

Designing problems of antennas integrated with solar batteries

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Abstract. Designing problems of microstrip antennas placed on the solar battery surface and using it as a substrate are considered. Computational models taking into account the elements of its construction and parameters of solar battery were performed by means of ANSYS HFSS. A number of numerical experiments for several antenna models were fulfilled. The aim of them is to design microstrip antenna integrated with solar battery without decreasing of solar elements effectiveness. The results of numerical experiments for several projects of microwave radiators with solid or mesh surface of the patch are presented

1 Introduction

The creation of new technologies in the field of electronics, the development of modern element base allowed to drastically reduce the sizes and weights of the devices. A lot of problems prevent the further progress in this direction [1]. In this regard there are appeared a number of papers which attempt to project an antenna integrated with the other components of electronic systems, and in particular with the aircraft board covers [2, 3], and solar cells [1, 3 - 11]. The last direction is of particular interest, because solar panels have considerable dimensions making possible to place a number of microstrip radiators.

Currently there are three types of solar cells: monocrystalline, polycrystalline, and on film (amorphous). The last ones are at the stage of development and, as a rule, is not used. Single crystal having of the same size can produce more energy as compared with a polycrystalline, but has a shorter term degradation and is more sensitive to luminance decrease.

In the process of developing such an integrated antenna engineers must solve two opposite problems: to design an antenna with prescribed parameters (input impedance, radiation pattern, gain, operating frequency range) and do not impair the characteristics of the solar cell (energy conversion efficiency).

In this article, we present a brief overview of some of the published attempts of antennas designing, integrated with solar panels and show some results of electromagnetic simulation of microstrip antennas, located on the surface of the solar battery.

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2 Variety of integrated antennas with a reduced battery shading

Analysis of publications dealing with the problem of creating integrated with solar panels antenna shows that the proposed designs are usually based on the use of batteries as the substrate surface of the patch antenna. There are a special interests in solving problems [1-3] of avoidance of a significant reduction of solar battery effectiveness caused by shading the battery surface with the structural elements of the antenna.

The simplest design integrated antenna suggest placing microstrip element directly on the surfaces of the battery [3, 8, 12] or slightly raised above it [7, 8]. In the first embodiment there is situated microstrip mesh of thin wires which forms "ground plane screen" for the antenna. The radiating microstrip patch element is placed on the dielectric layer. Its configuration and dimensions selected so as to provide the required impedance, polarization and directional characteristics.

For improvement of antenna matching some authors suggest to use metamaterial as a dielectric substrate [15]. Along with dipole radiators there are papers devoted to investigation of slot radiators [4, 13] constructed using the same principles. The antennas "raised" above the surface of the solar battery used the metallic [8] or dielectric supports [9], retention metallic patches.

In order to improve the transparency of the antenna element and reduce shadowing of solar battery surface there known investigations not only "mesh" radiators [4, 12], but also radiators made of optically transparent conductive films based on Indium Tin Oxide, Antimony Tin Oxide, Titanium Indium Oxide, Gallium Zine Oxide or AgHT-4 [11, 14]. There are variations of a lower degree of integration, in which the solar battery do not replace ground plane, but joined with it as an additional elements [13, 16].

Below there are presented the results of computer models research of the two antennas integrated with solar battery making possible increasing the efficiency due to reducing the shadowing its surface.

3 The solar battery substrate as a microstrip antenna

Consider a model of an integrated antenna, in which the role of sophisticated composite substrate performs a solar cell. Microstrip radiator with length L and width W disposed on a thin transparent acrylic substrate, the "raised" above the surface of the solar battery up on height h (Fig. 1). The patch surface is not solid, but made from a grid of conductive strips of width t . Dimensions of the grid cells were selected in the process of optimizing the antenna parameters. The simulation was performed in WLAN and WiMAX frequency bands when changing the width of grid conductors and their number on the opposite sides of the patch. Radiator's dimensions are equal to $L = 37,2\text{mm}$; $W = 51,4\text{ mm}$; $h = 5\text{ mm}$, which provides best matching at 2.45 GHz. The width of the wire array-valas varies from 0.2 mm to 1.0 mm, and the number of conductors on the sides of the patch was varied from 5 to 15.

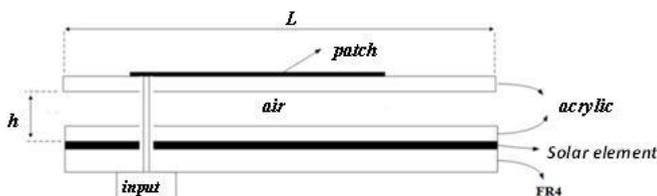


Fig. 1. The radiator on the surface of the battery.

Characteristics of mesh radiators were compared with the characteristics of patch radiators with a solid surface. The calculation results show that the change in width of the conductors leads to a slight change of input impedance in frequency band and is manifested in a certain increase of the fluctuations of the curve (5-12%). For this reason, a grid of thin wires was 0.2 mm, more preferably, because it provides high value of antenna element about 0.81. For comparison, a grid of conductors of 1.0 mm width provides transparency 0.07 with almost the same values of the input radiator impedance.

The number of mesh wires has more significant impact on the antenna parameters. Radiators parameters are most sensitive to the number of wires in a plane parallel to the lines of electric current (E plane). Their numbers were chosen in the process of the radiator performance optimizing. The criterion of optimum was chosen as closeness of curves selected frequency dependence of resistance and reactance of the mesh and fully metallic radiators. The best result provides a grid of conductors 15 in the E-plane and 10 conductors in the H-plane. Fig. 2 and 3 show frequency characteristics of the active and reactive input impedance of the radiator with a mesh (curve 1) and metallic patch (curve 2).

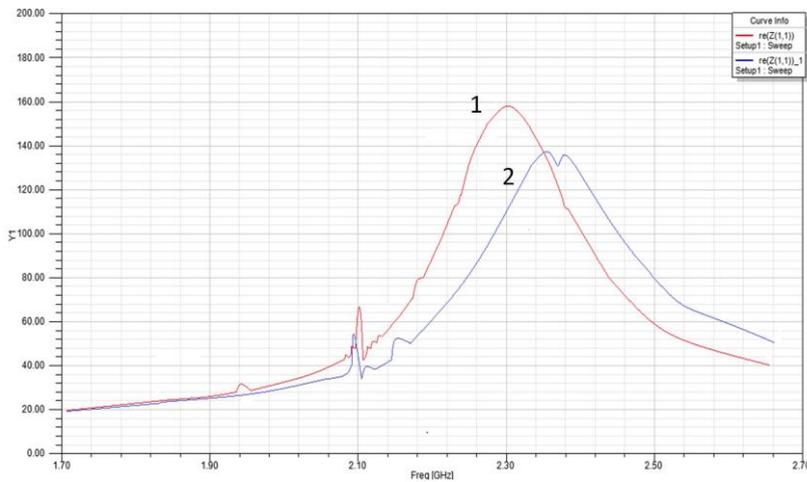


Fig. 2. The resistance of the integrated radiator.

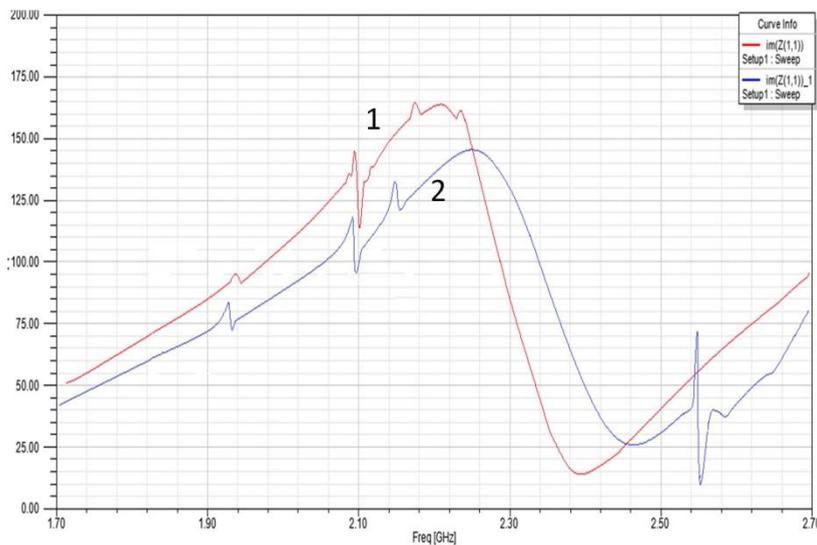


Fig. 3. Reactance of integrated radiator.

The simulation results show that using of mesh patch provide some shift of resonance towards lower frequencies.

Replacing the solid surface of the patch to the wire mesh does not have a significant impact on the direction properties of antenna. Fig. 4 and 5 show the antennas radiation pattern in the E plane and H plane.

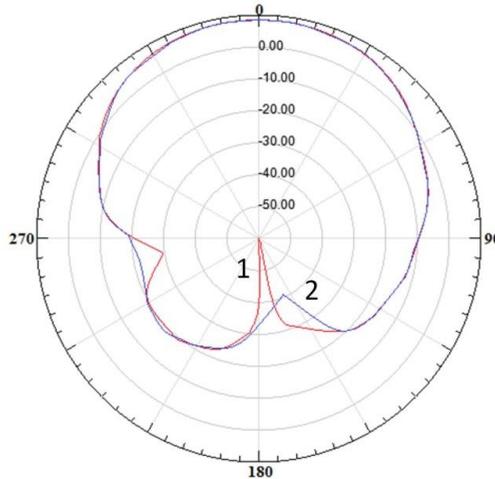


Fig. 4. Radiation patterns in E-plane (1 - mesh patch, 2 - solid patch).

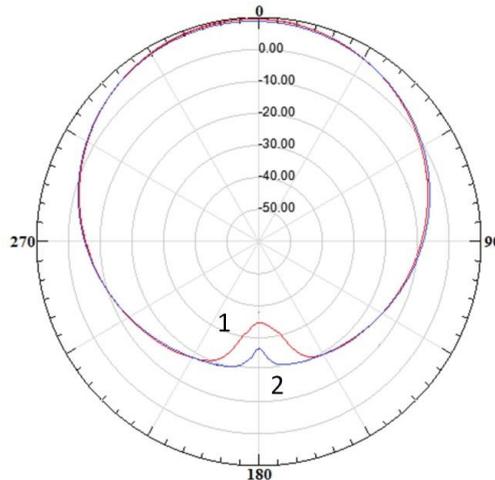


Fig. 5. Radiation patterns in H-plane (1 - mesh patch, 2 - solid patch).

Modeling of antennas integrated with a solar battery (fig. 1) has shown that the replacement solid patch surface to the mesh leads mainly to a certain shift of the antenna resonant frequency while maintaining the critical parameters at the same level and greatly reduce shading of solar cell surface.

4 The solar battery as a patch of antenna radiating element

Due to the fact that the upper and lower solar battery contacts are wire mesh it is interesting to simulate the integrated antenna, in which solar battery element is used as a patch with the desired dimensions. Consider the antenna structure with a substrate of FR-4 dimensions of

100 × 100 mm. Above the substrate at height $h = 5$ mm solar battery cell is placed (fig. 6). The antenna is excited by microstrip line.

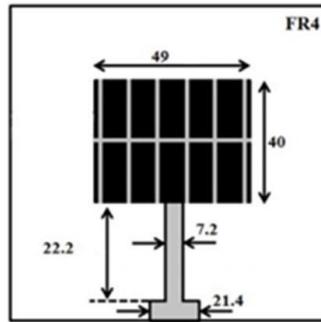


Fig. 6. The model of integrated antenna

Such antenna simulation procedure coincide with the calculation of conventional microstrip antenna. Fig. 7 - 9 show the results of the integrated antenna modelling.

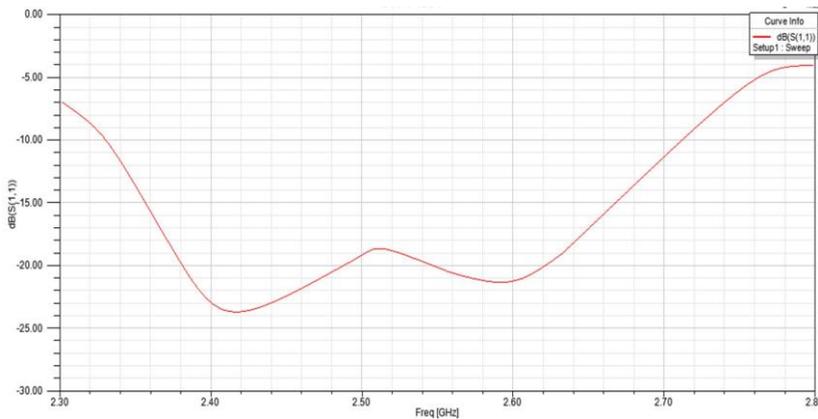


Fig. 7. The frequency dependence of the input antenna reflection coefficient

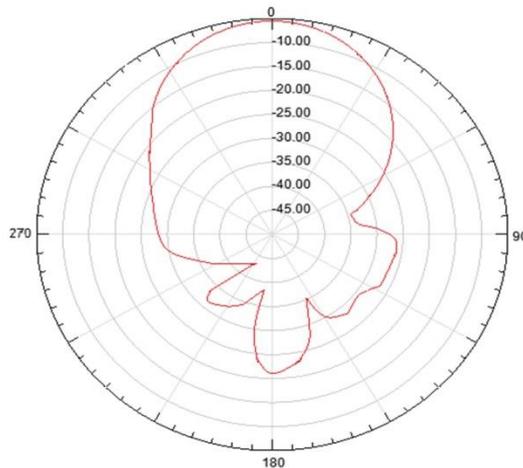


Fig. 8. The radiation pattern of the antenna in the plane E.

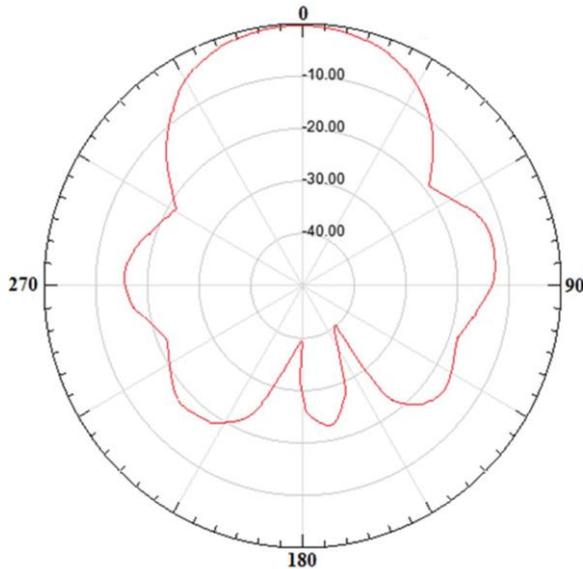


Fig. 9. The antenna pattern in the H plane.

5 Conclusions

The numerical experiments show that using of mesh surfaces as a patch in the design of antennas, integrated with solar panels, makes it possible to largely resolve one of the major contradictions of the creation of such the radiators and significantly reduce the shading surfaces of the battery, keeping its energy efficiency. While calculating there may be required necessary adjustment the resonant dimensions of mesh radiators.

Integrated antenna using a solar cell as a radiator, may be used for constructing an antenna array. Such an approach will not only improve the directional properties of the antenna, but also increase the battery capacity due to increasing of its total surface.

The studies and the results of computational experiments demonstrates the principle possibility of the development of integrated systems that combine in one device solar cell and antenna system. Optimization of constructive parameters allows to receive microstrip antennas and antenna arrays with acceptability characteristics and the least possible shading of solar batteries.

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