Biomedical Signal Processing
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Lecture – 32
Waveform Analysis (Contd.)

So now in this session, we will go for analysis of activity and as a part of it first we will look for that root mean square value.

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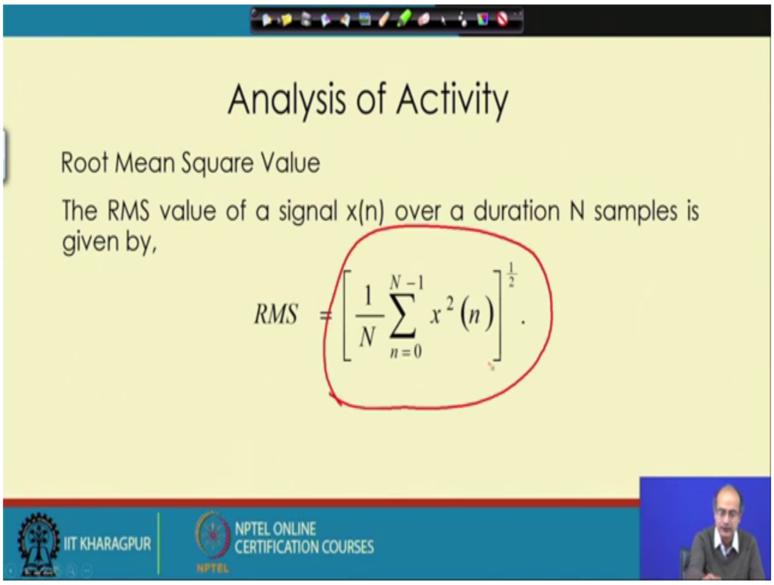

Root Mean Square Value it can give us actually a notion of the energy of that signal. So, if you have a signal xn, and we have n samples of it; that root mean square can be given by this formula, that we can compute the RMS value as the square root of the average of the individual instantaneous energies of all those instances.

This is a the formula that that can actually help us to get the RMS value.

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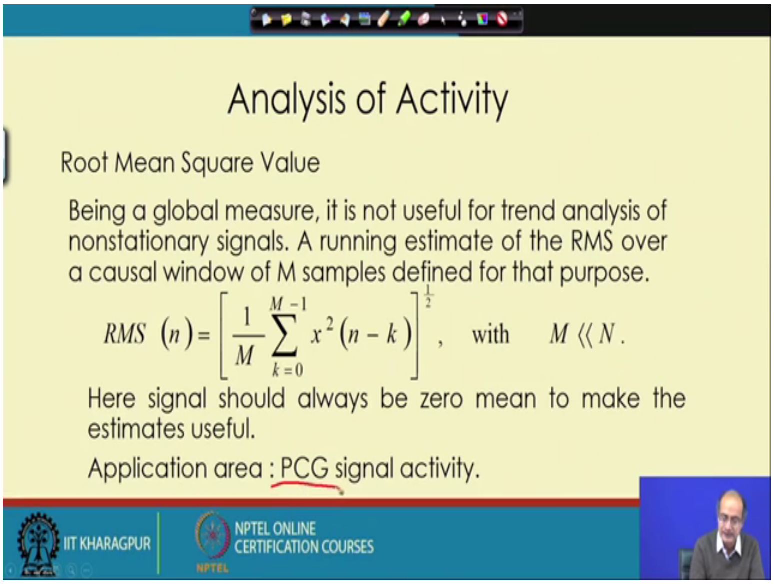

Now, this RMS value this has actually one disadvantage; that it is making use of the full signal length, and in case of non-stationary signal, where the signal characteristics is varying that; this average over the complete period of the signal is not something very useful.

So, if we are interested to get the variation of the energy over the time. What we should look at is not the that the RMS value, but a running estimate of the RMS. We should get a running estimate of the that RMS value, and in that case the formula is slightly modified. What we have; that we have the RMS at instants n. It is even as that the sum over M samples only, and that that is starting from n and moving actually backward.

So, we are taking an window of M number of samples, starting from the instance n and backward, we are looking at and we compute the RMS, where this M should be much, much smaller than the total number of samples. Then only we would be able to get the variation of the RMS value over the that signal interval. So, that is the; that that part we get from the RMS value, and here the signal should always be 0 mean. That is one of the thing sometimes it may not be written in the book, but we should be careful that it should be 0 mean, otherwise it will give us a bias which is of no use.

Actually, what we are interested in is that change in the energy level of the signal. So, DC bias if it is present it actually a gives a false notion that energy is present all the time. But that is what we are not looking at we are rather interested in the variation in the energy. So, the signal should be 0 mean in this case to make the RMS estimate as a useful quantity. And first people have used this one in biomedical engineering for the PCG signal. Because for a phono cardiogram, we want to know that how much energy is there in s 1 and s 2. So, that for small interval, that the people have computed the energy of the signal in this way, and that is how that we have computed the that that RMS value.

Here one thing that is a different from the previous techniques of the envelope detection, that there they have used a window, where the latest actually the point is getting more weightage. In case of RMS no such actually that that window function is there, it means all the that the values all the samples present within that window they are getting equal weightage. So, that is one of the that small difference with the that previous techniques.

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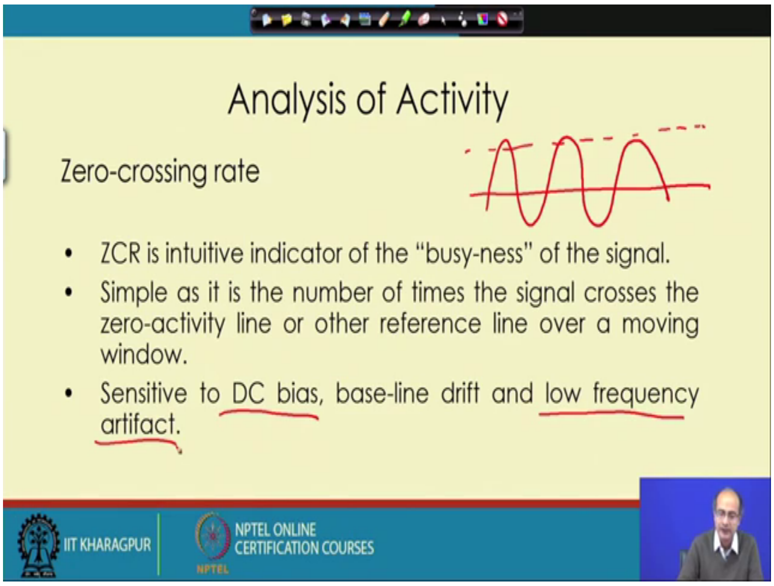

Next, we get another actually measure of activity, that is called the 0 crossing. And in this 0 crossing actually, what we are looking at that in this case that what we assume that signal is becoming more active means, it has actually more number of z transitions through 0. It is having actually change in frequency quite often or becoming high frequency signal is coming. It is becoming more active that is the notion. And in that case that 0 crossing is a very good actually indicator, because that if we look at the number of times it crosses the 0, we can get the rough frequency of that signal also.

So, and we take a moving window, like the previous case of RMS, to get actually the change of the 0 crossing over the time; however, it is actually sensitive to the DC bias.

What do you mean by that? Let us take a signal, now if we take the DC value is at the middle. So, if we take that we had one kind of result. Now if we take it by a DC bias if we take it here, we get a different kind of 0 crossing.

So, that the DC bias of the signal, that can actually affect the result and same way the low frequency artifacts can also actually affect the result. So, that is the part of the challenge here.

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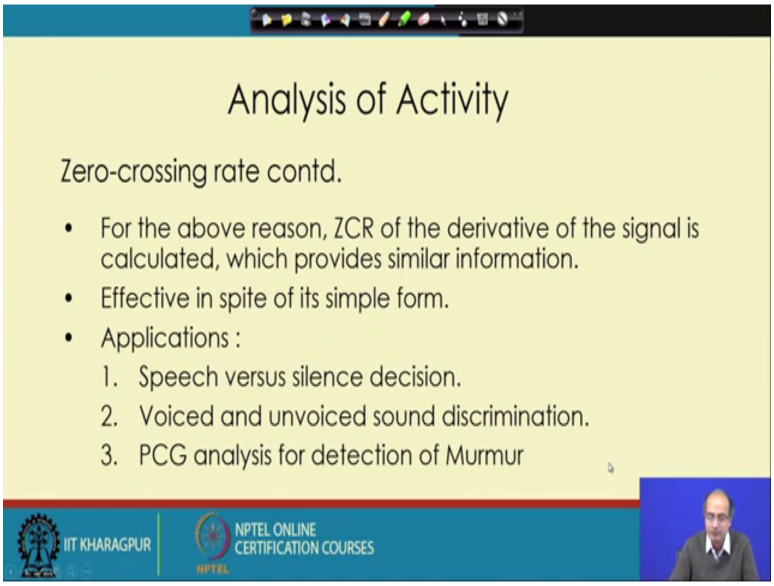

And to take care of that; what it is done that many researchers, what they have suggested that for 0 crossing rate? Let us take the derivative of the signal and then we apply actually or calculate that 0-crossing rate.

Here you can take it in this way that whenever we are taking the derivative of the signal, derivative is a high pass filtering operation. So, that is removing the DC bias. The derivative will become free from the DC component, of force the DC component to 0. Same way that the low frequency artifacts; that means, low frequency noise that is also eliminated by that derivative operation.

So now that the remaining signal if we take the 0 crossing, we will get actually a replica of the original 0 crossing. Again, how we can assume that? We can assume that any signal it can be represented by it is Fourier series. So, it constitutes off actually it can be constituted by number of sinusoids. And now if we can constitute them by sinusoids, and if we take the derivative that they are also sinusoids. So, that 0 crossing rate does not change for a single sinusoid.

So, that gives the rationale that why we can take the that derivative of the signal to compute the 0-crossing rate, and still we can get something which is useful. Now this is that one of the key attraction of these that 0 crossing rate, that it is actually it is a very simple. But it gives us some idea or notion of the frequency of the signal. So, that is why it is so attractive. And let us now look at the applications of it. The first thing is speech versus silence decision.

When we are talking over the telephone or the mobile, we are speaking some time and in between there are some silence period; where we are actually either breathing or we are listening to the that other end. So, for all such gaps, or we call as silence, that when the subject is not speaking. Now during that if we actually use the that communication channel, that would be actually very what I would call that inefficient utilize of the resource. You would be utilizing the bandwidth, we drain the power of the that your mobile phone by sending that signal. And what actually we are transferring either a silent patch, if we are in a recording room. Or if you are outside, then a lot of environmental noises are there, those things are actually getting picked by the mic. And we are transmitting that.

But that is not actually giving us a any useful purpose. They are not serving any useful purpose. So, if we want to have a good recording or good transmission of the speech, then we should know that what part is the speech is present, and what part is the silent period is there. And one of the easy way to find that out is the 0-crossing rate. How that happens? If we look at the speech it has a particular range of values for that 0-crossing rate, or we can say that the bandwidth of the speed speech is fixed.

Now when you are in a recording room when there is no noise it is shielded from the noise, then 0 crossing would be 0 because there is no signal. Or if you are outside, then other kind of noises would come. They would have completely different spectra or different actually frequency band. And so, that 0 crossing rate also would be different. So, if we can study that thing, then we can easily find out that what part of the signal is speech and what part it is actually that silence period. So, that is the first application.

Next is the voiced and unvoiced sound discrimination. That voice speech and unvoiced which we know; that they have their mechanism of the generation is little different. For the voice speech we generate the wave by the glottis, and that gets modulated by the transfer function of the vocal tract, and we get the sound outside. In case of the unvoiced speech; however, the wind comes from the lung, and that is forced through that vocal tract. And that that the wind which is coming in a turbulent way, it is a noise like correct since it has. And noise means if it is a white noise, we know from the definition of white noise, it has all the frequencies present in the signal.

So, once we pass it through the vocal tract, which is a filter, what happens that? All the frequencies present in that input signal, some of them they are actually getting shaped some of them they are completely dropped some of them they are getting attenuated. So, in the output signal, or sound what we get? We get actually the replica of the that spectrum of the vocal tract. So, that the 2 kinds of sound, one is the voice sound, and unvoiced sounds they are different from the that; in that in terms of their that starting point that is, what is the source of the that signal.

And because of that they vary much in terms of their that the intensity as well as the frequency content. When we are looking at the glottal pulse, it is they are periodic waves. So, that they have a limited set of bandwidth. So, they are again getting shaped by the vocal tract but because they are limited only those frequencies. A part of it can actually come in the output, and those frequencies are much more limited in frequency, and they are low frequency compared to the unvoiced sound spectrum.

So, as a result when we look at the 0-crossing rate of the voice speech we get the number of 0 crossings over a period is much low, compared to that of unvoiced speech. In other word the 0-crossing rate of the voice speech is much lower than the unvoiced speech. So, that gives us a easy way to find out that which part of the speech is voiced and part of the that the sound is the unvoiced part using the 0-crossing rate.

Next, we can look at the PCG signal for the detection of murmur. That when we have some kind of abnormality, that if we have stenosis in the arteries, that or we have the calcification of the that the valves. We get changes in the PCG signal, the s 1 and s 2 waves. Now those murmurs they are associated with not only high energy, but changing frequency. In the signal and the changing frequency of that signal or murmur; that is, picked by the 0-crossing rate very effectively. So, that is a another actually use of that 0-crossing rate.

So, what we see that 0-crossing rate though it is very simple, it has number of applications, and it is very attractive, because it is very simple to do. The only thing we need to keep in mind that it has a that problem of DC bias. So, either we need to make sure that DC bias is 0 all the time. Or the simple thing what we can do; we can take the derivative of the signal, and then for we can forget about that DC bias, and we can go for the 0-crossing rate.

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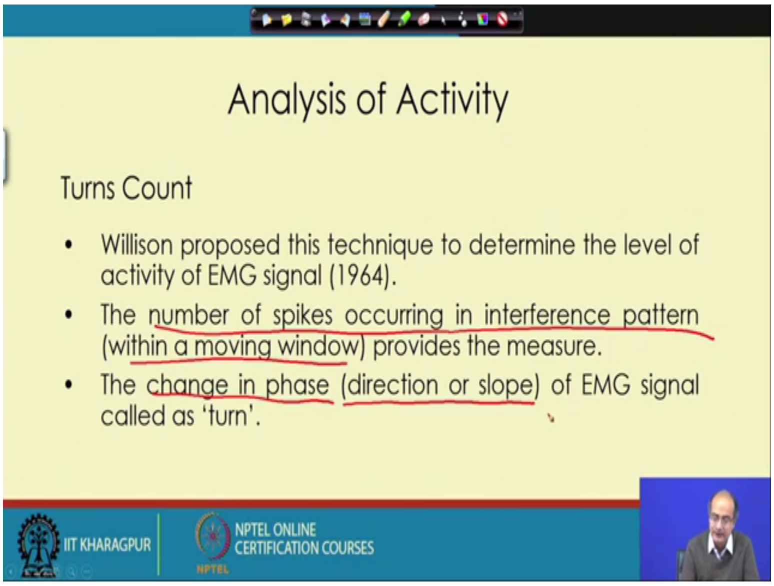

Now, let us look for another technique that is called turns count. Turns count again that measures the activity of the signal and it was proposed by that Willison. In 1964 for the EMG signal they wanted to find out the level of activity of the EMG signal; that means, when we are trying to say do some activity that through them with the help of the muscles maybe lifting a small weight we want to do that, how much actually that effort we need to give that that can be measured by the EMG signal.

If the muscles are weak then we need to actually whip it again and again and engage them again and again. So, the EMG signal strength will increase, and that gives rise to higher turns count. In fact, if you look carefully, that this turns count is very much actually related with the 0-crossing rate. 0 crossing rate is measuring that amount of activity, or how the change in frequency is occurring in the signal. The turns count also is giving the same thing.

The difference is that in 0 crossing rate we are taking as a reference that is a that usually the midpoint midline, and how many times we are crossing that that is the way we are trying to find out the frequency in case of turns count we are looking at the then local that extremum, and from there that we want to find out that how many times they are changing the actually the turning and changing their gradient.

So, thereby we want to find out that number of turns. So, that is the difference. So, what it is trying to get? It is finding out the number of that spikes occurring in the interfering pattern. So, that is the motivation and again that is counted within a moving window that to give us a measure of that how many turns have occurred and how they are changing over the time.

Now, here what is important, if we want to get a definition of it we are actually looking at the number of time the phase is changing or to be in more simple ones the direction or the slope of the signal is changing. Then in every extrema, whether we look at the maxima or the minima, that there is a change in direction or slope. We can say that slope changes the sign. For the EMG signal, that is what they called as a turn. And using that that, they wanted to get that what is the amount of activity is happening for the EMG signal.

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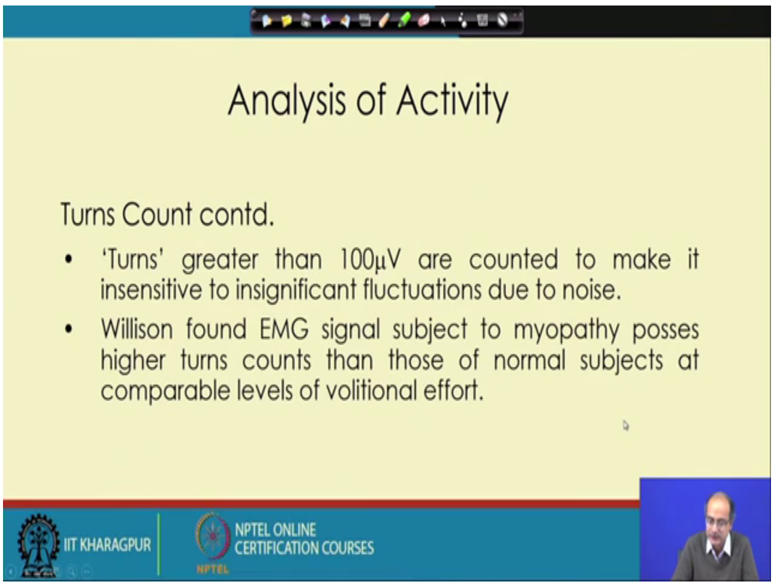

Now, here one problem comes in the way that whenever we think of a signal let us take a slowly varying signal, that we are looking at we have taken here a sinusoid.

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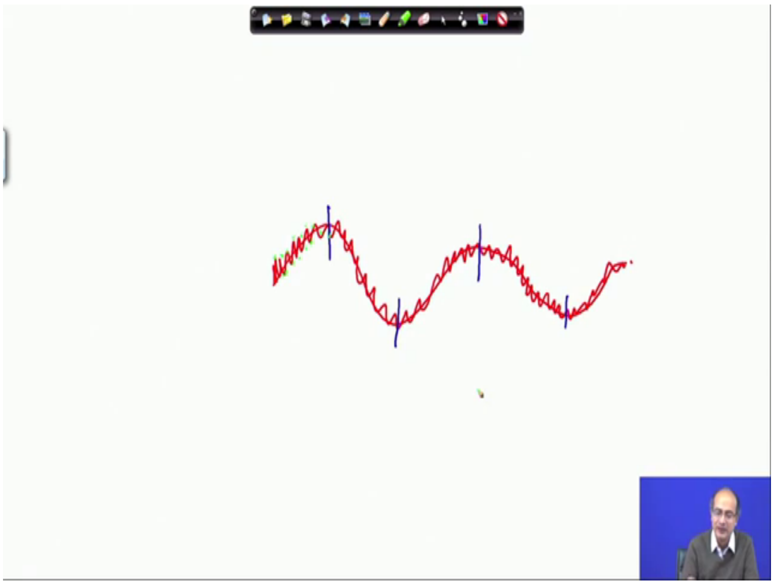

Now, if we have the white noise or the power frequency noise along with that, it will come actually riding on this signal. So now, after these noise has been added with that signal; that what actually we were expecting earlier we should get a say maxima here we should get a maxima here and that will here also minima we can take that number of turns we can count in that way.

But because of the noise we are getting at every point that here, here, every place we are getting one turn. Which will completely destroy the result and make actually turns count completely a useful sorry useless function. So, to get rid of that, what is suggested that they wanted to the researcher stole that they want to take only the prominent turns. And they define the prominence by some magnitude; that turns must be greater than 100 microvolt to be counted to make it insulin sensitive to insignificant fluctuations due to noise.

So, what they wanted that if there is noise; which is all the time there and we cannot avoid that noise, but what we can do if we keep a high threshold; that means, only the prominent turns should be counted. And small turns or small king kind of thing in the signal, if we can avoid then, we can get rid of much of this effect of this noise. So, that is a taken as a strategy and that was implemented and they have given a concrete number also for PCB signal and sorry, EMG signal here. They have taken 100 micro volt is a number if you change that signal or change the setting of your amplifier this number need to be again actually calibrated.

So, Willison when they used it for the EMG signal having the problem of myopathy; that means, some disease of the muscles; what they have found that turns count actually is higher than those of the normal subject for comparable level of volition. Now what that means; that if a normal subject is lifting a small weight and the same task is given to a subject having myopathy or disease of the muscles.

Because of the weakness of the muscles, we need to actually exert more actually force or a excite the muscles more and more times to leave the same weight. So, in that case the activity of the EMG signal would be much higher. So, that was the observation by Willison, and they found that turns count is a very effective tool for finding out the activity of the EMG signal.

So now let us move ahead. We go for another thing called form factor.

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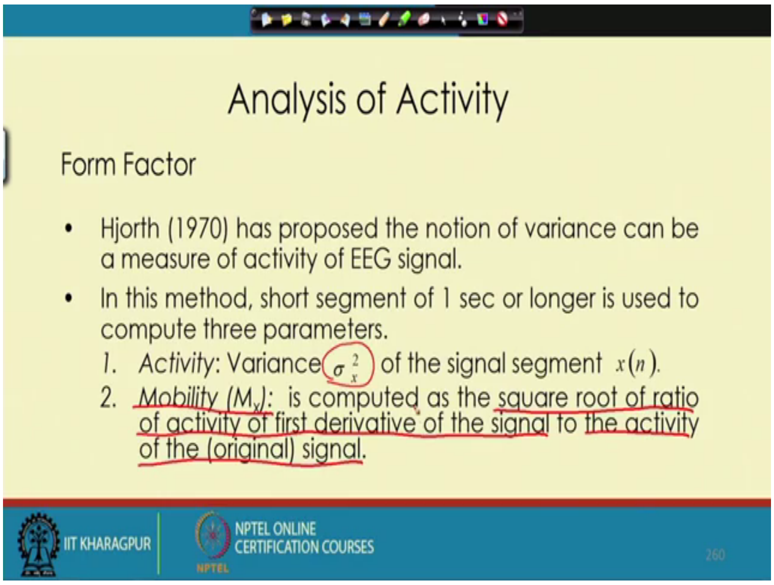

This is another measure. This measure was proposed by Hjorth in 1970. This 1970 is what they have suggested this technique. And their goal was to find out the activity of the EEG signal. Now keeping EEG signal is in mind; that they wanted to see that how the activity changes for every second.

So, if you take a window of one second, how that activity changes for every second or you may take a longer window. And for that purpose, Hjorth suggested; that 3 measures. The first one is the variance of the signal xn, and we know that if the signal is actually freed from DC component; that means, if we remove the DC bars, then it gives us the energy of the signal or how much it is varying. That is the first thing we get.

Next, they have suggested that we should take the mobility he has defined something called mobility of the signal. Now mobility is nothing but the square root of the ratio of the activity of the first derivative of the signal to the activity of the original signal; that means, what that mobility is looking at that if we take the first derivative of the signal, that we want to get that how much activity is there in that derivative signal with reference to the original signal.

So, for that purpose we have taken the ratio and we have taken the square root; that means, instead of the standard deviation. Sorry the variance we are actually interested in the that the ratio of the standard deviation of them.

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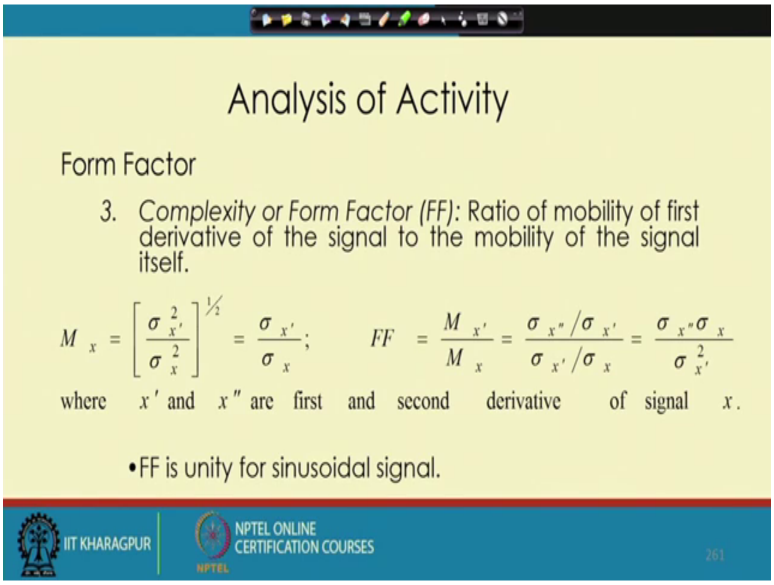

So, that was the that suggestions from Hjorth, and he suggested one more thing the third parameter. That is the complexity or the form factor. This form factor again, it is a relative term. It is taking the ratio of the mobility of the first derivative of the signal to the mobility of the signal itself.

So, again; that means, they are taking derivative to compute the mobility and it is giving the ratio of the 2 mobilities. So, let us look at the formulas to get it more clear; that here that we are getting that the first one first formula, that we are getting the that form factor, that first we know before the form factor we look at the mobility part of it. Mobility of the signal is computed by taking the activity of the signal, and the derivative of the signal; where if x is the signal then x is the first derivative and x double dashed is the second derivative of the signal x.

So, taking the ratio of the that activity, and then the square root of the square root of that we could get that the mobility of that signal, which is nothing but the ratio of the standard deviation of the that the derivative signal, and that original signal. And then the form factor is actually the ratio of the mobilities of the first derivative of the signal and the original signal mobility.

So now to compute that that we need the double derivative of the signal for mobility of x dashed. So, we replace actually those values, and what we get that the form factor is actually a function of the standard deviation of the double derivative of the signal, that the standard deviation of the signal, and the standard deviation of the derivative of the signal. So, using that that the form factor is determined and here. One more information I think would be useful that if we take a sinusoid, every time we take the derivative we get another sinusoid the phase only changes there.

So, that for a sinusoid the form factor is actually unity. So, that means, that what form factor is looking at; that how is a variation from actually unity, or in other words how the signal is different from a sinusoid. Or it is moving apart from a sinusoid. So, that is what you are looking at and not only the form factor along with that we have the measure of the energy that is given by the previous the parameter, that we got the activity of the signal as well as the ratio of the activity of the that the derivative signal and the original signal that is the mobility.

So, these 3 together in other what it is giving the energy of it, and how far it is? Different from the sinusoidal signal. So, that is again giving some idea about the shape of the signal, and thereby it is helping us to do the shape analysis of the waveform.

Thank you.