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NPTEL ONLINE CERTIFICATION COURSE

Course
on
Analog Communication

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Lecture 15: Amplitude Modulation

Okay so far we have already discussed about some aspect of signals like Fourier series, Fourier transform and then energy spectral density power spectral density, what is the significance of them? Given one example why autocorrelation function is important to evaluate energy or power spectral density. So this is something we have already covered, now let us see means so far there were some touches where we could talk about communication but we have not gone inside the communication aspect. So today what we will try to do actually try to see how this understanding of signal can make us means to communicate okay or can aid us to communicate.

So this is something which we will be targeting today, so if we start seeing communication as we have discussed RDF there are two aspects of communication, so one is of course the signal which is the source means that is the thing that has to be communicated and the other part is the system, which somehow is a transmitter receiver in between a channel, so either the transmitter or receiver processes the signal. So this system receiver or transmitter is actually a system which processes the signal towards a desired output, so that the signal can be transmitted faithfully at the receiver side and all the information can be faithfully transmitted.

So this is the purpose of the system design right, so system design has some purpose because it operates on a signal, so any system that we are targeting must serve those purpose. So for a communication system the most important part as we have so far exposed is probably the modulation and demodulation, so this is the first thing we will be exploring that how to devise a system does modulation and demodulation add transmitter and receiver respectively okay. So if you just start seeing communication there is in a way two types of communication.

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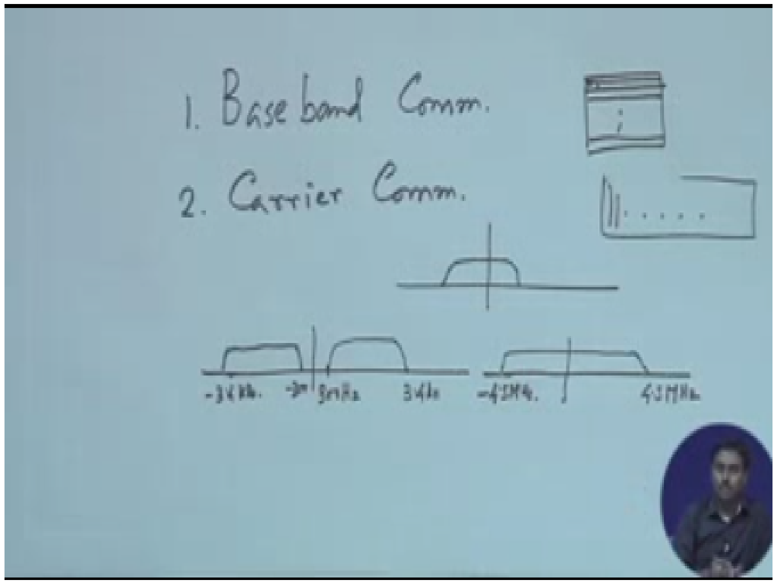

One is called baseband communication and the second is carrier communication, so what we mean by these two? So baseband communication means we actually transmit it as a low-pass signal, so whenever we are transmitting if in the frequency domain we try to see it will occupy some low pass band. So that is generally called baseband communication, so why it is called baseband communication generally the signals that we generate the raw form signals, let us say we generate wise signal through a transducer, so basically we talk the transducer converts it into an electrical signal.

If we just try to see how that electrical signal looks like we will see for wire signal it occupies a band starting from 300 halts towards 3.40 halts, so it occupies some band like this and of course because it is a spectrum and it's represented by Fourier transform form so it should be having equivalent negative part, so - 300 to - 3.4, so this is typical voice signal that looks like if you if you have the most two most popular signals probably where one was wise signal and the other one was which was popularized by radio transmission okay. So and the other one was probably the video signals okay.

So if I just try to see the video signal that has a higher band that means again there should be a video transducer which converts the video signal into equivalent electrical signal, so what it does actually if you have a screen so every second there are few frames, so frame represents the entire screen and then you have pixels on the screen all those pixels will have their own grayscale value if it is a black and white if it is colored then there will be three composite colors and each color will have their own value gray scale value okay. So those signals has to be means if I just put them on time, so for each frame we just one after another pixel value we put we get a signal and that particular signal if I just represent it in electrical domain the way I have told.

So basically if you have a screen you scan them pixel by pixel from this direction left to right again you do for the next line and so on you do all lines every pixel value you put a voltage X pixel value you put another voltage and you put it on time so this is overall frame if you do that will be one frame followed by another frame and another frame so on, so you get a signal equivalent electrical signal, if you just again do our Fourier transform of that and you represent it in frequency domain you will see that it occupies up to 4.5 Mh, that is quite big of course the video signal has a higher bandwidth it occupies the higher bandwidth.

So this is the raw video signal as you can see these are all low-pass equivalent signals okay, so it is centered around zero and it through a low-pass filter you can always extract that signal okay low-pass filter bandwidth has to be according to adjust it. So these are the signals which are means if raw signal I wish to transmit that will be termed as baseband signal okay, so if I wish to transmit that should be a baseband signal, that is about baseband signal. Even telephony which is probably we have already talked about telephony, so what happens? There also we transmit avoid voice but the voice is encoded.

So basically if I in the last class we were demonstrating that the voice I will be sampling each sample will be represented by binary bits and if we just transmit that binary bits we have already seen that a random sequence of binary bits if, I just see the spectrum through autocorrelation we have drawn the spectrum autocorrelation was something like this and the corresponding spectrum was $\sin^2$ right.

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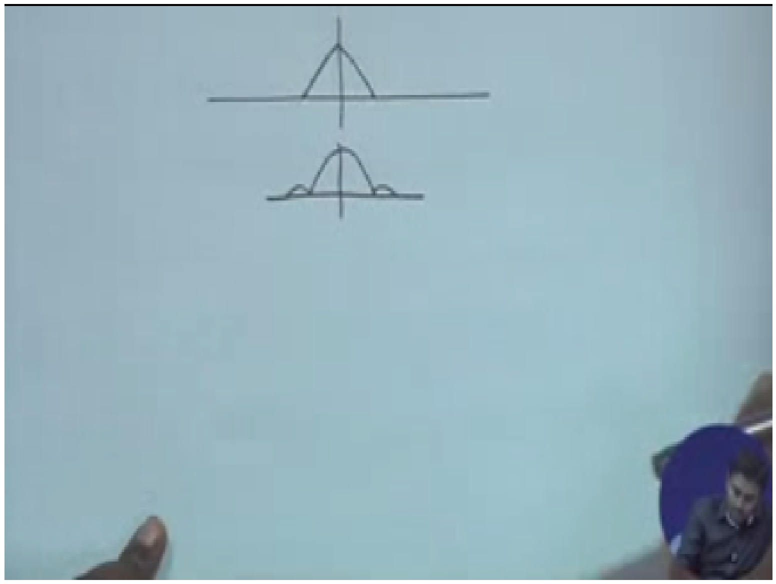

So it was like this again a if you just see it is a low-pass equivalent signal, so these are all baseband signal if I wish to transmit them RAW this would be baseband signals, so and the corresponding communication will be termed as baseband communication. So I do not do any modulation over here that means I do not put it in any higher frequency, so as long as I am not doing that that particular communication is termed as baseband communication.

If instead we have already talked about frequency division multiplexing that means in frequency domain I wish to put those signals which are band limited in different frequency location okay. So that I can multiplex multiple signals and simultaneously transmit them they are in time domain they will be overlapping okay but infrequency domain there will be non overlapping and I can always employ a band pass filter to extract my own desire.

So basically a meaningful transmission can be or simultaneously multiple meaningful transmission can go through the channel, it can utilize the same channel and I can transmit multiple signals. So that that is a basis or the basic requirements for doing a modulation okay, we have also discussed that there is another reason why we should do modulation?

That was typically for radio transmission, so if we wish to broadcast the signal that has to be received by a antenna and the antenna size has to be comparable to the wavelength of a signal so this is something we have already discussed that if I wish to do that the frequency has to be higher, so I should instead of if I wish to transmit baseband signal antenna size would be very big, instead of doing that same signal I can actually modulate it will serve two purpose first of all because it goes to higher frequency my actual antenna which catches the signal will be much smaller and then after that I can employ a low pass filter to extract that signal and then do a demodulation to get that signal again back to baseband.

Remember the signal is by itself is defined in baseband, so if I wish to again either listen to that voice or watch that television I need to convert that to the baseband, so my demodulation actually means if I do a modulation then the modulation actually means again from that pass band I have to bring that signal to the basement. So this is all that we mean by demodulation so definitely now you can see that there is a purpose to purpose probably, one is for multiplexing another one is for reducing the antenna size, we need to do modulation and that is when the first hurdle of communication comes into picture or first design off system comes into picture.

That I have to now devise a system which modulates the signal that means does the frequency shifting and I have to design a signal which demodulates our system which demodulates the signal that is already modulated signal, I can catch through antenna after doing low band pass filtering I need to demodulate it to bring it back to baseband, so that I can put it to the transducer and again either listen or watch whatever I wish to do okay. So let us try to see what this modulation means and why we are saying that to be a carrier modulation okay or carrier communication.

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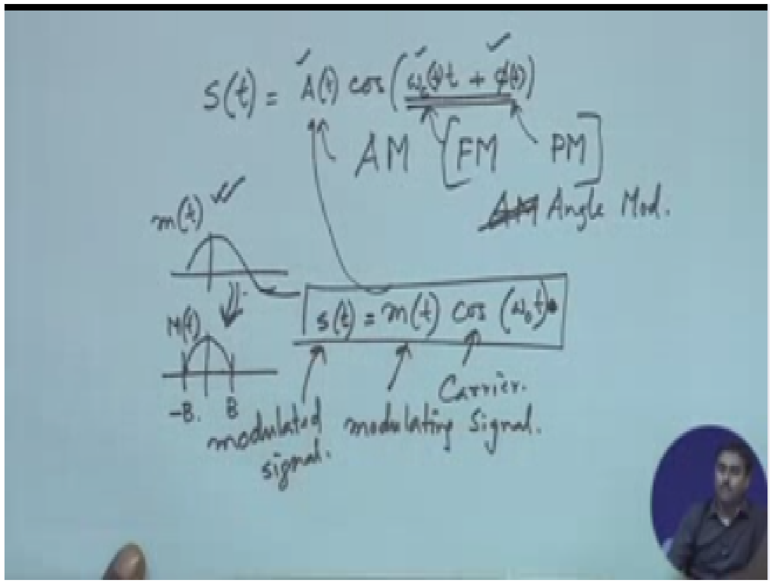

So let us say whenever we are talking about carrier I have a signal I am just representing a sinusoidal signals, so sinusoidal or co sinusoidal it must have a cause and it has actually three parameters. One is the amplitude of this co sinusoidal which I can write as A, the other one is the frequency of this co sinusoidal which I can write as ω_C or $2\pi F_C$ whichever way I wish to write x t + there should be a phase right, let us call that π. So this is a sinusoidal at frequency ω_C and generally what we say because this is at some frequency we call that a carrier.

Why it is carrier? That will be clear because it does not by itself carry any message or any information, if somehow modulates the message that it carries, so that is why it is a carrier it is almost like a envelope that carries your latter okay, so it just helps you to carry the letter it has no importance just it has to carry the carry the thing that you are trying to transmit just delivers it to the destination and after that it has no use usage. So you will be again demodulating so if we get getting rid of this carrier okay. So right now we can see there are three terms in the carrier, so while modulating I can use one of these three to carry my signal okay.

So suppose I have a message okay what I can do I can either make this amplitude time varying which is proportional to my message signal okay, so that way also I can carry my message signal on of this one or I can vary the frequency with respect to time which is proportional to my message signal again over a frequency I am carrying the signal or I can vary the phase proportional to my message signal and accordingly there will be different kinds of modulation, so if I carry it in my amplitude that is called amplitude modulation AM, if I carry it through my frequency so that is called frequency modulation or popularly termed as FM and if I carry it through my phase and that is called phase modulation or PM.

So accordingly there will be three kinds of different kinds of modulation which has their own advantage disadvantage, they will have their own types of system designing will see those things so we will try to explore these things, amplitude modulation, frequency modulation and phase modulation, so these are the three predominant analog form of modulation that exist. Of course it is going over a sinusoidal carrier okay.

So the carrier is there and I wish to do some modulation so initially for the beginning of our course probably will be more concerned about amplitude modulation later on will explore the other things, which are these two are again termed as angle modulation because overall this can be termed as a phase of a sinusoidal okay it has a frequency part is it has a phase part. So overall I can talk about with the T in it we can talk about that store all time varying phase or the angle okay, so that is why it is called angle modulation or I should not write am then it will be confused with amplitude modulation.

So it is actually angle modulation okay, so initially we'll be concerned about the amplitude modulation. So let us try to see the most basic form of amplitude modulation, so we have told that in amplitude modulation my message let us say I have a message signal which looks like this okay, so some message signal this looks like this it is empty of course it might have random variation as we have already turned about it that if it is a voice signal for the receiver it must be a random signal.

So anyway it is some kind of signal okay which is time varying and the time variation might be random and on top of that we also have another requirements that this possibly band-limited that means if I take the Fourier transform, how we will be taking Fourier transform? Again will be probably knowing the statistical property of this and we will do our time autocorrelation function and we will do a Fourier transform so we will get some Fourier transform, let us say this is the Fourier transform this one our requirement is this Fourier transform should be essentially band limited okay.

So that means the frequency terms that are existent for this signal are essentially within certain band or otherwise we can say if it is not band limited the out of the band or whichever band we are targeting beyond this there might be some frequency component but those are insignificant okay, so we do not have to be bothered about that whether that is transmitted or not that will not distort the signal beyond something beyond our perception.

So we will say that this is band limited so this goes from - B to + B okay right. So I have a signal now which is a random signal probe which has a equivalent Fourier transform representation or I should say a power spectral density I have okay. So these two things are there or I can always say it has a means MF correspondingly it will have mod MF^2 which is either energy spectral density or power spectral density depending on how you define it okay, so we are just right now thinking about that we have a signal.

And we have corresponding amplitude spectrum that is the simplest way to represent it just other things can be done later on okay. So these two things are known suppose for a signal, now we have to design a system which does modulation so what we need to do the first way of doing modulation is frequency using frequency shifting property of Fourier transform.

So if I have mt we have already told that it should be carried by the carrier so empty must come here, so my modulation must look like mt cos ω_{CT} + some π constant π, which must not be time varying because we are just putting the message in the amplitude not in frequency or phase that should be remaining constant. So even for simplicity we can take that as zero even if you take a constant value that will not disturb you, so we can say this is my modulated signal.

So here the terminology will be this is my carrier this is my modulating signal or the message signal and this is the modulated signal, as you can now see we are familiar with this already.
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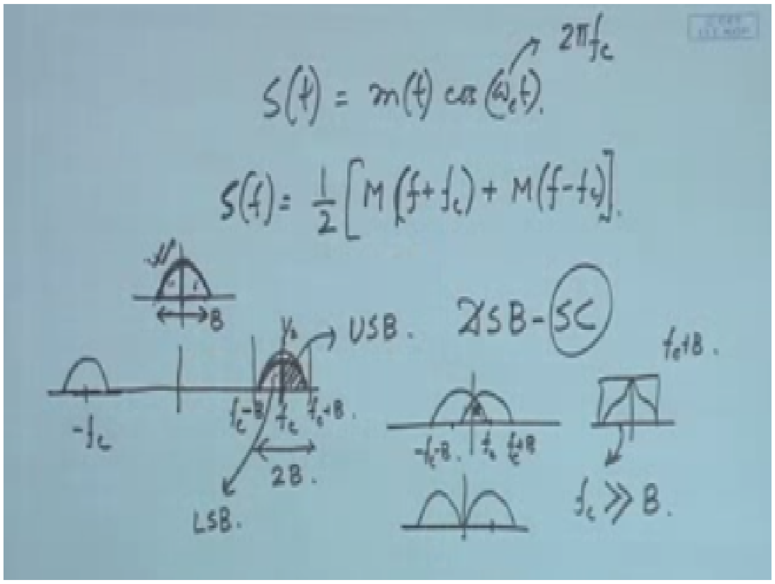

So if St becomes mt cos ω_ct immediately if I do Fourier transform of this so Sf should be we have already derived this that the famous frequency shifting property, so that becomes M f + suppose this ω_c is 2 π fc and should be + fc + M f - fc right, we are saying this is our amplitude modulation. So how this the spectrum will look like so if I was having M f like this wherever I modulate that goes around fc and - fc and the corresponding strength becomes 1/2 so if this is like this will be half of that amplitude will be half of that, but the shape will remain the same so that is the mf- fc and this is the mf+ fc and you can see after modulation because it is a real signal.

So it is a even symmetric representation okay, so the conditions are that this f – e whenever I model it there are two things which are happening, what was the bandwidth of this signal? The bandwidth was it is up to B right, so the overall bandwidth is zero to B and 0 to - v-half I can ignore to define bandwidth, so it is actually bandwidth is B so the baseband signal has bandwidth B whenever I do modulation what happens because the shape remains the same this should be fc - B and this should be fc + B. So overall bandwidth will be doubled that is called 2B okay and what happens if you see this signal was even symmetric.

So this particular half and this particular half this half does not carry any extra information as long as I know the pattern of this half that will be repeated in the just in as a mirror image in the other half also okay, so basically the information is contained in one half or within if I say just a baseband then within that B bandwidth what is happening after modulation my band width this getting increased now the overall band width if you see it is defined from fc - fB 2 fc + fB just if I see the positive house negative up we do not have to see for bandwidth calculation so that becomes 2 B and what is happening this is still even symmetric.

So this is symmetric and + around this because the shape remains the same around this point fc it is still even symmetric or this is symmetric so still the information is carried by this particular band on which we term a supper sideband and this particular thing we call as lower sideband and upper sideband are lower and lower side band are just our image to each other, so they do not carry extra information whatever upper side band carries same information about that signal is being carried by lower side band.

But unfortunately whenever I do modulation I will be requiring this entire to be band to transmit my signal. So what is happening eventually my signal bandwidth is B but after doing modulation I am occupying at least to be band and that's being occupied by me my own signal. So in a way there is a band width wise if we start asking there is a wastage or I should say double wastage because for every B band width signal I am occupying to be band width later on we will see if we can have some band width efficient modulation technique.

But right now we should be content with that, that is the simplest form of modulation I just do this I get this particular thing I know that band width wise it is not the most efficient and of course we will be requiring this because band width is a commodity you can see that if you have some sudden band to operate you will be putting your signals one after another and they should be non overlapping if they are band limited.

So basically how many signal you can put within that band will be restricted by what is the band it is occupying, so therefore if you can reduce the band of course it will be occupying more number of signals that means more number of simultaneous transmission you can do. So here what will be happening if you just do this modulation as many for us for same band suppose where you can operate if you can operate with n number of means you can transmit n number of simultaneous communication, what will happen? If I could have reduced this to half I could have transmitted twice that number that's a big number suppose I can transmit 6 radio channel over a band now I can say I can transmit 12 radio channel within that same band.

So cost-wise that will be much more effective will be definitely targeting that but right now it should be contained with this modulation, so this is this particular modulation is called double sideband with suppressed carrier we will talk about why it is suppressed area right, now it is double sideband that is really understandable because we are transmitting both the side pack upper as well as lower sideband.

When we are see after doing modulation we will be putting it in the antenna now it is actually serving me to purpose one is it has been translated to a higher frequency, so the antenna size will be smaller and it is occupying a particular band so I can actually multiplex, if I was trying to transmit raw base band signal to Y signal will be occupying the same baseband and we won't be able to multiplex them.

So two purpose are being served another thing that has to be seen is what should be my fc very carefully see if I have chosen my fc over here okay, so by signal whenever I modulate it will be left shifted and right shifted, so what will happen this two things after left shifting and right shifting they will overlap with each other and in the frequency domain you cannot actually separate them, now you cannot employ any filtering technique to separate them out okay.

So what will happen? Your signal will have some distortion because it will this gets overlapped, so it will look like something like this which is a completely distorted version if I just so it still remains a low-pass signal which has a frequency. Suppose I am centered at fc so it goes up to fc + B and it is of course - fc - P right so now I cannot employ up after doing this modulation I cannot employ any kind of band pass filtering, so I will have to employ a low-pass filtering off bandwidth fc + B okay.

And that will distort the signal if I now put it in the means of course it is already based band, so if I just try to see the time domain signal it will be distorted because the frequency for components has been distorted, so signal will be distorted. So therefore if I do not wish to have Distortion what I need to do is at least I should ensure, that whenever I put them they are separated.

So that means my fc this fc must be bigger than the B and generally it should be much bigger than the B, so that is some criteria which has to be satisfied, whatever modulation you do wherever you wish to put but you have to always ensure that whatever frequency you are choosing for your carrier that must be greater than the bandwidth of the signal, and that is why it is very essential that you know the Fourier or energy spectral density of your signal.

You are modulating while whichever way you are modulating because it has a much lower bandwidth, if you employ the same thing for video probably it will not work because video is occupying a much bigger baseband frequency. So you have to accordingly see where I can put which particular frequency I can choose and put my video signals that is very essential.

Whenever you are doing modulation that is one part which is essential and also you have to see what frequency you are choosing because according to your antenna size will be decided, so both the things will actually determine what frequency you should choose okay. Now let us see what happens to this DSPSC.

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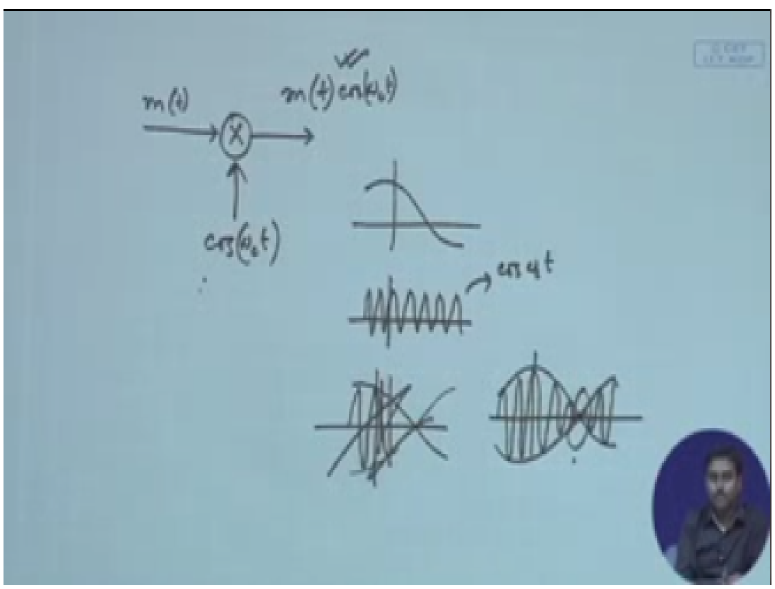

So basically what has happened I have a signal mt for modulating what I have to do I need to multiply it with cos ω_Ct so basically from signal I am now trying to devise a system okay, so what I need is a multiplier circuit somehow I have to realize this multiplication. A circuit which where I will be giving two input one is my message signal itself or modulating signal empty and I will be giving a carrier signal and somehow my system should multiply, this will see how this multiplication can be done and then the output will be mt cos $\omega_C t$ for my purpose this is my modulation.

So if I can realize a multiplier circuit that makes my modulator system ready and then I just put it in the antenna and it will be transmitting this particular signal because this characterizes what I wish to achieve in modulation okay. In time domain what will be happening, so suppose I had a signals which I have shown earlier here if I wish to modulate it, so basically what will be happening I am modulating with the carrier frequency which is cos $\omega_C t$ as you can see the time varying of amplitude which is much slower than this time variation, because it is at very high frequency okay.

So that will be happening now if I just multiply this the amplitude of this one this carrier frequency must carry this signal, so this must be reflected in the amplitude so what I will see is something like this should make my envelope of the carrier so if I just envelope means it should be from both sides. So that draws the envelope within that the carrier will be oscillating, so it should if this is 0 sorry this is 0 let me draw it again with something happening over here we will discuss that in the next class but this is what will be in the time domain okay, were in the envelope the message will be carried over.