Comparative Analysis of Q-factor For Notch Filter Designing in Cardiological Signal Processing

Rohit Gupta
ME scholar
PEC University of technology
Chandigarh

Sulata Bhandari
Associate Professor
PEC University of technology
Chandigarh

Sandeep Kaur
Assistant Professor
PEC University of technology
Chandigarh

***Abstract* –Electrocardiogram is a signal which measures the electrical activity of the heart. Normal heart beat for human is 70 cycles per minute. Any change in natural sequence of activities of heart like beating too fast, too slow or erratically is Arrhythmia, and this can be detected by analyzing ECG of the subject. The recorded ECG potentials are usually contaminated by power-line frequencies which lie within the frequency spectrum of ECG signal making it difficult to extract useful information from it; this interference is suppressed using 50/60Hz notch filter. It has been shown that notch filter application deforms the QRS complex of the electrocardiogram. In this paper a comparative analysis of the impact for different values of Q-factor of the notch filter, on QRS complex of Electrocardiogram has been shown.**

***Keywords*- ECG, Q-factor, Notch filter, interference**

I. INTRODUCTION

Electrocardiogram (ECG) is the record of electrical activity of heart (Fig. 1). ECG machine is a device through which we record this electrical activity. This device is connected by wires to electrodes pasted on patient's chests at particular position [1]. Around 12 million deaths occur worldwide each year due to cardiovascular diseases as stated by the World Health Organization. Due to the insufficient supply of blood in the heart the clogging occurs and thus Coronary Heart Disease (CHD) takes place [2][3][4]. The cardiac arrhythmias accounts for ninety percent of the deaths due to cardiovascular diseases [5]. Arrhythmias are seen as an abnormal function of the heart.

There have been several researches in the field of arrhythmia detection. Adams and Choi [5] proposed a method based on ANN to classify different arrhythmias using the QRS complex as features of ECG. Another neural network based classification of ECG for Premature Ventricular Contractions using Wavelet transform was done by Inan et al [6] with an accuracy of 88%. Patel et al [7] proposed arrhythmia detection method based on peak detection of QRS complex. They concluded that QR S complex is an important feature for classification of arrhythmia. Rahman and Nasor [8] used the QRS complex to define and classify different types of arrhythmia. Li, Zheng an d Tai [9] detected ECG characteristic points using wavelet transforms for the detection of QRS, T, and P waves [10].

ECG signal consists of a P wave, a QRS complex, and a T wave (Table 1). Before contraction the electric currents due to atrial depolarization causes P, while the depolarization due to ventricle contraction causes QRS complex. During recovery of the ventricles from the state of depolarization the T wave is formed.

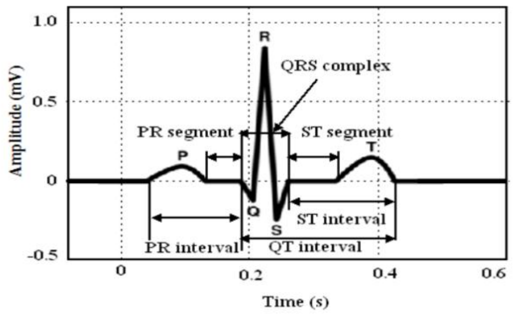

Fig. 1 Schematic representation of normal ECG waveform

Table 1 Amplitude and duration of waves, intervals and segments of ECG signal.

Sl. no.	Features	Amplitude (mV)	Duration (ms)
1	P wave	0.1-0.2	60-80
2	PR-segment	-	50-120
3	PR- interval	-	120-200
4	QRS complex	1	80-120
5	ST-segment	-	100-120
6	T –wave	0.1-0.3	120-160
7	ST-interval	-	320
8	RR-interval	-	(0.4-1.2)s

The T-wave is characterized as the wave of re-polarization. Fig. 1 shows a representation of an ECG with the waves [11].

II. NOISE IN ECG SIGNAL

Unfortunately the acquired ECG does not only consist of the components derived from the electrical functionality of the heart, but it is very often contaminated by artifacts that can interfere or interrupt the signal and result in loss of information. Sometimes, these artifacts might even present with similar morphology as the ECG [11]. The most commonly found artifacts in the ECG are:

1. Power-line interference, which is characterized by a frequency of 50 or 60 Hz depending on the country.
2. Steep voltage changes form the loss of contact between the electrodes and the skin.

3. Electrical activity from muscle contractions that varies from dc to10kHz.
4. Baseline drift which is usually caused from respiration at very low frequencies, around 0.1v 0.3Hz.

III. POWER LINE INTERFERENCES

In this paper we will deal with only Power line interferences that contains 60 Hz pickup (in U.S.) or 50 Hz pickup (in India) because of improper grounding.

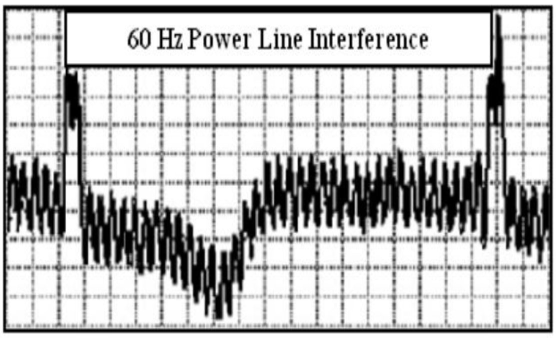

Fig.2 60 Hz Power line interference.

It is indicated (Fig. 2) as an impulse or spike at 60 Hz/50 Hz harmonics, and will appear as additional spikes at integral multiples of the fundamental frequency. Its frequency content is 60 Hz/50 Hz and its harmonics, amplitude is up to 50 percent of peak-to-peak ECG signal amplitude. A 60 Hz notch filter can be used remove the power- line interferences [11].

IV. CASE STUDY

For this study, the data used is publicly available MIT-BIH arrhythmia database at physionet.org [12] The complete data set consist of 48 sets each containing set of 2 channels. Each set is divided into normal and arrhythmia set. The length of each recording is 27.7 seconds. The sampling rate of data is 360 Hz. In most records, the upper signal is a modified limb lead II (MLII). The lower signal is usually a modified lead V1 (occasionally V2 or V5, and in one instance V4 [13]

V. NOTCH FILTER

The Notch Filter, (BSF) is another type of frequency selective circuit that functions in exactly the opposite way to the Band Pass Filter. The band stop filter, also known as a band reject filter, passes all frequencies with the exception of those within a specified stop band which are greatly attenuated.

If this stop band is very narrow and highly attenuated over a few hertz, then the band stop filter is more commonly referred to as a notch filter, as its frequency response shows that of a deep notch with high selectivity (a steep-side curve) rather than a flattened wider band.

Also, just like the band pass filter, the band stop (band reject or notch) filter is a second-order (two-pole) filter having two cut-off frequencies, commonly known as the -3dB or half-power points producing a wide stop band bandwidth between these two -3dB points.

Then the function of a band stop filter is to pass all those frequencies from zero (DC) up to its first (lower) cut-off frequency point f_L, and pass all those frequencies above its second (upper) cut-off frequency f_H, but block or reject all those frequencies in-between. Then the filters bandwidth, BW is defined as: $(f_H - f_L)$[14].

VI. NOTCH FILTER DESIGNING IN MATLAB

IIR NOTCH Second-order IIR notch digital filter is designed in MATLAB [15] as

[NUM,DEN] = IIRNOTCH (ωo,BW)

It designs a second-order notch digital filter with the notch at frequency ωo and a bandwidth of BW at the -3 dB level. The bandwidth BW is related to the Q-factor of a filter by

$$BW = \omega o/Q. \qquad [1]$$

VII. RESULTS & DISCUSSION

FFT spectrum of all the cases considered reflects almost equal suppression of power line frequency for all values of Q considered as shown in Fig. 3-6. Comparative analysis of filters with different values of Q shows that for higher value of Q the spectrum obtained (Fig. 7) is more close to the unfiltered signal (for frequencies other than power line frequency). Table 2 and 3 shows the change in position of peaks of QRS wave for different values of quality factor considered.

Removing 60Hz frequency Component

For Q=2

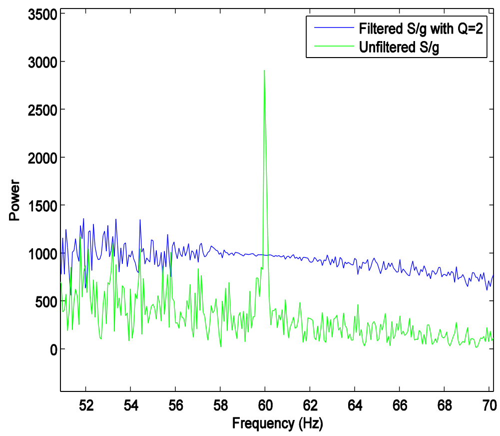

Fig.3 FFT spectrum of filtered and unfiltered ecg signal withQ=2

For Q=15

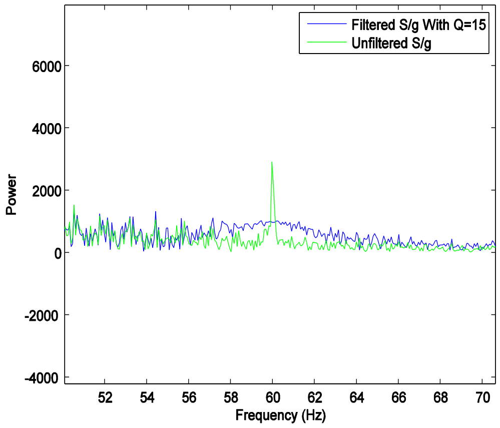

Fig.4 FFT spectrum of filtered and unfiltered ecg signal withQ=15

For Q=35

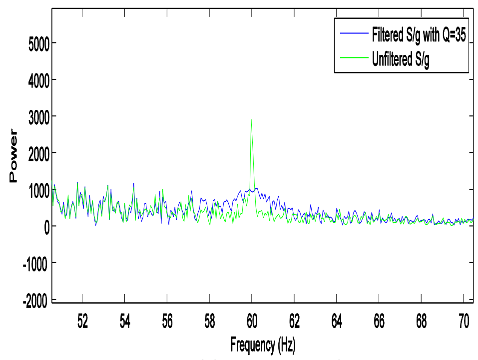

Fig.5 FFT spectrum of filtered and unfiltered ecg signal with Q=35

For Q=60

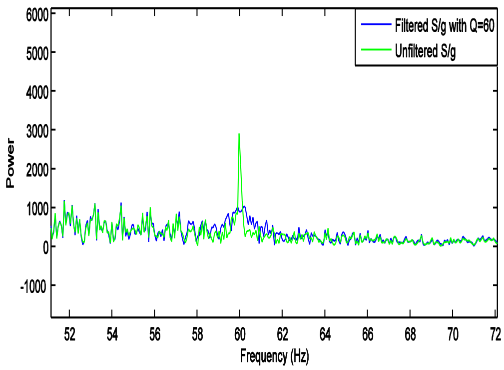

Fig.6 FFT spectrum of filtered and unfiltered ecg signal withQ=60

Comparison of notch filtered output of Q=35 and Q=15

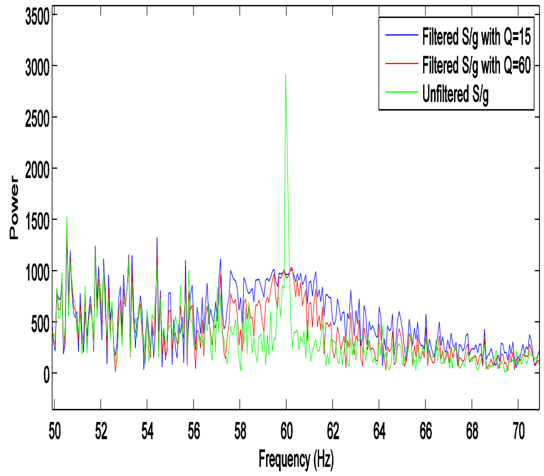

Fig.7 FFT spectrum Comparison of filtered ecg signal with Q=15 and 60

Table 2. Results showing Index no. of R-peak for Q-factor=2 and Q-factor=35

S.No.	Q Factor	Peak No	Index of R peak	Q Factor	Peak No	Index of R peak
1	2	1	5	35	1	
2	2	2	79	35	2	78
3	2	3	372	35	3	371
4	2	4	665	35	4	664
5	2	5	949	35	5	948
6	2	6	1233	35	6	1232
7	2	7	1517	35	7	1516
8	2	8	1811	35	8	1810
9	2	9	2044	35	9	2046
10	2	10	2404	35	10	2404

Table 3. Results showing percentage change in amplitude of R-peak for Q-factor=2 and Q-factor=35

S.No.	Peak No	Percentage change in amplitude
1	1	-
2	2	6.00785
3	3	1.225169
4	4	5.646113
5	5	4.500548
6	6	3.776180
7	7	5.628712
8	8	3.751535
9	9	2.838984
10	10	3.320069

VIII. CONCLUSION

For the filtering of power line frequency (60Hz for U.S.A and 50Hz for India) designing of notch filter is important step. Only after this we can extract various features from ECG signal i.e. R-R interval, Q and S peak, R peak etc. For notch filter designing the value of Quality factor is crucial. The FFT spectrum of filtered and unfiltered signal with different values of Q is shown above. As seen from the results, for low value of Q deformation of frequency spectrum is more as compared to the higher Q-factor. All the plots above reflect that for all values of Q, there is significant suppression of 60 Hz component. Results shown in table1 and 2 clearly indicate towards the deformation of QRS complex due to the notch filter used for suppression of power line frequency. It can thus be concluded that deciding Q-factor for the notch filter plays important role in its implementation.

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