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Solar-Panel Receiver design for Optical Wireless Communications and Simultaneous Energy Harvesting

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Abstract: This paper presents a completely different design model from before of an optical wireless communications receiver by using solar panel as a photo detector. Simultaneous data transmission & energy harvesting can be done using proposed system. A modulated light signal can be converted into an electrical signal by using a solar panel which doesn't require any external power. User can use a generated energy for the system or this energy can also use to prolong the operation time of system. This paper focuses on the parameters which are considered important for the design of system using solar panel applied for simultaneous communication & energy harvesting. This paper describes actual practical implementation of orthogonal frequency division multiplexing (OFDM). Described system can establish a communication link with data rate of 11.84 MBPS for received optical signal.

Keywords: Photodetector, energy harvesting, multi-crystalline silicon solar cells, OFDM.

I. INTRODUCTION

Now days, Wireless connectivity is a fundamental part of our everyday lives & is regarded as an essential thing like gas, water & electricity. Today we are facing the imminent storage of radio frequency (RF) spectrum. The data sent through wireless networks is increasing day by day. As a result, optical wireless communication & visible light communications are discovered as new technologies. [1] The electromagnetic spectrum used by them is completely free from regulation, offers big amount of bandwidth for wireless data transmission without any interference & also it allows safe communication.

The transmitter converts electrical signal into optical signal & detector or receiver converts the optical signal into electrical current. LEDs can be used as optical sources & photodiodes as (PDs) as a receiver. [2] In the VLC systems LEDs are used for data transmission as well as for illumination. [2] A white off the shelf phosphor coated LEDs can give 1Gbps data rate. However, RGB LEDs can present a better solution for high data rate VLC. A data rate of 3.4 Gbps is reported by white off the shelf RGB LED. [1]

Avalanche photodiodes (APDs) & positive intrinsic negative (PIN) are having a good ability to provide high speed linear photo detection at a practical illumination so both are very commonly used at the receiver side in OWC systems. PIN photodiodes are diodes with a wide, undoped intrinsic semiconductor region between p - type & n - type semiconductor region. The PIN photodiodes is having a disadvantage of external power requirement which can be replaced by solar panel. Solar panels can convert optical signal into an electrical signal directly by using sunlight.
In 1954 first solar cell which can convert enough sun's energy to power to run electrical equipment in everyday life is invented in Bell Laboratories. [3] Multi-junction III-V concentrator cells have highest energy conversion efficiency reaching over 40 % with several different types. [4] Multi-crystalline and single crystalline silicon solar panels also having good conversion efficiency i.e. more than 40%, but they are costly than thin film solar cells. Thin film solar cells have less conversion efficiency approximately 10% [5]. In this paper, first generation multi-crystalline silicon solar cells are used in an indoor environment.

II. SOLAR PANEL OPERATION FOR ENERGY HARVESTING AND COMMUNICATION

A. Solar panel model for energy harvesting
Ideally Solar cells behave like a current source if it is connected in parallel with a diode. [7] A solar panel model for energy harvesting is shown in figure. Since second half of last century it is studied and well established. This model includes resistors to represent the losses and also the phenomena related to the diodes. [6] The circuit includes a current source, one diode and two resistors i.e. one in series and one in parallel. [7] Each element implies one parameter has to be determined in equivalent circuit.

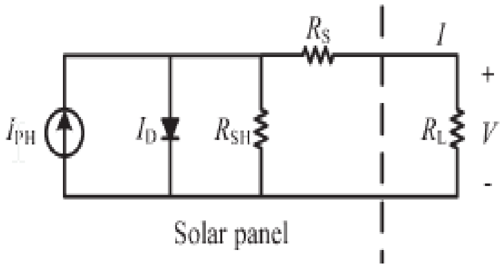

Fig. 1 Solar panel model for energy harvesting

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The current and voltage outputs of solar model have nonlinear relation. A photocurrent source I_{PH} is connected in parallel to a diode D. The forward current of the diode is denoted as I_D. A shunt resistor R_{SH} shows leakage current in the solar panel, and a series resistor R_S shows internal voltage loss because of cell interconnections. [8] Using the circuit diagram I-V characteristics of solar panel can be given as:

$$I = I_{PH} - I_D - \frac{(V + IR_S)}{R_{SH}}, \qquad (1)$$

Where $V = R_L I$ and

The environmental parameters of model should also take into account like temperature irradiance. These parameters should be set during simulations or user can measure it directly during outdoor tests. To evaluate such parameters a best- fit algorithm can be used on the basis of measured data. [8]

$$I_D = I_0 \exp\left[\frac{(V + IR_S)}{n_s V_T} - 1\right]. \qquad (2)$$

In equation (2) I_0 denotes the reverse saturation current of the diode D, V_T is the junction thermal voltage of the diode, nS is the number of cells in the solar panel connected in series , and V_T is given by,

$$V_T = \frac{AkT}{q}, \qquad (3)$$

Where A shows the diode ideality factor, k is Boltzmann's constant, T indicates temperature in Kelvin and q denotes electron charge [1]. The parameters ns, k, T, and q are 'p-;-known in advance, while IPH, I0, A, RSH, and RS, are unknown parameters. They depend on the overall light irradiance over the solar panel. The I-V characteristics of solar panel can be presented by following graph.

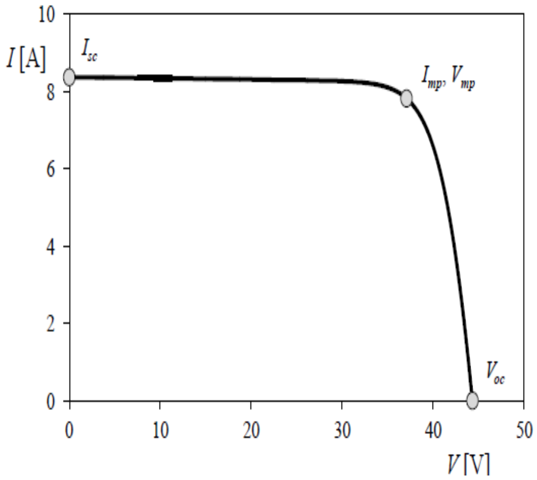

Fig.2 I-V curve of solar panel

B. Solar Panel Model for Communication

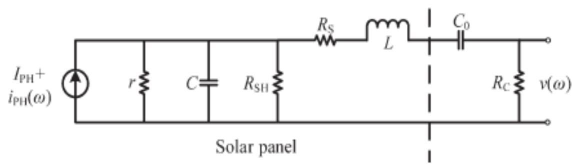

Fig.3 Solar panel model for communication

Fig. 3 shows the solar panel model for communication purpose. It is assumed that the AC component of the light signal is always having small variation compared to the magnitude of DC component and all these parameters needs in the design of DC parameters of the solar panel .The diode is replaced by a equivalent resistor r. Inductor L is used to model the inductance of if there is any wire connections to solar panel. To block DC components a capacitor C0 is added before the load resistor $R_{C,}$ because only AC components of photo- generated current is used for communication. A voltage across load resistor R_C represents information signal. The frequency response for solar panel configuration for communication can be given by equation

$$\left|\frac{v(\omega)}{i_{PH}(\omega)}\right|^2 = \left|\frac{\frac{R_C}{R_X}}{\frac{1}{r} + \frac{1}{\frac{1}{j\omega C}} + \frac{1}{R_{SH}} + \frac{1}{R_X}}\right|^2, \qquad (4)$$

Where ω indicates angular frequency and j=√-1. R_X is parallel with RSH, which can be given by

$$R_X = R_S + j\omega L + \frac{1}{j\omega C_0} + R_C. \qquad (5)$$

In (4), parameters R_{SH} and R_S are set by the DC operation point of the solar panel. Parameters r, C, and L are described next.

C. A Solar Panel Model for Simultaneous Energy Harvesting and Communication

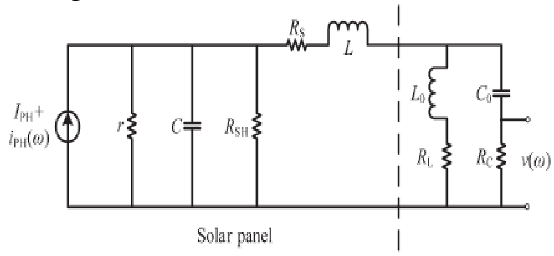

Fig. 4 Solar panel configuration for simultaneous energy harvesting & communication

Fig. 4 shows the receiver circuit which can be used for simultaneous communication and energy harvesting with a solar panel. Circuit shows that branch for energy harvesting is added parallel to the communication branch. The capacitor C_0 and load resistor forms the communication branch. The energy harvesting branch consist of a resistor R_L and an inductor L_0 as the RF choke, which is used as a battery in many real world applications. The inductor L_0 is used for attenuation of AC signals and to remove ripples from the DC signal and simultaneously it improves the gain in the communication signal. The frequency response of the complete system is given by

$$\left|\frac{v(\omega)}{i_{PH}(\omega)}\right|^2 = \left|\frac{\frac{R_{LC}}{R_S + j\omega L + R_{LC}} \frac{R_C}{\frac{1}{j\omega C_0} + R_C}}{\frac{1}{r} + \frac{1}{\frac{1}{j\omega C}} + \frac{1}{R_{SH}} + \frac{1}{R_S + j\omega L + R_{LC}}}\right|^2. \qquad (6)$$

Eq. shows RLC which is resistance of network connected in parallel after inductor L. The photocurrent consists of

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both the AC and DC signal components, i.e. i_{PH} (ω) and I_{PH}. The capacitor C_0 blocks the DC component I_{PH} and only passes through the energy harvesting branch. The AC component i_{PH} (ω) passes through both branches. However, it is highly attenuated by the inductor L0 in the energy harvesting branch.

III. PROPOSED EXPERIMENTAL SETUP

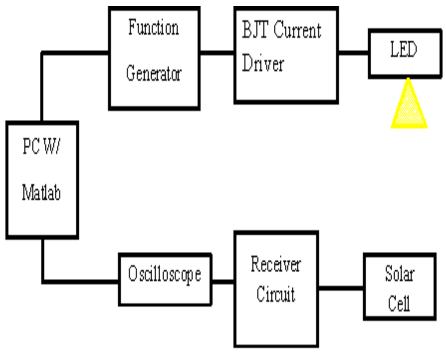

Fig. 5 Experimental setup for proposed system

A diagram shows the experimental setup to verify communication properties of the solar panel based receiver. Using MATLAB a discrete orthogonal frequency division multiplexing (OFDM) signal is generated through MATLAB with a serial step of: pseudo- random bit generation, M-ary quadrature amplitude modulation (M-QAM), adaptive bit and energy loading, inverse fast Fourier transform (IFFT), oversampling and pulse shaping.

The OFDM signal samples are passed onto an arbitrary waveform generator (AWG), which supplies a custom-built transmitter circuit with an analog waveform, suitable to modulate the light source. The solar panel captures the emitted light from the transmitter and generates an electrical signal. The latter is decoupled in the receiver circuit from Fig.4. Where the DC component is dissipated through the energy- harvesting load while the communication signal over RC is buffered with a voltage amplifier and passed to an oscilloscope, Agilent MSO7104B. The latter performs the digital to analog conversion. The digitized signal is retrieved from the oscilloscope and processed back in MATLAB through a series of steps that include: synchronization, matched filtering, down- sampling, fast Fourier transforms (FFT), channel estimation, equalization, and M-QAM demodulation.

IV. CONCLUSION

The paper proposed models for communication and simultaneous energy harvesting using solar panel as a receiver. Solar panel can act as a photo- detector and it also converts modulated light into electrical signal without power supply. Experimental setup is useful to achieve the feasibility of a communication link at a data rate 11.84Mbps and a BER of 1.6 x 10^{-3} for a received optical signal.

REFERENCES

[1]. Wang, Z, Tsonev, D, Videv, S & Haas, H 2015, 'On the Design of a Solar-Panel Receiver for Optical Wireless Communications with Simultaneous Energy Harvesting' IEEE Journal on Selected Areas in Communications, vol 33, no. 8, 7010358, pp. 1612-1623., 10.1109/JSAC.2015.2391811

[2]. H. Elgala, R. Mesleh, and H. Haas, “Indoor optical wireless communication: Potential and state-of-the-art,” IEEE Commun. Mag., vol. 49, no. 9, pp. 56–62, Sep. 2011.

[3]. US department of energy “The history of solar”.

[4]. “S R. R. King*, D. Bhusari, D. Larrabee, X.-Q. Liu, E. Rehder, K. Edmondson, H. Cotal, R. K. Jones, J. H. Ermer, C. M. Fetzer, D. C. Law and N. H. Karam solar cell generations over 40% efficiency,” Progr. Photovolt, Res. Appl., vol. 20, no. 6, pp. 801–815, Sep. 2012.

[5]. M. A. Green, “Third generation photovoltaics: Ultra-high conversion efficiency at low cost,” Progr. Photovolt., Res. Appl., vol. 9, no. 2, pp. 123–135, Mar./Apr. 2001

[6]. Wolf, M.; Rauschenbach, H. Series resistance effects on solar cell measurements. Adv. Energy Convers. 1963, 3, 455–479.

[7]. Explicit Expressions for Solar Panel Equivalent Circuit Parameters Based on Analytical Formulation and the Lambert W-Function Javier Cubas , Santiago Pindado and Carlos de Manuel Institute.

[8]. F. Adamo, F. Attivissimo, A. Di Nisio, and M. Spadavecchia,“Characterization and testing of a tool for photovoltaic panel modeling,” IEEE Trans. Instrum. Meas., vol. 60, no. 5, pp. 1613–1622, May 2011.