Principles of Communication- Part I
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Module No 3
Lecture 13
Power of Amplitude Modulated (AM) Signals and Power Efficiency of AM Signals

Hello welcome to another module in this massive open online course. So today let us look at the power of an AM signal.

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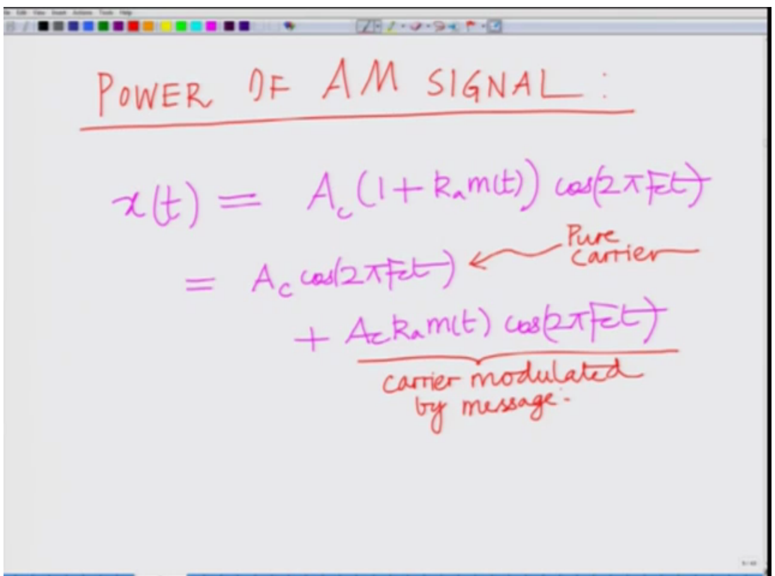

Power of amplitude modulated that is the AM signal and we know that a typical AM signal is given as s(t) or x(t), let us use the notation x(t) equals A cosine or basically Ac one plus ka m(t) into cosine two pi Fct which is the carrier component Ac cosine two pi Fct plus the message component that is AA Ac that is a carrier modulated with the message that is Ac ka m(t) cosine two pi Fc of t, correct?

Now this is the pure carrier component, correct? And this is carrier modulated carrier modulated, so we have to components one is the pure carrier Ac co sine two pi Fct and the other is the carrier modulated by the message that is your ka Ac m(t) cosine two pi Fct, okay. So let us try to let us now to compute the power of the AM signal that is x(t), let us compute the power of each of these components separately and add them to get the power of the AM signal.

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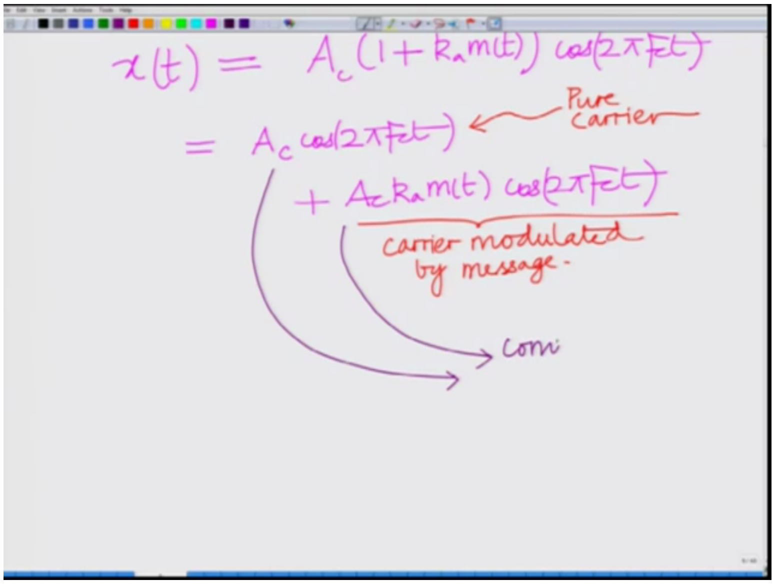

So we compute power of each of these two components compute power of each component separately, okay. Now the power of the carrier, well that is straightforward and we already know this thing this is a Sinusoidal signal. So the power of this of this that is Ac cosine two pi Fct is amplitude square that is half Ac square. So the power of the carrier, correct? The power of the carrier component we already know that that is a Sinusoidal there is a pure carrier. That is a Sinusoid signal, so the power is half amplitude square that is half a six let us now compute the power in the carrier that is modulated by the message.

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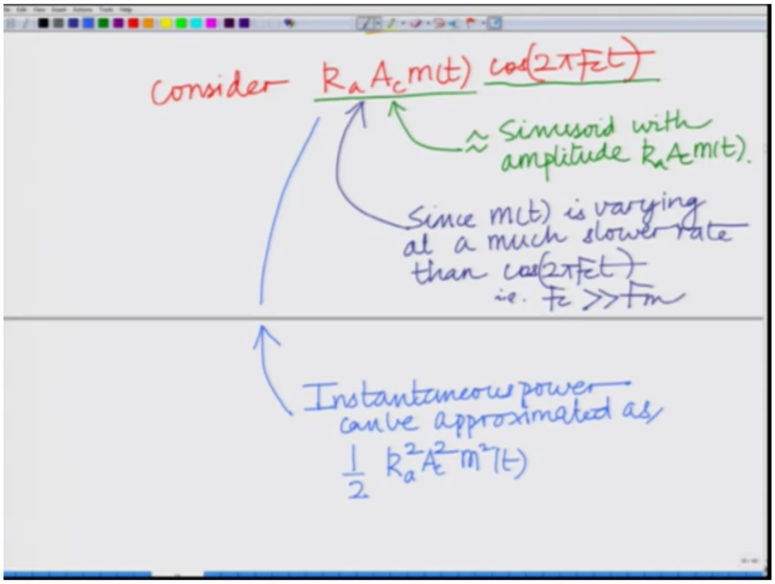

So now consider the other component that is Ka Ac m(t) co sine two pi Fct now you can think of this as the carrier and this as the amplitude that is you can think of this although this is not exactly correct you can think of this as Sinusoid with amplitude that is I am writing using the approximate signs Sinusoid with amplitude ka Ac m(t). Well, correct? Although strictly speaking that is not true because when you multiply m(t) time varying signal m(t), correct?

With a Sinusoid it is no longer a Sinusoid but since m(t) message signal is varying much because the carrier frequency Fc is much higher than Fm that is the maximum frequency component of the message therefore m(t) that is this envelope or this amplitude of this (Sinuso) this m(t) is slowly much varying at a much slower rate than the Sinusoid, correct? Cosine two pi Fct. One can approximately think of this as the Sinusoid cosine two pi Fct with instantaneous amplitude given as ka Ac m(t).

This so let us write this justification also since this is not always true this approximation is valid since m(t) is varying at our much lower rate than cosine two pi Fct that is your Fc is much greater than Fm that we already know, alright. The carrier frequency is much greater than the message frequency therefore the power of this can be (approxi) instantaneous power.

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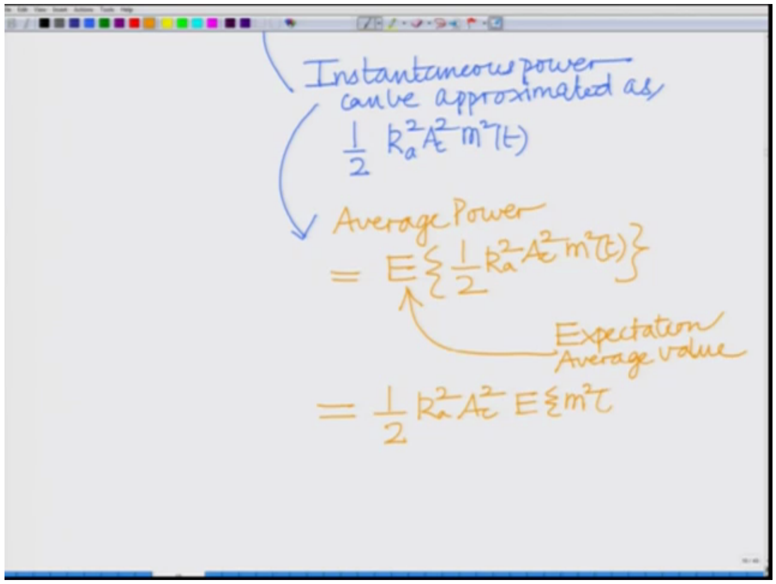

Again can be approximated as half this amplitude square that is half ka square Ac square m square t, this is the instantaneous power and therefore average power from this is your average power can be obtained the average power can be obtained as that is expected value of this quantity half that is average, remember E stands for the expected value expected value of a random variable or a random process in this case m(t) is a time varying signal, so it is a random process. E stands for expected, this is the expectation or the average at the average value and therefore this is equal to I can bring the constants outside half ka square Ac square average value of the quantity m square t.

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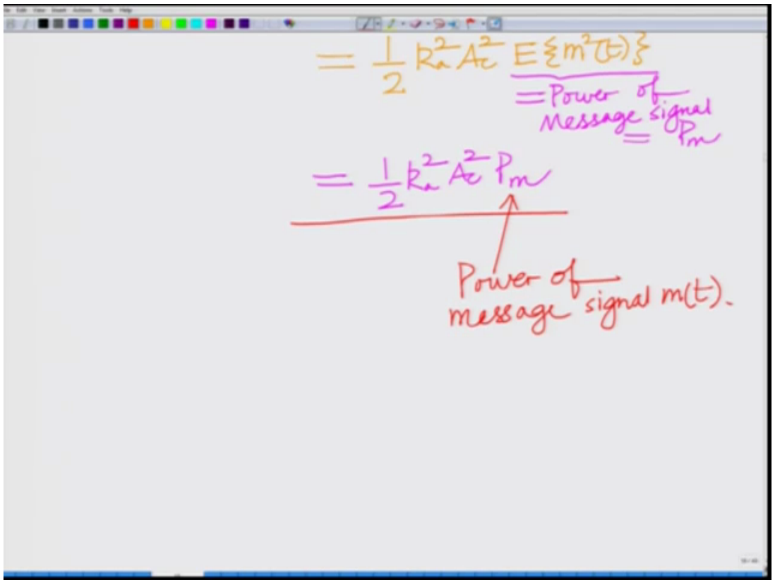

But now realize average value of this quantity m square t is nothing but the power of the message signal we can denote this by the quantity Pm, okay. So this average quantity this is nothing but the power expected value of therefore let us say this is denoted by Pm, so this is half Ka square Ac square Pm where Pm is the power of the this is the power of your message signal where Pm is the power of the message signal m(t), alright.

So we have derived the power in the pure carrier component and now we have derived the power in the component that is a carrier which is modulated by the message m(t) and we are saying that power is a proximity half ka square Ac square into Pm where Pm is the power of the modulating signal that is the message signal signal m(t).

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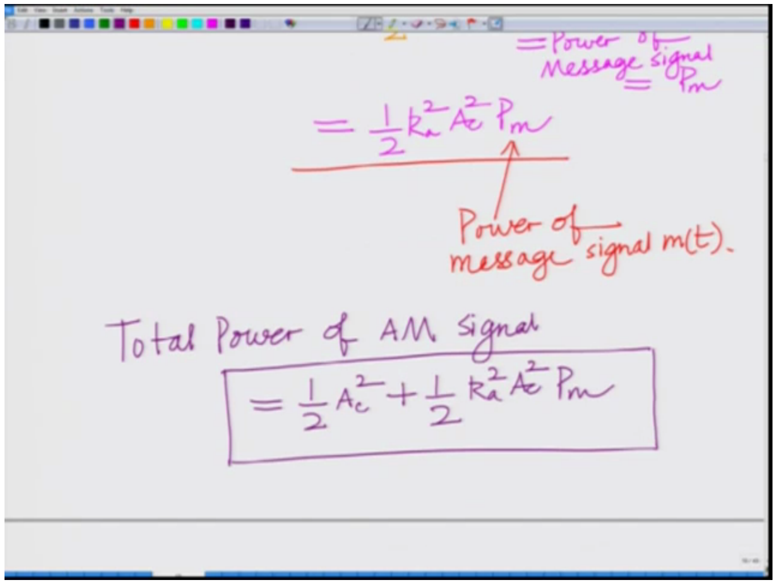

And therefore now the total power is the sum of these two powers the total power of your Am signal equals half Ac square plus half Ka square Ac square into Pm. This is the total power this is the total power of the AM signal that is half Ac square plus half ka square by Ac square into Pm, okay. So this is the total power of the AM signal. Now let us define another quantity that is the efficiency, the efficiency of this AM signal is basically the power in the message signal divided by the total power that is a power in the carrier class plus power in the power in the carrier modulated by the message divided by the power in the pure carrier plus divided by the total power, right.

Because remember the only (udh) useful part of the amplitude the AM signal amplitude modulated signal is the part that corresponds to the carrier modulated by the message because that is actual component that is carrying the message signal which is conveying the information the pure carrier is only being transmitted for to enable envelope detection, alright. Otherwise by itself it does not convey any information therefore the efficiency of this scheme can be denoted by the power in the message component. That is power in the carrier modulated by the message divided by the total power of the AM signal, okay.

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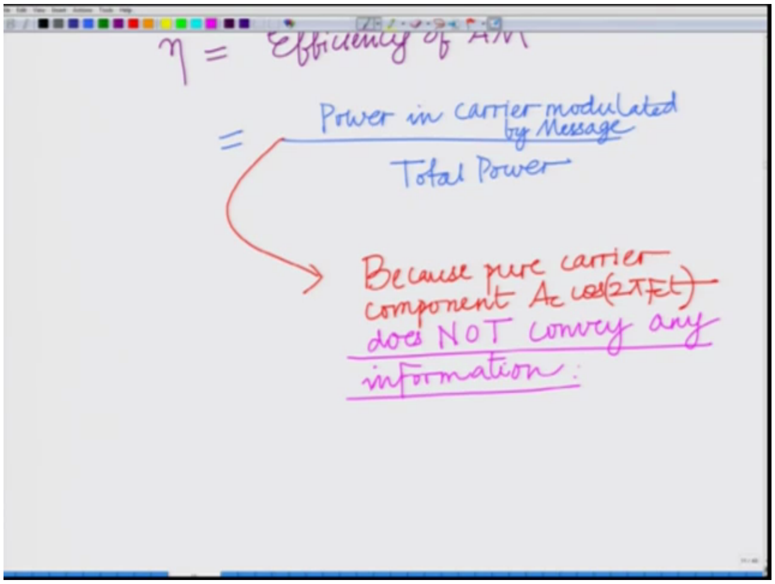

So the power eta equal to efficiency of AM and this is equal to power that is power in carrier modulated by message divided by the total power and this is because remember the justification this is because a pure carrier component which is Ac co sine two pi Fct does not any information. This does not convey any information does not convey any (inf) the information is contained in the message signal m(t) therefore the pure carrier is only being transmitted for envelope to enable envelope detection, alright. That is the reason why the carrier component is being transmitted, alright.

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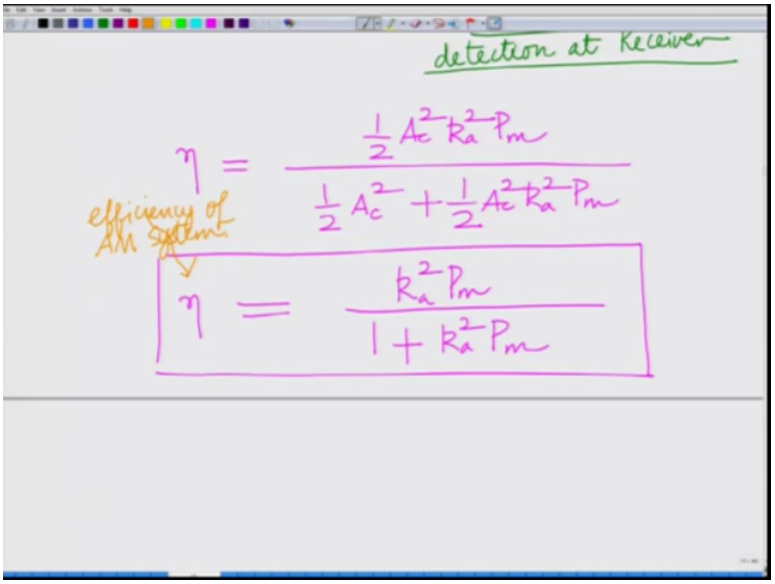

So you realize that if there is no information why is being transmitted? The pure carrier is being transmitted simply to enable is being transmitted simply to envelope detection at the simply to enable envelope detection at the receiver and therefore eta that is the efficiency is the power in the carrier that is carrier modulated by the message that is half Ac square ka square Pm divided by half Ac square plus half Ac square ka square Pm which is basically that is eta equals, well that is your cancelling Ac square this is ka square Pm, remember ka is the sensitivity Pm is the power in the message signal divided by one plus ka square Pm.

So this is the efficiency of the AM system, correct? So I can write this as the efficiency this is the efficiency of the amplitude modulated system that is Ka square into Pm divided by one plus ka square Pm where ka is the sensitivity and Pm is the power of the message signal. Let us try to compute this efficiency for a Sinusoidal message signal.

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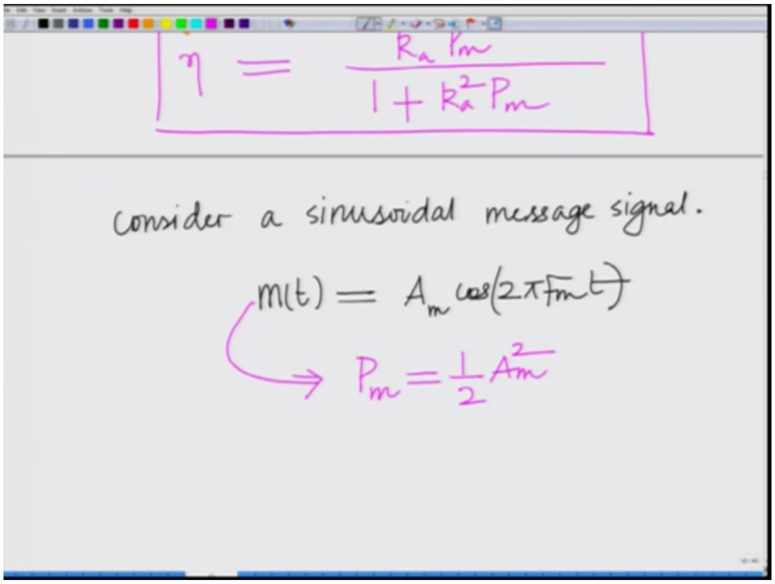

Consider now the specific case of a Sinusoidal message signal, consider a Sinusoidal message signal m(t) equals Am this is our message signal with amplitude Am cosine two pi Fmt, alright. Therefore this implies that the power of the message signal Pm equals half Am square.

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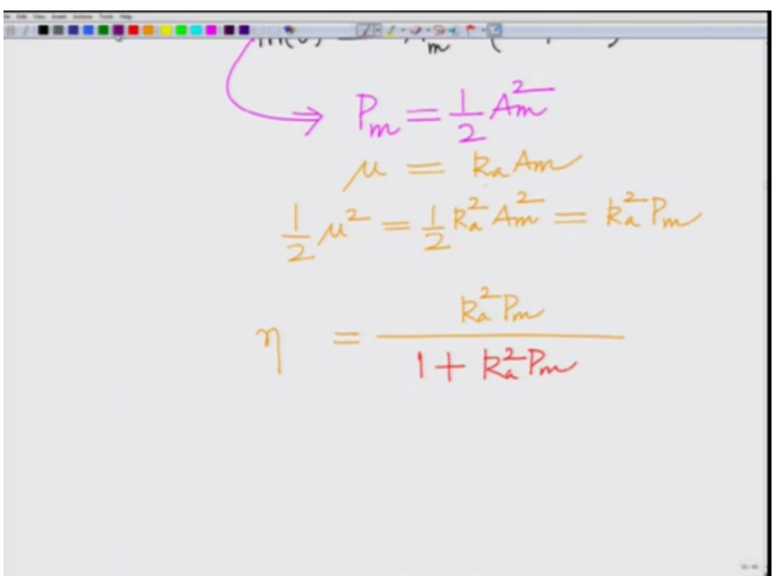

This is the power of the message signal also realize that mu the modulation index equals remember modulation index this is defined we have defined the modulation index and the modulation index for this Sinusoidal signal is basically mu equals ka times Am basically we have defined mu in one of the earlier modules and we have shown that for a Sinusoidal (modul) for a Sinusoidal message signal mu equals ka times Am, correct?

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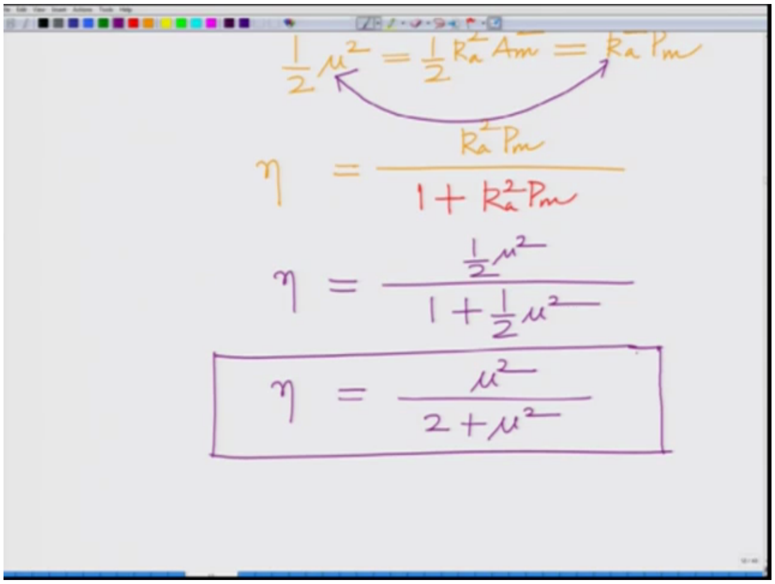

And therefore now we can also write half, correct? Mu square equals half ka square Am square but half Am square equals Pm, so this is equal to ka square into Pm which means the efficiency eta the efficiency eta of the AM signal, correct? For the Sinusoidal modulating signal that is remember that is half ka half remember that is ka square Pm which is now I can write this half mu square divided by let me just write it completely this is ka square pm divided by one plus ka square Pm which now for this Sinusoidal modulating signal is half mu square, well ka square we have just shown that half mu square equals ka square Pm.

So this is half mu square divided by one plus half mu square this is equal to, well mu square divided by two plus mu square and this is another important relation of the efficiency of amplitude modulation for a Sinusoidal modulating signal, correct?

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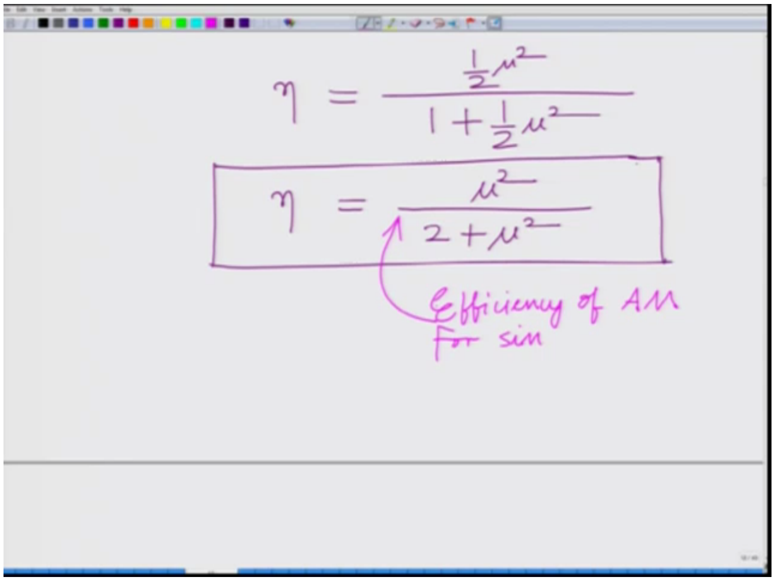

This is the expression for efficiency of AM for a efficiency of AM specifically for a Sinusoidal modulation where mu is the mu is the modulation index. This is specifically the efficiency of a Sinusoidal modulating signal where mu is the modulation index, alright. Correct?

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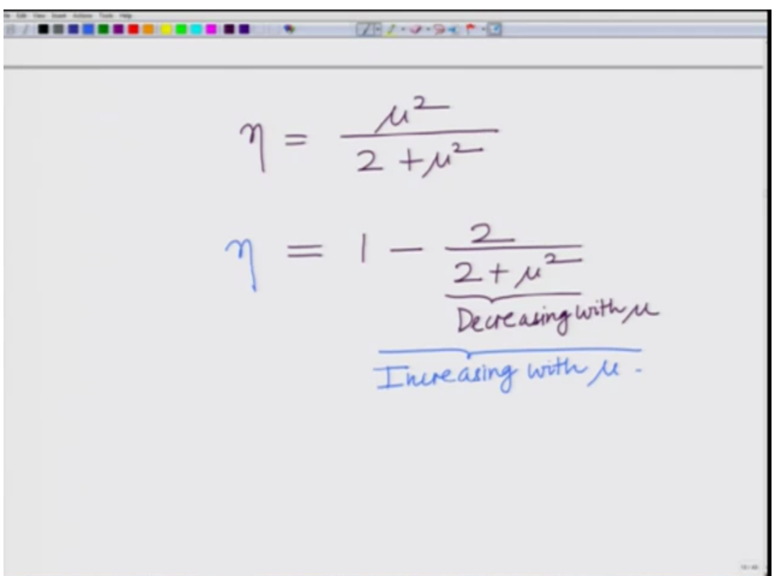

And also now realize that if you look at this expression eta again look at this expression eta equals mu square divided by two plus mu square, I can write this as one minus two over two plus mu square look at this two over two mu square this is decreasing with mu and therefore one minus two over two plus mu square this whole thing is increasing, so I can write the efficiency eta as one minus two over two plus mu square. Two over two plus mu square is decreasing with mu as mu increases this quantity is decreasing therefore one minus two over two plus mu square is increasing with mu which means as mu increases the efficiency eta of the modulating of the Am of the Am signal improves, correct?

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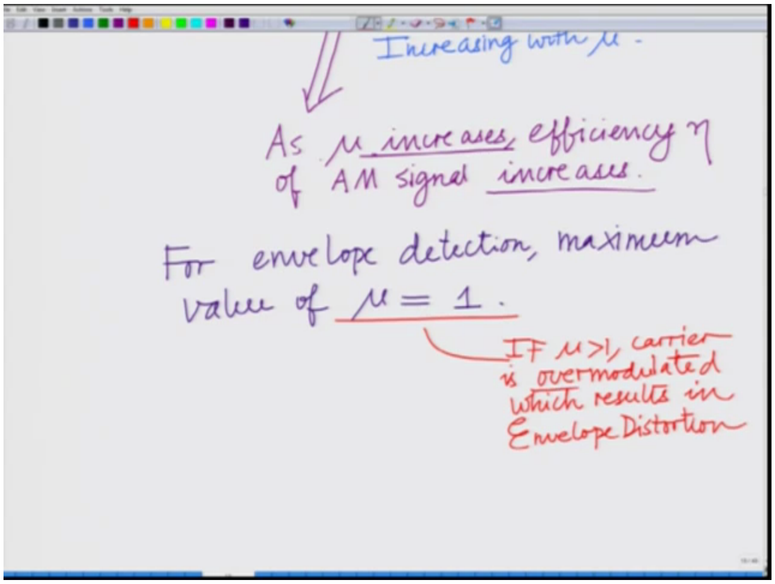

So now you observe this implies as Mu increases efficiency eta of AM signal increases this is important to remember as mu increases the efficiency increases. Now however interestingly mu remember for envelope detection the modulation index mu has to be less than or equal to one if mu is greater than one the signal becomes over modulated therefore for envelope detection mu has to be the maximum value of mu can take is one.

For envelope detection for envelope detection maximum value of mu equals one otherwise if mu is greater than one than the carrier the lead becomes over modulated, correct? At this leads to envelope (dis) distortion remember, correct? Since if mu is greater than one carrier is over modulated this is termed as modulated which results in envelope distortion carrier becomes over modulated this results in envelope distortion put these two things together now you can see that efficiency is increasing with mu maximum value of mu is equal to one for envelope detection therefore maximum efficiency occurs for mu equal to one.

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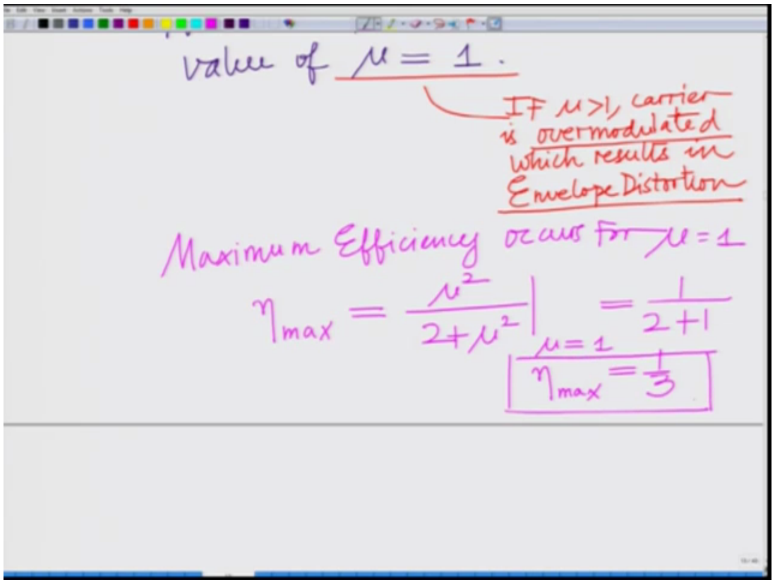

Maximum efficiency occurs which means eta max equals mu square by two plus mu square evaluated at mu equal to one which is one by two plus one which is one over three, alright. So this is eta max.

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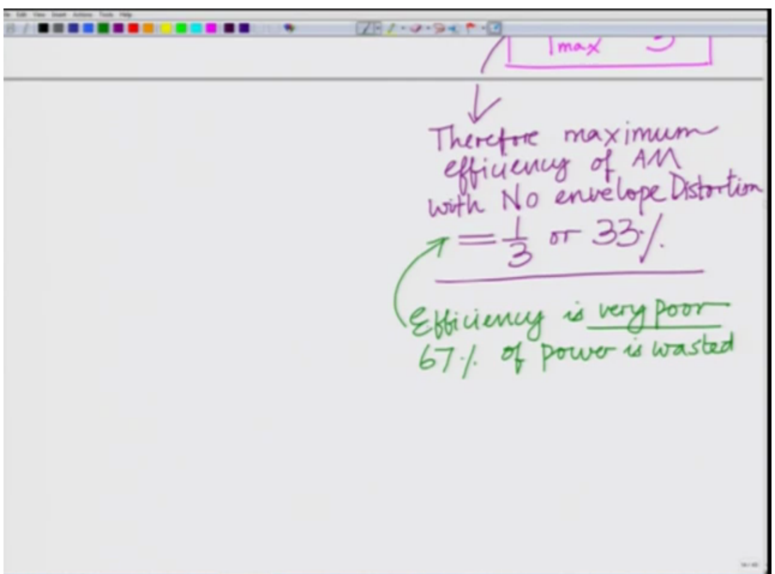

Maximum efficiency of AM with envelope detection, if envelope detection has to be allowed therefore maximum efficiency of AM with no envelope distortion equals one by three or only thirty-three percent which is a very surprising result and this tells us that the efficiency of amplitude modulation is very poor. That the maximum efficiency that is possible is only thirty-three percent which means close to sixty seven percent of the energy is basically wasted, correct? So this is very poor efficiency and realize that this is arising because we want to enable envelope detection at the receivers for which purpose is we are transmitting the pure carrier.

So the efficiency can be improved but that means the power of the carrier can be (dec) should be decreased or the carrier should not should not be transmitted altogether and that is what we will discover in the subsequent (modu) subsequent techniques of amplitude modulation that is double side band suppressed carrier etc. So therefore to conclude this efficiency is very poor to improve efficiency that is sixty six percent or sixty seven percent of power is wasted.

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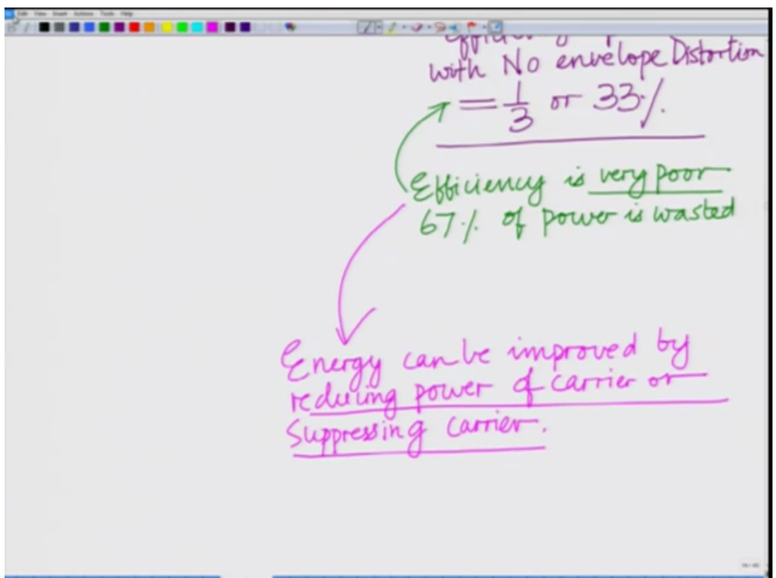

Therefore now efficiency can be improved by reducing the power of the carrier or suppressing power of the carrier energy can be improved or reducing power of carrier or suppressing the carrier. So the energy can be improved by reducing the power of the carrier or suppressing the (co) power of the carrier this is what we are going to look at in the subsequent techniques that is when we look at DSBSC double side band suppressed carrier that is a much higher efficiency because the carrier is suppressed there is no power is wasted on transmitting the pure carrier, alright.

So in this module we have calculated the power the power (effi) power of an AM signal, the power efficiency and also the maximum power efficiency with amplitude with envelope detection we have seen that this modulation index mu is less than or equal to one the maximum efficiency possible is thirty three percent. So let us stop here.