Signal Processing Techniques and Its Applications
Dr. Shyamal Kumar Das Mandal
Advanced Technology Development Centre
Indian Institute of Technology, Kharagpur

Lecture - 03
Characteristics of a signal

So, in this today's class, we will talk about the Characteristics of a signal. So, you know the analog signal, digital signal, continuous signal, and discrete signal; what are those?

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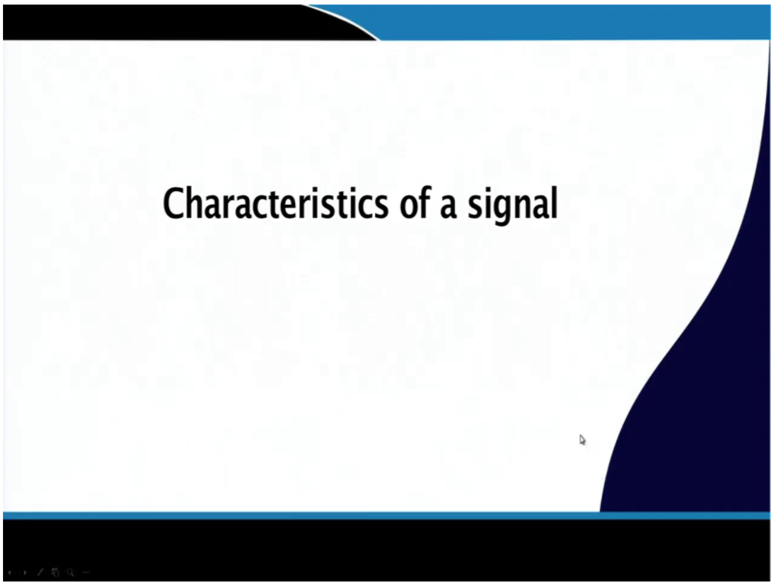

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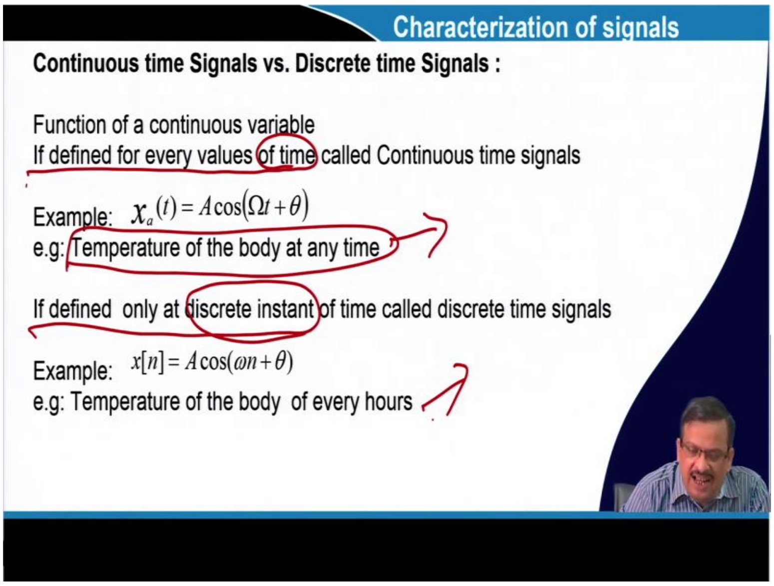

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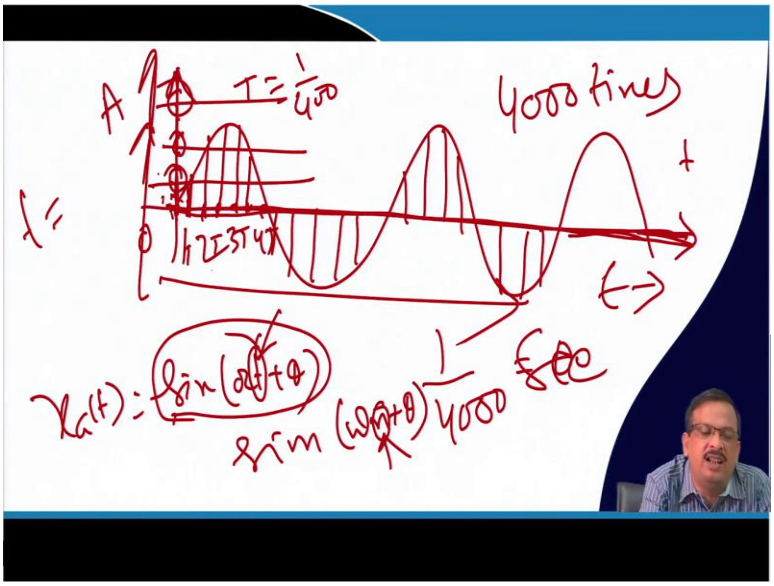

So, let's talk about continuous time signals and discrete-time signals. Let us forget about the slide; suppose I have a signal like this. This axis is time; this axis is the amplitude A. Signal is, let us say, and θ is equal to 0 in this case ok.

$$x_a(t) = \sin(\omega t+\theta)$$

So, I said continuous time signal you can read the slides; slides are there. So, you can read the slides; I am not reading the slides. So, how do you define continuous time signal and discrete time signal? So, what is a continuous-time signal?

So, when I say I take the t, it is continuous. So, t can take any value from minus infinity to infinity or finite or infinite range, any value. So, if I say the signal exists for any time, what is this definition? It is defined for every value of time. So, the signal exists for every time value; I call it a continuous-time signal. Let us say $\sin(\omega t+\theta)$.

A real example is the temperature of the body at any time. So, I am continuously monitoring the temperature of a human body; let's say when I say continuous monitoring, that means it is a continuous-time signal; continuous monitoring. So, in the time axis, it is continuous.

Now, what is a discrete signal, a discrete-time signal? Now, instead of continuous time, let's say I take the signal. I am monitoring the signal this time, this time, this time, this time. So, in 1 second, I will take the signal 4000 times, so 4000 points I will take. Let's say this is 0 and 4000 seconds.

So, I am taking the time; every 1 by 4000 time, I am taking the signal. So, instead of continuous t, I am replacing it with $\sin(\omega t+\theta)$; n is the index. So, what is the index? This is the 0 time and the number 1, 1 time, 2 time. So, what is the difference T? T equals 1 by 4000.

So, it is 1T, it is 2T, it is 3T, it is 4T like that. So, this 1, 2, and 3, which are defined by index n, are ok, but here, t is continuous. So, when I say that I am not taking all the time, I am measuring the signal at a discrete instant of time. So, every 1 by 4000 seconds, I am saying I am measuring the signal. So, that is a discrete instant of time, or I can say every 1 second, I measure the signal once.

So, it is every discrete instant of time. A life example is the same thing; instead of continuously monitoring the temperature of a body, I can say every hour or every 24 hours, I am measuring the temperature of the body of a human being. So, in the time axis, it is every 24 hours. So, it is discrete in time.

So, I said it is a discrete-time signal. So, a signal can be a continuous-time signal, or a signal can be a discrete-time signal. So, if it is the time axis, it is discrete, then I call it a discrete-time signal. If it is the time axis, it is continuous; it is called a continuous-time signal. Now, if you see this is the continuous time is done, what is the y-axis? y-axis, is the value of the signal ok or not?

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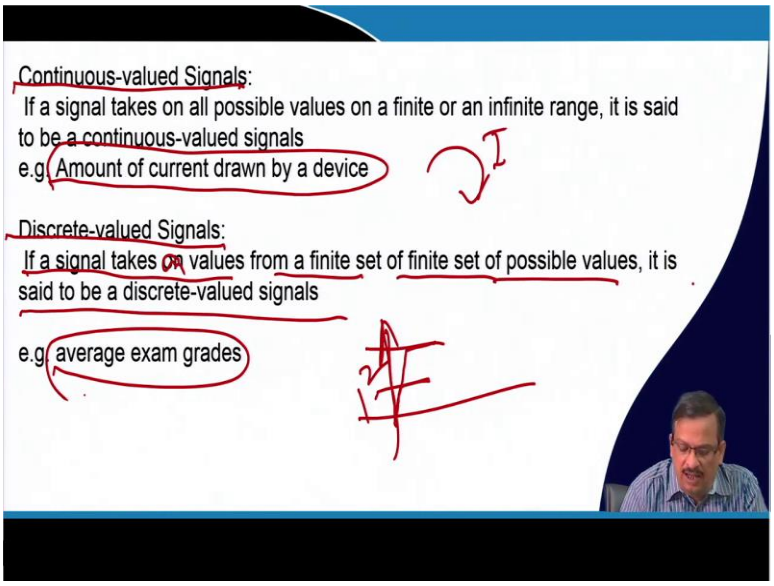

So, similarly, I can say the continuous-valued signal and discrete-valued signal. So, if I say in the y-axis, I take if the signal takes all the possible values in the y-axis, which may be finite or infinite, it may be infinite. So, I call all the possible values, if I take them, a continuous-valued signal; that means every value I am counting. Now, instead of that, if I take this value and then this value and then this value. So, I take only this value, this value and this value.

So, I can say then that instead of taking all possible value, I have said any instant value. So, when I talk about the instant value, I say it is a discrete-valued signal. So, if a signal takes values from a finite or infinite set of possible values, it is said to be a discrete value signal. So, when I quantize the signal, it is a discrete-valued signal. So, I said this is continuous. I said up to 1 volt represented by 1 after 1 to 2 volt represented by 2, let us say. So, then, it is a discrete-valued signal.

Say a quantized signal is a discrete-valued signal. In a real-life example, I said the amount of current drawn by a device. So, the current is continuous. So, I is flowing in a device continuously. So, I can measure the amount of current the device takes with respect to time. But when I say average exam grade, an average grade of an exam, I take a discrete value ok.

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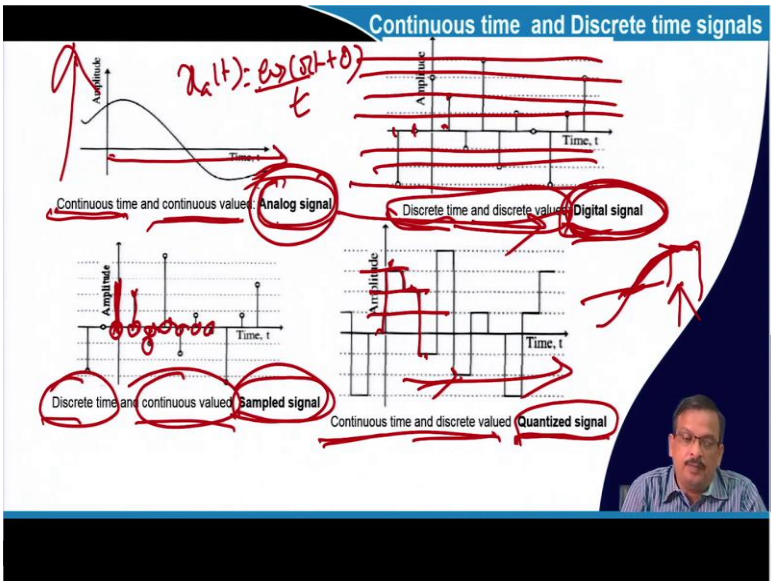

So, let us go for another pictorial way to represent this. So, here, if you see the time axis is continuous, the amplitude axis is continuous. So, I can say continuous time, continuous-valued signal, which is why it is called analog signal. So, when I say analog signal, it is continuous time and continuous value. If I say;

$$x_a(t) = \cos(\omega t + \theta)$$

then I said the value of cos is continuous in time, and also, I am calculating all possible cos values.

So, it is continuous in time and continuous in value. So, that is called an analog signal. Is it clear? Continuous valued continuous time, time axis continuous amplitude axis continuous, then I say it is a continuous-valued and continuous time signal, an analog signal. Discrete-time continuous-valued. I said I take the time instant for this one of this one and this one, but the value is continuous; the y-axis is continuous. It that this time instant, it can take any value in this axis.

However, I measure the signal at a particular time on the time axis. So, the time axis is discrete. So, I say discrete time continuous-valued signal, which is called sampled signal. The time axis is discrete, and the y-axis is continuous, so a discrete-time continuous-valued signal is called a sampled signal.

Now, I said I take a signal like this, this is the step. So, it can either take this value or this value or this value. So, I said a signal is continuous in time, but the value can be discrete. So, it is continuous in time and discrete value; then, it is a quantized signal. Understand or not? Quantized signal. So, I said let us assign value; if it is this, this value, this will be one value; if it is this value, this is not taking all the values here. I am taking this value and this value only.

So, it is discrete in the value y-axis, but in the time axis, it is continuous. So, it is called a discrete-valued continuous-time signal, which is a quantized signal. Now, I said both are discrete. So, I am taking the discrete-valued a discrete time, and I am quantizing each of the samples. So, when I quantized, then I said I was taking discrete value and discrete time. So, discrete time and discrete value which is a digital signal.

I am taking a discrete time and discrete value; value is also quantized, and time is also discrete, so that is why it is called discrete time and discrete-valued signal, which is called digital signal. So, people may ask you what you mean by continuous-valued signal and continue discrete-valued signal.

So, you can say if a signal takes all the possible values, and if you say the signal is a vector, it has an amplitude in a direction. If you take all the values in the amplitude domain, I would say they are continuous. If it is quantized, I said it is discrete value, which is okay. So, analog signal, digital signal. Now, I say analog and digital signals; what is the difference? An Analog signal is a continuous-valued, continuous-time signal, but a digital signal is a discrete-valued and discrete-time signal.

While I take the analog signal, I design the processing; we call analog signal processing. While I said the digital signal and we all designed the algorithm, we said digital signal processing. So, analog signal processing is nothing but a system because if I want to design an analog amplifier, I have to design a system. But when I say discrete amplifier, I have to design an algorithm to convert the signal to another level. Both are processing. So, one is analog signal processing; the other is digital signal processing.

This course talks about digital signal processing. It is not an analog signal processing course. So, in digital signal processing, we always talk about discrete time and discrete-valued signals.

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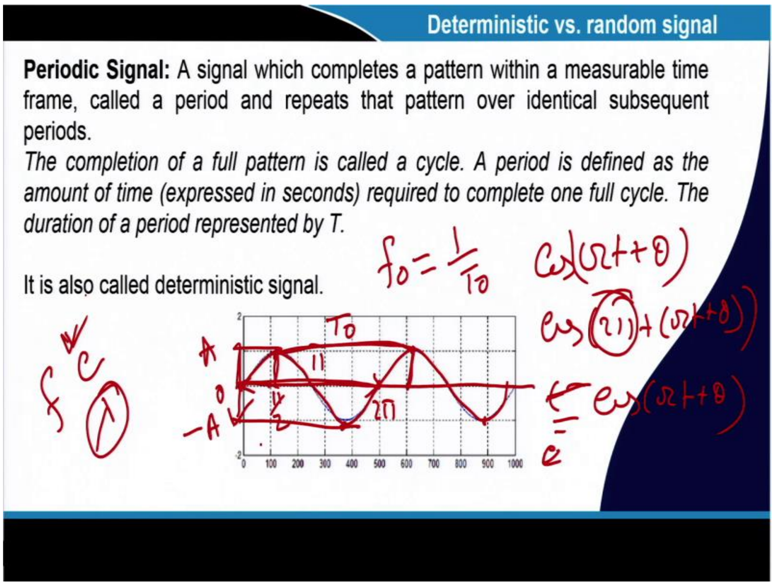

Then, there is a call periodic signal and a non-periodic signal or aperiodic signal. If I say a sine wave, let us say I have a sine wave, and this is the sine wave, okay? So, this is the x as the time axis, and this is the amplitude axis. So, if I say what the period is, What is the definition of the period? If a signal repeats itself after a certain time interval, then we call that time interval the period of the signal.

If I say this signal starts at 0, this is $\pi/2$, this is π, this is 2π. So, I say

$$\cos(\omega t+\theta) = \cos(2\pi+\omega t+\theta)$$

So, I can say 2π is the period of the signal. So, I can say when the signal repeats itself. So, if you see this point repeated here, this point may be repeated here.

So, I can say here to here is a period, and here to here is also a period. So, in the time domain, if I say it is T_0, let us say this distance to this distance is T_0. So, you know that fundamental frequency (f_0) is;

$$f_0 = 1/T_0$$

So, T_0 is a period, and f_0 is called fundamental periodic frequency or periodic frequency ok, and this is called amplitude. So this is called peak amplitude; here to here is peak-to-peak amplitude. So, this is positive A; this is negative A. So, I can say this: 0 to A is the positive half, and 0 to minus A is the negative half. So, a positive peak to a negative peak is called peak-to-peak amplitude.

So, you know λ, what is λ? What is the relationship between frequency, velocity, and wavelength? Say fundamental; what is the relationship? What is the period? λ is called a period, and the length distance is in d. f is the signal's frequency, c is the velocity of the signal, and λ is the signal's wavelength. So, what is the relationship between the c, λ and f? I will not say it. I think you know it, ok.

So I can do all of the conversions. So, I know T_0, the fundamental frequency, period, and amplitude. and also, I know this relationship. I will do many things using this ok, and if a signal is a periodic signal, then it is also called a deterministic signal. So I can determine and predict the signal. That is why it is called a deterministic signal. So, there is a deterministic signal and a random signal.

If the signal is I, any time of any time I can a signal which is complete a pattern with a measurable time frame called a period and repeats the pattern over an identical subsequent period. So, I is predictable; the signal is predictable, which is why it is deterministic.

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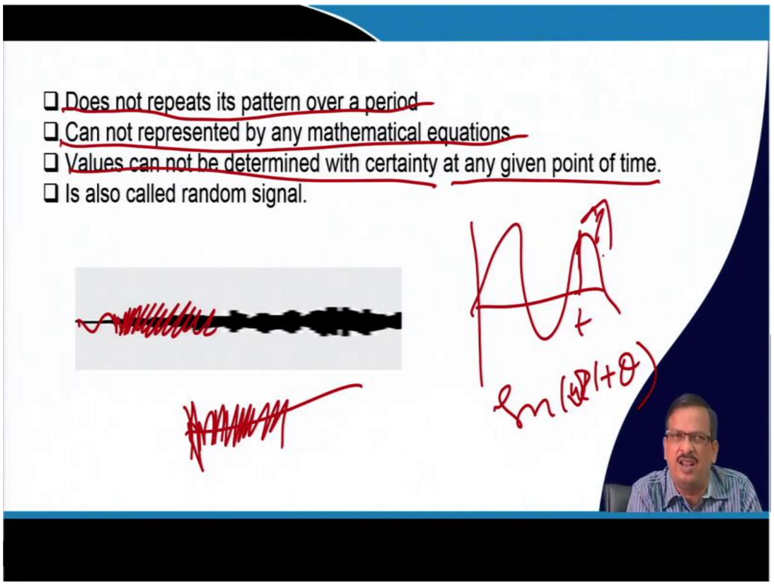

The random signal does not repeat its pattern over a period. Let us say take a sibilant, noisy signal. If we record, it will be recorded as a sibilant and noisy signal. You can do that, and then, you see it does not repeat its pattern over a period. It cannot be represented by any mathematical equation. If I say it is like this, I can say I know this $\sin(\omega t + \theta)$.

But if I have a signal like this, it does not have a period; random noise are there. Just record and then see the signal. Value cannot be determined with certainty at any given point in time. I do not know what the value should be. I can say, at this point, what should be the value of the signal? So, it is a deterministic signal.

When the value cannot be determined at a certain point in time, I said it is a non-deterministic signal or called a random signal. So, I said real signal, so I again summarised the signal. I said real signal, complex signal, time-dependent signal, time-independent signal, multi-channel signal, multi-dimensional signal. So, those are the properties of the signal.

Multi-channel signal, multi-dimensional signal; I said periodic signal, aperiodic signal; I said random signal, deterministic signal and random signal ok and then, I said this continuous-time signal, discrete-time signal, continuous-valued signal, discrete-valued signal and what is analog signal and what is digital signal ok.

So, by these two lectures, you should have an idea of what a signal is. So, multi-dimensional, multi-valued, multi-channel, multi-discrete valued, continuous time, and discrete-time signals. So, the time axis is discrete, and the amplitude axis is discrete; so, if both are discrete, it is a discrete signal. If both are continuous, analog signal. There are analog signal processing and digital signal processing.

So, in the next class, I will talk about analog to digital conversion.

Thank you.