**Principles of Communication- Part I**
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**Module No 4**
**Lecture 20**
**Generation of Single Sideband (SSB) Modulated Signals through Frequency Discrimination**

Hello welcome to another module in this massive open online course. So we are looking at single sideband modulation that is SSB and we have talked about SSB modulated signals and there comparison the DSB modulation we have seen that SSB uses half the bandwidth of DSB, alright. So today let us look at the generation of SSB modulated signals, alright.

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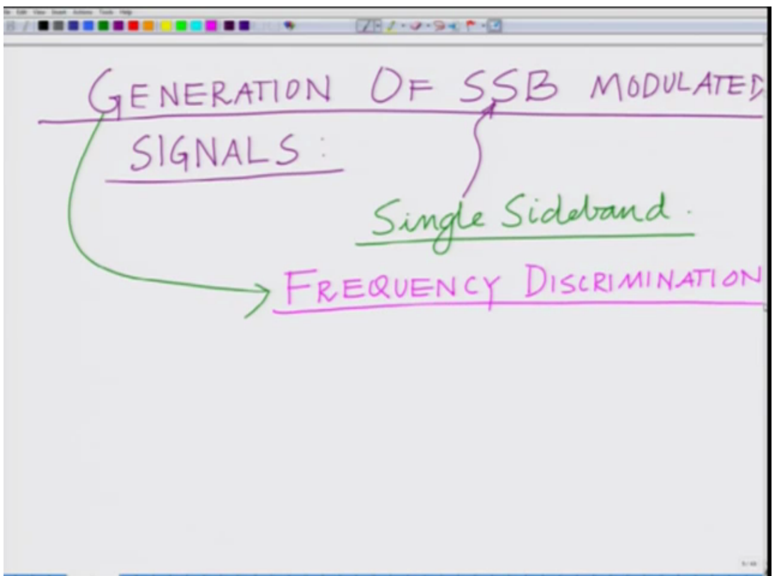

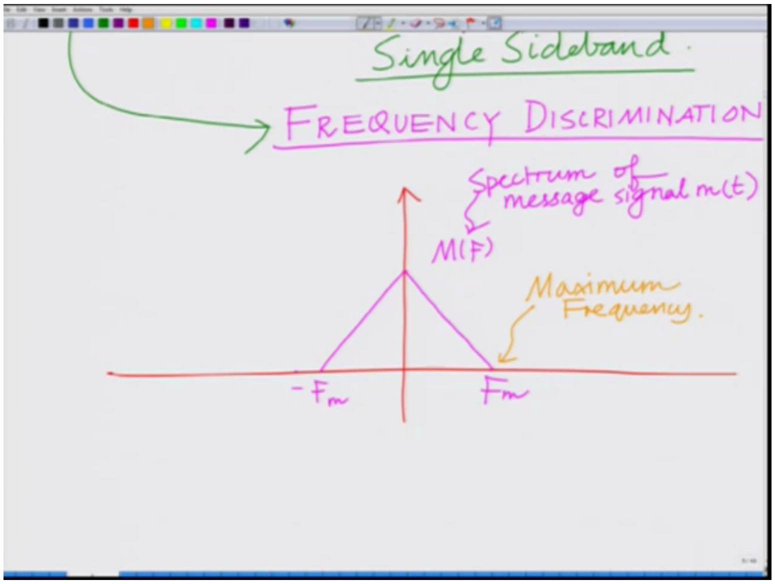


So in this module we want to look at the generation there are various techniques for the generation of SSB (modul) of SSB modulated. Generation of SSB modulated signals there are various techniques to generate SSB modulated signal, remember SSB stands for single sideband modulation, correct? Single sideband, there are various techniques and in particular the technique that we are going to look at is termed as frequency discrimination.

So the frequency discrimination technique for generation of FS F SSB modulated signals, alright. So the technique the specific technique that we are going to look at is termed as frequency discrimination. Look at frequency discrimination for the generation of SSB modulated signal and as we have seen yesterday if we start with a message signal m(t) let us say I have my message signal m(t) which is given by the spectrum between minus FF Fm and plus Fm, correct?

So this is your minus Fm this is your m Fm this is M(F) which is spectrum for basically the Fourier transform of message signal of the message signal m(t), correct? And Fm is the maximum frequency, alright. So the message spectrum M(F) is between minus Fm to Fm, now first we generate the frequency discrimination first we generate the DSBSC that is the double sideband suppressed carrier signal by modulating with the cosine carrier.

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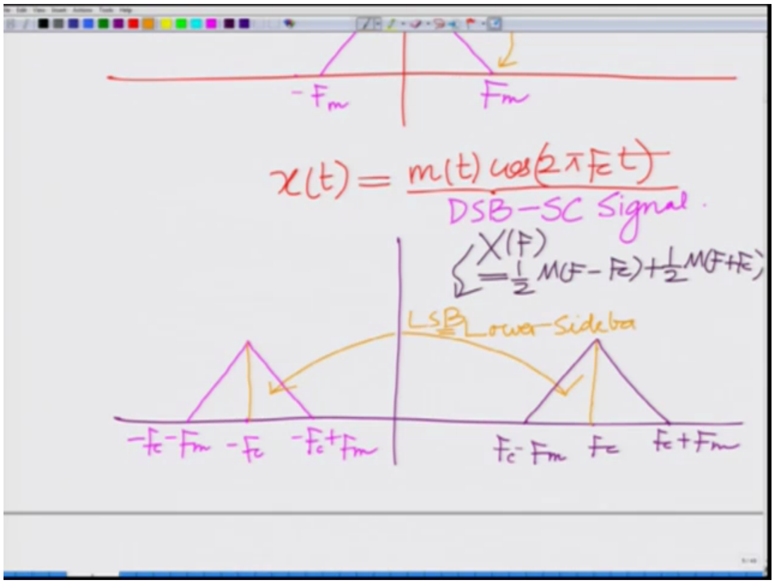


So the DSB SC signal which again we have seen is x(t) equals m(t) cosine 2pi Fct this is also your DSB SC this is your DSB SC signal. The double sideband suppressed carrier signal and this has the spectrum that comprises of 2 bands between centered at Fc so from Fc minus Fm to Fc plus Fm to Fc. So band shifted to Fc and another band shifted to minus Fc so we will have at this is the band shifted to minus Fc.

That is minus Fc plus Fm and minus Fc minus Fm what we have seen and of course, this is basically this spectrum is a spectrum of X(F) which is half M(F) minus Fc plus half M(F) plus Fc and what we have seen in this spectrum is that we have 2 side bands which are symmetric one is the lower sideband, correct? So this comprises your LSB equals lower sideband and we have the upper sideband, correct? We have the upper side band which is comprised of the, so you can also look at this the lower side band is basically the inner bands, alright. In this DSB SC spectrum the lower sideband is basically comprised of the inner bands the upper sideband is compressed of the outer bands.

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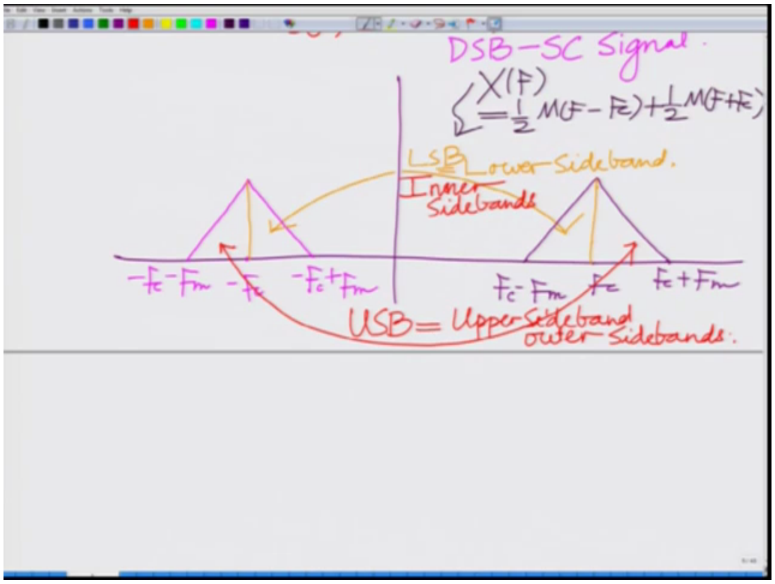


So the lower sideband is comprised of the inner side bands and this USB is the upper side this is comprised of the outer this stands for upper side band and this stands this is basically the outer side bands and now you can clearly see the inner side bands are separated from the outer side bands in the frequency domain. Hence we can use filtering to basically extract either the inner side bands or the outer side bands that is basically the lower side band of the spectrum or the upper side band.

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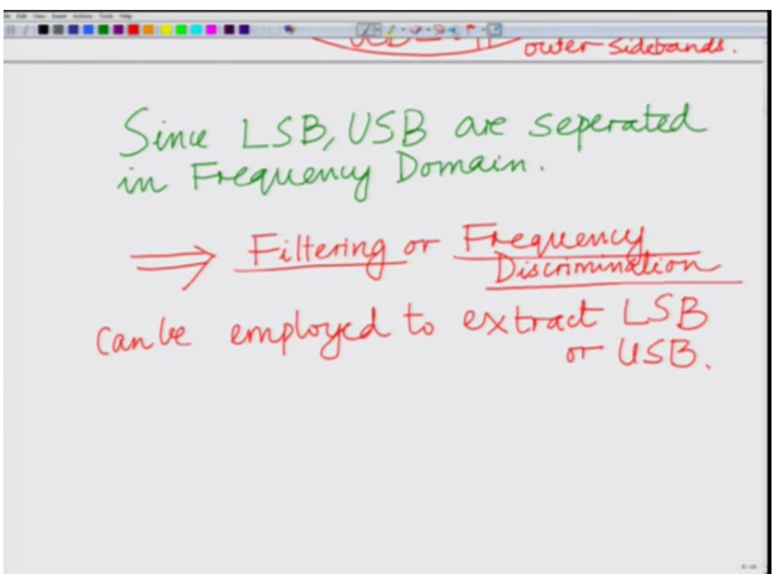

So the lower sideband, so since the LSB, USB are separated in the frequency domain, correct? This implies that filtering or basically frequency discrimination can be employed filtering or frequency discrimination can be employed to extract the LSB or the USB they extract either the lower side band or the upper sideband. So one can use filtering or basically frequency discrimination to extract the LSB or the USB and specifically how this frequency discrimination is done you can clearly see that if I want to extract the lower sideband then I employed a low pass filter if I want to extract the upper sideband I employed a high pass filter.

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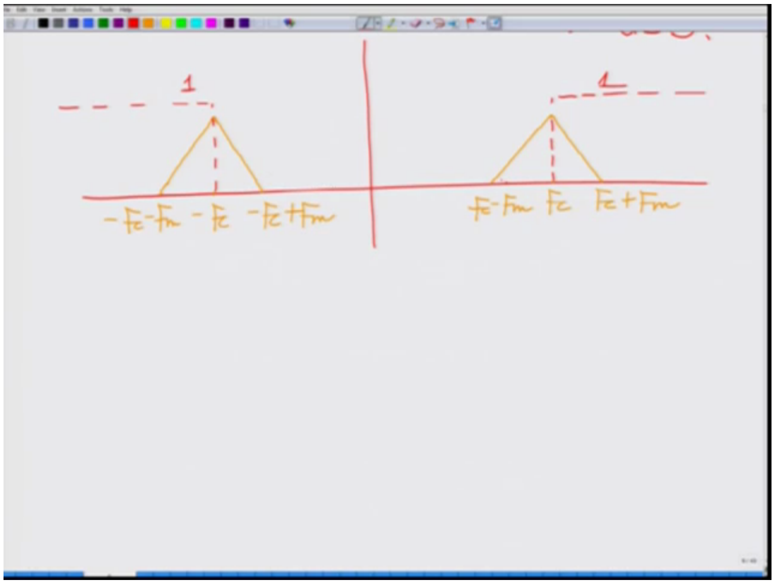


So let us first start with the upper sideband, now if you look specifically at double sideband let me redraw the spectrum again if you look specifically at double sideband, so I have this band which is centered at centered at Fc, correct? So I have Fc, Fc plus Fm Fc minus Fm and similarly I have another band which is centered at minus Fc so I have to bands and this is at minus Fc minus Fc plus Fm minus Fc minus Fm and therefore now if we want to extract the upper sideband I employ frequency discrimination I pass this through a high pass filter with cut-off frequency at with that of frequency at Fc that is a filter which is 0 from minus Fc to Fc and it is one, if so if I pass it through a high pass filter let us draw the high pass filter if I.

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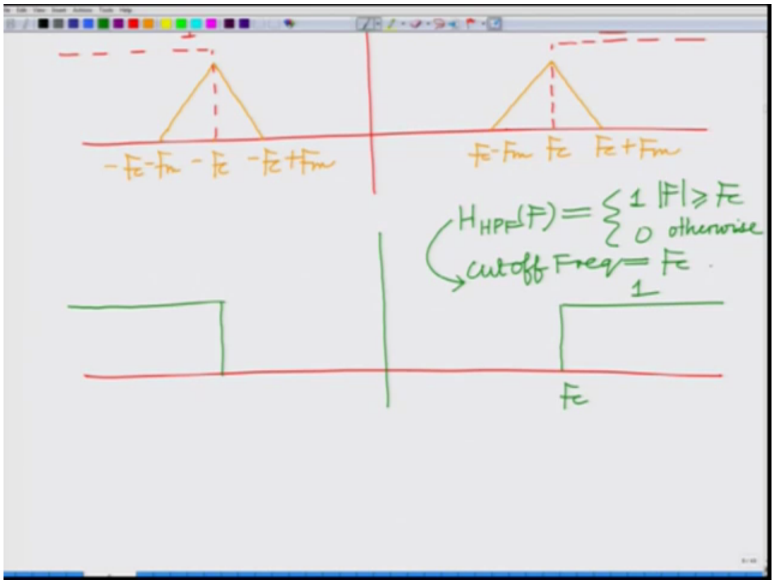


Now you can see if I pass it through the high pass filter this is 1 for F greater than or equal to F magnitude of F greater than, so this is my high pass filter or specifically the spectrum of my high pass filter. Which is equal to one if when F magnitude of F greater than or equal to Fc and 0 otherwise I pass it through the high pass filter, correct? So which implies basically the cut-off frequency is equal to the high pass filter with cut-off frequency equal to FC that is basically that it is an ideal high pass filter realize this is an ideal high pass filter and (practic) it is very difficult to design such filters but it is an ideal high pass filter which has a gain unity, alright.

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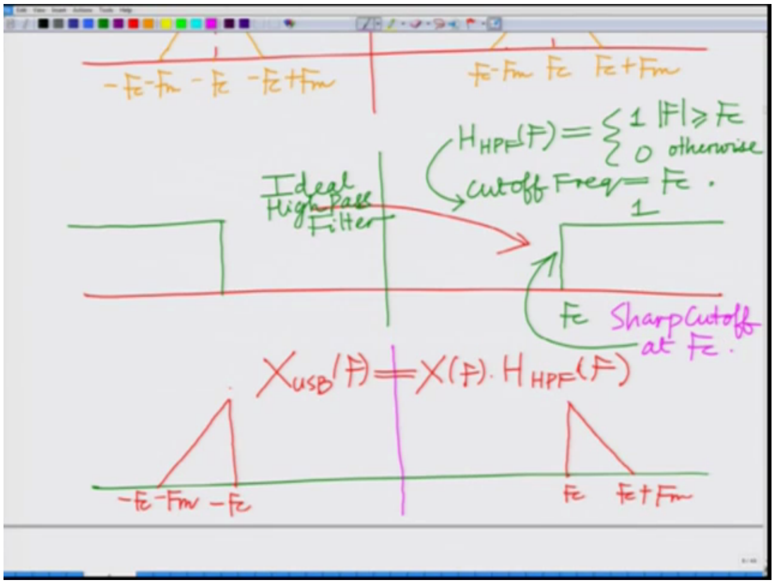


For all frequencies greater than or equal to Fc and it has gained exactly equal to gain equal to 0 for all frequencies between minus Fc to Fc. If I pass the (dy) DSB SC signal that s X(F) or the DSBS SC signal x(t) through this then naturally what this gives me is the upper side band and what I able to extract? Let me just show this again I pass this through this filter and what I am naturally going to get is X(F) times, so if I call this as your X(F) the output is X(F) times the HPF which is where h is the spectrum or the Fourier transform of your high pass filter and therefore what you get is basically, it is basically given by, say you can see you can extract the upper sideband.

So this is minus Fc so this is minus Fc minus Fm this is your X(F) times H the high pass filter which is basically equal to the spectrum of your upper sideband signal and notice that this is an ideal high pass filter which means which means it is exactly 1, it has gained exactly unity for all frequencies greater than Fc entered a sharp cut-off at Fc and for all frequencies less that is between minus Fc to Fc the gain is 0. So it has a very sharp, notice that it has a sharp cut-off at Fc, it has a very sharp cut-off it has a very sharp cut-off at Fc, okay. So this is a spectrum so this is X(F) times H of HPF so this is a spectrum of the upper side band modulated signal.

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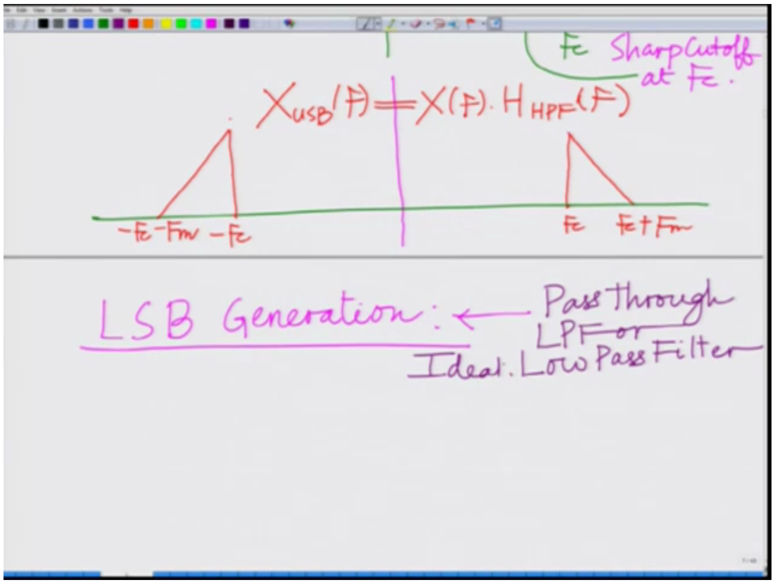


Now similarly to generate the LSB for LSB, so this is basically talks about USB generation so this is basically your USB this is the generation of the USB signal, now that is the upper sideband signal now to generate the LSB signal naturally one has to pass it through a to generate upper lower sideband naturally one has to pass it through the, so for the upper sideband that is extracting the outer sidebands we have to pass it through the high pass filter to extract the lower side bands naturally one is to pass it through a low pass filter, alright. Alright so pass through the pass through LPF or basically your low pass filter once again I can add that we desire an ideal low pass filter and you can see again if I have the spectrum that is given as follows, correct?

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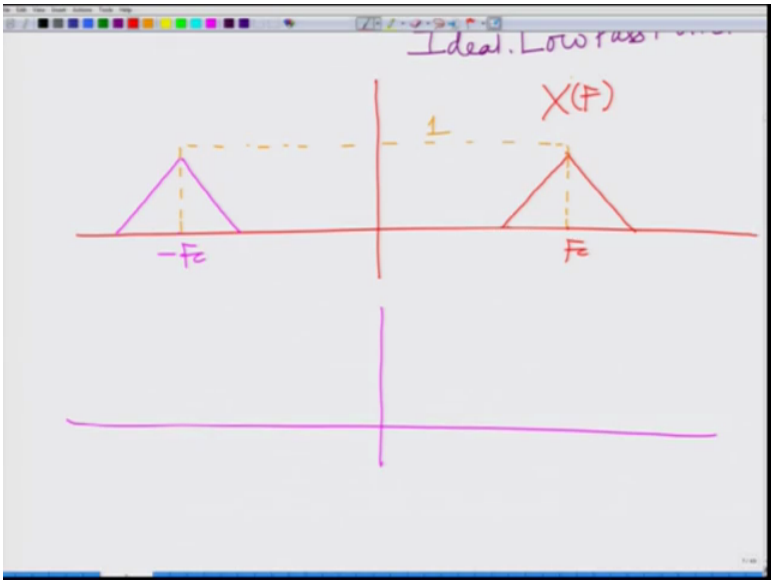


So this is this is a spectrum X(F) Fc, correct? This is other band which is from minus Fc to Fc and now I low pass filter this pass this through a low pass filter again I choose an ideal low pass filter, look at this if the low pass filter is 1 between minus Fc that is if I pass it through an ideal low pass filter which is 1, correct? Between so this is my X(F), alright which is a spectrum of DSB SC signal, I pass it through this low pass filter which is has a gain of unity for the signal for the range of frequencies between minus Fc to Fc that is your this is my low pass filter H LPF which is 1.

Now for all frequencies less than or equal to Fc between minus Fc and Fc and 0 otherwise and also again it goes without saying that this what we are considering is an ideal LPF and you can again see that there is a sharp cut-off at Fc and what this yields? Is this gives me the lower side bands of…

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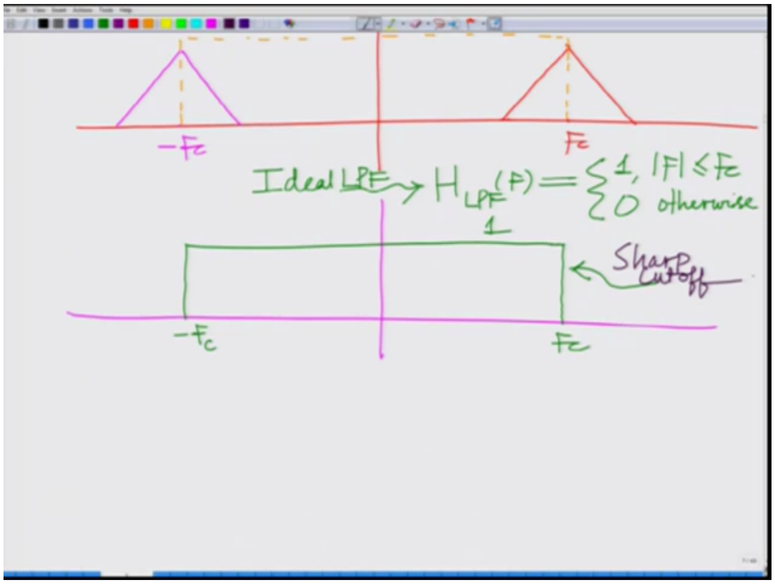


This gives me now gives me the lower sideband this gives the lower sideband and if I have to draw this so this is from this is my Fc this is my minus Fc, minus Fc plus Fm, Fc minus Fm and this you can see is the LSB signal or your, this is the lower sideband signal, correct? And what you can also and the spectrum X LSB F therefore it goes without saying that this is X(F) the DSB SC signal times the spectrum of the ideal low pass filter, so basically I can use frequency discrimination that is passing it through the high pass filter to generate the upper side with the ideal high pass filter to generate the upper sideband modulated signal and the ideal low pass filter to generate the lower sideband modulated signal this is termed as frequency discrimination.

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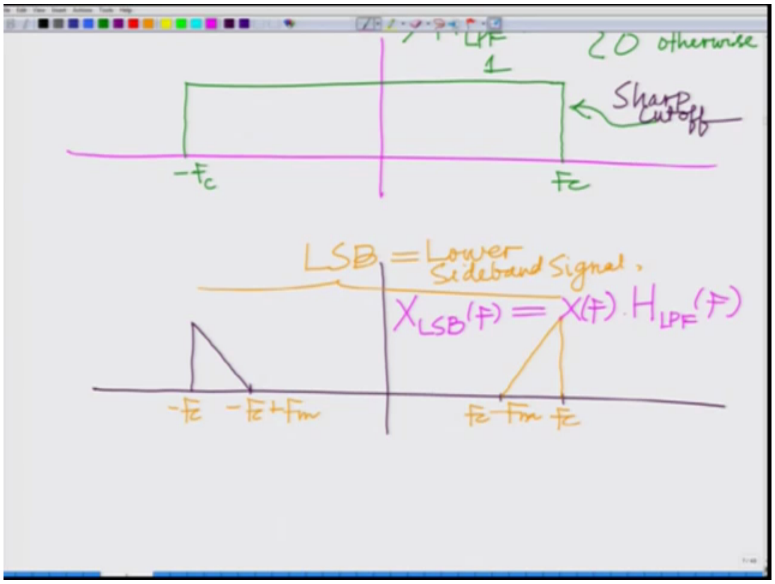


So what I have over here to draw this schematically I have my signal, so to draw a schematic blog diagram for USB generation I have basically your incoming message signal this is your message signal m(t) pass it through a modulator cosine 2 pi Fct and output pass it through your high pass filter and the high pass filter has the response of unity for all frequencies greater than or equal to Fc and less than equal to minus Fc and outcomes my, so this at this point x(t), this point is the upper sideband modulated signal.

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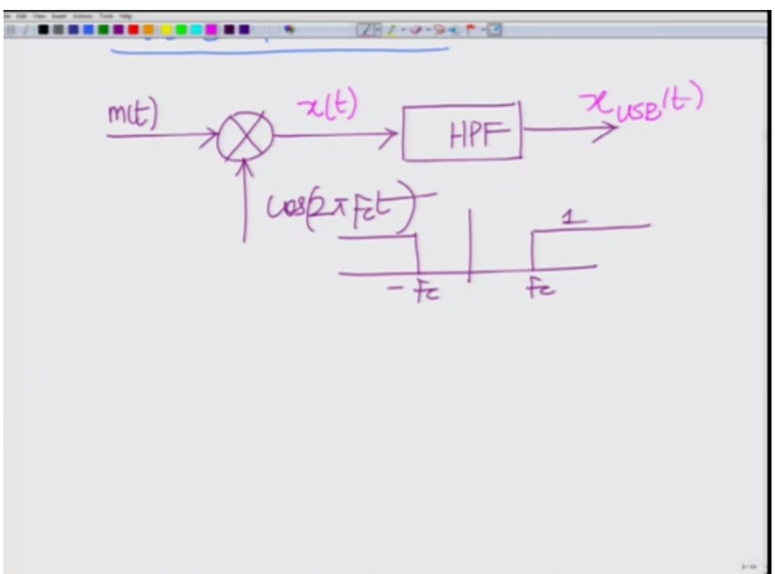

Similarly for LSB generation I start once again with the same signal m(t) this step is the similar for both LSB and USB I modulated with cosine 2 pi Fct to generate x(t). Now at this point pass it through your low pass filter and outcomes the LSB lower sideband modulated signal and again it is not difficult to see that the low pass filter has frequency response that is unity for this is your H LPF.

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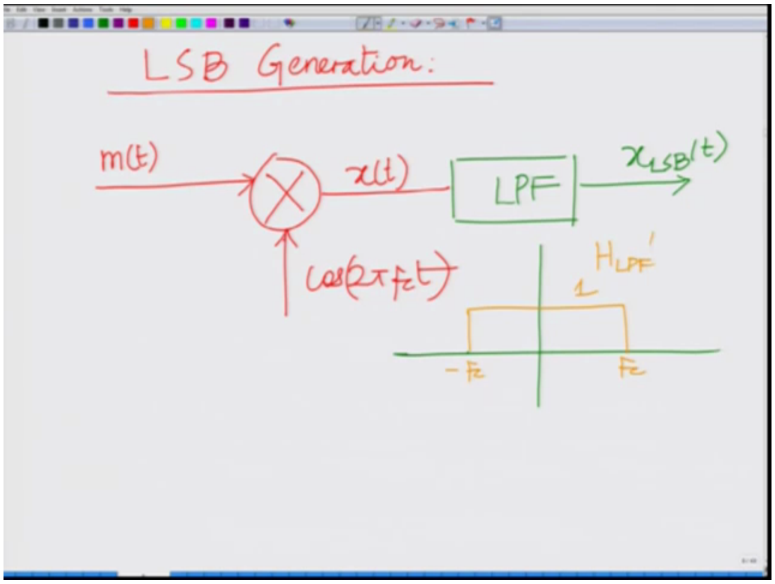


And this is your H spectrum of the high pass filter, the low pass filter has is basically it is an ideal low pass filter as you have seen that the sharp cut-off with a gain of unity for all frequencies within the range minus Fc to Fc. And therefore naturally the question that arises is what happens when these filters are not ideal because in practice it is very difficult to design filters with such sharp cut-offs.

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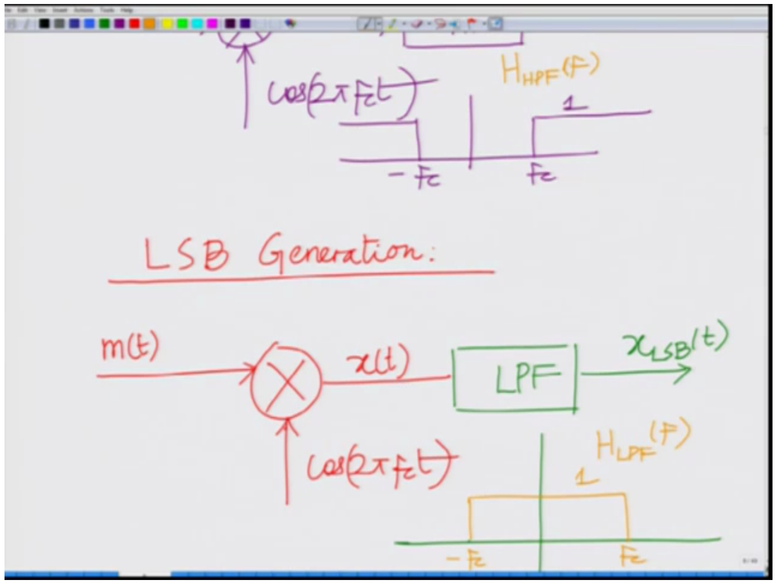


So in practice it is very difficult to design filters with such very difficult to design filters with such sharp cut-off, that is unity for F greater than Fc, 0 for F less than Fc or in the case of low pass filter 0 for F greater than Fc and unity for all F between minus F and Fc. So therefore now that is basically there is no transition band, alright. There is a pass band and there is a stop band and there is no (transi) in practice frequently we have filters have a transition band.

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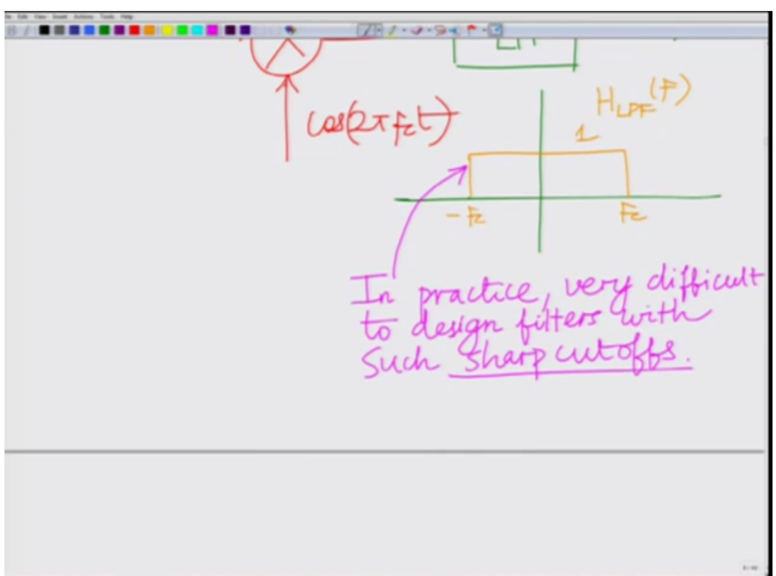

So we have low pass filters which are not ideal low pass filters but they have a transition band, so if this is your Fc so gain of unity gain of 0 or close to 0, correct? And if this is F, correct? Minus FC so there is a band in which it is transitioning from 1 to 0. So these are your basically transition, so this is your stop band where it is equal to 0, this is your pass band where it is gain is equal to unity which means these frequencies are passed and these bands where it is transitioning from the stop band to pass band or pass band to, alright. So the transitioning from 1 to 0 or 0 to 1 these are the transition bands, alright. So ideal filters have a 0 transition band but practical filters have a finite bandwidth of transition.

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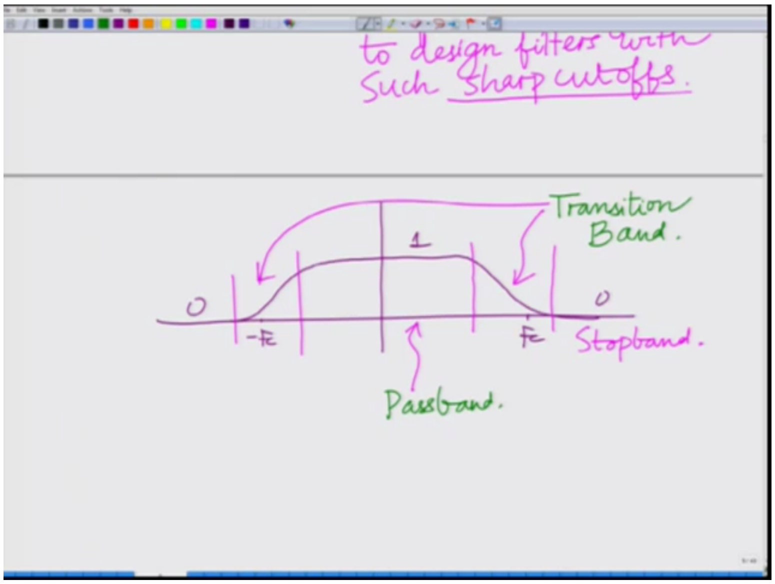


So practical filters have finite transition bands, so practical filters have finite practical filters have finite transition bands and therefore if you pass for instance for the generation of an LSB signal again let us start with your DSB SC signal, correct?

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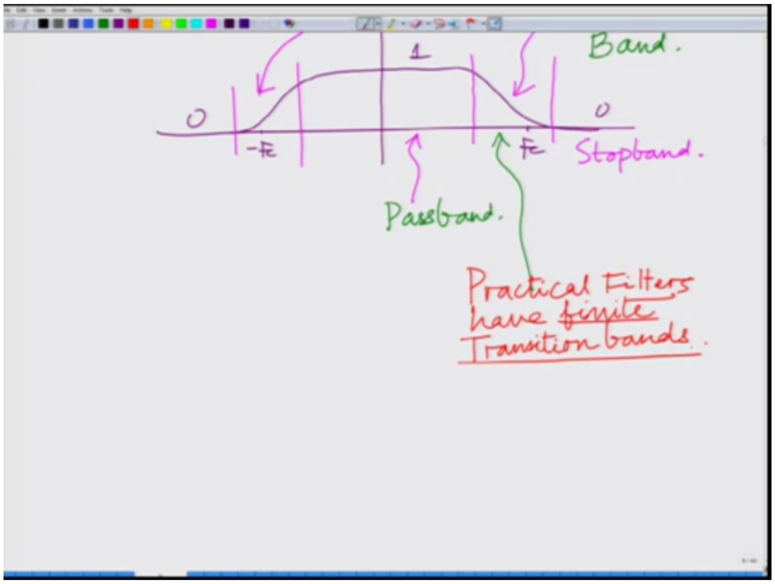


So let us start with your DSB SC signal and you have the bandwidth between Fc and the band at you have the band at minus, so you have the band that minus Fc this is the band at minus Fc and you have a low pass filter which has a transition, so this is your let us say this is your ideal LPF characteristic then you have an approximate low pass filter which has a finite transition band so that looks something like for instance something like this and then again a finite transition band here to transition from, let me just draw it.

So these are the finite transition, so this is your finite so this is your practical LPF which has a finite transition band that it is not exactly good to 0 for all F greater than Fc and F less than minus Fc but it is transitioning from 1 to 0 or a (fini) so there is some frequency is less than Fc for which the gain is less than one unity and if there are some frequencies greater than Fc for which the game is greater than 0, so it is transitioning from 1 to 0 and naturally if we employ this for low pass filtering what you are going to end up with is not exactly a lower sideband.

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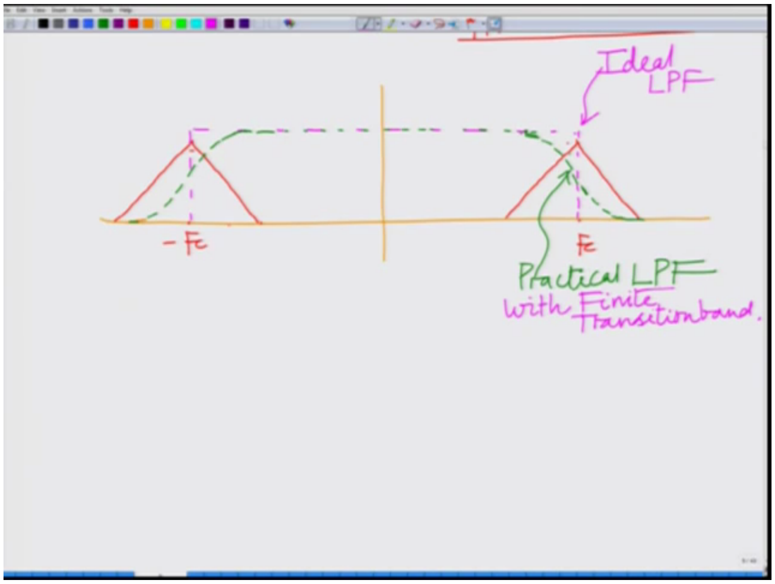


But you will have in this whereas this was your ideal LPF, correct? Your ideal upper sideband characteristic with an ideal LPF might have looked something like this, so this is your ideal LSB characteristic, okay. So this is your ideal LSB characteristic but what you will have is, so this is minus Fc, okay. So this is your ideal I am sorry this is a lower sideband module, so the ideal LSB characteristic will have looked something like ideal (LS) will have look something like this, this is your ideal LSB, correct?

So look what would have looked ordinarily like this, now because of the (disto) because of the non-ideal nature of the LPF it looks something like this, it looks something like, alright so there is a part of the band that is a part of the band that is outside Fc and outside of that is less then minus Fc also picked up, so what you have what you will have is something that looks like, so something that looks like some characteristic that looks like this.

Where there is some part of the band less than minus Fc part of the band outside, so what you have is parts of bands less than minus Fc and that is parts of bands less than minus Fc and greater than and greater than Fc and these parts these small parts that are picked up because of the non-ideal nature these are termed as vestiges these are termed as vestiges, there is a term for this, these are termed as vestiges that is these are the parts small bands of the DSB SC signal that are picked up because of the non-ideal nature of the low pass filter that is because there is a transition band which is not exactly, so therefore the LPF characteristic is not exactly 0 for all F greater than equal to Fc or al F greater than Fc and all F less than minus Fc but there is a small band around Fc for which it is transitioning from 1 to 0.

So that picks up vestiges of the original spectrum vestiges are basically small portions of the spectrum vestige basically means a small portion, so it picks up vestiges of the original spectrum which are greater than Fc and less than minus Fc these are termed as vestiges and we will later see a modulation scheme, alright which employs this vestiges which is termed as vestigial sideband modulation, alright.

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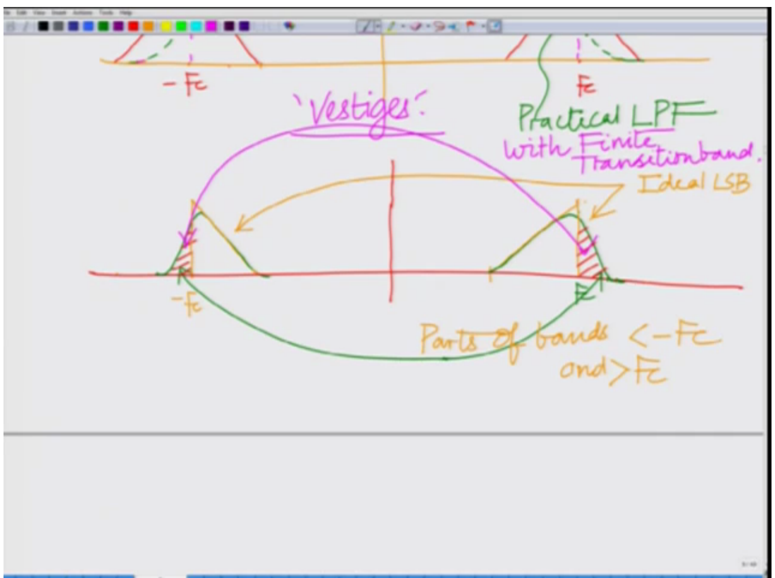


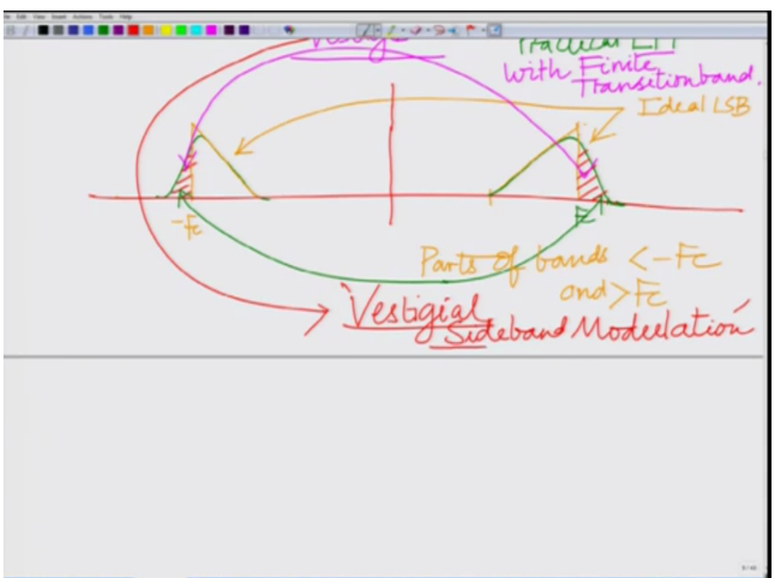

So vestigial sideband modulation is a specially suited for such scenarios so we have vestiges and we have we will see a scheme which is termed as vestigial sideband modulation specific early for such scenarios where it is difficult to design ideal low pass filters and for the same token high pass filter. When you have an non-ideal high pass filter which is a small transition band where it is transitioning from 0 to less than Fc to 1 greater than Fc, alright.

So it picks up vestiges when you pass it through (wa) if you pass it through an ideal high pass filter you have some we get an ideal upper sideband modulated signal but when you pass it through a non-ideal or a practical high pass filter it picks up vestiges of the original DSB SC spectrum corresponding to components corresponding frequencies between minus Fc and that is small vestiges of the original signal which would have not been otherwise present, had the filter being an ideal high pass filter, alright.

So therefore to deal with it, alright we have a different modulation scheme called vestigial sideband modulation which we are going to explode later, alright. So this is one scheme and there is another scheme is which we will cover later that is by basically using the Hilbert transform or basically the phase shifting method to generate an SSB modulated signal. So there are different techniques deal with it that is this non-ideal nature of the filter since it is very difficult, so practical filters always have a finite transition bands so the different techniques are to use either a phase shifting mechanism which we will discuss subsequently and also vestigial sideband modulation which handles this vestiges of the original spectrum that are retain by non-ideal filter is, alright.

So in this module we have specifically looked at the generation of SSB signals using frequency (dis) discrimination both upper sideband modulated and lower sideband modulated signals using ideal high pass and low pass filters respectively and we have also seen their schematics and what happens when you have practical filters when with finite transition bands, so let us stop here and we will continue in the subsequent modules, thank you.