Principles of Communication- Part I
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Module No 5
Lecture 29
Frequency Modulation (FM) with Sinusoidal Modulating Signal and Pictorial Examples, Insights of PM and FM Signals

Hello welcome to another module in this massive open online course, so we are looking at and modulation of which phase modulation and frequency modulation are particular types of modulation, alright. So we have also looked at phase modulation with Sinusoidal modulation, so in this module let us look at frequency modulation with a Sinusoidal modulating signal, okay.

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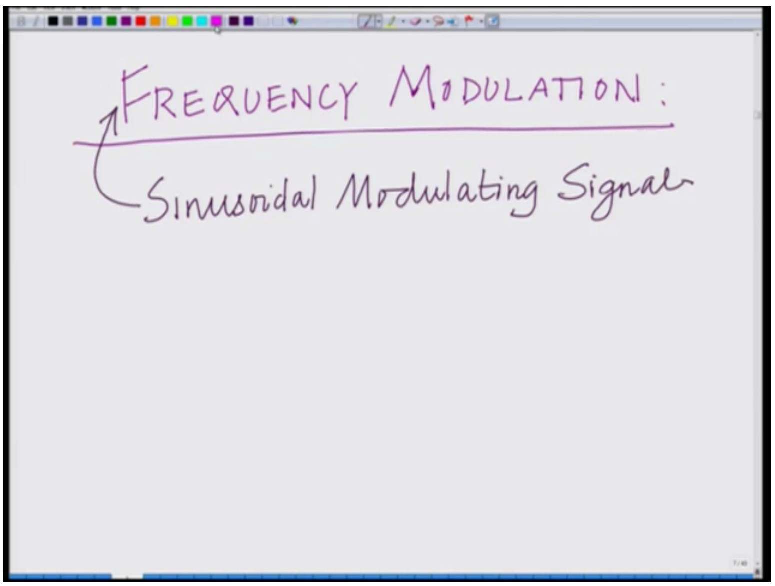

So what we want to start looking at is frequency modulation that is Fm, frequency modulation with our Sinusoidal modulating signal, okay. So with a Sinusoidal modulating signal okay.

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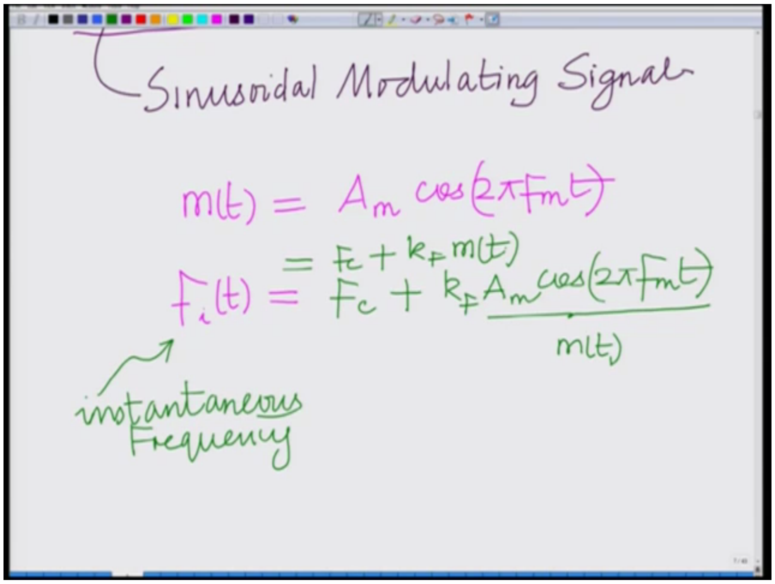

So let m(t), alright. So let the message signal m(t) be m(t) equal to Am cosine Am cosine 2pi Fmt then our frequency Fi(t) instantaneous frequency, remember Fi(t) is the instantaneous frequency this is the instantaneous frequency and this is equal to your Fc the frequency of the carrier plus the component from the message that is k kF times Am into cosine kF Am into cosine 2pi Fmt this is the this is your instantaneous frequency, okay.

So the frequency is basically the frequency of the carrier unmodulated carrier F Fc to that you are adding a component, so that the frequency is now modulated by the message signal, so instantaneous frequency becomes Fc the carrier frequency plus kF times Am cosine 2pi Fmt, okay because Am cosine 2pi Fmt is of message signal, so this is m(t) so this is remember this is our message signal, alright. So what we are doing is we have Fi(t) is Fc plus kF times m(t) where m(t) is the message signal, okay.

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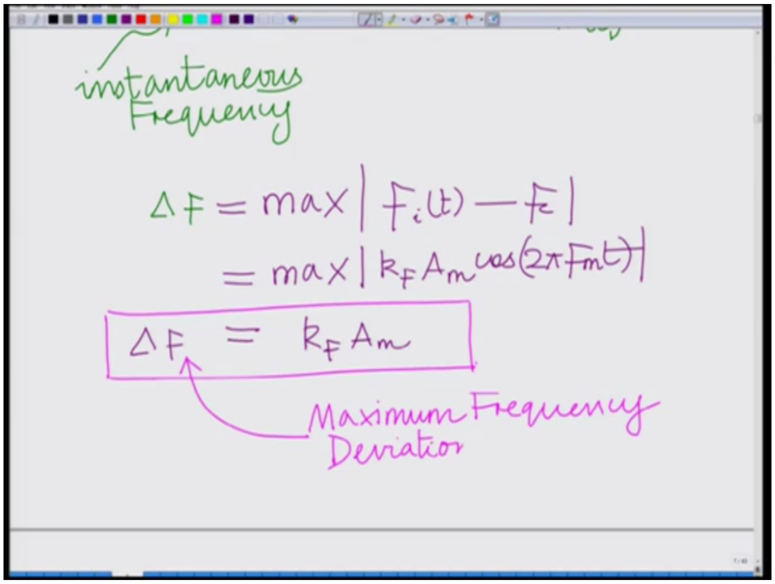

And therefore now if you look at the maximum frequency deviation of frequency deviation Delta F equals this is given as the maximum of Fi(t) minus Fc where Fc is the carrier frequency that is equal to the maximum of well, kF Am cosine of 2pi Fmt and the maximum of this is nothing but kF times Am.

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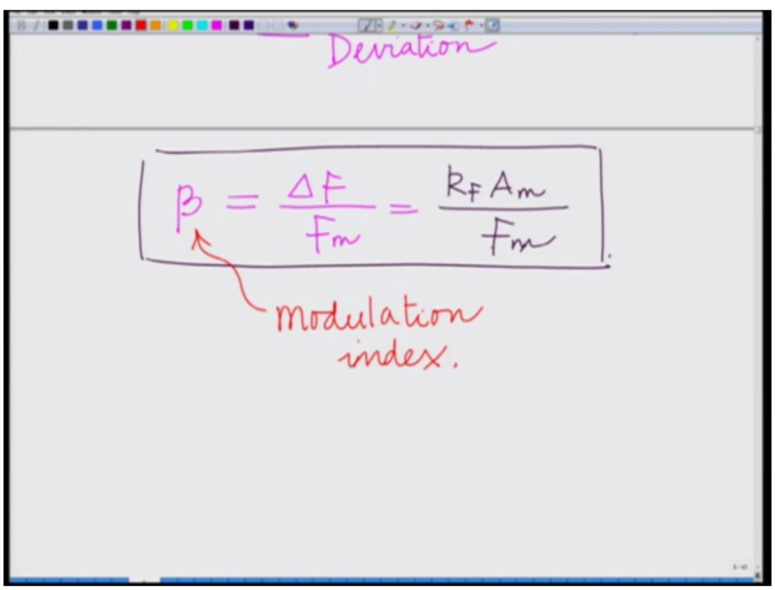

So delta F the maximum frequency deviation the maximum frequency deviation equals kF times Am and beta that is modulation index. Therefore equals the frequency deviation divided by Fm the message frequency Delta F divided by Fm which is equal to kF into Am divided by Fm, okay. So this is beta your modulation index. So beta is basically the, this is the modulation index. This is the modulation index, okay.

So we have shown that the maximum so we have been the modulating signal is a Sinusoidal modulating signal that is m(t) is Am cosine 2 pi Fmt we have shown that the frequency deviation is kF times Am the modulation modulation index beta is kF Am divided by Fm there is a frequency deviation peak (freq) peak frequency deviation divided by the frequency of the message signal, okay.

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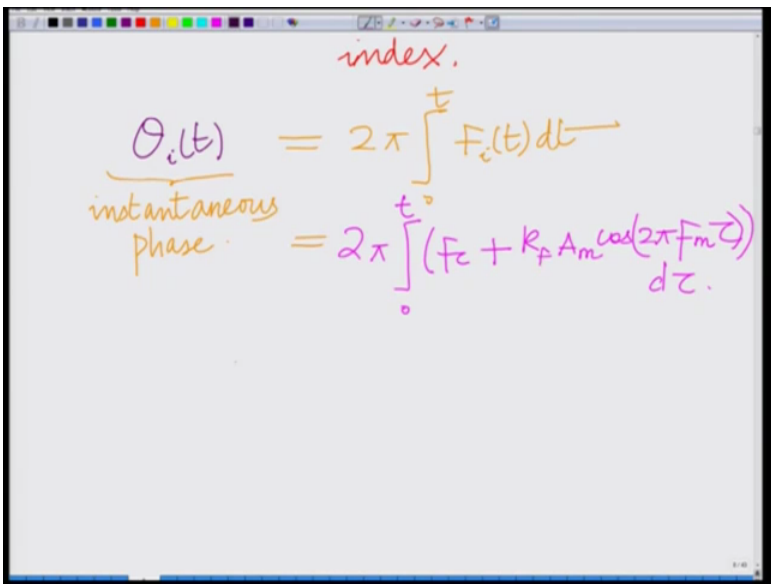

Now theta i t coming to Theta i t you can see that theta i t is the phase remember this is your instantaneous phase. We have frequencies the rate of change of phase, so phase is the integral of the frequency in fact 2pi times 0 to t Fi(t) dt which is equal to 2pi 0 to t Fc plus kF Am cosine 2 pi Fm Tau into d Tau.

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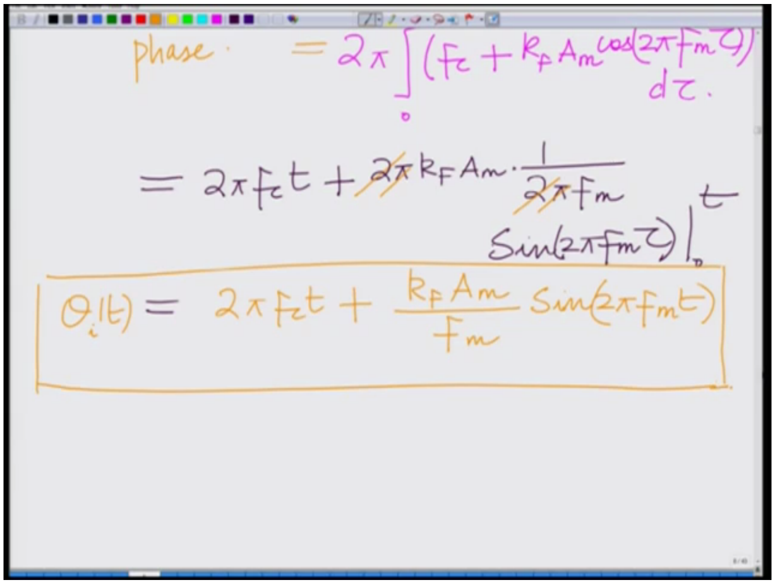

Which is equal to well 2pi Fct plus 2pi kF Am times integral of cosine 2pi Fmt Tau d Tau that is 1 over, well 2pi Fm times integral of cosine 2pi Fm Tau is sin 2pi Fm Tau evaluated between the limits 0 to Tau and therefore now if you can see we have this 2pi factor cancelling, so we have 2pi Fct plus kF Am divided by Fm sin 2pi Fmt, okay. This is basically the expression for your phase theta i t, okay. So this is basically the expression for the phase the instantaneous phase theta i t. And therefore the modulated signal, correct? This is the expression for the phase theta i t which is given as the integral of the instantaneous frequency Fit and therefore the modulated signal st is Ac cosine theta i t, alright.

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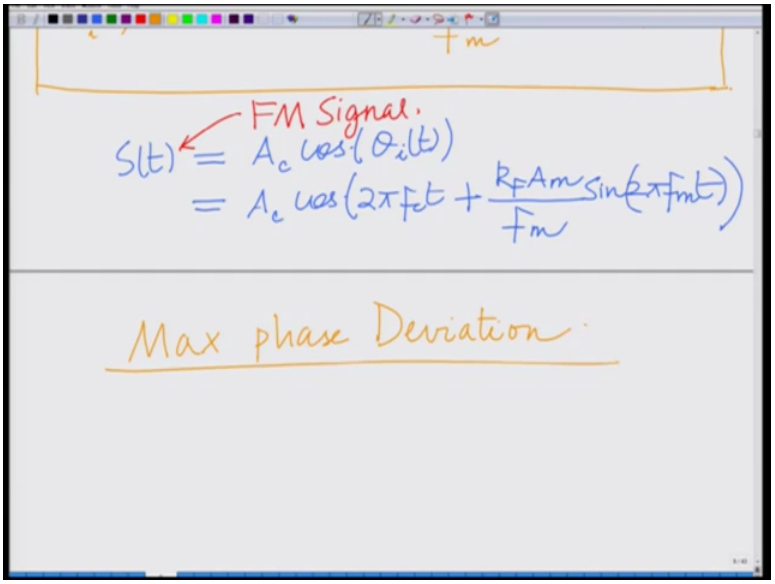

So the signal the FM signal is Ac cosine theta i t which is Ac cosine 2pi Fct plus kF Am by Fm sin 2pi Fmt, so this is basically your this is basically the modulated or this is basically your FM signal this is basically we can say this is the FM signal, okay. This is basically the FM signal Ac cosine theta i t that is Ac cosine 2 pi Fct plus kF Am divided by Fm sin 2pi Fmt.

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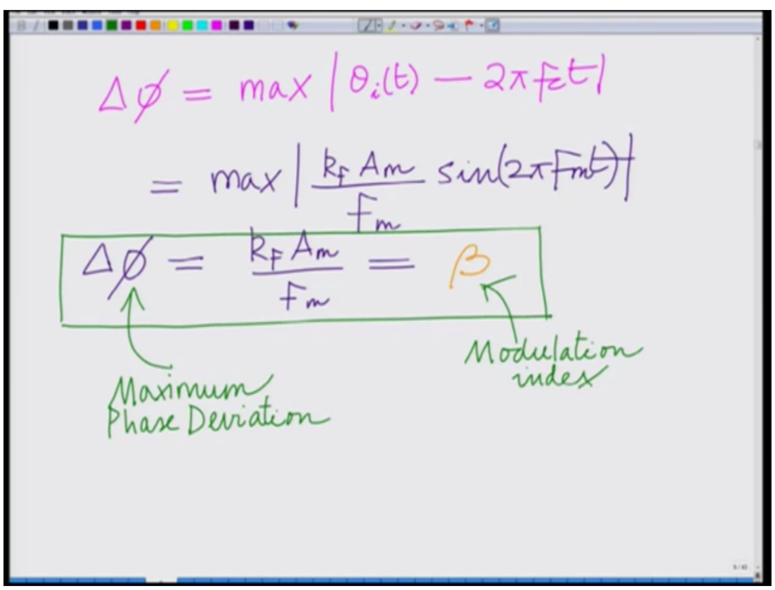

Now therefore now let us find the maximum phase deviation the maximum phase deviation will be Delta phi is maximum of theta i t minus well, 2 pi Fct which is maximum of well, you can see kF Am by Fm kF Am by Fm sin 2pi Fmt which is equal to kF Am by Fm which is again equal to you can say this is nothing but your modulation index beta.

So again the modulation index beta again for the frequency modulation also is equal to your phase deviation. So this is nothing but your beta which is basically your modulation index and this is the maximum phase deviation again it can be seen that even for the case of frequency modulation the modulation index is basically (eq) also equal to the maximum phase deviation, okay.

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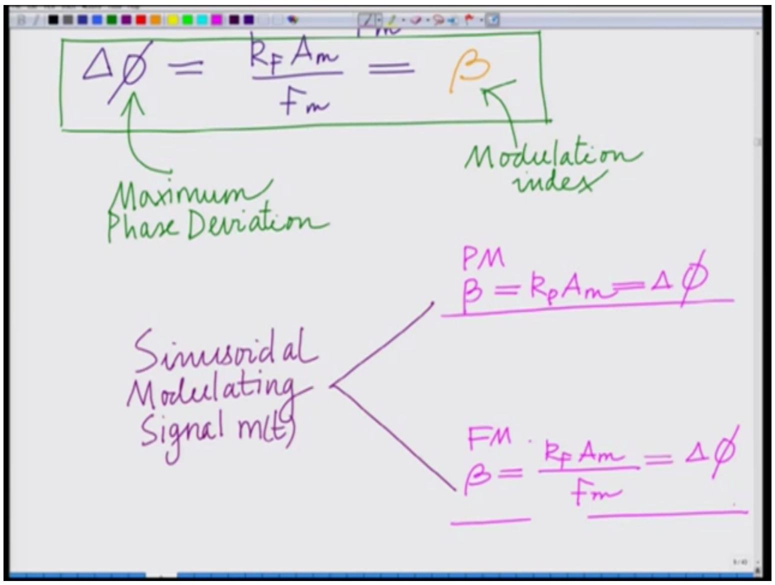

So we have looked at both your Sinusoidal module that is the frequency modulation that is if you look at a Sinusoidal modulating signal that is when you look at a Sinusoidal modulating signal m(t) we have the modulation index beta equals kP times Am for phase modulation and for frequency modulation we have beta equals kF times Am divided by Fm and in both cases this is also equal to your delta phi which is the maximum phase deviation, okay.

So for phase modulation it is beta equals kP times Am we have for frequency modulation beta equals kF times Am divided by Fm, okay. So that is what we have for our Sinusoidal modulating signal, alright. So we have considered both phase modulation and frequency modulation with a Sinusoidal modulating signal and we have derived the modulating index beta and the maximum phase the maximum frequency deviation modulation index and also the maximum phase deviation both the for both the scenarios and also the modulated signal, okay. So now what I want to like to do is like to demonstrate an example of a or basically pictorial example of a frequency and phase modulated signal, alright.

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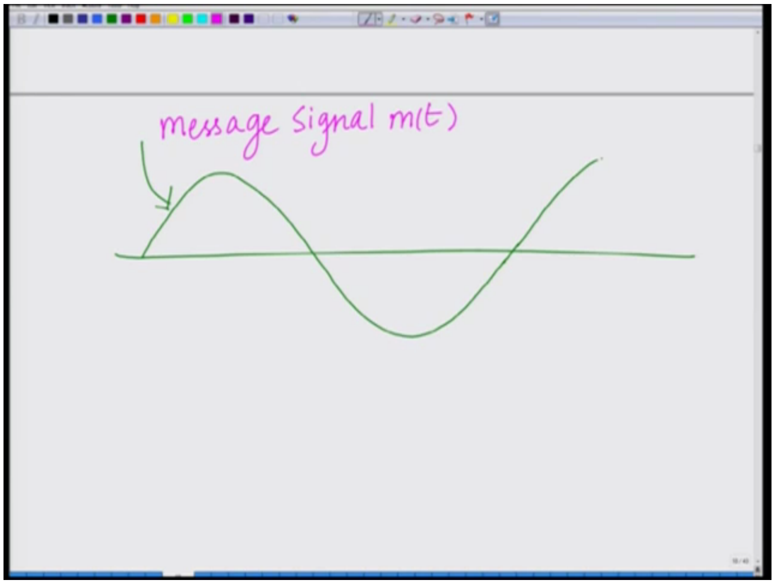

So let us consider a simple Sinusoidal modulating signal so let us say we have a simple Sinusoidal modulating signal, okay. So let us say we have a simple Sinusoidal modulating signal, okay. So this is your modulating signal or message signal let us call this the message signal m(t).

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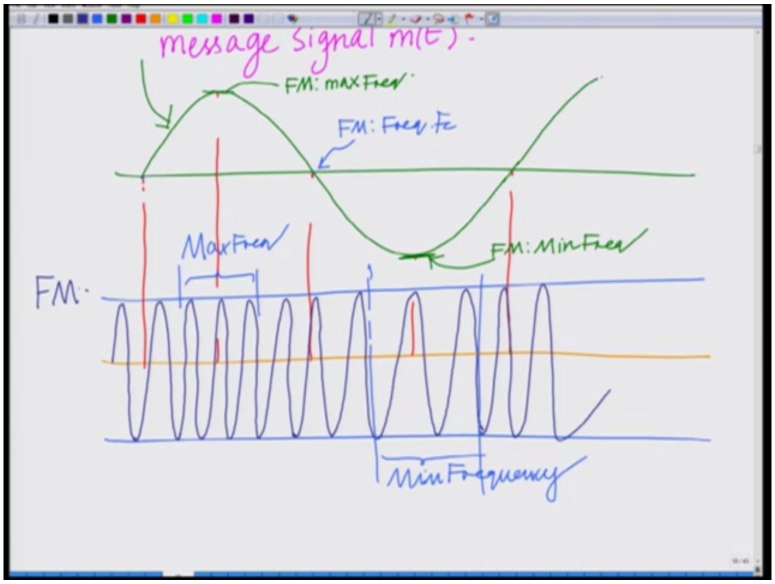

This is your message signal m(t) and now let us say we have a carrier which is modulated by this message signal m(t), so let us say I have a carrier which is modulated by this message signal m(t), now if you look at this there are a couple of points which are of special interest, correct? So this is your, okay. So I have a carrier which is modulated by the message signal m(t) and now you can clearly see that in this part if you can look at this, so this part where the message is high remember the message is modulating the frequency.

So this part corresponds to follow the Fm this part will be maximum frequency this part the lower the lowest part of the function will be for Fm this will be the minimum frequency and therefore here let us say we have a carrier at this part of course message is 0, so for Fm at this part frequency will be simply the frequency of the carrier because the message signal is 0 at the 0 crossing since message signal is 0, the message with a frequency of the carrier the instantaneous frequency will be simply the frequency of the modulated carrier that is FC.

So if I draw this it will look something like this at this point I will have the frequency of the modulated carrier slowly as it comes to words the as it comes towards the peak of the signal the frequency increases and once again it starts decreasing it starts decreasing to the frequency of the unmodulated carrier, okay. And then it becomes the frequency of the unmodulated carrier and frequency further decreases at this part which is the minimum this part corresponds to the lowest frequency and again it starts at when the 0 crossing it again it starts becoming equal to the frequency of the unmodulated carrier.

So here you can see that this portion somewhere around this portion corresponds to the maximum frequency this portion corresponds to the somewhere around this portion corresponds to the maximum frequency for frequency modulation and this portion somewhere around this portion corresponds to the minimum frequency this portion corresponds to minimum frequency and this is for a frequency modulated signal this is for a frequency modulated signal.

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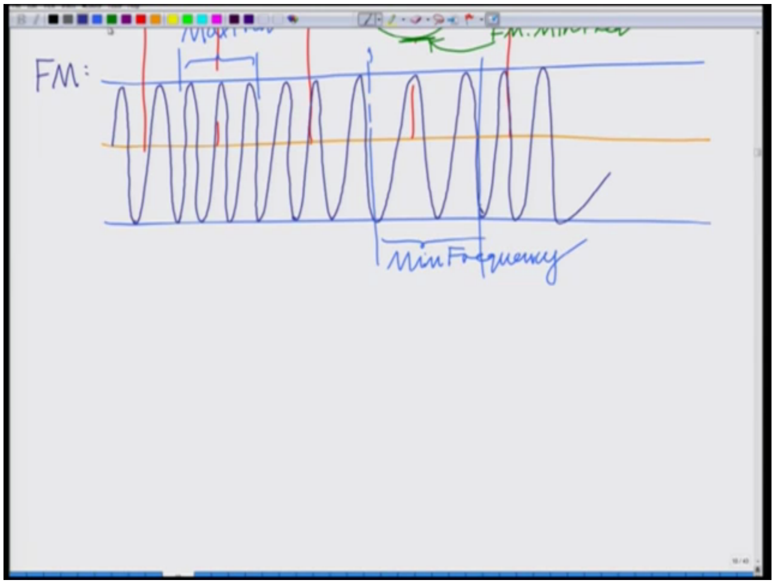

Now for phase modulation if ever to draw the same diagram for phase modulation we will observe something interesting, now for phase modulation, okay. Let us say this is envelope, remember the envelope is always going to be constant because the amplitude is not changing, right? So the envelope is always going to be constant. Now if you look at the phase modulation the message modulates the phase and the frequency is given by the derivative of the phase. So the frequency is maximum where the derivative of the phase is maximum.

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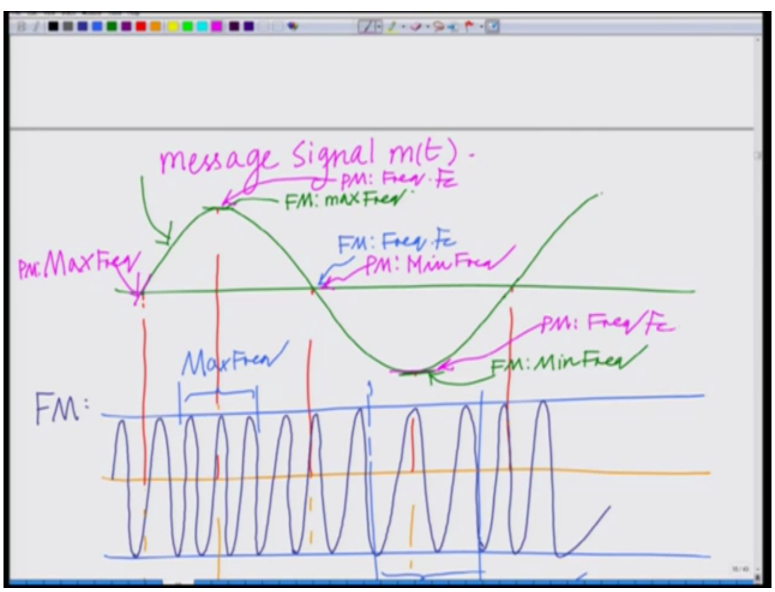

Now if you can see the message signal at this point we have maximum derivative that is the maximum derivative occurs at this point, so here that is at the 0 crossing the maximum (cros) that is at the 0 crossing with increasing amplitude the derivative is maximum, so this corresponds to maximum frequency phase modulation and this point here the 0 crossing where the (pha) amplitude is decreasing this corresponds to the minimum frequency. So this corresponds to minimum frequency for the and these 2 points where the derivative is maximum there function is maximum the derivative is 0. So for phase modulation this corresponds to simply the free carrier frequency that is Fc and also the minimum where the derivative is 0 for phase modulation corresponds to frequency corresponds to frequency simply Fc.

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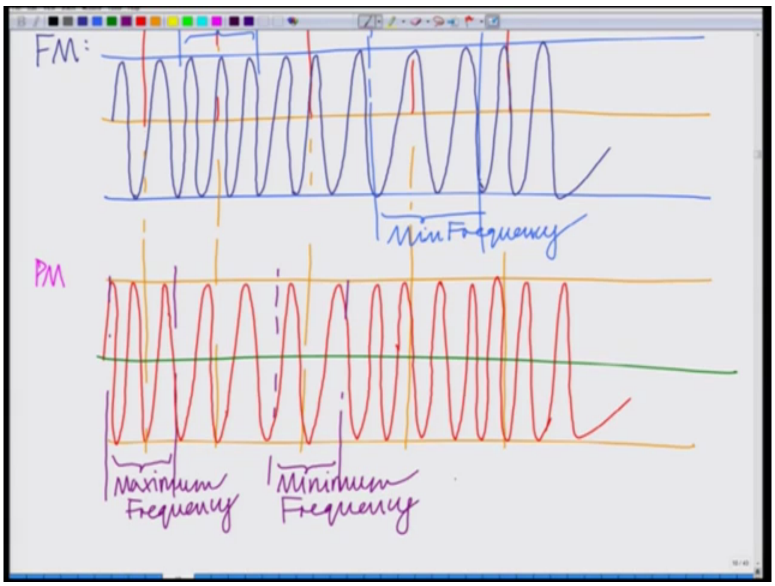

So if I draw this phase modulation at this point you will have maximum derivative, so at this point you will have frequency that is you will have frequency that is that is maximum slowly at where the function reaches the message reaches the maximum the frequency will become the free running carrier frequency that will become that will become Fc that will become Fc and at that point where the derivative is negative maximum therefore it will have the lowest frequency before again becoming the free running carrier frequency when the function reaches the minimum since the derivative is 0 and then again it reaches the maximum frequency when the derivative is maximum and so on.

So if you look at this function, this is your phase modulated signal, okay. If you look at the phase modulated signal the maximum will occur where the derivative, so this corresponds to the maximum frequency and where the derivative is where the (deri) where the derivative where the derivative is negative maximum that corresponds to, for instance this region this part corresponds to the corresponds to the corresponds to the corresponds to the minimum frequency.

So this is a simple example or a simple pictorial illustration or a good intuitive good insight into this frequency and into the free nature of frequency and phase modulated signal remember the message is modulating the frequency in a frequency (modulati) frequency modulated signal. So the frequency is maximum when the message is maximum and the frequency is minimum and the message is minimum. On the other hand in a phase modulated signal since the message is modulating the phase the frequency is maximum when the derivative of the message signal is maximum the derivative of the modulating signal is maximum and the frequency is minimum when the derivative of the modulating signal is minimum that is the negative peak, the negative peak of the modulating signal the frequency of the modulated signal is minimum and at the peaks of the modulating signal.

At the extrema of the modulating message signal since that derivative vanishes therefore in those points the frequency of the modulated signal is same as that of the frequency of the un-modulated carrier that is Fc, alright. So these are some things these are (su) these are interesting insights into the nature of both frequency and phase modulated signals.

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And also you will not that the envelope, note that the envelope is constant both for frequency modulation and phase modulation envelope.

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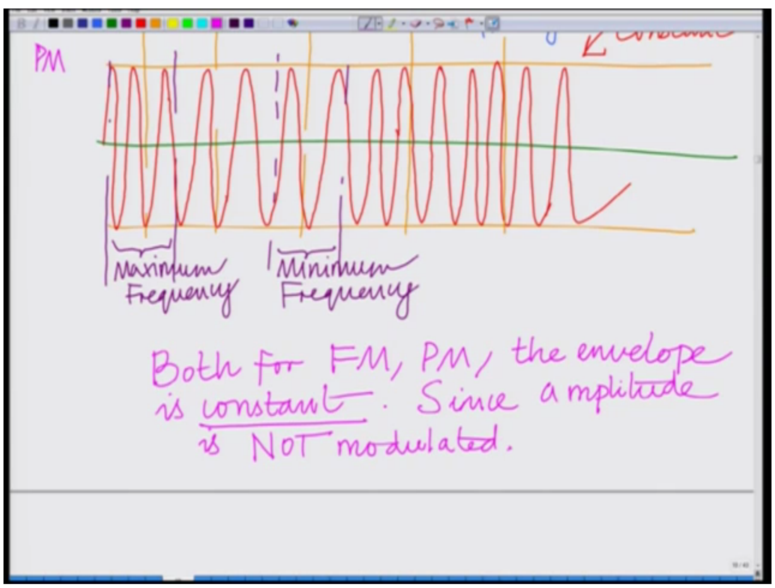

So both for frequency and phase modulation the envelope is constant because amplitude is not, both for FM and PM there frequency modulation and phase modulation the envelope the envelope is constant this is because amplitude is not modulated. Since amplitude is not so the envelope is constant it is just that the frequency or the phase varies according to the message signal.

And also the other thing that we have seen is that in phase modulation in particular if there are discontinuous in message if there are discontinuities is in the message signal that results in discontinuities in the phase of the modulated carrier and that causes problems because that gives rise to high frequency components which increases the bandwidth which drastically increases the bandwidth of the signal, alright.

So frequency modulation is preferred in comparison to phase modulation because frequency modulation does not even if even when the even when there (discontinuis) discontinuities in the message signal the phase the resulting phase of the frequency modulated signal is still continuous because frequency (modul) because the phase of the frequency modulated signal is given by the integral of the integral of the instantaneous frequency, alright.

So even if there is discontinuities in the message signal they will be smoothen out by the integration operation, alright. So that avoids the high frequency components, alright. So these so in this module we have looked at frequency modulation with Sinusoidal modulating signal derived the modulating index the frequency deviation and the phase deviation and also we have looked at summary presentations or (())(24:41) insights into the nature of this frequency and phase modulated signal by giving a pictorial description of some simple frequency and a phase modulated signal, alright. So we will end this module here and look at other aspects in the subsequent modules, thank you.