

Advanced nanoantenna for photovoltaics

D.A. Poletaev¹, B.V. Sokolenko¹, A.A. Nudga¹, A.V. Starosek¹

¹V.I. Vernadsky Crimean Federal University, Vernadsky av. 4, Simferopol, Russia, 295007

Abstract. In this paper an advanced nanoantenna was proposed. The aim of the work is a theoretical analysis of the construction of the proposed nanoantenna. It was shown that proposed nanoantenna has more than 2 times less reactive resistance than the monopole antenna. The area occupied by the proposed nanoantenna compared with monopoly antenna increases only twice.

1. Introduction

Nanoantennas are widely used in modern science and technology [1–4]. Some of those devices are used for directry convert light into electrical energy [4]. However, the range of wavelengths in which a nanoantenna operates effectively is rather narrow [5]. To extend it the sets of nanoantenas were used [6]. The disadvantage of such system is a large surface area occupied by a single element. In scientific works [7–8] tie-bow nanoantennas are described. However, they can not operate over a wide range of wavelengths. It is advisable to propose a construction of a nanoantenna that capable efficiently operate on a wide range of wavelengths. The aim of the work is a theoretical analysis of new advanced nanoantenna's construction.

2. Theoretical part and simulation results

2.1. Theoretical data

The proposed advanced nanoantenna consists of two connected monopole antennas formed by square copper prisms (figure 1). The height of the first prism is d_1 , the second – is d_2 . The sides of the square of the base of the prisms are the same and equal to b . Each square copper prism of this nanoantenna has its own capacitance and inductance. Their values depend on the geometric and electrophysical parameters. The capacitance and inductance of each square copper prism form an oscillatory circuit with its own resonant wavelength. The degree of connection of these resonant circuits varies depending on the wavelength, because of the presence of the skin layer in real conductors. The equivalent circuitry of this nanoantenna is shown in figure 2.

Values of square copper prism's inductance and capacitance are calculated with sufficient accuracy, for example in [9]. The magnitude of the resistances R_1 and R_2 for the first and second prisms, respectively, are nonlinearly dependent on the length of the electromagnetic wave, due to the presence of the skin effect [10]. The impedance of such a nanoantenna can be written as:

$$Z = \left[\frac{1}{R_1 + j2\pi cL_1/\lambda} + \frac{1}{R_1 - j\lambda/(2\pi cC_1)} + \frac{1}{R_2 + j2\pi cL_2/\lambda} + \frac{1}{R_2 - j\lambda/(2\pi cC_2)} \right]^{-1} \quad (1)$$

where j – is the imaginary unit; c – is the speed of light in a vacuum; λ – is the length of the electromagnetic wave.

The electromagnetic wave interacts simultaneously with both prisms (upper and lower, which are shown in figure 1). The amplitude of an electromagnetic wave propagating along the upper prism decreases at least 7 times, due to its size, passing from its upper surface to the surface of the lower prism. An electromagnetic wave interacting with the upper surface of the upper prism is transmitted to the radiation receiver. Therefore, the highest part of the energy of the electromagnetic wave will take the upper prism.

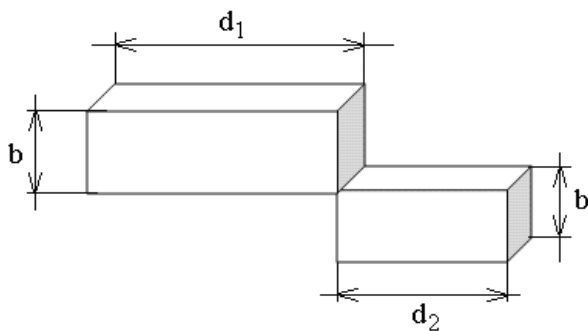


Figure 1. Structure of the nanoantenna.

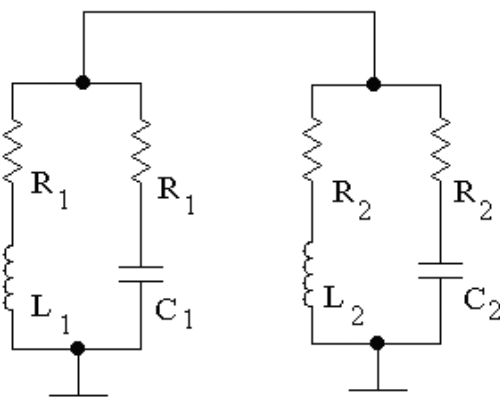


Figure 2. Equivalent circuit of a nanoantenna.

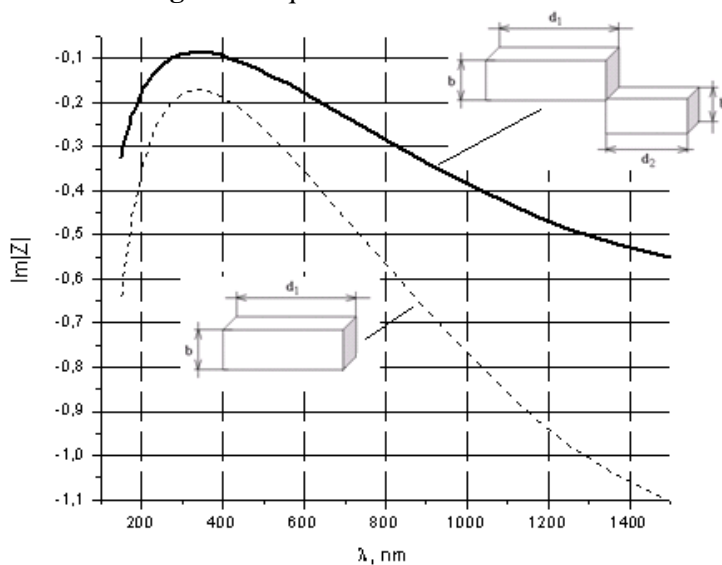


Figure 3. Dependence of the imaginary part of the nanoantenna’s impedance from the wavelength.

2.2. Results and discussion

Antenna operates efficiently in a range of wavelengths where its impedance is purely active [10]. The graph of the dependence of the imaginary part of the impedance of a copper nanoantenna (1) with optimized sizes $d_1=d_2=35$ nm, $b=48$ nm from the wavelength is shown in figure 3. In this graph other curve is shown for comparison the dependence of the imaginary part of a single monopole antenna formed by a square copper prism with height $d_1=35$ nm with the side of the square's side $b=48$ nm.

As can be seen from the graph (figure 3) in the solar radiation wavelength range [4], the proposed nanoantenna has more than 2 times less reactive resistance than the monopole antenna. However, the effectiveness of this nanoantenna is much greater than the efficiency of the monopole antenna, due to a wider wavelength range. The minimum of the reactance is in the near ultraviolet region [4]. This makes it possible to compensate the absorption of the ultraviolet part of the spectrum in the atmosphere. The proposed nanoantenna can be used in photovoltaics.

A patent for this construction of nanoantenna had been applied. A positive decision regarding the patent in the Russian Federation was received.

3. References

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