A Survey on Fetal Electrocardiogram

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***Abstract*—The fetal electrocardiogram (FECG) is a technique of recording bioelectric current generated by the fetal heart. It is obtaining mainly from maternal abdomen. These signals are corrupted by various types of noise. This paper mainly focuses on the artifacts affecting the FECG characteristics. Methods already available to extract the FECG from the noises are also explored.**

***Keywords* — ECG, FECG, MECG, QRS complex, heart rate**.

I. INTRODUCTION

Fetal Electrocardiogram (FECG) is a method to determine the electrical activity of fetus heart during pregnancy and at childbirth. It provides information about both fetal heart rate and fetal heart condition. This is required for diagnosis of any cardiac defects in fetus heart [1]. An ECG obtained for adults is a non-invasive test to detect the proper functioning of the heart and is obtained by placing the electrodes on the skin in specific locations [2]. But for measuring the FECG, there are no such exact positions available. FECG is obtaining by mainly two ways: one invasive and non-invasive. In invasive case, the electrode is directly placed on the fetal scalp during labor. This gives almost pure FECG. The disadvantage associated with the technique is that both the mother and fetus are prone to infections [2]. Non-invasive method, which is generally used, is done by placing the electrode on the mother's abdomen. The FECG is very much related to the adult ECG, containing the same basic waveforms including the P wave, the QRS complex, and the T wave, in some cases, U wave. A normal FECG signal is shown in figure 1. The P wave occurs at the beginning of atrial contraction, QRS complex is associated with the contraction of the ventricles, and T wave corresponds to the repolarization ventricles, which follows each heart contraction [3]. Normally FECG has a bandwidth of 0.05-100 Hz. The maximum amplitude of QRS complex is usually oscillates from 100 µV to 150 µV for maternal recording and up to 60 µV for the fetal recording.

II. NOISES IN FECG SIGNALS

The FECG signals are generally distorted by noises present in and around the fetus. The shape and structure of the FECG signal also depend on the placement of the electrodes. Common noise sources affecting FECG signal can be categorized into the following types.

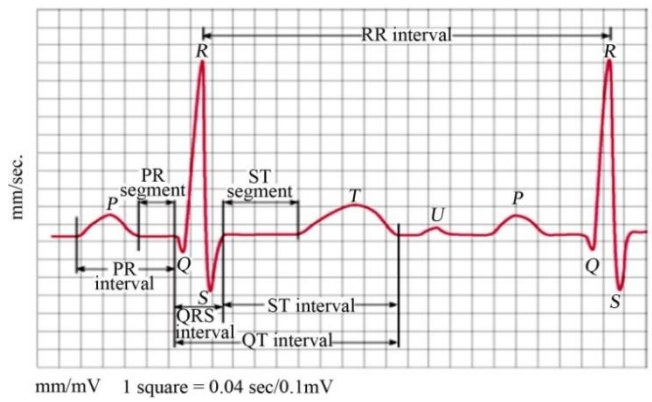

Figure 1. Normal FECG Signal with labeling

A. *Power line interference(PLI)*

This type of noise occurs through two mechanisms: capacitive and inductive coupling. First refers to the transfer of energy between two circuits due to coupling capacitances present between the circuits. The value of the coupling capacitance decreases with increasing separation of the circuits. Inductive coupling is due to the mutual inductance between two conductors. When current flows through wires it produces a magnetic flux, which can induce a current in adjacent circuits. The geometry of the conductors as well as the separation between them determines the value of the mutual inductance, and hence the degree of the inductive coupling. Capacitive coupling introduces high frequency noise while inductive coupling introduces low frequency noise. For this reason inductive coupling is the dominant mechanism of power line interference in electrocardiogram.

B. *MECG signal*

Maternal ECG (MECG) is the most predominant interfering signal with FECG in the abdominal signal. The frequency spectrum of this noise overlaps that of the FECG and therefore filtering alone is not sufficient to achieve adequate noise reduction [3] [4].

C. *Muscle noise*

Muscle noise is due to maternal movement, often from the leg and abdominal muscles and may be picked up from the reference pad on the maternal thigh. Electromyography (EMG) activity in the muscles of the abdomen and uterus is the source of this kind of noise.

D. Electrode contact noise

This kind of noise caused by loss of contact between the electrode and skin which affect the measurement of signal parameters.

E. Motion artifacts

Motion artifact is due to movement of mother/fetus or improper arrangement of electrodes. Motion artifact can be reduced by proper design of the electronic circuitry and setup [5] [4].

F. Ambient noise

Electromagnetic radiation is the source of this kind of noise. The surfaces of the human bodies are constantly inundated with electric–magnetic radiation and it is virtually impossible to avoid exposure to ambient noise on the surface of earth [3].

III. AVAILABLE NOISE REDUCTION TECHNIQUES

The extraction of FECG is very important and is required to get reliable information about the status of fetus, abnormalities present in fetus heart, to enable the adoption of measure for assuring fetal well-being and to determine twin pregnancies.

Extended Kalman filters are applied to extract single channel FECG [6] from MECG and examined the performance of extracted FECG with noise level, amplitude ratio and heart rate ratio parameters. The method was able to detect R-peak correctly.

Some AI techniques mainly based on neural networks have been proposed for processing FECG signal. Neural network is a computing technique that evolved from mathematical models of neurons and systems of neurons. During recent years, neural networks have become a useful tool for categorization of multivariate data. This kind of technique is very useful for real-time application like FECG signal recording and analysis Khaled Assaleh [1] designed adaptive neuro-fuzzy system to extract FECG from the signals recorded at the thoracic and abdominal areas of the mother's skin They also identified the nonlinear relationship between maternal component in abdominal ECG and thoracic MECG. They performed that technique on both real and synthetic ECG signals.

Zarzoso and Nandi compared the noninvasive FECG extraction through blind source separation and adaptive noise cancellation technique and found blind source separation technique more robust and accurate [7].

An adaptive filter uses iterative computation to minimize the error. Different variants of adaptive filters have been used for maternal ECG cancellation and FECG extraction. The adaptive filter uses the thoracic signal as the reference of the MECG signal and it removes the MECG signal from the abdominal recording.

A time sequenced adaptive filtering of FECG signal enhancement was proposed by Ferrara and Bernard Widrow in 1981. The method requires two channels containing correlated fetal ECG component and uncorrelated noise component. The advantage of time sequenced adaptive filtering is that the power spectra of the signal and noise need not be known a priori [8].

Fuzzy decision systems were also used to detect QRS complexes from FECG signals [9].

Least mean square algorithms based adaptive noise cancellation techniques were proposed by Maniknandan et.al to extract FECG from MECG. Through this technique, they were also able to identify heart rate [10].

FECG physiology, basics and opportunities were explored by Raza Sameni et.al in [11]. Various noise models for FECG were also explored.

Prashant K. et.al extracted FECG signals from noisy FECG using adaptive filters in MATLAB simulink [12].

Noor Abdul Khaliq et.al [13] proposed LMS based adaptive filter to acquire FECG from hospital FECG monitoring system. The model was real time and the reconstructed signal was transmitted through web page to physicians for monitoring diagnosis of fetal heart.

Dessai et.al are developed a system using the MATLAB for extraction of the FECG parameters from the composite abdominal signal. The system deals with the identification of maternal QRS complex by using wavelet transform, then QRS complex is subtracted by template generation and matching [2].

IV. CONCLUSION

FECG signal contains the valuable information about the fetal heart. The main use of FECG is to diagnose the heart diseases by using signals generated by fetal heart. That could assist clinicians in making more appropriate and timely decisions. These signals are corrupted by various noises during acquisition, transmission and storage. So, addition of noises may changes the morphology of FECG signals and thus affects proper diagnosis. In this paper, factoring affecting the morphology of FECG signals is explored. Various techniques implemented to extract FECG signals are also discussed.

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