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

Lecture - 02
Introduction to Digital Communication System (Contd.)

Welcome to the second lecture of modern digital communication techniques. So, in the previous lecture we got an review or introduction to digital communications while viewing it with an experience of analogue communications. So, what we did was a harping on the fact that we have already done a course on analogue communications, we tried to explain to you how would you look at a digital communications systems with that knowledge, and what changes would it require.

So, effectively if we would summarise we are going to use almost the entire knowledge of analogue communications to establish a digital communication system however, the input message that we do that was in the previous lecture.

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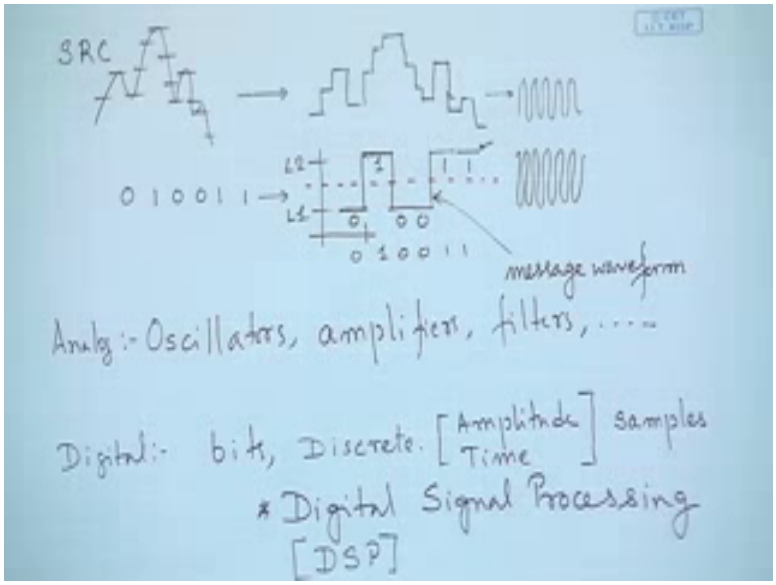

what we said is suppose the input source is an analogue source that means, if we have this analogue waveform what we said is you would have to first convert it into discrete; that means, let us say you quantize that into these levels and once you quantize these into these levels. So, your waveform might look like this and so on and this one you pass on to a carrier, and then we said that well this is the first step towards the transition and now

we again said that let there will be a digital source. So, if we have a digital source end of the day this information is saved in forms of ones and zeros in your computer in a file or if it is a smart phone or a mobile or a memory device it is again stored it form the bits and bytes. So, those are also ones and zeros.

So, now if you have ones and zeros and so on you could translate these to two different levels level for level 1 and a level 2. So, whenever you encounter a 0 you would sent level 1 for certain duration of time, whenever you get 1 you would send level two and so on and so forth. So, this indicates there is a 0, there is a 1, there is a 0, 0 there is another 1 there is another 1. So, this is matching with respect to this particular signal right and at the receiver what you are supposed to do is we would have to choose a threshold.

So, if the received signal is below the threshold I would decode this voltage to indicate a 0 and this level of the signal let us say the electrical signal to indicate a 1, and I would again re generate my signal this is what we said. So, at this point I could use this signal to modulate carrier and the entire study of analogue communications would come into play; that means, the message waveform is this.

This is the particular message waveform and today we will take off from this particular point and we continue there, but just like to mention at this point that when you are looking at analogue communications and you have digital communications on the other hand, typically if you close your eyes and think of an analogue communication system what comes to our mind is generally pictures of oscillators, we think of amplifiers, we think of filters etcetera whereas, when we think of digital communication system. So, when you think of analogue the picture that you get in mind is this if you think of digital the picture that we get begins with the picture of bits, if it is a little bit more advanced then we would think going beyond bits we will go to discrete. So, when we say discrete we mean discrete in amplitude and in time. So, when we have these two things this amplitude this is actually a discrete signal that is we talking about, and if it is only two levels it is basically binary. So, in other words we are talking about samples right and the other thing that comes to our mind is digital signal processing.

So, as we said last time this unnecessary power of digital signal processor. So, this kind of summarises in some sense that when you talk of analogue or when talk of digital what are the different pictures that come into our mind, today we will spend some more time

in trying to explain that when you take digital communication system what are the ways 1 should start looking at the digital communication systems, we will spend a few more time on this before we actually begin with the details integrates of a digital communication system.

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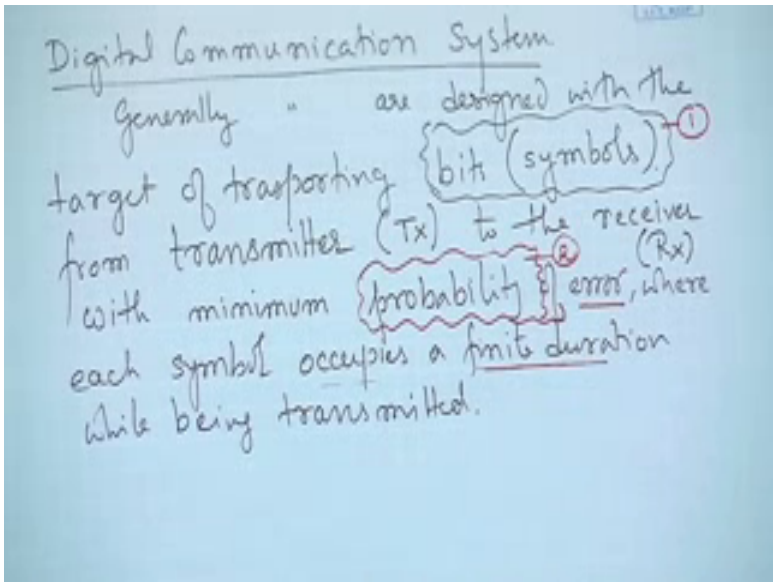

So, let us continue with this and we can define in general terms a digital communication system, we can generally talk about these are systems we can talk about generally we can say generally digital communication systems are designed with the target, we can write this of transporting we are using a bit lay man term in the beginning transporting bits ok.

So, earlier it was messages. So, from messages now we have come to bits and if you little bit more advanced you can say that is it is involve with symbols. So, it is transferring of symbols from the transmitter we are all familiar with the transmitter and we will use the notation T x in our discussion to the receiver which will denote by R x with now there are certain conditions with minimum probability of error where further we have also stated where each symbol occupies a finite duration while being transmitted.

Now, while when we put forward this particular statement, we are actually bringing few important words for the first time in this particular course. So, we will spend a little while trying to elaborate on them so that we get into the more of thinking in those terms. So, one of the things that we have a made quite different compared to the analogue

communication system is this symbols or bits one of the things here, and the second thing that we have here are the probability this is the second term that we have. So, this is the second term that we have and well if we can think of errors it is another third term that we can talk about.

And we have also said that this symbols occupies a finite duration while being transmitted. So, in that sense this can also the third of the as if fourth thing, but these are too much details at the very top level we can talk about this two. So, essentially we are saying that we are not transferring anything other than bits or symbols. So, that is fundamentally different, we are beginning with bits we are ending with bits or we are beginning with symbols and ending with symbols that is one arena. The second we are talking about is we are broad in a criteria of probability this also important to note and these things are pretty from your earlier notion of a communication system.

Now, these this is not very obvious why we are talking about probability; about bits and symbols it is somewhat clear to you going by this particular picture, but will see more of it while we talk of bits and symbols. So, with probability I will talk about it anyway in this probably in this session or may be in the future sessions that why we bring in the notion of probability, because the way we look at communication in digital systems is quite different than earlier versions.

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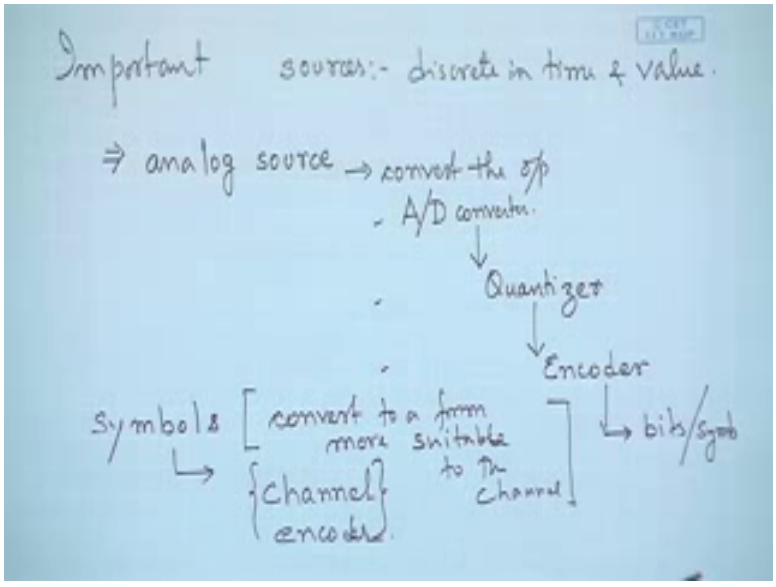

So, as we move ahead. So, so for digital communication system it is important that we will look at sources which are discrete in time and in value or in magnitude. So, this is one of the requirements of digital communication systems and we have already mentioned that digital communication systems are like that, but now we are putting into the different way we are saying that for a digital communication system we require the source to give discrete levels of output and indiscrete instants of time. So, now, we are defining that.

And. So, this means this actually means that if you have an analogue source, this must be converted. So, you have to convert the output using an analogue to digital converter. So, you have to send it to analogue to digital converter this output has to go through a quantizer, and a quantizer output can further go into an encoder and once it had passed the encoder, the encoder is going to generate bits or it can also generate symbols right. So, this is how the things will be. So, these symbols that you have a would finally, go into something called the channel encoder because these are still symbols which are in abstract form. So, one has to convert this again convert it to a form which is more suitable to the channel we will see this in a short while.

In this particular course as we go down in time, we will take up the source encoding in few lectures and in that we will talk about the analogue to digital converter, we will talk about the quantizer, we will talk about the encoder and we will spend a lot of time in this encoder and while doing so we will be clear that why we have talked about a probability one particular area that where probability plays a wide role. So, once we have this symbols when we say it is gets converted to cannel through the channel encoder, what we mean is that the channel is basically the physical channel that we are talking about, and we will we will soon show you or we will soon tell you that when you have to send this abstract symbols into the channel you must convert it. So, that is what we are going to do now.

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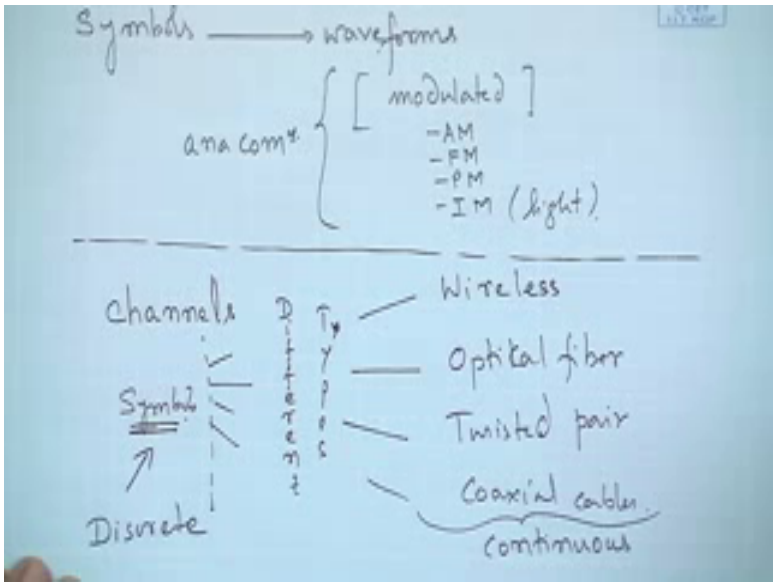

So, typically the symbols they get converted to wave forms and why wave forms, and what kind of wave forms if you think of. So, these are like you can say they are modulated in other words. So, what you have is this symbols they actually used for amplitude modulation, they could be used for frequency modulation, they could be used for phase modulation, and they could also be used for intensity modulation if you are doing light waves communication.

So, if we look at our first lecture and when we say this. So, this symbols this could be representing symbols, the encoding over here this amplitude level they could reflect the symbols. So, this could be symbol 0 0 0 this could be 0 0 1 or this could be 0 1 0 and this could be 1 0 0 this particular level and this could be 1 0 1 and so on and so forth these are different symbols and those are used to modulate this particular carrier. So, that is what we meant in this particular statement. So, they are converted to the wave forms by means of modulation and this is what you are studied in ana com analogue communication.

So, as we are going into digital communications we will not going to this part rather we will almost always remain till the point you are converting them to wave forms. So, things will be clearer slowly with time as we go on describing each of the modules in more details. So, when we talk about the channels. So, channels could be different types there could be different types of channels, one of the classification could be a wireless

channel, the other type classification you could say it is an optical fibre, the other one could be a twisted pair then there could be coaxial cables.

So, now if we look at these different channels one can say that if it a wireless channel then you have to modulate the electromagnetic wave, if it is the optical fibre of course, it still light. So, you are still talking about e m waves, but the kind of modulations could be different, you can talk about controlling the intensity of the light that goes into the fibre. So, if there is a 0 there is some amount of intensity if there is 1 there is higher amount of intensity possibly one would go for on of thing on the period of one and of for the period of zeros or vice verses that could happen if it is twisted pair you can talk of two different voltage levels if it is coaxial cables again you can send different signals to it.

So, basically this same symbol before going into the channel could be all same that means, you document your symbols, but when it is send over different types of channels you could send it differently for example, we can say that you want you are interested in sending the image which is again the sequence of zeros and ones to a friend or to the other side of network to a node or a computer to a phone or to a Wi-Fi device it goes wireless media. So, then zeros and ones could be used to modulate the amplitude or the frequency or the phase of the electromagnetic wave if it is the wireless, if it is if it is connected through the optical link, it could be a visible light optical link, it could be laser it could be wireless optical, it could be fibre optic, then the same 0 could be used to change a different property of the different you can say physical resource here it is the spectrum of electromagnetic waves which comes under the light, visible light band or the infrared or even altar violet.

So, basically you are choosing a different frequencies it is similar, but your opting to a different property when you gone to twisted pair instead of sending electromagnetic waves you can directly send electrical signals which is in form of voltage across this twisted pairs and you can communicate sequence of zeros and ones to the other side coaxial cables again you modulate the wave from and you send it again across through this wave guides and this acts as wave guides.

So, what we are trying to say that the same symbols could be used and sent across different channels. So, our study would be limited to this region where we generate the same symbols and the this is almost independent of this part when it gets converted to a

particular type of channel; that means, the this is matched to a channel that is waveform matching what we will discuss is of course, there is something called the pulse shaping which is corresponding to the properties of this channel, but again we can we can characterise the channel in terms of it of it is impulse response in terms of it is frequency response. So, if we can characterise the channel in terms of it is impulse response and frequency response we can still design pulse shapes in base band probably I am using the term for the first time in base band; that means, not with the carrier that means, without the carrier and still design the system. So, the rest of it would be the digital to analogue conversion well we can still remain in that part, but from analogue signal electrical signal to the appropriate is not what we are going to cover in this particular course.

So, that should be noted and again what we can see is these type of channels are continues in nature and when we talk about this is discrete right. So, I hope some things have improved from the last discussion about analogue and digital communication systems, where the boundary comes in this is very difficult to define an exact boundary, but it is we are very close to it in defining a separation between analogue and digital communications. So, that is the right perspective that we need to send before we actually set forth into the journey of digital communications ok.

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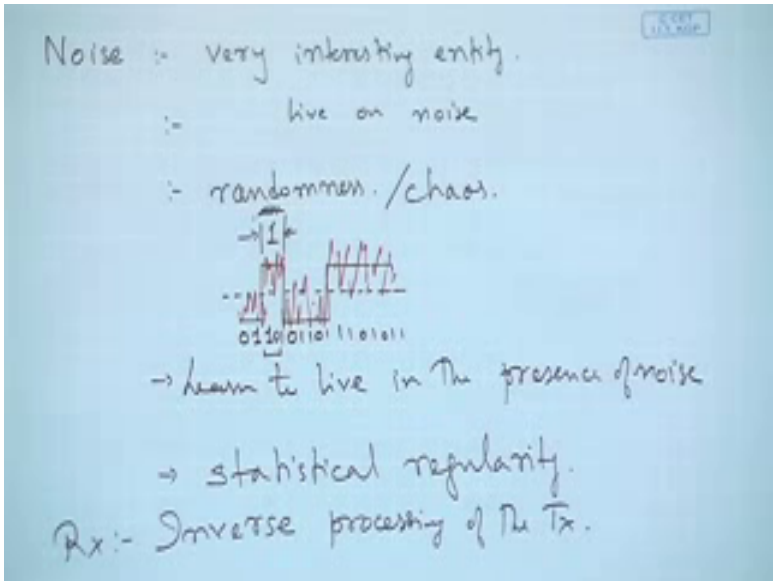

The next very interesting thing in the study of communication systems especially digital communication systems is noise. I would say it is a very interesting entity I do not know

if I am hurting somebody, but it is really a very interesting entity. So, generally we hate noise right we do not like to hear noise we do not like to experience noise, but again very silly thing to say, but without noise your life is communication engineer would be very limited because noise is what has given rise to all kinds of innovation and all kinds of smart and advanced communication system design.

So, as communication engineers you can say that you live on noise had noise not been there things would have been very different. So, when we think of noise, noise generally remains of randomness it us of chaos. So, I could write down the word randomness or chaos. So, when we talk of randomness what comes to our mind is distributions probabilistic the chances right was the chance that I send a 1 it becomes a 0, I send 0 it remains a 0 or I send a sequence of zeros and ones it gets converted to other sequence this highly possible because of noise.

For example if we try to look at the picture that we draw earlier here. So, here if we add noise to this when is being sent at over a this a fire the signal could get distorted. So, for example, we use a similar picture I have send let us say this because of this noise this when noise gets added what I receive could look like this right; and now at the receiver if I am making a decision threshold here what I am going to receive is probably a 0 and then in between I might get a 1 I might I get a 1 in between I get a 0 because of here I get a 1 I get 0 I might get two ones I might get 0 1 and 1 I a 1 0 a 1 0 a 1 1 and so on and so forth.

Because the signal is cross this threshold at some point so; that means, the signal that the input sequence gets completely changed when it comes to the receiver. So, noise is very important and since this happens we are left with no choice, but to process the signal in such a way that we recover the most and we make minimum errors and that is how we started of designing defining the communication system when we said that target of transmitting bits or symbols from transmitter to receiver with minimum probability of error. So, why we say this because when this happens we do not know next time when I am going to send a 0100 whether the same pattern of noise has going to come, it is absolutely unknown nobody knows right.

So, we have to prepare to handle this kind of uncertainty in the system and that is why we study digital communications. So, that we can design an appropriate transmitter we

can design an appropriate receiver so, that we can minimise these kind of errors right. So, we would rather say that one should learn to live in the presence of noise it is not possible to irradiate completely some things will remain, but we can definitely reduce the effect of noise on the received signal that we can definitely do and that is what we will do in our course as we progress with time.

So, our objective you can say is to achieve the most in presence of noise I am not writing that down that that is pretty obvious. So, although noise is random I mean since you have studied noise probably in analogue communication as well, but still there is some kind of regularity in the in this; that means, there is some kind of statistical regularity. Statistical regularity would mean that although I know that there is randomness; that means, I cannot predict was going to happen in the next moment; that means, when I send a 1 whether that 1 is going to become a 0 or it is going to remain a 1 I do not know that is randomness, but I can tell for sure if I send a 1 million ones, what fraction of those would get converted to a 0 and what fraction would remain as it is.

Now, this fraction is sometimes called the probability of error the one getting converted to 0 and 1 minus that fraction is basically probability of given correct. So, this fraction or this probability is going to be consistence and it is going to be consistence with larger observation windows and that brings us to the notion of stationarity. So, of course, we will be using the notion of stationarity because if it is a no stationary system that would mean that when I said 1 million bits now, and let us I send I million bits few while later the percentage which becomes 0 in the earlier case to the percentage it becomes 0 in the latter case across the same system if that very significantly then we are handling a non stationary system.

If we are handling a non stationary system, that is very difficult to design a communication system for them. So, at least you can think that you we will be handling piece wise stationary if not anything at least for the time that we are considering the system it is statistical properties does not change with time. So, of course, there are different definitions of stationarity there could be sticks and stationary white end stationarity will be mostly taking to white end stationary. So, at least that again gives us a hint that why we need to use this technician of probability or why we send that probability is very important term in the study of digital communications right.

So, further you will note at some point that this noise is actually represented in almost in a finite dimension, it is going to whatever I take the component I get a component of it. So, in other words it is very difficult to define noise completely and if you use statistical means of define it well you can define it in some way so; that means, in the statistical sense there is regularity. So, I can handle it in a in a statistical fashion and I will design my transmitters and receivers in a statistical way accordingly right. So, that is what will be doing.

The receiver of course, well we can write in brief over here the receiver is the inverse processing of the transmitter right that is the that is the next part and in our communication systems we will actually do a lot of receiver design lot of components of receiver and I have told you in the introductory lecture if you have gone through it that in a in a digital communication system, the receiver plays a very important role where there has to be synchronisation entity; that means, with synchronisation carrier which you may have studied in an analogue communication as well carrier recovery and followed by you have timing synchronisation because as you are seeing that here time is a major factor right.

So, we know that one was sent in this period of time right if one was sent in this period of time in that case at the receiver even if the receiver generates a 1 0 in this period, we should actually take one of these two or we should take a representative single bit for that duration of time. So, this indicates that time synchronisation plays a major role in digital communication systems. So, the kind of time synchronisation we are trying to defect over here is bit synchronisation or clock synchronisation, there is frame synchronisation beyond that as we talk about this channels earlier as we talk about this channels each channel is unique in it is own way.

So, when we send the same bits 0 1 0 1 0 0 across the wireless channel or the same sequence over the optical fibre channel, the chances that sequences 0 1 0 1 0 0 is only remain the same in these two different channels is very different they have to be very very different. Now that dependence upon the channel properties which includes the amount of noise in the system usually we ascribe noise to the amount of noise at the receiver. So, basically when we talk about channel system I am going to distortion that this channels bring in so, the needs to be equalization of the effects of the channel. So, first the channel is to be estimated followed by equalization of the channel.

Now, you can easily see that these few things that as I have described is not required in this part which is the transmitter before it sends into the channel right. So, receiver has to do a quiet a few extra things which are very specific to the system, but again we will find methods to represent the different channels as we have here in an abstract from. So, that we can capture the effect of these channels on the signal that we are getting that we are transmitting; that means, we transmit the signal let us say x of t we receive a signal which is y of t. So, y of t is a function of x of t and the channel properties.

So, if we can abstract and make a model of the channel which will of course, show you in this course, we can reverse engineer we can recover the effect of the channel and we reconstruct the signal in it is original form so that we as less error possible. So, those are some of the things we will slowly slowly get to know with time in this particular course.

Thank you.