NPTEL

NPTEL Online Certification Course

Course
On
Analog Communication

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Lecture 21: VSB-SC

Okay so in the last class probably we have discussed about SSP of course suppressed carrier, so we started already exploding modulation technique which are bandwidth efficient. So you have already shown that whenever we do a modulation India is BSC we have shown whenever we do modulation basically the bandwidth gets doubled.

And because in the baseband of the spectrum symmetry in the positive and negative half the double band width will have the upper sideband and lower side band which are just better image to each other. So means immediately it is clear that we don't have to transmit that whole information the information is already contained in one of the side band, so either upper sideband or lower side band.

So it will be good if we can just transmit one of the side band and somehow devised a technique where we can modulate in such a way and also we can demodulate it so this was our target right and in that process we have shown that yes it is possible, it is possible through a transform called Hilbert transform, so if you do Hilbert transform.

Then you can represent this particular signal as some mt cos ω_ct plus m_ht sine ω_ct of course it Is plus or minus so accordingly will be getting either lower sideband or upper sideband. So that's actually we have proven from the spectrum that if we have SSB SB signal that can be represented as this where this m_ht is nothing but the Hilbert transform that means mt passed through a transformer which is the Hilbert transform and we get m_ht correspondingly okay.

So that is what we have already shown that this is possible so all we have to do is take the signals do a Hilbert transform multiply the original signal by cos ω_ct and the Hilbert transform signal by sine $\omega_c t$ through our adder either add or subtract accordingly we will get your means overall representation of upper sideband or lower side. So this is what we have already shown that is one way of defining it but we have seen the Hilbert transform is not that easy to realize, what we have seen that actually the Hilbert transform is almost like it keeps the amplitude same, so whenever it passes through that transform it keeps the amplitude same for phase it gives for every frequency component it gives $\pi / 2$ phase shift.

That's something we have discussed that which is difficult to achieve okay, so that is why we have devised another method which is called wavers method, which is means selective filtering method that means we just do the filtering have means to do a modulation in such a way that in the low means we put a low pass filter at the low frequency domain we can do the filtering and then we can translate it to the frequency where we wish to put it okay. So that way we can generate this kind of signal but for that we require that the signal has zero components or zero power around the frequency zero, so that means no DC value and around that nothing is there because that is where the filter roll-off can be put or okay.

So that is required so there are two methods to actually modulate or generate SSB signals this is something we have seen and then for demodulation it's pretty easy we have seen that also that this particular signal that π SSB SCT that we have got you just multiply this with a cos $\omega_c t$ immediately you will be getting a term which is related to baseband of that signal.

And then there will be terms of higher frequency cos 2 $\omega_c t$ and sine 2 $\omega_c t$ you put a low-pass filter those things will be rejected all those higher frequency term you can get extract your empty but for that you have to remember that I need to have a local carrier okay, which is completely in synchronous in phase and frequency with respect to the incoming signals means carrier frequency and phase.

That is absolutely required we will try to see whether that Is possible or not okay, so this is something we have discussed so far. What now would like to discuss that is there any other demodulation technique that is possible in SSB, SC or I should not say SSB SC is there any other demodulation technique if I add carrier to it okay so all we are trying to do now.

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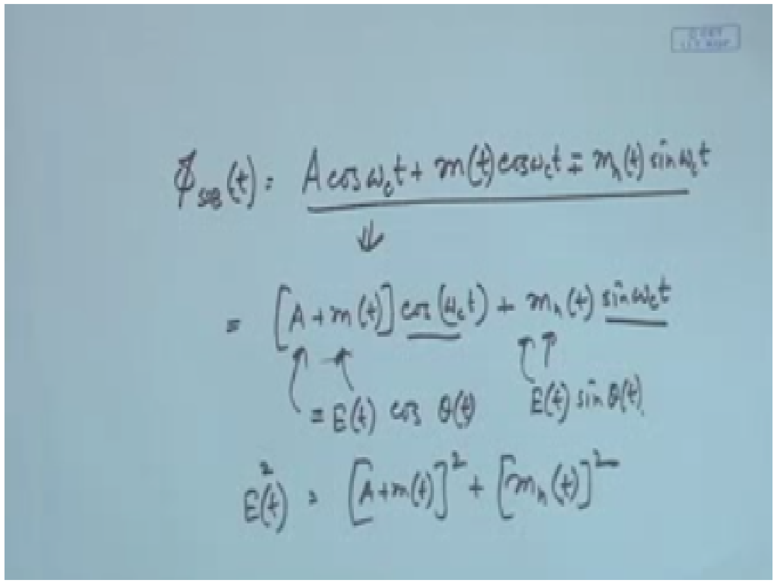

We are calling this as SSB signal that means no suppressed carrier so we will be adding carrier to it a cos ω_ct and the original SSB signal which is if my message signal or modulating signal is empty so mt cos ωct minus or plus depending on whether upper side band or lower side band I am taking m_ht sine ω_ct this is the representation of SSB, I am just adding carrier to it at the transmitter end I can always add the carrier because that is where I have the local carriers which with which we are modulating it so I can always add the carrier to it okay.

So this is what I will be now transmitting through the air instead of just transmitting SSB so that is why we are calling it it says be on the SSB no subtext carrier so carrier is already over there, so that this particular signal I can re represent as a plus mt cos ωct plus or minus I am just taking one of them so m_ht sine ω_ct okay so it is a cost term and a sign term I can represent these two terms as another some amplitudes, let's say Et into let us say cause another θt whatever phase that that is that might have some frequency term phase term whatever it is overall phase if I just say θ t I can always write that this is my cost means Et cos θ t and this is my Et sine θ t.

I can write that way and then immediately I will be getting another co sinusoidal term that you can already see that the way I represent it accordingly I will be getting another co sinusoidal term of which the amplitude will be this square plus this square right since that Et ^{2} okay so whatever that Et so this I can write as Et cos θ T and this let us say I write a T sine θ T I can always write that where as what will be the Et so if this is equivalent to this is equivalent to this if I just square this and add that should be T ^{2} so therefore Et ^{2} should be a plus mt^2 plus m_ht ^{2} okay.

So what does that mean that means that same signal I can actually represent as a Co sinusoidal signal and this Et becomes the envelope of that co sinusoidal signal that means it is a co sinusoidal signal whose amplitude is varying with time, now it is no longer a constant term it is a time varying amplitude similar like DSV or amplitude modulation we have done so there also there was a means carrier and the amplitude was modulated right, so same thing is happening over here so Et is the envelope which is carrying that message signal in some way it has a term which is equivalent to this mathematically and of course there will be a phase associated with it but I am not bothered about θ3 right now.

Because what we are trying to do because we have added the carrier we want to actually do envelope detector okay, so carrier detection we have already seen in amplitude modulation we could add carrier in such a way that with some condition that the carrier strength should be at least bigger than the lowest amplitude okay, modulus of that.

So we have tried to do employ the same thing we are adding carrier hoping that we can do same thing there it was very simple it was just something into co sinusoidal here we have constructed that co sinusoidal because we want to just track the envelope of that co sinusoidal that is what we are trying to do. So now let us see if the envelope detector gives me the signal back that is what we are trying to do.

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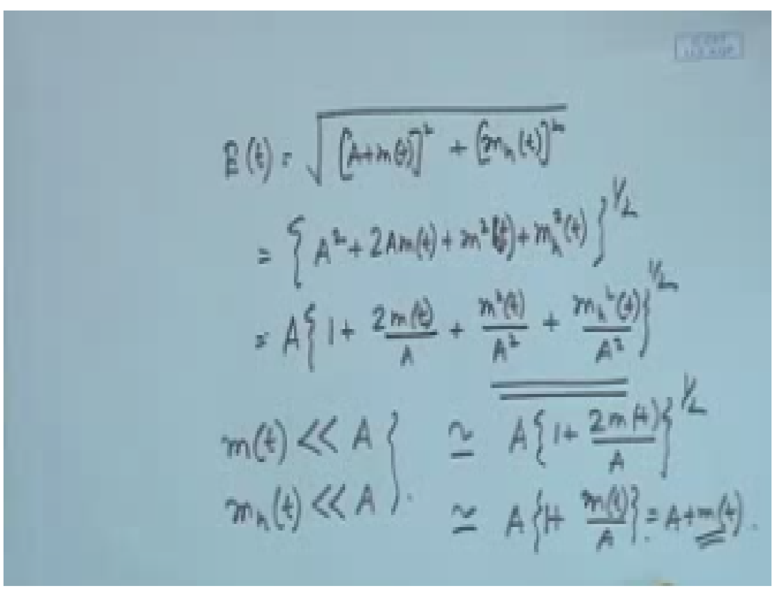

So if that is e square then what is Et because this is the envelope I will be detecting through a diode detector if I just put a pass it through a diode detector and then charging discharging the way I have designed it so if I just do that that should be √A + mt ^{2} plus $m_h t^2$ so this I can further write this to the power half a square plus A + mt ^{2} plus $m_h t^2$ that I take A out so A^2 out because there is a square root so it should be A so I get 1plus 2 mt /A plus m ^{2} t / s square plus m_h^2 t / s ^{2} to the power half now I will try to put some approximation okay means where I can actually detect empty.

So I know that the square terms are bothering me so I need to somehow take this out when I can neglect this if MT is much less than a and also you can see Hilbert transform what it does every frequency component it actually gives the same amplitude so if MT is much less than T I can also write MHT that should be also much less than a so this is something I can write because in the amplitude of Hilbert transform it's in the transfer function.

The amplitude actually gets translated with unity gain every frequency component so I can write this safely if this is the case then what will happen this quadratic term I can neglect if this is happening MT divided by a and you can also see because I want to put this that is why I have taken out a okay so approximately this I can write as a 1+ 2 empty so the linear term remains and all other quadratic comes are ignored now what I can do again I can do a another approximation because MT by a again I know that all higher order terms can be neglected.

So this to the power half I can put in Taylor series okay and all higher out To town starting from quadratic to cubic and all those things I can neglect and this will be approximated as a 1 plus there will be a half factor coming because the second term will have half so this 2 will be cancelled I will get 1+MT divided by a ok so that's again approximately this immediately you can see this is actually a+ Mt I just have to put up VC blockers.

And I get my empty back so the condition is in SS B also like AM CD as we had a wash on a.m. where I was adding carrier right and with carrier I was able to do my receiver very simple or do my receiving very simple in a very simple way so I was able to do that what I was doing I was just putting envelope detector followed by a DC blocker same thing I can do over here but there is a condition for a mall.

So there was a condition right that modulation index has to be just less than 1 or I need to say that this mod of Mt ok at least the negative part of it and modulus of that must be less than a this condition has to be satisfied always ok I was having this condition less than equal to now I have a condition which is much more stronger what does that means we have already seen that this was when it was taking equality with the tone modulation we have proven that at that time I had the energy efficiency which is 33%anything more or mu lesser than 1 the n energy efficiency will be lesser.

And lesser here what is happening I need to choose a which is much bigger than empty so therefore the modulation index corresponding to this or I should say energy efficiency which will be much more Watts because I have to really put very strong carrier so I'm just wasting power by putting a very strong carrier because otherwise I won't be able to detect this okay because for detection I have already seen mathematically I need to have that approximation if that is not there all quadratic term and cubic term will be coming into picture and that will actually distort my signals okay.

So on top of mt level DM square T and M cube t and all those quadratic all higher harmonics terms will be coming and mixing with the signal that will distort my signal so I cannot really afford to do that if I wish to detect I need to have this condition and immediately the power efficiency goes right ok so basically as we have stated that there are no free lunches SSB the bandwidth efficient scheme that's very nice but in SSB if you wish to do the receiver technology little bit simplified and you are a carrier and that carrier strength how carrier power has to be very high so you pay in power as penalty say and later on when the carrier recovery circuit will be designing you'll also see for SSB.

And the other version VSD that will be discussing probably later on you will see that for them carrier recovery is almost impossible you cannot really do carry a recovery for this bandwidth efficient schemes it is very hard to do that will prove that so if that is not possible then definitely we have to take this particular thing where you do not suffice the carrier and immediately the power efficiency goes for a toss so we have two options either you make it bandwidth efficient but then power efficiency will not be that good or you make it power efficient then bandwidth efficiency will not be that good.

So this is what we could see so far we have discussed something about single sideband now in single side band we have also talked about that it is only good if you wish to really do this receiver circuit sorry transmitter circuit will be simplified like the wave or circuit okay where you can just put filtering approach for that you need to have a spectrum of the modulating signal which is devoid of any component around DC okay.

So that's pretty much required but we have seen that for voice that's true this is this fortunately this was happening so people could employ SSB invoice but for video the spectrum looks like this so there are strong term around DC value and you cannot ignore them so that is not possible to ignore this if you will know that probably signal will be distorted so you you are not installed modulation you cannot really distort the signal that's something you is not allowed for modulation.

So that this is the case SSB is almost impossible we have said if we wish to do it through filtering that filter should run like this sharp cut off which makes it non realizable in reality so it will not be stabilizer right so what's the technique that we should employ so here will probably do a complication will do will take some mount of bandwidth efficiency means we'll compromise on bandwidth from SSB but also will gain little bit on power will show you that demonstrative that okay.

So that is the vs BSC that means whenever we do BSB so if you just demonstrate suppose this is my MT and corresponding MF which has a bandwidth B if I do d SB then at FC and minus FC this will be modulated and it will occupy band from minus B to means FC minus B 2 FC plus B so almost to be bad bit right if I do SSB then I will be taking if I take upper sideband I will be just taking one of the side pan the upper one okay so this is at FC minus FC again this is B.

So it's bandwidth efficient instead of to be this and because I cannot create this if something around zero is already there what I will be doing I will try to create something which is like this okay so basically what I am trying to do I am trying to suppress some portion in my valid band of USB.

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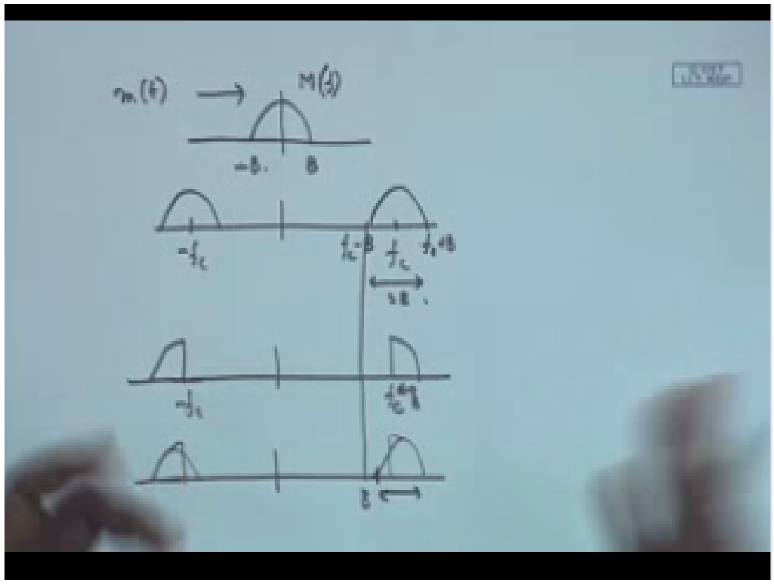

And I am including some portion in the LSB okay and with that I am not including that whole band I am NOT going running up to B it will be somewhere it will be ended so my overall bandwidth will be this much let's say 70% 75% of the overall to be so I still I am benefitting by saving25% of the overall band okay where as from s l's be compared to SSD I am taking X star let us say band okay so this is what I will be trying.

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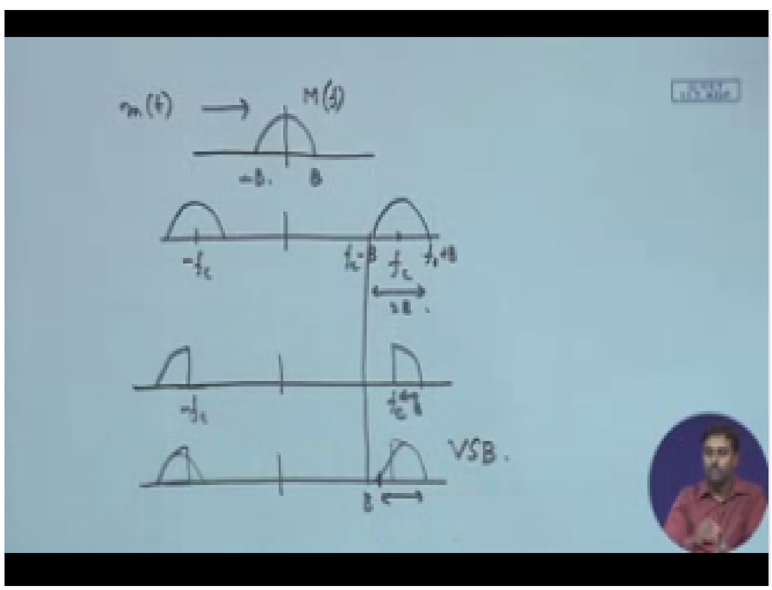

And if I wish to do that the corresponding filtering you can see that might have a nice roll off because I do not have to do a sharp cutoff at that frequency so this is called the VSP or we call it vestigial sideband okay so it's a little bit distorted sideband we are taking and we are actually taking a mix of both side band both way distorted but you will see that will in such a way we will design the filter so that we can actually get back the original sign alright.

So basically what we are trying to do is something like this again will employ the same SSB technique we will try to appreciate it because it's being appreciated at the frequency domain we will try to appreciate it from the frequency domain. And then go back to the time domain characteristics okay so it's actually nothing but the modulated signal means or we can say the DSBs see that is the modulated one followed by a band pass or sorry a high-pass filtering okay either high pass or it can be a band pass also you can you can end it later on so the upper one it's not a problem anywhere you can it only the lower part the filter has to be properly designed okay so we can say it's modulated signal let's say which is MF+FC and MF- FC this is just the spectrum of the SBS C followed by a filter transfer function.

The filter transfer function we know that it has a either high-pass or we should say a bad pass characteristics okay it might be high-pass we can just run it start from here and run it for the entire these things but later on we will also understand if we try to do that probably that's not really required we do not have to really include that entire band so what we can do we can just end it somewhere so we can just put us band pass filter with the typical characteristics.

So this band pass filter we are defining as h if so basically to generate my PhD signal all I have to do I have to modulate it followed by a band pass filter right now let's say I need to so this is my modulated signal after modulating I wish to because VHD and SSB almost looks like similar thing so what I wish to do my demodulator should be almost similar if I don't add carrier so it should be something like this modulated signal will be transmitted over the channel.

And then at the receiver I will first through antennas take that I will multiply this with a cos ωct okay followed by some low-pass filtering that is what we do because whenever you multiply there will be a means baseband term as well as some high frequency term at 2 FC or minus 2 FC you want to reject them so followed by a low-pass filters the same technique I wish to employ but while employing them I need to understand what kind of no pass filtering I will be putting so that it is consistent with this h if which I am putting that band pass filtering I am putting at the transmitter and I get my signal back that is what I am trying to do now.

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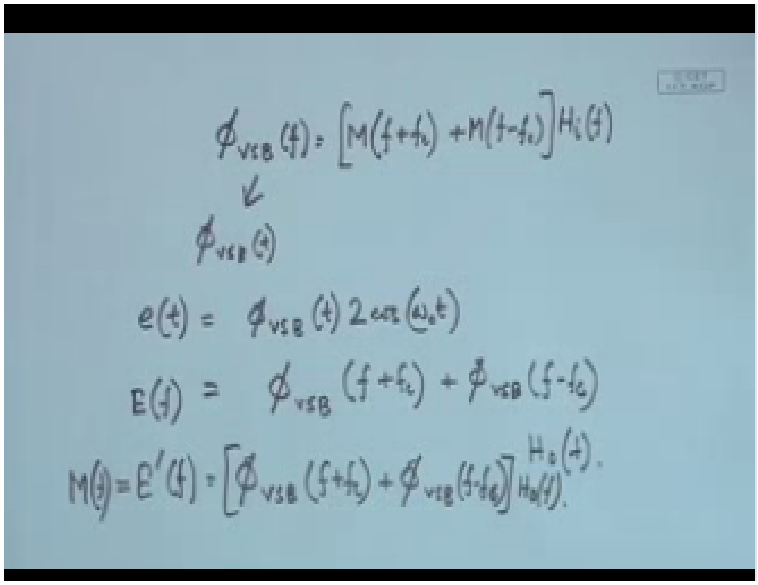

So what I will do suppose corresponding to this signal I have Vv SB T so it's just the Fourier transform or inverse Fourier transform of this okay so whatever this is right now I am not bothered about it so by detection or demodulation will be suppose it's after multiplication I will get this et so that should be five years V T multiplied by a co sinusoidal I am just deliberately putting us to amplitude to so that is just a constant it does not matter you will see that this to is required right this is what I wish to do so immediately the frequency domain how it will look like so if I just try to plot EF how this should look like so that should be5 vs B now 2 cos ωct if I have given.

So it should be plus FC minus FC so this should be if F plus FC right so this is what we get after on taking this now what will do we have to follow means pass this EF through a low-pass filter so let's say that has a transfer function of HOF so then whatever ii - fi will be getting that should be this vvs b signal or this x co sinusoidal that must be passed through this so that should be vs b s plus FC + v v SB f - FCx HOF right and what do we expect and if I design my HOF correctly this should be my M F right so I should get my signal back because I am doing the demodulation.

So in the demodulation I will be getting my 5 vs be like SSB or Das V I will multiply by cost and then put a low pass filter I should get my signal that is what I have done for all other modulation so same thing I should expect over here okay so that should be MF now5v as B I already know the characteristics right so that I will put over here and also I am aware that this is a low-pass filter so any higher frequency term that will be created low-pass filter will be able to reject them right. So let us try to put that so what do we get I will get so let us just in this v vs b f plus FC.

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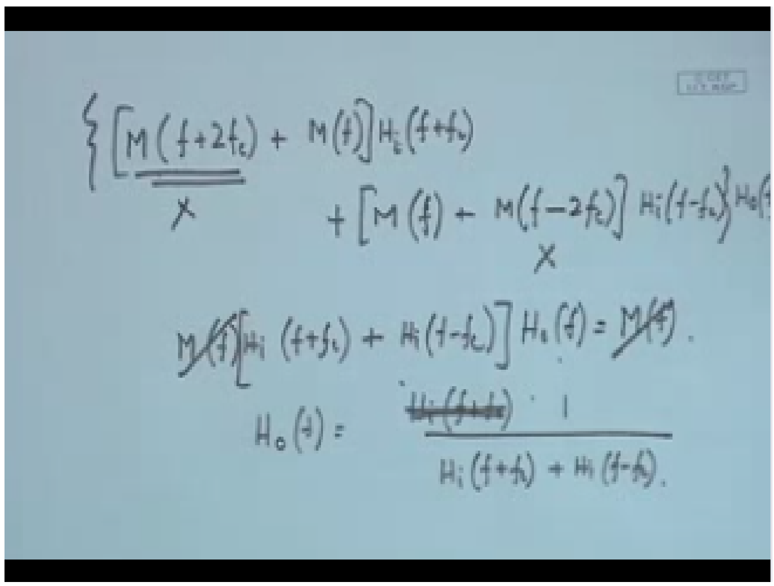

Let us replace by f plus FC and for F minus FC let us replace F minus FC and put it over here that is all we will be doing so that should create MF plus 2 FC if I am considering F plus FC and then the next term which is MF minus FC and F minus FC plus FC so that should be MF followed by H I it's F plus FC because it was F.

So it should be F plus FC and the other term should be M F minus FC minus FC so that should be MF + Mf-FC + h i f minus FC right this is the this is this EF part ok just by replacing this over here ok so this is the EF part in EF I have just substituted this and wherever required in place of fi i put s plus FC or F minus SC and I have substituted that multiplied by HOF must give me MF this multiplied by HOF but now we have to see whenever I multiply by HOF that's how the higher frequency term will be canceled look at this term where it is going it's actually MF shifted by 2fc in the negative half.

So this must be cancelled because this is followed by a low-pass filter so pass filter must cancel this same thing will be happening over here this must be canceled so what we'll be left with is M F H i f FC plus again M F so I can take common MF + H I F - fc *HOF= M(f) because that must give me after passing through pass filter I must get back my signal so that is the condition and it gets cancelled I get a relationship between my input filter and the output filter or I should say filter at modulator.

And filter at demodulator I get a relationship among them so I can just write my output filter should look like this right so that should be the output filter given the input filter okay so this is the relationship which will be happening okay now what we'll do we have just created a relationship between the filters we have still not seen how the vsb will look like means how do we characterize this filter so all those things we'll do in the next class thank you.