WIRELESS POWER TRANSMISSION THROUGH SOLAR POWER SATELLITES (S.P.S)

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Abstract

In this paper we present the concept of Solar Power Satellite. In this seminar report the Solar cells in the Satellite convert Sun light into Electrical energy, which will changed to radio frequency energy, then the beam to receiver site on earth and reconverted to electricity by using antenna with the technology of wireless power transmission (i.e, transmitting power as microwave in order to reduce the transmission and distribution losses).This concept is also known as Microwave Power Transmission. The advantages, disadvantages, impacts and applications are also included

INTRODUCTION:

Can't we use solar power at the night? This question may look somewhat absurd since there is obviously no meaning of "Using solar power at night"! Now-a-days we are using the solar power to generate electricity by the solar panels mounted on the earth. But, in outer space, the sun always shines brightly. No clouds block the solar rays, and there is no nighttime. Solar collectors mounted on an orbiting satellite would thus generate power 24 hours per day, 365 days per year. If this power could be relayed to earth, then the world's energy problems might be solved forever. We propose a new method for power generation in which the solar power is converted into microwaves through satellites called Solar Power Satellites (SPS) and it is received using a special type of antennae called rectenna, mounted on earth surface.

The concept of free space power propagation is not a new concept and it is the topic of discussion for nearly four decades. In this paper we explain the same for the generation and reception of electrical power using the rectennas. Rectennas are special type of antennae that could convert the incoming microwave radiation into electricity and this electricity can be sent to grids for storage and future usage.

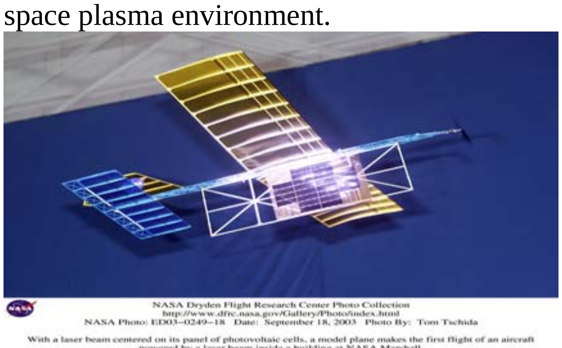
The paper first discusses about the history of free space power transmission and gives a brief introduction to the rectenna concept. The important component of the rectenna, the Schottky barrier diode is explained. Then the functional model for the Solar Power Satellite is explained. The importance of the solar energy is explained both in terms of the cost and its echo friendly nature. The paper is concluded explaining our model of a simple rectenna, which could be readily built using the components from the laboratory.

HISTORY OF FREE SPACE POWER TRANSMISSION:

The post-war history of research on free-space power transmission is well documented by William C. Brown, who was a pioneer of practical microwave power transmission. It was he who first succeeded in demonstrating a microwave-powered helicopter in 1964. A power conversion device from microwave to DC, called a rectenna, was invented and used for the microwave-powered helicopter. The first rectenna was composed of 28 half-wave dipoles terminated in a bridge rectifier using point-contact semiconductor diodes. Later, the point contact semiconductor diodes were replaced by silicon Schottky-barrier diodes, which raised the microwave-to-DC conversion efficiency from 40 % to 84 %. The highest record of 84 %

efficiency was attained in the demonstration of microwave power transmission in 1975 at the JPL Goldstone Facility. Power was successfully transferred from the transmitting large parabolic antenna dish to the distant rectenna site over a distance of 1.6 km. The DC output was 30 kW.

The concept of the SPS was first proposed by P. E. Glaser in 1968 to meet both space-based and earth-based power needs. The SPS will generate electric power of the order of several hundreds to thousands of megawatts using photovoltaic cells of sizable area, and will transmit the generated power via a microwave beam to the receiving rectenna site. Among many technological key issues, which must be overcome before the SPS realization, microwave power transmission (MPT) is one of the most important key research issues. The problem contains not only the technological development microwave of power transmission with high efficiency and high safety, but also scientific analysis of microwave impact onto the space plasma environment.



WHY TO USE SPS?

The SPS concept arose because space has several major advantages over earth for the collection of solar power. There is no air in space, so the satellites would receive somewhat more intense sunlight, unaffected by weather. In a geosynchronous orbit an SPS would be illuminated over 99% of the time. The SPS would be in Earth's shadow on only a few days at the spring and fall equinoxes; and even then for a maximum of an hour and a half late at night when power demands are at their lowest. This allows expensive storage facilities necessary to earth-based system to be avoided.

In most senses the SPS concept is simpler than most power systems here on Earth. This includes the structure needed to hold it together, which in orbit can be considerably lighter due to the lack of gravity. Some early studies looked at solar furnaces to drive conventional turbines, but as the efficiency of the solar cell improved, this concept eventually became impractical. In either case, another advantage of the design is that waste heat is re-radiated back into space, instead of warming the biosphere as with conventional sources

The Solar Power Satellite (SPS) concept would place solar power plants in orbit above Earth, where they would convert sunlight to electricity and beam the power to ground-based receiving stations. The ground-based stations would be connected to today's regular electrical power lines that run to our homes, offices and factories here on Earth.

Why put solar power plants in space? The sun shines 24 hours a day in space, as if it were always noontime at the equator with no clouds and no atmosphere. Unlike solar power on the ground, the economy isn't vulnerable to cloudy days, and extra generating capacity and storage aren't needed for our nighttime needs. There is no variation of power supply during the course of the day and night, or from season to season. The latter problems have plagued ground based solar power concepts, but the SPS suffers no of the traditional limitations of ground-based solar power.

Fig2:Solar power satellite system

WIRELESS POWER TRANSMISSION TO THE EARTH:

Wireless power transmission was early proposed to transfer energy from collection to the Earth's surface. The power could be transmitted as either microwave or laser radiation at a variety of frequencies depending on system design. Whatever choice is made, the transmitting radiation would have to be non-ionizing to avoid potential disturbances either ecologically or biologically if it is to reach the Earth's surface. This established an upper bound for the frequency used, as energy per photon,

and so the ability to cause ionization, increases with frequency. Ionization of biological materials doesn't begin until ultraviolet or higher frequencies so most radio frequencies will be acceptable for this.
To minimize the sizes of the antennas used, the wavelength should be small (and frequency correspondingly high) since antenna efficiency increases as antenna size increases relative to the wavelength used. More precisely, both for the transmitting and receiving antennas, the angular beam width is inversely proportional to the aperture of the antenna, measured in units of the transmission wavelength. The highest frequencies that be used are limited by atmospheric absorption (chiefly water vapor and CO2) at higher microwave frequencies.

For these reasons, 2.45 GHz has been proposed as being a reasonable compromise. However, that frequency results in large antenna sizes at the GEO distance. A loitering stratospheric airship has been proposed to receive higher frequencies (or even laser beams), converting them to something like 2.45 GHz for retransmission to the ground. This proposal has not been as carefully evaluated for engineering plausibility as have other aspects of SPS design; it will likely present problems for continuous coverage.

RECTENNA:

Rectenna is an acronym for RECTifying anTENNA. It is a special type of antenna that rectifies the incoming microwave radiation into DC current and hence the name Rectenna.
A rectenna comprises of a mesh of dipoles and diodes for absorbing microwave energy from a transmitter and converting it into electric power. Its elements are usually arranged in a mesh pattern, giving it a distinct appearance from most antennae. A simple rectenna can be constructed from a schottky diode placed between antenna dipoles as shown in Fig. 1. The diode rectifies the current induced in the antenna by the microwaves. Rectenna are highly efficient at converting microwave energy to electricity. In laboratory environments, efficiencies above 90% have been observed with regularity. In future rectennas will be used to generate large-scale power from microwave beams delivered from orbiting SPS satellites.

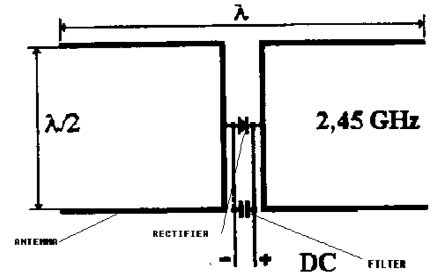


fig 3: Rectenna

BRIEF INTRODUCTION OF SCHOTTKY BARRIER DIODE:

A Schottky barrier diode is different from a common P/N silicon diode. The common diode is formed by connecting a P type semiconductor with an N type semiconductor, this is connecting between a semiconductor and another semiconductor; however, a Schottky barrier diode is formed by connecting a metal with a semiconductor. When the metal contacts the semiconductor, there will be a layer of potential barrier (Schottky barrier) formed on the contact surface of them, which shows a characteristic of rectification. The material of the semiconductor usually is a semiconductor of n-type (occasionally p-type), and the material of metal generally is chosen from different metals such as molybdenum, chromium, platinum and tungsten. Sputtering technique connects the metal and the semiconductor.
A Schottky barrier diode is a majority carrier device, while a common diode is a minority carrier device. When a common PN diode is turned from electric connecting to circuit breakage, the redundant minority carrier on the contact surface should be removed to result in time delay. The Schottky barrier diode itself has no minority carrier, it can quickly turn from electric connecting to circuit breakage, its speed is much faster than a common P/N diode, so its reverse recovery time Trr is very short and shorter than 10 nS. And the forward voltage bias of the Schottky barrier diode is under 0.6V or so, lower than that (about 1.1V) of the common PN diode. So, The Schottky barrier diode is a comparatively ideal diode, such as for a 1 ampere limited current PN interface. Below is the comparison of power consumption between a common diode and a Schottky barrier diode:
P=0.6*1=0.6W
P=1.1*1=1.1W

It appears that the standards of efficiency differ widely. Besides, the PIV of the Schottky barrier diode is generally far smaller than that of the PN diode; on the basis of the same unit, the PIV of the Schottky barrier diode is probably 50V while the PIV of the PN diode may be as high as 150V. Another advantage of the Schottky barrier diode is a very low noise index that is very important for a communication receiver; its working scope may reach 20 GHz.

DEVELOPMENT OF A FUNCTIONAL SYSTEM MODEL OF THE SOLAR POWER SATELLITE, SPS2000:

SPS2000 is a Strawman model of solar power satellites with microwave power output of 10 MW, which was proposed by the SPS working group of the Institute of Space and Astronautical Science.
(ISAS). The primary objective of SPS2000 research is to show whether SPS could be realized with the present technology and to find out technical problems.

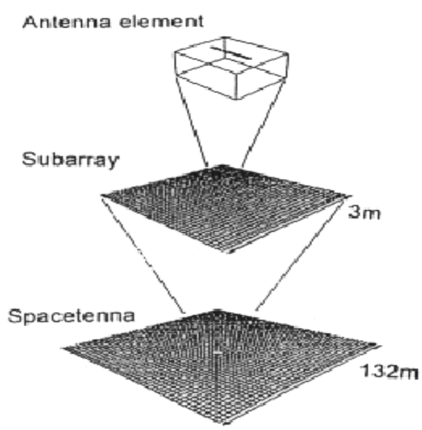


Fig 4: Configuration of the spacetenna

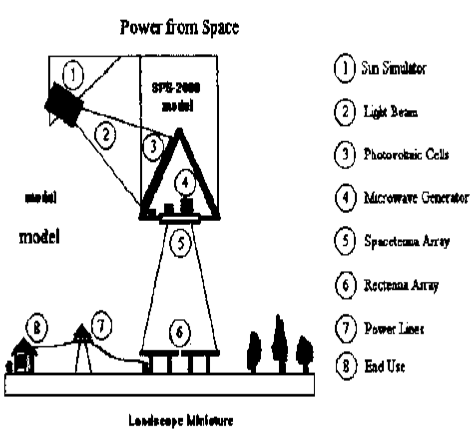


Fig.5:Development of functional system model

The general configuration of SPS2000 has the shape like a triangular prism as shown in Figure 2. The prism axis is in the latitudinal direction, perpendicular to the direction of orbital motion. The power transmission antenna, spacetenna, is built on the bottom surface facing to the earth, and the other two surfaces are used to deploy the solar panels. SPS2000 moves on an equatorial LEO at an altitude of 1100km. The choice of the orbit minimizes the transportation cost and the distance of power transmission from space. The spacetenna is constructed as a phased-array antenna. It directs a microwave power beam to the position where a pilot signal is transmitted from a ground-based segment of power system, the rectenna. Therefore, the spacetenna has to be a huge phased-array antenna in size with a retro directive beam control capability.

So, microwave circuits are connected to each antenna element and driven by DC power generated in the huge solar panels. A frequency of 2.45 GHz is assigned to transmit power to the earth. Figure 2 also shows a scheme of microwave beam control and rectenna location. SPS2000 can serve exclusively the equatorial zone, especially benefiting geographically isolated lands in developing nations.

Figure 3 illustrates a configuration of the Spacetenna. The Spacetenna has a square shape whose dimension is 132 meters by 132 meters and which is regularly filled with 1936 segments of sub array. The sub array is considered to be a unit of phase control and also a square shape whose edges are 3 meters. It contains 1320 units of cavity-backed slot antenna element and DC-RF circuit. Therefore, there will be about 2.6 million antenna elements in the spacetenna.

Figure 4 illustrates a block diagram of the spacetenna. The spacetenna is composed of pilot signal receiving antennas followed by detectors finding out the location of the rectenna on the earth, power transmission antenna elements and phase control systems. The left and right hand sides in Fig.4 correspond to parts of power transmission and direction detection, respectively. The antenna elements receiving the pilot signal have a polarization perpendicular to the antenna elements used in the power transmission so as to reduce effectively interactions between both antenna elements.

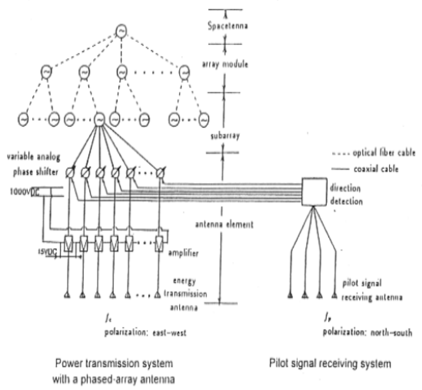


Fig 6 : Block diagram of spacetenna

Moreover, the pilot signal frequency and a frequency for the energy transmission are different from each other. Using two kinds of frequency for the power transmission and the pilot signal prevents each other from interfering and makes it possible to find out the accurate direction of a specified rectenna.

SOLAR ENERGY; A LIMITLESS SOURCE OF ENERGY:

The solar energy that reaches the Earth is about 10,000 times total human energy production today and the energy available in near-Earth space is limitless. A solar panel on an average can deliver 19 to 56 W/m² where as SPS rectenna would deliver about 23mW/cm² (230 W/m²) continuously.Research is being done on many different ways of using solar power economically on Earth, and many of these will be successful. Terrestrial solar energy is going to become a colossal business. However, sunlight is diffuse and not available continuously at the Earth's surface. So one additional possibility is to collect solar energy 24 hours per day in space, and transmit it as microwave beams to receivers on Earth. Hence power can be delivered wherever needed by redirecting its microwave beam, if additional ground-receiving Rectenna arrays are available.

CONCLUSION:

Solar energy is a promising alternative to using fossil fuels for the development of a sustainable carbon-free fuel economy. Thermo chemical and biological conversion processes are promising technologies with potential for high efficiency. The most obvious problem for the SPS concept is the current cost of space launches. But solar energy has a large potential to be a major fraction of a future carbon-free energy portfolio. The deployment of solar technologies for energy production at a large scale requires the involvement of both political and economical players, but also further improvements in the conversion efficiency and reduction of manufacturing cost. A large ongoing research effort aims to find innovative solutions to overcome these barriers. In the last decade, photovoltaic technologies have experienced an astonishing evolution that led to the increase of the efficiency of crystal-silicon solar cells up to 25%.

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