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SATELLITE BASED SOLAR POWER GENERATION

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***Abstract*-Satellite Based Solar Power system (SBSP) is an energy system which collects solar energy in space and transmits it to ground. The system generates electricity by the solar array and converts the DC power into microwaves with a frequency of 5.8 GHZ. There is unlimited constant solar energy supply in space, free from the weather conditions, which is different from the closed earth system. The concept of SBSP is to tap the solar energy using a large-scale photovoltaic array in space and to transmit it to ground using microwave beam. In remote areas or places like Polar Regions and deserts, the generation of power is more difficult. Especially in Polar Regions, the generation of power solar system is impossible and also in high solar irradiation places, the power production through solar is not greater than 8 hours. The time average power per unit area in space is 5-10 times larger than that on the ground.SPS can power or tap the solar energy using a large-scale photovoltaic array in space for 24 hours, 365 days gives the reliable operation free from the weather conditions, quite different from that on the earth and SBSP has a competitive advantage over the solar power system on the ground. This paper introduces the concept of SBSP, and presents microwave power transmission technologies necessary for SBSP and futureprospects towards commercial SBSP.**

I.INTRODUCTION

The most important global issues to be resolved to sustain our society is 80 % of energy in our life comes from non-renewableresources. If we continue to use the non-renewable resources at the current consumption rate, they will be completely exhausted within 100-150 years. Furthermore, the huge amount of consumption of non-renewable resources like fossil fuel increases CO2 concentration in the atmosphere, which raises series environmental concerns. So we need alternative energy resources to overcome the above problems. Solar energy system which can make considerable contributions to solving some of the urgent problems the world now faces. There is enormous solar energy supply in space free from the weather conditions quite different from that on the earth. This solar energy is tapped by solar modules which are carrying by satellites and the power is transmitted to ground with the help of wireless power transmission. Power loss for the wireless transmission/reception is expected less than 30 %

At the end of 19^{th} century Heinrich Hertz and Tesla had validated the possibility of wireless transmission firstly in theory. Then Tesla, who put forward and realized AC made further research to wireless transmission and done series of wireless transmission related experiments. According to power transmission distance, wireless transmission can be divided into 3 categories: *short range, medium range and long range wireless transmission.*

Short range wireless transmission mode: In this mode the power transmission mode the power transmission is within several millimeters and the typical representation of such transmission mode is based upon electromagnetism Induction Technology. When transfer distance is limited in several millimeters its transfer efficiency can reach 60% but once beyond these range efficiency will decrease greatly and be no longer fit for practical application.

*Medium range wireless power transmission mode:*In this mode there are two categories, they are ultrasonic mode and Electromagnetic resonance Induction

A.Ultrasonic Mode:

Ultrasonic is sound wave which frequency is more than 20000HZ and belongs to mechanical wave. Ultrasonic possess very strongdirection property and

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also famous for strong power transfer. So ultrasonic is very fit for medium of wireless power transmission. The research about ultrasonic wireless power transmission is mainly focused on small power wireless charging system there is still many problems remains to be further exploration

B.Resonance Induction:

Electromagnetic wave possess strong radiation property, when transmission distance is relatively long transmission efficiency of IPT mode is very low and receiver can only receive a very small power. To resolve this problem resonance induction Technology is developed. This efficiency is very high and transmission distance can reach 3m~4m, transmission power several KW. Present problem persisted in these research is over big antennae.

C.Long range transmission mode:

Transmission of long distance wireless power transmission can reach several decades KM which mainly includes two categories: *Laser Transmission and Microwave Transmission.*

D.Laser mode:

Laser is famous for its better directional property bigger power carrying capability and so on. There are some demerits in wireless laser power transmission. The efficiency of converting electrical power to laser or converse process is not so high. No barriers be permitted locating in the path of power transmission path. Absorbing loss of transmitting in atmosphere will also cause loss of power transmission. So Microwave power transmission is commonly used for long range transmission mode.

E.Microwave Transmission:

Microwave is the kind of electromagnetic wave whose wavelength is 1mm ~ 1m, frequency from 0.3 GHZ to 300 GHZ. These leads to the investigate spotlight of microwave wireless power transmission main focus on SBSP (Space Based Solar Power). Most of the SBSP models proposed so far uses microwave rather than laser for the wireless power transmission, because the power efficiency both at the transmitter and receiver is generally higher and attenuation through the atmosphere is lower for microwave as compared with laser.

II. GENERAL BLOCK DIAGRAM OF SBSP

The Satellite Based Solar Power Generating system has the following components: Satellite with solar cell, transmitter,and rectenna in ground.

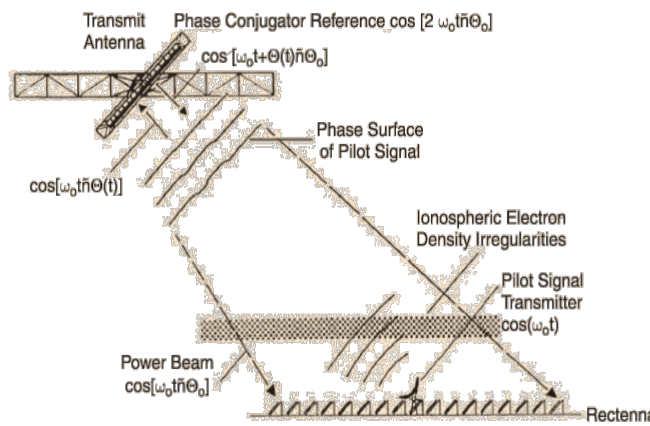

Figure. 1. General Diagram for SBSP

A. Satellite with solar cell:

Satellite revolves in orbit helps to carry solar cells which must be directed towards the sun. Assemblies of solar cells are used to make solar modules which are used to capture energy from sunlight. When multiple modules are assembled together, the resulting integrated group of modules all oriented in one plane is referred to solar panel. The electrical energy generated from solar modules, referred to as solar power or solar energy is in the form of DC. It is fed to transmitter section.

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B.Transmitter section

It converts the DC supply from the solar modules to the Microwave frequency and transmits it to the ground in a range of 1-10 GHz, compromising between antenna size and atmospheric attenuation. If we choose a frequency in the industrial, scientific and medical (ISM) radio bands, 2.45 or 5.8 GHz is the potential candidate. 2.45 GHz was selected in the early phase study, but 5.8 GHz has been recently considered as a more desirable frequency due to recent accelerated progress in C-band RF technologies. As for the microwave generator, tubes such as magnetron, klystron, and TWT have been proposed for the SPS use because the power conversion efficiency is reasonably high more than 70 % at low cost.Semiconductor amplifier is another potential candidate as the power efficiency has been considerably improved to 60-70 % with low cost expectation. Besides the power efficiency, beam pointing technologies to transmit the microwave power beam precisely to the receivingsite are essential for the power transmission.

They are peculiar to the wireless power transmission, not covered by the existing communication technologies. A beam angle 100 μrad with a 10 μrad pointing accuracy is required for the 5.8 GHz transmission from an antenna of 2 km square in the geosynchronous orbit to a reception site of 3.5 km diameter on the ground. The transmitting antenna will be assembled by a number of array antenna panels which consist of sub-array antennas. Totally more than 1 billion antennas will be installed. A retro-directive technology with a pilot signal from the ground will be used to control the microwave beam from each antenna panel directing to the ground station. Although eachpanel is sufficiently stiff for microwave beaming, relative motion between the panels cannot be avoided for the large antenna assembly. In order to form a microwave beam precisely focused at the ground station, the phase of microwave from each panel needs to be adjusted between the panels, which requires revolutionary new technologies.

Table 1: 2.45-GHz RF tube comparisons

Parameter	Klystron [19]	Magnetron [20]
Amplifier output power	50 W	4.39 kW
DC-RF power efficiency Overall efficiency	74%	87.5% 81.7%
Carrier-to-noise ratio	120 dB @ 10 kHz 135 dB @ 1 MHz 140 dB @ 20 MHz 160 dB @ 100 MHz	110 dB @ 10 kHz 137 dB @ 1 MHz 160 dB @ 20 MHz 196 dB @ 50 MHz
Lifetime	25 years*	50 years [18]

** Projected*

In the 5.8-GHz klystron transmitter, the output power of the most powerful tube located at the array center is 26 kW with an operating voltage and current of 28 kV and 1.12 A, respectively. Although not validated by measured results, the high-efficiency 5.8-GHz klystron design is based on previously built units that have efficiencies over 70%. This modified design uses a multicavity configuration with one of the cavities tuned to the second harmonic and with five stages of depressed collectors.

The tube body and solenoid operate at 300 degree C, and the collectors operate at 500 degree C. Preliminary design simulations revealed that the overall efficiency (i.e., combined electronic and circuit efficiencies) to be a conservative 76% without the depressed collectors. Including the collector recovery of 50%, the overall efficiency is 83%. Due to the 10-dB Gaussian amplitudetaper, the approach taken with this transmitter design was to place the 26-kW klystrons in the array center and reduce the tube's output power to 2.6 kW at the array's edge in ten tapered steps. This transmitter configuration is very similar to the Reference System design, albeit with a smaller power modules of 1 m2.

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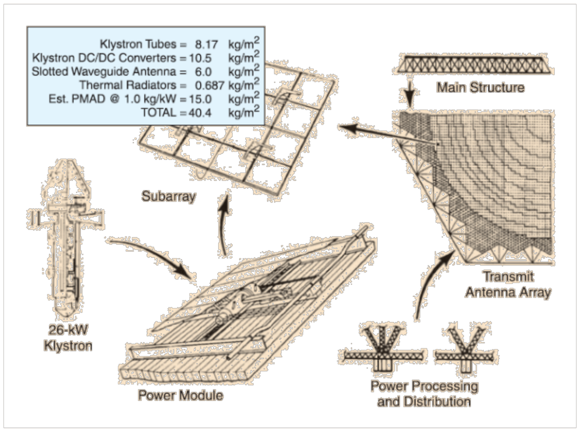

Figure.2. Klystron transmitter

The second tube approach to the 5.8-GHz transmitter applies a phase-locked magnetron directional amplifier (MDA), whose proposed output power and efficiency are 5 kW and 85.5%, respectively. The MDAoperates at 6 kV and dissipates the waste heat at 350 degree C with a pyrolytic graphite thermal radiator. The MDA is basically a phase-injection locked magnetron oscillator with an augmented magnetic bias coil on the permanent magnet for controlling the output power and an output tuning slug for adjusting the frequency.

Thus, the phase, amplitude, and frequency could all be independently varied. Similar to the klystron transmitter, the MDA is married to a slotted waveguide antenna, whose sub array size is 4*4 m.The third type of transmitter studied in the SERT program uses solid-state devices. Unlike the slotted waveguide array where a tube would feed many radiating slots, the solid-state transmitter places a 5.8-GHz power amplifier and phase shifter behind every radiating element. Because a phase shifter is located at every element, the advantage of this approach over the tube transmitters is the elimination of grating lobes when electronically steering the beam.

However, microwave filters are needed on each element to suppress both close-in carrier noise and harmonics generated by the power amplifier. Similar tothe klystron approach, the 10-dB Gaussian taper is approximated by ten distinct power levels, where each of the center elements radiate 59 W, and the edge elements radiate 5.9 W. The operating voltage and junction temperatures for the power amplifiersare assumed to be 80 Vdc and 300 degree C, respectively.

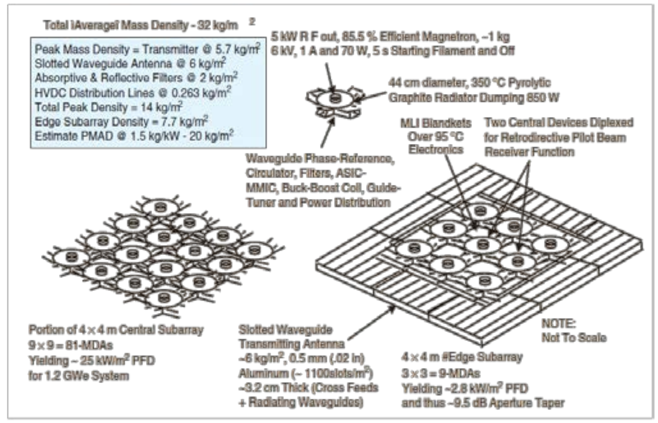

Figure.3. Magnetron directional ampilifier transmitter

C.Beam Control

A key system and safety aspect of WPT is its ability to control the power beam. Retro directive beam control systems have been the preferred method of achieving accurate beam pointing. As depicted in Figure 6, a coded pilot signal is emitted from the rectenna towards the SBSPS's transmitter to provide a phase reference for forming and pointing the power beam. To form thePower beam and point it back towards the rectenna, the phase of the pilot signal captured by receivers located at each sub array is compared to an onboard reference frequency distributed equally throughout the array. If a phase difference exists between the two signals, the received signal is phase conjugated and fed back to the phase control circuitry of each dc-RF converter. In theAbsence of the pilot signal, the transmitter will automatically dephase its power beam, and the peak power density decreases by the ratio of the number of transmitter elements. This aspect of retro directive beam control is an inherent safety feature of the system. Today's wireless service industries are continually discovering methods to expand their networks and capacity to accommodate greater volumes of voice and data traffic. To handle the

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increased demand, smart antenna technology is being deployed globally to reduce signal interference.

D.Receiver system

Since the early 1960s, rectennas havebeen researched and developed atvarying levels of intensity. Brownwas a pioneer in developing the first2.45-GHz rectennas that includedthe basic circuit components stillevident in today's rectennadesigns. Measuredin 1977, Brown's aluminum"bar-type" rectenna still holdsthe highest recorded efficiencyof any rectenna in the microwavefrequency range at91.4% .Due to the substantialamount of research performedat 2.45 GHz over the last 40years, efficiency at this frequency is used as a standard for estimating the highestconversion efficiencies attainable at the higher frequencies.

This efficiency comparison is made possible bykeeping the gain of the 2.45-GHz rectenna (6.4 dBi) constantand scaling in frequency the effective areas ofrectennas at 5.8 and 35 GHz. With an effective area of 52Cm2 for the 2.45-GHz rectenna, the effective areas for thehypothetical 5.8- and 35-GHz rectennas are 8.92 and0.245 cm2, respectively.Since the middle-to-late 1980s, interest in rectennadevelopment has shifted to higher frequencies, dual andcircular polarization and printed-circuit formats. Emphasishas been placed onthin, lightweight, low-cost approachesto make powerbeaming to high-altitude communicationplatforms morefeasible. In the SERT program, ahigh gain and circular polarizedprinted rectenna arraywas developed with over 78%efficiency at Texas A&M University. Similarto dual polarization, circularpolarization adds the flexibilityto WPT systems that aremobile, such as beamingpower to a high-altitude communicationsplatform. Because the antenna is a dualrhombic, the element gain was measured to be 11 dBi.Highgains allows the rectenna elements to be arrayedwith wider separations in the effort to lower the numberof diodes in a large rectenna array. The rectenna used inthe SERT 5.8-GHz system was sized to be 7.5-km in diameter, requiring millions of diodes. Also developed atTexas A&M during the sametime was a dual-frequencyrectenna with efficienciesgreater than 80% at both 2.45and 5.8 GHz.

Fig.4 shows a block diagram of the rectenna element. Thiselement is composed of a DC block capacitor, a matchingcircuit for input RF signal, a low barrier height diode for lowlevel power detecting, a smoothing capacitor and a filtercircuit to control the impedance of RF-harmonics. Input RF frequency is 5.8 GHz. In the rectenna element, arectifying circuit is arranged on the backside of a patchantenna. The substrate has three layers. The rectifying circuitsshare the ground plane with the patch antennas. They areconnected by the vertical feed. Circular polarized wave isused. The rectifying circuit improves the RF-DC conversionefficiency dealing with the impedance of the RF harmonics.

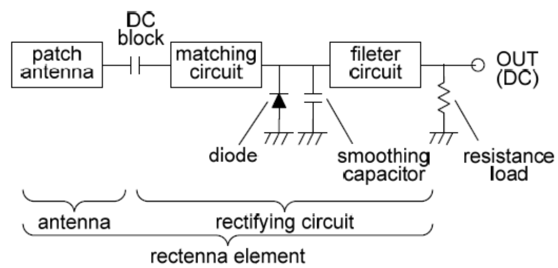

Figure .4. Block diagram of the Rectenna Element

In well-matched rectennaarrays, the diode is the mostcritical component to achievehigh efficiencies because it isthe main source of loss.Schottky barrier diodes utilizingSi and GaAs have beenemployed with rectificationefficiencies greater than 80%.

Although the electron mobilityof GaAs is over six timesgreater over Si for high efficiency,Si has a higher thermalconductivity for better reliabilityProper diode selection for a WPT application isdependent on input power levels, and the diode parametersshould be chosen carefully for an efficient rectifierat a specified operating frequency. The breakdown voltage(*V*br) limits the diode's power handling capabilityand is directly related to the series resistance and junctioncapacitance through the intrinsic properties of thediode's material and structure. For instance, increasingthe breakdown voltage increases either the series resistanceor junction capacitance. Decreasing the series resistancewill

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decrease the power dissipated in the diode;however, the breakdown voltage will decrease or thejunction capacitance will increase. Increasing the junctioncapacitance will lower its cutoff frequency. Theseparametersmust be traded in selecting the proper diodefor high- power applications.The Output DC from the rectenna is fed to the inverter which converts DC to AC and it is connected to the grid.

III. CONCLUSION

One of the most critical technologies for the SBSP ismicrowave power transmission from the geo-synchronous orbitto the ground. Evolutionary microwave technologies arerequired for high power conversion efficiency more than80 % from/to DC and an extremely high-precise beam controlwith 10 μrad accuracy.At 5.8 GHz,dc-RF converters with efficiencies over 80% are achievabletoday. Rectennas developed at 5.8 GHz have alsobeen measured with efficiencies greater than 80%.

The SBSP will be a central attraction of space and energytechnology in coming decades. At present, technologicaldevelopment of theMPT at 2.45 and 5.8 GHzis still ongoing. However, the overall efficiency goal of64% from dc provided by the solar panels to dc outputfrom the rectennas is not far away. The target of 80% atboth transmitting and receiving systems is achievablein the near future.

REFERENCES

[1] S.Sasaki, K.Tanaka and Advanced Mission Research Group,“SSPS Technologies Demonstration in Space”, IAC-10.C3.4.1,61st International Astronautical Congress, Prague, Sep.-Oct. 2010
[2] P.E Glaser, “Power from the sun: Its future”, Science, vol.162, pp.867-886, 1968.
[3] Matsumoto,Research on solar power station and Microwave Power Transmission in Japan : Review and Perspectives.IEEE Microwave Magazine,December2002,pp.36-45