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Performance Comparison of PIN Diode and APDS in Optical Fiber Communication Systems

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Abstract: This study presents the comparative performance between two different photodiodes PIN and APD (Avalanche Photodiode). New development in this technology of both photodetectors opens a modern design for optical communication systems to improve the influence of several properties and parameters of those photodiodes which used for practical applications and different significant constructions. We use eye diagrams to evaluate the value of Q-factor in each case and every chosen cases to estimate the results. Therefore, the input power (dBm) and the fiber cable length (km) as well as bit rate (Gb/sec) have been used in this analyzed work to enhance the efficiency and performance for practical optical communication systems. These results implemented and analyzed by the OptiSystem Software through transceiver systems.

Key words: PIN, NRZ, APD, OCN, Q-factor, eye diagram, BER

INTRODUCTION

Optical fiber communication systems are light wave to transmit the information in the range of visible light or close to infrared electromagnetic field. Worldwide networks today led to many advance in the design of optical receivers for different approach to modify avalanche photodiodes APDs structure of high performance and resulted inconsiderable improvement of the influence-ionization factor for the movement of electrons (Almeida *et al*., 2017). This avalanche effect, imparts an internal current gain effect, as the initial photoelectron generates additional free electrons through multiple collisions with the silicon lattice.

In this type of photodiodes, the typical gain is around 100. However, some specially tailored devices can be operated at very high reverse-bias and provide very high gains. Photodetector need a confident smallest current to control consistently in order to translate into a minimum power by permitted responsivity. So that, they are need to choose a slighter quantity of optical power. In addition, to there are several various types of semiconductors offer alter wavelengths of light due to their particular energy bandgap (Kharraz and Forsyth, 2013a, b).

In general, fiber-optic communication systems have three main components. Firstly, the optical sources transmitters such as Light Emitting Diode (LEDS) or semiconductor lasers diodes. Secondly, the optical receivers which depend on semiconductors, structure like PIN or APD photodetectors. Furthermore, the link of fibre from point to another can be able to join by any suitable fiber mode cable such as single-mode or multi-mode fibres that may be add consultable and modern field techniques which are necessary to complete the network without losses and zero dispersion. This design of circuit placed together to form a useful light wave transmitting to receive the information data in optical communication systems.

MATERIALS AND METHODS

Photoconductors: A photoconductor a device converts energy and information from an optical form into an electrical form photoconductors can obviously be used as light detectors. This phenomenon means an opto-electrical where a material's conductivity increases due to the absorption of em radiation. When, light illuminates a semiconductor, some photons with the right energy are absorbed. Electrons from the valence band obtain enough energy to jump from the conduction band to implicate quickly near the n-or p-side to determine by the rechargeable field. This means conductivity increases because of the higher number of conduction electrons (Azadeh, 2009).

The main factor significant the sensitivity of a photodiode is its Quantum Efficiency (QE). it is distinct

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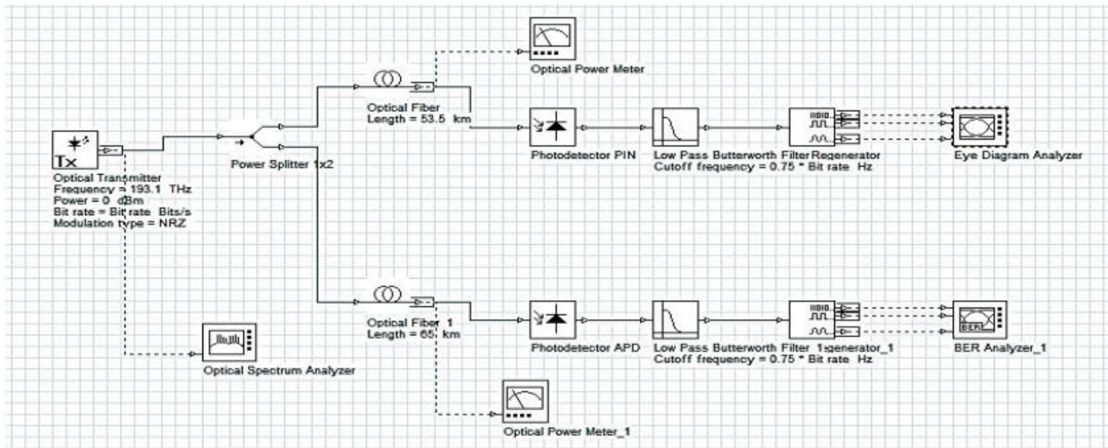

Fig. 1: Simulation layout for PIN and APD comparison in terms of Q factor and receiver sensitivity

as the proportion of instance photons creating electron-hole pairs which consequently add to the production signal depends on wavelength, material, internal electric fields and sensor architecture. The Responsivity R(λ) of photodiode is the amps of photodiode current acquired per watt of instance lighting. (Atef and Zimmermann, 2016).

PIN photodiode: A PIN photodiode is a reverse-biased PN junction diode. when we applied a positive bias to N side of the diode and the negative bias applied to P side of the diode there is no current flow in the junction. If a photon with appropriate energy is occasion on the junction, it can be immersed. Therefore, the absorption creates an electron-hole pair as an electron jumps from the valence to the conduction band can be removed over the junction in contrasting direction. This creates a photocurrent in the photodiode. Photodiodes are distinguished the size are small and thoughtful with low power also altered semiconductors are penetrating to diverse wavelengths of light due to their particular energy bandgap (Courjon, 2009).

The PIN photodiode consist P-type/intrinsic/N-type or P-type insulator/N-type that has thicker depletion is called intrinsic region which allows a reduced capacitance, even at low reverse bias and also improves quantum efficiency.

A avalanche photodiode: Avalanche Photodiodes, APDs share many characteristics with simple photodiodes such that the size is small and indicated to be sensitive to low power as well as can detect photons with energies higher than the bandgap. So that, different materials used for different spectral ranges.

Avalanche photodiodes are operated at high reverse bias typically more than 100 V. This imparts a lot of energy to the photoelectrons. Impact ionisation or the avalanche effect, imparts an internal current gain effect, as the initial photoelectron generates additional free electrons through multiple collisions with the silicon lattice. Typical gain is around 100 but some specially tailored devices can be operated at very high reverse-bias more than 1 kV) and provide gains of more than 1000. Also, the design of avalanche photodiodes APDs differ from the PIN photodiodes by adding layer during the second electron-hole couples are produced when impact ionization (Kharraz and Forsyth, 2013a, b; Kaur and Kinger, 2014).

Design and simulation: Fiber optic communication system has been formulated for the performance comparison characterization and OptiSystem 7.0 Software has been used for simulation purpose. The block diagram of design link is shown in Fig. 1.

Firstly, in the proposed design the complete link has the same specification of the optical transmitter. Then the signal is transmitted through the power splitter (1×2) to divide the light power of two channels. After that, the signal received to the optical receiver which consist of an APD and PIN photodiodes. The optical receiver is used to generate the electrical signal. It consist of a 3R regenerator, photo diode and a low pass filter. Secondly, the regenerated signal is fed to Bit-error- rate analyzer and displays Q- factor and eye diagrams of the signal. Finally, analysis is performed for NRZ line codes with various different wavelengths of APD and PIN.

RESULTS AND DISCUSSION

The software used for simulation is OptiSystem 7.0 to implement the circuit designed which include the PIN and

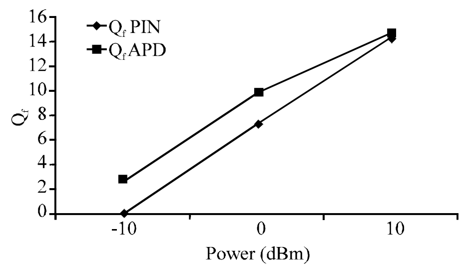

Fig. 2: Q factor of proposed system at different transmit power levels

APD photodiodes. The results obtained used to analyzed and evaluated the performance and identify the practical function for both.

Performance analysis of transmitted power effects: The data rate is 1Gbps used to simulated the circuit designed to gives the results, Fig. 2 shown is describe clearly the performance of both PIN and APD photodiodes. When, the Q factor varying according to vary the value of input power in optical transmitter source but the distance value is fixed at 50 km .

Avalanche photodiode APD is appeared the good performance at minimum value of power send (-10 dBm) and the value of Q factor is (3.123) with BER 1.41 exp (-4) at the same time.

The achievement of PIN is zero due to multiplication factor of APD and high revisers voltage applied which is proportional directly with sensitivity of depletion region. So, the photo current is increased when the value of power is varied to middle point (0 dBm) the APD is better performance but when the power value is elevated to high level at (10 dBm) the performance is the same value for both.

The characters Y&Y1 is represent eye height Fig. 3 shown is depicts that Y1>Y due to low transmitted power level. So, the total jitter effect with distortion in PIN is more than APD.

Performance analysis of data rate effects: The circuit has be designed to compare the performance of both PIN and APD in terms of the impact of the data rate. It sets the value of power (0 dBm) (the middle point of power level used to send the optical signal with low drawback for medium of transceiver system).

Avalanche photodiode APD was appeared performance much higher than PIN due to more permitted electrons in depletion region that's make it high speed. When the data rate is elevated to 5 Gbsec APD still high performance than PIN but in this case, it was the Q factor of PIN is more closer to Q factor of APD when the data rate changed to (10 Gbsec) the Q factor is decreased.

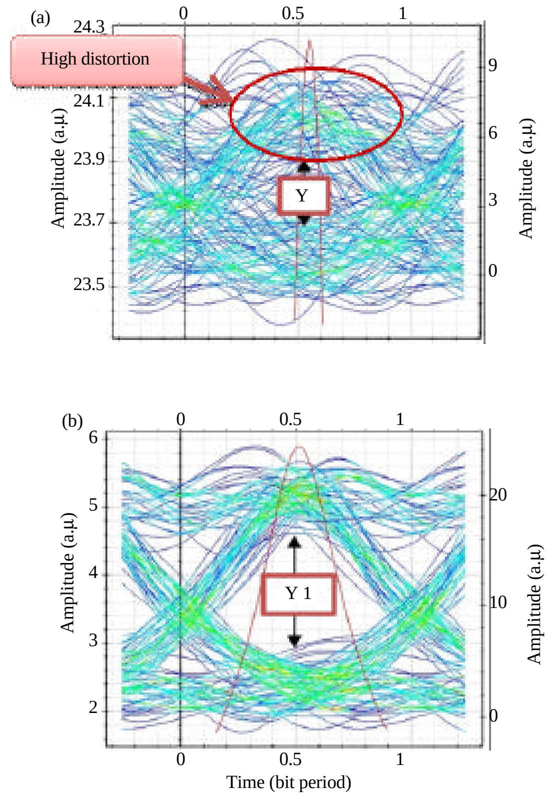

Fig. 3: Eye diagram of: a) PIN and b) APD at (-10 dBm)

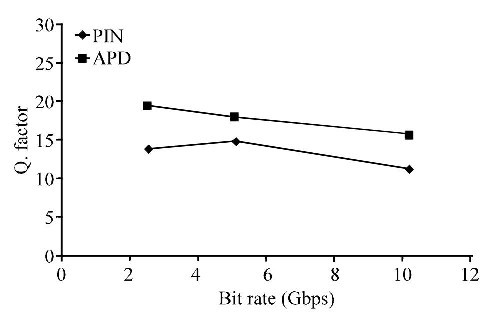

Fig. 4: Q factor of proposed system at different data rates

Figure 4 shown is describe the data rate at minimum value (2.5 Gbsec) gives the value of Q factor is 19.12 and 13.73 for APD and PIN, respectively. So, the value of Q factor measured to different value of data rate is gives the good option to choose the photodiode device APD or PIN for optical receiver system.

Performance analysis of transmission length effects: In this case of the stimulation the design of the system, we carried out 10 Gbps and employed the value for transmit power about (-10 dBm), so that, Fig. 5 as shown described the behavior of both devices PIN&APD and then the

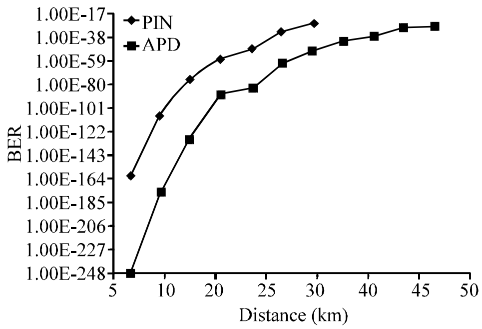

Fig. 5: BER of proposed system at different transmission distance

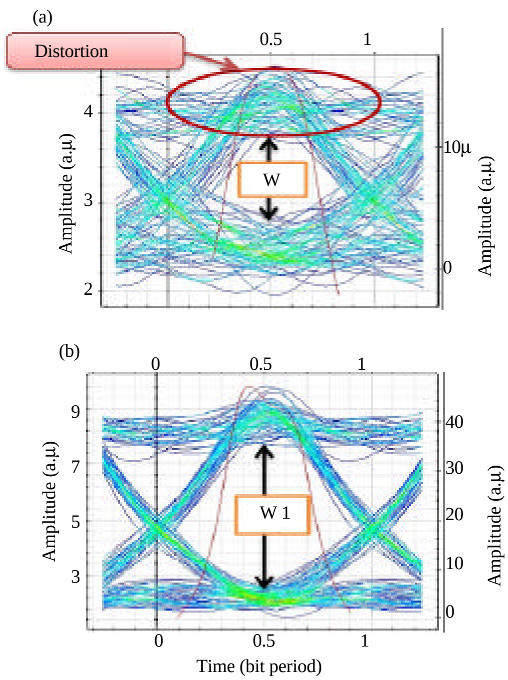

Fig. 6: Eye diagram of: a) PIN and b) APD at 30 km

result measured after simulated at the same value of BER (1.29 exp-9). However, the APD was supported the fiber length up to (50 km) compared with PIN which its able up to (30 km).

The characters W&W1 is represent eye height Fig. 6 shown is depicts that W1>W due to fiber length of channel is same (30 km). So that, the total jitter effect with distortion in PIN is more than APD. But its acceptable for both in this case.

CONCLUSION

In summary, the analysis of performance has be compared in terms of PIN and APD optical photodetectors in receiver side of the networks of optical communication systems. Firstly, the design of the circuit in which higher Q factor achievement, the response has better for long haul communication systems. As results a high sensitivity in high data rate applications and high speed where the cost is inevitable. Secondly, it is a good candidate in high-speed network access systems. It has concluded from the above-mentioned discussion the APD is preferred over PIN at lower transmit power levels and high data rates with long haul communication networks. However, PIN is more suitable at low data rate less than 5Gbsec and shorter length <30 km and high transmit power levels applications. Finally, avalanche photodiode APD gives better Q factor than PIN photodiode. In future, the research will be increase the data rate to 20 Gbpsec and the performance will evaluate for other cases.

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