Machinery Fault Diagnosis and Signal Processing
Prof. A. R. Mohanty
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 25
Practical Signals

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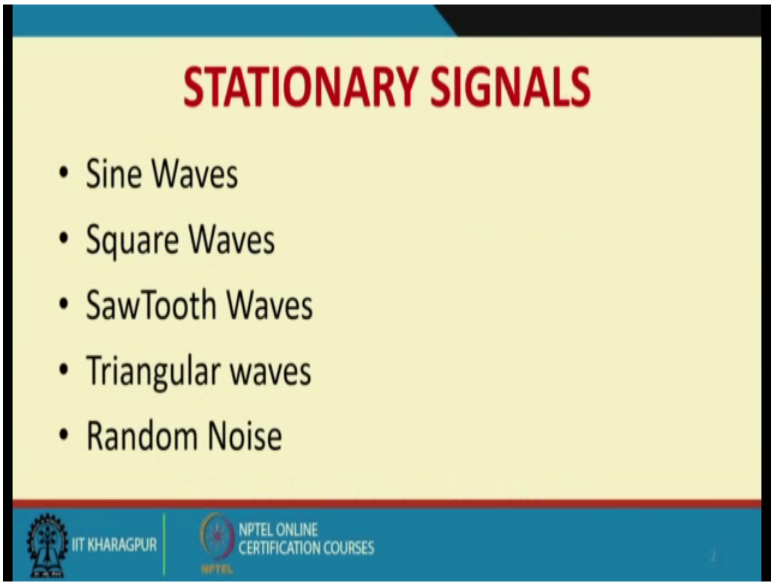

In this lecture, I will be discussing about certain practical signals and then I will give you a demonstration of few signals, which occur in practice; and look at them in both in the time domain as well as in the frequency domain on the run.

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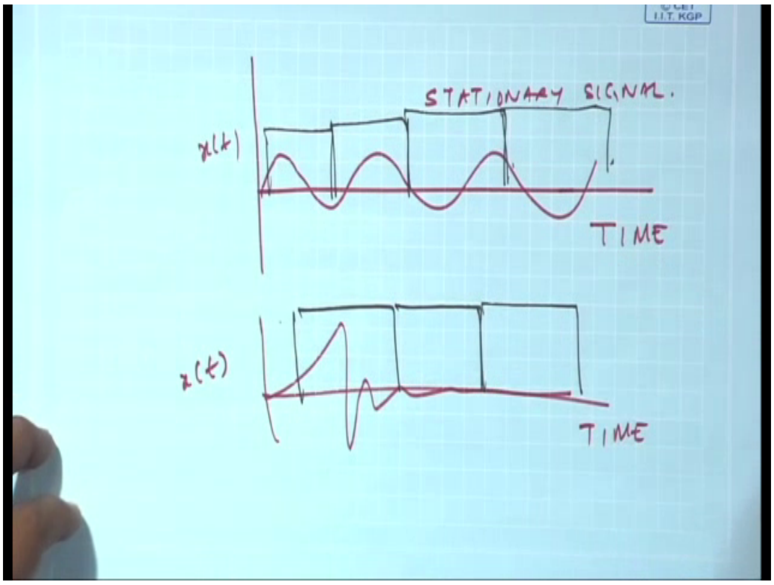

So, as you would have seen or by now would have realized that the signals can be continuously periodic or they can happen only once and that is it. So, this is a stationary signal. And the definition of stationary signal is that the time domain ensemble properties of these packets of the signal not change with time where else and this signal you would have seen that the values change which is not true in this case and so on. And some of the stationary signals which are there are sine waves, square waves, SawTooth waves, triangular waves and some of the random noise.

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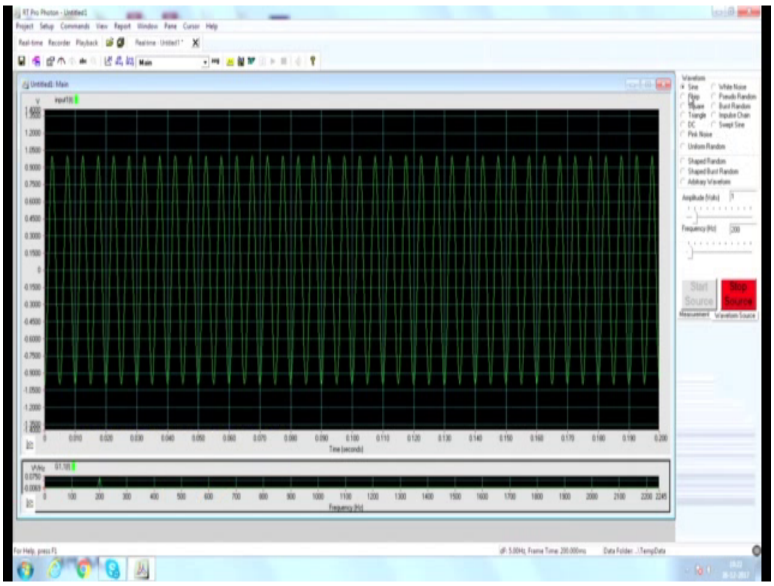

So, I will describe to you for example, here I have a signal generator wherein I can generate a sine wave of 1 hertz of 1 volt amplitude peak amplitude and 200 hertz, I can just stop the source. So, this is a sine wave, where the delta T is 199.3 microseconds. For example, I have about 2400 lines, so 2.456 about 1024 points. See, if you see this total time is about 0.2 seconds, I can change the number of lines to 800 and this will become double. So, I have taken in more data points, and I am taking in now more data points you notice here this is the total time in seconds 0.8 seconds with 600 lines. If I half it, 0.4 seconds, we further reduce it 0.2 seconds. The reason behind that is I am taking the values of N as 1024, make it 2048, make it 6400 and so on.

You can see for 3.2 seconds, I will reduce it right. So, one can play around with the number of data points I can further reduce it. And you see this is a sine wave of about 1.1 volt peak amplitude, 1 volt peak amplitude, I can measure it through a cursor here. It is about 1.004 volts yeah point. So, I am generating for 200 hertz a sine wave of 1 volt peak amplitudes, and then I will go to measurement, I can stop it. I can now generate are different waveform types also, but one thing which you noticed here is we have not changed.

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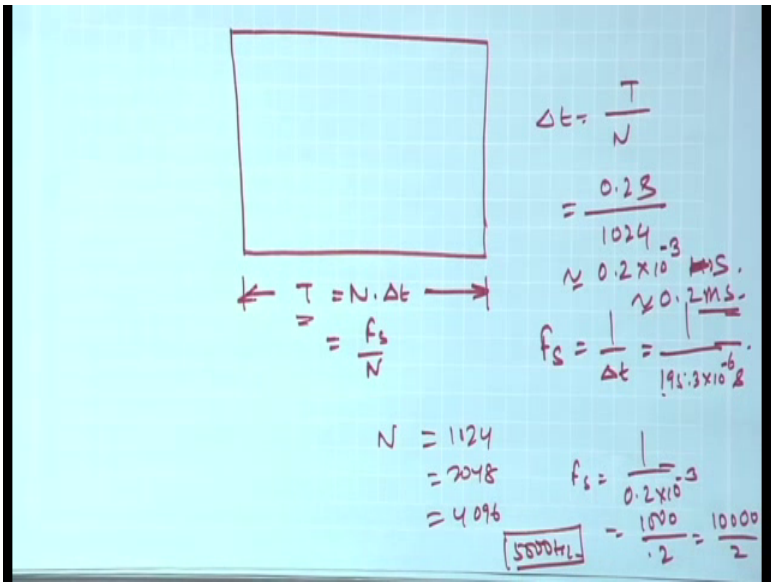

What I have done here is my T this N times delta T or nothing but F s by N are kept as F s as one by delta T that is a 1 by 195.3 10 to the power minus 6 seconds. And all I have done is varied and from 1024, 2048, 4096, so T is proportionately changing. So, when I have N is equal to 256, this 0.04, 4 times it becomes you know 0.2, so 1024 points this becomes 0.2 seconds.

So, you can in fact find out delta T in another way also delta T is nothing but total time by N. So, total time is 0.2 seconds and N is 1024 approximately 0.2 10 to the power 3 seconds. And then F s is nothing but so delta T is 0.2 milliseconds close to 0.195 milliseconds, 0.2 milliseconds. If delta T is 0.2 milliseconds, F s is 0.2 10 to the power minus 3 1000 0.2, 10000 2 close to 5000 hertz. So, I am sampling at 5000 hertz which I have I am not changing.

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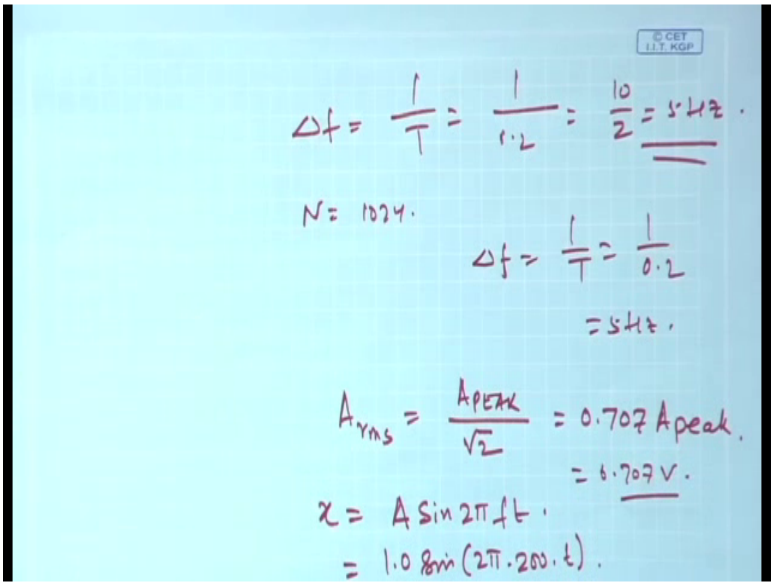

All I have done is you know it so you can find out the delta f is nothing but delta f is nothing but one by T that is 1 by in this case it was 1 by 0.2 it is 10 by 2 - 5 hertz. We will see that when we do f of t for N is equal to 1024. So, just to give you an idea I mean I will change this again to 800, this becomes 0.4 seconds, and delta T is not changing. Now, I will go to a square wave. So, this is the same square wave of 200 hertz. And the reason you see this glitches here is because I do not have infinite terms, because the way this is being constructed is summing up a lot of sine waves and then you will see this is also a periodic stationary wave of 1 volts amplitude and 200 volts. This is another triangular wave.

I will go to random noise. So, this is a random noise, which is happening of certain rms value 0.0537. I can increase the rms value. So, the value is very, very high 2.07 volts. So, I can play around the voltage of the source by changing this frequencies. So, these are examples of some of these stationary signals, I can have a dc value, where I can give a 1.3 volts it is time for the filters to settle length for the gains of the amplifier to settle in that is why you see this jumping around. But eventually this is going to settle down around 1.3 volts. I will give you a pink noise here of 0.755, a white noise and so on. The bust random noise, you see this 50 percent period, if I can change this to 25 percent period and so on.

Let us see what happens if I make it a 100 percent, obviously, you would not; I can make the bust by having 75 percent of the time period as burst and then remaining 25 percent is low. So, this is a burst random is a good example of a non stationary signals because in stationary signal would have assumed, we would have assumed that this is true for all times but which is not sure, not the case here because there is a no signal here. And that is the burst random with 75 percent period and it has a certain rms value.

I can generate an impulse chain quiet zone active zone I can reduce it, quite zone seconds (Refer Time: 11:36). So, these are all impulses, I can make the acting much, much smaller, these are all impulse strain which are generated. So, these are examples of non stationary signals. I can generate a switch sign where in the low frequency is this much I will reduce the high frequency. And then sweep rate can be (Refer Time: 12:46) mechanism. So, you see this in the same time window 0.2 seconds, I am having the signal frequency go from 200 hertz, 2000 hertz. I can further reduce it, maybe a little more. So, these are all sine wave of certain amplitude 1.2 amplitude is not changing peak value is 1.2, but the signal is increasing from 20 hertz to 800 hertz, and at a rate of 0.25 seconds per sweep. So, these are few examples of actual practical signals which have been generated in the case of with a signal generator.

Now, we will see how this signals look in the FFT domain. So, let me change the signal go back to my sine wave, and we will see I will make this as 1.0. So, I have generated a sine wave, wherein of 1024 with the sampling frequency of. So, let us see what happens in the FFT domain. So, look at the bottom window here. And if I move the cursor, this is the magnitude 20 unit rms. So, you see here to begin with I have generated or 200 hertz sine wave of 1 volt amplitude which you can see here if I move the cursor, this cursor here, close to 1.005 volt or 1 volt peak.

Now, what I have done, and if you go to the measurement, I have taken 1024 points and if you come here to the frequency domain my delta f right now is 135, if I move it next point is here. So, every 5 hertz, I have delta f is equal to 5 hertz as per this equation here delta f is 1 by T 1 by 0.2 that is 5 hertz. I can improve and of course, let me go back to 200 hertz here. So, 200 hertz I have rms as point seven not seven because I said A rms is nothing but A peak by root 2 that is 0.707 A peak .I have generated a sine wave x is equal to A sine 2 pi f T where A is actually 1 volt, sine 2 pi f is 200 hertz T. So, A rms will be nothing but 0.77 volts is what I am seeing at 200 hertz in the bottom curve here. Now, I will demonstrate to you in the last class, which are told about picket fence of it.

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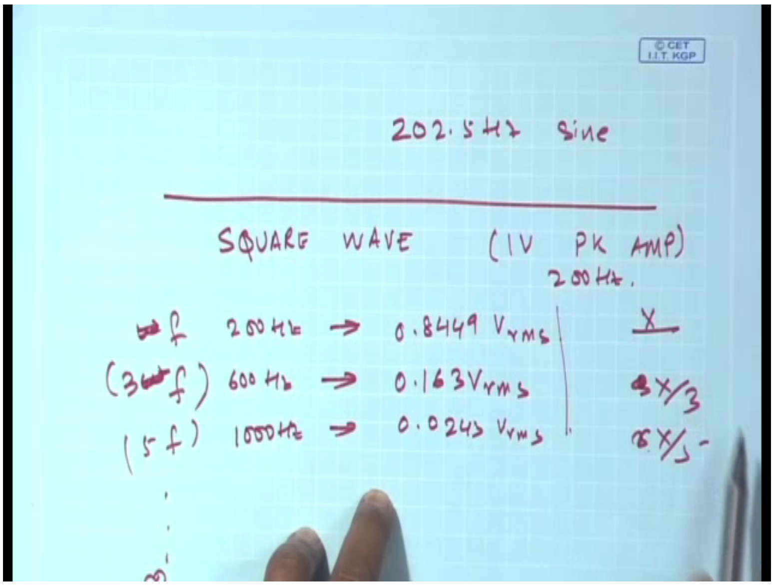

Imagine if I gave a value of 202.5 hertz sine wave. So, let me go back to my waveform source and make it 202.5. And I started source. You see if I move the cursor here, you see I quite not getting at because 185, 200, 200, it is giving me a value of point six naught six, 205, it is giving me point six naught six, and 210 it is coming up. So, I know the value is somewhere between you can closely see here, it is almost a horizontal (Refer Time: 18:08). Because my delta f is only 5 hertz if delta f was 2.5 hertz, I should be able to catch it, and how can I change that I will just go to my measurement and increase this to 800. Now, you see it becomes 800 then this becomes 0.4. So, delta f would become 1 by 0.4 that would become 2.5 volts.

Now let me see, so I do the measurements you see here, it is 87.5 19. So, I have got delta f s to 2.5 hertz. So, if I come close to 200, see 200.358, 202.5, I have got point seven naught seven, and this is what I have demonstrated to you as a picket fence effect. I could have done the windowing, I have used and windowing function handling. I could use different types of window in functions here, maybe I will use flattop here in this case it may not show me much difference, but let me see 0.7123, it is usually best to stick on to hanning and there are different types of.

Now we saw this in the sine wave so we just saw what we saw was different types of signals being generated. And then we saw the case of sine wave we showed you FFT the frequency domain and because there is a single frequency signal, you only saw one frequency are demonstrated to you, the effect of delta f being small or large and how by changing the value of N, we could change the delta f value.

Now, what I am going to do is go back and measure for the case of a sine wave for a square wave. So, square wave of 1 volt amplitude, and I will make it 200 hertz, yeah I want a square wave here of 1 volt peak amplitude and then 200 hertz is the fundamental frequency. Now, go to the measurement here in the bottom screen here you will see I have got an amplitude of 200, a certain amplitude and I can move the cursor. Here at 200, it is 0.849 hertz. For a square wave, 1 volt peak amplitude of 200 hertz. I have seen that at 200 hertz, this is 0.8449 volt rms. The next harmonic is three times that and that is at 600. So, square of essentially is mirrored of sine waves of different components at 600 hertz three times omega, it is 3 omega or f it is 0.163 volt rms. Then I will see at 5 omega that is 1000 hertz and so on. This goes to all the odd harmonics till about infinite at 500 hertz oh sorry 5 times a 1000 hertz I have an amplitude of 0.0243 and so on.

So, if you look at the Fourier series of a square wave, we will see this is a certain a certain x then 3 x, 5 x and of course x by amplitude will be x by x, x by 3, x by 5 and so on this will be approximately somewhere on that figure and then V rms and so on. So, square waves we can see the FFT, now if I change the waveform source now let me go back here change the frequency here, make it 100 hertz. You see there will be many components 100, 300, 500, 700 all the odd harmonics are there and the amplitudes also decreasing this goes all the way till infinite. So, this is the frequency domain representation of a square wave.

Now, let me change the waveform type let me make it triangular. And for triangular you get its frequency content and so on. Let me make it random noise. Now, interestingly in a random noise all frequencies are present. We will see here and if I can do an averaging here. I can increase, do an average and then I will get the frequency domain signal. Now, if you go to the chirp signal, you see because the frequency has changed you will see frequency has started I can start again see this is a good example of a non stationary signal. If you look here, the amplitude is almost same and then frequencies decreasing again increasing.

So, we will go all the way from 0 does gone up and then again come down. So, there is a lot of frequency smearing. So, this is a stay non stationary signal and this is the FFT signal, FFT of that. Assuming that it is a stationary signal and this is quite not right, the right representation of such signal because this says you know what a frequency of 400 hertz of maybe 0.07 amplitude exists at all times that is not true here. So, we need to do what is known as a time frequency analysis of such signals.

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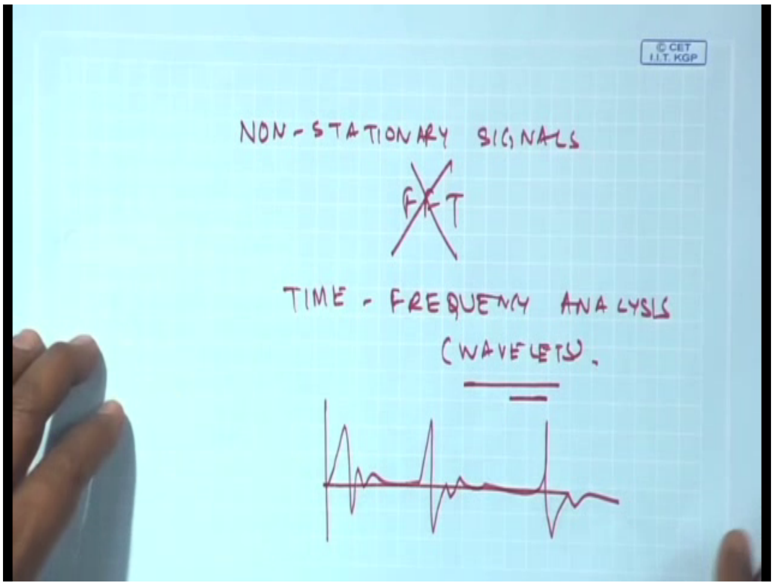

For non-stationary signals FFT is not to be used rather a time frequency analysis is to be done like wavelets and so on. So, I had shown you certain non stationary signals like a chirp signal is what we have it on the screen here or an impact where I had change the duty period.

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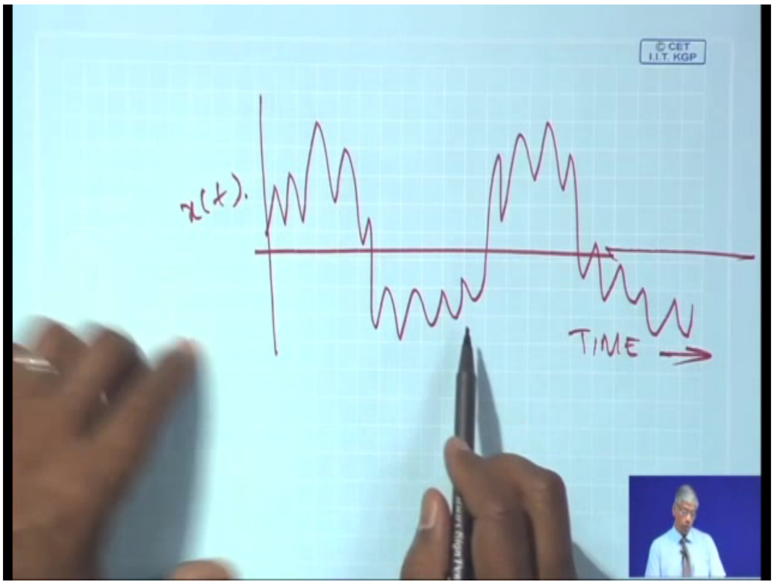

So, a real world signal from a machinery is actually a combination of all these this is a real world machine in a signal. And later on in the classes you will see any transducer I put on a machine I will get such time varying signals. So, we have to do an analysis as to how do you find out the frequency content of this signals. So, you saw the effect of how this frequency can be changed in such signals and so on.

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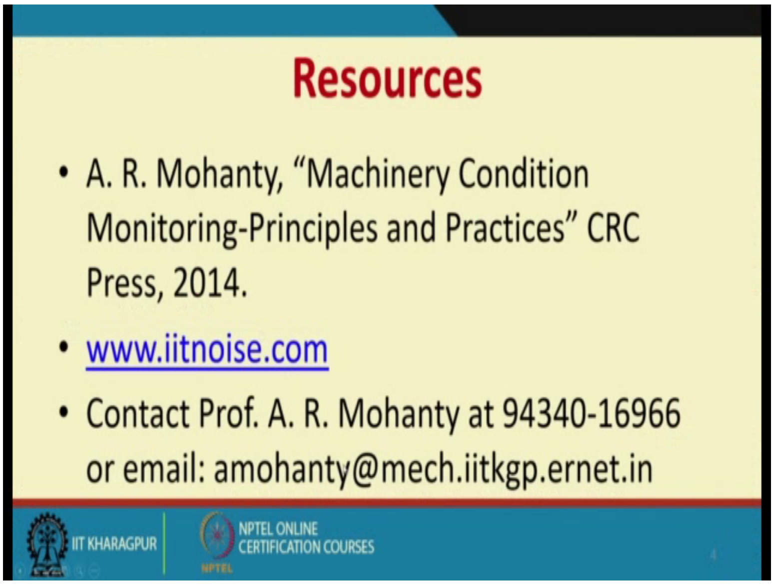

So, more examples of this you will see in my book and particularly to finding out the features of some of these signals in the time domain and also to see how these FFT can be done and so on.

Thank you.