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NPTEL ONLINE CERTIFICATION COURSE

Course
on
Analog Communication

by
Prof. Goutam Das
G S Sanyal School of Telecommunications
Indian Institute of Technology Kharagpur

Lecture 24: Comparison of Different Modulation Techniques

So far we have discussed different analog amplitude modulation schemes, so let us try to lift all that we have discussed so far.

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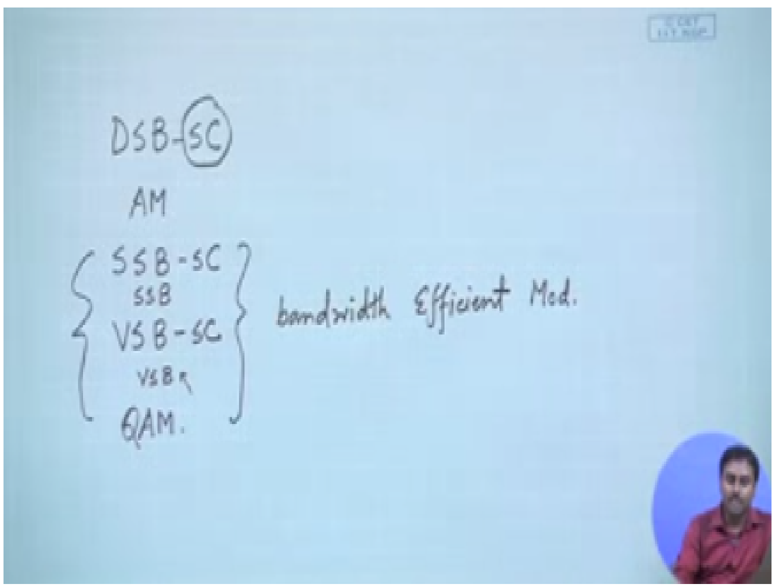

So one is basically DSB-SC that is the first one probably we have discussed and then we have seen a simple variation of that so that is also a d DSB-SC but we add I means some carrier to it so we can call that as amplitude modulation or just simple DSP with carrier okay, so this is just a derived version of that and then we went towards more bandwidth efficient modulation schemes which are single sideband maybe suppress carriers maybe with carriers so we will see that also so every modulation schemes that we can think of will have suppressed carrier that means you do not add any carrier so in the frequency domain there will be no Δ term at ω_c which is the carrier or it can be with carrier so there will be a Δ term.

And then we have talked about another one which is called VSB vestigial sideband may be with suppressed carrier again maybe with carrier, so it might be just SSB VSB with carrier okay, and then finally we have talked about quadrature amplitude modulation. So these three actually comes under so I should say comes under band width efficient modulation and the corresponding version where we add carrier seducer with carrier and wherever we are suppressing carrier that we write with this term SC okay.

So let us try to see the means just a comprehensive summary of all this the relative advantage disadvantage what can be done what cannot be done let us just try to summarize all these things because we have already covered all of them. So for DSB-SC in time domain.

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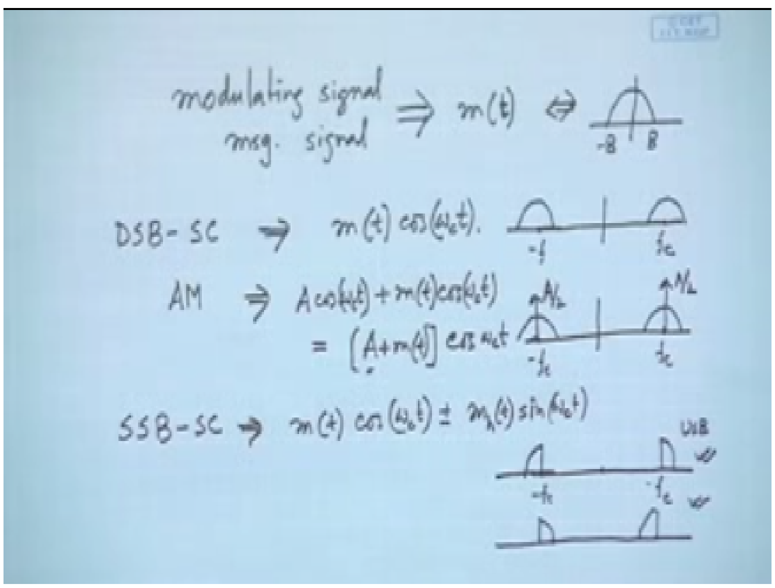

Suppose I have a modulating signal or you can call that as a message signal which is m(t) always remember that whenever we are trying to modulate it, it has a corresponding Fourier transform in frequency domain and that must be band limited, so frequency components are defined up to it is mostly base band signal whenever we are talking about that is baseband limited up to B bandwidth the significant frequency components are there beyond that those are all insignificant or nothing is present okay.

So that is our assumption so modulating signal m(t) and if I wish to represent DSB-SC so we have already seen that in time domain the representation should be m(t) $\cos(\omega_c t)$ right, it is just a multiplication with respect to a cosinusoidal term correspondingly the modulated frequency domain response will go around $+f_c$ and $-f_c$ and the shape will remain the same if I just talk about another version AM then I add a carrier to it so it is A $\cos(\omega_c t)$+m(t) $\cos(\omega_c t)$.

So we just try to now summarize everything and I will show what we have achieved of us so it is nothing but A+m(t) $\cos(\omega_c t)$ so therefore it is just like a DSB modulated signal but the modulating signal you add with a DC level A or actually in circuitry you add a carrier to it with strength A okay, for power $A^2/2$ so what will happen the corresponding spectra will just look like DSD-SC at f_c at $-f_c$ but there will be a carrier added to it that is the Δ function which is being added.

So this is something we have seen probably in that course of our discussion we have not talked about something which will try to reveal but before that let me just characterize the other things also and then will reveal that okay, so for SSB-SC what we do is of course the m(t) will be there and that needs to be multiplied by $\cos(\omega_c t)$ but then we actually that same message signal should be passed through a Hilbert transform and or go through Hilbert transform.

And correspondingly we get $m_h(t)$ after getting a Hilbert transform the message signal where Hilbert transform we have already characterized it is nothing but introducing or adding a phase π/2 or each frequency component irrespective of the frequency component it is always adding a constant phase, okay.

So this will be + or - depending on whether we are targeting USB or LSB means upper sideband or lows lower sideband and this should be multiplied by $\sin(\omega_c t)$ so the corresponding frequency domain response should be either this that means only one side band at area f_c or $-f_c$ will be there or the other side bands so this is the USD upper sideband and this is the LSB okay, so either this one or this one okay.

So whatever I was mentioning just a few minutes back that there is something we have not talked about so the thing is that here whenever we represent this you can see that it has a predominant representation that a particular signal multiplied by a cosinusodial term of the carrier and some modified version of that signal multiplied by a sinusoidal term right, so this is what is happening so this whenever we multiply with the cosinusoidal of the carrier whatever we put over here that we call it as in phase term.

And whenever we multiply with sinusoidal we call that a quadrature term or Q term okay, so this is in phase and this is quadrature or we simply call that I or Q okay, so for SSB-SC you can see the in phase term is m(t) and the quadrature term is the Hilbert transform of m(t) whereas for DSB-SC the in phase term is m(t) quadrature term is 0 nothing is there okay, for amplitude modulation the in phase term is A+m(t) so a DC added to the method signal and there is no quadrature term but all is happening so this is just characterizing the signal.

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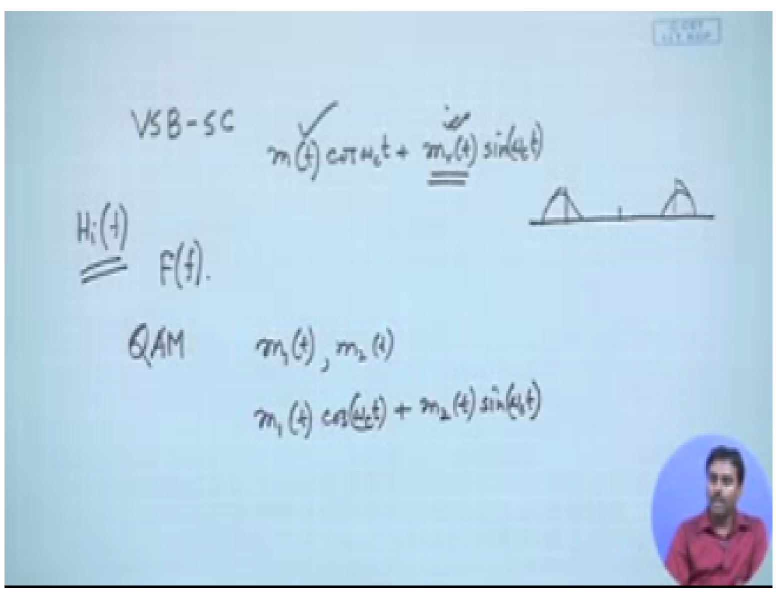

For VSB-SC again we have seen so we just try to summarize again so it cshould be m(t) cos(ω_ct) okay, + mv(t) this is actually that filter we were talking about right, so for VSB-SC if you remember what we have said that we will be generating a DSB signal then pass it through a filter band pass filter which is characterized as or the transfer function is $H_i(f)$ okay, so we are talking about this filter if we just pass it through that particular correspondence and corresponding to that there is a filter and we can get a representation of $m_v(t)$ which was we have represented that filter as F(f) right.

And if I pass my message signal through that filter whatever I will be getting that we term as $m_v(t)$ okay, so we have already done this thing so this can be read next represented the modulated signal can be represented as so again we can see there is a in face term and there is a quadrature term for this for both SSB and VSB-SC we can add carrier signal at any time if we wish so the corresponding signal should look like so if this was SSB it should be something like this okay, so that should be VSB-SC and then we have talked about QAM which actually takes the entire band but it represents two signals.

So basically what we have said if we have a message signal $m_1(t)$ and $m_2(t)$ and we can represent this at $m_1(t)$ we can put in in phase sum and $m_2(t)$ in quadrature term, so I can just write $m^1(t)$ $\cos(\omega_c t)$+ m2(t) $\sin(\omega_c t)$ so that in a nutshell of course the bandwidth will look like same but it will be just added part the frequency response will be added with respect to m_1 frequency response and m2 is frequency response right.

So that should be the case but we have seen already we have demonstrated that this can be very clearly separated out okay, so that can be done. So there is something we have already seen so far and we have means these are the versions or variation of amplitude modulation schemes that we have, now if you just compare them let us try to compare these things.

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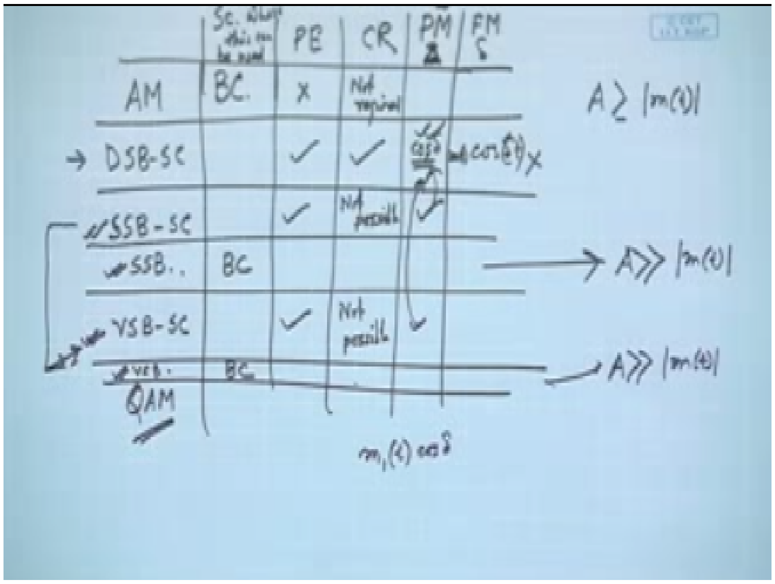

So if you just write a m VSB-SC, SSB-SC we can write SC general SSB also we can write VSB-SC and let us say I am right, now let us try to see where this things can be used of course we can also have a just VSB okay, so AM generally used for broadcasting okay, because we have seen that whenever we use em and if we have this condition that my A is just greater than equal to for all values of t as long as this is happening I know that I will not have any phase reversal so just by envelope detection with a diode followed by a charging and discharging circuit.

I can actually demodulate it so the detector circuit becomes very simple and that is why probably I will be targeting this for a broadcasting system because everybody will have the receiver they are not transmitting anything it is just receiving things like television broadcasting or radio broadcasting that used to happen earlier so it is in that case I will probably employ this because a receiver which is at the user premises will be more cost effective so that is something we have already seen.

But of course because we have to add that carrier so this will not be that power efficient, so we have also seen that if we talk about so this is scenario where this can be used right, so next if I talk about power efficiency this is probably not that power efficient of course the corresponding DSB-SC will be much power efficient because I have to add that carrier and unnecessarily means we have already demonstrated that right, with the modulation index and then we have also talked about the power efficiency.

So this will be power efficient SSB-SC definitely will be power efficient because they are also are not adding care yet but here we have already shown that if we wish to add carrier and then we want to demodulate probably a huge amount of carrier has to be added. So here if I wish to add carrier and we want to demodulate through that envelope detection A must be much, much greater than this m(t) so the amount of power that will be wasted for transmitting carrier which is not useful means signal so there will be wasting huge amount of energy right.

Again DSB original VBS-SC will be power efficient or energy efficient I should say this will not be okay, so here also that same condition as we have stated probably not proven for SSB you have proven similar argument will come for the VSP also there also a must be much, much bigger than this m(t) will be able to show that because it is almost similar structure, so this can be again proven so of course this will not be energy efficient and even what will happen this SSB and VSB if we wish to do for means use them for broadcasting then definitely we will have to means operate at very low our efficient scheme, okay so that would be always happening so if we wish to do that.

We have also proven another thing which is called the carrier recovery can we do carrier recovery or we cannot this one actually does not require carrier recovery it does not require because I can whatever happens because I am doing amplitude modulation so carrier recovery is not required carrier is already inbuilt I can just put a diode and we have demonstrated that acts as if the carrier is already there and we are de-motivating.

So this does not require so I can say not required whereas for DSB-SC yes, carrier recovery is required that is a bit circuitry we have already started talking about the carrier recovery we have promised that next we will be discussing phase lock loop which is integral part of carrier recovery. So the DSB-SC definitely require carrier recovery SSB-SC this is where there is something that we have proven in the last class that this for SSB-SC the carrier recovery is very difficult.

But the SSB-SC we have seen that we square it we always get back the carrier but for but for SSB-SC + VSB-SC even if we square you get the carrier camp your carrier term it will not be at $2\omega_c t$ so there will be a phase variation with respect to time so you would not be getting the pure carrier, so carrier recovery is not possible here also it is not possible that is a big blow in modulation technique.

Because these two are really efficient in terms of bandwidth SSB particularly it gives us twice the benefit right, so two signals I can put in place of one signal compared to a.m. and DSB-SC whereas DSB-SC not that much efficient as SSB but okay it gives some benefit but the problem is I cannot really and they are also energy efficient because I am not putting carrier to it but I cannot really do carrier recovery from them the original signal that has been transmitted from there I cannot extract the carrier so all I will have to do probably I will have to separately transmit pilot carrier along with them if I wish to do demodulation properly.

So that is the additional headache that will have to take if we wish to do that these two okay, carrier recovery means I am putting carrier so it is possible that I have to do carrier recovery I can just do same envelope detection over here but energy efficiency is very low that is what happens okay. So these are the few things that I wanted to discuss means this is something we have already covered we have proven all of them but I wanted to summarize them.

Next another one thing probably we have discussed that is actually related to the carrier mismatch okay, so there are two mismatch we have seen these are the things also we have demonstrated that there might be a phase mismatch between the incoming carrier and the local carrier that has been generated once will be discussing this PLL you see that that that is possible that might be happening.

So if there is a constant phase mismatch between the incoming carrier and my locally generated carrier whichever way I can I can square that pass it through a PLL whatever carrier I get if that has a constant phase mismatch then what will happen, so if I have phase mismatch of Δ and then we have also discussed a frequency mismatch of some Δ so this probably we have given as some Δ and something like this right.

So if I have a phase mismatch what we have seen for this one DSB-SC we have demonstrated already what we have seen that probably will get the signal intact but all it is that there will be a attenuation of this term $\cos\Delta$ so modulated signal after we demodulate I will get back my m(t) but m(t) will be multiplied by this $\cos\Delta$. Now the problem is if the phase mismatch goes around $\pi/2$ then this $\cos\Delta$ will be 0 so attenuation will be very high I would not get my signal back so that is the detrimental effect that we will have.

But if there is a frequency mismatch what we have seen that this will be multiplied my m(t) will be multiplied by cosΔ(t) so there will be a modulation term which will be and which will vary the essential nature of the message signal itself so that little more detriment also if there is a frequency mismatch I have to be very careful about that so I cannot really allow frequency mismatch in the incoming carrier and the local carrier I am generating.

All these things will be very clear in PLL we will see the strategy that we have to take to ensure these things knowing that this will be happening then for QAM we have discussed some more things that if there is a phase mismatch so we have already seen that okay, probably it will not means the message signal will have something like that $m_1(t)$ suppose I want to be modulate $m_1(t)$ so it will have this cosΔ term but there will be also additional term with respect to m2(t) so that will actually give me interference to my signal, so that is even more detrimental for QAM.

So QAM in terms of phase mismatch and frequency mismatch it is more vulnerable because I am actually modulating two signals and putting in the same band so I will always expect if there is a phase mismatch immediately there will be our interference coming from the other signals which will power up my signals so that will happen whereas for phase mismatch in DSB nothing will happen it will just have attenuation top same thing will happen if just you carry on the same technique you will see that it will be just repeated over here also it will have similar effect as DSP-SC okay.

So VSB or SSB if you carry out the same thing you will see that similar effect will be happening for them but clamp that is more detrimental so if you just modulate with respect to QAM or if you are transmitting with by employing QAM you have to be very careful about the frequency and phase mismatch in your local carrier okay, frequency mismatch of course there will be modulation sorry, interference term plus there will be additional modulation term which will be coming out similar to this okay.

So these are probably what we have discussed so far okay, so just if we should summarize that where, what can be used and what are the things that I need to take care of so whether its energy efficient where the carrier recovery is required not required accordingly the receiver circuit how it will be can we use it for broadcasting, can you use it for one-to-one communication or point-to-point communication and if there are in the carrier recovery if it is required at all that means I cannot employ a means envelope detection.

Then what kind of effect I will get if there is phase mismatch or frequency reason so this is something we have so far discussed. There are the word some more things which has to be means which we have also discussed in the process that was related to two of the in a sorry, bandwidth efficient schemes.

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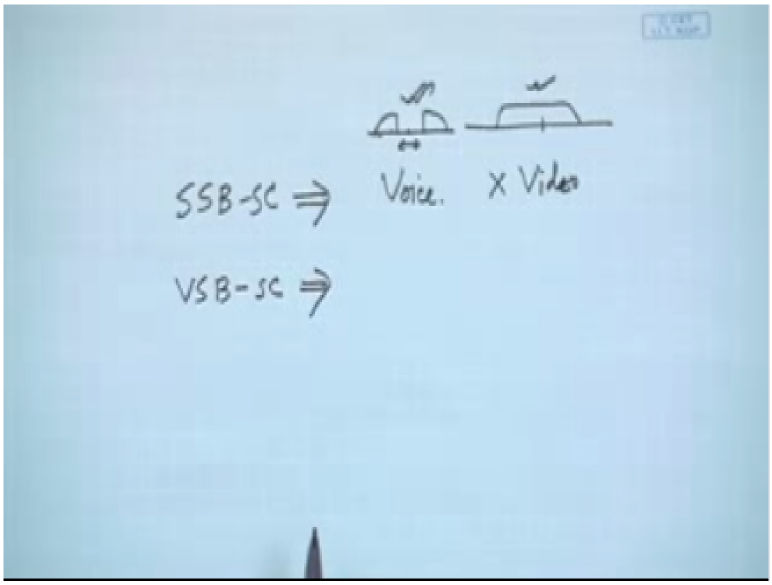

So one is SSB let us say sis DSC and the other one is VSB-SC so we have seen that this is good for if we employ a whether circuitry this is good if we have a signal which has nothing around 0 in the frequency band so that is voice signals so this is good for wise modulation but this is not good for video motivation because that has something so video spectrum looks like this whereas voice spectrum looks like this, so nothing around 0 okay.

So for this SSB-SC is good we know that s SBS-SC can be generated by filtering approach okay, so for that filtering approach only we are talking about this for the other approach where you have to take Hilbert transform that is very difficult because every frequency component has to be given π/2 phase shift which is very critical and that is very difficult to realistic circuit we have given alternate circuit which is called wave a circuit which is with respect to filtering so you do first filtering then you modulate then you do another filtering and you get your signals right, modulated signal.

So for that we need we can only modulate voice signal we cannot really employ this technique for video signal whereas VSB was actually designed keeping in mind that if a signal has something around 0 what should we do so the this particular thing can still be realized using a realistic filtering technique, because it allows the filters to have some role of some DSB roll on, so that is something which we have discussed so far okay.

So now we can see that the only part which is still not very clear probably is the carrier recovery so we have to now discuss in big details about the carrier recovery and what is the consequence when we get some phase delay when we get frequency delay sorry, when we get some phase delay among the carrier and the locally generated carriers or some frequency deviation among the locally generated carrier and incoming carrier.

So in the next class what we will try to do will try to means get into inside the PLL circuit and try to see what happens over there and do some analysis okay, thank you.