Principles of Communication- Part I
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Module No 6
Lecture 34
Demodulation of Frequency Modulated (FM) Signals, Condition of Envelope Detection

Hello welcome to the module in this massive open online so in the previous module we have looked at the bandwidth of an FM signal the approximate bandwidth occupied by an FM signal which is given by the Carson's rule, okay. So in this module let us start looking at the demodulation of an FM signal.

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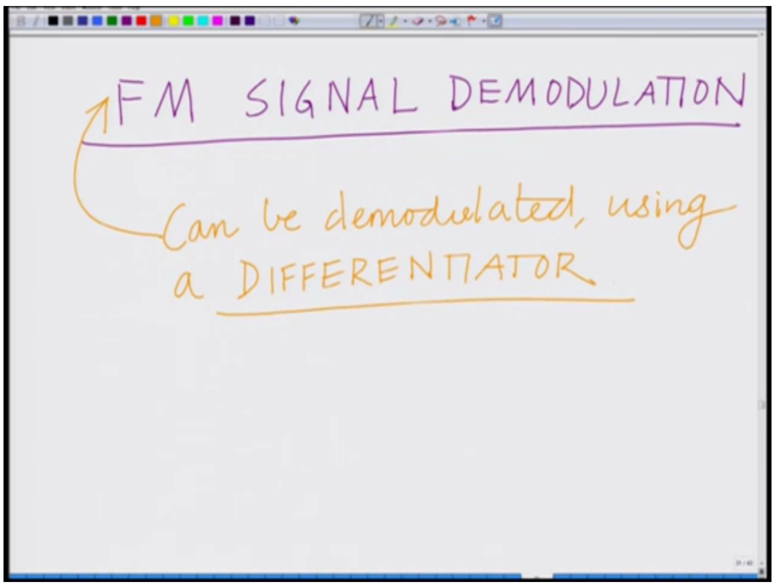

So we want to start looking at basically we want to start looking start looking at FM signal demodulation that is a demodulation of an FM that is a demodulation of an FM signal. And FM signal can be demodulated the technique for demodulation the FM signal is through the use of a differentiator circuit, okay. So we are going to illustrate how to demodulate the FM signal using a differentiator. So FM signal can be demodulated this can be demodulated using a differentiator the idea is basically we have this FM signal, okay.

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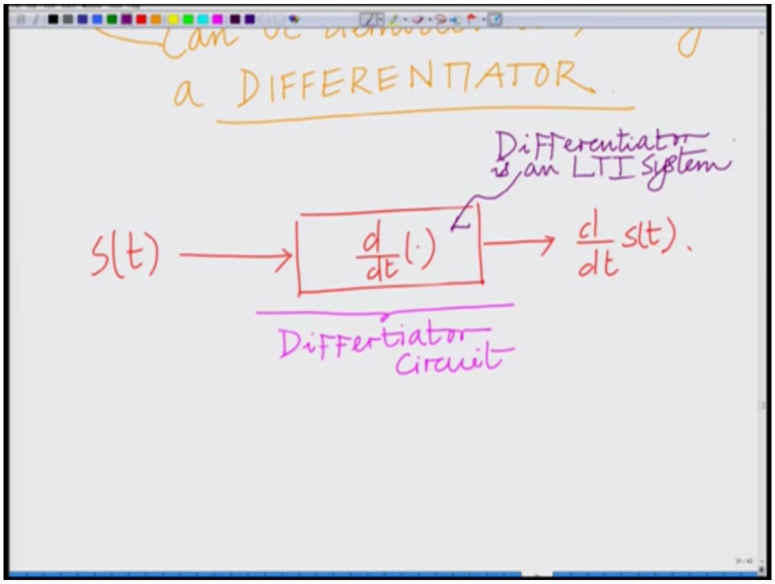

So I have an FM signal s of t I can give it as input to a differentiator circuit which performs the operation which differentiates the input and the output is d by dt of st this is your differentiator this is your differentiator circuit. By the way a differentiator you can realize you will realize is a linear time invariant system, okay. So it is this is a very important property of a differentiator, correct? So this is a linear time invariant system, okay. So you can also note that the differentiator the differentiator is an LTi system, okay.

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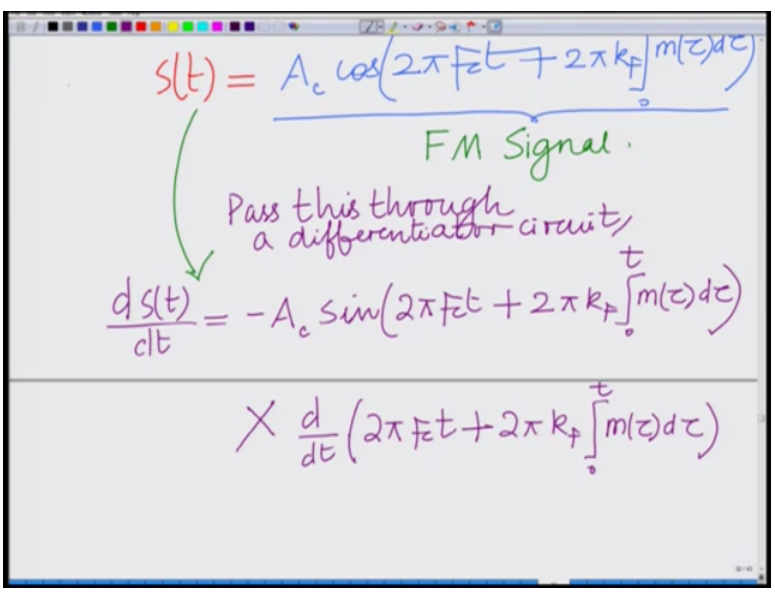

And now let us consider our FM signal our standard FM signal which is given as St equals Ac cosine 2 pi Fct plus 2 pi kF integral 0 to T m Tau d Tau, okay. This is my FM signal, okay. We have seen this several times before this is an example of a canonical or a general this is an example of a general FM signal. Now if we pass this through a differentiator now when we pass this through a differentiator so when we pass this through a when we pass this through a differentiator circuit the output is well, we have seen that it differentiates the input that is d st by dt that is the derivative of st which is Ac cosine the signal is Ac cosine the signal is Ac cosine 2 pi Fct plus 2 pi kF integral m Tau d Tau we can see the derivative of this is minus Ac derivative of cosine is minus sin, so minus sin 2pi Fct plus 2pi kF integral m Tau d Tau times the derivative of well, the argument that is 2pi Fc Tau plus 2 pi integral 0 to t m Tau d Tau that is argument of the cosine function, okay.

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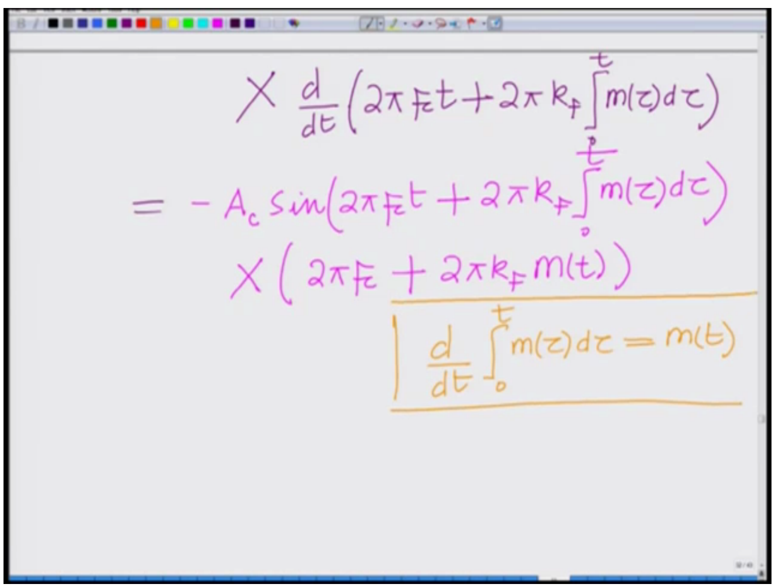

So we are employing the chain rule for differentiation which is basically equals which basically equals minus Ac well, sin 2 pi Fct plus 2 pi integral 0 to t m Tau d Tau times now you can see the derivative of 2pi Fct plus 2pi kF integral 0 to T m Tau d Tau is nothing but 2pi Fc plus derivative of 2pi kF integral 0 to t m Tao d Tao is nothing but 2 pi kF m(t), okay. Here we have use the property the derivative we are using the property that the derivative which is respect to t of integral 0 to t m tau d tau is nothing but m(t), okay. This is the property that this is the property that we are that we are basically using, okay. It is a very simple property that if you differentiate the integral of a function you get the function itself, okay.

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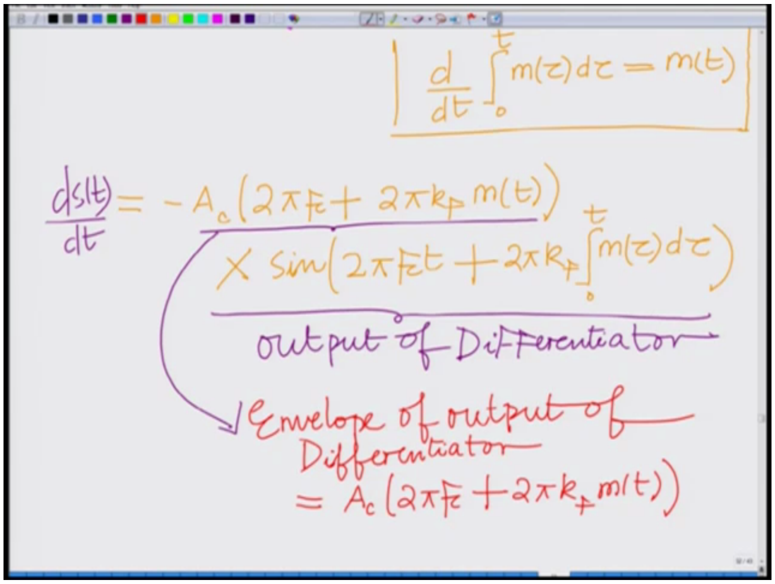

And therefore now I can rewrite this as minus Ac bringing the argument to the front 2pi Fc plus 2pi kF m(t) times well, sin of 2pi Fct plus 2pi kF integral 0 to t m Tau d Tau and now if you look at this signal the resultant signal, so this is basically your output of the differentiator, correct? That is this is basically your dst by dt and now if you can see look at the output of this differentiator you can see that the envelope of this is basically envelope of the output the output is a Sinusoidal signal the envelope the output is basically the envelope of output of differentiator equals Ac 2pi Fc plus 2 pi kF m(t), so what you can see is that the envelope of the output of this differentiator is proportional to m(t), okay.

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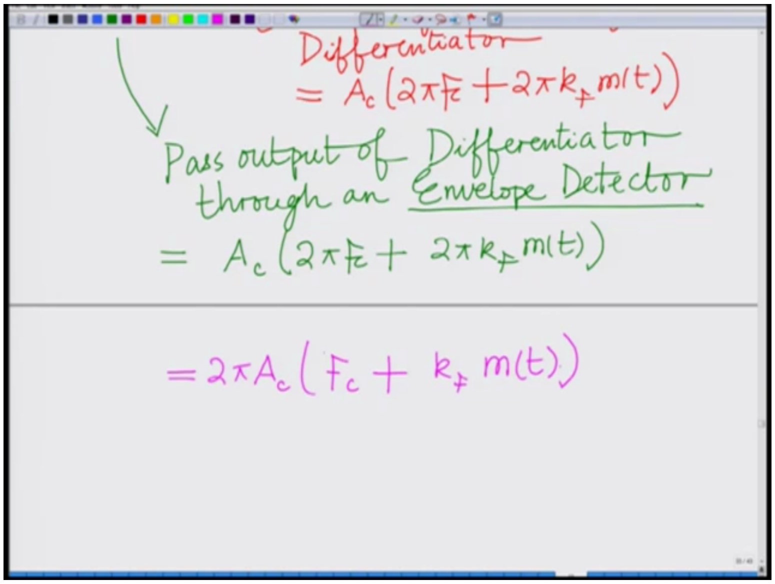

And therefore we pass this the output of the differentiator to an envelope detector, okay. So pass this through an envelope detector we have already seen the envelope detector so pass output of differentiator through envelope detector. So pass output of differentiator through the output of differentiator through an envelope detector, correct? And the resultant output is and the net output is that will give us the envelope which is basically Ac 2pi Fc plus well, 2pi kF m(t) which is basically now consolidating the terms this is basically Ac into 2pi, correct?

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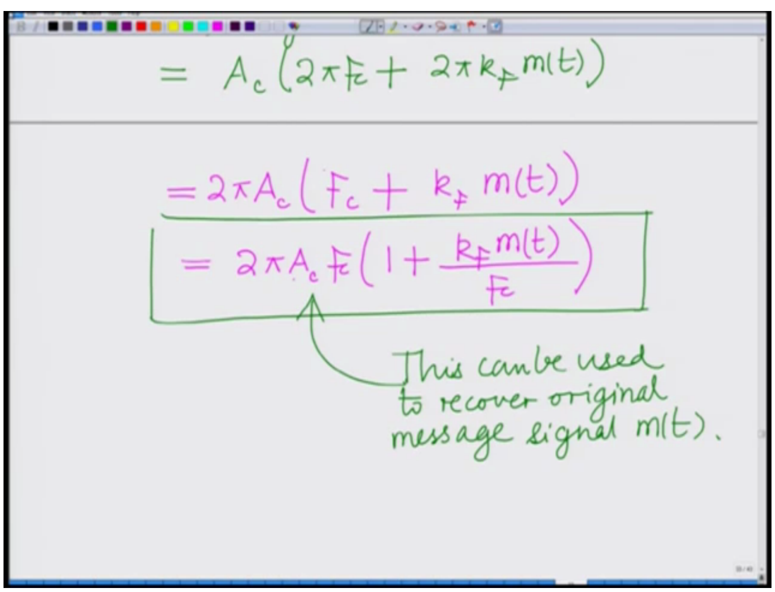

Fc plus kF m(t) and which is equal to basically now if you can look at this which is equal to 2pi Ac Fc into 1 plus 1 plus kF m(t) divided by Fc, okay. And now we know, correct? So now we have the output of the envelope detector this is given by this is your output of the envelope detector which can be used to recover, so this is the output of envelope detector and this can be used to recover the original message signal m(t). This can be used to recover the original message signal m(t).

So this is the output of the envelope detector which can be used to recover the original message signal m(t), however remember for no phase reversals, alright we need a condition, correct? That is the the the amplitude (modu) remember when we looked at an amplitude modulated signal for envelope detection the condition (wi) no phase reversal is that the signal should not be over modulated, correct?

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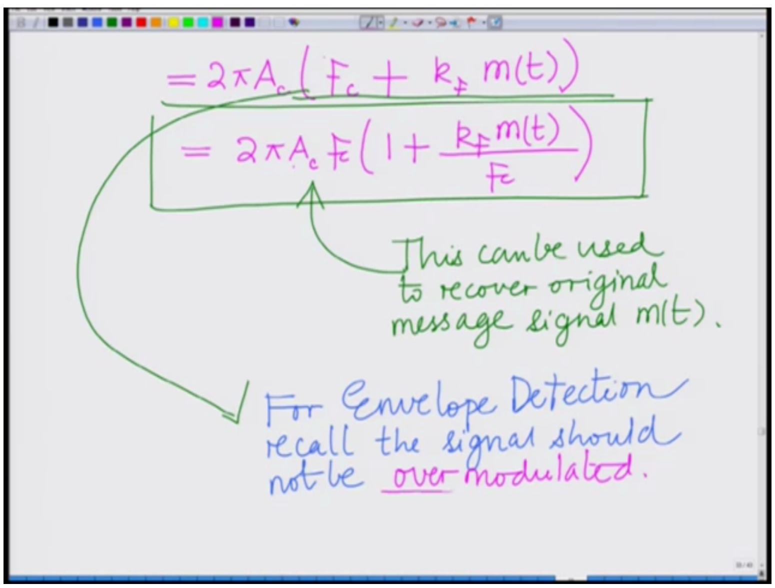

Which means that is if you can look at this quantity here signal should not be over modulated which means for envelope detection recall that the signal should not be, for envelope detection recall the signal should not be over modulated, okay.

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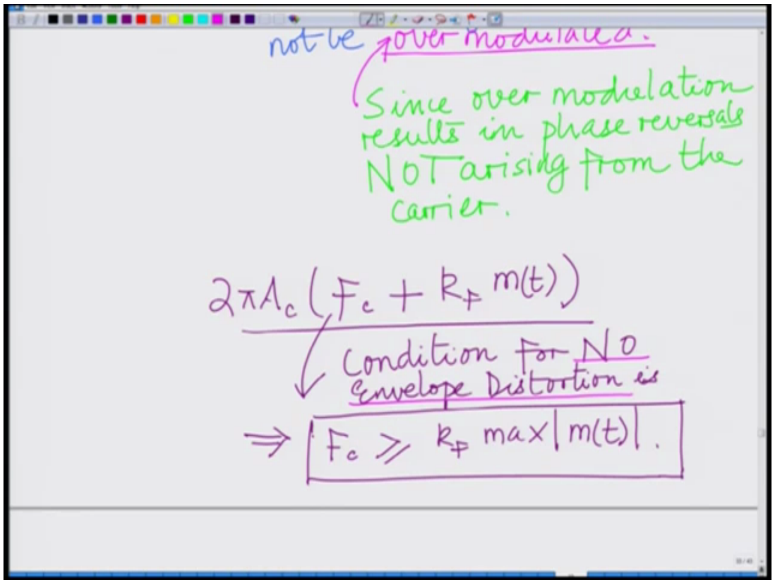

Since over modulation results in phase reversals not arising from the carrier, remember since over modulation not arising from the carrier and the condition for and now if you look at this signal look at this signal 2pi Ac times Fc plus kF m(t), now if you look at this signal if you look at this signal, okay. The condition for no envelope condition for no envelope distortion is that this has to be greater than 0 which implies basically Fc has to be greater than or equal to kF times maximum of magnitude m(t), okay.

So basically your kF has to be greater than equal to maximum of magnitude of, so this is the condition that we require this is the condition that we require remember this is a condition that we require for no envelope distortion that is Fc the carrier frequency has to be greater than equal to kF times maximum magnitude m(t) that is the maximum of the magnitude of the message signal. And now if you look at our frequency, correct?

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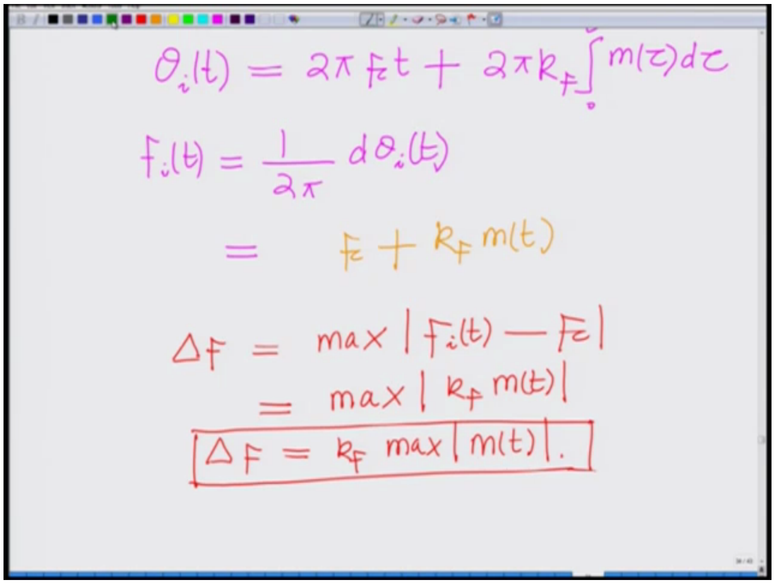

Now let us go back to our frequency the frequency the instantaneous frequency Fi(t) is basically if you look at that that is basically your well, the phase let us look at the phase 2 pi well, Fct plus 2pi kF integral 0 to t m Tau d Tau, now the instantaneous frequency is 1 over 2 pi derivative of the phase which is equal to well, 2pi Fc plus 2pi kF m(t) which is equal to again 2pi Fc 2pi Fc plus plus 2pi kF 2pi kF m I am sorry Fc plus kF m(t) because there is a factor of 1 over 2pi, so this is simply Fc plus kF times m(t) and therefore the frequency deviation, if remember our frequency deviation Delta F equals maximum of magnitude Fi(t) minus Fc this is how we derived the frequency deviation which is maximum of magnitude m(t) which is kF times maximum of magnitude maximum of magnitude, so our Delta F our frequency deviation Delta F is nothing but kF times maximum of the magnitude of m(t).

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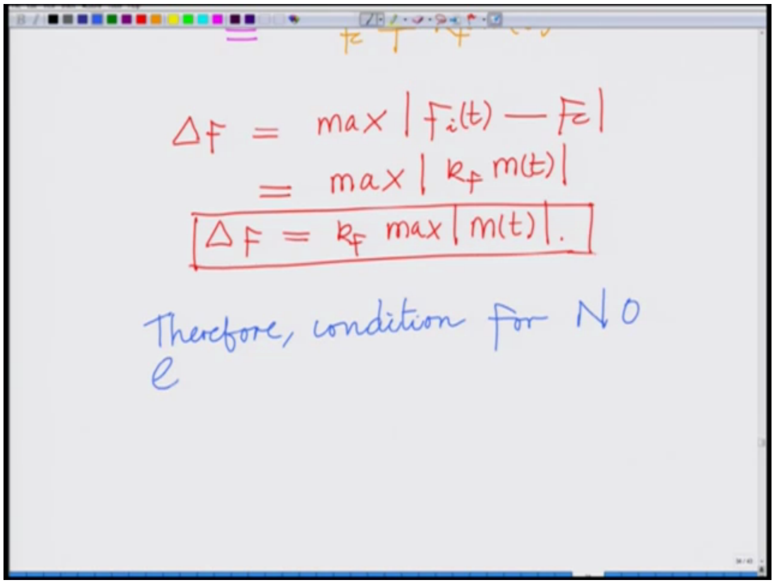

And now if you look at this you will realize that this quantity kF times maximum of magnitude l m(t) is nothing but Delta F therefore the condition for no envelope distortion what it reduces to basically the fact that the frequency carrier frequency must be greater than the maximum the peak frequency deviation of the Fm signal.

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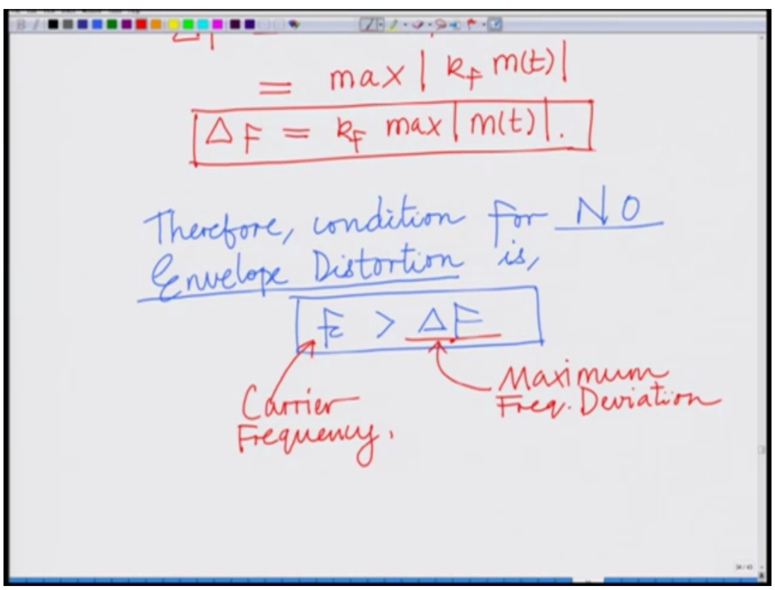

Therefore condition for no envelope distortion very interestingly the condition for no envelope distortion is basically Fc greater than Delta F, okay. So Fc so if remember this is your maximum frequency deviation, okay. Let me also mention that this is your this is your maximum frequency deviation and this is your carrier frequency this is the maximum frequency deviation and this is the carrier frequency and the condition for no envelope distortion is that Fc is greater than or equal to Delta F and therefore if this condition is satisfied the reason carrier frequency of the FM signal is greater than the maximum frequency deviation there will be no envelope distortion. However you can see that this is naturally true for an FM signal since the carrier frequency is a very high quantity compared to the frequency deviation for instance let us look at a typical example, okay.

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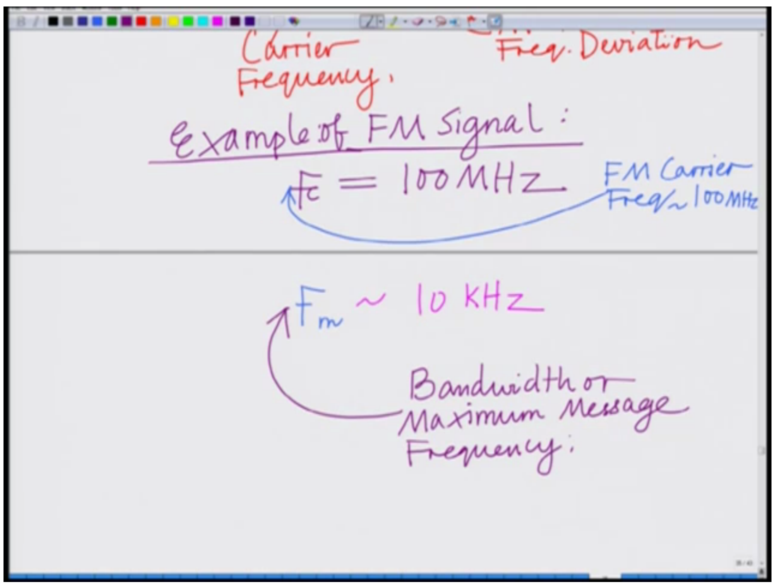

Let us take a typical example of an FM signal, okay. You can see the carrier frequency Fc equals Fc equals well, for FM signal that carrier frequencies are typically in the range of 100 megahertz these are the FM carrier (seque) frequencies, okay. Its 90 megahertz to about 105-110 megahertz, okay. FM carrier frequencies approximately or they are of the order of basically 100 megahertz and the bandwidth or the maximum message frequency you can say Fm, right. Fm is approximately of a order of let us say 10 kilohertz you can say this is the bandwidth or the maximum message frequency, okay.

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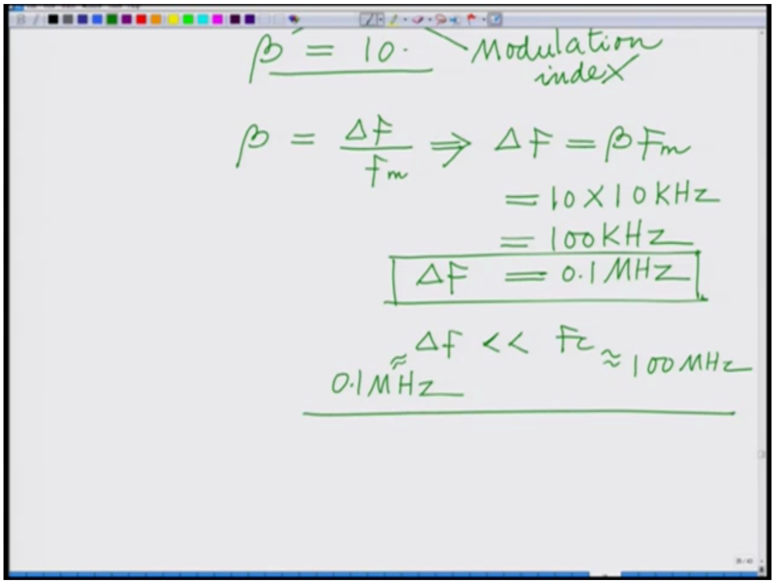

It is a bandwidth or maximum message frequency and therefore now if we have a modulation index beta equals 10 let us say this is our modulation index and we know that Delta beta is basically Delta F divided by Fm the maximum frequency component which implies Fm which implies Delta F which implies the frequency deviation Delta F is beta Times Fm which is 10 times well, our bandwidth is well, its 10 times 10 kilohertz which is equal to 100 kilohertz which is equal to 0.1 megahertz.

So your Delta F is approximately 0.1 your carrier frequency Fc is basically of the order of hundred megahertz, so you can clearly see that Delta F is much smaller than Fc this is approximately 0.1 megahertz this is approximately 100 it is approximately 100 megahertz, okay. Fc so this is your Delta F this is Fc, so Fc is approximately 100 megahertz your Delta F is approximately 0.1 megahertz, so what you can see is that this Delta F this quantity Delta F is typically that is a frequency deviation it is typically much smaller than Fc carrier frequency for a frequency modulated signal, okay.

So this quantity since the frequency deviation is much less then carrier frequency, tracing back our steps it means that basically there is going to be no envelope distortion, alright. There is going to be no envelope distortion because envelope because this quantity Fc plus kF times m(t) is always positive there therefore there is going to be no envelope distortion and that in turn means that differentiation followed by envelope detection can be used for that can be used as 1 of the techniques for demodulation of an Fm signal, okay.

And which is rather simple because it has a low complexity technique which requires a differentiator followed by a envelope detector again as we have seen envelope detector is a simple circuit that can be implemented with relatively low complexity, so we will stop this module here and look at other aspects in the subsequent modules, thank you.