Principles of Communication- Part I
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Module No 7
Lecture 38
Introduction to Pulse Amplitude Modulation (PAM) Sample and Hold, Flat Top Sampling

Hello welcome to another module in this massive open online course, so we are looking at sampling and we have looked at multiplying by an impulse train which we termed as ideal sampling in this module let us start looking at a different technique for sampling which is termed as pulse amplitude modulation, alright.

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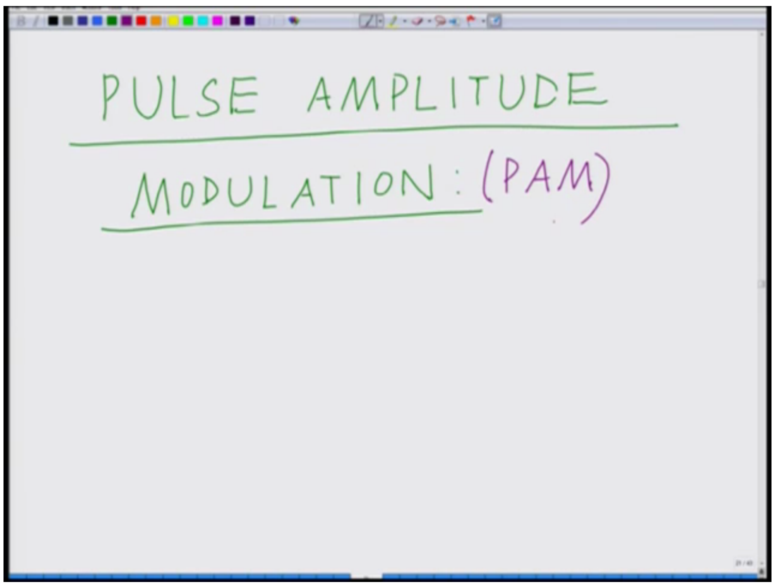

So we want to start looking at different technique for sampling which is basically your pulse amplitude pulse amplitude modulation that is pulse argued modulation which is PAM, okay. So we want to look at pulse amplitude modulation.

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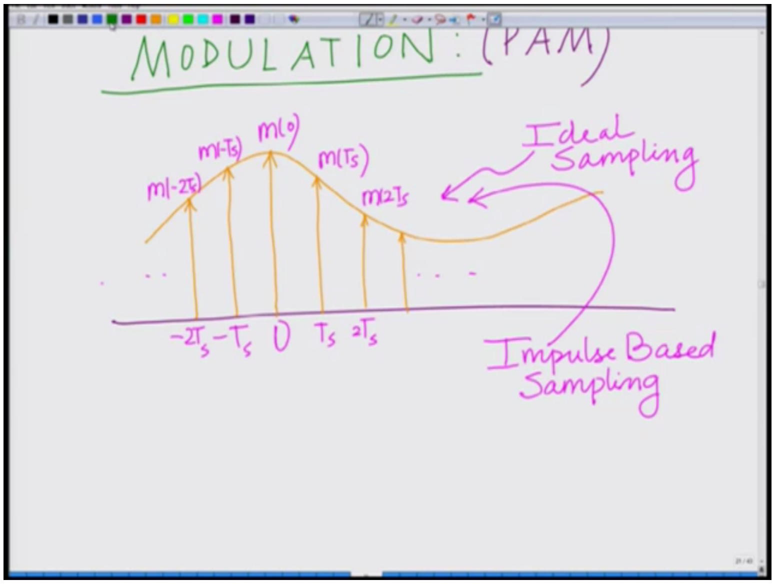

So far we have looked at sampling in which we have a signal, correct? And that is sampled using an impulse train, correct? Using a train of impulses where each impulse is at a multiple nTs and the impulse is scaled by the impulse is scaled by the sample the value of the signal at nTs. So we have this impulse for instance at 0 this is scaled by m of 0 this is impulse at Ts which is scaled by m of Ts this is at 2Ts which is scaled by m of 2Ts minus Ts which is scaled by m of minus Ts this is m of minus 2Ts at minus 2Ts and so on. So this is your basically impulse ideal sampling, okay or basically impulse-based sampling.

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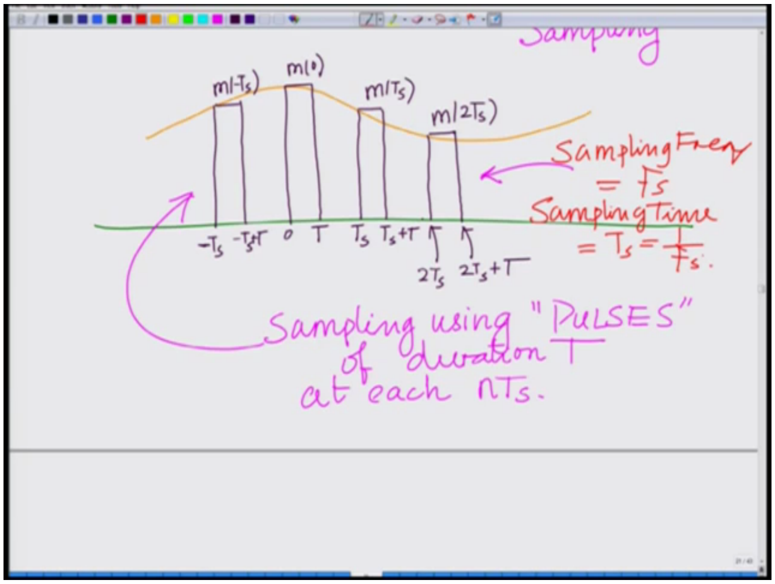

Now what we want to do now is we want to generate rather than using impulses we want to consider pulses so we still have pulses so we are sampling still at every nTs so our sampling frequency so let us say we have this signal and rather than having impulses we have a pulse, so for instance at 0 we have a pulse of height m 0 and duration T at Ts we have another pulse of duration T and height m Ts at 2Ts we have another pulse this is at 2Ts this is naturally 2Ts plus T we have another pulse of height 2Ts similarly at minus Ts we have a pulse which is minus Ts from minus Ts to minus Ts plus T this is of height m of minus Ts, so what you can see is basically at every so we still have pulses at each pulses at each multiple of nTs.

So rather than using impulses we are using pulses of duration T so we are sampling buy pulses, so this is basically sampling using pulses of duration T rather than using pulses, right? Not impulses using pulses of duration T at each nTs, so the sampling frequency is the same sampling frequency is still your best sampling frequency is Fs the sampling time equals or sampling interval equals Ts equals 1 over Fs, so this is still the same but rather than using impulses we are using pulses. And what are we (doi) we have the pulse at every nTs.

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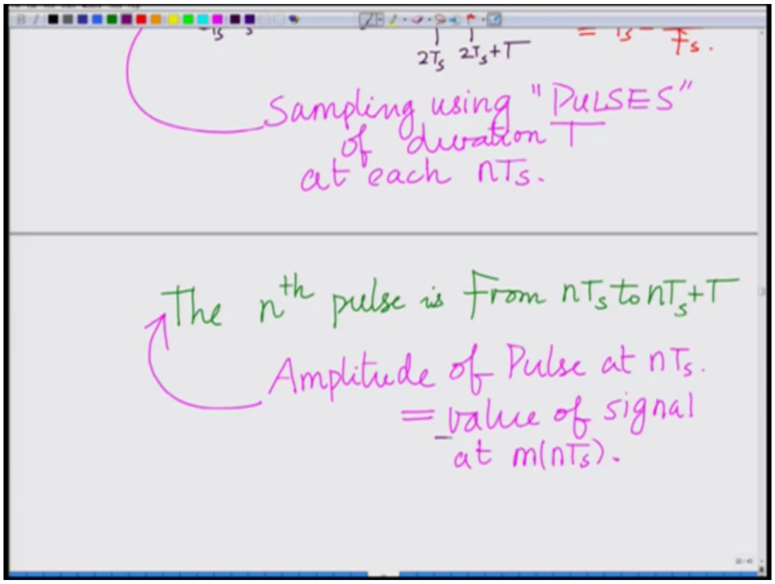

So the nth pulse is from nTs to nTs plus T so pulse is of duration T, alright. And the height of the pulse corresponds to the sample corresponds to the sampled value or corresponds to the signal value at m of nTs. So each pulse is the nth pulse is from nTs to nTs plus T, there? And basically what is happening and the amplitude of the pulse equals value of signal at m nTs amplitude of the pulse amplitude out of pulse at nTs is basically the value amplitude of the pulse at nTs is the value of the signal at mTs, okay.

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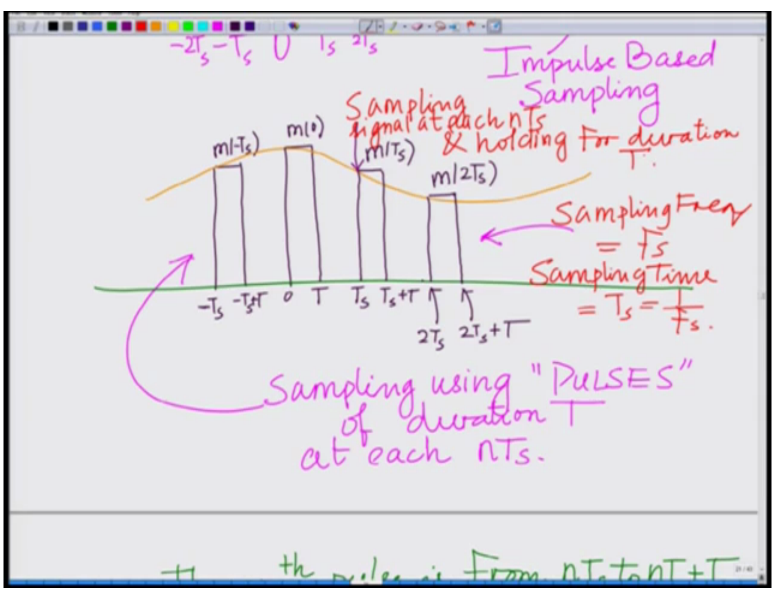

So that is what we have and you can clearly see basically what we are doing is we are sampling the signal you can also see that you are sampling the signal at each at each nTs and holding for duration that is the pulse duration T. So what we are doing is we are basically sampling at each nTs and we are holding that sampling value concept, previously it was simply an impulse which was momentary (())(7:36) just for that instant nTs, now we are sampling it each nTs and holding it constant for a duration T which is the duration of the pulse.

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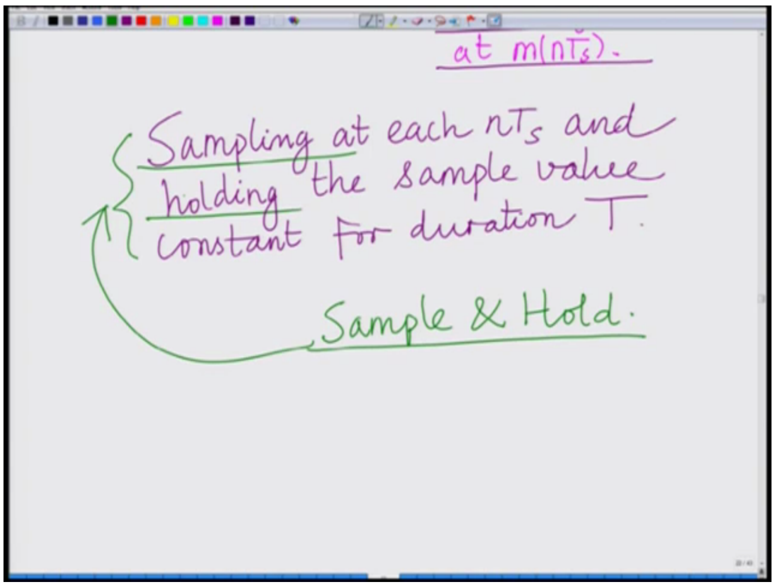

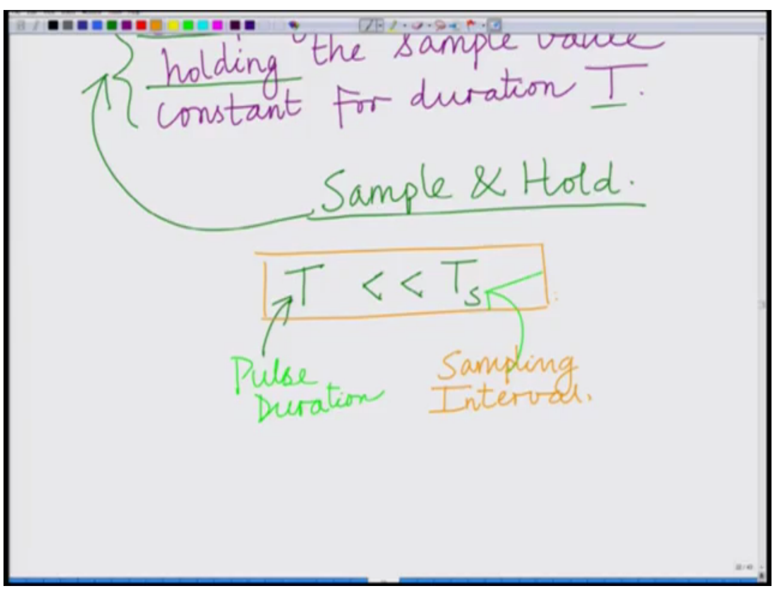

Therefore we are sampling at each nTs and holding the sampled value constant for duration T, so we are sampling it and holding at and therefore this is also termed as a sampled and hold operation so this is also termed as a sampled and hold, okay. So what we are doing is we are sampling and we are holding it for a duration T and you can see this duration of pulse T is much less then Ts. So we have T which is our pulse duration this is our pulse duration. And Ts is basically your sampling interval and Ts is basically the sampling interval and what we desire is we desire that T is much less then Ts so we would like to have this quantity T to be much less then much smaller than the sampling interval Ts.

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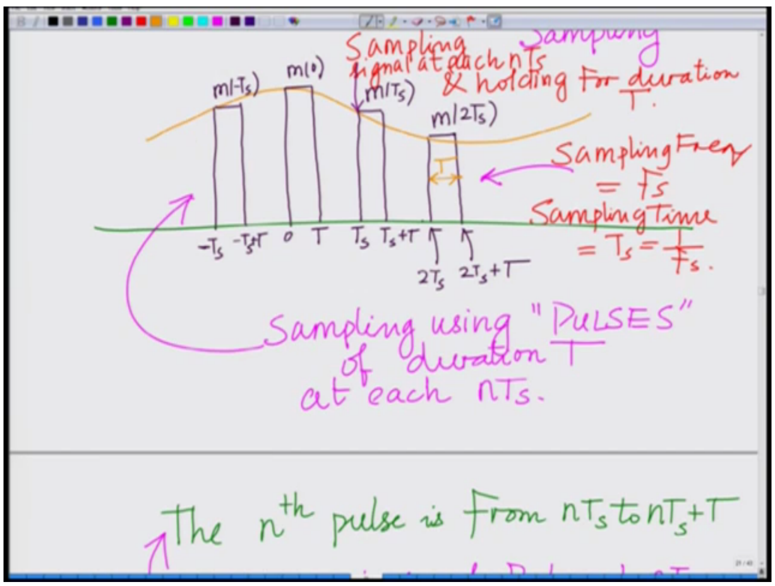

So this duration of the pulse this pulse duration T should be much smaller than T should be much smaller than the sample. So the pulse is confined to a relatively small portion of the sampling interval. And the smaller the duration of the pulse the more precise your sampling is, alright. So the pulse is simply spreading it is a sample and hold operation so it is basically spreading it is spreading the value of the signal over the duration of T, alright. And this is also known as pulse amplitude modulation so this is also known as Flat Top sampling because you are employing Flat Top pulses, so each pulse is a Flat Top pulse.

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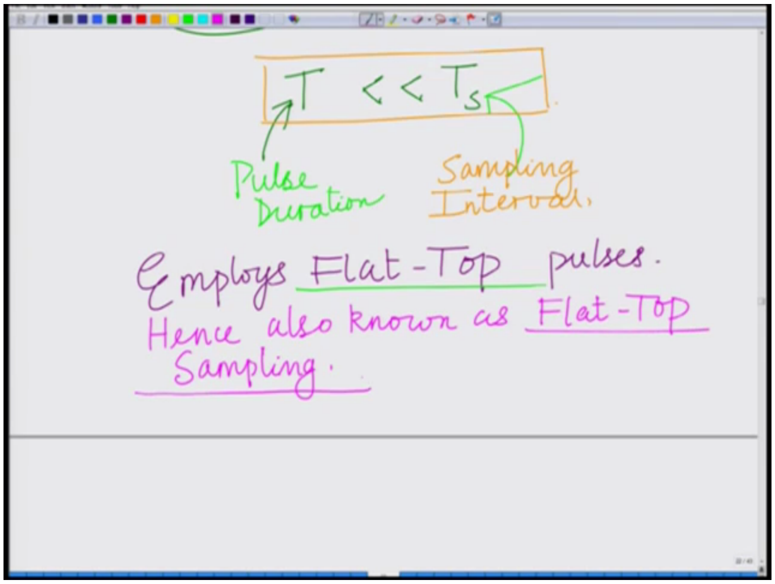

So we are employing Flat Top pulses so this employs, what are known as Flat Top pulses hence this is also known as Flat Top sampling hence this is also known as Flat Top sampling Flat Top sampling, since we are employing Flat Top pulses this is also known as Flat Top sampling.

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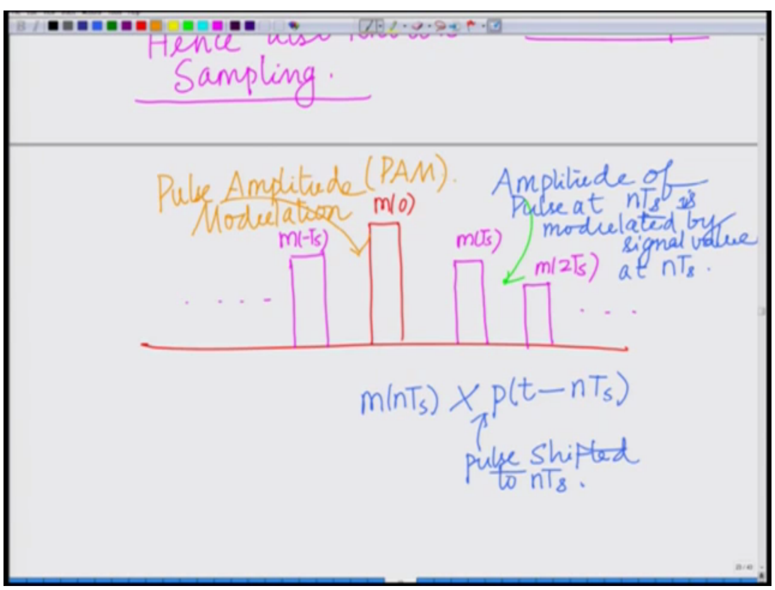

What we are also doing is we are modulating the amplitude of each pulse remember, we have a pulse at each nTs that is scaled by the value of the signal at nTs that is mnts times the pulse that is each pulse is of unit amplitude let us say and it is scaled by m nTs that is the value of the signal, so this is the pulse whose amplitude is (modu) being modulated by the values of the signal at the sampling instances, so therefore this is also termed as pulse amplitude modulation.

So you can see that at each nTs, if you look at this basically what you have is this is the pulse at 0, correct? This is your pulse at Ts mTs this is your pulse at m2Ts and so on and also this is your pulse at minus Ts and so on, so what we can see is that is that amplitude of the pulse of pulse at nTs is modulated is modulated by signal value at nTs. So we are taking m nTs multiplying that by the pulse h let us say h our pulse waveform is P shifted by Ts this is your pulse which is shifted to nTs. So you are taking the pulse shifting it to nTs modulating it or multiplying it by the value of the signal at nTs that is m of nTs that is what we are doing so this is also termed as pulse amplitude modulation this is also termed as pulse amplitude modulation and simply denoted by PAM pulse amplitude modulation, okay.

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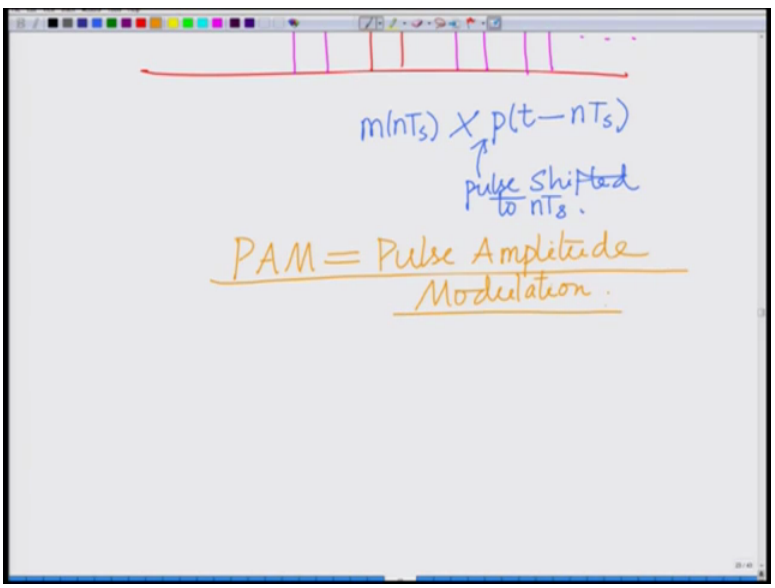

So PAM stands for pulse PAM also stands for pulse amplitude modulation and it is also so this is known by 3 names basically what we have seen it is known as basically sample and hold, right? Sample and hold type of sampling, Flat Top sampling or also pulse amplitude modulation, alright. The sampling frequency is the same Fs sampling duration that is the interval between the samples consecutive samples is same that is Ts which is 1 over Fs, the sample is now of is not an impulse anymore it is a finite duration T, right? Capital T which is much smaller than Ts which we expect to be much smaller which practically should be much smaller than the sampling interval Ts okay, alright. So that is basically your pulse amplitude modulation where we are sampling using rectangular pulses and the amplitude of each pulse at nTs is modulated by the value of the signal that is mnTs at the sampling instant mnTs, okay.

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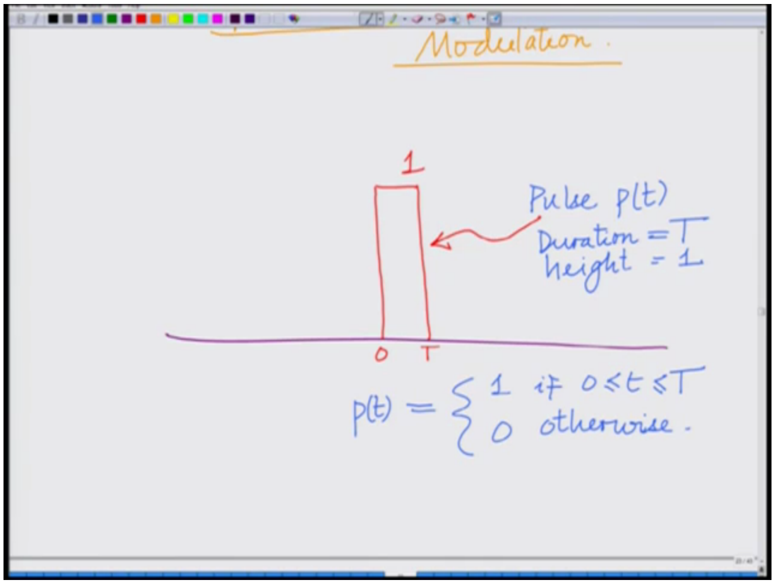

Now if you look at the pulse the pulse as we have already seen is basically the pulse as they have already seen is basically it is basically of height 1 of duration T, so this is my pulse pulse let us say we denote it by Pt equals it has duration height equal to 1 I can represent this pulse as 1 if 0 less than equal to T less than equal to 1 and 0 and 0 otherwise this is my this is my pulse that am using for I am sorry 0 less than height 1 and (dura) duration of capital T and height equals 1. And this is less than or equal to one if 0 is less than equal to T and 0 otherwise.

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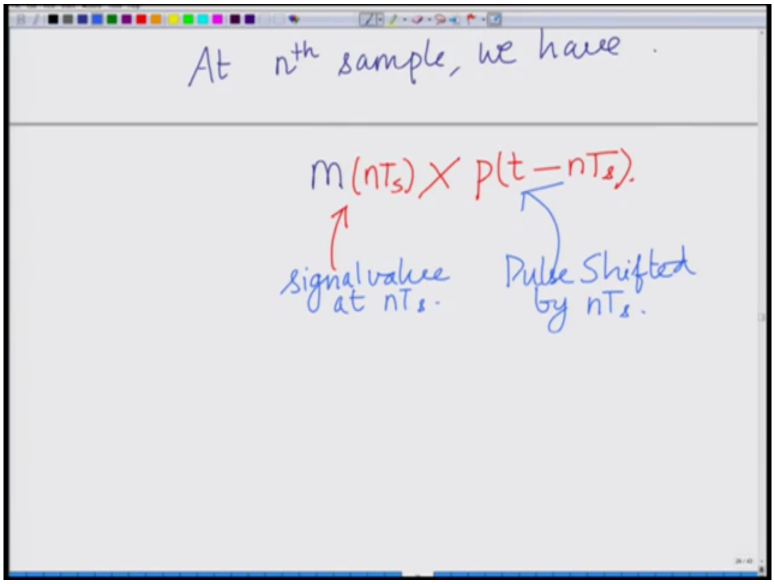

And now what you are seeing is at the nth sampling time we have at nth sample or at nth sample we have you have m of nTs sample at n times the sampling instant multiplied by the pulse gifted by nTs, there? This is a pulse shifted by nTs this is your sample at or signal value at nTs this is your pulse shifted by this is a pulse shifted by nTs. So there you have each sampling instant you have the pulse you are shifting the pulse scaling it by the amplitude of the signal at the sampling instant, alright. And this we will do you see this is similar to the impulse sampling where instead of where previously in the impulse or (ni) ideal sampling we have the impulse, alright. Impulse shifted to every nTs and its impulse scaled by mnTs. Now instead of the impulse we have the pulse. So the pulse shifted to (())(18:10), okay. So what we have here is basically pulse shifted to nTs scaled by (())(18:15) and then the sum of all these pulses that is our pulse stream.

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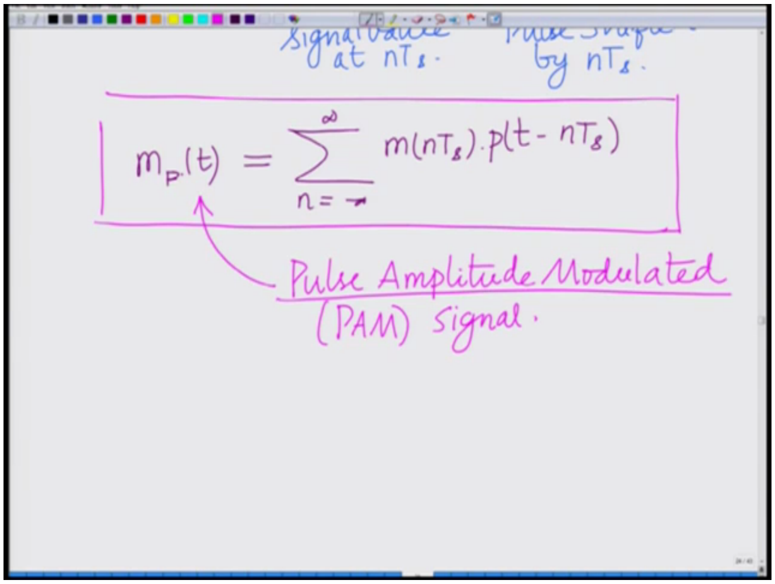

So our pulse stream for pulse amplitude modulated stream is basically n equal to minus infinity m of nTs P of t minus nTs this is our let us say this we call it as our mF of or mP of t which is our pulse amplitude modulated stream this is our pulse amplitude modulated stream. This is our pulse amplitude modulated stream. Pulse altitude modulated stream or basically pulse amplitude modulated or PAM signal or we can call it as a pulse amplitude modulated you can also call it as a pulse amplitude modulated signal.

This is our PAM signal which basically a stream of pulses amplitude at each stream of pulses each pulse pulse at every nTs that is nth multiple of Ts and it is amplitude is scaled by m of nTs This is a stream, alright summation n equal to minus infinity to infinity m of nTs times P of t minus nTs where previously we had a modulated that is scaled impulse train, alright. A train of impulses, impulse at every nTs with with scaled by m of nTs now we have pulse at every nTs scaled by m of nTs and naturally this can be expressed as now if you look at it you can think of this as basically at every Ts, correct?

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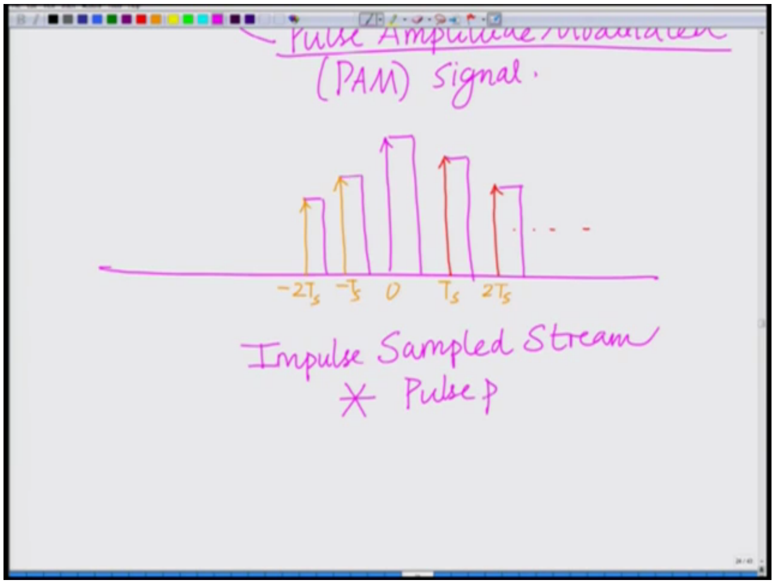

At every nTs you can think of this as the original your original impulse stream convolved with the pulse because we have our original stream of impulses, correct? Remember we have our original stream of impulses, correct? At Ts minus Ts and so on your original stream of impulses 0 to Ts minus Ts minus 2Ts and now what we are doing in addition we can convolved it with a I can it convolved with a pulse, correct? So if I convolved it with a pulse this impulse stream if I convolved it with a pulse will give him a, so I have the impulse stream or impulse sample stream I represent it as impulse sample stream convolved with your pulse that is P Pt.

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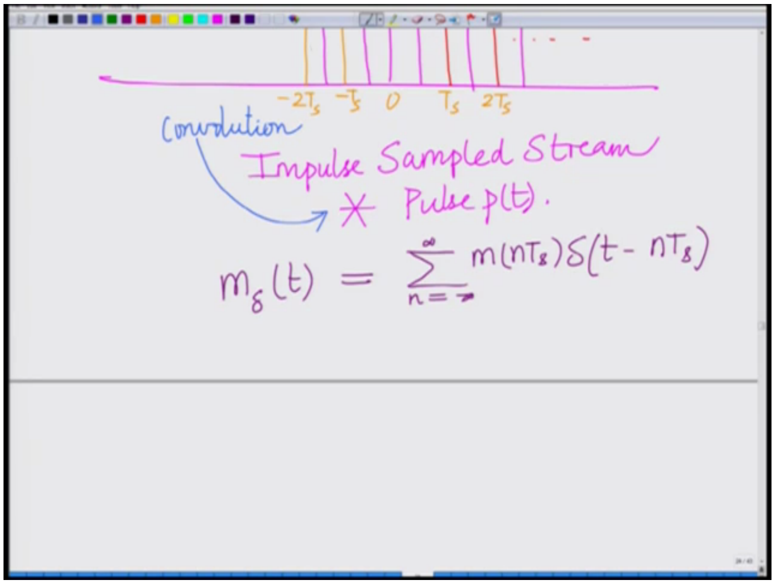

So our impulse sampled stream or impulse sampled signal is remember, m delta T equals well, summation n equal to minus infinity to infinity m of nTs into delta t minus nTs, okay. Now this is basically the convolution operator this star represents convolution, now I take this m delta t, correct?

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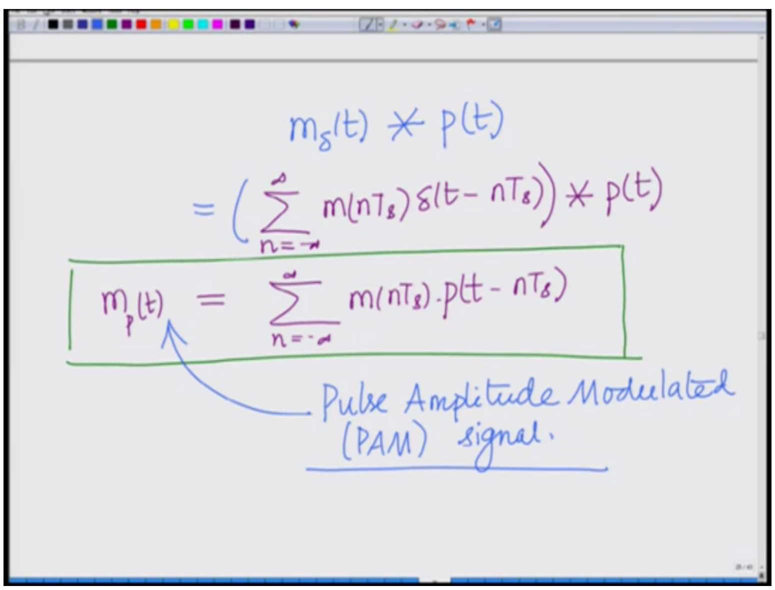

M delta t and convolve with, okay take this m delta t (con) convolve it with P of t that is basically my substituting for m delta t that is basically my summation of n equal to minus infinity to infinity m of nTs m of nTs into delta t minus nTs convolved with P of t, so that basically gives me summation n equal to minus infinity to infinity m of nTs delta t minus nTs convolve with Pt that is basically P of t minus nTs which is nothing but my mP of t that is nothing but my pulse amplitude modulated signal.

So this signal which is basically m of nTs P of t minus nTs summation and equal to minus infinity to infinity m of Ts nTs into P of t minus nTs this is basically my pulse amplitude modulated signal this is my or this is basically my PAM this is basically my pulse amplitude modulated signal or basically my PAM signal, okay. So therefore we have derived the expression for the PAM signal, what we are saying is so what we have seen is that basically rather than ideal sampling of course which is difficult to implement because one has to generate impulses a train of impulses and train of impulses is impractical, right?

that is impractical to generate so one can replace them by pulses which are more realistic pulse which has a finite amplitude and finite duration, alright. A pulse of certain height which has a finite duration much lower than the sampling duration of we desire it to be as low much lower than the sampling interval that is the pulse of width capital T which is much less than the sampling duration sampling interval Ts, alright.

And therefore now one can sample the signal at each Ts (multi) or each nTs and hold it for a duration of T which is the duration of the pulse, alright. This is known as slack top sampling or also known as a sample and hold and this can be represented as analytically it can be represented as the convolution of the original impulse sampled signal although it is not the operation that we are performing it is not that the signal is the pulse amplitude modulated signal is being generated by first impulse sampling and a followed by passing through filter with response given by the (()) (25:58) rather it is simply a representation.

So this Flat Top sampling operation can be analytically represented as the as basically sampling or impulse sampling the original message signal m(t) followed by passing through a filter with impulse response given by the pulse (())(26:17) Pt, alright. So that gives us basically the stream of pulses each shifted to each nTs and scaled by the amplitude or the value mnTs of the signal at the nth sampling instance so this is the pulse amplitude modulated signal and subsequently we look at the frequency response and also how to reconstruct the original signal from this pulse amplitude modulated signal, thank you.