

# Study of Situation Based Environment towards Noise Reduction during ECG Acquisition

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## ABSTRACT

Even with the development of more advanced technology of ECG, there are still problems on interference to ECG signals. Many attempts have been made to detect and eliminate the source of noises and artifacts from the original ECG signals. Several studies have been done to observe and study the EMI effect, however, most of them only focus on the EMI effect of mobile phone during ECG acquisition. Thus, this study is emphasized on the interference problem when other medical devices were being used together with the ECG device. The R-R peak distance of the ECG signal was detected by using QRS detection algorithm invented by J. Pan and W. J. Tompkins. The data from the experiment showed that even the EMI from the medical devices did not affect the physical shape of ECG, but it does affect the R-R peak distance of the ECG signal.

**Keywords:** Electrocardiogram; Electromagnetic Interference; R-R Peak Distance

## 1. Introduction

The increasing number of medical devices used in health care facilities [1] has guided many researchers to study about the potential problem of electromagnetic interference on medical device [2]. This study is done due to the concern towards the possibility of malfunction of life supporting system, such as electrocardiogram and electroencephalogram when it is being used in a close proximity with other medical devices. Electrocardiogram (ECG or EKG) is a simple yet painless test that used to record the electrical activity of the heart [3]. ECG device is used to detect and amplify the tiny electrical changes on the skin that caused when the heart muscle depolarizes during each heartbeat. Those tiny electrical changes on the skin will then convert into wavy lines to be analyzed by the doctor. Since ECG was able to record the electrical activity of the heart, it is being used in diagnosis for the heart disease. Generally, the recorded ECGs and EEGs signal will always be contaminated with many types of noise and artifact. In this study, the concern will be emphasized on the interference problem from other medical devices that being used together or nearby with the ECG and EEG device. It is important to ensure that there will be no interference problem occurs when it is being used together with other medical device since some equipment used in healthcare centre is designed to emit electromagnetic energy [4]. Several studies have been done to observe and study the interference effect,

however, most of them only focus on the effect of mobile phone during EEG and ECG acquisition. Those types of studies always treat medical devices as the ‘victim’ and mobile phone as the ‘source’ of electromagnetic interference. [5-7].

## 2. Literature Review

Since numerous types of Electromagnetic Interference, EMI were introduced, the effect of the EMI on the electronic device performance being studied. The study includes the tests of radiofrequency susceptibility on 8 types of medical devices [5] which shows that all 8 devices being tested is easily affected by the emitted electric field at frequencies varies from 1 MHz to 2000 MHz with electric field intensity at 10 V/m. Most of the tested devices such as Fetal Monitor and Infant Incubator showed incorrect presentation of data when the electric field intensity was as low as 0.012 V/m. Based on the result of the study, the electric field intensity emitted by cellular phone or two ways radio undoubtedly can affect the performances of medical devices since the electric field of those two devices are 15 V/m and 5 V/m respectively. Even it is hard to foretell the occurrence of failure causes by EMI, it is highly recommended to avoid or reduce the usage of cellular phone and two ways radio in hospital area especially the area that equipped with life supporting system and in intensive care unit since it is the most critical area.

In order to strengthen the idea to ban the usage of cellular phone in hospital area, there is a study done to identify the susceptibility areas in the hospital by performing immunity test on medical devices [6]. The immunity test was done by subjecting several medical devices to electric field generated by cellular phone that operates in its maximum power. The result from the study shows that 80% of medical devices that being tested was affected by the radiated electric field.

As many researchers only focusing on the EMI effect cause by cellular phone, few of them study on the effect of interference of medical device when it is used in close proximity to other medical devices [8]. The study includes several case studies on performances degradation on apnea monitors, automatic implantable cardioverter defibrillators (AICD) and Cobalt 60 therapy system. Based on the result of each type of study, almost every author comes up with the same conclusion and recommendation such as the needs to establish clear policies for the usage of mobile phone in critical area in the hospital. They also emphasize on the safety distance between medical devices and any other type electronic device especially the one that emit powerful electromagnetic signal.

### 3. Methodology

The measurement was taken in the situation where different types of medical devices operated during ECG data acquisition within 1 meter range of distance. KL-75001 Electrocardiogram Module was used to take ECG signal from a healthy subject (a female, aged 20 years old) and with the assistance of oscilloscope to display the signal. As a precaution, the subject was ensured to be in a good health condition and not taking any medication before the experiment. The acquired signal was saved in .txt format for further observation and investigation through Matlab. The signal was compared with the reference signal (free from noise) in term of the wave pattern and RR Peak Distance.

Data analysis was done to emphasize that EMI from

other medical devices when being used in the same area with the ECG does affect the ECG data. There are 8 types of medical device that being tested during the experiment (one at a time). The duration of experiment for each type of medical device is 10 second. **Table 1** and **Figure 1** below shows the list of medical device and the block diagram of the experiment respectively.

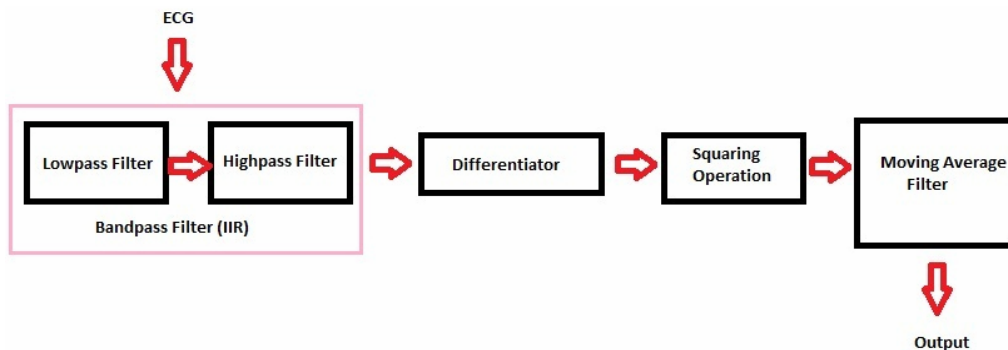
### 4. Result and Discussion

Several testing had been conducted to observe the ECG signal patterns. All data from those testing were obtained. From those data, analysis was made to clearly state the comparison between the reference signal and the acquired signal.

**Table 2** showed the signal acquired from the experiment. Physically, there is no obvious alteration towards the wave shape. The shape of the ECG signal is still maintained. The noise is hardly compared or extracted from the ECG signal. Unlike the electric field intensity that radiated from cellular phone or two ways radio, electric field intensity emitted by medical devices is definitely low. Even the signal does contain several type of noise; it does not alter the amplitude of PQRS of the ECG.

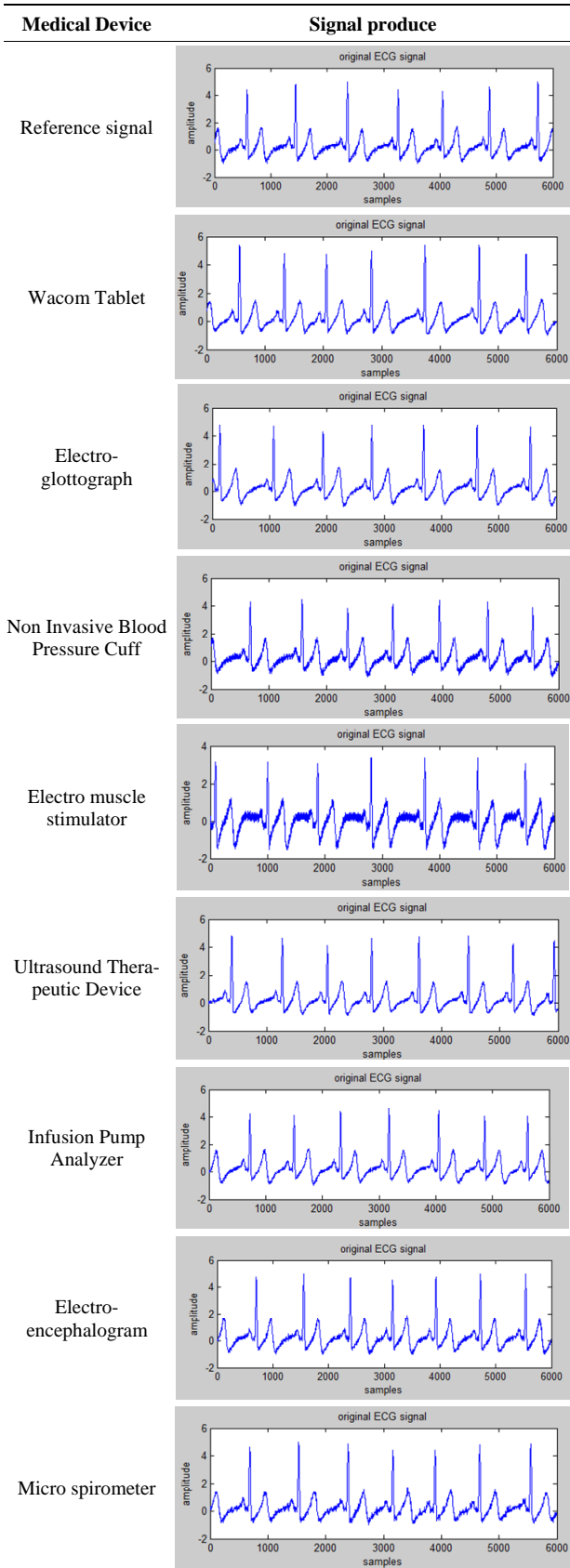
**Table 1. Types of medical device that being tested during the experiment.**

No	Medical Device	Year Acquired	Shielding Standard
1	Wacom Tablet	1999	3V/m
2	Electroglotograph	2001	3V/m
3	Non Invasive Blood Pressure Cuff	2001	3V/m
4	Micro Spirometer	2008	10V/m
5	Electro muscle stimulator	2009	10V/m
6	Ultrasound Therapeutic Device	2009	10V/m
7	Infusion Pump Analyzer	2009	10V/m
8	Electroencephalogram	2011	10V/m

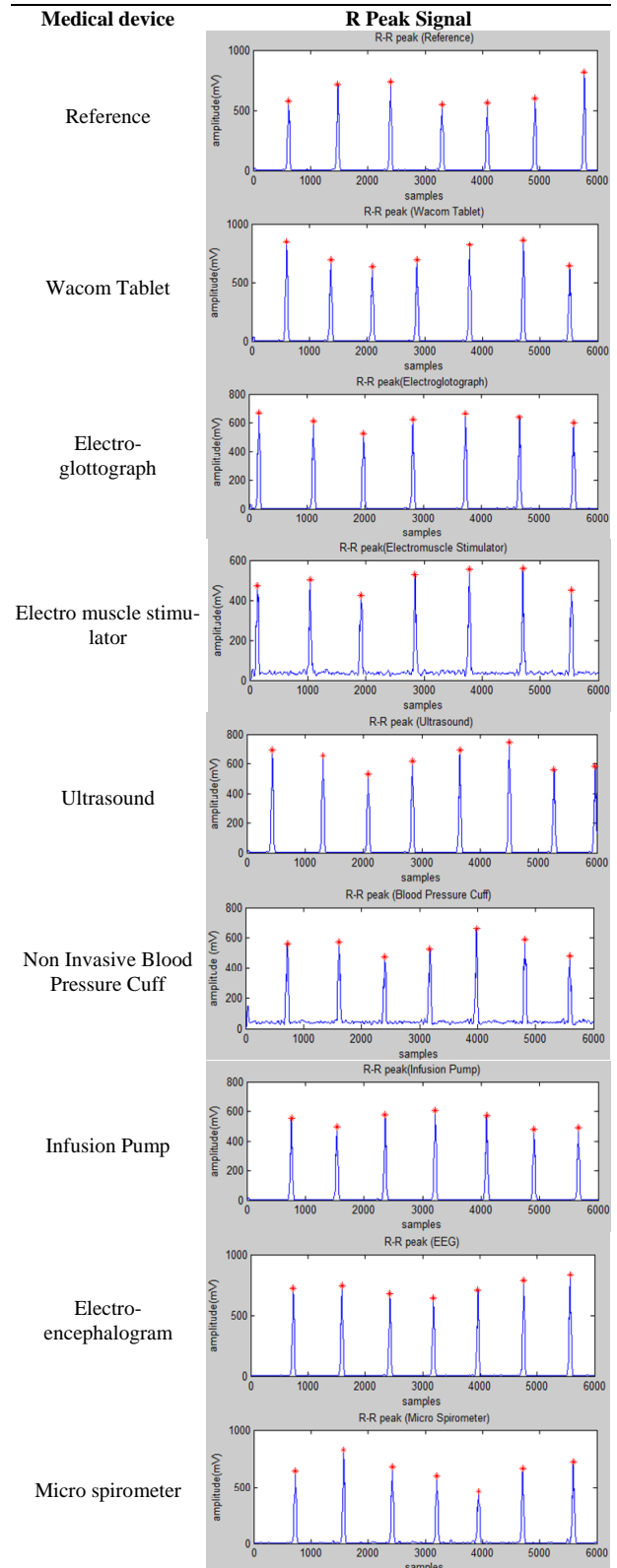


**Figure 1. QRS Detection algorithm [9].**

**Table 2. Signal acquired from experiment.**



**Table 3. R-R peak signal of each device.**



Since the reference signal and the test signal are hard to differentiate in term of physical shape, the average of

R-R peak distance of each signal were compared. In order to calculate the R-R peak of the ECG, the QRS complex detection was done by using Pan & Tompkins algorithm. The detection of R-R peak is important during ECG signal analysis as its can be used to show the condition of the heart, calculation of heart rate and even can be used to define various heart defectiveness [10-11].

As stated previously in introduction section, even the electric field intensity emitted by medical devices is low; it does affect the ECG signal. This phenomenon is proved by the graph of R-R peak distance of each tested medical device shown in **Table 3**. The detection of R-R peak was done based on the Pan & Tompkins's algorithm as shown in **Figure 1**. As the R-R distance of the test signal and the reference signal was compared, it shows that the space between each R peak is not evenly spaced and its include 6 of 8 (75%) tested medical devices such as ultrasound, infusion pump, Wacom tablet, EEG, and blood pressure cuff.

## 5. Conclusions

Different approaches in analyzing ECG signal should be done to get better observation on the effect of EMI towards the signal. As described in [3], the author calculated the peak to peak value of noise embedded in the signal and many other authors that observed any changes in device function, including failure, distortion of displayed information, erroneous readout or activation of an alarm. However, some types of analysis may be unable to detect the effect of EMI on ECG signal. Thus for this study, analysis was done by observing the RR peak distance in order to strengthen the fact that EMI from other medical device can definitely affect the ECG signal data.

Even all medical devices are certified with their own electromagnetic compatibility standard, some of them still being affected by the EMI within or lower than the standard value [5]. In spite of the simplicity of the analysis, the result however emphasized the need of separating the easily susceptible medical device from the other medical device for better performance. Several precautions must be taken in order to avoid any harmful effect caused by device malfunction due to EMI.

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