Modern Digital Communication Techniques

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Lecture - 06
Source Coding

Welcome to the lectures on modern digital communication techniques. So, in the past few lectures I have given you an introduction to the domain of digital communications, I have explained to you how to look at digital communications when you already have a perspective of analog communications. I have also tried to explore the different components of a digital communication systems and how they play a role I have also discussed the aspect of noise the channel and the characteristics of a source, we have also discussed how to view the source or the channel as once where the options and the selection or the choice is very very important rather than a particular result, and we have also explored how probability is important for the study of digital communications.

In this particular course we will assume that you will you have already taken a course on probability so, that as and when necessary we would be using the theories and the expressions. So, if you have not explored much of probability I would request you at this point to take refresher course or revise the concepts because those will appear again and again at in different intervals at appropriate times. The last thing that we discussed in the previous lecture was the block schematic over transmitter, we continue our discussion and we start off with the block schematic of the receiver and then we will slowly move into the first component of a digital communication system that is the source encoder.

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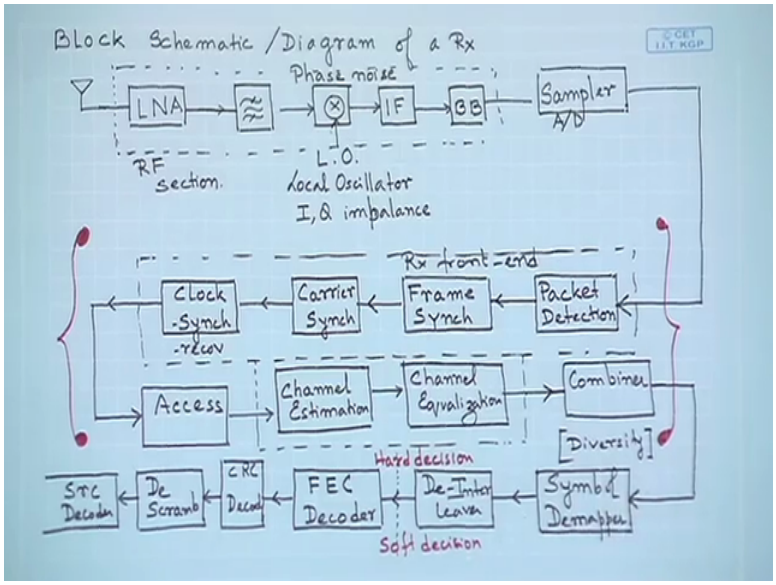

So, with this let us begin the block schematic or the block diagram of a receiver. So, I am going to write Rx whenever a receiver comes into play. So, I am not going back to the transmitter structure. So, here we will consider an antenna although I have mentioned that we are going to look at wire line systems and we are not going to look at non line of sight. So, well these studies that we do are also applicable for direct line of side wireless communication systems for example, satellite links or even microwave links. So, putting antenna does not really violate our scope or the assumptions or the premise that we have already explored.

So, hoping that there is an antenna and typically there is a low noise amplifier in the front of receiver, and then there would be some kind of a filter let us say a band pass filter; that means, it allows a certain band of frequencies followed by there would be a mixture, which is fed by a local oscillator and then one goes depending upon systems to the IF stage followed by the base band stage. So, that is the down conversion. So, this local oscillator could bring to the if stage or it could bring to the base band stage that is the carrierless removing off all the carriers and we can put grossly in a rough way we can group all of these and we can claim that this group forms the RF section the radio frequency section or the sub section.

And here where there is this local oscillator the effects that come in could be a phase noise, there could be IQ imbalance and interestingly although these are affects of analog

components of a communication system, when you design a digital communication system many a times you design methods or algorithms or signal processing techniques in the base band, to take care of these non idealities we call it non idealities because in an ideal system we would assume a perfect oscillator perfect frequency match and so on and so forth. So, which are usually not present, so your design should be able to take care of some of these non idealities of the analog subset.

So, here when it gets converted to base band you have the sampler and or the AD converter analog to digital conversion. So, once we have this sampler you get samples out of it. Next part is interesting which is the packet detection then you could have frame synchronisation, once you have the frame synch then you could logically talk about the carrier synch well at this point what we would say that there would be a local oscillator there would be phase matching at this point which tries to continuously lock on to this phase, but this carrier synch especially in digital communication system also plays a role and there could be a feedback path going to this, this could be controlling. Then followed by there would be a clock synch also sometimes called clock recovery depends upon different sources of the material, I mean the text material they would call it the clock synch or the clock recovery. So, these groups of methods or algorithms of the receiver you can group them together logically and once you logically group them you could call these as the receiver front end ok.

So, once these things are done, now why these are important just briefly a packet detection because in digital communication systems you may encounter transmission in frames or you may encounter in packets, one particular example is the Wi-Fi which you commonly use, where these burst mode of transmission. So, suddenly there is a packet and suddenly there is nothing transmitted whereas, the receiver it should be constantly awake and should be listening to the transmissions now while it is awake it is not good idea to make the entire receiver operation on it can simply keep the detection part on which would setup an alarm or a alert that yes a packet is being received.

So, once the alert comes the rest of the receivers can wake up right. So, this is going to reduce the energy consumption or the power consumption of the system. So, there are different methodologies. So, that is why we can have a packet detection in the beginning, then we have a frame synch because when you have doing packet detection your simply detecting whether a packet is present or not. So, at a clock rate you will be this module

will be sending a one or a 0 whether this is a packet. The moment there is a confirmation that there is a packet immediately afterwards the frame synch should start which should identify at which exact point the frame gets started; because you have seen we are sending a sequence of zeros and ones and if we are not recording this sequence at the appropriate moment of time then we may land into errors.

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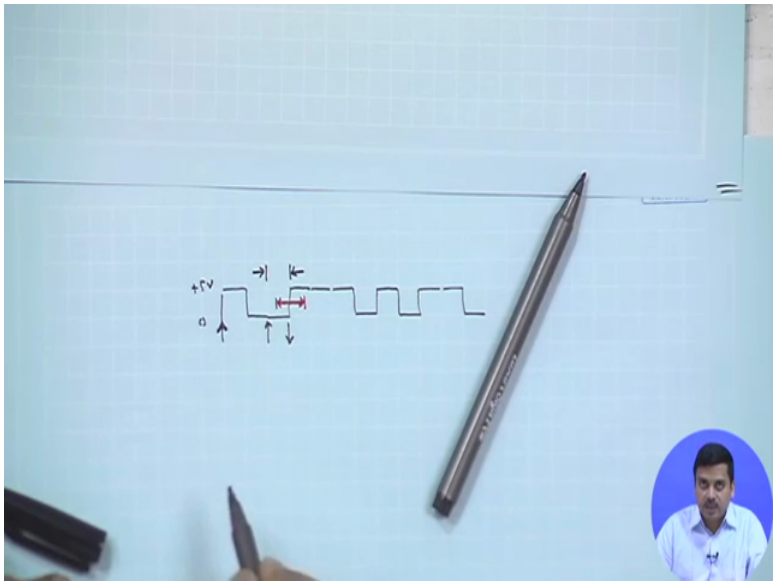

For instance suppose I am taking a very simple sequence and so on; this could be a sequence of let us say plus 5 volts and let us say 0 volts or minus 5 volts. So, I am trying the base band. So, one must know that exactly where to read the frames this starting point of frame, now once you do this there is carrier synch because whatever residual carrier off set is present that gets tracked over here and one could correct this and in analog part or one could do a phase correction in base band also.

And then clock synch is also very important because now the point is you have to identify which is the bit duration or the symbol duration ideally speaking this one, but once you identify that yes this is the starting point and this is the ending point. Instead if one tries to capture this interval which will see in a later lecture that if one tries to capture in this interval then what happens half the interval there is 0 half the interval there is a 5. So, overall you are going to get a something which is in between and it will not be able to decide whether a 0 was sent or one was sent. So, this is very important to

do this synchronisation tasks at the receiver, so that is why we have this sequence of operations at the receiver right.

So, once this is done one may put the corresponding block of the transmitter which is the access; access basically deals with the part which is with respect to multi user communication. So, it is that part which can be thought of a demultiplexing or identifying that section of the transmission burst which belongs to this particular user or user equipment. If it is the down link from base station to the user side and if it is reverse direction then the base station must identify that which particular part belongs to which particular user. So, that is why we have this access.

Exact sequence may vary depending upon situations then you have channel estimation followed by channel equalization why we need channel estimation the simple reason is we have said in the previous lecture that the channel is given it is not which is the designer does something designer has control only on the transmitter and on the receiver. So, if the channel is given and the receiver has to reconstruct the transmitted signal it has to find out what the channel is and then compensate for the effects. If you would remember we have written a convolution expression with the channel. So, it is almost a process of de convolution that we do in this equalization.

So, these can also be grouped with the receiver front end, then after this there could be something known as the combiner well if you will be studying code division multiple access or spectrum communication combiner plays a very important role and in wireless communications if you are studying multiple antenna base system, then again combiner plays a very important role where you combine signals from multiple paths. If you are doing diversity this combiner again plays a role of the diversity combining. So, we can talk about diversity combining.

Generally essential for wireless communication. So, once you are through with the combiner, the next block that you would encounter is this is symbol de mapper. This is the opposite of the symbol mapper we will discuss it of course, followed by the symbol de mapper well we now have the opposite sequence inter leaver de inter leaver we had inter leaver at the transmitter, now we have a de inter leaver once you are through with the de inter leaver you will have the FEC that is the forward error correction code decoder, this is decoding the forward error correction code at this point one may have

hard decision output or one may have soft decision output we will see them at different stages.

So, once you have the FEC decoder then you will have the CRC decoder we are running out of space in this page trying to put everything together, then you have these de scrambler we have following the exact opposite sequence that was there followed by I would club everything into source decoder and I am making it to open box indicating all the components. So, one thing that is clear in this picture is if you would compare it with the diagram that you had for the transmitter, this particular picture is much more elaborate it contains many more components especially the ones in this section which are unique; unique in the sense these are not present in the receiver, these blocks sorry in the transmitter these blocks are special for the receiver, and in our course of study we are going to go through these blocks one by one.

Because if a receiver does not have these it will not be able to proper symbol de inter leaver all these process where that whereas, the transmitter goes through the reverse of this path, but these all are necessary because the receiver is at a different location it is not coupled with the transmitter it has a independent oscillator it has an independent clock. So, those have to be synchronised the channel is not known. So, now, when you talk about the digital communication system a major part of the study is spent in understanding or designing these things which we are going to do. So, our study we will be covering almost all of these components.

So, with this we would like to bring our discussion to a close for the part where we talk about the transmitter and the receiver structure. Now this particular picture as you see here will be available to you in form of additional material which you can always refer to. So, with this we complete our overview of the communication system and then we can now move into the study of source coding. So, when we look at the study of source coding we are talking about sources.

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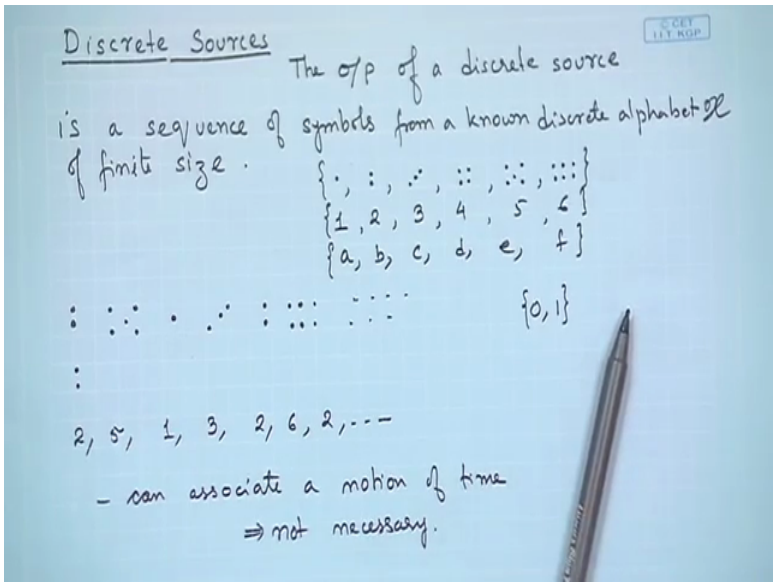

So, basically we are talking about discreet sources, I have hinted different discreet sources earlier. So, when we talk about discreet sources what we mean that the output of a discreet source is a sequence of symbols from a known discreet alphabet x of finite size.

So, what it means is basically this capital X as we have written it is a set which contains certain specific symbols one example could be the dye which we use for playing ludo let us say. So, that is a source and it has 6 symbols 1 2 3 4 5 6. So, it could be 1 dot, 2 dot, 3 dot, 4 dot, 5 dot and the famous 6 dots. So, this could be source where this is the alphabet right you could represent it as 1 2 3 4 5 6 or you could also indicate to be a b c d e f.

Now, this is important to understand at this point that what we are talking about and what we mentioned earlier is the receiver knows that you are going to choose from 6 different options, whether this is a one whether it is a dot whether it is a one whether it is a is rather not important, but what is more important is that there are 6 possible options and you want to choose any one of them and they are distinct this is very very critical it could be independent by this diagram it could be independent by this sequence by these set of symbols or this set of symbols or any other set of symbols which you can think of.

So, what the source produces it produces a sequence almost like you throw a dye. So, first you might get 2 let us say then you might get a 5 well you can get a 1, you can get a 3, you can get 2, again you can get a 6 right you can get 2 again and so on and so forth

and this could be represented in another way that I get a 2 5 1 3 3 6 or 2 and so on and so forth and you can similarly do with the these particular symbols. Since it throwing out discreet means a distinct symbol at every instant of time, so, that is explanation of discreet source and it is not necessarily this, it could be a letters of any other alphabet let us say the Chinese or the Hindi or the Bengali or any other particular script, we are also think of letters from those alphabets coming out so that would characterise the discreet source.

Well 0 and 1 sequence is also a discreet source it generates a 0 and a 1 after another right. So, these are examples of discreet sources and in today's world we are mostly in the discreet sources and we also mentioned that if we have an analog source you can convert it and once you convert it then it becomes a digital source which is the sequence of zeros and ones. If you look at a text file it is already having letters a b c d e and so on and so forth right. So, these are discreet source and you can associate notion of time with this, but that is not necessary. What do we mean by this, what we mean by this is that suppose it is event and things are happening one after another. So, it is generating these symbols one after another example life stream a life stream of video has a sequence of zeros and ones getting produced at certain rate and if I want a file transfer then it is a file which contains all these symbols right, it could be the letters of English alphabet or could be the zeros and ones and I am transferring them from the source to the destination.

Now, when you are doing this you could be doing this transfer over a slow link or you could be doing this over a fast link or you could be physically carrying it and the file comes as it is. So, in that case the notion of time may not be critical. So, notion of time is not a compulsory must to define a discreet source, discreet source essentially means that it produces a distinct symbol every time there is a there is an output or it contains sequence which has this discreetness time could be part of it or it would be come in a bulk where there is a particular sequence. So, this is all about discreet sources that we are going to discuss.

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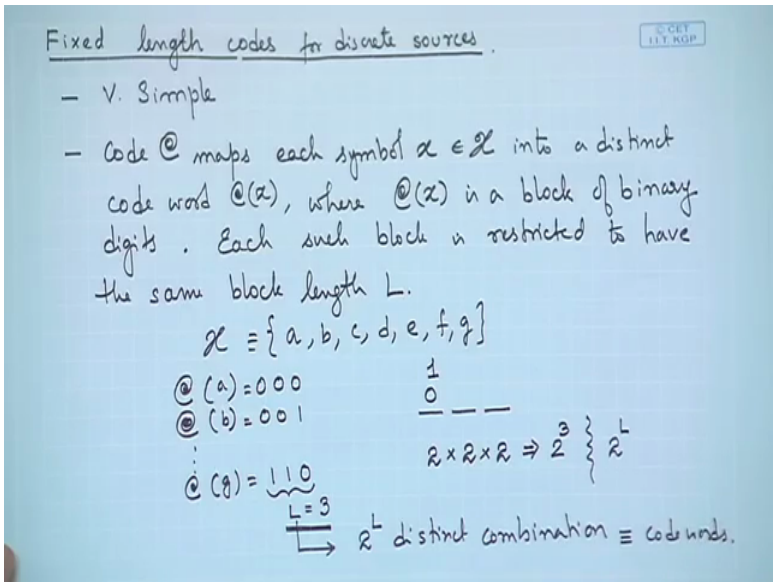

Next we move on to how to take care of coding because we are talking about source coding. So, one of the first basic coding techniques is known as the fixed length codes. So, we will complete it for discreet sources. So, one of the characteristics of this fixed length codes is these are very very simple a very simple to use, very easy to understand and we would define code with the curly c which maps each symbol x. So, x can take values 1 2 3 4 or a b c d and this capital X is defined as this particular set and these individual ones are x.

So, each symbol x element of capital X into a distinct code word c of x, you can think of it has a function almost I get the symbol I put into c I get c of x which is the code word things will be very clear. So, where c of x is a block of binary digits each such block is restricted to have the same block length L this is important. So, when we say fixed length code what we means is that a symbol a or b or c or this 1 2 3 4 whatever it is, gets mapped to a sequence of binary digits and when a gets mapped to a sequence b gets mapped to another sequence the length of these sequences are the same. So, that is fixed length and that length is fixed to L. So, for example, if we have x defined as a, b, c, d, e, f, g then we could say let c of a be equal to 0 0 0 the code for b is 0 0 1 and so on and the code of g is equal to 1 1 0 we could assign this.

So, if we look at this particular length this is L which is equal to 3, and what we would we can say is that suppose we fix this length it is almost obvious that I have 3 positions

to fill each position take a value of 0 or 1. So, when each position can take a value of 1 there could be 2 possible options on the first positions, there could be 2 possible options for the second position, there could be 2 possible option for the third position which would imply that there is 2 to the power of 3 possible options. So, which you can easily connect to 2 to the power of L in this case so; that means, if there are L is the length of the code. So, there are 2 to the power of L different or distinct combinations that are possible for code words that are possible and if our set of x.

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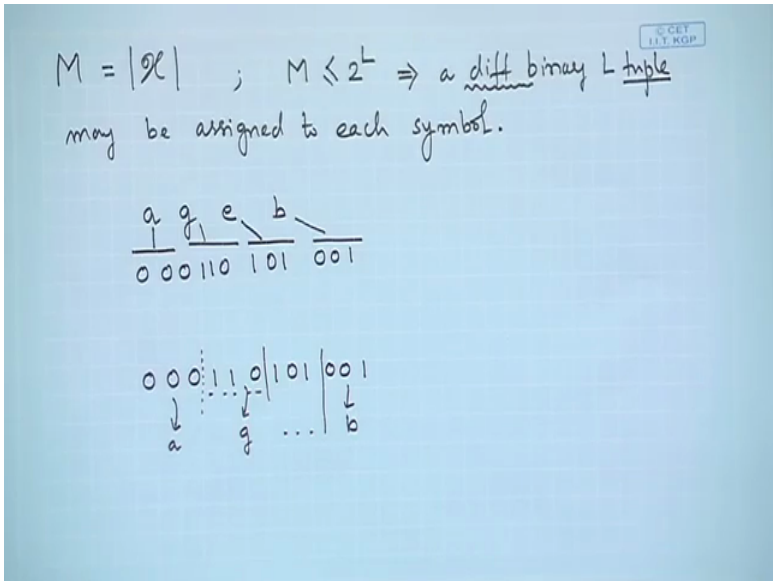

This set of x that we have and we say that there are M elements in it which we would identify as the cardinality of x cardinality of x at this particular symbols means number of elements in it.

So, if m is less than or equal to 2 to the power of L then it can imply that a distinct a different binary L tuple I am using certain terms if you are going to use L tuple means it is group, it is group of bits binary L tuple may be assigned to each symbol right. So, this is very very important it should be different because if it is not different at the receiver what we are getting is only sequence of zeros and ones it is this clear from here. I have this source I will map it to these sequences. So, at the receiver suppose I am sending suppose I am sending a g e and so on b, what I am going to get is 0 0 0 for a, for g you are going to get 1 1 0 this is going to give you 1 0 1 let us say, and no it will be 1 0 0 f

would be something else and suppose b it is 0 0 1 say for example, this the receiver only sees this sequence, the receiver only sees this particular sequence.

Now, the receiver must distinguish that what it has received. So, the receiver should know that these few bits I group them together I go back to my table and I find means an a. So, receiver will decode it to be an a, similarly these will be grouped together and receiver will look back there and it will find it is a g and so on and this will be mapped to b. If 2 different code words mapped to the same symbol in that case the receiver would be confused. So, that is why this particular statement is very important it will be very clear why I am stressing this particular thing in the next lecture that each symbol must map to a distinct code word and that leads to something known as unique decodability which we will see soon after discussing about the variable length coding.

Thank you.