

A Research on Space Solar Power

K.Sai Srujana¹; T.Sai Saran²; B.K.Annapoorna³ & M.Ganesh Dattatreya⁴

^{1,2,3,4} Btech Final Year , Pragati Engineering College, East Godavari Dist., Andhrapradesh India

Abstract:

Can't we generate solar power during night times? Yes this paper suggest a solution to generate solar power during night times. It is probably well known that we are running out of fossil fuel. Most of the energy sources we are using are non renewable. Oil and gas are not to last longer than about fifty years, whereas coal will probably last another two or three centuries. Uranium and nuclear plants will not last forever either. So, in order to provide the generations to come with energy, we have to find the way to use unlimited sources. And this is where SPS gets in action. It provides solutions to use one of the most renewable and unlimited source on earth : the Sun.

Keywords : Solar Power; Wireless Communication; Rectenna; Micro Waves; High Frequency Systems

SPACE SOLAR POWER (SPS) : a great idea !

Still someone might ask why using SPS and not solar panels on the surface of the earth ? With the SPS, problems such as daylight and bad-weather conditions, which one might have to deal with , when using solar panels, do not exist. Neither does the need of storage in order to have continual provision of energy and especially considering our inability for adequate energy storage on earth. With SPS the maximum energy loss due to eclipses is only a hundred and twenty hours a year. Furthermore the energy received by the rectenn as on earth is ten times more than that received by solar panels of the same surface.

The solar panels used on the surface of the earth prevent sun beams to go through them and consequently prevent any kind of cultivation of the earth under them. But with SPS the photo voltaic cells are in space, so we have no problem with the area needed. In addition the rectennas on earth are semi-transparent allowing sun light to go through them and making possible the cultivation of the soil. So we have no waste of space.

Probably in the future there will be other sources of energy such as fusion, in fact we are already using renewable sources like either hydroelectricity or geothermal energy. SPS might be one of several renewable energies we will use in the future .

Now that we have seen several reasons why SPS could be a great project, let's keep our feet on the ground. There are still some problems to solve before we can see the first SPS working.

INTRODUCTION TO SPS:

The SPACE SOLAR POWER (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 none of the traditional limitations of ground-based solar power.

INTRODUCTION TO RECTENNA:

A rectenna is a rectifying antenna, a special type of antenna that is used to directly convert microwave energy into DC electricity. 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. The diode rectifies the current induced in the antenna by the micro waves. Schottky diodes are used because they have the lowest voltage drop and therefore waste the minimum power.

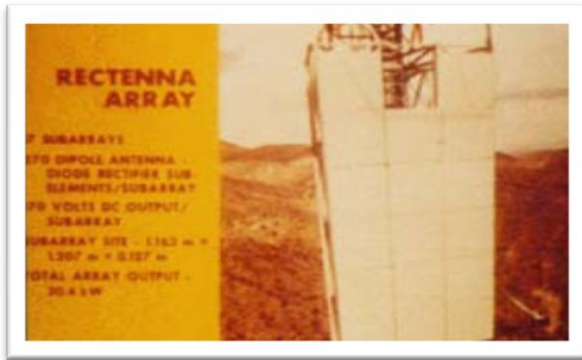


Fig.1, Rectenna Array

Rectennae are highly efficient at converting microwave energy to electricity. In laboratory environments, efficiencies above 90% have been observed with regularity. Some experimentation has been done with inverse rectennae, converting electricity into microwave energy, but efficiencies are much lower—only in the area of 1%. Due to their high efficiency and relative cheapness, rectennae feature in most microwave power transmission.

SPS MODEL :

The satellites would be placed in so-called "geostationary" or "Earth synchronous" orbit, a 24-hour orbit which is thus synchronized with Earth's rotation, so that satellites placed there will stay stationary overhead from each's receiving antenna. (Likewise, today's communications satellites are put into geostationary orbit, and each TV satellite dish on the ground is pointed towards one satellite "stationary" in orbit.) The receiving antenna is called a "rectenna" (pronounced "rektenna").

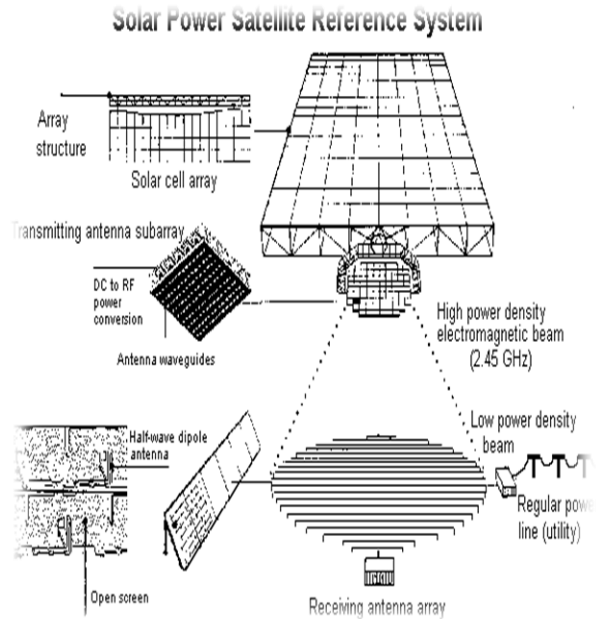


Fig.2, Space Solar Power Reference system

Geostationary orbit is very high, 36,000 km (22,500 miles) above the surface of the Earth. It is far above the range of the Space Shuttle, which has a maximum range of about 1000 km (600 miles) above Earth's surface.

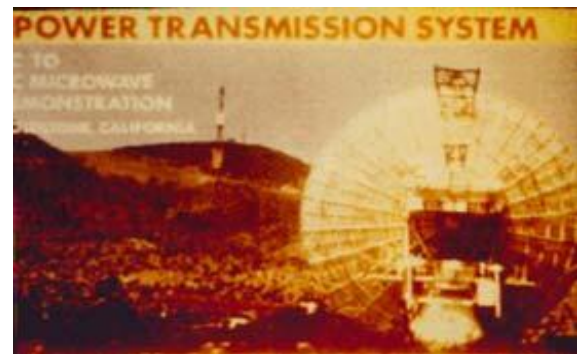
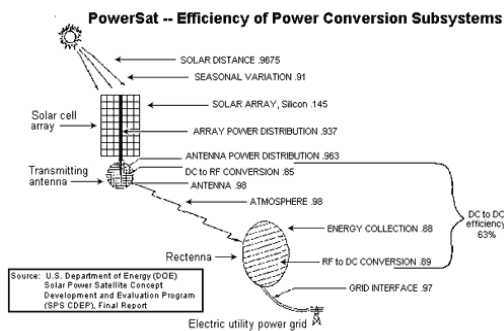


Fig.3, Power transmission system

The SPS will consist of large sheet of solar cells mounted on a frame of steel-reinforced lunarcrete or astercrete. The solar cells produce electricity from sunlight with no moving parts. The only moving part on the satellite is the transmitter antenna(s) which slowly tracks the ground-based rectenna(s), while the other solar cell array keeps facing the sun. Each transmitter antenna is connected to the solar cell array by two rotary joints with sliprings.

The transmitter on the SPS is an array of radio tubes(klystrones), waveguides, and heat radiators.They convert the electricity from the SPS solar cell power plant into a radio or microwave beam.The Ground –Based Rectenna consists of an array of antennas and standard electronics to convert the energy into regular AC electricity which can then supplied into today’s power lines.

The rectenna consists of an array of dipole antennas connected to diodes to convert the radio frequency energy to DC voltage, which is then converted to regular AC electricity and wired to homes, factories, etc. While DC to AC conversion can occur at the rectenna, if the consumers are a long distance away, e.g., in another state, it may be more efficient to transmit by DC power lines and then to convert to AC at a local power grid. The efficiency of the SPS is often stated in terms of "DC to DC efficiency", i.e., from the DC input at the solar cells to the DC output of the rectenna. The DC to DC efficiency is generally estimated at 63% with losses shown in the figure 4 below.



The satellites can have a useful lifetime of many decades. As space development takes off, they are more likely to become obsolete than to be taken out of service due to problems. Old SPSs can be either upgraded (e.g., the transmitter or the solar array) or sold off to a less developed country and moved to that country's space in geosynchronous orbit.

MAKE YOUR OWN RECTENNA:

The components required to construct rectenna are :

- SHOTKEY DIODE
- LIGHT EMITTING DIODE

- MICROWAVE SOURCE(i.e, MICROWAVE OVEN).

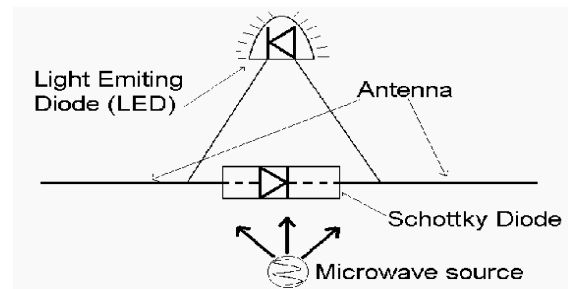


Fig.,5 Rectenna Model

It is very easy to construct, you just have to put the "plus" side of the LED with the "minus" side of the schottky. Still, you have to be careful not to bend the schottky and leave its connectors straight for them to act as an antenna.

Now we got a rectenna, lets try it .We have a closed microwave oven, which we turn on, and then when we are moving our rectennas around the oven, and it lights. "How is this possible" .

Initially the electrons in the conductor are in rest position,when a microwave of 2.4GHZ hits the electron ,the electron gets excited and enters in to shottkey diode ,the entered electron doesn't go back and the negative charge density increases on one side because of this the electrons come out from another side and enters in to the LED which makes it glow.From this experiment we can conclude that we got wireless power which makes the LED glows as shon fig.,5.

This section puts the SPS beam into a bigger perspective in a general sense. The SPS beam is basically a radio beam. When people hear the word "microwave", they think of a microwave oven. The SPS beam intensity does not need to have the power intensity anything near a microwave oven, and current designs have the intensity as hundreds of times less above the rectenna, indeed a power intensity about one-tenth that of sunlight. Also, a microwave oven is designed to operate at a frequency which is absorbed by water (which is why dry stuff doesn't heat up well in a microwave). The SPS will operate at a frequency designed to NOT be absorbed by water in the atmosphere, and to pass through clouds and rain.

Microwave frequencies are harmlessly used in communications, using different microwave frequencies which avoid absorption by water in the atmosphere so that they travel a long distance. The SPS beam will use a frequency tuned for minimal absorption by the atmosphere, clouds and storms.

Microwaves cause heating, but much else. The intensity would not be anything near that inside a microwave oven, a microwave oven operates at powered sites hundreds of times higher.

The Reason why microwave "radiation" is safer than is of much lower frequency than the ultraviolet light you receive from sunlight outdoors, and from the x-rays coming from your tv and computer screen. X-ray and ultra violet radiation are ionizing radiation which can disrupt molecules in the body. Microwave radiation by the SPS is even less potent than infra-red radiation from heaters and stoves. If the SPS beam is significantly absorbed by biota, it would produce only heating, and usually not significant heating.

EFFECT OF SPS ON COMMUNICATION:

Microwaves are Effects of the SPS on communications is another "environmental" topic that has been studied by a number of professionals. Frequencies near the proposed 2.45 GHz SPS beam frequency are currently being used by some communications sectors, but they're a tiny segment of the communications services. Those operating at 2.45 GHz would probably want to switch frequencies, though ameliorative measures are feasible for frequencies close to 2.45 GHz in areas not near a rectenna. The SPS can be made to not interfere with other communications in general.

A major factor in setting the "baseline" SPS beam power density to peak at 23 milliwatts per square centimeter was its effects on the ionosphere, a layer of the upper atmosphere used to bounce some kinds of traditional communications, e.g., long range radio, TV (non-satellite and non-cable), and microwave relay of telephone calls. Only the spots of the ionosphere above rectennas would be affected, and those spots may not work as well in reflecting (actually, refracting) these kinds of communications back down to the Earth's surface if the beam intensity is pushed too high. Whether the SPS would significantly affect users of those kinds of communications

in certain areas has yet to be determined, but it was later thought that the 23 mW/cm² setting was considerably lower than the threshold for significant effects on the ionosphere. However, with fiber optics, larger satellites, and internet, those traditional ionosphere-reliant methods of communications are being phased out.

Experiments were conducted transmitting a 2.45 GHz beam up through the ionosphere (using the large Platteville, Colorado and the Arecibo, Puerto Rico high frequency transmission dishes) and taking many measurements over time. (171-177) "Experiments have shown that the limit is too low, and theory now suggests that the threshold is soft. The current consensus is that the limit of 23 mW/cm² can be at least doubled, and perhaps more, pending further tests." (178) Further, it was concluded that atmospheric heating could be reduced by 80% by switching to the 5.8 GHz frequency.

There are 10 different bandwidths used for communications -- EHF, SHF, UHF, VHF, HF, MF, LF, VLF, VF and ELF. The SPS beam falls within the **UHF** band.

There would be interference with some communications operating at the 2.45 GHz frequency of the SPS beam and some of its harmonics. 2.45 GHz falls within the UHF part of the communications spectrum. The SPS beam of 2.45 GHz is located in the microwave area of the radio communications spectrum, near the TV and FM radio frequencies, and falls within the 2.3 GHz to 2.5 GHz bandwidth allocated for police, taxi, citizen's band, mobile, radiolocation, amateur, amateur-satellite and ISM (industrial, scientific and medical) applications -- the UHF band. The vast majority of these other applications do not use 2.45 GHz but use other frequencies near or somewhat near to 2.45 GHz. Many of these applications (except FM and UHF TV) have also been allocated frequencies in other bandwidths (outside UHF) by the authorities.

However, analytic studies concluded: "With the exception of sensitive military and research systems, equipment more than 100 km [60 miles] from a rectenna site should not require modification or special design to avoid degradation in performance," (157) and that conventional mitigative techniques would even permit operation of almost all devices at the rectenna boundary by filtering, nulling, minor circuit modifications and other mitigative

techniques (158-162) which would cost between 0.1 to 5% of the unit cost to modify. Tests confirmed the effectiveness of these mitigative techniques. Sensitive military equipment would generally not be affected as long as the closest rectenna was more than 400 km (250 miles) away.

Pacemakers and other medical electronic devices would not be affected.

In summary, some kinds of communications would be adversely affected by the 2.45 GHz SPS beam, but the vast majority of today's communications would be unaffected.

However, the benefits to communications due to large scale space development would be immense.

COMMUNICATION SATELLITES BENEFITS:

Looking at the effects of SPSs on communications satellites is a waste of time unless we consider the revolutionary effects of large scale space infrastructure associated with SPSs. If SPSs are put into place, satellite communications will boom due to the related space-based manufacturing. Currently, satellites are small with weak transmission powers and small reception antennas. Satellites are not constructed in space at all, but are small, compact objects built on Earth and deployed in space.

Space development will bring about large satellite platforms and "Orbiting Antenna Farms" (OAFs), allowing many times the number of satellites to be placed in geostationary orbit, and solving crowding problems. Bigger antennas in space mean smaller footprints on Earth, mitigating interference and allowing multiple use of each frequency. Larger power sources and larger antennas also make for clearer signals and smaller Earth ground stations. New frequencies currently not used due to partial atmospheric absorption will become usable. Linking satellites together on large platforms will lead to enhanced services. Fuel propellants from non terrestrial materials will be used to ferry up satellites, provide station keeping in geostationary orbit, and extend the life of satellites (e.g., selling old satellite to less developed countries). As for satellites in lower orbit passing through the beam on occasion, "Improved electromagnetic shielding and other minor modifications would be expected to eliminate or substantially reduce effects to allow normal performance."

(169) e NOT like ultraviolet and other "ionizing" radiation which you get from walking in the sun.

ADVANTAGES AND DISADVANTAGES

- 1.The idea collecting solar energy in space and returning it to earth using microwave beam has many attractions.
- 2.The full solar irradiation would be available at all times expect when the sun is eclipsed by theearth. Thus about five times energy could be collected, compared with the best terrestrial sites.
- 3.The power could be directed to any point on the earth's surface.
- 4.The zero gravity and high vacuum condition in space would allow much lighter, lowmaintenance structures and collectors.
- 5.The power density would be uninterrupted by darkness, clouds, or precipitation, which are the problems encountered with earth based solar arrays.
- 6.The realization of the SPS concept holds great promises for solving energy crisis.
- 7.No moving parts.
- 8.No fuel required.
- 9.No waste product.The concept of generating electricity from solar energy in the space itself has its inherentdisadvantages also.

Some of the major disadvantages are:

- 1.The main draw back of solar energy transfer from orbit is the storage of electricity during off peak demand hours.
- 2.The frequency of beamed radiation is planned to be at 2.45 GHz and this frequency is used bycommunication satellites also
- .3. The entire structure is massive.
- 4.High cost and require much time for construction.
- 5.Radiation hazards associated with the system.
- 6.Risks involved with malfunction.
- 7.High power microwave source and high gain antenna can be used to deliver an intense burst of energy to a target and thus used as a weapon

CONCLUSION:

The increasing global energy demand is likely to continue for many decades. New power plants of all sizes will be built. Fossils fuels will run off in

another 3-4 decades. However energy independence is something only Space based solar power can deliver. Space solar power (SSP) concept is attractive because it is much more advantageous than ground based solar power. It has been predicted that by 2030, the world needs 30TW power from renewable energy sources and solar energy alone has the capability of producing around 600TW. The levels of CO₂ gas emission can be minimized and brought under control. Thus the problem of global warming will be solved to a great extent. Based on current research space based solar power should no longer be envisioned as requiring unimaginably large initial investments. Moreover, space solar power systems appear to possess many significant environmental advantages when compared to alternative approaches to meeting increasing terrestrial demands for energy including necessity of considerably less land area than terrestrial based solar power systems. Though the success of space solar power depends on successful development of key technology, it is certain the result will be worth the effort. Space solar power can completely solve our energy problems long term. The sooner we start and the harder we work, the shorter "long term" will be

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