Course on Principles of Communication Systems-Part 1
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Lecture 50
Module 8
Frequency Division Multiplexing (FDM), Carrier Spacing in FDM

Hello, welcome to another module in this massive open online course. So this module let us start looking at Frequency Division Multiplexing, ok.

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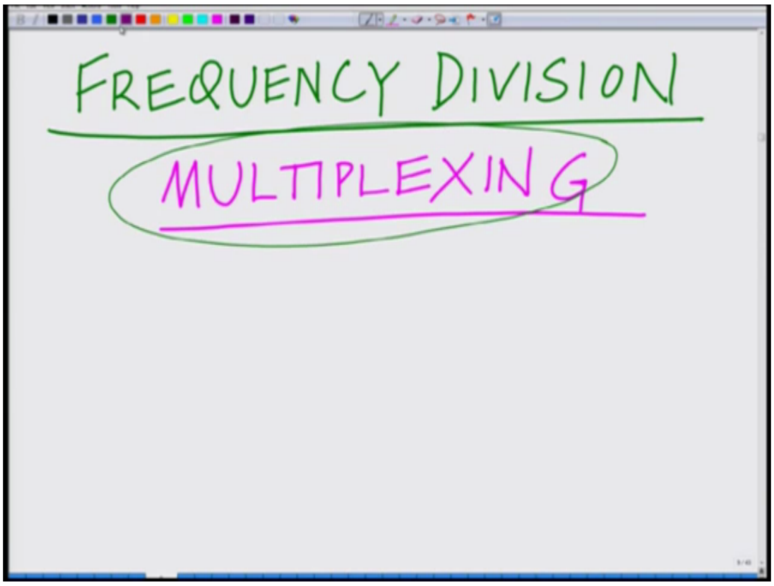

So in this module we will start looking at a different concept that is frequency division frequency division ok Frequency Division Multiplexing. Now the key word here is multiplexing ok notice that we have this term which is called multiplexing what is the meaning of this term multiplexing.

Now notice that multiplexing basically means that several signals multiplexing means multiple signals are combined into a single composite signal for transmission over the channel alright. There by you are using the same channel for the transmission of not a single signal but multiple signals, ok.

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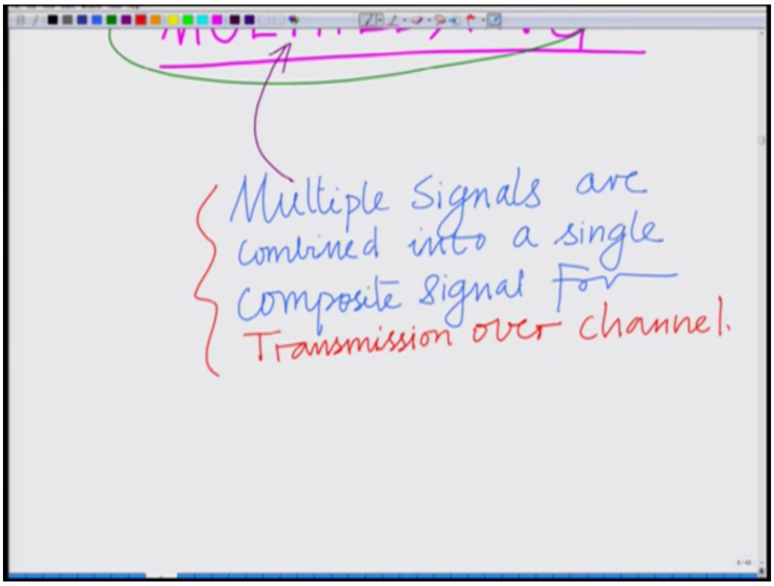

So the key idea behind multiplexing is that multiple signals multiple signals correct multiple signals are combined multiple signals are combined into a single composite for transmission over the channel transmission over the channel ok so multiple signals are combined into a single what is the advantage of this the advantage of this is you are using the same channel right the same channel for the transmission of multiple signals instead of a single signal ok.

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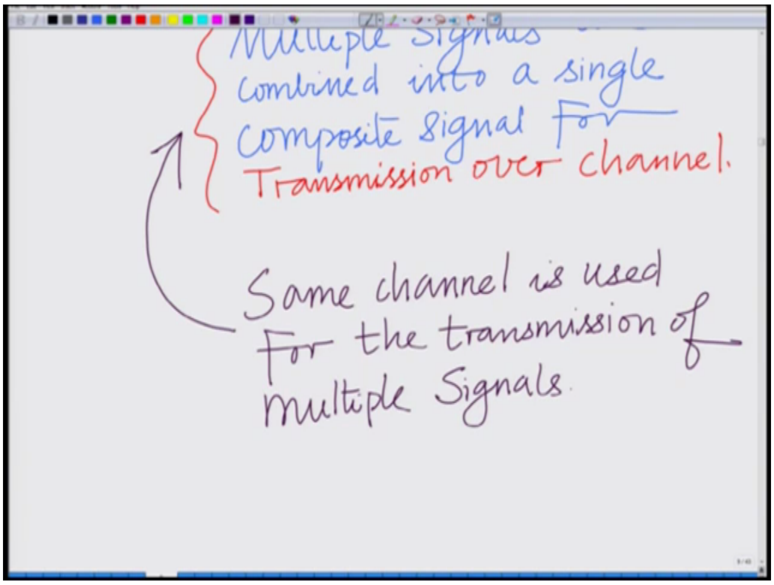

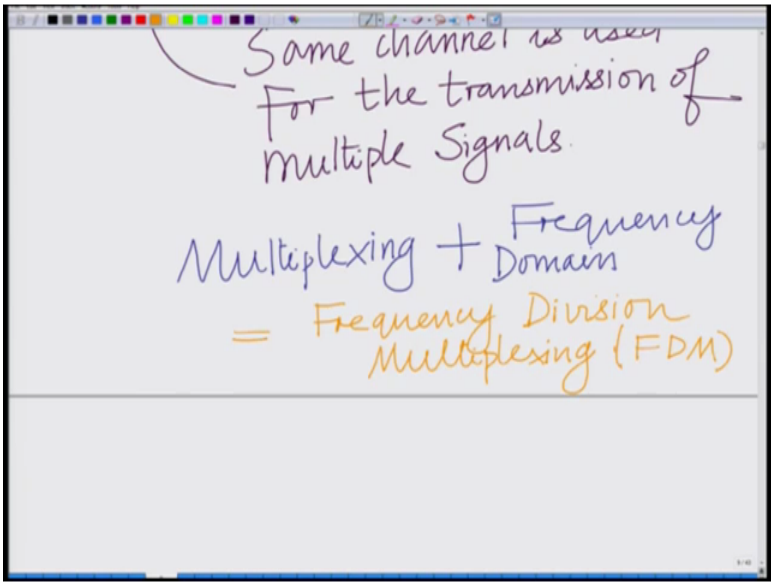

So this makes the channel usage efficient so channel so same channel is used for the transmission of multiple signals. So basically the channel usage becomes very efficient, ok. And now multiplexing is done in the frequency domain so there are various ways to do multiplexing so when multiplexing is done in the frequency domain that becomes Frequency Division Multiplexing that becomes Frequency Division Multiplexing, ok.

So Frequency Division Multiplexing is (FDM) alright when large number of signals correct, large number of signals right are multiplexed in the frequency domain that is they are separated by different frequencies that becomes Frequency Division Multiplexing. So we take a large number of signals multiples in frequency domain make a composite signal transmit over the channel, correct.

For instance when you look at a typical radio receiver correct we have a large number of radio stations all of them are transmitting over the same channel, alright and we are able to tune the receiver to the appropriate radio station and receive the signal corresponding to that appropriate radio station this is an example of Frequency Division Multiplexing where a large number of signals are multiplexed right multiplexed into a single composite signal and transmitted over the same channel.

Now how is this done Frequency Division Multiplexing, this is done by translating the different signals through different carrier frequencies.

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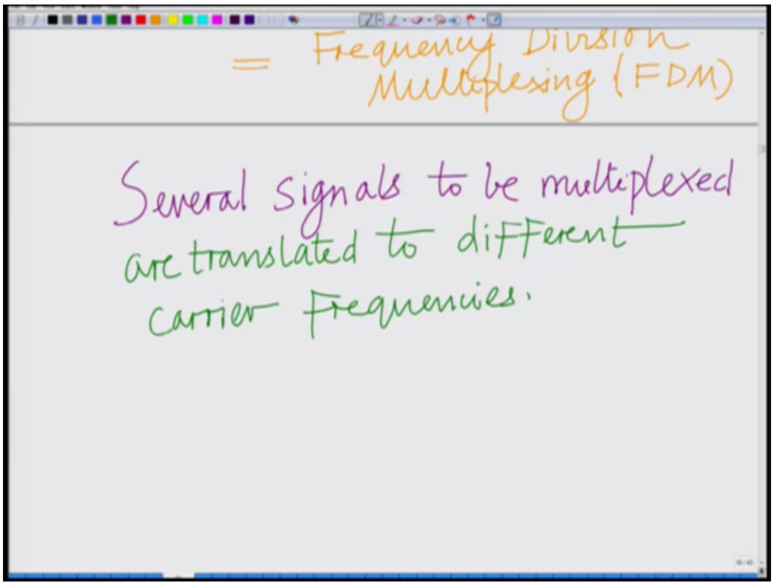

For instance let us take a look at this how is this Frequency Division Multiplexing done alright the several signals are translated several signals to be multiplexed ok that is the key here to be multiplexed are translated different carrier frequencies center frequencies or to different they are translated to different carrier frequencies.

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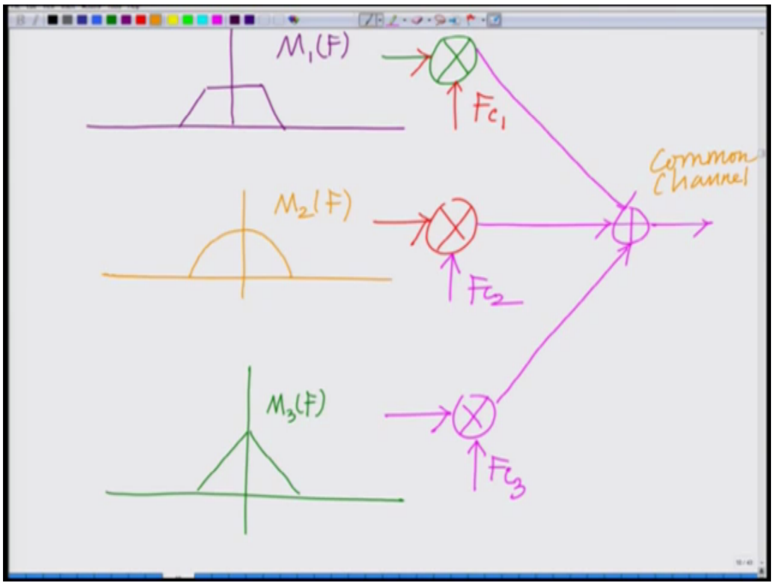

For instance if you take a look at this let us consider as simple example let us say have these three different signals correct with spectrum M1(F) let say this as spectrum this is the spectrum of signal this is M1(F), take another signal m2(t) this is the spectrum this is the spectrum M2(F), take another signal m3(t) ok this has spectrum M3(F), now what I am going to do is I am going to take this signal I am going to take this signal I am going to translate to carrier frequency I am going to translate to carrier frequency Fc1 ok, now I am going to take this signal I am going to translate this to a different carrier frequency let say I translate this to Fc2, I am going to take this signal I am going to translate this to a different carrier frequency let say Fc3, ok. Now I am going to now I am going to combine all these things and transmit them over a common channel, ok.

So what I have done is I have taken the first signal with spectrum M1(F) correct first signal with spectrum M1(F), I have translated this to the carrier frequency Fc1, I have taken the second signal right spectrum M2(F) translated it to a carrier frequency Fc2, third signal translated it to a different carrier frequency Fc3, so on and so forth right I can I can keep adding number of signals as long as I am translating them to the different carrier frequencies finally combine them to form a composite signal and then transmit them over the common channel, ok.

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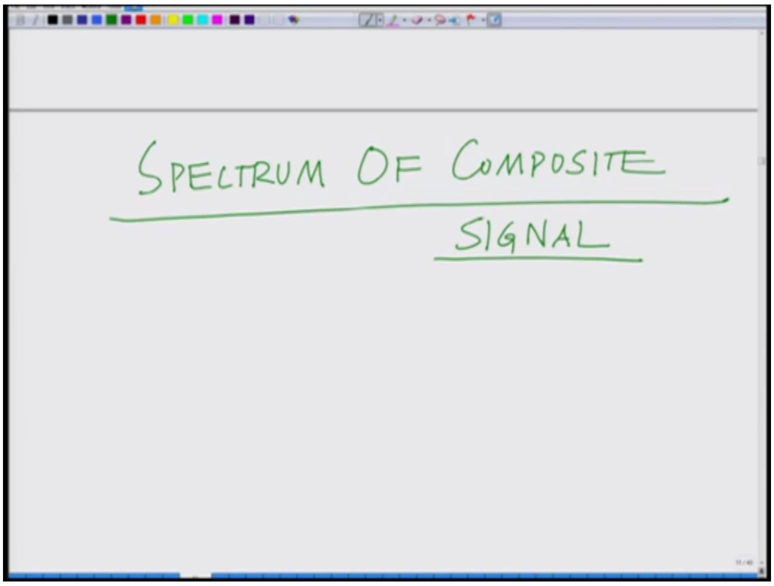

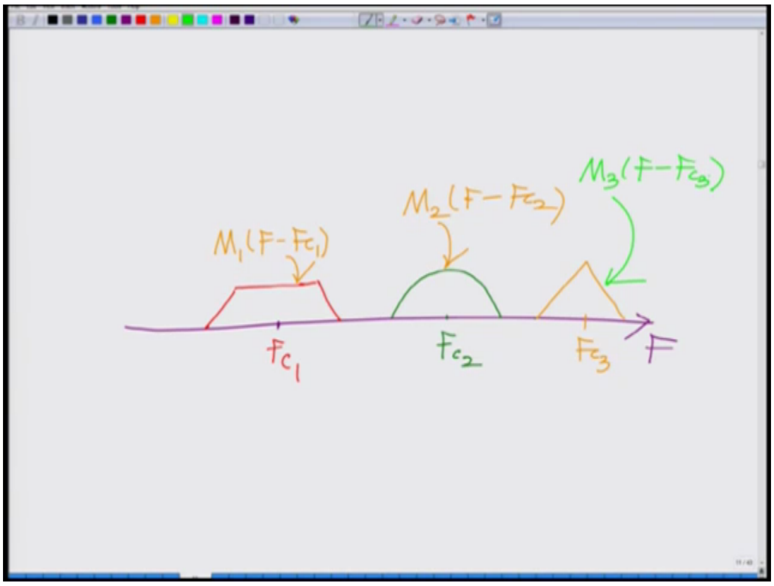

So the spectrum of the combined signal will now look as follows the composite signal spectrum, if you look at the spectrum of the composite signal the spectrum of the composite signal will look as follows, I will have in the frequency domain this is F, I will have the spectrum 1 that is translated to I will have spectrum 1 that is translated to that is translated to Fc1, ok. This is your spectrum 1 which is translated to Fc1, correct.

Spectrum 2 that is translated to (Mc) Fc2 and spectrum 3 that is translated to Fc3. So this is what M1(F minus Fc1), this is corresponds to M2(F minus Fc2) and this corresponds to M3 translated to Fc3 (F minus Fc3), ok. So this is your spectrum of the composite signal, ok. And therefore as I have already told you this is the spectrum of the composite signal.

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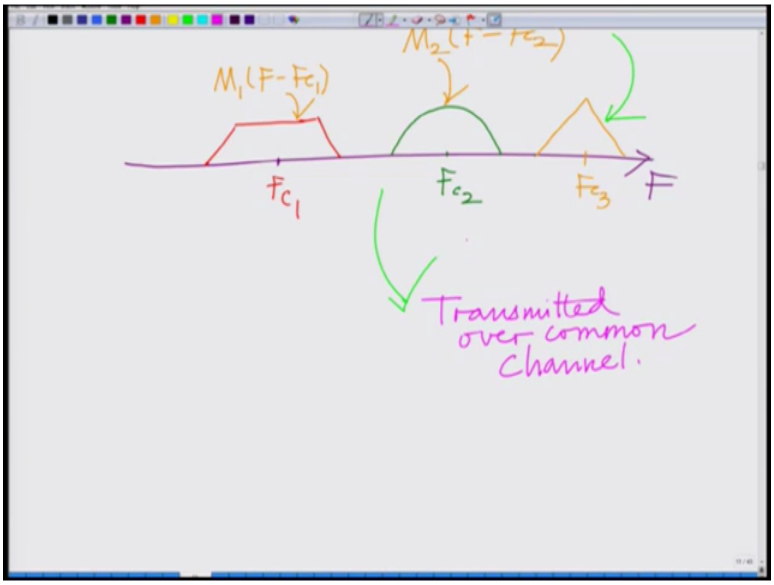

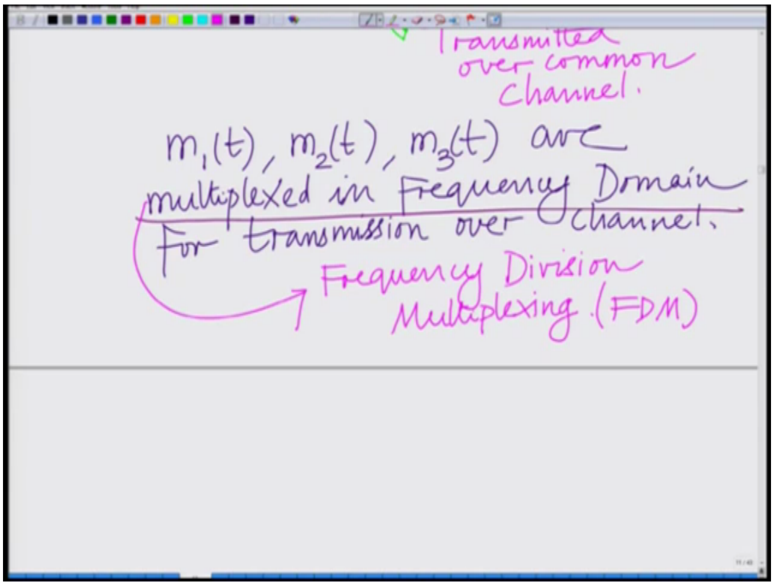

Now this composite signal is transmitted over the common channel. So basically what are we doing we are multiplexing m1(t), m2(t) and m3(t) for transmission over the composite channel they are multiplexed in the frequency domain therefore this is Frequency Division Multiplexing. So m1(t), m2(t), m3(t) are multiplexed in Frequency Domain for transmission over channel, ok and this is basically this is nothing but this Multiplexing in the Frequency Domain this is nothing but your Frequency Division Multiplexing this is nothing but Frequency Division Multiplexing or FDM, ok this is Frequency Division Multiplexing or FDM.

Now at the receiver we have to (()) (12:30) so these signals are multiplexed we have composite signal. Now at the receiver we have to separate these signals to extract the individual signals alright. Now obviously since these are separated in the frequency domain we can extract each signal by appropriately Bandpass filtering at the corresponding center frequency.

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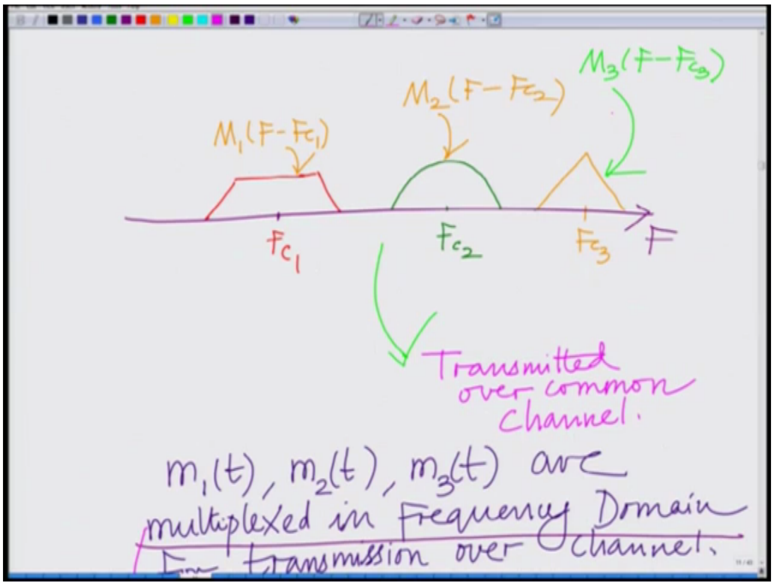

For instance to extract M1 I have to filter at Fc1, if I have to extract M2 I have to consider Bandpass filter centered at Fc2, to extract M3 I have to consider Bandpass filter centered at Fc3.

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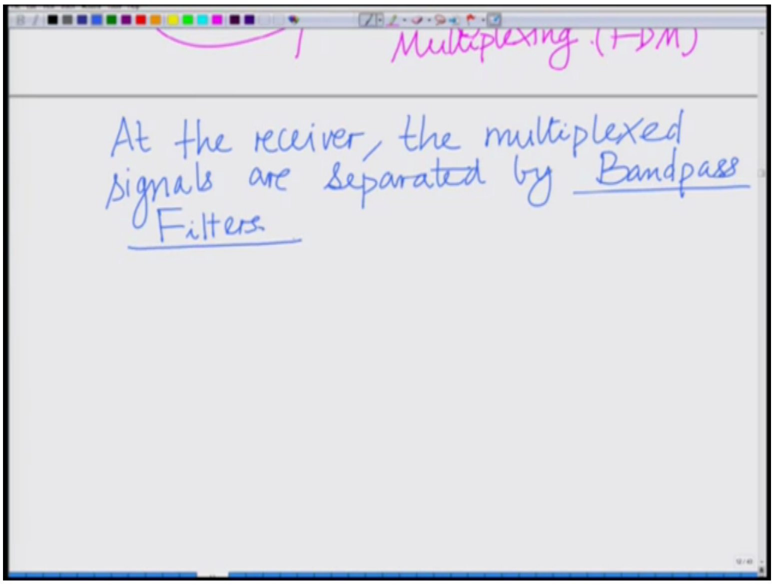

So therefore at the receiver the multiplex signals are separated by Bandpass filters, so this is at the receiver the multiplexed signals are separated by these are separated by Bandpass filters, correct.

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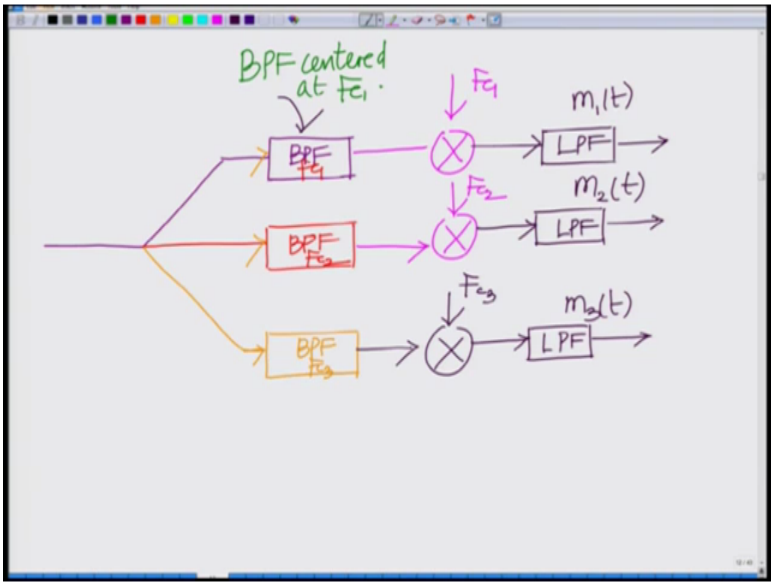

So what are we doing we take the received signals we Bandpass filter we pass it through appropriate Bandpass filter, correct BPF with center frequency for instance Fc1, another BPF with center frequency Fc2, another BPF with center frequency naturally BPF with center frequency Fc3. Now this is the corresponding carrier frequency for the first Bandpass filter is Fc1. So this is demodulate with Fc1 corresponding carrier frequency is Fc2 therefore demodulated Fc2 corresponding carrier frequency is FC3 so therefore demodulate at Fc3 and then pass it through the low pas filter pass it through a low pas filter, ok.

So you get m1(t), m2(t), m3(t), ok. So you are demodulating with Fc1 so this is Bandpass filter centered at Fc1, ok. For instance this represents Bandpass filter centered at BPF centered at Fc1 then demodulate by Fc1 or demodulate by carrier frequency Fc1, ok.

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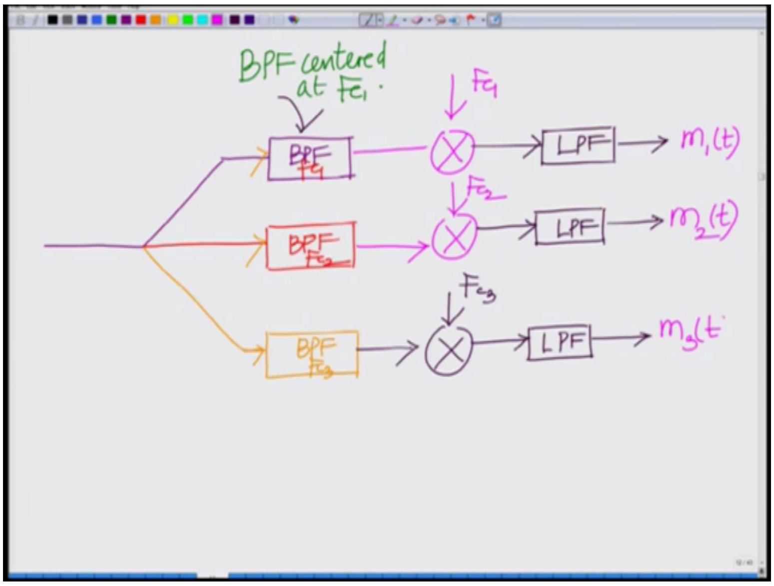

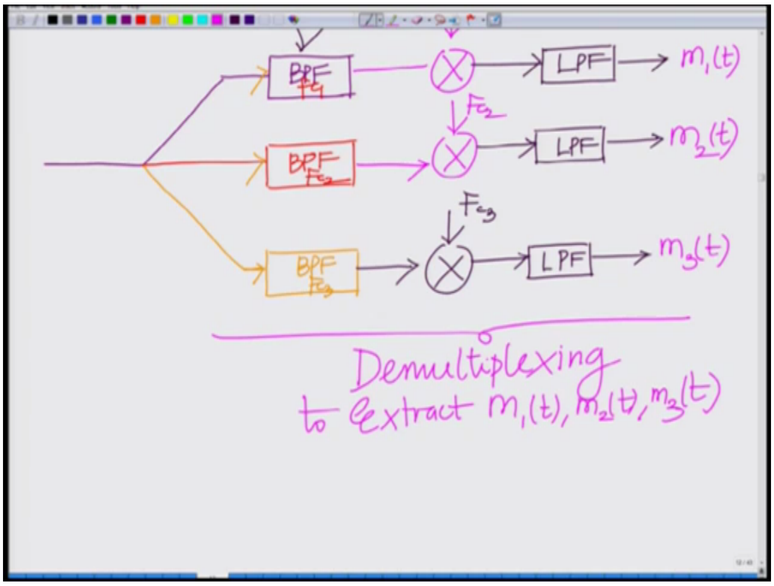

Next we have Bandpass filter centered at Fc2 demodulate with carrier frequency Fc2, Bandpass filter centered at Fc3 demodulate with carrier frequency Fc3, ok. And then we are able to separate, ok so this will give us your m1(t), give you your m2(t), this will give you m3(t). Now this is basically a Demultiplexing Demultiplexing to extract m1(t), m2(t) and m3(t), ok demultiplexing is nothing but you have a composite signal from that you are extracting the separate component m1(t), m2(t), m3(t).

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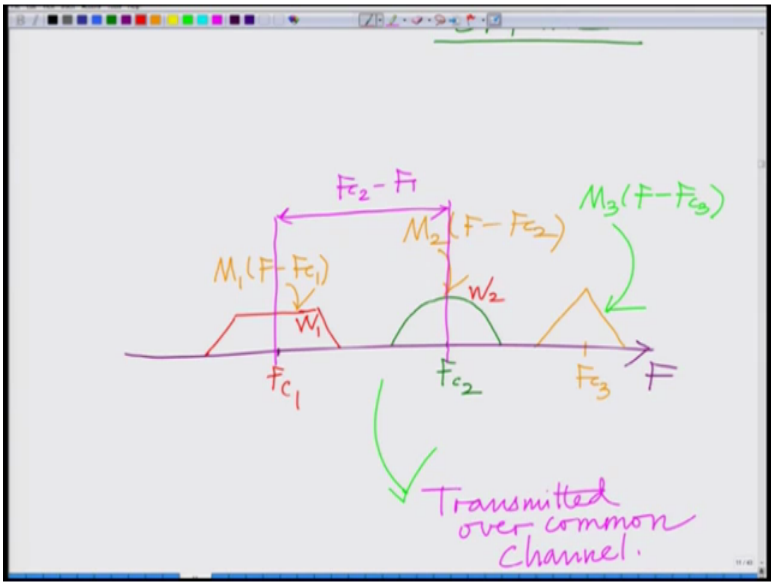

Now let us look at the condition for this Frequency Division Multiplexing now if let us look at the condition for this Frequency Division Multiplexing you will notice that. For instance you have here carrier frequency Fc1, ok and you have here carrier frequency Fc2. Now the spacing between them is Fc2 minus Fc1, now let us say this signal has bandwidth W1, this signal has bandwidth W2.

Now W1 plus W2 that should be less than Fc2 minus Fc1, you observe that some of the bandwidths should be less than Fc2 minus Fc1 to avoid spectral overlap right otherwise the translated spectra are going to overlap so we must have to avoid overlap what we see is the condition in FDM.

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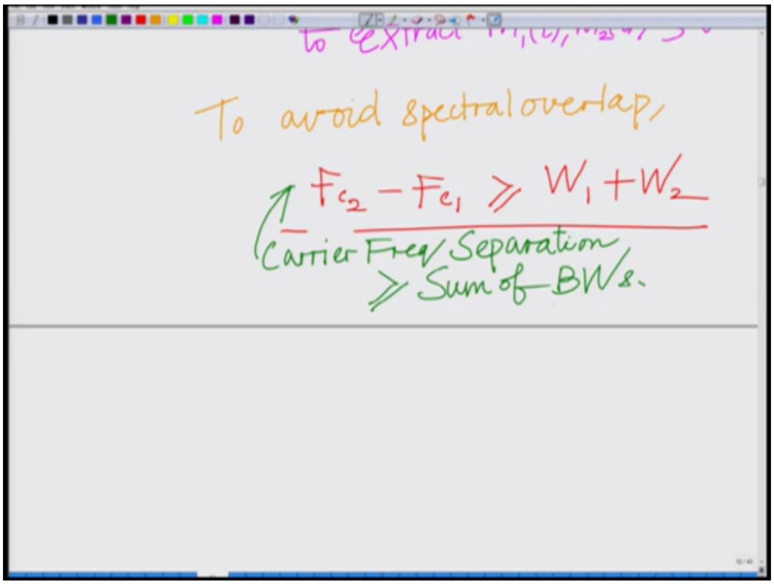

To avoid overlap to avoid overlap we must have Fc2 minus Fc1 greater than or equal to W1 plus W2, ok. This means that basically your carrier frequency separation must be greater than separation must be greater than or equal to the sum carrier frequency separation must be greater than or equal to sum of bandwidths now this is for DSB, ok.

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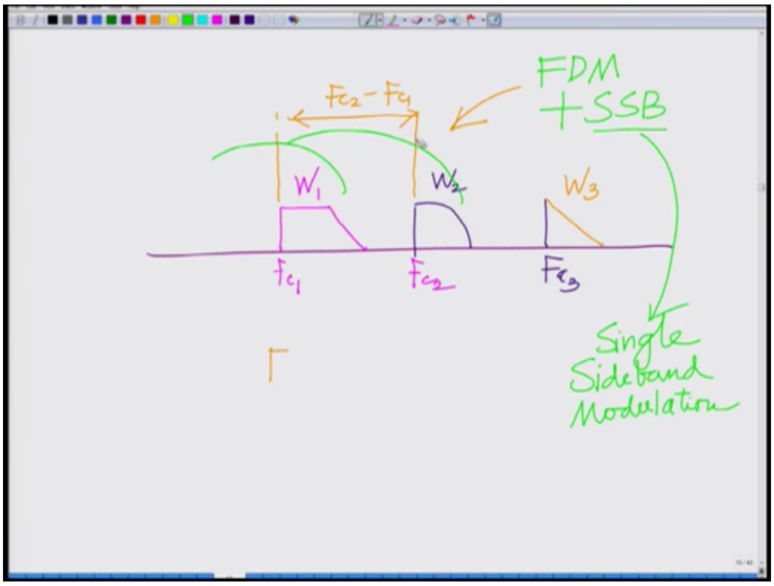

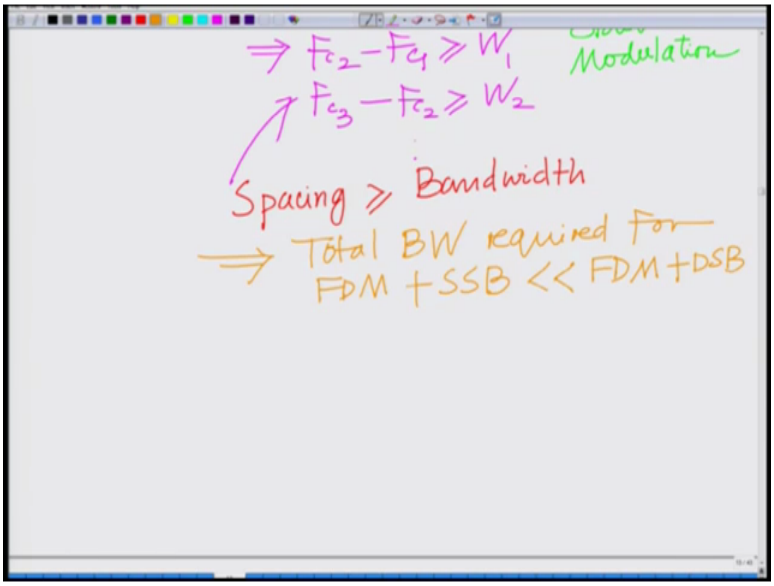

However for SSB now if you look at SSB modulation again let us consider the three spectra we are transmitting only a single side band. Now if you look at SSB you will notice something interesting at SSB again if we have FC1 we are transmitting only a single side band. Let us say we are transmitting upper side band, so this is basically your W1, now this is Fc2 again here you transmitting only upper side band so this is W2, now this is Fc3 here again you are transmitting only the upper side band W3.

Now if you can look at this this is the spacing Fc2 minus Fc1 this is the spacing Fc2 minus Fc1, we see that Fc2 minus Fc1 need to be only greater than W1. So for no overlap, so this is with FDM with SSB Frequency Division Multiplexing plus SSB. Now in single side band modulation, right SSB stands for hope you are remembered SSB stands for Single Sideband Modulation. In particular here we are using USB transmitting only the upper side bands right in particular here we are transmitting only the upper side band.

So for no overlap we need this implies Fc2 minus Fc1 greater than or equal to W1, similarly Fc3 minus Fc2 greater than or equal to W2 and so on. So basically the point is so the point is the difference between the carrier frequency alright so the point here is that the difference between the carrier frequencies has to be only greater than the bandwidth not the sum of the bandwidth therefore you can space the carriers more closely which means you are saving the total bandwidth, ok. So SSB is more efficient in that way in Frequency Division Multiplexing the total bandwidth required is much smaller, ok. So here spacing needs to be only greater than greater than equal to bandwidth.

Therefore total bandwidth required, so total bandwidth required for FDM, FDM plus SSB that is Frequency Division Multiplexing with Single Sideband Modulation is much smaller than the bandwidth required for FDM plus DSB. In fact FDM plus SSB will you can see that it requires half the bandwidth of total bandwidth of FDM with DSB alright similar to the advantage of SSB or DSB.

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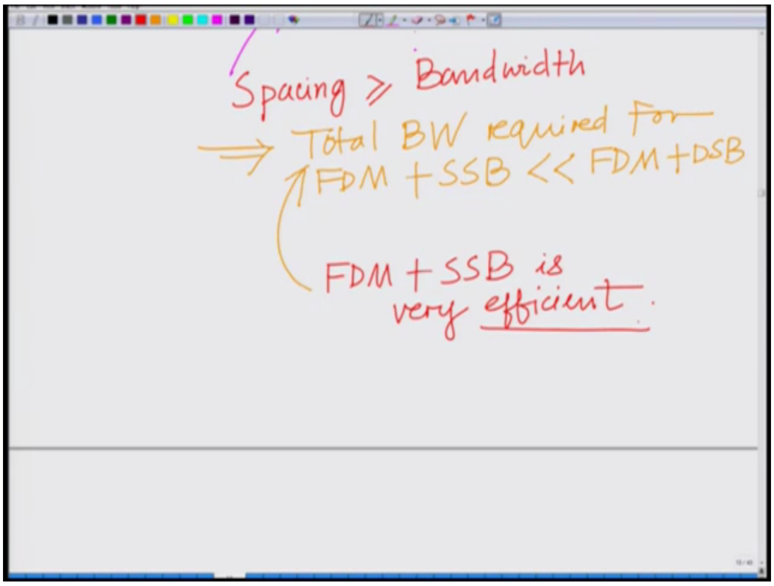

Therefore FDM plus SSB is much more efficient and comparison to FDM Frequency Division Multiplexing with DSB Double Sideband, so FDM plus SSB so which implies FDM plus SSB is very efficient FDM plus SSB is very efficient.

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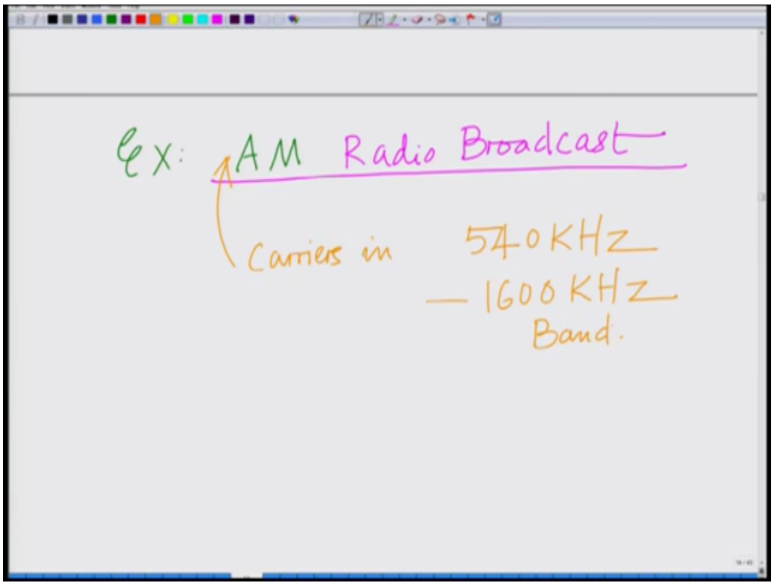

Let us take a simple example example of AM broadcast again or AM Radio Broadcast AM is amplitude modulation AM Radio Broadcast. In AM Radio Broadcast we have carriers in the 540 kilohertz to 1600 kilohertz band, ok.

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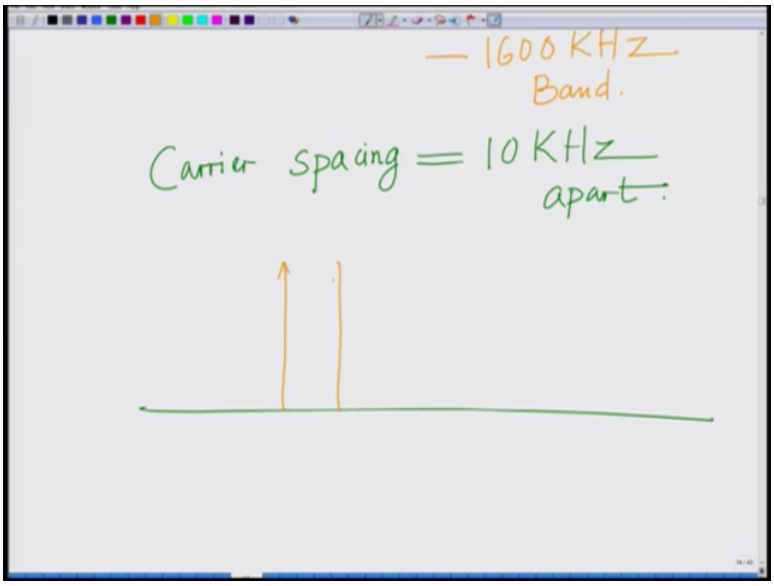

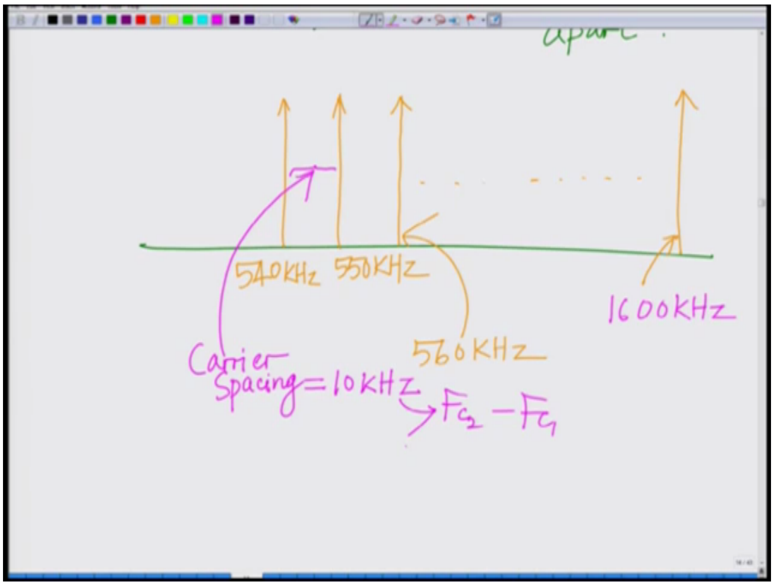

Now carriers spacing is 10 kilohertz, the carriers are spaced 10 kilohertz apart. So carriers are spaced 10 kilohertz apart, so if you look at carriers these are spaced so you start at 540, 550 kilohertz than you have the next carrier at 560 kilohertz so on and so forth you will have carrier the last carrier will be at obviously this is not according to scale the last carrier will be at 1600 kilohertz.

So carrier spacing if you can look at this carrier spacing is only 10 kilohertz that is your Fc2 minus Fc1, ok carrier spacing is only 10 kilohertz.

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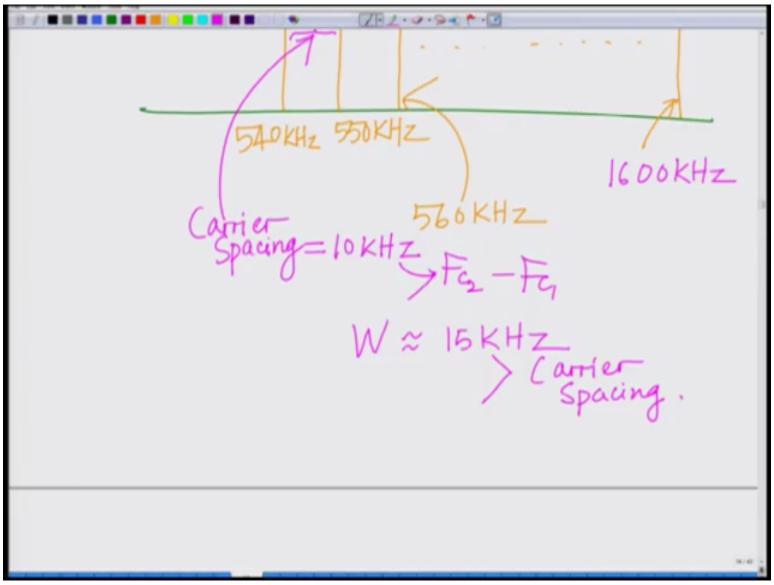

However the message bandwidth W is typically around 15 kilohertz alright so W is approximately equal to which is basically greater than your carrier spacing, which means that two carriers which are adjacent to each other that is 10 kilohertz separation only cannot be used for Transmission Frequency Division Multiplexing alright in the same area.

Because if there is let us say frequency 540 kilohertz being used another signal 540, 550 kilohertz at carrier frequency 550 kilohertz than there is going to be spectral overlap between these two signals and they are going to interfere with each other.

Therefore since the message signal bandwidth in AM Radio is typically around 15 kilohertz, adjacent carriers cannot be used for transmission in the same geographic area. So adjacent carriers have to be deployed in widely separated geographical areas so that there is no interference, so the adjacent the carriers that are employed in a certain geographical area have to be widely separated, alright adjacent subcarriers cannot be employed in the same geographic area, alright otherwise they are going to these signals are going to interfere with each other.

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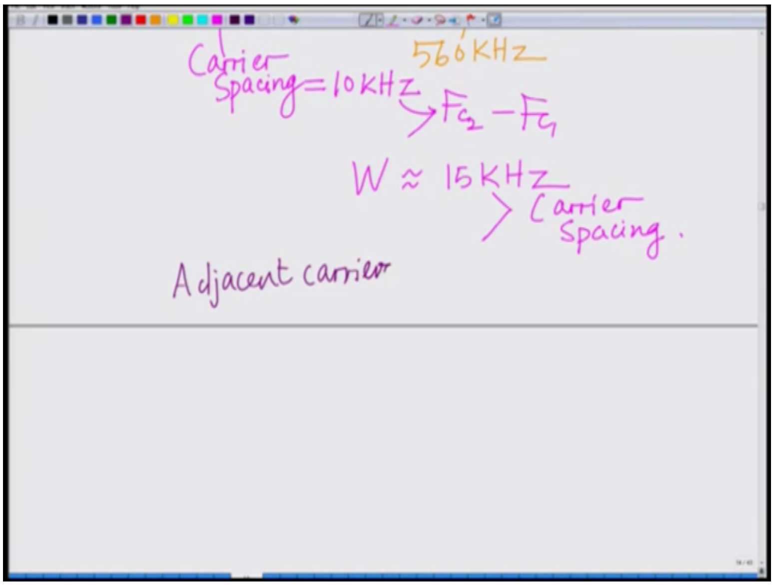

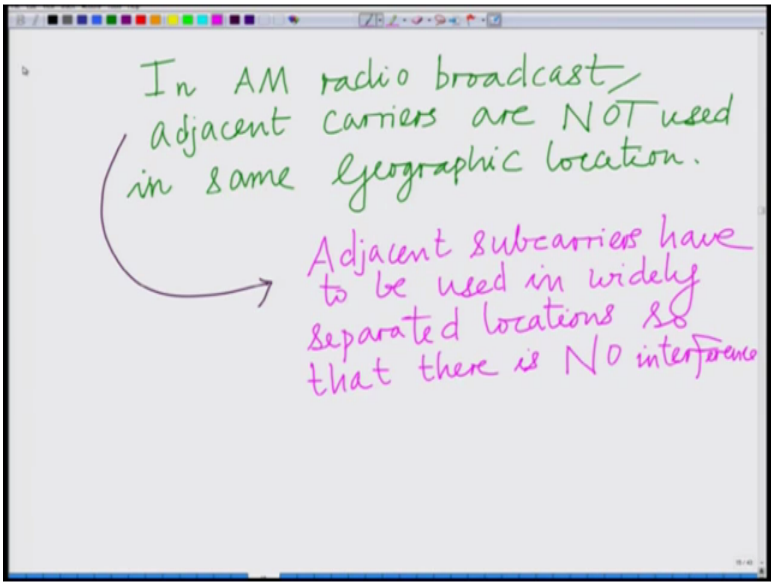

So adjacent carriers, so carriers so in AM Radio adjacent carriers in AM Radio adjacent carriers are not used at the same location, ok in AM Radio Broadcast adjacent carriers are not used adjacent subcarriers are not used in the same geographic locations these have to be widely separate. So adjacent of subcarriers have to be separated so adjacent of subcarriers have to be adjacent of subcarriers have to be in widely separated locations so that there is no interference so widely separated. These have to be used in widely separated locations so that there is no interference, ok so that is basically the point, ok.

So what we have in AM Radio Broadcast we have carriers from 540 kilohertz to 1600 kilohertz at a spacing 10 kilohertz intervals alright, but the AM message bandwidth is 15 kilohertz which is greater than the carrier spacing so adjacent carriers cannot be used in the same geographic location alright.

So in this module what you have seen is Frequency Division Multiplexing the methodology of Frequency Division Multiplexing alright what is the motivation for Frequency Division Multiplexing took combine, multiplex several signals right (trans) to multiplex several signals into a same composite signal for transmission over the channel alright and when done in the frequency domain this is Frequency Division Multiplexing which is achieved by transmission to different carrier frequencies alright such that there is no spectral overlap and at the receiver alright they are separated with different Bandpass filters and modulated, demodulated is in the different carrier frequency alright. And also we have seen an example corresponding to AM Radio Broadcasting alright. So will stop here and look at other aspects in the subsequent modules, thank you.