Communication Engineering

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Lecture – 1
Introduction to Communication Engineering

I will go through a very brief introduction to the subject that we are going to study, in this semester, and we will start with a block diagram of a typical communication system.

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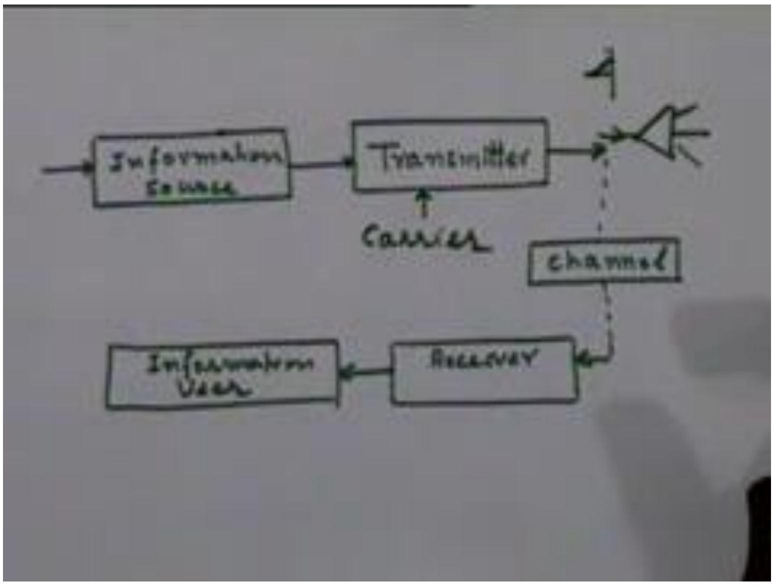

A typical communication system starts with the concept of a source of information, which outputs that information of interest which you want to send somewhere. Typically, this information will first have to be converted into electrical form through appropriate transducer. This source of information after its electrical conversion is given to a system, some equipment, which at the moment; we will simply call a transmitter. And the job of the transmitter is to prepare this information for actually sending through some physical channel, some physical medium through which, the propagation of the information has to take place.

So, in a sense the transmitter matches the characteristics of the signal which is coming from the information source to the characteristics of the medium, through which the information has to be transmitted so that, efficient transmission is possible. I will elaborate on this point a little further, after a few minutes and the information is now ready for putting in a channel. The physical channel, the physical medium through which we transmit this information, we will call the channel.

So, the channel is an abstraction for every kind of physical medium through which, we will transmit the information. At the other end at the receiver end well at this moment I will not go into details, we simply say that you have a receiver, whose job is to ensure that the information is given to the information user in a nice form so that, you can interpret it properly or we can use it for whatever purpose we want to use it.

Well, so really speaking in a communication system, there are these five major blocks of which the most important components are information source, transmitter, channel and receiver. The job of the receiver as I just mentioned is to undo some harmful degradations that might have taken place, while the signal has been transmitted through the channel. Also additionally, it will try to amplify the signals, because typically signal will attenuate as it propagates.

But, in addition to providing simple amplification it also has to remove noise; it has to remove other kinds of interference about which we shall briefly talk in a few minutes. So, this is a typical block diagram of an information communication system. Now as I what I like to do now is spend a little more time on each of these blocks so that, we get a better feel for each of these aspects of communication engineering.

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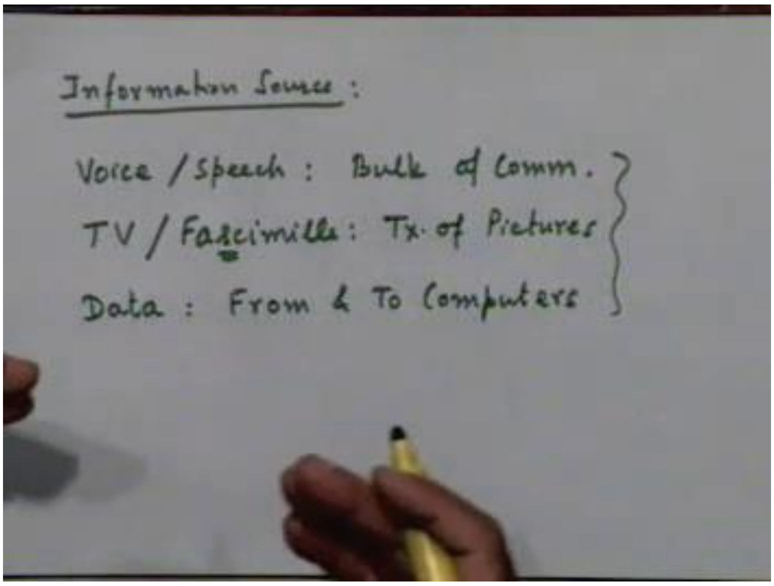

Let me first start talking about information source. There can be many kinds of sources of information; our speech is one kind of information. So, the most commonly used information source is voice, because human communication, 90 percent of the time takes place through voice communication. So, voice or speech; it forms the bulk of information communication that takes place. Then of course, there is picture transmission, picture transmission could be in a form of television signals, which is essentially moving pictures, moving at a normal pace at which light goes on.

It could also be still pictures, for example facsimile. I think I got the spellings wrong, but never mind. So, this is transmission of pictures, it could be data, data from computers from and to computers. But having the same sometime above the kind of communication system that you would like to design would depend on what is the information source that we are working with; whether we are working with voice, music, audio, TV, facsimile, data whatever.

Because, each of these kinds of information source has different kinds of requirements from the communication system, through which it must be passed so that, effective communication can take place. So I would like to spend just a few minutes on giving you a feel for the various kinds of information sources that I just mentioned. The data; this is not an exhaustive list, but more or less it captures the essence of various kinds of information, various types of information that you used.

For example, you will also the data that I am talking about here may not be from a computer, it may be the data that you are measuring by using telemetry instruments. We will be measuring the parameters of the ocean floor, you put some devices there and that device reduces. Let us say the data about the temperature of a particular layer in the ocean as a function of time. It produces that information and through some kind of a communication system, it keeps on transmitting that information to an off shore station, may be on a ship or may be on the shore itself or it could be telemetry from free space or some satellite or whatever.

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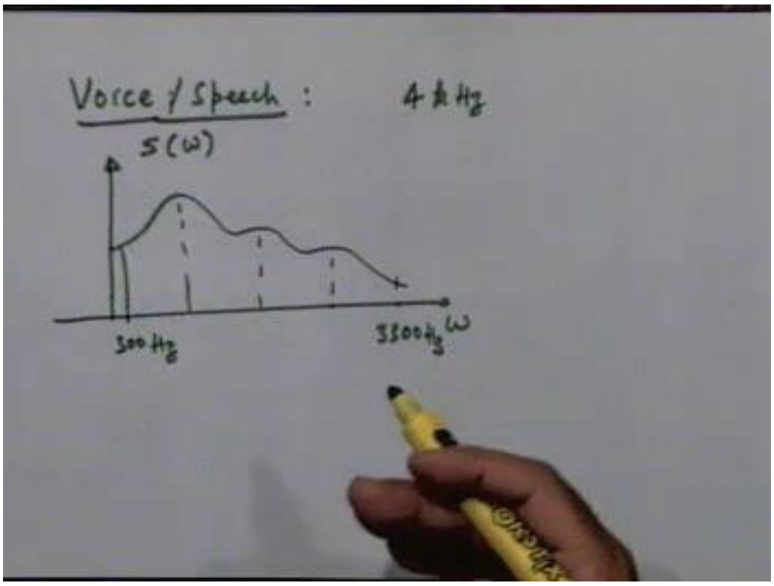

So, let us talk about these information sources in some more detail. I start with as I said one of the most common sources of information for us which is voice or human speech. Now, what are the important features of information sources which will be particularly relevant to the discussion on communication systems is this spectral band; the spectral occupancy. I believe you all are familiar with the concept of spectrum of a signal.

Spectrum of a signal is nothing but, well in a very rudimentary sense, the free transform of the signal. If you have time linear deterministic signal, then its spectrum is just the Fourier transform of the signal, of course the Fourier transform of a real signal in general, would be a complex entity, if you have a real part and an imaginary part or a magnitude part and a phase part. So, we can talk about an amplitude spectrum which is a plot of the amplitude of the various frequency components as a function of frequency. And it could be a phase spectrum, which would be part of the phase angles of the various frequency components as a function of the frequency.

If it is a non deterministic signal, if it is a random signal it is usually better to talk not about the spectrum of signal, but about the power spectrum of the signal. I believe you at least are familiar with these terms at the moment that familiarity is all that I am requiring for talking about these concepts, but we will take up these issues as and when required later in more detail.

So, as I said spectral occupancy of a signal is one of the important attributes that, we need to look at when we are talking about communication signals. And for a speech signal for the human’s speech signal, I am saying humans speak as if we have other kinds of speech. But I think, who knows may be, there are some kinds of animals also speak to each other, like doctor does little or something, but I do not know about that; we are talking about our speech here.

So, we see the spectrum has this kind of a nature; it builds up from low energy at the lower frequency end. So, this is typically the notation for power spectrum S of omega as a function of omega, so this is what I am plotting here. If I plot power spectrum, then there is a question of phase in them, because power spectrum wholly gives information about the distribution of power as a function of frequency, similar power as function of frequency.

And typically this is the tool that we employed, when we are talking about random signals. And if we modulate speech as a random signal, it is not really all that random; although there is randomness in it. One can see that the power spectrum looks something like this; goes up to slightly lower energy at lowest frequency end with that to some peak values, peak energy at about a few 100 hertz, which will vary from speaker to speaker. And which will vary from the information that you are speaking vary with that information.

So, this spectrum is not really fixed, it is just a typical plot that you might see, so as you see there will be a few major peaks in the spectrum. But, on the whole the spectrum will start decaying after a few 100 hertz and for telephonic communication it is found that if you concentrate on the energy between 300 hertz to about 3300 hertz. You capture most of the intelligence as well as essence of speech, without losing much on either the intelligence or the let us say the quality of speech.

So, for most telephonic communication purposes the band from 300 hertz to 3300 hertz is the one which is important. So, that is why we say that a voice bound channel has a bandwidth of about 4 kilohertz, that 4 kilohertz includes some guard band, some additional frequency band to make sure that we do not lose anything. So, typically the bandwidth of a speech signal is provided to be less than 4 kilohertz, but I must mention this is not the actual bandwidth of a speech signal.

Actual bandwidth, the actual energy plot extends beyond this and goes on up to about 7 to kilohertz, if you want really good quality, studio quality speech to be heard, you must process that entire band properly. But, this is the standard value that we take in telephone communication, it is found to be adequate. Now, before I leave this signal, I would just like to say a little bit more about it.

What can I say more about it; I like you to know that speech signal is a highly studied kind of signal. It is a signal which has been extensively researched for various reasons, it has been researched by linguists for their research to understand the nature of languages, the way they are spoken, the way they are perceived by people. So, it has that kind of background, studies done on it. But from the communications point of view, we learn some of the later that, the amount of information that is being conveyed by signal is not necessarily proportional to the bandwidth of the signal.

The signal may have a very large bandwidth, but it must not necessarily imply that it is conveying a lot of information to us, why I am saying this. Because again this is related to the fact, that we learn a little later that bandwidth is a very important attribute of a communication system, it is a very important resource. If a signal has more bandwidth it will occupy more bandwidth somewhere in the spectrum of communication signals. And it will disallow other signals to be transmitted in that frequency band, because the frequency band is already occupied by this particular signal.

And therefore, bandwidth becomes a very important resource for us, for a communication engineer as we learn there are two main resources that we need to deal with, one is the bandwidth available to us. Because, a large number of people want to communicate with each other, everybody has to work in some band or the other. And it becomes obvious that, if they all start talking together, if they all start transmitting information in the same frequency band together, there is going to be a lot of problems. They are going to be able to hear each other; they are just going to hear some junk which is not very desirable.

So, bandwidth is a very important resource for us, similarly power the amount of power that transmitter outputs is a very important parameter in a communication system. We may have to transmit a large power if we want to send the signal to a large distance the long distance. But, at the same time a large power output of a transmitter is not necessarily a very nice thing to do. Not that it implies that you have to have a lot of power at the transmitter, which also becomes a limitation sometimes.

For example, if the transmission is taking place from a satellite that you have sent up there, then the amount of power that is going to be available to you for sending is going to be limited by the power that you have in the satellite. So, at times that is a limitation, but more importantly when you put a large power in the transmitter output, it has a potential to interfere with other signals, much larger number of other signals which are much larger distances. So, therefore power is a very important resource, the smaller the power that you use the better or more efficient your communication system is.

Student: ((Refer Time: 17:39))

Good question, the question is if I have already fixed the bandwidth of a signal in which no other signal is being transmitted, how can it be a source of interference for others. Well I will come to this issue a little later, but right now I can say this much, that particular band that is allotted to you is typically allotted to over a for operation in a certain area. But, if you transmit a very large power you may have significant component of that frequency in a relatively distant area also, where that frequency band has been allotted to somebody else.

So, therefore, it has a potential to interfere, so at the moment I will only say this, but I will come back to this point. So, the original point that I was making from which we digressed was the bandwidth is an important resource, communication signal has a bandwidth of 4 kilohertz and voice signal has a bandwidth of about 4 kilohertz. But, it does not necessarily mean that the information made by a voice signal when I am talking to you is proportional to 4 kilohertz is of this order because, this bandwidth is a property of the waveform speech waveform, that is coming out when I am speaking.

But, the actual amount of information that I am conveying to you is something different altogether in fact, it is in terms of bits per second as a measure of information it is really very small amount. It is something like 100 bits to 200 bits per second of that order, which as you can see is very, very small as compared to 4 kilohertz and this is 4000 and that is 100 to 200.

As in the orders are magnitudes difference in the amount of information that is being conveyed to you or information rate that is coming out and the rate of variation of the signal itself. Let us say rate of variation of the signal itself. Now, this is very important, because this means that may be by just sending the raw information, raw wave form. I am not doing the most official kind of communication, in terms of bandwidth requirement bandwidth resources.

And for this reason communication engineers have studied these commonly used kind of signals very, very in great depth. To understand how we can transmit information by using bandwidth much less than 4 kilohertz by exploiting our understanding of how a speech signal is produced by the human body. Seeing, what the attributes of the speech production mechanism are and then transmitted only those attributes, rather than the actual waveform. And that in the process will be able to come do a much more efficient communication, then by just transmitting the raw waveform itself. But, that is a more advanced way of looking at a source right now I just wanted to say this much.

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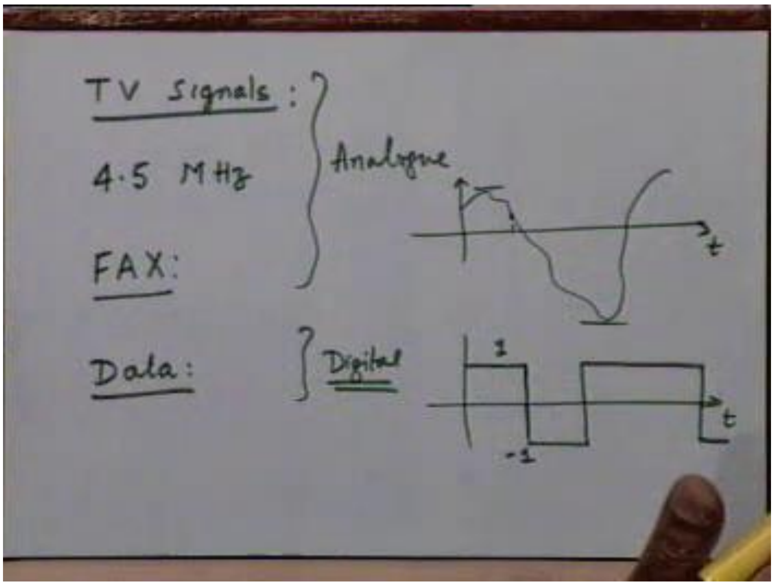

So, we will return to this point later if required, now let me briefly talk about some picture signals. The two kinds of picture signals that we have talked about is the TV signal and the facsimile signal, the TV signal is a moving picture signal. So when it is a moving picture signal, you have to make sure that you do not reduce the essence of motion itself. So, typically as I said you have to first convert this signal into an electrical signal, which will be done through a TV tube, a TV camera over through an optical lens system capturing picture.

And then, somehow convert this into an electrical signal and scan that electrical signal, let us say line wise to convert this into a one dimensional signal. Otherwise, signal is a two dimensional signal, it has two spatial coordinates, but ultimately what I am going to transmit is a time signal, signal of time. So, I convert this spatial information into temporal information by scanning this information, line by line and transmitting it and I must make sure that the time taken to scan a picture complete picture line by line is sufficiently small.

So that, I do not lose if the picture changes because of motion a few seconds later, I must be able to capture the motion also. So, I must be able to scan sufficiently fast, I must scan sufficiently fast so that, I do not lose the essence of motion also, otherwise it will look like a transmission of a few still pictures, one after another rather than a moving picture. So, that is very important and it is therefore, clear that the scanning will be fast and if the scanning is fast, it essentially means that the signal that we will be transmitting will have a large bandwidth.

Because, bandwidth is related to the rate of variations in a signal, if you are scanning it in a very fast rate it will lead to a large bandwidth signal. Typically, it turns out I am just giving you information and this is a good point for comparison with other signals, for a TV signal the bandwidth requirement is to the tune of 4.5 net megahertz. So, as you can see that it is three orders of magnitude higher, than the bandwidth of a speech signal.

So, bandwidth requirements of a picture signal will be much higher than the bandwidth requirements of a voice signal. And therefore, communication system that you have designed for transmitting voice signals will be absolutely no use to us, when it comes to transmitting TV signals moving picture signals. On the other hand, if I am transmitting still pictures I have less constraint. We have a requirement that I must scan it very fast I can scan it slow, make it compatible with the bandwidth that I have available in the communication system, against scanning sufficiently slow.

Because, there is no requirement that because no requirement that by the time I scan it the picture might have moved somewhere else. The action might have moved to some other action, the picture is still there the same picture. So I can scan it slow and that is precisely what you do in a fax machine, facsimile signal and that is the reason I can transmit the fax through a telephone line, which is designed to carry only 4 kilohertz of bandwidth.

Because, the rate of scanning is under my control and there is no particular ((Refer Time: 24:51)) from the point of view of the nature of the picture that I want to transmit to scan it fast. Of course, if I scan it fast there is an advantage, what is the advantage; I will use I will occupy the communication resource for less amount of time. I will pay less amount of bill. If I scan it fast and send it fast that is there, but from the nature of the picture itself there is no such requirement. I can scan it sufficiently slow.

So that, at least it is possible to transmit it through this channel and that is why facsimile transmission is possible over the telephone line whereas, TV signal transmission is obviously, not possible over the telephone line. Although, there are new techniques which will again compress this like I talked about the compression of the bandwidth of the speech signal, it is similarly possible to compress the bandwidth of the picture signal.

Because, once again the amount of information conveyed to the picture or moving pictures is not proportional to this bandwidth that we are going to use for it. So, it is possible again to use to compress this bandwidth and use the communication resources more efficiently. So, it is possible, but that is a very advanced topic and we will not discuss it now. So I think this much discussion about the information sources for the moment is good enough, except that let me say the last thing about the data sources.

The sources that I have discussed so far are basically different from this source in one major way and that is they are analog sources, you understand the difference between analog and digital. Today usage of first understand it too well an analog signal is one in which there is continuous variation. So these are all analog signals and this is basically digital, but I will come back to this digital issue again in a few minutes.

So, by analog basically what I was saying is, if I look at the signal as a waveform as a function of time, there is a continuum of various of amplitude, the amplitude of the signal at a given point and time can be any real value. Theoretically, any value from minus infinity to plus infinity, but even practically any value from let us say minus k to plus k, it could be a value like 4.923or whatever.

So, you can have any real number as if a value whereas, in a digital signal the values that the signal can take are just two. Let us say 1 or minus 1, so the signal can only take a binary set of values or in more general terms a discrete set of values, there is continuous set of values and a real number between one lower and one upper limit. But, in this case it could be 2 it could be 4 it could be 8, it could be a set of discrete values, the binary case is an example. But, it could be 4 away, it could be 8 away, it could have 8 levels or 16 levels or 256 levels, the moment you have that it becomes a digital signal.

So, that is what essential difference between these three previous sources of information that I talked about and the digital signals that we typically tend to use. However, we must remember that the physical word, particularly the physical medium through which you are going to transmit information is not digital in nature. The physical medium, the free space, the cable it looks at the signal as if voltage waveform is a function of time and it hardly bothers whether it is a continuous range height, height is a continuous range, it means height is a continuous thing to it.

So, it treats the signal in the same way, and there is a small issue here, the issue is this really matched to the medium, it is not. The real medium is analog it has some advantages; we have some advantages we will work with a digital formulation of our signal. But, the advantage tends to get lost unless we keep in mind that the physical medium through which the information is finally, going to be transmitted is still analog in nature. We need to keep that in mind even when we are transmitting digital information.

So, digital communication which is a follow up subject of this communication, this is a issue on which we spend a lot of time. But, right now it is just a matter of just drawing you are attention to this point, before I leave with the data signals. One last thing I would like to say about it is, the bandwidth requirement of a data signal is something that will depend on what will become on.

Student: ((Refer Time: 30:11))

Anything else?

Student: ((Refer Time: 30:17))

Let me give you the answer, it will primarily depend on the rate at which you are wanting to transmit it because, if you see as I said the bandwidth depends on the rate of variation in a signal maximum rate of variations. So the rate at which you want to transmit 1's and 0's if that becomes large, the bandwidth requirement becomes large. So, for data signal I do not say it requires this bandwidth or that bandwidth or that this bandwidth, it will depend on what is the rate at which you want to transmit the information.

Of course, people will say the highest possible rate, but then if you are ready to pay the cost for it you can get the highest possible rate. So, everything has a cost associated with it, soyou can have a low bandwidth data signal or you can have a high bandwidth data signal it depends on the requirements on your ((Refer Time: 31:22)). So, if you now comeback to this block diagram we have discussed to some extent the nature of the information source, particularly with reference to the bandwidth requirements.

Now, let us discuss little more about the issue of the transmitter, what do the transmitters have to do, what are the basic functions of a transmitter. As I mentioned earlier, the basic functions of a transmitter have to do with the fact that, you have to match the signal characteristics coming out of the signal source with the channel characteristics to which signal will have to be actually finally, transmitted.

Now, what do we mean by that let us take an example, let us say you want to use free space as a medium through which you synchronize with the transmitter. Now, if that is the case, the transmitter we have to radiate information into free space. It essentially means if you have to have as limited mechanism, an antenna here which, usually schematically is denoted by this notation, this is the notation for an antenna.

So, this is the signal coming in and it radiates, this triangle is usually used to be denoted in a communication system block diagram. But, physically the antenna could be one of many types depending on what frequency range you are working with, now the question is, so what. Now, let us say you are transmitting a voice signal, if you know some electromagnetic theory perhaps you also know the fact that the efficiency of radiation of an antenna will depend on the size of the antenna related to it is wavelength, you appreciate this fact.

If for example, the wavelength is let ussay10meters, wavelength of the electromagnetic wave you are working with is 10meters. Then, for efficient transmission of information into free space we require an antenna aperture in the size of an antenna at least the order of 5 to 10meters of this order. Now, I do not know when you can do quickly do one calculation, let us say you are transmitting voice signal, what is the highest frequency component we have there.

Student: ((Refer Time: 34:16))

Let us say 3000 hertz or 4000 hertz, can you make a quick calculation what will be the wavelength of this, if it is seen as an electromagnetic wave. Because, here we are converting this into an electrical signal and let us say amplifying it and putting it into an antenna, what kind of wavelengths will you have order of magnitude.

Student: ((Refer Time: 34:39))

Five meters.

Student: ((Refer Time: 34:45))

So, it is about 100 kilometers can you radiate it unless you have an antenna of that order that size it is simply impossible to radiate it. So, you can see there is a problem here. I want to transmit a voice signal through free space by radiation. But the internet size it will we require will be that of a very, very large dimension it will simply be not possible to have such an antenna.

So, what do I have to do I have to make sure that this signal is first embedded on to some other signal, for which the antenna size requirement is much smaller. So, if I that is the concept of a carrier, so a typically a transmitter would require as another input to it in addition to the signal, another signal which we call the carrier. The job of the carrier is as I mentioned earlier, to carry the signal along with it, to carry the information signal along with it.

Typically, not always typically the carrier is a pure sine wave signal of a suitable high frequency, why high frequency so that, it is easy to design an antenna which will be able to radiate it and so therefore, what you do is you have to that brings us to what the transmitter has to do, the transmitter has to put this information appropriately or embed this information appropriately into this carrier. And typically this is done through a process of what is called modulation; you modulate a specific parameter of the carrier along with the signal. For example, the signal might modulate the amplitude of the carrier it depends on what is the amplitude of this analog signal here, you modify the amplitude of this carrier.

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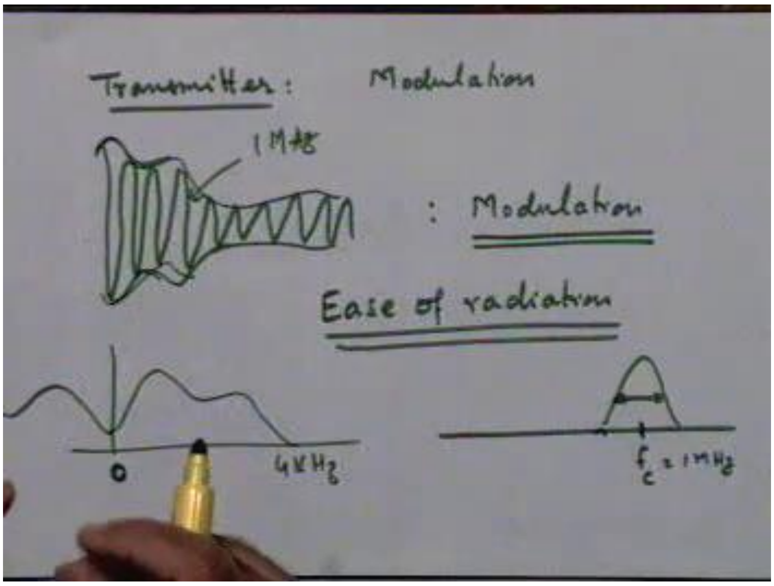

So, amplitude of the carrier now carries the information and you get a communication signal, which looks may be I suppose this is your basic information, signal as a waveform of time. So, I will not be able to draw very precisely, but the modulated signal will look something like this, so this amplitude of the signal as a function of time is the same as the information signal.

So, the transmitter has to do it is job of converting that information signal which looks like this into a signal which looks like this, is it clear and that operation is called modulation. Now, it is not necessary that you modify the amplitude, you could modify the phase, you could modify the frequency ((Refer Time: 37:57)) frequency of the signal and so on and so forth all these are different kinds of modulation that we can have.

Now, so that is the reason for modulation using modulation, modulation helps me to translate the spectrum of the signal, which was earlier lying in the band from let us say 0 to 4 kilohertz, where ever spectrum transmit to now, what is the spectral occupancy of this signal.

Student: ((Refer Time: 38:29))

Let us say this carrier I choose as 1 megahertz it is a carrier frequency of 1 megahertz, so the center frequency of this will be around 1 megahertz. So, you will typically have of course, I am not showing the same thing here is a plotting if there is signal which has a spectral occupancy in the neighborhood of 1 megahertz. And this bandwidth 4 kilohertz is a very small friction of 1 megahertz of the center frequency.

So, more or less the entire signal the lowest frequency components and the highest frequency components are all of the same order 1 megahertz minus 4 kilohertz to 1 megahertz plus 4 kilohertz, they all are of the same order of 1 megahertz. So, antenna size required to radiate this would correspond to 1 megahertz rather 4 kilohertz.

Student: ((Refer Time: 39:34))

That is a good idea, that you must do this modulation in such a manner that it is possible for the receiver to get back the information.

Student: ((Refer Time: 39:48))

It is; obviously, implied here that at the receiver I will have an appropriate demodulator, which will undo what the modulator did. So, it will be able to extract the information of interest which is in the amplitude of the signal and convert this into the actual signal itself, which was intended to be transmitted in the first instance. That the point is, so one instant value, so the point is that the transmitter has a very important function to perform and that is of modulation and this modulation is required for several reasons, I only mentioned one reason.

One reason is what is the reason that we discussed here ease of radiation, particularly if you are transmitting, this is particularly valuable this point if you are going to transmit this information through free space. But, there are other reasons why you will like to do modulation, and this is a very important reason. Suppose I am not transmitting through free space and there will be a requirement of radiation, even then it may be required to go through this process of modulation in some applications, can you think of other reasons.

Student: ((Refer Time: 41:12))

Decay.

Student: ((Refer Time: 41:18))

No I did not get that.

Student: ((Refer Time: 41:25))

No, no, no.

We are discussing very basic fundamentals here.

Student: ((Refer Time: 41:31))

No.

Student: ((Refer Time: 41:34))

That is a point, any other point, let me summarize some other points that have been made and some of my own points, so let me discuss it on a separate piece of paper.

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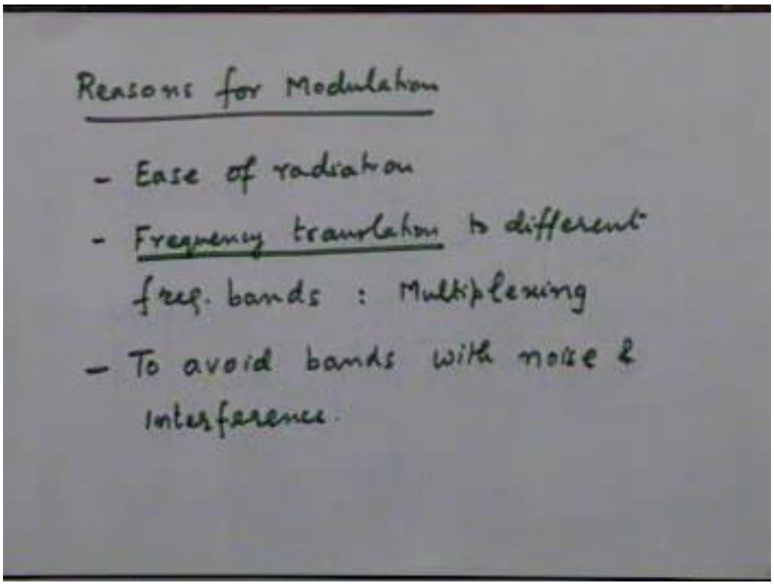

So, other reasons for modulation, ((Refer Time: 42:07)) we discussed one reason in detail ease of radiation, we turn out that certain frequency bands are highly noisy or there is a lot of interference in those frequency bands. We would like to make sure, suppose you are transmitting several let me take into case of say wires transmission, but through different situation now.

Now, I have to give this example I have to go that gives a little bit doesnot matter let us digress. As you know as far as telephone communication goes from your subscriber end of the line that is from your home that the telephone instrument lies to the local exchange, you basically have one pair of wires which are dedicated to you no problem. But, the exchange has to carry out this transmission of this kind of information which are coming from several subscribers, large number of users to other telephone exchange, because after all you may be talking to anyone from anywhere to anywhere.

So, now it has to transmit the job of the exchange is to transmit a large number of signals from one location to another location. And let us say it has a cable associated given to the job, cable has a certain bandwidth much larger than 4 kilohertz. So if the exchange were to put every signal in the same bandwidth from 0 to 4 kilohertz what will happen, they will all overlap in spectrum and they will all interfere with each other. So what should we do, we should put them in different frequency bands.

And therefore, once again we like to do modulation, different signals which the same exchange is transmitting to another local exchange or another near exchange, what it has to do is, put all the signals in the cable, but after shifting them to different frequency bands. So, basically modulation helps you to carry out what you call frequency translation to different frequency bands and this in turn allowsyou to make sure thatsignals do not interfere with each other yes please.

Student: ((Refer Time: 44:50))

The modulation, in generalthat is not the purpose of modulation. If the bandwidth increase happens in a particular kind of modulation that is incidental that is not desired, that is not necessarily required. All that we want is not increasing the bandwidth, we are increasing we are modifying the location of the spectrum. Please remember bandwidth and locations are different issues. If you go back to this picture that I had some time ago, this bandwidth is 4 kilohertz, this bandwidth at the more becomes 8 kilohertz, more important is, not the fact that this 4 kilohertz bandwidth has become an 8 kilohertz bandwidth. Because, it is 4 kilohertz this way and 4 kilohertz this way, we study the nature of the signal later. But the fact that instead of actually if you count both positive and negative frequencies even this signal has 8 kilohertz bandwidth of course that 4 kilohertz is imaginary, this is negative.

So, the important point is that the location of the spectrum is not around b c it is not around 0 frequency, but around some other carrier frequency, some other frequency at 0. So, you are not increasing the bandwidth, bandwidth is what this band of the spectrum, whether it lies in one frequency band or another frequency band. So you must understand that the difference between the center frequency concept and the bandwidth concept, they are different concepts.

Student: ((Refer Time: 46:23))

Yes.

Student: ((Refer Time: 46:27))

We will discuss different kinds you are curious about other kinds of modulation, we will discuss those later. In fact, we have to discuss all kinds of modulation result, right now in thisgiving a brief introduction to the block diagram, so let us not digress too much into other subjects.

Student: ((Refer Time: 46:45))

Bandwidth of a channel is important; the question is what do you mean by bandwidth of a channel. The bandwidth of a channel refers to the frequency range over which it can support propagation of radio waves or propagation of whatever kind of waves upto be propagated through it. Typically, every channel you can think of some kind of a filter with some lower cut off frequency and some upper cut off frequency. If your signal lies anywhere in this lower and upper cut off frequencies, it will transmitted, it will propagated otherwise it will attenuated greatly.

So, that is what we mean by bandwidth of a channel is it clear, an optical fiber provides a much larger bandwidth than a cable or some other kind of communication media channels. Now, that will be done on the technology which you are working with, typically since this point has been raised, but I think it is an digressionI will come back to it later it is an important point, but I will come back to it later.

Let us talk about other uses or reasons for modulation, this particular issue this particular application of modulation is called multiplexing. Basically, what are we for making it possible; we are making it possible to transmit multiple signals, through the same physical medium by making sure that they are translated to different frequency bands. So, this is called multiplexing multiple signals through the same physical medium at the same time, and actually another point that I wanted to make was to avoid bands with noise and interference.

Basically, think of modulation as a frequency translation operation, if you carry out some frequency translation operation you find, in that particular there is a lot of noise, there is a lot of interference coming from several times you like to modify it. So, basically it allows you to choose what bandwidth you should use, so that you are not susceptible tonoise and interference if it is frequency dependent. So, these are some of the reasons of using modulation and as you know discussed as I said some time ago modulations techniques forms a very important component of this whole course.

So, let us not take up all the discussion of modulation right now, we are going to spend a lot of time on various kinds of modulation techniques, let us now come to the next ((Refer Time: 49:58)) of block diagram the channel.

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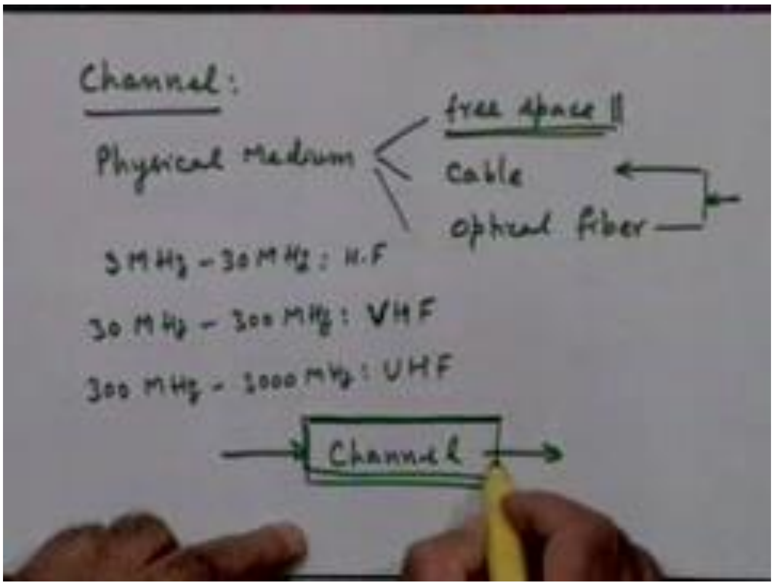

Now somebody asked me the question about the bandwidth of the channel, so let us discuss channels in a little bit more detail. So, channel as I said earlier it represents a physical medium and if we have different kinds of channels will have different characteristics. Particularly let me give you a few examples of this physical medium it will have free space, it will have cable, it will have optical fiber, it could have various kinds of channels physical mediums.

Now, one important characteristic of the channel is the bandwidth, it can support and basically as I mentioned it is the band, the bandwidth will be determined by the band over which it can support propagation. The band of frequencies over which it can support propagation, it could be useful as a home exercise for you to learn about the spectral bands that communication engineers work with, communication engineers have divided the entire particularly when we are talking about free space this is very relevant.

The entire range of operation you see frequencies bandwidth are very important resources for communication. So, you must know a lot about this, if you look at any of these two books that I mentioned that is Lattice book and Higgins book. You will find information in there about the way the radio spectrum has been divided into different frequency bands which is standard frequency bands. Starting from let us say about 3 megahertz to the lowest side, actually you have even below 3 megahertz there is a band called the VLF band.

Then, the low frequency band in 3 megahertz to 30 megahertz is the, so called high frequency band; you will find that these bands have been divided by in terms of decades. So, 3 to 30is one decade 30 megahertz to 300 megahertz is the next decade, which is typically called as VHF band very high frequency band and so on. I would like you to look up the entire spectrum for radio frequencies that has been standardized; you just call them UHF band and so on and so forth.

All these frequency bands are ((Refer Time: 53:10)) used by communication engineers for some purpose, some application are in another. Each of these bands gives you different kinds of mediums to work with; it is all free space we are talking about free space. But free space in this frequency range it is very differently from free space in this frequency range and so on and so forth. Actually, speaking the actual propagation of your radio waves or electromagnetic waves is quite different, depending on which frequency band you are actually working with, because the channel behaves differently for each of these bands.

So, some of these issues I will discuss in the next class about free space propagation, but briefly these two are the easier kind of mediums to work with cables. Because, typically coaxial cables are pair of wires that we are working with and optical fiber, they are typically much cleaner media as compared with free space media. And therefore, the kind of performance that you can get here, within the bandwidth limitations of the cable ((Refer Time: 54:19)) is much better than what you can get in free space.

One last thing that I like to say about the channel is for the purpose of a communication engineer, the channel is not just a physical medium. A channel when I write a block with channel written in it, it is also an abstraction for me, abstraction in the sense that it is supposed to model this block is supposed to model all the effects good or bad, that the entire communication system introduces in the signal.

For example, so when I say characteristic of the channel I will in this block try to model things like attenuation, things like the fact that noise gets in it, things like the fact that the signal may go through some distortion and so on and so forth. All the good and bad things that might be happening to the signal will be modeled by this block. So, when communication engineers draw a block called channel, he is not necessarily just talking about a physical medium, he is also talking about the effect that physical medium and the rest of the communication system introduces on the signal. We will stop here and we will continue.

Thank you very much.