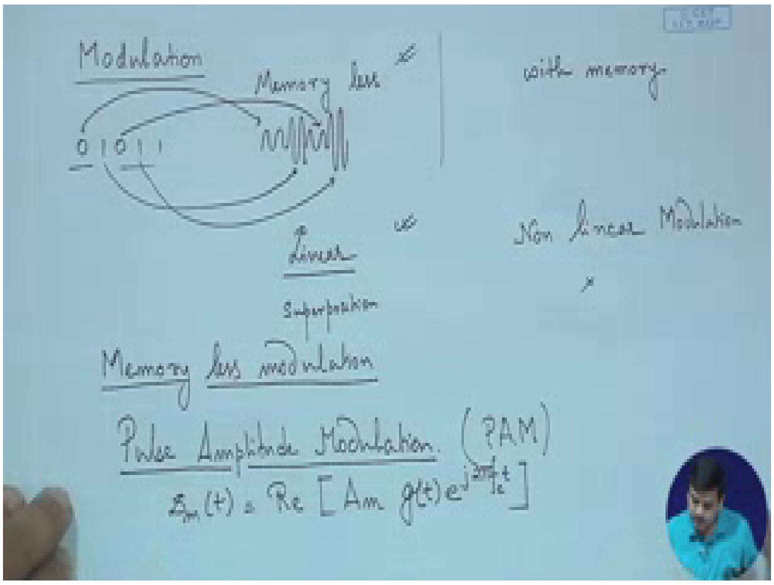
Modern Digital Communication Techniques
Prof. Suvra Sekhar Das
G. S. Sanyal School of Telecommunication
Indian Institute of Technology, Kharagpur

Lecture – 25
Memoryless Modulation (Contd.)

Welcome to the lectures on Modern Digital Communication Techniques. We are continuing our discussion on digital modulation methods. In the previous lecture we have given an introduction to digital modulations where we have identified the fundamental essence of digital modulation. And we have used the terminology symbol mapping which we have described in qualitative terms, what is meant by symbol mapping. So, will continue further to take a look at a few modulation methods in this and subsequent lectures.

So, when we when we consider digital modulation, as we have been doing.

(Refer Slide Time: 01:01)



So, it can be classified in various ways. So, one of the ways would be memory less modulation and naturally the other counterpart would be with memory right. So, when we say memory less what we mean is that, suppose I have a sequence of 0's and 1's, right. A memory less modulation would map this particular 0 let us say to a waveform which is here and then let us say a 1 to a waveform which is here and then a 0 again, right. To this one and again a 1 2 let us say, right this 1. And what we mean is that, when it maps this symbols to these waveforms it only looks at the current symbol and maps to the waveform. It looks at the current waveform map suited, look at the current sum current symbol, maps to this current symbol maps to this. It does not look at anything more. It does not look at what was the past modulation and what could be potentially the future symbol that would be sending into. Whereas, with memory modulations would clearly look at the previous and the future bits that are going to come or the symbols that are going to come.

So, it is basically looking at the previous output, that what was the previous output. So, there is some kind of memory involved in the past, memory means it is a past right. So, when we say with memory it uses some information of the past in taking action on the present. So, that is a basic way of classification. And you could also classify further as linear modulations and naturally non-linear modulation. So, when we say linear modulation what we effectively mean is, a principle of superposition holds and here it does not hold that is as simple as that. So what, what it effectively means is that if I have a 2 inputs then the output could be expressed as a superposition of the outputs of 2 different inputs. So, in that case it will linear modulations will be mostly dealing with a linear modulations. Brief note on with memory.

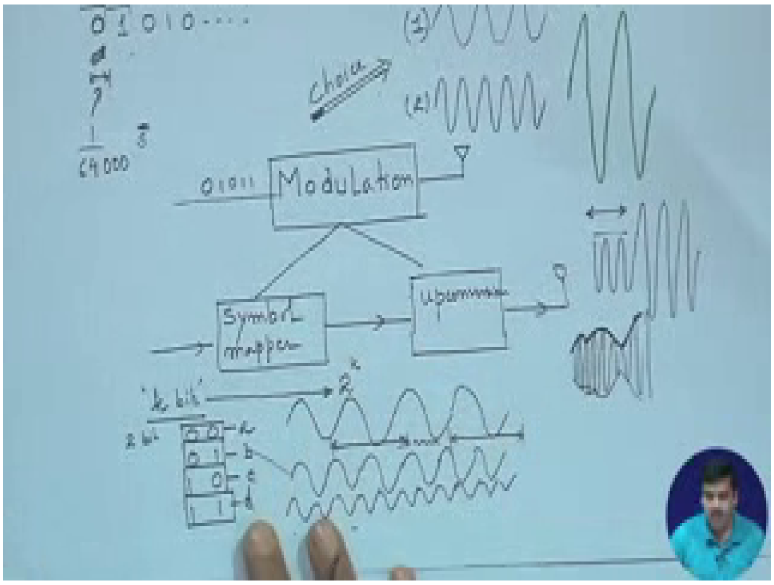
Now if you look at a transmissions which a use memory. So, one particular example could be the trellis coded modulation where there is a particular way of traveling a particular graph and there involve some kind of memory. And these kind of modulation techniques are generally very robust techniques and they are used for to encounter certain kind of errors which the symbols might have in the channel.

So, they usually have an inbuilt error production mechanism into these, into their transmission procedure; however, most of the common modulation techniques that you would encounter let us say, in everyday life in commercial systems mostly. You would find that the modulations used mostly these days are memory less modulations and this error correction codes are usually handled through a special technique known as forward error correction codes. So, there is a whole lot of theory on forward error correction codes and one would use encrypted or encoded bits, these bits are then passed on to a particular to the modulator which is memory less. And the modulator job would be to send the signal across the channel and the error correction codes job would be to protect the bits from getting into errors right.

So, generally we would talk about memory less and generally will also talk about a linear modulations, but we would also spend some time on non-linear modulation at an appropriate point of time right. So, with that brief classification between memory less and with memory modulations or let us say linear as well as non-linear modulations. It is important or it is time now that we get into one of the earliest one of the first modulation techniques and one of the first modulation techniques in the class of memory less modulations which will begin with. So, will begin with memory less modulation and the first signal or the first modulation technique that we are going to look at is, pulse amplitude modulation right.

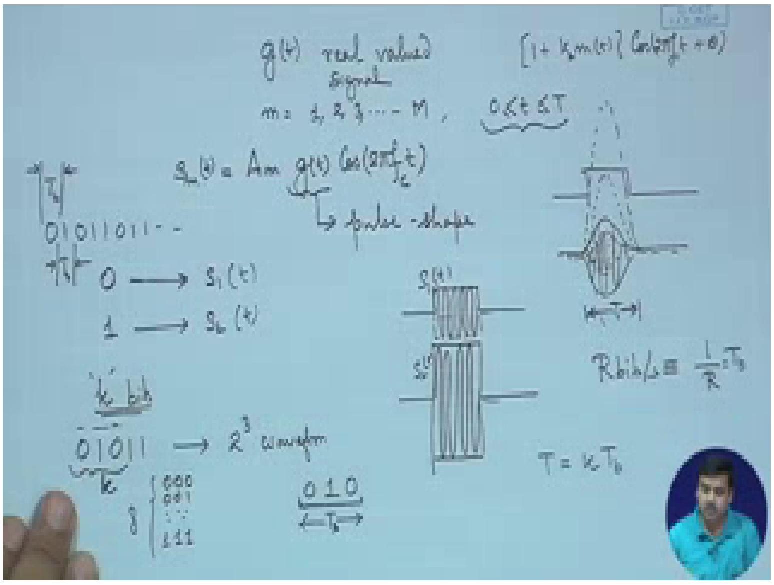
So, when we talk about a pulse amplitude modulation in short, you will usually encounter this named PAM, right. A pulse amplitude modulation so, what it does it basically maps these inputs to waveforms which differ from each other in terms of amplitude, right.

(Refer Slide Time: 07:04)



This is, this is what we mean by pulse amplitude modulation. So, a pulse amplitude modulated signal s m of t we could write it as s m of t is usually represented as the real part of A m, right. M indicating message or modulated. So, this is A m is the amplitude there is g t and there is e to the power of j 2 pi f c t right.

(Refer Slide Time: 07:57)



So, at this point you may recall amplitude modulation which you have studied before. A amplitude modulation you would have 1 plus k amplitude modulation coefficient times m t times cos 2 pi f c t plus of course, there is some theta associated with that. And if you look at this it will be real part of A m. So, if A m takes real values will be A m and g t would be again taking real values which is indicating the pulse. So, basically what we have is g of t is a real valued signal right. So, A m is the amplitude and where m takes on values 1, 2, 3, capital m. And this is valid, this particular notation is valid for time less than equal to capital t which is greater than or equal to 0 right.

So, will shortly explain what is this. So, with this particular representation what you get over here is A m g t cos 2 pi f c t. So, this is not much different from amplitude modulation if I remove this a 1 which is basically the suppressed carrier. So, is a suppressed carrier double sideband amplitude modulation that you get. The difference with amplitude modulation that you have over here is, you have amplitudes with certain possibilities right. So, we are selecting one particular amplitude and this amplitude selected is further shaped by a waveform which is known as the pulse shape. This is one of the very important things of digital communications. So, with the pulse shape and this signal is valid for a duration between 0 to capital t. And since you are selecting the amplitude pulse with an amplitude, by pulse we mean some duration of time, this is a rectangular pulse you could have pulse which looks like this.

So, pulse and you are selecting an amplitude for it so that means, you could have a pulse with this amplitude, or you could have pulse with this amplitude, or you may have pulse with this amplitude. And there is carrier so, when you are modulating that your signal would appear like this or if you are modulating this here your signal would appear in this form and so on and so forth right. So, is an amplitude there is an pulse and your modulating the amplitude of the pulse. So, that is why pulse amplitude modulation and because you are modulating; that means, you are changing the amplitude of a carrier therefore, you are calling it the modulation right.

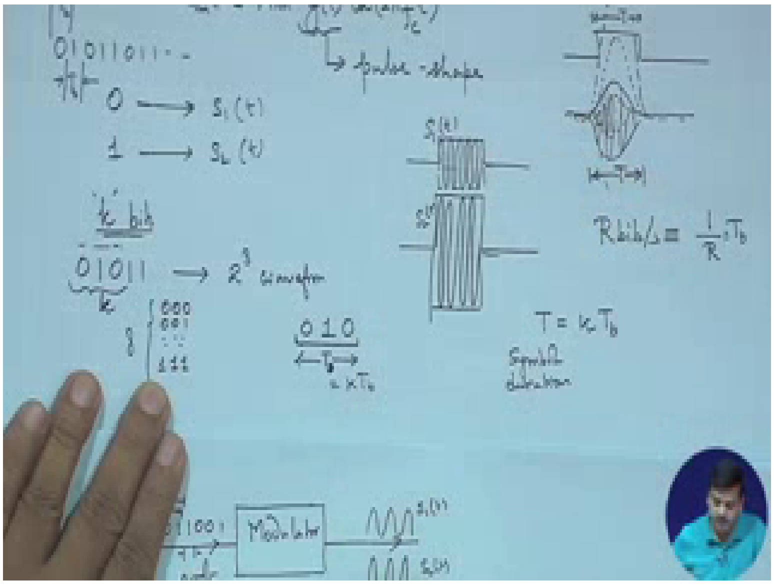
So, is a lot of similarity with analog communication except that you have the waveforms to select which are discrete in number of options. But the waveforms themselves are analog. So, so if it is a rectangular which is easier to visualize let us take one and let us take another. So, these both are valid for the duration 0 to t. So, in the first case the modulated this is s 1 of t and this is s 2 of t that we get. So, you have to 2 choices s 1 and s 2. So, if you get a 0 you might choose s 1 if you get a 1 you get s 2. So, these 0's and 1's are the sequence of 0's and 1's that keep coming, and this choice would be valid for this duration T right.

Now a some interesting things come in. So, instead of just having 2 options if I would have let us say more options, as we just discussed earlier if there are k bits so that means, we are grouping k bits. So, in this particular picture it represents 3 bits. So, we should have 2 to the power of 3 waveforms because, whenever you select 3 you going to get 0 0 0, 0 0 1, dot, dot and So on up to 1 1 1 which are basically 8 waveforms, right. Sorry 8, 8 possible combinations each combination should map to a waveform this means I should have 8 different amplitudes. This is not dependent on n as per this representation only the amplitude is different dependent on m.

So now, these things come at an interval let us say, we define T b has the duration of the bit, right. Duration of the bit as T b, if this has a duration of T b then you have to wait for k bits, you know wait for k bits; that means, in this case 3 bits before you get your group of 3, before you can form this particular symbol. So, once you have waited for this 3 bits in this example or k bits and your form this k bit word or this k bit symbol, now you can select a particular waveform. So, you get a bit you wait you get the second bit you wait and then till the end of the third bit you wait. So, in this interval now you have formed a word consisting of 3 bits right.

Now, the next word will again take this much duration of time. So, what the transmitter does it sends this particular waveform whatever is a waveform for a duration of time which is basically T s which is known as the symbol duration with same as this T. So, therefore, what we are doing is T or T s as you may call is equal to k times T b, because now each of these waveforms should accommodate 3 bits. Now why did we have such a relationship? And of course, at some point you can say that if you have R bits per second that would definitely mean that one upon R is equal to T b that is what we are using is seconds per bit right.

(Refer Slide Time: 15:46)

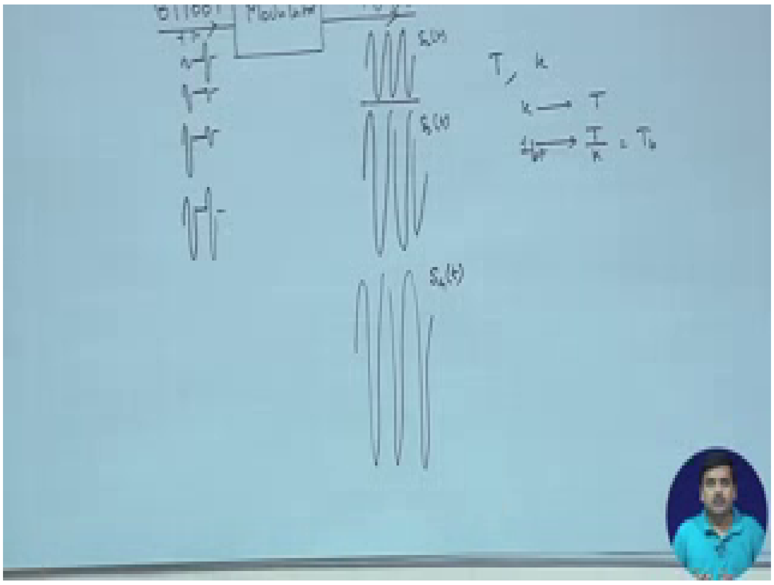


So, why do we need this? We need this for the reason, because if we are taking the modulator at some point in the transmitter. We know that bits are coming into it. And we know the modulator should choose a waveform or let us say a waveform like this, right. Let us take 4 options or let us say even a bigger one. So, these are the 4 options. So, this is s 1 of t, s 2 of t, s 3 of t, s 4 of t. So, if it has to choose between these 4 so that means, it will be grouping 2 bits at a time, right. So now, if this was sent across one symbol during one bit duration; that means, I could send it in this short duration, if I would send it in this short duration, then in the next bit interval I would be sending nothing.

So, it means I would wait to form this group, but in this interval I would send away my waveform. So, I could send it away in this waveform, at send away like this. And then in the next bit duration I would not send anything. I would not send anything whatever had been my choice there again the next one, I could choose this a depending upon my sequence whatever it is, right. And again I had be sending nothing, right. This is a bit awkward from a multiple points of view, and one particular modulation scheme could be that the first waveform has an amplitude of 0. And the second waveform has an amplitude of something which is non 0 which is also known as on off keying which is a special case of what we are dealing over here.

So, in that case when you are not sending anything that could account for certain information being said. So, generally we would not cannot do a situation like this. Neither we are entitled to send this waveform which is longer than the duration of k bits. Because if you were to do that; that means, if you are to take a duration which is more than k multiplied by T b duration then, when you have a whole stream of bits coming in for a very long duration the modulator would have to create a huge buffer, and then the rate of things going out from the modulator would be at a slower rate than things coming in to the modulator and it would act like a sync, right. Now if the modulator sends things at the rate which is faster than the rate at which things come in; that means, it would be set generating waveforms even if there are no bit streams which would act like source which is again an undesired property. So, would like the modulator to work in a way where, the rate at which bits come in is the same rate at which effective number of bits go out.

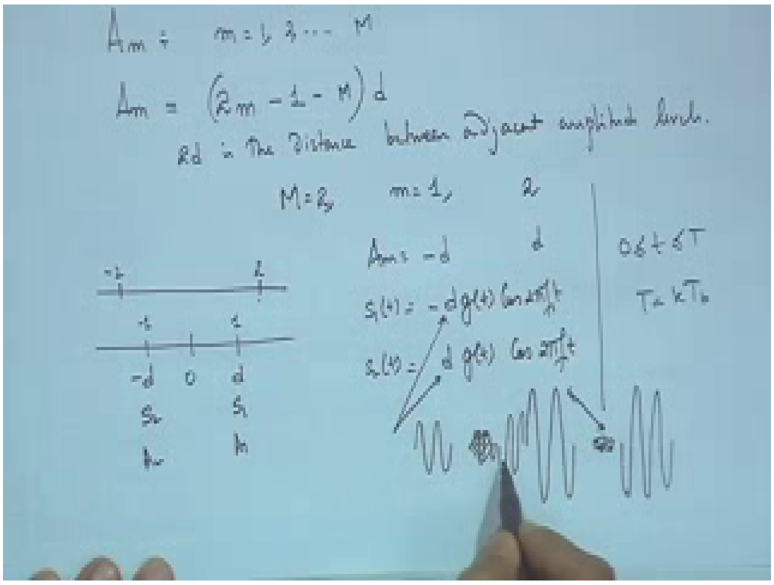
(Refer Slide Time: 19:25)



So, what we see over here in this duration t there are k bits that go out. So that means, in k bits take t duration to go out so, definitely one bit would take t upon k and one bit would take t upon k and that is T b and that is exactly what you have over here.

So, what we effectively mean is that if there are k bits, right. In that case your symbol t should be equal to k times T b; that means, this duration pulse duration should be equals to k times T b. So, this is also known as the symbol duration and these are your symbols these are your effective symbols. So, these are some of the essential a things that we should remember whenever we are studying a modulation process.

(Refer Slide Time: 20:25)

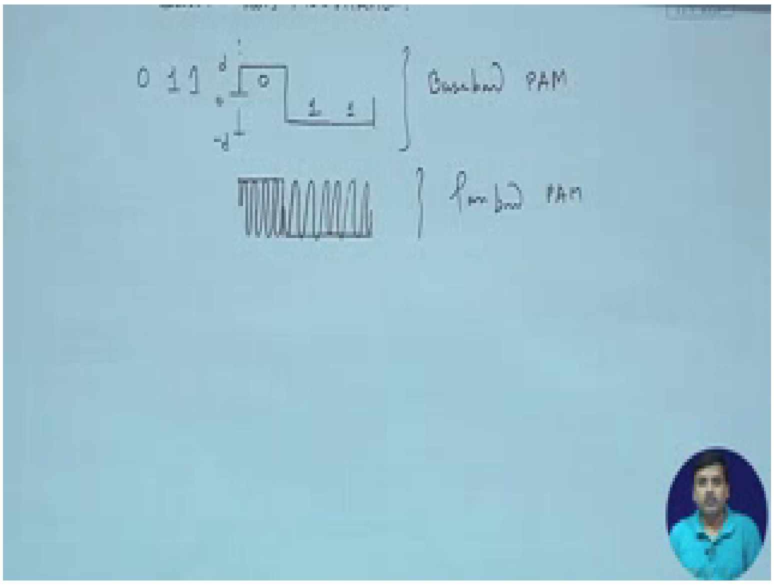


Now, we can move further with our discussion on amplitude modulation and we can say that these A m, amplitude values that you are taking is valid for m is equal to 1, 2 up to let us say, capital m this is for notation. And you could design A m as 2 m minus 1 minus m times d where, in 2 d is the distance between adjacent amplitude levels right. So, what we mean by this is one particular way of mapping to amplitudes, right. This is not an harden fast rule that you have must follow, but this is one standard policy or methodology by which you could select amplitudes. So, for example, I have m is equal to 2. So, your small m can take a value of 1 and 2 and A m would be 2 minus 1 that is 1 minus 2 right, that is minus 1. So, that is minus d and when m equals to 2 this 4 minus 1, that is 3 minus 2 it is 1 this d.

So, what we are saying in one case you have s 1 of t which is equal to minus d times g t cos 2 pi f c t. And s 2 of t equals to d times g t cos 2 pi f c t, right. And of course all of these are valid for the duration of time which is indicated by this and where of course, t is equal to k times T b right. So, effectively what we see over here, we still have this unknown parameter d right. So, if we would look at this diagram or this particular amplitude levels we could draw a picture indicating this amplitude levels, if this is 0 and this is plus t, this is minus t we could say this is s 1 and this is s 2, right. So that means, the amplitude or this is a 1 and this is a 2 this is the amplitude of the first symbol this is the amplitude of the second symbol and these are carried through, right. And what is d. So, by choosing a value of d you could make these amplitudes smaller or larger; that means, for a certain value of T my waveform could be this and the second waveform could be, right. A different value of d could have my first waveform as this and my second waveform could be same as this does matter or could be even smaller.

So, what I effectively mean is that this distance between the 2 is governed by d. If I make d equals to 1 then this value is 1 minus 1 and if I make d equals to 2 in that case, this will be 2 and minus 2. So, where it is 2 and minus 2 what we see that the distance between this is much more than the distance between these and what will be clear this situation will require more energy, but it will be more resilient to noise than this. So, effectively what we have is by suitable choice of d you could effectively have different waveforms, right. And in this particular case what we have is these are simply distinct by virtue of the d phase which is d and minus t. So, here what people say is that you are basically having wave form like this and you are basically having wave form of this, right. And of course, you have a bigger d equals to 1 in this case, d equals to 2 in this case you could say. So, one is, So there is a much more energy in this case, there is much lesser energy in this case and this will be more resilient to noise than this particular case, right. Ok.

(Refer Slide Time: 25:28)



So, how these things matter we can see even a bit further down. A further important concept here would like to bring into is the notion of carrier less modulation. So, if we let f c equals to 0, it means in this particular if we let f c equals to 0, well f with A m g t. So, if you look at A m g t in this case we would be able to, we can use almost this particular thing picture that we have here is, we would say that suppose I have a 0 and a one sequence. A 0 would mean I have an amplitude of plus d for the duration of t and a 1 let us say, would mean I have an amplitude of minus d for a duration of t, right. And then if there is another one I have an amplitude of minus d. So, if this is 0 this is d this is minus t. So, I have got 0. 1, 1, 2 sent 0, 1, 1. I am mapping 0 to plus d one to minus t this is what I am going to send.

Now, if I have a carrier my things would not look much different except that there is a carrier, right. And then there is a phase reversal; however, here there is continuity of phase because we are not changing right. So, what we see over here is that, in case of baseband. So, this is typically you would call baseband pulse amplitude modulation and this would be the pass band pulse amplitude modulation. So, this modulator that we had discussed earlier here, we could still analyze our system without up conversion and we would be able to analyze the system in our low pass equivalent form of what we have studied before.

So we, what we see is that we have now come to the point where we would be using whatever we have studied our previous, in our previous lectures that is the band pass signal and it is low pass equivalent representation. So, if you would recall the low pass equivalent representation is the translated signal from f c down to zero; that means, which is carrier less, will be using a similar form throughout the study and I have given you in just now a representation of how things will be for a typical carrier.

So, will continue on this in the next lecture where you look at the diagrammatic representation for a 4 level pulse amplitude modulation and the few relationships pertaining to pulse amplitude modulation. Then we will move on to phase shift keying and finally covering a quadrature amplitude modulation, a before moving on to a few more other modulation techniques.

Thank you.