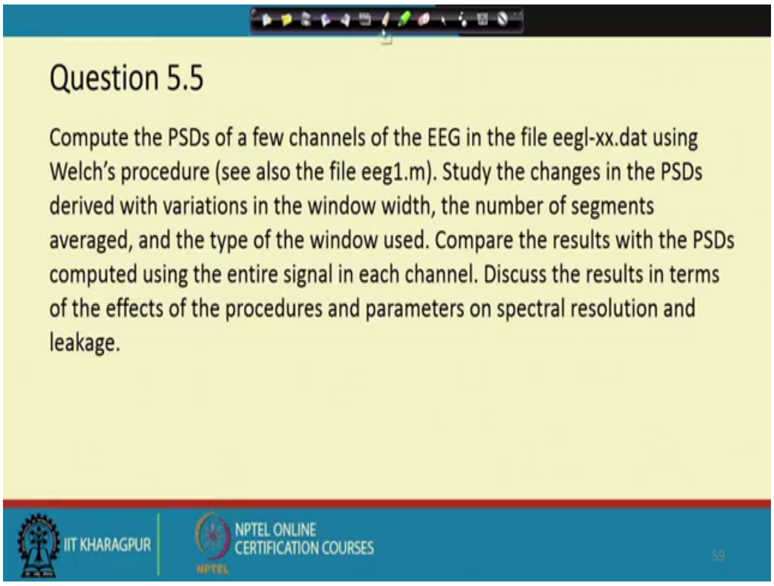
Biomedical Signal Processing

Prof. Sudipta Mukhopadhyay
Department of Electrical and Electronics Communication Engineering
Indian Institute of Technology, Kharagpur

Lecture - 67
Tutorial - V (Contd.)

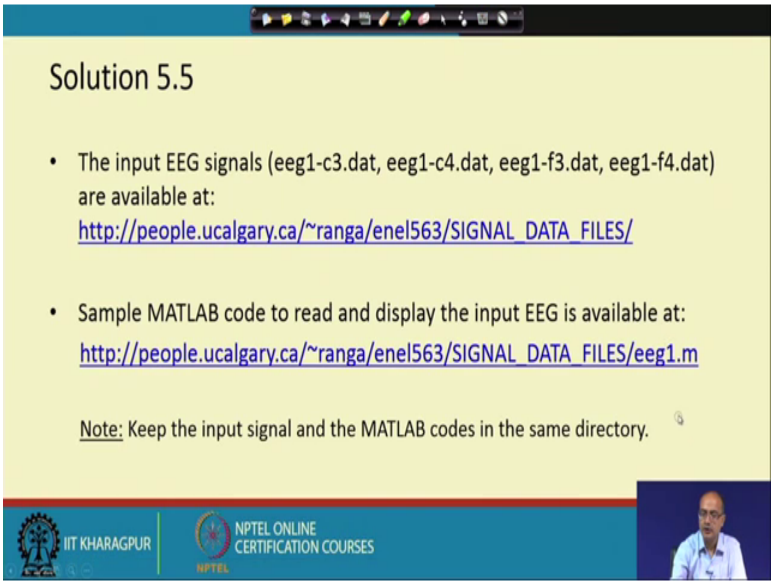
(Refer Slide Time: 00:18)



So, now we look at the fifth problem of the tutorial 5. So, here we are given few channels of the EEG signal and we have to use the Welch's procedure that is how to compute the average PSD ok. So, you have to study the change in the PSD with respect to that when we change that window width, number of segments averaged and the type of window used ok.

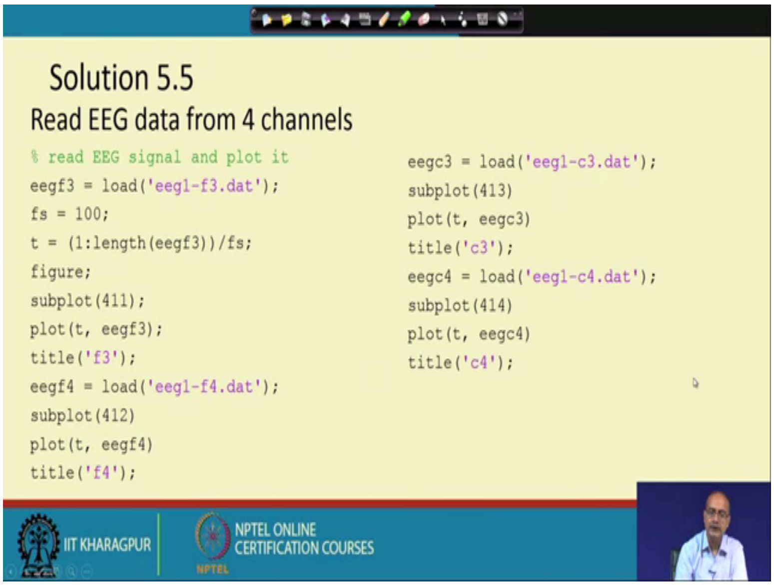
These 3 variables and we have to compare the PSDs computed with respect to the PSD computed with the entire signal; that means, without averaging if we take the entire signal and compute the PSD, what are the changes we get with different window width, different number of segments and type of window and we have to discuss about the result at the end. So, so that is a the task given to ask.

(Refer Slide Time: 01:35)



So, to start that first, we have to download the signals that force easy signals are given eeg 1 C 3 C 4 F 3 and F 4 4 eeg channels are given and they are given here in this location and the corresponding MATLAB file to read and plot them is given here. So, we need to keep them in the same directory there is a working directory of the MATLAB.

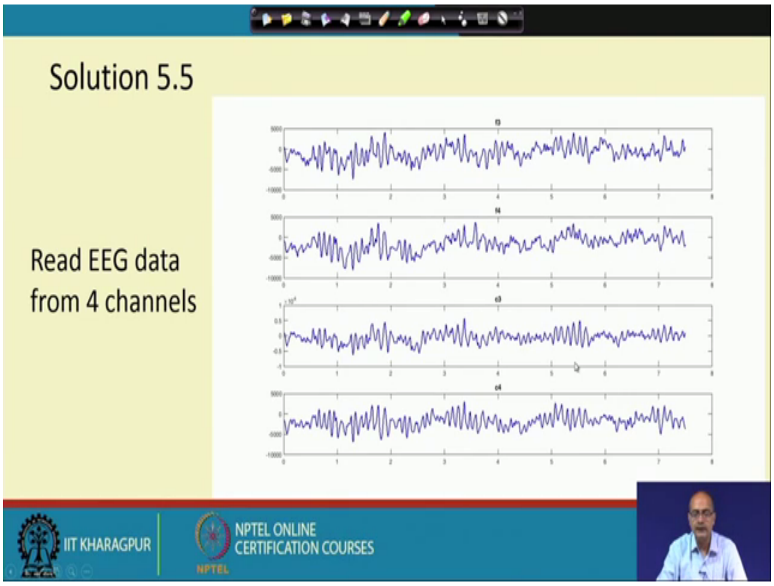
(Refer Slide Time: 02:10)



So, now first we read those 4 signals. So, what we do that, we load first that F 3 signal name it as eeg F 3 and sampling frequency is 100 hertz. So, we first look at that what is the length and we said the time axis, we plot that. So, to plot all the signals we divide the that plot area into 4 parts with the subplot comment ok. So, first we plot the that f 3, then we read F 4 and we plot F 4 in the second location or second row.

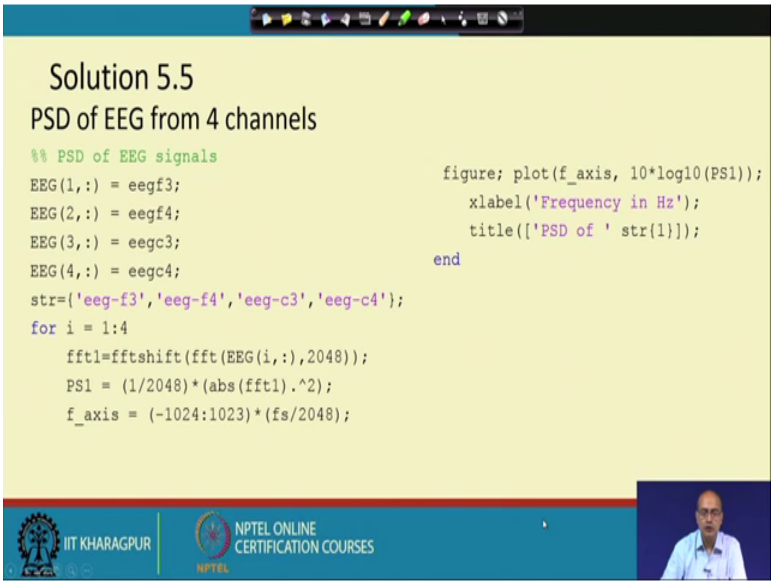
We can say then in the third row we are plotting the signal C 3 here we are plotting that and in the fourth row we are plotting the that signal C 4 here we have done that. So, let us see that how the these 4 easy signals they look like.

(Refer Slide Time: 03:42)



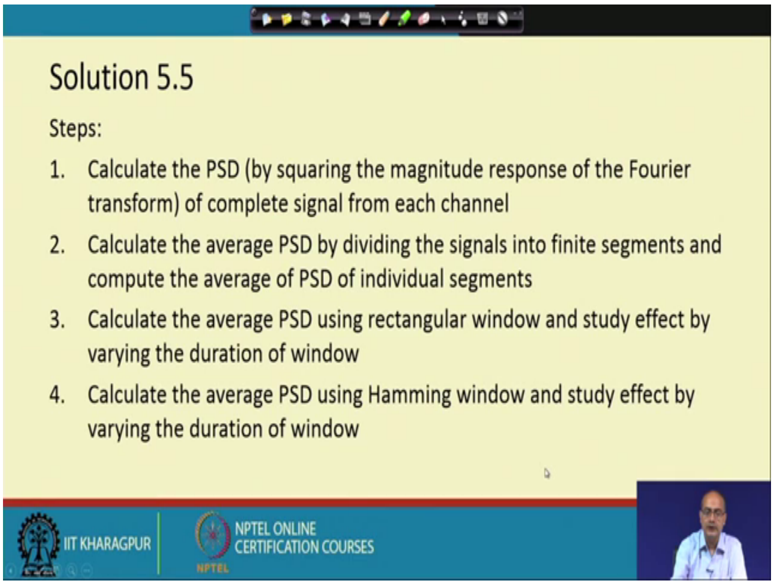
Here are the signals given one below the other starting with f 3, then F 4 then C 3 and c 4. All the signals they seems to be bit correlated they have similarity with each other. So, now, we have to go for that computation of the PSD.

(Refer Slide Time: 04:11)



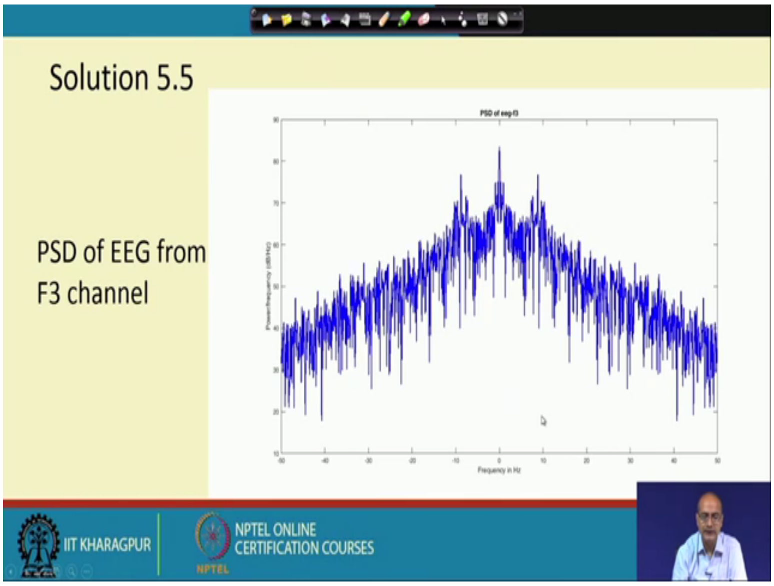
So, we compute the PSD of each one of them at a time first, for the whole signal and we display them and then we go for actually the step of the averaged (Refer Time: 04:38).

(Refer Slide Time: 04:26)



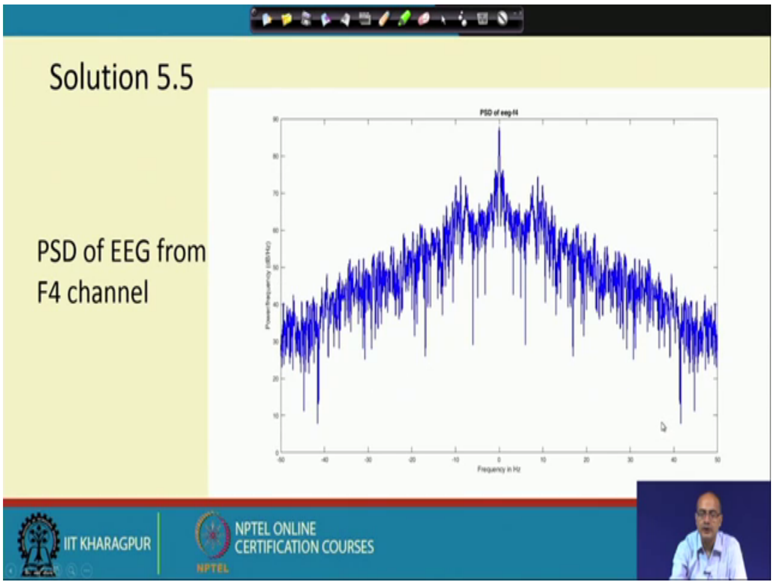
So, for that we have to calculate the PSD first of the that complete signal for the complete signal, we calculate the PSD of a channel and we do it for all the channel then we calculate the average PSD by dividing the signal into finite segments and compute the average of PSD of the individual segments ok. And here we have taken this segment they are non overlapping ok. And for that that for the average PSD, we use the rectangular window and study the effect of varying the duration of the window, which will automatically come that if we change the number of actually segments because total signal length is fixed. If we reduce the window size we have more segments and we repeat the same thing with hamming window and in that case also by varying the window duration, what is the impact we would note.

(Refer Slide Time: 06:14)



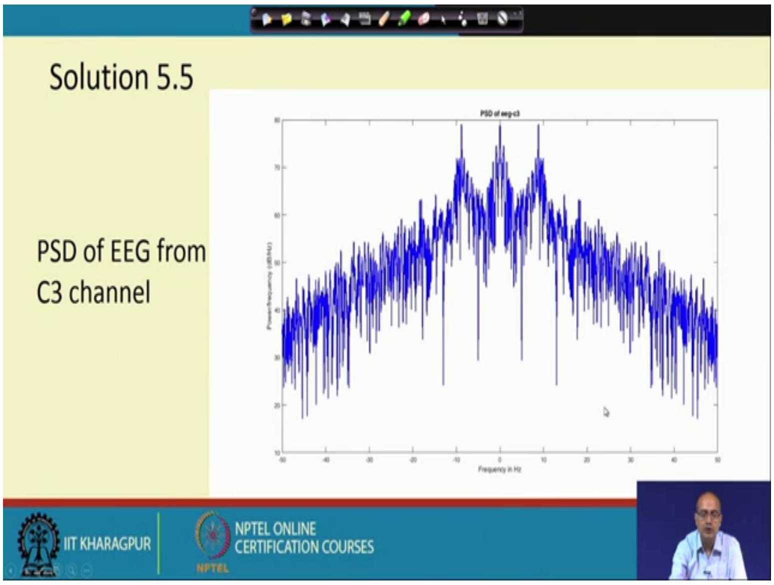
So, let us proceed first we are showing the PSD of the EEG channel that is the signal of channel F 3 ok. We get that dc has a peak then there is some peak near I think around 9 or 10 around 10 actually there is another peak.

(Refer Slide Time: 06:37)



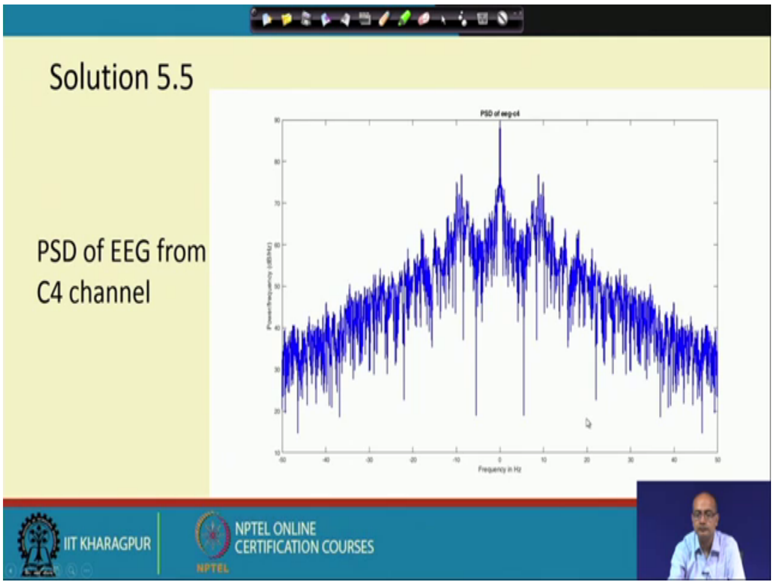
Go for the second signal F 4, again the same nature is here the maximum energy is there at the dc and there are peak around 10.

(Refer Slide Time: 06:53)

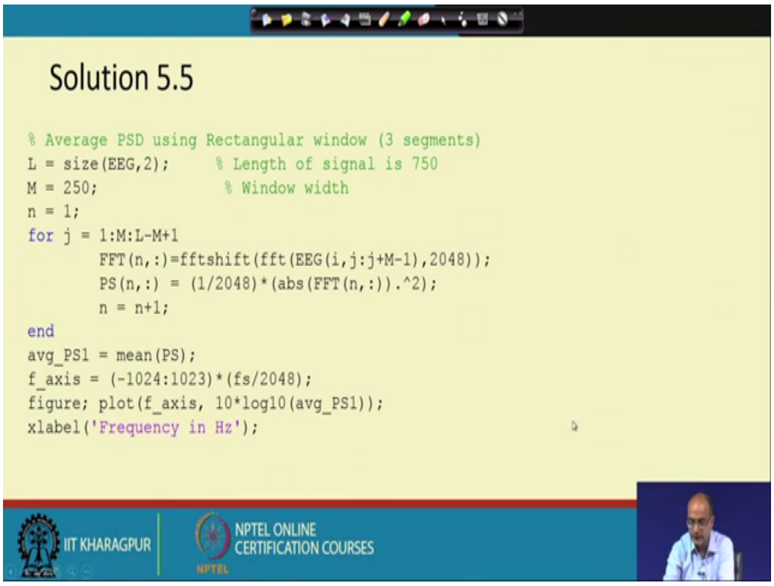


Then go for the channel C 3 that we get that around 10 the peaks are even more pronounced.

(Refer Slide Time: 07:06)



(Refer Slide Time: 07:09)

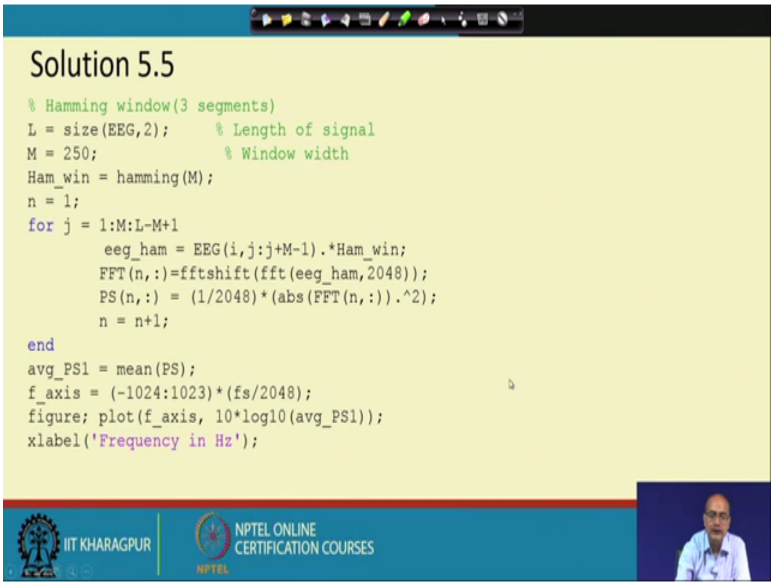


And now go for that that C 3 and then C 4 we get same nature, that C 4 has that spectrum though signals are strength is there around 10 that it is less than that C 3 here was a C 3 and here is the C 4 ok. Now, all the spectrum therefore, the entire signal and we get each of this case that there is high variation in the PSD or PSD we can say they are having a lot of fluctuations.

So, now go for different segments. So, starting with 3 segments; So, how do we do that? We divide the signal by 3 parts, we are taking lengths of 750, total is 750 is the length.

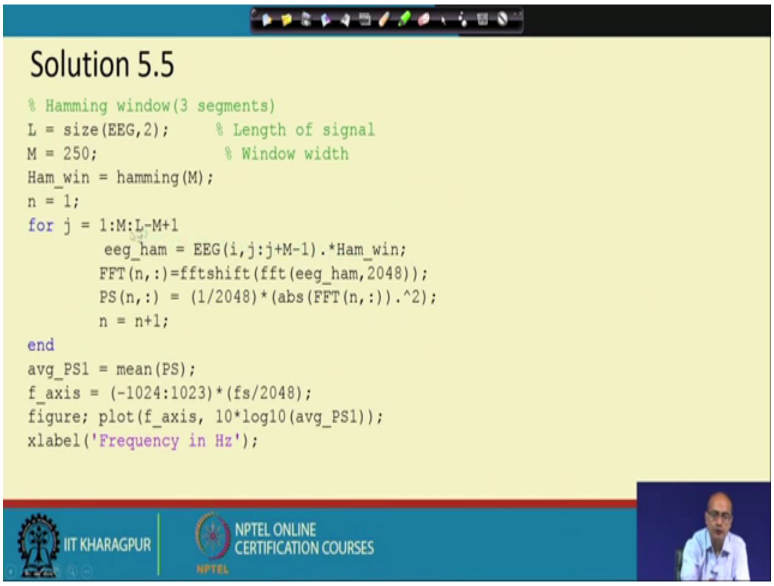
So, length of each of the 3 segments would be 250 each ok. So, we calculate the FFT and take the average ok. So, with that, we can get the output let us see that what we get ok.

(Refer Slide Time: 08:38)



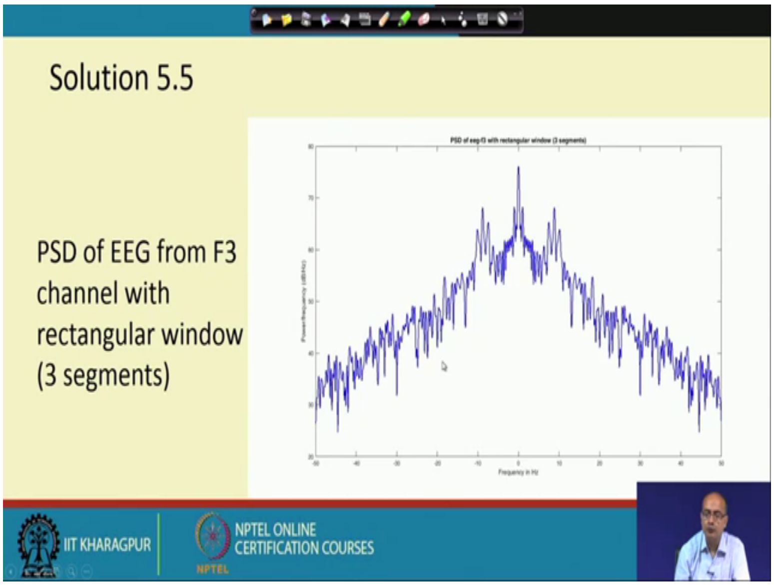
Now, for the hamming window it would be almost same the only difference would be that previous case we our previous case we are taking the that that part of the signal directly here is the difference that for the rectangular window, we are showing that that directly we are taking the part of the signal and we are computing the PSD compared to that when we are going for hamming window.

(Refer Slide Time: 09:21)



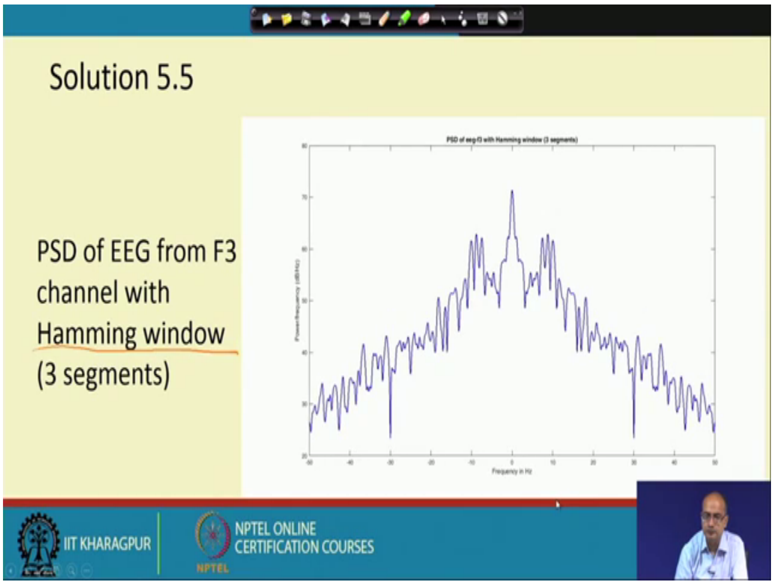
We are computing the hamming window and multiplying the signal with the hamming window for that many samples and then rest of the thing would be same ok.

(Refer Slide Time: 09:43)



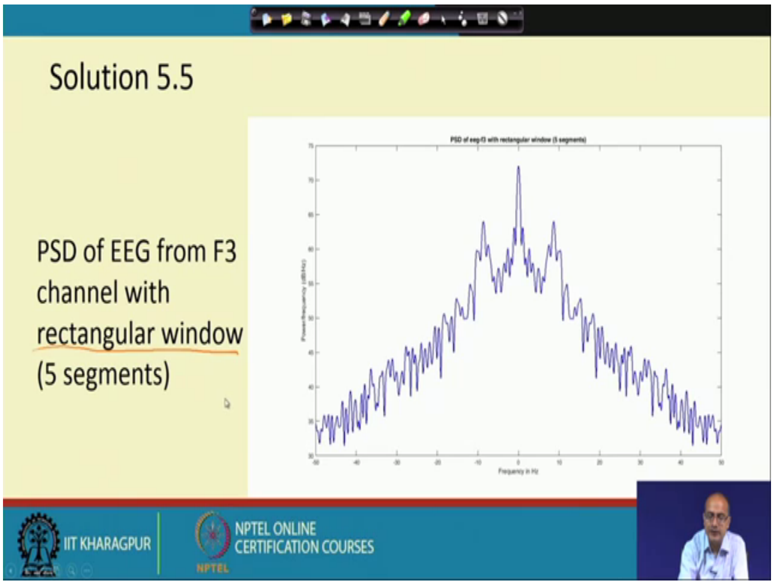
Now, here is a output we get for the 3 segments, we get the variation has been bit reduced compared to the entire signal with 3 segments, and here we are taking the rectangular window next we go for that hamming window ok.

(Refer Slide Time: 10:04)



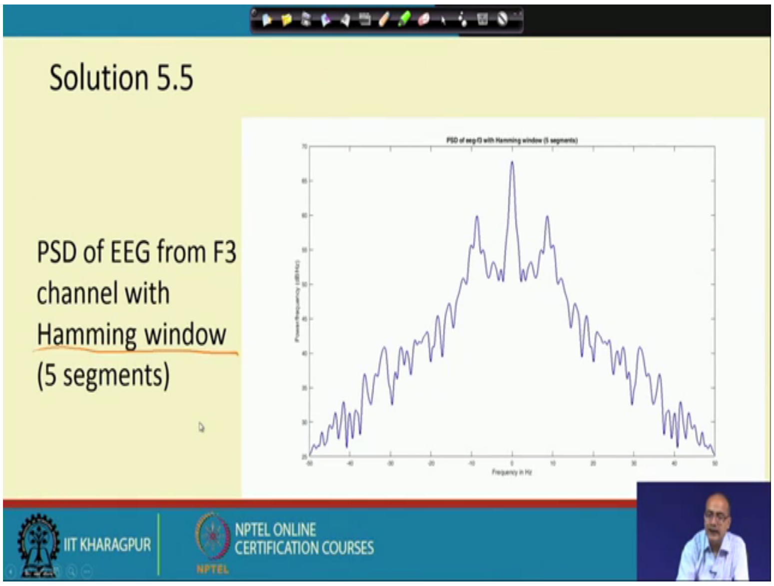
in case of hamming window we see it is a little more smooth, but then again that the peaks are become becoming little more wide; next we go for 5 segments for that rectangular window.

(Refer Slide Time: 10:22)



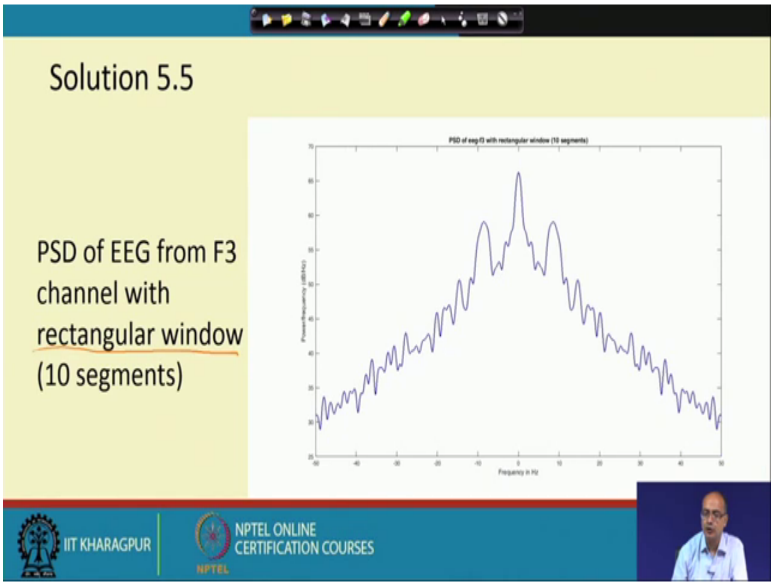
We see it is smoother than the 3 segments one ok.

(Refer Slide Time: 10:35)



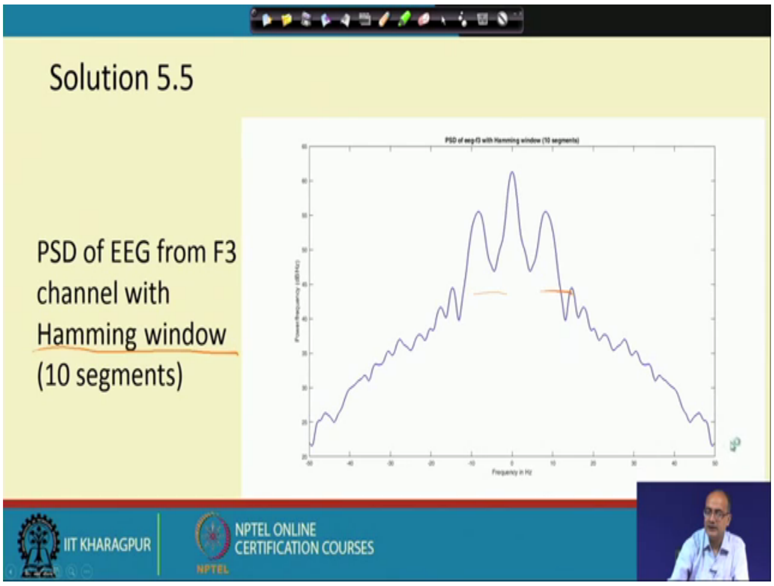
And now go for the hamming window with 5 segments ok. So, here we get that the side peaks they are getting merged in the hamming window. If we have gone for the the previous one you see that compared to that rectangular window, the hamming window is giving actually smoother one, but again the at the cost of that frequency resolution.

(Refer Slide Time: 11:10)



Next we go for the that rectangular window with 10 segments, we see that the side lobes what we are showing here they are getting merged ok.

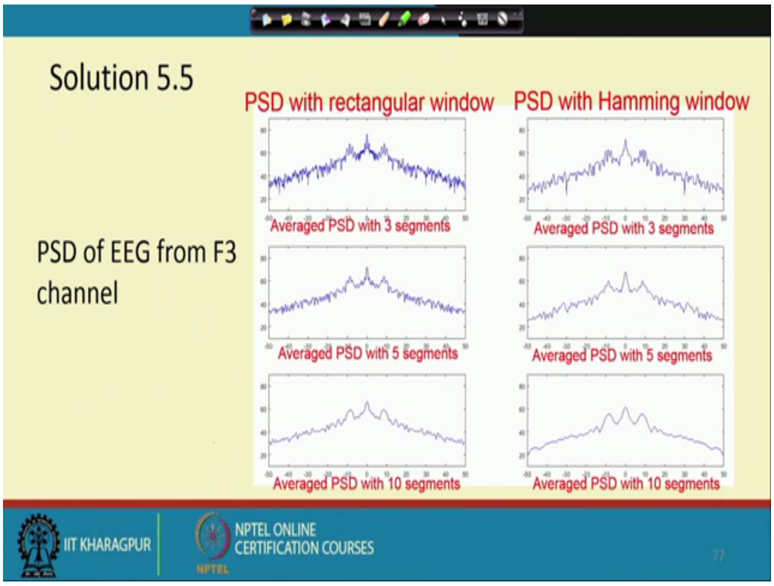
(Refer Slide Time: 11:33)



And we get the same nature for the hamming window also, but the signal PSD looks much more smooth.

So, this is all these things we see for the F 3. Now we go for the that the other channels we go for that the signal F 4 ok.

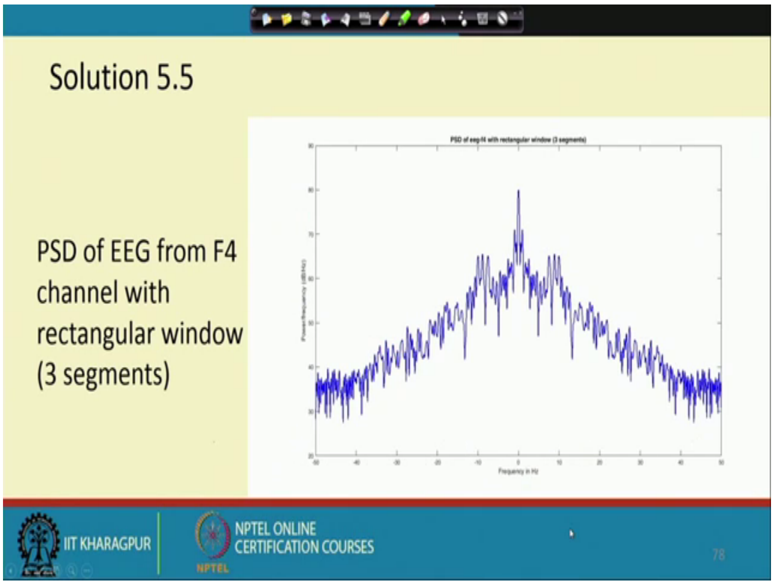
(Refer Slide Time: 12:04)



Before that we would like to see them side by side; before changing the another channel we would like to see them side by side and in the left hand side we are getting that the results for rectangular window, right hand side we get that for the hamming window. So, if we look at the compare that left and right we get, hamming window always is giving smoother PSD. And at the same time we can say that rectangular window is giving more sharp peaks and if we now go from top to bottom in any of them that for the rectangular window or hamming window, we see as we increase the number of segments from 3 to 5, 5 to 10.

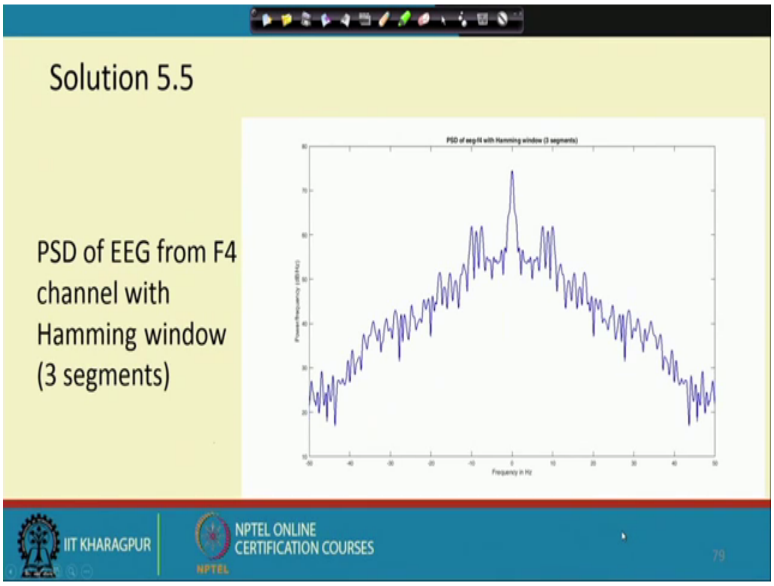
We get more and more smooth PSD, but along with that what we see that smaller peaks they are getting merged. So, that is the that downside of it. So, that is a we can say the overall assessment we get further that F 3 channel.

(Refer Slide Time: 13:31)



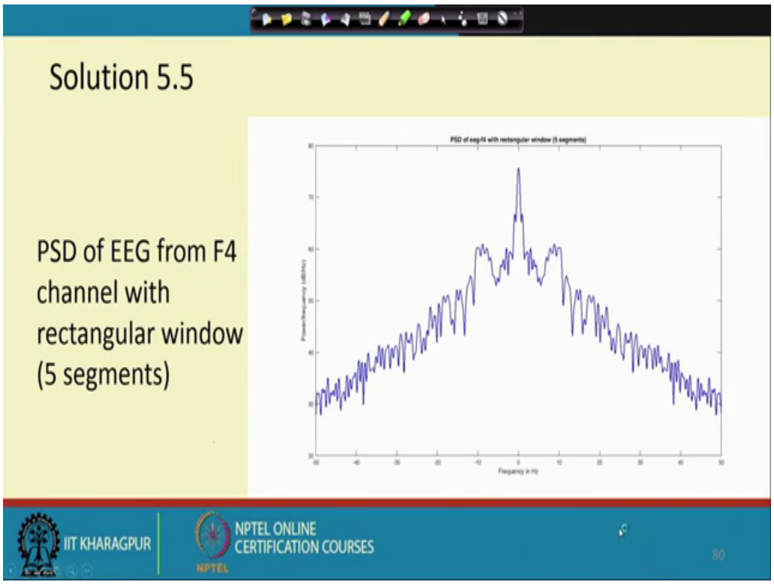
Next we go for F 4 start with the signal of the 3 segments with rectangular window.

(Refer Slide Time: 13:43).



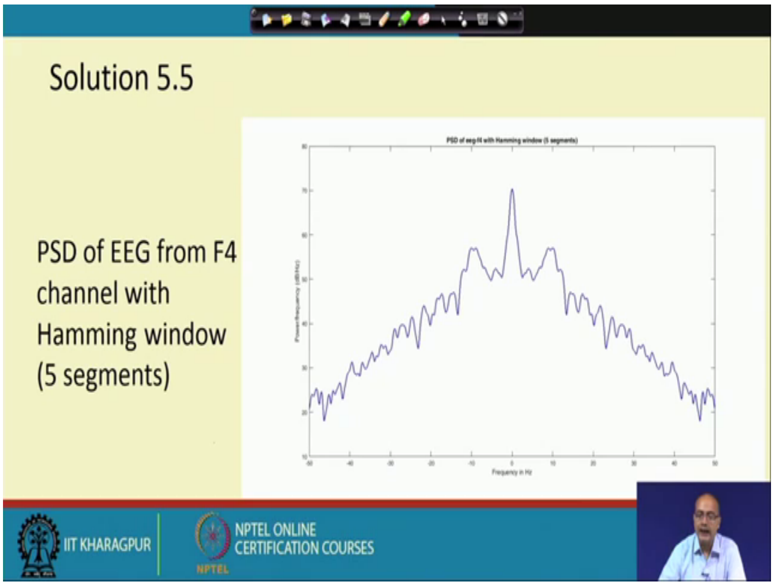
And then we look for the that average of the 3 segments.

(Refer Slide Time: 13:45)



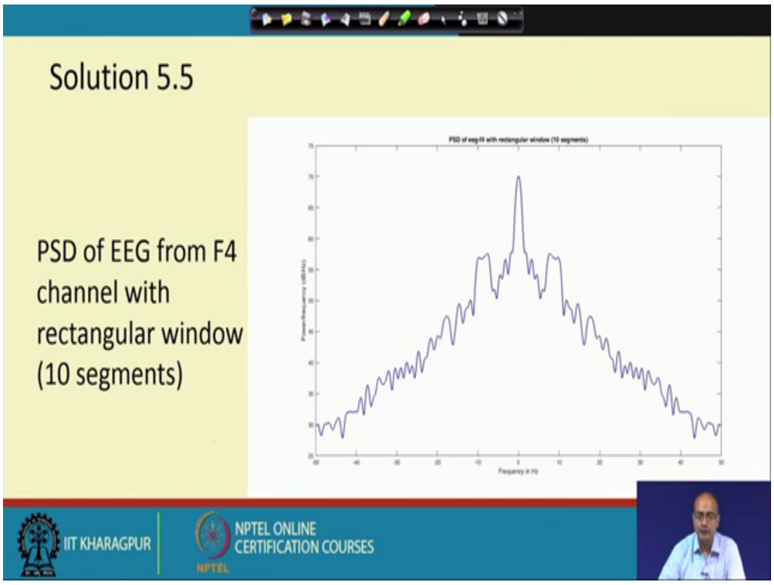
That of the for the rectangular window then hamming window, then look at the average of the that five segments of the rectangular window, we see it has become more smooth than the 3 segment version.

(Refer Slide Time: 14:11)



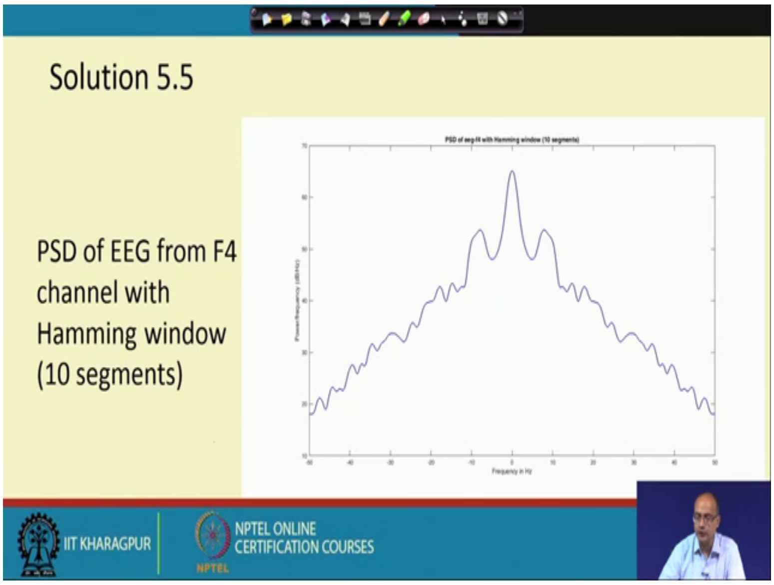
And when you go for rectangular window to our hamming window, then we get it becomes even more smooth.

(Refer Slide Time: 14:20)



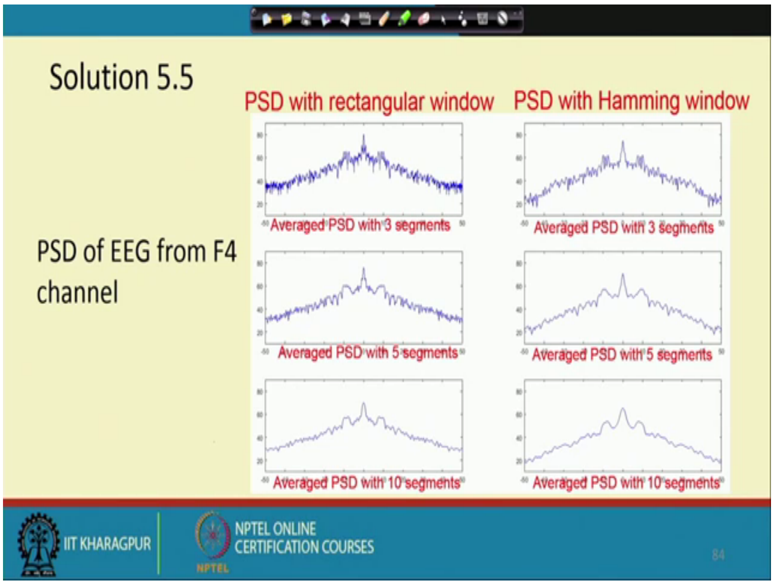
When you go for 10 segment we get the rectangular window, its more smooth compared to the 3 and the 5 segment cases.

(Refer Slide Time: 14:34)



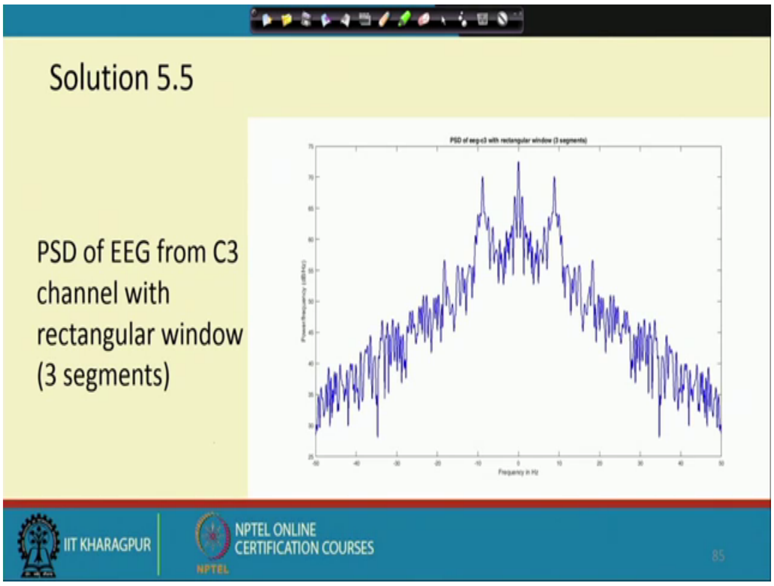
When we change from rectangular window with 10 segments to hamming window with 10 segments we get even more smooth PSD.

(Refer Slide Time: 14:39)



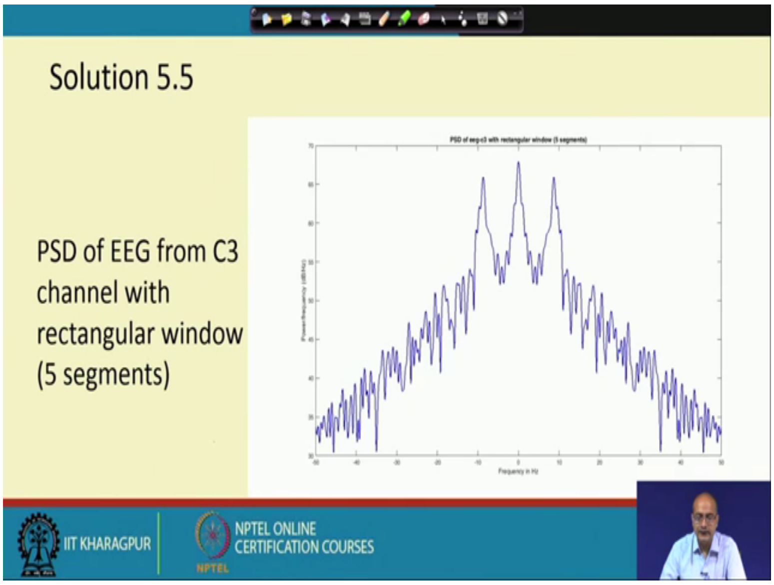
So, now we put them together to compare and like the channel F 3, we see the F 4 also gives us the same kind of conclusion that hamming window gives smoother PSD and irrespective of the window if we increase the number of segments, we get more and more smooth PSD, but we may lose actually peaks in that way, because they are getting merged as the frequency resolution is becoming more and poor as we are taking more segments to average.

(Refer Slide Time: 15:22)

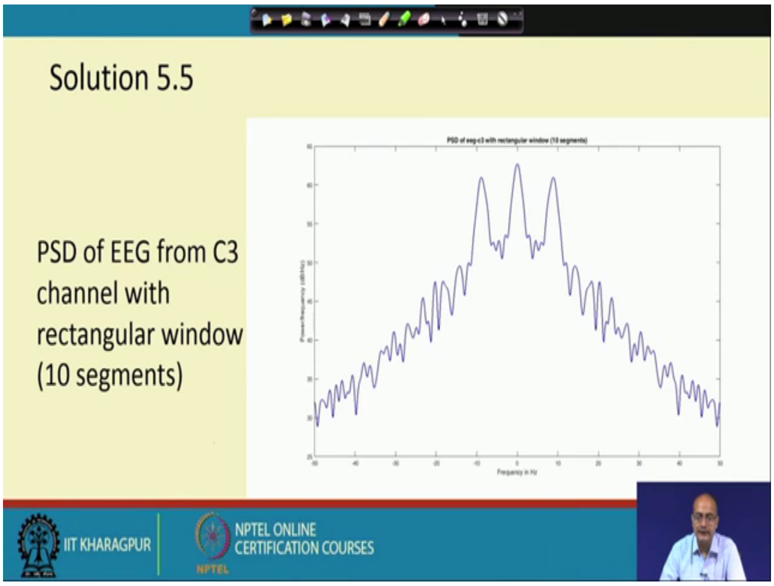


Now, we go for channel 3, first we look at the result of 3 segments, then we get the result of hamming window 3 segments; Then for 5 segments for rectangular window and 5 segments for the hamming window.

(Refer Slide Time: 15:39)

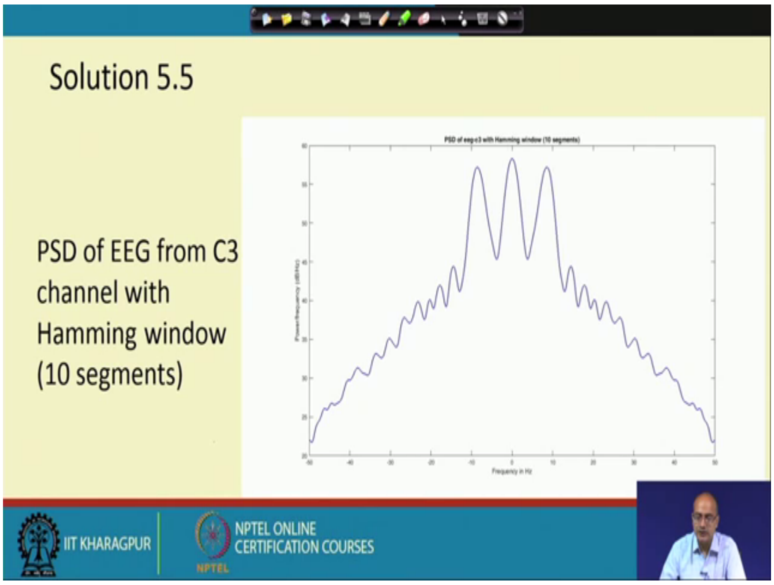


(Refer Slide Time: 15:52)



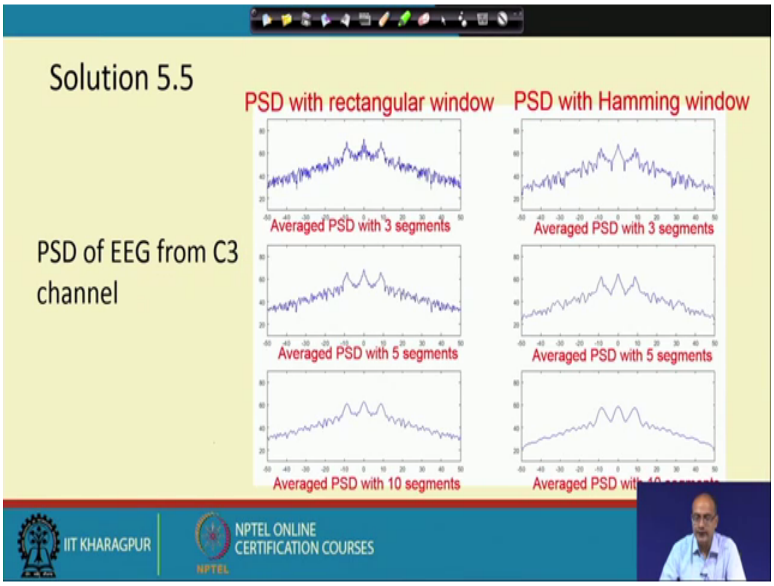
Then we go for 10 segments of the rectangular window followed by 10 segments of the hamming window.

(Refer Slide Time: 15:58)



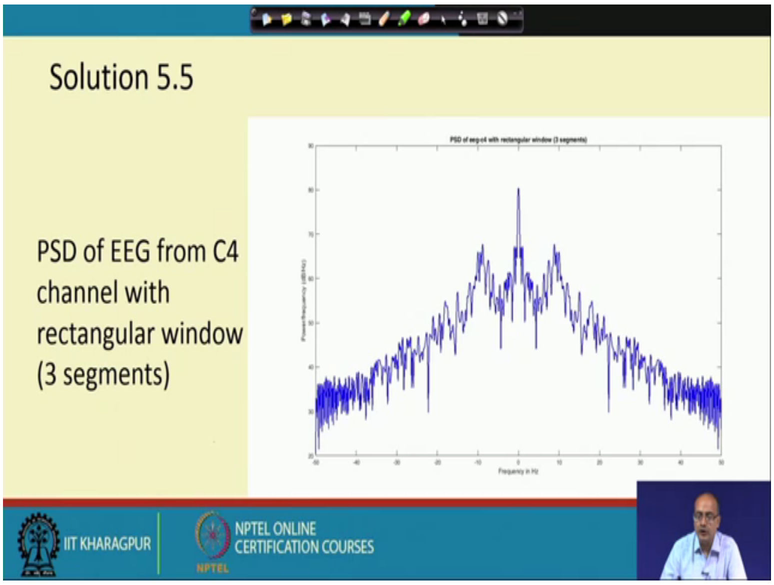
Now, we put all of them together.

(Refer Slide Time: 16:02)



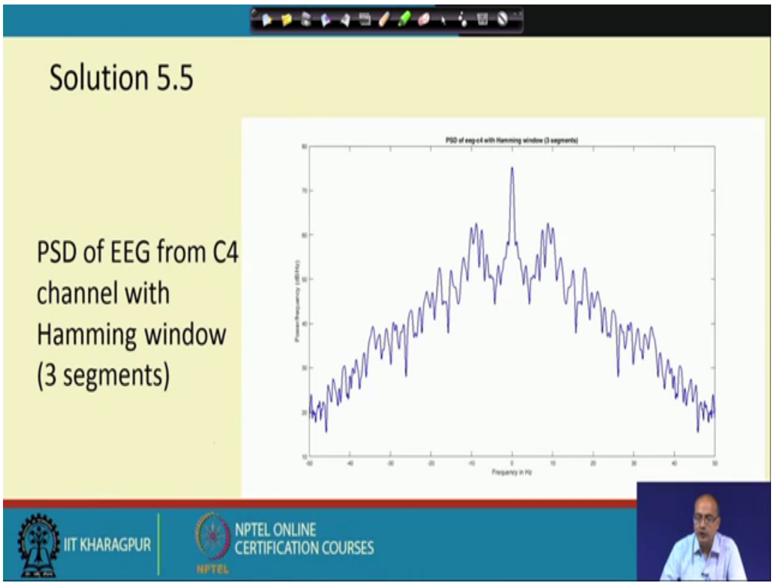
And you see in the left hand side the rectangular window is used right hand side the hamming window. Using having window we get more smooth PSD and for that our that hamming window not only we get it smooth, the smoothness also increases with number of segments, but at the cost of that frequency resolution or in other word what we can say they are smaller peaks, they are getting much to give a bigger peak. As we increase the number of segments or reducing the dimension of the or the duration of the window.

(Refer Slide Time: 16:59)



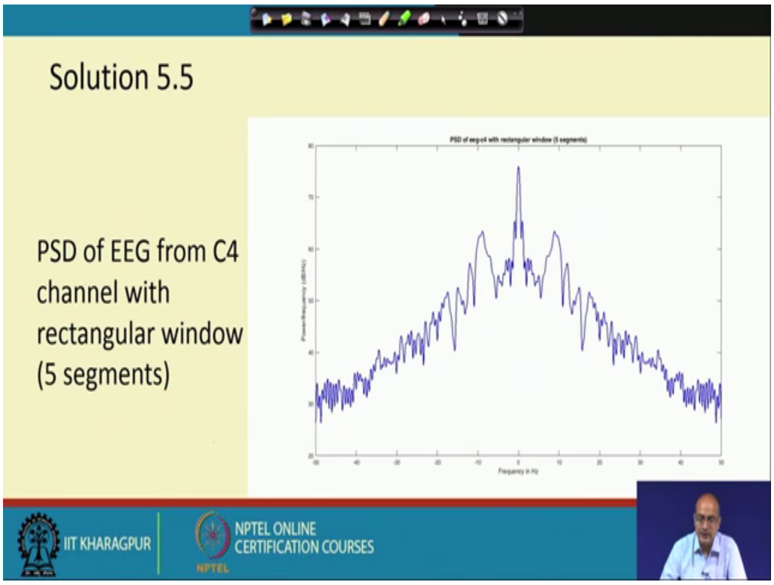
Now, we go for the channel 4 you start with first the 3 segments with rectangular window we get lots of undulations, but it is undulations are less compared to that the PSD when we take the entire signal.

(Refer Slide Time: 17:20)



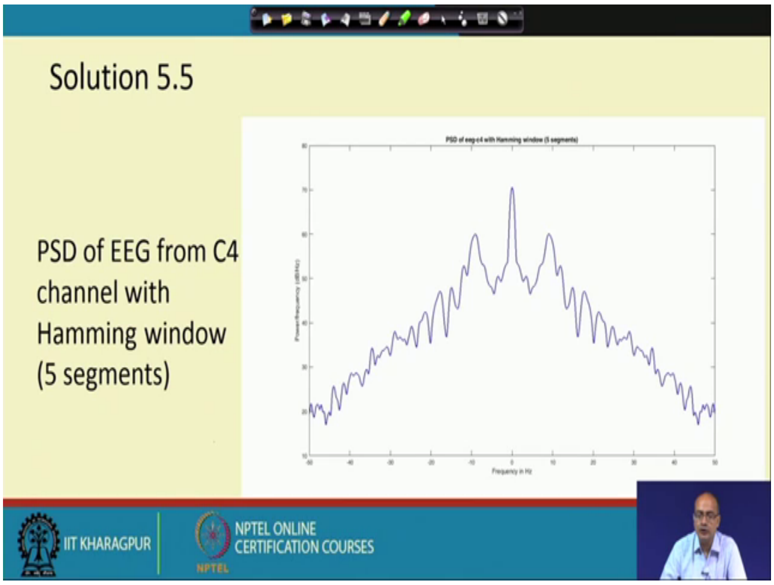
Now, we change the window from rectangular to that hamming window and we see that we get a little more smooth that PSD.

(Refer Slide Time: 17:31)



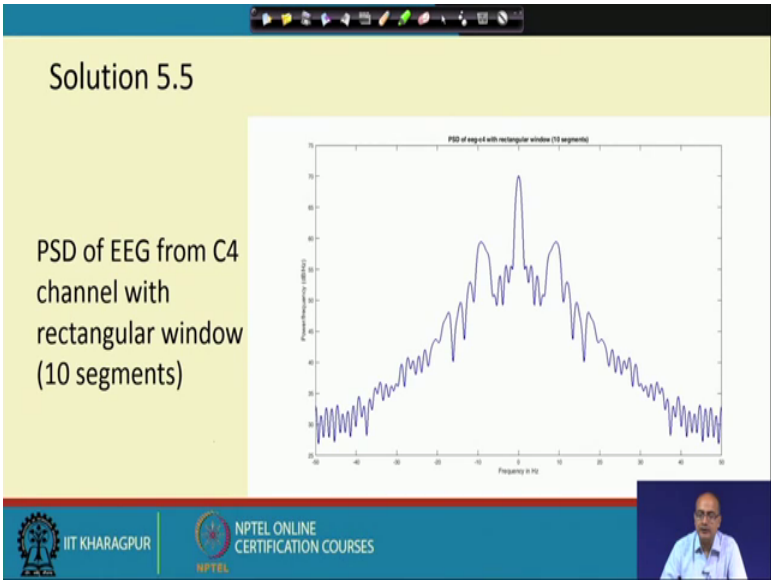
Next we increase the number of segments for the rectangular window, we get it is more smooth.

(Refer Slide Time: 17:36)



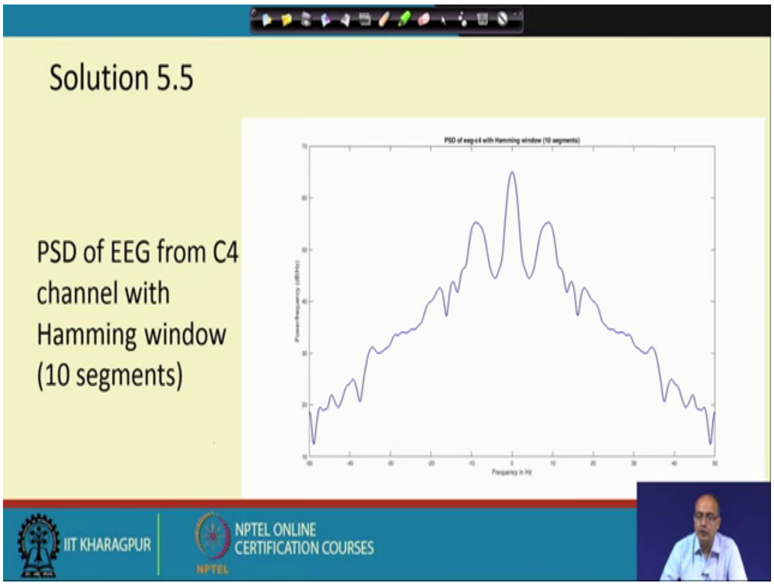
For the hamming window it is even more smooth for 10 segments.

(Refer Slide Time: 17:42)



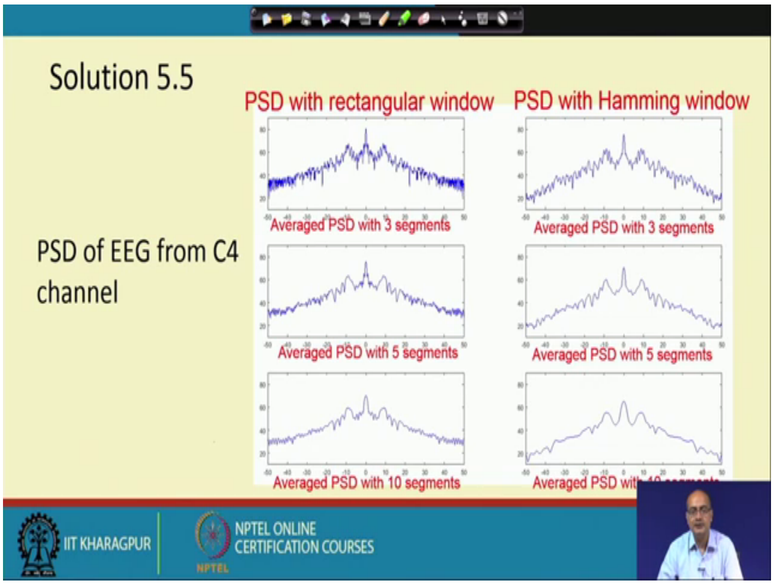
For the rectangular window we know we get the best or smooth actually the PSD compared to that 3 segments and 5 segment cases and for the hamming window with 10 segments.

(Refer Slide Time: 17:56)



We get it is even more smooth.

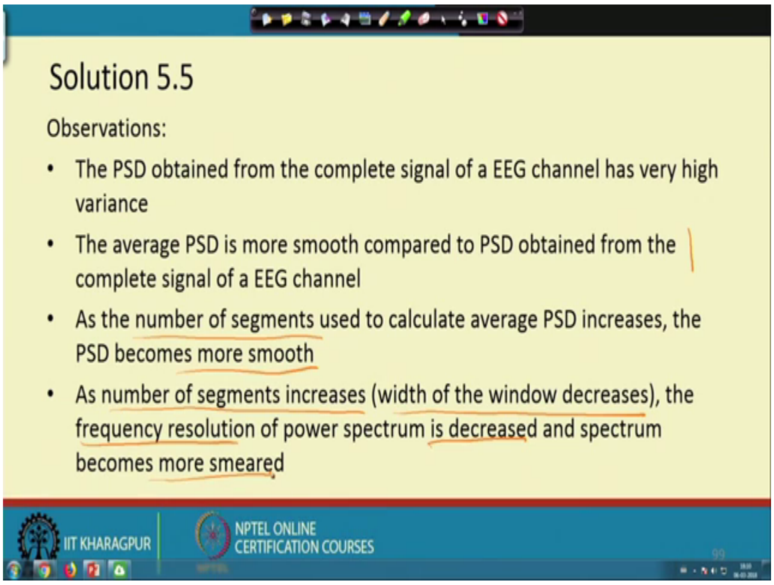
(Refer Slide Time: 18:00)



So, we put all of them together to get a perspective that how they are changing, we get the sharpest speed, we are getting sharp sharper peaks we are getting for the rectangular window and among these examples for the 3 segment average for the rectangular window is giving the sharpest peak and more undulations. As we change from the hamming window in each of this case, we get less actually undulation or smoother spectra and if we go for more number of segments that is smaller duration of the signal and more averaging, then we have the that decrease in the frequency resolution at the same time we have smoother PSD.

So, this is these are the results we get, now we summarize the results first.

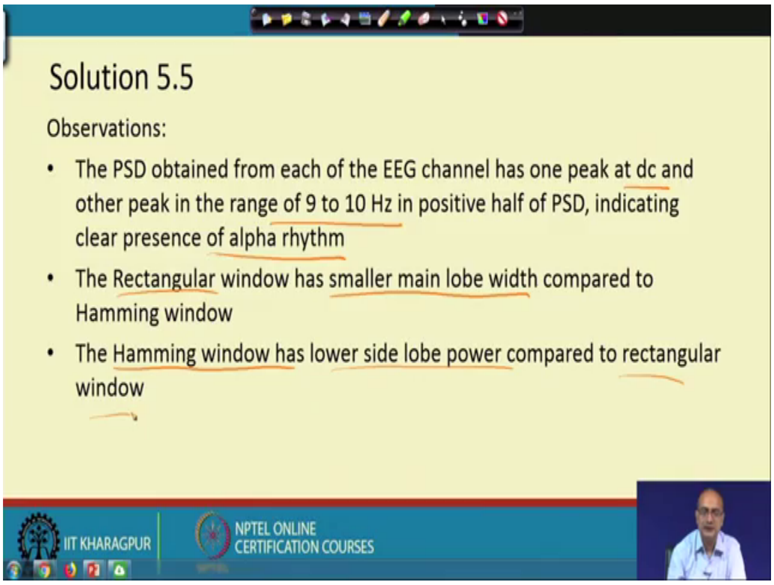
(Refer Slide Time: 19:04)



We would look at the PSD obtained from the single channel of EEG it has very high variance or the undulations are very high we can say. Next what we get that if we use that average PSD, it helps to actually smooth out the PSD compared to the PSD of the complete signal ok. And next observation what we get as we increase the number of segments that is number of segments used for averaging, we get more smooth actually PSD.

But this smoothness comes at the cost as the number of segments are increasing and thereby the size of the window is decreasing, the frequency resolution is decreased and what we get we get the spectrum which is more smeared; that means, that if we have two frequencies they are very close to each other, if we are having more and more segments and thereby the window size is keeps on decreasing these two peaks can get merged.

(Refer Slide Time: 20:50)



Now, we have let us look at few more observations that, when we look at the PSD in each of these case we see that apart from the peak at the dc, we have peaks in between that 9 to 10 hertz that clearly indicates that the presence of alpha rhythm ok. So, each of these case alpha rhythm is the prominent actually the signal that what we get.

Now, we look at that what is the window use and what is a impact of that. For the rectangular window we have smaller main lobe and because of that we are getting sharper peaks and compared to that the hamming window, which has lower side lobes compared to the rectangular window it is giving more smoothing.

So, with this we conclude the fifth experiment of the tutorial 5.

Thank you.