Principles of Communication- Part I
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Module No 5
Lecture 28
Introduction to Angle Modulation, Description of Phase Modulation (PM) and Frequency Modulation (FM)

Hello and welcome to another module in this massive open online course, so today we will start looking at a different type of modulation that is angle modulation, alright.

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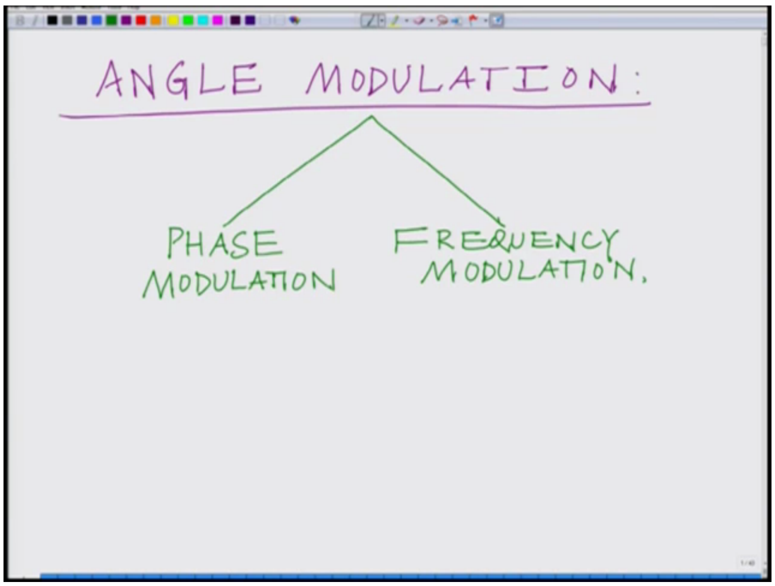

So in today's in this lecture will start looking at so far we have looked at amplitude modulation we will now look at different form of modulation that is termed as angle modulation, okay. An angle modulation can belong to 2types either it can be either phase modulation. So angle modulation can either be phase modulation or it can be, frequency modulation or it can be frequency modulation and we will start looking at both these different branch of modulation. So angle modulation can either be of the type phase modulation for frequency modulation frequency modulation, so first let us start looking at phase modulation, okay.

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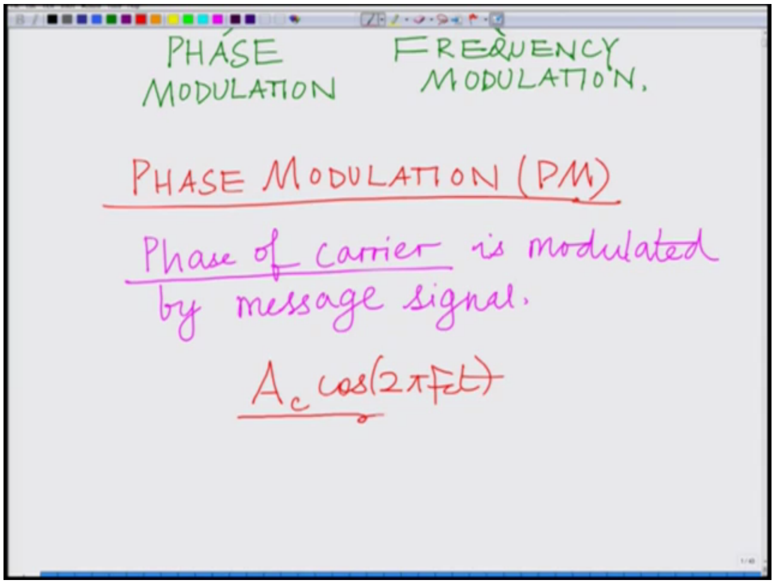

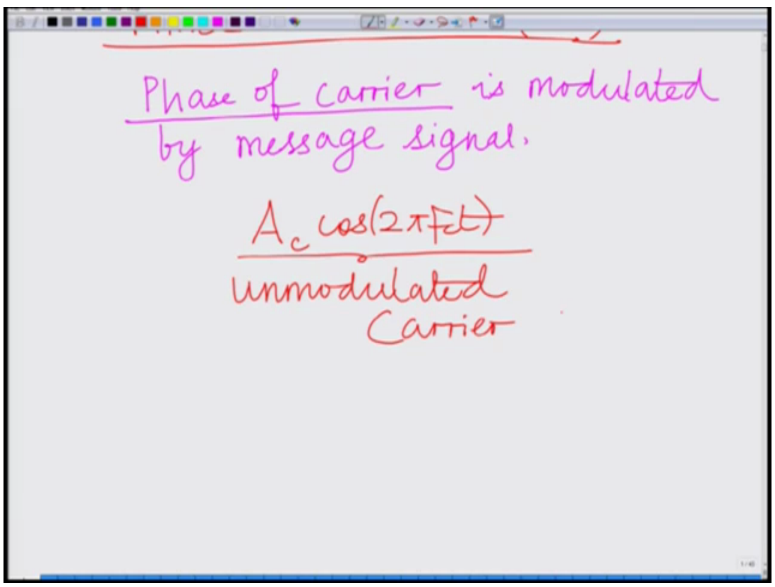

So now in phase modulation obviously as the name implies, so you phase modulation which can be denoted by PM. So in phase modulation we have the phase of a carrier, so phase of carrier is modulated by the message is modulated or varied by the message signal. So the phase of the carrier is modulated by the message signal for instance let us say your carrier signal is Ac cosine 2pi Fct this is your modulated carrier, correct? So this is the this is your un-modulated carrier signal, what we are going to do is we are going to we are going to modulated the phase of this.

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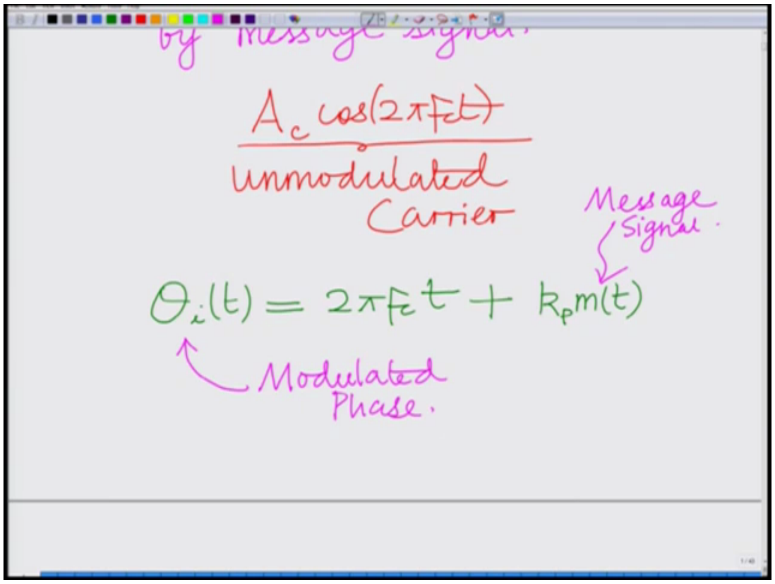

So if I take the phase that is theta i of t and if I modulated it as follows that is this is the un-modulated phase that is 2pi Fct plus, now modulated using a message signal that is m(t) where m(t), remember m(t) is the message signal so this is theta i t this is a modulated phase or this is basically your this is the modulated phase, so the phase of the modulated message signal is 2pi Fct plus kP times m(t). You can see the phase is modulated by the message signal m(t). So therefore the carrier with its phase modulated by this message signal is given as.

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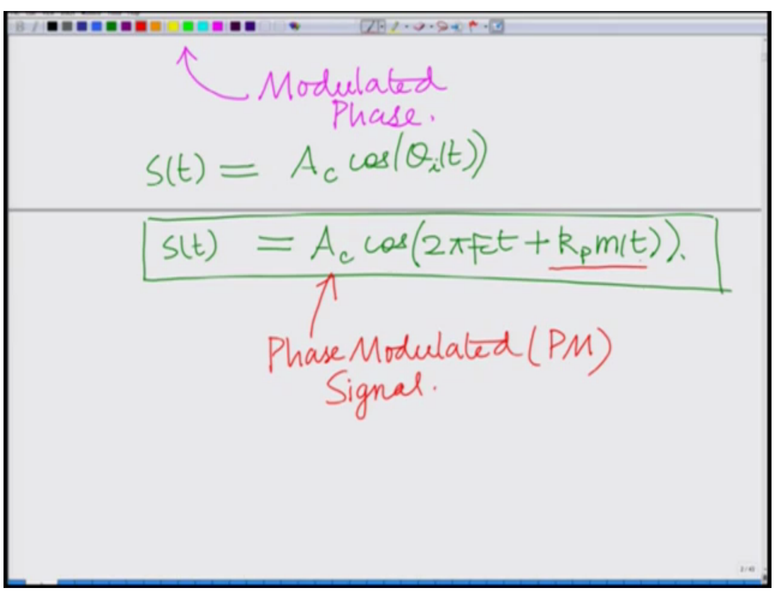

Now the modulated carrier is given as or the modulated signal is given as Ac cosine Theta theta i t which is basically Ac cosine 2pi Fct plus kP times m(t) so this is a phase modulated signal. So this is your this is your phase modulated signal where the face of the signal is modulated by the message signal m(t), okay. And what you can see is because of this message signal where the phase is modulated by the message.

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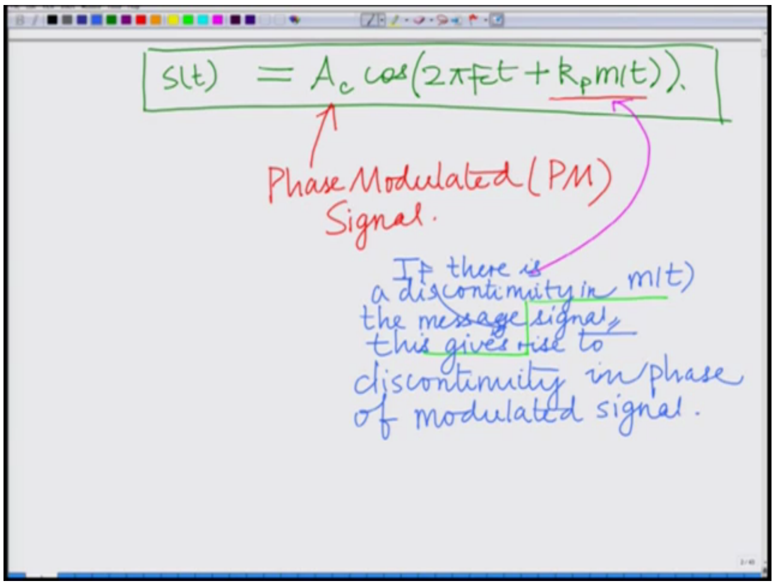

What you can see is if the message has a discontinuity if the message has a discontinuity that is for instance if the message is a step function for instance if the message has a discontinuity than the phase of the modulated signal experiences a discontinuity this gives rise to high frequency components. So what happens the disadvantage with this is that if there is a discontinuity or if there is a discontinuity or let us say this is your m(t) if there is a discontinuity in the message signal this gives rise to this gives rise to discontinuity or this gives rise to discontinue in the phase of the continuity in phase of the of the modulated signal which leads to and this leads to high frequency components.

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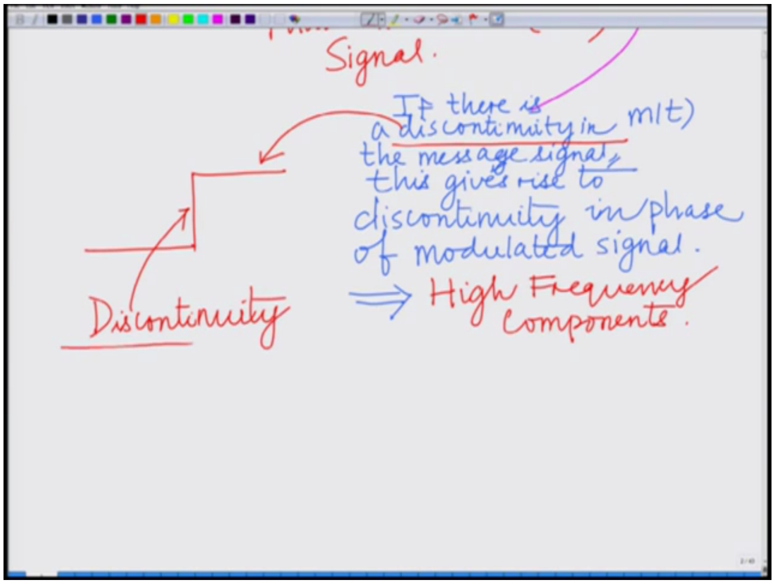

This leads to high frequency components and output, so what we can see is if we have a signal which is discontinuous, right? If there is a discontinuity in the message signal which is something like this. If there is a discontinuity in the message signal, so this is your discontinuity, okay. If there is a discouraging the message signal that means there is going to be a discontinuity in the phase of the modulated signal and this discontinued and the phase of the modulated signal gives rise to high frequency components in the output therefore to avoid this we use another different form of angle modulation that is termed as frequency modulation.

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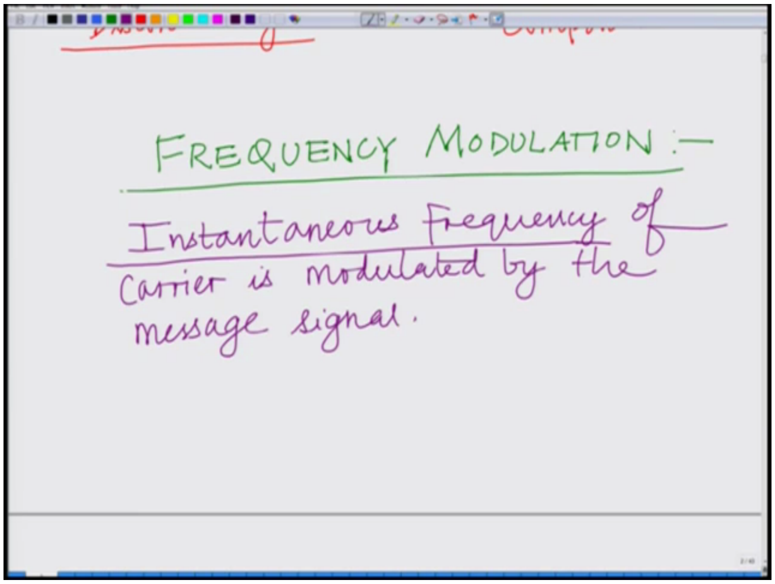

So frequency modulation is another kind of angle modulation so frequency modulation so let us now come to frequency modulation in the frequency modulation instantaneous frequency of the modulator scared so the instantaneous frequency of carrier is modulated by the message signal. So in this what we have is the instantaneous frequency is modular rather than the phase in the phase modulation the phase of the signal carrier is modulated by the message which results in phase discontinuity.

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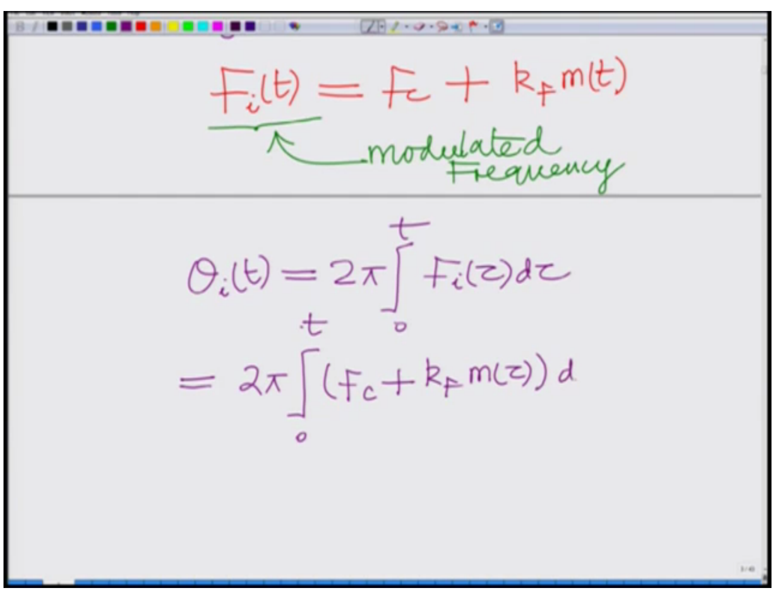

However in frequency modulation the instantaneous frequency is modulated by the message signal and this can be expressed as follows, so if Fi(t) is the instantaneous frequency so the instantaneous frequency equals Fc that is the steady state frequency, frequency of the modulated carrier plus kF times m(t). Once again m(t) is the message signal, so this Fi(t) is the modulated frequency modulated frequency or basically the, now you can think of this as the instantaneous frequency of the modulated signal so you can think of a signal carrier wave in which the frequency at every time instant depends on the modulating message signal m(t), okay.

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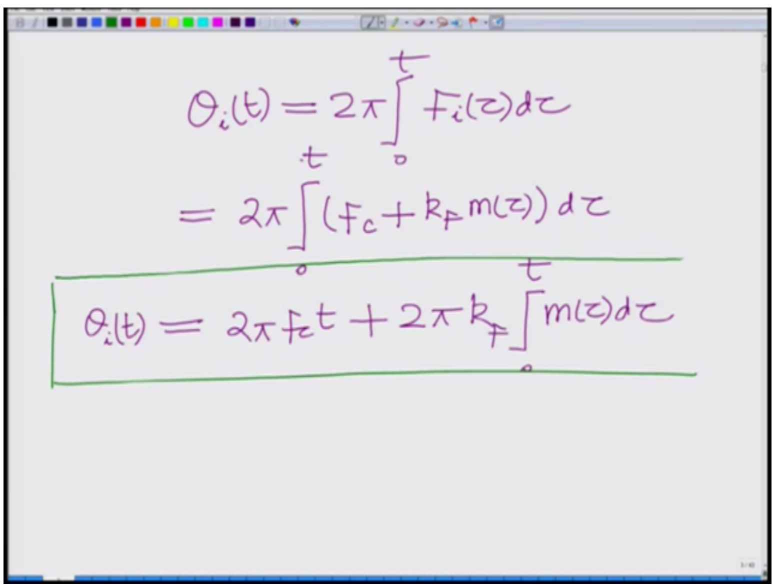

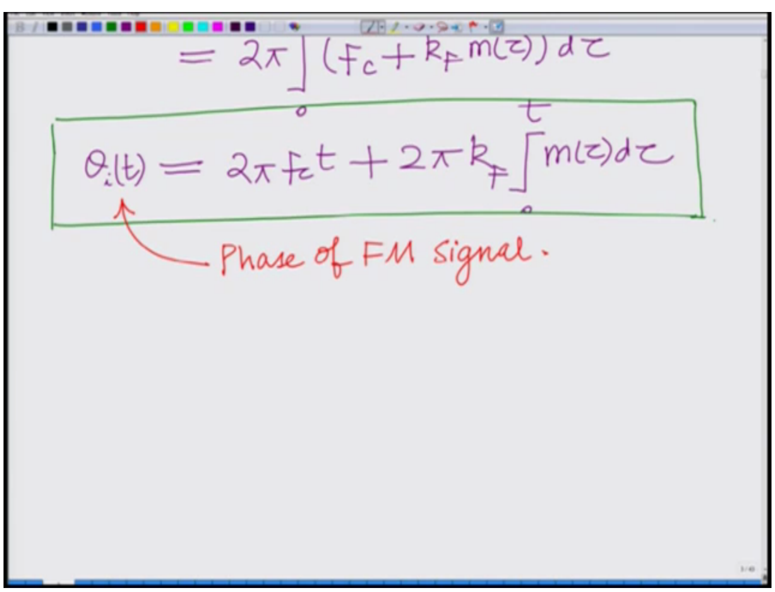

So therefore the phase now remember the phase frequency is the rate of change of phase therefore the phase of this is given as theta i t equals 2pi integral 0 to t Fi Tau d Tau which is basically 2pi integral 0 to t Fc plus kF m Tau d Tau which is equal to 2pi Fct plus 2pi integral 0 to t kF or rather 2pi kF since kF is a constant 0 to t m Tau t Tau that is your theta i that is your theta i this is the phase this is a phase of the frequency modulated signal.

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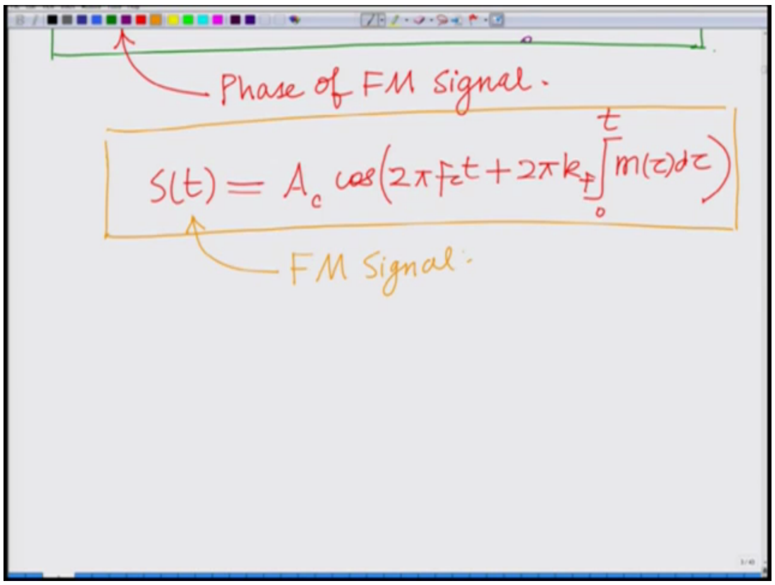

The frequency modulated signal or Fm signal therefore and therefore and now you can see and therefore the modulated carrier is given as you are st is basically Ac cosine well, 2pi Fct 2pi kF integral 0 to t m Tau d Tau this is your frequency modulated signal, okay. So this is the expression for the Fm, so this is st is your frequency modulated signal, okay. So we are saying that the carrier the frequency instantaneous frequency Fi(t) is basically 2pi is basically Fc plus kF times m(t) and therefore from that by integrating the frequency from 0 to t you can get the phase because the phase is the (rea) because frequency is the rate of change of phase and from the phase you can get basically the modulated carrier, alright. And this gives you the expression of the Fm signal.

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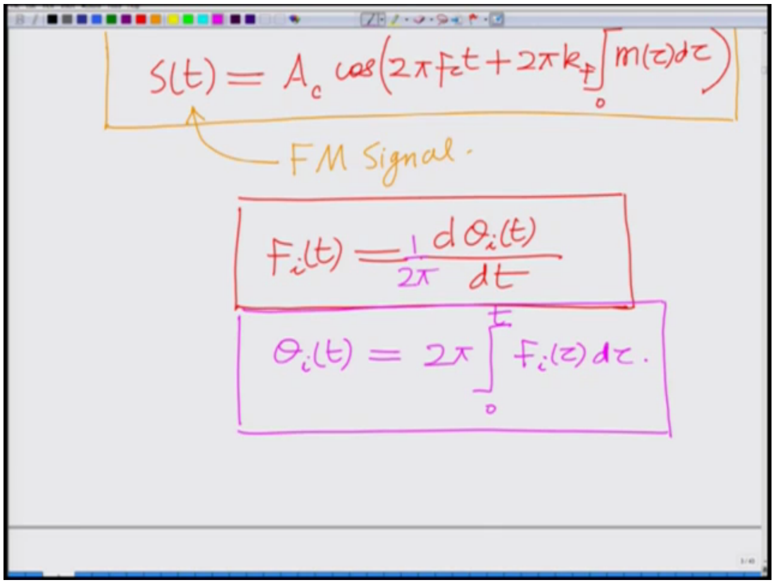

Also now Fi(t) remember Fi(t) equals we you are using this relation we can also get Fi(t) remember this it makes sense remember this relation Fi(t) in the instantaneous frequency is the rate of change of the instantaneous phase that is the theta i t divided by dt dt and also we have used basically the relation that therefore follows that theta i t equals and this has to be there has to be a factor of 1 over 2pi and theta i t is basically integral 0 to t Fi tau d fi tau d tau that is the that is the expression for the expression for the instantaneous phase, okay.

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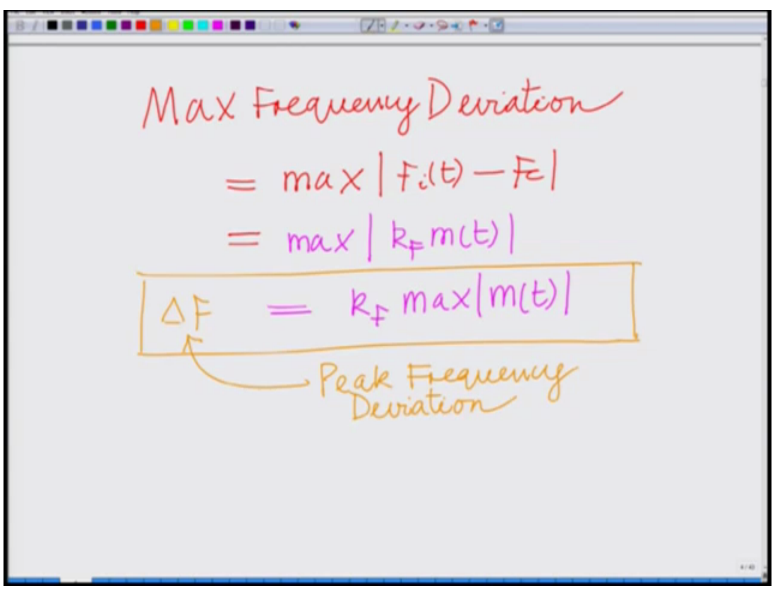

That is the expression for the instantaneous phase and further one can define the peak frequency deviation of this the maximum frequency deviation can be defined as well maximum you can see deviation can be defined as this can be defined as maximum of magnitude of Fi(t) minus Fc which is equal to the maximum of magnitude Fi(t) minus Fc you can see that is equal to kF times m(t) which is equal to well, kF times the maximum of magnitude m(t) that is your Delta F.

That is your maximum the maximum frequency deviation or basically the peak frequency deviation, so this Delta F is basically your maximum frequency deviation or basically it denotes the frequency deviation, okay. This is the meaning this is the definition of the quantity Delta F, okay. Now let us consider a simple example let us look at a Sinusoidal modulating signal so let us consider a specific example of Sinusoidal modulation.

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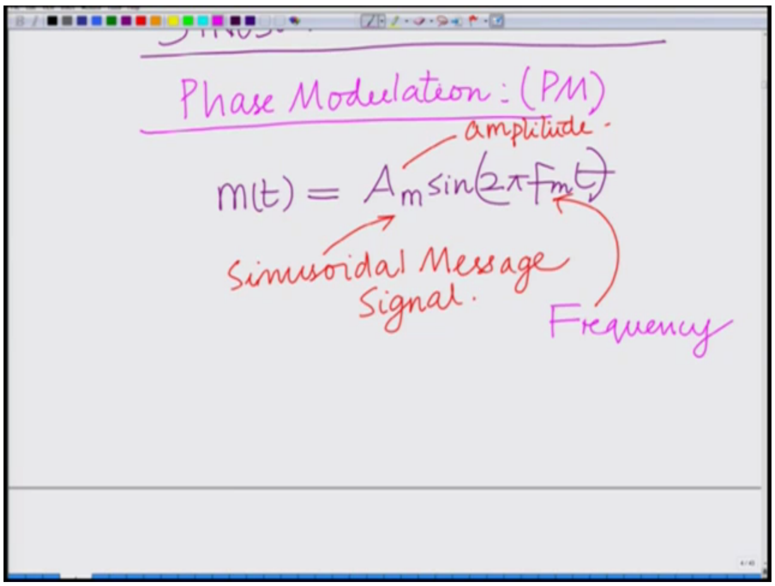

Let us look at the specific example of Sinusoidal modulation in that let us again once again start with let us once again start with phase modulation that is PM and let the modulating message signal the m(t) modulating message signal is m(t) equals Am sin 2pi Fmt we are considering a Sinusoid modulating signal, correct? We are considering a m(t) we are considering specifically to be a Sinusoidal a Sinusoidal message signal, okay. We are considering the specific case of Sinusoidal message signal with amplitude Am this is as you know Am is amplitude Fm is the frequency of Sinusoidal message signal Fm is the frequency of the Sinusoidal message signal, okay.

And therefore in this scenario remember in phase modulation the message signal modulates the phase of the carrier therefore we have theta i t is basically 2pi Fct that is the regular phase 2pi Fct plus the phase offset which is given by the message that is kP times m(t).

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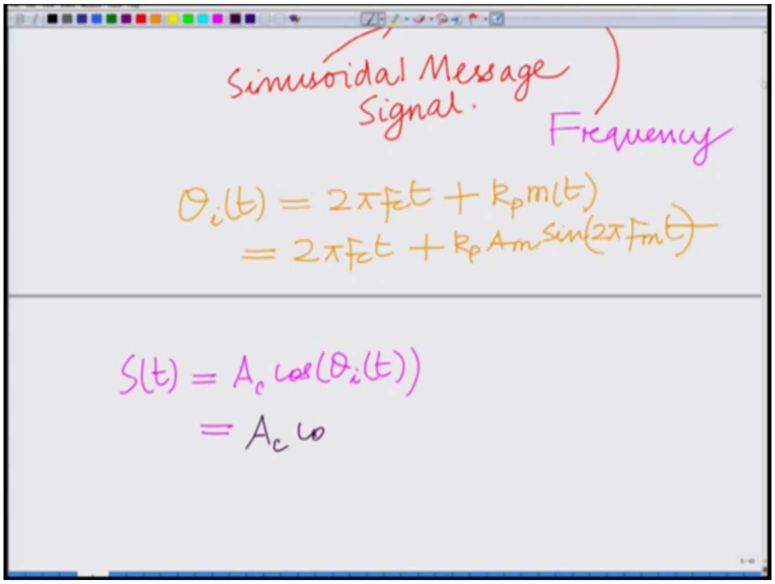

Therefore we have theta i t equals 2pi Fct plus kP times m(t) but we have m(t) is Am sin 2pi Fmt, so this is simply your 2 2pi Fct plus kP times Am sin 2pi Fmt.

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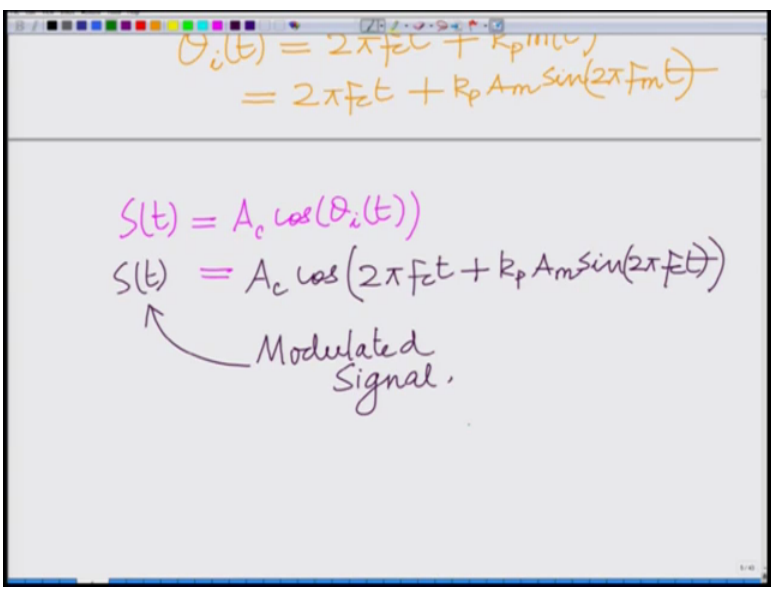

So this is your theta i t the net modulated message signal is given by st equals Ac cosine theta i t which is basically your Ac cosine 2pi Fct plus kP Am sin 2pi Fct this is the modulated signal, okay. St is your st is the modulated signal, okay. Now Fi(t) that is we have theta i t.

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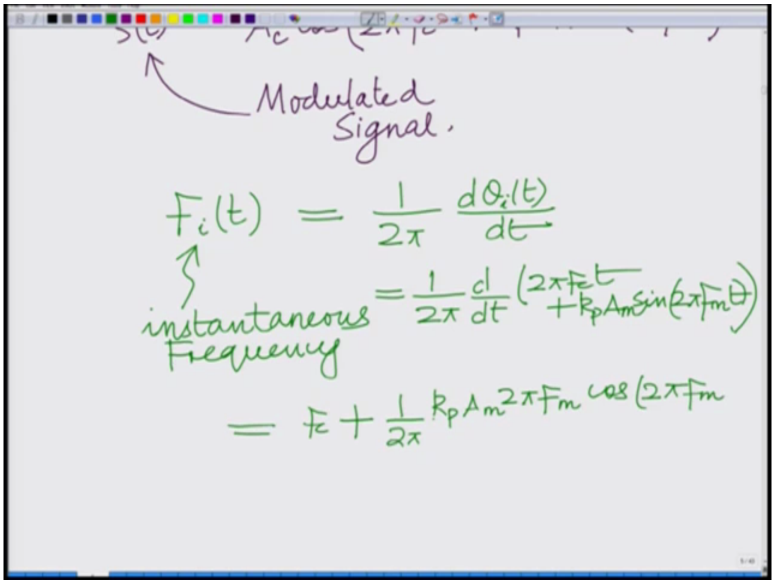

Now the frequency instantaneous frequency Fi(t) remember, Fi(t) is your instantaneous frequency, okay. So this so the instantaneous frequency is given as1 by 2pi d theta i t by dt which is basically given as which is basically equal to this is equal to Fc, well one over 2pi let us write the expression for d over dt of well, theta i t as we know 2pi Fct plus kP Am sin 2pi Fmt which is equal to well, Fc plus well, the derivative 1 over 2pi times derivative kP Am sin 2pi Fmt which is kP Am into 2pi Fm into the derivative of sin 2pi Fmt is cosine 2pi Fmt and now basically this can be simplified further as Fc plus we have the 2pi is cancelling.

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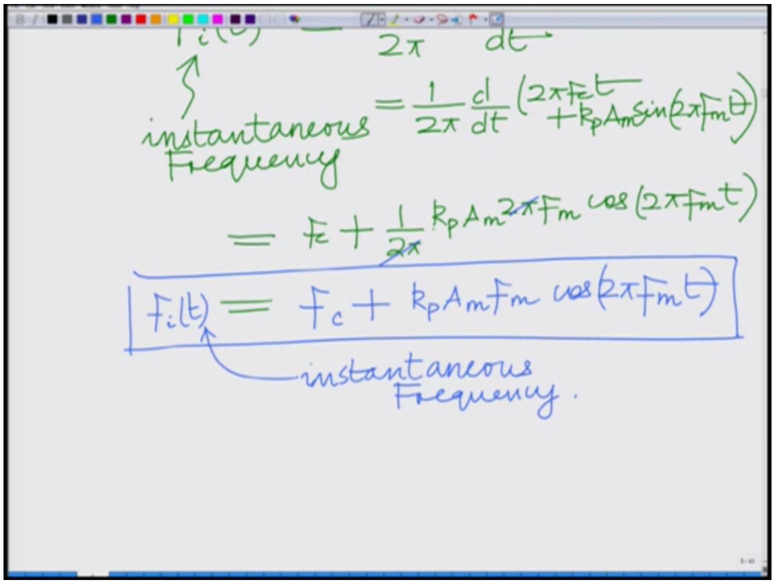

So this is kP Am Fm kP Am Fm into cosine 2pi Fmt this is the instantaneous frequency. This is your expression for the instantaneous frequency. This is the expression for the this Fi(t) this is the expression for the instantaneous frequency Fi(t) of this phase modulated signal phase which is modulated by the Sinusoidal message signal Am sin 2pi Fmt, okay.

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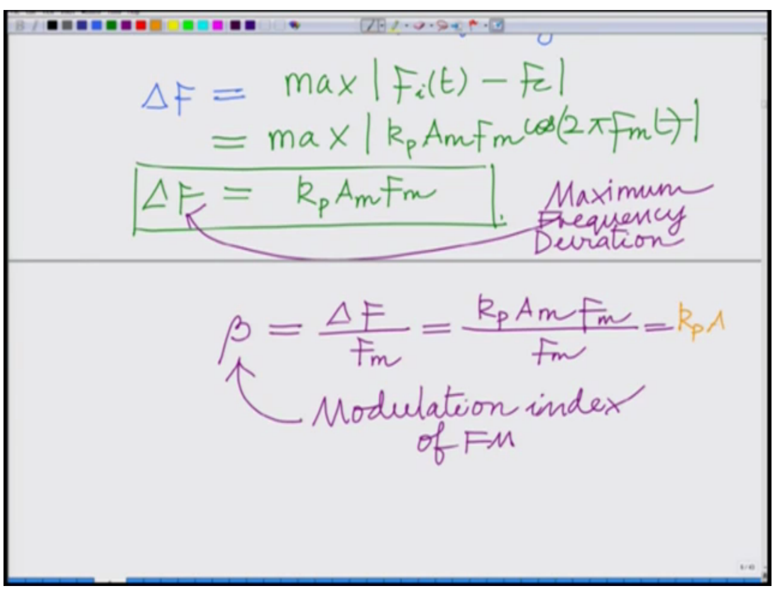

Now this is Fi(t) let us find the frequency deviation of this remember Delta F frequency deviation is the maximum of Fi(t) minus Fc there is a unmodulated frequency of the unmodulated carrier which is basically maximum as you can see from above Fi(t) minus Fc is kP Am Fm cosine 2 pi Fmt and therefore the maximum of kP Am cosine 2pi Fe Fmt the maximum magnitude of this is basically kP Am times Fm. So we have Delta F that is the frequency deviation, remember what is Delta F? Delta F is the maximum frequency deviation, okay.

This is the maximum frequency deviation equals kP Am times Fm which implies that beta, now beta can be expressed as therefore beta can be expressed as Delta F by F remember beta is the modulation index of Fm which is equal to kP Am from the above a it's kP Am well, Delta F by Fm kP Am well, let us write the complete thing kP Am Fm divide by Fm which is equal to kP times Kp times Am.

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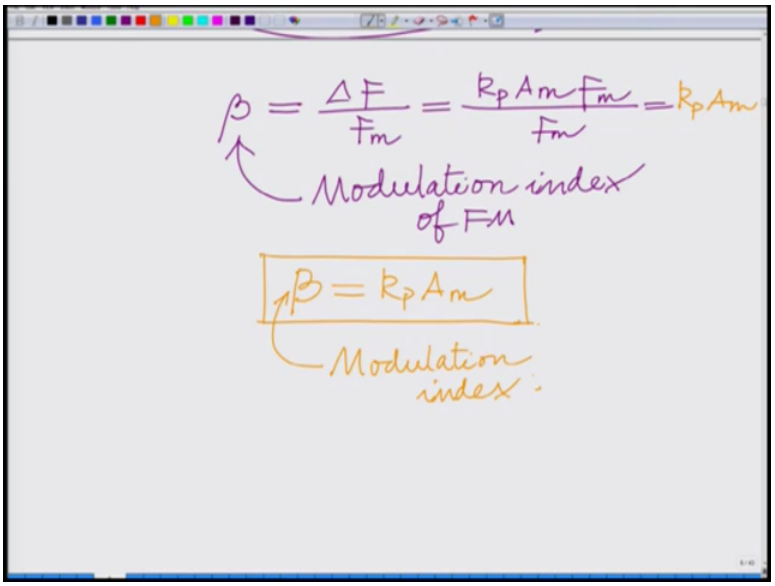

Therefore beta this is the modulation index equals kp times Am and look at this you can see this kp times Am this is also equal to the maximum phase deviation.

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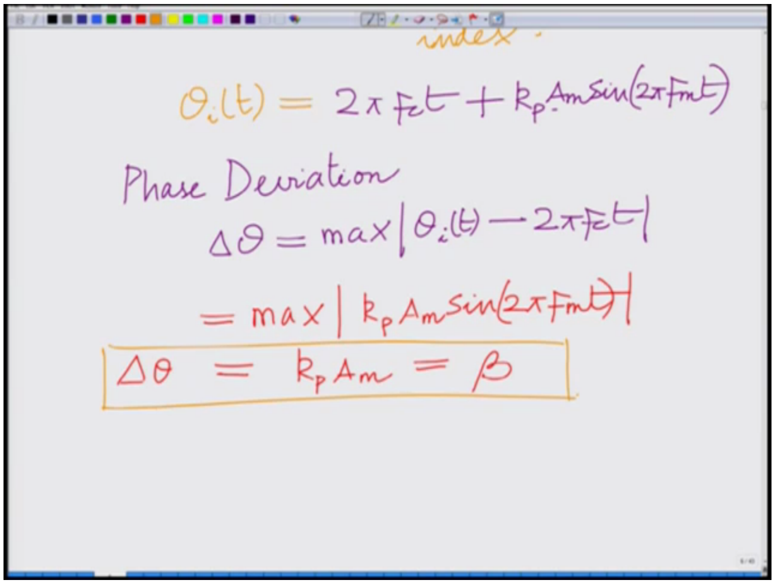

For instance if you look at if you look at this thing if you look at the phase remember the phase is theta i t theta i t equals well, theta i t equals 2pi Fct plus kP Am times sin 2pi Fmt, now phase deviation Delta theta equals maximum magnitude Delta I theta i t minus 2pi Fct which is equal to the maximum of well. Substituting theta i t minus 2pi Fct we get kP Am sin 2pi Fmt which is equal to maximum of kp Am sin 2pi Fmt is equal to kP Am, so this is equal to Delta theta and you can also see, so this is the Delta theta and this is also you can see this is also equal to your beta that is the modulation index.

So for Sinusoidal modulation what you can see is beta equals that is with phase modulation with Sinusoidal modulating signal with that is where the phase is given by 2pi Fct plus kp times m(t) what we have been able to show that is for m(t) equals Am sin 2pi Fmt what we have been able to show that this modulation index beta which is defined as peak frequency deviation divided by Fm the frequency of the modulating signal that is equal to kp times Am which is also seem to be the maximum phase deviation of the signal, okay.

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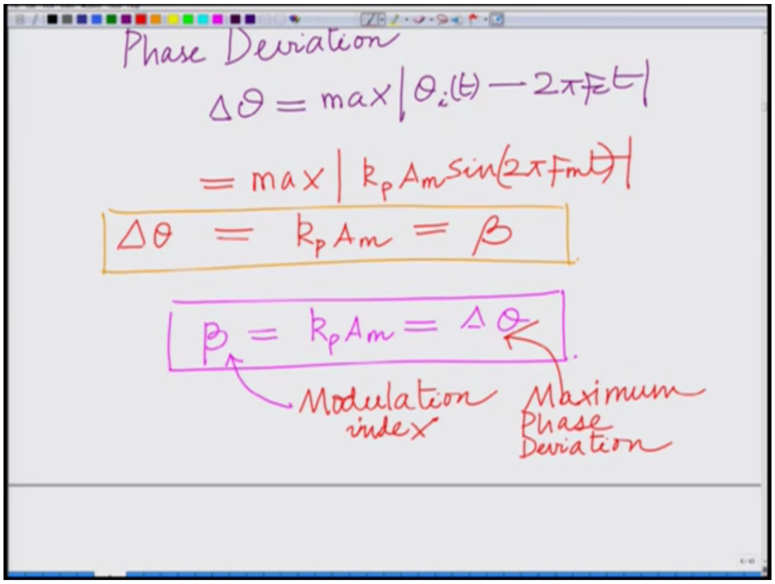

So we have beta equal to what we have derived is we have beta equals the modulation index equals kP times Am which is also equal to Delta theta which is also basically so your beta is basically the beta is basically the modulation index and Delta theta is basically the maximum phase deviation and Delta theta is the maximum phase deviation, alright. So in this module we have seen an introduction, alright. We have started looking at angle modulation we have said that there are 2 different kinds of angle modulation namely phase modulation and frequency modulation we have described overview we have given an overview of both phase modulation and frequency modulation and we have also seen the specific case of a (phan) phase modulated signal for a Sinusoidal modulating message signal, alright. So we will stop here and continue with other aspects in the subsequent modules, thank you.