Journal of Scientific Research & Reports
6(3): 201-209, 2015; Article no.JSRR.2015.145
ISSN: 2320-0227

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Performance Analysis of Free Space Optical Communication Link Using Different Modulation and Wavelength

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Authors' contributions

This work was carried out in collaboration between both authors. Authors GS and HK designed the study and author HK wrote the first draft of the manuscript. Both authors managed the literature searches, analyses of the study performed the simulation analysis. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2015/15503
Editor(s):
(1) José Alberto Duarte Moller, Center for Advanced Materials Researchl, Complejo Industrial Chihuahua, Mexico.
Reviewers:
(1) Anonymous, China.
(2) Anonymous, China.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=964&id=22&aid=8225

Original Research Article

Received 29th November 2014
Accepted 6th January 2015
Published 24th February 2015

ABSTRACT

In this paper different modulation formats NRZ and RZ and different wavelengths 1550 nm and 1310 nm and two photodiodes APD and PIN has been investigated on free space optical communication link. The value of Q has been observed in all the cases in different eye diagrams. It is clear from the observations that the Q value is highest when we use wavelength of 1550 nm, NRZ modulation format and APD photodiode. On the other hand it is lowest when the same wavelength is used with RZ modulation format along with PIN photodiodes.

Keywords: APD; free space optics; non-return-to zero; return–to zero; PIN.

1. INTRODUCTION

Free Space Optics (FSO) is a telecommunications technology that transmits data in the form of optical signals across the air and, as such, can be considered as a wireless (line-of-sight) [1-9] transmission system; this technology is capable of handling data rates

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at the Gbps level, does not require licensing, and can be deployed at very less cost as compare to the optical fiber cable; also, the narrow beams employed in the transmission of signals are very difficult to be affected by jamming, interception or interference [9-13]. Free space optics can also be termed as optical wireless (OW). Free Space Optical communication link can be obtained using different optical sources such as Lasers and light emitting diode (LED). FSO can enable a link between transmitter and receiver placed at some distance and having data rates more than 1Gbps [1]. There should not be any obstacle between receiver and transmitter because FSO is based on line of sight [6]. FSO is very useful as it has many advantages like it does not need for licensed frequency band allocation. It is easy to install. The cost of installing the FSO system is very less [6]. Data can be transmitted at very high speed. The chances of interference are very less due to secure transmission of data it is also used in military application. The performance of FSO link depends upon number of parameters. These parameters can be internal parameter and external parameters [3-7]. Internal parameters includes lasers types, wavelength used, beam divergence etc. All the internal parameters should be kept at appropriate valves to get the desired results. There are various challenges which effect the performance of FSO in free space. First challenge is free space path loss phenomenon [5-12]. Second challenge is due to the weather conditions of different places at different time of the day and night. These conditions create problem in FSO performance and appears in dealing with scattering [5], turbulence [4] and scintillation [4,6-7]. The performance of FSO link also depends upon the link elements. There are many modulation schemes such as NRZ, RZ, CSRZ, PPM, BPSK and DQPSK. We have number of light sources like LED, VSCEL lasers, APD and PIN [14-19] laser diodes. After choosing the suitable optical light source and modulation method various wavelength can be evaluated. The suitable wavelength can be chosen from the optical transmission windows. There are three optical windows. First window consists of wavelengths from 780 nm to 850 nm. Second window is the very popular 1310 nm window and the third window is the 1550 nm window which is most widely used know a days [4,15].

There are many types of losses which degrades the FSO system. Atmospheric attenuation is one of them. When some part of the transmitted signal lost in the channel it can be considered as atmospheric attenuation. In atmospheric attenuation whole of the transmitted signal can also be lost. In this way the signal degrades and become weaker in the channel. The other reasons which degrade the signal strength are absorption, scattering, and scintillation [4-6,11]. Absorption is caused due to the presence of water particles in the form of fog, water vapors etc [5-8]. Scattering is of two types mie scattering and rayleigh scattering. Mie scattering affects the signal when the size of wavelength and water particle is comparable. In Rayleigh scattering size of the particles is smaller than the wavelength [5,7]. Scattering and absorption give worse effect in low visibility and in long distance communication [4].

1.1 Geometeric Loss

Geometric losses are those losses that occur due to the spreading of the transmitted beam between the transmitter and the receiver. Typically, the beam spreads to a size larger than the receive aperture, and this “overfill” energy is lost. In general, larger receive apertures or smaller transmit divergences result in less geometric loss for a given range. For a uniform transmit power distribution with a non obscured transmitter or receiver, geometric losses can be approximated with the following formula [15]:

$$GL(dB) = 10 * log\left\{\frac{RX\ Aper\ Dia\ (m)}{TX\ Aper\ (m) + [Range\ (km) * Div\ (mrad)]}\right\}^2 \quad (1)$$

Equation (1) can also be used to approximate the geometric losses for a Gaussian power distribution by use of the 1/*e* divergence but with slightly less accuracy because it assumes a uniform power distribution. It should also be noted that Eq. (1) is appropriate for FSO systems only and is not typically used in microwave link budgets where geometric loss is based upon assumptions for transmit beam diffraction as limited by the antenna.

1.2 System Modeling

FSO design has been developed for performance characterization and Optisystem 7.0 has been used for simulation purpose. The block diagram of FSO link used in simulation is shown in Fig. 1. In the proposed design, the complete link can divided into three parts. First is optical transmitter, then there is a FSO channel and the last is the optical receiver. In optical transmitter first block is the Pseudo-Random Binary Sequence (PRBS) generator. PRBS generator generates the sequence of ones and zeros randomly. Next block in transmitter section is the NRZ and RZ pulse generator. The output of PRBS is fed to the NRZ pulse generator. This block generates non return to zero coded signals. The third block is the directly modulated lasers measured. This laser allows us to specify different parameters such as line width, chirp, side mode, suppression and relative intensity noise. After this the signal is transmitted in the free space. This free space is called channel. It is distance between transmitter telescope and receiver telescope. The various parameters which affect the FSO link in the channel are link distance, attenuation, geometric losses, transmitter loss, receiver loss, beam divergence, additional losses etc. The optical receiver consists of an avalanche photodiode (APD) and PIN photodiodes. The receiver is used to regenerate electrical signal. Optical receiver consists of a photodiode, a low pass filter and a 3R regenerator. The regenerated signal is fed to BER analyzer. This analyzer is used to calculate the bit error rate (BER) and displays the Q factor and eye diagrams of the signal.

2. RESULTS AND DISCUSSION

In this proposed system, the performance of free space optical link has been evaluated on the basis of different modulation format, different types of photodiodes and different wavelengths. The simulation link on optisystem 7.0 has been made for different modulation formats such as RZ, and NRZ. A comparison has been performed between two photodiodes such as avalanche photodiodes (APD) and PIN photodiodes. Another comparison between two wavelengths 1550 nm and 1310 nm has been performed. Various parameter used in this simulation for FSO link are: Link length 8500 m, Data rate 5 Gbps, transmitter Wavelength 1550 nm, transmitter aperture diameter 5 cm, transmitted power 7 dBm, receiver aperture area 17cm, Divergence angle 0.3 mrad, Geometrical loss 23.69 dB, and additional losses 1 dB and attenuation 4 dB/km. These parameters are kept constant for both NRZ and RZ coding and for both the photodiodes and also for two different wavelengths. Fig. 2 shows the eye diagram of a system having wavelength 1550 nm. The modulation format used in this system NRZ and APD photodiode is used to detect the optical signal. From the eye diagram it is clear that the Q factor in this design is 43.43. The Q factor in this system is highest among the other system discussed in this paper. Fig. 3 is the eye diagram of a system having wavelength 1550 nm. The modulation format used in this system NRZ and PIN photodiode is used to detect the optical signal. From the eye diagram it is clear that the Q factor in this design is 16.57. The Q factor has been decreased from 43.43 to 16.57. This decrease in Q factor is due to the use of PIN photodiode.

Fig. 4 is the eye diagram of a system having wavelength 1550 nm. The modulation format used in this system RZ and APD photodiode is used to detect the optical signal. From the eye diagram it is clear that the Q factor in this design is 35.82. Q factor in this system is less than Q factor of NRZ modulated using APD photodiode but higher than the second system discussed above in this paper.

Fig. 5 is the eye diagram of a system having wavelength 1550 nm. The modulation format used in this system RZ and PIN photodiode is used to detect the optical signal. From the eye diagram it is clear that the Q factor in this design is 13.34. Q factor in this system is less than Q factor of other systems discussed above in this paper.

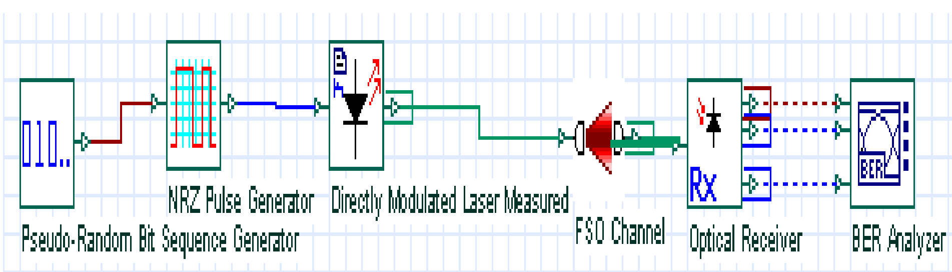

Fig. 1. Block diagram of FSO link design

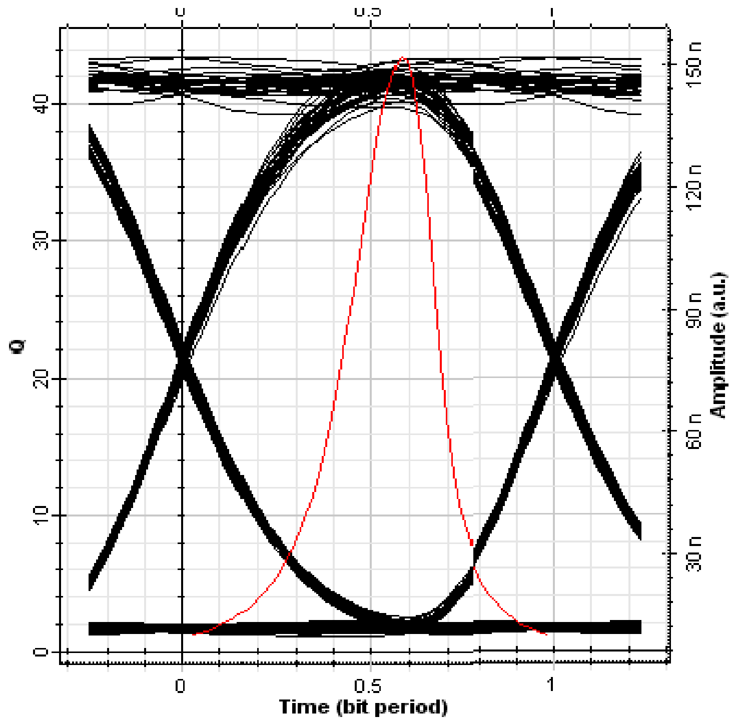

Fig. 2. Eye diagram NRZ modulated using APD photodiode used system

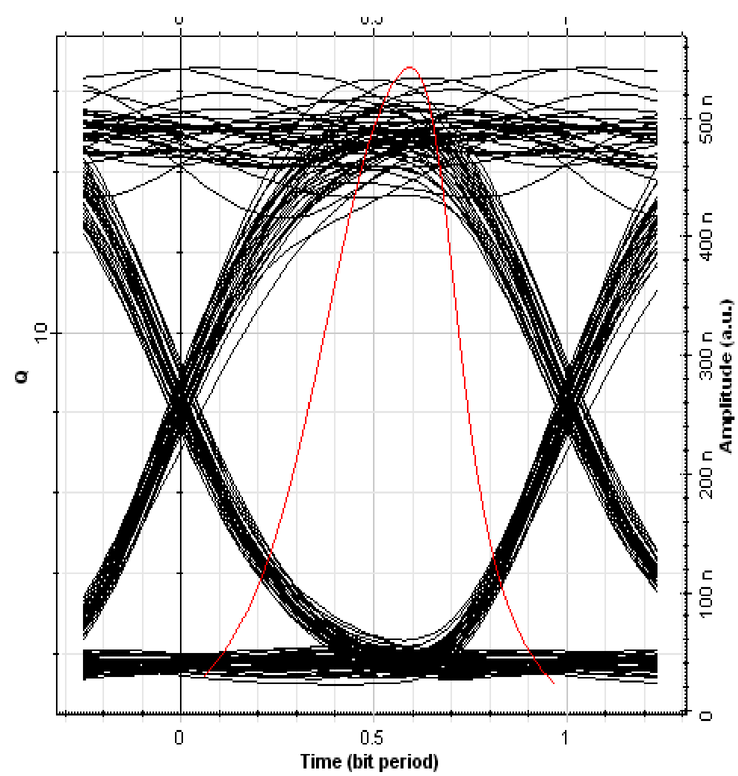

Fig. 3. Eye diagram NRZ modulated using PIN photodiode used system

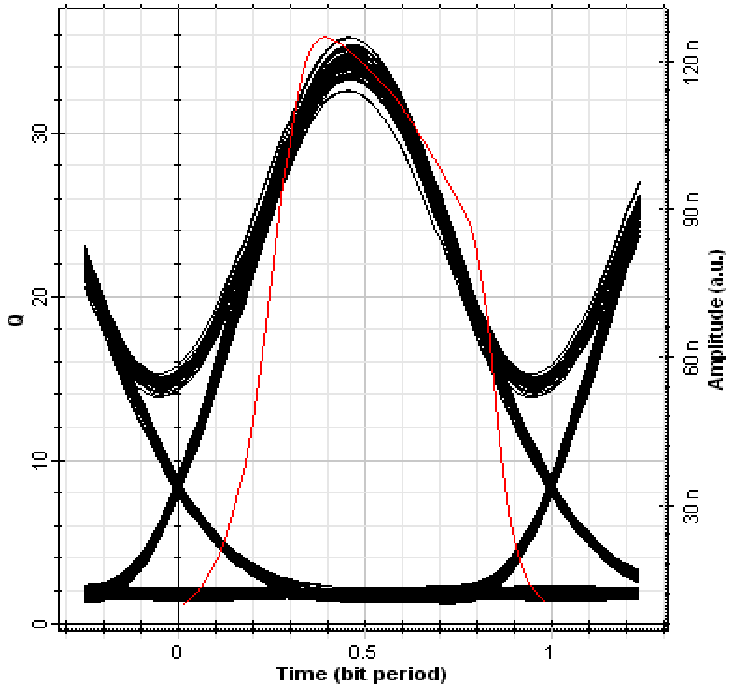

Fig. 4. Eye diagram RZ modulated using APD photodiode used system

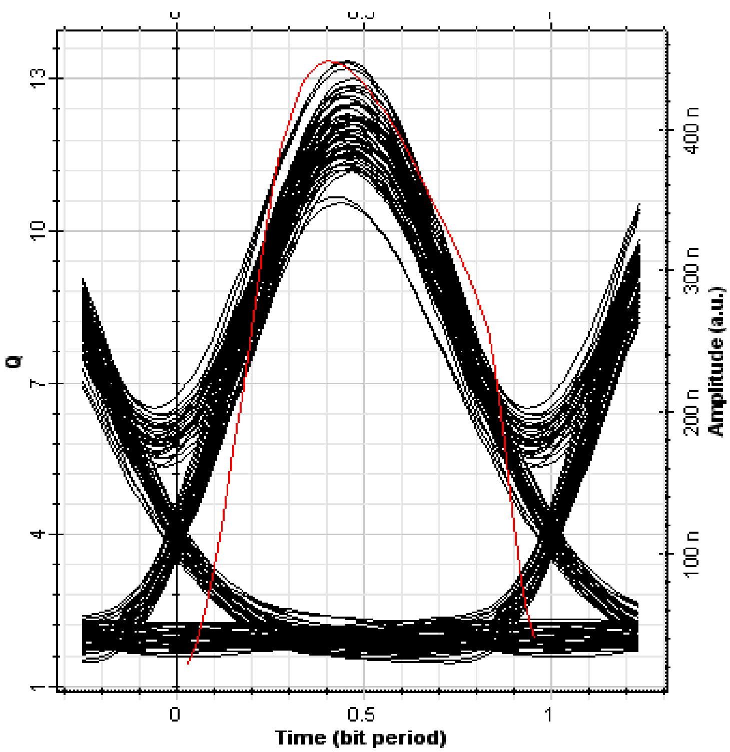

Fig. 5. Eye diagram RZ modulated using PIN photodiode used system

Now if talk about 1310 nm wavelength and keeping the other parameters unchanged Q factor is almost same as it was at 1550 nm. The eye diagrams of system designed at 1310 nm are discussed below. Figs. 6 and 7 are the eye diagram of system having wavelength 1310 nm. The modulation format used in these systems is NRZ, photodiodes APD and PIN respectively are used to detect the optical signal. From the eye diagram it is clear that the Q factors in these designs are 43.43 and 16.57 respectively. APD photodiodes give better Q factor in this case again at 1310 nm.

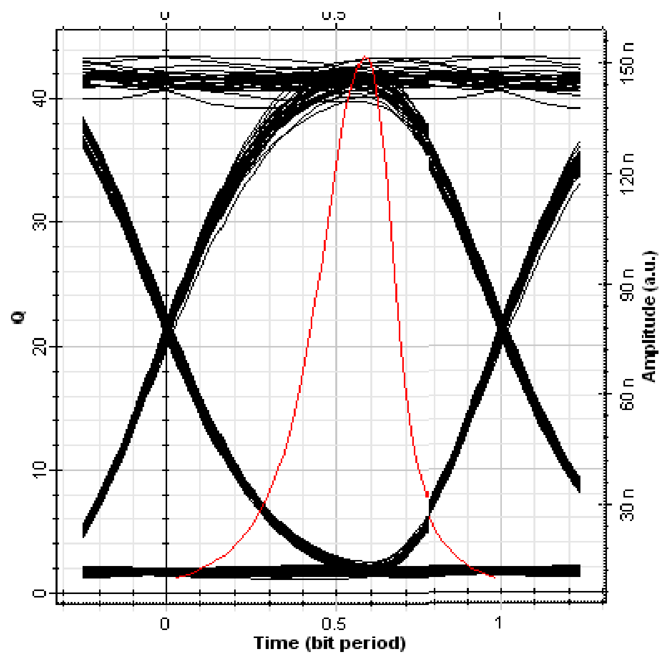

Fig. 6. Eye diagram NRZ modulated using APD photodiode used system at 1310nm

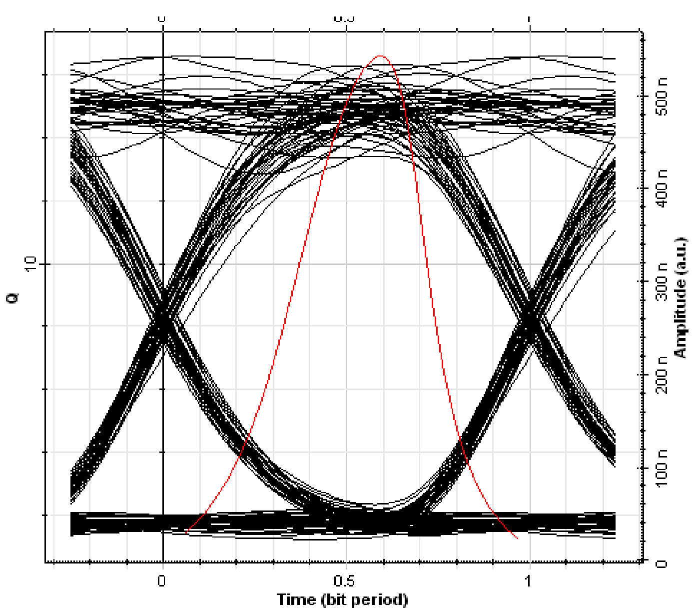

Fig. 7. Eye diagram NRZ modulated using PIN photodiode used system at 1310nm

Figs. 8 and 9 are the eye diagram of a system having wavelength 1310 nm. The modulation format used in these systems is RZ and APD and PIN photodiode are used respectively to detect the optical signal. From the eye diagram it is clear that the Q factor in these designs are 35.82 and 13.34. Q factor in Fig. 9 is less than Q factor of Fig. 8.

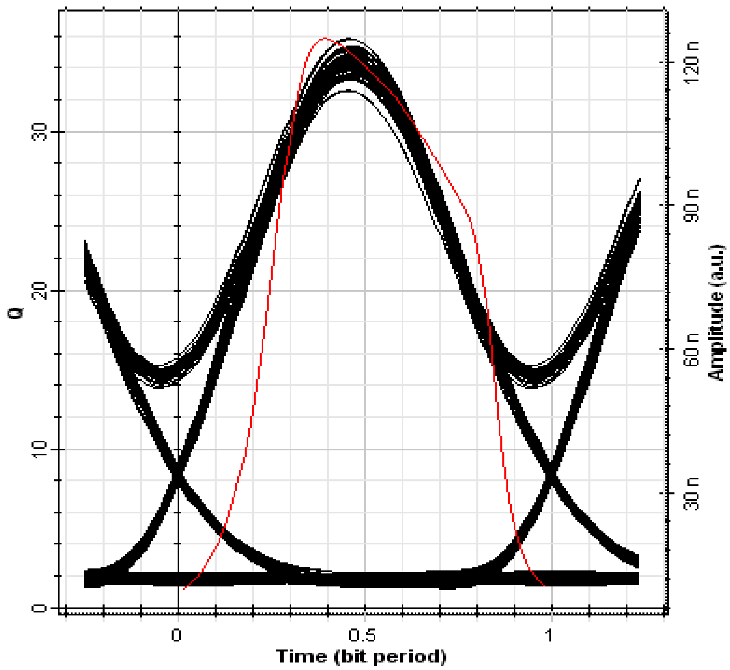

Fig. 8. Eye diagram RZ modulated using APD photodiode used system at 1310nm

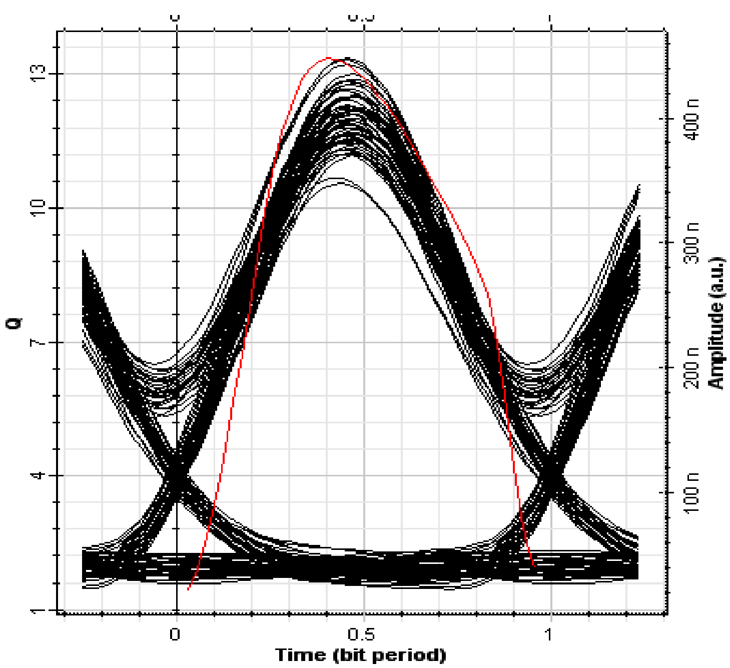

Fig. 9. Eye diagram RZ modulated using PIN photodiode used system at 1310 nm

3. CONCLUSION

This article targets the impact of different modulation formats NRZ and RZ, different photodiodes APD and PIN and two different wavelengths 1550 nm and 1310 nm. It is concluded from the above discussion that there is considerable decline in Q factor which lies within (43.43 – 16.57) and (35. 82 – 13.34) respectively. In case of two different wavelengths such as 1550 nm and 1310 nm the results of Q factor are almost same in all cases. In case of photodiodes APD gives better Q factor then PIN photodiodes. The value of Q varies between (43.43 – 35.82) in case of APD and (16.57-13.34) in case of PIN photodiode.

ACKNOWLEDGMENTS

The authors would like to express their thanks to the Department of Electronics & Communication Engineering, Amritsar College of Engineering & Technology, Amritsar, Punjab (Autonomous college, NBA, NAAC accredited) for their support and encouragement in developing the system and for carrying out this research work in the research and development lab which is being empowered by world class Sophisticated, centre of excellence hardware and software from National instruments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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