At every place the transmission and distribution system should have protection and switching devices. Even Power theft can also be considered as a drawback. Thereby efficiency is decreased to 60-70%.

These problems in wiring system make scientists to look over the wireless power transmission system as an alternative. Several re-searches are under process to improve efficiency and for making simplest solution. Here comes the high efficient wireless power transmission method using microwaves, in which power can be transmitted to long distances. In 1961, Brown proposed the microwave power transmission for the first time. He demonstrated a microwave powered model helicopter that received power microwave beam at 2.45GHz frequency [2].

2. WIRELESS POWER TRANSMISSION:

As researches moves on day by day regarding wireless power transmission several methods has been discovered. Here are some of the methods

2.1 Mutual inductance (short range) works on the principle of transformer in which primary coil and secondary coil plays a key role. They are not physically connected but magnetically coupled. When supply is given to the primary winding, flux is produced in the primary due to alternating current. This flux links with secondary coil and so emf is induced in the secondary.

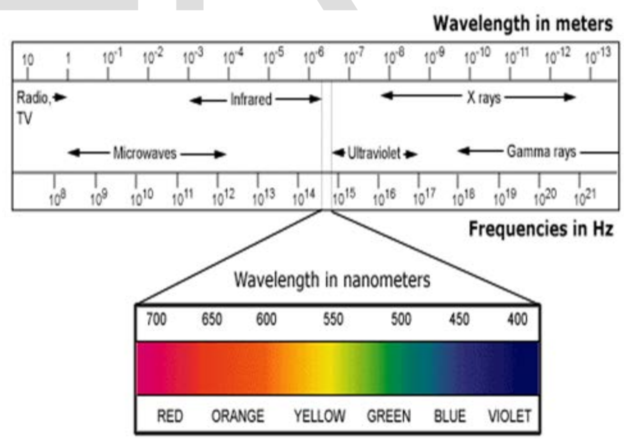
2.2 Resonant inductive coupling [3] (moderate range) consists of two coils, primary and secondary. The primary coil is resonated at certain frequency and if secondary also resonated with same frequency then electrical energy transfers to secondary.

2.3 Laser power transmission [4] is used to transfer power from a transmitter to receiver in a straight line (point to point transfer). There should not be any obstacle in between transmitter and receiver.

2.4 MICROWAVE power transmission (long range) is more efficient method. Here the electromagnetic waves are transmitted at frequency ranging from 1 GHz– 40 GHz.

3. Microwave power transmission:

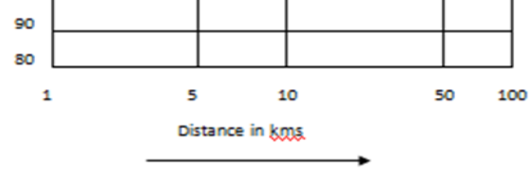
The Wave Length (λ) of Microwaves lies between 1mm –1m. The electrical energy is converted into microwaves using microwave generator and transmitted to longer distances. At receiving end the mi-crowaves are converted into electrical energy using rectenna .The fre-quency of microwaves in electromagnetic spectrum are shown in following figure.



Electromagnetic spectrum

4 .Existing methods:

4.1 Solar power satellite (sps) is a proposal in which micro waves are used for transmission. Sps consists of a solar panel arranged in a satellite. It receives solar power from sun and gives DC output. This DC output is converted to microwaves using microwave generator. The high beamed microwaves are transmitted through space to earth. A large rectenna is installed on the earth. The rectenna receives microwaves and convert microwaves to DC output. At last the output is sup-



plied to load [6].

4.2 Microwave power is transmitted as energy packets from main stations to consumers. The main station transmits microwave at higher frequencies by transmitter and the consumers should have rectenna which converts microwaves to electrical energy .This method is as like DTH service.

4.3 Over head microwave transmission with waveguides mounted on top of the towers at regular intervals [5].

5. Draw backs in existing methods:

There are several drawbacks that should be considered.

5.1 For any system to be designed, the first and foremost thing to be considered is human safety. It has biological impacts on living things. Microwaves produce electromagnetic radiation. If these moves in free space, it causes severe Skin Diseases and may lead to cancer.

5.2 The right of way factor should be considered as drawback for over head microwave transmission using waveguides. The area of land required is more and it also need maintenance, thereby it is less economical.

5.3 Interruption of other waves decreases the efficiency, rainfall also decreases efficiency.

5.4 Since transmission is through space it has considerable losses known as free space losses. Increase in distance increases losses.

Free space losses are given by following equation

$(P_t/P_r) = (4\pi d)^2/\lambda^2 = (4\pi f d)^2/c^2$

Where Pt is transmitting power
Pr is receiving power
d is transmission distance,
λ is wave length,
f is carrier frequency,
c is speed of light $(3*10^8)$m/s [10]

5.5 The losses at microwave frequency can be shown by the following semi log graph plotted between losses and distance.

Loss equation is given by

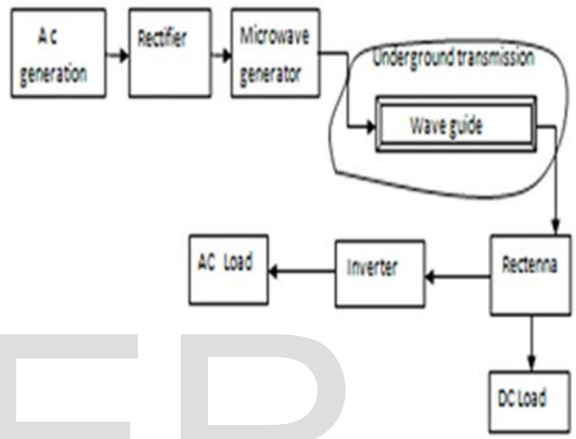
$L_{db}=20\log(\lambda)+20\log(d)-10\log(A_t A_r)$

Where A_t is effective area of transmitting antenna,
A_r is effective area of receiving antenna [10].

6. Proposed method:

The transmission of micro waves using wave guides that are installed under the ground. This method is proposed mainly to overcome the drawbacks of existing methods. In this method efficiency can be increased.

6.1 Block diagram:



We receive AC power from AC generator and by using rectifier, AC is converted to DC. Since we use magnetron as a microwave generator, it needs DC input.

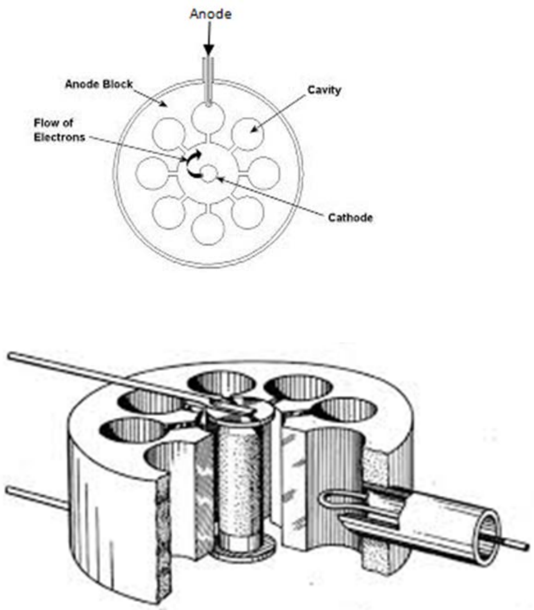
6.2 Microwave generator:

Microwave generator is used to produce microwaves for transmission. Some of the microwave generators are magnetron (2.45GHz), klystron, travelling wave tube, microwave power module, semiconductor microwave transmitters and amplifiers (GaAs MESFET, Sic MESFET, HFET and InGaAs) [7]. But here we considered magnetron as microwave generator.

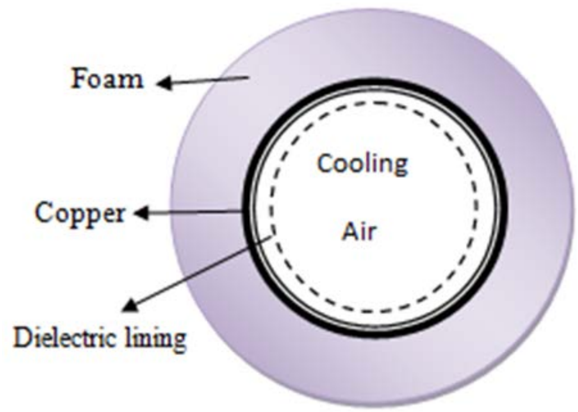
DC is converted to microwaves by magnetron. The magnetron consists of anode and cathode. When electrons (negatively charged particles) are injected to magnetron, they reach negative end due to attraction and they are pushed back. The electron bounces back & forth between anode and cathode that increases speed of electrons.

Magnets are used in magnetron to build magnetic field around electrons. This causes them to be pushed in a circular motion in the cavity. In this way, they produce cycles per second, which is nothing but frequency [7]. Through which microwave output is obtained.

ISSN 2229-5518



Inner cavity of magnetron



Foam wave guide

The transmission medium can be preferred is foam wave guide. It transfers microwaves with high efficiency and to longer distances.

6.3 Transmission medium:

Transmission of microwaves from magnetron to rectenna needs wave guides. Wave guides are hollow metallic pipe like structures used to transfer electromagnetic waves. Since wave guides are closed structures no losses or less losses. Using wave guides we can overcome drawbacks of over head transmission.

Some of the wave guides are rectangular wave guides, circular wave guides and foam wave guide e.t.c. Any waveguide can be used for transmission, but they have their own drawbacks.

Here it is preferable to use foam wave guides when compared to others. Even though we can use rectangular and circular wave guide, due to certain losses that occur inside wave guide they are not preferable. Due to increase in dimensions of rectangular wave guide, it is not suitable to operate at low frequencies. It is preferable to operate at narrow bandwidth. Both rectangular and circular waveguides are bulky, not flexible and not economical [9]. The circular wave guide undergoes field distribution (electric and magnetic fields) in several modes of operation [5]. Change in modes of operation leads to considerable losses [5]. To avoid such losses foam wave guide is preferred.

At 1-40GHz frequency, losses due to attenuation over distance (d) at Wave length (λ) is expressed as

$$L= 10 \log (4\pi d / \lambda)^2 \text{ db.}$$

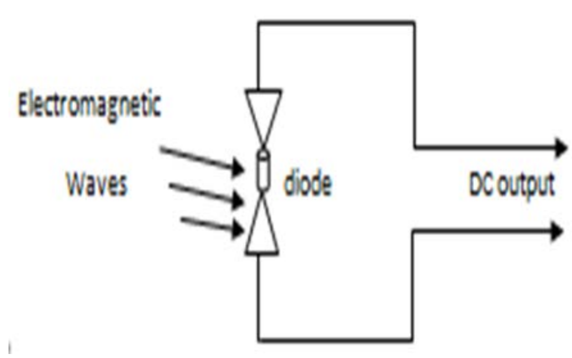
Where $d= 7.14\sqrt{Kh}$, K=adjustment factor due to earth curves.

Foam wave guide is made of polyurethane foam, reinforced by fiberglass skin. This is not made up of metal, it weighs much less than metallic or ceramic wave guides. It consists of thin coat coating of copper to support electromagnetic fields. It also consists of Teflon dielectric lining with thickness, which depends upon radius of curvature. Cooling air is present inside the guide which acts as good heat insulator to carry the heat out [5]. It is flexible wave guide.

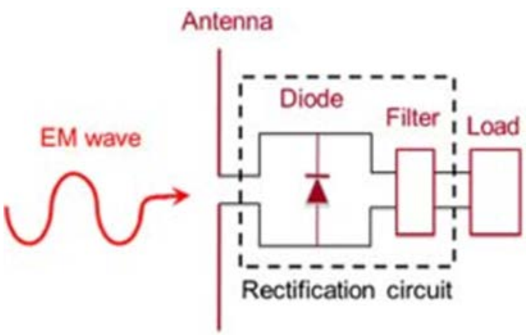
6.4 Rectenna :

Rectenna is a microwave receiver or antenna. It was conceived by W.C. Brown of Raytheon Company in 1960s. The name itself specifies rectifying antenna. It converts microwave energy into electrical energy (i.e microwaves to DC). It has low pass filter in between antenna (dipole) and rectifying diode. The dipole antenna has high efficiency than others. Due to immediate recovery time, less forward voltage drop and good Rf characteristics, schottky barrier diodes (Ga As-W, Si, Ga As) are generally used depending upon frequency range, in rectifying circuit.

A dipole antenna with a schottky diode placed across dipole elements. The diode rectifies microwaves (AC) to DC power. We can obtain efficiency over 95% using amplifiers [8].



Rectification



Antenna gain is given by
Gain (G) = $(4\pi A_e / \lambda^2)$
= $(4\pi f^2 A_e)/c^2$
Where A_e =effective area,
λ=wave length,
f=carrier frequency and
C= speed of light ($3*10^8$ m/sec)

7. Conclusion and future scope:

Due to some considerable drawbacks and effects of microwave power transmission in free space, the proposal idea of underground Microwave power transmission stands ahead. The primary installation cost of transmission medium under the ground may be high, but it has its own advantages. Further work on this paper will be helpful to design a real time system in future which acquires pollution free, efficient and effective power transmission.

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