Modern Digital Communication Techniques
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Lecture - 04
Introduction to Digital Communication System (Contd.)

Welcome to the lectures on modern digital communication techniques we have started discussing about the different components of digital communication system, we are also talked about little bit about the concept of layering and standardize interfaces. So, we will quickly review what we discussed in the previous class.

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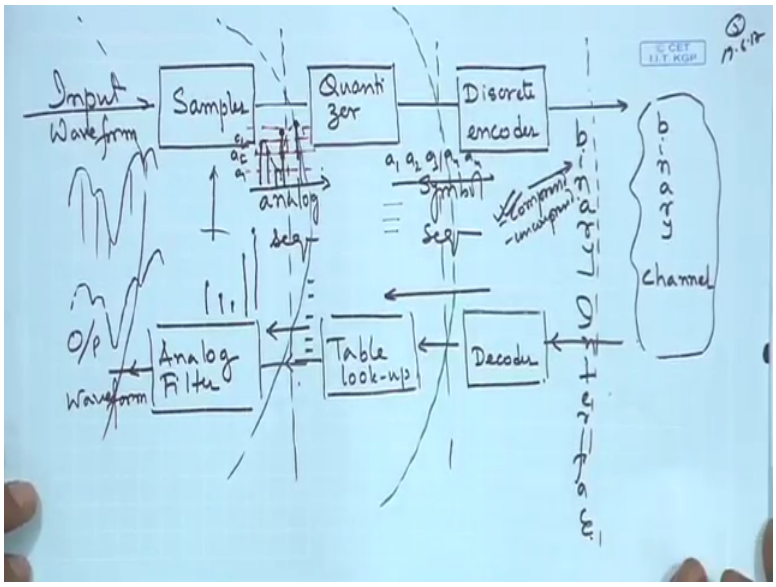

We have looked at the source encoder roughly speaking this is the source encoder in the previous lecture and we have we have said at the last moment that well this binary interface was a pretty well defined in the previous lectures, and then we added the different interfaces that coming in between these components and this can be thought of as layers different layers, and what we said is that these interfaces are very important.

So, the last thing that we also said in the previous lecture is that if I would take a view from this point; that means, I would see from here when I am seeing from this side, I can think of as if this whole thing is a channel and symbols are going in symbols are coming out and what we discussed before is I can think the whole thing is a channel binary symbols are going in binary symbols are coming out this is a multi amplitude symbols,

and if you are here because there is a sampler these are discrete samples. So, analogue sequences why analogue because it has it is just the sampler. So, it can take continuum of values and this one quantizes this values. So, that is the difference between this interface and this interface it takes specific levels, and this one takes a whole continuum range of values; and this because it is stable lookup it gives similar analogue sequences.

But of course, it is going to produce these quantized values and this analogue filter is going to recreate this waveform. So, here again if I look at it this would appear like a analogue sequence channel this whole thing taking sequences giving out sequences. So, overall this is the way we talk about standardized interfaces and layers we will continue this a little bit more and see some other important aspects of digital communication system before, we take a deep dive into each of the components in upcoming lectures.

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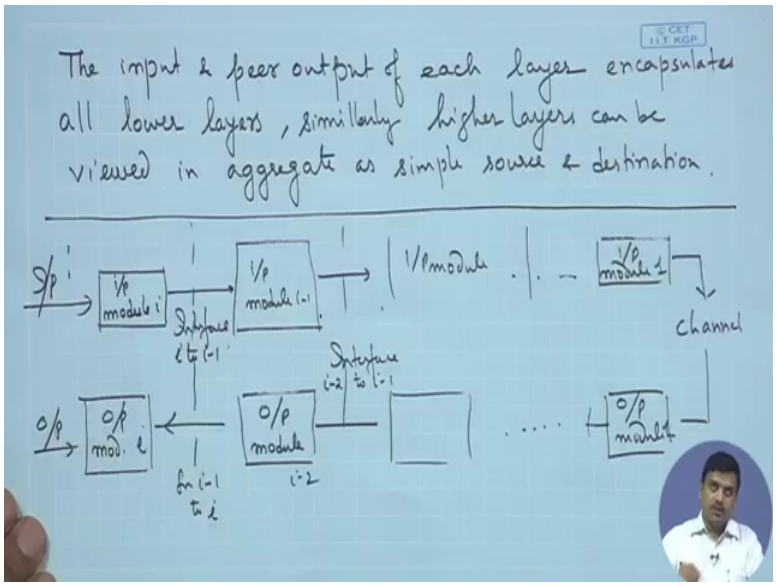

So, continuing further we can more or less say that the input and peer output of each layer encapsulates all lay lower layers.

Similarly, higher layers can be viewed in aggregate as simple source and destination. So, like we are seeing the lower layers any interface like when we talk about input and peer output, the input and peer output look at this these two they encapsulate all lower layers that is what we have said these inputs actually take care of this lower layers we do not need to bother about it, similarly if you are viewing from this angle if you are seeing from this side what you can say is that as if this is the source this is the destination that is

true for this and if you are here in the middle, if I am here in the middle and I am looking from this side you can simply say there is some source which I do not know what kind of source it is, but it generates a sequence of symbols and this is some destination which takes a sequence of symbols that is it. So, this whole thing becomes a source this whole thing becomes a destination.

Similarly, if I put my boundary point here I would say that it is some source which produces binary signal it is some destination which takes binary. So, I can compare this input to output and say what kind of channel is this, how much percentage of error is there similarly I can compare here and say what kind of distortion has come in here again since this is a symbols. So, I can talk of symbols going into here error I can talk about sequences the signal to noise ratio or the distortion the total amount of distortion here I can talk about bits in errors an so on and so forth. So, that is what is summarized in this particular statement that the input and peer output of each layer encapsulates all lower layers as you just discussed.

Similarly, the higher layers can be viewed as aggregate of simple source and destination. So, what this is telling you is to partition the big complex communication system in to interfaces through which I can encapsulate everything on the left and say let that be the source if it is a transmitter and if it is a receiver I can say that is the destination. If I look it look at on the other side I would say that is the input to the channel and that is the output from the channel and so on and so forth.

So, if we move forward with this description, now let us take a look at a brief overview of the different components of a communication system. A well I have another different picture to share with you in general of course, we can talk about communication systems is this layering a general picture is of course, there let me just quickly draw the general picture so that we completed this is module I this is the input this the interface this is input module I minus 1 this is a very very generic picture and there is an interface and so on it continues. This is the output module and this is the interface from I minus 2 to I minus 1 look at this, this is the I minus 2 this is the I minus 1 and this is from I minus 1 to I because this is I output module I and this is of course, the input this is of course, the output.

So, this is the interface of I to I minus 1 I to I minus 1, I minus 1 y minus 2 this side it is I minus2 to I minus 1 right. So, these are all input modules and goes on dot dot dot dot to the last module input module 1 goes into the channel. This is output module one and so no and so forth dot dot. So, this completes the picture and this definition along with it now with this since we have been talking about the source the point to point source. So, we will continue and briefly tell you about the other parts. So, whenever we have a communication system, what we have just described is a point source and a point destination, but as you are aware that and we have also mentioned in the beginning we were talking about a big networks.

So, this study is divided into the core network which is all network theories and also point to point links which is basically what you are going to consider over here and when we talk about point to point links since there are various parts of the chain things are in so great details that there is all there is a specialization for antenna designs specialization for Rf circuits there are specializations for VLSI integration for analogue to digital even conversions. So, what we are going to look at is that part which where we generate bits from bits right to the point where we are generating samples which going to digital converter, and back at the receiver from the point where the signals get converted to digital and inside till it gets converted to bits.

So, the this is the broad or main section where we will be putting our efforts and focus in this particular course, we will not look at much in to networks because that requires development of a whole set of theory it is not this particular course. So, with that a brief disclaimer you can say we can still talk about a few pictures about the network and how to encapsulate them in a similar way.

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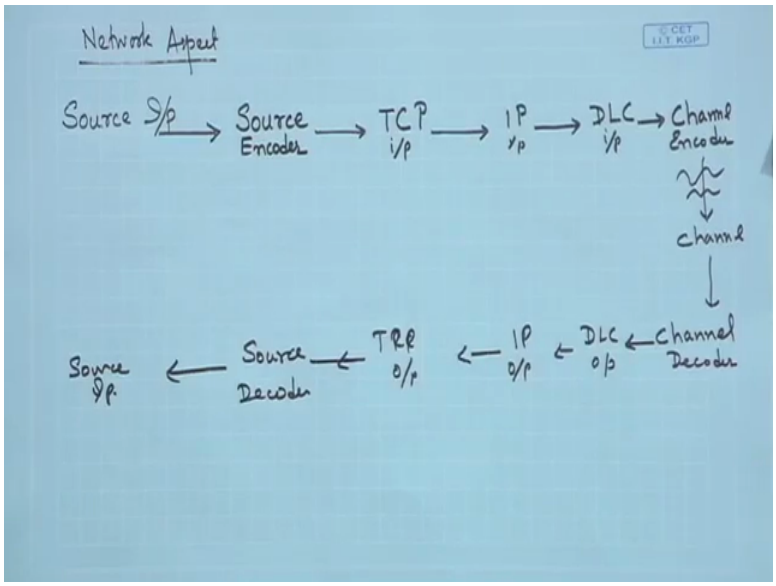

So, if we take the network aspect probably only once that say it just to complete the story the network aspect in a similar way we have resource input that is what we have been doing, the source input goes into the source encoder whose block diagram we have discussed and we will going to each details of the source encoder blocks later on.

Then we can say that the source encoder output goes into the TCP input. By TCP input what we mean is the transmission control protocol or the TCP protocol which you generally used for the TCP IP address setting for or which one you use for quality of service error corrections and so no and so forth. So, this is going in to the network layer, there also we can put this interfaces and layering and probably people in that particular area are more often encounter the word of layering and interfaces than the digital communications, but it spans over the entire region. So, from the TCP again you have a interface to the internet protocol which is again the input, then again you have the data link controller input and finally, going to the channel encoder right.

So, when we had written channel encoder if we did not mean these things, but again these could become part of channel encoder in our earlier diagram, but this is generally what it happens. From the channel encoder which generates waveforms it goes to the channel and the reverse procedure we will see some of the components, this is the IP output this is the TCP output goes finally, to the source decoder of course, you can several components in between this also which is representation layer and so no and so

forth right. So, this is also applies a to the network layers or the TCP layers the way of layering and interfaces, and the interfaces here in these points more or less much clearly defined than the interfaces that we have been talking about in our earlier discussions ok.

So, moving on further when we talk about now let us go in to and talk about the different components of the transmitter and the receiver or the channel that we have and talk about briefly about their attributes which can help us in getting a broad overview of the systems that we are going to encounter.

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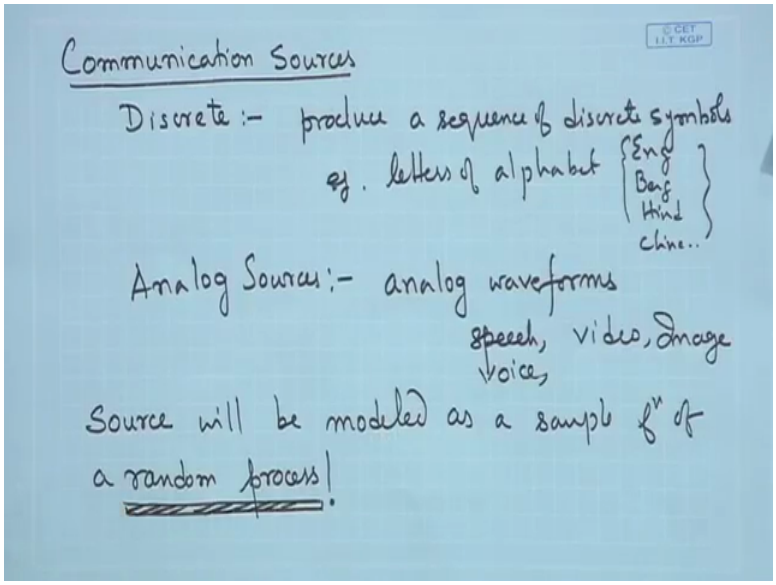

So, if we talk about the communication sources, they can be discrete in nature which we all know and it can produce a sequence of discrete symbols and example of them could be letters of alphabet, it could be any language; could be English could be Bengali could be Hindi could be Chinese and so no and so forth. When is that discrete their specific symbols and they have a whole set or a group from which they have selected this is these are kind of discrete sources and you also have analogue sources.

So, when you have analogue sources their analogue waveforms of course, example speech, voice you can say voice video image photograph and so no and so forth of course, they can be digitized that is what we have said the you can always digitize them, but primarily they are analogue sources a picture is an analogue source the original one, but then of course, the way you capture it could be it becomes a digital thing. And now if you if you look at this what we have with us is this source will be modeled as a sample

function of a random process, this is important to know because if it is a analogue well what kind of waveform is going to come we do not know, if it is image what kind of image we do not know.

So, that is random of course, if you are talking about discrete sources let say a passage or an or an essay which is gain or (Refer Time: 15:25) lecture or some something which is going to get transmitted, we do not know beforehand what particular sequence is going to go through all though we know that they are from the English alphabet, but we do not know that what specific letters or what specific words are going to get formed in this particular transmission. So, we can model it as a sample function of a random process. So, this is something important which we should keep in mind at this stage. Well, this particular thing could be making sense here when we talk about this analogue process, but it is it is not quite obvious when that things would be treated as a random because if you look at the way earlier communication systems were designed they used to take a communication system and think of it as carrying sinusoids exponentials. So, you could also think of a speech or a video or any particular signal if I say that that we have a particular signal let say I have this signal.

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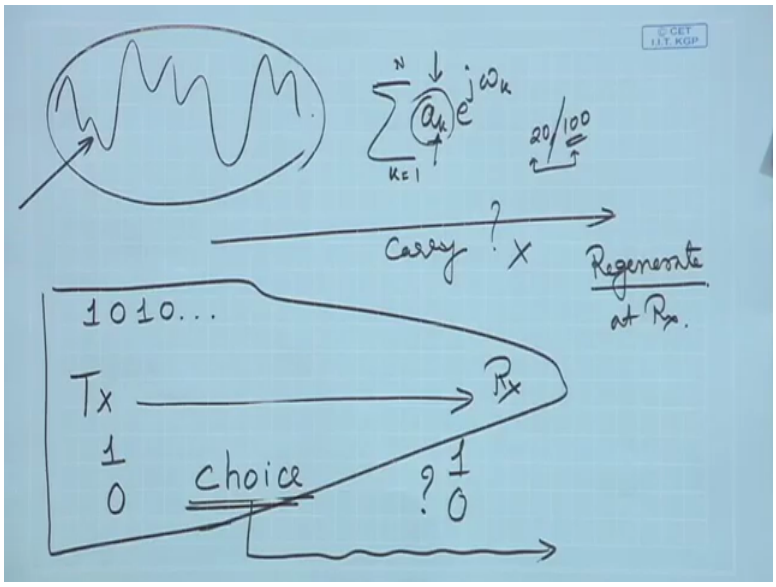

Now, what comes t your mind is a through Fourier analysis you can break it down and you can find the components of frequencies which build the signal. So, they will be let us say a whole set of sinusoids huge number depending upon the bandwidth that restrict

your system, and you find a coefficient for it is sinusoid. So, when you add them with the appropriate phase and amplitude you can regenerate this particular signal. So, what they studied initially is that as if what is a response of a system to a particular sequence of order to a particular set of communication or sinusoids.

So, you would excited by sinusoids you will get the signal and if you would look at very early communication systems or telecommunication systems what they did is the carried these original voice messages across miles and miles tens and hundreds of miles across and they just simply carried the signal across through this whole entire region. Now then there was a change of view at a certain point of time what was realized is that well if this signal is made up of several sinusoids means let say I call it ak e to the power of j all over k if I say I can re create it k equals to let us say one to actually it goes to infinity, but still let say we have a finite number k is the index. So, that is why I am taking it only positive. So, it could be the values could be anything.

So, if we have that then we could say that well if I can break it down into this frequency components, and I can again re generate it by using appropriate coefficients which has amplitude and a phase factor, then what is the need to actually carry this whole signal across what is the need to carry you probably do not need to carry it. You can simply re generate it you can simply re generate it at the receiver. Now to re generate it at the receiver what do you need you are what you need is basically these coefficients which capture with amplitude as well as a phase. So, you have to pre define that at the receiver it knows the set of frequencies which are going to be used. So, if there is a certain amount of bandwidth let say present in the system, you say that well I am going to use a 20 or let say a 100 different frequency components of course, there will be distortion there will be some kind of a error there will be some kind of a problem, but if it is acceptable then you would fix to a certain number that so many components of frequencies I am going to use to generate re generate my original voice message if it is true then what you need to do is send these coefficients across.

If you can send this coefficients across then at this point it can generate. So, again what points what it turns out is that you are choosing a certain set of coefficients for a certain set of sinusoids to be transmitted and they gets re generated at the receiver. Again you can break down the problem further and you can analyze it or you can think of it that end of the day what you are doing is a sending sinusoids; that means, the receiver knows that

I am dealing with sinusoids, if it is English then if the receiver knows that it has to choose from the set of letters that is present in it right.

So, what we are trying to stress over here is that this particular waveform or the particular word that is going to be transmitted is not important rather the choice which is important this is this is quite different from the earlier view. When you mean choice what we say is that suppose I know that there are ones and zeros, the receiver also knows there are ones and zeros. So, basically the transmitter and receiver should know the language they are talking that is very very essential and that is always true because even if you think of communication when we talked to another person we use the same language. So, we are talking about the language of communication, we are talking about the syntax or the grammar of communication the same things apply over here.

So, they know what language they are talking about and they also have to agree upon what is the syntax or the protocol or the method of communication. So, one that is established then communication would mean that the transmitter is going to send to the receiver that at this point whether it has want to send or whether it has a zero to send, this is not known a priori what is known a priori at the receiver is one will come or a zero will come or nothing else will come.

We are not going to get a, you are not going to get b, you are not going to get a sinusoid what you are going to get these two. In this particular case if you are talking about transmission of a English letters, the transmitter knows it has to send this letters the receiver knows what it is going to receive are only letters of the English alphabet and nothing else, but the receiver does not know which particular letter of that alphabet is going to come in this particular example that we are drawing over here. In this particular example the receiver does not know at this instant of time whether a one is going to come or a zero is going to come.

So, what we can do conveyed you at this point is what is important is that there is a choice, which is actually going across from the transmitter to the receiver and nothing else. It is not actually this zero or this one this could be represented in any way this English letters could be represented in any way the picture the image could be represented is anyway what is important is the choice. Now once we are assured that we are talking about a choice then things become a bit different. So, we can summarize what

we said and this is primarily due to Shannon that is where we are talking about information theory.

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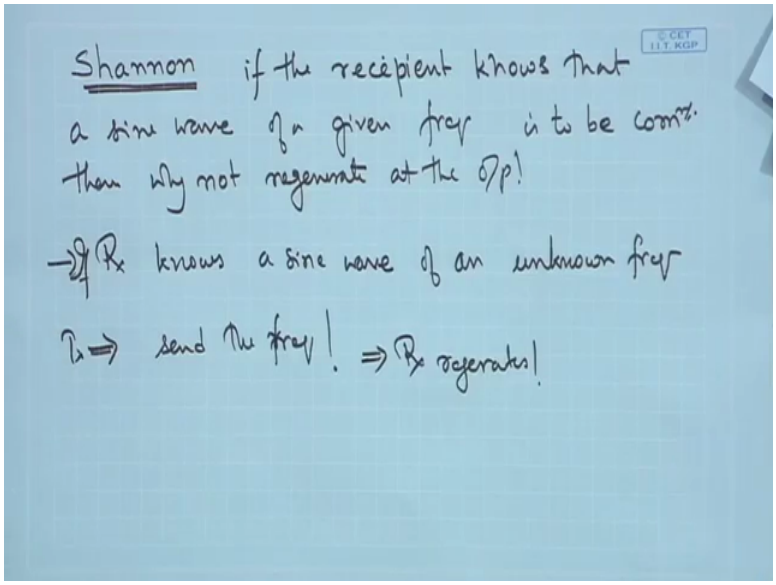

So, primary due to Shannon his view was that if the receiver or if the recipient knows that you can summarize what we have written that sin wave of a given frequency is to be communicated then why not regenerated at the output right this is one of the views that you are stated. The second thing that we are going to state is that if the recipient knows if the recipient knows sine wave and nothing else is going to come if it knows that the sine wave is going to come of an unknown frequency, then what does a transmitter need to do? The transmitter needs to send the value of the frequency that is it.

If it changes the value of the frequency this is taken by the receiver regenerates right this is primary idea from which it expanded or it got abstracted to the point where we are talking about the choice. So, if it is a continuum it is a little bit difficult problem, but if it is a discrete or if you can break it down in discrete and that is what we said in the earlier lectures that if at all you can communicate you can communicate in a binary mode so; that means, you are able to bring it down into binary going to binary finally, you have a choice between zero and one.

So, if you have a choice between zero and one what is important is not the zero or the one, but the choice between zero and one that is what is getting communicated from the transmitter to the receiver.

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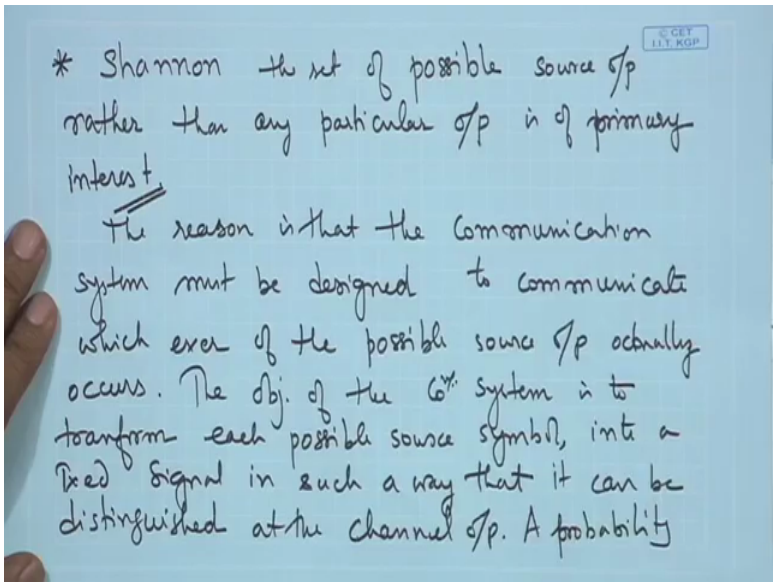

Now, here this is very very important. So, again according to Shannon what we would write is the set of possible source output rather than any particular output is of primary interest, because the reason is that the communication system must be designed to communicate whichever of the possible source output actually occurs and then we can write the objective of the communication system is to transform each possible source symbol this is what you have said it earlier, but we are defining it source symbol into a transmitted signal in such a way that it can be distinguished at the channel output.

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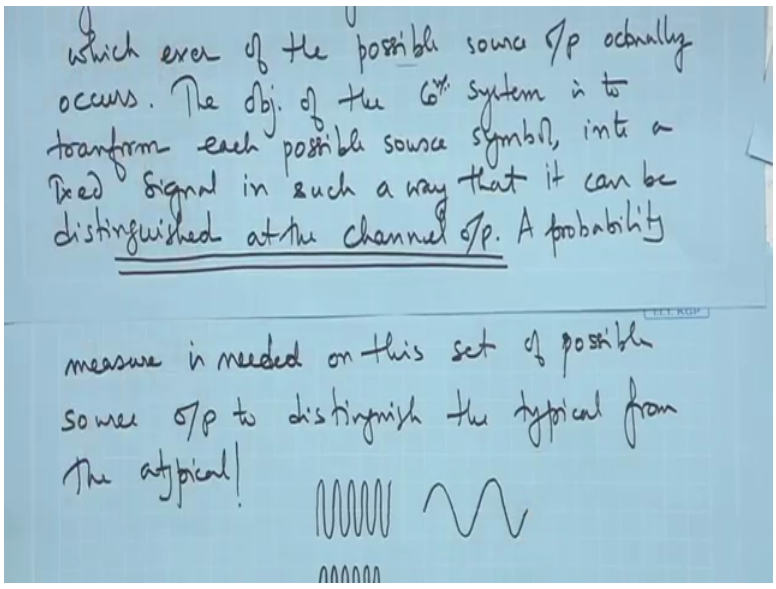

And hence a probability measure is needed or rather specify this a probability measure is needed on this set of possible source output to distinguish the typical from the a typical now this might be a big cryptic.

So, let us go through it and this will finally, converts to what we have already said. So, what we are saying over here is the reason, reason for this that what is important is a choice rather than the particular output is that communication systems must be designed to communicate whichever of the possible for outsource output actually occurs is clear because we know that a zeros and ones are going to come. So, the one or the zero is not important, but which of the two is the choice basically that is important. So, the communication system must be designed to communicate whichever of the possible source output actually occurs, and the objective of the communication systems it should transfer from each possible source symbol; that means, the zero or the one in to a particular wave form that is what we have said earlier.

But now we are you refining it in a little bit better way that the transmitted signal can be distinguished at the channel output this is important earlier we said reliable. So, this is the part of wave shaping. So, suppose I send a sequence of zeros and ones, the way you should design the communication system all it is trying to say is that the one when it is sent and received and zero when it is sent and received should be distinguished. So, the very very simple example is if I am talking about sending a one using this wave form and sending a zero using this waveform right I should be able to distinguish based on the frequency, if I am using this as one I could use this is zero distinguishing it by the amplitude, then we could also use the phase information, but the way we should do it is that we should be able to distinguish.

If you are not able to distinguish; that means, we are going into error and hence it said at the last point that a probability measure is needed on this set of possible source output. Now what it tells is that if I have a source; that means, let us say which is generating English letters let us say as humans source let us say which is speaking it is generating some text textual matter, in that case if you plot the histogram of the words or if you plot the histogram of the letters then what you finally, land up into is a probability measure on the letters. So, basically you can say each symbol has the certain probability of occurrence, what we will come to clear how does that help us in designing the first component of a communication system which we are going to see in the next lecture.

Thank you.