Modern Digital Communication Techniques
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Lecture - 05
Introduction to Digital Communication System (Contd.)

Welcome to the lectures in Modern Digital Communication Techniques. In the previous lecture we have expressed the importance of probability and randomness in the communication system. So, we will begin today's lecture by looking at the different components of a communication system, where probability plays a distinctive role and we will see how exactly it comes in, depending upon the way we progress we might look at little bit of history or may also proceed towards the source coding.

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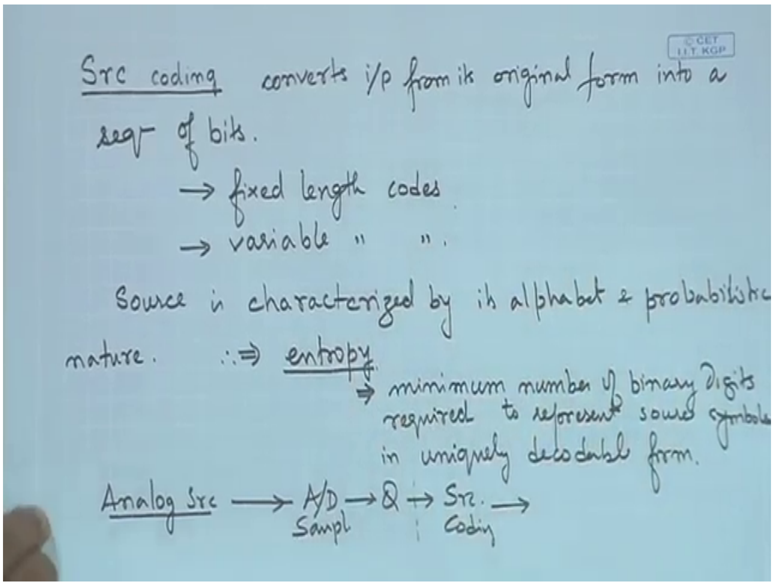

So, when we look at the communication systems we have drawn several times the first component of the communication system is the source coding part. We have discussed about source. In the previous lecture in the previous lecture we said that the source is can be thought of as one which generates sequences or which generate symbols. What is important are the not the particular symbols, but the choice of the source at that particular instant of time.

For example, basic minimal example that we discussed is: if we have source which generates a sequence of zeros and ones this 0 or the 1 is rather not important rather what is important the choice that it is choosing a 0 or it is choosing a 1. If it was free known that 1 0 1 0 1 1 to be sent at the receiver there is no point in communication. This is what has been stressed in the previous lectures. We now proceed further and look at the different components.

The first thing which comes out of the source and goes into the first block of communication system is the source encoder. So, when we talk about the source coding it basically converts the input from its original form into sequence of bits. This is what is the primary job of a source coding. Now it converts to sequence of bits and does not stop there it also does something more. So, let us look at that.

So, beyond a conversion to a sequence of bits; now this sequence of bits they can be fixed length codes- we will slowly understand what is meant by codes and what is fixed length code they could be converting into a variable length code and that is what we are going to see. And we also state at this point at a source is characterized by its alphabet which we described earlier and probabilistic nature.

For example: if I take again a very basic example. Let us take we have a b c d has the different source symbols or let say I have a source we generates three colours: red blue and green, what you can say is that these are three colours so three symbols could be r g and b; red blue and green. So, r b g and then we can assign certain probabilities that out of all possible things that are coming out, 30 percent of them are red, 30 percent of them are green, and 40 percent of the blue. So, you could do it this way or you could say 10 percent, 50 percent, and 40 percent and so on and so forth.

That is what we mean by it is characterized by an alphabet and its probabilistic nature. And therefore, you can say it has associated entropy with this which we are going to define. And what is meant by entropy? It means it is basically expressing the minimum number of binary digits required to represent source symbols in uniquely decodable form. We will see each one of these terms are quite soon; that what is meant by unique decodability, and what is meant by the entropy, and what is meant by the minimum and so on and so forth. We will see all these details in the upcoming lectures.

Now, if there is an analogue source: we have said you first convert through an A D converter then quantizer to look in to details. A D converter is basically the sampler or rather the sampler quantizer and then this source coding. So, here itself you get bits or symbols output you go through the source coding to generate the same set of things that you have here.

Going beyond the source coding the next part that we need to look at or we need to see and of course there are many parts in the communication system, one of the very important part is the communication channel.

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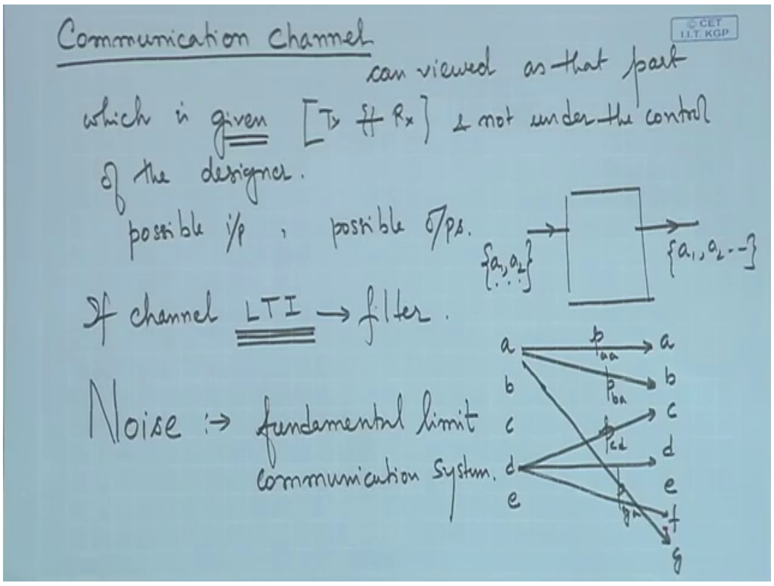

So, when we talk about the communication channel earlier in the previous lecture I have given you a one particular view of a communication channel where we said that you could probably create interfaces, and through the interfaces you could view whatever goes from the previously added the transmitted to the next layer, and what comes out at the pier layer to be entirely encapsulating the channel.

And what we said again is that there could be binary input, binary output channels; there could be samples of quantized symbols input, symbols output as channel; and there could be a analogue samples into this into the channel analogous samples out; and finally there could be analogue signal input, analogue signal output. So, this is the different ways you can view the channel.

So, communication channel which forms part of a communication system it can be viewed as that part which is given of course, it lies between the T X and R X it lies in between the T X and R X I do not need to describe that. It is given and not under the control of the designer. So, this is a very very fundamental, this is very important to note that when we are talking about the channel we are saying that it is available; this is what will become clear in a short while from now.

And whereas when we talk about the source encoder you are saying that you are designing. It you are doing something you your algorithm is running into it. But when you are talking about the channel we are saying that it is something which is already present. What could be different is that the way you look at it could be different, that means its manifestation would be in different forms, but inhalant characteristics you cannot change. Inherent characteristics are going to remain. So, we will we will slowly take a look at the channel part.

So, when we are talking about the channel, we can think of channel as a system which has a set of possible inputs and it has a set of possible outputs. So, what it means is that this is the channel there is there are a set of things which goes in and something comes out from a set. What can happen probably is that a symbol a can go into the channel and it can come out as a; what could also happened in the channel is a can go in and it can come out as b. That means, it has there is a set of possible inputs and this is a set of possible outputs, this set of possible outputs could be the same as the set of possible inputs so I am talking about the same set, but given one particular input how it affects the output is basically a property of the channel.

For example: I may have a b c d e as possible inputs and I could also have a b c d e f g as possible outputs; so what it means is that- a can become a, a can become b, a can become g, this could be the set. Now this change over could be assigned certain probabilities p aa p ba p ga. Similarly when a d comes in d could become a c, it could become a d, it could become an f with certain probabilities p c d and so on and so forth. Now these probabilities are basically characteristics of this channel. So, it is a set of input it is a set of output and the way these change over happens is a property not under the control of the designer. This is what is meant by this particular statement. So, these kinds of channels are known as discrete channels.

Now, these channels could be memoryless, could be with memory and so on and so forth. What we will mainly consider in this particular course are memoryless channels, as of now if there are a special cases we will definitely mention; now again there could be channels which are non discrete. So, we could write if the channel is not like this, if the channel is a linear time invariant system. So, this is a very very common kind of channel that you would encounter. So, by a linear time invariant channel we mean that the input output relationships are linear. So, when we say linear we in turn say that superposition holds.

And time invariant means that it is not affected by shift in time. The y at t would be the same as y at t minus t, if I give the input as x t earlier and now I give the same input at a time t minus capital T. That means, if I change the input; if I give the input now or I give the input let say sometime later on I am going to get the same output which depends only on the input and the channel characteristics and these channel characteristics do not change with time. So, that is meant by a linear time invariant system. And in this case it is represented by a filter model. Things will be clearer quite soon.

So, further another important thing which happened was that noise was identified as one which gives the fundamental limit to the communication to the maximum fundamental limit of communication system we can write. Again it was kind of Shannon who identified this and he formulated and give us precise definitions by which we could find the maximum bits per second per hertz; that could be sent across given a certain amount of transmit power and certain a noise power in the system irrespective of what you can do; so that gives the upper limit.

So, he almost established that a noise is a fundamental entity which limits to the maximum extent that we can achieve for a particular communication system.

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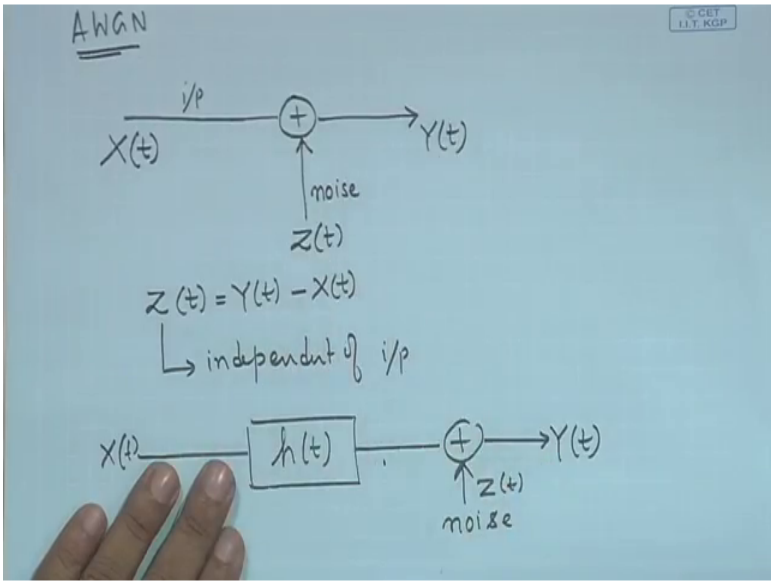

Now, beyond a these kind of channels which are like discrete and let say LTI; we can talk about channel models which we are going to encounter are AWGN. Well, before I go into this so just to remind at this point that again probability plays a very important role. That means, it is unknown, it is not known a priori, but there is some probability which is present. Now when we talk of noise and additivity we could have a model where let us say we have signal X of t coming into the system which is the input, then there is addition of noise represented by Z of t and what you receive is Y of t. Now this is a model a very very simple model where we say noise is additive.

Now, if somebody gives you this particular model one could say- ok since it is a simple linear and additive model we could write Z of t as Y of t minus X of t. That means, you could determine noise, but you could determine the effect of the amount of noise if you know X of t. But now, what is additional he said is that z is independent of the input it does not depend on the input. So, even though there is a additivity property which is present it is not tied to the input directly.

So, this independence makes the system very much interesting for study. Going beyond such systems there are other systems where instead of simple additive noise you could have X of t when there is a box which is in LTI and you could say let there be h of t which represents the channel impulse response followed by noise and then this is the received signal. Now for these kinds of systems that we have which we are going to encounter

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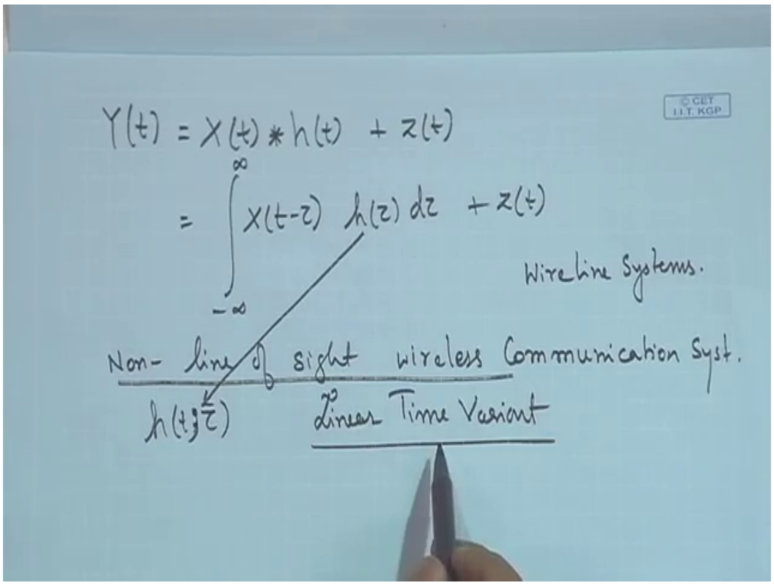

So, in this kind of systems you could write that Y of t is equal to X of t; since this is a filter this is an impulse response. So, at this point it is a convolution of X t and h t followed by these additions of noise which is Z t as we have identified plus Z t. So, this is the model and which you could basically write it as minus infinity to infinity X of t minus tau h of tau d tau plus Z of t. So, this is the kind of models which we are going to encounter in our communication system. And in this particular course towards the end an especially we will use it when we talk about matched filters or when we talk about equalization and so on.

These kinds of channels are pretty useful especially for wire line systems. Now, in case of non-line of sight wireless communication systems what you are going to encounter is that this h of t that we have seen which is an impulse response or h of tau that you are saying here. This h of tau will get replaced by h of t comma tau. What it means is that this impulse response, this model will be linear but it will be time variant.

And these systems we will not study in this particular course, but these are important to know because you will be using them in any course on wireless communications. Now before you get into this it is important to understand systems where you have this AWGN like model as in this particular picture, then you have a LTI like systems will be mostly restricted to these systems. And once you are quite familiar and strong with these systems then you can move on to study the non-line of sight wireless communication systems where this become a linear time invariant.

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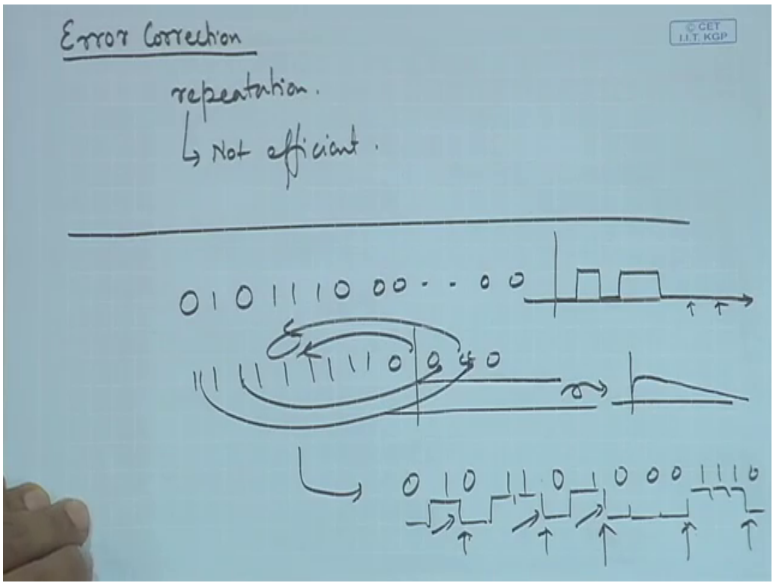

So, the next important components in a communication system that you would encounter are the error correction coding; error correction system. So, what was identified is or very simply when you are speaking or uttering something when you are sending something there is a chance that the recipient does not understand what has been communicated. This is pretty place language. Then one of the ways of taking care of it is the recipient sends back a no acknowledgement. There is a nack usually known as a nack.

So, once the recipient sends back a nack the transmitted or the sender once again sends it. So, it keeps on doing this process until the receiver or the recipient makes a logical meaning out of it. There could be multiple issues; it could be that some particular word was sent the receiver did not make any meaning out of it aspirarory transmission. Now, if the receiver made some logical meaning out of it although it is not the same word you would encounter the situation where that the receiver is making an error which is unaware of. So, those things are also part of it.

So, there could be repeatation coding. Repeatation coding means it simply repeats; that means, it sends instead of sending a it will send a three times. Imaginary distribution rules at the receiver could be used that if two out of three are of the same symbol then you would go by that particular symbol. But then it was found that this is not an efficient take me there is a whole field of a error correction codes which have been developed, which try to improve the performance and to the limit that the extra redundancy that gets added become smaller and smaller as you group the number of symbols together and from larger error correction code blocks. So, that particular section we are not going to study in this course. There are special codes, there is an error correction codes which will take care of such things.

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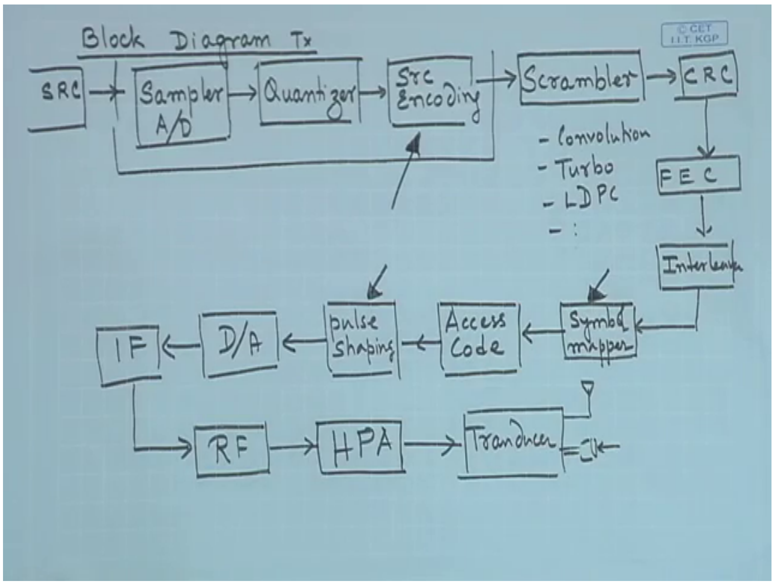

So, moving further at this point of time what we will do is we will try to briefly construct the blocks schematic the block diagram of a transmitter. And we will look at what are the components that are present that we have just discussed. So of course, we have the source which we have described qualitatively which will see in details while later then you have the sampler or the analogue to digital converter followed by quantizer which is followed by the source encoding which is followed by a scrambler followed by a CRC. Why we need a scrambler, we will be clear as we go into the course but I will briefly tell you.

So, when we have a source which generates a sequence of let us say zeros and ones and so on. So, suppose we have a long sequence of zeros or a long sequence of one. So, if I am going to convert these to voltage levels which are like a for 0 its minus 5 volt or a 0 volt and for 1 it is a plus 5 volt what I would encounter in this case is 0 1 0 then again 1 1 1 and then you get a 0. So, if it continues like this one of the problem is we are not going to remember at what points we should sample. So, there could be synchronization problem. If you look at this particular sequence you might get you would be generating this at the receiver this might cause because they would be RC circuits slowly decay and you are not able to distinguish between 0 and a 1; it will slowly convert to 0.

So, in order to avoid such situations and to bring back synchronization usually I we are not going to get a whole sequence of ones throughout that is almost meaningless you are going to mix this zeros and ones in a random fashion. So, that is the job of the scrambler so that finally you end up with a sequence where there are random ones and zeros, so that you keep getting your clock at means a certain rate. So, at least there is a change, there is a change, there is a change. So, when you do clock recovery you will find that these edges become very very important for recovery of clock.

The job of the CRC it is the known as a cyclic redundancy check, a cyclic redundancy check is like a code. Suppose I have a message it is like parity you can think of let say odd parity or even parity I was explaining the in one of the early lectures is that suppose I have 3 bits and I want to put make it odd parity. So, I would put one extra bit where the sum of ones in them will come to a odd number.

If the receiver finds it is just received a even number of ones in any group of 4 bits it is going to send back that I have received an erroneous group of bits; CRC is basically used for that. So, ones CRC is true you would send; so basically its a useful for error correction codes. Then you can have a forward error correction code block which adds error correction code. Some of the examples of forward error correction code, could be convolution codes it could be turbo codes, would be LDPC codes and there are.

So, many other course after the forward error correction code you would have block known as the interleaver. After the interleaver you are going to have the block which will be the symbol mapper. From the symbol mapper you may add an access code, optional depends upon a particular link. Then you have the pulse shaping. Once you have the pulse shaping you would feed it to a digital to analogue converter. From the digital to analogue converter you will have the RF section, so it begins with the IF section up conversion. Then there will be in the RF the radio frequency section where you go to the particular carrier frequency. And there would be the high power amplifier which would amplify the signal to the desired levels so that it makes the link budget. And then there would be the transducer. The transducer are the common examples of the transducer could be the antenna or the kind of coupler which will be used to connect to the next sequence.

So, in the next lecture we will begin with this particular block and we will rather begin with source encoding which we started of describing in this particular lecture. Following source encoding we will look at these two components so that that will compound that will complete the source encoder overall. Then we will move on to a symbol mapper, then we will look at pulse shaping.

So, these are some of the important blocks where we will look at in the transmitter side. At the receiver side however we will not only look at the corresponding blocks of the transmitter, but also we will look at some of the more important functions of the receiver like synchronization, channel estimation, equalization which we will finally help us in designing the important parts of a basic transmitter receiver system.

Thank you.