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NPTEL ONLINE CERTIFICATION COURSE

Course
on
Analog Communication

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Lecture 17: Amplitude Modulation (Contd.)

Okay, so we have seen few types of modulator to generate just multiplication of two signals, now what we have promised that we will try to see the relative advantage and disadvantage of these things. Now we are actually coming into the engineering part of it, so let us say the previous one that we have done there.

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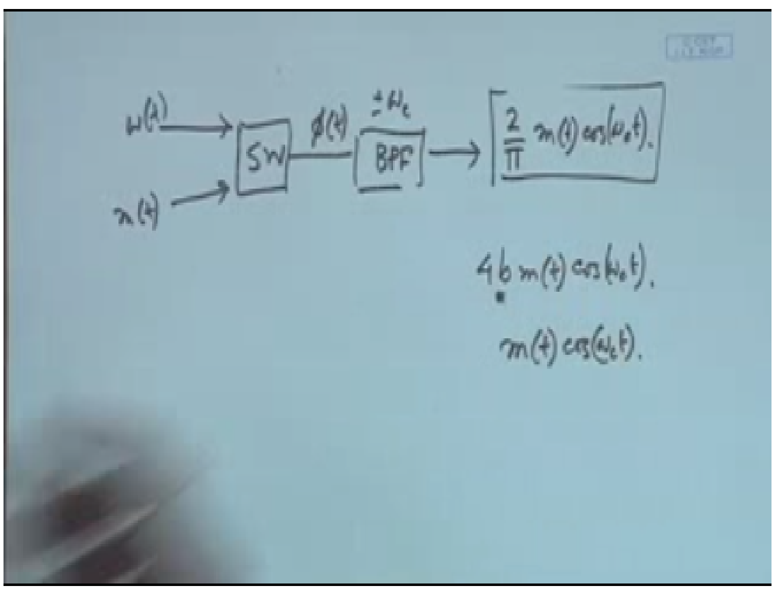

We have got the output as 4bm(t) cos(ω_ct) if we just multiply we get m(t) cos(ω_ct) right, so these are the three things we are getting, so what is happening if you just carefully see especially this one when I am doing multiplication think about my power most of the power because it was having the infinite Fourier series representation many part of power has gone to 3FC, 5FC, 7FC and all those things so those power because I just employ up and pass filtering those things are all wasted right, so that is why I am getting a pretty low power 2/π which is getting linked over here right.

So that is one disadvantage of doing this, so if I do with the switching circuit I will be actually leaking power into higher harmonics. So effectively has we losing power and that is very important because whatever or I put I want to actually employ that for my modulation purpose on t so they are all getting wasted so it is very important that I carefully design my system and that is why probably people have tried to employ direct multiplication instead of doing this circuit okay.

So that is one aspect of it that we should think of directly multiplying it if we can okay, and that is why there are devised multiplier chips which will be generally using for multiplying the signals okay. Now linear one also is quite alright as long as my B is not very small if the nonlinear device I means where the biasing is very sensitive if the coefficient becomes too small especially that quadratic related to that coefficient becomes too small then probably again this will be very low and I will be most of my power will go into the linear part which is anyway getting canceled out, okay so that is also very important okay.

So after this let us try to see another form of modulation okay, so the other form of modulation is called that is actually termed as AM.

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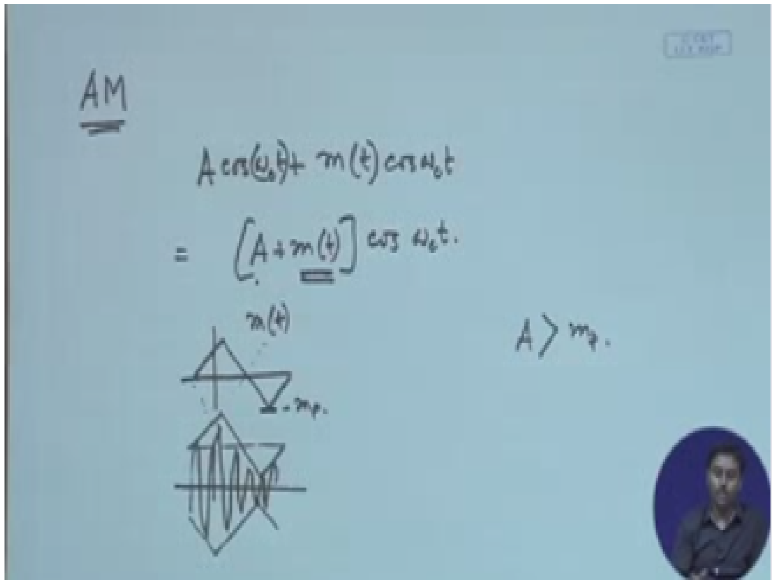

Because historically that came before amplitude modulation so you can call that as DSB with carrier okay, so that will also have double sideband but the carrier will be present what does that means so that means you are at earlier generating m(t) cos(ω_ct) I will add a carrier to it which is pure carrier Acos(ω_ct) where A is amplitude of the carrier, so this is what is amplitude modulation so it is a very simple one but you will see that lot of advantage will get out of this and this is being employed for broadcasting generally.

Because the ct corresponding we see what becomes very simple, so we just add a carrier to it and you will see that the entire complicacy of recovering carrier and then multiplying with the carrier just vanishes. How we will see now, so if I just do this I can write it as Am(t) cos(ω_ct) right, so what is happening it is almost like a DSBSC it is just my m(t) is DC shifted so whatever message signal I have suppose I have a message signal something like this okay, so this is my m(t)corresponding sum m(f) I have.

Now if I directly do modulation the way I was doing DSBSC what will happen this will create envelope and then there will be a carrier okay, and fd 0 crossing there will be 1080 phase shift this is something we have seen. Now what we are doing this m(t) we are adding a DC to it so basically this will be that is let us say that is A so m(t) will be over this and suppose this is the minimum which is called my -m_p okay, the minimum voltage of my m(t) message signal and somehow my A is greater than this m_p then the entire signal will be above 0 level.

So basically what I am trying to do is I am trying to avoid any 0 crossing that is all I am trying to employ over here, so by doing this that means adding carrier actually means that in the message signal I am adding a DC term and why I am doing that because I knew that whenever I will be multiplying by cause if there is a 0 crossing there will be a phase reversal I want to avoid that phase reversal.

For good reason we will come to that, but once we avoid that phase reversal what will happen now if I multiply this with $\cos(\omega_c t)$ my envelope will look like this and inside the carrier will be flowing and we know that we have avoided 0 crossing so there will be no 0 crossing inside okay, and there will be no phase reversal inside fine, why this is so much advantageous or what is the advantage of this and what is the disadvantage of this let us try to discuss that.

First the advantage part, the corresponding demodulator will be much more simplified, so let us try to see what kind of demodulator I can put for this.

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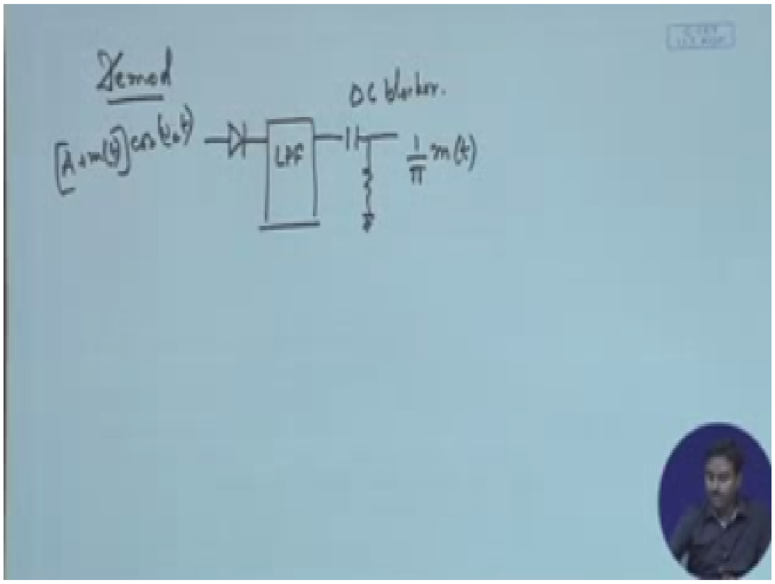

So what I will do, I will actually for the demodulators I will pass it first through a diode I completely changing the demodulator now I am no longer multiplying it with $\cos(\omega_c t)$ I know that multiplying with $\cos(\omega_c t)$ will still give me result but I do not want to do that I am just simplifying it, so I will pass it through a diode, what diode will do this it will act as a half wave rectifier right, so only in the positive half it will pass the signal negative half it will make it a 0 okay.

So it will just almost take out this half where it is less than 0 so that part it will take out after passing it through a diode what I will do is I will pass it through a low pass filter and then I will pass it through a capacitor followed by a resistor which is just nothing but a DC blocker we will see why that is required and that will make give me my m(t) or very precisely I will get half sorry $1/\pi$ m(t) as long as I am putting this $A+m(t)\cos(\omega_c t)$ over here that means amplitude modulated signal if I put it over here if I just do this circuitry I will get this so let us try to prove that, okay. So let us see whenever I pass it through a diode what is exactly happening.

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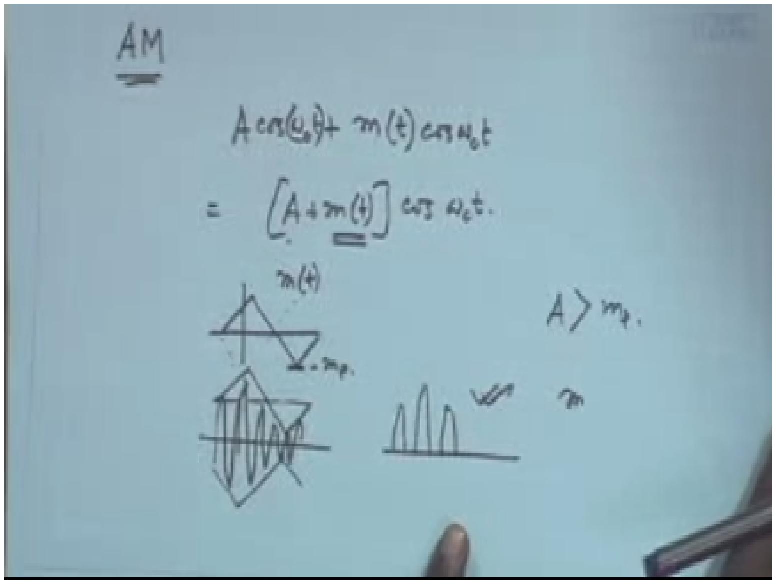

So I have this signal once I pass it through a diode it is just taking the positive half and the negative half it is taking out it is again taking the positive half negative how it is taking out again taking the positive half what does this means this almost means this signal multiplied by a pulse strength which is exactly synchronized with this co sinusoidal is not it, it can be represented as this because I am sending this signal only the negative of is going off that means in the negative half if I have 0 and multiply this it will become 0 and in the positive half if I keep 1 it will just represent that signal.

So basically this after diode or the diode can be represented as a multiplier which will just multiply the signal whatever is coming A+m(t) cos(ω_ct) multiplied by a w(t), where w(t) is represented by.

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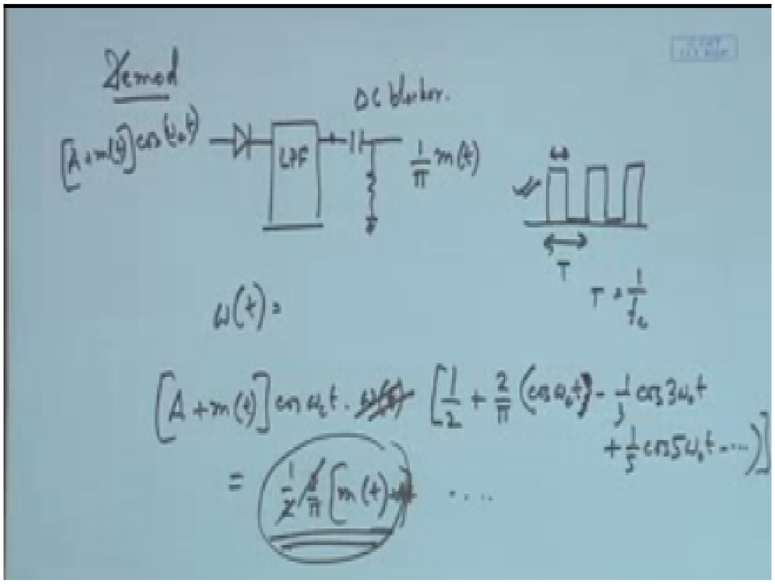

That all strength which looks like this, remember for the pulse strength it should be having 50% duty cycle because for a cosinusoidal I have to take the full positive half and I have to negate the full negative house so it must be 50% duty cycle pulse that is the first thing. Second thing is this time period must coincide with the cosinusoidal time period, so I had this $1/f_c$ time period that must be this T so that should be exactly equivalent and that is automatically happening because I was is doing that I do not have to really bring a signal which is of this nature it is actually the diet characteristics is almost like this ωt as if completely synchronized with the signal getting multiplied, right.

So I can write my output as A+m(t) cos(ω_ct) which is my original signal multiplied by w(t) that is output of the diode I can write this now this w(t) I can again expand in Fourier series this signal I can expand in Fourier series so I can write that w(t) in instead of w(t) I can write again that expansion Fourier series expansion which we have seen just assume means in the previous class probably so 1/2 2/π cos(ω_ct)-or I can keep 2/π out so 1/3cos3(ω_ct)+1/5cos5(ω_ct) and so on.

Now just to the multiplication what I will get this A+m(t)cos(ω_ct) into this one that is the first term, second term will have A+m(t)cos(ω_ct)2π into this cos(ω_ct) that will give me actually one base band part and the other higher frequency part and all other multiplication if I see that will be all either at ω_ct or some high harmonics of ω_ct, so if I just pass it through a low pass filter only that part will come out which is nothing but it is 2/π into half will be there.

So 1/2[2/π m(t)] will be there plus there will be all other harmonics if you just multiply all these things we will just see there will be all other harmonics some terms into m(t) $\cos(\omega_c t)$ and $\cos(2\omega_c t)$ $3\omega_c t$ and all those things okay, so I will only have this part now if I put the pass filter which will take out all these harmonics which will give me just this which is 1/π m(t) right sorry, m(t)+A there should be this term remains the same.

So m(t)+A1/π so at this point after low pass filter I will be getting 1/π m(t)+ a DC term, now this capacitor resistor that will just act as a DC blocker so it will just block the DC that A part I will get 1/πm(t) so what has happened the one that has happened over here my receiver circuit has become very simple I just have to put a diode no complicated carrier tracking I do not have to do that carrier track because automatically the diode is doing the carrier tracking for me.

You see where that $\cos(\omega_c t)$ multiplication is happening over here I had this term earlier I was deliberately multiplying it with $\cos(\omega_c t)$ now diode is actually helping me to multiply it with w(t) which has a $\cos(\omega_c t)$ okay, so basically my signal itself is carrying the carrier which I have told earlier also so it has the carrier information but in such a way it is now carrying that with a diode I can actually do the multiplication and I get everything out I do not have to do any synchronization.

You know why this is happening because this is a periodic signal w(t) I can write as a periodic signal. If there was a random phase reversal which was happening in DSPSC then what will happen let us see I have a random phase reversal.

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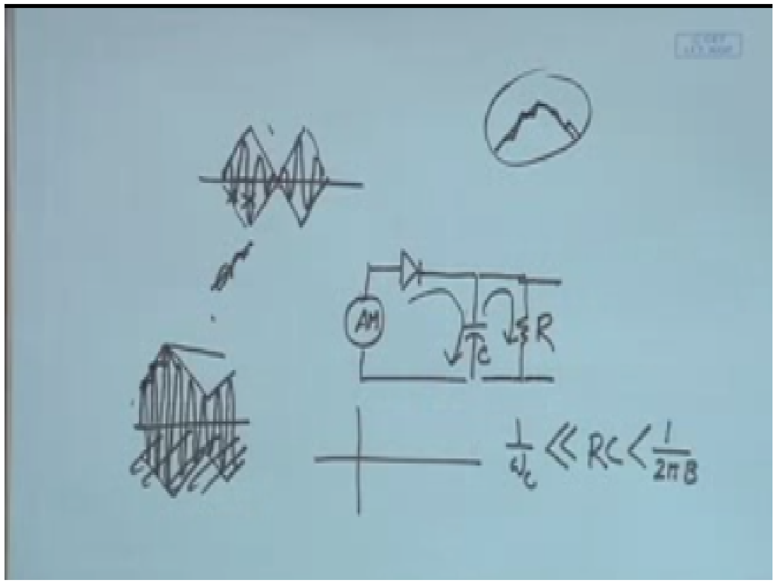

So my signal was like this I do not add any DC so what will happen within this, this will sorry this will become my envelope and within this there will be a cosinusoidal which will be just having a carrier flip over here. Now I pass it through a diode what will happen, diode will be that w(t) corresponding to that diode it will be positive here negative here positive here or I should say positive here 0 here okay, because it is taking out all these negative cycles but here there is 180 phase reversal so there will be positive followed by positive that is breaking my periodic nature, right.

So the w(t) I will be multiplying that is no longer periodic that is a random signal, now because where that crossover will be happening I do not know that depends on the signal, so anywhere it can happen so that completely breaks out my periodic nature of w(t) so at that point I cannot write my w(t) as this one very nicely.

So therefore that multiplication I was getting I am not sure now and that is the reason why I will not be getting my signal back if I just put a diode so that diode detection that followed by low pass filtering detection can only be possible if I put a DC term so that my entire message signal goes into the positive half.

And whenever I do modulation no 0 crossing is there in the envelope and correspondingly no phase reversal is happening as long as that is happening I know my diode detector will be all good multiplier. You can also think about this see it this thing is carrying the carrier information but let us try to see how I can extract the carrier, so basically whatever is coming over here I can excite up model means this things a sinusoidal generated by this but what will happen after some time the excitement will be given by this which is a phase reversal.

So that will just counteract on the exciter whatever excitation it was creating it was creating a sinusoidal now it will just be a phase reversal version of that so it will just counteract and it will actually negate that thing. So basically if I on a long term basis I wish to track the carrier I will not get anything because it will keep on reversing and I will keep on means denying my carrier generation process so that is what happens whenever we do DSPSC.

So DSPSC carrier recovery has to be done completely separately we cannot really employ these things, whereas if we just add that A term into it wonderful thing happens and my receiver becomes very simplified because in the receiver I just get a diode followed by low pass filtering that is it nothing else is required. The same receiver we can also employ or we can also think that receiver in a different manner.

Suppose I have my AM signal which is mostly this is called the envelope detector but which is mostly employed so I will be putting a diode on this okay, and then followed by a kind of charging and discharging path and here I will be taking the signal out that is my receiver, so what is happening over here let us say I have this signal of course it has to be AM so let us say I have this signal and inside I have this carrier.

Okay, now whenever it passes through diode I will be just getting rid of this so I will be getting this positive half and then see whenever the diode is on this thing will pass it through it and probably what will happen this capacitor will get charged through this okay, so if diode internal resistance I assume to be very small so this RC value will be sufficiently small to make the charging time constant very quick it will be charged very quickly okay, so this is the charging path.

Whenever diode is in reverse bias condition then this capacitor is not getting any supply so it must be discharged but it does not get any passed through this diode because now it is in reverse bias condition so it should be discharged through this path now if I put design by R and corresponding C in such a way that while discharging it just tracks the envelope okay, so basically what is happening.

I have this so while charging it quickly charges whenever diode is on it follows the carrier very quickly gets charged but while discharging if the discharging time constant also is fast that means this RC value is in such a way design that it is also faster then it will discharge full wave. But basically to receive my message signal I want to detect this envelope because that envelope only carries my message signal, so what I wish to do is while discharging it does not get discharged very quickly.

Again next cycle comes back then the diode gets charged so it again gets charged quickly, but while discharging again it follows a slower path it is not discharging very quickly then what will happen it will just keep tracking the envelope okay, if the discharging time constant is too slow then what will happen if you see this negative slope then the discharging time constant will be too slow will be too slow that is also something which I have to take care of, the discharging time consent should be such that I will be always tracking the envelope to do that I have to design my RC.

So basically what should happen this RC must be greater than or much, much greater than $1/w_c$ okay, so that it does not follow the carrier but it must be less than my $1/2\pi B$, where B is the highest frequency that I can have in my message signal so this envelope, so this RC must be less than that so that whenever it is getting discharged it is not even slower than my slope of the message signal so as long as I am actually considering this particular condition because B and w_c are known whenever I am doing modulation I know with what frequency I am modulating and I also know what is the, if the signal is message signal is band limited what is the maximum frequency that it contains.

So if I know these two parameter and if I know this condition I will be accordingly designing by RC and immediately I know that it will be tracking my envelope, so finally my signal will look like some which is almost tracking the signal right, after that there will be there are some aberration just a low pass filtering will do this will make it smoother okay, so immediately I get this so this followed by another low pass filtering probably will smoothen the envelope and of course there should be a DC blocker that has to be there because this help this will whenever I track the envelope that will have a DC I should have a DC blocker so immediately I get that minus such.

So there are two circuit that we have discussed one was diode followed by a low-pass filter almost employing similar technology or I can think it from time domain so that is to representation one I was thinking in frequency domain that my diode generates a signal which has all components all harmonics as well as the baseband why I was employing the low-pass filtering so that all other harmonics are rejected.

And after that I knew that it is A+m(t) so as I was putting a DC blocker here I am actually seeing it from time domain so that is why both the representations are good so I am seeing it from time domain what I am trying to see is in the time domain whenever I pass it through a diode it is actually just giving me the positive half next it just has to track the envelope so for that I need a very faster charging and very slow discharging time constant that is what I have devised and immediately we could get the envelope tracker.

After that it is some low-pass filtering DC blocking to smoothen the signal according to my requirement okay, so this gives a very simplified way of the modulating and this particular modulation technique for that reason is as we have seen that it has a carrier. So just if we now try to see the frequency domain representation of the modulated signal.

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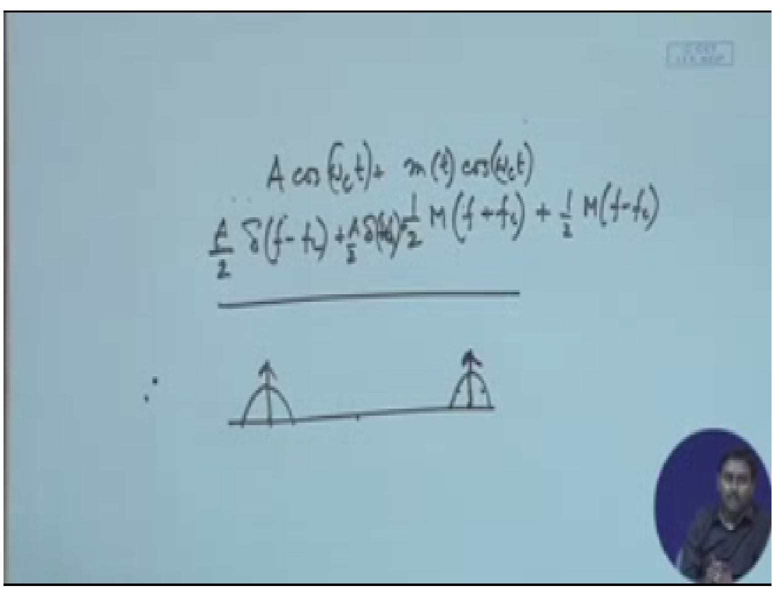

Which is a $\cos(\omega_c t)$+m(t) $\cos(\omega_c t)$ if I do a frequency domain representation this m(t) $\cos(\omega_c t)$ of course that will be $1/2m(f+f_c)$+ $1/2(f-f_c)$ this is all right but this $\cos(\omega_c t)$ that will be 2Δ function right, so this will be A/2 a Δ function at $+f_c$ Δ function at $-f_c$ right, so basically if I just try to draw the spectrum what will happen at f_c there will be these two term m(f) term and there will be a Δ function which is actually eventually representing the carrier, so that means it has two side band like earlier one but it also has this carrier term so that is why it is called just DSP or AM I am not suppressing carrier.

Whereas in the other one I was actually deliberately suppressing the carrier I was just sending the multiplication term I was not putting the carrier into it but I know now the difficulty for the receiver if I do not transmit the carrier, but is it all rosy in the next class will probably prove that is not the case whenever we put a carrier we are again sending unnecessary signals due to that there will be extra amount of power I will be sending so the overall power efficiency will be lesser in this system.

And that is why probably you will see the transmitter has to release more amount of power to get similar kind of effect at the receiver, so that means transmitter has to be has to employ some power amplifier and all those things okay, so because it has to transmit huge amount of power transmitter becomes more means engineering design wise more complex and more costlier. So we will try to in the next class we will try to see that how four AM the transmitter is costlier which was our design target that I want to for a broadcasting system I want to make the transmitter little costlier whereas the receivers will be much more cheaper.

And for point to point I want to make the transmitter little bit cost effective and receivers similarly costly okay, so we will see that part also that this has one advantage but there will be another disadvantage in to it. So once we have done that in the next class we will go towards more bandwidth efficient modulation amplitude modulation those are like single side band we are now transmitting double we have already discussed that both the side bands are carrying equal amount of information.

So we do not need both side band, so we will try to see some more bandwidth efficient modulation like single sideband which is called SSBSC single side band suppressed carrier again we would not be transmitting carrier or there is something called vestigial side band we will see the application of these two some cases like for voice you can employ single sideband whereas for video you cannot employ that you have to go for vestigial side band so we will see that and it is single side band probably will be the most bandwidth efficient whereas the serial side band will be less bandwidth efficient.

There is also another modulation scheme which is also bandwidth efficient which is called quadrature amplitude modulation that also will discuss and we will see that relative advantage and disadvantage of them.