Networks and Systems
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Lecture-29
Lab Demo

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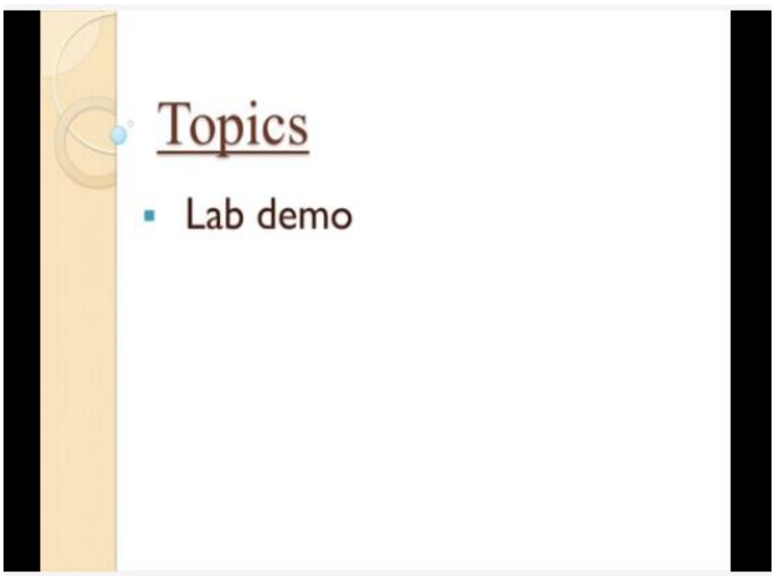

So, at end of this exercise; let us go to the laboratory to where we have the demonstration experiments, illustrating some of the concepts on Fourier series that we have been discussing so far.

(Video Starts: 00:36) What we have here is an experimental, Set up to demonstrate the harmonic analysis of a square wave we have a function generator here, which generates the square wave. And that is how displayed on the oscilloscope this is the square wave of 2 units pit to peak value or 1 unit peak value.

Now, what we are going to do is; put this square wave through low pass filter which is this. So that, we can allow only harmonic up to certain order to go through and come out of the output. And the output voltage will also be displayed on the oscilloscope in the bottom trace.

So, let us see what we have here, is a 500 square wave. And now, I am putting a low pass filter cut off frequencies. So, that only the fundamental pass through and when you do that. You, observe that the output of the low pass filter corresponds only, the fundamental frequency a pure sine wave.

And this has the amplitude which is about 4 upon 5 times the amplitude and square wave as we should expect. Now this is the, that is the only the fundamental is pass through. Now, if you allow other frequencies for example, if I increase the cut off frequency at the low pass filter. So, that I allow up to the third harmonic.

Now you can see, the third harmonic frequency also allow; Therefore, not only the fundamental the third harmonic. Is also coming through and we can increase the cut off frequency and allow more and more harmonic come through. And as you can see, as you pick up more and more harmonics the output becomes closers to the square wave.

In fact, if you go to very cut off frequency, almost a square wave. A point which we should notice here is, that just at the pointer jump just immediately after the jump there is a overshoot as we expected from the discussion in the earlier lecture classes. This is due to Gibbs phenomenon and immediately after the discontinuity the series Fourier series will not converge.

At the point of discontinuity it will not converge uniformly; therefore, we expect lower shoot. The surprise thing is that, in strict mathematical analysis you should have lower shoot both immediately after the jump and immediately before the jump. So, strictly speaking mathematically you should have over shoot here also.

But, in practice experimentally you never get that the reason is that the our low pass filters are not ideal low pass filter in that all the frequency component that they allow will not be faithfully passed out, but there will be phase distortion there will be phase delay. Because of this reason you will not get this kind of overshoot just, before the jump.

This is all also in accordance what is called principle of causality because no physical device can anti speed the jump that is going to take place latter. So, no physical device can respond to jump that is going to occur later and start ringing here. Therefore, it is physically is not possible for us to construct any experimental set up where you can demonstrate this kind of ringing even before the discontinuity.

So, this just demonstration of how the various harmonics is going to built up the square wave. Let us go back, once again this is when all harmonics up to let us say 30 third harmonic pass through and you go back as you allow small and smaller only up to smaller order harmonics the wave form is no longer is square wave. And in fact, when you have the cut off frequency just above the fundamental only the fundamental is pass through. (Video Ends: 04:34)

As mentioned in the lecture you can perform harmonic analysis.
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Using instruments known as harmonic analyzer or spectrum analyzer. It is also possible nowadays to use the computers to affect the harmonic analysis of any given periodic wave form through software. And here is the demonstration 1 such situation we have square wave here and computer has calculated the various harmonics and displayed them in the windows that are shown here.

This is the fundamental, this is the third harmonic, this is the fifth harmonic and sum of the fundamentals third and fifth harmonics are displayed here and we also observe this is the spectrum of this. The spectrum shows peaks at the fundamentals third and fifth and so on. and we also observe the peak progressively go down you would expect that the amplitude of the various harmonic orders will go in the manner 1 over n where n is the order of the harmonic.

Now, strictly ideally speaking the spectrum should be line spectrum there should be lines at the discrete frequencies. But, because of the various round of computational errors and inter phase on the system. You will only get the peaks it will not be a pure line spectrum in the sense that you have a complete blank between 2 lines.

Rather you have some kind of continuous spectrum, but at the frequencies which are presented in the composite wave. The computer programs will also calculate the various amplitudes various components and displays them with suitable scale factor on the screen. So, this is very convenient way of analyzing the any given periodic wave form and finding out the various harmonic components.

Now, let us use the computer program to find out the harmonics of another wave form rather than the square wave.

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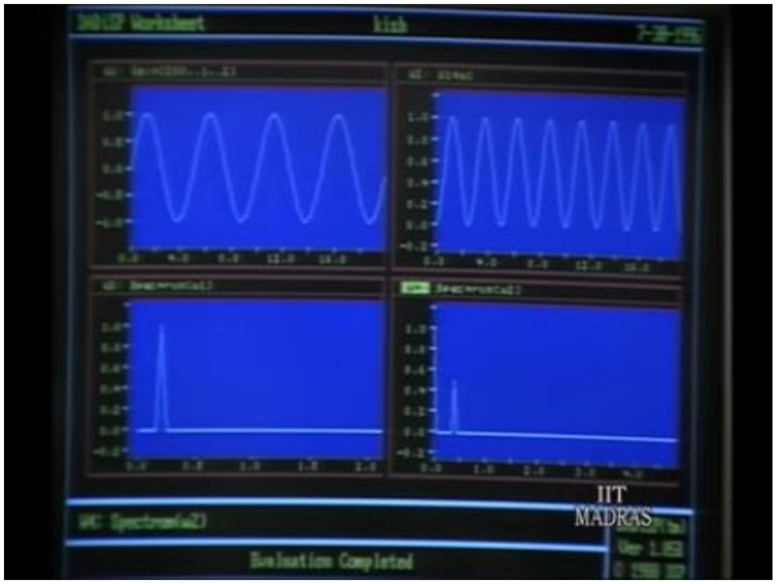

As a second example, let us take a pure sine wave and perform its harmonic analysis so; obviously, this spectrum consists of only 1 line at 1 frequency which is the frequency of the sinusoid; therefore, this is the spectrum of the sine wave. You have 1 spike at the fundamental frequency and no other harmonics are present.

Now, if i multiply sine wave by itself, get sin square theta this can be expressed as sum of a dc component plus second harmonic component. And that is what is shown here, this is the function which is obtained by squaring this. And the spectrum of that; obviously, consists of a dc term plus sinusoidal which is not the twice the frequency of the fundamental and that is these are the 2 lines corresponding to that.

These are dc components and this is the sinusoidal and all other harmonics are absent. You observe that the both these wave form are very smooth. In the sense that they are infinitely differentiable. So, all the derivatives whatever order you take are continuous and therefore, the spectrum comes down.

The amplitude of the spectrum comes down very past larger than n to the power of k .Where k is any large that as you wish and therefore, you observe the spectrum lies down 0 after few harmonics. Because the 2 functions very smooth functions.

(Video Start: 08:11) What you are hearing now, is the sound of the time signal which we get before the beginning of the news broadcast on the all India radio. This is the type of wave form which has been given to you as the part of the problem in the last exercise. These are 1000 cycles sinusoidal which is the blank per 9 second of the period and then it is kept on the onto off ratio is 1 to 9, so every 100 million seconds on and 900 million second is off.

So, these such time signals produce this kind of sound. Now, let us see the wave form of this on the screen. The sound you just now, heard corresponds a wave form like this. Where you have thousand hertz sinusoidal which is kept on the certain small amount of time. One- tenth of the period and then it switched off for the remaining nine-tenth of the period. So, you have burst of sine wave and it itself periodically.

So, this is the wave form that you get. And if you increase this, this is how it looks you have actually it can be produced by multiplying a sine wave with periodic pulse time of width corresponding the interval of time. And in the exercise last exercise you are given this kind of wave form and you asked to find out the various harmonic components given the data into the frequency it is on and also the blank period at the mark period of the pulse time. (Video Ends: 09:53)

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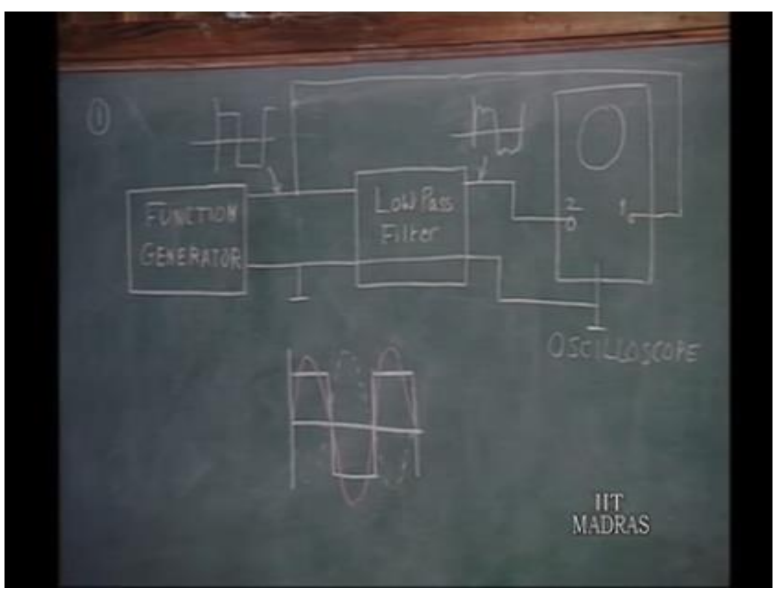

The few comments on the demonstration we have just now witnessed in the first part of the experiment. You had a function generator which produces the square wave. This is put through low pass filter which allows frequencies up to certain order to pass through. And both these square wave and output of the low pass filter are displayed on the oscilloscope. oscilloscope has 2 channel 1 channel you have the square wave and the channel below we displayed this type of wave form.

When frequencies only up to a point with just above the fundamental frequency of the function generator is put, ideally this is the square wave you should get sine wave which is the fundamental which is 4 by 5 times of the amplitude of the square wave. Some of you might have observed that the square wave.

The if this is the square wave the sine wave is not sitting here at this point, but slightly shifted like this as shown by the dotted lines here. This is because the low pass filter gives the phase shift when it is allowing the signals to go through and because of the phase shift produced by the low pass filter, but particularly frequencies which are very close to the cut off frequency you would observe the phase shift.

Those of a few might have noticed it will know that the reason is the phase shift produced by the low pass filter. It is because of the phase shifted produced by the low pass filter for different frequencies, that 1 half of the Gibbs phenomenon is lost finally, we allowed a whole lot of frequencies you find the Gibbs phenomenon overshoot occurs at this point not at this point.

That is again because of the phase shift produced by a practical low pass filter this is the reason for this.

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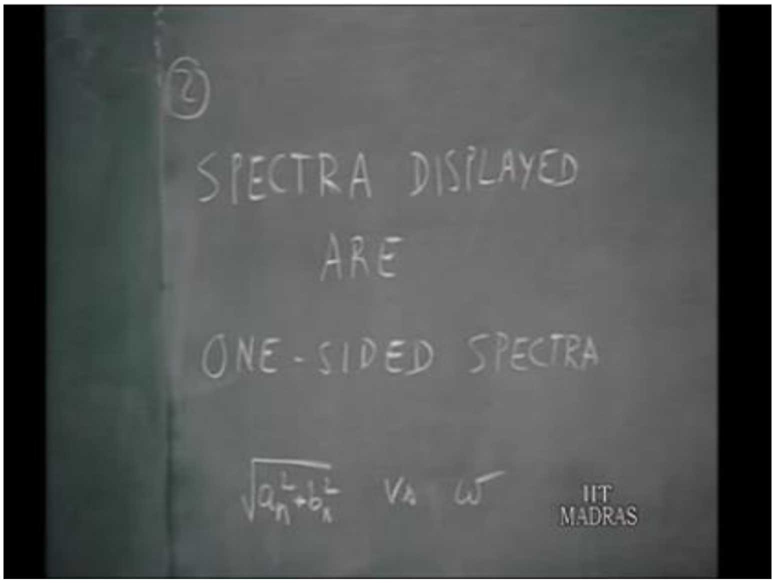

Now, let us move onto the second part of the experiment where on the computers screen you have seen. The spectra that are displayed for different types of wave forms; the spectra that are displayed there are 1 sided spectra not the 2 sided spectra not cn versus omega for both positive and negative values of omega.

But only for positive omega we are talking about the amplitude of the sinusoidal versus omega. So, that is why the dc is that at 1 end of the displayed wave spectrum. So, it starts from and dc and goes up to higher frequencies. So, you recall that is 1 sided spectrum whatever is displayed not the 2 sided spectra that we have been talking about the lectures. Let us go to the third part of the demonstration where we had a time signal.

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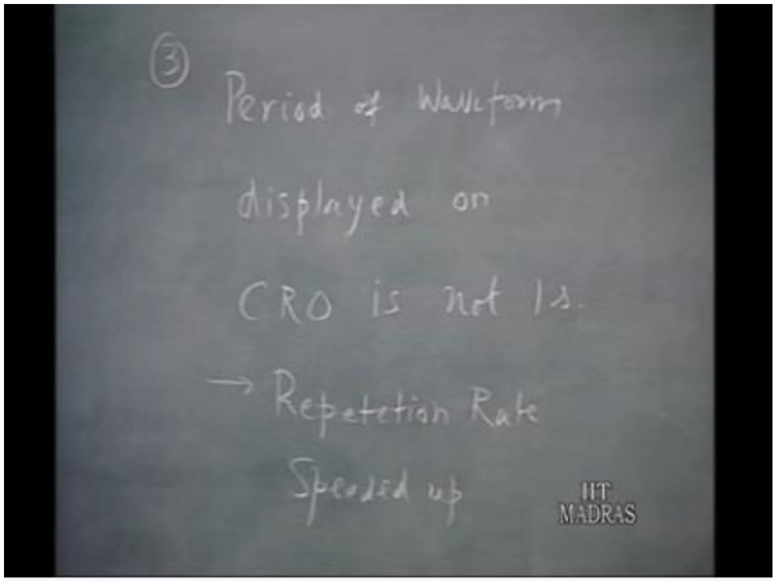

That is we had the time signal and then we displayed the burst of sine wave on the screen. Now, we played a little trick there they actually sound of course, 1000 cycle signal which is repeated at 1 second, but then if you repetition rate of 1 second is too slow to enable us to capture on the cro.

Because the writing speed is too slow; therefore, what we did was the repetition rate speeded up it is not 1 second it is something much less. So, that is the reason why in the burst of the each sine wave you will not see hundreds of cycles, but may be 4 or 5 cycles only you have seen.

That is because the while the general shape of the wave form is the same, but the repetition rate has been increased and that is why you would not see in the single burst of the sine wave a number of cycles. Actually the sound we heard is of course, is corresponds to 1000 hertz repeated at once per second. That is; the reason for this. So, these are common you can now go back and look at the demonstration once again please go ahead.