

The transfer of energy from the solar-space power station to the Earth

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Abstract. The resulting problem in the transmission of electrical energy from space to the Earth by means of microwave electromagnetic waves is discussed. The main parameters and principles for constructing the space and ground segments of such a solar power plant are given.

1 The essence of the problem

Solar power plants (SP) are the leading direction in alternative electric power industry, accounting for about 6% in the electric power balance of the leading countries in the world.

The specific power of solar radiation in outer space is 1.4 kW / m² or 12,000 kWh / m² of energy per year. Due to the reflection of sunlight in the atmosphere, the first indicator in clear weather in the equatorial zone of the Earth is reduced to 1 kW / m², and in other areas to an even smaller value. Approximately the average daily value of this indicator for different regions of the Earth does not exceed 0.3 - 0.4 kW / m².

Taking into account all the factors (atmospheric dispersion, weather effect, daily and annual indicators of the Earth's surface illumination) with the efficiency of solar cells 20% [1,2], the conversion of solar energy into electrical energy is 1%, i.e. the specific energy value per year is 120 kWh / m².

The view of such a small value of this parameter was the birth of a proposal for the removal of SPS into outer space where the influence of the atmosphere is excluded, and intensive irradiation of solar batteries occurs continuously throughout the day and the whole year [3]. Since then, there have been practically no publications on the problem submitted. However, at the present time, in connection with the appearance of powerful microwave transistors, with the help of which it is possible to convert the energy of solar batteries into microwave radiation, the idea of building a solar-space power plant becomes technically feasible. As calculations show, the efficiency of such solar-space power stations (SSP) can exceed the ground-based ones by 10-20 times and make up 1200 kW-h / m² of energy per year. All the data are summarized in Table 1.

One of the technical problems in the implementation of the idea for the creation of SSP is the transfer of the energy it generates to the Earth. The general

scheme of SSPS, in which energy from space to the Earth is transmitted by microwave radiation, is shown in Fig. The scheme includes two segments: space and ground. Consider the principles of their construction and basic parameters

Table 1. Comparison of two types of solar power plants

Location: Solar Batteries	Specific Power Solar Radiation	Specific amount of radiated solar energy per year	Specific amount Electrical Energy per year with EFFICIENCY = 20%
Dimensionality	kW / m ²	kW-h / m ²	kW-h / m ²
In space	1,4	12 000 (100%)	1200 (10%)
On Earth	0,3 - 1	600 (5%)	120 (1%)

2 Space segment of the SSP

This segment includes:

- solar batteries, facing their flat surface to the Sun;
- a certain number of microwave semiconductor generators that convert the direct current energy generated by solar batteries into microwave electromagnetic oscillations;
- the same number of radiators forming a phased antenna array directed towards the Earth;
- two extreme systems of automatic control, the first of which provides maximum consumption of solar energy batteries, the second one - the continuous direction of the antenna array's directional pattern to the desired place on the Earth, where the receiving antenna is located.

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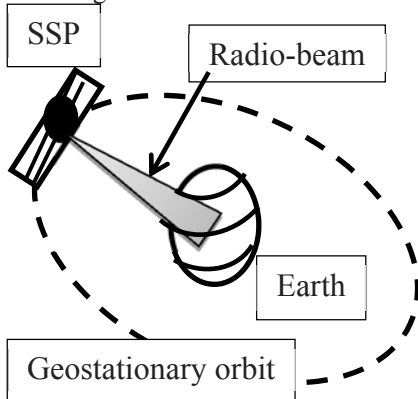


Fig.1. The scheme of transmission of microwave energy from space to Earth.

The general scheme for the transmission of microwave energy produced in a geostationary orbit to Earth is shown in Fig. 2, where the following designations were adopted: 1- solar array, 2- satellite in geostationary orbit, 3-phased array antenna, 4 - a set of receiving terrestrial antennas, D_A - their total diameter. H - is the height of the antenna array above the Earth. The signal frequency emitted by the phased array, $f = 6$ GHz, i.e. the wavelength $\lambda = 5$ cm.

At $H = 36 \cdot 10^6$ m (more accurately $H = 35,786 \cdot 10^6$ m - height of the geostationary orbit), and $D_A = 25 \cdot 10^3$ m, we obtain for the angle of the antenna pattern opening, located on the space object,

$$\alpha = 2 \cdot \left(\frac{180}{\pi} \right) \cdot \text{atan} (D_A / 2H) = 0,044^\circ. \quad (1)$$

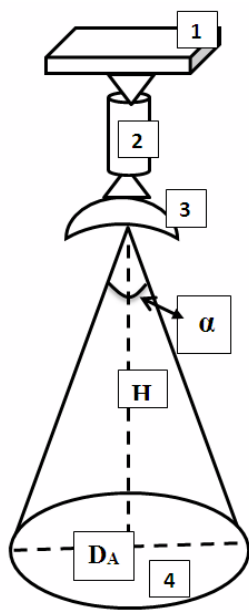


Fig.2. The scheme for determining the antenna's angle of directivity

The very diagram of the direction in one plane of the antenna array on two scales is shown in Fig. 3, where the angle is in degrees. Angle $\alpha = \Delta\Theta = 0,044^\circ$ is the width of the ray of the diagram of the direction of the 0.7 level with respect to the maximum value of the field strength.

To obtain such a directional diagram with a wavelength $\lambda = 5$ cm in each line of a flat phased array antenna, 1000 emitters should be located, and their total number is a one million. As the radiators of a phased array, it is possible to use micro strip antennas of the Vivaldi type (Fig. 4) [4]. The distance between two neighboring radiators is $b = \lambda = 5$ cm.

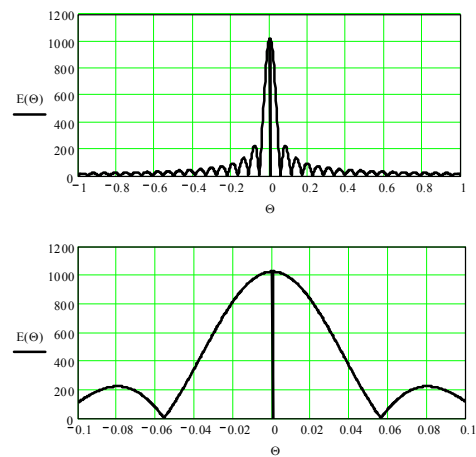


Fig. 3. Directivity diagram

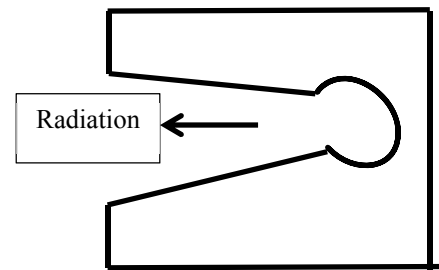


Fig.4. Outward visible Vivaldi

3 The terrestrial segment of the SSPP and the main parameters of the SSP

The ground segment includes:

- the antenna array receiving the microwave signal of the space segment;
- an ensemble of detectors that convert the received microwave signal into direct current;
- microprocessor system for automatic control and monitoring of operation of all elements of the facility.

When calculating the SPS-Earth radio link, it is necessary to take into account:

- the power and frequency of the microwave signal supplied to each of the radiators of the CFA,
- the total number of such emitters,
- the dimensions of the receiving terrestrial antenna,

of this problem is important for some projects of today.

These include, in particular, remote charging of batteries unmanned aerial vehicles. The ground station such a system includes a microwave generator with a frequency of 2.45 GHz, a power of 1 kW from the mass-produced microwave oven; parabolic antenna with a diameter of 3 m and the device of its guidance on an unmanned aerial vehicle, hovering at a height of up to 100 m.

The equipment on board the unmanned vehicle includes: a phased array antenna with a number of 32x32 emitters, microwave detectors attached to these emitters, and a rectifier connected to the battery to charge it.

Thus, it is possible to carry out remote charging of batteries by an unmanned aerial vehicle without landing on the Earth, which is extremely necessary in many cases.

7 Conclusion

1. The conducted comparative analysis of two types of solar power plants ground and space - shows unquestionable advantages in terms of the energy performance of a power plant of the second type.
2. Within the framework of the first stage of the implementation of this project, it is necessary to solve the problem of today: remote charging of unmanned vehicle batteries.

References

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