Biomedical Signal Processing
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Lecture - 08
Artifact Removal (Contd.)

Good morning. So, first we will go through some case studies to understand the problem of noise and then will get into the techniques to remove them.

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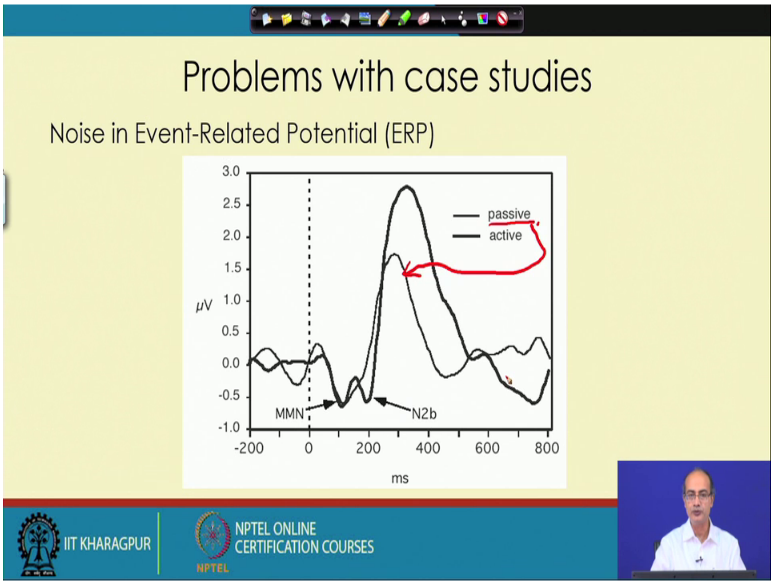

So, first we will take the example of event related potential. Now, this event related potential or in short ERP we are getting two curves, the passive one, the passive one here that this one is the curve with lower magnitude, that this one is passive and the active one is the one drawn in ethical line. Now the difference between these two is that we have that these signals are EEG signal and in EEG we are doing performing some test of listening.

So, that the first the subject is told to listen to some tunes passively; that means, they will just listen to that and because of that some; that in the parietal lobe that there will be some changes in the EEG signal and that is that the passive signal that there is our brain is working listening to it and is recognizing there is a tune played so for that a signal is generated.

Now, in the next case where the active actually signal is collected that the suggestion is that out of these two tunes one is a rare tune that is played only say 20 percent of the time and other is the dominant tune or the more frequent tune which is played 80 percent of the time. Now at the beginning of the experiment the subject is actually given the introduction that which one is a reactive which one is that the more frequent tune and after that that subject is instructed to count only the rare tunes. So, now, that subject not only listens to that tunes, but the subject has to distinguish that which tune is played and keep a count of that.

Now, due to that added activities there is a change in the ERP signal and here we get that this is the signal is generated that is active and here 0 is a point the tune is played. So, after listening to that with the delay we get the change in the EEG signal. So, though it is a EEG because of the that it is evoked by a response that its evoked by a stimulus that is why the name has come as event related potential.

Now, next will see that what kind of actually challenge we can get in the signal.

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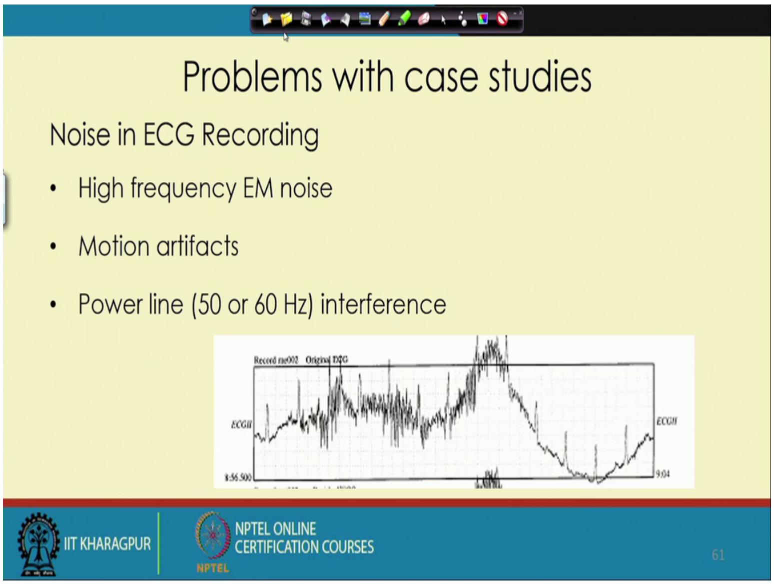

That when we record the signal the first kind of actual set of noises are the high frequency noises. Now, what are the sources of high frequency noises? We know that there are lots of sources like the mobile towers when you get a call in your mobile you see that the nearby that recording device it picks up some noise these are all high frequency noises, if you have a pump and that operates sometimes it creates noise if you have a DC motor where the commutator is used that the breaking of current makes a lot of high frequency electromagnetic noise. So, all these are source of this noise and we are actually embedded in that noise.

So, whenever you are recording the signal that recording leads they acts as an antenna and that the noise induced on it get actually rides on that signal and get recorded along with the signal. So, that this high frequency noises are nowhere contributing to the signal they just obscure that observation. So, we would try to remove them.

The second kind of noise that is our motion artifact is a special feature for the biomedical signal where high, high frequency noise is there for any kind of recording you can face that. The motion artifact comes from that fact that usually we use actually patch sensors they are actually added on the scheme to collect the potential, whether it is ECG, is EEG, or EMG we do not pay for the that invasive kind of that probe or needle kind of sensor. So, the patch one is better it does not hurt the subjects. So, when the actually patch sensors are actually stick on the body due to motion what happens, the pressure between the that the patch and the skin that changes and that gives rise to change in actually the resistance of the contact resistance between them and because of that what we get that there is actually change in actually the signal which is a very low frequency in nature.

Below we see that there is an ECG signal and it seems that it is riding on very what you call that low frequency some signal and this is the best line is moving or wondering we say or sometimes because of the motion there is a abrupt change and the baseline simply moves when moving in one place suddenly it moves to other place and it goes like that. So, all these things are the baseline wandering and that what we is caused by the motion and that is why they are called as motion artifact.

Next, we get another prominent kind of noise that is power line interference. And power line interference is 60 hertz in United States and in Europe in India this places we have 50 hertz, that in both this case this signals are much lower frequency compared to our communication signals, but they are very well within the band of our biomedical signals. So, we need to think about them. And how you get them? That when we recording the biomedical signal where in a room and wherever the civilization is there that now that electricity is there. So, that we have the electrical lines and that acts as a source of that the electromagnetic interference at power frequency and the leads we actually used for the recording of the biomedical signal they acts as an antenna and catches that electromagnetic noise and that interference gives actually gets recorded or get added with the biomedical signal. And we always get a 50 hertz or 60 hertz power frequency hum along with the signal.

Again this is not the native characteristics of the biomedical signal which campus actually the analysis. So, we need to find a way to remove them.

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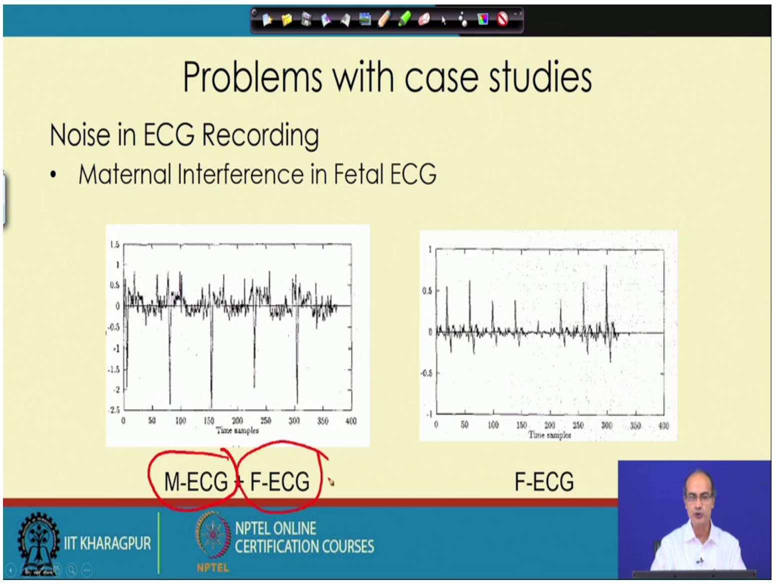

So, next we look for other kind of interference. Now, here we should first make it clear that what is our signal and what is our noise. The fact is what we are interested in is our signal and what we are not interested that is our noise, otherwise that would be the only definition because one when we see that something is signal that for other that may be a noise. For example, when we are actually in this class room we are listening to the lecture now if there is any tune played outside and you like that music then the lecture could be a noise to you, but those who are interested in listening to the lecture for them that the nice tune that is played outside that maybe the noise. So, it depends on your actually focus or interest.

Now, in this case in this particular example we have taken two signals one is a ECG of the mother that we write as M-ECG and that mother is carrying a baby in the womb that is called F-ECG. Now we may be interested in the health of the Fetals. So, in that case, the mothers ECG, we would say is interfering other noise. Your focus also would be to the health of the mother in that case you will tell that the Fetals ECG is interfering with the mothers ECG and we need to remove it. So, depending on your focus you select that which is your signal and which is your noise and such interference may occur. And as we see here in this case that we see that this big beats are for the mothers ECG and the small beats which are shown separately here also that they are because of the that Fetals and another thing we know that the Fetals the ECG beats there much closer; that means, the heart beats the rate of actually that pumping is more in case of the that Fetals.

In fact, there is a peculate in nature bigger that the animal the heart beats are slower, the smaller the animal you take you will find the heart beats are actually faster. Now here in this case we are just getting for the same species, but the womb actually is having higher heart beats and they actually added with each other and it is me as the signal we do not get the real nature of the mother's ECG. So, if you have to study mother's ECG or the Fetals ECG, then we need to actually remove the other. So, this is another kind of noise we got and now we need to look at that that what would be the ways that we could get rid of them.

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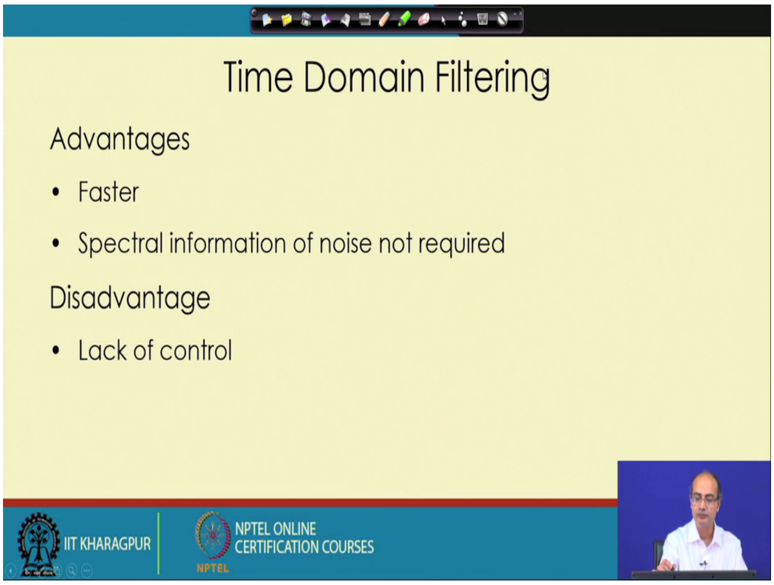

Now, first we go for that time domain filtering. The time domain filtering it has the biggest advantage is it is fast and we would say it is faster than all the other techniques we know.

Then another advantage it gives that it does not demand a lot of thing, many times that when you go for the filter design, we would ask a lot of questions that please tell us that how is a noise what is the spectral characteristics of it, what is the strength of it. So, all these questions should come, but in case of the time domain filtering no such questions are asked. We do not need any particular actually that information about the characteristics of the noise. So, that makes it easy to apply them.

The only disadvantages is that there is no control on how it will work. Actually it works based on some very simplified assumption that if any high frequency noise is there then if we do smoothing then we can get rid of the noise. So, it actually works on such simple principles. So, we do not have actually control over it the very actually loose control over the process we can do more smoothing or less smoothing, but we cannot actually customize it depending on the situation at hand. So, let us see now that how is a form of the signal.

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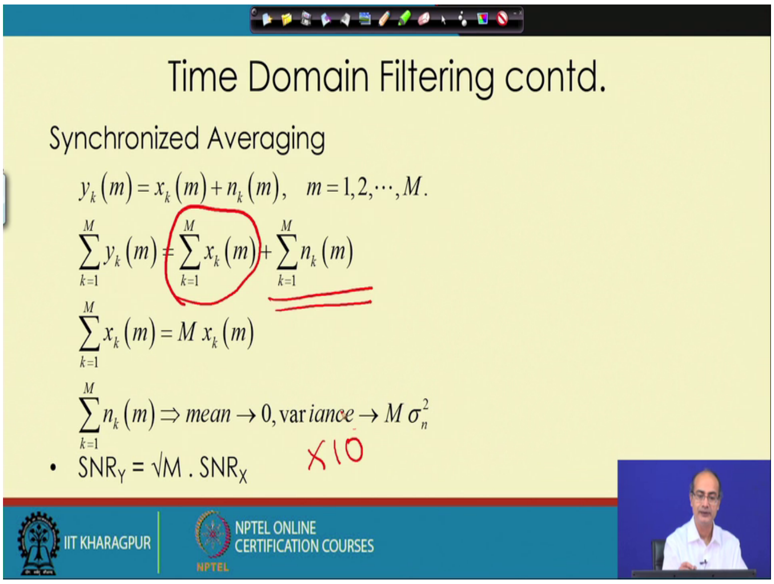

So, here to show the first example of synchronized averaging, that is the first example of the time domain filtering. Now, I hope you recall that we took that example of that throwing a die. So, here we are talking something very similar that we have the signal x k with which that the noise n k is added and because the noise is added what we can observe that is y k we cannot get access to x k directly and our intention is to actually get rid of n k, that noise component.

So, in this case if we have one multiple n symbol of that signal; that means, if we have multiple examples of that signal and then in that case that we use that index k to denote that n symbol and a means actually keeping the time index, then what we can do. We can sum all those n samples and if sum them what will happen that when you look at the first term here that the signal component when we add them we get the single signal components, they will add up and that will we get m times of the signal. And to get that actually one thing is very important that we need to align the signal properly without that we cannot actually get it. And when we look at the next term that is a the noise part that summation of the noise now what will get it will give us the mean of the noise or m times the mean of the noise and if the noise is 0 mean which is the case for most of the signal the high frequency noise the power frequency noise. So, all the high frequency or power frequency noise they are 0 mean.

Then the as the mean is going to 0 then this sum will go to 0. However, it has some variance the variance is not going to 0 when we take the sum the mean is going to 0, but the variance is we are getting the M time the variance of the original the noise, but because our that signal is multiplied or scaled by M times. So, variance of the signal or energy of the signal would go up by M square time. So, there is improvement in the SNR and here we get that for the observed signal y after the summation that we get the SNR improved by square root of M times.

So, if you could actually add up the signal by synchronized averaging for 100 times we can get the resulted SNR would be multiplied by 10 times. So, that would be a great improvement.

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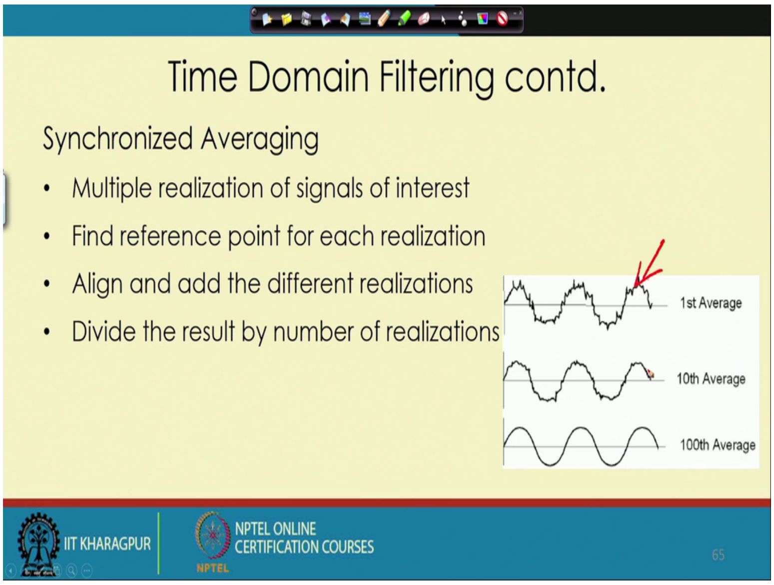

Now, let us look at that what are the requirements of it. The first thing that we need to look at that we need to have multiple realization of the signal of interest. Now how we can get that for example, we have that ERP signal, we can actually conduct these experiment number of times and we can collect that signal and then we can actually add them up. If we think of ECG signal that in case of ECG we can take actually multiple cycles of the ECG and we can add them up to actually to make the synchronous averaging possible. So, in that way we need to have multiple signal without that we cannot make use of this synchronous averaging.

The next important point for that synchronous averaging is we need to align the signals because without aligning if we add them they the signal component itself can cancel each other they would not a have a reinforcement effect. So, we need to align them together and that trigger for alignment come from different sources, first thing that it can come externally. For example, in this ERP we are playing some tune, so the point in time where when the tune is played that is the, that here marked as 0. So, that can see this, this point that point 0 that is signifying the time when the tune is played. So, that can act as a trigger, that every time we take the 0 point from where that tune is played, with the help of that we can actually align the different realizations of ERP.

It can be done in another way also. Let us look at that the form of that ECG signal, ECG signal looks like this. So, here is a P wave here it is Q R S and T then after a long gap again it repeats P Q R S and T.

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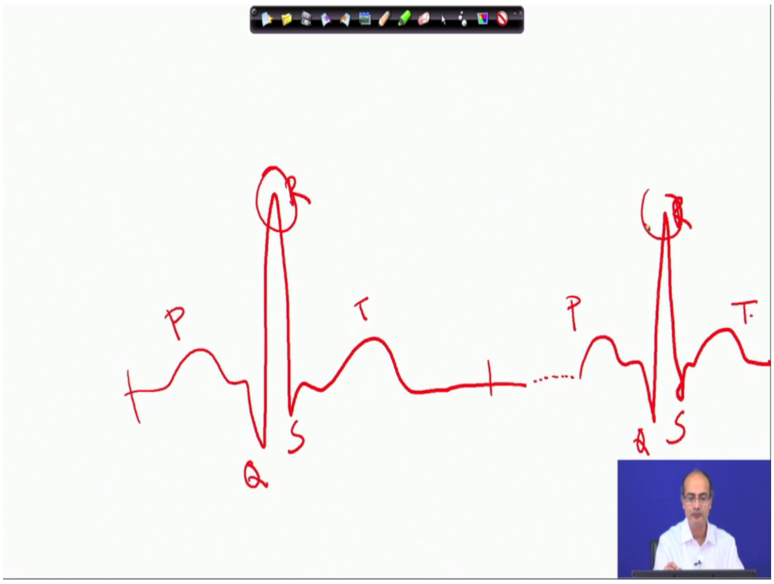

Now, most prominent point here and unique point is this R. So, we can take a cycle maybe this part we can take one cycle from here to here another cycle. So, that way we can take the different cycles and we can take these R points as the reference and we can align them. So, it can be done through that using that signal also that alignment is possible. So, we need to first find the point of this each of this realization that which can be used for the alignment and then we have to align and add the different realizations.

The third or the last step is that divide the result by the number of realization; that means, because we have added them up so many times the signal is reinforced by that time. So, there is a scaling of the signal, we need to get rid of that scaling. And in the right hand side we are showing some example that white noise is added with the sinusoidal signal. So, it is riding on the signal and we get the first one the signal is very spiky, that. So, then if we average it first time; that means, two realizations we take and add them up then still it seems to be equally spiky.

Now, once 10 such actually averages are performed then we get that it has actually reduced to some good extent and now it looks more or less like a sinusoid. When we go for 100 times then we see it is difficult to say that it is not sinusoid, the noise are actually gone down to that extent. So, what we get the more number of times we can have the realization of that synchronous averaging and more times actually we can add him we can have actually better and better answer or result out of the synchronous averaging.

Now, what is the challenge in this? The challenge is that if we want to do it in say real time then it can throw up a challenge. Usually we investigate one patient and for that patient we want to actually analyses that signal, and here if you take the ECG signal for example, for the from that patient for a particular lead we need to take we cannot take different leads and actually add them up different signal. So, we have to take a day record it for a long time and then we can actually add them up together and then we can get rid of the noise, but that means, it becomes a block process we are adding it up for sufficient amount of time and then we get that answer.

So, as a result what is happening that it is becoming non real time kind of operation? Though it is very simple and effective, so for real time applications this is not actually the technique to use.

Thank you.