**Satellite Communication Systems**
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**Lecture – 19**
**Propagation-1**

Welcome. We have already discussed the link power budget and obviously, related to noise and interference and now we are going to disuse about the propagation channel through which these signal pass through. So, next couple of class will continue our discussion on the propagation channel, what happens is a big subject there are lot of research papers and PhD's on that. So, we will take up what the physics part of it will assume physics part of it and what is the effect will try to see and our main interest will be how to mitigate those effect for a communication purpose.

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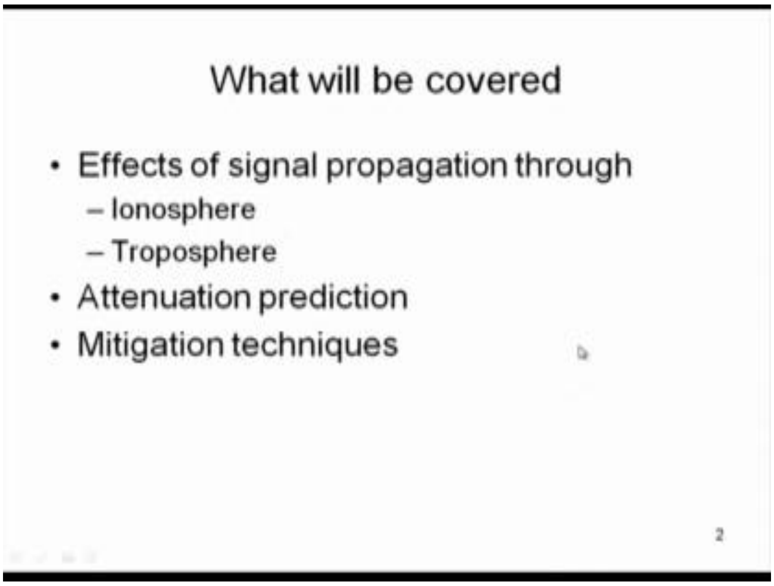


So, let start satellite communication system propagation. In these couple of lectures, we covered the effects of signal propagation through mainly to sphere that is ionosphere and troposphere and then will see the some models for attenuation predication and then what should be the different mitigation techniques, so that we can do proper communication with a good quality of service.

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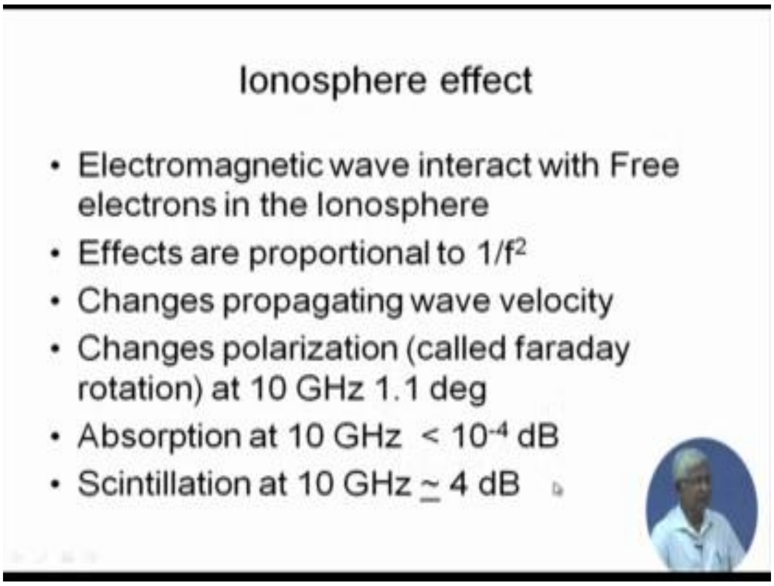


Now, ionosphere is from our school days we are aware that there are high above the earth surface of the order of 700 kilometers above that is 1000 kilometers or even higher about that the oxygen molecules the break up due to suns effect and we have free electrons and irons that move around and since they are charged particles obviously, they try to follow the magnetic ah magnetic a magnetic effect of the earth that is from the equator to the pole the magnetic lines they follow depending on the type of charge.

So, therefore, during the day the density of these irons and electrons vary at different paces and obliviously by the time initially there they generated with a sun light and then by that time they travel higher latitude not the iron southern sunset occurs and slowly they recombine. So, near the pole there is not much of effect maximum effect is near the equator that equator region and middle latitude region some effects are there, but let us just see some summarize the effects what is seen there the electromagnetic be which comes from the satellite or which is going from the ground to the satellite.

They interact with these free electrons in these ionosphere and the effect of interaction is proportional to the inverse square of frequency 1 by f square this is very important for us when we do low frequency communication of the low frequency is the order of megahertz and then on 100 megahertz then the effect is dominant whereas, as we go up in the spectrum in the gigahertz region particularly in satellite communication most common is ku ban which is above 10 gigahertz. So, acting gigahertz they affect obviously, will very law.

So, some of them are effects are it will change the propagating wave velocity. So, when the signal passes through the ionosphere because of the interaction it will go not with the velocity of free space which we assume velocity of light it will slow down this slow down will have a some delay effect for general communication what we are talking that is for video reception video broadcasting data communication or audio communication these delay is its tolerable, but when we introduce these delay for calculating some things else which is done in in the case of satellite navigation satellite base navigation in these delay is very important these delay through these delay we calculate the range.

But anyway if and if some effect is there that at higher frequency as I mention that since it is 1 by f square this propagation delay is very, very small effect it also changes to the polarization the electric feel vector will get rotated which is call faraday rotation and at the ten gigahertz it is about one point one degree very, very small. So, because of this depolarization w at above the residual vector which remains in the intended polarization that is reduce very small amount.

So, they a polarization depolarization effect of course, it will create certain cross polarization component which also very small amount because of the small degree of rotation, but this is just a typical number it various as I said from place to place time to time depending on the total electric content or the density of the electrons through which the signal is passing through there is some absorption which we can call it attenuation this is at ten gigahertz its very, very small, we can see it is of minus 4 db very, very small and there is some effect which is called scintillation is a small time effect in a small region just like a like a babble going up in a liquid babble is moving around in a liquid it is you can think of similar concept babble is actually a gas inside a liquid. Here, it is dense electrons free electrons localized a form because of some perturbation and they again dispose.

So, when they remain nearby and through that if the signal passes then it will have this affects dominating polarization will change, the absorption will change and this absorption will vary peak to peak 4 db possible at 10 gigahertz. So, this short term fading and this may be of interested two a, but this has to be counted, but in general the effect at ten gigahertz is very, very low for the ionosphere. We can we can we can neglect this effect for the time being, but for detail calculation obviously, it will come into picture.

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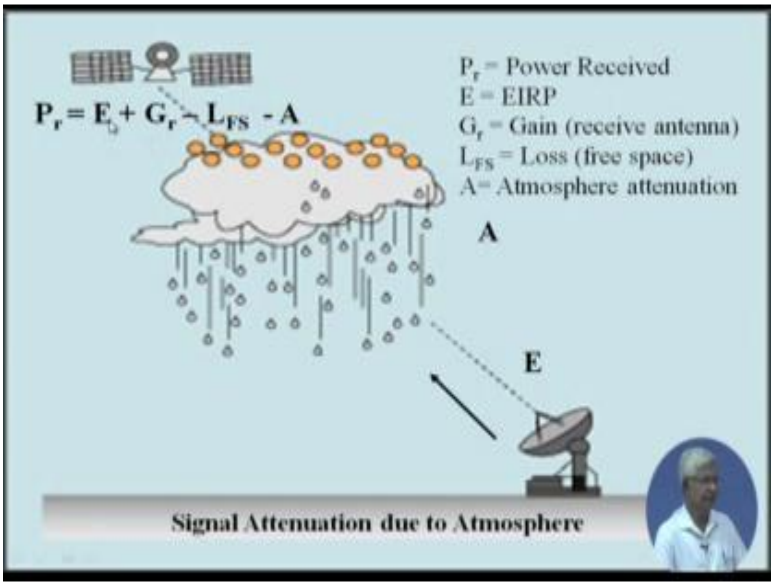


Now, let us see what happens in the troposphere. Here is a just sketch of picture satellite shown on the certain clouds and rain formation and rain specification is taking place and as if signal is passing from satellite to earth or earth to satellite. Here is earth satellite arrow is given, it can be any direction signal is passing through these impairment which is not the clear sky no clear is there it is water vapor as well as water itself it is there now that will create.

Obviously, some attenuation here I have listed only as a atmosphere attenuation and the received power say from the satellite is coming or from earth which is going to satellite whichever direction that is receive power will be the EIRP from the other direction, the transit side and receive antenna gain and that free space loss or what p is call path loss and that is supposed to be clear sky and when it passes through these step of disturbances like a cloud and rain then it will go it will have certain attenuation.

So, power received will be less. So, d b equation are very simple p r is equal to EIRP plus the received antenna gain minus the part loss of a space loss minus attenuation. This is shown as a simply atmosphere attenuation, but then in addition to attenuation there is a polarization change also. The water will absorb water contained are rain drops will absorb some electromagnetic energy also it will rotate the polarization because of that also there will be some loss. Let us look at those things slightly details.

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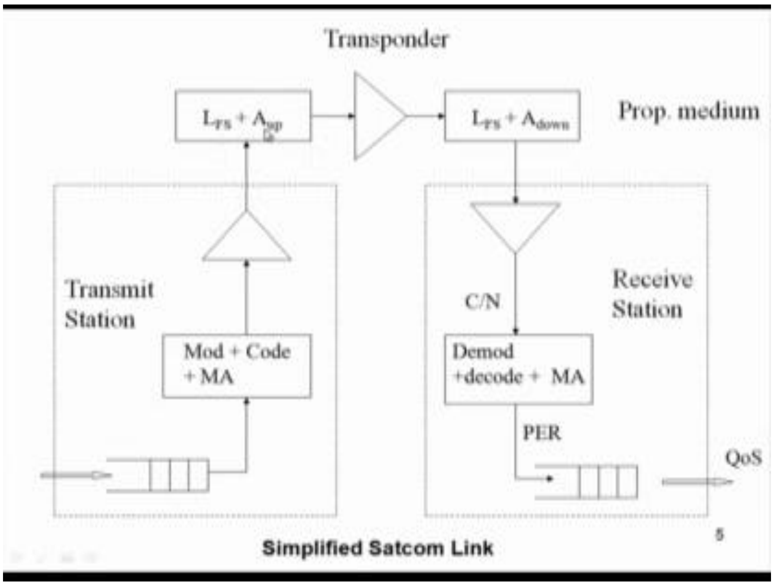


Let us see before that let us look at the total communication link is a Satcom in a very brief way that say it is a packet communication. So, packet circuit at the transportation and based on the multiplexes requirement the packets are multiplexes modulated and if necessary, it is coded, modulated and coded for this code is for electrician coding not the base band coding and then type of multiplexes for many people accessing we will disuse multiplexes and later just you here take this word there is a multiple users are accessing in these case I have drawn only one user.

So, they have to share the transparent that very something call multiplexes there is sharing business is there. So, these are certain blocks sub system in the transmitter station it is up converted amplified and put into the put into the atmosphere troposphere, it is going to the satellite here, the transponder of the satellite and showing as the simply amplifier. So, actually frequency translator also it is amplified, but while going up his signal from the transmitter to the transponder it has certain free space loss or path loss and also in the uplink there is re certain attenuation as we have shown in the last slide that they attenuation it could be dominant when it is rain or rain drops or water type of things.

We will see more details of that there some aping attenuation and that transponder it signal is amplified frequency translated, and down link frequency from the transponder to the receive station comes through again down link free space loss and down link attenuation which is frequency its different if the stations transmitter receive stations co located or nearby located they down link attenuation will be a different because as the frequency is different and if the stations are faraway of course, free space loss and whether the down link is facing the same amount of water contained or different amount of gas are ionosphere there down link a down will be different than a r then it is received at the received station it is down converted demodulate first to demodulator and channel decoder and corresponding multiplexes sub system takes care.

So, at the input of the demodulator we have this carrier to noise ratio which we have discussing last couple of lectures the carrier to noise ratio depending on the demodulator function will be the how much how much good quality or how many errors that will come in the depending on this signal to noise ratio to carrier to noise ratio c by n and the after that let us say there certain packs formed and those packets will be put into the queue to send to the user. So, corresponding to the bit error rate there will be based on the size of the packet there will be packet error rate which will comes out and base on the packet error rate and the user who look the quality of service what how many packets are in error this is a very general very briefly talk about one link of simplified satellite communication.

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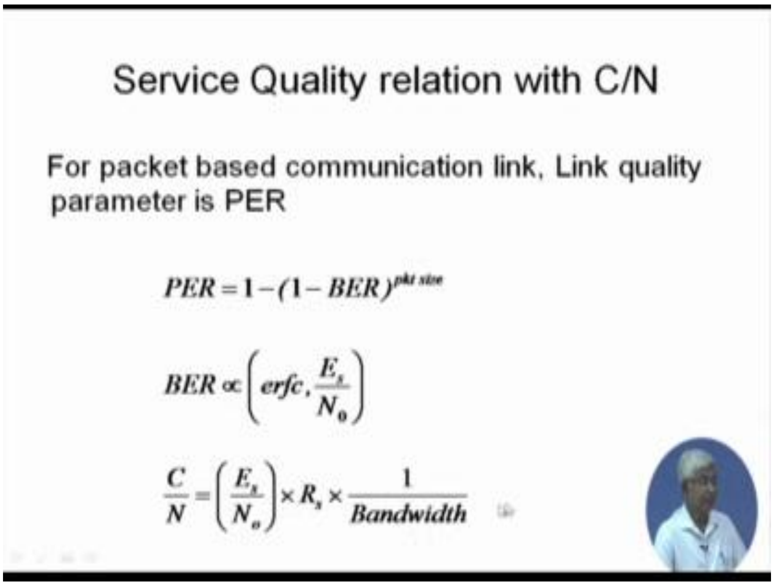


Now, service quality relation with c by n before proceeding further just let us just clear certain things that is for packet communication link quality parameter is generally taken as packet error rate or packet error ratio generally, we will call it packet error rate, but take its actually ratio how many are error out of the total number of packets that it. So, its PER now, this packet error rate and we are very familiar while discussing earlier while we have studied earlier in B. Tech that is the BER; bit error rate in digital communication instead of signal attenuation ratio, we call bit error rate after the demodulator that defines the quality how many bits are in the error out of so many bits.

So, when a packet size is defined in a binary symmetric channel one minus BER to the power packet size and one minus of that quantity is packet error rate. So, this is a simple relation of packet error rate to BER and based on the size of the packet and of course, BER is based on our modulation and that is proportional to the error function complimentary error function and the energy per symbol by noise power density e s by n not, I have called n g plus symbol that is it could be energy per bit also. So, e b by n not or e s by n not whichever be you take it, BER is proportional to this.

Now, this complimentary error function will depend on that type modulation what we used etcetera, but this e s by n naught is actually talking to us about the energy per bit or energy per symbol that is the corresponding to the signal power. So, this is part is important to us see this decrees BER decrees its BER decrees PER decrees. So, there is a relation between e s by n naught e v by n naught to the PER.

Let us see the other way little more clear that is our c by n we were discussing how much carrier power is received and how much noise power we have received c by n. Now, c actually is a total average carrier power received that is power symbol multiplied by the bit symbol rate of power bit multiplied by the bit rate s multiplied by r s here s r is symbol rate or e b energy per bit multiplied by r b in that case it will be b. So, these two multiplied gives us the c that is carrier power average carrier power and n not is noise power by the bandwidth. So, this is multiplied with bandwidth you get c by n that is n n is equal to n zero into bandwidth. So, I can rewrite c by n in terms of es by n not rs and bandwidth as es by n not multiplied by rs multiplied by one by bandwidth.

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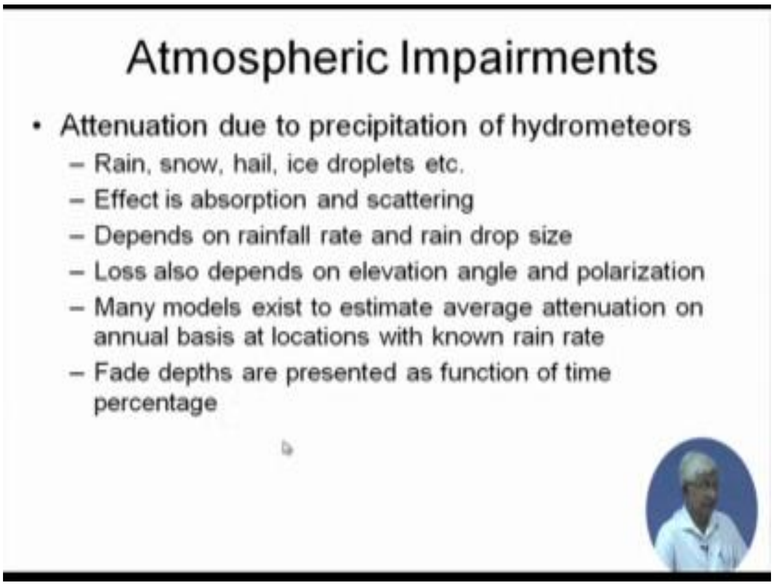


Now, e s by n not is very important and correspondingly c by n not will be affected. So, let us talk at c and n now atmospheric impairments are attenuation due to precipitation of hydrometeors that is rain, snow, hail, ice droplets, etcetera effect is absorption and scattering. You can see that it can absorb and depending since it is a different media that is from free space suddenly it has come or from air suddenly which has another medium has come.

So, from the surface of that particular medium, it will scattered depending on the rain fall rate and rain drop size that we mainly dominating thing is rain will see, and this loss that is absorption will also depends on at what elevation angle and polarization which is coming we will see a little more detail on that and many models exist. It will try to do model because this is a statistical phenomenon. So, many rain drops are there it is not deterministic and the rate of appearing the rain drops in front of the signal is also changing the rain rate.

So, there many models exist estimate the average estimation and that is done on annul basis and a location with known rain rate rain rate is a related to the attenuation people have done got of modeling, but this is very long term basis annual basis now much is the attenuation that called depth fade depth depths and using a word fade here the fade depths are presented as function of time of percentage time percentage we will see a car under stand on that.

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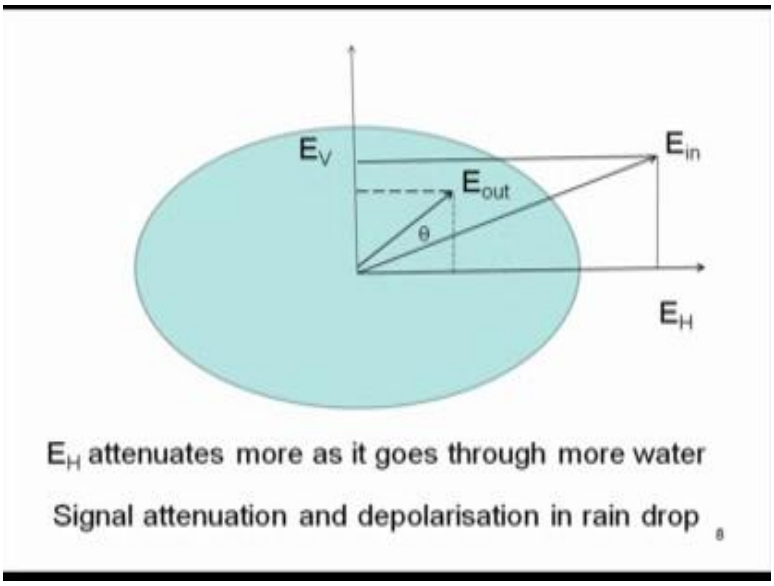

First let us look at the rain drops when rain is ideally created it is a sphere of water drop when it is coming down because of it weighted to the ground because of the air pressure it may take a different form may be a left side. So, in ideal case let us take a rain as a left side it may till that different direction based on the wind speed wind deduction in speed etcetera.

Let us take a simply a steroid which is a rain drop and it is a major access and minor access of that we take and let us see there is a e vector that is the electromagnetic vector e field is falling on the that rain drop falling at a particular angle. So, this is e n e vector which is coming into the rain drop there will be some scattering when the transistor takes place, but what happens inside the rain drop. This rain drop shape is different one side it is a major access side it is more water and less water in minor access side. So, if resolve this e in vector into two components that is horizontal component here. Let us take it horizontal and a vertical component e v is this much and e horizontal or horizontal component is more than vertical component in these case in this particular it angle.

Now, just look at it that is that eh part will get see more water content. So, as water absorbs electromagnetic energy it will be reduced more compare to the minor axis side that is e b. So, let us see e h is reduce to this much were as e v is reduced this much now this resulting to vector when the electromagnetic waves comes out the rain drop will have a different amplitude and different locations. So, e out amplitude is different and e in amplitude and there is a theta rotation of the e vector you can see there is a absorption and polarization change and because of the polarization change also there is absorption is obviously, a is there because of that only its whole thing is happening. So, this general type of diagram showing you that the absorption and depolarization both are happening depending on the safe shape and size of the rain drop and that direction at which angle the input incident e b e vector is hope this as given some clarity to you.

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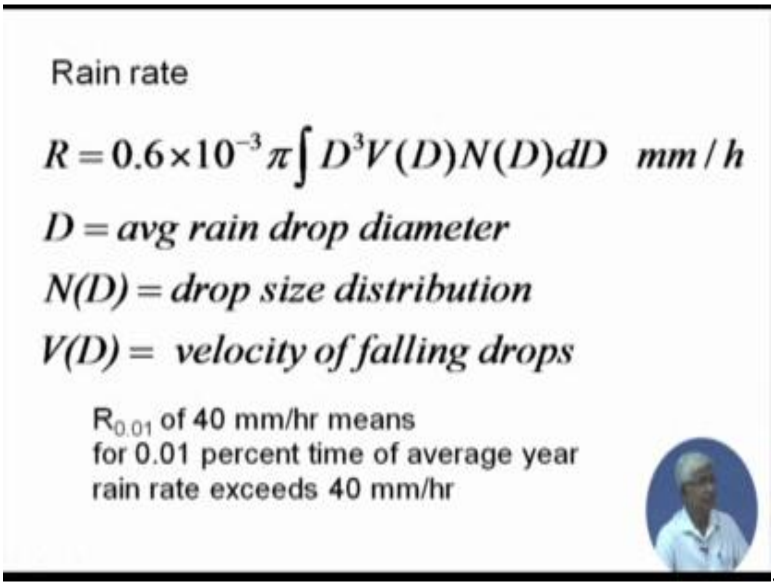


Now, there is another thing, what we get familiar, how do you measure the measurement is generally available called rain rate and rain rate can we modeled in terms of the diameter of the rain drop average diameter d; d is a average diameter of the rain drop the velocity of these rain drop through which it is going towards the earth that is the precipitation velocity and d is drop side distribution that is in s one cubic meter how many such rain drops are there. So, that is a density of the rain drops. So, every either cubic meter or cubic centimeter which we have wave view take the unit cubic millimeter whichever you take there is a distribution which will vary from spatial which will vary place to place.

So, the model relation is the rain rate is equal to point six into ten minus three pi and the integration of rain drop diameter cube velocity of rain drop and the drop size distribution that will be available in millimeter per hour and this is a measurable quantity what is measured our metrological departments what they announce the measure and many other agencies also they measure over a area how many millimeter of rain fall has happen in an hour. So, actually they do it any different way, but whatever announcement they make that is millimeter per hour. So, many millimeter of rain drop per hour it is happen. So, these gets recorded and this model is available that is called rain rate. So, rain rate unit is millimeter per hour and a model like this is available.

Now, it is take like that r 0.01 of 40 milliliter per hour what is the meaning of that this the 0.011 percent of time of a average year every year rain is not same rain rates are not same. So, year is 365days then multiplied by 24 hours. So, in the average year a 0.01 percent of the time this 40 millimeter per hour rain rate exceeded it might have rained at some place only for few minutes 50 millimeter per hour which is more than 40 millimeter per hour and some other time half an hour for 40 millimeter per hour.

So, like that those whole year if you cumulatively add them and then you can find the 0.01 percent of the time that is 0.01 percent of 365 days multiplied by 24 hours is during that much time you can calculate that how many how many hours it is how many minutes it is. So, that much time cumulatively in average year rain rate has exceeded 40 millimeter per hour.

I repeat r 0.01 of 40 millimeter per hour is the cumulative percent of time in average year then the rain rate has exceeded 40 millimeter per hour, it may be 50. Therefore, for 0.001 percent of the time when it less percent of the time it might have exceeded 50 millimeter per hour, which is normally the meaning of this slide this 0.01 percent of the time is generally accepted thumb rule. So, people normally refer rain rate as 40 millimeter per hour means it is 0.01 of time, but we can go to specific that for 0.001 percent of time for 0.0001 percent of time what very short time the you can see that we might design a system where the attenuation which is happening that can be taken care for this much path time, but we may need a system where main freely or loss of signal much less time. So, I should look for a rain rate 0.001 percent or much lower than that.

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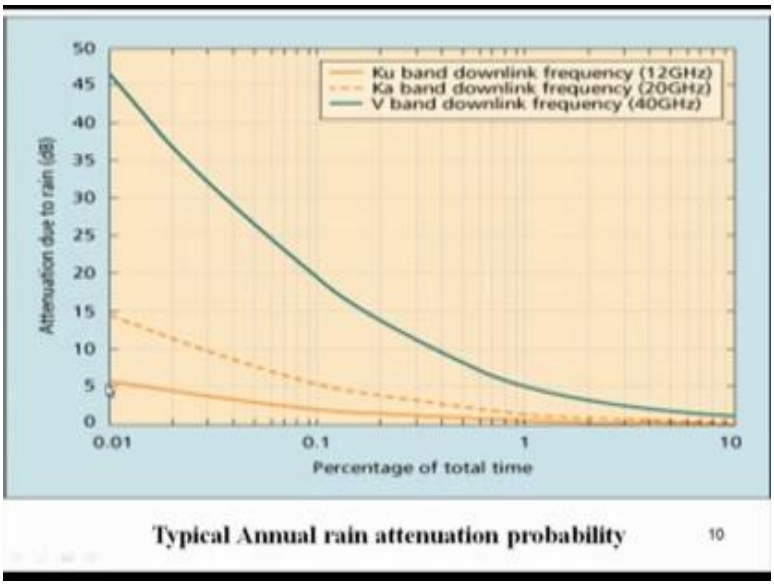


Now, this you can see the curve here of course, there are three different frequencies that is 12 gigahertz, 20 gigahertz and 40 gigahertz, three curves are shown and for these three curves the total percentage of the time of a average year in the x-axis and the attenuation due to rain in d b is just plotted it is take any one of them. Let us take the dominant one lets a 40 gigahertz one which is this blue line you can see that one percent of the average year of the time that is 3.65 the attenuation is 5 d b whereas, 0.01 percent of the average year which is 0.365 days means it is only 0.365 multiplied by 24 hours.

So, that may in minutes there rain rate has is, for this rain rate you have attenuation of 20 d b. So, this is much more than for a long for a longer duration of time. So, for a short duration time there may be burst of rain heavier rain. So, attenuation during that time is much more for longer duration time the burst of heavier rain for short duration or all accumulated together you can have an lower attenuation. So, what your quality of service that means, how much time I can give a guaranteed service that why my at system will not fail will not go below the signal to noise ratio or edit noise ratio level you can determine and accordingly that much attenuation should you should protect.

So, this are the many you can see that Ku band which is very common man as a talking 12 gigahertz, it is 0.01 percent of the time is roughly more than slightly more than 5 db. So, we stop here for the time being and will continue this discussion in the next.

Thank you.