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Real-time Wireless Healthcare system for Angular Transmission of EEG signal using VL-OCC

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Abstract

Examining the brain activity has immense scope in diagnosing specific diseases such as epilepsy and comma. The electrical activity of the brain read from the scalp is known as Electroencephalography (EEG). The traditional EEG systems deploy RF protocols suffering from electromagnetic interference (EMI) which might have harmful effect on health of patient especially in RF restricted zones such as hospitals, hence VLC is preferred due to free from EMI, reliability and enhanced security. Also, the advancement in technology in smartphones and cameras have led to the use of camera or smartphone as receiver in VLC systems rather than using photodiode as receiver unlike traditional VLC systems. Hence, this paper proposes a new novel technique and the system reliability for angular transmission of biomedical EEG data VL-OCC system at data rate of 2kbpswith 30 fps camera frame rate deploying modulation namely, On-Off Keying Non- Return to Zero (OOK_NRZ).

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Keywords: Visible light Communication (VLC); Radio Frequency (RF);Optical camera communication (OCC);Organic light emitting diode (OLED); Electroengephalography (EEG)

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1. Introduction

Epilepsy is the most prevalent brain disorder and in 2015, in UK there were 0.6 million cases of epilepsy and about 60 million worldwide out of which 75% cases have been reported in developing countries [1,2].People with epilepsy have high risks of personal injury, such as premature and sudden unexpected death, and the impact of epilepsy extends to unemployment, depression and anxiety [3]. Monitoring the human brain has great potential in helping us to understand how it functions and ultimately be able detect early signs of disease and thus prevent mental disorders

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and cognitive decline [4]. Electroencephalography (EEG), discovered by Hans Berger (1873–1941), is widely used in the healthcare in analysing the brain activity through the scalp using electrodes in order to diagnose several diseases such as epilepsy, brain death etc; thus, examining the brain disease [5].Evolution in the radio frequency (RF) based wireless technology has not only minimized the requirement of wired EEG solutions but has also moved to the current wireless EEG devices, which are more adjustable and flexible to patients and the medical staff [6].

The authors in [7] reported that in dissimilarity to the traditional EEG monitoring where wet electrodes were used, current wireless EEG devices or systems make use of dry electrodes, however hair affects the immediate connection between scalp and the electrodes, thus ensuring in an obtrusive path in measuring EEG signals. Predominantly, the conventional silver/silver chloride electrodes with conductive gels were used to record EEG, however due to long-term monitoring the conductive gel dries and thus affecting the recording of EEG [8].Yan-Jun Huang et al [9] proposed an active comb shaped dry electrode to separate the layer of hair to minimize the attenuation of the signal and phase shift, however the device was designed only for brain computer applications [9]. Yi-Hsin et al [10] used metal pogo probes in the design of dry sensors which could be used for EEG monitoring. However, even with high precision and quality the dry sensors produced discomfort. Valentin Goverdovsky et al [11] used in-ear sensors, which provided a low input impedance and immunity to several motion artifacts. Even with their ability to measure several responses, the device failed to provide comprehensive study of the human brain [11].

Healthcare Wireless systems should be light weight thus offering intelligent communication system ideal for both patients and mass market [12]. Presently, the RF based wireless is the only technology used in EEG or clinical applications, which suffers from lack of the frequency spectrum and electromagnetic interference [13], which the latter also has adverse effects on patient's health and the medical equipment especially in RF restricted zones like ICUs. It is well known that RF signal do suffer from multipath induced fading and distortions, which might affect the system performance and the extensive usage of mobiles and electronic devices in RF restricted areas such as ICU might have abnormal have harmful effect on brain signals too[14]. In healthcare applications, due to shortcomings of RF, VLC technology is optimum solution as it is free from electromagnetic interference, eco-friendly, highly secure and reliable [15,16]. Such a green technology could be used for patient monitoring, patient's data collection and transmission within hospitals as well as at home, and other places without using RF based technologies.

Optical camera communication (OCC) has gain interest due to popularity of smartphones with embedded cameras where data is transmitted in the form of binary bits through a screen and is captured by camera through video followed by image processing in MATLAB [17,18]. Furthermore, EEG recording from scalp electrodes is done from electrodes situated at different angles and distances on the scalp for the comprehensive study of the brain, Optical Camera Communication (OCC) is the recent development of VLC and an extension of VLC IEEE standard 802.15.7, first proposed due to advances in imaging [18,19]. The rise in smart devices usage and improvement in technology over the last decade opens a possibility of Visible Light Optical Camera Communication (VL-OCC) without any need of hardware modifications [19,20].

Hence, this research work experimentally demonstrates the real -time system for wireless angular transmission of EEG signals based on OOK-NRZ modulation using VL-OCC deploying OLED screen as transmitter and camera as receiver, thus illustrating the BER performance at different angles at several distances achieving the data rate of 2kbps with camera frame rate of 30fps. The remaining paper is set as; Section 2 describes the proposed system model of VL-OCC for EEG. Section 3 experimental set up and hardware description. Section 4 lists the results and discussions and the Section 5 concludes the paper.

2. Proposed VL-OCC System model for EEG

EEG Lab toolbox [21] was used to obtain the EEG signals shown in Fig. 1 and 2 using MATLAB and thereafter the signal processing was followed comprising of amplification as EEG signal is of low amplitude, filtering to remove the artefacts and Analogue to digital conversion of 16 bit was used to reduce the quantization error. A preamble of 400 bits comprising of all 1s was used to distinguish between the first and last frames during image processing and video capture.

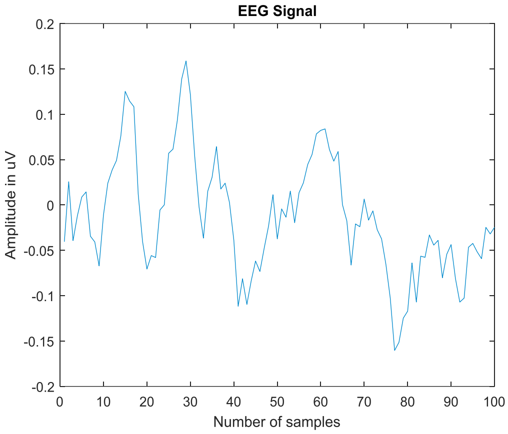

Fig.1. EEG signal captured from EEGlab using Matlab

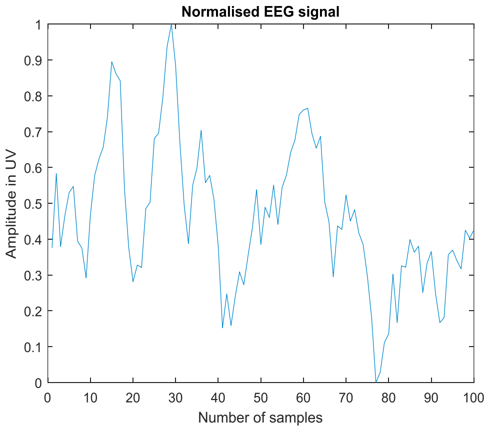

Fig.2. Normalised EEG signal

Figure 2. shows the Normalised EEG signal i.e EEG signal has values between 0 and 1. AWGN is the dominant noise, the data stream was received by a receiver unit comprising of Camera followed up by offline processing. In Figure 3, proposed system model is illustrated where b_n represents the useful data bits to be transmitted following modulation OOK-NRZ. The transmitter used is OLED (Organic light emitting diode) which is represented by rows and columns, hence information bits transmitted are in the form of rows and columns given by $N = R_1 \times C_1$.

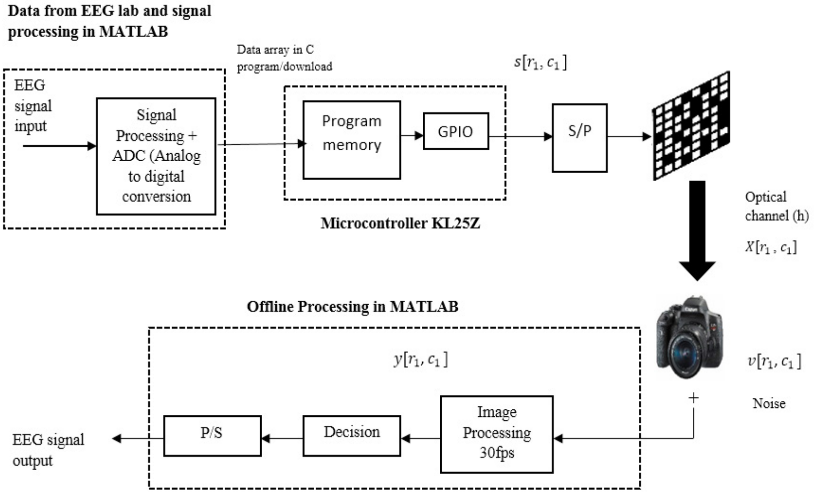

Fig. 3: Proposed System model [17]

Furthermore,$s^{(t)} = [r_1,c_1]$ is the signal obtained after serial to parallel conversion with $r_1$and $c_1$represents the spatial coordinates of the OLED screen formed by rows and columns. D represents the square pixel where consisting of information bits, where the number of data bits transmitted per frame of OLED screenthat changes with change in value of D is given by

$$(S_{z_{row}}/D) \times (S_{z_{column}}/D) = R_1 \times C_1 . \tag{1}$$

Where, $S_{z_{row}}$ and $S_{z_{column}}$is rows and columns number respectively.Thereafter, the optical channel signal becomes

$$x^{(t)}[r_1,c_1] = (s * h)^{(t)}[r_1,c_1] . \tag{2}$$

In equation (2), h represents the impulse response. The signal received is given in equation (3).

$$y^{(t)}[r_1,c_1] = (x)^{(t)}[r_1,c_1] + (v)^{(t)}[r_1,c_1] . \tag{3}$$

Representing received signal by camera which is the matrix formed by pixels. Also, $(v)^{(t)}[r_1, c_1]$ represents White

Gaussian noise (WGN) which is independent of the pixels.The video captured using camera is followed by image processing in MATLAB for BER calculation at different angles and several distances for the reliability of the proposed system.

3. Experimental setup and Hardware Description

Figure 4(a) Shows the experimental set up hardware design consisting of Microprocessor, switching board, OLED (Organic Light emitting diode) and voltage regulator. Voltage regulator LM series used to regulate the power voltage from dual power supply. The equipment used for experimental work along with model description listed below in Table 1.

Table 1. Experimental Equipment

Equipment Required	Model Description
OLED Screen	DD-160128FC
ARM processor	KL25Z
Thorlabs Camera	DCC 1645C
Coding language used	C language and MATLAB
Voltage Power	2.8V

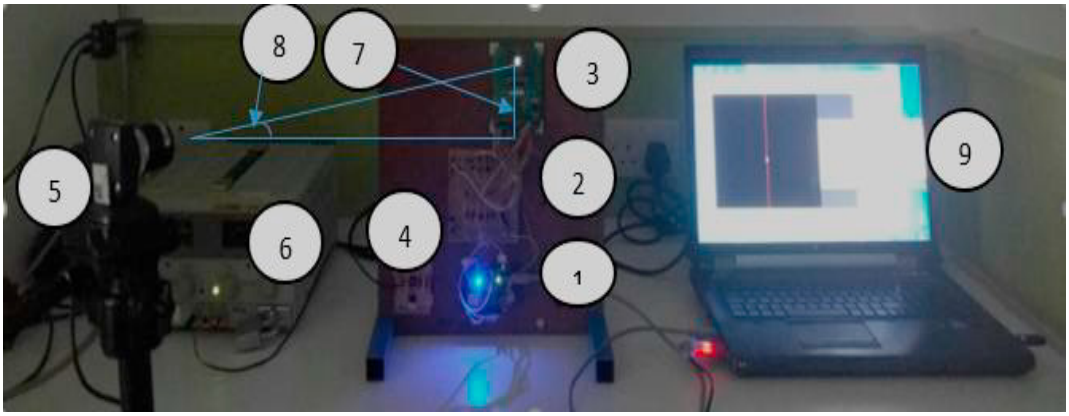

Fig.4. Experimental set up

Figure 4. shows the experimental set up where:1. Microprocessor; 2. Switching Board; 3. OLED screen; 4. Voltage Regulator; 5. Camera as Receiver; 6. Power supply; 7. Normal at 0 -degree angle; 8. Angle deviation (θ); 9. Laptop

After the signal processing of EEG signal obtained from EEGlab, the EEG signal in the form of bits uploaded to ARM processor from laptop with the help of cable USB cable wire from PC connecting the ARM processor. The OLED screen works on a voltage of 2.8 V and the ARM processor on 3.3 V, so the switching PCB board used between the OLED screen and processor, which reduces the voltage to 2.8 V from 3.3 V.

Table 2. Description of OLED screen per pixel size and transmitted bit information

S.No	Size of each block (in pixel)	Number of Rows * Columns as per size of block	Number of data bits can be transmitted per image/frame
1	32	5*4	20
2	16	10*8	80

3	8	20*16	320
4	4	40*32	1280
5	2	80*64	5120
6	1	160*128	20480

Table 2 lists the description of OLED screen per pixel size and transmitted bit data information. Depending upon the pattern of bits and the bits that single frame can transmit an OLED screen is represented as shown in Figure 5(a) and 5(b) respectively. The white section represents the transmission of ‘1’ and the black section represent the transmission of ‘0’ following the modulation scheme OOK-NRZ. At the receiver, side camera used followed by with image processing to detect the bits and to calculate the BER at different distances at different angles.

4. Results and Discussion

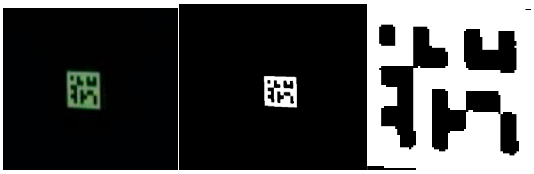

Fig. 5(a) Image Processing at an angle deviation of pixel size 16

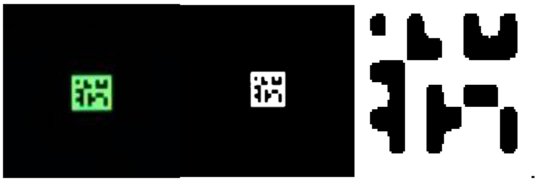

Fig. 5(b) Image Processing at an angle of 0-degree pixel size 16

At angle deviation the image received in Figure 5(a) is tilted depending upon the angle between the normal, transmitter and receiver. As shown in Figure 5(b). Larger angle deviation increases the image tilt thus resulting in an increase in BER as shown in Fig 6 at 50cm. Figure 7 shows the BER performance with distance and clearly states that with increase in distance the BER increases significantly. Thus, the BER increases significantly with increase in both distance and angle deviation respectively.

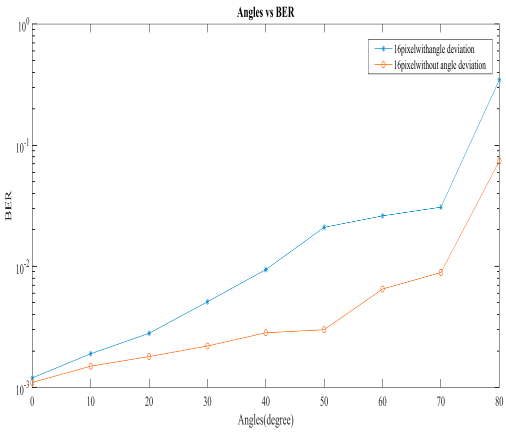

Fig. 6. Angles vs BER

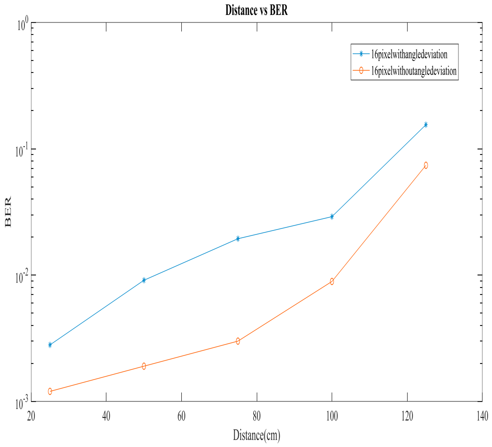

Fig. 7. Distance vs BER

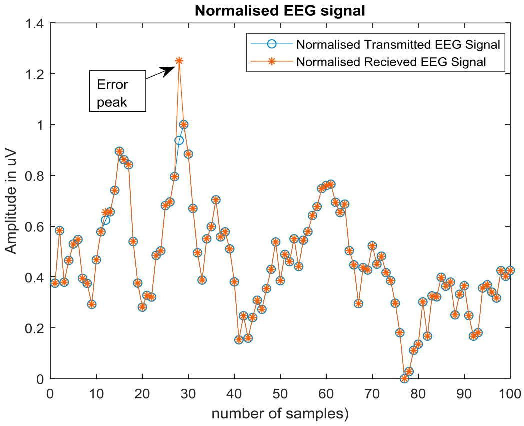

Fig. 8. Received EEG signal in Normalised form

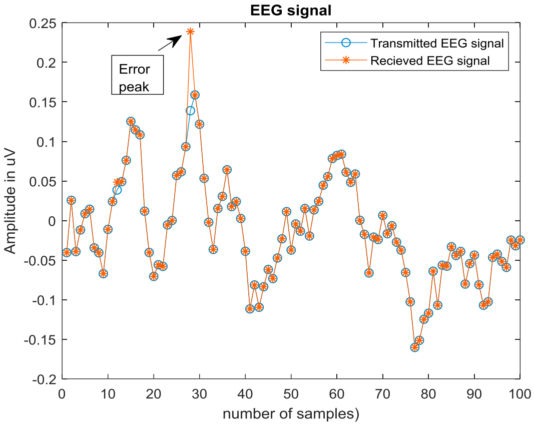

Fig. 9. Received EEG signal

The increase in distance and the higher angle deviation enhanced the BER significantly; however, during the EEG monitoring most of the electrodes placed on the scalp follow the 10-20 system [22]. Therefore, the ideal distance between two electrodes placed on scalp is of few millimetres and the maximum angle deviation range is from 0 to 30 degree [22]. As, using the VL-OCC system, the EEG signal was successfully recovered as shown in Figure 8 and Figure 9 thus implicates the reliability of the proposed system. Figure 8 shows the normalised transmitted and received signal while Figure9 shows the received and transmitted EEG signal without any normalization, henceimplicates the successful transmission of EEG signal using VL-OCC. There is one error peak which can be clearly seen in Figure 8 and Figure 9 when comparing the transmitted and received EEG signal at 50cm illustrating the BER increases significantly when angle deviation and distance between the transmitter and receiver is considerably increased.

5. Conclusion

The work in this paper suggested and experimentally proven novel technique to be deployed in hospitals for angular transmission of EEG signals using wireless VL-OCC system with achievable data rate of 2kbps using the camera frame rate of 30 fps. The BER obtained from the size of block of OLED screen in pixel size 16 irrespective of angle deviation is 10e-3 at 50 cm. thus demonstrating a successful transmission of EEG signal using VL-OCC system. The achievable data rate is enough to detect EEG signal in applications where instant recording is required from couple of seconds to few minutes to detect the brain activity. This research work could be helpful in healthcare applications especially brain monitoring as presently the brain monitoring is done though traditional wired systems which is tedious using RF based technology suffering from EMI.

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