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“Power Transmission through Solar Power Satellite to Earth Surface with Minimum Power Loss”

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Abstract: ***Now days, expanding needs of photovoltaic cells and other solar oriented power establishments are in administration around the globe and in space. These utilizations extend from essential electric power source for satellites, remote site logical experiment and towns in creating nations to enhancing the commercial electric grid and giving fractional power for individual organization. In space, power produced by photovoltaic cells after conversion from sunlight will become mainstay of power source for Earth and geostationary satellite bodies. The conspicuous reason is daylight on earth is excessively untrustworthy, whereas in space energy can be harvest by 24 hours. The challenge is to harvest maximum energy and transmit the energy from space to earth in the form of microwave frequency with minimum power loss. In this work to harvest maximum power,s we change the directivity range of receiving antenna to -40 dB, Received microwave frequency from transmitting antenna is in the form of beam of rectangular array, In previous work, directivity ranges from 0 to -8 dB for receiving frequency 70.00 MHz causes cutoff of transmitted frequency for below 2.45 GHz, if directivity ranges increase from 0 to -40 dB then transmitting frequency ranges till 2.00 GHz will be utilized by which after conversion in rectenna we get total 223.42 MW power.***

Keywords:Rectenna,SPS,SBSP,WirelessPowerTransfer, WPT

I. INTRODUCTION

In the coming future due to extensive use of energy with limited amount of resources and the pollution in environment from present resources e.g. (wood, coal, fossil fuel etc.), alternative sources for production of energy and new ways to generate power which are eco-friendly, efficient, cost effective and produce less amount of losses are of great concern. Wireless Power Transmission (WPT) has become a major point as research point of view and these days it lies in top 10 future hot trending technologies that are under research work. The complete block diagram of system is shown in Fig 1 it consist of two sections transmitter and receiving section, In Transmitter section power will produced from sun using solar panels in the form of DC which is converted into AC using voltage source convertor (VSI) which is further convert into microwave frequency and transmit through Tx antenna and in receving section

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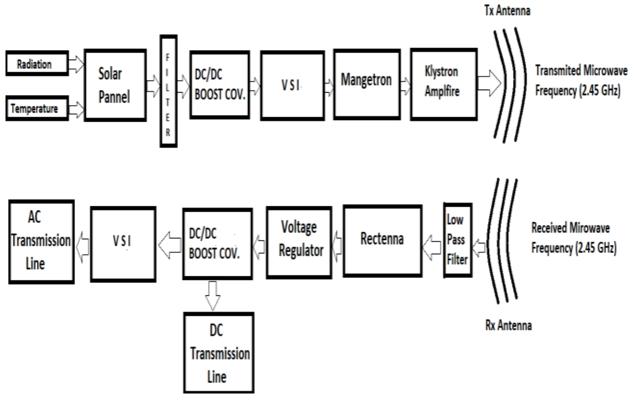

Fig 1 : Block Diagram of Complete System.

received microwave frequency is will convert into DC voltage using rectenna and some voltage transmits directly whereas rest voltage is again converts into AC power and transmits. A PV cell (can be called as a sun powered cell) is a semiconductor gadget that changes over the daylight vitality into power without experiencing any vitality transformation steps. This change happens by photovoltaic impact and consequently they are called Photovoltaic (PV) cells. It creates voltage and current at its terminals when daylight episode on it. The way and the measure of intensity created by a sun powered cell rely upon the daylight falling on it. This likewise incorporates a few factors, for example, power of light, point at which the light falls on it and region of the cell. The more is the power created, if higher is the light force. In the event that the zone of the cell is more, the power created is likewise more. What's more, the ideal power is produced by it when light falling is opposite to the front side of the cell.

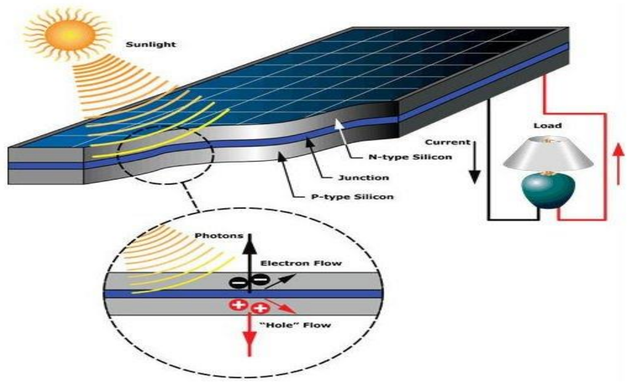

Fig 2 Photo Electric Effect.

The simplified block diagram of the microwave generator is presented in Figure 3. It uses a continuous wave magnetron as the heart of the device, mounted on a waveguide with a coaxial adapter to feed an applicator.

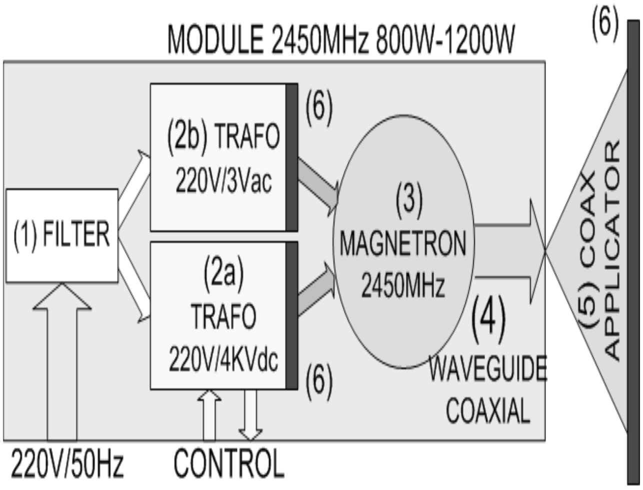

Fig 3 Microwave Generator Structure: 1-low pass filter (LPF), 2a-anode supply, 2b-filament supply, 3-magnetron, 4-waveguide to coaxial, 5-coaxial applicator, 6- isolation barrier

A continuous wave, 2458 MHz magnetron, model AM701, evaluated at 850W, has been utilized see fig 3. The power supply is a zero cross, PWM, high voltage anode transformer pursued by a voltage doubler. The filament is controlled from a different, exceedingly secluded, transformer. This specific providing topology, in which the anode is precisely and electrically stacked, it doesn't meet the electrical segregation criteria with respect to the patient, as stipulated by the IEC60601 standard. That is the reason, an electrical separation obstruction between the microwave waveguide and the patient is mounted on the utensil gap, the detachment hindrance between the power supply and magnetrons being guaranteed by the transformers. Two sorts of isolator materials have been utilized for the tool, both straightforward to the microwave radiation: FR2 (pertinax) and PFTE (teflon).ance of SPS is costly and testing.A Klystron is a microwave generator that takes a shot at reflections and motions in a solitary hole, which has a variable recurrence. Reflex Klystron contains of an electron firearm, a cathode fiber, an anode cavity, and a terminal at the cathode potential. It offers low power and has low ability. The electron gun creates the electron shaft, which allows through the hole in the anode pit. These electrons navigate towards the Repeller cathode, which is at high negative potential. The electrons repulse back to the anode cavity, Due to the high negative field. In their returning adventure, the electrons give more vitality to the hole and these motions are supported. The constructional subtleties of this reflex klystron is as appeared in the subsequent figure 4

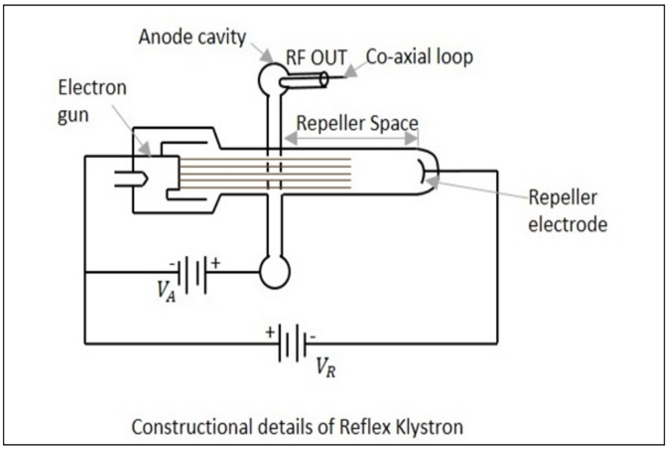

Fig 4 Constructional Details of Reflex Klystron.

It is normal that changes beforehand exist in the cylinder and they are proceeded by its task. The electrons while transient through the anode hole, increase some speed Rectenna configuration is explored as remote vitality reaping device working at 2.45 GHz with 15 dBm. Miniaturized scale strip antenna and rectifier circuit are structured. Therefore, the rectenna has a deliberate proficiency is above 3.6% and the relating yield DC voltage is 0.47 mV over a 200 Ω improved burden opposition. The mimicked qualities of the receiving wire are broke down also. The receiving wire is created and its deliberate return misfortune is additionally broke down. Great assentions between the reenacted and estimated attributes are gotten. The rectenna is likewise estimated by utilizing horn antenna as transmitter and multimeter.**[7]**

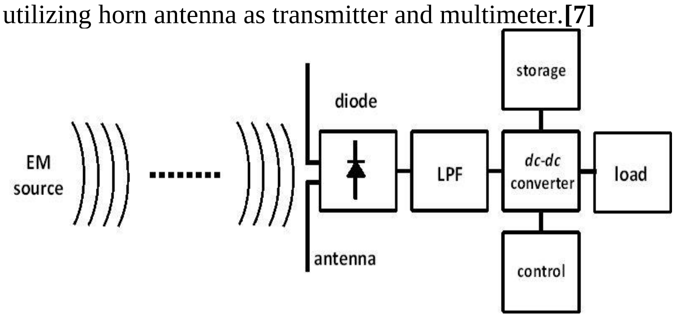

Fig. 5 General Recenna Design

II. SOLAR POWER SATELLITE

Power generation is one of the crucial elements of space vehicles and of future infrastructures on planets and moons. The increased demand for power faces many constraints, in particular the sizing of the power generation system, driven by eclipse periods and the solar intensity at the operational spot. In the medium term, Earth orbiting platforms will require higher power levels. Interplanetary exploration vehicles face the problem of distance to the Sun, especially when high power levels may be needed. Large infrastructures on the Moon and planets, like Mars, are constrained by environment attenuation, long eclipse or distance to the Sun. New systems and technologies have to be found, which go beyond simple improvements of the current technologies. Solar Power Satellite (SPS) systems, based on wireless power transmission, are attractive candidate solutions to provide power to space vehicles or to elements on planetary surfaces.

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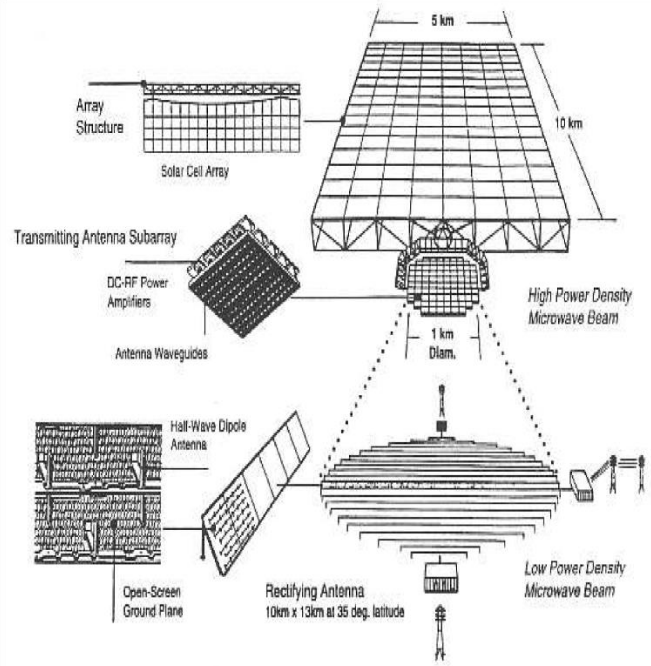
Studies have been carried out for many years on the problem of providing renewable electrical energy from space to Earth with SPS. Recently, an ESA funded study, led by EADS Atrium with the support of the University of La Reunion assessed the utilization of SPS concepts for space-to-space and space-to-planet applications. This research reviews the main results of this study for the SPS power delivery to elements on Mars and Moon.



Concept of Proposed SPS PowerTransmission

III. PROBLEM IDENTIFICATION

The optimum available frequency is 5.8 GHz, an internationally recognised, unlicensed ISM (Industrial, Scientific and Medical) band, having a wavelength, λ, of 51.7 mm (2.04 inches). At this frequency, atmospheric losses are <0.3 dB down to 15° elevation for CD 0.99, i.e. transmission is better that 93.3% for a Cumulative Distribution of "99% weather", which includes heavy cloud and storms. For a zenith beam, this loss is less than 0.05 dB (98.8% transmission, CD = 0.99) [3].

From GSO altitude (35,786 km), the minimum beam spot diameter (i.e. the Airy disc containing 84% of the beam power, typically captured by the rectenna) is given by (1):

$$DRX = 2.44 \times \lambda \times R/DTX \qquad (1)$$

Where DRX and DTX are the receiver (rectenna) and transmitter diameters, and R is the beaming distance (35,786 km). For a transmitter diameter/length of 1.43 km at GSO, the minimum rectenna diameter to capture the Airy disc is 3.16 km. The aperture is the sinusoidal projected area (2):

$$ATX = 2 \times DTX^2 / \pi = 1.3E6 \text{ m2} \qquad (2)$$

Which, at AM0 (Air Mass Zero solar intensity = 1,365 W/m2 at one astronomical unit, 1AU) intercepts 1.77 GW of sunlight. Assuming 40% efficient CPV and 85% DC:RF conversion efficiency, this gives a total RF power, P0, of 600 MW. The peak beam intensity is given by (3):

$$I0 = P0 \times ATX / (\lambda 2 \times R2) = 228 \text{ W/m2} \qquad (3)$$

Using equations (1), (2) and (3), The maximum directivity at 868 MHz and the RE (%) of the wire-SSRR versus all the design parameters: the variation of each parameter is from 90% to 110% of each initial value. In all the latter cases, the antenna resonates, i.e., the reflection coefficient is **below −10 dB**. So the considering receiving frequency directivity range between **0 to -8 dB** plus reduced expectations of CPV efficiency (reduced concentration for greater solar acceptance angle), a 34 metre diameter Cassiopeia massing 200 kg – 400 kg could **deliver 100 - 200 kWDC to a 74 metre diameter** temporary (reloadable) rectenna, with a peak beam intensity below the 230 W/m2 safe limit.

For SSP, the kilometre-scale transmitter necessities forced by microwave diffraction optics underneath 10 GHz, requiring different dispatches and on-circle development, would seem to support Sun-synchronous LEO choices over GSO. Be that as it may, the radiating impressions appeared are constrained essentially by the base height at the rectenna. With Cassiopeia sent at GSO in a close central plane, each 1.43 km satellite would mass somewhere in the range of 400 and 900 tons, **conveying 430 MW** to a rectenna estimating 3.16 km width (estimated in the east-west heading; more noteworthy estimated north-south, as indicated by scope.

IV.PROPOSED SPS SYSTEM

A constellation is a set of satellites distributed over space intended to work together to achieve a common objective. The characteristics of a satellite drastically vary with the altitude, inclination and size. Most of the constellations are used for communications, navigations, surveillance, guiding and other similar applications where the global earth coverage is difficult to achieve by other means. The constellation deign is expensive and hence satellites with lost costs are preferred.

The principle parameters for the constellation design are described as follows.

Coverage: Coverage is the principal performance parameter and is the primary reason for creating a constellation. Based on the application we can choose if we need continuous coverage or coverage for a particular area of interest. Altitude, minimum angle of elevation and constellation patterns is the major elements which determine the required coverage.

Number of satellites: Number of satellites is the principal cost driver. Hence the goal in a constellation design is to achieve maximum coverage with minimum number of satellites. Smaller constellation may require larger and complex satellites. For example a constellation with 20 satellites in LEO may or may not be cheaper than 3 or 4 satellites in Geosynchronous orbit.

Launch options: A given coverage can be obtained with a fewer satellites at a higher altitude. But, when the mass increases due to the power and performance then lower altitudes are preferred.

Environment: constellation design is independent of factors like thermal, vacuum and zero-g but is largely dependent on radiation environment which increases if the spacecraft is in the Van Allen belt.

This limits the life time of the components like solar arrays, cells and computers. Hence it is preferred that the satellite is either above or below the Van
Allen belt.

Orbit perturbations (station keeping): The drag perturbation on the earth’s satellite is dependent on the altitude and the earth’s oblations effect depends on inclination, altitude and eccentricity. These perturbations cause a drift of the position of the satellites and this can be avoided by keeping all the satellites at a same altitude and inclination.

Collision avoidance: The single largest threat to constellation design is the collision within a constellation which creates a cloud of debris within the system causing inter collisions. The only way to avoid this collision is by designing the entire system for collision avoidance.

Constellation buildup, replenishing, End of life: One of the important factor to be considered is the condition when a spacecraft fails and so is the end-of- life of a satellite. This is a major cost driver. After the end-of-life the satellite is removed from the constellation pattern to avoid collisions.

Number of orbit planes: moving satellites within a plane takes extremely small amount of propellant, whereas changing the orbit planes takes very large amount of propellant. Hence constellation with a smaller number of orbit planes will have more performance as the system builds up. However depending on the constellation patter these orbital planes can also be determined.

V. THE ARCHITECTURE OF THE PROPOSED SPACE BASED SOLAR POWER GRID

A constellation is a set of satellites distributed over space intended to work together to achieve a common objective. The proposed Space Based Solar Power Grid (SSPG) aims for a constellation which can download 140GW of power at ground stations. Since each satellite can download an amount of 1GW of power we require a total of 140 satellites. This Design issue has many arrangements. One of such arrangement is architecture of the system including the spacecraft structures and another type of 3D view of the system in MATLAB. When these 140 satellites are distributed in 2 orbits there are 70 in each equally spaced. The orbit is at the center of mass of one unit grid.

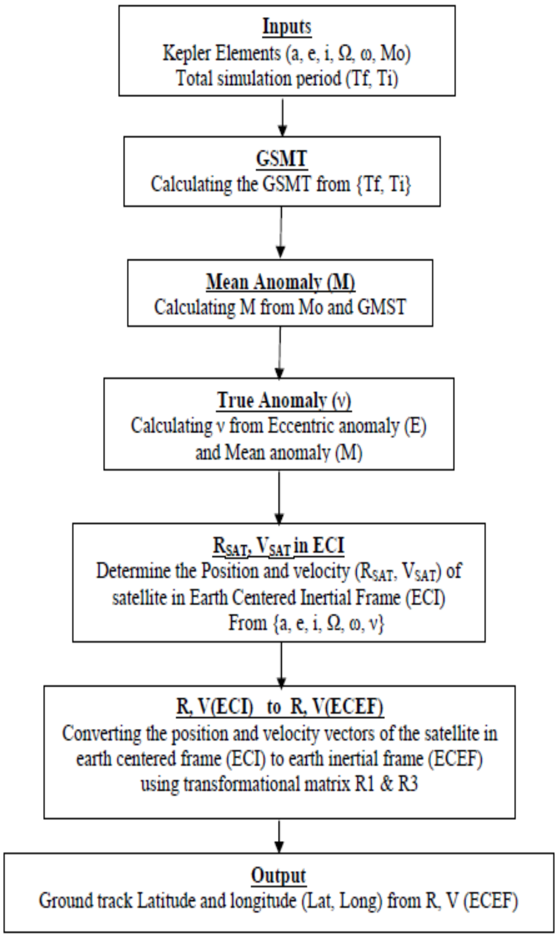


Figure 6 Algorithm for ground track.

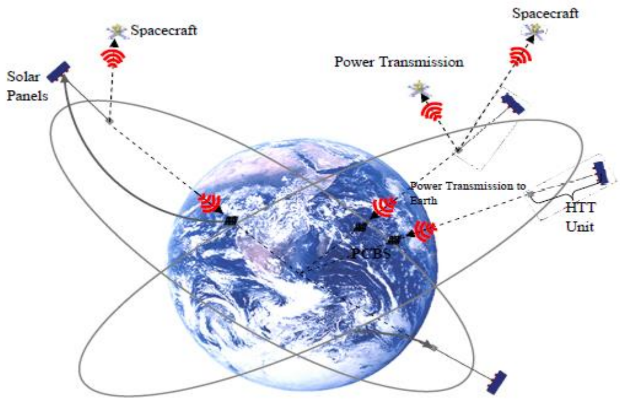


Figure 7 Constellation Design for the proposed Space Base Solar Power Satellite System.

Power collected= collector area* efficiency* solar cell harvest capacity

Power collected= 100m* 100m * 100% * 1400 W/m2

Hence, *Power Collected* $=1.4 * 10^7$ *W*

After calculating the net losses during the transmission, Power transmitted is
Calculated by using the following formula.

$$P_{t,dB} + G_{t,dB} + G_{r,dB} = L_{SBSPG,dB} + P_{r,dB}$$

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Where,
$P_{t,db}$= Power transmitted by SOPHU in dB
$G_{t,db}$ = Gain transmitted in dB
$G_{r,db}$ = Gain received in dB
L SBSPG = Total Losses of the Space Based Solar Power Grid in dB
$P_{r,db}$ = Power received in dB

VI. RESULT AND ALGORITHEM

To generate microwave frequency 2.45 Ghz we select solar radiation range from S= [100 80 60 40 20] inmW/sq.cm. in which radiation above 50mW/sq,cm can able to generate 297 Watt of power and this much of power is our minimum requirement for a radar to detect receiver antenna on ground and to send 2.45Ghz frequency,

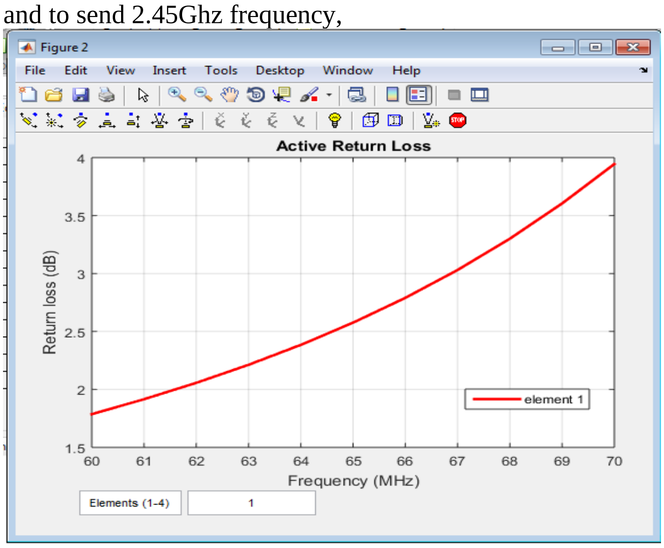

Figure 8 losses Outcome.

```
freq = 4e9;
v = 23.0;
lambda = physconst('LightSpeed')/freq;
dopplershift = speed2dop(v,lambda)
freq = 9e9;
df = 400.0;
lambda = physconst('LightSpeed')/freq;
speed = dop2speed(df,lambda)
waveform = phased.RectangularWaveform('SampleRate',5e6,...
    'PulseWidth',6e-7,'OutputFormat','Pulses',...
    'NumPulses',1,'PRF',1e4);
```

```
Command Window
dopplershift =

  306.8790

speed =

   13.3241

Pt =

  297.0740
```

Figure 9 Transmitting power.

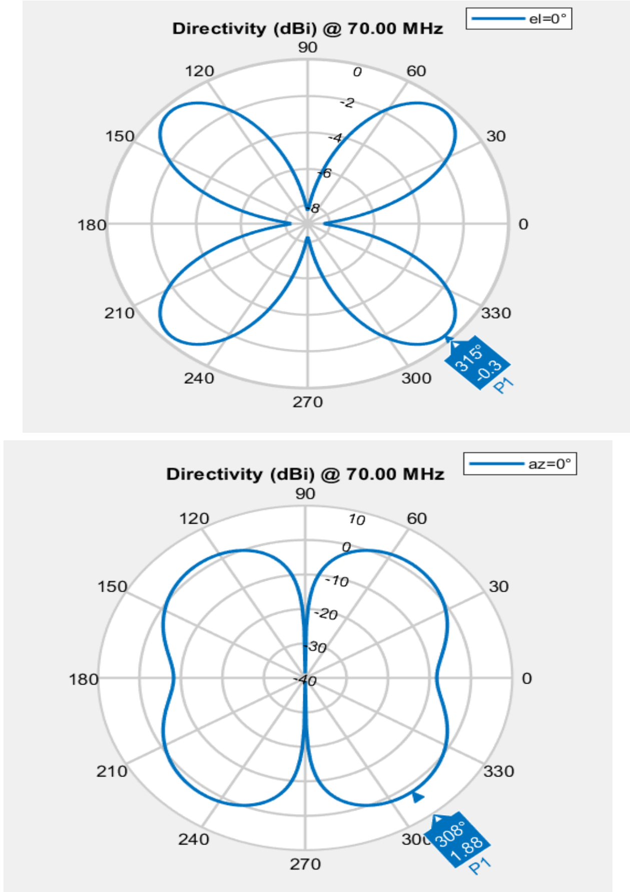

Figure 10 Directivity Pattern comparison

Received microwave frequency from transmitting antenna is in the form of beam of rectangular array, According to previous research work directivity ranges from 0 to -8 dB @70.00 MHz which causes cutoff of frequency below 2.45 GHz, if directivity ranges from 0 to -40 dB then frequency ranges till 2.00 GHz will utilized by which after conversion in rectenna e get total power 223 MW.

```
Ar=500;
At=170;
c=3*(10^8);
f=70*(10^6);
lemda=c/f;
D=5;
t=(lemda*D)^2;
Pt=120.7;
Pr=((Ar*At)/t)*Pt*10e-3;
fprintf('\nPr  :  %3f2', Pr);

% A=4*3.14*(R^2);
```

```
Command Window
>> repower

Pr  :  223.4291112>> repower
```

Figure 11 Rectenna Power

Microwaves beam are transmitted from SPS from Geo to earth surface is situated on the electromagnetic spectrum with frequencies ranging from 60 MHz to 70 MHz. According to Friis transmission formula received power from far place as follows

$$Pr = \frac{ArAt}{(\lambda D)^2} * Pt \quad (1)$$

$$Pr = \tau^2 * Pt, \tau^2 = \frac{ArAt}{(\lambda D)^2} \quad (2)$$

$$(Beam\ efficiency)\eta = \frac{Pr}{Pt} = 1 - e^{-\tau^2} \quad (3)$$

Here Pr, Pt, Ar, At, , D are gradually Received power, Transmitted power, Aperture area of receiving antenna, Aperture area of transmitting antenna, wavelength, Distance from transmitting antenna to receiving antenna. Is a parameter it also refers efficiency of Friis equation. Hence by putting our all work values on above equation we get receiving power 223.42 MW, Fig 11

VII. CONCLUSIONS

Power transmission from solar power satellite to earth surface in the form of microwave frequency can be considered as a tremendous scope in future prospects for power generation unit. Petroleum derivative electric power plants create ozone depleting substances which are in charge of an unnatural weather change. Power transmission through solar power satellite can beat these issues well because power generation through solar panels is more economical and ecofriendly. In earth surface we face some limitation for power generation through solar panels because we can generates power up to 10 hours/day, whereas in space power generation makes possible to harvest power for whole day. In this work complete process of SPS power - generation, transmission, receiver and conversion is shown with minimum power loss.

REFERANCES

1. William C. Brown "Microwave Power Transmission Systems"Solar Energy Vol. 56, No. 1, pp. 3-21, 1996.
2. Satyam Anil Singh , Umeshkumar Prasad , Ravesh Chauhan , RutviThakar "Wireless Power Transmisson using Resonant Inductive Coupling" IJRASET, Volume 6 Issue IV, April 2018.
3. Shyma.S, Sindhuja.E "Wireless Power Transmission from Solar Power Satellite" International Journal of Scientific & Engineering Research, Volume 5, Issue 2, February-2014.
4. C. Cougnet, E. Sein, A. Celeste , L. Summerer, "Solar Power Satellites for Space Exloration and Applcation" 55th International Astronautical Congress 2004.
5. Combes, P F. "The solar power satellite". France: N. p., 1982
6. Volker Blandow, Patrick Schmidt, Werner Weindorf, Martin Zerta, Werner Zittel, Marco C Bernasconi, Patrick A Collins, Thomas Nordman, Thomas Vontobel, Joelle Guillet, "Earth and space Based solar power generation a comparisons studies",A study of ESA advanced concept team, Jan 2005.
7. A. M. Shire, N. Abdullah, E. Mohd. "Design of rectenna for wireless energy harvesting", IEEE Student Conference on Research and Development (SCOReD), 2016.
8. E.L. Ginzton ; A.E. Harrison "Reflex-Klystron Oscillators" Proceedings of the IRE (Volume: 34 , Issue: 3 , March 1946).
9. Joseph R. Laracy1 , Damien Bador2 , Danielle Adams3 , Annalisa Weigel4 "Solar Power Satellites: Historical Perspectives with a Look to the Future"josephrlaracy 2007.
10. Ian Cash SICA Design Limited "CASSIOPeiA Solar Power Satellite" IEEE International Conference on Wireless for Space and Extreme Environments (WiSEE),October 10-12, 2017, Montréal, Canada.

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