Digital Communication.
Professor Surendra Prasad.
Department of Electrical Engineering.
Indian Institute of Technology, Delhi.
Lecture-1.
Introduction to the Course.

Professor: In this course we are going to be primarily be working with digital communication, that much is clear. Now what is not clear perhaps to me is whether you have also done something about digital communication. For example, you must have done at least PCM?

Student: No. (())(1:24).

Professor: You have not done PCM also…

Student: We have not even done Pulse analog.

Professor: Analog pulse modulation schemes.

Student: (())(1:31). We have done (())(1:42).

Professor: Noise analysis in analog communication you have done completely?

Student: Yes.

Professor: Okay, you may have your doubts for which you may want the clarifications. That is what you are saying? Right. I, what I suggest we will do is as far as our formal lecturing of these 3 hours per week are concerned, let it be on new topics so that you learn new things. I will, I am ready if you are ready to devote an extra hour every week, to an extra hour every week, if you give me a suitable timeslot where we will clarify your old doubts as well as any doubts that are created in these lectures. You know we have slightly less flexibility as far as these lectures are concerned because I know we are talking in a slightly formal way.

We can meet in a normal classroom in the 4th lecture and be normal selves and you know talk as we should, okay. Is that okay with you? Will you be able to give me your 4th slot in which we can discuss these things nicely, whatever doubts are left?

Student: (())(2:59) Thursday 1 to 2.

Professor: Is that okay with everybody, Thursday 1 to 2? I will have to conform with my timetable, I still do not know my full-time table and I will confirm it in the tomorrow's class. Okay, Is there any other slot available?

Student: (())(3:23). Thursday. Thursday 1 to 2 is good.

Professor: Okay, that sounds fine with me though, I hope it is okay with me but I will just check. Now maybe I can just start a little bit, I do not know, I did not know where to start, so I am not really prepared. Maybe I will just tell you what kind of course outline that I can plan for you. One possible course sequence would be as follows.

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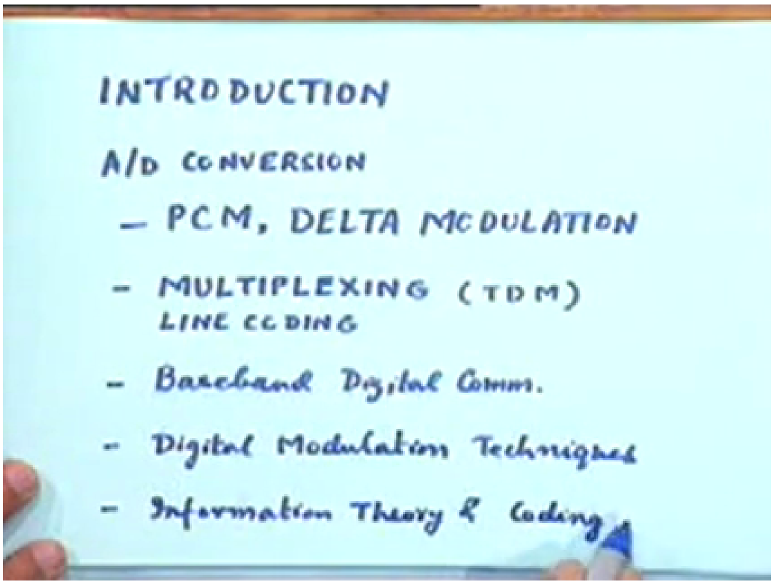

Professor: Our course starts with some introduction and since you have not done anything on PCM and Delta modulation. Delta modulation you have done?

Student: No.

Professor: So no analog to digital conversion of any kind?

Student: No.

Professor: At least in Sorry…?

Student: (())(4:32).

Professor: You know the A to D conversion technique but you do not knew that in the context of communication, right? So we will do the A to D conversion techniques and that will include PCM and Delta modulation, off course all of you know what PCM stands for. After discussing the basic principles of pulse code and Delta modulation we will look into some of the associated problems of transmission of these kinds of signals, particularly some advantages like multiplexing, Time division multiplexing. You must have done frequency division multiplexing in the context of analog communication in digital communication we…

Student: (())(5:46) How it is done on telephone.

Professor: Alright, whatever little, whatever extra you think you have not done, we will take care of in the 4th slot, rest assured, right, we will do that, no problem about that. But multiplexing that we will do as part of this course is really TDM, time division multiplexing, that is what that will be all about. Also concepts like line coding associated with transmission of digital information, all right. Next we will take up digital communication in a baseband form. Now digital communication can be done in 2 ways, one is in the baseband form, other is in the modulated form. Just like analog communication is done in the modulated form, but the digital the medication could be done in both the ways depending on the kind of channel you have you working with.

When you have wideband channel on which baseband signals can be supported or whether you have a radio channel which you must 1st introduce the information or embed the information onto a carrier, in which case you have to do some kind of modulation again, right. So 1st we will take up the question of or the techniques of baseband digital communication, right. Now there will be number of concepts here, I will give you a summary of this course outline separately, but I will just want to give broad titles of the things that we are going to cover.

After doing baseband digital communication techniques which involve what kind of pulse shape we use and concepts of intersymbol interference that arises due to band limitation on a channel. We will see also some techniques of how to take care of such problems, we will going to want you call digital modulation techniques, okay. And finally we will spend some time on information theory and coding. That broadly covers the main topics that we will deal with. If we do have time beyond this, I will spend some time on some other specs of digital communication like digital switching, switching which is required to connect many users to each other, for talking to each other or communicating with each other.

So that takes care of the modern electronic exchanges for some extent but I am not sure whether you will have the time to do it but if time permits we will just spend some time on that and brief overview of data networks and computers communication networks. Although we usually have elective courses on these topics separately later on in the curriculum, so we may not cover very much of these. So that is broadly in the course outline that we are going to have to deal with. Let me start by just very briefly indicating to you the advantages of digital communication, why digital communications, right.

Student: Book?

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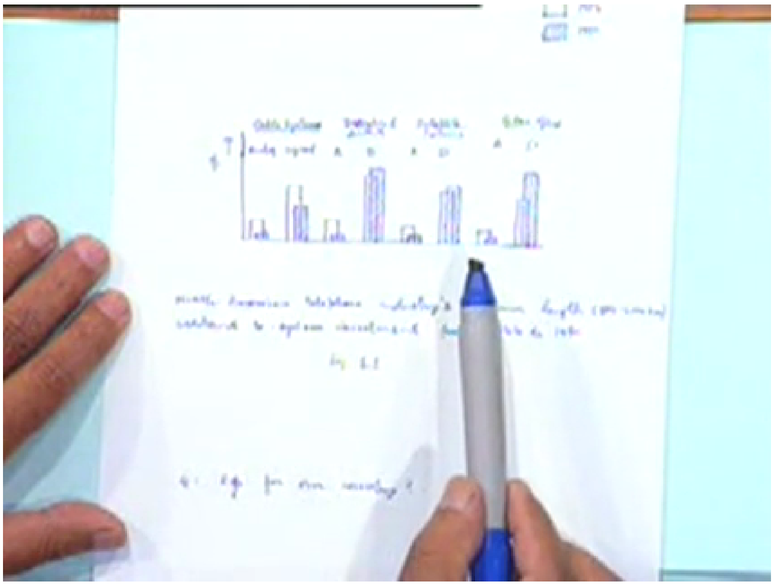

Professor: Okay, I will come to the book maybe next time And, I have not yet decided on the final book that I should recommend to you. Now if you look at the various communication systems that exist today in this country and abroad, we still find that significant portions of the systems has still analog in nature. Because of historical reasons, because most of the earliest form of communications evolves in the form of analog communication, right. But the other thing that you will notice, if you look at these communication systems that exist today, then they are undergoing a very fast transformation. They are rapidly being replaced by digital communication systems, very rapidly in fact.

In fact the projection is that in a decade or maybe at the most a decade and a half from now, there will be practically hardly any analog communication systems left, except in the most, somewhere takes very minor role here and there. Most of the communication systems that you are going to come across in future are going to be digital communication systems. To give you an idea of how things have happened in North American continent (())(11:36) you can read this slide here.

Student: (())(11:39).

Professor: In future I will make the slides on these papers but today I just have one plain paper and obviously the size is not huge enough, so I will just read out to you. At least you can see the bars, right? I have broadly divided for the purpose of this illustration the various kinds of communication systems into 4 broad categories. These are called cable systems, you know that as you communicate from one place to another place over a cable or terrestrial microwave systems, I am sure you are familiar with these, you must have seen microwave towers sprouting all over the countryside which link one place to another through a microwave channel.

Satellite systems and finally fibre-optic systems. I do not think one needs to, these are very common knowledge kind of thing and I am sure all of you are quite familiar with these systems. Now what I have shown in each of these kinds of systems is the extent of analog, the fraction of analog part and the digital part. And the way things were in 1984 and the way things were in 1990, okay, so that shows evolutionary trend between analog and digital.

As far as cable systems are concerned, well, you will find that more the things have come down a little because cable systems are being rapidly replaced by other kinds of systems because laying cables are you know very expensive affairs and very cumbersome affairs. So cable systems in general both in the analog and the digital form have come down. And this is a North American continent story. Coming to the terrestrial microwave, the analog part has come down quite significantly, the digital part has correspondingly gone up, similarly for the satellite systems and similarly for the fibre-optic systems. And this trend is going to continue in the next decade or so even there.

And it is going to be much more pronounced in our country where a lot of communication systems are just being established and obviously all the new kinds of communication systems are going to be largely digital in nature. So this picture gives you an idea of the importance of data communication as a very major futuristic technique of communication in the days to come. Now why this, replacement of analog communication techniques or systems by digital communication systems? There are many advantages, I will just list down a few of these.

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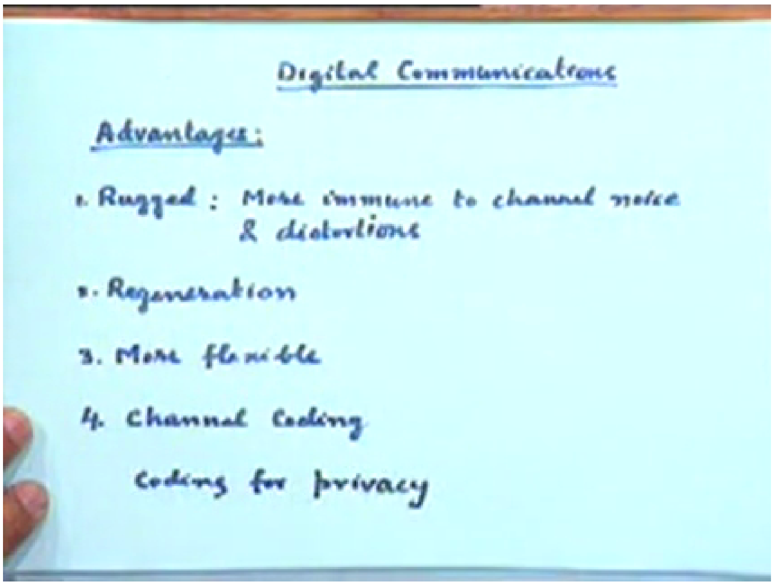

First of all they are believed to be really rugged, what I mean by this is that digital communication systems in general are more immune to noise and channel distortions. Now the reason why they are more immune is this in fact, also a part of the 2nd reason I am going to give here and that is because of regeneration along the path. Now what I mean by regeneration? I believe all of you are at least familiar with the fact that digital communication takes place in the form of let say ones and zeros, transmission of ones and zeros, translation of discrete symbols, discrete level of information, right.

Information represented somehow in a discrete form and we learn, when we learn about pulse code modulation, we will see how that is done. But let us assume for the timing that it has been done and that is what you are finally transmitting, ones and zeros. Now as the signal which contains information about ones and zeros propagate along any channel, any kind of channel, they undergo some kind of distortion due to the various nonideal effects that are present in the channel. Also it collects a lot of thermal and other kinds of noise that is produced along the path and within the communication system.

And therefore by the time the signal comes back to you at the receiver, it comes to the other side, 1st of all it is very weak because it has propagated over a large distance, secondly it has undergone these changes which contain noise and distortion, with the result that the received signal to noise ratio in very poor and it is very very difficult to decode the information correctly, right. Now in a repeater, what you can do is you can at least amplify the signal along the way. You tap the signal somewhere along the way, amplify it and retransmit it.

But that will not help as far as the noise and distortion are concerned. It will certainly help to increase your received signal power because you are reamplifying it and retransmitting it along the way, right. But it will not help the signal-to-noise ratio because signal and noise and the distortions will all be amplified with the same proportion, to the same extent, right. So it is not going to help you to decode the information correctly very well. So what you have to do is somehow while you are doing this amplification, also remove some of the noise if possible.

Fortunately that is what is possible in digital communication. At the point of regeneration, at the point of amplification or what is called regenerative repetition, you, not only you are able to amplify the signal but are able to take away the noise that was introduced in that leg of transmission, between the, between the let say between the transmitter and the 1st repeater or ith or i+1th repeater. Whatever noise was introduced, channel distortion was introduced, you are able to take it away and retransmit a clean signal, right. And therefore repeated transmission of clean signals take place.

And that is what really brings in the advantage in a digital communication system. You get ultimately noise and distortion not for the entire propagation path but only for the small segment of the propagation path which is easy to remove and again clean it off, right. So that is the reason why digital communication systems are primarily having all the major advantages. In addition to this very major advantage, we also have other advantages and some of them are as follows. They are more flexible, particularly they are more flexible from the point of view of hardware implementation.

We can use, it is possible to exploit the tremendous amount of technological advancements that have taken place in VLSI when you are in digital communication as compared to when you do analog communication, right. It is much more easier to exploit those advantages if you do things digitally rather if you continue to do them in analog form. So that is the flexibility aspect, then when we do digital communication we can also do all kinds of coding of information, that is just not possible in analog domain or at least not easily possible in the analog domain, right.

And the all kinds of coding that one can think of and one type of coding that is particularly relevant here to talk about is called channel coding. We can do the channel coding to combat or take care of whatever little effect the noise may still produce for you, whatever little problems the noise will still produce for you can be taken care of through this kind of coding, right, channel coding. You can also do coding for high fidelity and you can also do coding for privacy, right. All these things are possible in the digital domain. Well, it is not that these things are entirely impossible in analog domain but they are much more difficult to achieve and are not as effective as in the digital context.

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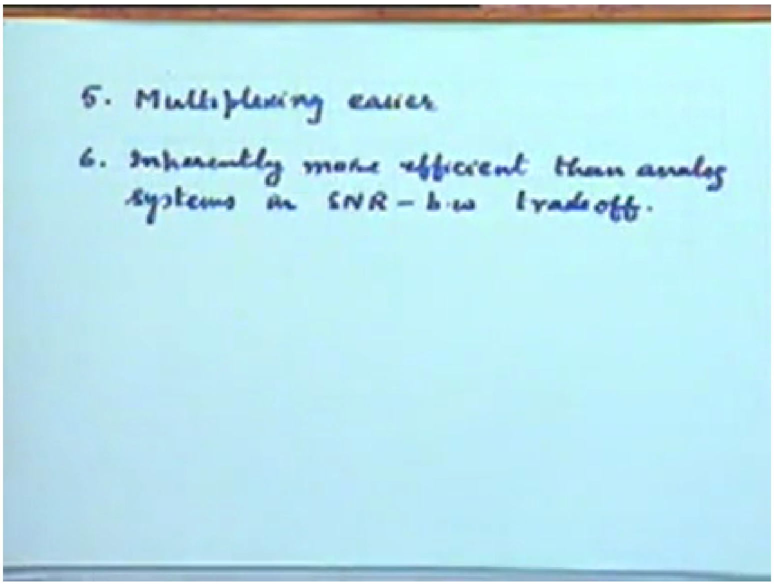

So channel coding can be done and also coding for let us say other uses like privacy. The next advantage is that it is easier and more efficient to multiplex fatal signals than it is to multiplex analog signals, okay, so multiplexing is also easier. I will elaborate on this further when we will talk about multiplexing. Finally, in a nutshell what I would like to say is that ultimately what is important is the transmission of information in a correct and reliable manner. And usually the resource that we use to do that is bandwidth, the most important communication resource is bandwidth.

The higher the bandwidth you have the higher the rate at which the information can be transmitted on a channel with that high bandwidth, okay. So after all when you say you want to transmit information, we need the basic resources that we need for that is bandwidth. If you want to transmit a lot of information at a very fast rate, then you need more bandwidth. That is one aspect, the other aspect is that we need it to be done reliably. And the question that arises is can one thing be traded off with another? And the usual is yes, we can trade bandwidth with performance.

We can get better performance provided we are ready to sacrifice or gain more bandwidth. All other way, in other words give you have less bandwidth, maybe you will not get as good performance. So this is the cost that you have to typically pay in a communication system. The questions then arises is what other good ways of trading off, because one can trade off in a bad way and one can trade off in a good way. You can do this kind of trade off also in analog communication. For example you are familiar with AM and FM situation. In analog communication FM has superior performance compared to noise as compared to AM, but it has, it takes up much more bandwidth do so, right.

So that is also a kind of trade-off between noise performance and bandwidth which is a major communication resource. The same kind of trade-off is going to be taking place in digital communication. Now fortunately for us it is again digital communication again scores over analog communication in the sense that this trade-off is more effective summarise. You can trade of bandwidth versus noise performance more effectively by using proper techniques. So they are inherently more efficient than analog systems in SNR bandwidth trade-off.

So I believe that these 6 or for reasons that I have given you should be convincing enough about the usefulness of digital communication is and also as to why they are becoming more popular in real life than analog communication systems these days. I think I will stop our discussion here today with any questions from the floor because I have not really prepared anything beyond this, not knowing what your background was. So we will start with PCM and Delta modulation next time. Any questions are welcome.

Student: Book.

Professor: As far as book is concerned, let me make the comment next time, I will give you more definite… As far as marks distribution is concerned, it is basically a lecture course, so we will have 2 minors and one major and if you want on the Thursday class we will have quizzes, also. So that will take care of, keep you kind of…

Student: (())(26:45).

Professor: Maybe most of them, if not all of them, all right, we will see. That also depends on how efficiently I can correct them and evaluate them. So if we interview this kind of a breakup of tests, we can have about 30 percent for, no I think 25 percent minor 1, minor 2, 40 further major and 10 percent for the quizzes. Does that sound okay? Does it add up to 100? Oh Yes. Any other question?

Student: You were talking of repeaters. That means (())(27:45).

Professor: There could be any kind of communication, if you are doing long-distance communication you require repeaters. You require to regenerate signal lines retransmit it because the signal is going to become weaker and weaker and noise is going to get more and more difficult…

Student: What I mean is that if you transmit on a cable, you transmit your single but the old signal is already been transmitted as a receiver is going to receive both signals.

Professor: You are talking of let us say radio propagation?

Student: Yes.

Professor: Well, the radio propagation technique, okay, one thing I would like to mention is that we are not talking of broadcast situation here, right. There are 2 kinds of communication systems, broadcast systems and point-to-point communication systems. Broadcast systems will, will continue to be analog for a long time to come, right, we are not really talking about them, where there is one transmitter and many receivers, right. We are here talking about point-to-point communication systems where you are transmitting from one person or one station to another person or another stations located elsewhere.

Now in this situation usually you have to have some kind of a very fixed kind of link, either cables or microwave or satellites or fibre-optic, okay. So we are Broadly talking about this. Does it answer your question? Anything else? Please feel free to discuss or… Although it is slightly artificial environment but I think just try to be as naturalised as you can be in this.

Student: With broadcast system you mean television and radio transmission?

Professor: Right.

Student: They will continue to be in analog form?

Professor: With some…

Student: You have that digital TV now.

Professor: Digital TV and all that, that is why I do not want to make a commitment to say yes of all times but largely I would say yes still.

Student: Up to what extent is optical fibre communication (())(30:03) how much of that is being developed now?

Professor: Most of the cable systems are being replaced by optical systems and the reasons are obvious because you have much more bandwidth and you can transfer twice for information, right. But there are limitations still, there are limitations as to the amount of fibre-optic cable you can lay and the problems that arise, they still need to be sorted out but they are becoming very very extensive. And I think I will not be wrong in saying that in the next decade, optical channels will be the most important channels, that can be (())(30:49). Like today it is a satellite and the microwave, microwave than the satellite, well I think this is going to be largely replaced with fibre optic in the next decade.

Student: Why (())(31:01) of microwave?

Professor: I believe you must be knowing about various frequency band into which the communication spectrum is divided. And the microwave band is one such band, I mean you start from very low frequency band, go up to the maybe I can just briefly take a slide on that. I will not be able to give you think that frequency ranges here because I am not got them here with me. But I am sure you can check them in the textbooks.

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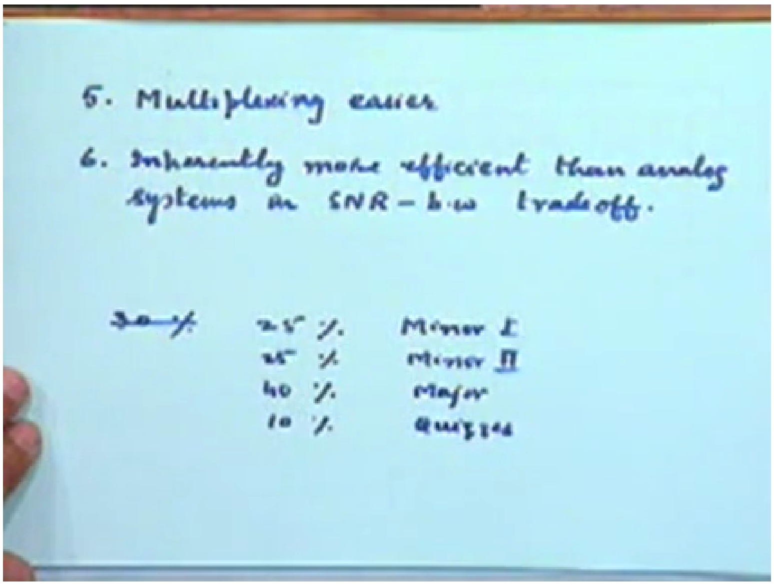

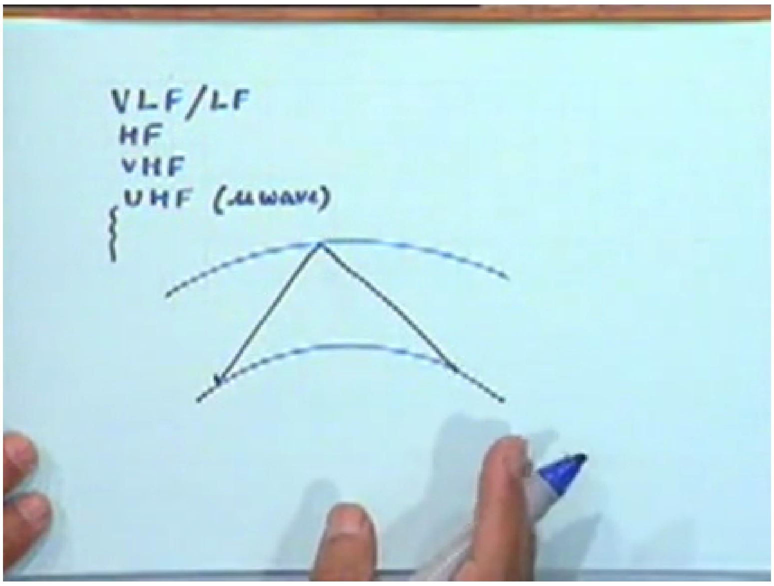

You can start with as low as what is called as VLF band, very low frequency band, then come up to the HF bands. I will say VLF and low frequencies, then the high-frequency band, then the VHF band, then the UHF band, which is also the lower end of the microwave band, okay, UHF and microwave, they merge in, then we have the high-frequency bands. So microwave starts somewhere from here and goes up to about a few gigahertz. The exact frequency range you can check out in your book, they are all there.

So when you do communication in this frequency band, the microwave band, we say it is microwave communication, right. The propagation modes that are used in different bands are different. For example UHF and microwave use what is called skywave propagation, you are familiar with that? Skywave or line of sight propagation?

Student: (())(33:04) up to a point it goes straight and…

Professor: That is right, there is a direct path between the transmitting antenna and the receiving antenna, right. That is why and obviously because this path has to be direct, they are limited by the over, the over the horizon distance, I mean you cannot go beyond the horizon. So if you want to increase the distance of propagation, you have to increase the height of your transmitting and receiving antennas. That is why you will find microwave towers to be pretty high so that they can space them out as far as feasible. If you are watching with the VHF band or HF bands, your, particularly the HF band you are using the ionospheric propagation.

That is transmitting antenna actually reflects upwards and then the ionospheric layer in the upper atmosphere reflects these radio waves back towards the Earth, actually it bends it back towards Earth. And this way long-distance communication is rendered possible because you can communicate, suppose this is your earth, this is your ionosphere and you may be able to receive here beyond the horizon. So you will find a lot of broadcast being done in the HF for example. A lot of other kind of communication, point-to-point communication also being done in HF, right.

And of course there are other similar considerations in VLF and VHF, I thought you are familiar with these things so I did not take that up because that this typically done in the 1st course in communication.

Student: Why cannot FM be broadcast over long-distance?

Professor: Same reasons, because you are using a band of frequencies which propagate in that particular, because you need a higher bandwidth in FM, if you need a higher bandwidth you need a higher carrier frequency and that carrier frequency will be in the VHF or the UHF band and therefore you are limited to the skywave propagation mode, okay. So it is an indirect reason. Any other questions?