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Solar Power Satellites (SPS): A Solution to Clean Energy Issues

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ABSTRACT
Energy crisis is the main headache of scientists at present world. It will be a great problem in future. The conventional sources of energy(oil, coal, gas, nuclear energy) have limited reserves. So human being must find out new source of energy. The future alternate energy sources must satisfy some very basic criteria. First, it must be nondepletable, so it will not have to be replaced by the next generation. Second, it must be low cost, or it will not be developed to produce large quantities of energy. Third, it must be environmental friendly, so the Earth will not be affected. Fourth, it must become available to everyone. Fifth, it must be in a useful form *so* it can support the developing societies as well as the developed nations. Sixth, it must be in convenient form, so that it can be converted to any energy forms easily. Day by day our demand on electricity increases but the sources from where we can produce electrical energy is decreasing day by day.So,we need to find out alternate sources. Solar Power Satellites (SPS) can be a good alternate energy source. The Solar Power Satellite system is the only energy source with known technology that can meet the criteria for a viable major new energy source and move the world into the fourth era of energy.As the main problem of solar system is that sunlight is not available at all times and its strength is also variable in different seasons.If we set our solar panel in satellite then sunlight is available at all time and if we can transmit this produced electricity to earth then it can be a good source of energy. In this paper different factors associated with Solar Power Satellites are discussed and its importance as an energy source is mentioned.

Keywords
SPS, MPT,WPT, Fresnel area, Utilization factor , Gauss distribution.

1. INTRODUCTION
Wireless energy transfer or wireless power is the process of transmission of electrical energy from a power source to an electrical load without wires. There are 3 major ways of Wireless energy transfer. First , Electromagnetic induction which is used for Short range. Second, Coupled Magnetic Resonance used for Medium range and third Microwave Power Transfer used for long range.

Microwave Power Transfer (MPT) is a form of wave power transfer that, obviously, sends energy through the air in the form of microwaves (other forms can use lasers and visible light). MPT has a range miles longer than its inductive counterparts, and it's being investigated as a way to beam power to space or vice versa . According to a study done by NASA , to transmit energy from space to earth would require a 1km diameter transmitter and a 10km diameter receiver. Possible health risks associated with beams of microwaves.

Solar Power Satellites (SPS) could be an application for MPT. In the SPS system, microwaves are converted from DC power available from solar panel and sent via a large transmitter. On the other end, the transmitted signals are caught" by an even larger receiver and converted to AC power. Here disk shaped rectifying antenna or "rectenna" is used whose conversion efficiency is more than 95%.The main problems associated with SPS are antenna design,absorbtion of microwaves in different layers of earth atmosphere, interference of microwave with communication signals, health hazards and cost.

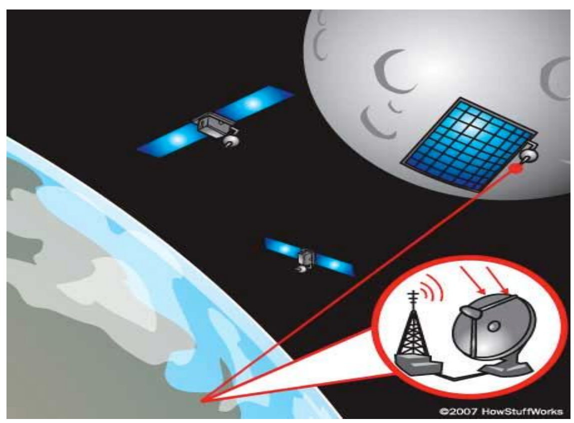

Figure1: Solar Power Satellites (SPS) system

2. ANTENNA DESIGN FOR SPS
The main disadvantage of microwave Wireless Power Transmission (WPT) is that that the significant part of the radiating energy does not reach the given area of space because of the diffraction divergence. As the transmission distance increases as compared to diffraction length of the radiating antenna this disadvantage is most conspicuous. The size of the radiating and receiving antennas must be selected so as not to exceed the diffraction length of the radiating aperture. It shouldn't go out of the Fresnel area.

It is supposed to use the solution of quasi optical problem to minimize the losses. In WPT the correlation between wave length λ, the distance between the antennae d and the transmitting and receiving antenna half sizes a and b is defined by the Fresnel parameter

$$C = 2\pi \frac{ab}{\lambda d} \qquad (1)$$

Usually it equals about 2-3. The receiving antenna is situated near of the Fresnel area.

As it is shown from above equation the increase of the distance d requires for the increase of the ratio $\frac{ab}{\lambda}$

The transmission is considered to be optimal, when the receiving antenna does not intercept the minimal part of the transmitted energy. The distribution of current on the transmitting antenna is the taper type (usually it is used Gauss field distribution). The radiation from the transmitting antenna is focused in the center of the receiving one. This distribution is not optimal .There are two peculiarities in the taper field distribution: The first: The maximum of energy flow density at the transmitting antenna can't be made unlimitedly large , the admitted power density limits it. If this maximum is fixed, the noticeably more energy may be transmitted by means of best filling of the aperture, for instance at the uniform distribution. Of course in that case the losses of the transmission will be bigger. But as the accounts[1] shows we will create more energy at the receiving end of power transmitting system.

The second: The side maximums are not so small at the .Gauss transmission. They occur because the Gauss function is limited (it is cut at the edge of antenna). The first diffraction maximum at the level of - 13dB occurs at the uniform distribution (a table form function). The side maximums of the cut Gauss distribution depend on a value of coefficients σ in the expression of the Gauss curve

$$e^{-\frac{\sigma r^2}{a^2}} \qquad (2)$$

If the value σ is large the cutting of Gauss curve takes place at the low level and the side maximums on the receiving side are small but effectiveness of WPT is small too because the antenna surface is used very poorly. It is found that the optimal field distribution has a taper form too. If the value σ is small the level of the wave field out of the receiving aperture reaches also about -13dB.

The product of the effective cross sizes of two antennas (receiving and transmitting antennas) is increasing at the change of the taper distribution to the uniform one. Therefore the field is contracted at the receiving side. It means that the field at an edge of receiving antenna is decreased. Calculations showed that the field at the receiving antenna edge for taper transmission is about equal to the field, which will take place in the diffraction maximum at the uniform distribution. So from the point of view of the field level at the edge of the receiving antenna the uniform distribution slightly differs from the optimum one. But the aim is to transmit as much energy as possible. It is realized only with the uniform distribution. The most effective and the most technological method to make a good antenna for the WPT is to use incompletely filled aperture. If separate parts divide the continuous aperture and these parts (sub apertures) are situated on the radiating plate in the determinate order (discontinuous array), the effectiveness of the WPT is increased. This idea at first was reported at the WPT'95 Conference in 1995 (Japan) [2].

Discontinuous antenna [3] has a wonderful feature. It allows creating on the receiving antenna essentially more energy by comparison with continuous antenna if the efficiency and active antenna squares are equal. It is because they (discrete antennas) use the aperture edges better than the continuous antennas. Of course in that case the sub apertures must be distributed correctly. Apparently unequal distant distribution of sub apertures allows improving the result.

Differently, the substitution of the optimal continuous aperture with the same discontinuous antenna, which consists of identical sub apertures with uniform amplitude distribution, can be used. Practically equal efficiency leads to the higher transmitted power (if the permitted level of amplitude is limited and its value is in the center of a continuous antenna). It is very good for practical purposes.

Radiating antenna of the WPT systems usually has a taper distribution of the field. This distribution allows to increase the efficiency and to decrease the field out of the receiving antenna.

The efficiency of energy transmission is expressed by the functional

$$\Lambda^2 = \frac{\int_{-\frac{q}{2}}^{\frac{q}{2}} |E(\xi)|^2 d\xi}{\int_{-\frac{Q}{2}}^{\frac{Q}{2}} |E(\xi)|^2 d\xi} \qquad (3)$$

Here $Q \times Q$ is the total area where the energy of the electric field E(x) is radiated and $q \times q$ is the square plate of the receiving antenna. For simplicity we take square of transmitting and receiving apertures, which have separating amplitude distributions $U(x, y)= U(x)U(y)$.

To increase Λ the field distribution on radiating aperture is made as a tapered distribution. It is shown that the best result is obtained at the field distribution which is close to the Gauss one $\exp\left\{\frac{-\sigma x^2}{r}\right\}$ and which has edges cut on a definite level. For example,σ is ⊓ and the Fresnel parameter C is about 1 (it is usually 2-3). High value of Λ is supposed to be in the majority of known projects of the WPT systems. However, the effectiveness of the WPT system is defined not only by the value of Λ. It is also determined by the rectangularity of the field distribution on the radiating aperture, which for the square antenna is equal to

$$\chi = \frac{\left\{\int_{-a}^{a} |U(x)|^2 dx\right\}^2}{4a^2 |U_m(x)|^2} \qquad (4)$$

where U (x) m is maximal admissible value of the field on the radiating antenna. It is usually situated in the center of the antenna. The rectangular distribution factor in the theory of antennas is usually called the surface utilization factor χ.The meaning of these two parameters Λ and χ is discrepant because to increase Λ^2 it is necessary to have the field falling down to edges, but to increase χ it is necessary to have a uniform field. The purpose is to find the conditions at which this discrepancy is cancelled.

A demand to increase c has been shown in literature before [1]. The increase of c permits to increase the transmitting power without the extension of sizes of the radiating antenna but the efficiency Λ^2 is decreased at the same time. To increase the effectiveness of WPT system it is necessary to increase the product $\Lambda^2 c$, though the requirements for each of both multipliers are opposite. This product is named a generalize criterion. It is possible to find the way out of this contradiction if the antenna is discontinuous (discrete) one. Let us produce the field distribution in the radiating discrete antenna falling to its edges not by means of creation of non-uniform distribution of the field but with the help of irregular situation of identical sub apertures, each of them having the uniform field distribution. It is supposed that the number of these apertures is sufficiently high in order to admit the approximation of the integral optimum monotonous Gauss distribution by means of step function. The places of sub aperture disposition can be found by the differentiation of this step function.

Discrete distribution of sub apertures presents non-equadistant antenna array consisting of the similar elements. Such optimization is optimal in Chebyshev's sense since the maximum error tends to zero while the number of sub apertures is tended to infinity. So the field in the place of observer's disposition would be similar to step and the monotonous signal source.

The dismemberment of continuous apertures and slight moving of them apart in the space when all of apertures are equal and uniformly feed increases their effectiveness (the generalized criterion is increased). The generalized criterion determines the quality of the WPT Systems better than usual criterion.

The optimal distribution form may be reached for the large radiating apertures where dismemberment at many parts is easily realized by disposition of sub aperture clots in places, which correspond to high field intensity (first of all it concerns the center of the radiator) and relieving sub aperture density at edges of antenna. This construction allows to approach to unit the value both of coefficients Λ^2 and χ . As a result the effectiveness of the WPT system will be essentially increased.

The resolve of the synthesis problem of the WPT shows that WPT efficiency may be improved by using special current discontinuous distribution on the antenna. Here we have three possibilities [4]:

1. To use a discontinuous equidistant array with the quasi Gauss distribution.
2. To use a discontinuous non-equidistant array with the uniform distribution.
3. To use uniform continuous phase synthesis antenna array.

The possibility of decrease of the wave beam expansion permits to make the WPT systems less expensive. Such approach to the problem of the continuous radiators and of the real antennas, which can be created, is new.

3. SOLAR ENERGY IN EARTH'S ATMOSPHERE

Scientists think of our atmosphere as having several distinct layers with specific traits. Let's quickly review the structure of the atmosphere, since some aspects of that story are relevant to how and where solar energy gets absorbed.

Nearest ground level is the **troposphere**. It extends upward from the ground to an altitude of about 16 km (in the tropics, or 8 km near the poles). Most weather occurs, and most clouds are to be found, in this layer. Convection currents keep the gases in the troposphere well mixed. The troposphere is warmest near ground level, and cools gradually the higher up in it one goes.

Immediately above the troposphere lies the **stratosphere**. Some high-altitude clouds can be found in this layer. Temperatures actually increase with altitude as one moves upward through the stratosphere. Jet airliners fly in this layer, for it is far less turbulent than the underlying troposphere. The stratosphere extends upward from the top of the troposphere to an altitude of about 50 km. The ozone layer lies within the stratosphere.

Moving upward, the next layer is the **mesosphere**. By this point the atmosphere is very thin. Temperatures once again decline with increasing altitude (as was the case in the troposphere), falling as low as -100° C (-146° F) in the upper mesosphere. This layer is relatively poorly studied, for it is above the reach of most aircraft but below the altitude where satellites orbit. Most meteors burn up in the mesosphere. The top of the mesosphere lies about 80 to 85 km above Earth's surface.

Above the mesosphere lies the extremely tenuous **thermosphere**. This layer is so thin, in fact, that many satellites orbit within it. This region is one in which temperatures once again rise with increasing altitude, reaching as high as 2,500°C (4,500°F) in the daytime! Embedded within the thermosphere are several layers of the **ionosphere**; regions where ionized gas particles can reflect radio waves, a feature that people used to send messages beyond the line-of-sight range of the horizon before the advent of satellites. The thermosphere extends to somewhere between 500 and 1,000 km above the Earth's surface. Many of the atoms and molecules in the thermosphere (and above) have lost electrons, thus becoming electrically charged ions; so the motions of particles in the upper atmosphere are partially influenced by electrical currents and Earth's magnetic field.

Though not universally recognized as a layer of our atmosphere, some scientists consider the **exosphere** to be the outermost layer of Earth's atmosphere. Starting at the top of the thermosphere, this extremely tenuous layer gradually gives way to the vacuum of interplanetary space.

When choosing the position where SPS is to be set up some factors must be kept in mind. Where enough solar energy is available that layer is preferable one, it is seen from above that top most position is suitable where temperature increases with the increase in altitude. But, when microwave travels within the layers it interferes with different particles in different layers so suitable frequency must be selected so that least interference and absorption occurs but another problem here arises, different layers have different particles which have also different effect on a particular frequency wave. Frequency converter can be solution to this problem. In different layers frequency converters can be set up. In a particular layer the converter converts the frequency to a suitable level for that layer.

4. BIO-EFFECTS

A general public perception that microwaves are harmful has been a major obstacle for the acceptance of power transmission with microwaves. A major concern is that the long-term exposure to low levels of microwaves might be unsafe and even could cause cancer. Since 1950, there have been thousands of papers published about microwave bio-effects. The scientific research indicates that heating of humans exposed to the radiation is the only known effect. There are also many claims of low-level non-thermal effects, but most of these are difficult to replicate or show unsatisfying uncertainties. Large robust effects only occur well above exposure limits existing anywhere in the world [5].

The corresponding exposure limits listed in IEEE standards at 2.45 or 5.8 GHz are 81.6 W/m^2 and 100 W/m^2 averaged over 6 minutes, and 16.3 or 38.7 W/m^2 averaged over 30 minutes [6]. This low compared to average solar radiation of 1000 W/m^2.

A clearly relevant bio-effect is the effect of microwave radiation on birds, the so-called "fried bird effect". Research is done on such effect at 2.45 GHz. The outcome showed slight thermal effects that probably are welcome in the winter and to be avoided in the summer. Larger birds tend to experience more heat stress than small birds [6] .

The overall conclusion of bio-effects research is that microwave exposures are generally harmless except for the case of penetrating exposure to intense fields far above existing exposure limits. Further discussions about the maximum microwave power density are necessary. A range of environmental issues and safety-related factors should continue to receive consideration because of public concern about radio wave and microwave exposure.

5. CONCLUSION

In this paper different factors associated with SPS system have been discussed. Here, only theories are analysed. But, if we properly design antenna, select proper altitude of the SPS above earth surface and properly select frequency then practical design of SPS system can be possible. Cost can be a matter but when successful implementation of the system will be possible then a step to reduce the cost can be focused. There is no doubt that SPS can be good alternate energy source in future. This energy source have many advantages. It will not pollute the atmosphere, it is not suffered from limited reserve, and sufficient amount of power can be produced.

REFERENCES

[1] Garmash V.N., Shaposhnikov S.S, "Matrix Method Synthesis of Transmitting Antenna for Wireless Power Transmission". IEEE Trans. On Aerospace and Electronic Systems, 36. 4. 1142-1148. 2000.

[2] R. T. David Microwave Link Transport 30 kW DC over 1 mile. Microwaves. Oct. 1975. P. 9-

[3] S.S. Shaposhnikov, B.Z. Katsenelenbaum, R.B. Vaganov, V.A. Permjakov «Innovative Approach to the Small Divergence Wave Beam», Report 4-2 at the Second Wireless Power Transmission Conference (WPT'95), 1995 (Kobe, Japan), It was published in Space Energy and Transportation (SET), Vol.2, No., 4, 1997, P.189.

[4] www.sspi.gatech.edu/antenna.pdf

[5] Health and safety issues for microwave power transmission, John M. Osepchuk, Solar energy Vol. 56, 1996

[6] White paper on Solar Power Satellite Systems, URSI, September 2006