Biomedical Signal Processing
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Lecture - 17
Artifact Removal (Contd.)

So, now we will sum up that that the different techniques we have gone through for the removal of artifacts.

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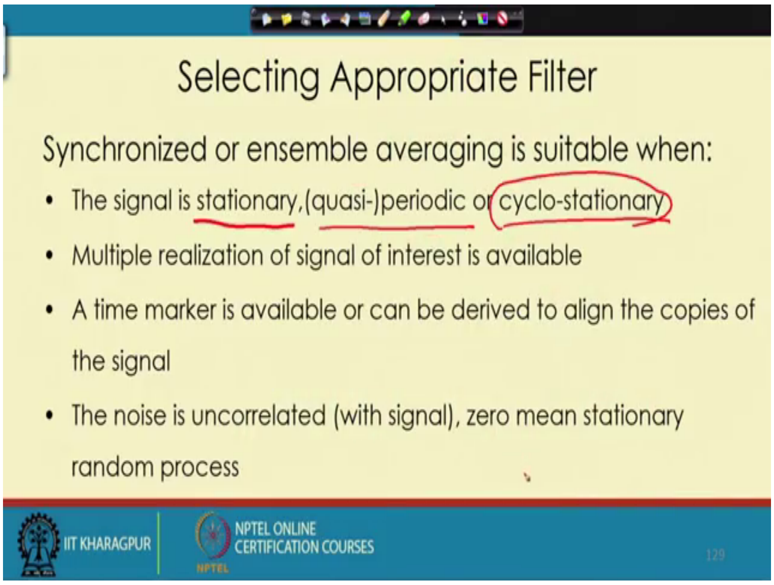

First will go for the time domain technique, that is synchronized or ensemble averaging what you see that it is a effective technique, when signal is stationary or quasi periodic or cyclo-stationary. What do you mean by that that stay here the by stationary you mean that it is at least weak cell stationary or if it is periodic, it is not exactly periodic that it is the periodicity is slowly changing. So, it is quasi periodic that slightly changing and if the; that the articulation function they are that periodic in nature then the signal is called quasi cyclo-stationary.

So, if a signal is periodic, then we get this condition of cyclo stationarity. So, if it is stationary quasi stationary or cyclo-stationary, that that condition it will first fulfilled. The next actually condition that we need to full fill it multiple realization of the signal of interest is available, it can come from multiple experiments just like that we can perform the experiment of throwing a dye or throwing a coin, number of times and take the ensemble average.

Same way for the biomedical signal we should have multiple realizations of it, but sometimes it becomes a challenging task in that case, what we could do we can take actually the experiment over the time and take the period say for example, in case of ECG what we could do? We can take one cycle at a time and those cycle that we can take as each cycle as a separate ensemble and taking them as multiple realizations of the same signals, then we can actually apply the synchronous averaging.

And now to do this averaging, another important thing a time marker is required why that is required? We have to align the copies of the signal unless we align them properly; the averaging will actually destroy the signal of interest. Because the alignment is very important to have that the signals of interest should add up with each other and should not destroy it. So, for that that alignment is very much required and for that we need a reference what time marker. Then next the assumption what we have to meet is that the noise is uncorrelated with signal the noise what we are trying to remove from the signal of interest, it is uncorrelated with the signal and it is also a zero mean stationary random process.

So, you see there are number of actually that assumptions of number of requirements that stationarity, uncorrelatedness of the signal and the noise should be zero mean then we need multiple data for multiple realization of the signal and a marker for reference is required for the alignment of the signal. Now this technique is very good if we can meet all these condition, but in many cases it could be difficult to meet all the condition and as we need multiple data that having the real time operation could be a very difficult task. In fact, that is impossible if that we have to find out the reference for the time marker. So, we will look for the other technique which we expect to be a little more flexible.

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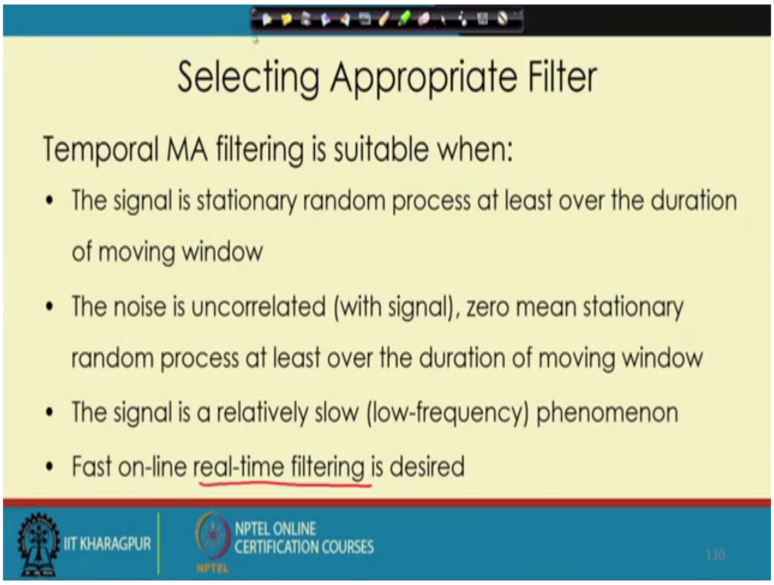

The next important actually the type of filter what we have taken is temporal MA filter it is suitable, again when the signal is stationary at least over the duration of the moving window we have a duration of the that the moving window filter or the m a filter at least over that period it should be stationary and again noise should be uncorrelated with the signal and zero mean stationary process, again at the it should be stationary, at least over the duration of the moving window. Next with a that the signal is relatively slow frequency phenomena; that means, that m a filtering and as well as the synchronous averaging in both the case that, what we are assuming that here the signal should be slowly changing and the noise is having high frequency, so that by the averaging that the effect of noise could go down ok.

That is the averaging is a low pass filtered operation, the noise is eliminated by that averaging or the implicit low pass filtering by that and m a filter is one of the that main attraction is it is for fast online real time filtering, when it is desirable then m a filter is very good. Because it actually acts on the present data and few past data so the competition is low, and that way that it is possible to stop the signal in real time. So, now, we look for the next technique that is a frequency domain fixed filter.

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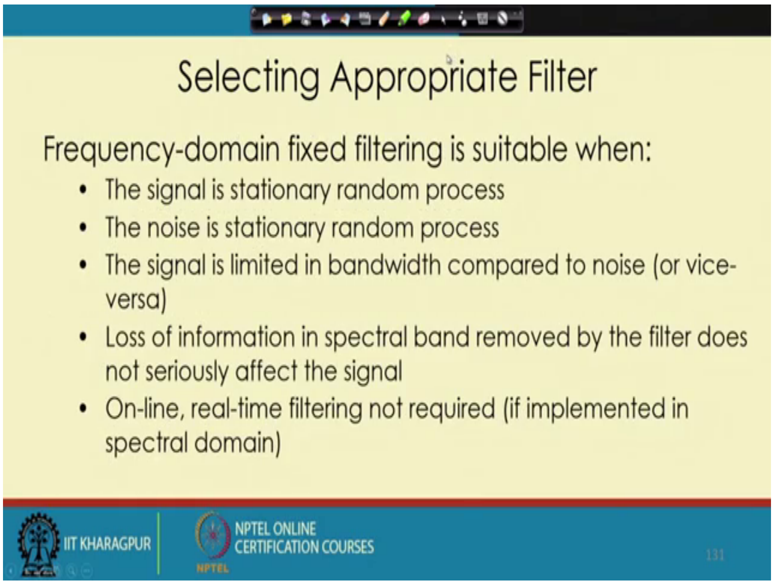

Now, we have seen that we can have that the filter design in the frequency domain, and we can apply it on the that observe signal to remove the that artifact of the interfering noise. Now again in this case what we need that the signal should be stationary, random process the noise should be stationary random process, and signal is limited within the bandwidth compared to the noise; that means, there should be a separation of that the bandwidth between the signal and the noise. If they are having actually more overlap it will be difficult actually for that frequency domain filter to work effectively or to remove the noise.

Because in that case its not possible to eliminate the noise without losing some part of the signal and they are by we prefer that the signal should be band limited, and there should be somewhat separation between the spectrum of the signal and the noise. Now they are the loss of information in the spectral band, removed by the filter does not seriously affect the signal. So, that again we are entering actually a emphasizing that thing that even if some overlap is there that overlap should be minimize. So, that when we remove the noise and thereby we take out some part of the signal spectra that should have very less energy. So, let it does not affect the signal itself.

And some of the frequency domain filtering that is actually not suitable for that frequency domain filtering the most some of them they are not good for online or in real time filtering, because if the implementation is in the spectral domain in that case you have to wait for the block of data then once to get a block of data the Fourier transform is applied to get the spectral content, and then after removing the noisy component we have to perform the inverse Fourier transform to get back the signal. So, as that is a block process it is not suitable for the real time filtering.

So, now how about if you have a time domain filter designing the frequency domain. So, that is like any other MA filter and that can be applied on the real time.

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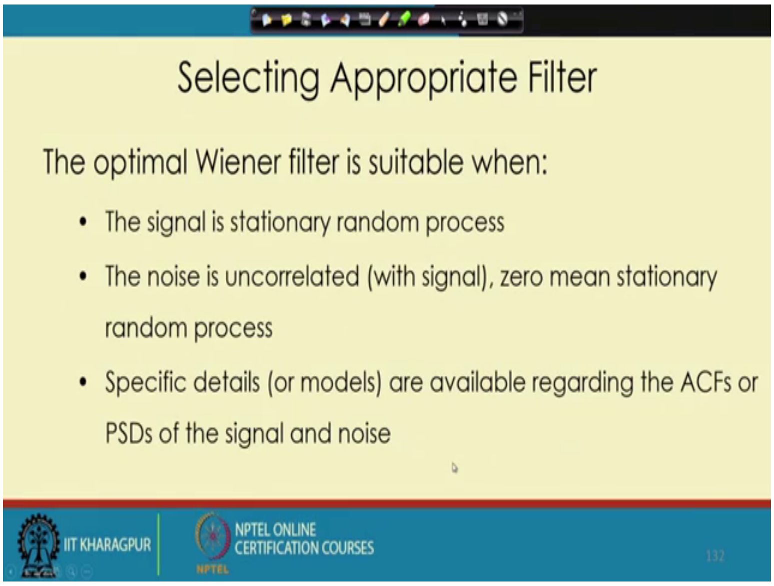

So, let us move next. Now we go for the optimal filtering or wiener filter. Here again the requirement of stationarity of the signal and that of noise is maintained the signal and the noise should be uncorrelated and the noise should be zero mean. So, these are the condition we need to meet and we also need some more information some specific detail of the autocorrelation function or the power spectral density of both of the signal and the noise. Now the benefit is in this case that if we know the s e a for the spectral characteristics of the signal and the noise we can design the optimal filter.

And with the added information, we can have the best possible filter implementation for the stationary signal corrupted with additive uncorrelated stationary noise. And compared to the previous filter the error would be minimal and we get the best possible output in this way.

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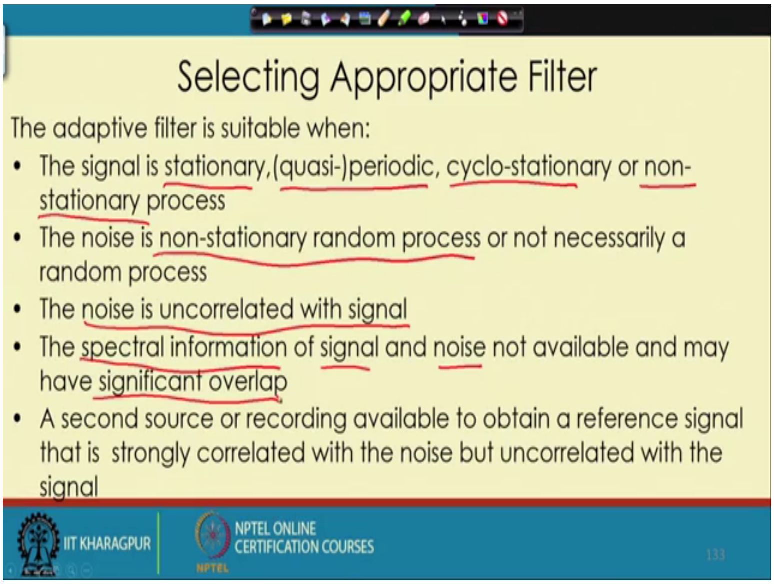

Now, let us look at that the most advanced one, that is the path what we have covered at the end that is the adaptive filter, in this case the least amount of constant or assumption is there in the signal. So, signal can be stationary, quasi periodic, cyclo-stationary or you could does not fit any of these definition then we can tell it is a non stationary process.

Same way the noise is also can be in a non-stationary random process, not only that that it could be stationary also and if it is not a random process if it is a deterministic noise then also we can go ahead with this technique. So, what is the constant really here in this case? The noise is uncorrelated with a signal you see for all this technique that this is one constant that remains same that noise should be uncorrelated with the signal of interest next the domain what is made by the wiener filter to get the optimality, that the spectral information of the signal and the noise that is not required anymore, and in this case even if both has actually significant overlap in the spectral domain still it can work.

It can give the best possible and search way we know that if they are separated in the spectral domain it will always give any filter will give a better output, and one more actually information is required we need a second source. A second source or recording is required the recording of what a reference signal, which is strongly correlated with the noise, but uncorrelated with the signal. So, this is another thing that is required at and; however, this does not seem to be a very compelling constant because whenever there is a noise, we can actually get some other source to capture it for example, if the power frequency hum is the noise we are worried about and we want to remove it from the biomedical signals, in that case what we can do? We can actually take the voltage from the power line which will certainly be correlated with the power frequency hum and as a power frequency hum and the signal is uncorrelated this new reference signal is also uncorrelated with the signal of interest.

Or let us take the second scenario that we want to get the ECG signal of the mother and the ECG from the fetus that is actually interfering with that what we can do? We can take the reference from the needs placed on the abdomen that is near to the fetus, where the fetus ECG would be stronger and that can act as a reference signal. So, what we see that in case of biomedical signal, that it is possible to get that kind of reference of the noise and whenever we can do that, we can have the adaptive noise canceller, and effectively we can get rid of all this noises even if the scenario is weak in the sense that the signal and the noise they are not complying to the constant or stationarity, they are varying with time and their strength is also changing.

So, adaptive filter can take care of them. So, among the techniques what we have learnt what we find the adaptive filter is the best to use in case of challenging scenario, and that is why it gets the maximum use in the practical life.

Thank you.