

Non-Contact Electronic-Textile Sensor and Signal Classification Modeling

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Abstract—This work proposes and examines the development of a human electromagnetic field (EMF) sensor system used to perform EEG signature detection in an unstable environment. A wearable e-textile based sensor that can detect physiological signals, such as EEG and ECG, without requiring direct contact to the human body has been developed and compared with a traditional contact sensor. Signals detected by this no-contact system undergo processing algorithms to enhance signal clarity and reduce noise pollution in a noise-heavy environment. The sensor could be used for monitoring human performance and medical diagnostics from a remote area.

I. INTRODUCTION

In a dynamic, fast changing environment, and especially a zone one might need to change their moving speed and position rapidly, it is preferable to be able to accurately, timely, and reliably monitor the health condition of a field operator. EMF signals from the human body and human brain are one of the indicators that reflect the status of an operator [1-2]. Traditional EMF signal detection utilizes contact-based electrodes. The electrode can be a tiny patch that connects to the operator (the one being monitored) for sensing bioelectric potential. This electrical activity can be viewed as a small electric field or flux of charge-carrying particles (i.e., the current). The electrodes work as transducers that convert the current flow from the body into the electron flow of the metallic wire. Often a high ionic concentration gel is used in the skin-electrode interface to increase conductivity due to the small signal magnitude of human electrical activity. The drawback of gel usage is that it usually cannot last a long time for continuously monitoring and it is not convenient to apply the gel in an unstable outdoor environment. Non-contact sensors, which have demonstrated the effectiveness in the detection of ECG and EEG signals, offer a solution to solve these concerns [3-5].

Most health monitoring devices are typically operated in a static environment, i.e., the patient not in motion, due to the usage of external power supply and hardware for signal processing and display purpose. The proposed sensor system can provide regular direct contact mode and newly developed non-contact mode, which includes passive detection and signal processing capabilities. The system adopts wearable electronic-textile probes [5-6] to receive the EMF, to reduce the weight of the sensor, and to ensure comfort for the operator. A specially designed signal processing algorithm will be used to process the collected data and generate results for machine or medical professionals to read and give recommendations to the operator.

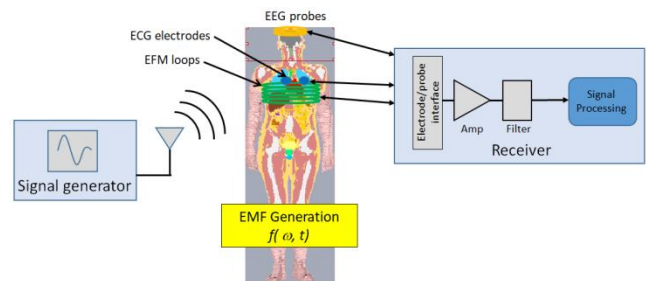


Figure 1. System block of the wearable electronic-textile sensor.

II. SYSTEM DESIGN

The concept and sensor presented in this work provide non-contact EEG detection and analysis based on a portable system in the field applications as shown in Figure 1. The bio-potential amplifiers may have high input impedance and are designed for safety, since excessive induced current may produce a significant shock to the living organism. Isolation and protection circuitry limit any currents through the electrodes to safe levels. To ensure proper interface to outside circuits, the output impedance of the amplifier should be very low to allow the driving of any external loads with minimal distortion. The amplifiers should have a high rejection ratio (e.g., in differential mode) to eliminate large offset signals. The key performance elements presented in this work include effective sampling bandwidth, e-textile design for the EMF collection, and noise/interference impacts. The same concept can be used for ECG and other physiological signals.

The detection algorithms will extract the EM signatures based on several signal processing techniques such as the moving average and decomposition. If the EMF signals can be separated into different sub-data sets, then it will be easier for vital signature to be identified and tracked. Gathered information can be used as feedback for the purpose of body condition and possible medical diagnostics. EEG is a standard neuroimaging tool that clinicians use to study brain activities and assess traumatic brain injuries. Researchers have investigated quantitative-EEG (qEEG) for evaluating neural activities. Time and frequency domain features such as power spectrum, autoregressive coefficient, and frequency bands are traditionally used in such studies. The EEG classification model used here is based on the wavelet transform (WT), which helps identify brain activities.

A. E-textile electrode

The electrodes and associated wires to the receiver are e-textile based fabrics and threads which can be shaped to fit the

platform or become part of clothing, as shown in Figure 2. The electrodes for the contact mode and the non-contact mode are designed separately because of different use conditions. The conductive fabric buttons and embroidery buttons produce resistance comparable to metal buttons (e.g. copper tape or dimes).

B. Sensor Placement

Traditionally, only contact-based electrodes have been used for bioelectrical signal detection because there are several challenges to non-contact EMF detection. Even the dry-contact or the non-contact methods mentioned in some literatures still rely on a medium to collect the signals. Antenna-based EEG signal detection occurs at a distance from the skin that is greater than the distance between a contact-based electrode and the skin. The impedance change due to this air gap may result in the signal in the time domain appearing different from what is normally observed in the contact mode. The sensor placement is illustrated in Figure 3, where the electrodes are placed at the locations close to C_z (reference point), F_{p2} , and F_8 , based on the 10-20 system.



Figure 2. The E-textile electrodes suitable for wearable devices and knitted on the desired objects.



Figure 3. EEG sensor placed on a helmet.

III. DETECTION AND CHARACTERIZATION

Through the use of traditional contact sensors, a reference signal is tested with a contact mode eye-blinking check. As shown in Figure 4(a), the eye-blinking pattern (every one second) can be clearly observed in the first seven seconds as the result using the regular EEG sensor. The signals using the non-contact mode can be found in Figure 4(b), where the eye-blinking can be still detected, but the pattern is very different from the contact mode. In the contact mode, there are two obvious primary peaks (up for eyelid closure, and down for eyelid opening). In the non-contact mode, multiple peaks appear and they can be grouped for further analyses. It is believed that this phenomenon is caused by dispersion due to medium changes, including spatial dispersion created by the electrical signal now passing through the air medium.

Eye-blinking signals from the contact EEG sensor are easier identified and tracked, as the signal is relatively clean.

Although the signal from the non-contact sensor is not as clean, it is still possible to extract pattern features from the data by removing noise from the signal. From our observation, the trend is for the signal to have three peaks (up, down, and up). The moving average filter with convolution has been applied to compare their differences. As shown in Figure 5, the contact mode remains between the range of 0.4 and 1, while the non-contact mode value is consistently between 0.1 and 0.5. A more sophisticated method will be needed to track this physiological response.

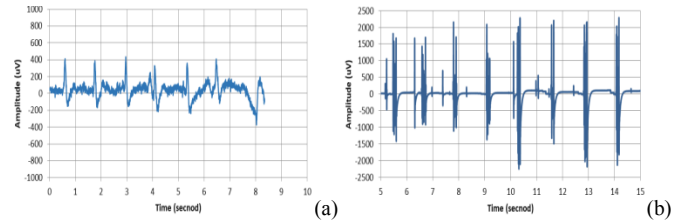


Figure 4. Eye-blinking signals with (a) the contact mode and (b) non-contact mode.

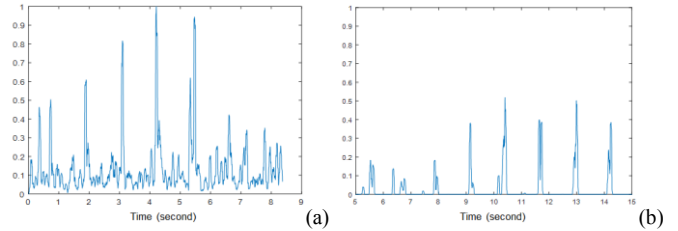


Figure 5. Eye-blinking signals with (a) the contact mode and (b) non-contact mode when the moving average filter is applied.

IV. CONCLUSIONS

A wearable non-contact sensor for simultaneous EEG and vital signals detection for healthcare applications has been proposed. The proposed new e-textile electrode design can provide reliable data delivery for human performance monitoring. Extraction and analysis of EMF signals based on direct time-domain results and signal processing techniques to improve the signal to noise ratio and accuracy of the sensor have been demonstrated.

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