Machinery Fault Diagnosis and Signal Processing
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Lecture – 17
Wireless Data Acquisition

In this lecture, we are we are going to talk on wireless data acquisition. Now in the previous classes we had talked about computer aided data acquisition. And well, CBM or condition-based maintenance is done in industries where the conditions are very harsh, and machines are not accessible. And today the state of the art is such that I did not have signal cables coming down from the transducer to the receiver or to the unit where the signal analysis has been done.

Rather we send it wireless in a the air. We can send it wireless through receivers send it over the cloud through satellites, you know for example today. We can be sitting here in IIT Kharagpur in the mechanical engineering department and doing analysis of a turbine which is working in Alaska, other corner of the globe. So, well this is possible. In fact, this is possible in real time also provided of course, you know nobody we need not have wires. So, we can acquire the data, right locally at that turbine in Alaska send it as wireless signal to the satellite, and then over the cloud or the internet this can be accessed. And then we can download it at Kharagpur, and do this signal analysis and that is this state of the art.

Now, let me tell you the day will come when we will have everything wireless, everybody communicating over the Wi-Fi and transducers being very small embedded into devices. And every device has in having a distinct internal sorry IP internet protocol address. So, the internet protocol version 6, IPV 6 which is going to come up and which is there every inch of the earth on the land underwater above the ground is going to have an unique IP address.

And that is; that means, everybody you know right now in our country it is everybody's adhar number which is it ones identity, but in a they will come when every devices IP number is going to be their address because this can be mapped to one inch of every surface on the earth above earth and below the ground.

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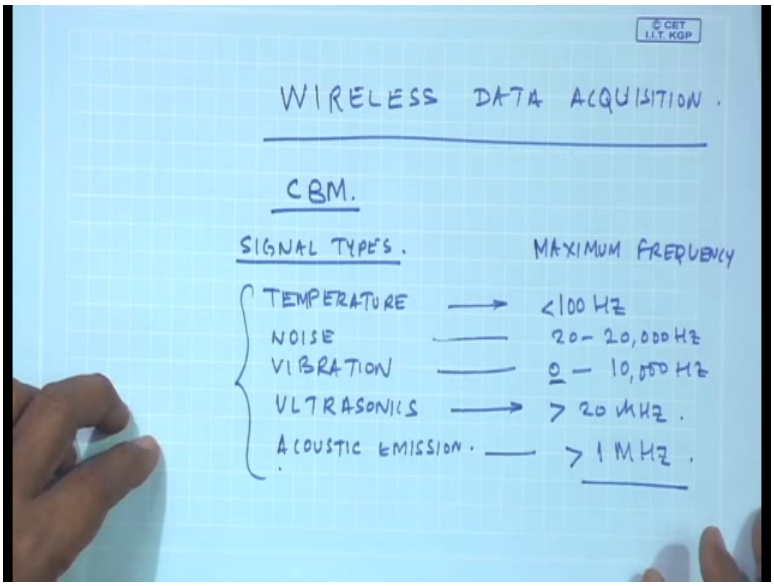

So, wireless data acquisition is the need of the day. And of course, is also happening to some extent. So, I will briefly in this lecture introduce you to wireless data acquisition as to what are the pitfalls in wireless data equation event even today when we talk about wireless data equation, why do we need to then you know cable connect LCD video projector, or even the projector which is beaming us through cables. So, there are limitations, and if that limitations is overcome they will come and will have signals flying around in the air in wireless.

But I will in related to CBM I will again tell you the signal type and the frequency content if I see the signal types. And possible maximum frequency say for example, temperature, noise, vibration, ultrasonics, acoustic emission. Now typically in the mechanical the this frequency of this is less than 100 hertz. This 20 to 20,000 hertz vibration anywhere from 0, I am because you know you can measure all the way everything is vibration, but what we call vibration is you know maybe 10,000 hertz, because all the sources of vibration like in electrical motors IC engines machineries, I think there is enough information till about 10,000 hertz in the of course, you have to be careful about the low frequency vibrations ultrasonics anything greater than 20 kilohertz though you use ultrasonics or NDT.

Ultrasonics are used in sonars for navigations. An acoustic emission could be greater than 1 megahertz. So, in CBM we are going to come across all the signals, but as you know end of the day we have to do what is known as digital signal processing.

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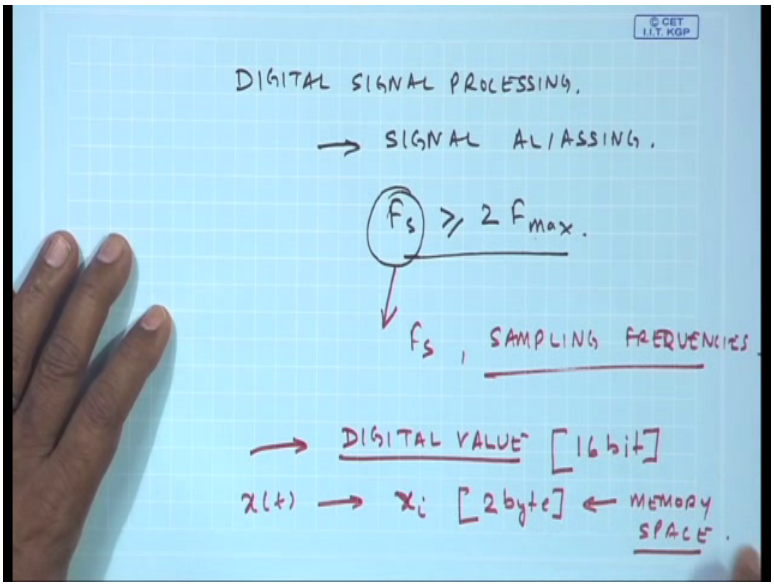

So, if you recall the class on computer data acquisition, I had mentioned to you about the condition of signal aliassing. So, to avoid signal aliassing we have to have the sampling frequency which is greater than equal to twice of f max. So, the type of the signal when we talk about acoustic emission, greater than 1 megahertz or 2 megahertz, when we talk about temperature signals less than 100 hertz.

So, there is a wide requirement in the type of data acquisition devices which you require which comes with something frequencies sampling frequency. The sampling frequencies required by different data acquisition units are different, but finally, you see in the wireless data acquisition what I do is you know. If I have digitized data it will be stored in a digital value.

So, some xt which I have if a corresponding to an x i suppose this is a 16-bit data acquisition. So, every x i will require 2 byte of memory space.

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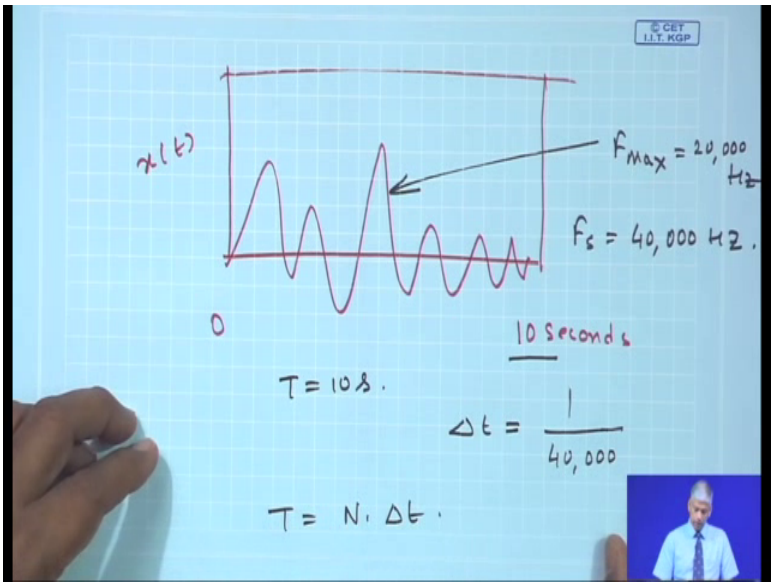

And if you for example, I have. A signal which is happening at time and this is 0; this is 10 seconds some signal xt. So, if I want to capture 10 seconds of signal where capital T is 10 second. And imagine if this was maybe a acoustic signal. So, the maximum frequency here f max is 20,000 hertz. So, at least my sampling frequency should be 40,000 hertz. Now, that means, your delta T is 1 by 40,000, right.

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So, what is T? T is equal to n times delta T right. So, from this example.

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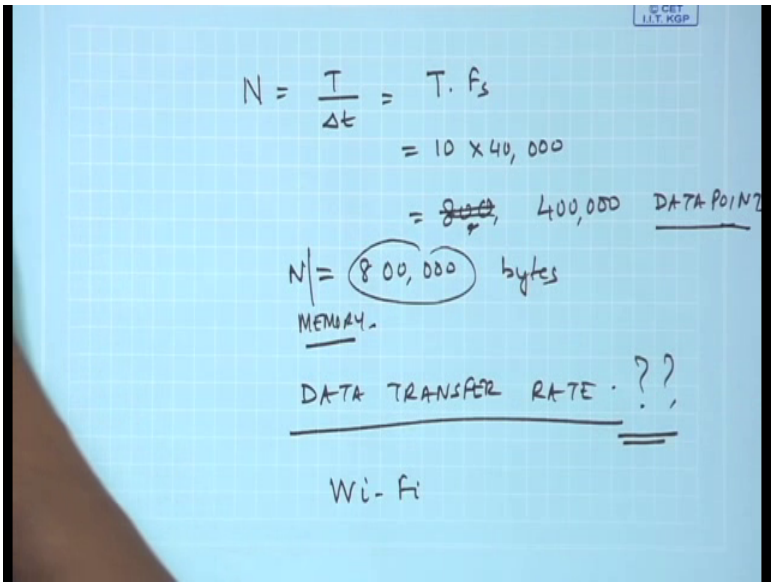

N is nothing but T divided by delta T or t times Fs. So, that is 10 times 40,000. So, this is 80, 800. Sorry, sorry 400,000 data points. And as I was telling every data point takes 4,000. So, the total number of space is 800,000 bytes the memory require is so much. So, I require 8,000 of bytes and if I want to send it at a rate of you know whatever is the throughput.

This has to be sent as packets, or I can you know by throughputs I mean I can send them continuously or I can send them out this packets. So, I need to have a device to store this much amount of data, and transfer and transfer at a faster rate that it has to be less than this sampling interval otherwise the signal would have changed. Because if continuously this data has to be sent by the time, the new signal comes out within 10 seconds I have to send 8,000 you know bytes of data.

So, the data transfer rate, rate is something which we have to see. So, data transfer rate is a quantity which plays a significant role in wireless transmission.

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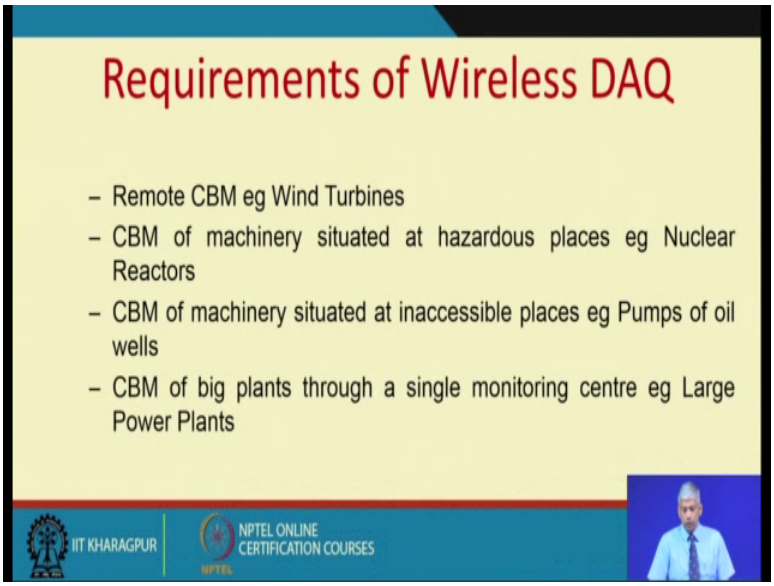

So, just to recap you know we will discuss this, but then what are the requirements of a wireless it is helpful to remote condition-based monitoring of wind turbines. Imagine a wind turbine which is you know there in the high seas where we it is just not possible to lake cables some signals be acquired through cables inside nuclear reactors inside you know pumps of oil wells etcetera. So, these are good candidates where in the wireless data acquisition can be done in mines and so on.

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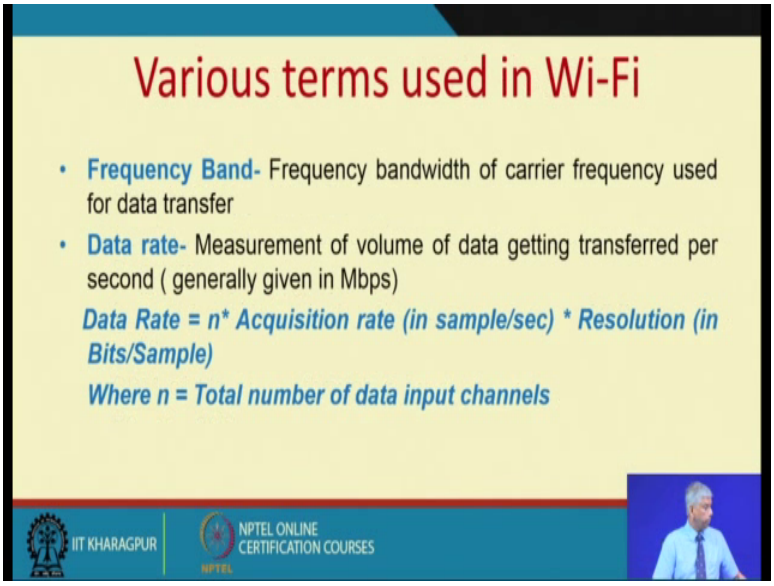

So, this is what I was talking about the data rate and it may. So, happen as I was telling you it is just not one channel t here are multiple data points.

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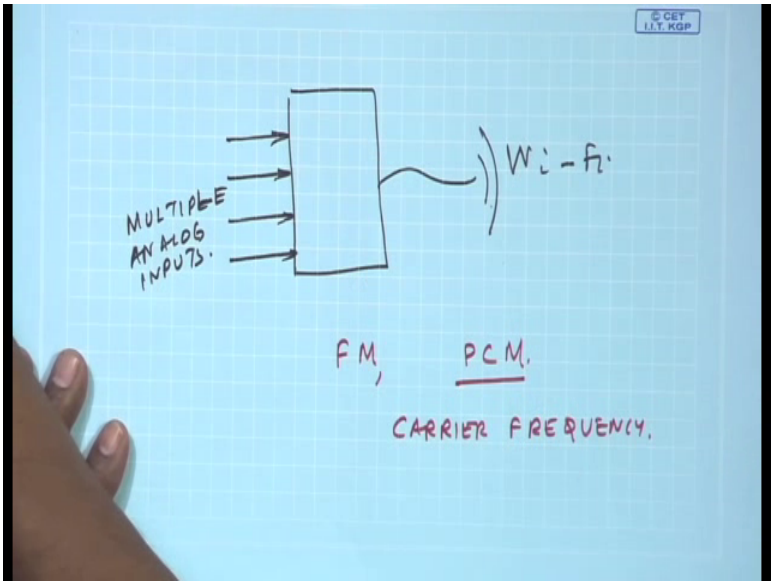

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Multiple analog inputs. And then this has to be transfer over the wi fi. So, one is certain frequency band of the carrier frequency used for data transfer, because sometimes this data transfer like you said is send over by digital modulations you know we talked about FM waves in digital there is something called PCM pulse code modulation. So, the frequency band of the carrier frequency plays a role today we have the mobile sets in the gsm network, or the CDMA network.

They have certain carrier frequencies. So, based on that carrier frequencies, we modulate our signals or the voice which we talk, and this is transmitted over Wi-Fi, but the question is the data rate measurement of volume of data getting transferred per second generally in mbps. So, this mbps is very, very important. I am in we just saw the example if I was to store even 10 seconds of data. Because this acquisition rate in samples per second in the previous example we had an acquisition rate of 40,000 samples per second. So, for per second I need to spend 40,000 data, and then resolution is bits per sample. So, it is to 8 bits per sample or 2 bytes sorry, you know it was 16 bit. It was 16 bit per sample. So, it is 2 bytes per samples.

So, you can see what is the data rate in terms of bytes per second, and if there are 4 channels you have to multiply them by 4. So, this is very important one has to take in account. Today we know the data transfer rate over Wi-Fi in our in our country we are talking about 4G now we have 3G, 5G.

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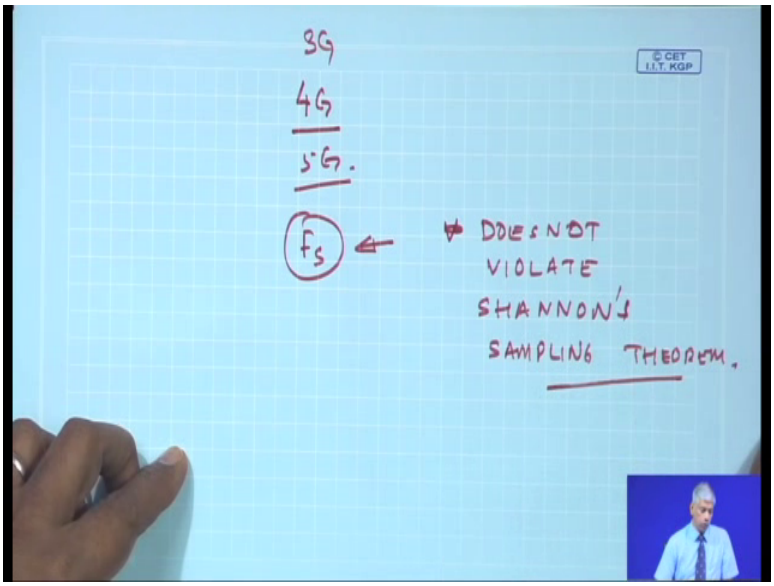

So, this is nothing but gigabits per second. So, that is the maximum allowable data which is available data transfer rate which is available to us. So, once this increases I can transfer more datas at high speeds. And when I say more data at high speeds it is very important, this acquisition rate is something which has to be in such a rate. So, that it does not violate the does not violate Shannon's sampling theorem. There is something one has to be careful about.

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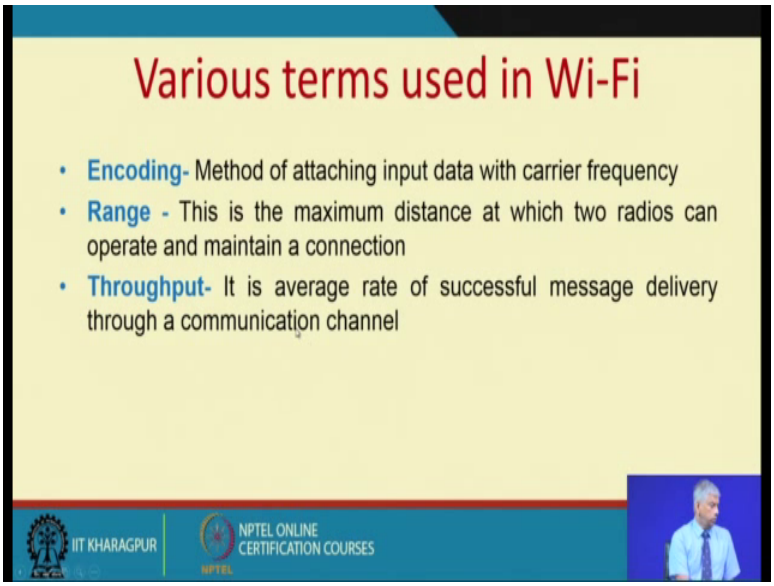

Certain terms which are used in Wi-Fi method of attaching input data with the carrier frequencies. And this is very important. This is the maximum distance at which 2 radios can operate and maintain a connection. You know Wi-Fi we would have seen at you know even in mobile communications we have Wi-Fi towers. Which just you know acquired the signal and then again retransmitted. Because there is a certain limit at which this cannot transfer. And it is the average rate of successful message delivery through a communication channel.

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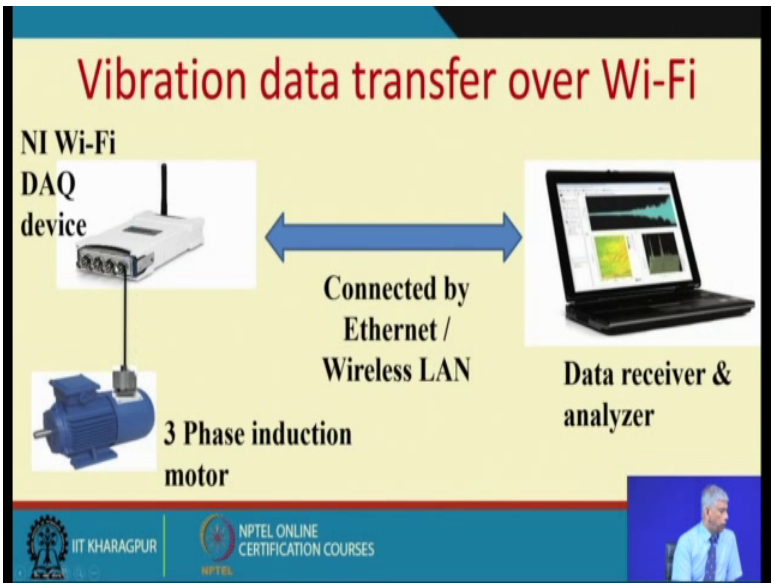

So, I will show you an example where even we are doing a vibration data transfer over Wi-Fi, you know in the in the laboratory. So, what we have here is a motor. We have an accelerometer which is or a sensor which is used to measure the vibration. And this is an data equation device which can take in frequency here 4 analog inputs. And it acquires it, and then it transmits it over the Wi-Fi.

And then we have another receive, so the data acquisition and the data conversion is done here. So, the a 2 d conversion is here d1 plus the data is transferred at a particular rate. And then we have our normal laptop which is a receiver it can be either connected over the wireless or to the ethernet. Suppose, this is going this as an unique IP as I was telling you. So, this can be transferring things you know today people are talking about internet of things you know that is a big buzzword in our country and throughout the world IoT.

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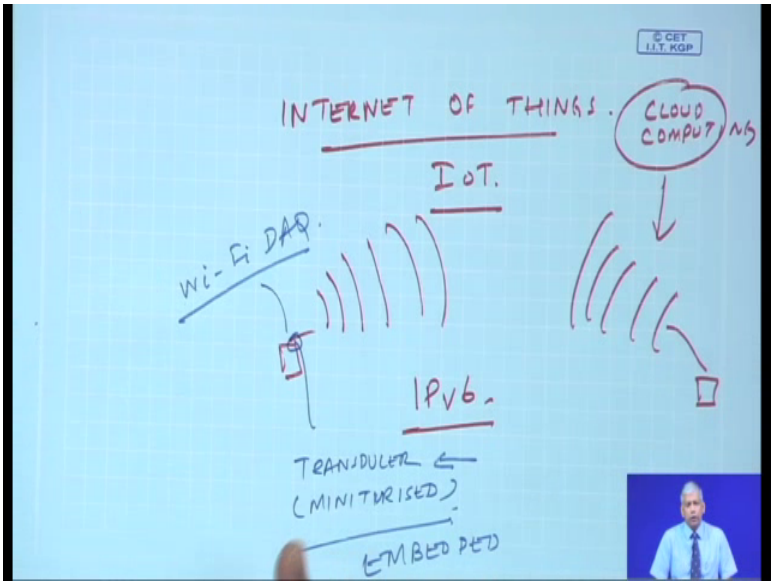

So, you see every device if they try to transmit data and then somebody receives it. So, all the data can be analyzed, you know today we are talking about IoT then then they are having a cloud computing, and the data has been sent.

So, like I was telling you right in the beginning you know today when you are talking about IP v 6; if every device has an distinct IP address, and then they acquired data, but the physics is not only changed. You know, we still need to have the transducers. Of course, transducer today are miniaturized, but there with the electronics they are

embedded, and then we have an Wi-Fi DAQ or data acquisition system sitting on it. And transmitting signals whatever the transducer is designed to measure.

So, today we have I will tell you a story I mean this is this may sound like a fiction, but this is what is going to happen, and it is happening. I mean imagine if a service technician came knocking at the door of your house telling you that in your refrigerator compressor is having a problem, and you were not aware of it. Well, how this is possible let me tell you.

Suppose, the transducer was pre-installed in the refrigerator and it had a unique IP corresponding to the serial number of the refrigerator the location where it is located. And then this transmitted signals as required by this CBM engineers. And this data from the compressor of your refrigerator went to their central server where the data processing has been done. And if the data after the data processing the results indicate there is something wrong in the processor. It will give an alert to you the customer or to the service technician in the field, that to certain such place this refrigerator compressor is perhaps you know lack of lubrication it is having excessive vibration etcetera whatever be.

So, this is what is going to the order of the day and we will not have cables coming from every machines. So, every machine will be having embedded sensors be it machine be it small big, and then there will be sending data over the cloud and of course, not to rate people are talking about machine learning, deep learning. These are you know I would say in a personally speaking these are you know then the same thing you know it would be harsh for me to say, but it is the old wine in a new bottle you know things.

Like y is equal to mx plus c does not change the physics. So, but then the data for y is equal to mx plus c is what Wi-Fi is enabling us to get this information. And then once we have this data we can use the same algorithms to process it, and come up to the level that we can say what is wrong with the machine. So, we demonstrated this in the laboratory. So, this is the data acquisition unit where we have an accelerometer which is used to measure vibration.

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It connects at the machine and through the cable, but then this entire unit is kept at the machine unit, and then we have an Wi-Fi transmitter which transmits the signal.

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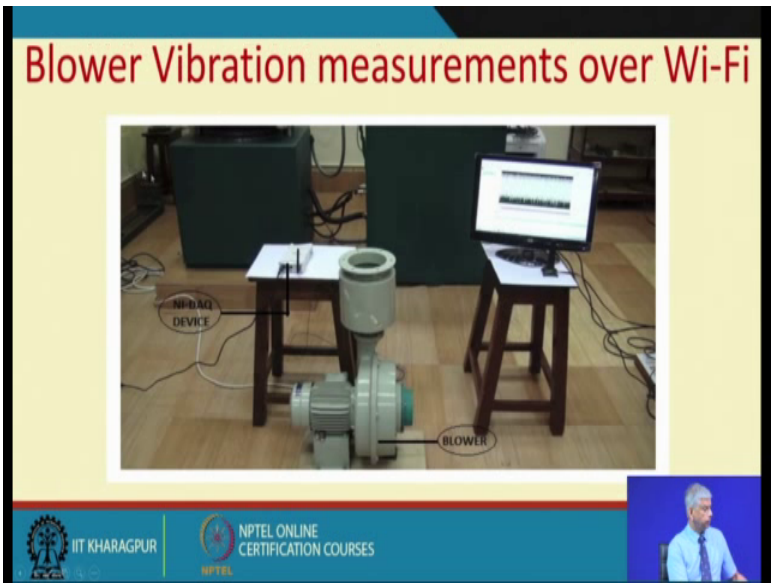

In the laboratory we have a blower; it is actually 3 phase motor. And if you see here there is an accelerometer which has been mounted on the blower. And this is the Wi-Fi device which has been put here. So, all the cable goes in here. And on the blower was run at a certain speed, this data was acquired and it was transmitted.

So, I had another laptop here which had the Wi-Fi receiver. It received the signal, and then we can see the time domain signal.

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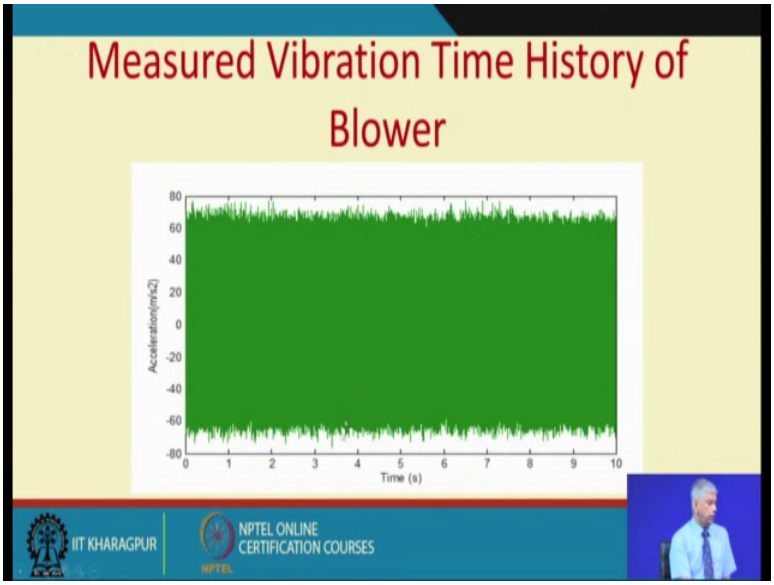

And you see this is the 10 seconds of time data of the acceleration in meter meters per second square of course, these are not been calibrated leave to some units and then measured vibration time history of the blower. And there was an excessive amount of vibrations. So, you see this signal measure from this blower and for the sake of discussion here I am showing the Wi-Fi unit to be very close to the blower, but there could be much away or if they are away we could take additional helps in terms of you know the receivers having multiple receivers or having a server where the data is stored. And then this is data is transferred over the internet.

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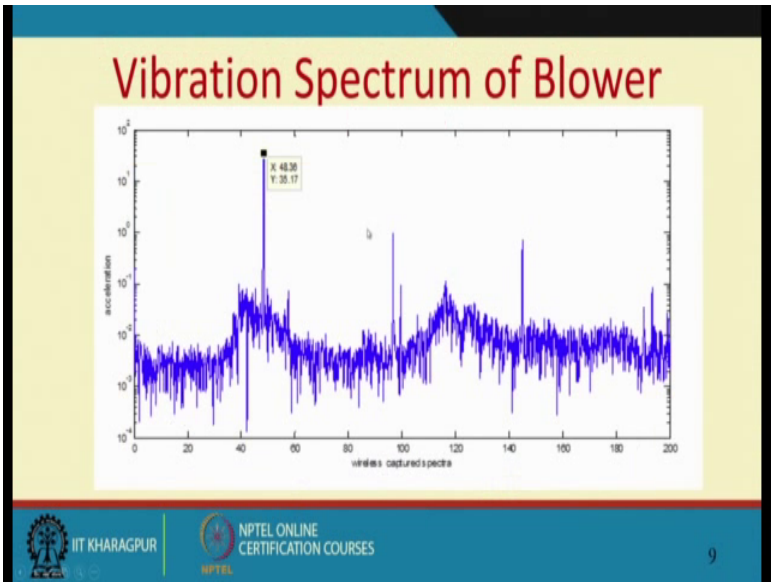

And then we analyze the vibration spectrum of the blower. See if you see here the wireless captured data in the frequency domain. Once we did the FFT you see here there is a frequency of 48.38 and what could this be this was an induction motor.

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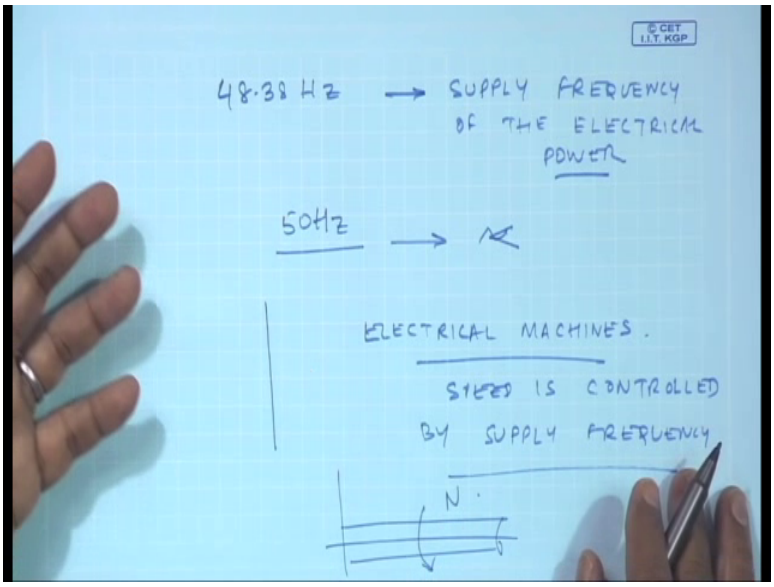

And this is a 48.38 hertz there is nothing but the supply frequency of the electrical power. I must tell you a many times we take in our country that 50 hertz is the supply frequency, but sometimes it is less than 50 hertz. The problem is you know if it is a

constant that is fine. But many times, many of the electrical machines which we will discover later on or study later on.

Their speed is controlled by supply frequency. Now the supply frequency changes what is going to happen the speed of the motor is going to change. Now if speed changes you know we had seen from an analysis point it is difficult for us that the FFT he would get smeared. But look at the loading; this should give rise to what is known as fatigue loading.

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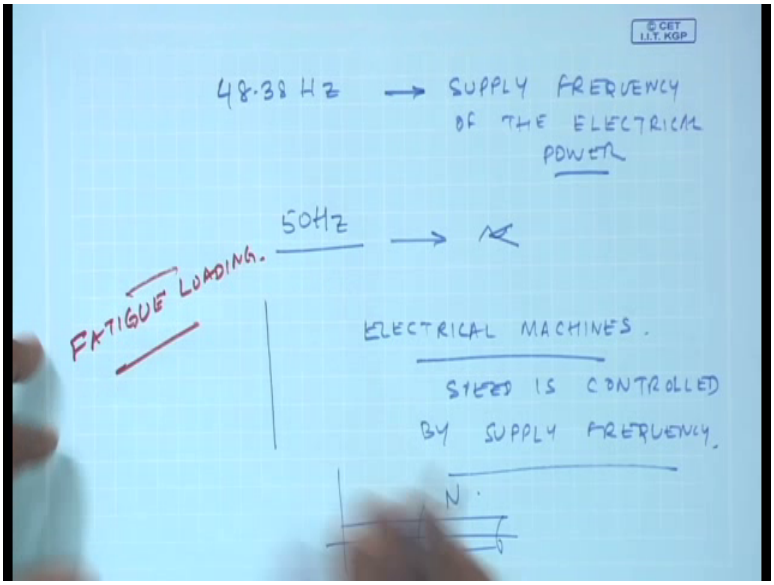

Because if you had increasing speed decreasing speed increasing speed, this will lead rise to fatigue failure in the shaft very quickly. And there is something which you just keep in mind that we will discuss this later on when we talk about. You know case studies where faults have been used introduced by wrong speeds or fluctuating speeds in rotating shafts. But just to summarize, we are very careful in wireless data acquisition as the limits of the data transfer frequency available to us you know today we are talking about 5 g is the data transfer rate over Wi-Fi, but then if you talk about acoustic emission where the frequency is 2 megahertz, or 5 megahertz.

So, you can understand very, very high rate of data transfer is required. And that is a problem or that is a challenge. If it is the low frequency phenomena like a temperature less than 100 hertz. So, we are fine I mean we can still do it over the Wi-Fi, and today we would see in a in a mobile see will get alerts of real time alerts of you know temperature

at a location, but temperature does not change. So, drastically or so quickly as in noise and vibrations.

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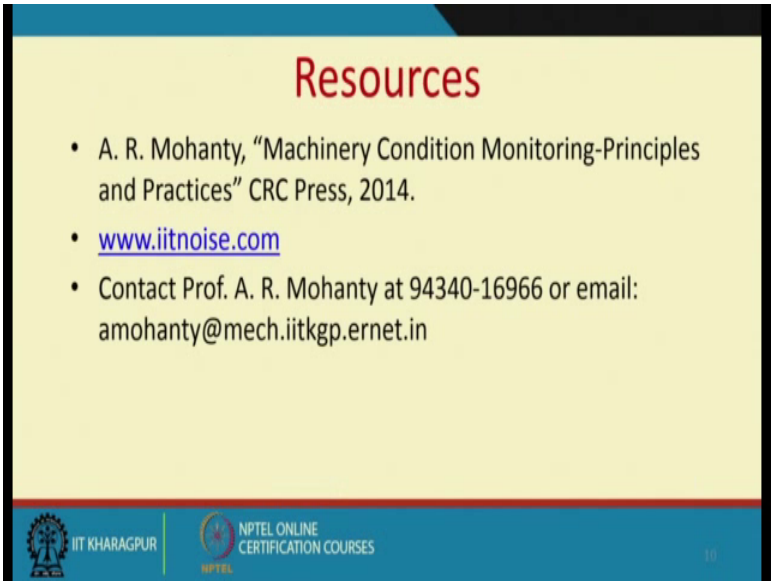

So, you can see more of these in and my book.

Thank you.