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Design of A Highly Efficient Wideband Suspended Solar Array Antenna

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***Abstract*—This paper presents the design of a wideband suspended solar patch array antenna for WLAN and ISM band applications. The suspended silicon solar cells, which have been replaced with traditional microstrip patches and work as antennas within the design, are able to receive and transmit the EM signals while producing a DC current as a result of the photovoltaic effect. A unique and effective quarter-wave DC/AC decoupling circuit, which enables the produced current to be withdrawn from the system without affecting the RF performance of the antenna, has been designed based on microwave circuit topology. Experimental and full-wave simulation results of the presented solar antenna operating within the frequency band of 2.3-2.75 GHz, confirm the suitability of the proposed design for wideband communication systems with a wide impedance bandwidth of 18.36%, 450 MHz, and a high gain of 12.2 dB.**

I. INTRODUCTION

With the ever increasing demands for low profile antennas and a growing move towards microgeneration of electricity, primarily photovoltaics (PV), there is an increasing need to provide highly efficient compact communication systems combined with solar cells.

Microstrip antennas have drawn much attention in terrestrial and satellite communication systems and are widely used at microwave frequencies as they bring various kinds of advantages together, like being in low-profile and low-cost to manufacture, and having a simple design process [1].

An increasing number of research has been conducted recently to combine solar cells with microwave antennas, mostly microstrip patches, into a single device to overcome the difficulties caused by the use of some autonomous communication systems, in which solar cells and antennas are two separate devices, and to create cost effective and low-profile designs.

Various kinds of techniques have been offered in the literature in order to incorporate solar cells with antennas. The combination of a polycrystalline silicon solar cell with a microstrip patch antenna as a microwave ground plane has been carried out with a narrow bandwidth of 3% and a reduced efficiency due to the blockade effect of the patch antenna over the solar cell [2]. The concepts of using slot-fed and H-slot microstrip antennas combined with solar cells have been investigated in [3, 4]. The selection of slot antennas in order to minimize the effect of DC operation of solar cells on the RF performance of the antenna has resulted in a narrow bandwidth, which makes these designs impossible to use in wideband communication applications. Another design, which includes a complex DC/AC decoupling circuit that has been realized by means of concentrated reactive elements with a maximum gain of 5.6 dB, has been done in [5]. A recent work has also demonstrated a microstrip patch antenna, which is made out of a transparent film, AgHT-4, with a minimum visible light transmission of 75%, mounted on the surface of a silicon solar cell [6]. In this approach, the use of transparent conductive materials makes the antenna rather complicated and expensive.

In this paper, an effective, low cost and easily designable suspended solar array antenna is presented for WLAN and 2.4 GHz ISM band applications. In the proposed design, silicon solar cells have been replaced with traditional patch antennas in order to eliminate the disadvantage of the blockade effect of the patch antennas on solar cells.

A significant factor which has also been considered in this proposed design is the requirement of producing a low impedance DC connection to the cell while maintaining a high RF impedance. The decoupling circuit which isolates the DC conncetions, that are used to collect the current produced by the solar cells, from the RF lines has been achieved by using a unique and very simple technique, quarter-wave microstrip PCB transmission lines, based on microwave circuit topology without bringing any complexities or other disadvantages mentioned above unlike the previous designs.

II. THE SOLAR ANTENNA AND MEASUREMENT RESULTS

The fabricated suspended solar patch array antenna is shown in Fig.1. The substrate layer, which is constructed from FR4, has been raised up by 5mm over the aluminum ground plane to create a suspended design in order to increase the impedance bandwidth. The silicon solar cells have been replaced with patch antennas and mounted on the suspended substrate.

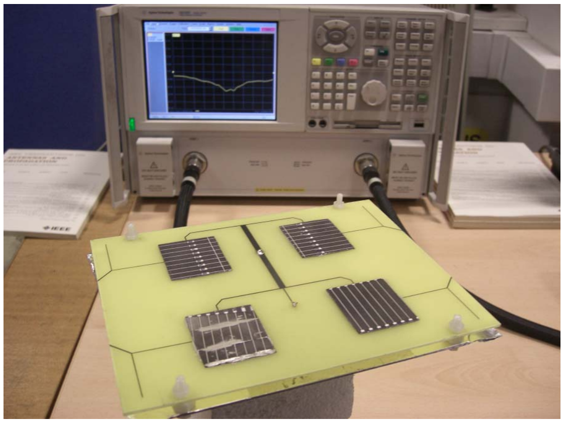


Figure 1. Fabricated suspended solar array antenna.

Each solar antenna has its own DC/AC decoupling circuit preventing the DC current path from affecting the RF radiation characteristics of the antenna. Fig. 2 provides a closer look at the decoupling circuit which consists of three microstrip PCB lines.

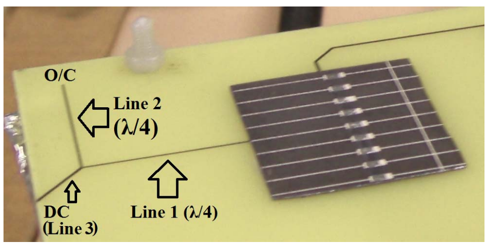
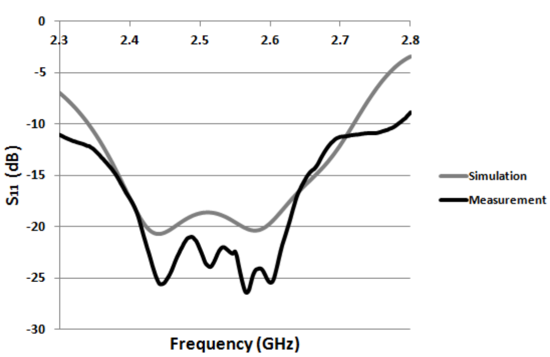


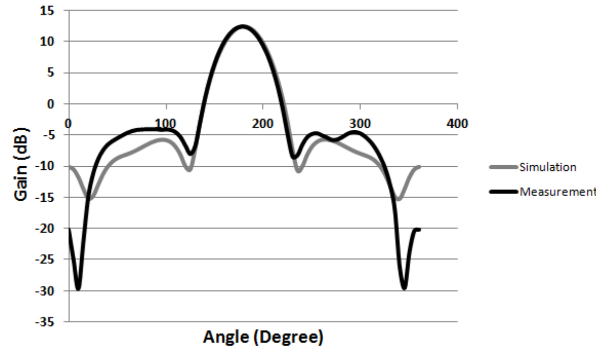
Figure 2. The DC/AC decoupling circuit.

The first and second PCB lines, with a length of λ/4, are to create a high RF impedance to the cell while the third line is to transfer the DC current to the load through the first line. As the impedance at the end of the second transmission line is very high, ideally open circuit, it results in a very low impedance, ideally short circuit, at the beginning of the first transmission line which is then converted to open circuit at the input of the cell. That means, there is no effect of the PCB microstrip lines, through which the DC current flows to the load, on the RF radiation characteristics of the antenna.

The simulated and measured S-parameter and far-field radiation characteristics of the solar antenna are shown in Fig. 3(a) and (b).



(a)



(b)

Figure 3. Comparison of simulated and measured S-parameter and far-field radiation patterns (horizontal cut).

A gain of 12.2 dB has been obtained by using the proposed solar array antenna consisting of four solar cells, working as antennas, while a wide bandwidth of 18.36% has been obtained as a result of placing the solar cells on a suspended FR4 substrate.

III. CONCLUSIONS

This paper offers an effective solar antenna design for compact wideband communication system applications, particularly WLAN and ISM, in which low-profile antennas with a wide impedance bandwidth and high gain are required. An array combination of solar cells, which have been replaced with microstrip patches and mounted on a suspended FR4 substrate, has resulted in a wide impedance bandwidth of 18.36% with a gain of 12.2 dB. The isolation of the RF lines from the DC lines has been achieved by using highly efficient quarter-wavelength microstrip transmission lines without using any circuit elements or other techniques, which offset the disadvantages mentioned above. The simulation and measurement results of the proposed antenna have been presented in figures.

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