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Design Of Metamaterial Absorber to Enhance the Efficiency Of The Solar Energy Harvesting

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ABSTRACT:

In this research, a proposed metamaterial absorber is created to increase solar cells' effectiveness. A copper sheet serves as the design's ground and is covered in circular forms with printed rectangular gaps at the top surface. In order to absorb the entire solar spectrum infrared, the structure functioned at terra frequency bands. Additionally, the constructed metamaterial unit cell is utilized to create a metamaterial array absorber, thereby maximizing the capture of solar energy. Two absorption rates were found, roughly 99.98% at resonance frequency 80.2, and 99.32% at resonance frequency 68.35 THz.

KEYWORDS:

Dual Band, Antenna, Infrared Radiation, Solar Energy, Metamaterial Absorber.

1. INTRODUCTION:

Fossil fuels and other non-renewable (conventional) energy sources account for 87% of all energy utilized globally, according to the 2014 Global Energy Statistical Report [1]. In addition to making fossil fuel production more challenging, this high percentage seriously harms ecosystems. Finding a clean, renewable alternative to current energy sources is therefore important. Given that it generates heat, light, electricity, and other types of energy [2]– [4], the sun is one of the most productive renewable energy sources. Solar energy is converted into electricity using solar cells, also known as photovoltaic cells. The main component of solar cells is silicon, which interacts with sunlight's photons inside the cell to cause atoms to check their electrons from semiconductor material and produce electronic holes that produce energy [5], [6]. Any solar-cell-based system's capacity to function without requiring a regular battery replacement is its most favorable feature. However, the effectiveness of these cells is just 30% since they can only absorb specific frequency bands of solar energy. The energy band gap, which prevents cells from converting all solar radiation into electricity, is to blame for this low efficiency [7].

Recently, a method that was created and based on the metamaterial's methodology is being applied to improve solar cell design. Metamaterials are brand-new artificial materials created in a way that gives them abilities that are not found in other kinds of materials. Due to their intelligent properties that allow them to process electromagnetic waves [8] by blocking [9], absorbing [10], [11] or bending waves [12] and having negative refractive [13] factors that enable them to make super lenses [14], metamaterials are arranged periodically at smaller scales than the wavelengths of phenomena that affect them.

Metamaterials absorbers have received a lot of investigations and studies from many researchers as it is reported in literature. Where there are many different forms that express Metamaterial absorbers [15] – [17]. In [18] a metamaterials-based absorber incorporates an endless number of multi-resonance nanoscale particles is designed. The absorber allows for significant solar energy absorption. In [5] a completely new form of metamaterial absorber in different frequency bands is developed, characterized, and investigated. In order to efficiently use solar energy, this metamaterial-based construction is specifically provided in the spectrum of the sun's rays. The designed metamaterial-based solar cells provide the best possible absorption of the visible and infrared spectra. Moreover, there are many new innovative and unconventional ideas to increase the antenna array and metamaterial features

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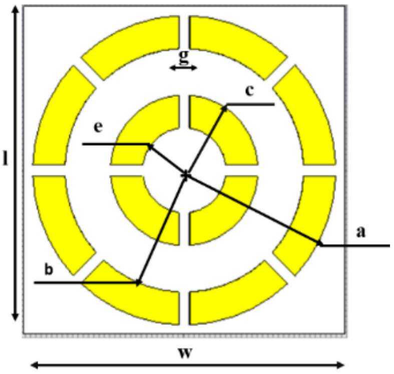
in most types of antennas and materials have been introduced [19] – [24]. One of these techniques has been applied to increase the features in the proposed metamaterial antenna array, by parameter sweep for the important and effective parameters that most effect on the metamaterial antenna array characteristics such as absorbing rate. Additionally, a structure made of super-absorbing materials has been developed to capture solar energy, with absorption rates approaching 99% [25].

In this study, a brand-new metamaterial absorber design is put out to increase solar cells' effectiveness. A straightforward structural unit cell with two distinct layers and rectangular gaps with constant size can absorb a lot of infrareds at different tera frequencies.

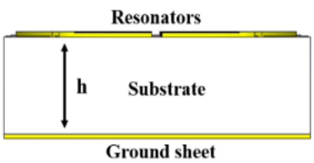
The last part of the paper is organized as follows. Section II, describes the design and the detailed parameters of the proposed unit cell. Section III, discusses simulation results for the proposed design and the metamaterial absorber. Finally, a conclusion is drawn in Section IV.

2. DESIGN OF THE PROPSED METAMATERIAL UNIT CELL:

The unit cell's suggested design features printed circular forms with rectangular gaps on the substrate's upper surface, together with a copper sheet acting as a ground, As shown in Fig. 1, The design of the proposed unit cell is based on the previous studies and investigations presented in the literature [5] – [7]. The reference shape is inspired by [5]. A modification is made to the reference's shape to be simpler, more compact, and achieve dual bands operation. An extensive parameter study is carried out on the proposed unit cell to work well at the intended frequency bands. This method involves mixing two distinct particles into a unit cell in such a way that one particle has negative permittivity and the other has negative permeability, i.e. one particle should be an ENG metamaterial and the other should be an MNG metamaterial. This method's operation is based on the idea that when resonance-sensitive material is exposed to an axial magnetic field, it exhibits extreme values of effective magnetic permeability close to resonance, showing strong positive values in the narrow band below the quasi-static resonant frequency of the rings and strongly negative values in the narrow band above [26]. The lower groundsheet of the construction has been recognized as a 3 m x 3 m infrared copper plate for zero transmission, followed by the insulating layer, which served as the substrate. The substrate is made of Rogers 4350B, which has a thickness of 0.76 mm, a loss tangent of 0.0037, and a relative permittivity of 3.66, respectively. The copper sheet is chosen with the electrical conductivity, thermal connection, and thickness of 5.8 107 S/m, 401 w/K/m, and 0.0035 m, respectively. Two copper circular forms with rectangular gaps of 0.1 m wide are printed on the top surface of the substrate. After looking at the geometrical dimensions of the unit cell, Table 1 provides the ideal parameter dimensions of the suggested unit cell along with a parameter explanation.



(a)



(b)

Fig.1: Proposed Designed absorber unit cell (a) 2-D front view, (b) side view.

Table 1: The geometric dimensions of the proposed absorber unit cell.

Parameters list	Value (μm)	description
w	3	width of the substrate material
l	3	length of substrate material
h	0.76	thickness of the substrate material
g	0.1	rectangular gap width
a	1.41	the outer radius of the outer circle
b	1.11	the inner radius of the outer circle
c	0.68	the outer radius of the entire circle
e	0.38	the inner radius of the entire circle

3. RESULTS AND DISCUSSION

The computer simulation technology (CST) microwave studio simulator is used to simulate the structure. The simulation outcomes are displayed in the infrared spectrum with a bandwidth of (50 THz to 100 THz). Two major resonant frequencies are provided by the suggested structure in the form of two absorption peaks. As shown in Fig. 2, where A(ω) is the rate of absorption and S11 is the reflection parameter, the findings show that the two greatest absorption peaks occur at 80.2 THz, 4386.14 nm and 68.35 THz, 3738.061 nm resonant frequencies and wavelength, which are equal to 99.98% and 99.32%, respectively. The performance of the unit cell is affected by the rectangular gap width, as shown in Fig. 3.

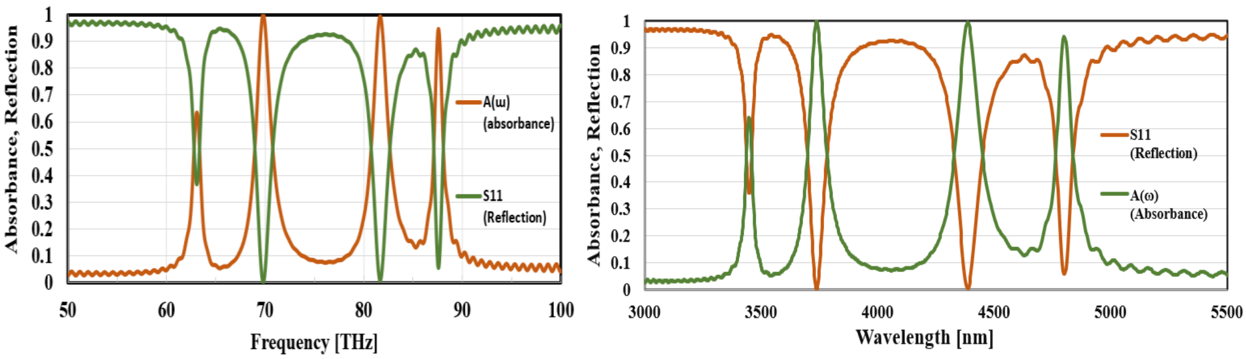


Fig. 2: Simulated reflection and absorption rate of the proposed unit cell absorber at the infrared.

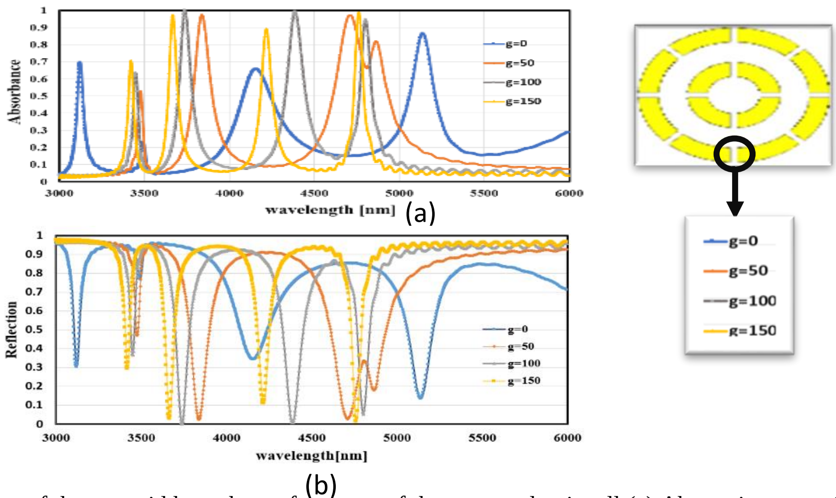
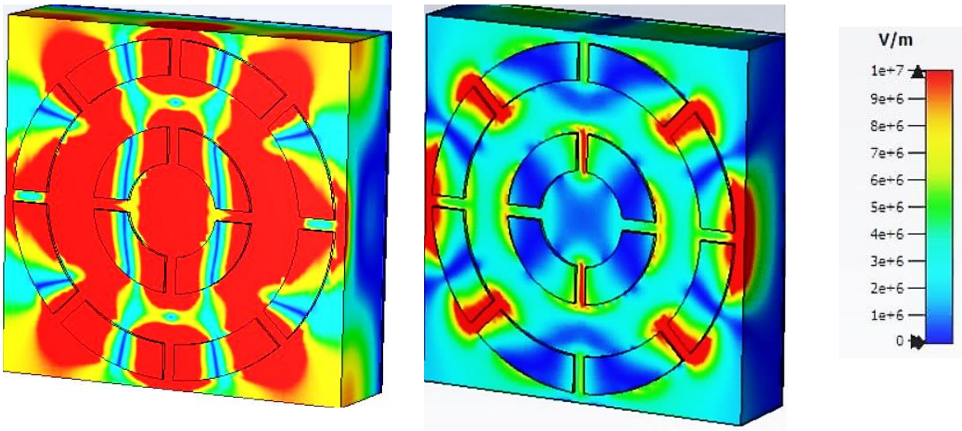


Fig. 3: The effect of the gap width on the performance of the proposed unit cell (a) Absorption rate, (b) Reflection

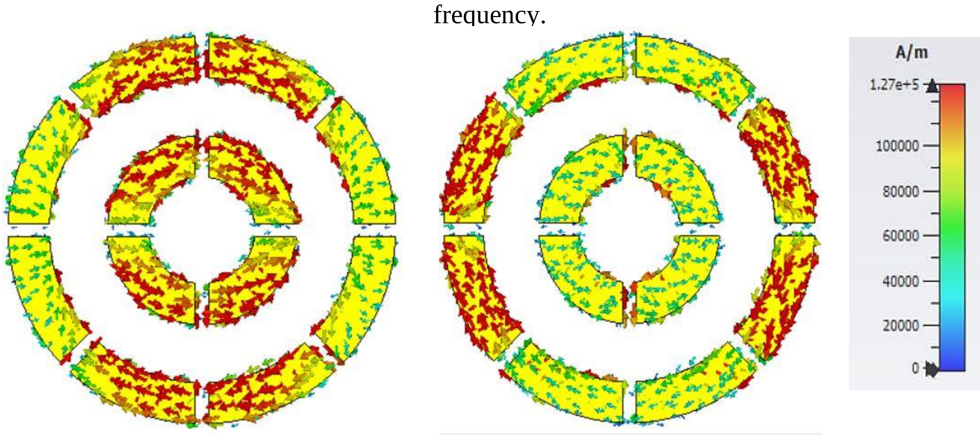
The figure shows that the absorption rate is low and the reflection coefficient does not exceed 0.4 when the circular slices have no gaps (g = 0 nm). The absorption and reflection coefficients have been improved as a result of etching a gap with variable width g, At the maximal absorption

rate is around 97% with a reflection of 0.16 at (g = 50 nm). Additionally, two absorption peaks of 99.98% at wavelength 4386.14 nm and 99.32% at wavelength 3738.061 nm are attained at (g = 100 nm), with reflection coefficients of 0.01 and 0.08, respectively. And when the gap is increased to (g = 150 nm), the absorption rate dramatically decreases. According to the data, g=100 nm is the ideal value for the gap width for which the greatest absorption is produced. The results are given in Figs. 4 and 5. Distributions of the electric field and surface current at resonance frequencies are analyzed to confirm the physical mechanism underlying the operation of a solar cell based on metamaterial at resonance. At 68.35 THz and 80.2 THz, respectively, Figure 4 shows the distribution of the electric field inside the cell. We see the electric field's intensity at frequency 68.35 THz throughout the circular slices, but especially in the upper and lower as well as the side rectangular gaps. Focus is only on the side rectangular gaps but is less intense at a frequency of 80.2 THz. Figure 5 depicts the surface current distribution at the two resonant frequencies. As observed in the picture, the current is primarily concentrated on the full circle shape for the resonant frequency of 68.35 THz while it is primarily concentrated on the outer circular form for the other resonant frequency of 80.2 THz.



(a) (b)

Fig. 4: Distribution of the unit cell's electric field at (a) 68.35 THz frequency, (b) 80.2 THz frequency.



(a) (b)

Fig. 5: Distribution of the unit cell's surface current at (a) 68.35 THz frequency, (b) 80.2 THz frequency.

4. CONCLUSION

In order to absorb the infrared radiation of the sun's spectrum, a dual-band absorber based on a metamaterials approach is proposed. The proposed design constitutes two circular shapes with engraved rectangular spaces. Simulations expressing the design were made. Based on the results of the simulations used to evaluate the performance of the proposed epitaxial absorption design, it was found to provide a near-perfect 99% absorption rate at 80.2 THz and 68.35 THz.

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تصميم ممتص المعادن لتعزيز كفاءة حصاد الطاقة الشمسية

الملخص :

في هذا البحث ، تم إنشاء ماص مادة خارقة مقترحة لزيادة فعالية الخلايا الشمسية. تعمل الصفيحة النحاسية كأرضية للتصميم وهي مغطاة بأشكال دائرية مع وجود فجوات مستطيلة مطبوعة في السطح العلوي. من أجل امتصاص الأشعة تحت الحمراء للطيف الشمسي بالكامل ، يعمل الهيكل في نطاقات تردد تيرا. بالإضافة إلى ذلك ، يتم استخدام خلية وحدة المادة الفوقية المُنشأة لإنشاء ممتص لصفيف المواد الخارقة ، وبالتالي تعظيم التقاط الطاقة الشمسية. تم العثور على اثنين من معدلات الامتصاص ، ما يقرب من ٩٩,٩٨٪ عند تردد الرنين ٨٠,٢ ، و ٩٩,٣٢٪ عند تردد الرنين ٦٨,٣٥ تيراهيرتز.