Digital Communication
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Lecture - 01
Introduction

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Hello, everyone welcome to the course on digital communications; in this course we will see what happens inside a digital communication system. Let us first see what is the purpose of any communication system?

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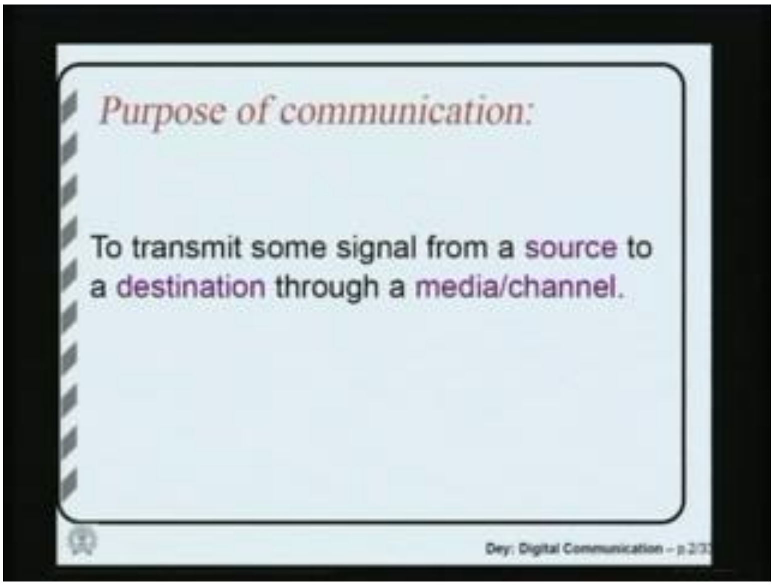

The purpose of any communication system is to transmit some signal which is generated by a source to a destination through a media or channel. So, there is a source which is generating some electrical signal which is possibly captured from some real life image or audio. And, then the signal generated by a transducer and then that needs to be transmitted to a destination through a media which is technically called the channel. So, we have a source, a destination and a channel.

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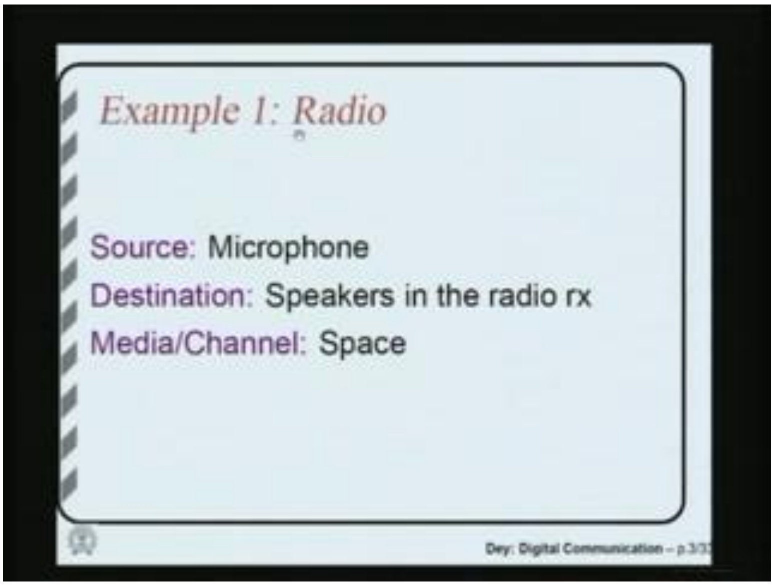

So, let us see some examples; radio is a very common example. The source in this case is a microphone which captures a signal from reality and then converts it to an electrical signal. And, then that needs to be transmitted through space and it should reach the destination and should be reproduced at the radio receivers at the users place.

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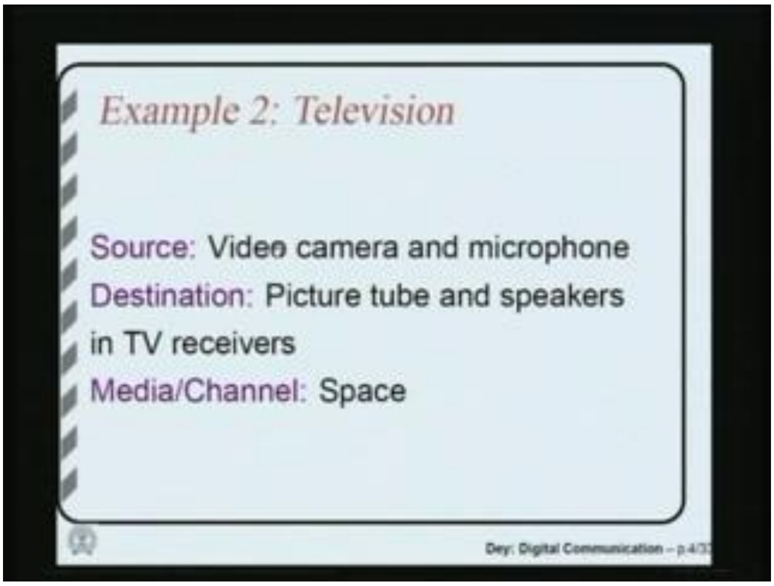

The next example is a similar example television; where the source and destination are similar except that in this case we are dealing with video instead of audio signals. And, the source of the electrical signal is the video camera and microphone because there is video as well as audio signal. And, then the media is again the space and the destination is a T V set which has picture tube which should display the video that was captured by the video camera. And, the speakers in the radio T V receivers which should reproduce the sound that was captured by the microphone.

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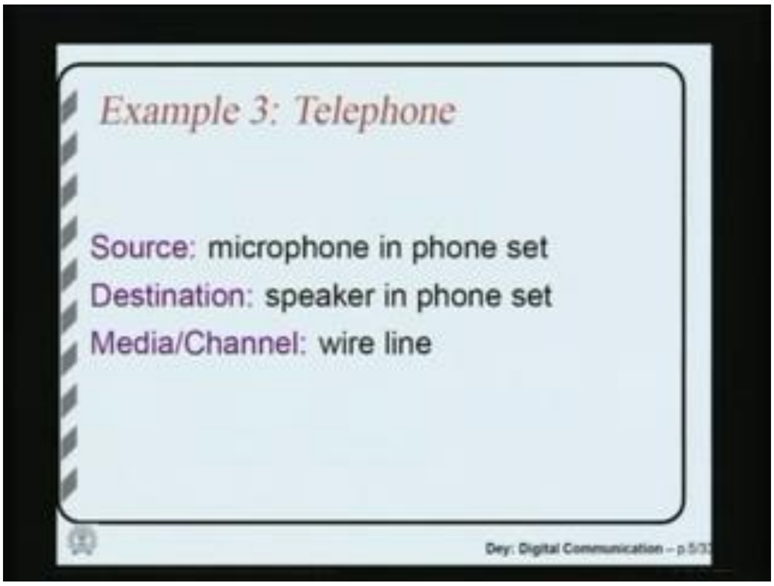

The next example is a telephone system; where the source is the microphone in a phone set; and the destination is the speaker in another phone set. And, the media in this case is wire line, the twisted pair wires.

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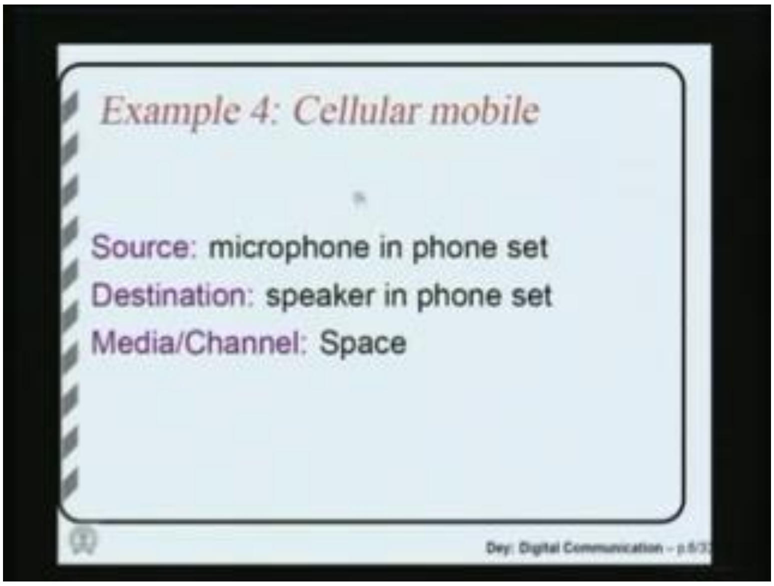

In the next example we have again a telephone but it is a cellular mobile phone. And, the channel in this case is space unlike the twisted wire in the case of telephone, traditional telephone. So, in this case again the source is a micro phone in the phone set and the destination is a speaker in the phone set, another phone set.

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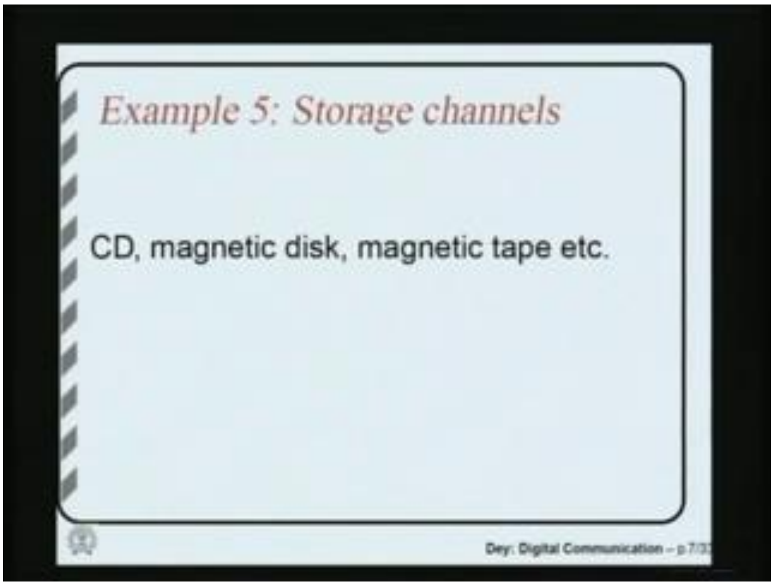

There are some not so obvious types of channels other than what we have considered. For example, what are known as storage channels like C D, magnetic disk, magnetic tape etcetera. So, these though they do not seem like channels actually they also can be considered a channel. And, when you are writing on a C D or recording in a magnetic tape that can be considered as a that we are transmitting some signal. And, then when the time progresses the tape or the C D may be damaged in the due to some phenomenon like there may be a scratch on the C D, there may be some magnetic interference in the tape and the magnetization may change in the course of time. And, as a result when you play it back we may not receive the same signal as it was recorded.

So, this writing on a C D and reading from a C D till the reading from a C D this whole process may be consider as a communication system. And, what are the different type of sources that you come across in digital communication?

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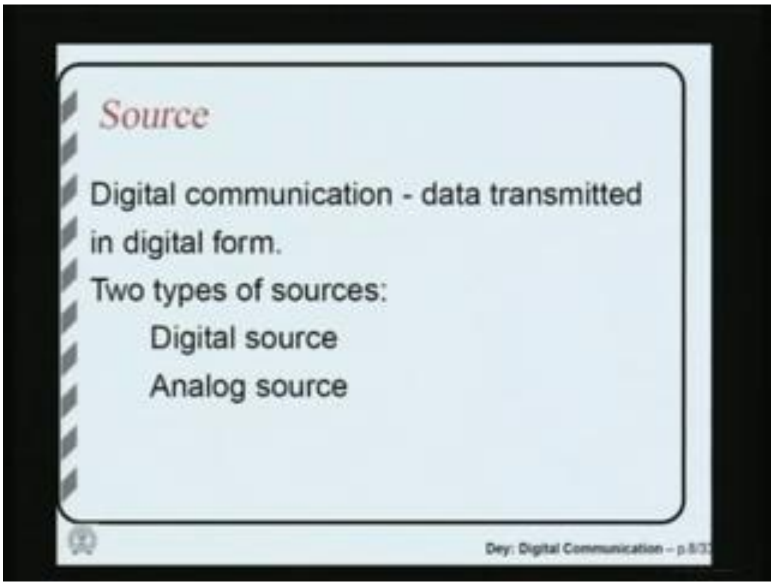

In digital communication the data that is to be transmitted is in the digital form; there are different types of sources in reality but in digital communication the source has to be converted to a digital form. The source to start with may not be digital may be digital or may not be digital; if it is digital there is nothing to be done if it is not digital then it needs to be converted to a digital form. So, there are 2 types of source and they are digital source and analog source.

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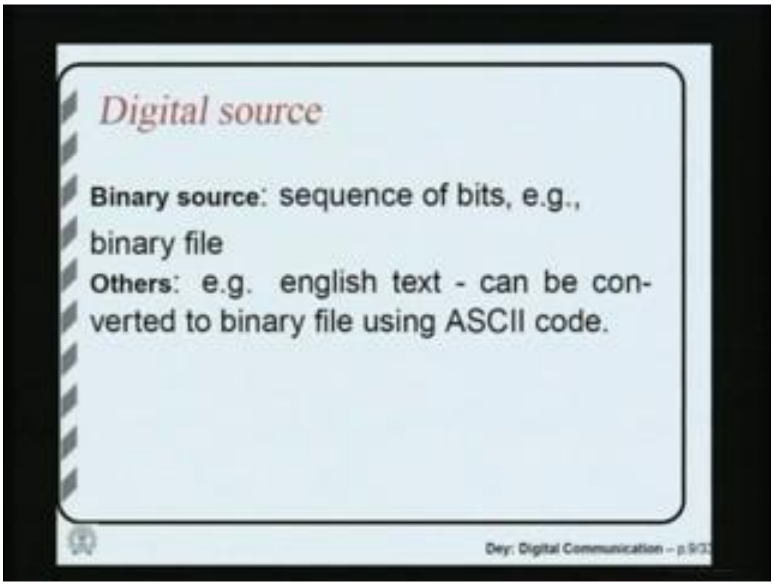

A digital source may be of different kinds; for example it may be binary source like a like a binary file and a computer and that has many bits. So, it is a sequence of bits. So, when you want to transmit such a file it is basically that you want to transmit some bits in sequence and there are other type of digital sources which are not binary in nature. For example, when you are typing we have we are basically typing English text. So, that English text is also implicitly a digital signal because every character can be one of the set of finite set of characters. So, it may be one of the 26 alphabets capital letters, small letters so there are 52; there are numerical characters, there are punctuation marks and so on. So, in total there are finite number of character that would like to transmit that the English text has. So, this is also a digital signal. So, a digital signal is characterized by the fact that every point, every sample is can take only finite number of values unlike an analog source; where every sample is at every point the value may be one of the infinite number of values. So, for example it may be a real number which has infinite possibilities.

So, English text is an example of a digital source, digital signal. And, however though it is not binary in nature it can still be converted to a binary signal by using some form of binary code for every character. So, for example ASCII code is one very popular stranded for converting for representing the English characters in the form of binary strings. So, every letter or every character is represented by 8 bits in this code. So, by using this code we can convert any English text. For example a whole book in English into binary form. So, you can convert it into a binary file. So, to summarize we have any digital source represented in the form of binary strings; we can represent any digital source in the form of binary sequence.

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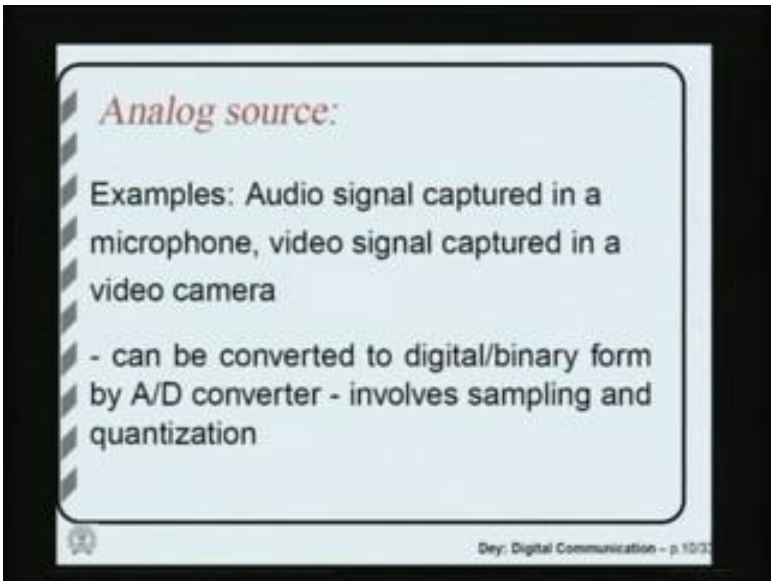

Now, there are also analog sources signature. For example, the audio signal that we capture from microphone is basically an analog signal; it is continuous in time and also it is continuous valued meaning by at any point of time the voltage level that is generated at the microphone can be can have infinity possibilities, it is a real number. Similarly, the video signal that is a captured in a video camera has infinite possibilities for the color at every point or infinite possibilities for the gray level at every point. So, it is basically an analog signal, it is continuous valued signal and also it is continuous time in nature. There are even if we have 1 second duration of audio or video signal there are infinitely many samples in that 1 second duration. So, it is continuous in time as well as it is continuous valued signal. So, analog sources are continuous time and continuous value.

Now, we have just know said that in a digital communication system the source has to be represented in the digital form. And, then will use digital techniques to transmit the digital data. So, analog signal also has to be converted into digital form for us to be able to use digital communication systems to transmit that signal. So, the common block that is used in this purpose is called the A to D converter is the abbreviation for analog to digital converted. And, this usually involves 2 operations and we will come to that in a moment. So, the they are basically sampling and quantization and we will come to that in a moment.

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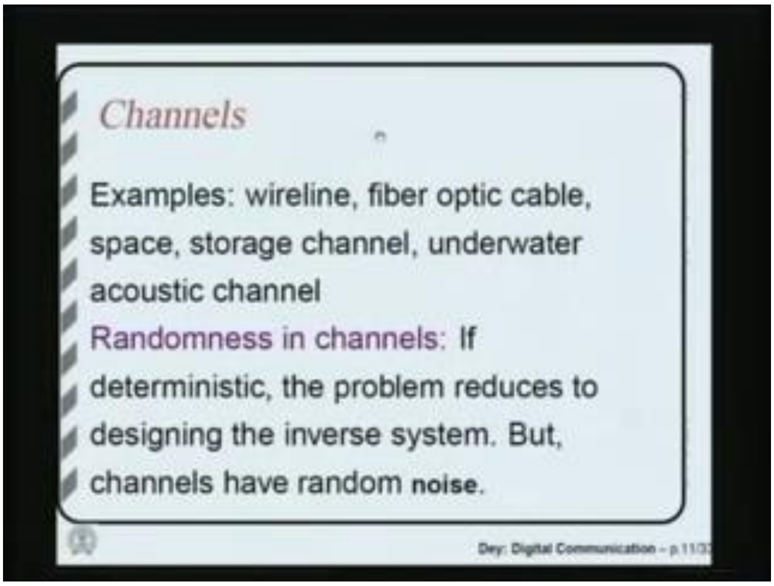

So, we have discussed source to some details. Now, let us see what kind of channels we usually see in practice. So, the common examples of channels are wire line channels like that is there in telephone, fiber optic cable, space where for example mobile cellular phones operate, satellite communications use, space, as channel, storage channel; just now we discussed about magnetic recording channels they are basically storage channels or C D, optical recording channels CD, then magnetic tape etcetera. And, there is also underwater acoustic channel; where the signal is transmitted from one point in under sea to another point under the sea. So, if the signal goes through the water. So, that is little different from the space.

Now, these channels if they behaved in a deterministic manner. For example what you mean by that is that if we knew exactly how the channel will change the signal when we transmit the signal. Then, our job will be quite simple we would like to get the transmitted signal back. So, if the job of the receiver now is just to invert the process of the channel. So, we need to design an inverse system. So, that will solve the problem; but in practice the channels do not behave in a deterministic manner. And, that gives raise to all the problems and that actually, that is actually why we need to study so much and do so much about digital communication. And, the channels are not deterministic and there are most of the times… why they are deterministic? They are not deterministic is that there is noise in the channel.

So, the noise may be introduced from the channel or it may be in the receiver. So, there are different kind of noise; then the noise themselves may be different kind of noise may be either man made noise or there they may be generated in the nature processes like lightening and so on or manmade noise like switching also generate noise. Now, there are different kind of noises in nature thermal noise, flicker noise, impulsive noise these are just to just few different types of noise; though there are this different types of noise the most predominant type of noise that we come across in communication systems is the thermal noise. And, this thermal noise though as we said noise is random in nature; there is no way to predict exactly what value the noise will take at any point of time.

So, does not mean that we do not have any information about the noise? No, it we do have some information about the noise usually we assume that we know the statistic of the noise. And, that usually can be estimated by performing experiments or there are models for the noise that are reasonably good in practice. So, they reasonably well approximates the noise that we come across in practice. And, thermal noise is usually modeled as Gaussian noise. And, the most common type of channel as a result that we come across in communication systems is what is known as additive white Gaussian noise channel or that is abbreviated as AWGN channel.

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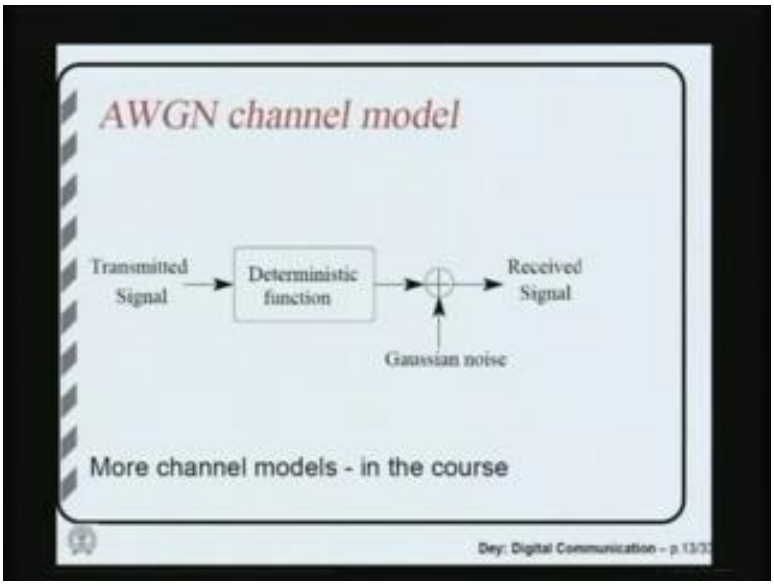

In this channel model the transmitted signal goes through a deterministic change in the channel and then a Gaussian noise is added. So, this is basically the thermal noise that is generated a different electronic devices in the receiver. So, thermal noise is modeled as Gaussian noise and it is added to the signal that we get after it goes through the deterministic change. So, the received signal is the transmitted signal changed deterministically plus a Gaussian noise. And, usually this Gaussian noise is assumed to be white and what it means is that the noise is uncorrelated. That means, at one point of time the noise value that we see has no correlation with at any other point of time whatever noise value you see.

So, 2 different noise samples at different time instances do not have any correlation; that is what white noise means. We will see more about this white noise in a later class when we discuss some background material about probability and random processes ok.

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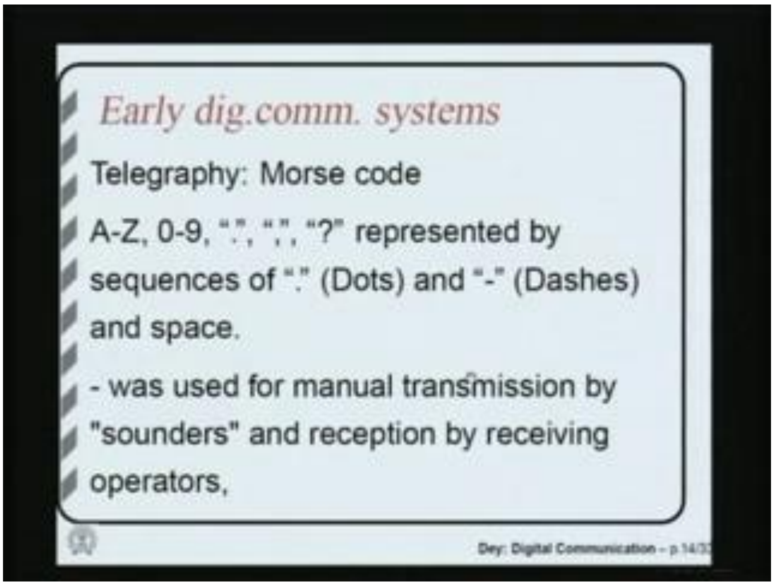

So, though we know the most of the early communication systems are analog in nature. For example, radio, television and a telephone the one of the earliest communication systems was digital in nature and that is the telegraphy system; it was a very nice and efficient digital communication system which actually had lot of advanced ideas in it. And, there the purpose was to transmit English text and as you discussed sometime back the English text is not a binary signal in nature.

So, they have so this famous code called Morse code actually encodes this characters A to Z 26 of them, 0 to 9 the numerical characters and this 3 punctuation marks. And, they are expressed as sequences of dots, dashes and space. And, they there was a nice system designed to transmit English text using this code. So, A has a particular sequence of dots and dashes. And, similarly all the other characters and at the transmitted end if an English text is to be transmitted every letter will be coded individually according from this using this Morse code and they will be transmitted by dots and dashes. So, in this case dot usually means a short pulse, short duration pulse of electrical signal. So, short electrical pulse of current and a dash will mean a longer duration electrical pulse. So, and the space is a gap between gap when there is no signal transmitted.

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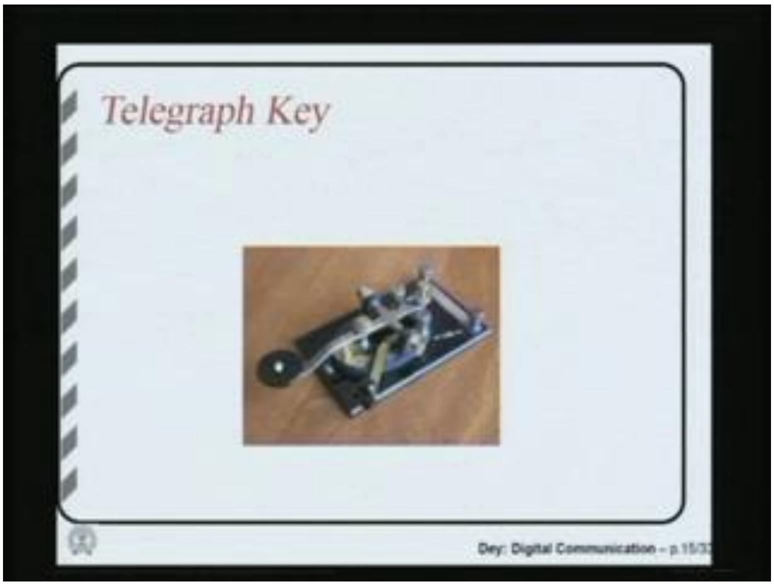

So, in this form there is a interesting instrument where so will this was the one of the earliest instruments that was used generate the electrical pulses; in this there is a key here which can be placed to make contact between 2 metallic parts. And, when you press it there will be a contact and then there will be current flowing through the wires that go to the other end of the through to another telegraph center. And, this can be pressed for a shorter duration or a longer duration by the operator though avoiders were used to be called sounders. Because when this switch is pressed it makes a clicking sound. So, tick tick sound is made by this key when this pressed.

So, the sounders will actually encode the English text and they are they usually know the whole Morse code by heart. So, they can encode any English text really very fast. And, at the other end of the at the receiving station there will be also receiving operators; who will actually hear the pulse coming in the sense that the pulses that come the electrical currents that come they will be used to generate some sounds of shorter or longer duration at the receiving station. And, the receiving operator who will be a person he will hear the signal that is coming and you will immediately write down the massage after decoding. So, these receiving operators will be trained people, they will be trained on Morse code just like a language. So, they will learn Morse code as a language. So, that they can hear any signal in Morse code and they can decipher in running time.

So, this telegraph key this kind of telegraphic key was used for long time to transmit English text through telegraph.

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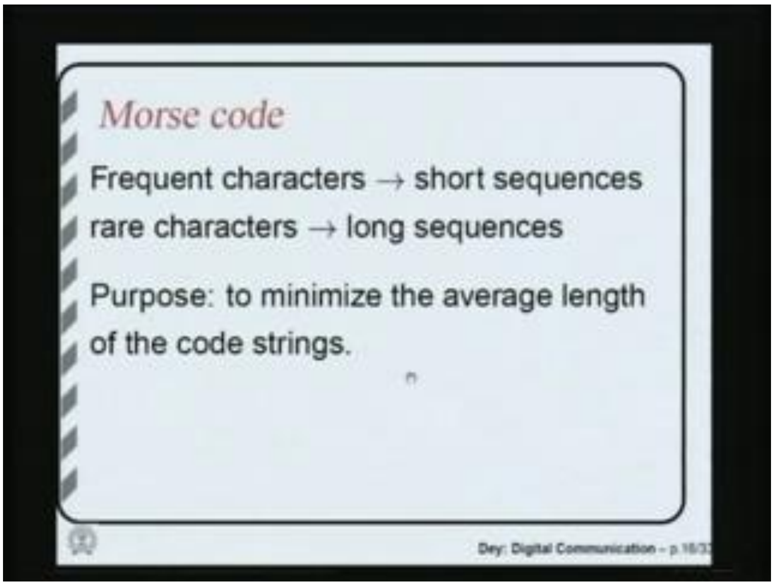

And, in the Morse code there are some very interesting ideas used which even nowadays advanced techniques use. So, the idea is that all the letters and all the characters that were encoded where not encoded by same number of dots and dashes; the number of dots and dashes that will be used to represent a character was kind of inversely propositional to the frequency in which those characters come in English text. So, frequent characters will be represented by shorter sequences of dots and dashes. And, the real characters like Z and punctuation marks like interrogation marks they will be represented by long sequences of dots and dashes. So, that on average if you see an English text represented by Morse code it will have a minimum length. So, that is that is what is desired you do not want to take a lot of time to transmit a message.

So, for that the characters which are more frequent; so they will be they need to be transmitted more in number. So, they will be represented by smaller number of dots and dashes and the rear characters like Z will be represented by longer sequences of dots and dashes. So, the purpose is to minimize the average length of the code strings. So, when you discuss source coding in a later point of time in this codes; we will see the that is the basic idea that is used in source coding; to minimize the average length of code strings we try to assign longer sequences of bits to the real characters or real symbols and shorter sequences of bits to the frequent characters.

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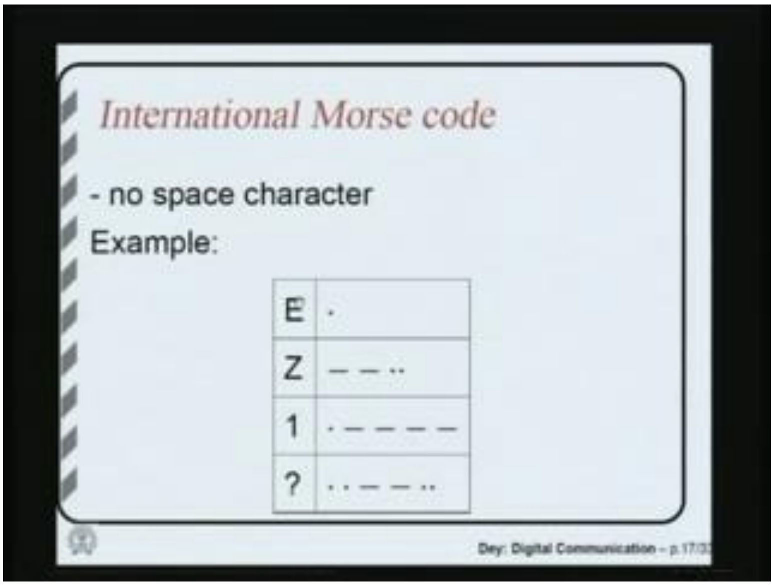

And, here is an example of some Morse code for some of the letters, some of the characters. This is not really the original Morse code; original Morse core had some spaces in it. And, later on when manual transmission and reception was ruled out and it was automated; it was found that this space is difficult to due to the space the Morse code is difficult to implement in an automatic way. So, it is not perfectly binary in nature. So, this space character was removed and another Morse code which is called international Morse code was developed for this purpose; and here space character was not used. So, here we see that in this example E is represented by single dot, Z is dash dash dot dot, 1 is dot dash dash dash dash; 4 dash it is; and interrogation mark is dot dot dash dash dot dot. So, here you see that the E has the character E has only 1 dot; it is encoded by a single dot.

So, the purpose is quite obvious because E is the most frequent letter in English text, in English language. So, if E is represented by a short sequence the shortest possible then will save a lot of time in encoding English text. Because E needs to be encoded many times. And, then on the other hand Z has very it comes in English text is very rarely; its frequent is very less. So, as a result we want to encode Z by a longer sequence; there is no harm if we encode Z by a longer sequence than other more frequent letters. So, that what is done. And, the numerical characters are even less frequent in English text and that is why the numerical characters are encoded by longer sequence. In fact, all numerical characters add encoded by 5 symbols in this international Morse code. And, this interrogation mark this type of punctuation marks are encoded by 6 characters, 6 dots and dashes.

So, we see that the one of the most, one of the earliest communication system was a digital communication system. And, it used very fantastic idea about encoding English into a binary form dots and dashes. So, we can say the dots are just 0s and dashes are just 1s. And, say that this is binary encoding of the English text and the Morse code also has the basic idea of source coding that will see in details in a later class.

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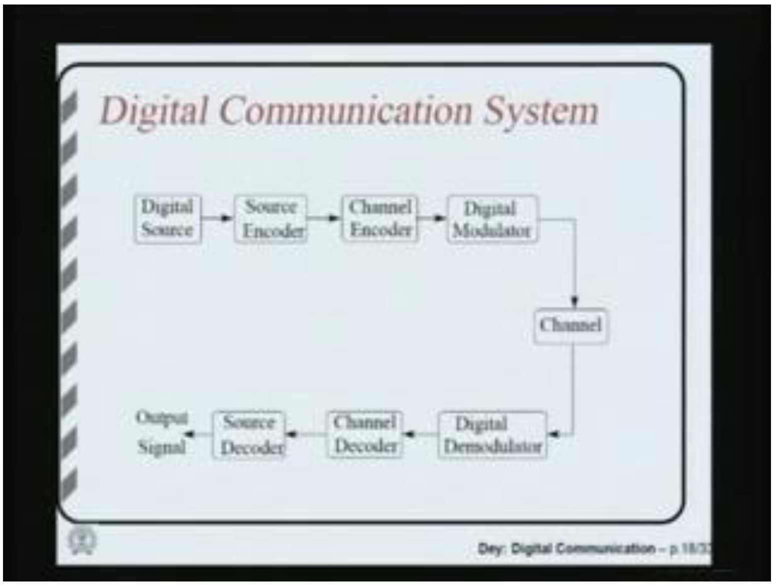

Now, let us see what a digital communication system has; the basic digital communication system has today? We have a digital source the output of this digital source is some kind of digital signal; though in most of the course we assume that the digital source generates binary signals and that assumption is not really a lot of restriction. Because it is it is not a strong assumption because we are dealing with digital source and a digital signal can always be represented by binary sequence. So, by using ASCII code we encode English text or by Morse code. So, digital source there is no harm in assuming that the digital source is a binary source. And, then there is a source encoder which tries to compress the data that it is receiving from the digital source into minimum number of bits. Because we do not want to use a lot of bandwidth in this channel to transmit the same amount of data.

So, the there is different reason for which the source may be generating redundant information. So, that the 100 bits here may not contain really the maximum amount of information that 100 bits can carry. So, as a result there may be scope for compression of the source. And, we know that the we can compress a binary file for example to a great extent by using different compression software’s like ((Refer Time: 28:27)) and so on. So, those are basically source encoders; those softwares implement some source coding techniques. And, the reason why there may be some redundancy in the output of the digital source is that first of all there may be the 0s and 1s here; if it is binary signal may not be equiprobable. So, there may be more 0s than 1s on average pair. So, for example if there are 90 percent of the bits are 0s then obviously they do not carry so much information. Because at the other end most of the times we can guess that the bit will be 0 than 1.

So, the 0 does not carry so much information. So, there is there would possibility be a way of compressing the output of the source; if the source is of that type if the source generates bits where 0 and 1 are not equiprobable. Another reason why there may be redundancy in the source output is that there may be correlation between the conjugative bits. So, for example in an image signal if one pixel is blue, if it is a blue pixel then the probability that the next pixel is also blue pixel is very high; usually the neighboring the pixels have similar color. So, in an image signal there is high correlation between neighboring pixels. And, as a result we can say that all the pixel do not carry really independent information; if we know 1 pixel value there is no need to transmit equal number of bits for transmitting the next pixel.

So, there is possibly way of transmitting some difference between the pixel; for example which will require less number of bits. So, the reason why there may be scope for compression of the digital source is that either the source signal may not be the signal samples may not be independent of each other; there may be correlation or the signal values may not be equiprobable. Then, the next lock is the channel encoder; where it receives some bits here and then it tries to transmit the signal in a way that is suitable for the channel. And, so it takes care of what kind of channel the system has and then it raise to shape the signal in a way so that the receiver will be able to get the maximum information from what it receives. So, another a very traditional way of doing channel encoding is to do error correction coding where the if we have K number of bits to be transmitted; we actually transmit few more bits add few more bits. But they are not extra information bits but those bits are actually derived from the K number of bits that we want to transmit. And, so those bits do not carry any extra information, they are redundant bits. But those bits allow enable the receiver to correct some bits if the channel introduces some error. If the channel introduces some errors that is flip some bits then the receiver will be able to correct to some extent; the bits that are in wrong. And, the next is digital modulator; where which is specially used for analog channel; the channel most of the channels are analog in nature and so we want to transmit digital signal. So, this or the input is digital but the output of digital modulator is an analog signal. So, this is the interface between the digital part and the analog channel.

Now, the receiver. So, this part is the transmitter and here is the receiver. And, in the receiver gives the counter parts of these blocks are there in the opposite sequence; first there is a digital modulator here at the front end of the transmitter. So, here we have to demodulate the signal that is coming from the channel that we have receiving. So, this digital demodulator we will receive the analog signal and try to estimate what value was transmitted here. So, if it is binary it will try to estimate what is the bit that was transmitted here; from the wave form it receives. So, its output will be bits. And, then the channel decoder will try to correct some errors if they have some errors in the detection here.

So, channel might have introduced some distortion in the analog signal due to which the digital demodulator detected some bits wrongly. So, if the digital demodulator detected some bits wrongly and the channel decoder will be able to correct those bits with the help of the extra information bits that were transmitted by the channel encoder. So, that will be possible that the cannel decoder will be able to do to some extent not that whatever is the number of errors that the channel introduces or the digital demodulator introduces the channel decoder will be able to correct. It will able to correct say may be up to 2 bits in error or 3 bits in error that depends on the design of the system. And, so we have to see that we have to we have to note that if we choose to correct more and more errors we need to add more and more redundant bits.

So, as a result we need to compromise on the rate of transmission. So, we will see we will discuss this in details in a later class in the course. And, the channel decoder then gives its output to the source decoder; which take this signal and then reproduces the signal that the source generated. So, this is the output signal at the receiver.

Now, though the digital source is assumed in this block diagram; the source in practice may not be digital as we said. So, in that case we need to convert the analog signal coming out of the analog source to a digital form. And, that involves 2 operations; one is the sampling and the other is the quantization and coding. So, the analog source needs to be digitized by sampling and quantization.

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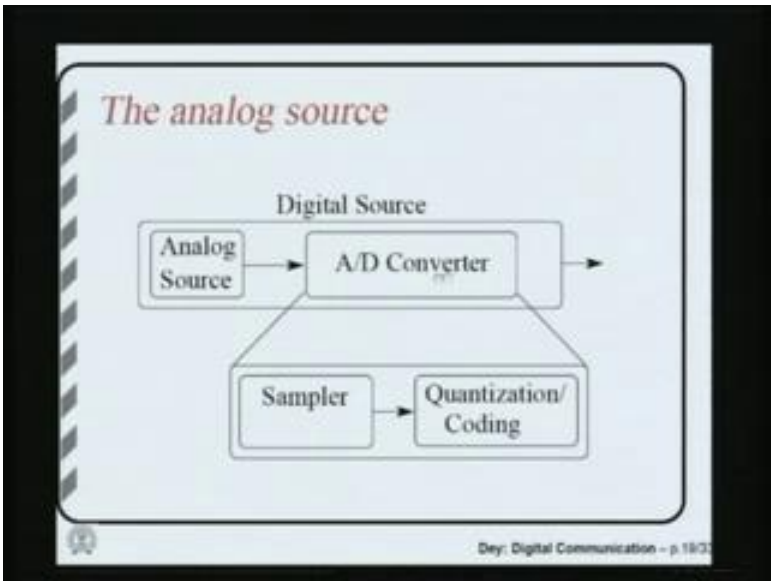

So, if we have an analog source to start to start with we need to A to D converter, analog to digital conversion. And, that involves sampling and quantization and coding So, quantization; so what does sampling do sampling? Basically so the analog source is generating the signal which is continuous time. But we cannot transmit the signal at all time instances because there are infinite number of time instances even in 1 second duration of signal. So, we need to discretize the signal in time we cannot transmit the signal value at every time instant. So, we will be so what is done usually is that we cut the time instances into some points in regular intervals. And, then we take the values of the signal only at those regular time intervals and then transmit the signal value at those time instances.

So, that is the job of the sampler. And, we will discuss in detail the sampling in detail in a later class; in the next step that is done is quantization and coding. So, in quantization the each sample value is still analog; in quantization we like to discretize the amplitude value amplitude also.

So, here only finite number of values will be taken as a representative values. And, then when we see that the sample has a particular value we try to see what is the nearest representative value that we have chosen. And, we will only like to transmit that representative value not the exact value of the sample; because to transmit the exact value of the sample we need infinite number of bits. So, we chose only finite number of representing values in a certain range. So, we have some representative values of the sample. And, then we have a particular value of the sample and we choose the nearest level or the representative value. And, we encode that we represent that level with some bits; remember that we have only finite number of levels now. So, if there are 8 levels for example we can assign 3 bits to each level, 3 distinct bits to each level. And, then corresponding to the level that is nearest to the sample value we have those three bits and those 3 bits is the encoded string for the sample.

And, of course in this process there is some error because the level is not the actual value of the sample but it is an approximation. So, there is no way of getting the exact sample value back from the quantized sample; there is some loss of information. But most of the times that would like to quantize in with a sufficient number of bits; that is in a sufficient number of levels. So, that the quantization noise the error is small enough in our that is it is in our toleration level. So, once we have this A to D converter the analog source and the A to D converter together can be considered as a digital source.

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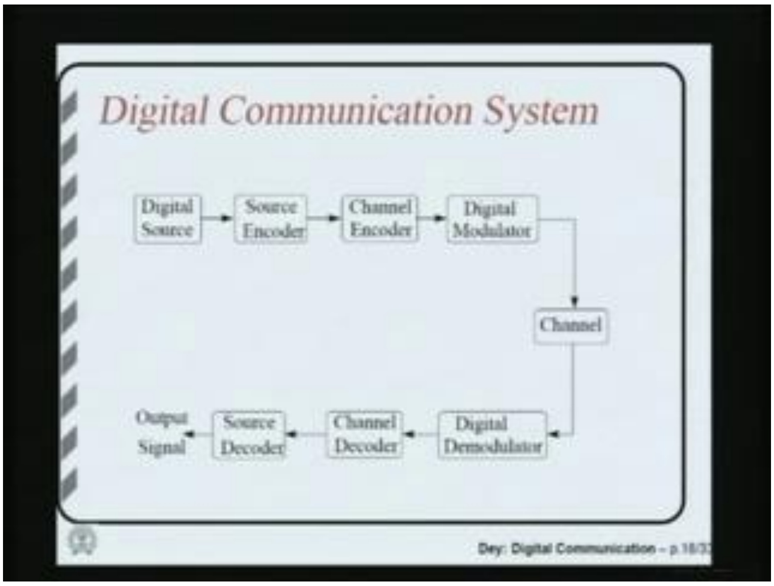

And, then it fits perfectly in our pervious digital communication system. So, this digital source now if the actual source in the system is analog; this digital source is actually the source that is shown here; it is actually an analog source together with an A to D converted, this output is a digital signal. So, though in this main block diagram we have shown channel encoder and digital modulator separately; in most modern communication systems this channel encoder has 2 parts. And, this demodulator, this digital modulator is usually combined with some coding and that block is called coded modulator.

So, there is something called coded modulation which combines coding and modulation together to get better performance. And, the of course there is still a channel encoder kept usually a still a separate channel encoder used for further error correction.

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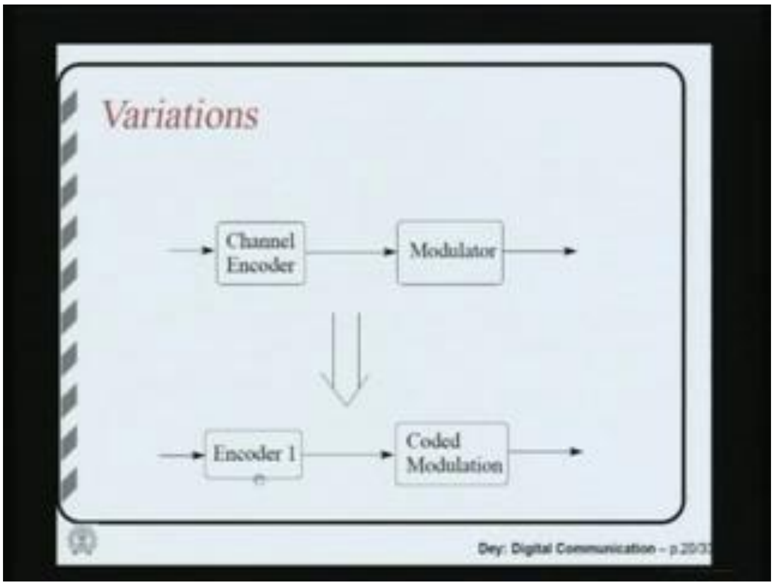

So, in the in many systems today the block diagram that is useful is this; there is an encoder and then there is coded modulator block, this encoder is channel encoder. But there is also some coding here; this is combined with the modulation.

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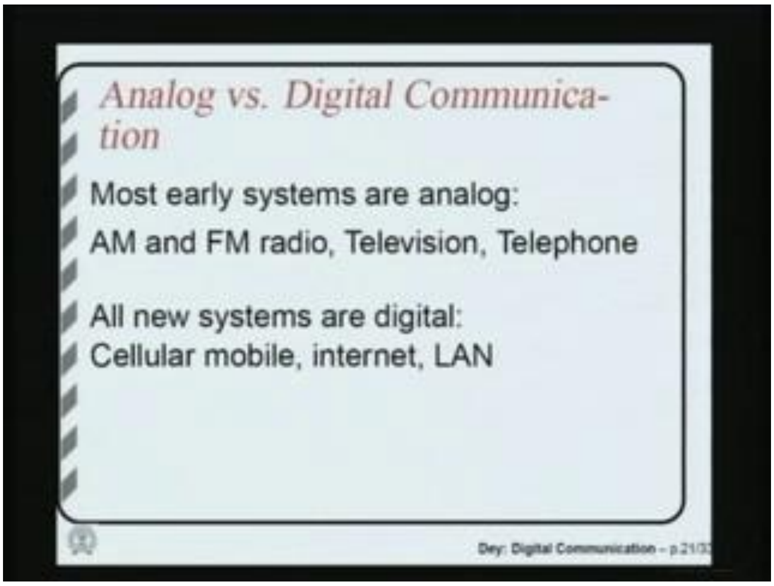

Now, we have discussed the digital communication system to some extent. But why go why do digital communication at all; specially when the source is analog? Why do you want to convert it to digital and then transmit using digital communication systems? Most early communication system that use, that that transmit analog information is analog in nature; in F M radio, television, telephone system everything was analog communication. So, why do we do digital communication into today? Almost every system, every new system that we design is a digital communication system. For example cellular mobile, internet, communication, local area network everything is digital in nature. So, why is it that we communicate using digital communication techniques; even if the source is analog in nature? The reason is that first of all the digital communication technology has developed to a great extent and the technology is very advanced today.

So, when we want to implement a digital communication system it is often much cheaper and easier to design than analog communication system. Because the digital electronics has become very cheap and easy to design; and there also very, very easy to design because there many digital electronics is electronic devices are programmable in nature. So, as a result they are they are often very easy to design. And, also with the advanced digital communication technological that we have today we can achieve near capacity rates. So, in other words for every channel there is a maximum rate at which we can communicate; that is called the capacity of the channel. And, the today's digital communicate technological has gone to a such an advancement that the we can achieve almost that rates near capacity.

So, digital communication becomes almost the obvious choice when we want to implement a new communication system today.

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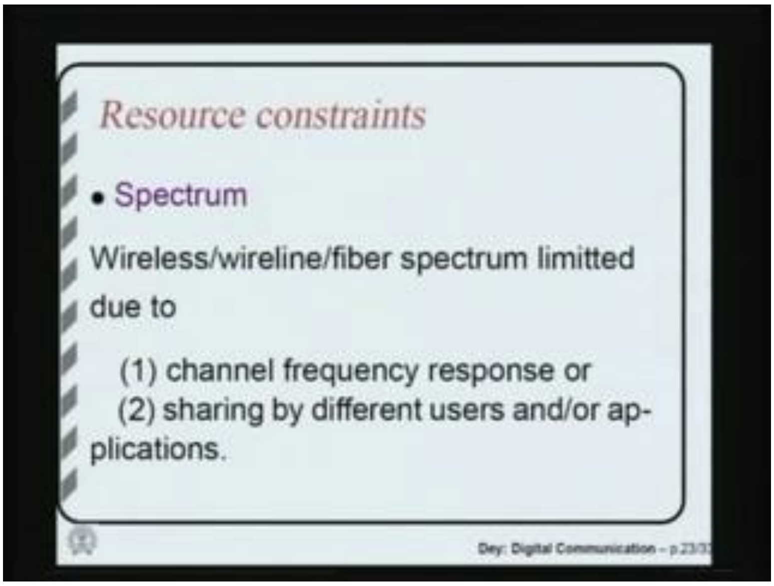

Now, in a communication system we need to know very clearly what are the constraints that we have? And what are resources we have? So, the resources we have is the channel is of course the main resource that we have we need to transmit whatever signal we have through the channel. So, how much is the capability of the channel that is a fundamental question. And, the how much information can be transmitted through the channel most of the times depend on the spectrum that is available. The spectrum available in a channel is limited in a in practice. And, that is because of mainly 2 reasons; one is that the channel frequency response itself may be limited, the channel may have very high attenuation outside some particular bandwidth. And, as a result we have to transmit our signal only in that band; where the channel response is good enough.

And, second whatever bandwidth the channel has that also may not be available to us for a particular application and for a particular user. Because it may be shared by different users and or different applications. For example in a cellular mobile system the spectrum available is actually large; but then a particular service provider for example BSNL has a particular bandwidth assigned; but they can use for this purpose they cannot go outside that bands. Because the other bands are used by other service providers or other applications there is military application, there is police application, there is medical application, there is a numerous applications that use wireless media for communication.

So, because of so many application, so many users using the wireless channels; the spectrum that is available for a particular user for a particular application is limited. And, even for the users using the BSNL service the they have to share the same spectrum that is allocated to BSNL. So, BSNL will now allocate different spectrum either in frequency domain or of course they can do it in time domain; they can allocate also different time. So, in any case the resource will be allocated to different users and to different applications in practice. So, that is the reason why this the spectrum available to a particular user for a particular application is often limited?

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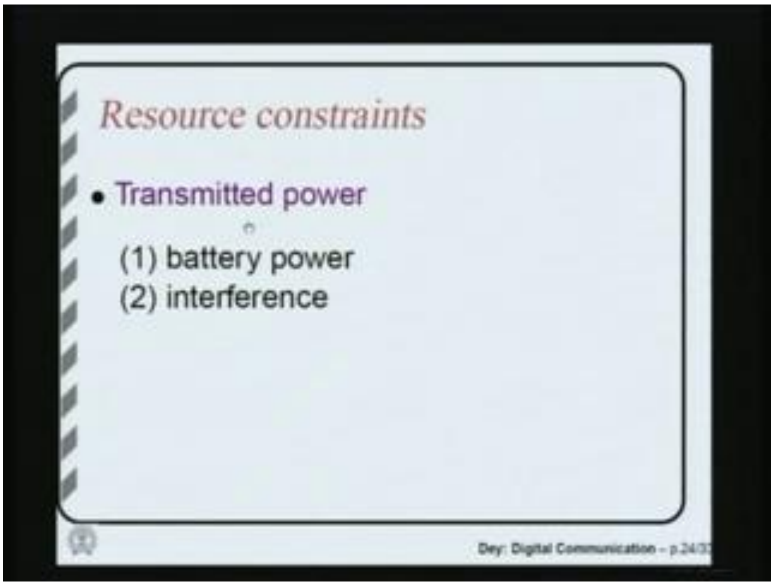

The next resource that is the available to us which is also very crucial is the transmitted power. And, the transmitted power is often is also limited in nature, a limited in practice. The reason for that is first the constraint on battery power; many communication systems, many transmitters operate on battery power. For example, mobile phone there is a battery which needs to be recharged periodically. So, if the if we transmit a lot of power then the battery will be drained too fast. And, then we need to recharge the battery more frequently and that is not desired. So, as a result we need to design systems which use less transmitted power.

So, that is one reason why the transmitted power is constraints. And, the second reason is interference the consider the wireless application, wireless communication application where the media is actually common for many applications and for many users. For example, in a particular cell the mobile I have a mobile which is transmitting some signal in a particular cell I am in a particular cell. Now, in another cell may be some distance away from myself there are other user who are using the same frequency. So, if I transmit a lot of power in the same frequency; then the users in the other cell were using the same frequency will be interfered by my signal.

So, my the transmitted signal power that is transmitted by my mobile phone needs to be limited to avoid interference with other phones. So, transmitted power is limited because of battery power limitation and also because of interference to other users and application.

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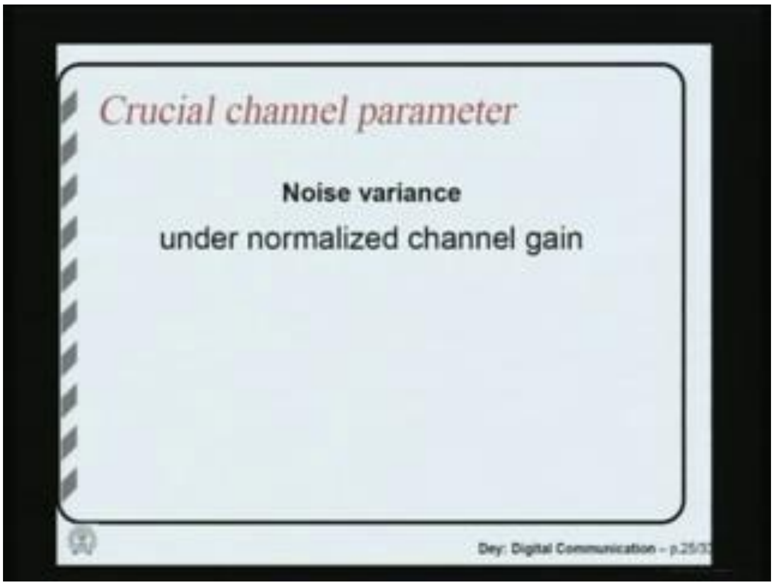

And, one crucial parameter, channel parameter that will play a very important role in the course is in a communication system is the noise variance. The noise variance the we can of course intuitively feel that the if the channel has more noise the we can transmit lot of information. Because the channel is distorting to a high extent, channel distortion is high.

So, of course we can argue that there is if the noise variance is high you can always attenuate the signal received at the output of the channel at the receiver. And, then the noise variance at the output of the attenuated will be less, we can attenuate the noise. But then if we attenuate the received signal the transmitted signal that is coming with the received signal is also attenuated. So, that does not help either both the transmitted signal and the noise are attenuated by the same factor. So, that does not help. So, when we say when we talk about noise variance what we assume is that the channel attenuation is one; there is no channel attenuation. So, if there is channel attenuation we can amplify the received signal. So, that the overall channel and the amplifier together has a gain one. And, then we can talk about the noise variance at the output of the amplifier; amplifier will also amplify the noise. So, when we normalize the channel gain what is the noise variance; that is what matters to us that will also dictate what is the signal to noise ratio at the receiver?

If we amplify the received signal the signal to noise ratio does not change. So, but of course SNR is not only dependant on the noise variance, it also depends on what was transmitted; what energy was transmitted by the transmitter? If the transmitter energy is more the SNR will also be more. So, will so noise variance on the other hand is parameter which depends only on the which is included only in the channel model; though we say that this is a noise introduced by the channel we have to strictly remember that the most of the noise specially the Gaussian noise that is the thermal noise is not introduced by the channel. But it is generated at the receiver; it is generated in the devices electronic devices in the receiver. So, it is actually it is often called receiver noise instead of channel noise ok.

So, we will discuss the topics that we have seen in the block diagram of digital communication system in detail in the in this course. And, there are plenty of text books available for digital communication as we go on for different topics; I will keep suggesting different text books which you can refer. And, to start with you can refer digital communications by ((Refer Time: 53:36)) that is the fairly good text book. And, we will come across other book and I will refer other books in the due course as you go on.

Thank you.