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Non-obtrusive Cardiac and Neural Monitoring by Using Contactless ECG and EEG with PPG and IoT Technology

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Abstract

The upcoming wireless health revolution will be propelled by ubiquitous physiological monitoring. Electrocardiogram (ECG) and electroencephalogram (EEG) are two crucial health indicators that can only be improved with continuous monitoring over time. In this study, we propose a chest-attached, non-intrusive photoplethysmogram (PPG) measuring system for everyday use with the help Internet of Things (IoT), sensor amplifier circuits capable of adjusting the light intensity to suit clothing properties can be used without skin contact. Despite developments in wireless technology and electronics downsizing, the inconvenience and pain of wet adhesive electrodes limit the usage of wireless home ECG/EEG monitoring. In recent years, research has focused on developing non-contact ECGs and EEGs, which are wireless biopotential instrumentation systems that use non-contact capacitive electrodes that operate without skin contact. Results reveal that non-contact capacitive electrodes work similarly to electrodes made of Ag/AgCl with chest and headbands, which are presented in-depth, along with comprehensive technical information, circuit schematics, and manufacturing methods. ECG chest strap, EEG headband, or a motionless electrode location can all be used with the non-contact electrode. Future mobile health applications will benefit greatly from these IoT based wireless systems and wearable design, which is far more pleasant for patients to use than more traditional contact-based systems.

Keywords

Non-contact electroencephalogram, Electrocardiogram, Wireless health, Photoplethysmogram sensors, Ag/AgCl electrodes, Internet of things

Introduction

At any moment, patients may access their physiological status and monitor their health. Body sensor networks are a key driver of the wireless health revolution. Long-term monitoring of EEG and ECG biopotential signals, 2 critical health indicators, is possible using body sensor networks Although electrical EEG/ECG has become more widely available thanks to wireless technologies and electronic reduction, the discomfort of using traditional wet contact electrodes has kept it from being widely used [1-3].

Due to the discomfort and irritation of clinical-grade adhesive electrodes, many people avoid using them at home. Dry electrodes, on the other hand, are becoming more and more common However, dry electrodes, like wet electrodes, make direct skin contact for the same reason. The skin's condition has a greater impact on the performance of dry electrodes, which is why they are more susceptible to motion artefacts. Technology that is easier to use and less obtrusive is needed to keep up with the progress in wireless body sensor networks.

Body sensor applications can benefit greatly from the fact that non-contact electrodes don't require any prior preparation and are completely unaffected by skin conditions. However, a patient-friendly non-contact biopotential sensor has yet to be developed, despite its existence for decades. The latest discrete low-noise amplifier designs, including some wireless ones, have been presented to the scientific community by a number of authors in recent years. For non-contact sensing, many clever and sometimes unique circuit designs have been used to keep the electrodes in place [4]. This sensor with greatly enhanced noise performance is presented in this paper as a follow-up to work previously presented. a wireless EEG/ECG system that doesn't touch the body is also described in detail [5, 6].

The convergence of non-obtrusive cardiac and neural monitoring, facilitated by contactless ECG and EEG technologies along with PPG and IoT advancements, showcases a transformative application in the realm of healthcare. Nanotechnology plays a pivotal role in enhancing the precision and efficiency of these monitoring systems. Nanoscale materials, such as nanowires or nanoparticles, enhance the sensitivity and specificity of these sensors, enabling the detection of subtle physiological changes. Moreover, these nanomaterials contribute to the miniaturization of devices, ensuring a compact and wearable form factor. The seamless integration of nanotechnology into these systems marks a significant advancement in personalized and preventive healthcare, fostering a new era of precision monitoring and timely interventions.

Background on PPG

PPG is an electro-optical signal that measures pulsations associated with changes in blood volume without the need for invasive treatment. Initially, Penaz introduced the method. First suggested by Marey (1876) and subsequently described by Shirer, the unloading approach provides the foundation for the continuous monitoring of blood pressure waveforms (1962). Unconstrained biological signal measurements are becoming increasingly popular as people become more concerned about their health. Free measurements can only be performed with sensors in direct contact with the user's skin when using "fixed-on environment" electrodes. Electrodes "fixed-on-the-environment" are not as widely used as they might be because individuals often cover up much of their skin while they go about their everyday lives. For this type of sensory system to be used in the real world, the ability to detect biological signals while wearing clothing is essential. Despite recent advances through clothing. That's why our PPG measurements were based on this idea. Measuring the signal from the body through clothing [7, 8].

Plythysmographs are devices that track changes in fluid pressure. For absolute changes in blood volume in the limbs, chamber-plethysmography is the only method that is reliable. Blood flow can be calculated using the formula F = dV/dt. But in some cases, such as monitoring the heartbeat, we only care about the relative volume. Rather than in signal amplitude or shape, the timing is where the information resides in this case. Photoplethysmography or electric impedance plethysmography may be used in this situation if necessary (PPG) [9-11]. Figure 1 presents block diagram on non-contact EEG, ECG and GPRS to doctor.

Methodology

According to the Beer–Lambert law equation of spectroscopy, light travelling through a medium with an absorb material is reduced exponentially in intensity as the absorption coefficient and optical path length increase. Light passes through a variety of media in conventional PPG measurements, including skin pigmentation, bone structure, and venous and arterial blood. Because cloth might be seen as an additional layer of light-absorbing media, a weaker output signal will be received through cloth than through a traditional PPG measurement. To generate an adequate PPG signal, it is also important to employ a high-intensity light source and a sensor that can vary depending on the kind of cloth, as different cloth types have varying absorptive qualities and optical path lengths. Please refer to figure 2 and figure 3.

System design

A high-level diagram of the wireless, non-contact EEG/ECG system is shown in figure 4 and figure 5. In the system,

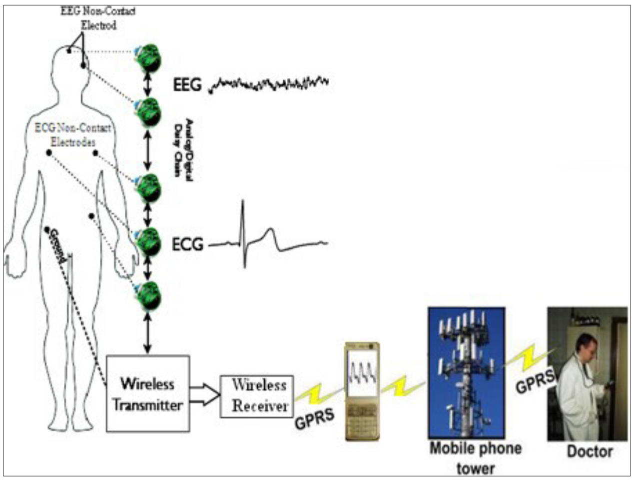

Figure 1: Block diagram on non-contact EEG, ECG, and GPRS to doctor.

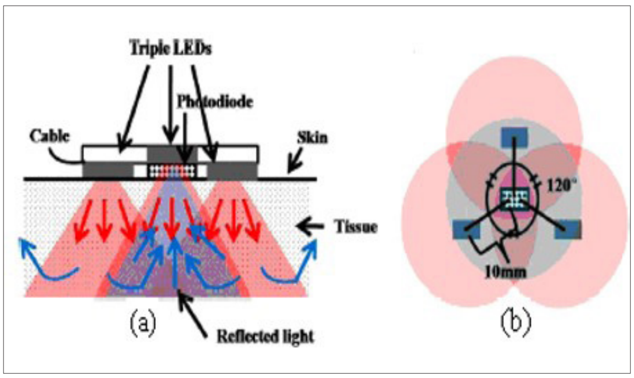

Figure 2: Three light sources are shown in figure as conceptual representations of the proposed PPG sensor. **(a)** This is a view from the front and **(b)** View from the side.

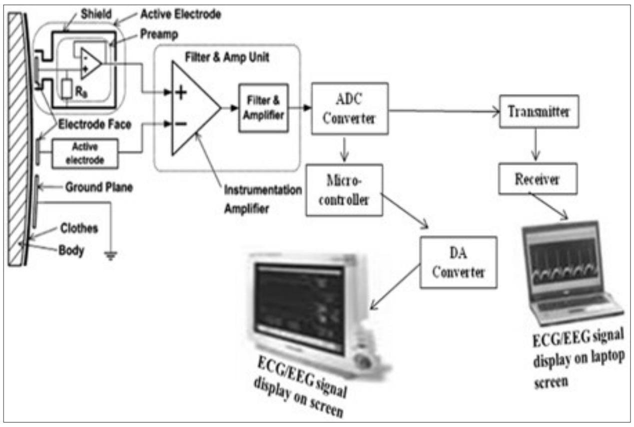

Figure 3: Block diagram of the indirect contact ECG measurement.

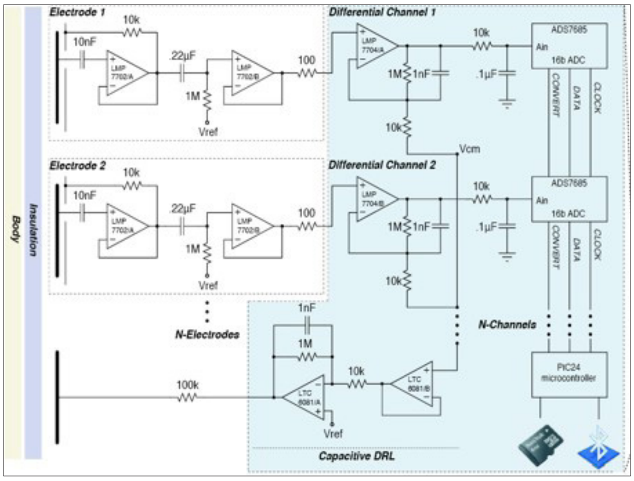

Figure 4: Detailed diagram illustrating the non-contact electrode's frontend, differential amplifier, and 16-bit ADC.

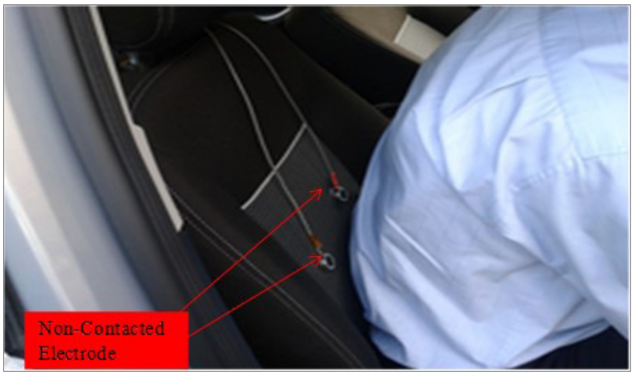

Figure 5: Non-contact electrode connects to chair.

non-contact biopotential electrodes are connected by a single common wire. Sensors can be worn on the skin or incorporated into clothing and other materials. The system transfers data wirelessly to a computer or any other external device and is powered by a tiny base unit. A single sticky or dry contact sensor is placed anywhere near the base unit to serve as the system's ground reference. Each electrode is made up of two quarter-sized PCBs [12]. The upper PCB houses the low noise differential amplifier and the 16-bit ADC. Because the electrode produces a digital value rather than an analogue signal, it can be utilized in a serial daisy chain, drastically reducing the number of wires needed. Power, digital control, and analogue common mode are all carried through a 10-wire ribbon cable that runs from electrode to electrode.

Observation data

The wireless system was utilized to demonstrate the non-contact electrodes' higher signal quality. A spectrogram and time-domain plot of an EEG recording with two electrodes in the FzA1 areas can be shown in figure 5. During the first half of the recording, the subject's eyes are open, and eye blinks are clearly visible. When the subject's eyes are closed, there is a considerable rise in alpha activity. Figure 6 illustrates the EEG signal and alpha waves in greater detail.

The EEG signal and alpha waves should be examined. The electrodes' performance in cardiac applications was also tested in a series of experiments. As depicted in figure 7, the best-case performance can be achieved by pressing an electrode directly against the body. It is apparent to see the PQRST complex, and the trace is equivalent in quality to that generated from a conventional clinical adhesive ECG electrode.

Insulation such as fabric and clothing can be passed through non-contact electrodes, as was previously mentioned. As can be seen in figure 8, two different types of t-shirts and sweater were used to obtain ECG data. In most cases, the transmission of signals is unaffected by very thin insulating

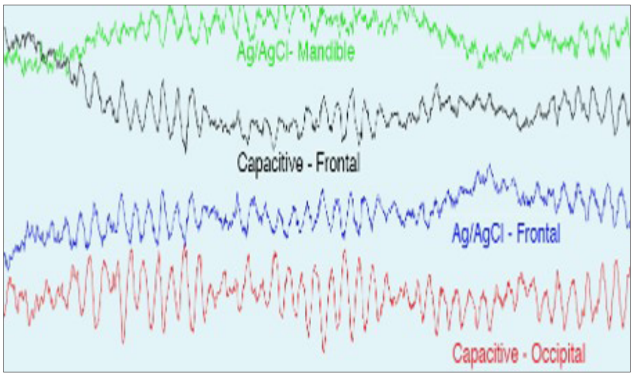

Figure 6: EEG trace close-up showing beginning of alpha waves after subject had closed his eyes.

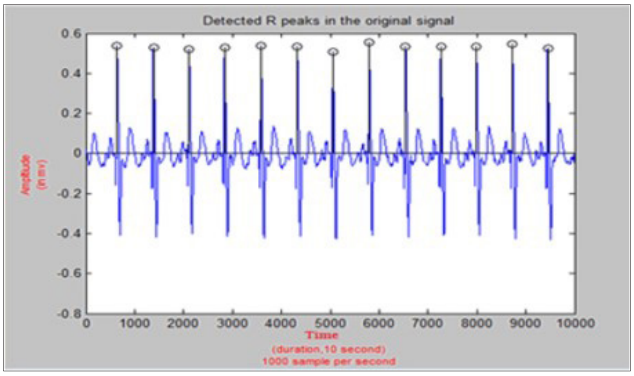

Figure 7: An example of a high-resolution ECG tracing recorded from electrodes placed directly on the skin above the chest. The whole PQRST wave sequence is visible, and the signal is comparable to that obtained with sticky contact sensors.

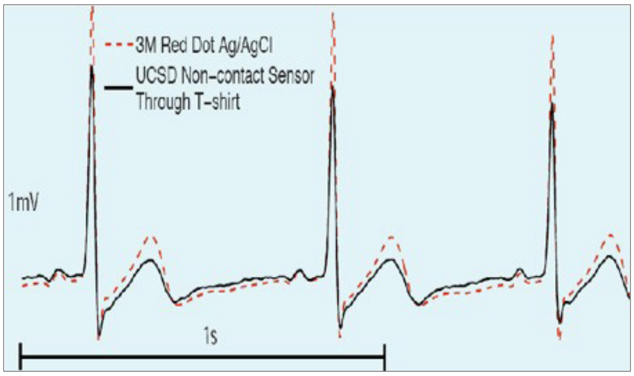

Figure 8: A thin t-shirt and a heavier cotton sweater were used to record ECG data on the chest.

layers. The P-wave is hidden by noise, but the signal quality is still good enough to pick up heartbeats even though the insulation is thicker.

Results and Discussion

The PPG signal, in contrast to electrical signals like an ECG, is site-dependent in terms of upstroke time, amplitude, and form. Allen and Murray, on the other hand, claim that bilateral PPG signals are significantly linked. According to our findings, PPG signals collected from the back and thighs using the recommended PPG measurement technique showed different characteristics but remained closely linked to those of reference signals obtained from the other side of the body while wearing just undergarments. In the analysis, the rms error was very low, and the correlation value was really high. Also, the PPG signal showed that our method had a baseline that changed with the heartbeat and breathing.

PPGs are extensively employed in healthcare settings because of their capacity to monitor a wide range of physiological indicators. There is a problem with the present PPG monitoring systems in that they do not fully conform to the notion of unrestricted monitoring since the user must actively place the skin site to be measured on the sensor. It's possible that our approach, which measures PPG through clothes, may lead to a completely unrestricted monitoring.

Some apparel, such as polyester, failed to transmit a PPG signal and despite the use of maximum LED intensity, despite the presence of a PPG signal in our studies. Even at maximum light intensity, optical path length and absorption coefficients could restrict the amount of light that can pass through clothes. It is possible, however, to use an LED with a greater forward current tolerance.

Figure 9a shows 2 PPG signals and their accompanying ECG signals. Figure 9b shows the results of CC, which reveals a high connection between the two PPG signals. The highest correlation lag was extremely near to zero for all measurement locations and segments. Cross-correlation coefficients greater than 0.87 were found in all segments with zero lags. As a result of the low rms error and strong correlation coefficient, it was concluded that the PPG signals recorded by the usual approach and the one proposed were quite comparable.

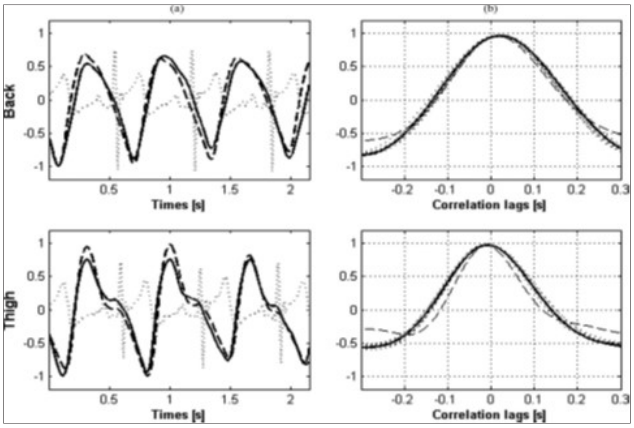

Figure 9: (a) Normalized reference waveform (dashed line), suggested PPG waveform (solid line), and ECG waveform (dotted line). **(b)** Cross correlation coefficients with regard to correlation lag for each segment (dotted line) and the mean of all segments (dashed line).

Conclusion

The PPG test can be done on people who are sitting on chairs in casual or business clothes. PPG uses, such as the monitoring of heart rate and breathing, as well as the estimation of blood pressure from an ECG wave, can benefit from this method. In addition, we could use red-wavelength LEDs and sensors to add a pulse oximeter to measure oxygen saturation in the body while wearing garments. Non-contact electrodes will be used to create for EEG/ECG recordings. A low-noise capacitive electrode with simple schematics is shown. More effort will be made in the future to reduce the wireless transmitters and power consumption of digital, as well as the electrode's miniaturization and improved packaging.

Acknowledgements

None.

Conflict of Interest

None.

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