Wireless Communications

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Lecture No. # 08

Mobile Radio Propagation

This lecture deals with mobile radio propagation. This is a new topic but let us first see what will be the outline for today's talk.

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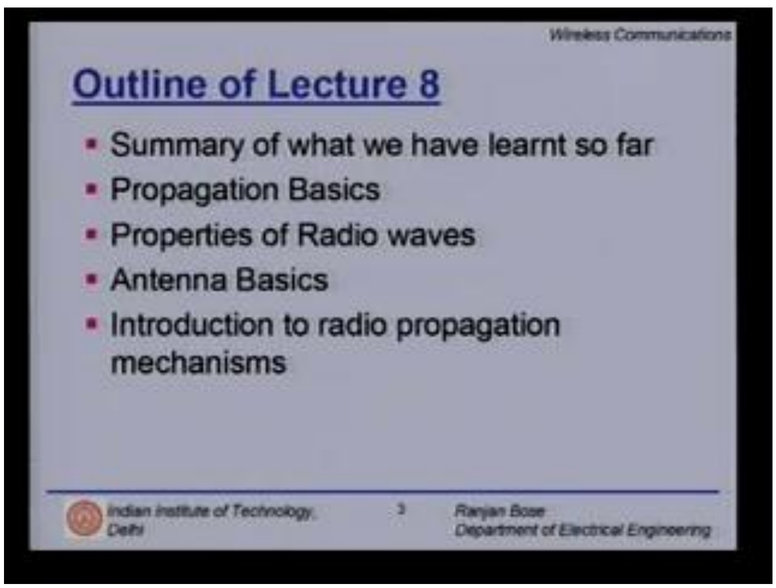

We'll first summarize what we have learnt so far. Then we will talk about propagation basics. we can look at certain properties of radio waves like why do we use radio waves for transmission, what is so great about radio waves, etc. of course, to radiate something and to receive back, we need antennas. We will look at certain antenna basics. Finally we will look at a few of the radio propagation mechanisms. So this is the brief outline of the talk. Let us begin by summarizing what we learnt so far.

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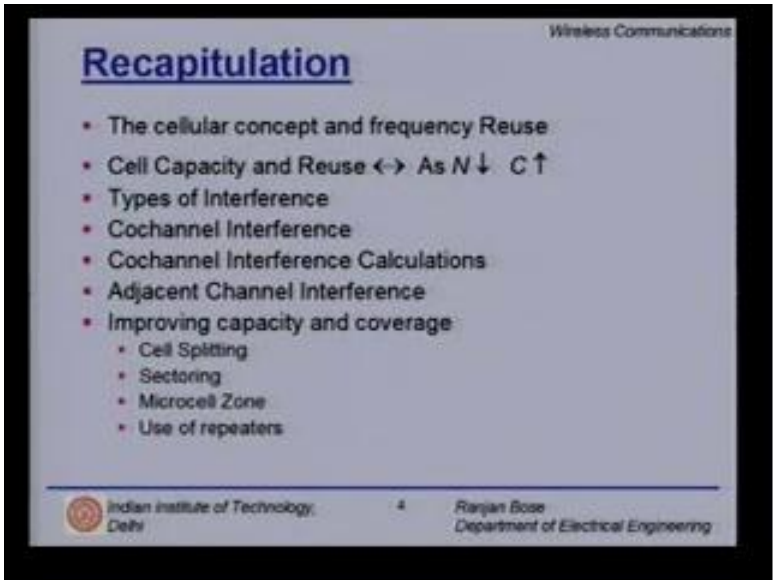

We have looked at the cellular concept and the concept of frequency reuse. We have seen that capacity i.e., the number of users that can be supported throughout the system is of importance and in order to increase the capacity, we must reuse the frequency spectrum. The same frequency band may be subdivided and distributed over clusters of cell and these clusters are repeated so as to increase the overall capacity of the system. This is the fundamental concept of frequency reuse. We also saw that as the cluster size decreases, the capacity increases. We have also seen some examples and how to calculate the actual capacity. We have also seen basics of traffic theory and how you can find out the probability of a call being blocked or a call being delayed beyond a certain duration in time. Then we looked at types of interferences, specially co channel and adjacent channel interference.

We also realized that systems can quickly become interference limited. That is, you cannot increase the capacity any further because you are now limited by interference and not by capacity. Therefore we also looked at certain basic interference mitigation techniques. We looked at co channel interference in detail. We learnt how to calculate co channel interference. Finally we looked at the adjacent channel interference and how to space out frequency allocation in order to reduce the effects of adjacent channel interference. We looked at improving capacity as well as coverage. We looked at certain techniques. Some of them are cell splitting, sectoring microcell zoning and of course the use of repeaters. So this is what we have done so for. What we start today is a little different. We would like to look at the propagation mechanism. What affects it, how do we actually send the desired signal right up to the receiver and how do we interpret the signals received and make get some useful information out of it.

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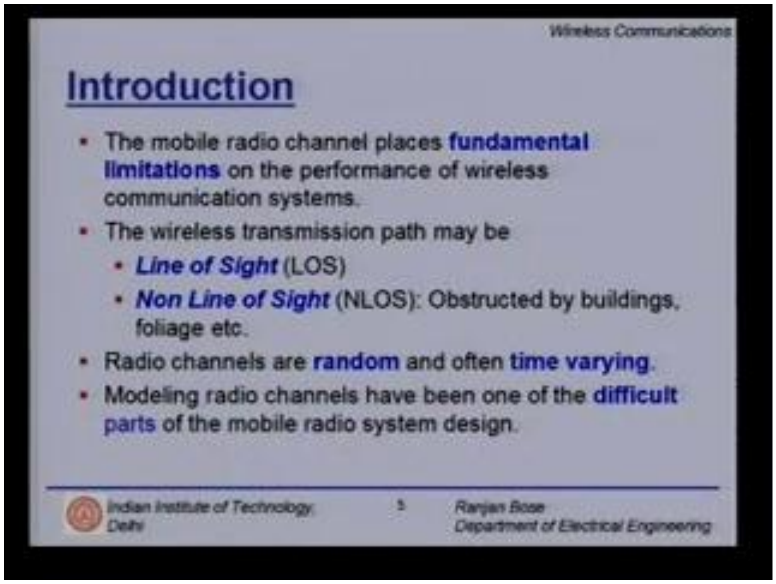

First we start with a brief introduction. The mobile radio channel places fundamental limitations on the performance of wireless communication system. This is the very important point. Wireless by definition, is a very hostile environment. We do not have the luxury of a fixed line copper or the luxury of a large bandwidth like fiber. We have to deal with the uncertainties of the channel. Coupled with that is multipath propagation, attenuation, scattering and host of other problems. Now the widest transmission path may either be line of sight, if I am lucky. That is, I have a direct line of sight from the transmitted to the receiver or I can have a non-line of sight in which case my signal is actually obstructed either by building or foliage or hills or even cars on the streets. In general, we deal with the non-line of sight situations in our cellular mobile systems. We do not have the luxury to be in direct line of sight with the base station. Radio channels are random and often time varying. This is important. Not only is it random, that is, you can take enough measurements; come up with a statistics to model it but with time, the statistics might change. This is a fundamental issue.

How to model a radio channel effectively and remember radio channels behave differently in different frequencies. So for example, the model that I come up with for 900 MHz frequency band may not be entirely applicable for 2.4GHz band or for the LMDS28GHz band. We will realize why it is different the lambda, the wave length of transmission is going to be effected and how it gets reflected, obstructed, absorbed or diffracted depends on the size of the wavelength. Modeling radio channels have been one of the most difficult parts of the mobile radio designs. This is because when we have to come up with a whole system model, I must plug in the channel characteristics. I should have a reliable channel model so that I can simulate my system before actually implementing it. Remember mobile systems are expensive systems. I randomly cannot put a base station, measure the power and then decide, “Look, I didn’t do a good job. Let me shift the base station because I didn’t get enough power”. So measurements are carried based on these fundamental measurements. You try to come up with a realistic channel model. Most of the channel models are random but as we will see, as you move to higher and higher frequencies that is, lower band wavelengths, you will have to go to deterministic channel modeling. so random channel models are good for lower frequency bands. By lower I mean 900MHz, 1000MHz and 2.4GHz and by higher, I mean above 10GHz.let us now look at some propagation basics.

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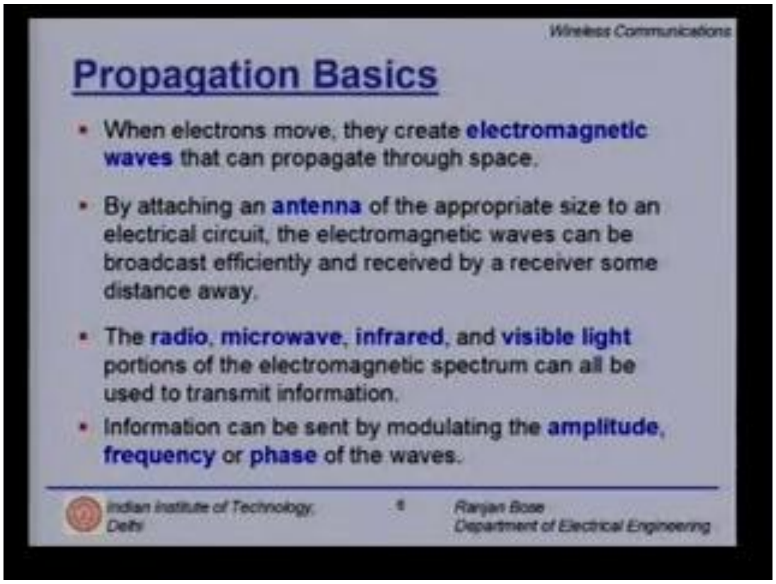

We start right from this start. That is, when electrons move, they create electromagnetic waves that can propagate through space. So we start with a circuit where we make the electron move in a certain fashion so as to generate a certain kind of hopefully a sinusoidal wave form. By attaching an antenna of the appropriate size to an electrical circuit, the electromagnetic waves can be broadcast efficiently and on the other hand, received by a receiver at a distance away. So antenna is an interface between the circuit and the wireless channel. Please remember the size of the antenna has a lot to do with the wavelength. In fact many times we measure the size of the antenna in terms of wavelengths. If I deal with a lower frequency band that is, a larger wavelength, then my antenna size will be larger and wise verse. So as we are translating to higher and higher frequencies, our antenna size is diminishing. This is good for us.

As we move to higher spectral band, my mobile handset will become smaller and so will the antenna inside it. The radio, microwave, infrared and visible light portions of the electromagnetic spectrum can all be used to transmit information. Remember all of this is wireless. Wireless radio, point to point microwave link, infrared links right inter-building intra-building and visible light not guided but unguided. May be across buildings I can have links which are visible light links. That’s also wireless channel but clearly visible light has to have a line of sight. I cannot have any obstructions. Infrared too must have a line of sight. Microwave gets very highly diffracted if you have scatters around. So it’s preferred to have a microwave line of sight link. However for radio which is at a much lower frequency than the above 3 can propagate without having a clear line of sight. Information can be sent by modulating one of the properties of the waveform. It could be the amplitude, frequency, phase and these are not the only possibilities.

for example in ultra wideband, we use pulse position modulation because we have luxury to send very narrow pulses and where the pulses are placed with respect to a reference can tell me what kind of bit pattern I am trying to convey.

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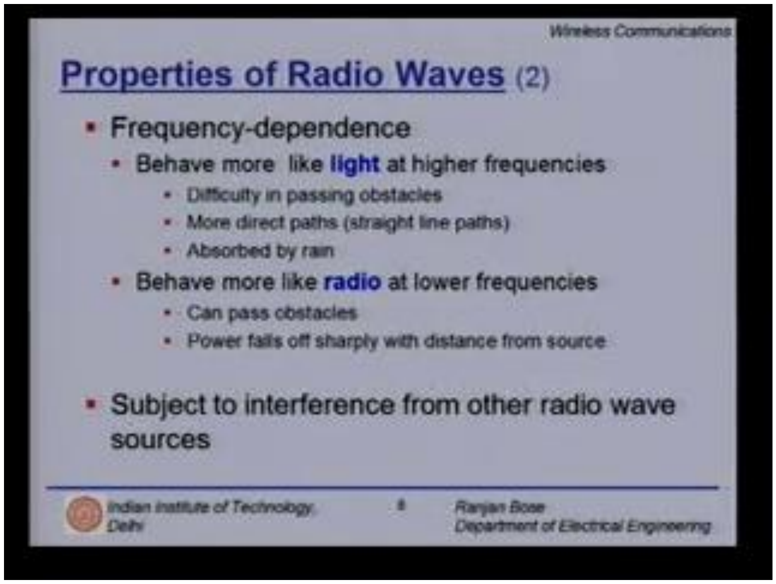

Properties of radio waves here are some of the reasons why we would like to use radio waves. They are easy to generate. The technology is 50 years old. We have the technology. They can travel long distances usually without line of site because the moment we talk about long distances, we should start thinking about no- line of sight they can penetrate buildings. So I can sit in the basement and still talk on my mobile phone. May be used both for indoor and outdoor communications. They are omnidirectional and we can narrowly focus them at higher frequencies. So we can actually communicate from one satellite to another satellite or from satellite to a base station on earth because they can be focused at a small point. Let us look at some other properties. The first and the foremost is frequency dependence. The radio waves at higher frequencies tend to behave more like light. That is, they have difficulty penetrating obstacles.

They rather move in direct path that is, rectilinear propagation and they can get absorbed by rain fog particles, dust particles, etc. For example, if I am working for IEEE802.16 metropolitan area network frequencies or frequencies above 10GHz, my propagation will be affected by rain. If suddenly during the transmission there is snow fall or rainfall, then my signal power at the receiving end will go down significantly. This is not the case when I am using my mobile phone. I will not perceive any perceptible drop in the quality of the voice received on my mobile phone whether it is raining or not. But at the lower frequencies, they can pass obstacles and the power falls sharply as we move away from the source. How the power falls off has already been studied. It depends simply not on the inverse square law formula. It also depends on the path loss exponent which is related to your density of buildings whether it’s a concrete jungle whether you are foliage or any other parameter subject to interference from other radio wave sources. So radio waves we have a very high probability that some other sources radiating in a closer band and I have the chances of emissions or even out-of- band emissions.

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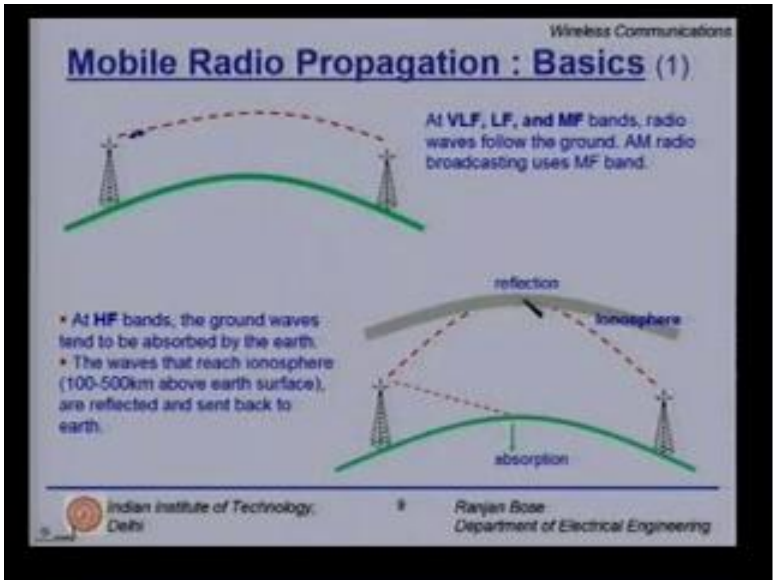

Let's look at some basics of the mobile radio propagation. So here I am talking about VLF, LF and MF bands. These are the various frequency bands depending upon what is the frequency you choose. Radio waves follow the ground. So here let's look at an example. This is a contour of the earth and I have put two towers. Let's not call them base stations. Right now they are just trying to communicate with each other. What they are trying to do is send some signal and take it back. Usually the surface of the earth is working as a guide. It directs and helps it to propagate. So please note that the curvature is taken into consideration and still I am able to communicate. On the other hand at HF, high frequency bands the grounds waves tend to be absorbed by the earth. I did not have this luxury that we saw earlier. So we use ionospheric reflections. Let's look at the contour of the earth. Here is an ionosphere. It has lot of charged particles.

Let us again put two towers, not necessarily base stations. If they want to communicate, they use this as a reflection. Please note that the ionosphere shown here is not really a continuous band. It has many bands from which the waves can be reflected. So clearly this path is a multipath propagation. The reflection here is not through a single reflecting surface. There is a continuum of reflecting surfaces here. So what you receive here is actually a faded signal we will see later on that fading result basically from multipath. Your signals can reach the receiver not only from a direct path but by reflections. All these signals add up either constructively or destructively and generate something which is entirely different from what you send. Therefore you tend to get something called as a faded signal. We will talk about fading and types of fading in later lectures. The problem with HF band is when you transmit it and it hits the earth, it gets absorbed. So I have no choice but to direct to my antenna upwards for reflection and comes back.

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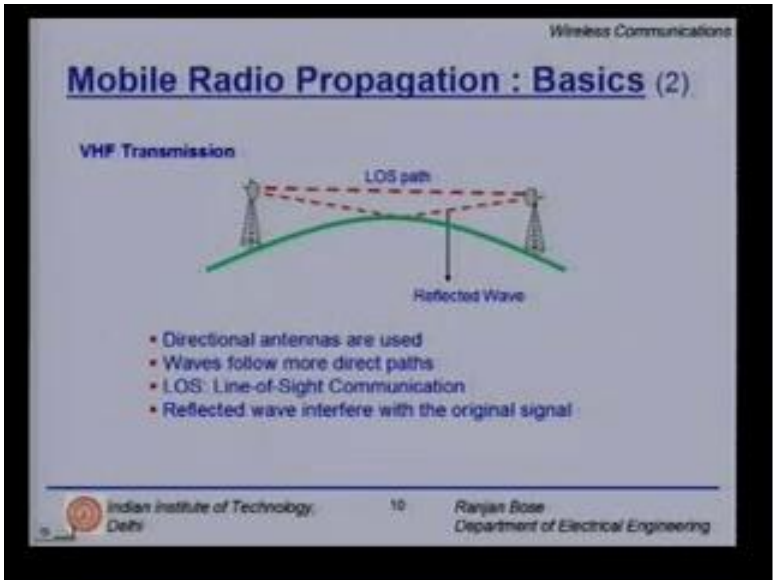

A lot of defense applications are still using these HF communications. For VHF- very high frequency, we can have a direct line of sight path. It's important. We have increased the frequency. I do not have the luxury of bending all going through the HF channel. I have to have a line of sight. Of course it doesn't get absorbed very much. So whatever goes on hits the earth and it's reflected back. Clearly this can also form a multipath channel unless of course my antenna has a very narrow half power beam width. That is, it is a very directional antenna. It can only look at a very narrow beam width. In that case, I will filter off most of the reflected waveform. Please note this is the first time we do not want extra signals to come. Typically, you want the signal power to be as high as possible. Here I am getting signal through the line of sight and I am getting more of the same signal through reflections. I don't want that because this signal will reach at a slightly later duration in time and will actually end of corrupting it because here I am picking up signals through an antenna.

The antenna gets excited by the electromagnetic radiations and it generates a current. Now because of the super position theorem, the first path will generated its own current and second path will also generate its own current. These two will interact and there will be a sum. Usually there will be a vector sum which will cause some kind of a fading effect to take place. The signal strength will actually appear to go up or down randomly. So we must have directional antennas. Remember there is a relationship between directionality, antenna gain and half power beam width. If my antenna is actually omnidirectional i.e., it radiates on all directions, that antenna gain will be low.

Clearly you are wasting most of the power. You're transmitting in all directions whereas your intended user is only in a certain direction. You are trying to listen to the waves coming from all directions whereas your intended sender is only at a specific direction. So it is much better to use a directional antenna. In previous lectures, we have seen that directional antennas can be effectively used also to curtail interference. Here we are putting directional antenna to an entirely different use. Of course, there is a problem with directional antennas. There is no free lunch. The first problem is if you have a very narrow half power beam width, then it is very difficult to align. Please remember if you are not aligned, you miss a whole of it and this is what we are talking about kilometers separation.

So they are separated by several kilometers. So if they are even half by half a degree here, by the time you reach here, you might entirely miss the beam. The second problem with highly directional antennas is that they have a very sharp cutoff. So even if because of wind or any other physical reasons the antenna gets vibrated or moves a little bit off centre, you are in trouble. They are on top of high towers. So they have to be secured very well. The very high velocity winds might move them by a couple of millimeters and you miss the beam. So directional antennas have both pros and cons. here in VHF, waves do follow more direct paths. We do need line of sight communications. As mentioned the reflected waves do interfere with the original signals thereby almost corrupting them. Of course you can recover it back.

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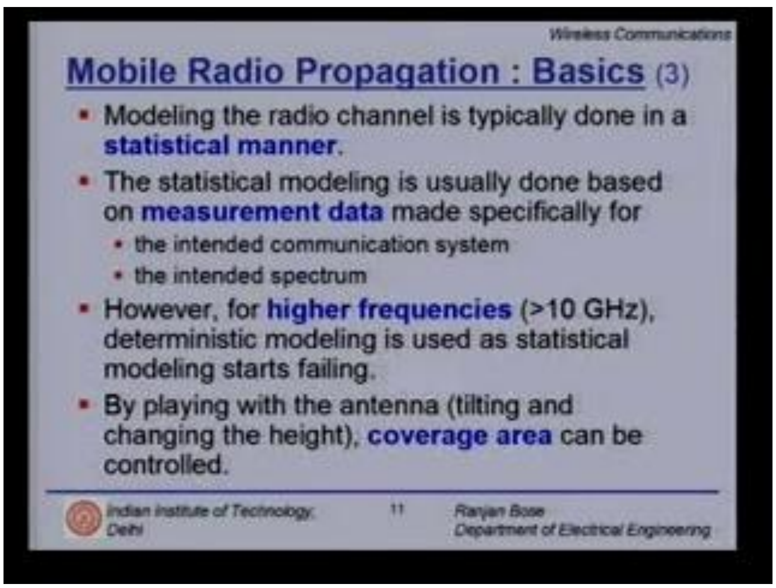

Modeling the radio channel is typically done in a statistical manner because we need to have a very good channel model in order to simulate the system that we want to put in place. the statistical modeling is usually done based on measurement data. So lot of measurement campaigns are done where in you put a power meter in a car or a truck and you move around away from the base station or the transmitter and keep taking. If you are doing indoor measurement campaigns you put a transmitter on one corner of the room, you put the receiver at different grade locations within the room and take measurements. Currently an evolving technology is the ultra wideband where still measurement campaigns are going on where we actually are trying to collect a lot of data and based on the data figuring out how to model this data. The measurement data is taken based on the intended communication system and the intended spectrum. Both the factors will require us to take different sets of measurement data. measurement data can be taken either in the time domain that is, we either send a CW - continuous wave and try to measure its amplitude or the data can be taken in the frequency domain where we sweep the entire frequency band of interest, collect the data, take the inverse Fourier transform and try to find out the impulse response of the channel. However at higher frequencies, above 10 GHz, deterministic modeling is more useful than statistical modeling simply because there are no good statistical models. We cannot take one good statistical model that can explain the behavior at greater than 10 GHz. so we actually do something called as deterministic model and certain techniques such as retracing. That is you actually trace the rays from the transmitter to the receiver and find out what you actually receive is actually implied. The other thing to note is we can play with the antenna by tilting it or changing its height and change the coverage area. Please note all of these efforts have to do with two things. How far we can send the signal and how reliably we can send the signal. So we must keep both the parameters in mind.

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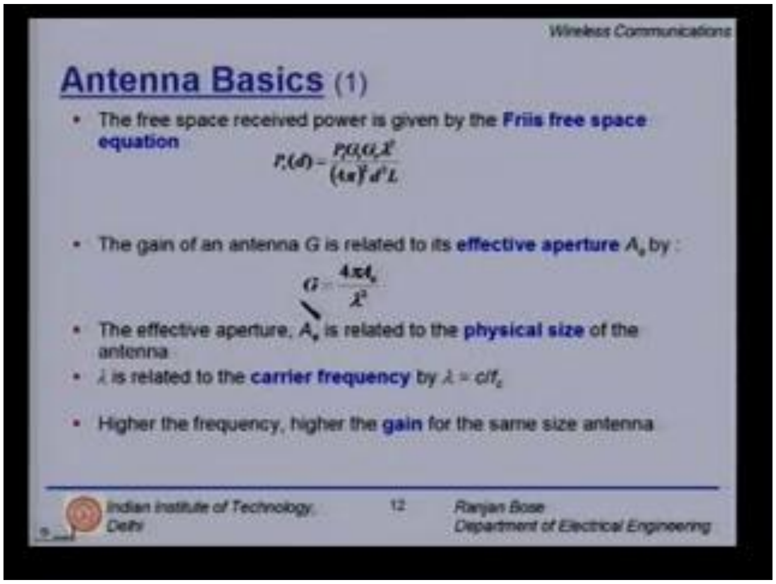

Now we have seen that antenna form the basic interface between the radio circuit and the radio channel. let us look at some antenna basics. the free space received power is given by the free space equation which is the received power ‘Pr’ at a distance ‘D’ which is related to ‘Pt’- the transmitted power times ‘GT’- the gain of the transmitted antenna, ‘GR’- the gain of the receiver antenna, ‘lambda’ squared where lambda is the wavelength, ‘d’ is the distance at which I am trying to receive the signal and ‘l’ is a system loss factor which has nothing to do with the actual propagation.

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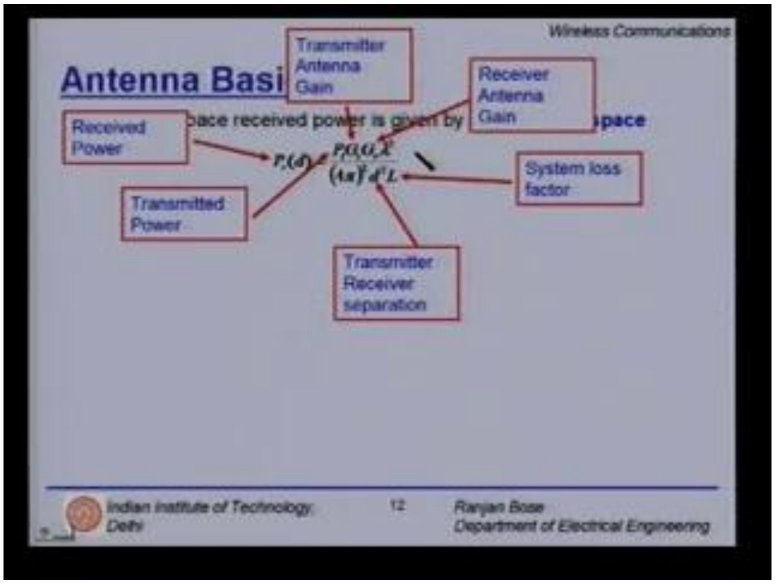

So what is important to understand is that the received power depends on a host of things. it is not just the transmitter power. Now the two factors - antenna gain at the transmitter and receiver are of importance. If I have a very directional antenna, my gain automatically goes up. Unfortunately for your mobile handsets, you cannot have a very directional antenna because you do not know which way you are facing and where the base station is located. In fact you must be receiving signals for more than two base stations at a time. You have to have an omnidirectional antenna. So the gain of the receiver by design can be only taken to a certain extent but cannot be increased further because I do not have the luxury of directive antennas. I am talking about the down link right now. The gain of the antenna at the base station can be played around with. Today we have moved to a domain where we only use directional antennas. It not only helps us to reduce interference. It gives us a higher gain. The lambda figures in in the received power. This is interesting. It tells us that the received power for the same transmit power. Antenna parameters would change if I am going to a higher frequency.

The higher the frequency, lower the wavelength and the lower the received power. So the problem is that as we go on to higher frequency bands, by definition we are getting lower and more received power. As we move to higher frequency bands, my size of the cell decreases for the same transmit power. It’s important to know. In fact the ultra wideband which I am referring to more than once is working in the 3.1 to 10.6 GHz band. It’s a bandwidth of 7.5 GHz. it’s only in door. It is supposed to work only up to ten meters. Of course there are other related issues. We want the emissions to be at the noise level so that we do not interfere with others. d comes in the denominator. Please note that there is a d squared here because this is the free space formula. This can be replaced by d raised to power n where n is the path loss exponent. But there are other special formulas also. l is the system loss factor and has nothing do with the actual propagation path. We will soon see that this equation holds only under certain conditions. The gain of an antenna ‘G’ is related to its effective aperture, A_e which is defined by gain is equal to 4 pi Ae divided by lambda squared. Again the gain is related to the wave length.

Many times the effective aperture is also represented in the units of wavelength. The effective aperture is related to the physical size of the antenna. Lambda is related to the carrier frequency by lambda = ‘c’- the speed of light divided by carrier frequency f (c). Higher the frequency the higher the gain for the same sized antenna. Look at the g formula here. Gain is inversely proportional to the square of the wave length. So for the smaller wave lengths larger frequency band the gain is higher. The directivity is higher. We can focus more right. So this is some of the antenna basics.

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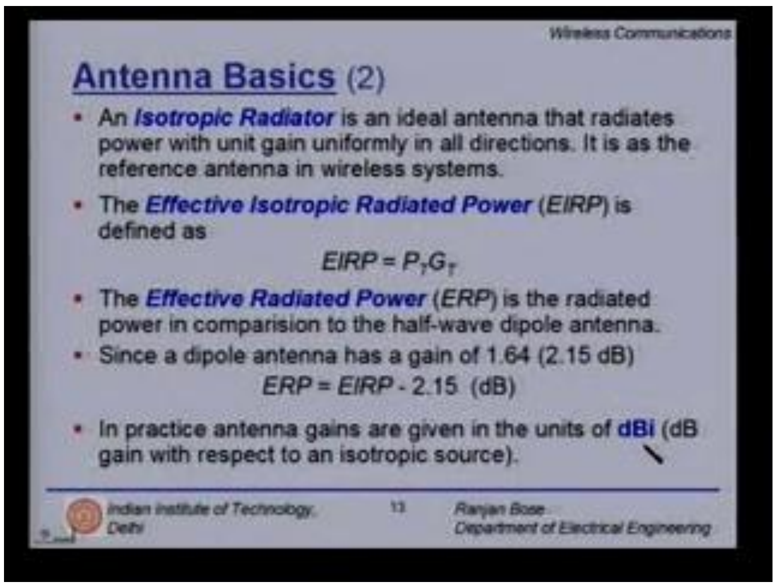

Now let us look at some definitions. An isotropic radiator is an ideal antenna that radiates power with unit gain uniformly in all directions. It’s an idealistic definition but still important because it will help us to have a reference. If we have a directional antenna maybe we can talk how good or bad it is with respect to this isotropic radiator. It is as used as the reference in wireless system. The effective isotropic radiated power is an important parameter which you will see more than once. EIRP is defined as PT - the transmitted power times the gain of the transmitter antenna. So you cannot just say that ‘look, I have a transmitted power of ten milliwatts. I would like to know what is the antenna gain ? If the antenna gain is more, my affected isotropic radiated power would be more and vice versa. The effective radiated power - ERP is the radiated power in comparison to the half wave dipole antenna. Since the dipole antenna has a gain of 1.64, this can be found out from some basic antenna equations which is equal to 2.15 db. The ERP is nothing but EIRP – 2.15 n dB. Frequently we would like to code these figures in dB because the free space equation translates into a series of additions. The products become summations. So dB is a very comfortable way to express these things. In practice, antenna gains are also given in the units of dBI which is the gain with respect to the isotropic source.

So this ‘I’ is for isotropic. With respect to the isotropic antenna I can have a non-isotropic antenna which is a directional antenna. My gain will be better. How much better I can find out with respect to the isotropic and represent it as dBI. So if you buy an antenna of the cell, you will find that may be the gain is 10 dBI. You know what they may?

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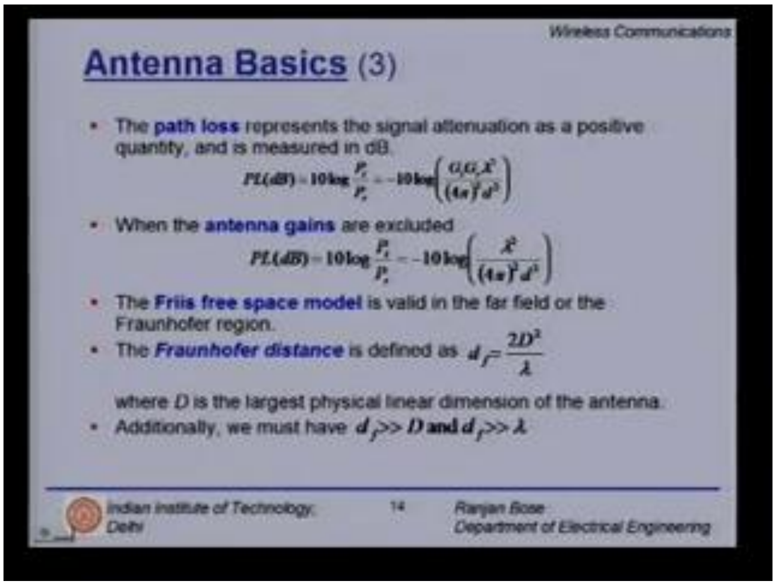

The path loss represents the signal attenuation as a positive quantity and is measured in db. So we are now talking about a transmitter and a receiver which is located at a distance ‘d’. Clearly when you send a signal, what you receive gets attenuated. Path loss is the linkage. So path loss in db is nothing but 10 log P_t over P_r and from the Friis free space equation, it is nothing but -10 log GT GR lambda squared divided by 4 pi squared d squared. Given this, you can find out the path loss in free space. when the antenna gains are excluded, suppose you are using antenna gain of one for both the transmitter and receiver, then you simply have the path loss as -10 log lambda squared over 4 pi squared d squared. Please note there is a negative sign. so you get an attenuated signal. The Friis free space model is valid only in the far field also known as the “Fraunhofer region”. So you cannot just randomly use the equation any where you want to.

First, before using the Friis free space model, you must calculate what the near-field region is, what is the far field region. We will consider how to calculate these. Only then your calculations will hold good. The Fraunhofer’s distance is defined by dF = 2 D squared divided by lambda. D is the largest physical linear dimension of the antenna. So if I have a horn antenna with a cross sectional area which is rectangular, then d will be taken as the larger of the two sides. If I have a spiral antenna again, I have to figure out what is the largest physical dimension and then use it for your Fraunhofer distance. In addition to that, we must have ‘df’ the Fraunhofer distance much greater than D and df much greater than lambda. So only when you are beyond ‘df’, if your receiver is farther away from df with respect to your transmitter antenna can you start using these path loss equations.

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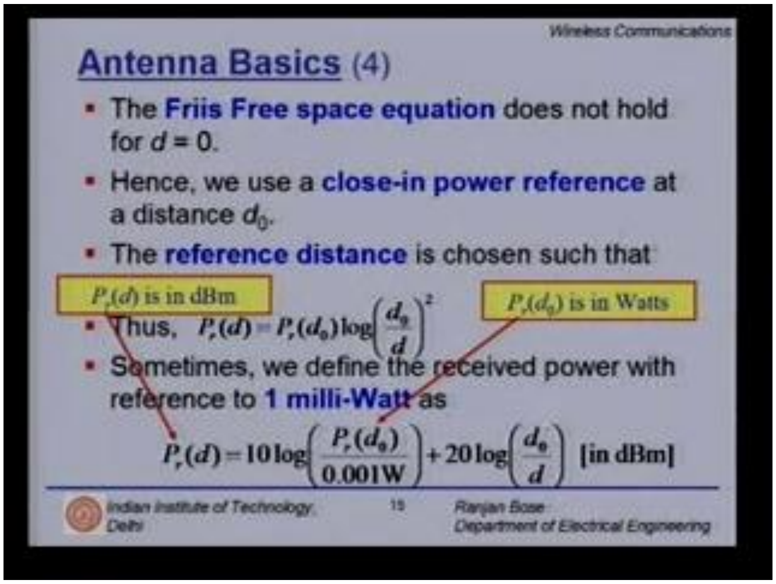

Clearly, the free space equation that we are talking about does not hold for D =0 if I am sitting at the base of the base station. Well, theoretically I am not at the far field. Hence in order to have our calculation, we use a close in power reference at a distance D_0. So now a convenient way to say how much power do I receive, I can do so with respect to a reference distance. The reference distance is chosen such that d_0 is still greater than the Fraunhofer distance 'df'. Thus the received power 'P_r' at a distance 'd' is nothing but the received power at a reference distance d_0 times log d_0 over d whole squared. If a path loss exponent changes to 2.3, maybe I can as a first level approximation put 2.3 here but for the Friis space, it is 2. Sometimes we like to define the received power with reference to 1 mW.

So the received power at a distance 'd' is nothing but 10 log the received power at a distance d_0 normalized with respect to 1 mW + the path loss we experienced from going from d_0 to d. the units will be in dbM and here the P_r calculation is done in watts. Therefore I have normalized with respect to .001 W. so many times, when you pick up your mobile phone and if you look at the reference manual, you might see that the receiver sensitivity is -100 dbM. Immediately you can find out that with respect to 1 mW, what is the minimum power that your mobile handset can use. So in this equation, if you are putting Pr in watts and I have put in here 0.001 W, then the received power is in dBm. So we have learnt so far that we can represent the antenna gain in terms of dBI with respect to reference isotropic antenna and the received power in terms of dBm which stands with respect to 1 mW of power.

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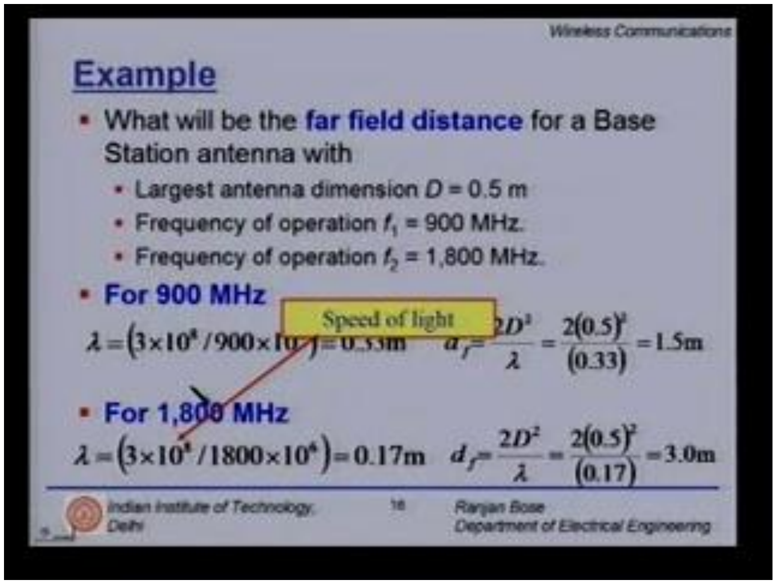

Let us look at some examples. The question is: what will be the far field distance which is also the Fraunhofer distance for a base station antenna with following parameters? What are the parameters? the largest antenna dimension ‘d’ = 0.5 m. it is not a very bad assumption if you worked out and look at one of the base station antennas outside. they typically range from 0.5 m to 1 m. the frequency of operation is the GSM 900 MHz and the case 2 will be 1800 MHz. so what we would like to know is: what is the far field for 900 MHz and 1800 MHz. For the 900 MHz frequency band, first we calculate the wave length. The wave length is nothing but the speed of light divided by the frequency of operation 900 MHz and we get 0.33 m, the fairly long waves. In fact just because they are so long that they can actually bend around, the corners get diffracted and you can still receive it on your mobile handsets even when you do not have a line of sight. Clearly these are different from the millimeter wave communication systems which we will also study in later lectures. Having calculated the wave length for your GSM 900 MHz range, we calculate the df simply as 2 D squared over lambda.

But d is your largest antenna dimension 0.5 and so you get 1.5 meters, it’s not bad. So clearly as long as you are a stone through away from the base station, you are in the far field and all of the equations which we have talked about holds good. What will happen to this 1.5 meters if you now start operating in the other band which is 1800 MHz? The other dimensions‘d’ is the same. So first we calculate the wavelength. Frequency is doubled and the wavelength must be half. So the df is calculated to be 3 meters. It’s very interesting as we go to higher and higher frequency bands. My far field distance moves farther and farther away from the transmitter but again 3 meters is not too bad.

The question being asked is: what will happen to the size of the antenna where you move from 900 MHz to 1800 MHz because we have fixed the‘d’ the largest physical dimension as 0.5?

So the answer is: yes. The antenna size has to be either optimal for 900 MHz or 1800 MHz. It cannot be optimal for both. So most likely you are using a sub optimal antenna which can go from 900 to 1800 MHz. Clearly the gains will be different and you have to take that into consideration.

But as long as my physical dimension ‘D’ is 0.5 meters, I have no business with the gain. The gain will come automatically when you put in the physical dimension in terms of the effective aperture of the antenna. Those are separate issues. But the Fraunhofer distance is dependent only on this largest dimension and the wavelength. So we are using 3 x 10^8 m, the speed of light.

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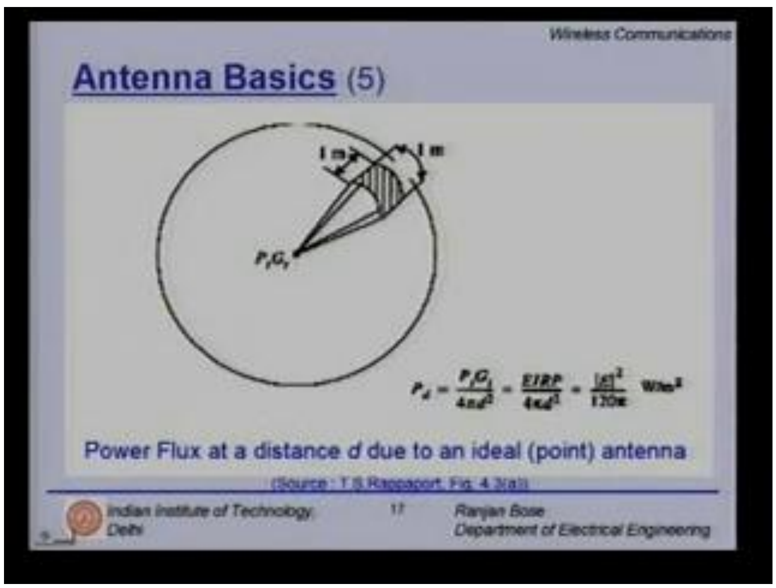

Let us look at some more antenna basics. So the way one simply comes up with some simple equation is to assume an ideal radiating point. Now of course no antenna is a point but for the sake of deriving certain basic equations, we can assume that your radiating source is a point source and this as a transmit power ‘Pt’ and a transmitted gain Gt. it’s omnidirectional. So it’s radiating in a sphere. Of course you can look the power flux at a distance d from the radiating source. That is nothing but P_TG_T divided by 4 pi D squared which is the area here. So that gives you the power flux at a distance D due to an ideal point antenna. Now P_TG_T is nothing but the effective isotropic radiated power. So this is ER EIRP divided by 4 pi D squared which can be calculated as absolute value E squared over 120 pi watts per meter squared. Clearly if I put an antenna of the receiver, the power flux generates an electromagnetic field and hence a current and then I can pick up that current that is generated, amplify it and interpret what was being set.

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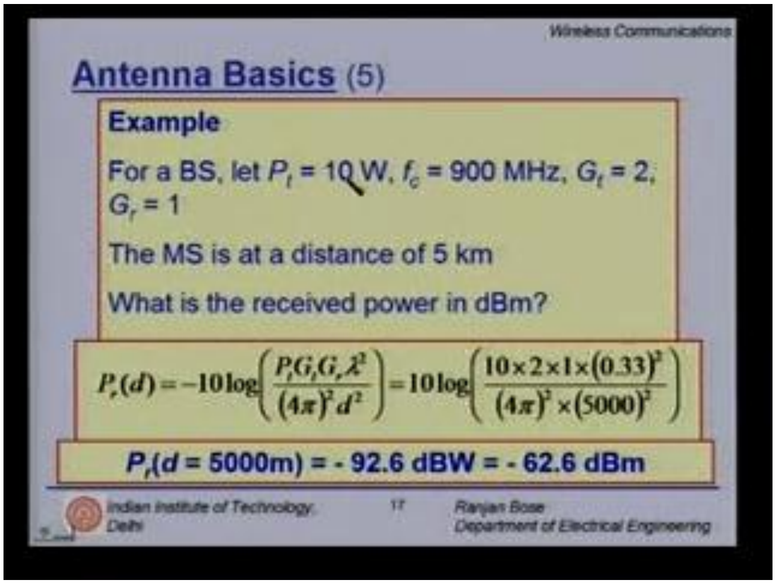

So let us look at an example. Let us consider a base station. But this time, the base station has a transmit power of 10 watts because the base station is on all the time. So if you are going to do a good design, you must ensure that the base station power is as low as possible but should provide enough coverage. The transmission frequency F_C is 900 MHz. again this time, the gain of the transmitter at the base station is 2. So I am talking about a down link. You are radiating from the base station and you're trying to receive at your mobile handset. So the gain is 2. That is, it has some directivity. That is not too bad. I can put a directional antenna at my base station but the gain at the receiver G_R is one kind of an isotropic antenna here. Now the mobile station which is free to move anywhere in the cell is at a distance of 5 km.

The question being asked is: what is the received power in dBm? So we use our basic calculations. 5 km is clearly in the far field. We have not talked about the size of the base station antenna here. It can be calculated back using the antenna gain but we know that 5 km is much greater than that couple of meters which is the restriction on the near field for a base station. so in the far field, the received power Prd is given by minus by - 10 log P_TG_T G_R lambda squared divided by 4pi squared D squared. We are now familiar with this equation. We plug in the values. Please note the unit is 10 watts. The gains of antennas are dimensionless. The wavelength is 0.33 meters. We calculated in the last example and the distance is again in meters. So we are dimensionally correct. So if you do this calculation, you get the received power at a distance of 5 km as -92.6 dB watts. Why do we say this is dB watts because here I have put 10 in terms of a watt but if you want to base it with respect to a milliwatt, then you get an increase of 30. So you get -62.6 because when you are in the denominator, you will get 0.001 watt. So when we normalize it and try to get something with respect to dBm, you get a -62.6 dBm. Let us look at another example. I feel this base station power is too high plus lower it down and this distance of the mobile station is also 5 km. let's talk about bigger cells. So I move the mobile much farther. So I would like to explore how much low the received power can become. So let us look at another example.

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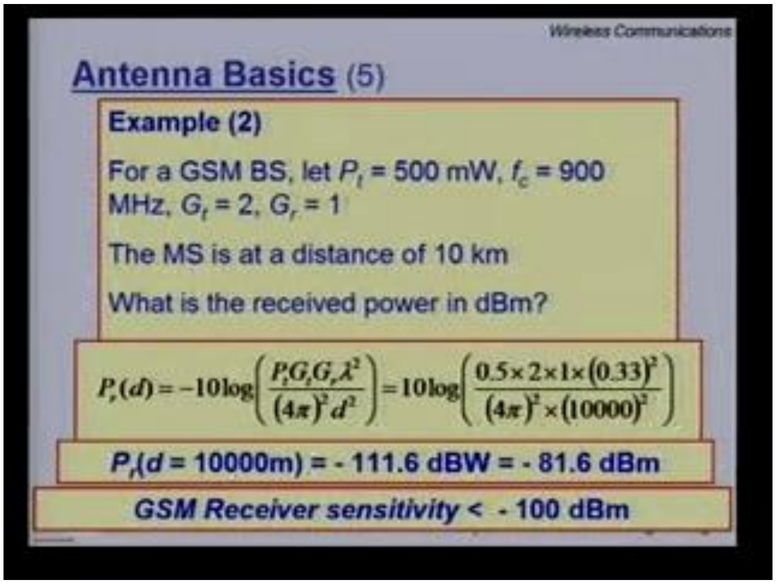

Let us have the transmit power at the base station. It's only 500 milliwatts. I have drastically reduced that power again. I am working at 900 MHz. same parameters for the transmit and receive antenna. The gain of the transmit antenna is 2 and that of the received antenna is 1. But this time, the mobile station has off to the boundary of the cell which is almost at a distance of 10 km. normally we do not have cell sizes larger than 10. So I am actually looking at a worst case scenario.

The question that we want to know is: what is the received power in dBm? We use the same formula of course. We expect the received power to be much lower. How much lower? So use the same formula again. This time I have substituted 0.5 W and here the distance has been increased to 10000 m and the received power is -111.6 db W which is equal to -81.6 dBm. So can my handset work? Is this a good value or is it a bad value? Remember it is 81.6 dB lower than the 1 mW power.

So the basic question is: is this good enough? So we would like to know what is the receiver sensitivity of a standard GSM phone. What is the minimum power level that is required for your GSM phone to pick up the signal and work with it effectively? The answer is: the receiver sensitivity of an average GSM phone is less than 100 dBm. In fact for a better design system it can be -110 dBm. So clearly my GSM phone can not only pick this up but very happily work with this. But remember these parameters are important to decide what the size of your cell is, what is the link budget and what is the possible coverage.

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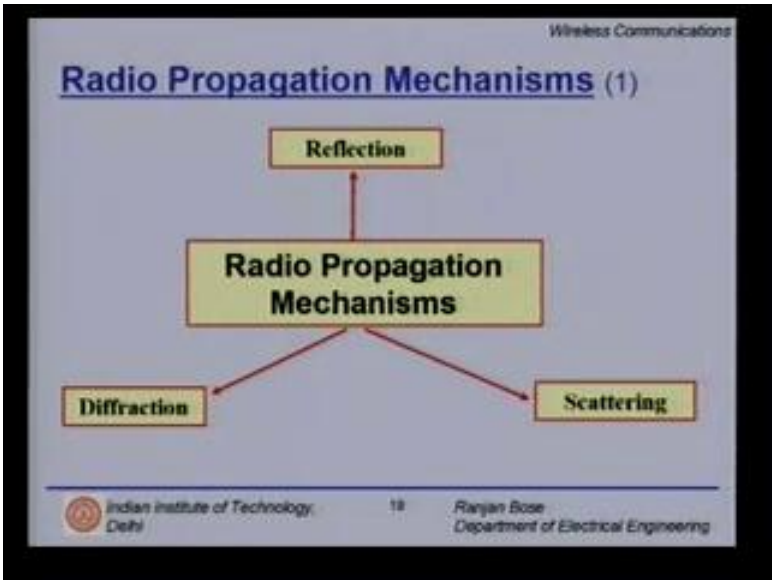

Now let us briefly look at some radio propagation mechanisms.

The question being asked is: as we move away from the base station, clearly the path loss increases and continuously the power received at the mobile station changes. It keeps on going down as you move away. The reverse side is also true. as you move closer to the base station, the received power at the base station increases and we have to take care of the near-far problem as we discussed that when you go closer to the base station, you have to progressively lower your transmit power to ensure that what the base station receives is just above the receiver sensitivity of the base station and no more further. I should not radiate too much because if my received power is much higher than the threshold, then of course I can work with signal but I have already contributed to some interference somewhere.

The power control & power monitoring are two key parameters that are taken into consideration while designing any cellular mobile system. However when we say that I am getting an attenuated signal, my signal may be coming directly or it may be coming through a reflection or a series of reflections or through diffraction or even through scattering. So it is important to understand how the signals which emanate from an antenna actually reach the receiver antenna. So very briefly let us look at what are the radio propagation mechanisms this time. So one of the most important is through reflections. Again there can be various kinds of. You can have a wave reflected of a metallic source. it could be a metallic reflector it could be a non metallic reflected. Could be wood, trees, foliage or any other thing. Then you have a possibility of scattering. So you do not have a line of sight but through scattering, you receive the wave forms or you can even have diffraction across the edges. Now all these parameters will change depending on which frequency you are working on. So the radio propagation mechanism is different for different frequency bands. They have their associated problems. So when you try to look at propagation issues for various bands of frequencies, you have to see whether your problem is arising due to multiple reflections or diffraction or scattering or combination of all three.

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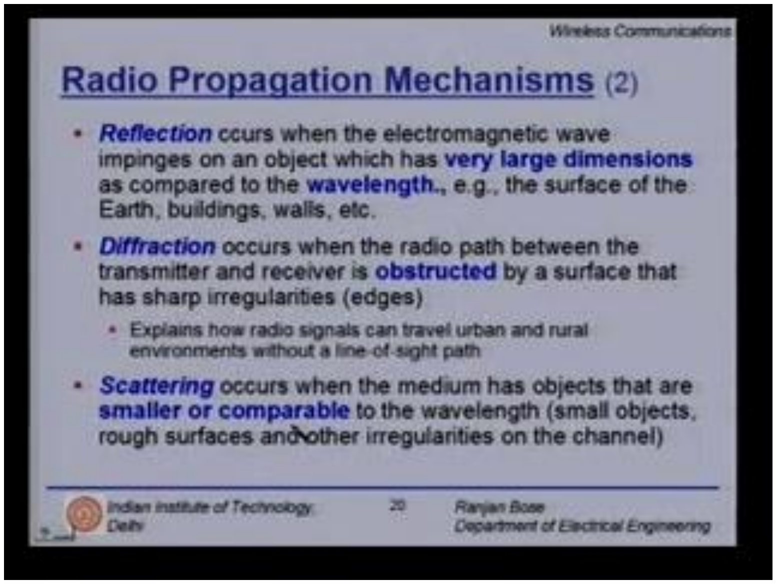

So what are these? Reflection occurs when the electromagnetic wave impinges on an object which has a very large dimension as compared to the wavelength. Everything is with respect to the wavelength. So the surface of the earth, buildings, walls, large table surfaces etc are reasonably large. For 900 MHz, we know that the wave length is 0.33 m. for 1800 MHz, it is 0.175 m. so all of these things listed here are large with respect to the wavelength. Now what do we mean by large? Typically I would like to have at least an order of magnitude difference. So if I am looking at 0.17 meters, then any object which is larger than 1.7 meters is good enough to be called as large and a reflection might take place. Diffraction on the other hand occurs when the radio path between the transmitter and receiver is obstructed. Clearly we are talking about the non line of sight.

So it’s obstructed by a surface that has sharp irregularities, for example edges. So we live in this man made world which is lot of objects with sharp edges. So diffraction is a part of life and it is a very good because it explains how radio signals can travel in urban and rural environments without a clear line of sight path. So it’s good for us. Scattering occurs when the medium has objects that are smaller or comparable to the wavelengths. So it’s an antagonistic approach to reflection. In reflection, the object is much larger than the wavelength. Here we are talking about much smaller than the wavelength. So small objects, rough surfaces, irregularities, water droplets, rain snow, dust particles can cause scattering. In fact when you say smaller, they should be relatively small. But if it is too small, then the effect may not be perceptible. So the word comparable has been highlighted here. Scattering is prominent when the objects are comparable. Let us look at a millimeter wave for example. So the wavelengths are in millimeter. Rain drops are also of the diameter millimeters. So scattering will be prominent in millimeter wave communications when it is raining. But it will not be so for 900 MHz even though the rain drops are much smaller than the wavelength. So all these factors and a combination of them together form why and how a propagation happens.

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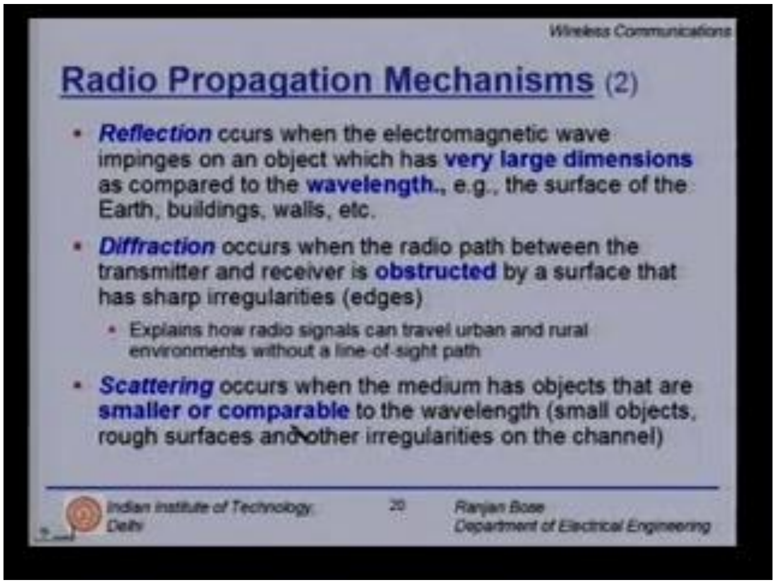

Let us now summarize today's lecture. We talked about propagation basics. We also looked at some of the properties of radio waves - why they form good candidates? What is so good about radio waves are there being popularly used? We then looked at antenna basics. We looked at the gain, the effective aperture and how with respect to the antenna gains we can get the received power. We looked at some of the radio propagation mechanisms which are the reflection, the diffraction and the scattering. So we will conclude our lecture here today and will look at the details of reflection refraction and diffraction and put a look at the models for propagation in the next lectures. Thank you.