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Design of a Compact Meshed Antennas for 5G Communication Systems

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***Abstract*—**This paper presents a hybrid system solar cell antenna for 5G mobile communications networks. We propose here a solar cell antenna with either a front face collection grid or mesh patch. The solar cell antenna of our contribution combines both optical and radiofrequency signals. Thus, we propose two solar cell antenna structures in the frequency bands of future 5G standard respectively in both 2.6 and 3.5 GHz bands. Simulation using the Advanced Design System (ADS) software allows us to analyze and determine the antenna parameters proposed in this work such as the reflection coefficient (S11), gain, directivity and radiated power.

***Keywords*—**Patch antenna, solar cell, DC, RF, 5G.

I. Introduction

THE growth of information traffic in radio mobile communications requires the improvement of the hardware systems performance used for transmission. A vital component of these systems is the antenna, which is one of the most important design issues. In such domain, the diversity of standards (GSM, UMTS, LTE ...) led us to design antennas fulfilling many constraints such as: low manufacturing cost, multi-frequency operation, signal reception... The major challenge of many communication systems is the power supply of such systems in remote places where the power grid is not available. In order to address this challenge, the use of photovoltaic in communication systems has recently been the subject of much more researches. Solar powered communication systems received considerable attention thanks to their ability to work without necessity of being connected to an electricity grid. Traditionally, telecommunication antennas and solar cells do not mix. The antenna and the solar cell must operate independently and therefore cannot interfere. This constraint, for example, has repercussions on the weight and size of communication systems: they must have a larger surface enough to accommodate both the antenna system for transmitting and capturing data and solar cells and for the supply of electricity [1]. The integration of solar cells with microwave antennas in a single multifunctional device gives potentially a wide range of benefits in terms of volume, weight, smart appearance and electrical performance to many applications when compared with a simple combination of antennas and solar cells. New product designs and cost reduction become possible [2]-[9].

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In this paper, a method for combining a patch antenna and a photovoltaic cell in a single hybrid system for 5G standard has been studied. The rest of the paper is organized as follows: Section II presents the frequency bands for the future 5G standard. Section III describes the meshed solar cell antenna. Section IV draws the simulation results. Finally, concluding remarks are given in Section V.

II. Frequency Bands for the Future 5G Standard

A. Reserved Frequency Bands for 5G

In order to satisfy the future expected provisions, such as great high bit rate, bigger system capacity, higher data rates, reduced latency, huge device connectivity with devices, and energy discount and cost reduction, the 5G mobile communication system has been actively investigated all over the world.

Unlike previous generations, 5G should not only outcome in the deployment of new frequency bands. Indeed, if deployment of 4G goes through the use of 800, 1800 or 2600 MHz bands, 5G will need spectrum in these three ranges to achieve optimal coverage and thus satisfy needs of all users. Frequency ranges are those below 1 GHz, between 1 and 6 GHz and above 6 GHz [10].

Some approaches use the high-SHF (super high frequency: beyond 6 GHz) and EHF (extremely high frequency: essentially 30-60 GHz) bands [11], [12]. These bands are very attractive because they easily offer larger frequency bandwidth. Nevertheless, it does not target small cell environments. That's why other frequency bands should be investigated.

Concerning the frequencies distribution below 1 GHz, such as the 700 MHz band, it has been officially declared by the European Union that it will be among the reserved bands for 5G. This band is considered a gold one thanks to its best ability in buildings penetration more than its better coverage when compared to bands greater than 1 GHz. [11]. The spectrum range between 1 and 6 GHz provides a logical mix of both coverage and capacity for 5G services since that a reasonable amount of existing mobile broadband frequencies is used to ensure the first wave of 5G deployments [10]. Hence, for example, the band of 2.6 GHz and which of 3.5 GHz, well be used for 5G [14]-[17]. In addition, these two bands can be used for mobile networks, connected objects networks or the provision of fixed internet in rural areas [12]. So, to ensure global coverage of the territory, the use of frequencies bands above 6 GHz is necessary to reach ultra-broadband mobile. These high frequencies are well known around the world as the key of 5G's ultra-fast services since in their absence, 5G will not be able to provide much faster data speeds or support the expected growth of the marked increase in mobile traffic [10]. That's why we can say that high frequencies are intended to absorb better the traffic, but the broader the frequency, the more it can bring in speeds and therefore support users.

B. 5G Future Applications

With the appearance of 5G, data transmission speed will increase. This acceleration will affect the time response of high-tech applications such as connected and stand-alone cars that can operate safely with the sending and receiving of huge amounts of data reliably and at high speed. In addition, telemedicine, remote machine management and much more applications will be ever possible with the arrival of the 5G, and we can again find emergency services, connected drones and Internet of things, ... which are all potential applications that the 5G network can make reachable.

C. Antennas Specification for 5G

The growth of the users' number of certain applications required with the appearance of new techniques has a considerable and growing interest for antennas, which leads to the design of new reconfigurable antenna devices.

The prodigious evolution of the printed structures is linked to the considerable improvements in the field of miniaturization, the electronic circuits' integration and especially with low losses dielectric substrates. Designed antennas should be able to modify their operating frequencies, bandwidths, polarizations and radiation patterns independently to be adapted for both the change in their environment and the context of use by optimizing their performance. The basic advantage of such an antenna is that, from a conventional fixed-function antenna and by applying a switching technique of an electrical, mechanical, optical or other nature, we extend the trends and improve the functioning and the performance of wireless terminals with minimal impact on the complexity and cost of these systems.

III. Meshed Solar Cell Antenna

A. Approach

The use of printed antennas became widespread in all mobile communication systems. For this reason, we propose here a solar cell antenna scheme for 5G standard, future generation of mobile network. Several attempts to integrate solar cells with patch antennas have been studied [2], [4], [7], [8], but they did not pay attention to the antenna patch when placed above a solar cell. To correct these misdeeds, especially of limited surface area, encountered during the patch antenna integration with a photovoltaic cell, we propose here types of antennas based on photovoltaic cells optically transparent with mesh patch. Mesh optically transparent patch antennas are antennas that have a certain level of optical transparency. These ones fit potentially when integrated with solar cells for small satellites. Traditional patch antennas used on small satellites compete with solar cells in the surface. However, a mesh patch antenna can be placed directly on the solar cells and solve the problem of surface limitation. For such integration, a high optical transparency of the patch antenna is required from the side of solar cells, since these latest require sufficient sunlight to generate adequate electrical power. On the other hand, the antenna must have some acceptable electrical properties to radiate correctly and efficiently [13]-[15]. The hybrid system is dedicated to the energy recovery and the RF transmission. This structure was made of a photovoltaic cell in which the front grid has been designed to have a miniature antenna fitted to the band transmission and minimizing the power loss of the cell intended to energy conversion. The received electrical energy is used for complete system functioning.

B. Meshed Solar Cell Antenna Structure

The designed structure used in this paper is a printed solar cell antenna with a substrate containing different layers of two major components, the multi-layered substrate of solar cell antenna (Fig. 1) shows the proposed design as the radiating element and the solar cell structure which consists of three main layers: anode lattice, silicon and cathode. The materials used in this design for the anode and cathode layers are respectively silver and aluminum. The silicon is based on an insulating layer SiO_2 which confers to the components, realized a higher operating frequency and an ability to operate at low voltage, low power consumption and insensitivity to the effects of ionizing radiation.

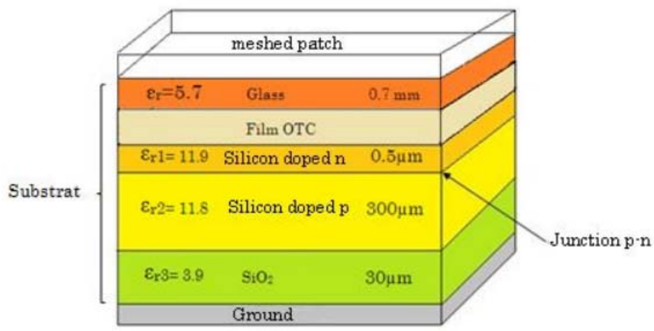

Fig.1 Multi-layered substrate of solar cell antenna

IV. Simulations Results and Discussions

The solar cell antenna has been studied in another work by determining its collected electrical power according to the geometric parameters of the patch or its front face collection grid [19], [22]. Some of the parameters concern the width of lines constituting the patch, the metal height or the distance between the lines. The optimum values of these geometric parameters obtained are used for the design of solar cell antenna [16]. The optically transparent mesh antennas dedicated to the frequencies bands of 2.6 and 3.5 GHz are studied here to test the parameters of the proposed solar cell antenna, such as the reflection coefficient S11, directivity, gain and radiated power. We propose two solar cell antenna models (Figs. 2 and 3) simulated using ADS software.

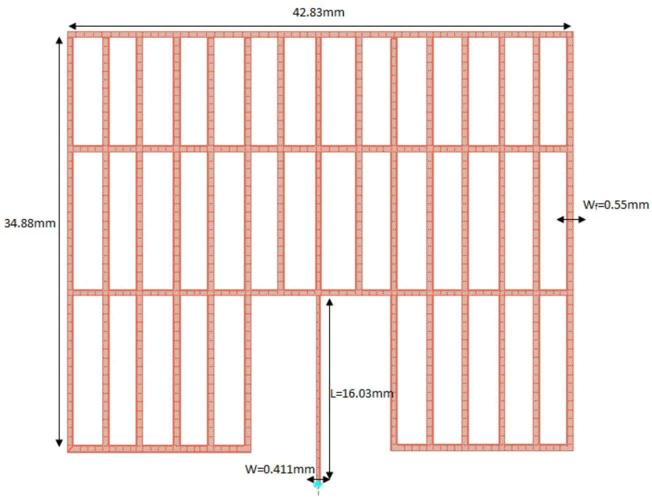

Fig. 2 Solar cell antenna for 2.6 GHz

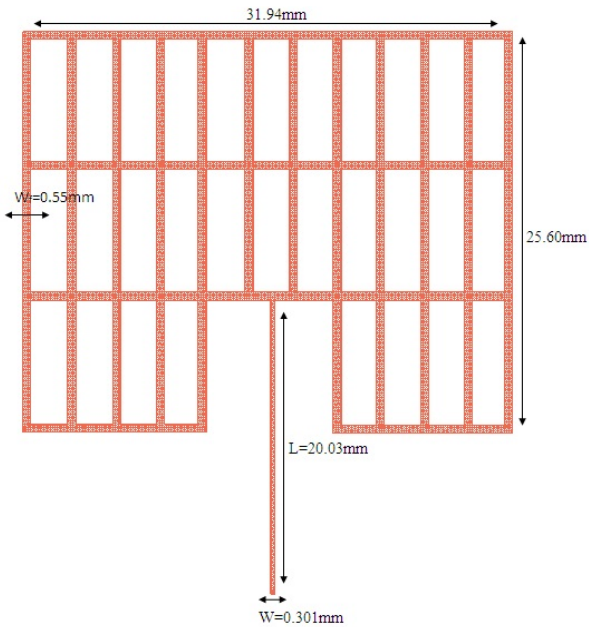

Fig. 3 Solar cell antenna for 3.5 GHz

Solar cell antenna was simulated and the reflection coefficient S11 is presented in Figs. 4 and 5. In antenna theory, such as patch antennas, an antenna should be a perfect radiator rather than a perfect absorber. The results of the simulation show that the solar cell antennas designed at 2.6 GHz with S11 = -23.82 dB and at 3.5 GHz with S11 = -39.96 dB can be used for digital satellite communication systems.

When designing an antenna, the gain must be taken into consideration since it is an important metric. The good values of S11 and VSWR are not enough to confirm a good radiation. Figs. 6 and 7 show the gain radiation diagram for the two frequencies. In other words, a gain of 2.66 dBi is obtained at 2.6 GHz, but 7.28 dBi is reached at 3.5 GHz.

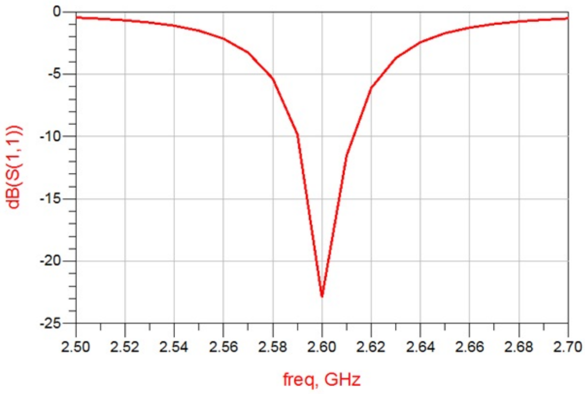

Fig. 4 Parameter S11 for 2.6 GHz

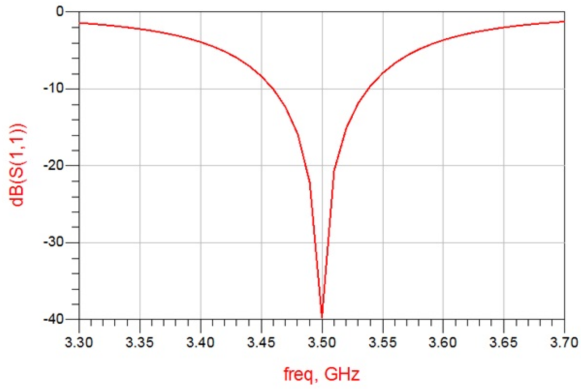

Fig. 5 Parameter S11 for 3.5 GHz

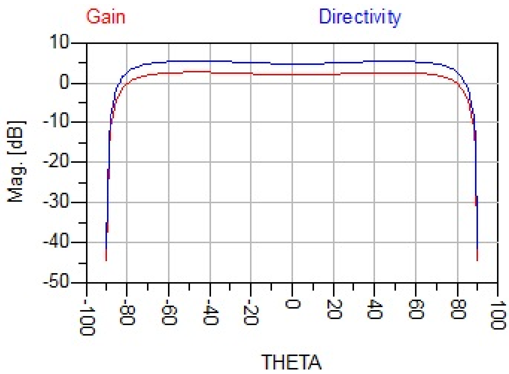

Fig. 6 Gain and directivity for 2.6 GHz

Figs. 8 and 9 show the radiation diagram in the plane E and H for both frequencies. This reflects a very directive radiation by offering a total directivity of 5.43 dB at 2.6 GHz and 7.37 dB at 3.5 GHz. This allows the antenna to be used especially in the point to point transmission systems.

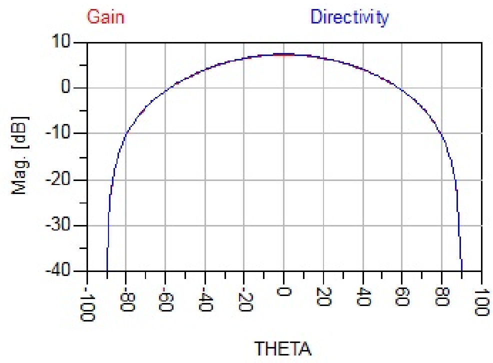

Fig. 7 Gain and directivity for 3.5 GHz

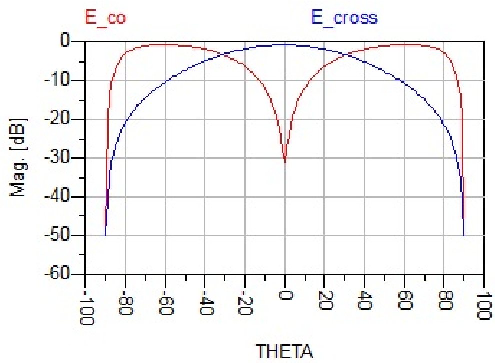

Fig. 8 Far field radiation pattern in E plane for 2.6 GHz

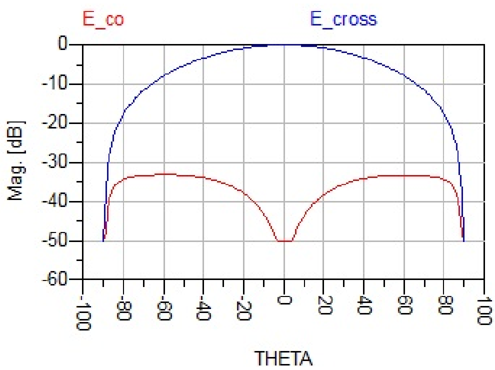

Fig. 9 Far field radiation pattern in E plane for 3.5 GHz

V. CONCLUSION

In this work, we have presented a two solar cell antenna for energy harvesting and RF transmission for the future standard 5G. These are optically transparent meshed solar cell antennas printed on a multilayer substrate such as glass which is a totally transparent layer, an OTC film with conductive and transparent properties and semi-transparent silicon layers. Good results of simulation are obtained, such as the electric power collected as a solar cell; and the gain, the directivity, the reflection parameter as an antenna.

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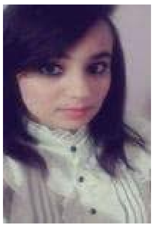

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