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A NOVEL TECHNIQUE FOR DENOISING OF ECG SIGNAL USING EFFECTIVE HYBRID WINDOW FUNCTION

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ABSTRACT

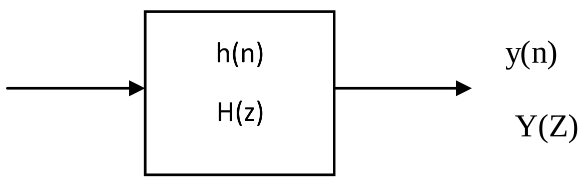
This project's main goal is to clean up the electrocardiogram signal, which has been tainted by white additive gaussian noise. During ambulatory patient monitoring in a wireless ECG recording scenario, the noise may interfere. So, a successful hybrid window function is established in order to achieve this goal. The suggested windowing approach is used to create a linear phase FIR low pass filter utilising a hybrid window function. Blackman and flattop windows are multiplied by hybrid windows, however the window coefficient is changed.Even at low SNR, receiving a noiseless signal is important for successful identification. The suggested hybrid window function's proposed filter has a qualifying transition bandwidth based on comparative study with other existing window functions. Even at low SNR, the ECG denoising is more accurate when filtered with designed hybrid window technique.The ECG denoising is more accurate even at low SNR when filtered using a specially developed hybrid window approach.

Key words: FIR filters, Electrocardiogram signal (ECG), Additive white gaussian noise, Hybrid window functions, Transition Bandwidth.

I. INTRODUCTION

Filters' primary function is to separate the undesirable signal from the original signal. These filters may be divided into two categories. Digital filters and analogue filters[6]. Among these, digital filters produce more precise results for giving the specified input signals legitimate outputs. These digital filters are easy to test and use on any workstation and do not affect any circuitry components. Digital filters are incredibly capable of reacting and maintaining their stability despite any changes in time and temperature. Digital filters are therefore essential to processing. FIR [5] (finite impulse response) and IIR (infinite impulse response) are the two main types of digital filters. The design aspects have a major role in filter selection. One of these, known as linear phase[20], prevents information loss. This indicates that FIR filters have linear phase characteristics and higher, more stable filter orders.

Since FIR filters lack the recursive component of a filter, they are also referred to as non-recursive digital filters. When the characteristics of the transfer function and its departure from the ideal frequency response evolve[17], the filter order and window functions are created.



$$H(Z) = \frac{Y(Z)}{X(Z)} = \sum_{n-0}^{N-1} h[n].Z^{-n} \text{..........} (1)$$

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II. ECG

The electrical activity of the heart as seen from key locations on the human body is reflected in the electrocardiogram signal, which is a quasi-periodic voltage signal. ECGs are real-time signals that are highly good at detecting continuously ambulatory patients. The equipment might keep track of cardiovascular patients' everyday activities and alert them if they have a cardiac arrhythmia. The input taken into account is the potential difference between the electrodes positioned on the surface of the body[1]. Researchers were able to create a lightweight system with low power consumption and cheap cost thanks to recent developments in networking technologies and wireless communications [2].

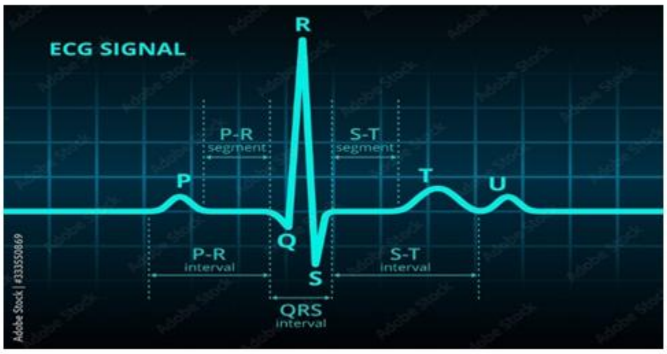

Figure.1: Electrocardiogram signal(ECG)

Amplitude		Duration	
P wave	0.26mv	P-R interval	0.10 to 0.20 sec
R wave	1.50mv	Q-T interval	0.34 to 0.45 sec
Q wave	25% of R wave	S-T interval	0.05 to 0.15 sec
T wave	0.1 to 0.5mv	P wave interval QRS interval	0.10 sec 0.08 sec

Table.1 Amplitude and Interval Duration of ECG signal

BASELINE WANDER:

The patient's breathing and movement cause this low frequency artefact to appear. Due to this impact, the entire signal shifts from its typical foundation, moving up or down instead of straight ahead[3].Its frequency is in the 0. 5 hz band.When the body is moving during an exercise session or a stress test, the frequency content of the bandwidth may rise. The baseline in the ECG may be estimated and removed using Finite Impulse Response (FIR) high pass zero phase forward-backward filtering with a cut-off frequency of 0.5 hz[3].

POWER LINE INTERFERENCE:

It features a 0.5Hz frequency-dependent interfering voltage. Loops in the patient's cable, loose connections on the patient's cable, and filthy electrodes all contribute to the interference, which is caused by the stray effect of the alternating current fields[2]. These noise's frequency ranges make it simple to identify. Low frequency ECG signals like the P wave and T wave are entirely superimposed[1]. So, we can eliminate this noise by using adaptive filtering[4].

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ELECTROMYO-GRAPHY:

Because of the strain on it and the pace of muscle action, high frequency noise exceeding 100 Hz has developed. The spectrum content of the muscular activity significantly overlaps that of the PQRST complex, making it impossible to eliminate using narrow band filtering techniques like baseline wander[3].

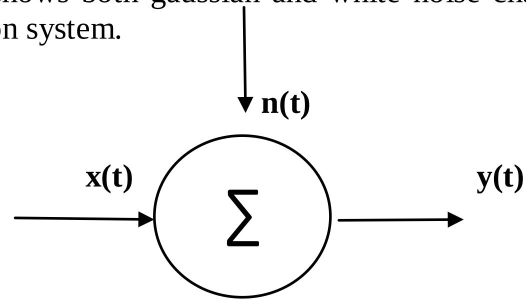
ELECTRODE MOTION ARTIFACTS:

Noise that results from the electrode moving in respect to the patient's skin is called a motion artefact.Utilise an accelerometer to measure body gestures while concurrently detecting the ECG to reduce background noise.

III. ADDITIVE WHITE GAUSSIAN NOISE

IV. A fundamental model in information theory is additive white gaussian noise. The word "Additive" refers to the fact that the transmission signal's values of noise signals are added to them, while "White" and "Gaussian" relate to the properties that imply the uniformity of the noise power and random amplitude values of thermal noise in time, respectively[4].

White gaussian noise is the name given to a random process that combines both gaussian and white characteristics, indicating that it shows both gaussian and white noise characteristics. Think about AWGN as a normal communication system.



Here consider x(t) is a transmitted signal and n(t) is a noise signal; y(t) is received signal. The addition of noise signal to the original signal is as additive noise[20].

$$y(t)=x(t)+n(t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

V. EXISTING WINDOW TECHNIQUES

RECTANGULAR WINDOW:

$$w_R(n) = 1; for\ -\frac{(l-1)}{2} \leqslant |\mathrm{n}| \leqslant \frac{l-1}{2}$$
$$0; otherwise$$

………… (3)

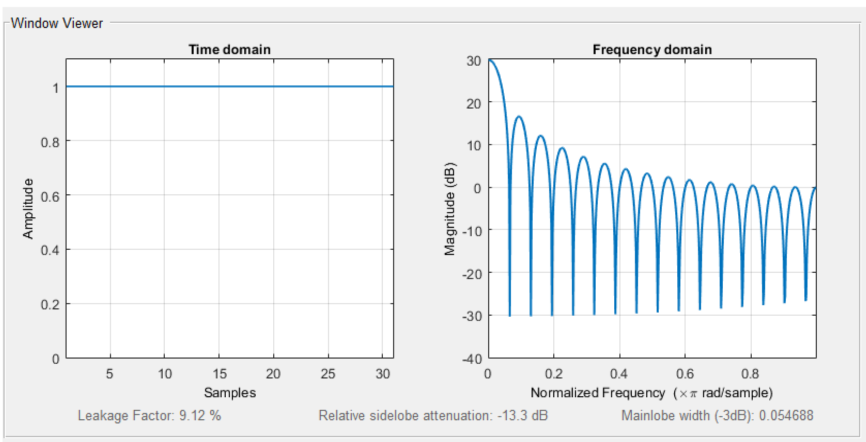


Figure 2. Time and Frequency response of rectangular window for l=31

RAISED COSINE WINDOW:

HANNING WINDOW:

$$w_{Hann}(n) = 0.5 - 0.5\cos\left(\frac{2\pi n}{l-1}\right) \qquad ;for\ n = 0\ to\ l-1$$

0 ; for other n .... (4)

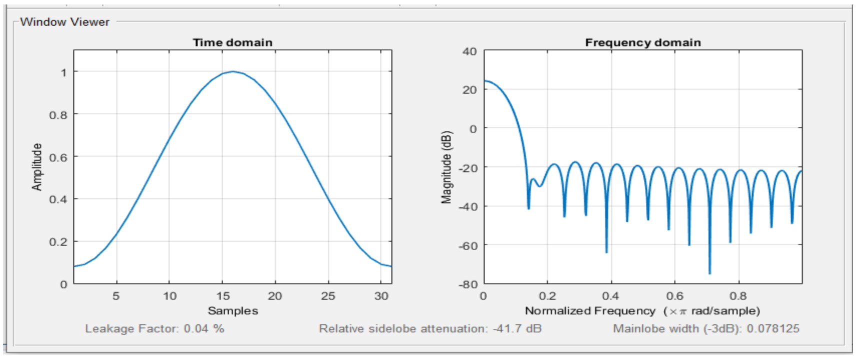


Figure 3. Time and Magnitude response of Hanning window for l=31

HAMMING WINDOW:

$$w_{Hamm}(n) = 0.54 - 0.46\cos\left(\frac{2\pi n}{l-1}\right); for\ \ n = 0\ to\ (l-1)$$

0 ;for other n

.... (5)

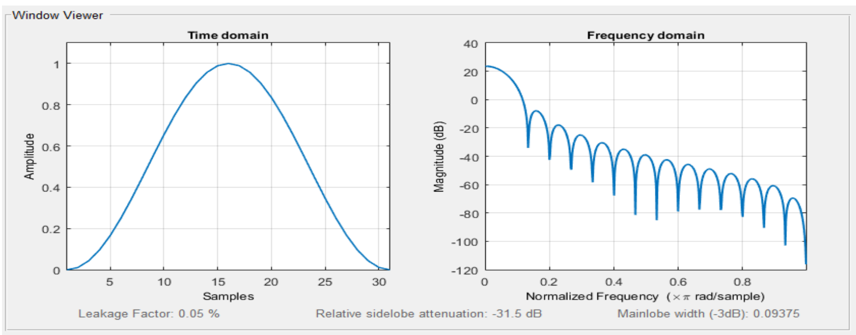


Figure 4. Time and Magnitude response of Hamming window for l=31

KAISER WINDOW:

$$w_{Ka}(n) = (I_o(b))/(I_o(a)); for\ -(l-1)/2 \le |n| \le (l-1)/2$$

0 ; otherwise

Where b=a$[1 - \left(\frac{2n}{l-1}\right)^2]^{0.5}$;

a = Tuning parameter,

....

(6)

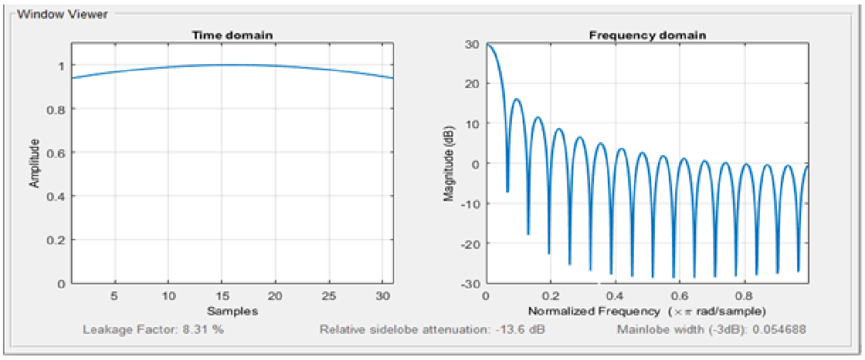


Figure 5. Time and Magnitude response of Kaiser window for l=31

BLACKMAN WINDOW:

$w_B(n) = 0.42 - 0.5\cos((2\pi n)/(l-1)) + 0.08\cos((4\pi n)/(l-1))$; for n=0 to (l-1)

0 ; for other n

…………… (7)

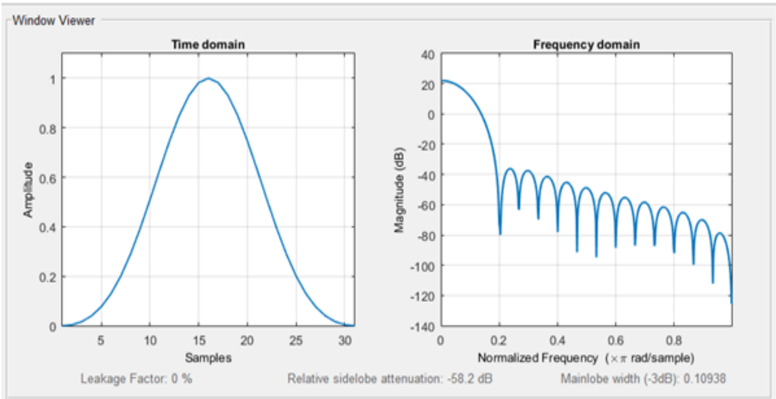


Figure 6. Time and Magnitude response of Blackman window for l=31

FLATTOP WINDOW:

$$w_F(n) = \delta_o - \delta_1\cos(\Psi) + \delta_2\cos(2\Psi) - \delta_3\cos(3\Psi) + \delta_4\cos(4\Psi)$$

where, $\Psi = \frac{(2\pi n)}{l-1}$; l = order of the filter,0⩽n⩽(l-1)

$\delta_0 = 0.2155789$, $\delta_1 = 0.4166316$,$\delta_2 = 0.27726316$, $\delta_3 = 0.08357895$.$\delta_4 = 0.00694737$ …………… (8)

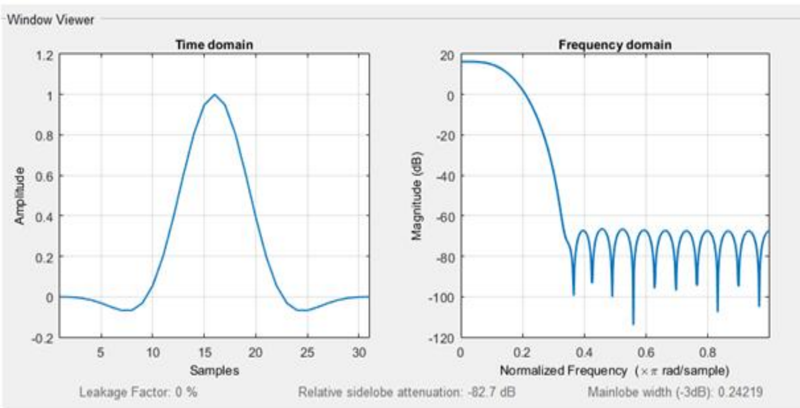


Figure.7 Time and Magnitude response of Flattop window for l=31

PROPOSED WINDOW TECHNIQUE:

The side beam attenuation characteristics need to be low for a window to operate better. If we compare Blackman and flattop among the currently used window approaches, they have side beam attenuations of -58.2 dB and -82.7 dB, respectively. Therefore, the end result of these windows is better.$w(n) = w_B(n) \times w_F(n)$

$$= \sum_{i=0}^{6} (\delta_i \times \cos(i \times \varphi))$$

……….(9)

The proposed window function is examined that the response of the blackman and flattop window functions are very smooth and flexible.

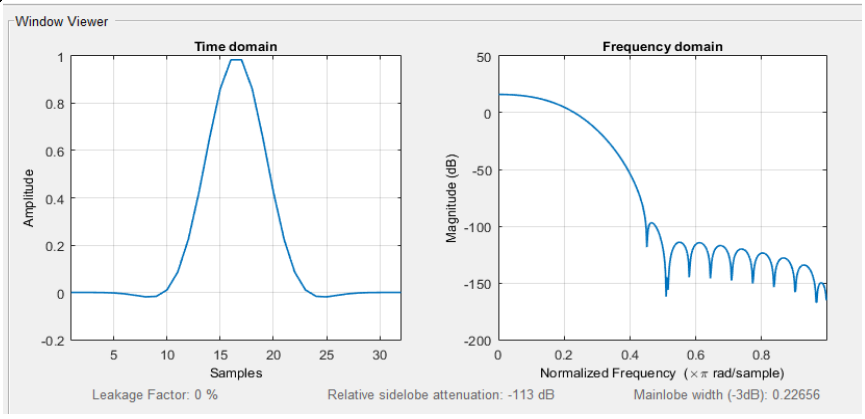


Figure. 8 : Time and magnitude response of proposed hybrid window function for l=31

The following are the benefits of flattop and Blackman windows:

1. Blackman and flattop windows have more terms in the window sequence function[9] than the remaining windowing algorithms combined.
2. The Blackman window function has additional cosine terms that can be used to determine the side lobes for improved performance. There will be an improvement in efficiency with no power loss by minimising the side lobes.
3. The precision of the Flattop window is superior than all other window features. Therefore, this will be a significant benefit for a window function that works[20].

Therefore, it follows that the Blackman and Flattop window techniques are superior to other window techniques and ideal for designing fir filters.

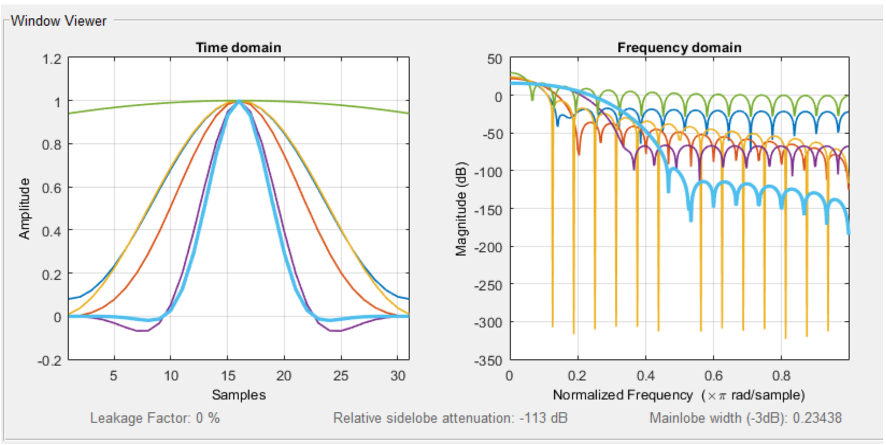


Figure.9: Comparison analysis of exiting window techniques with proposed window

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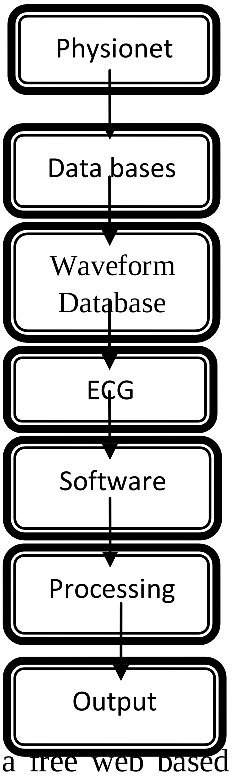
METHODOLOGY:



Step 1: Firstly, open physionet which is a free web based access to collect all different types of signals.
Step 2: From the physionet the available option is physionet bank in which the databases are stored for the processing.
Step 3: The waveform databases is collected from the physionet ATM in which it consists of various kinds of ECG signals with different specifications.
Step 4: From the specification listed, collect the desired ECG signal i.e. MIT-BIH arrhythmia signal[20] is selected for further signal evaluations.
Step 5: Load the ECG signal in software called Matlab and add noise to the original loaded ECG signal.
Step 6: Processing is done by denoising the signal using FIR filter[16] designed by the hybrid window function.
Step 7: At last, the outcome of filtered ECG signal is observed with-out any loss.

WINDOW SPECIFICATIONS:
The windowing coefficients can be calculated using a variety of variables. This measurements are processed using a programme called Matlab. The elements are carefully analysed and described in accordance with the window functions[20]. As follows:
MAIN BEAM WIDTH:
The minimal distance from the centre necessary to ensure that the window-transform magnitude never exceeds the designated side lobe level anywhere beyond the specific interval is known as the main lobe width. A extremely narrow bandwidth in the response is necessary to accurately depict tiny spectral features. Therefore, the test signal will be more distorted in the frequency domain the wider the main lobe.
2.SIDE BEAM ATTENUATION:

Attenuation of the side lobes that are present in a given window function's response is referred to as side beam attenuation. The windowing function's output is a mix of time and frequency responses, where frequency responses are made up of a combination of main lobes and side lobes. It ought to be as low as is practical.

3.LEAKAGE FACTOR:

In most cases, the term "leakage factor" relates to the result of windowing, in which each signal with a different type of window function will multiply by itself. Less of a proportion of leakage factor will exist for greater functionality[20]. Windowing is a technique that may be used to get around the problem of spectral leakage, which is a problem that is brought on by discontinuity in the original signal. The amplitude of the discontinuities at the boundaries of each finite sequence that the digitizer has acquired is reduced by windowing.

4. SIDE LOBE ROLL OFF RATIO:

As we can see in the time and frequency response of the window technique, the results of any window function include the existence of a greater number of side lobes.However, they roll-off, or become attenuated, with a specific frequency and rate factor. The windowing is chosen based on the side lobe roll off ratio's value. Therefore, it is predicted that the window with the highest side lobe roll of ratio will be the best choice for future design needs.

RESULTS AND DISCUSSIONS:

The results are obtained for various ECG signals i.e. MIT-BIH arrhythmia database like 100,107,115,118,124 signals which are different in amplitudes and timing responses.

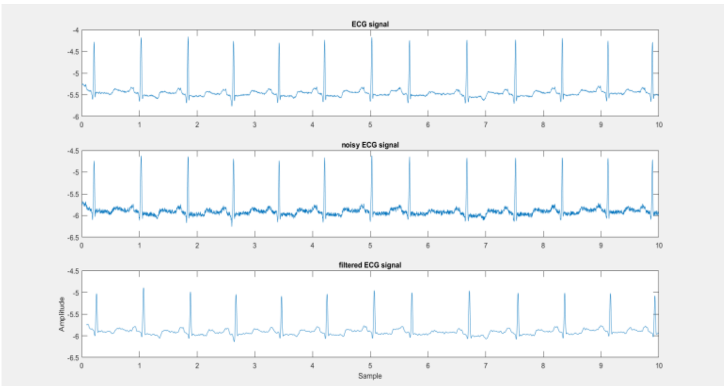


Figure.10: Proposed filter response for MIT-BIH arrhythmia (100m.mat) database

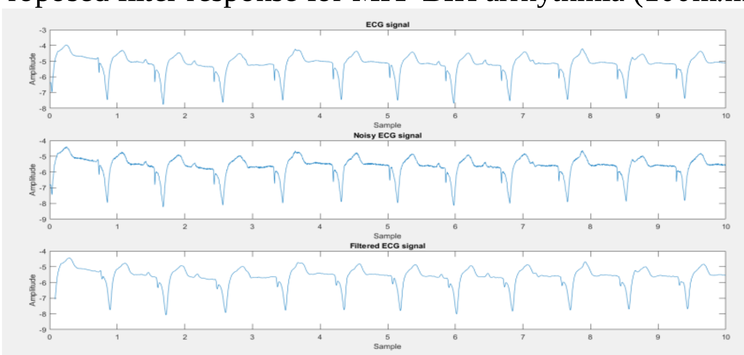


Figure.11: Proposed filter response for MIT-BIH arrhythmia (107m.mat) database

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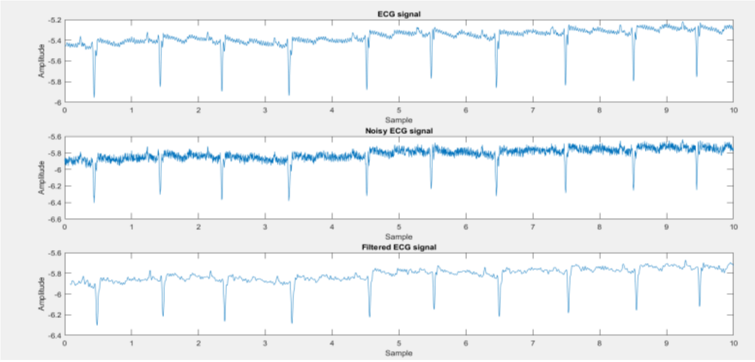

Figure.12: Proposed filter response for MIT-BIH arrhythmia (115m.mat) database

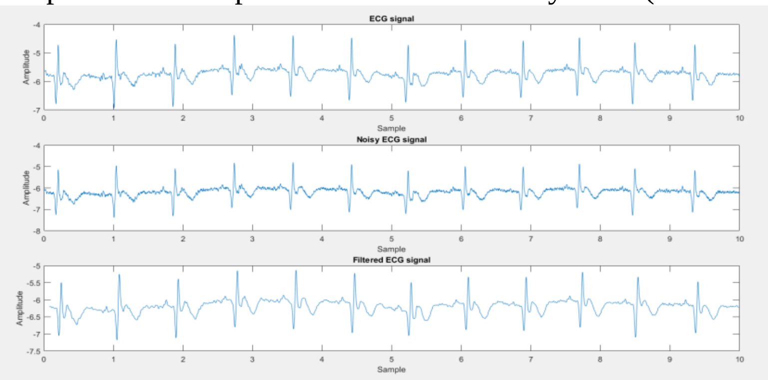

Figure.13: Proposed filter response for MIT-BIH arrhythmia (118m.mat) database

Figure.14: Proposed filter response for MIT-BIH arrhythmia (124m.mat) database

From the careful analysis it is decided that the various ECG signals are considered and for those ECG signals the additive white gaussian noise is added. From the Noisy ECG signal obtained we can denoise the ECG[14] which is corrupted by noise using various types of filters so for accurate results FIR filters[13] are the best suitable technique used to remove the noise added to the original signal.
Various techniques are used to design FIR filters, but windowing analysis yields the best results[18]. So, using the two window technique, an effective hybrid window function can be created from the existing window functions. In order to reduce the greatest amount of noise present in the ECG data when processing into the visualised electrical machines, a filter is created utilising this window function and the necessary filter coefficients.

OBSERVATIONS

WINDOW	SBA(dB)	MLW(3dB)	LF	SLRR
Blackman	-58.2	0.10938	0%	-18dB

Flattop	-82.7	0.24219	0%	-6dB
Rectangular	-13.3	0.054688	9.12%	-6dB
Hamming	-41.7	0.078125	0.045%	-6dB
Hanning	-31.5	0.085938	0.05%	-18dB
Kaiser	-13.6	0.054688	9.31%	-6dB
Proposed	-113	0.23438	0%	-6dB

Figure.15: Comparison table of all window functions with proposed window function

CONCLUSION

As of right now, it has been determined that the suggested window function provides a lot of benefits when it comes to creating FIR filters to eliminate noise from ECG data. Due to many types of influences, such as an ambulatory patient's location, the distance between the electrodes and the skin, etc., random noise has the potential to contaminate an original ECG signal in biomedical applications. Therefore, we must employ the appropriate techniques for designing filters in order to remove the noise present in the signal. Windowing is the greatest technique for creating FIR filters because it produces filters with strong main lobe width and low side lobe attenuation, and it is particularly useful for creating prototype filters like low pass, high pass, band pass, and band reject filters. The data show that the suggested window has the benefit of having reduced side lobe attenuation and that the main lobe width decreases with increasing length. The primary aspect taken into account is the leakage factor. In comparison to all currently installed windows, the suggested window has a leakage factor of 0%, making it more appropriate for correctly creating a FIR filter.

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