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NPTEL ONLINE CERTIFICATION COURSE

Course
On
Analog Communication

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Lecture 16: Amplitude Modulation (Contd.)

Okay so in the last class whatever we were describing is we are trying to show that if we do a simplest form of modulation which we are calling as DSBSC that DSB part is clear probably SC is still not clear that will be clear after some discussion some amount of discussion but that particular modulation which is the simplest of amplitude modulation where just we multiply a signal m(t) with cos $\omega_c t$ so we have shown the frequency domain response of that.

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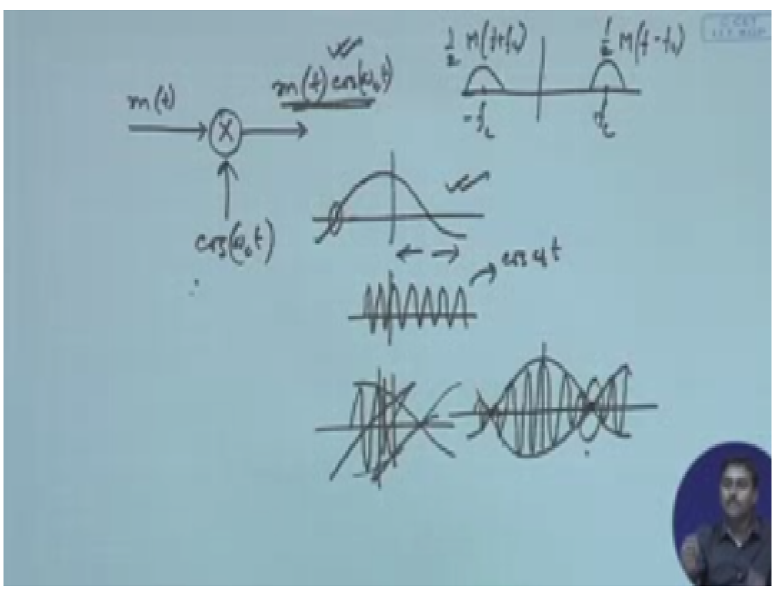

So basically it will be just centered around FC and that same criteria will be coming that this will be MF - FC this will be MF + FC and of course with half, so it will be centered around FC, so this is the frequency domain representation and the corresponding time domain representation we have understood from this particular thing that it is carriers whose amplitude is instantaneously varying with respect to the message signal which is a slow varying signal according to our assumption.

Here also that assumption comes into picture because FC has to be much bigger than B which is the highest frequency component that the message signal has, so therefore that will be much slower varying signal and amplitude of that carrier will be slowly varying accordingly, so that means that m(t) should be observable in the envelope of the signal that is being transmitted so it is a co sinusoidal signal only the envelope will be tracing that m(t) okay.

So what is happening there is a possibility that m(t) might be positive or m(t) might be negative like over here, so this is the crossover point right beyond this m(t) is positive just after this m(t) will be negative so what will happen in the carrier, so the carrier that cos is going up to this point it is positive immediately after this point will be negative so in the frequency means in the phase of the carrier what will happen from positive to negative immediately jumps.

So there should be a 180 phase shift immediately right because the amplitude is yet just getting means from positive to negative, so therefore in the carrier phase there should be 180 phase shift so wherever there will be 0 crossing in this DSBSC in time domain if you just observe the signal you will always see180 phase reversal whichever way whichever phase it cuts over there it will just be 180 phase reversal.

So every point you will be getting that that is a huge implication we will see that that makes the demodulation very costly will come across that and that is where the suppressed carrier and non suppressed carrier comes into picture we will come to those things but we have from the time domain we just try to analyze whatever is happening okay so there is we know as many times there will be this zero crossover that many180 phase the word cell will be happening if this was also having a pattern like this there also we would have observed similar things.

So it will be like this the envelop will be just like this and again if things are coming out like this there will be a 180 phase reversal immediately okay, so as many 0 crossover will be happening that many phase reversal will be happening, so we have understood what is the modulation right what will be corresponding demodulation that means I will be getting receiving this m(t) cos $\omega_c t$ signals from the air through my antenna. Now I have to get back my m(t) okay so how do I get that very simple operation another multiplication will give me that.

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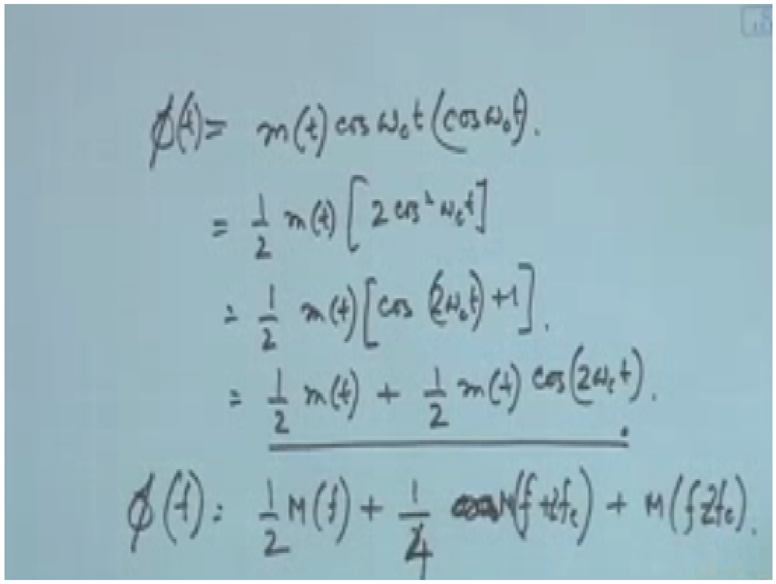

If you just see m(t)cos ω_ct I am getting if I just multiply it with another cos ω_ct locally generated what will happen, so this is if I just take ½ m(t) this is 2 $\cos^2$ ω_ct $\cos^2$ ω_ct can be written as cos 2ω_ct right we can just write this immediately what we get we separate this 2 out I get ½ m(t) + ½ m(t) cos2 ω_ct fine this is what I get now just see the signal now you will appreciate why this Fourier transform and all those things were so important why time domain and frequency domain we have to observe the signal.

Let us try to do a Fourier transform of the signal of this composite signal let us call this as ϕ (t) and then I wish to evaluate ϕ (f) what is ϕ (f) so I have ½ over here so that should be ½ m(t) the Fourier transform should be M(f) and this is multiplied by cos 2 ω_ct so therefore there should be a frequency shifting property so I can write ½ and then this particular part should take me to cos f + f_c sorry of course m f+ f_c + m f- f_c right this is fine okay.

So I will get that particular thing but there should be a ½ also coming out of this one because this whenever I multiply by cos there should be another ½. So this must become ¼ right sorry there is 2 ω_c so it should be 2f_c okay fine, so if I now just plot this frequency response.

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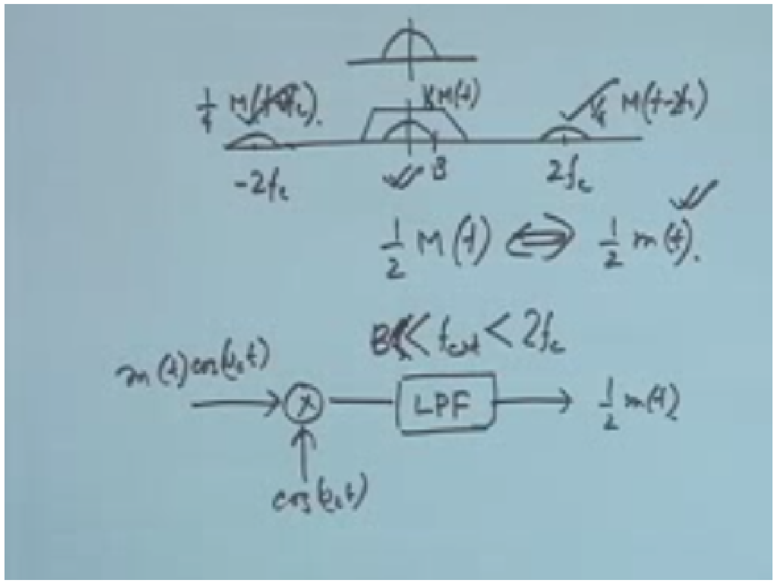

How it will look like so this is suppose my M(f) was something like this so this is M(f) ½ M(f) so this is that ½ M(f) and at $2f_c$ there will be ¼ M(f) – f_c and at – $2f_c$ there should be ¼ of M(f) + f_c fine to exit a fine. Now it is very simple you can see that just by putting a filter I can extract my signal back I will be putting a low-pass filter over here which has a cutoff frequency which is much lower than this 2 f_c but bigger than this B so I just employ a filter like that I will be getting my ½ M(f) back which has a Fourier inverse transform which is ½ m(t) so I will be getting this signal back so immediately you can see my demodulated circuit is almost ready what I need to do in demodulators.

Whatever modulated signal m(t) cos ω_ct I will be getting I will do another multiplication with cos ω_ct whatever I get I pass it through a low-pass filter even the filter design is also known the cutoff frequency must be suppose the cutoff frequency f_c cutoff okay so that must be bigger than B we should not say much bigger than because B but that must be lesser than this$2f_c$ at least as long as I am doing that I will be getting my signal ½ m(t) over here because this part will be rejected.

So very nice we could realize see this is the importance of signal and from signal to system that is why probably we have devoted so much time in doing frequency response Fourier transform how to see a signal infrequency domain so those are the things just giving us tools enough tools to actually manipulate the signal and then understand what kind of systems I should put so that whatever I wish I will be able to achieve that so basically your modulator and demodulator is now ready for this DSB- SC of course we still have not characterized what this multiplier circuit will be how do I achieve a multiplication.

Okay but we have now understood that if I know how multiplication has to be done I need a multiplier circuit followed by a low-pass filter that will make my demodulator I need in the modulator I need just a multiplier circuit nothing else okay, so now let us try to see what are the difficulties over here the first difficulty that comes out is generating this one that is a big challenge because if you see very carefully the frequency and of course the phase also we are not writing the phase these two has to completely match over here.

Then only that $\cos^2 \omega_c$ will be coming out and then only the Fourier transform will give me very nicely m(t) later on will prove that if there is a phase drift or frequency drift and if we multiply these two I have a chance of not getting anything over there okay so it is we have been very cautious about generating this local sinusoidal that has to be completely in sync with the carriers by which the signal has originally modulated the problem is that nobody will give me that signal right.

Because if the modulator and demodulator are sitting at the same place what is the point in doing communication because when we wish to do communication we wish to transmit it over a longer distance if I know that same carrier I can give in both places from the same circuit then probably my modulator and demodulator are already sitting in the same place or otherwise I have to separately again communicate the carrier as well right to a long distance so just to send my message over a carrier I have to again transmit my carrier along with it.

That is one difficulty okay the second difficulty is even if I try to send my carrier there is a possibility that this modulated signal and the carrier because they are going through the channel they might go through some frequency and phase drift it might happen due to Doppler effect due to other effects means that are there due to the channel effect mostly, so there will be a drift in phase as well as frequency of the carrier signal and that will be random as well as the modulating signal.

So if I wish to really means even if I have that carrier and I am transmitting along with that there is a possibility that these two are going through different phase and frequency drift and at the end they are not in sync in terms of frequency and phase again if I multiply I will not get the proper representation, so what I have to generally do that this particular signal that I am getting already I know that it already has of course are contaminated sinusoidal can I extract that carrier out of this.

If I can do that from there if I can generate this cos ω_c then I am fine so that is called a carrier recovery there is a means there will be in this course only there will be a few classes devoted towards that that how do we do that carrier recovery that is a big circuit again it must be locked with the incoming frequency and phase that is termed as phase lock loop will see those circuitry but that is the part which is required otherwise your demodulation will not be good.

So that is the difficulty we are having in this particular modulation scheme that we need to have another carrier which is completely in synchronism with the incoming carrier frequency and phase this is the one difficulty that we have that means the receiver design becomes little more complicated because we have to do this carrier recovery on top of this whole thing right so if I now ask when we are designing a system is this desirable for let us say a block broadcasting kind of system okay.

Broadcasting means like the radio transmission we had those big authority and all other things where we used to just transmit something from a big antenna okay and that was broadcasted to everybody was listening to same voice okay, so this was broadcasted and everybody must have their own receiver and they must detect it okay in that kind of thing I can actually make my transmit a little costly because that is common to everybody that cost will be shared among all the users whereas there are multiple users who are trying to willing to receive this signal their receiver must not be very costly.

Because if the receiver is costly that cost directly will come on the user so in a broadcasting system generally my target should be that the receiver is little bit simplified and the transmitter probably is little more complicated okay why I am saying all these things this will give me another design direction where I will probably take out this difficulty of getting this carrier recovery circuit into it and then multiplying it.

So this entire stuff I will take out and I will employ another modulation scheme which will be just a simplified modified version of this where the receiver will be will be becoming very simple but the transmitter will be little more complicated we will show you what kind of complication we will be having in the transmitter probably transmitter will be little less efficient okay but that is pretty obvious whenever we have one-to-one communication probably this is better.

Because then I cannot make the transmitter very costly is one-to-one communication again if I increase the transmitter cost that will come to the user so there I need to have a balance that transmitter receiver must be almost similarly equivalent complex, so there will probably we can employ this particular technique so that is why that short-range radio communication people have used SSB sorry DSB double sideband suppress carrier this particular modulation techniques that we are discussing about.

So whenever we have one-to-one that short-range radio communication which is not broadcasting in nature there we can employ this kind of technique okay now let us try to see that we have talked about this demodulation let us first for DSB - SC let us try to see what are the different kind of modulator that we can generate, so we have talked about that multiplier let us say there are if you go into market you will see that there are multiplier chips with differential amplifier and all those things it is little complicated okay.

So we can always employ a direct modulation by that technique but there are other techniques and which will be discussing other very simplified techniques to do modulation we will discuss those things.

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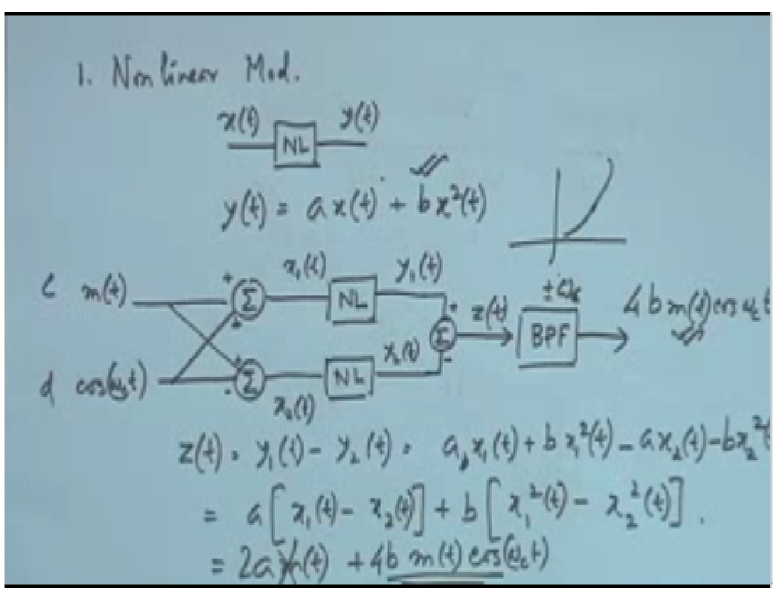

The first one is called the nonlinear modulator so in that case we will be using a nonlinear device okay what do we mean by nonlinear device that if I give our input x(t) the output will just not be a linear scale factor of this okay what will happen it will produce some square term as well it is just a nonlinear device, so output will be means showing non-linearity with respect to the input so suppose my x(t) is this and output is y(t) and if I have y(t) following this relationship a x(t) + bx ^{2} (t).

That is the simplest non-linearity we can get that is the quadratic one okay, so we can also have other non-linearity or other higher order like cubic so it will be having some another constant c x^3 or so on higher polynomial also but we can easily get this quadratic non-linearity and realize this by some devices which we all know like transistor or diode okay so they if you see their characteristic function that has a non-linearity because the characteristic function generally goes like this right.

And if you bias it in certain region you will see that it will follow quadratic nature okay, so this kind of nature so if you give input output will be just in a quadratic form with some A and B that will depend on the diode characteristics okay but if we have a nonlinear device which is let us say a diode properly biased so that we get a quadratic non-linearity into it and that is this device and now if we can connect this in this fashion so my two input if you know are m(t) and cos ω_ct I need to produce the multiplication term.

So what I do is something like this I have two adders so these are just you can put them as op amp adder okay to just add the signal so this goes over here this comes over here actually this is adder directed sorry and this is a subtract or so it is + 0r - I get x_1(t) over here x_2(t) over here and then I pass it through a nonlinear device of this nature again I pass it through a nonlinear device of this nature so I get y_1(t) and y_2(t) after passing it through this I pass it through another adder or I should call it subtract and then whatever I get I pass it through a band pass filter centered around +- ω_c or f_c okay and the output I will be getting will be proving that it is actually 4 bm(t) cos ω_c if I adjust my be to be ¼ then it is actually m(t) cos ω_c whichever is our target okay.

So how this works it is very simple you just refuse to those algebraic manipulations so if I have this x1 and x_2(t) after nonlinear device suppose this is z(t) what is z(t) is y_1(t) - y_2(t) whereas y_1 (t) is actually a x_1(t) + bx_1(t)^2 - y_2(t)is a x_2 (t) – bx2(t)^2 right or I can write as a x_1(t) – x_2(t) + bx_1^2 (t) – x_2^2 (t) right now what is x_1(t) x1(t) is m(t) + cos ω_t and what is x_2(t) that is m(t)- cos ω t ct okay so $x_1 - x_2(t)$ just m(t)will remain right so that should be 2m(t) and this is $(A + B)^2 - B^2$ because $x_1(t)$ is if this is or let us say a I should not say A let us say C and D.

So $(C + D)^2 - (C - D)^2$ that should be 4 right C x D so therefore it should be 4 x B C x D is m(t) into cos $\omega_c t$ so m(t) x cos $\omega_c t$ right now what we are doing now the frequency domain term will come into picture so this m(t) if I take it into frequency domain that should be m(f) and this if I take into frequency domain that should be m +m(f) sorry and m(f) + f_c if I put my band pass filter around f_c then this term should pass through and this will be not going through it so therefore at the end only this term will survive which is this right.

So you can see we can actually devise a multiplier circuit by two nonlinear device and three adder adders are very easy to device just take an op-amp and you can you can make a adder right so 3 f(m) op-amp and two nonlinear device properly biased let us say diode properly bias so that we get this quadratic relationship media tube and a band pass filter again band pass filter can be designed using op-amp and some active filtering okay.

So that is now you can see that the multiplication circuit so this is one way of doing multiplication there is another way that is called the switching modulation.

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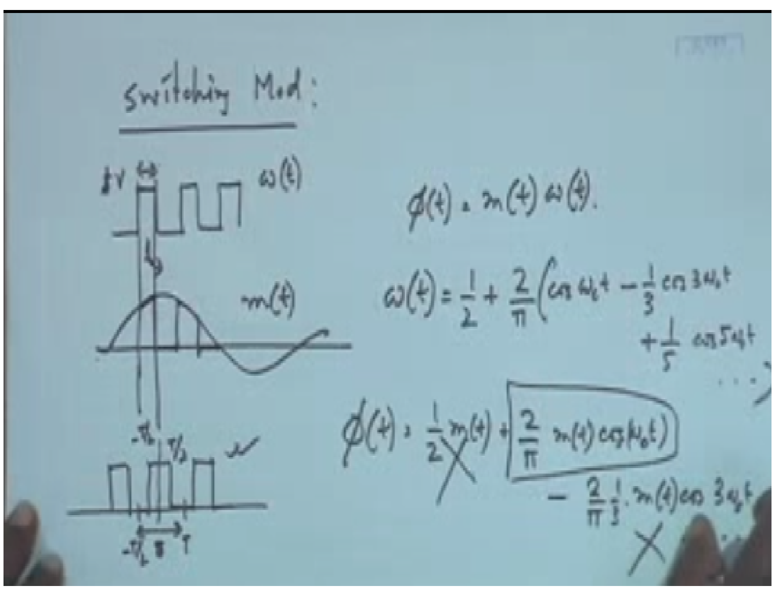

We are just trying to show you which other devices that can be employed to do this modulation right so for switching modulation what we will be doing we know that a particular transistor or

CMOS circuit can work as a switch so in the gate of a particular this switching transistor if we just put a signal like this which is having let us say +5volt for ½ the duration and it is being 0 for hospitalization.

So what will happen whenever this is being put in the gate it will be on so it will pass the signal so if I just put in the emitter to collector if I just put my message signal so whenever at the gate it is getting + 5 volt it will be on then that signal will be passing through it and whenever it is off that will not pass through it so if I just put a resistor across that if I take the voltage I will see that it is gets switched.

So basically if my signal is something like this and if I just switch it through this, so whenever this part is on the signals will follow rest of the part it will be 0 again the signal will follow rest of the part it will be 0 so basically what is happening my message signal is getting switched through this pulse okay so almost what we are doing message signal multiplied by this pulse okay so if I represent this as w(t) and this is m(t) I can actually connect this w(t) in the gate of that switch or transistor.

And in the emitter to collector I can put a resistor across which I will be taking the voltage and I across the bias this one an emitter I can put my m(t) signal okay so then the output of the resistor will be this modulated signal right or whether it is modulated or not I do not know it is a switched signal right now basically that output will be just multiplication of these two as I can see if this is I put this as one then immediately it will be just a multiplication okay.

So I get my output which we say ϕ (t) is just m(t) but the ω(t) if you carefully see that is a periodic signal so I can do a Fourier series analysis this is where you can see all those techniques that we have used will actually be used over here so ω(t) I can just expand it in Fourier series so you can just do it represent this one as this which we have already done probably something like this okay.

So it is this is overall T this is sorry this is this is T and this is- T / 2 this is T / 2 and this is- T / 2 and with this period it is period it gets repeated okay, so this one if you just do Fourier series analysis you can represent it as this ½ so that means the DC part will be ½ thatcoefficient next coefficient will be 2/ ϕ (cos ω_c(t) the next coefficient 2 ω_ct will not be there it is the 3 ω_ct part which will come 1/3 cos 3 ω_ct + so it gets alternative + and – so 1/5 cos 5 ω_ct and so on okay.

So basically it has all the odd frequency harmonics and the coefficients will be alternatively+- and the corresponding coefficient becomes 2 Π x 1 by whatever the frequency whatever the harmonics okay so this is what $\omega_c t$ is therefore my Π (t) will be immediately I can see I multiply this so ½ m(t) +2 / Π m(t) Π cos $\omega_c t$ - 2 / Π x 1 / 3 m(t) cos 3 $\omega_c t$ and so on okay again do a Fourier transform of this because Πf wish to see so if I do a Fourier transform I can see there will be some part at baseband next m(t)cos $\omega_c t$ so that should be around fc next will be around 3 fc.

Now if I just employ a band pass filter around fc properly design then I will be just getting this signal all other terms will be neglected so immediately I get my modulator because this is m(t) cos $\omega_c t$ okay so if I just.

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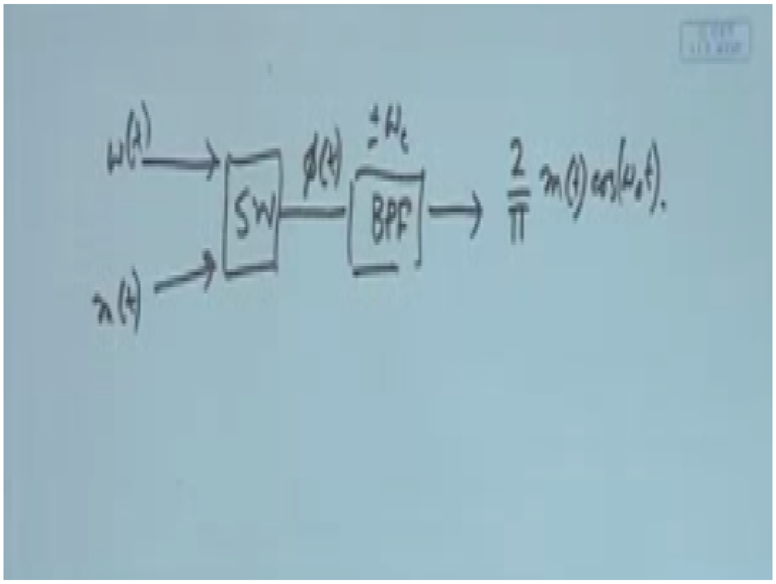

So basically what I have to do I have to put a switch which has two input one is that w(t) and the other one is that m(t)after that whatever I get that is this ϕ (t) must be passed through a band pass filter centered around +- ωc whatever I get that is actually 2 / Π m(t) cos ωc t right so that is another way of doing multiplication this is called the switching modulator so in the next class probably we will be discussing more about the relative advantage and disadvantage of all this circuitry.