Machinery Fault Diagnosis and Signal Processing
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Lecture – 22
Signal Processing using MATLAB

Well in this lecture, there go through certain signal processing examples using MATLAB. Like in the previous class you would have just seen an introduction to MATLAB; MATLAB, is a very popular software amongst students in the universities and those of you who are from the industry may not have ready access to MATLAB. But then you could also do the same logic in excel, and well we will the idea behind this lecture is to help you understand some of the signal processing processes or techniques which we have discussed and we will do them as we go in MATLAB. So, that you can feel of how the signals are generated and what kind of analysis is been done particularly to find out their frequencies and so on.

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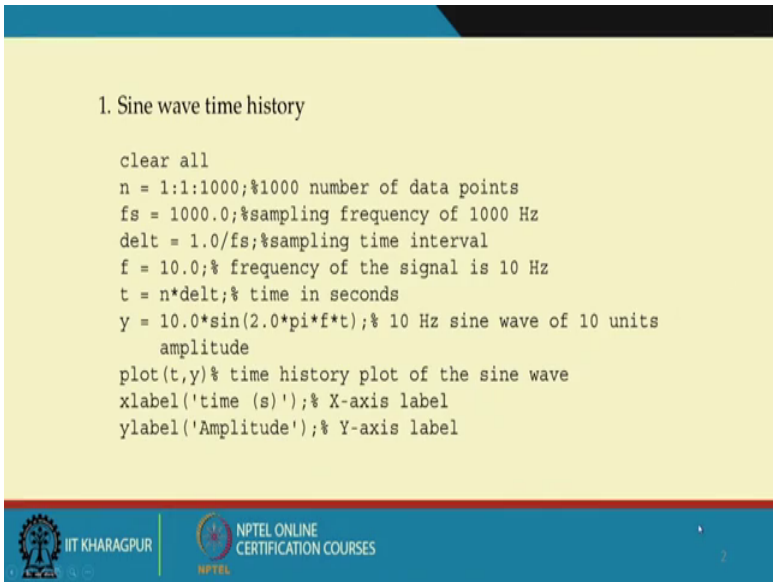

So, the very first example in MATLAB is just doing a sine wave time history I will explain you this, and then we will go through this in MATLAB. So, basically what I have done I have generated an in index from 1 to 1000 that is the time steps, I am sampling the signal at 1000 hertz. So the sampling interval is nothing, but 1 by 1000 that pends

seconds I have a signal of 10 hertz, by the way when you see a colon or a semi colon MATLAB ignores everything after the semicolon.

So, anything in percentage is actually in a comment statement, and such comments are given here for our understanding. So, for at any instance of n the time is given as n times delta t. So, now if I plot y is equal to 10 sine 2 pi f t, it will prop or it generate at 10 hertz sine wave of 10 unit amplitude, and will plot it as a sine wave of course, you can give a label x level anything you give within quotes time in seconds similarly y label within quotes the amplitude. So, let me just work it out in MATLAB for you all so n is equal to 1 I leave a actually very good idea is to always clear everything before you do MATLAB.

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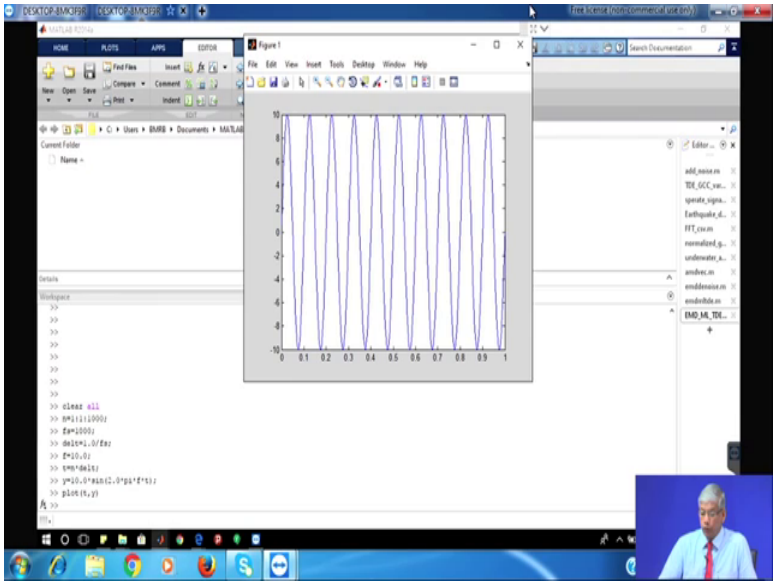

So, n is equal to 1 to my sampling frequency f s is 1 by 1000, i is 1000, so delta t is nothing but 1 divided by right (Refer Time: 03:15) first I will have a sine wave frequency of f is equal to 10, and then time at any instance t is n star del t I will plot y is equal to 10.0 star, sine 2.0 star pi, star f star t and before the execute this operation you would see that all the variables are already defined like pi is already defined in MATLAB, f is given t has been calculated and so on.

So, now I can plot see this I have generated a sine wave for a total duration of 1 seconds, now why is this 1 all of you those who have done signal processing will know that, since my I do not see the cursor coming in here, but let me come here. Then see I have

generated a index till 1000 sampling frequency at 1000. So, my total time when delta t is 1 by 1000 and n is 1000 the maximum value is 1 second, and my sine wave is of 10 hertz frequency.

So, the time period is 0.21 so, within a time of once second I would see 10 complete waveforms of the sine wave and that is what I see in this plot here, you can see this oh move makers are here this is a 10 complete waveforms I will see here on the MATLAB scream. So, this is 1 example which we did ok.

Now, let me quit let me clear so, nothing is that I can always do a whose to see that nothing is there remember it is clear no algorithm.

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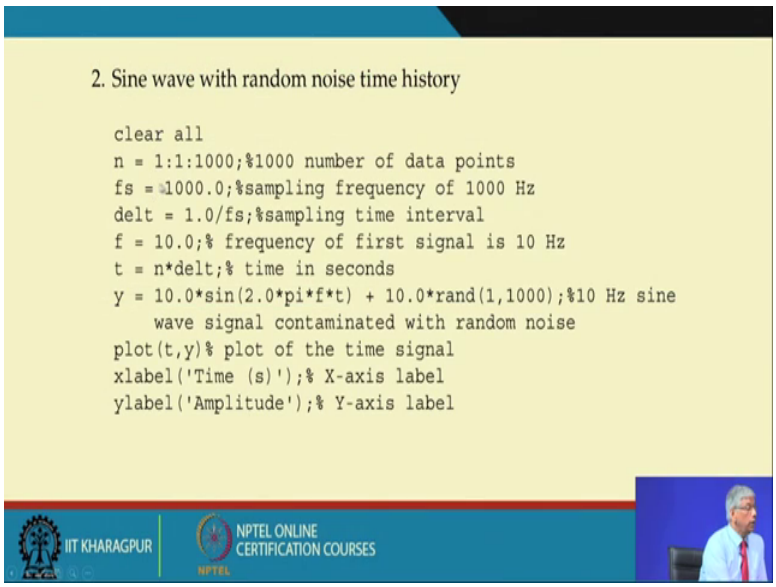

Next example a very to the same sine wave I have added a random noise you know everything also same, I have added a random noise. And then I am going to plot the sine wave with her random noise.

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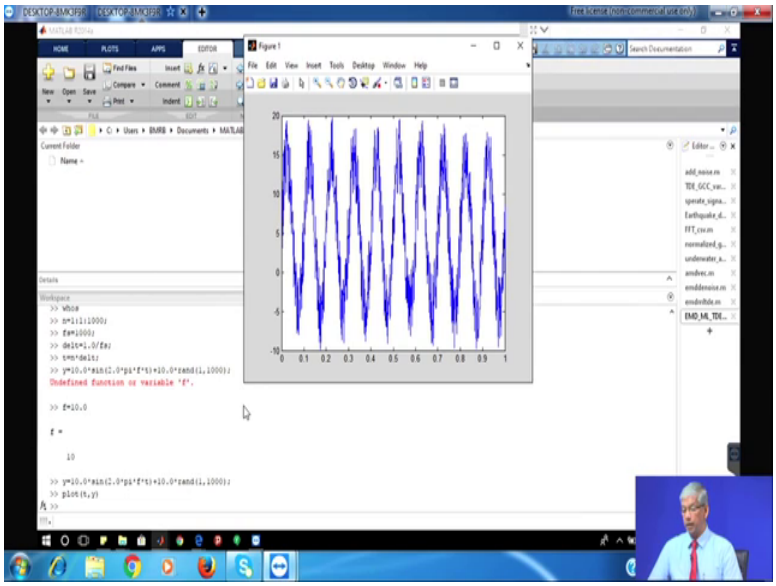

So, let me just quickly go through what we did and is equal to 1 t is equal to n times del t, and then I will add y is equal to 10.0 star sin 2.0 star, 5 star f star t and to this I am adding the random noise of this amplitude 10.0 star rand 1 yeah I have not defined f here.

So, I will make this f as a so what I could do is you know I have by typing are mixed the expression f. So, I will give f is equal to 10.0, and then execute this command. So, you see because while typing and miss f it was not able to compute this expression. So, once I given the value f and recomputed it has taken under value. So, now, I can plot you see earlier I had a very neat sine wave, but now to the sine wave a random noise has been added. So, you can see in MATLAB in fact many of the real signals which you will see will be having such signals.

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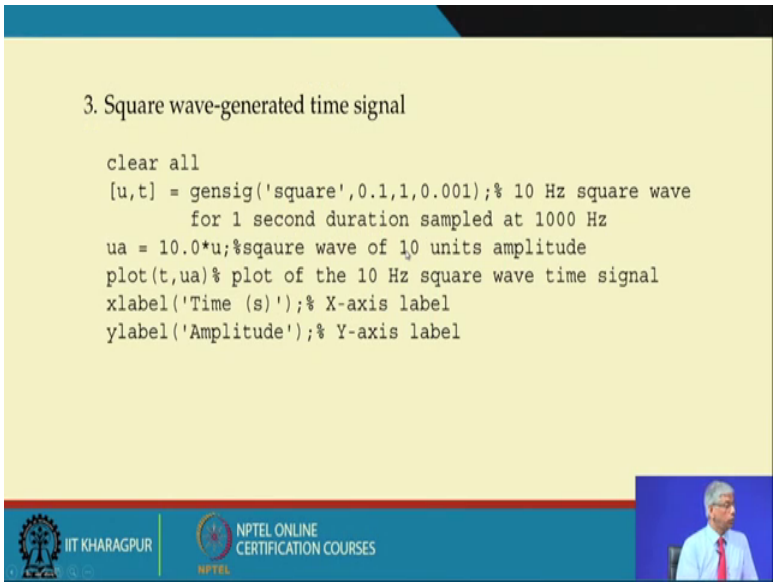

Now, this let us go to another command or another program. Wherein I am generating a square wave by given this expression gentie, were in I am generating a square wave for 1 second duration sample that 1000 hertz and 0.1 you know leaving the due to cycle, and then u a is equal to 10. So, you can always do help gensig just to be clear am I clear all here generate signal.

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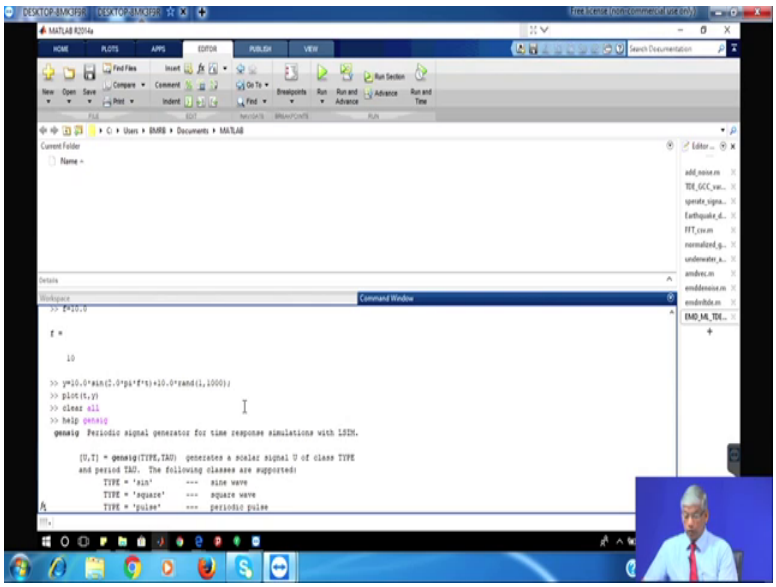

So, general signal type you can generate tau scalar signal u f signal type and period tau ok.

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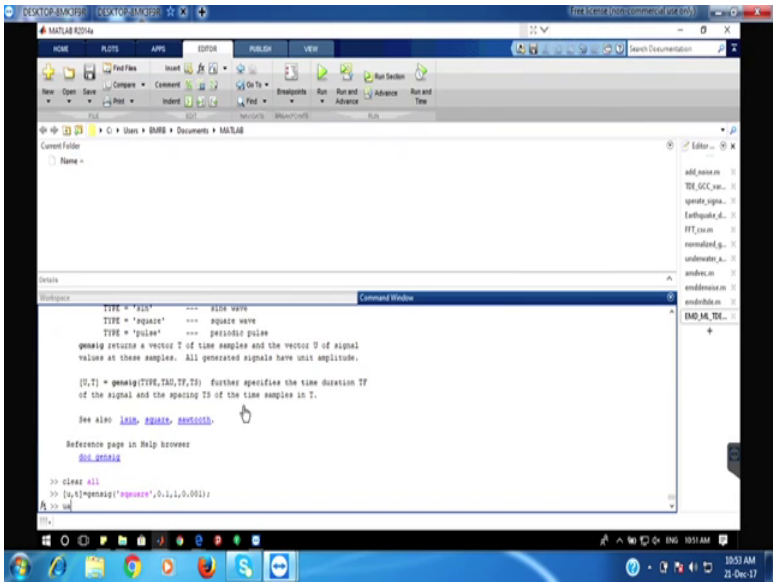

So, u t for the time duration of the signal spacing t s at the time samples in t seconds. So, let us do it like this clear all second back at u comma t is equal to gensig square 0.1, 1, 0.01 now I am amplifying the danube by a unit of 10 on our plot, because I have to generate t is equal to 1. So, plot t (Refer Time: 11:16) here, then I can always do a debugging online whose u a ok.

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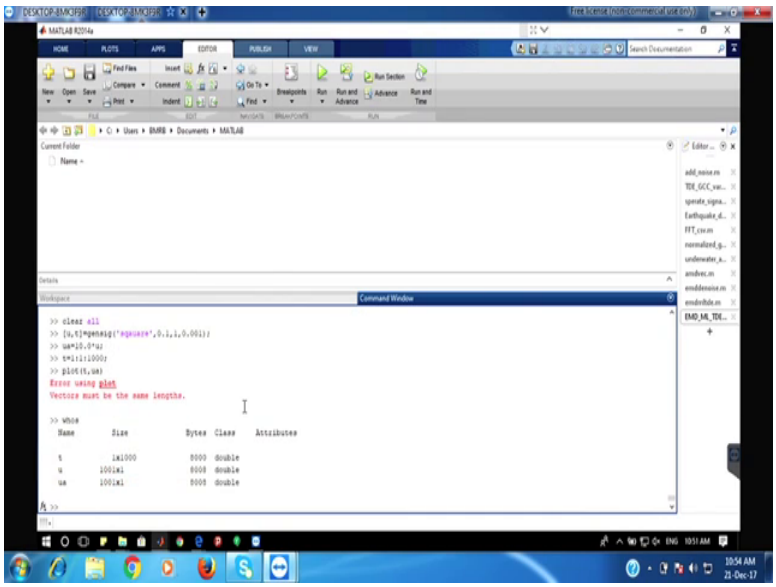

I can generate this t is equal to t transpose plot I mean (Refer Time: 12:01) 1000 1 let me t is equal to 1 plot sorry t is equal to e transpose plot t u a see. I have generated a square

wave and there was an error because you know I could quickly debug it you know for some reason u a is 1000 1 points, and gen initially are generated a 1000 points that is why I get this error fetes must be the same length.

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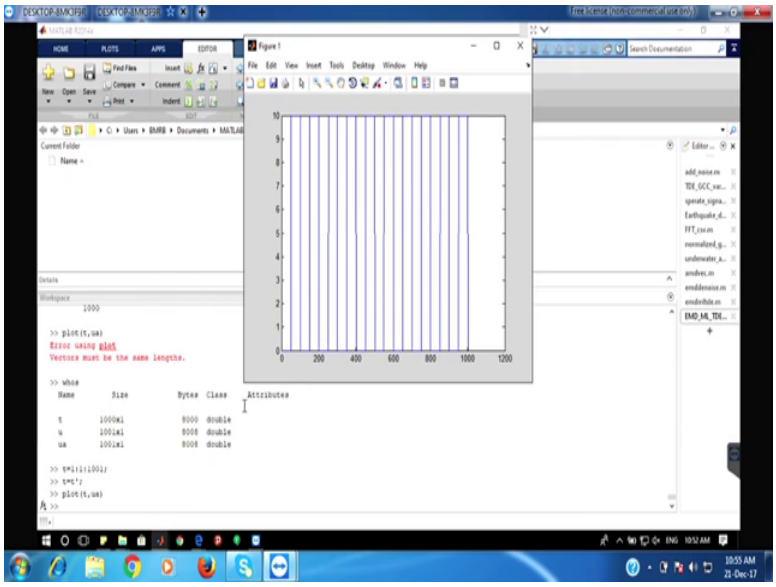

So, what I did is I increase t from 1 colon 1 to 1001, and then made a transpose and I plotted so, I have generated a square wave. I will now go to the next example of clear all.

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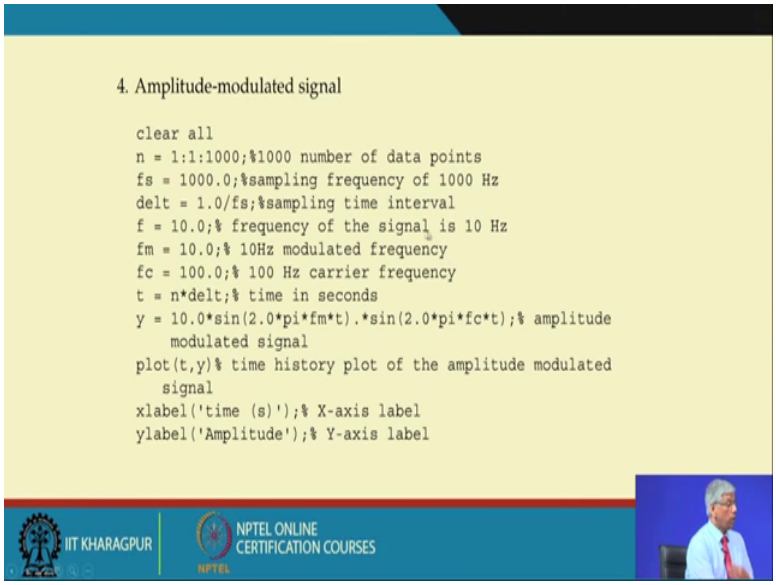

So, I am now generating an amplitude modulated waveform. If you all are not familiar with the end sampling frequency delta t frequency of the signal is 10 hertz. So, frequency

modulated frequency is 10 hertz, and the carrier frequency is 100 hertz. So, I am generating a modulated sine wave, and let us see how it looks like so quickly if I copy whatever is given here. So, n is equal to 1 2000 f s is equal to 1000 delta t is nothing, but 1.0 by f s, f is equal to 10.0 the modulated frequency, f c is 100.0 the carrier frequency, t is equal to n star del t, and then I will generate y is equal to 10.0 star sin 2.0 star pi star f star t. And you see this dot star sine 2.0 star pi star pi star fc star t, I did a typo here I can see here you should not do in the second bracket. So, I can correct it by pi this what I have been pi ok.

So, you can see in real time you can do such corrections. So, my amplitude modulated signal is there so, I can now plot t and y.

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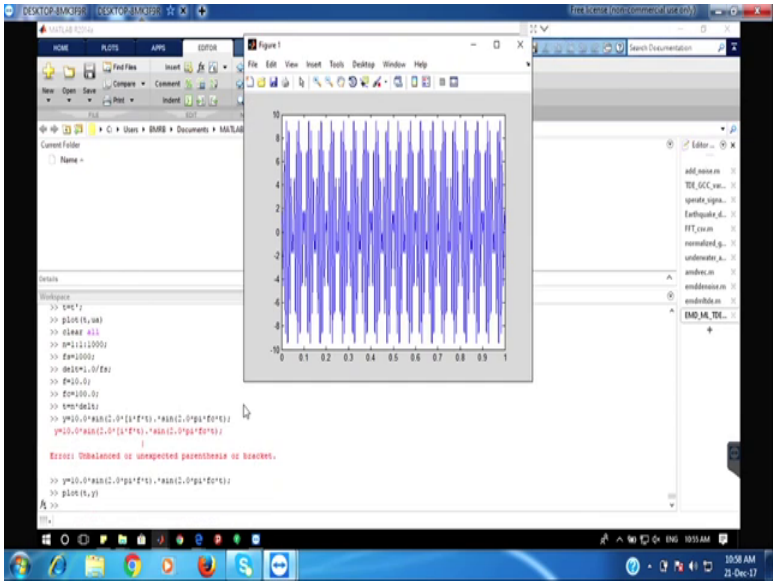

So, you can see modulations of the amplitude occurring. And there is an increasing decreasing again increasing and so on. So, within a period of 1 seconds I have got the time, once again total time it is a 10 hertz sine wave which is getting modulated by a carrier frequency of 100 hertz is how this is going to look like.

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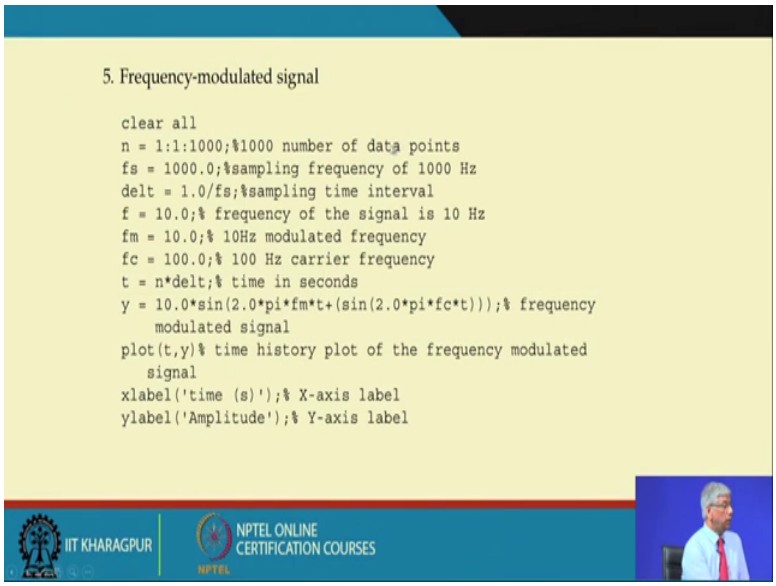

Now, I will go to the next example similarly for the frequency modulated signal I will not do this in at MATLAB here, but you can see the same sequence have been followed only thing is that when I have the frequency modulation expressions. Similarly I have to change the frequency contained by this expression, and this could be 1 of your home worlds to plot a frequency modulated signal in MATLAB.

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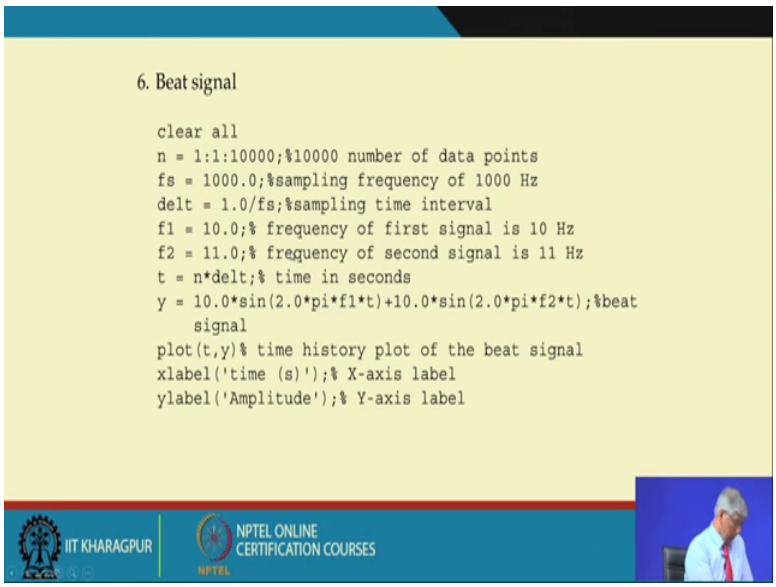

Similarly, I can generate a bits signal wherein I can we will see these bits of the signal, when we do the case of heterodyning where I have 10000 points. The only catch in bits

signal is the frequencies f 1 and f 2 are very close to each other, 1 is 10 hertz and others 11 hertz. And I am just adding 2 signals one being 10 hertz, another being 11 hertz. They will look something very close to an amplitude modulated signal, but they are not amplitude modulated in that sense.

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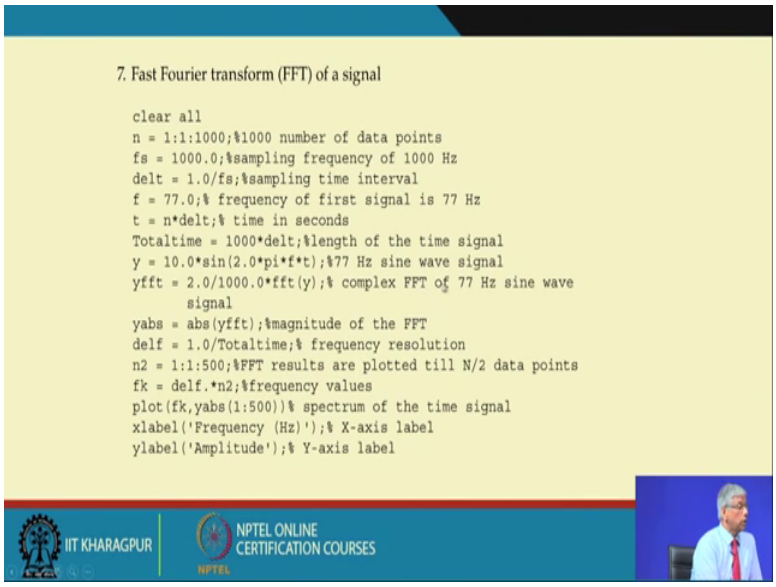

Now, I will come to 1 of the very important examples as in how do I do Fourier transform of a signal ok.

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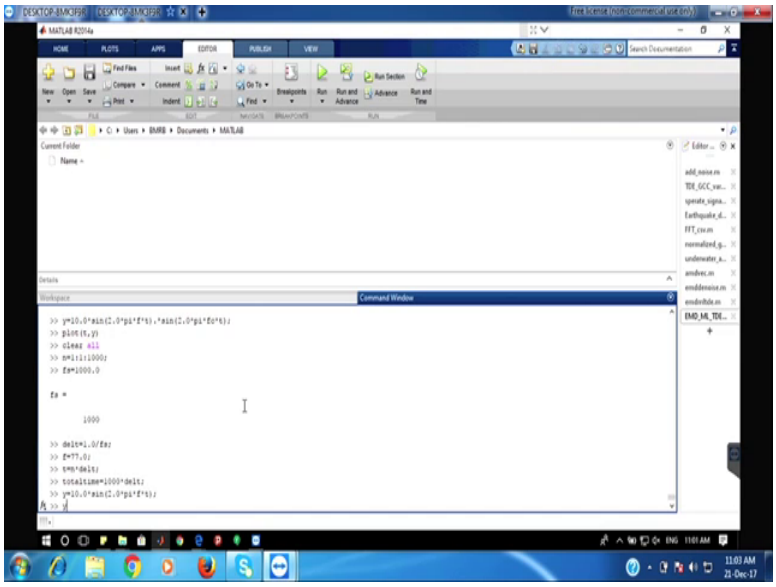

So, let us see this example here so, before I let me explain you what this is you all are not familiar with this index n is equal to 1 to 1000 sampling frequency is 1000 hertz. So, delta t is the sampling interval is nothing, but 1 by sampling frequency I have a frequency of 77 hertz, and total time of the signal is 1000 times delta t.

So, I have generated my sine wave time signal of 77 hertz by this expression y is equal to 10 star sine 2 pi f t, and this is the most important command here. Wherein I am doing the complex FFT of this 77 hertz sine wave signal. Wherein you see this is a scaling factor which we use to get the right amplitudes this is 2 divided by the number of data points, in our case the data points being 1000 I will multiply the scaling factor with the FFT, but as you know once we convert a signal from time domain to frequency domain it becomes a complex quantity.

So, why FFT is actually a complex quantity which I will just calculate and show you, and then to find out the magnitude I just do the y apps of the magnitude absolute value of the complex values of FFT. And the delta frequency in the frequency resolution in the frequency domain is 1 by total time; total time is given by this expression in it, and since the FFT results are plotted till and by 2 because of the negative frequency.

So, I am plotting from 1 by 5000. So, I can plot at any frequency till n by 2 the del f and I will (Refer Time: 19:17). Let us work this example out for everybody's benefit. So, n is equal to 1 colon 1, 1000 then I have f s is 1000 see did because I did not give the colon semicolon it did not prompt the delta t is nothing, but 1 divided by f s f is 77 hertz out of the frequency of my sine wave total time is nothing, but n times del t an instance t total time yes 1000 times del t. So, y is equal to 10.0 star sin 2.0 star y star f star d they are all been defined beforehand.

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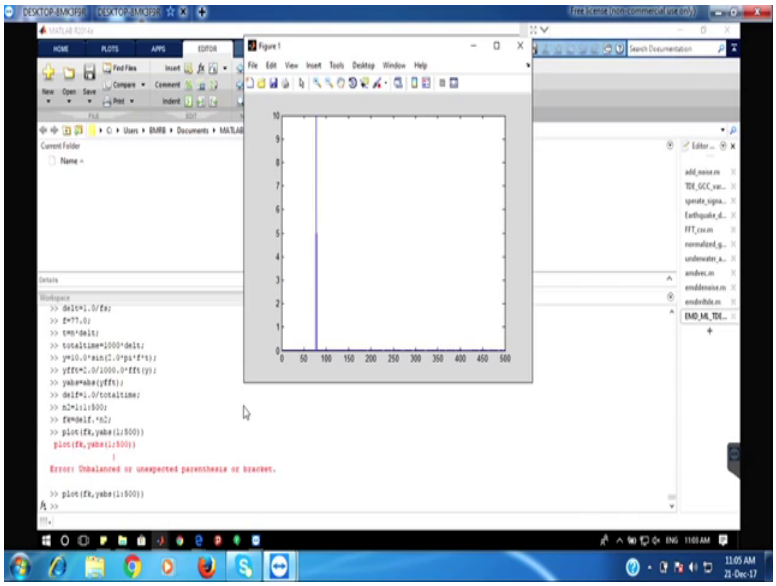

So, now I do the FFT y FFT is equal to this is very important you may not find them in the MATLAB handouts 50 y. So, the absolute value y apps was nothing, but a f t, and then I will plot the del f del f is nothing, but 1.0 divided by total time. And then in 2 is nothing, but a new index till the 500 points just to plot the first half frequency at any instance of n 2 is nothing, but this times sorry is equal to del f times into so, now I will plot fk and y apps the first 500 I made a mistake here.

This should have been colon instead of a semicolon. So, I will correct it by putting a semicolon it is good to do such mistakes so, that you get to phi. Now this is the frequency spectrum of the signal this is in frequency domain I had sampled at 1000 hertz. So, this is till 500 hertz and my magnitude is 10 hertz and this is close to 77. So, let me explain you what how we did FFT and what are the time block.

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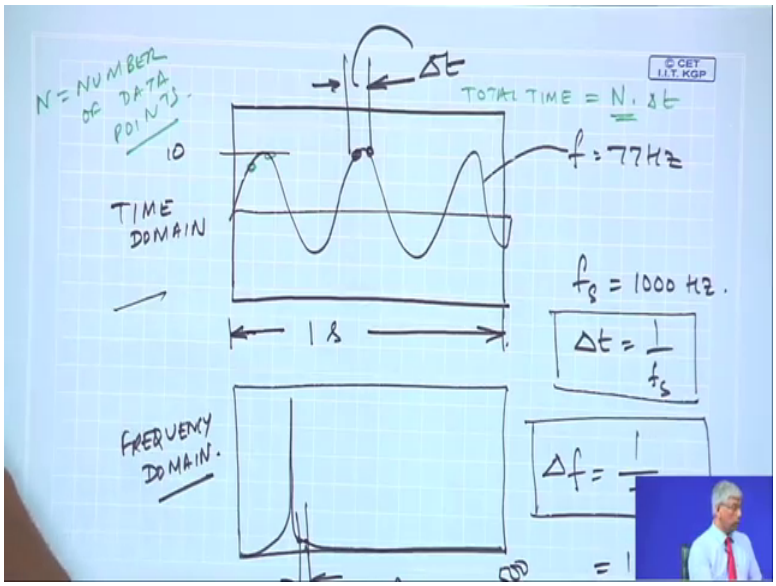

So, to begin with I generated a sine wave of amplitude 10 this are frequency is 77 hertz, where my sampling frequency was 1000 hertz. So, delta t is nothing, but 1 by f s so, at every 2 points this is my delta t. And this I took for n is equal to 1000 and this was only for total time was 1 second. Now once I went to FFT I plotted till 500 hertz, and the spacing just was this is here delta f. So, delta f is nothing but 1 by total time.

In this case because this is 1 second our delta f is 1 hertz. So, since the signal was 77 at 77 hertz I see a peak of 10 hertz, and this is what so this is in time domain, and this is in frequency domain. So, the relationship between delta f, and total time is very important and this. And you know how total time is related is the total time there is nothing, but N times delta t where N is the number of data points. Of course I have not talked regarding windowing etcetera no that is for a later course, but you know this is something which we need to understand in terms of the frequency content ok.

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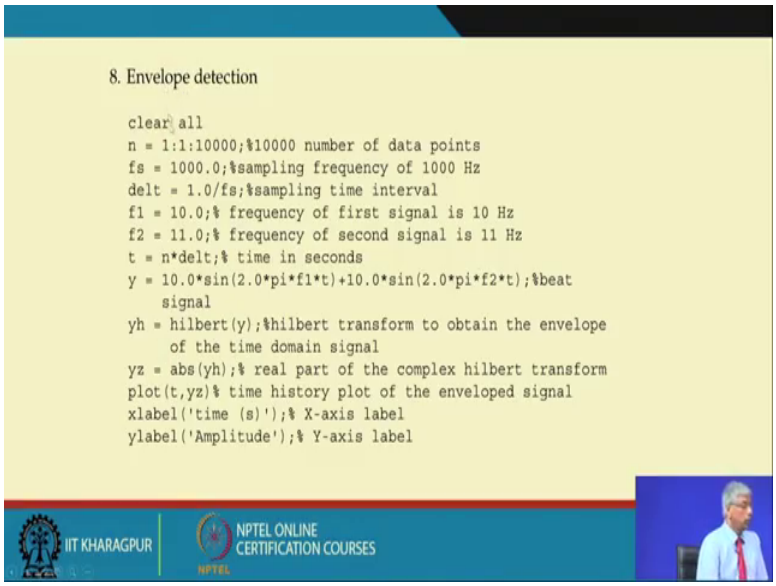

Now, I will move to the next. So, you can do an envelope detection because whenever we have the case of amplitude modulated signal so this is an amplitude modulated signal here. So, I will just do an Hilbert transform of this signal, and then absolute value of the Hilbert transform actually gives the envelope of that signal ok.

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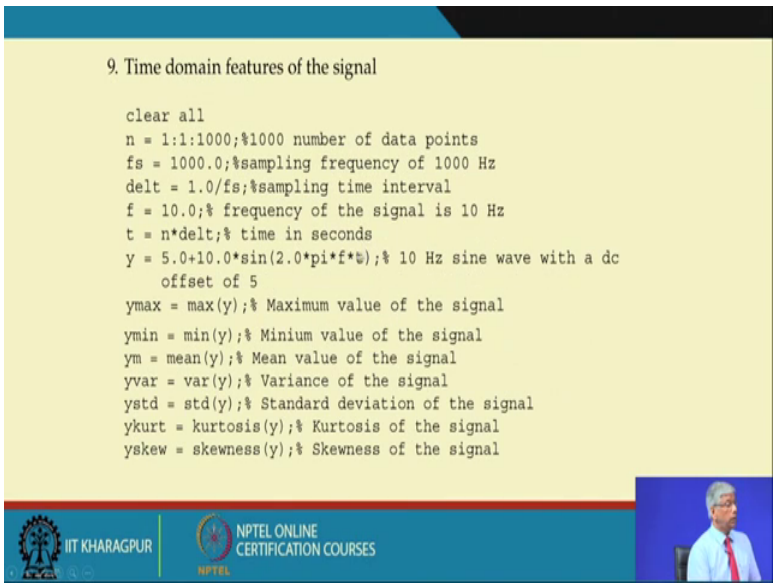

And similarly like I was telling you there are many features in a signal. So, if a signal has been generated is the 5 hertz has been a dc offset added to a signal of 10 hertz, I can find out certain parameters the maximum value minimum value mean variance standard

deviation kurtosis kunis these are all built in functions in MATLAB which could be used to calculate these expressions ok.

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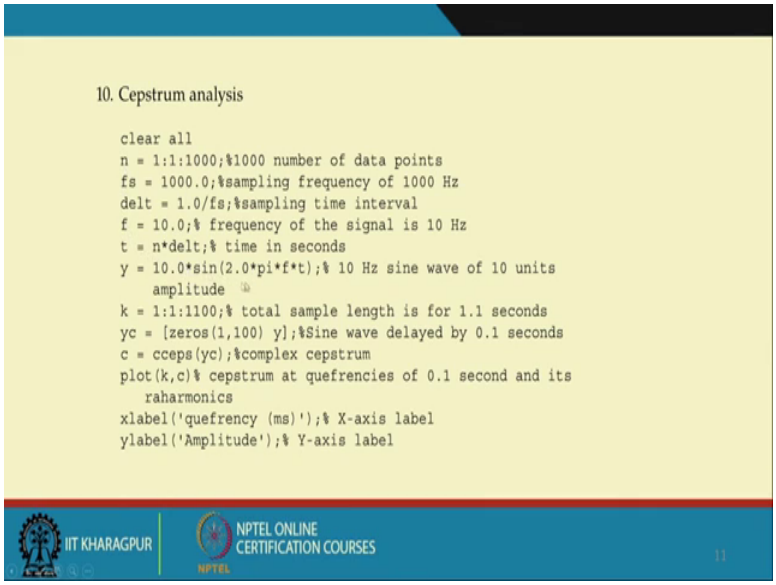

And then you will see the actual expressions for this in my book. And similarly another example which you all of you could try is the substances also. So, I have generated the signal have then added certain sample length. And where the sine wave is delayed by 1 second, and then I can see the complex sub strum by this command here and I can plot the cue frames is at point 1 second and its law harmonics. So, this is very important technique of substances complex substance is given by the c steps command.

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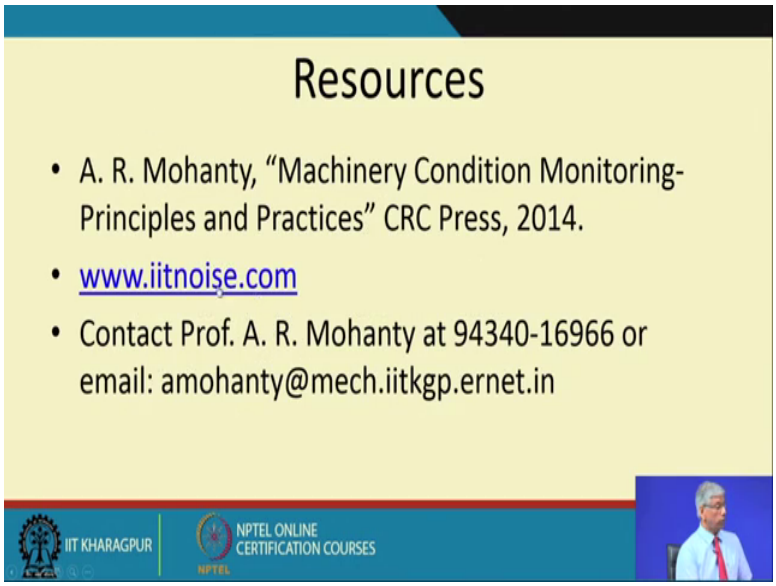

So, some of these examples which we discussed in this are given when my in an appendix so, all of you could perhaps try it out on your own using MATLAB. So, with this examples you know you got a feeling of how MATLAB could be used for signal processing. And then of course, in a later on I will showing you how such signals can be physically generated, and what kind of signals machines give out, and what kind of analysis, we can do either to a dedicated frequency analyzer or the software like MATLAB ok.

Thank you.