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Design of Nano Square Spiral Antenna in Terahertz Region for Solar Energy Harvesting

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ABSTRACT

This paper represents the design and characterization of a Nano square spiral antenna integrated on a silicon dioxide substrate. The antenna aims to crop the energy from the sun. This nano antenna acts in the desired terahertz region within the specified range of 3 to 30 THz. The antenna characteristics, specifically its resonant frequency and enhancement factor have been numerically investigated. The spiral square antenna captures the terahertz radiation. The radiation losses are much reduced to minimum level. Resonant frequency can be adjusted by varying the FSS (Frequency Selective Surfaces) parameters such as layer thickness, distribution structure and element size. High enhancement factor can be achieved by using low dielectric silicon dioxide substrate, where the unwanted reflection and scattering from the backside of the silicon is the major issue. Handling of which is the challenge work. So, use of an SOI substrate is eliminated. The proposed antenna efficiently crops the energy available from the sun.

Key words: Nano antenna, Terahertz radiation, resonant frequency, Enhancement factor, Energy Harvest, FSS

1. INTRODUCTION

An antenna is a radiating structure which can convert electrical energy into electromagnetic energy and vice versa. Practically it is a type of transducer. The energy from the guided structures will be radiated into free space as electromagnetic waves. Antennas are one of the necessary parts in all radio equipment. Almost all communication systems such as radio, TV broadcasting, wireless LANs, cell phones, radar, and spacecraft invariably uses antenna. The RF signal generated will not be transmitted and detected at the receiver without a proper design of the antenna. Antenna engineering is a vibrant field which is bursting with activity and is likely to continue in the foreseeable future. Perfectly designed good antenna can satisfy the system requirements and improve overall performance of the system. The antenna provides efficient radiation and matching wave impedances by minimizing the reflection. The micro strip antennas are an affordably low cost and ease to fabricate subsystem. The fabrication can be done along with other subsystems. Due to low profile, conformal to planar surface, micro strip patch antennas are an attractive for mobile and radio wireless communication.

Terahertz frequencies from 1 THz (10^{12} Hz) to 1000 THz (10^{15} Hz) embrace the infrared and visible wavelengths of electromagnetic spectrum. The region between far infrared and microwaves lies in the terahertz radiation. These frequencies correspond to wavelength between 1 mm and 300 nm including the visible spectrum between 400 and 700 nm. With techniques now available very small antenna structures can be fabricated making terahertz antennas feasible. Antennas have been proposed and patented to operate at this frequency for receiving solar radiation and converting it to dc electric power.

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1.1. Need for Solar Antenna

The total energy consumed worldwide for a period of one year is 4.1×10^{20} Joules, whereas the solar energy striking the earth in one hour is itself 4.3×10^{20} Joules. The available technologies for tracking solar energy are Concentrating Solar Power (CSP) systems and Photovoltaic (PV) cells. Both these technologies have low conversion efficiencies. An alternative solution to this is provided by using optical nano antennas that has a very high efficiency of more than 90%. The yearly energy consumption throughout the world is approximately 4.1×10^{20} Joules. Practically it is equal to consuming the power 13 trillion watts continuously. The rapid growth of the world population demands more power requirements nearly double the present requirement by 2050.

The other power generation methods create global issues such as ozone depletion, global warming, forest destruction, acid precipitation and air pollution. For the sustainable human civilization and survivals research towards alternate clean and renewable energy resources has to be done.

2. DESIGN OF NANO SPIRAL SQUARE ANTENNA

Nano Spiral Square antenna is a combination of a spiral antenna and 4 log periodic dipole antennas in a particular fashion. The radius of the spiral is important design factor of the antenna. The conductor length and spacing of the log periodic dipole antenna are calculated for the design of spiral square antenna. The working of spiral square antenna is shown in Figure 1.

2.1. Geometries

The various geometries of the proposed square spiral antennas considered for designing the spiral and log-periodic antenna are depicted in Figure 2. The proposed antenna composed of two conductor arms; both starts at the same point and gradually expand by a ratio *k* at each half turns like the log-periodic antennas. This is a type of Archimedean spiral antenna.

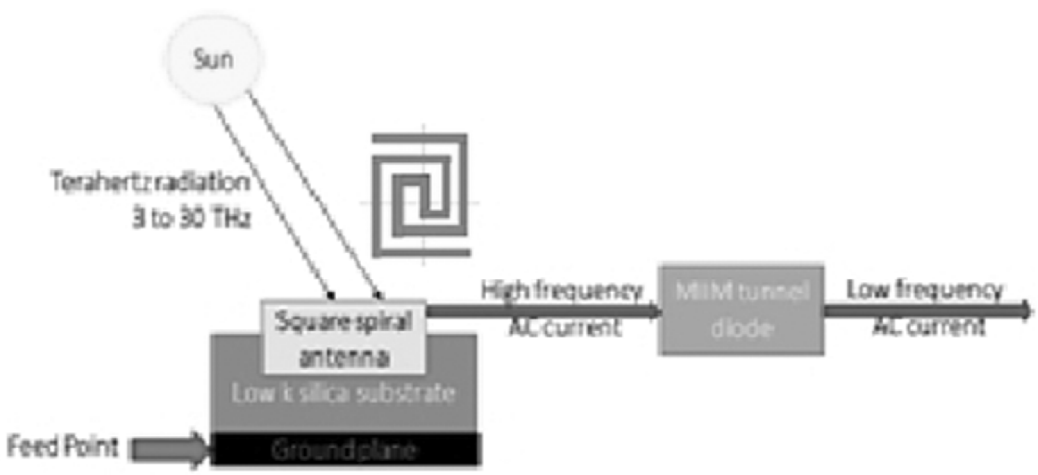

Figure 1: Operation of Spiral Square Nano antenna

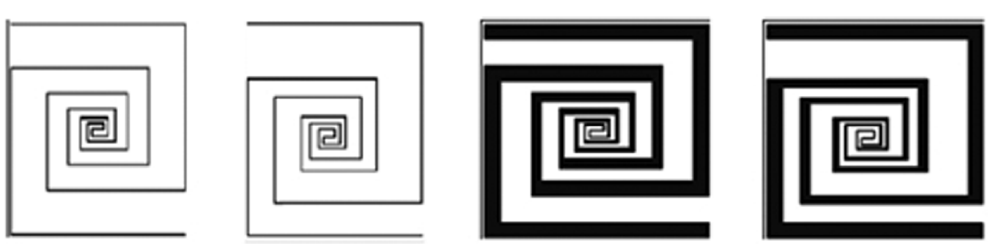

Figure 2: Geometries

3. DESIGN PROCEDURE

3.1. Design Parameters and Geometries

Desired Frequency Range of operation is from 3 to 30 THz. The wavelength of operation is from 10^{-4} to 10^{-5}m. Thus the width and length of the spiral square antenna is $\frac{\lambda}{4} = 250nm.$ The diameter of the antenna is given by $\frac{\lambda}{\pi} = 318nm.$ The Materials used are, Silicon dioxide (Optical) for substrate, Copper (Optical) for ground plane, antenna element and feed element. The feed element has length = –5.5 nm, Width = –5.5 nm and Height = 9.15 nm. The antenna is designed and simulated using CST microwave studio. Frequency domain solver is used to analyze this planar antenna.

Table 1
Dimensions of Substrate and Ground Plane

Parameter	*Substrate*	*Ground Plane*
Length (nm)	250	250
Width (nm)	250	250
Height (nm)	6	3
Diameter (nm)	318	318

The Nano Spiral Square Antenna has 6 horizontal patches and 5 vertical patches. The lengths and widths of the strips in the spiral are listed in Table 2. All the strips have the thickness of 3 nm.

Table 2
Dimensions of Patches

Patch No.	*Length (nm)*	*Width (nm)*
Patch 1	220	15
Patch 2	220	15
Patch 3	15	85
Patch 4	15	85
Patch 5	185	15
Patch 6	185	15
Patch 7	15	110
Patch 8	15	110
Patch 9	85	15
Patch 10	85	15
Patch 11	20	70

3.2. Simulation Methods

The wire and planar structures are analyzed and simulated using Numerical analysis techniques in two ways: Method of Moments (MoM) and Finite Differences in Time Domain (FDTD). MoM is used for wire geometries especially for ease of use and accuracy for this type of structures. FDTD is used for strip structures due to realization reasons, capability of modeling complex geometries and broadband analysis advantage of this method.

4. SIMULATION RESULTS

The perspective view of spiral square antenna is shown in Figure 3 and Figure 4 shows that the boundary conditions of the spiral antenna which have been simulated in the simulation tools.

The power absorption of the spiral antenna is shown in Figure 5 which has been simulated from the simulation tool. The result shows that a power of 6 μW is absorbed by single antenna.

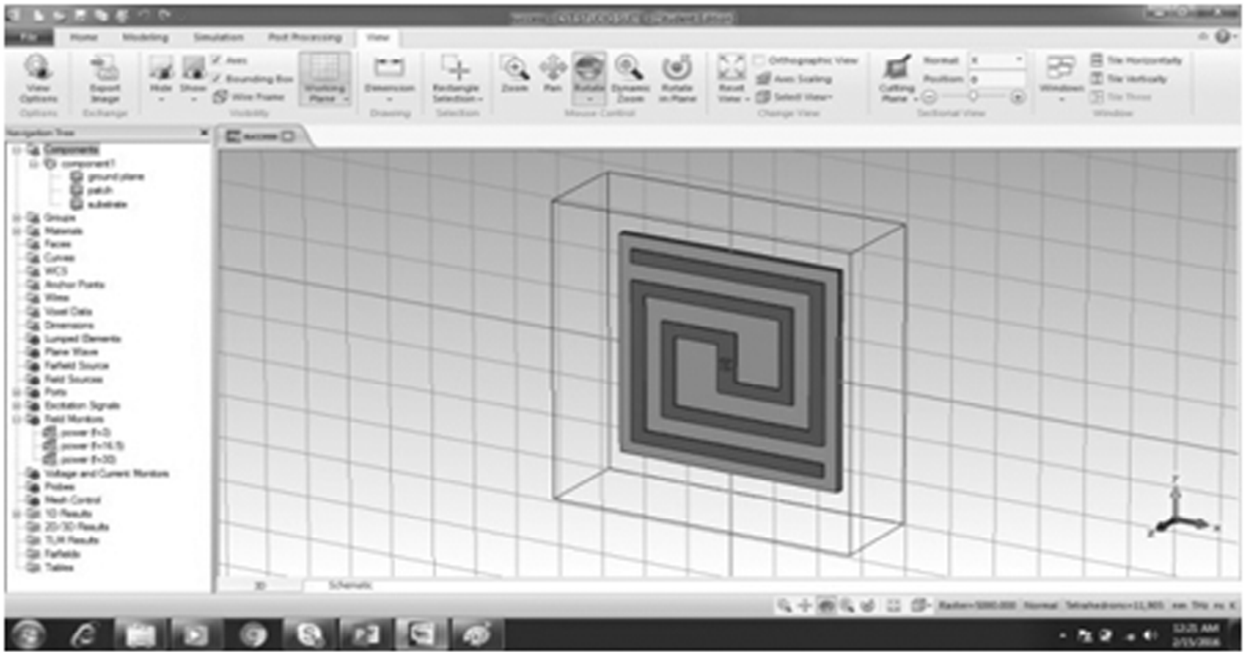

Figure 3: Perspective view of spiral square antenna

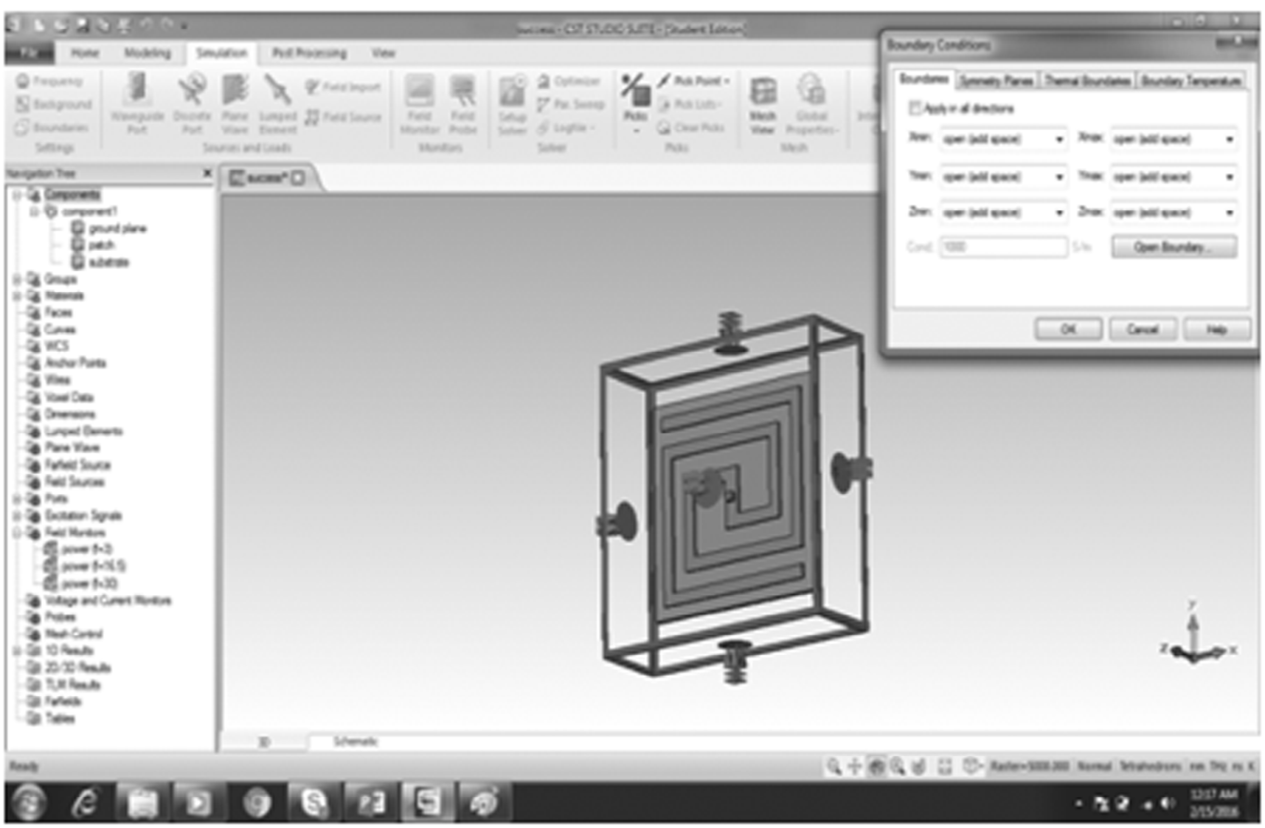

Figure 4: Boundary conditions

Figure 5: Power absorption of the antenna

5. CONCLUSION

An analytical approach of the design of nano square spiral antenna along with simulation with the help of EDA tool is discussed in this paper. The low dielectric constant of the substrate increases the enhancement factor of the antenna. This proves promising value of efficiency in the specified region of operation 3 to 30 THz. The optimal results are obtained after multiple iterations. The amount of power that could be absorbed by the antenna is 6iW for a single antenna.

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