Antenna With Corner Reflector Based on Solar Cells

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Abstract. The work explores the possibility of forming a reflector for an antenna system based on solar panels. The reflector design is formed on the basis of two solar panels, which form a corner reflector. Conducted studies show that the use of solar panels as a reflector makes it possible to ensure a high level of antenna directivity, provide a wide range of operating frequencies, and also provide electricity generation based on green (carbon-free) energy technologies. The results obtained are confirmed by the results of electrodynamic modeling, as well as experimental measurements of the antenna layout. The developed design, thanks to the use of a planar antenna as an irradiator, made it possible to ensure a high level of electricity generation, since a small overlap of solar panels is ensured. The results of measurements and simulations are illustrated with pictures of radiation patterns, as well as measurements of the characteristics of electrical energy that the solar panel produces.

1 Introduction

The use of reflector antennas makes it possible to achieve a high level of directivity, which increases the communication range and also improves the noise immunity of the transmitting and receiving systems. Achieving all such advantages is possible through the use of a reflector, which is usually performed by conductive plates made of copper or aluminum. However, due to the design of solar panels, there is an assumption about their possible use as a reflector. This design will not only maintain a high level of directional efficiency, but will also ensure the generation of electricity based on renewable sources, which is an important component of green (carbon-free) energy.

The implementation of methods for integrating antennas and solar panels has been discussed in many scientific papers. In [1], the authors propose a method for forming a planar patch antenna directly in the solar panel structure. The research results show that the characteristics of the resulting antenna are as close as possible to a similar antenna made of conductors. The disadvantage of this design is the need to change the design of the solar cell, which significantly increases the cost of producing such a design.

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Works [2,3] propose a technique for forming patch antennas in solar panels by forming the antenna location area by etching silicon and layers of the solar panel, as well as by changing the pattern of collecting contacts in the structure of the solar panel. The resulting antennas show high efficiency, a high level of directivity, which is stable over a wide frequency range. The disadvantage of such designs is the change in the design of solar cells, which reduces their operating efficiency and also reduces the useful area of the photocell location.

In [4], the authors propose to use patch antennas based on a transparent dielectric, as well as those made by applying a grid pattern to the substrate. The advantage of this design is that the resulting antenna rests against the solar panel and does not require changing the characteristics of the elements, which significantly increases the efficiency of using solar panels, since only a small energy collection area is covered. The above research results also confirm that thanks to the design of the solar panels, it was possible to increase the directivity of the antenna due to wave reflections from the solar panel.

The works [5-7] provide a review of methods for using solar panels as emitters. The studies carried out show the high efficiency of using such structures, while maintaining a high level of efficiency and directivity of antennas. However, the authors note that all proposed antenna designs are based on changes in the characteristics of solar panels, which leads to the need to use premium level solar panels and also reduces electricity generation.

This paper proposes the use of solar panels as a corner reflector of the antenna, while ensuring that the design of the solar panels is preserved without changing the design, which greatly simplifies the process of producing the antenna system and also reduces the cost. Based on the resulting design, an antenna prototype was assembled, which was used to measure the antenna characteristics.

### 2 Antenna design and electrodynamic modeling results

To form any reflector for an antenna, it is necessary to form a reflective surface from a conductor. A feature of the design of solar panels is that they are a multilayer structure, which contains both dielectric layers - protective coatings, silicon, glass; and conductive surfaces - the copper polygon of the positive contact, the thin lines of the negative contact terminal. Figure 1 shows a view of the solar panel design that was used in the modeling process.

![Solar panel model design](image)

Fig. 1. Solar panel model design: 1 – Protective glass ($\varepsilon_r=4.82; \tan\delta=0.0054$); 2 – Layer of collector conductors (silver); 3 – Silicon plate ($\varepsilon_r=11.9; \sigma=0.00025$); 4 – Ground layer (aluminum); 5 – Layers of protection (Fr-4).
As mentioned above, it is clearly visible that the solar panel has a multilayer structure, and in accordance with the laws of electrodynamics, electromagnetic waves penetrate through dielectrics, but are reflected from conductors. Thus, based on a solar panel, a reflective surface can be formed, which, in addition to forming a narrow radiation pattern, will make it possible to generate electricity using green energy technology.

For any reflective antenna, you need to select a feed that will be used to emit and receive electromagnetic waves. In our case, to form a reflective antenna, a Vivaldi antenna element made on the basis of an FR-4 dielectric was chosen, and the operating frequency range of the antenna was from 3.9 to 6 GHz, which corresponds to the optimal range for the formation of a small antenna with a corner reflector based on a solar panel. Figure 2 shows a view of the antenna element, as well as a view of the return loss graph, on the basis of which the operating frequency range of the antenna is determined.

![Figure 2](image)

**Fig. 2.** Feed Antenna: a) View of the Vivaldi antenna element; b) Graph of S\(_{11}\) parameters of the irradiator.

The selected feed has a wide range of operating frequencies, while in the entire range of operating frequencies the total efficiency of the antenna does not fall below 72%, and the Directivity in the range of operating frequencies is from 8.1 to 9.3 dB. Based on the resulting antenna element and two solar panels with a power of 0.11 W and dimensions of 170x170 mm, a reflective antenna with a corner reflector (opening 90 degrees) was formed. The antenna focus is located 100 mm from the corner of the two solar panels. To form the antenna housing, it is convenient to use 3D FDM printing, and the printing material is PLA, which is also biodegradable and environmentally friendly. The antenna model view, as well as the main characteristics are shown in Figure 3.

The obtained simulation results show that an antenna with a corner reflector based on solar panels allows you to maintain a wide range of operating frequencies (the increase in S-parameters is caused by reflections and the influence of dielectrics), provide a high level of Directivity from 13 to 16 dB in the operating frequency range (figure 3 shows characteristics at a frequency of 4.3 GHz: Dir.=15.5 dB, SLL=−9.3 dB, main lobe width 17.3 degrees), the total efficiency of the resulting reflector antenna does not fall below 69%. Thus, it is clearly seen that the use of solar panels as a reflector makes it possible to maintain the high efficiency of the antenna, form a narrow and directional beam, while ensuring the generation of electricity based on green energy components. Based on the developed model, an antenna layout was formed, which was used to measure the characteristics.
During the research, an antenna layout was formed, which was measured using a Rohde&Schwarz ZNH4 vector network analyzer. Since the measurement range is limited to 4 GHz, all antenna characteristics were measured at a frequency of 3.9 GHz so that the results were as close as possible to the simulation studies. The layout view, as well as the measurement results are shown in Figure 4.

The measurements carried out confirm the simulation results. It is clearly seen that the use of solar panels as a reflector makes it possible to form an antenna with a high level of efficiency, as well as the ability to release electricity. It is important to note that the total peak power generated by the solar panels when irradiated with sunlight was 0.2 W, so the irradiator, as well as the direction angle of the panels, reduced the energy generation efficiency by 0.02 W in total (a 10% drop). To reduce losses from the antenna element, it is possible to use a thinner dielectric, as well as more powerful and efficient solar panels. The research carried out in this work shows that solar panels can be used as a reflector, as they allow the formation of a highly directional antenna. Due to the fact that all elements obey the laws of electrodynamic similarity, it becomes possible to form antennas for different frequencies and with different panels, which can serve as a reflector in antenna systems.
4 Conclusions

The conducted studies show that the use of solar panels as an antenna reflector makes it possible to form a highly directional antenna, while ensuring the generation of electricity based on green energy systems. The implementation of such communication systems is possible thanks to the design of solar panels, and it is important to note that the use of monocrystalline solar panels also allows for a significant increase in the efficiency of the implementation of such a design, as electricity generation increases, and the thinner structure of the solar panel will optimize the penetration of electromagnetic waves, which will increase the total efficiency, as well as directional properties of antennas.

Antennas built on this technology will make it possible to implement autonomous communication systems, serve as an additional power source, and also implement communications in hard-to-reach regions. Further development of such systems will expand the distribution of green energy systems in communication systems, increase the availability of communication, as well as the security of communication equipment, thanks to the possibility of hiding behind solar panels.

References


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