Principles of Communication- Part I
Professor Aditya K. Jagannathan
Department of Electrical Engineering
Indian Institute of Technology Kanpur
Module No 4
Lecture 18
Introduction to Quadrature Amplitude Modulation (QAM) and Demodulation of QAM

Hello welcome to another module in this massive open online course. Today let us take a look at a different modulation scheme that is quadrature carrier multiplexing, alright.

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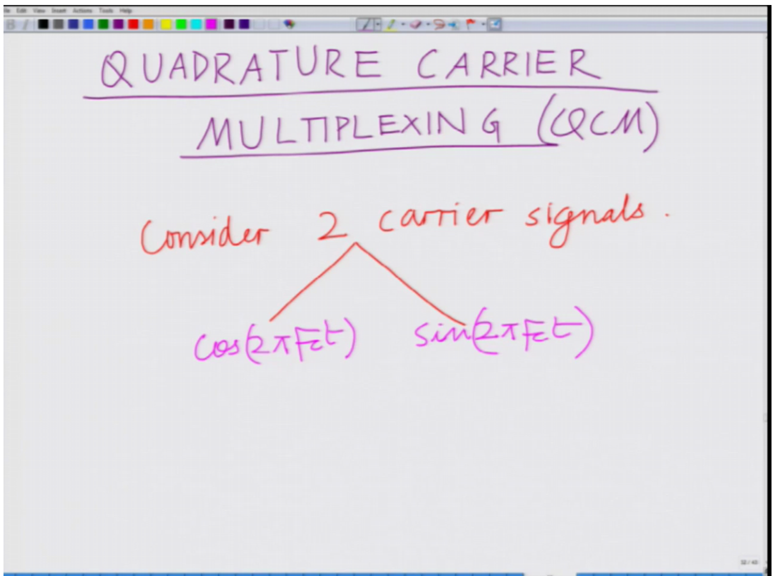

So we want to start looking at quadrature carrier multiplexing that is QCM. Now for this purpose consider there are 2 carriers or 2 carriers. Consider the carrier signals let us consider the following 2 carrier signals that is cosine 2pi Fct which is the standard carrier signal at carrier frequency FC and also now sin 2pi Fct, so these are our 2 carriers that is cosine 2pi Fct and sin 2pi Fct and Fc as usual is the carrier frequency.

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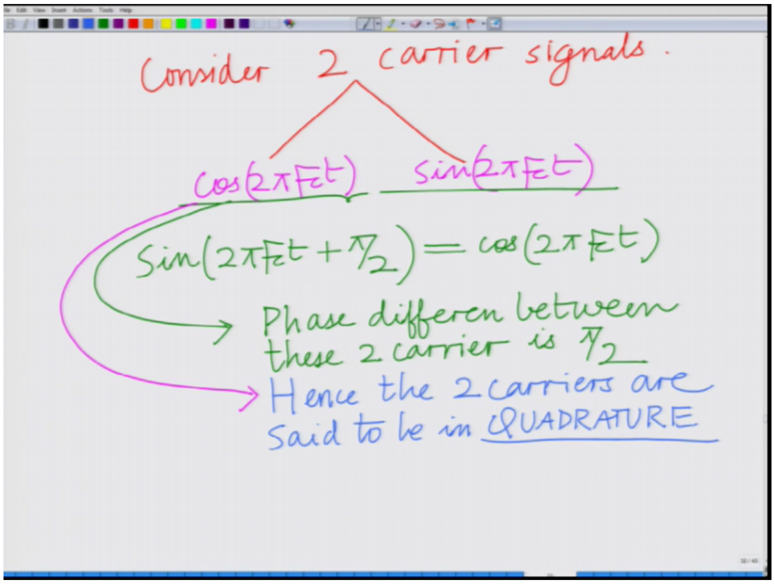

Now observe that the phase difference between these 2 carriers is 90 degree that is if you look at sin of 2phi 2pi Fct plus pi by 2 that is equal to cosine 2pi Fct therefore these 2 carriers therefore phase difference between these 2 carriers these 2 carriers is 90 degrees or basically pi by 2 radiance is pi by 2 hence these carriers to be in quadrature, quadrature denotes the phase quadrature basically denotes 90 degrees or a phase of Pi by 2 and cities to carriers that is cosine 2pi Fct and the sin 2pi Fct are said to be in quadrature, hence the 2 carriers that is cosine 2pi Fct and sin 2pi Fct these are these are said to be in these are said to be in quadrature these 2 quadrature is cosine 2pi Fct sin 2pi Fct, since the phase difference between them is pi by 2 these 2 carriers are said to be in quadrature.

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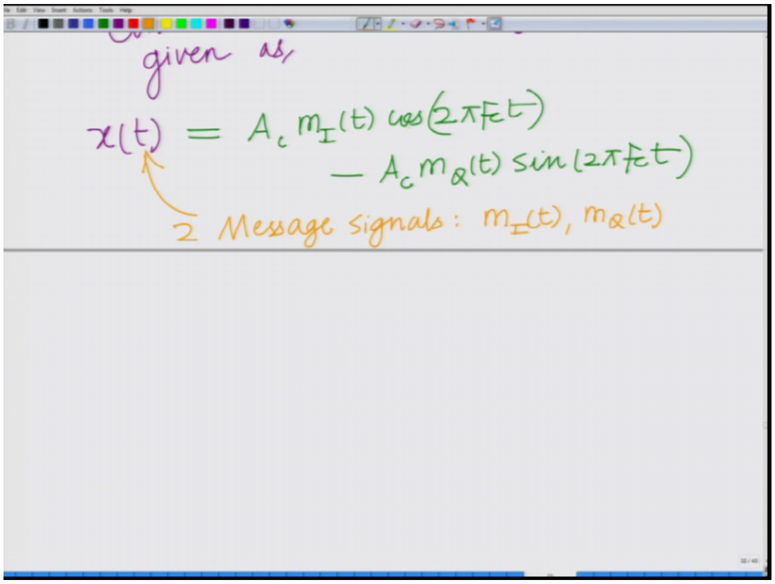

Now let us consider a modulated signal x(t) which is given as follows, alright. So we have x(t) consider the modulated signal x(t) given as consider the modulated signal x(t) equals x(t) is given as follows x(t) is equal to uhh Ac mIt or we can just write this as Ac mIt cosine 2pi Fct minus Ac mQ(t) sin 2pi Fct this is our modulated signal, now look at this there are 2 message signals in the above modulated signal previously we have considered only one message signal m(t), now there are 2message signals namely mIt and mQt, mIt is the message on the cosine.

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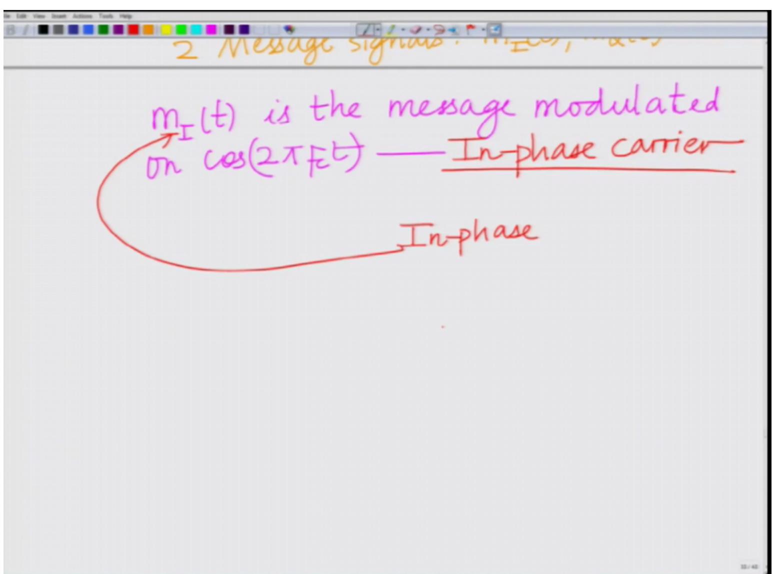

So we have mIt and mQt, observe mIt is the message which is modulated message which is modulated on the cosine carrier cosine 2 pi Fct, this is also termed as the interface carrier this cosine carrier is also termed as the in phase carrier, the cosine carrier is also termed as in phase carrier. So mIt with I subscript I stands for in phase, correct? The subscript I stands for in phase, correct? So mIt there are 2 messages Ac mIt the modulated signal x(t) which is Ac mIt cosine 2pi Fct minus Ac mq t sin 2pi Fct there are 2 messages mIt and mQt we are saying mIt is a message that is transmitted on the cosine carrier which is also termed as in phase carrier.

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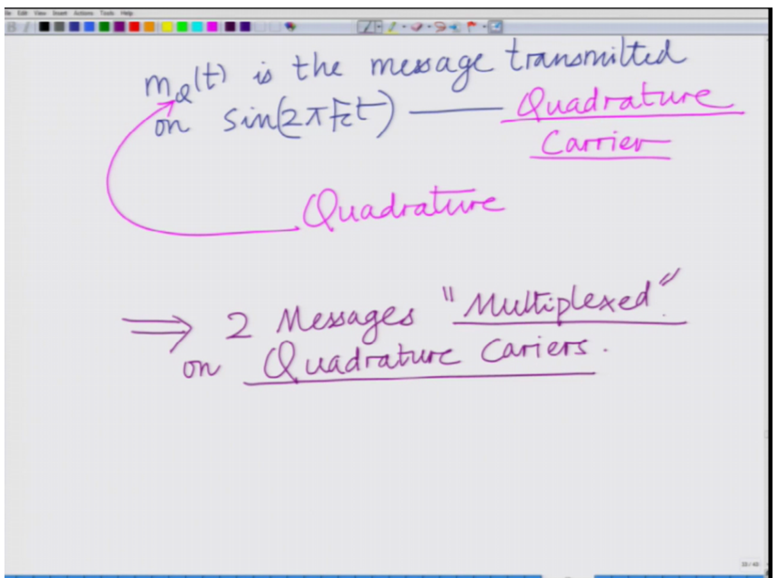

And mQt (simul) similarly mQt is the mQt is the message transmitted on the quadrature on on sin 2pi Fct which is also termed as a quadrature carrier, remember because sin 2pi Fct is in quadrature with cosine 2pi Fct so this is also termed as a quadrature carrier. So this Q subscript Q stands for the term quadrature. So we have 2 message signals mIt, mQt mIt is a message signal there is an in phase message signal transmitted on the interface carrier cosine 2pi Fct, mQt is a quadrature message signal transmitted on the (quadra) quadrature carrier sin 2pi Fct, alright. So we have 2 messages remember multiplexed on the on 2 quadrature carrier, so implies net we have 2 messages which are multiplex, correct? That is simultaneously transmitted on quadrature carriers.

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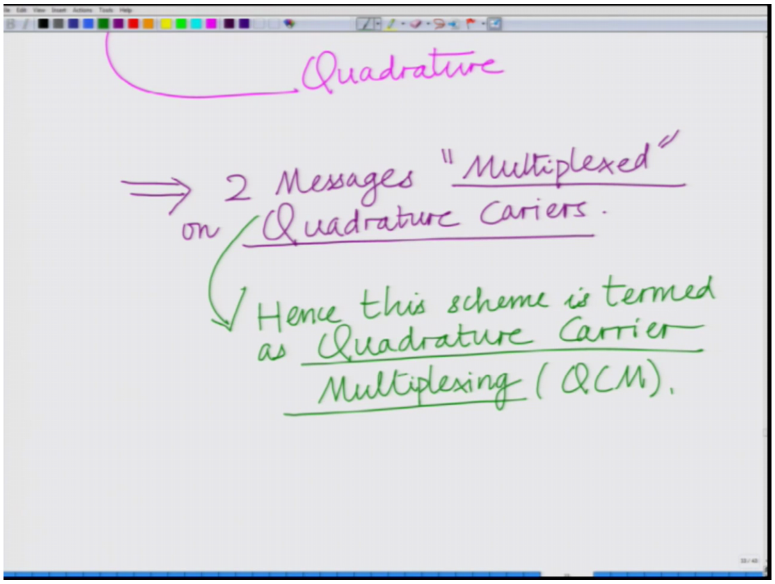

We have 2 messages which are multiplexed on quadrature carriers hence this scheme is termed as quadrature carrier multiplex this scheme is termed as quadrature carrier multiplexing which is abbreviated as QCM scheme will be transmitting 2 message signal is different message signals mIt mQt on quadrature carriers is termed as quadrature carrier multiplexing further notice an interesting property of these quadrature carriers notice an interesting.

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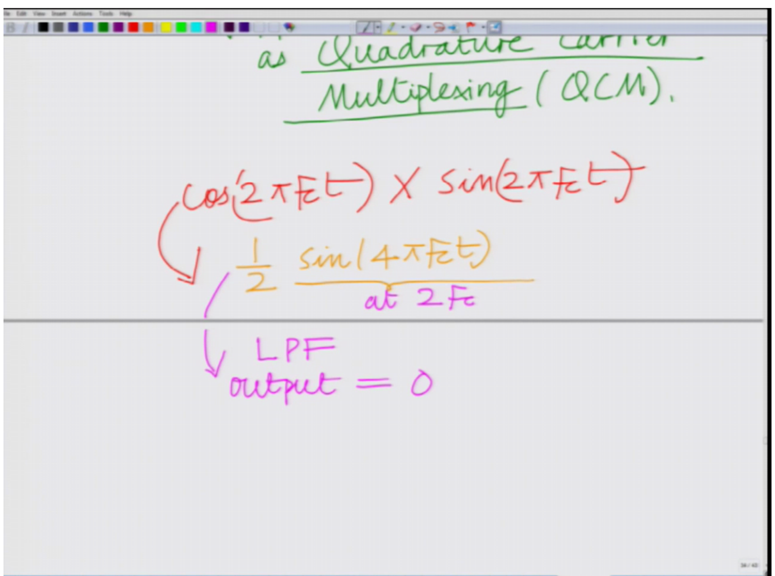

Consider now for instance let us say we multiply or demodulate cosine 2pi Fct by sin 2pi Fct that is we are multiplying at the receiver by sin 2pi Fct demodulating uhh cosine 2pi Fct by sin 2pi Fct that gives half sin 4pi Fct which is basically at 2 (freq) 2 times a carrier frequency 2Fc therefore if I low pass filter this LPF if we pass it through a low pass filter the resulting output equal to 0.

So if I demodulated cosine with the sin or sin with cosine, alright. You can see that they works either way, so cosine 2pi Fct into sin 2pi Fct is half sin 4pi Fct, right? Which is the component which is basically at 2Fc which is at twice the carrier frequency? So if it I pass it through a low pass filter such as uhh which is basically which is cut off frequency in the baseband then obviously the output of the low pass filter is going to be 0. Therefore these 2 carriers the cosines cosine 2pi Fct and sin 2pi Fct are orthogonal because if you demodulated cosine with sin or sin with cosine and low pass filter it the output is 0.

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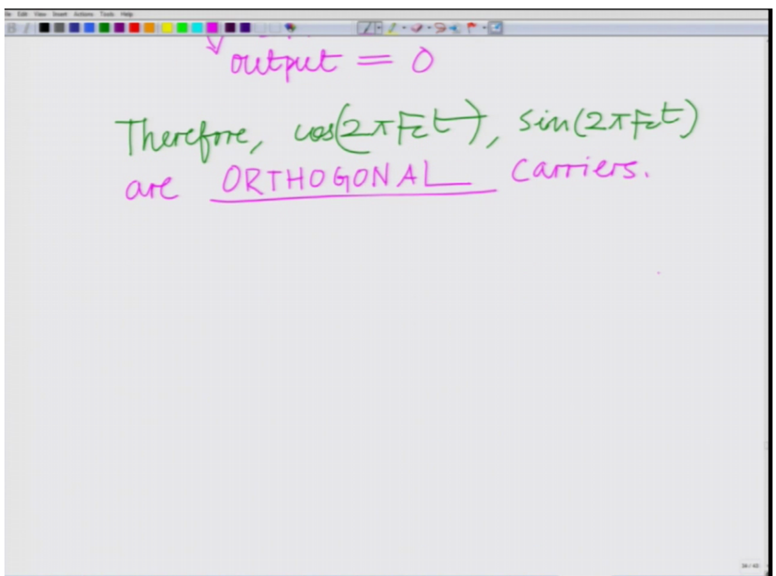

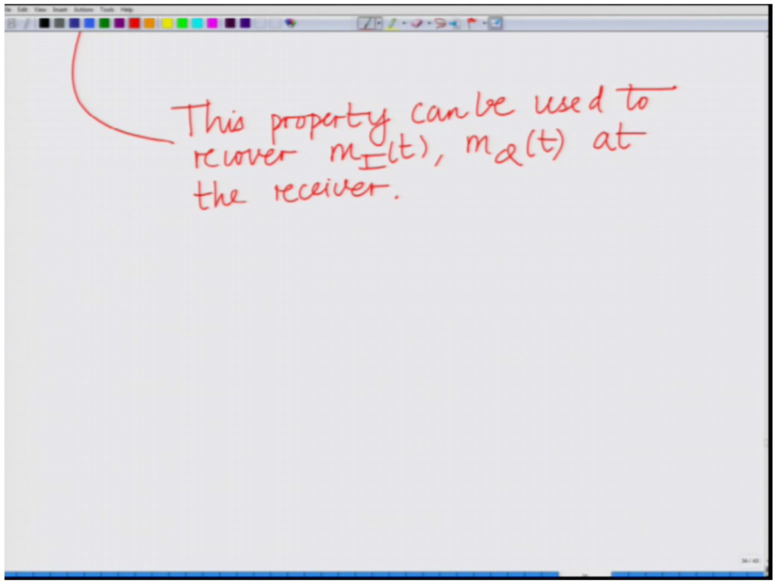

Therefore the cosine & sin 2pi Fct therefore these 2 carriers cosine 2pi Fct these 2 carriers cosine 2pi Fct, sin 2pi Fct these 2 carriers are orthogonal. These are this is an important property these are orthogonal carriers. Now this property can be used for demodulation of or this (mod) property can be used to demodulation or recover this property that is orthogonality can be used to recover can be used to recover mIt, mQt at the receiver, so we recover this the 2 message signals the in phase message signal mIt and the quadrature message signal mQt at the receiver using this orthogonality property of the carriers. Now how is that done?

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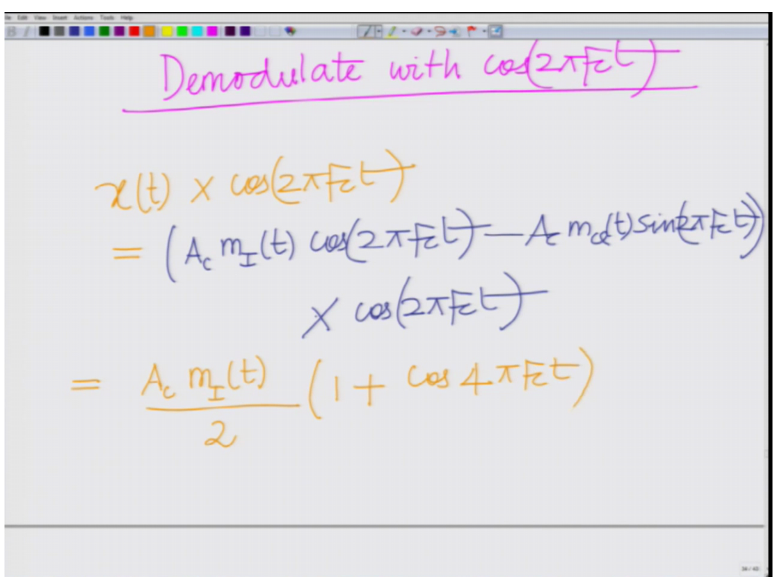

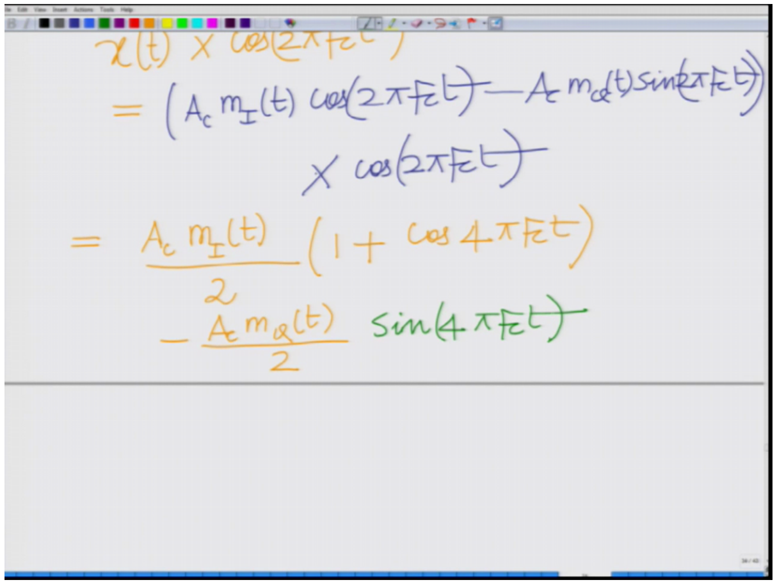

Let us illustrate that at the receiver for instance consider demodulation with cosine 2pi Fct if you demodulated cosine 2pi Fct, what we have? Your x(t) into cosine 2pi Fct which is equal to Ac or let me write it Ac mIt cosine 2pi Fct minus Ac mQt sin 2pi Fct into cosine 2pi Fct which is equal to, now look at this Ac mIt cosine square 2pi Fct. First-term is Ac mIt cosine square 2pi Fct which is which I write as Ac mIt divided by 2 into 1 plus cosine 4 pi Fct minus Ac mQt sin 2pi Fct which I can write as Ac mQt divided by 2 Ac mQt divided by 2 into 2 sin into Ac mQt divided by 2 to 2 sin 2 pi Fct cosine 2 pi Fct which is sin 4 pi Fct, okay.

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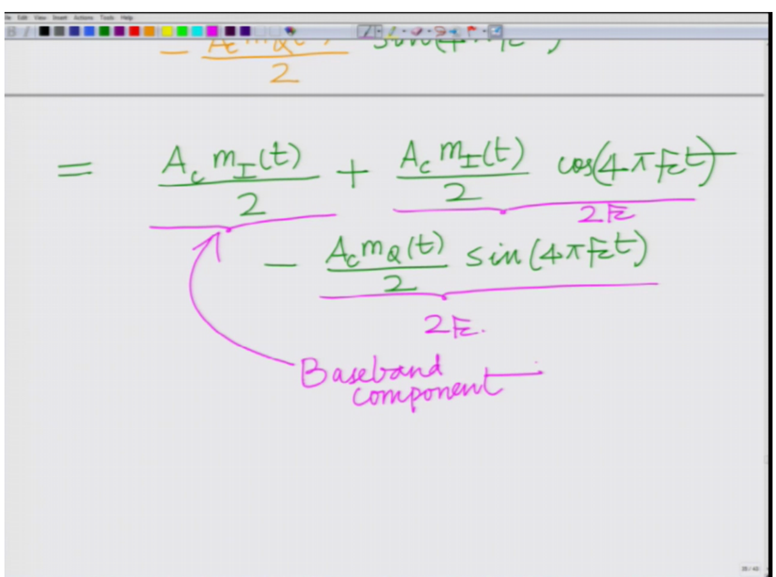

And now what I am going to do simplify this a little bit this is basically Ac mIt divided by plus Ac mIt divided by 2 cosine 4pi Fct minus Ac mQt divided by 2 Ac mQt divided by 2 sin 4 pi Fct now if you look at this you will realize that these 2 the last 2 components that is Ac mIt by 2 cosine 4 pi Fct and minus Ac mQt divided by 2 sin 4pi Fct these 2 components are at 2Fc, alright. So twice the carrier frequency, so this is at 2 Fc this is at 2 Fc of course, this is the baseband component Ac mi by 2 is simply mIt is scaled by a constant, so this is your baseband component which is centered at 0 frequency, correct? And let me just this is your baseband.

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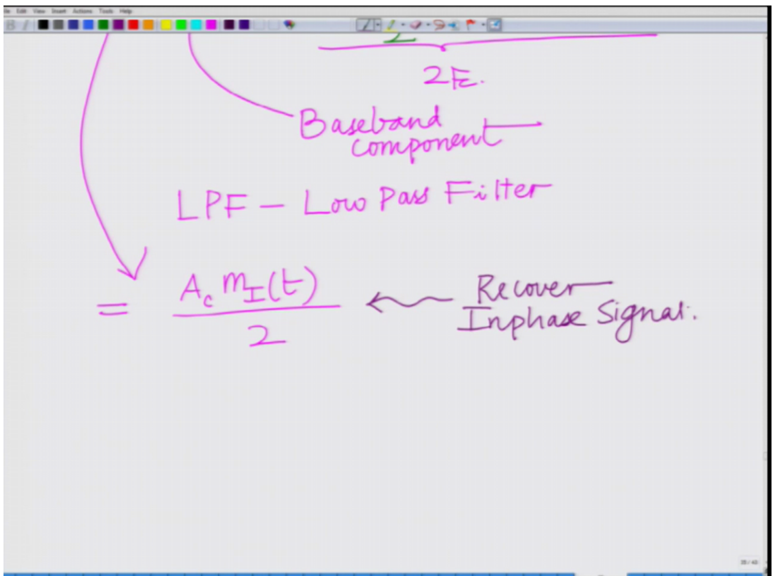

So if I pass this through a low pass filter I pass this through a low pass filter of appropriate cut-off frequency low pass filter that is basically I low pass filter this is the components at 2 Fc are filtered away and what I have is Ac mIt by 2 that is recover the in phase signal that is what I am able to do is I am able to recover the in phase signal and you can see that this is possible because of the orthogonality because once I demodulate with cosine 2 pi Fct at the receiver the sine carrier which is orthogonal, right?

The sin carrier is orthogonal to cosine 2pi Fc the cosine carrier therefore uhh the component that is mQt sin 2pi Fct when it is demodulated with the cosine that vanishes, alright and therefore I am able to recover the in phase messages signal, now similarly to recover the quadrature message signal obviously I am going to demodulate with the sin 2pi Fct, alright. And the in phase component which is on cosine 2 pi Fct is going to vanish because this is orthogonal to the quadrature carrier that is sin 2pi Fct.

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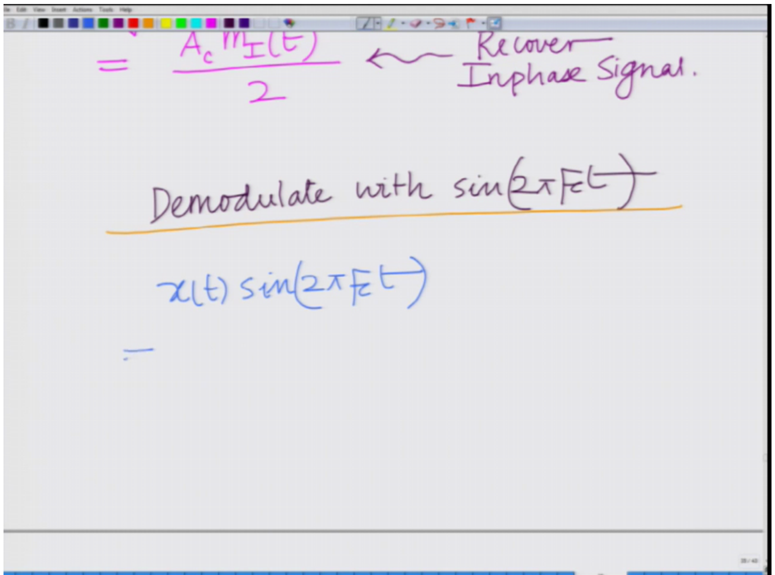

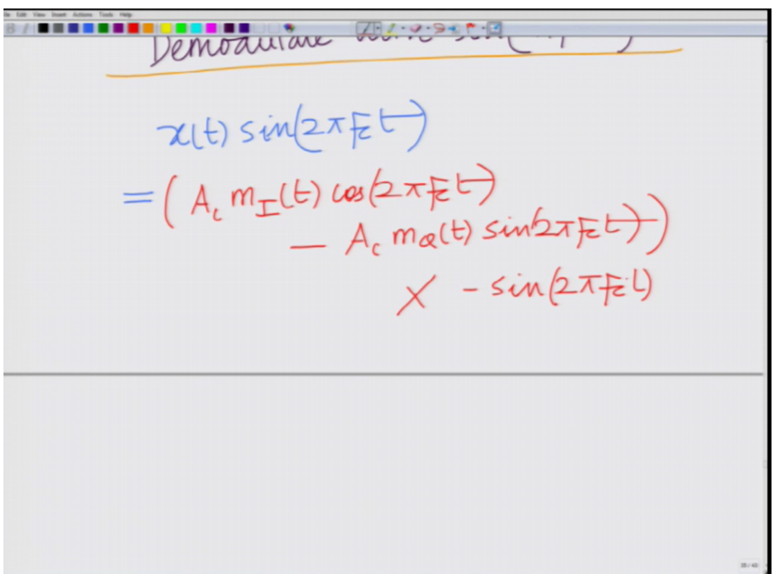

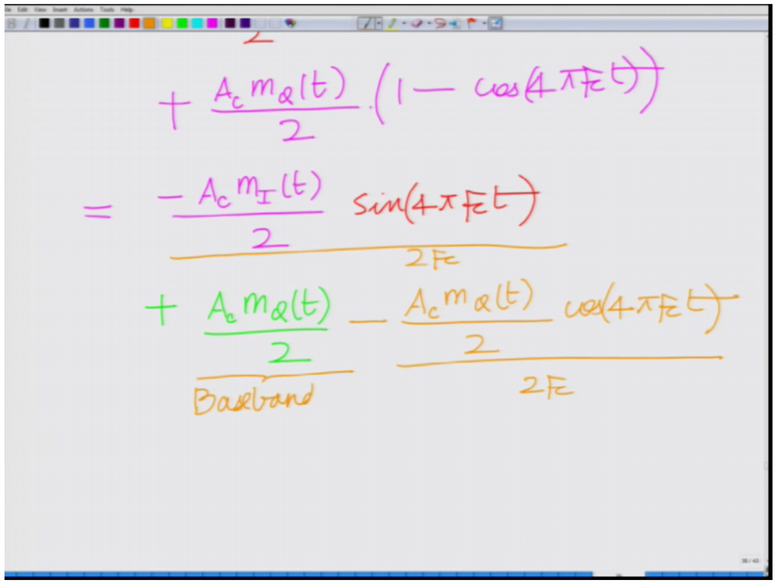

Therefore to recover mQt, let me illustrate that also briefly demodulate with sin 2pi Fct and when I demodulate with sin pi Fct I have x(t) sin 2pi Fct which is equal to Ac mIt cosine 2pi Fct minus Ac mIt sin 2pi Fct times sin 2pi Fct or let us demodulate with minus sin 2pi Fct is simply a phase changed version of sin 2pi Fct, okay. Demodulating with minus sin 2pi Fct, now the first term is minus Ac mIt by 2, cosine 2 pi Fct into sin 2pi or 2 minus Ac mIt by 2 into 2 cosine 2pi Fct sin 2 pi Fct which is sin 4pi Fct, correct?

Now minus or plus Ac mQt by 2 into Ac mQt by 2 uhh Ac mQt into sin square uhh Ac mQt into sin square 2pi Fct which is basically1 minus cosine 4 pi Fct divided by cosine 4pi Fct divided by 2 again simplifying this this is going to be minus Ac m(t) mIt divided by 2 uhh sin 4pi Fct 4pi Fct plus Ac mQt divided by 2, correct? Minus Ac mQt divided by 2 cosine 4pi Fct and now if you can look at this this component is at 2Fc this component is at 2Fc this is your baseband component, so once I low pass filter this again the components at 2Fct they go away and what I am left with is?

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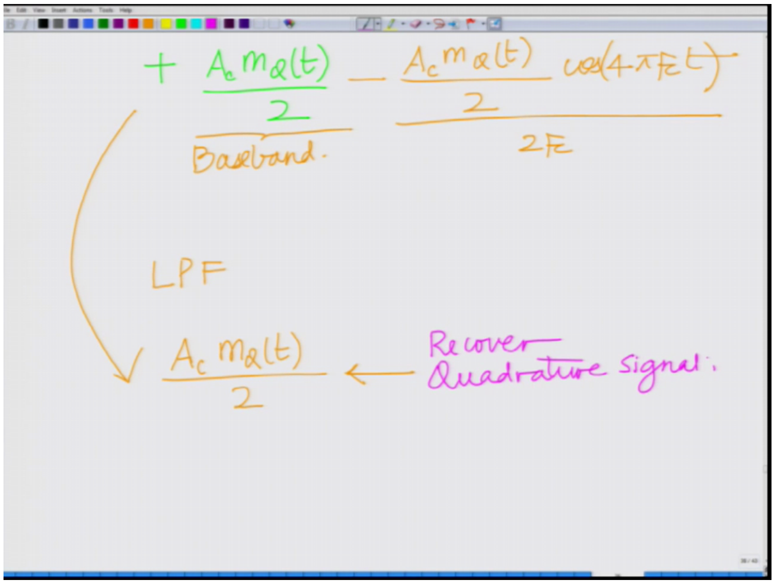

Now I am left with this quadrature message signal Ac mQt by 2. So basically able to recover the by recover the quadrature message signal. By so what we are doing is by demodulating with each of the 2 orthogonal sub carriers by the cosine carrier I am able to recover the in phase message signal by the quadrature carrier demodulating with the quadrature carrier that is sin 2pi Fct I am able to recover the quadrature message signal and the property that we are using essentially is that these 2 carriers the cosine 2 pi Fct and sin 2pi Fct which are quadrature carriers are orthogonal, alright.

So that is the importance and therefore we are able to multiplex 2 signals in parallel, right mIt mQt the in phase message signal and the quadrature message signal respectively on these 2 carriers quadrature carriers which are orthogonal and this is basically termed as quadrature carrier multiplexe, okay.

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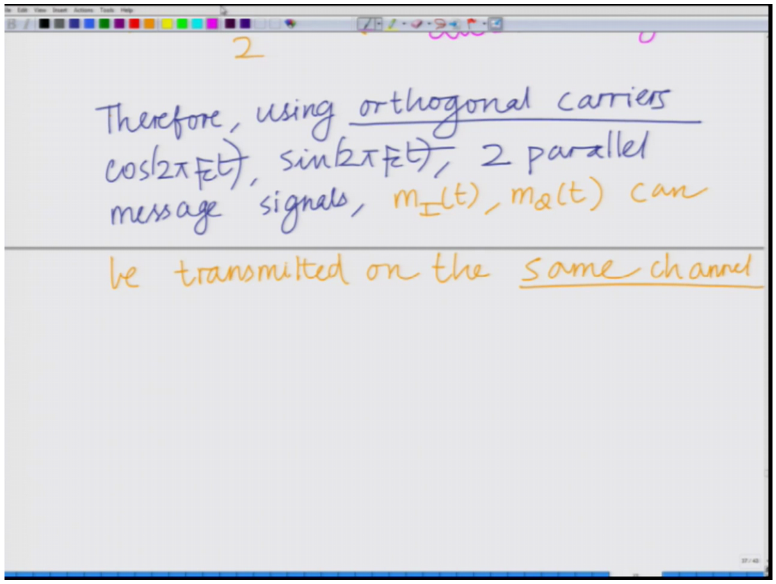

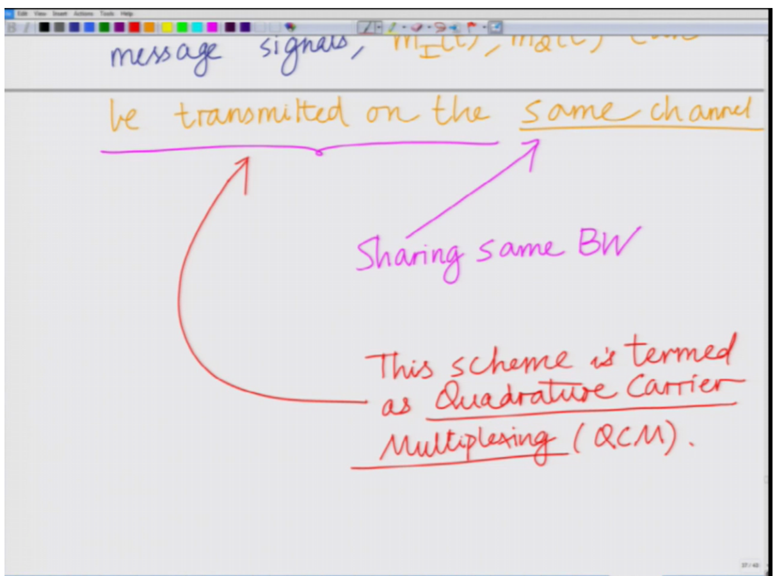

So therefore to summarize this therefore using orthogonal carriers to summarize the idea using orthogonal carriers that is cosine 2 pi Fct, sin 2pi Fct 2 parallel streams of information or 2 parallel message signals and these 2 parallel sig message signals are mIt, mQt can be transmitted on the same and that is important we are able to transmit on the same channel meaning the same sharing the same bandwidth. What we mean by this? We are transmitting them on the same channel is where basically they are sharing the same sharing the same bandwidth and this phenomenon this is termed as basically this principle or this scheme is termed as and we have seen this before this scheme is termed as quadrature carrier multiplexing or basically quadrature carrier multiplexing or basically QC M.

So what we have demonstrated in this module is how to use these 2 quadrature carriers, cosine 2 pi Fct cosine 2pi Fct which are orthogonal to multiplex 2 different message signals that is the in phase message signal and the quadrature message signal signals simultaneously on these 2 quadrature carriers which are orthogonal and uses orthogonality property at the receiver to recover both the in phase message signal and the quadrature message signal by alternatively demodulating first with cosine 2 buy a city and later with sin 2 pi city, thank you. So we will stop here and continue with other aspects in the subsequent modules thank you.