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Experimental Study of Effect of Noise and Link Distance on Infra-Red Based WBAN

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Abstract: The advent of wireless body area network (WBAN) has greatly facilitated the early prevention and instant information transfer in case of critical conditions. The WBAN presently deployed mostly utilize wireless technology based on Radio Frequency, Ultra-wide band or Microwave. Due the hazardous nature of these technologies to human tissues and organs, and overcrowdings of radio frequency spectrum; an alternative using Optical communication is proposed in this paper for WBANs. Various vital sign sensors data is collected and transmitted to a central unit i.e. an Arduino microcontroller using infra-red signaling. This paper investigates and compares the results of various photo detectors to be used as receiver and different LED drive circuits as transmitter. Various experiments are performed to observe the effect of varying link distance and white noise level. The results are compared through SNR and BER for these varying parameters. Our developed system is built by using simple, inexpensive and low power components to provide a low cost solution. The link distance is tested up to 4 feet. No external optics was used yet the experiments yielded good SNR values. The results demonstrate that the developed IR system can be used successfully for WBAN as an alternate of conventionally deployed RF based WBANsover a short range.

Keywords: LED, SNR, BER, WBAN, OWC, IR.

1. INTRODUCTION

The communication that take place in the range of wavelengths from infrared to ultraviolet (UV) frequencies are proving to be a viable alternative for Radio Frequency (RF) where bandwidth limitation, power efficiency, security loopholes, and electromagnetic interference are issues. Wireless Body Area Networks can prove to be one of the potential applications for optical communication. WBAN needs short distances and low data rate for vital sign information to be transmitted with security and reliability, perfectly provided by the OWC.

This paper analyzes the performance of optical system with least expensive and simple IR transceiver hardware designs for developing a prototype WBAN system. The data from the vital sign sensors is transmitted through IR LED connected with Arduino in the presence of sunlight, fluorescent and ambient light. Link distance and white noise levels are varied for analyzing how much the system is immune in terms of S/N and BER.

The paper is structured as follows: Section 2 reviews the work that has been done using Infra-Red signaling for short range communication. In Section 3, system design with component selection for transmitter and receivers is discussed. Section 4 discusses the experimental setup for the transceiver designs for WBAN. The parameters to analyze the system performance are enlisted in Section 5. The results are discussed in Section 6 and finally the conclusion is made in Section 7.

2. RELATED WORK

Most of the work that is done with infrared communication is for short range optical communication as discussed by Arvin *et al.* (2009) uses infrared communication to send and receive data packets for an autonomous mobile robot with obstacle detection. Borkar *et al.* (2011) compares RF communication with IR communication and investigates the suitability of IR communication for a wireless sensor network setup inside a metallic chamber. Chiarello *et al.* (2011) discusse the secure communication, through optical chaos, in an indoor wireless channel operating at 1550nm and is numerically analyzed, in presence of multipath reflections and ambient light noise. Cui *et al.* (2009) discusse potential choices for uplink and downlink optical links in terms of various parameters like path loss, light safety, background interference and device performance to exhibit the feasibility of the designed system. Elgala *et al.* (2011) review the state of art in Optical Wireless systems, supports the usage of LED as transmitters for its obvious advantages and encourages the intensity modulation with direct detection (IM/DD). It also discuss various modulation schemes that can be used for Optical Wireless Communication. Gfeller, Hirt, (1998) discusses that according to the specific requirements of the devices transmission range, data

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rates and power consumption should be optimized. Katz, *et al.* (2005) and Nohara, *et al.* (2003) highlights the importance of using optical links as a complementary technology for Short range communication and has dominant role in next generation networks. Potential applications and some research directions are also discussed in these papers. Wireless Body Area Networks are also for short Range communication within the range of 1 to 3 meters of a body. Plenty of work that has been done for WBAN comprise of using Bluetooth, ZigBee, Microwave or Ultra-wide band wireless technologies Boucouvalas, *et al.* (2015), Wu, *et al.* (2015), Movassaghi, *et al.* (2016) and Alam, Hamida, (2014). Very less amount of work is done using optical technology in WBAN in spite of its enormous potential advantages. This research aims to investigate the suitability and performance of IR transceivers for designing a prototype Optical WBAN.

3. WBAN SYSTEM DESIGN

The designed system measures and acquires galvanic skin response, temperature, airflow, ECG, pulse oximeter, Blood pressure and position of a subject using vital sign sensors. An Arduino Uno board is used as a controlling node, all the data from the sensors is gathered at this node arranged in star topology. The data from this node is transmitted through an LED drive circuit connected to pin no3 of the Arduino responsible for IR transmission. **(Fig.1)** shows different LED drive circuits which were used in experiments to enhance the link distance capability from which transistor drive circuitry performed the best.

From the several cheap photodetectors which are available in the market we have used three kinds of detectors i.e. photodiode, phototransistor and TV remote IR receiver IC for our developed IR based WBAN.

The open loop voltage across the photodiode is very low in magnitude thus a resistive biasing circuitry was incorporated due to which noise was added at the receiver. Photodiode circuit and its response are shown in **(Fig.2)**.

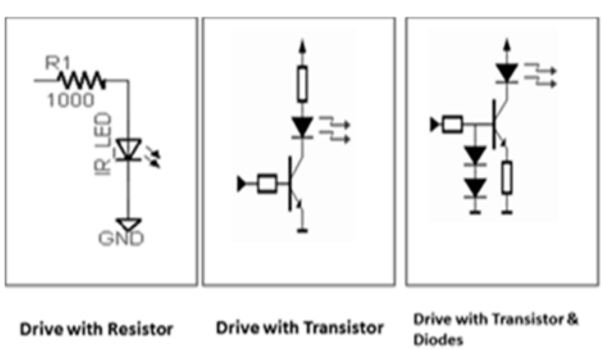


Fig. 1: LED Drive Circuits

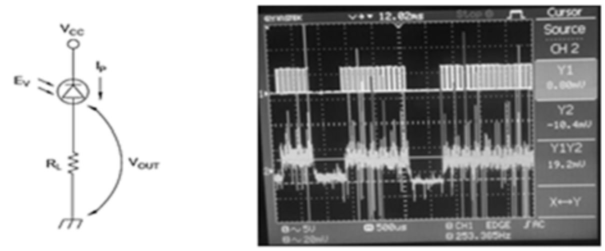


Fig. 2: (a)Photo Diode Receiver with resistive bias Circuit Vcc =+12V, RL=1KΩ (b) Photo Diode response with Resistor Biasing

To remove this added noise and improve the signal level, a photo transistor is tested with an amplifier as illustrated in **(Fig.3)**. This is our Transceiver Design1. This configuration significantly improves the received signal quality but it limits the transmission distance up to few centimeters which degrades significantly if the distance is exceeded from 5 cm.

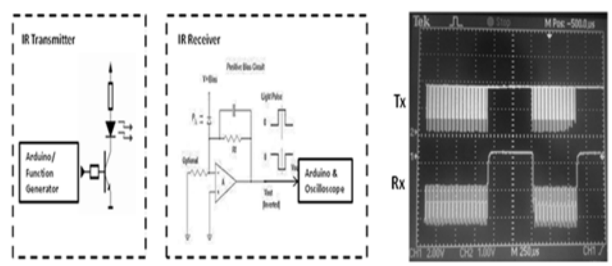


Fig. 3:Photo Transistor Receiver Design (a) Block Diagram of IR Transceiver Design #1 with Op- Amp, Rf=100KΩ,Ri=1K Ω,Optional R = 1K Ω, V+=12V, +Vcc=+12V,-Vcc=-12V,Vout=Rf/Ri (Vin) (b) Photo Transistor with OP-AMP Response for modulated output.

We have used two IR transceiver designs in this paper. The second design uses IR remote control receiver IC instead of phototransistor. The Transmitter and receiver both connected with the separate Arduinos, the transmitting side Arduino performs encoding and modulation whereas receiving side Arduino performs decoding. The transmitter sends vital sign sensors data encoded as remote control codes. The modulated IR packets are then sent through Arduino pin no 3 as shown in **(Fig.4)**.

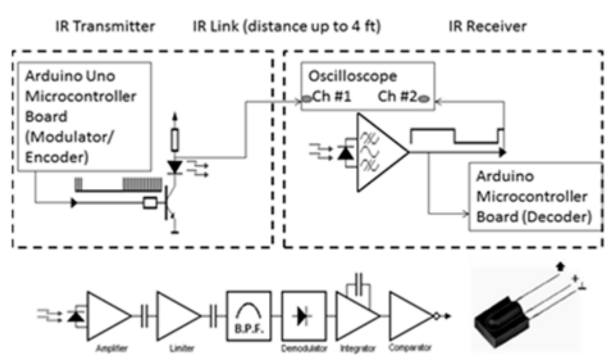


Fig. 4 : Block Diagram of IR Transceiver Design #2

There are various standard IR Remote Control Protocols based on Pulse Distance, BiPhase, Pulse Width, Pulse position Modulations etc. These protocols are developed for a range of carrier frequency from 36 Khz to 40 Khz to match with the IR Remote control Receiver IC detection frequency as described in (Bergmans, 2016) and a subset of which is supported by Arduino (Arduino-info.wikispaces.com, 2016). Any of these protocols can be utilized to make WBAN packets.

We have tested Sony SIRC Protocol and Phillips-RC5 Protocol in our experimental results. WBAN data is first encoded in developed protocol format as described by Baqai., *et al.* (2014). Then these packets are encoded using Sony or RC5 protocol using Arduino IR Remote library and transmitted. The data received by the IR remote control IC is read by pin 11 of the Arduino Mega which works as decoder. The decoded WBAN packet is then evaluated for performance analysis.

4. EXPERIMENTAL SETUP

The experimental setup is shown in **(Fig.5)**. Function generator or Arduino will generate the data which is transmitted through LED drive circuitry. The transmitted and received signals are visualized on oscilloscope. For noise effect measurements a noise signal is added from Agilent 33250A Function generator/ Arbitr ary Waveform generator with the input signal to be transmitted.

5. PERFORMANCE ANALYSIS

The IR Transceiver designs are evaluated over two parameters i.e. Distance and Noise for analyzing the performance of the system. Following formulae are utilized to calculate signal to noise ratio and bit error rate (BER).

$$SNR = \frac{Signal\ level\ (\ One\ level) in\ Volts}{Noise\ level\ (\ Zero\ level) in\ Volts} \quad (1)$$

$$SNR(dB) = 20\log(SNR) \quad (2)$$

$$BER = Q\left(\sqrt{SNR}\right) \quad (3)$$

$$Q = erfc\left(\frac{SNR}{\sqrt{2}}\right) \quad (4)$$

6. RESULTS AND DISCUSSION

The performance of both the Transceiver designs is evaluated by using eye diagrams over the two parameters i.e. Distance and Noise

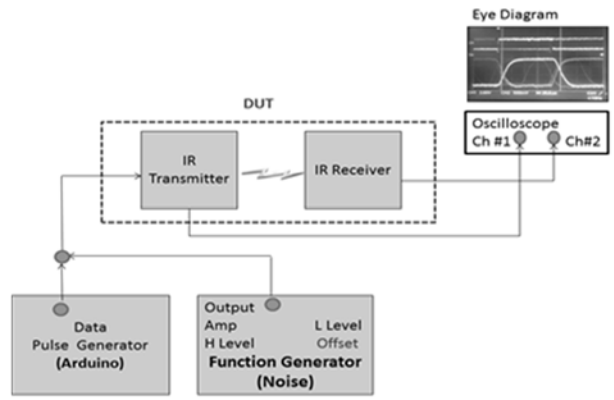
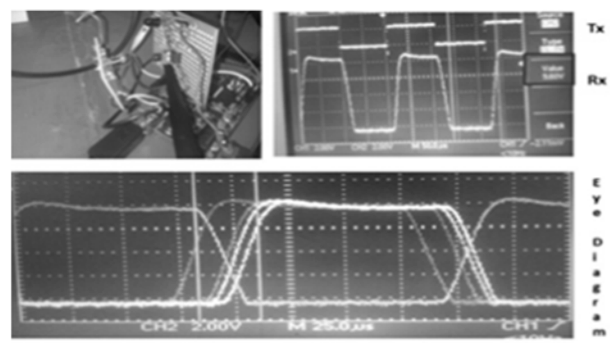


Fig. 5 : Test Set-up for Noise Effect Measurements

6.1 Transceiver Design 1 Distance effect readings

(Fig.6). shows the effect of varying link distance for IR transceiver design1 with the help of received waveforms and corresponding eye diagrams which clearly shows the degradation of the signal with increased distance.



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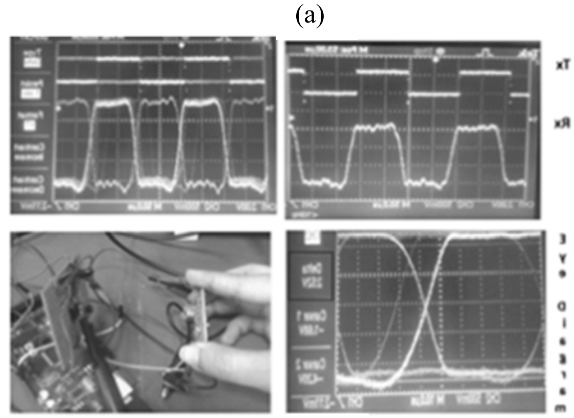
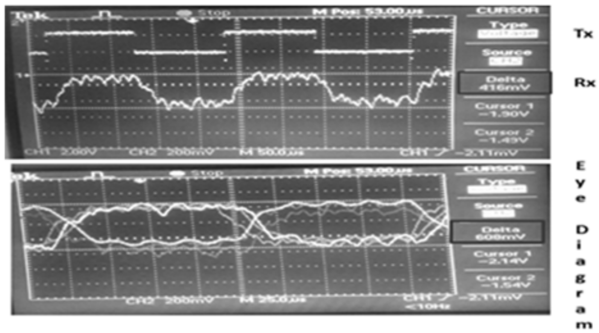
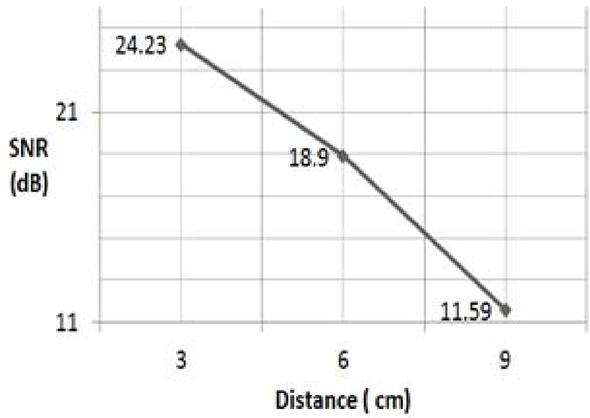


(b)



(c)



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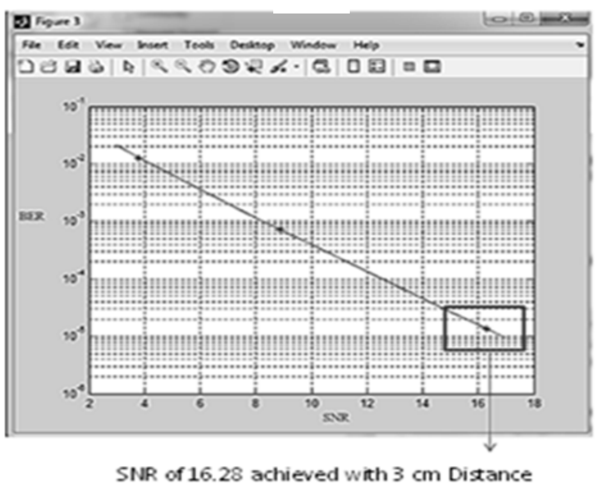
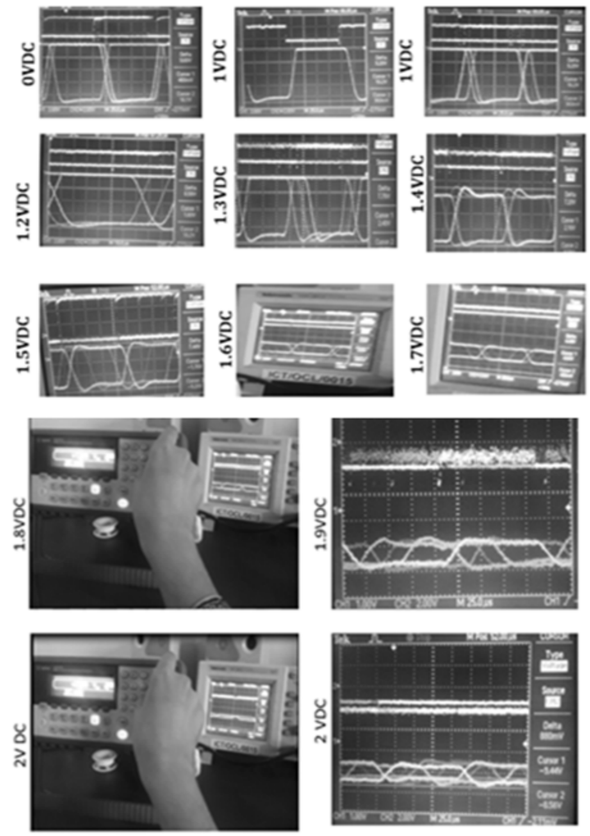


(e)

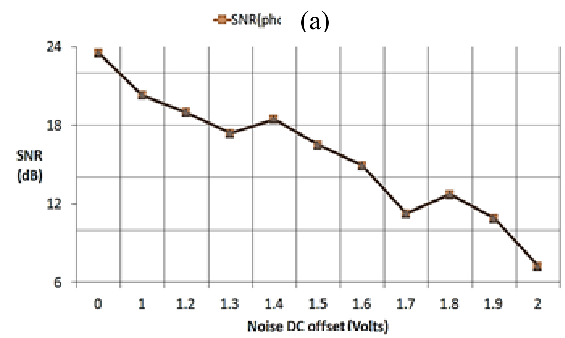
Fig. 6: Photo Transistor Response (a) Tx-Rx 3cm (b) Tx-Rx 6cm (c) Tx-Rx 9cm (d) Effect of increasing Distance on SNR (e) Matlab Simulation for SNR vs BER with varying distance for Transceiver Design1

6.2 Transceiver Design 1 Noise effect readings

White noise is added with the input in Transceiver design 1 but keeping the distance constant to 3cm at which SNR was best achieved in order to observe noise effect. **(Fig.7)**. illustrates the effects of signal degradation, noisy reception and reduction in eye opening with the increase of DC Noise offset from 0V to 2V.



(a)



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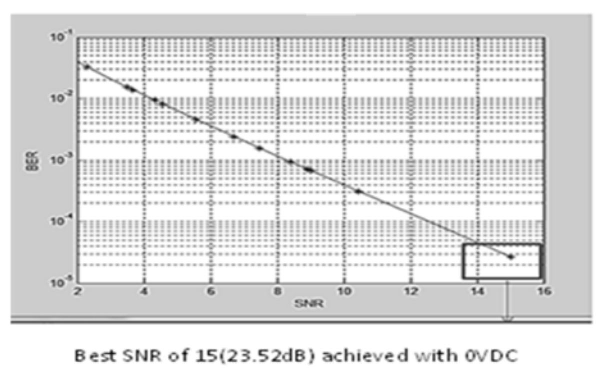


(c)

Fig. 7: (a) Results with adding Noise offset from 0V to 2V (b)Effect of increasing Noise DC offset on SNR (c) Matlab Simulation for SNR vs BER with DC offset Noise Value for Transceiver Design1

The Transceiver design 2 is tested by varying link distance from 1 ft to 4ft and DC Noise offset value from 0V to 2V in a well illuminated room as shown in **(Fig.8)**.**(Fig.9)** show that the distance does not play significant role in corrupting the WBAN vital sign data up to 4 feet. Also the IR Remote Control Receiver IC built in circuitry helps to provide pretty stable and high SNR value.

6.3 Transceiver Design 2 Noise effect readings

It is observed that after a particular DC offset threshold value corruption is started in the received data which is found to be 1.3V in Sony protocol and 1.7 in case of RC5 protocol. **(Fig.10)**illustrates this corruption for both protocols i.e RC5 and Sony.

Fig. 8: Experimental setup for Transceiver Design2 (Link distance up to 4 feet)

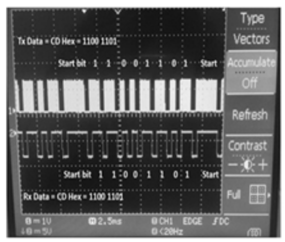
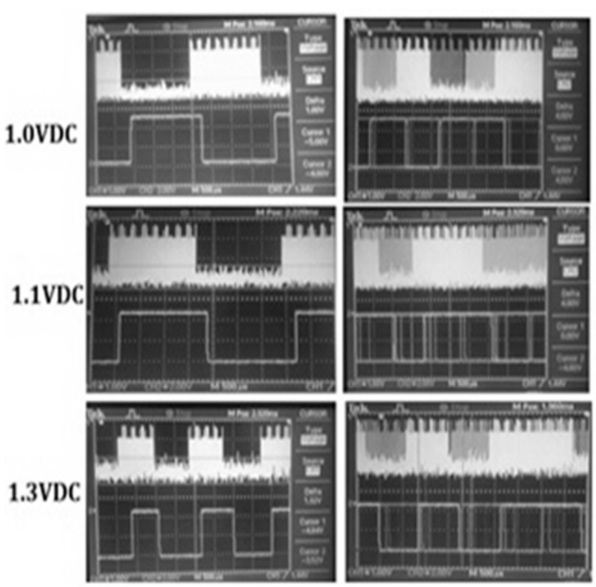
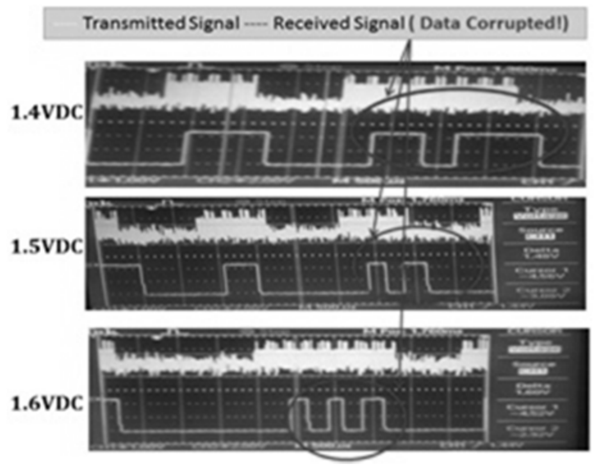


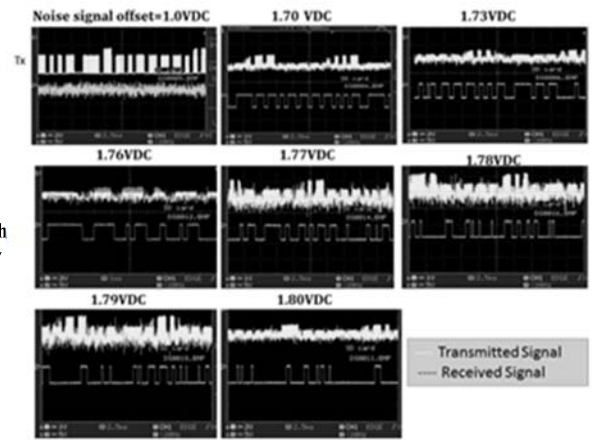
Fig. 9: Experimental Results with Receiver upto 4 feet apart (Sony Protocol)

Since the addition of DC offset noise does not affect the SNR much so SNR based calculation for BER gives incorrect results hence BER is calculated by comparing transmitted versus received bits. **(Fig.11)** indicates that DC Noise offset below 1.75 V DC threshold value produces BER of 0 to 1 %.

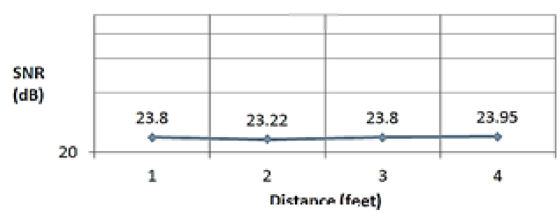




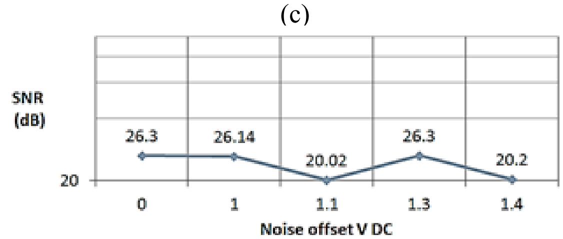
(a)



(b)



(c)



(d)

Fig. 10: Experimental Results for Effect of adding Noise offset in Transceiver Design#2(a) Sony Protocol (b) RC-5 protocol (c) Effect of increasing Distance on SNR (d) Effect of increasing Noise DC offset on SNR

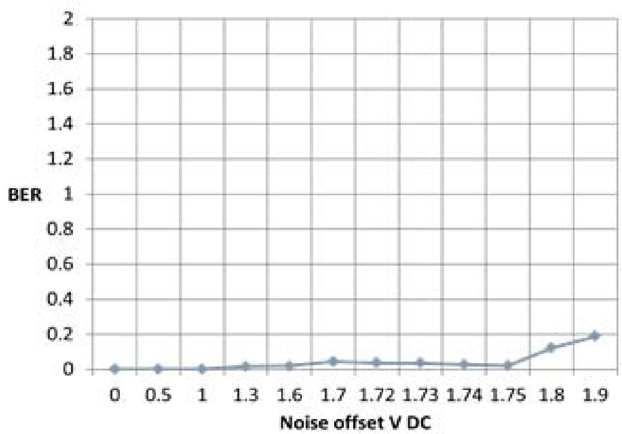


Fig. 11: BER curve with noise offset in Transceiver Design 2

7. CONCLUSION

In this paper the feasibility of cheap transceiver designs for WBAN is presented using optical signaling techniques. The experimental results reveal that the IR remote control receiver IC is quite suitable for vital sign data packets reception in context of distance range and its tolerable DC Noise offset threshold. The noise generated from the other sources of light are in acceptable range for our transceivers to be functional which results in a good maintained SNR.

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