Wearable Patch Device for Uterine EMG and Preterm Birth Monitoring Applications

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***Abstract*— Uterine contraction is a critical activity of pregnancy monitoring and can be used to predict preterm birth. Recently, wearable uterine EMG measuring devices have been introduced to monitor pregnancy such as pre-term birth. In this work, we proposed an abdomen attachable patch device as uterine EMG signal acquisition circuits. Multi-channel uterine EMG signals could be measured simultaneously and the device size is about 43 * 36 mm^2. The number of peak points of the EHG signal envelope and FFT integral value have been studied as new feature parameters for discrimination of preterm birth. The number of envelope peak points of EHG signals is expected to be useful in predicting preterm delivery risk. We conducted subject test and obtained real uterine EMG data from pregnant woman with the proposed patch device. We compared FFT plots of uterine EMG during normal state and uterine contraction state. FFT integral value of contraction state is also higher than the normal state subjects in 0.2~0.4 Hz frequency band.**

Keywords*— *uterine EMG, EHG, patch, preterm birth, prediction

I. INTRODUCTION

Uterine activity assessment is essential for evaluating labor progress, and can be used to predict preterm labor. Currently widely used techniques for uterine contraction monitoring are invasive intrauterine pressure (IUP) measurements and external tocodynamometer method. While the first method is regarded as reliable, its invasive properties cause contamination and limit its application. External tocodynamometer is non-invasive, but is less reliable and often inconsistent due to the indirect mechanical nature of the strain gauge transducer used [1][2]. An alternative is electrohysterography (EHG), the measurement of electrical signals resulting from the activity of uterine contraction EMG. EHG provides uterine activity information which is more accurate and reliable than tocodynamometer while maintaining the ease of use [3].

Recently, a few uterine EMG monitoring devices are introduced which measure uterine contraction activity such as Novii wireless patch of Monica Healthcare and Smart pregnancy tracker of Bloomlife[4]. In this work, we introduced newly designed multi-channel uterine EMG patch device prototype for preterm birth monitoring applications.

II. CIRCUIT DESIGN

Technology concept of uterine EMG based preterm birth monitoring is described in Figure 1. The system consists of uterine EMG patch device and smartphone application. The measured EMG signals transmitted to smartphone via bluetooth telecommunication module.

Fig 1. Technology concept of uterine EMG based pre-term birth monitoring

The proposed uterine EMG patch is designed as attachable type on abdomen of pregnant woman. Uterine EMG patch measure EHG(uterine EMG), FRH(fetal heart rate), maternal temperature and acceleration signals from physical activites of maternal abdomen. The simplified circuit block diagram of the designed uterine EMG patch devices is shown in Figure 2. The main block of the circuits consists of uterine EMG(EHG) electrode, FHR(fetal heart rate) electrode, temperature sensor, 6-axis accelerometer IC, active filter circuits, signal amplifier circuits, 8 channel high precision high resolution ADC, MCU and Bluetooth telecommunication IC for mobile devices interface.

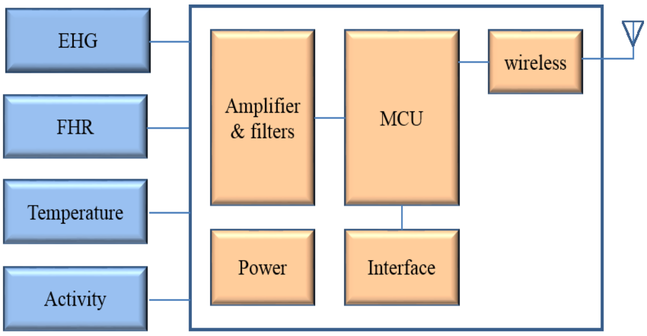


Fig. 2. Circuit block diagram of designed uterine EMG patch devices

III. PATCH IMPLEMENTATION AND TEST RESULTS

The proposed uterine activity monitoring patch and electrodes have been implemented in flexible PCB as shown in Fig. 3. The flexible PCB for electrodes are designed with shielded ground pattern for noise reduction. Fig. 3 shows the prototype module of multi-channel uterine EMG patch with ADS 1299 IC. ADS 1299 IC is proper device for low amplitude bioelectrical signals such as ECG, EMG and EEG. ADS 1299 has 8 differential acquisition channels and each channel is equipped with a programmable gain amplifier, up to 24 times, and with an analog to digital delta-sigma converter of 24 bits resolution [5].

In the ADS1299 the oversampling technique is used to reduce the noise, spreading it on a wider band of 1.024 MHz. The only filtering achievable is a digital low pass decimation filter with the cut-off frequency that depends on the output data rate: lower data rate means narrower bandwidth and turns in higher SNR, higher data rate means wider bandwidth and thus more noise is included in the signals [5].

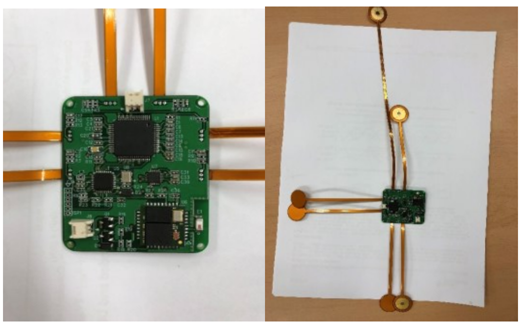
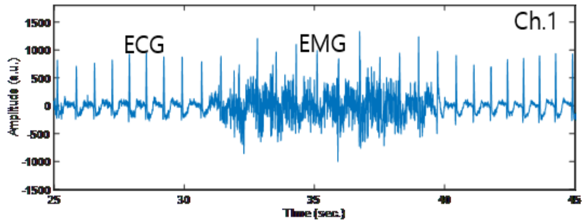
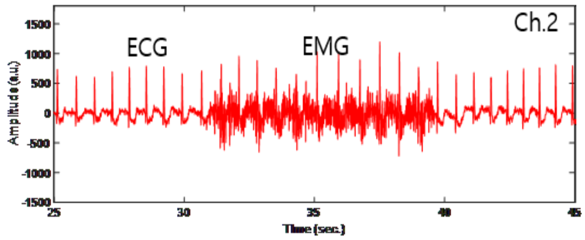


Fig. 3. The photograph of implemented uterine EMG patch devices with multi-channel electrodes

There are some complex bioelectrical signals in human abdominal area, such as ECG, EMG, etc. To extract genuine EMG signals we designed the circuits operated in differential mode which subtract one channel of signals from the other. Fig. 4 shows the measured results of abdominal EMG+ECG signals during abdominal physical activity. In early stage of Fig. 4(a), there is only ECG signals because no abdominal physical activities are done in this stage. In next stage, there are ECG and EMG complex signals because some abdominal physical activities are done in this stage. Fig. 4(a) shows measured EMG+ECG signals of channel 1 during abdominal physical activity. Fig. 4(b) shows EMG+ECG signals of channel 2 and Fig. 4(c) shows extracted EMG signals from difference between channel 1 and channel 2.



(a)



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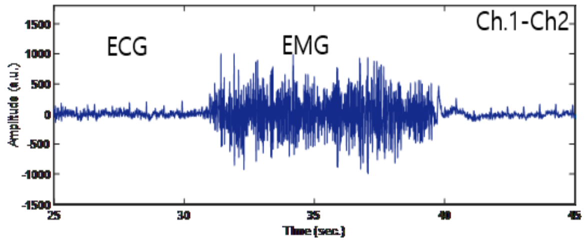
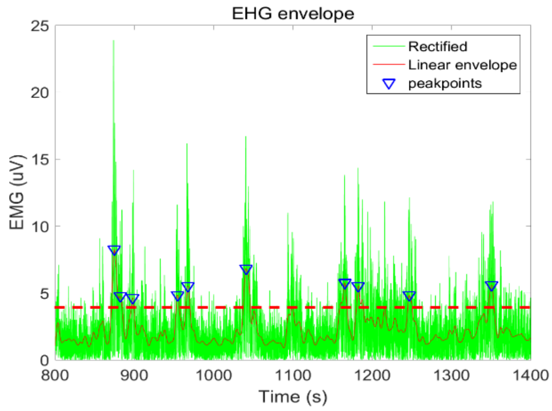


(c)

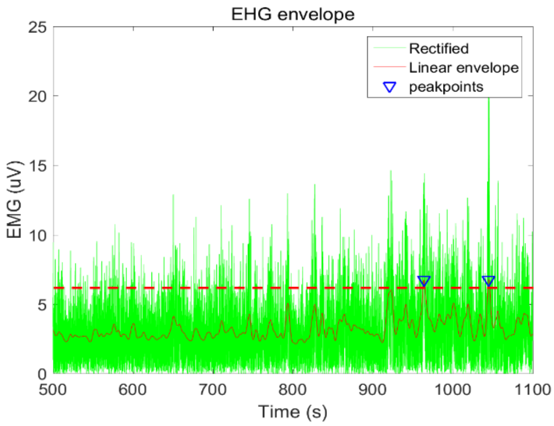
Fig. 4. The measured results of abdominal EMG+ECG signals during abdominal physical activity : (a) channel 1 signals, (b) channel 2 signals, (c) extracted EMG signals from difference between channel 1 and channel 2

IV. FEATURE EXTRACTION

At the initial stage we could not obtain EHG(uterine EMG) data from pregnant women subjects because the proposed patch device has not yet been approved for pregnant women. Instead, we proceeded with feature parameter studies using existing EHG data such as Physionet. In this paper, the number of peak points of the EHG envelope was selected as a feature parameter for discrimination of preterm birth. Envelope peak points feature extraction with cutoff frequency of 0.1 Hz for EHG data of 12 subjects selected from Physionet DB [6]. 6 data are for preterm birth and the other 6 data are normal case. The number of peak points of the EHG envelope was extracted and set as the threshold value twice the envelope mean. The uterine contraction characteristics were studied by calculating the envelope peak number larger than the set threshold.



(a)



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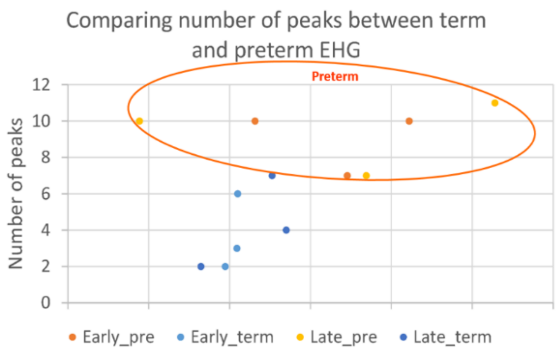

(c)

Fig. 5. The number of envelope peak points of EHG signals as new feature parameter for discrimination of preterm birth: (a) preterm birth, (b) normal pregnancy, (c) comparing plot between preterm birth and normal pregnancy

In the preterm birth case, more than 9 significant peak points were observed on average for 10 minutes as shown in Fig. 5(a). On the other hand, in the normal case, an average of 4 peak points were observed for 10 minutes as shown in Fig. 5(b). As shown in Fig. 5(c), the number of envelope peak points of EHG signals is expected to be useful in predicting preterm delivery risk.

Finally we conducted subject test and obtained real uterine EMG data from pregnant woman. Fig. 6(a) shows the uterine contraction signal measured in tocodynamometer plot during 30 minutes. Periodic high amplitude waves(marked by handwriting) in tocodynamometer plot means high mechanical strain during periodic uterine contraction. Fig. 6(b) shows uterine EMG raw data measured by the proposed patch device during 30 minutes. After FFT signal processing, we compared FFT plots of uterine EMG during normal state and uterine contraction state in Fig. 7. The FFT spectral energy of uterine contraction state is higher than that of normal state without uterine contraction in low freqeuncy band under 0.1Hz. Fig. 8 describes FFT integral value comparison between contraction and normal state of 5 test subjects in 0.2~0.4 Hz frequency band. According to the experimental data of Fig. 7 and Fig. 8, FFT spectral energy and FFT integral value of contraction state is normally higher than the normal state.

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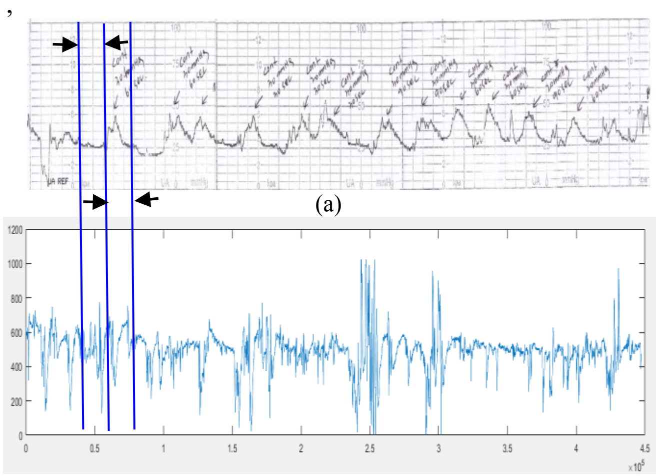
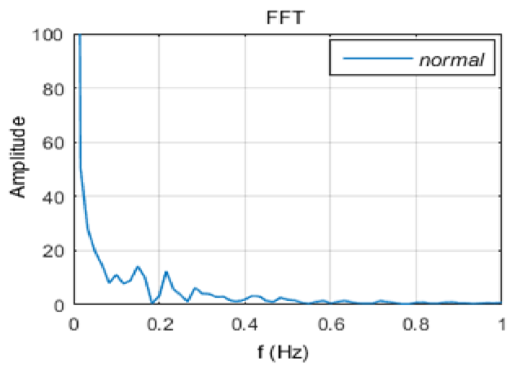


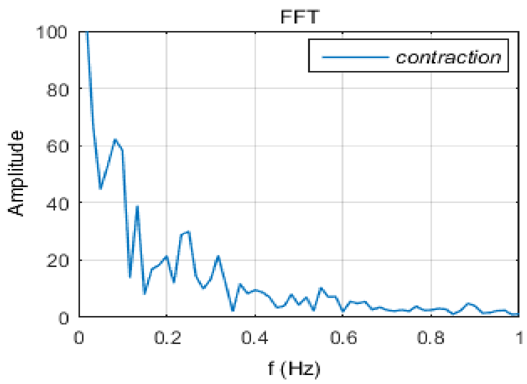
(a)

(b)

Fig. 6. (a) uterine contraction signal measured by tocodynamometer during 30 minutes, (b) uterine EMG data measured by the proposed patch device during 30 minutes



(a)



. (b)

Fig. 7. FFT spectral energy comparison of uterine EMG (a) during normal state and (b) uterine contraction state

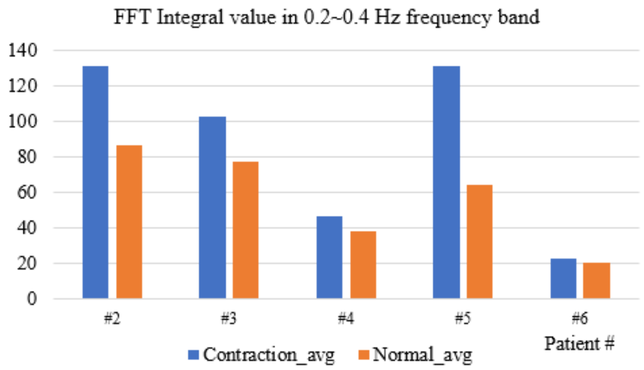


Fig. 8. FFT integral value comparison between contraction and normal state of 5 test subjects in 0.2~0.4 Hz frequency band

V. Conclusion

In this work, we designed a prototype of abdomen attachable patch device as EHG(uterine EMG) signal acquisition circuits to monitor pregnancy such as pre-term birth. Multi-channel EHG signals could be measured simultaneously and the device size is about 43 * 36 mm^2. Multi-channel abdominal ECG+EMG signals of test subject could be measured successfully with this patch devices and the measured signals could be communicated wirelessly to other smart devices successfully. To extract EMG signal from ECG+EMG complex, we designed differential mode circuit configuration and test results shows good extraction performance. The number of peak points of the EHG signal envelope was studied as new feature parameter for discrimination of preterm birth. In the preterm birth case, more than 9 significant peak points were observed on average for 10 minutes. On the other hand, in the normal case, an average of 4 peak points were observed for 10 minutes. The number of envelope peak points of EHG signals is expected to be useful in predicting preterm delivery risk. Finally we conducted subject test and obtained real uterine EMG data from pregnant woman. We compared FFT plots of uterine EMG during normal state and uterine contraction state. The FFT spectral energy of uterine contraction state is significantly higher than that of normal state without uterine contraction in low freqeuncy band under 0.1Hz. FFT integral value of contraction state is also higher than the normal state subjects in 0.2~0.4 Hz frequency band.

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References

[1] Bajlekov G, Rabotti C, Oei S and Mischi M : Electrohysterographic Detection of Uterine Contractions in Term Pregnancy, IEEE EMBC, pp. 5851-5854 , Italy(2015).

[2] Felezorz G, Kavsek G, Antolic N and Jager F : A comparison of various linear and non-linear signal processing techniques to separate uterine EMG record of term and pre-term delivery groups. Medical & Biological Engineering. & Computing., pp. 911-922, Germany(2008)

[3] HayesGill G, Hassan S, Mirza F and Cohen W : Accuracy and reliability of uterine contraction identification using abnormal surface electrodes, Clinical medicine Insights : Women's Health, pp. 65-75, USA(2012)

[4] Smart pregnancy tracker of Bloomlife, Website, https://bloomlife.com

[5] Mastinu B, OrtizCatalan R and Håkansson B : Analog Front-Ends comparison: on the way to a portable, low-power and low-cost EMG controller based on Pattern Recognition, IEEE EMBC, pp. 2111-2114 , Italy(2015).

[6] Physionet, The Term-Preterm EHG DB, Homepage, https://www.physionet.org/pn6/ tpehgdb/, last accessed 2012.