Large aperture antenna for collecting solar energy

A well-known methodology of using the antenna to harvest solar energy is studied by varying the antenna aperture area. The proposed antenna is a modified version of a cross-dipole antenna. It possesses a dual polarization radiation. This antenna has size of 2800 nm x 2800 nm compared to its corresponding cross-dipole antenna which is 150 nm x 150 nm. Larger antenna aperture enhances higher solar energy collection. The proposed antenna exhibits a wideband response of 3.2 to 1 in the light spectrum band. The bandwidth is improved to 3.6 to 1 by having more antenna elements and the total size is 6340 nm x 4844 nm. This antenna is sitting above a ground plane and radiates in the upper hemisphere. The measured S11 is well agreed with a result from the numerical analysis for a microwave frequency range.

Introduction: Harvesting solar energy is crucial in term of efficiency of the technology and methodology. The methodology of using antenna to collect solar energy was proposed in [1]. At any resonance frequencies antenna size can be scaled. Energy from visible light and infrared spectrum can also be collected based on the antenna theory. To achieve the high efficiency of the energy collection, wideband antenna, on the order of 4 to 1, with dual polarization was proposed [2]. The spectral irradiance shown in [3] indicates that more than 70% of the solar energy is contained in the frequency range from 200THz to 700THz.

A large aperture, wideband with more than one polarization antenna is proposed here. This is different from an approach of using many small aperture antennas connected as an array to improve the single antenna performance such as the collectible power, and output current [2], [4]. A generalized analysis of the partial coherence of sunlight validates a larger transverse coherence area [5]. This presents more than a factor of 3 of the collectible power for the antenna which its aperture area is enlarged approaching this range [5]. This research aims to increase the aperture area of the antenna for increasing voltage at its terminal which is corresponding to the non-linear response of the rectifier diode. The improvement of the received power incorporates with a promising rectifier diode which operates in THz band presented in [6] will increase the efficiency of the solar energy collection for our mankind.

The proposed antenna has a center feed as the cross-dipole antenna. Its size is 2800 nm x 2800 nm. This planar structure can be printed on a substrate such as ϵ_r = 1, or 2.17. At frequency 400THz the corresponding printed cross-dipole antenna has its resonance length of 150 nm. More antenna elements can be added to the proposed antenna to increase its lengths and aperture which the improvement of its performance will be presented in the next section.

Experimental and results: The numerical analysis was performed by the Finite Difference Time Domain (FDTD) simulator. The antenna was designed as a planar structure and placed at 21 mm (ϵ_r = 1) above an infinite ground plane. It is fed by a wire port, balance-feed, at the antenna terminal. The total length of each arm is 140 mm which is 280 mm x 280 mm aperture area with 1mm thickness. The proposed antenna was built. A 1mm thick copper sheet was cut by a laser beam according to the design configuration. The antenna was placed with a supporting structure over a ground plane sizes 500 mm x 500 mm. A pair of coaxial cable was used as a balance-line to feed the antenna by connecting to its terminals. The simulation result of S11 is compared with the measurement by network analyzer is shown in Fig. 2.

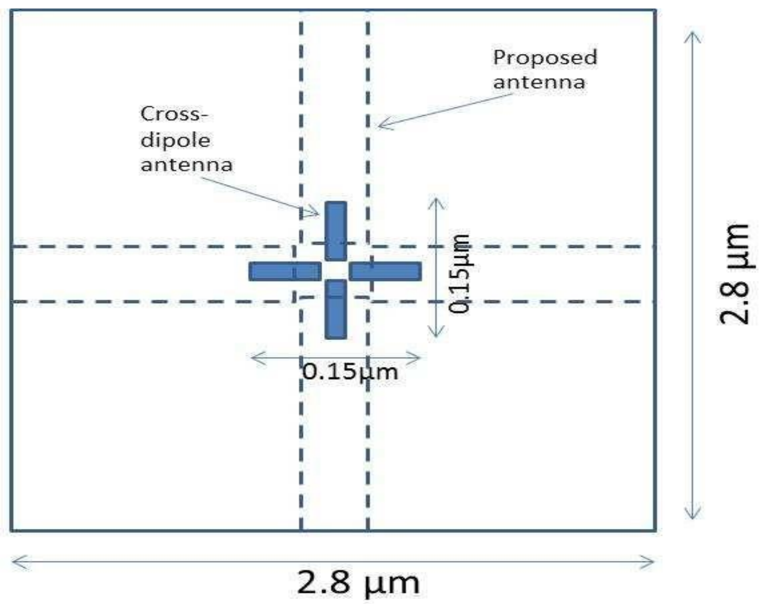

***Fig. 1** The proposed antenna's sizes compared with a corresponding printed cross-dipole antenna (resonance frequency at 400THz) (both are not on scale and the configuration of the proposed antenna hasn't been shown here)*

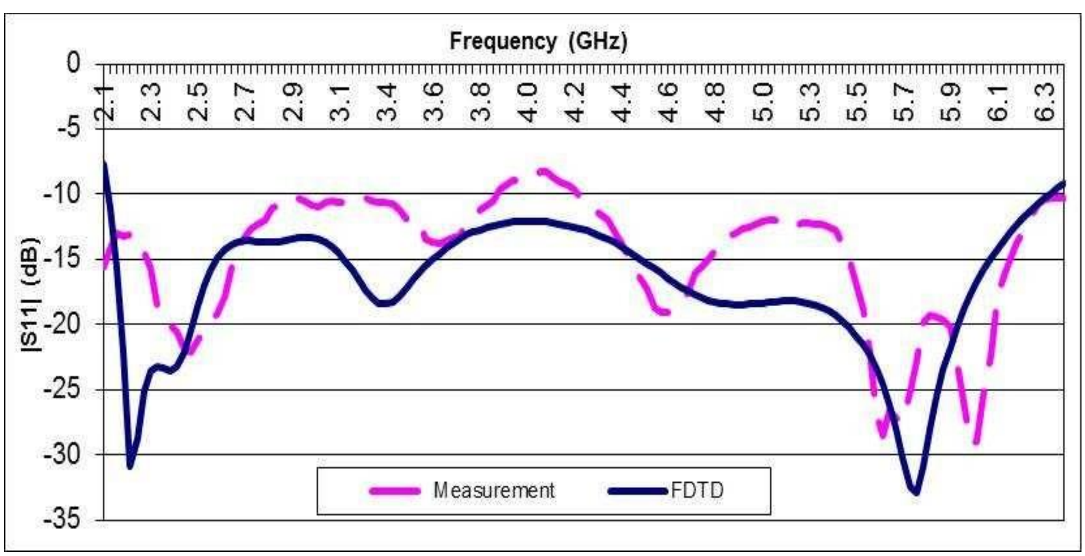

Fig. 2 *Measured and simulated results of S11 of the proposed antennaat microwave frequency range.*

Both results are well agreed and shown for a wideband response. The return loss of the proposed antenna is well below -10dB for 50 Ω input impedance for a frequency range from 2.12GHz to

6.36GHz. This presents 3 to 1 bandwidth for the proposed antenna. As mentioned, a pair of coaxial feed line was not simulated in the numerical analysis but was used to feed the antenna in the measurement.

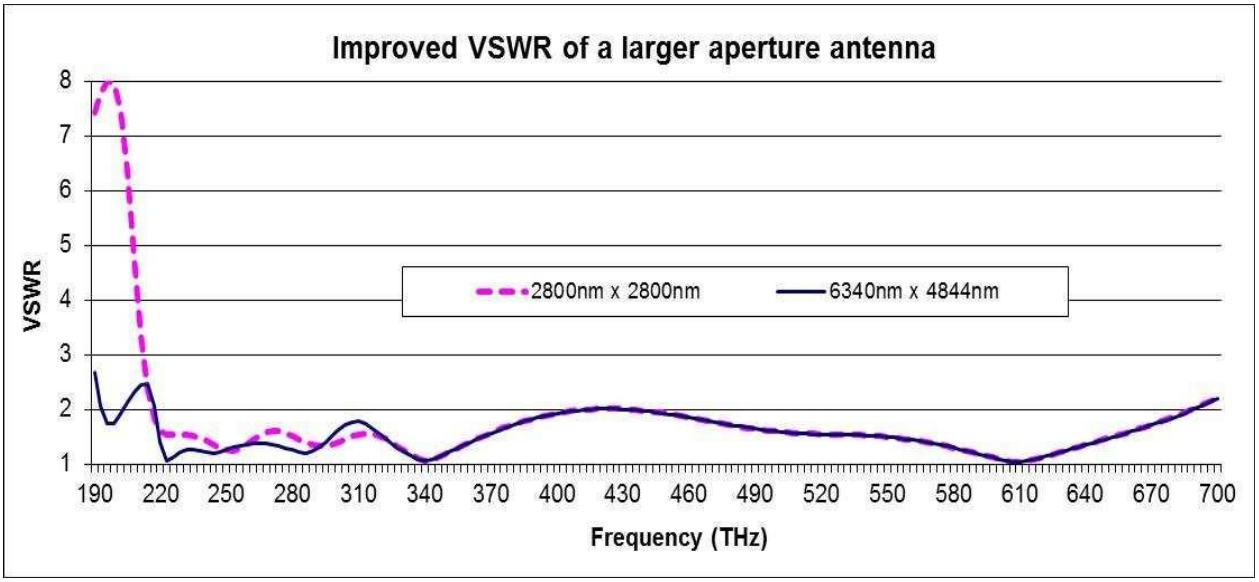

Fig. 3 *VSWR of the proposed antenna compared to its larger aperture version*

According to the antenna theory, the proposed antenna was redesigned for a frequency range in the visible light spectrum and placed at 160 nm above an infinite ground plane. The antenna exhibits a wideband response for 50 Ohm input impedance from 217THz to 691THz or 3.2 to 1. By adding more antenna elements to the proposed antenna to increase its aperture area the numerical analysis result is shown in Fig. 3, the improvement of VSWR better than 2:1 is around 12% more or 3.6 to 1 for an antenna sizes of 6340 nm x 4844 nm.

The antenna radiates in the upper hemisphere for all frequencies. The normalized radiation patterns of both the proposed antenna and the larger aperture version are shown in Fig. 4 for 450THz. In other frequencies the radiation patterns are similar except at low frequencies between 200THz to 220THz the maximum gain of the larger aperture version radiates toward -30° and 30° directions.

Conclusion: A large aperture antenna with wideband response in light frequency spectrum with 50 Ω input impedance is proposed. The antenna was built and tested in the microwave frequency range. The measurement and simulation results of S11 are well agreed. By adding more elements to the antenna its bandwidth is increased to cover more in the lower frequency range. The radiation patterns of both versions are similar except for some frequencies in the lower range. The configuration of the proposed antenna is a modified version of a cross- dipole antenna and radiates more than one polarization. According to (1) the received power can be increased due to the total aperture area of the antenna is increased. Next, the received power of the antenna will be intensively investigated.

Antenna Aperture = Po/PFD

P_o: Output power delivered by the antenna

PFD: Power Flux Density, the amount of radio power passing through a unit area

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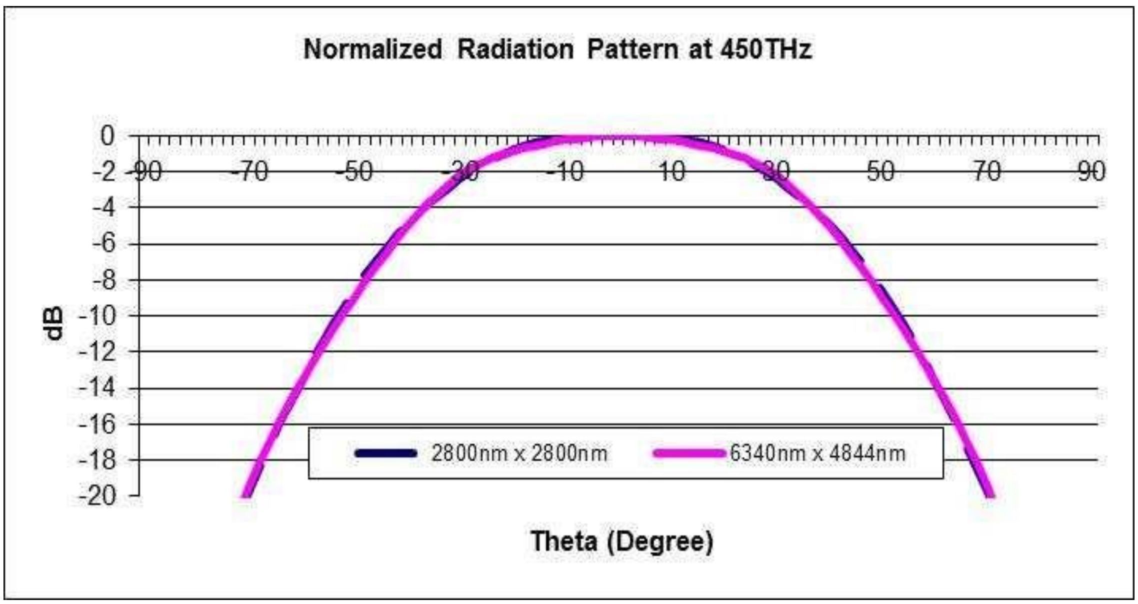

Fig. 4 *Normalized radiation patterns of the proposed antenna and its larger aperture version at 450THz. (Phi =0)*

References

1. R.L. Baily.: ‘A Proposed New Concept for a Solar-Energy Converter’, Journal of Engineering for Power, 1972, pp. 73–77
2. B. Berland.: 'Photovoltaic Technologies Beyond the Horizon: Optical Rectenna Solar Cell’, Final Report 1 August 2001-30, ITN Energy Systems, Inc. Littleton, Colorado, September 2002
3. D. Y. Goswami, F. kreith, and J. F. Kreider.: ‘Principles of Solar Engineering’. TYLOR & FRANCIS, Philadelphia, 2000.
4. M. Bozzetti, G. de Candia, M. Gallo, O. Losito, L. Mescia, f. Prudenzano.: ‘Analysis and Design of a Solar Rectenna’ Industrial Electronics (ISIE), 2010 IEEE International Symposium on, pp. 2001- 2004
5. Heylal Mashaal and Jeffrey M. Gordon.: ‘Fundamental bounds for antenna harvesting of sunlight’, Optics Letters, 2011, 36, (6), pp. 900– 902
6. Zixu Zhu, Sachit Grover, Kendra Krueger, and Garret Moddel.: ‘Optical rectenna solar cells using Graphene Geometric Diodes’, Photovoltaic Specialists Conference (PVSC), 2011, 37th IEEE, pp. 2120-212