Modern Digital Communication Techniques
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Lecture - 24
Memoryless Modulation

Welcome to lectures on Modern Digital Communication Techniques. So, till now we have covered some of the very important and essential components which will help us go through this particular subject. So, we will briefly summarize some of the important things. So, that it is refreshed in our mind and will be using them starting from almost this particular lecture. So, if we recall one of the early things that we discussed, it is basically the concept of layering and interfaces.

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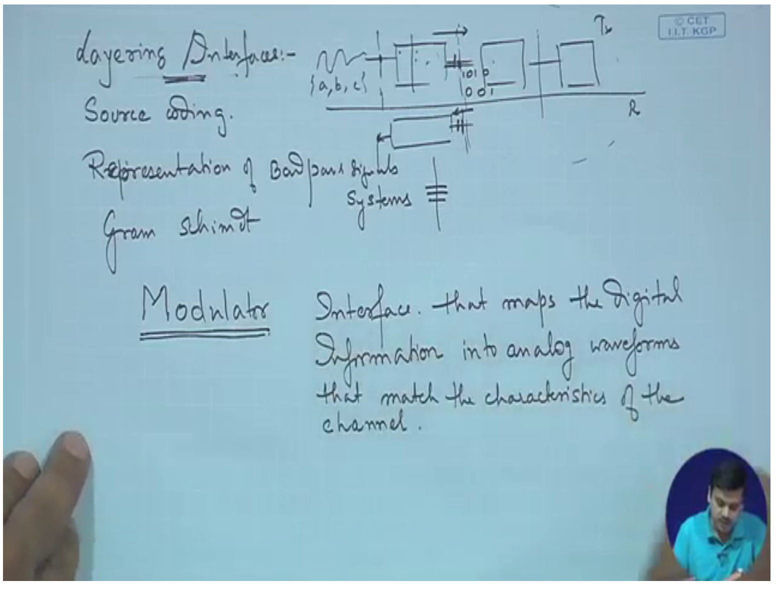

So, here I just like to remind you at this point that when we talk of layering and interfaces we are basically saying that you separate the functions in some logical form, in such a way that these operations here do not depend on this on the following section or the one before, save the inputs and in save the interfaces. And there are peers at the receiver.

So, if this is the transmitter and this is the receiver at the peers again a similar interface should be used to feed into the reverse procedure. And it would generate an output which is similar in form as the input in this one. And in this particular way, now we also said that one could see that as if this whole thing is the channel and you are sending signals into the channel, you are getting signals out of the channel. Or you could see that this is a source and this is a destination, you could also see it in that manner.

So, these are some of the important things that we did and following this we did look at source coding. Now why am I trying to tell you about all of these because it is important we are moving to a different phase of things we have been doing some particular topics, but now it is important that we do some different ones. So, it is important that we find out where does each one fit in. So, when we did source coding what we did was we took some source which could be analog or which could be discrete and what we produced at the output was binary sequence, right. This is what we produced at the output irrespective of the kind of source. And if it was analog source we of course, had some portions which would convert this analog to digital once in digital it will produce a binary bit sequence right.

So having done these things and of course, when you studied source coding we did find out where the source coding fit in to this layer diagram. And we were always discussing what was the kind of input and what was the kind of output that we would consider in terms of interfaces for this particular module. So, once you have done source coding then we moved on to representation of band pass signals and then we did representation of band pass systems. And one of the essential things that we studied over here, is that any particular channel is typically band pass.

So therefore, the signals that go into the channel are also band pass. But however, what we did is we found the representation of the equivalent low pass form through several steps and of course, one of the important things that helped us was the fully relationships. Now once we did these 2 we also figured out that if there is a band pass system which is excited by a band pass signal the output is; obviously, going to be a band pass signal. So, we again try to find the relationship of the response of a band pass system when excited by a band pass signal. And what we stated is that this output would be convolution of the impulse response of the system as well as that of a signal.

And then we figure out how to connect to the low pass equivalent representation of the output with respect to that of the channel or the system and the source and we found similar relationships exist. Finally, we also did the characteristics we did study the characteristics of narrowband stochastic process. And then we related these outcomes where we studied actually the correlation properties and the power spectral densities and we related this to white noise. So, we have essentially done some of the important parts of the communication of a digital communication system where given any source let us analog source we finally have binary sequence. And then once we have the binary sequence we need to now send this binary sequence across to the through the channel into the receiver. And before we do that we must use some notations which we have described and certain relationships.

And now is the time that we look into the details of this particular system. So, that we can use whatever we have developed before in subsequent establishment of the communication system as well as analyze the performance in later courses. So, the next important thing of course, what we did at some point was the gram Schmidt procedure. By the gram Schmidt procedure what we did was, we given a set of vectors, we started off with vectors. We said that you could find a set of orthonormal vectors given the set of vectors so that you could use these orthonormal vectors as basis and you could represent any vector using them.

That means provided these vectors that were given to you span the vector space. Or you would find orthonormal vectors within the vector space spanned by these particular vectors, all right. And then we moved on with that and we said that well, signals could also be represented in a form like vectors. So, for that what we did was we equated certain expressions for signals and we, we what we did was we found a similar set of steps by which given a set of signals you could find a set of orthonormal signals from those sets you could construct them. Using those orthonormal signal set you could represent the original signal. And then using the coefficients which are obtained by projecting the signal onto this orthonormal basis functions, you could take this coefficients as the components of the signal onto those orthonormal dimensions.

So if you have n number of orthonormal signals spanning a signal space, then given a particular signal this signal would have components on these signals. And these components would represent the coefficient of the signal on a particular direction which is basically a signal indicating a vector like behavior. We also said it follows cauchy schwarz inequality triangular inequality just like vectors. So, basically we have the vector space or the signal space concept which we are introduced. Again these will be necessary as we move on to the next important part of a communication system right.

So then since we have studied all this things. The next important thing that we come to meet is what we typically wait for in a communication system is the modulator. So, when we talk about the modulator, it is basically what communication system is generally all about. So, when we talk about analog communication we talk about an amplitude modulation. You talk about phase modulation, you talk about frequency modulation and when you talk about digital communication, you generally talk about let us say amplitude shift keying, phase shift keying and frequency shift keying and so on and so forth.

So essentially you are talking about modulation when you think of communications generally that is the perspective. So, this is one of the vital things of a communication system and our objective would be how do you represent a modulated signal and what is it all about is to what to look at. So, if we talk about the modulator all that we can say about modulator is that it is an interface right. So, we have been talking about layering and interfacing it is an interface that maps the digital information into analog waveforms that match the characteristics of the channel, right.

So this almost tells us some of the things that we mentioned in the beginning of this particular lecture is that, it is an interface. So, why do we say? So, because anyway we have talked about layering and interfaces, definitely when we talk about modulator, it is does act as an interface. So, there should be some interface that we are talking about. So, it is an interface that maps the digital information to the analog waveforms that match the characteristics of the channel. So, it is very close to the channel now right. So, previously you had seen some block diagrammatic picture where we have let us say the source right.

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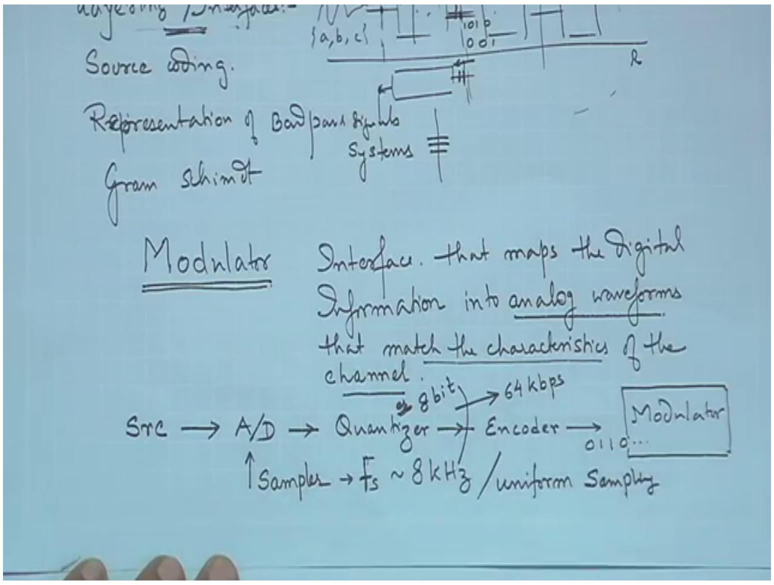

Let us say there is an analog to digital converter, let us say there is a quantizer, let us say there is an encoder. So now, at the output of the encoder you have let us say some binary sequence and then comes your modulator right. So, there sit is the modulator. It will map the sequence of 0’s and 1’s into certain waveforms. So, what we have is that in the analog waveforms right. So, that might raise a question that are we studying digital communications or we studying analog communications. So, again in the beginning we did mention that when we talk of digital communication we still require analog communications. And we did also give an example where we said that if your source is a discrete source; that means, it generates discrete levels of let us say voltage and it is used to modulate your analog signal, analog carrier then whatever you are studying analog communication could almost be used.

And we did also say that there is a notion of discrete time right; however, the rest of the things still analog communications of what you have studied before. So, it indeed uses analog waveforms, but there are certain differences which will highlight today. And there is another very important statement which said it matches the characteristics of the channel. So, before we move further we would like to spend little more time on this a trying to see that why is it like this. So, if we say that there is a channel which allows you to carry forward the signal in a coherent manner, then you could take up schemes for example, amplitude modulations right.

Whereas, if it says that it will not it will not restore the phase as it goes through, then you could think of intensity modulations, right. And there could be channels which could say that in some frequencies the amplitude would be attenuated whereas, in some frequency the amplitude would be amplified. So, then even think of modulations which would be almost resilient to amplitude fluctuations for example, let us say phase modulation of frequency modulation and things like that. So, what it essentially means is that these waveforms that you choose, they are based on the channel characteristics.

So again as we said, we will study in the beginning we said that we are going to study a very generic form of representation which will not be dependent upon the carrier, which will not be depend upon the medium. So, we should be able to write the expressions in a way by which you should be able to write any kind of system and you just have to pick the appropriate one matching with the corresponding channel, moving down further. So, when we say that it maps the digital information to the wave form what we mean to say is let us let us take a look at this particular picture what we have drawn here. We have a sequence of 0's and 1's coming out right.

So there is a sequence of 0's and 1's that are coming out from your encoder, right. And you have to choose let us say a waveform, it is one waveform right. So, definitely the moment when we talk about choosing at least there should be a second choice. So, we could say that let the second one be this which is at least visibly distinct from the first one. And the way these 2 are distinct we can clearly see is the frequency of this is, different than frequency of this one, right. We could also have had a different waveform instead of this we could have said, that our waveform is like this.

So in this case this is having a different amplitude right. So, at least we could have 1 and 2 as options or we could have 1 and 2 is options. So, as said that the modulator should map this sequence to a waveform, right. And generally what we would, what you we would say that the modulation process for the modulator usually takes n bits and it sends the signal out into the channel, right.

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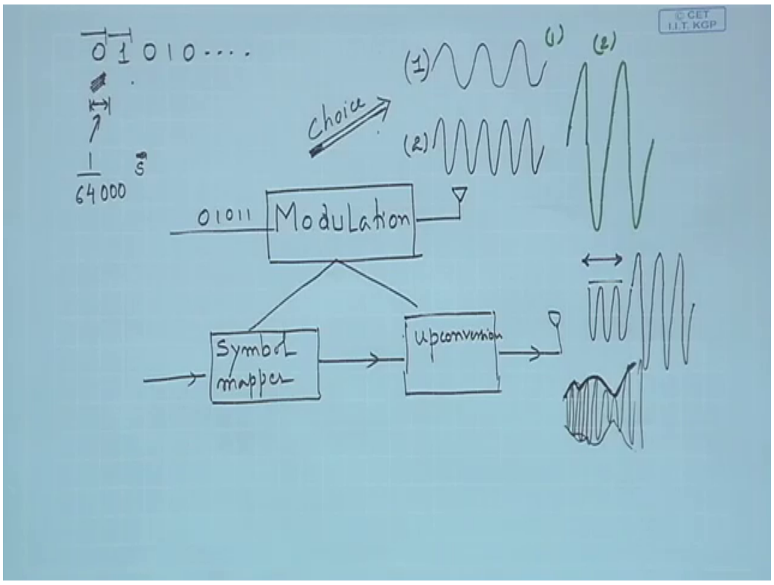

And then we could typically break down this in case of digital communications in 2 parts. Where the first part you could call it as this symbol mapper, which should be clear very soon. And then you could have the second part which follows in sequence as we up conversion, right.

So this follows in sequence and then it goes into the air right. So, our job is to map this sequence to this waveform. Now at this point things might be a bit confusing or it might be a bit clearer I do not know with respect to analog communications. So, in case of analog communications, what you do is you have the source signal and then you impinge the signal directly onto the carrier. So, what I mean by directly is, if you are doing amplitude modulation you would add some offset and then you would multiply this added offset to the carrier; that means, you are changing the amplitude of the carrier corresponding to this source signal.

If you are doing phase modulation, you are modulating the phase in proportion to the fluctuation of the signal amplitude of the source. If you are doing frequency modulation, you are again modulating or you are changing the frequency of the carrier in proportion to the original source signal right. So here also, here the things are a little bit different. So, if you look at what we do an in this particular case is, there is we are talking about choice, right. This one of the important things that we do talk about in digital communications whereas in analog communications, there is a continuum set of values.

What I mean by this is, you are not choosing between 2 amplitudes or you are not choosing between 2 different frequencies. You are continuously moving in the frequency range if you are doing frequency modulation. You are continuously moving in the amplitude domain, if you are doing amplitude modulation right.

But for example, you may have, could have a picture where your source signal is like this and it is basically this is the source signal. And then if you modulated a carrier, your carrier modulated signal would take a shape like this. But clearly in this case, if I am doing amplitude modulation if you have these 2 levels, then your signal may take a form which is, this picture is of course not drawn to scale, one waveform and then another waveform right, all right.

The next important thing which we may note is that these selections are corresponding to this information source, right. There is a correspondence between the selection as we clearly discussed over here whatever is the information bearing signal it will be used to choose. Now if you if you are doing a particular communication over here and let us say, there was some original analog source and if you would recall the sequence of steps that we follow, we have an ad sampler, right. The moment you have a sampler you talk about, a sampling frequency f s and if it is speech, right. The telephone quality speech not the high definition speech that we usually encounter when we speak in front of each other or you are in a movie.

So if it is just telephone quality speech we said that well, a number around 8 kilohertz is ok. And we also discussed the concept of uniform sampling by which we meant that you are able to you are sampling at regular intervals, right. You are doing the sampling at a continuous rate so, once you are doing that at 8 kilo generating the samples. And this quantizer let us say, you have a 8 bit quantizer right. So, together if you would have at this point you would get every instant you are getting 8 bits and you are getting 8 kilo samples per second.

So when you multiply together you are getting 64 kilo bits per second which effectively would mean well, if I do not do any compression which would effectively mean that, there is a particular duration of this bit. And that bit duration would be effectively 1 by 64000 second inverse, right; per second sorry 1 by 64000 second. Because it is kilobits per second so, second is on the numerator. So, so much is the duration of this bit, right.

Next instant there is another bit. So, the moment this information bearing signal changes there is a change over here.

So all what we are trying to mean is that there is a finite duration of fixed duration that is also involved with the existence or the choice of a particular waveform. So, there are 2 distinct differences that we see one is that, we are talking about a choice by which we are selecting between possible analog waveforms and the second, these waveforms are chosen for a particular duration of time in correspondence with the rate at which bits come in which is distinctly different from the continuum set of amplitudes or the continuum set of values bit in time or being amplitude or frequency of phase that you get to choose and also there is continuity in the time, that you see whereas, there is discreteness here in both case of selected values, as well as the duration over which this choice remains.

At this point you might have a question that well this encoder that we have, you studied could be a variable length encoder or could be a fixed length encoder, right. That is true it could produce a variable length encoder a fixed length encoder. So, if it is a fixed length encoder, in that case you are generating bits at fixed interval. If it is a variable length encoder you might argue that well, I generate bits for certain duration; I do not generate bits or certain duration. Or my bit duration in certain cases could be longer or shorter compared to other durations. Well when you are thinking of communication systems, communication system as a whole would generally involve use of buffers.

So when you have buffers you would generally stack up bits for a certain duration which would be sufficient for a packet, and then you would send it across. So, you are not sending bit by bit information into the channel. You are generally generating bits you are packing them into a packet and then sending packet by packet. So, by virtue of which when one packet gets transmitted across, yours getting a bit rate which is constant for that packet duration whereas, in the next packet duration which might happen at an arbitrary gap of time, you will again choose a certain rate of sending bits.

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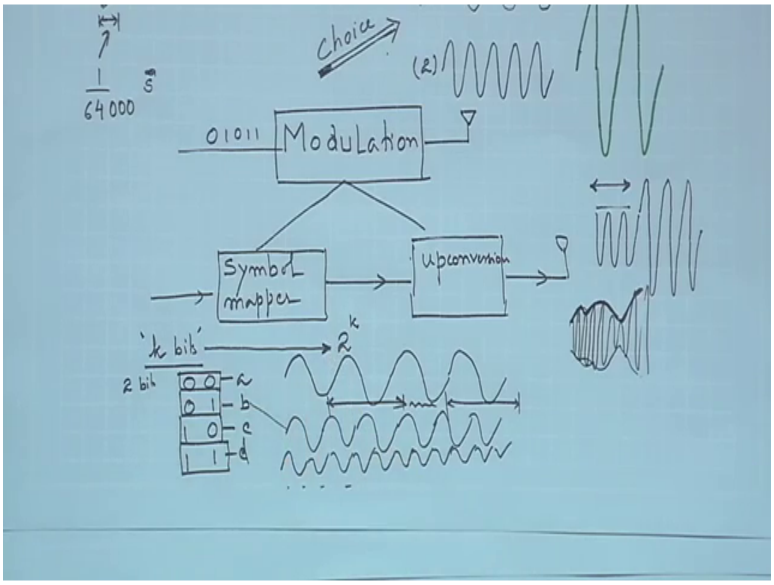

Now these 2 gaps between transmission of a packet and there is some gap would allow for adjusting the bit rate which you would encounter here. So, end of the day what I am trying to convey to you is that when the modulator receives bits, right. It would receive bits at a constant rate from the layer above it. So, there must be some pack module which will be packing this bits in forms of packets and which will be sending these to the modulator. So, when it does so, what happens is. So, we are we are not worried much about this variability here, we are just taking this constant sources right.

Now the other important aspect which we might be concerned with this, with this getting these bits into these symbols the question is, do we select? Or how do we select? Is it always true that we have one information going into one waveform, the other information going to the other waveform? And that is it well it is not a very, very it is not a very, very critical problem because for sure, when we have choice to a minimum number of options that you require to choose is basically 2. And that is what I have drawn in this particular picture.

So what is effectively done, is instead of 2 well, I just use this. You can say that I have k bits with, using k bits I can map 2 to the power of k possible waveforms right. So, that is why this particular name that you are mapping the symbols to waveforms. So, if you have k bits we have used this in source coding if there are k bits. So, let us see if there are 2 bits you have this combinations 0 0, 0 1, 1 0 and 1 1. So, once we have these you could say that this is my new symbol and I could mark this is a. This is my second new symbol, I could mark this is b, this is c and this is d. And all we need to do is, map this particular symbol to a particular waveform.

So it could be, right; b could map to another waveform, c could map to another waveform and similarly d could map to another waveform. So, all I am trying to tell you at this point is that, it is not necessary that we were restrict to 2 waveforms, but you could have a multitude of possible options at the transmitter and the job of the modulator in case of digital communications would be to get a group of input bits group them together, form a symbol map that particular symbol or group of bits to a particular waveform, which would be matching to the channel.

Now we should be sure at this point to remember that this mapping should also be unambiguous in a similar way that we define source coding. This is a form of coding in some manner you can say, now why do we call it should be unambiguous? Because for clearly, clear reasons if at all a and c would map to the same waveform at the receiver, what would we get? It will be confused that whether the symbol a that is 0 0 was sent or whether the symbol c which is 1 0 was sent. So, what we mean to say is that we should have different waveforms mapping to different symbols. So, that is why if you have k bits.

So you will have 2 to the power of k unique combinations or different combinations. Each of these combinations should map to one particular waveforms. In other words we should have 2 to the power of k distinct waveforms which are in no way similar to each other. There should be some distinct feature which will be exploiting in the demodulation process at the receiver by which will be reversing from the waveform back to the symbols or the bit sequence through the process of demodulation.

We conclude this particular discussion here. We continue with this particular topic in the next lecture.

Thank you.