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Power Line Based Biotelemetry System for Human Health Monitoring

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Abstract. Chronic patients have to been monitored continuously for reducing the risk in patient's life. Recent years, healthcare equipments uses the communication modules for Tele monitoring applications. Pre-established power distribution system has drawn the attention of many researchers for communication applications. In this paper, we present the application of Power Line (PL) as a communication channel for transferring the biosignals. Transducers are placed at the appropriate locations for acquiring the biosignals, which are transmitted and received using the low voltage single phase power lines. Personal Computer (PC) interfaced with the receiver unit will be displaying the decoded signals. In MATLAB, orthogonal frequency division multiplexing (OFDM) is used for transmitting the data over the simulated power line channel (SPLC) and its performance is evaluated based on Bit Error Rate (BER). From the experimental results, it was observed that EEG and ECG signals were deformed due to the PL noise and disturbances. From the simulation results, the BER can be reduced by increasing the Fast Fourier Transform (FFT) size and by varying guard time size. It can be concluded that, power lines will be an cost effective way for communication with considerable speed and accuracy.

Keywords: BER, ECG, EEG, OFDM, Power Line, SPLC.

1. Introduction

In olden days, patient's physiological parameters are measured by nurses, who manually record the parameters and later handover to the physician for analysis. Patient's safety depends on how fast the information are exchanged inside the hospital during emergency situation. Due to loss of medical reports, monitoring errors few hospitals in developed countries pay compensation to their clients. Hence automated monitoring systems are designed to reduce and avoid such problems. Heart Rate(HR), Oxygen saturation (SPO2), Blood Pressure (BP), Temperature, Electrocardiogram (ECG) and other vital parameters are monitored from the patient's and transferred using wire and / or wireless technologies. This products have some constraints like cost of installation, distance, line of sight etc.

In our paper, a physiological parameters monitoring systems using power line (PL) is proposed. BP, HR, Temperature, ECG and Electroencephalogram (EEG) were measured, transmitted and received using low voltage single phase PL inside the hospital building. A Power Line Channel (PLCh) has been simulated using the MATLAB for analysing and investigating the suitability of utilizing a low voltage single phase PL as a communication channel. PL channel is modelled based on its time-varying, frequency dependent, signal-to-noise ratio properties. Echo channel model is considered, as it offers reliable way of data transfer with minimum bit error rate (BER). The data is transmitted using the Orthogonal Frequency Division Multiplexing (OFDM) technique in the channel as it offers resistance against multipath, burst noise, frequency interference, dispersion, fading and distortion.

From the experimental and simulated results it was found that the Power Line Channel (PLCh) was a cost effective way for transferring the medical data inside a hospital building. Data was transferred at a considerable speed and accuracy. The error rate was less in the simulation results when compared with the

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practical results. In comparison with other technologies like zigbee, LAN, bluetooth the establishment cost, visible range problem and power consumption of this prototype was much less.

2. Physiological Parameters

ECG is a measure of electrical activity of the heart and it reflects the various heart conditions. Electrical impulse begins at the Sinoatrial node (SA) situated at the top of right atrium which causes the atria to contract. These impulses pass through the atrioventricular (AV) node and muscle fibres causing ventricular contraction. These continuous contraction and relaxation of the atrium and ventricular chambers produces ECG signal. Any deviation from the normal ECG pattern is probably an indicative of a heart disorder [1]-[4].

Human brain is the most complicated and an interesting study for neuroscience researchers for several decades to understand its functioning patterns. Brain is the primary organ which integrates and controls the process such as thinking, balancing, face recognition, taste, smell, place recognition, emotional reactions, hearing, responding to reflexes, regulating and producing hormones [4]-[7]. Electrical potentials are generated in brain due to inhibitory and excitatory behaviour of its nerves cell bodies and dendrites of pyramidal neurons. Measurement of brain’s electrical activity is termed as Electroencephalogram (EEG). Electrodes are placed on the scalp to record the brain signals which can be used to diagnose health disorder such as epilepsy, disturbances in sleeping, Parkinson's disease.

Blood consists of many components like water, red blood cell, white blood cells, haemoglobin, hormones and minerals. Haemoglobin is made up of protein consisting of iron molecules and responsible for oxygen binding and release. Haemoglobin allows wavelengths in the range of 660nm (red) - 910nm (infrared) to pass them and based on the light absorption coefficients HR is calculated. Pulse Oximetry (PO) technique is adapted to measure HR non-invasively. It is based on the Beer-Lambert's law which states that “when any incident light is passed through a uniform medium, a part of the light is absorbed by medium and the rest is transmitted through the medium” [7], [8].

Thermoregulation is the process of maintaining the core body temperature by heat transfer mechanisms such as conduction, convection and radiation coupled with physiological phenomenon such as blood circulation, urine excretion, sweating and metabolic activities. Normally human body parts vary in temperature. Commonly accepted average core body temperature is $37.0^{o}C$ (98.6F). The typical oral measurement is $36.8 \pm 0.7^{o}C$ or $98.2 \pm 1.3F$.[9], [10].

Heart beats continuously and pumps blood into the arteries. Due to these pumping action, blood exerts force on the arteries walls which is termed as blood pressure. BP is measured by wrapping a cuff around the upper arm such that its lower edge is 1 inch above the elbow bend. Cuff is inflated fully and pressure is reduced gradually by opening the valve slowly. As the pressure reduces, systolic and diastolic value of the blood pressure are measured. Normal BP is in the range of 110/75 to 120/80, pre-hypertension is 120/80-140/90 and Hypertension is 140+ / 90+[11].

3. Power Line Communication

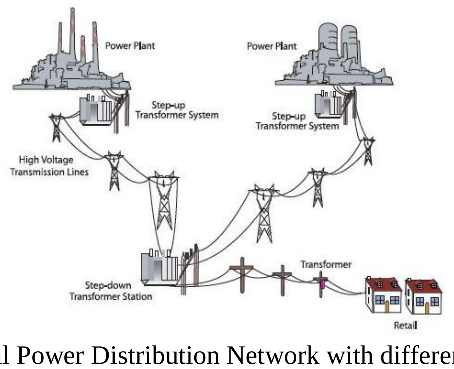


Fig. 1. Electrical Power Distribution Network with different voltage level

Power Line communication (PLC) is a technology that enables data communication using existing PL which provides electricity. Recently power line communication has been used in many applications such as Automated Meter Reading, home automation and high-speed internet service etc. Fig. 1 above clearly depicts different voltage level in the electrical power distribution network with substations. PLC is based on certain parameters such as electrical signal, information to be carried, number of nodes, electrical loads, distance etc. The quality of communication on a channel is evaluated based on the signal to noise ratio level (SNR) and the attenuation factors [12]-[15].

Power lines are designed for high energy and low frequencies signals. They were never used for high frequency and low energy signal transmission as the noise, impedance and attenuation levels are very high. Communication along a power line is affected by impedance mismatches, channel disturbance, signal aliasing, reflection, temporal and time variations. In PLM, the data is converted into a predefined sequence of signals and converts back into the data stream which is referred as modulation and demodulation [12]-[15].

When power lines are compared with other mediums such as twisted pair, coaxial or fibre optic they differ significantly in physical structure and topological properties. PL will be consisting of series of distribution cables, transformers, branching connections. In PL channel the signal will be interfered by various non-stationary noises and takes additional multipath. The following equation describes the echo channel model of PLC [12].

$$H(f) = \sum_{i=1}^{N} g_i A(f, d_i)\, e^{-j2\pi f\, T_i} \quad (1)$$

where, N - number of the path (for short delay i =1); A = Attenuation constant; T_i = delay of a path; d_i- length of path i and g_i- reflection coefficients or weighting factor for path.

PL channel is an additive noisy environment in which narrow band, coloured background, burst noise, periodic impulse, non-periodic impulse and Gaussian noise are added to the signal. Background, periodic and asynchronous impulses comes under non-Gaussian noise. Background noise overlaps with the narrowband interferences and its power spectral density decreases exponentially. Asynchronous noise consists of non-uniform impulses which are produced due to switching devices [12]-[15].

4. Description of the System

The health monitoring system using power line channel is shown in Fig. 2. Hardware consists of biosignals measuring unit, power line transmitter and receiver. Temperature, BP, HR, ECG and EEG are measured and converted into digital by using measuring and processing unit. The digitized values are modulated using Direct Sequence Spread Spectrum (DSSS) technique for transmission. DSSS provides high noise immunity and reliable data communication which is necessary for PLC. Receiver decodes the DSSS signal which are again converted back to original signal and displayed.

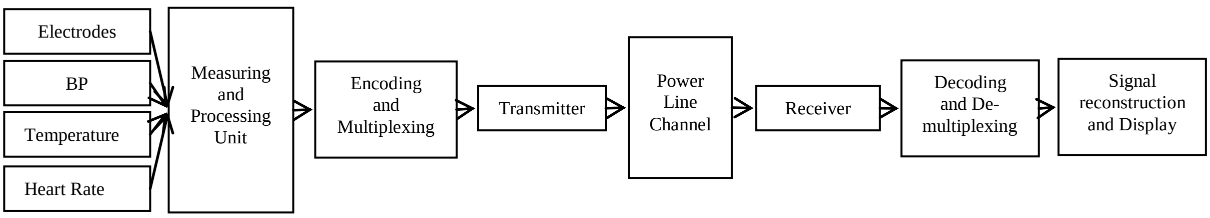
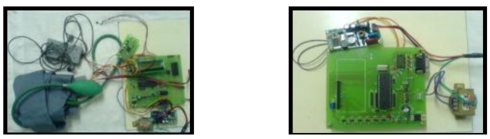


Fig. 2. Block representation of the Health Monitoring System



(a) (b)

Fig. 3. Health Monitoring System's (a) Measuring and Transmitting Module (b) Receiver Module

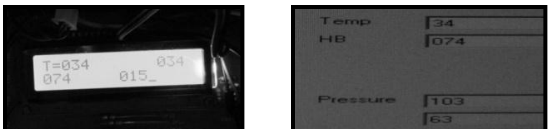
In Fig. 3a, the measuring unit with transmitter is shown. Temperature is measured using LM35 sensor. BP is converted into corresponding voltage by using a Pressure to Voltage (PV) transducer. HR is measured using the pulse oximetry method. Silver / Silver Chloride electrodes are placed on the human body and connected to instrumentation amplifiers (IA) for acquiring ECG and EEG.

Measured parameters are converted to digital signal using ADC converter and then fed to the microcontroller. These data streams are transmitted to the embedded power line modem (EPLM) using through the TXD and RXD pins of controller. EPLM is a modem has high noise immunity and can work in the of 220–250 V range. It works on the DSSS and transmits the data at the Baud rate of 300 bps. Here, single phase low voltage PL of 220V and 50Hz is used as the channel for communication. Fig. 3b shows the receiver unit which demodulate the signal and feeds the data to a personal computer (PC). Visual basic software tools are used for physiological parameters display.

The noisy characteristics of power line channel (PLCh) are simulated using the tool MATLAB. Data transmission and reception in PLCh is based on orthogonal frequency division multiplexing (OFDM). OFDM encoding is performed to reduce the inter-symbol interference (ISI) of the channel. Channels gain will be equal to the frequency response values of the Fast Fourier transform (FFT) grid. Inter-block interference (IBI) is reduced by introducing guard bits of length equal to channel order. In the receiver, guard bits are removed and FFT is followed by parallel to serial conversion. In this simulation work, HR, pressure values which are stored in the system are transmitted on the simulated channel using OFDM technology.

5. Result

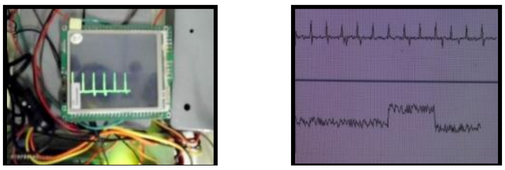
The biosignals are transmitted using embedded power line modem over the single phase power line. Heartbeat and temperature value measured at the transmitter side was as 34, 74 as shown in Fig. 4a. The circuit was designed such that it will update the values of heartbeat and temperature every 30 second; hence it shows the new updating value nearby. From the result obtained in the receiver end, it was found that physiological parameters such as HR, temperature and BP are received without any error as shown in Fig. 4b.



(a) (b)

Fig. 4. Heart beat and temperature value at the transmitter and receiver end

Fig. 5 shows the ECG signal at the transmitter and receiver end. Form these figures; we can see the effect of channel noise on ECG signal. In the received ECG, high amplitude QRS complex are less affected by noise when compared to P-wave and T-wave of lower amplitude. EEG does not possess a fixed wave pattern like ECG. Hence, the effect of noise on it cannot be identified clearly.



(a) (b)

Fig. 5. (a)ECG signal displayed on the prototype (b) ECG displayed on the receiver end on PC

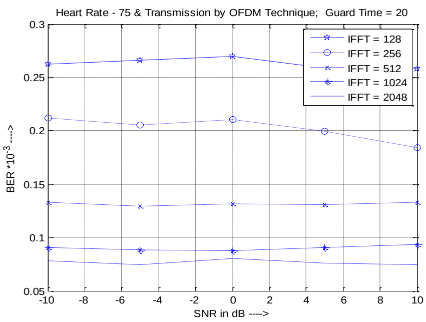


Fig. 6. SNR vs.BER for different Guard Time and IFFT Size

BER was used for evaluating the performance of OFDM method. HR was transmitted over the simulated channel with various IFFT and guard size. Fig. 6 shows the SNR vs. BER for different IFFT value with guard time. In simulation results, it was found that, the IFFT values and BER are inversely proportional. BER can be reduced, if guard time is more than 25 percentile of IFFT values. When the simulation and real time results where compared, it was found that, for non time varying signals the error rate was very much less. Whereas, the power line noise and disturbances are high in case of time varying signals.

6. Conclusion

Bio-signals were transmitted using low voltage single phase power line as a communication medium. Due to continuous time varying property of ECG and EEG signals, noise interference was more when compared with non time variant signals. Hence noise filters are required for elimination. Irrespective to the number of power outlets, power line modem used was capable of communicating up to a distance of 1 - 1000m range in a single phase power line. It can be concluded that the power line communication is a good and cost effective way for communicating biosignals with certain limitations. In future, filters will be implemented for noise reduction and more biological signals will be transmitted with less noise and minimum error rate for longer distance.

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