

BIOLOGICAL SIGNALS FILTERING IN FREQUENCY DOMAIN

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Abstract

Use of computer methods of signal processing enables the use of advanced techniques for filtration of the recorded bio-signals. Usually, IIR or FIR digital filters are used for single modification; however, the filters have their limitations and do not always satisfy the processing requirements. Many more possibilities are offered by modification of the Fourier image of the signal, which allows almost unlimited changes of spectrum in the frequency domain. In compliance with several rules, it is possible to modify the signal as well as when using an ideal filter with almost infinite slope and infinite suppression in the stop-band. The filtration of this type is particularly suitable for the suppression of typical disturbing frequencies such as 50Hz mains.

1 Introduction

Almost every biological signal obtained by measuring from the human body contains unwanted disturbance (distortion). This signal is partially corrupted and usually cannot be used for arriving at the right conclusions. Therefore it is necessary to perform filtration, which conveniently suppresses the disturbance and does not significantly damage the record (signal). Due to the low voltage potentials, which we try to record in biological measurements, it is difficult to achieve sufficient signal to noise ratio. One very common and frequent event (phenomenon) is leakage of network interference to measured biological signals. The method under review was designed precisely for purposes of suppressing this very narrow-band disturbance, and it achieves better results than classical digital filters, particularly in these applications.

2 Description of the Method

In this type of frequency filtration, the first step is to create a Fourier image of the signal, which is done by Fast Fourier transformation (FFT). Because of the difference between Fast Fourier transformation that works with discrete samples and the Fourier transformation that uses continuous time signals, this step is associated with few problems. The FFT algorithm works natively with 2^N number of samples. Although it is not necessary to adhere to this rule, the transformation computes more effectively when it is kept. Another bigger issue is spectral leakage, which is related with finite-length signals. The frequency resolution is limited by the number of samples and so when the energy of a particular signal lies between the frequency bins, its energy leaks into neighboring bins. To avoid this phenomenon at the frequencies of our interest, we must ensure the following equation (Eq. 1) to be valid. The cutoff frequency is the interest frequency for the filtration. Unfortunately, it is not possible to assure this in all frequency spectra. To reach that demand we are able merely to change the number of transformed samples. Because we do not want to lose any information, we can make the original signal longer by adding some samples. We arrived at two reasonable possibilities: to add zeros or to repeat part of the original signal from the beginning at the end of the signal. Both methods have their benefits. Adding of zeros causes interpolation of the frequency spectrum, but cuts the periodicity of continuous signals. Repeating of the signal itself causes not only interpolation of the frequency spectrum but also adds an amount of power to the frequencies contained in repeated part. The advantage is that continuous signals are not interrupted and periodicity is maintained. Every method is useful in different situation and it's not possible to decide which is better. Comparison of methods used for add samples is demonstrated to the synthesized signal with similar properties as the ECG signal. In this case is better suited to repeat part of the original signal which is evident from the waveform (Fig. 5) and PSD (Fig. 6).

$$L = N \frac{f_s}{f_c}$$

Eq. 1: Equation for the periodic sampling signal

*L – length of signal (number of samples), N – natural number,
f_s – sample frequency, f_c – cutoff frequency (frequency of interest)*

In the next step we can perform several modifications of the spectrum in the frequency domain. Usually we wish to suppress distortions, which have their own typical frequencies. The area around 50 Hz where interference from the electric power distribution network occurs is the most common distortion. We must pick the right bins for modification on both sides of spectrum. Changes in the frequency domain must be symmetrical by zero frequency, otherwise the inverse transformation is not correct. Thanks to this method of filtering, we can realize an almost ideal filter with nearly infinite suppression in the stop-band or we can change the power of these bins to the average of surrounding area to suppress distortion but not to lose information. We also can increase the magnitude power of certain wanted frequencies. After all the modifications are completed, we can attempt the next step. Now we must transform the signal from the frequency domain back to the time domain. This is done using Inverse Fast Fourier transformation (IFFT). If every modification was correct, the product of the inverse transformation should be the extended filtered signal. By cutting off the added samples we obtain the corrected signal that we wanted.

3 Comparison of results

As stated, this method of frequency filtration has benefits especially in applications like the narrow-stop-band filter. Other methods used for this task are FIR stop-band filter or IIR Notch filter. As we see in the graph of the ECG signal (Fig. 1) disturbed with 50 Hz frequency from the electrical

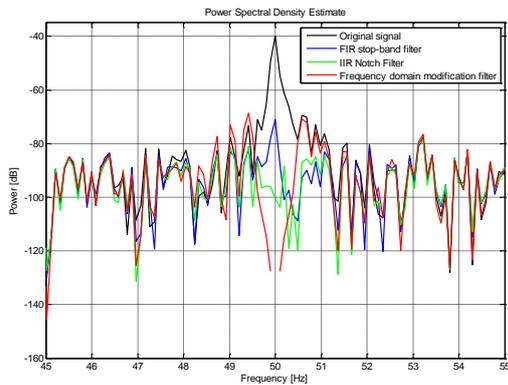


Fig. 1: PSD of signal filtered by various narrow-stop-band filters; discontinuous of the red waveform is caused by negative infinity value at 50 Hz

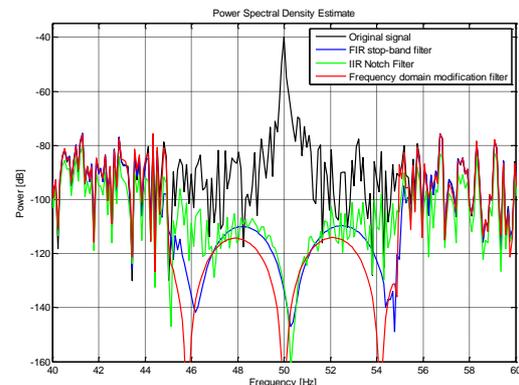


Fig. 2: PSD of signal filtered by various wide-stop-band filters

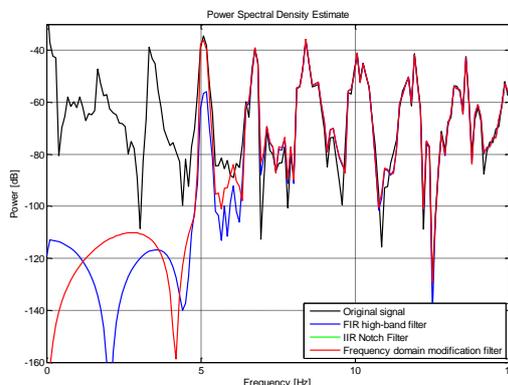


Fig. 3: PSD of signal filtered by various high-pass filters;

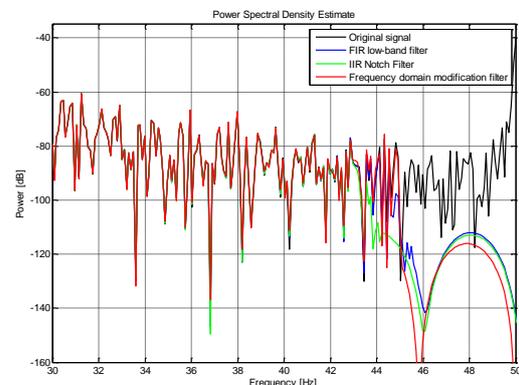


Fig. 4: PSD of signal filtered by various low-pass filters

grid, suppression of this method is higher than other ones. When we used filters with bigger bandwidth

(Fig. 2), the differences are likewise not as noticeable as in the high-pass (Fig. 3) or low-pass (Fig. 4) filters. The advantage of the frequency domain modification filter always remains the nearly infinite slope in cutoff frequency. The disadvantage is the spectral leakage issue, meaning that if we want to realize wide-band filters like pass-band or stop-band, it is better to do so in two steps with different signal lengths (number of samples) suitable for the required cutoff frequency.

4 Conclusions

Every time when we want to filter a specific signal, we need to know which frequencies are required and what modification can be performed without losing the information. It is also preferable to know what the pitfalls of the selected method are, such as example the nonlinear phase shift of IIR filters or the relatively higher delay of FIR filters. Not even this technique of filtration is free of any disadvantages. It is impossible to use this method for online filtration, and additionally it is computationally more demanding. Another inconvenience is the changing of signal length for FFT due to prevention of spectral leakage in the band near to the cutoff frequency. On the other hand, the greatest advantage is its high power suppression in narrow-stop-band applications, which makes it common for bio-signal filtration without significant deformation of the neighboring band. Each time we use the frequency domain modification filter we must decide which method of adding samples is optimal. The most suitable way is to check PSD estimate of output signal (Fig. 6).

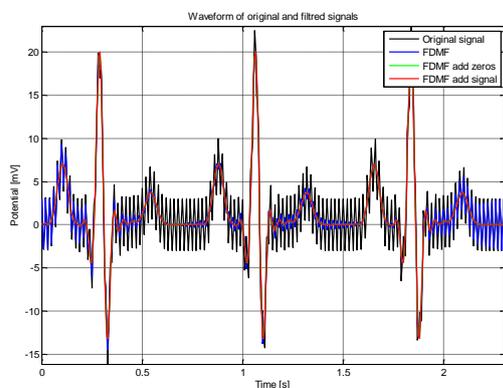


Fig. 5: Comparison with untreated signal filtering and signal length appended with zeros respectively repeating part of the last period

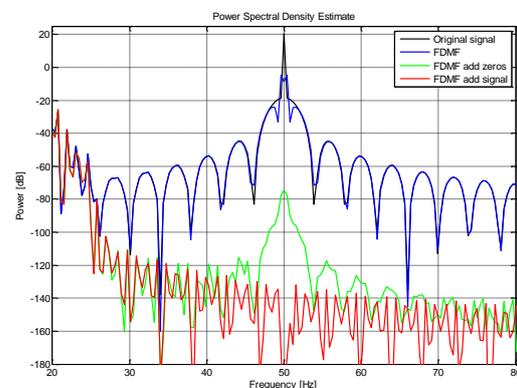


Fig. 6: PSD of signal filtered by various methods of the frequency domain modification filter

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