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NPTEL ONLINE CERTIFICATION COURSE

Course
On
Analog Communication

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Lecture 18: Amplitude Modulation (Contd.)

So far we have discussed about DHBSC and amplitude modulation, so these are two version of amplitude modulation that we have discussed to the previous few classes. So DHBSE was something where it is called double sideband but also suppress carrier that means you modulate it the way we model it is just frequency shifting actually so you multiply the message signal by a cos Ω C T where Ω C is the frequency of the carrier okay. So if you just do that then you get double sideband but if you on top of that if you add carrier to it then you get amplitude modulation.

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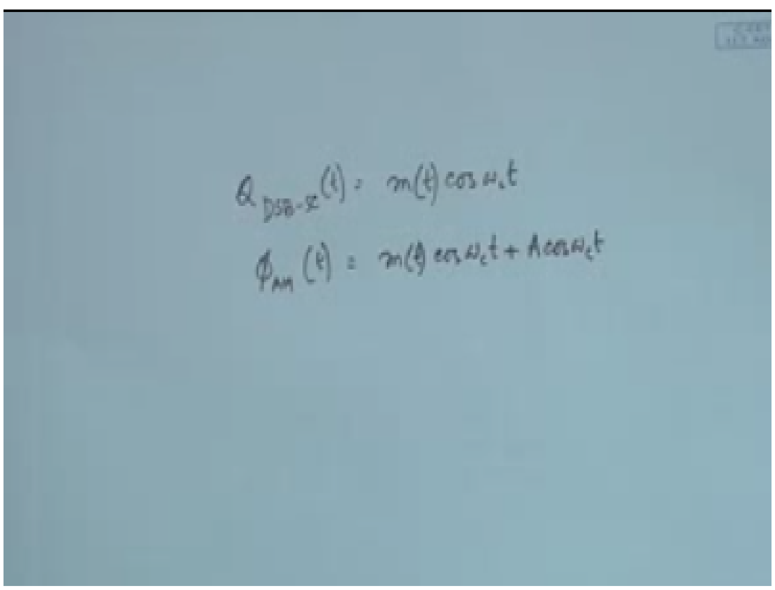

So the DHBSE if I just write φ DSB SCT that should be if my message signal for modulating signal is empty and carrier is cos Ω CT so this is d DHBSC and amplitude modulation is nothing but the same thing which is empty cos Ω CT plus a cos ΩC T so that is the carrier part we add to the signal and we have seen the benefit limited benefit of it.

So here in a.m. we have seen the receiver becomes very simple it is just envelope detector whichever way you do that we have already discussed two methods of envelope detection and for DHBSE we need in we need to generate local carrier, so for that we need to extract carrier from the incoming signal so that requires carrier synchronization and all those things.

So the modulation of DHBSC was very simple you have to again be multiplied with cos Ω CT followed by a map of sorry low-pass filter, so this is something we have already discussed now let us try to see it is just some more discussion about this you will be mostly seeing that there is a importance of tone modulation because through tone modulation we get means try to get information about what happens whenever we model it so tone modulation means it is just it is not a message actually this is the sinusoidal I want to model it.

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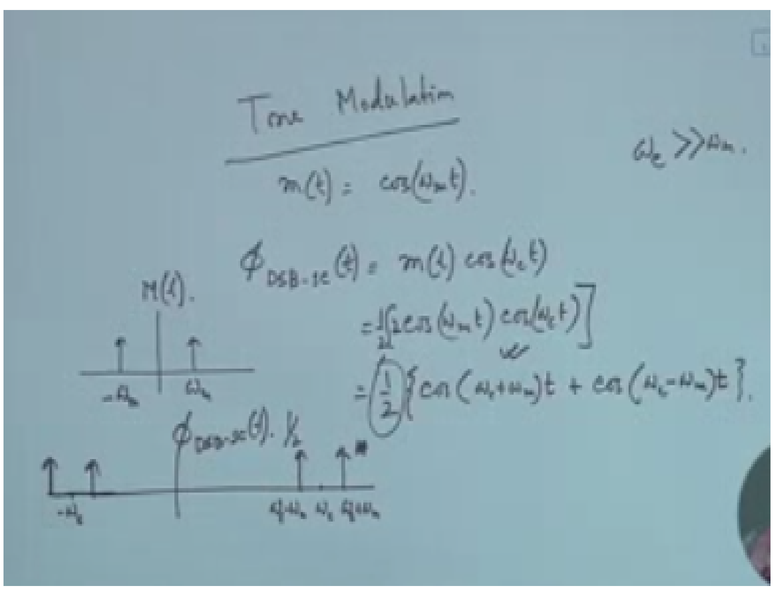

So my modulating signal that MT I have a specific representation so far we are not representing it okay, we are just saying it is some kind of signal it maybe voice signal or something. So here intone modulation, so we call it tone modulation it is just a indicating modulation actual modulation will never be that because modulating signal we have already discussed that must have some randomness in it and if you just say it is just cos Ω MT it is not carrying any information but it is just to say how the modulating modulated signal will look like what should be the frequency spectrum of it and all those things.

So if I have M T equal to cos Ω M T so therefore φ DSB SCT which is the modulated one must be empty into cos Ω CT which is nothing but cos Ω M T and E cos Ω CT so I take 1/2 x 2 so this I can put as cos P so it cos a c cos B formula, so I can just put that as of course our assumption is carrier frequency is much higher than for modulation that has to be there it should be Ω C – Ωn, so if you just try to see in the spectrum what is happening our modulating signal that was sinusoidal or a cos we have already said that cos in the frequency domain can be represented as 2 δ function right.

So if I just put this as MF so this is at Ω M this is at - Ω M so whenever we modulate what happens there are two cos now one is cos Ω C + Ω M so if this is Ω C there should be one cos function which is Ω at Ω C + Ω M and there should be another co sinusoidal which is at Ω C - Ω M and of course the negative half should have the symmetric part, so if this is - Ω C so there should be two part over here with amplitude half right.

So all this must have half amplitude so that is φ D as V SPF so whenever we model it actually if a tone we modulate with a carrier we just get to go sinusoidal and the corresponding time domain representation will be something like this.

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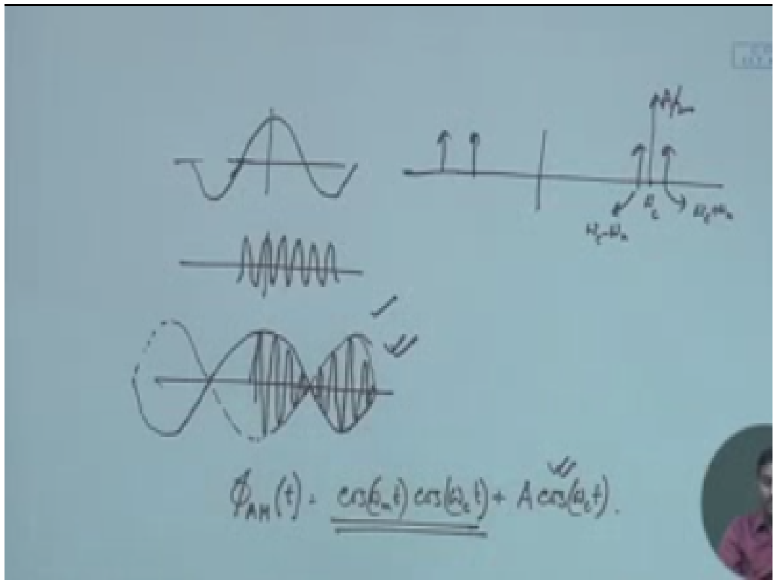

So this is your modulating signal with frequency Ω M and let us say that spec area which is having a frequency much higher so whenever you modulate what we see that becomes the since that should represent the envelope so it should be something like this and of a similar presentation and a positive and negative up and inside with Ω C frequency it should and there should be a phase reversal we have discussed about that also everywhere wherever there is a voltage means whenever it crosses 0 there should be a phase reversal.

So that should be the time domain representation so if you just try to see what this is this is actually two co sinusoidal bt with each other the addition of two co sinusoidal signal with frequency Ω C + Ω m and Ω C – Ω once you do that if you just take these two co sinusoidal signal and then add them together you will see that this pattern will be generated. So that is what is happening over here so this is how the SBS C should look like whenever we add carrier to it what happens.

So in the frequency domain if we try to employ so φ am T that of course cause Ω MT because that is the modulating one that must be multiplied by cos Ω CT plus there should be a cos Ω CT right okay carrier term should be there so therefore this part we have already been said what should be the frequency domain corresponding frequency domain representation. So that should be two co sinusoidal this should be Ω C so this must be Ω C + Ω M and this must be Ω C - Ω N and due to the presence of KD s there must be a by two strength carrier at Ω C.

So it is just we can see that whenever we have which carrier there should be a δ function which is just representing this carrier at Ω C and – Ω C of course because it must be given symmetric okay.

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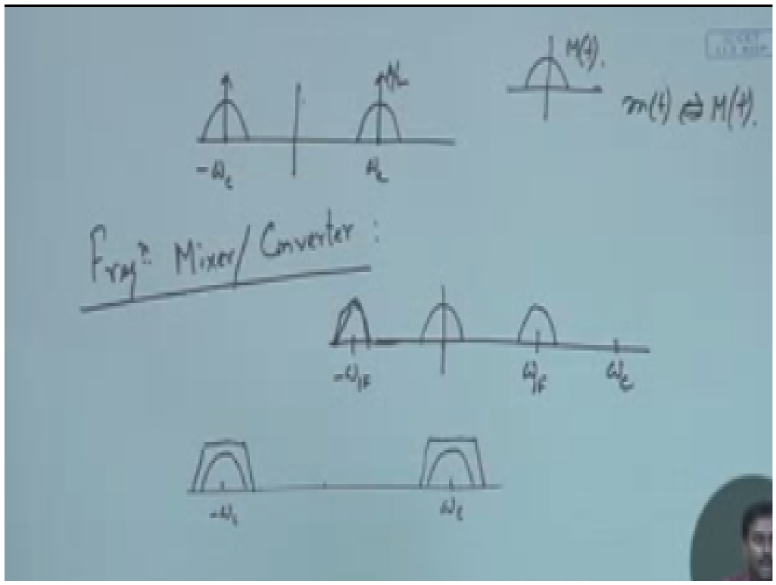

So if I have just general modulated signal of this MF so that is the MT has a Fourier transform of MF let us say so if I modulate that with Ω C that should be my representation if I do DHBSC if I add Caria there should be just a δ function at ΩC of plenty by – of course fine. So this is what we have been told and this is just a tone modulation version of that so now what we wish to do is we wish to see that the same modulation technique can we employ for other things one is called the frequency mixer or converter let us first tries to understand the utility of that.

So generally what will be happening suppose I wish to put some signal at a higher frequency okay, so the higher frequency at that higher frequency let us say the available frequency because I need to get a frequency slot which is in the chair media nobody is occupied okay so that might be very high pretty high. So what I need to do while putting I need to modulate with that ΩC but in between I might have to do some signal processing like I might have to amplify the signal and so on some other signal processing I might have to employ okay.

So if I wish to do that what I can do is something like this I can first modulate the signal or even demodulation also similar thing will be happening so I can put it into a intermediate frequency let's call it Ω IF similarly in the negative half also same thing will be happening and then after that from Ω IF will be actually translating it towards Ω c or sometimes I might do the reverse thing that after receiving okay whatever signal I receive so suppose my modulated signal is coming.

So this is centered around ΩC - ΩC I put a band pass filter centered around ΩC and the bandwidth should be greater than the 2 B value right we have discussed about the bandwidth for a moderated simple okay. So I will get just this one if there are some spurious thing in other frequencies that will be all means rejected I will just get my signal now once I get this signal I might have to amplify the signal okay.

So the receive signal has to be amplified but at that high frequency if I wish to put amplifier circuit at high frequencies any circuit design will be very difficult because they'll all start radiating things okay so there any circuit component you start putting they will be already getting so I cannot really do employ any signal processing at that high frequency. So what I wish to do I still need to do amplification on any other signal processing that I wish to do.

So I need to first translate it to a frequency band where I can do my signal processing so the good advantage is while modulating and transmitting the signal I am still using ΩC which is a requirement in the carrier or sorry requirement in the channel because I need to put a signal in that particular frequency event that is the only free frequency band, but I also know at the same time that processing I would not be able to do at that frequency.

So I have to first receive that so receiving is still alright I can put a band pass filter at that frequency centered around ΩC with to V bandwidth I can take that signal now with a very simple circuit if I can just down convert it to a lower frequency then I can employ all my signal pulsing things on that, so all I have to do is if I get this signal.

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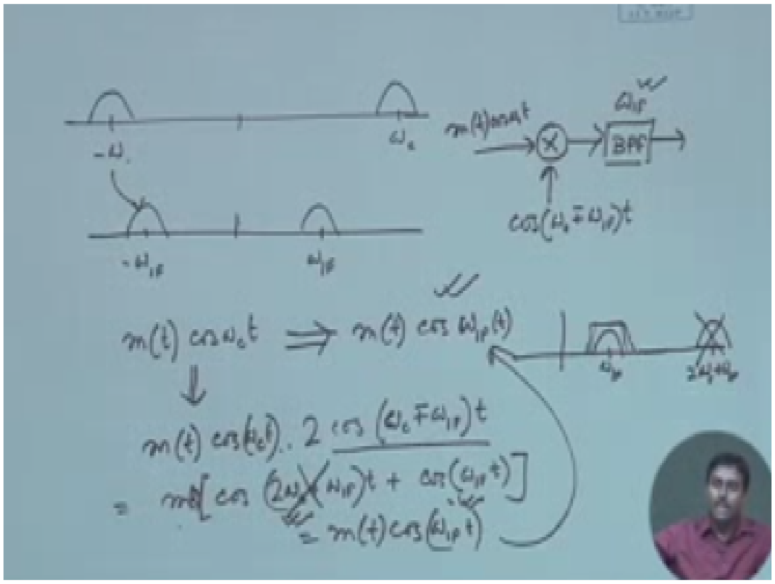

That is a center around ΩC - ΩC that is my receive signal I wish to at that frequency level. Now I have ejected after band pass filtering I have rejected all other things now I want to I cannot do σ passing over there I want to actually translate it back to ΩI F which is pretty low frequency where I can do signal processing, so all I have to do is from this to this I have to do a conversion okay which means seethe spectrum of the signal frequency components remains the same it is just getting translated into one frequency to another frequency.

So all we have to do is if the modulated signal was empty cos Ω CT from there I will have to create MT cos Ω IFT is all that I will have to create okay, so that is something we will have to create. Now this is something which can be done almost equivalent with a similar modulation technique. So what I can do suppose this is something I am receiving okay. So this whatever I am receiving cos ΩCT I will actually multiply this with two I am just taking it we will see that why I am taking two, but I just have to multiply it with something called cos ΩC + Ω is T okay.

So this is all that I will have to do so I have to locally generate a particular co sinusoidal which is centered at Ω C + Ωs or I can do it even at - both will give me same results okay, so I just have to do that and I have to multiply it. So my circuit will look like this is M T cos Ω CT which is coming to me I receive it through a antenna then I put a multiplier circuit whichever where we have already talked about how to design a multiplier circuit and then I multiply this with cos Ω C - or + Ω IF T okay.

Whatever I do get after that I put a band pass filter okay, which is centered around that Ω IF you will say that this will give me this particular signal back why let us try to manipulate this particular part, so I am just doing multiplication so after multiplication I will get because it is to cos x cos a cos B so I can I can put cos a + B + cos a - B so cos a + B suppose I am just taking the positive sin, so that should be 2 ΩC + Ω IF x T + cos and this final this.

So that should be just Ω IF T right which is my target. Now this is that ΩF this is at very high frequency twice of ΩC plus ΩF right. So if I just put a band pass filter around Ω if' okay which is having a bandwidth of to be so what will happen this whenever I see this will be creating something at Ω if' and it will be creating something at very far which is 2 ΩC plus Ω is right so that is what I will be getting.

Now if I just put a band pass filter I am just showing the positive spectrum similar things will be there in the negative half also if I just put a band pass filter this will be rejected so immediately what do I get I get this empty so this term will be cancelled the left over will be cos ΩI FP which is my desired signal right. So this particular methodology is called as either frequency mixer or frequency converter because what we are doing we are not changing the message signal we just translating the carrier from a higher frequency to a desired lower frequency which can be done.

Here also you might be asking that I have to generate a local carrier does that need to be synchronized with the input carrier because this is at a separate frequency we do not need any synchronization okay, so that is the advantage of it whereas when you are doing coherent demodulation in that or we should say multiplied demodulation that means you again multiply with cos ΩCT at that point also we are putting you are multiplying with it and we are putting a low-pass filter but they are the frequencies has to be completely synchronized we have talked about that that if this is cos ΩC T that has to be cos ΩT here neither the frequencies are synchronized so it must be some other frequency.

So I can always generate it and we will later on prove also the phase also need not to be synchronized with it okay so we will prove that when we talk about that carrier synchronization and carrier recovery okay but right now we can just give this information that we or this frequency converter we do not need additional requirement of synchronization no synchronization is required I can just multiply with any local carrier that I generate I need to just roughly know what is the ΩC okay.

So it needs to be closer to that and then I need to generate something at ΩC plus or minus ΩF as long as I am doing that that should be fine. So I will be able to do this so this is a very important tool in communication again because the frequency converters as I have already pointed out it might be required in many cases where you might have to modulate at a very high frequency and you might have to translate that down to a desired frequency band where you can do signal processing which might be a big requirement.

So that is one technique you can already see that which can be employed for communication but it is actually not affecting what you are doing in the channel you are still choosing that ΩC right so that is one thing we have talked about the other thing we wanted to talk about is actually the relative advantage or disadvantage due to this amplitude modulation okay. So advantage we have already talked about that the receiver side is very simple right we just need to do a envelope tracker or envelope detection which is a very simple circuit we have already talked about that that you need a just a diode and then followed by a low-pass filter okay either low-pass filter or a RC charging and discharging circuitry which properly design R and C we have already talked about that.

So it might become very simple you do not need any carrier synchronization you do not have to generate carrier yourself, so all those things are not required whereas if you wish to do without carrier that means not amplitude modulation as DHSBC sequence carrier a subset you might have to locally generate a carrier which is synchronized with the incoming carrier or you might have to actually take the carrier I mean extract the carrier from the incoming signal and then demodulate it that is you have to multiply.

So let us measure strategies it might be advantageous okay in that aspect let us try to see if there is any disadvantage because there are no free lunches if we try to get some advantage there must be some disadvantage. So let us try to see what the disadvantage we get so whenever we add a carrier what was our purpose this is also something we have discussed, that whenever we add a carrier the message signal whatever way it was.

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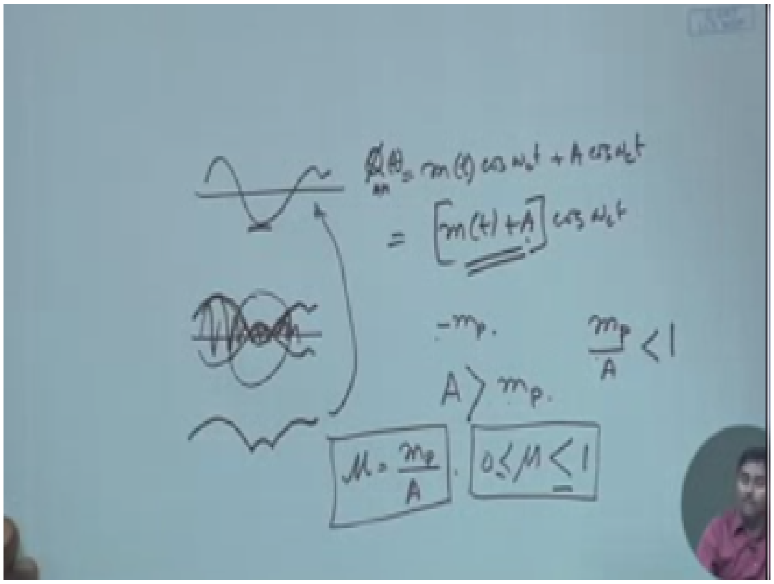

The lowest amplitude whenever we add carrier actually almost like adding DC value to the method signal and then doing the SBSC right, so the DC value which is actually the amplitude of the carrier that must be greater than the lowest amplitude of the message signal this is something we have already proven that my MT cos Ω CT I add a cos Ω CT to it which actually this is of φ φ a P so this is we can just say MT + a x cos Ω CT. So this is my new message signal where with empty I am adding a and if I wish to do envelope detection still we have seen that it must not have any zero crossing because whenever I have zero crossing I will have that phase 180 phase shifting and then I would not be my envelope tracker will not give me the signal back.

So even if I add a DC to it and its has some spurious part which is below means zero level so if I just try to see the envelope it will have this thing and then the carrier will run on top of this and there will be a phase reversal and if I wish to do envelope detection so envelope will detect this and this so my detected signal will look like this which is not the original replica of this one right. So whatever I need to do I need to take this up so carrier must be added in such a way that the amplitude of the carrier is always is whenever I add that amplitude of the carrier is always greater than even the lowest value of my message signal okay so let us say that lowest value is - MP okay.

So therefore I have a condition that a must be greater than this MP okay this must happen and in that aspect we define a term called modulation index which is defined as mu which is actually MP /A where MP is the lowest value of my message signal okay or you can write that as M in whichever is good for you but anyway this is the modulation index that has been defined. So if you just see this definition immediately you can see that μ must be of course greater than zero because if it is less than zero then A will be negative with respect to MP right MP is already a positive because - of MP is the negative values so MP will be always positive.

So modulus value of that and then if mu is negative then a will be negative which is not good okay, so all we will have to do is that mu must be that is a trivial one it must be greater than zero all this but the other one is very important because A must be greater than this so immediately from here I can write MP divided by a that must be less than one I just took a down say MP by a less than 1 so I can also write this at max I can have equality but anything other than equality I put always I will have the danger of this kind of scenario okay. So I should be this modulation index I should be always ensuring that this is happening okay

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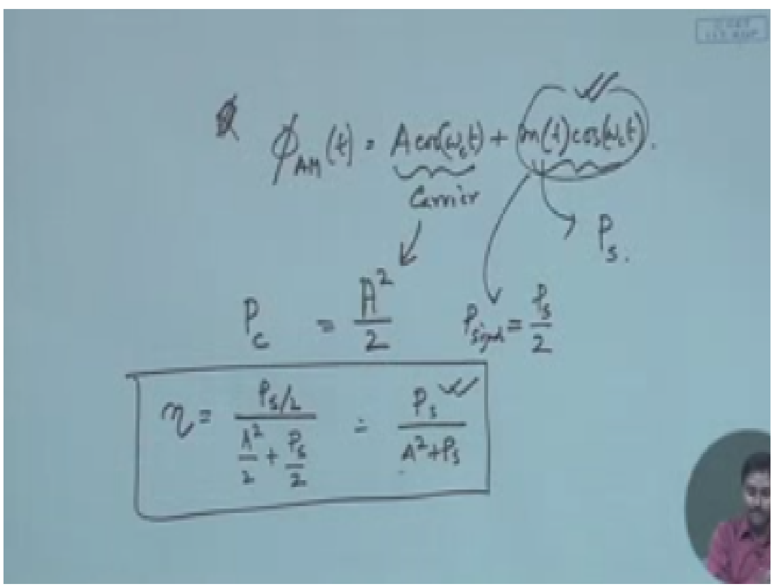

Now let us try to see what is the effect of this okay, so let us say I have some let us say I put a φ_{AM} t which is nothing but some a cos Ω CT that is the carrier part and I have some message signals into cos ΩCT right. Now this is the carrier part and this is that PSBs see what okay, so what is the power of this one so I am trying to calculate the power of this one so I know it is a co sinusoidal so it should be A^2 / 2 if you just evaluate the power of that so this is P carrier PC I call it and what is the power of P signal suppose MT has a power PS that is something I know already the message signal has a power of PS.

Now if I multiply with cos ΩCT we know that the power becomes 1/2 we have already discussed that in a previous class so this must be PS by 2 that is the power of this part okay fine. S so this is my 2 power so I call this P signals okay. Now let us say talk about some efficiency okay ultimately what I am trying to do I am trying to actually transmit empty through the channel okay.

So the significant amount of power which is which is actually required or which is the valuable power that is actually this PS right the signal power so that is the power I wish means I wish I could have transmitted if I was not employing any carrier modulation I could have been in the baseband I could have transmitted this the empty was getting transmitted so corresponding signal power was PS.

So this is the one I will be actually I will be wishing to transmit whereas due to this particular modulation I am transmitting a little bit more so what is the thing I am transmitting so I should have transmitted PS but right now I am transmitting what I am transmitting this A^2 / 2 + PS/2 okay if I compare it with D SBHC in d SBHC I will be transmitting only this so how much I will be transmitting PS / 2 so that I would have eventually transmitted if I was transmitting DHBSC.

Now because of this particular thing I have to transmit power for this as well as power for this so this is the overall power I am transmitting right so immediately I get so that is the efficiency to actually which I could have done with PS now I am transmitting A^{2n} + PS so that is the overall power efficiency that I get doing this right so I am transmitting extra amount of power which is a square. So this is always sitting inside okay.

Now let us try to see with this efficiency factor so better the efficiency I am better off if I just transmit DHBSC then below also I will be I will not be transferred in this A^2 so it will be 100% efficient that means whatever power I have to transmit I am just transmitting that much but if I do AM then probably I am transmitting little extra power that means I am wasting that power because for transmitting carrier I am getting no advantage that is not carrying my signal right so what I can write suppose if I have a tone modulation right.

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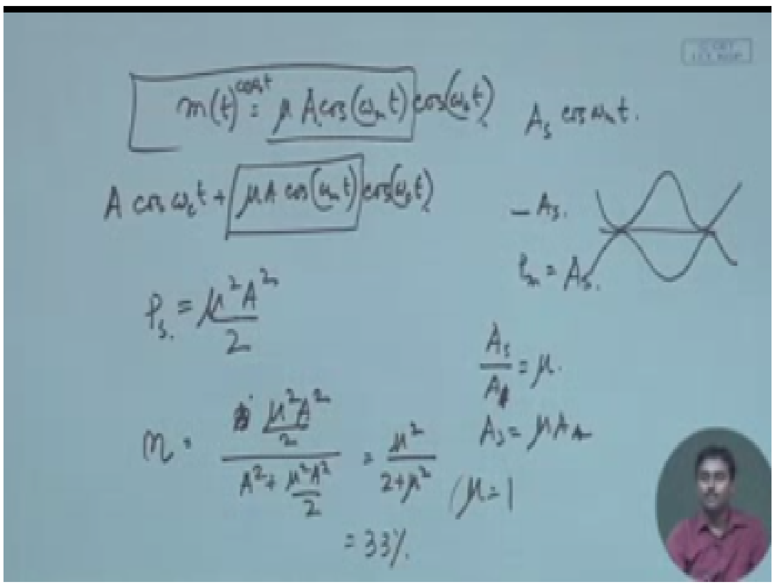

So my MP is something called a cos ΩMT and I have a modulation index of MU that is added to it okay, because if I just write it as some a s cos ΩMT okay, so what is the lowest value of that it is - a s okay what is the TM for this which I was talking about the lowest value of this that must be a s okay. So I should have my carrier signal AC so that means ACAS / AC must be my modulation index okay.

So therefore I can write a s as my μ whatever modulation index I am employing into AC so or a if I just put this as a so we will do a so I can write this right so that is my MT okay or MT cos ΩCT if I just write okay then this should be multiplied by cos ΩCT right. So my overall signal is a cos ΩCT + μ a cos ΩM T x cos ΩCT so this is what I am again we are demonstrating a tone modulation right.

So in this case for the message signal which is this part what is the power of it? It is μ^2 A^2 right so that is the power divided by two that is the power of the message signal so this I can call as PS and immediately I can evaluate the efficiency which is sorry μ^2 A^2 / 2 right divided by A^2 + μ^2 A^2

by two according to that formula that PS divided by PA or sorry a square plus again PS right. So this is what I get a I can cancel out so I get $\mu^2 / 2 + \mu^2$ right.
If I just put $\mu = 1$ that is the best I can do that is the highest modulation if $\mu = 1$ I will be seeing almost this envelop just touches it does not cross over anything bigger than that will be below this so if I just put $\mu = 1$ immediately what kind of efficiency I get to go to 1it will be 1/3, so 33% efficiency, so that is the best I can get so immediately you can see that is where I pay DHBSC whatever power efficiency I was getting compared to that in AM I am getting33% efficiency on D so that is 1/3 power is the useful power rest of the things are just wasted okay. So we will end it over here for this class next class we'll start defining other bandwidth efficient modulation.