

Plots and Explanations

Cross-Correlation with unfiltered data

From the cross correlation of 20 msec of data we can see the evidence of at least one signal, that can be perceived by the peak value of the cross-correlation array. But for time windows of 100 msec and 500 msec we see the evidence of more signals present in the data, as there are more peaks for 100 msec as compared to 20 msec and even more for 500 msec window.

Cross-Correlation with filtered data

Next we applied the butterworth band-pass filter to our data, in the range of 64 and 2048 Hz. Therefore, our data is whitened now. When we perform cross-correlation on our whitened data with different time windows, we can see many more signals present in the data. For 20 msec time window, there is evidence of at least 2 signals being present in the data. For 100 and 500 msec time window there are many more signals visible.

Comparison between unfiltered and filtered data

20 msec Time Window

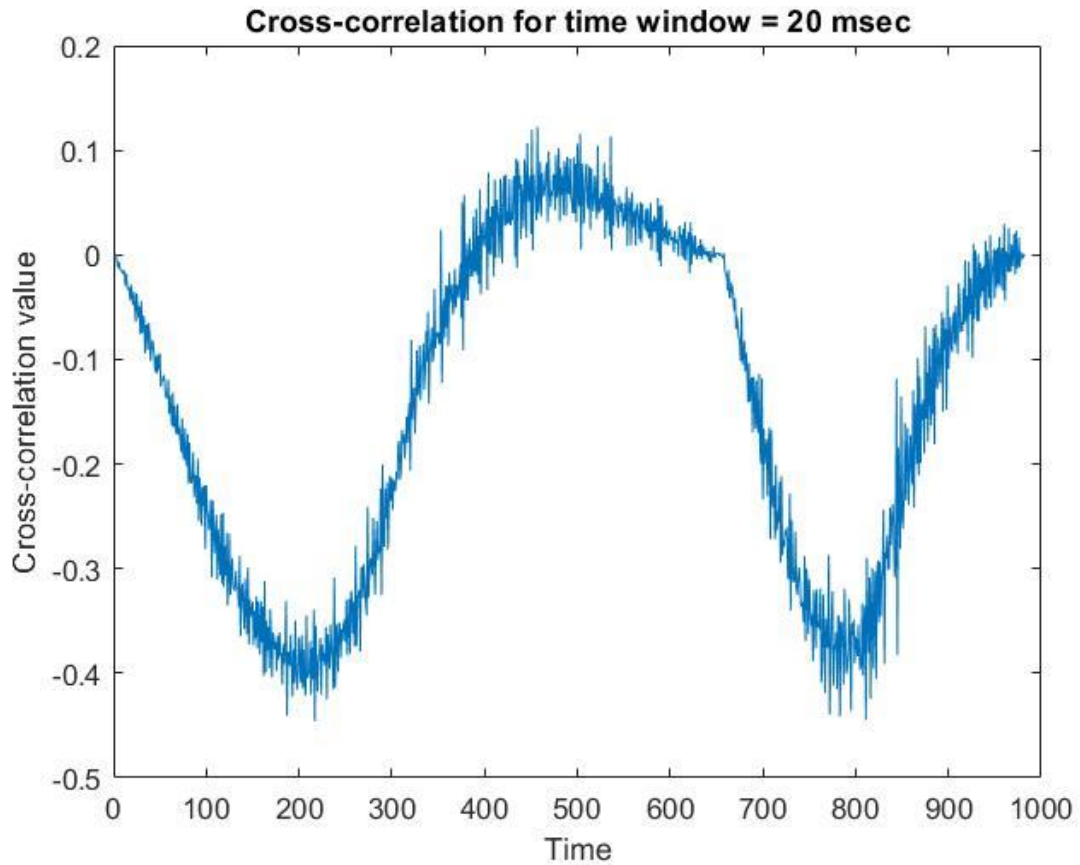


Figure 1: Cross-correlation for time window length of 20 msec with Time (seconds) in the X-axis and Cross-correlation value (normalized) in the Y-axis

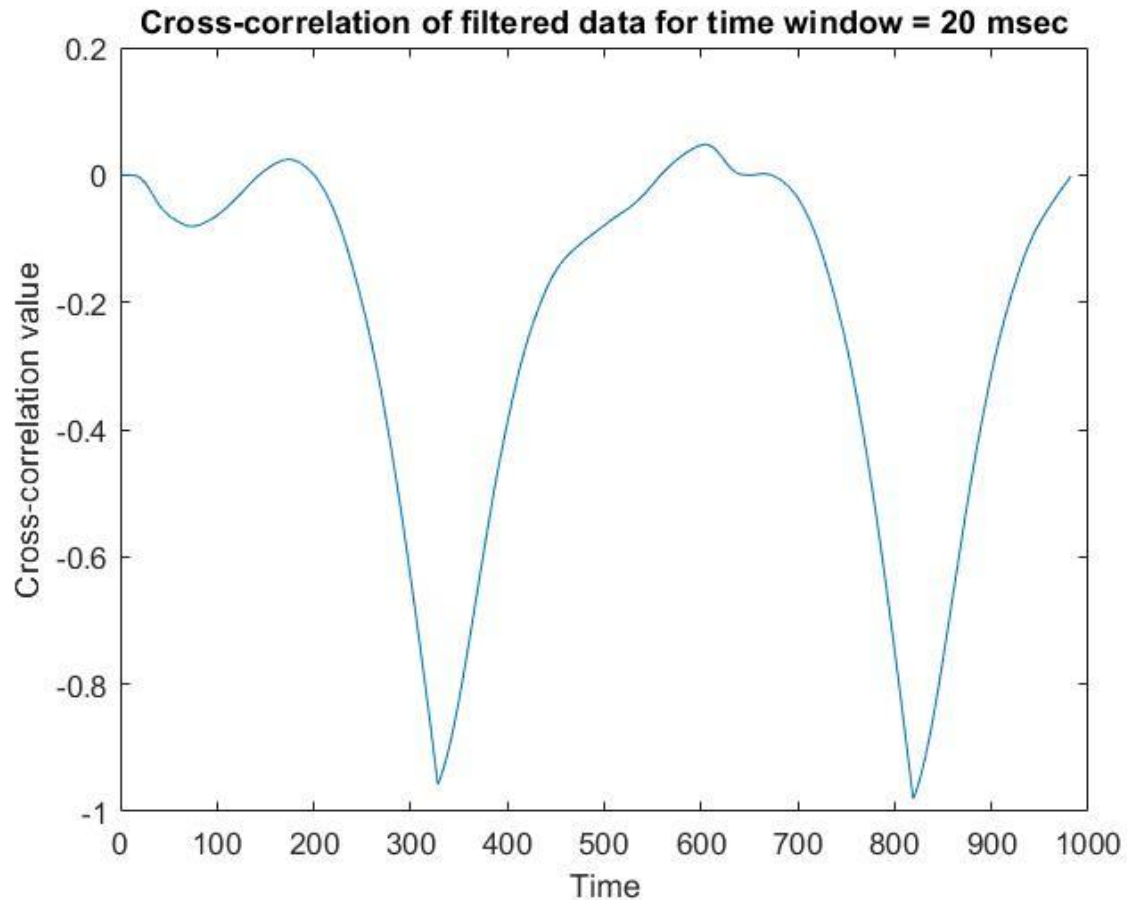


Figure 2: Cross-correlation of filtered data for time window length of 20 msec with Time (seconds) in the X-axis and Cross-correlation value (normalized) in the Y-axis

Comparing between the unfiltered and unfiltered data for 20 msec time window, it is evident that the data is much cleaner after filtering. Due to the noise outside of our filtering frequency range the first signal in the data could not be seen in the cross-correlation, which has been recovered in the filtered data.

100 msec Time Window

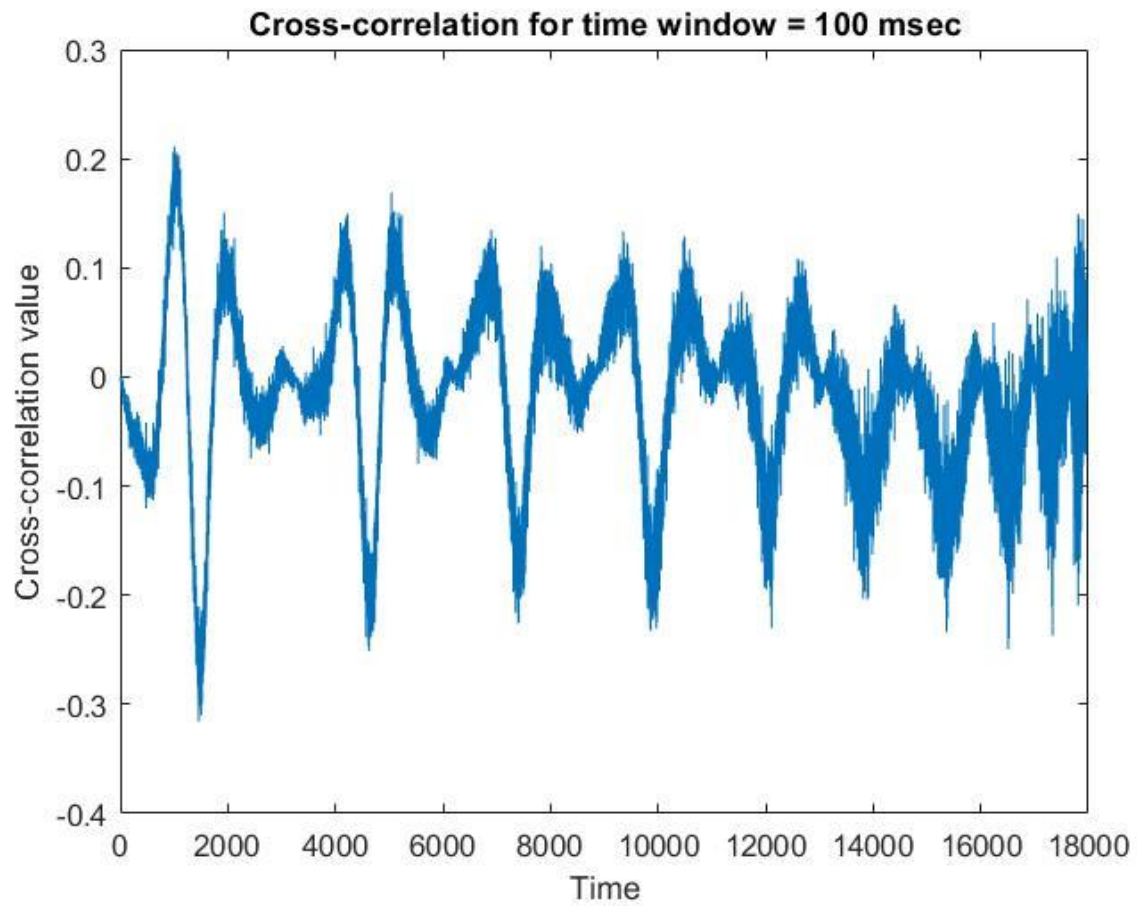


Figure 3: Cross-correlation for time window length of 100 msec with Time (seconds) in the X-axis and Cross-correlation value (normalized) in the Y-axis

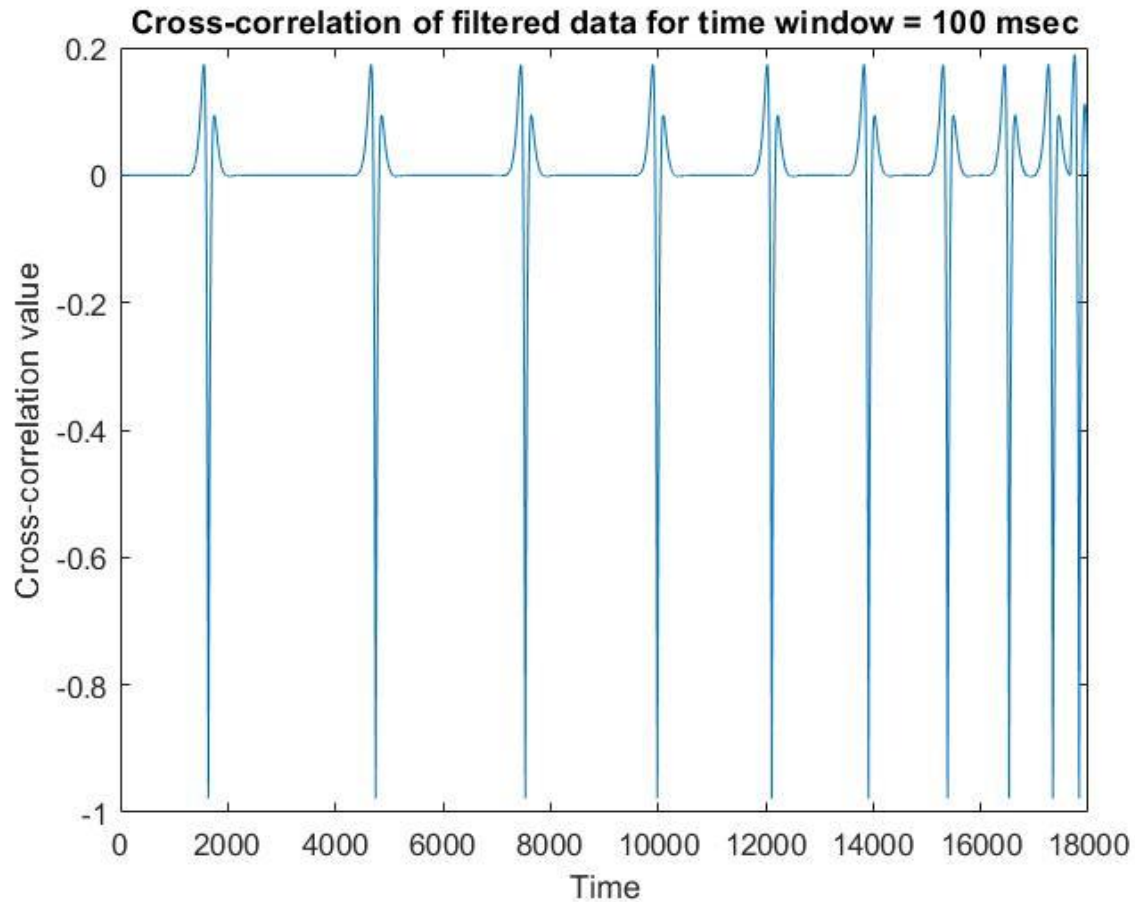


Figure 4: Cross-correlation for time window length of 100 msec with Time (seconds) in the X-axis and Cross-correlation value (normalized) in the Y-axis

We observe similar improvement in the filtered cross-correlation with 100 msec time window. Although at the beginning the cross-correlation with raw data showed good evidence of presence of signals, it was difficult to find and count the number of signals present at the end of the data, which is due to the noise present outside of the 64 to 2048 Hz range. On the other hand, after filtering, the cross-correlation is very clear in terms of peaks and showing the presence of signals in the data.

Comparing between 20 msec and 100 msec time windows, the 100 msec time windows gave us the evidence of many more signals than with 20 msec windows.

500 msec Time Window

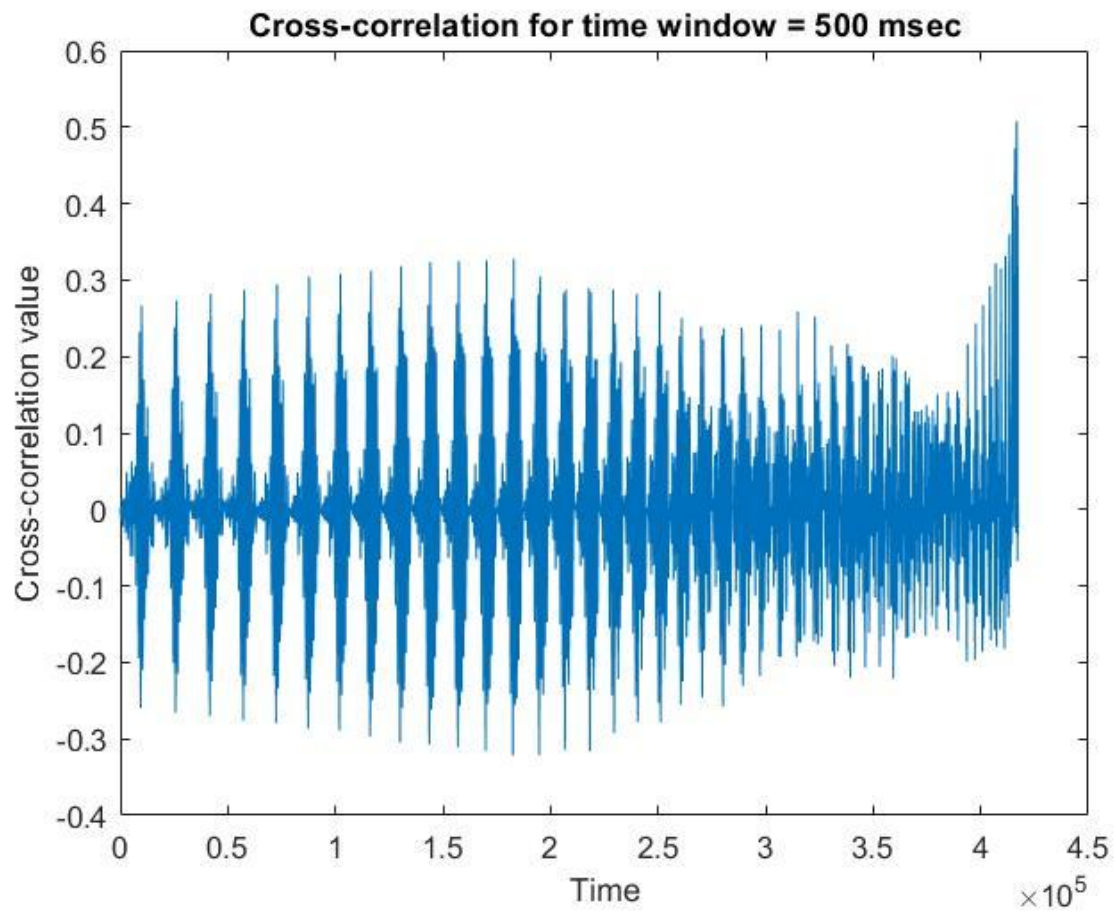


Figure 5: Cross-correlation for time window length of 500 msec with Time (seconds) in the X-axis and Cross-correlation value (normalized) in the Y-axis

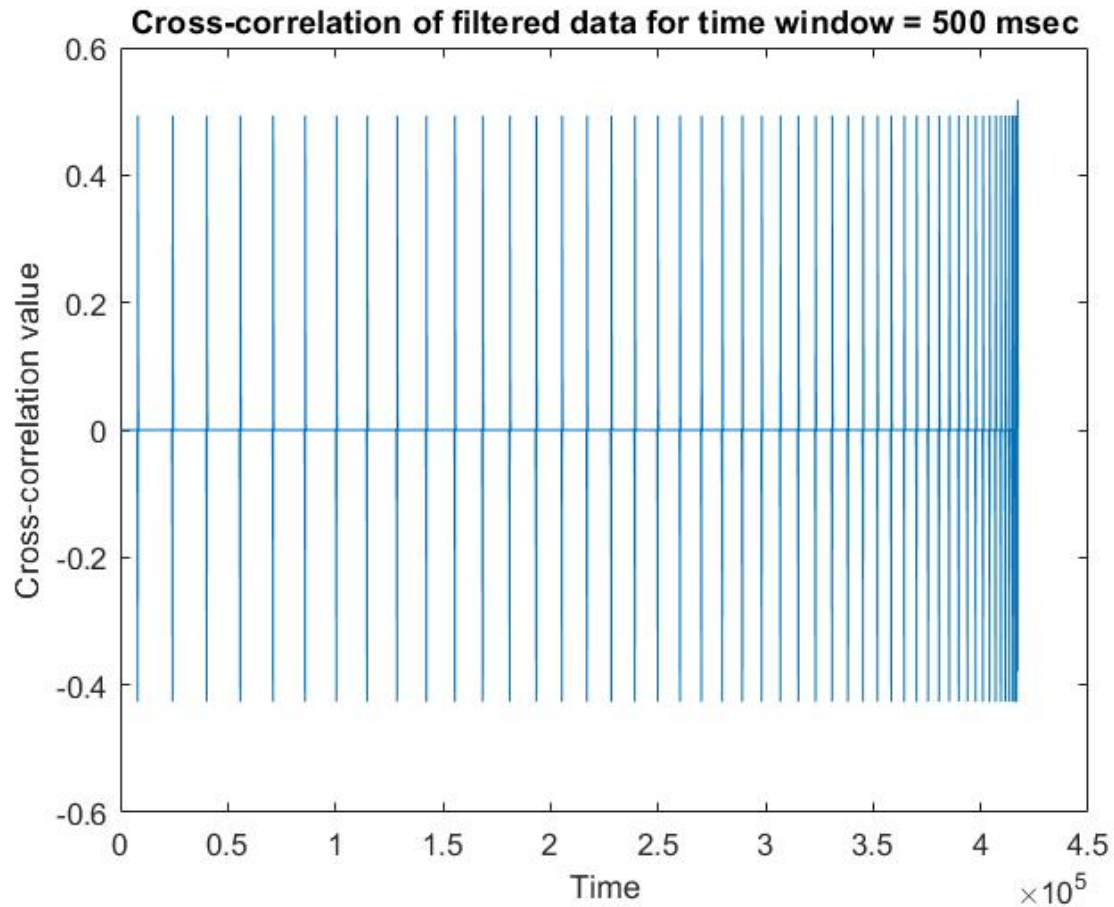


Figure 6: Cross-correlation for time window length of 500 msec with Time (seconds) in the X-axis and Cross-correlation value (normalized) in the Y-axis

Now we see the difference between the cross-correlation with unfiltered and filtered data using 500 msec time windows. As the previous two, in this case too the filtered data shows much clear evidence of signals as compared to unfiltered data. The cross-correlation of filtered data is very well defined than the unfiltered data.

We also notice that the 500 msec time window provided us with more signals as compared to the two time windows used previously.

Signal Strength

Another observation that is common for all the time windows is that the cross-correlation values of the filtered data are roughly the same for each time intervals along the data. This indicates that the signals embedded in the time series are all of the same strength. The unfiltered cross-correlation did not show this feature because of the noise interfering with our signals.

Effect of time window length on cross-correlation

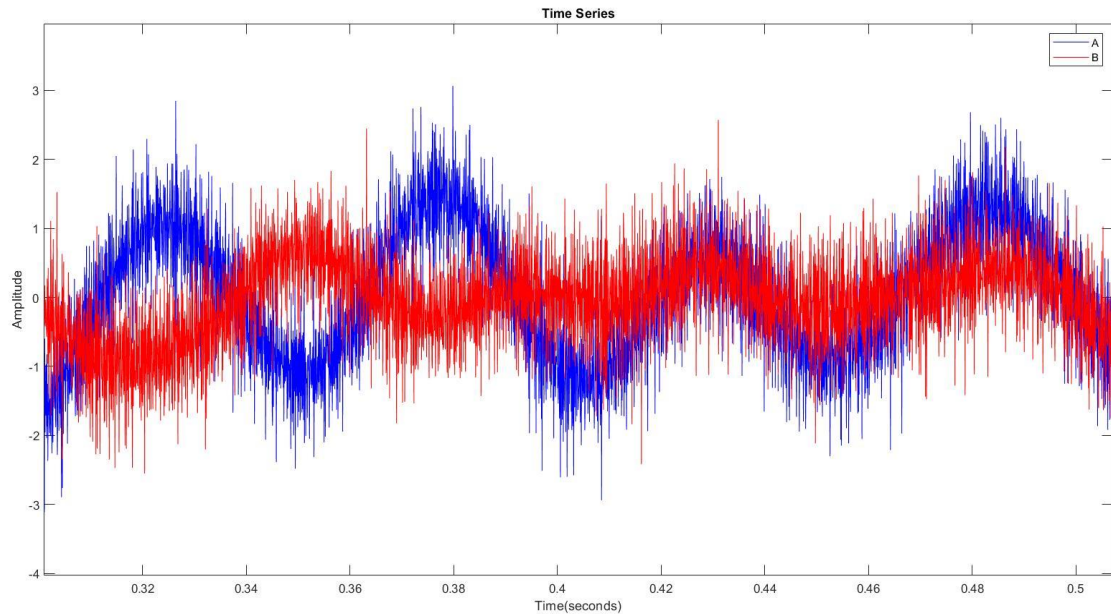


Figure 7: Time Series of raw data A and B

Here we can see a small portion of the plot of raw data A and B on top of each other. It is clear from the plot that in some parts the cross-correlation values are negative and in some parts it is positive. If we look closely, it is noticeable that for 20 msec time window the cross-correlation values will be either exclusively positive or negative. For example, between times 0.34 seconds and 0.36 seconds (duration = 20 msec), it is easily evident that the cross-correlation will have negative value. Therefore, despite being a larger number of signals present in the data it is not evident from the cross-correlation plot. However, when we increase the time window length to 100 msec and 500 msec respectively, this issue is resolved. That is why we can see the evidence of more signals present in the data. Therefore, it is important to adjust the length of time window according to the nature of our data and the analysis we desire to perform on it.