Satellite Communication Systems
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Lecture – 20
Propagation-2

Welcome back. We were talking about the propagation channel and signal impairment particularly microwave signal; signal which is coming from satellite or going up to the satellite what impairments happen in this propagation channel and particularly we will discussing about the ionosphere where the effect is very small and then we came to the troposphere where we discussing about the percentage of the time attenuation how it is shown. So, let us go back to the last slide what we are discussing that is it is generally available that for a percentage of the average year.

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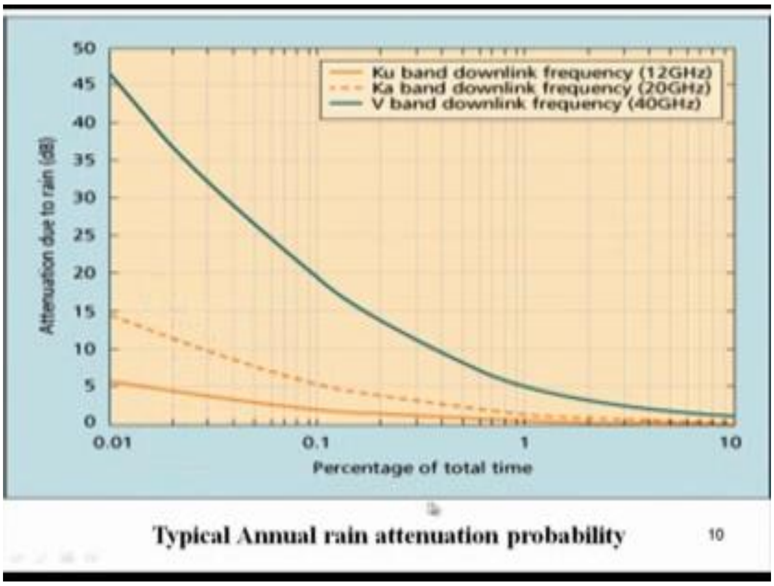

The rain occurs and because of that rain at different frequency level what is the attenuation in dB here.

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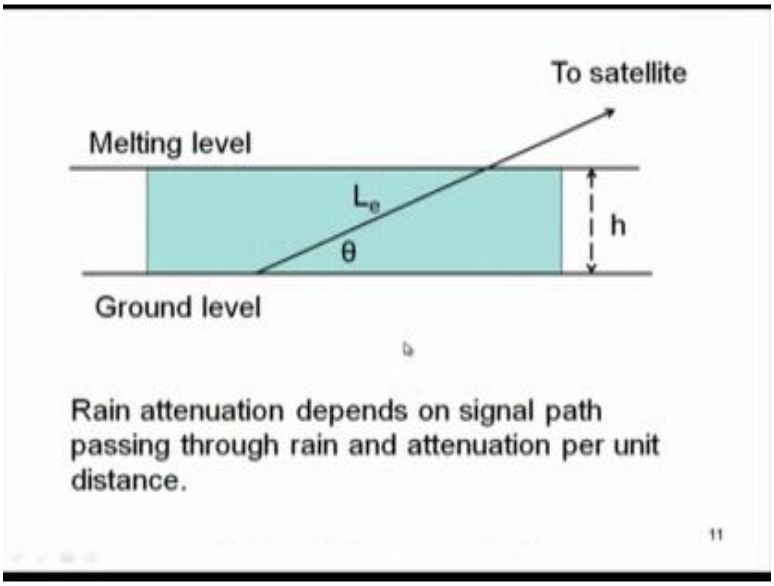

Let us go to the next slide. Let us look at the rain a little more little more deeply normally. This lets say this is the ground level and from the ground level as we go up vertically up in the sky the temperature is suppose to go down slowly. So, at a height normally at the temperature on the ground level may be 30 degree centigrade and sometimes then summer it may go higher as we go up this temperature reduces and it may go to 0 degree temperature 0 degree centigrade and below that it will be minus.

So, if there are water vapor that is cloud is present at they and if there is a formation of water droplets that will be at higher height that will be forming ice and that ice will start melt that is called melting level is at when it is that 0 degree is occurring below that it will be higher temperature. So, at this height ice melt this is very ideally shown actually this height varies, but generally thumb rule is about 4 to 4.5 kilometers to 5 kilometer vertically up this is the melting layer or 0 degree ice people call it different names, but it is at this point 0 degree and when the rain occurs or at due to some other reason the atmosphere.

If the temperature is lower this height may come down during the raining season monsoon season this height may come down to 4 kilometer or even lower, but that depends on place to place and environment and environment a season to season etcetera this is just some formula we showing ideal case let us take at a height h the melting level is occurring and from the ground level a signal is looking to sending to the satellite at a alleviation angle theta.

So, it is not the directly vertical height it is the signal how much length it is passing through this water and this green, this blue area is rain, it is the let us assume it is fully covered by the rain it may happen only part of this signal is passing through rain rest of the part at this height even it is not passing to the rain those are the different cases I am taking simple case where it a strati form rain.

So, rain attenuation depends on the signal path passing to the rain and the attenuation per unit distance per unit kilometer how much is the attenuation it is based on the that you can calculate the rain attenuation simple formula that is that a 0 that is attenuation for 0.01 percent of the time that point 0.01.

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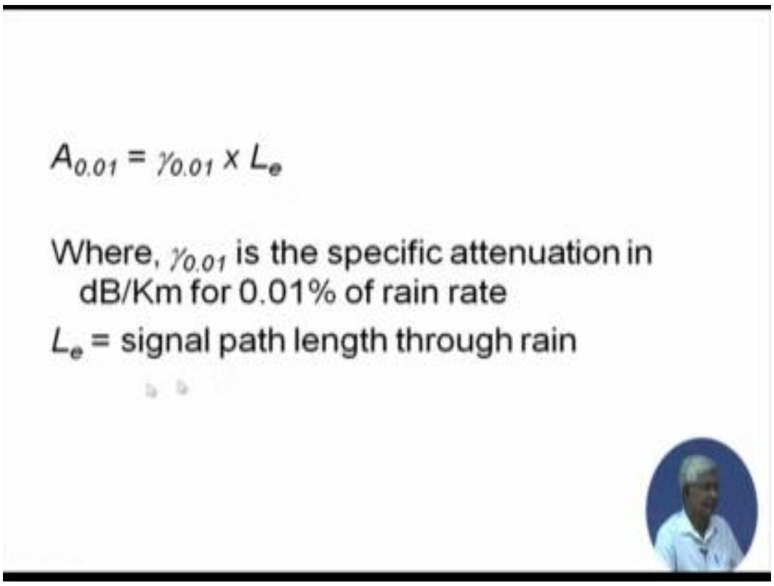

You know rain rate we have talk earlier is equal to gamma of 0.01 into l e what is gamma where gamma is called specific attenuation that is dB per kilometer, how much how many dB per kilometer for 0.01 percent of the time what is of the rain rate. So, gamma 0

.01 has to be return and l e is that length slant length through which the signal is passing through the water that is the rain signal path length through the rain.

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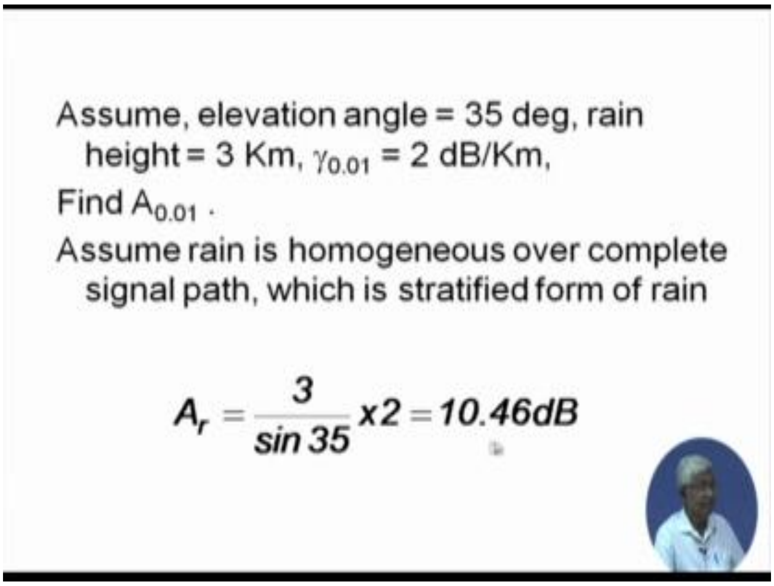

So, let us do a very quick calculation to understand the numbers that is assume that is elevation angle of 35 degree to the satellite from ground station and the rain height is 30 kilometer direct vertical height at 3 kilometer the rain is occurring and specific attenuation for these particular rain is gamma is 0.01 is equal to 2 dB per kilometer. So, find a, at the attenuation 0.01 a find a assume rain is homogeneous as we are shown in the last picture over the complete signal path which is namely stratified form of rain.

So, a R is equal to the attenuation due to rain is 3 by sin 35 because of the angle that is hypothesis multiplied by 2. So, it is 10.46 dB you can see though it is 2 dB per kilometer because of this 35 degree angle you are getting 10 dB attenuation. Now, let us look at this unit that is this parameter that is gamma from what this gamma depends which is 2 dB per kilometer if these increases whole thing increases if these decreases this is the whole thing decreases these depends on the frequency polarization etcetera.

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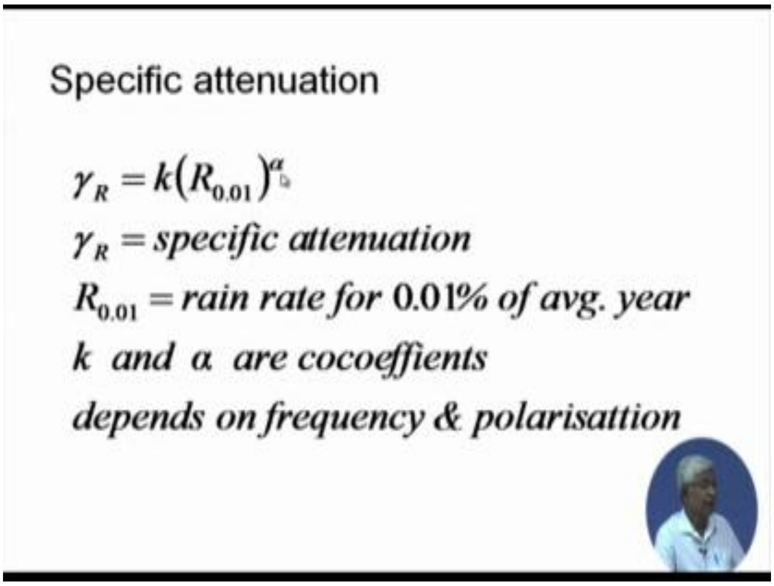

So, specific attenuation is modeled as a power model is there 2 constant k into rain rate at 0.01 percent of the time to the power alpha the k and alpha are two coefficients were gamma R is the specific attenuation of the rain and R capital R 0.01 is a rain rate for 0.01 percent of the average year. So, this k and alpha depends on the frequency and polarization details are available in the books. So, it just gives you idea that it varies based on the polarization and the frequency and of course, the rain rate the gamma R will change.

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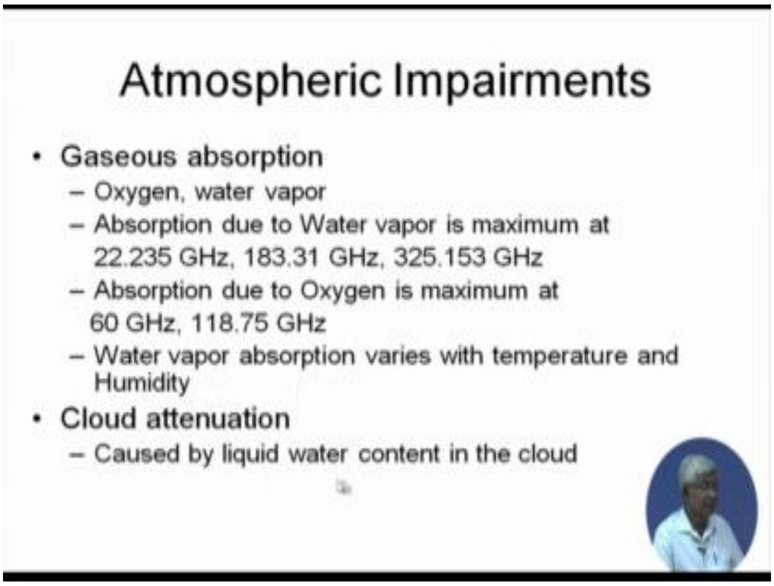

Now, what are the other possible attenuation other than rain there could be gaseous absorption you know where is form gaseous, which is oxygen may be water vapor also in the in the gas form of water then it is been seen that absorption due to water vapor is maximum at some particular frequencies that is at 22 gigahertz, 183 gigahertz, 325 gigahertz, etcetera and absorption due to oxygen is maximum at 60 gigahertz, 118.75 gigahertz, etcetera whatever the absorption varies with temperature and humidity there is; obviously, and there is water vapor is another form is cloud.

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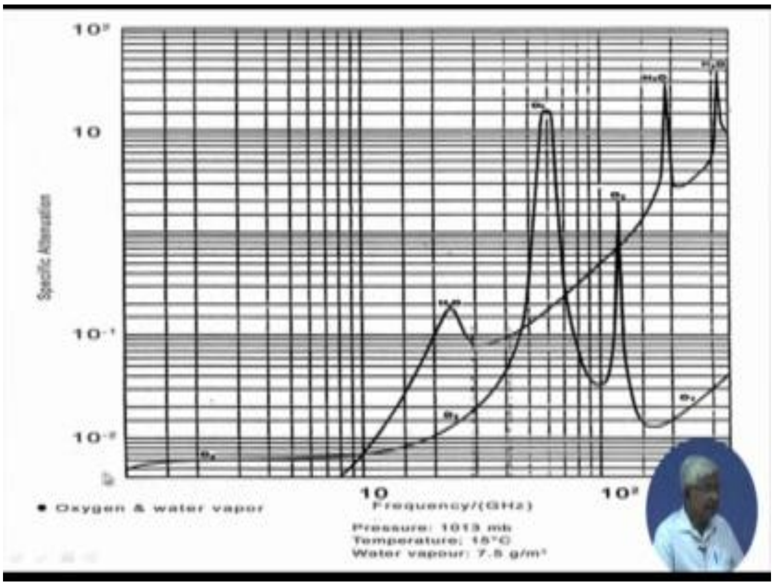

So, which is caused by liquid water content in the cloud and there are certain plots which people have a experimented and plotted particularly above sea level that is at a particular pressure temperature and water vapor content of that there two curves shown here which two over that is water vapor and you can see the x-axis is a frequency this is 10 gigahertz, this is 100 gigahertz. So, the range where we are normally operating satellite communication, you can see that is 0.1 dB per kilometer then at some point it peaks it lowest down and the goes up again at higher and higher frequency see may be oxygen peaks around 60 gigahertz first peak then subsequent peaks are there.

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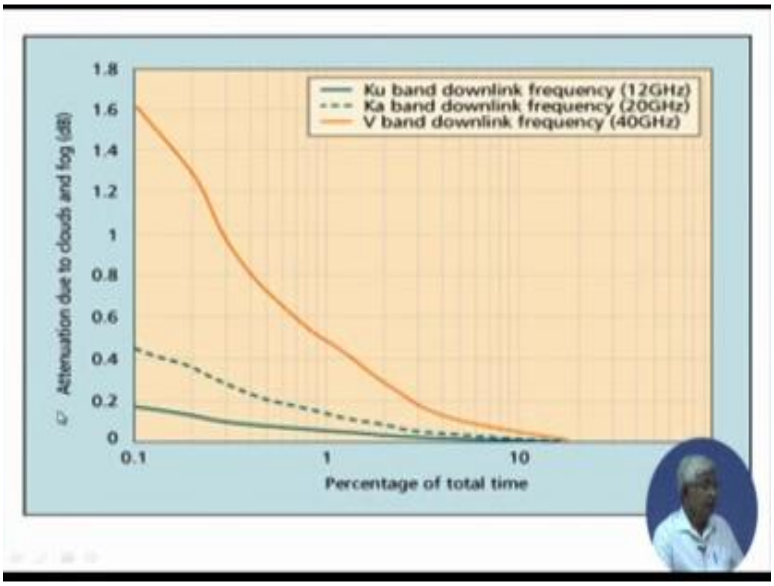

So, these are people have experimented and plotted these can be taken as a some numbers what calculations are initial estimates here I will show you some other plots that is percentage of the total time attenuation due to cloud and fog again for this different frequencies, 12 gigahertz, 20 gigahertz, 40 gigahertz, etcetera. So, there this different part of fog h in d b, but you can see the values of the dBs much, much lower compare to the rain at different percentage of time at different frequencies.

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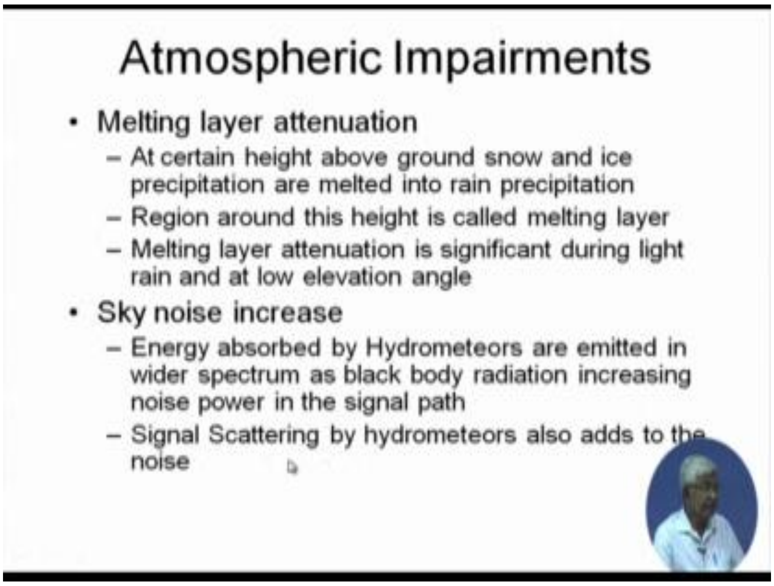

Then atmospheric impairments melting layer attenuation at certain height above ground snow and ice precipitation are melted into rain precipitation we already mentioned these one region around this height is called melting layer melting layer attenuation is significant during the light rain and low elevation angle, etcetera there is a effect is sky noise increase energy absorbed by these hydrometers are emitted in the wide, wider spectrum as block body radiation in increasing the noise power in the signal path. So, it absorbs the energy we radiates and all over the big spectrum. So, it is black body radiation with a increasing noise power signal scattering by hydrometeors also add to the noise scattering from other particulars add to you can say noise actually interference.

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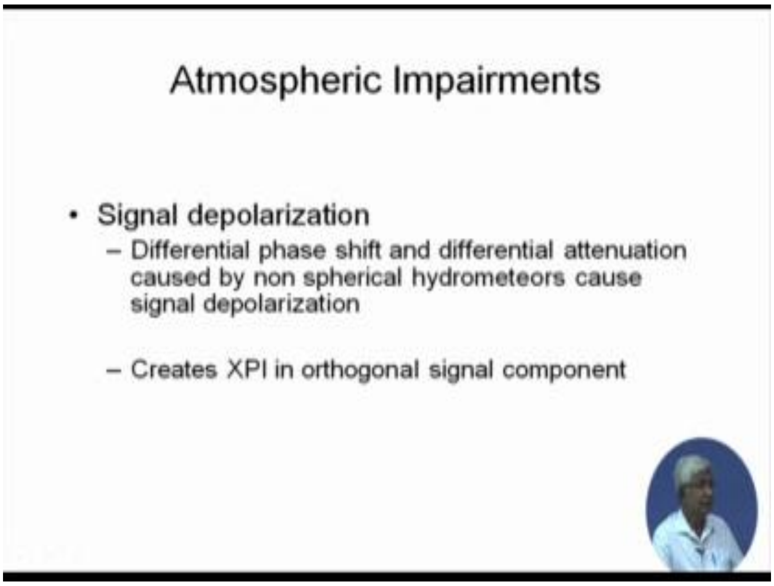

Then other interference other effect is signal depolarization we have seen rain drop depolarization differential phase shift differential attenuation caused by non spherical hydrometeors cause signal depolarization we have seen and it creates cross poll interference orthogonal signal component obviously, because your polarization has change.

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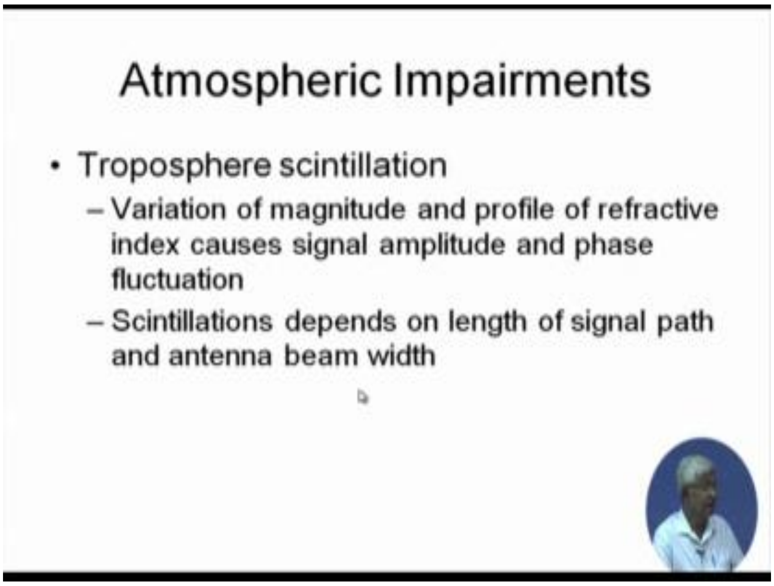

So, the cross polarization effect will be there if there is a orthogonal polarization communication going on the same path. Then there is something like ionosphere, scintillation troposphere, and scintillation can also occur with this small bubble like thing higher density and in a smaller region for smaller time. So, this variation of magnitude and profile of refractive index causes signal amplitude and phase fluctuation these scintillations depends on length of signal path and antenna beam, etcetera how much if the antenna beam which is very large then scintillation effect is very small this scintillation is very fast.

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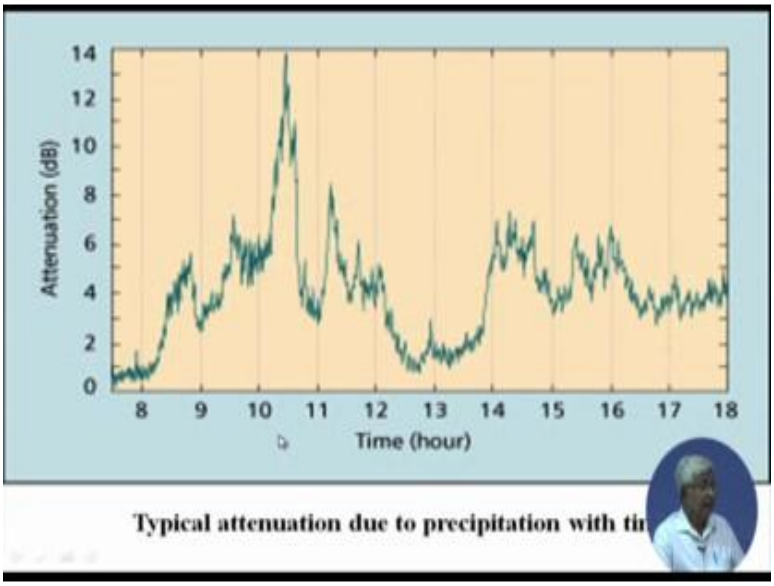

Therefore, the you can see the times are shown in hours here and you can see that attenuation is fluctuating sometimes very high again low high low, this is very important because we are not really communicating though we see availability of the signal over the year we can guarantee, but we have to see the effect of the signal in a very short period of time that is few seconds a very important event is going on in your watching in the TV and suddenly the signal get disturb for few seconds that is disturbance.

But, if you see in the over rate over the average year then very small time people, but if there is important event going on you may miss you might miss that boundary hit by Tendulkar or Virat Kohli just it that moment signal get lost I will be irritated for that, but your service provider may say that what the average year it was only few second. So, it is very important depending on the purpose you are using the communication for.

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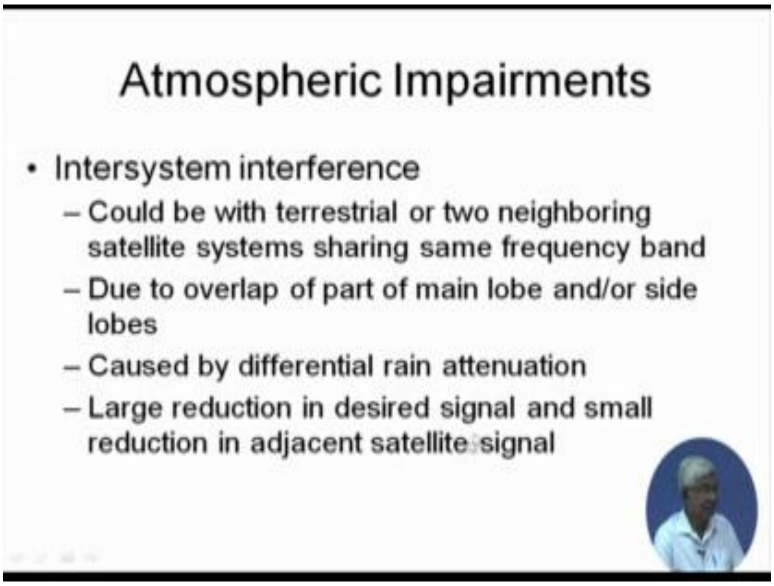

So, there is other possibilities are inter system interference that is the could be with terrestrial or two neighboring satellite systems sharing same frequency band, we have seen the C by i effect in the last period due to the overlap of part of main lobe or side lobes based on the antenna again and caused by differential rain attenuation caused by differential rain attenuation at the different signal path. So, they can they can scattered interfere and large reduction in desired signal and small signal reduction in adjacent signal path. So, there are possibility of inter system interference because of the rain which is coming.

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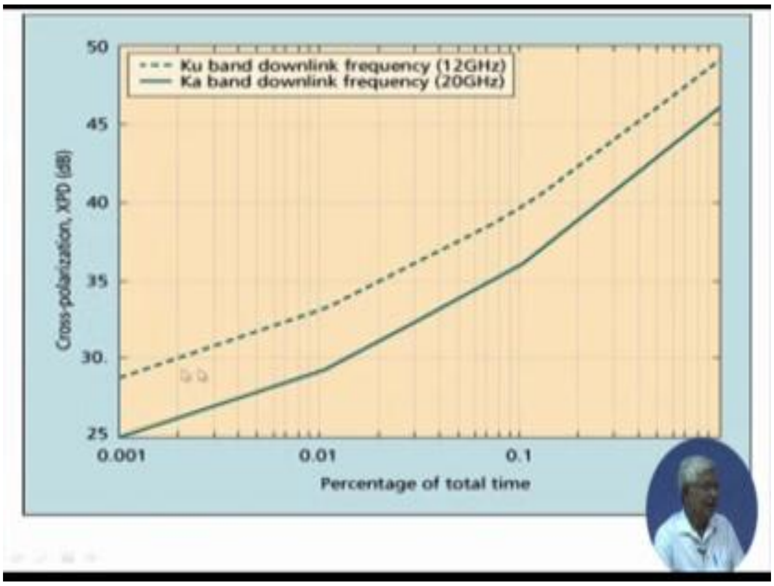

And that cross poll discrimination could be are plotted these are all again average numbers people have taken an based on certain experiment that is percent of the time, you can see very low percentage of time and cross poll interference is quiet high at two different frequencies.

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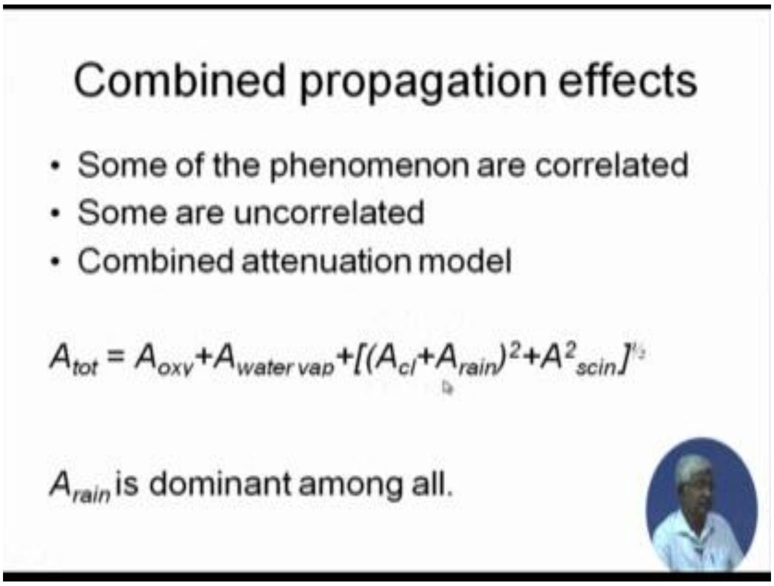

So, there are combine effect of oxygen water vapor cloud rain scintillation, etcetera some of this phenomenon are correlated some of them are uncorrelated. So, there is a model people say that total attenuation because of then can be can be framed as attenuation to oxygen plus attenuation due to water vapor plus attenuation, due to cloud and rain square plus attenuation, due to scintillation square and the whole thing square root of that is a certain model people have done and this is a combine attenuation model and the a rain out of that is most dominant for our frequency of interest right now.

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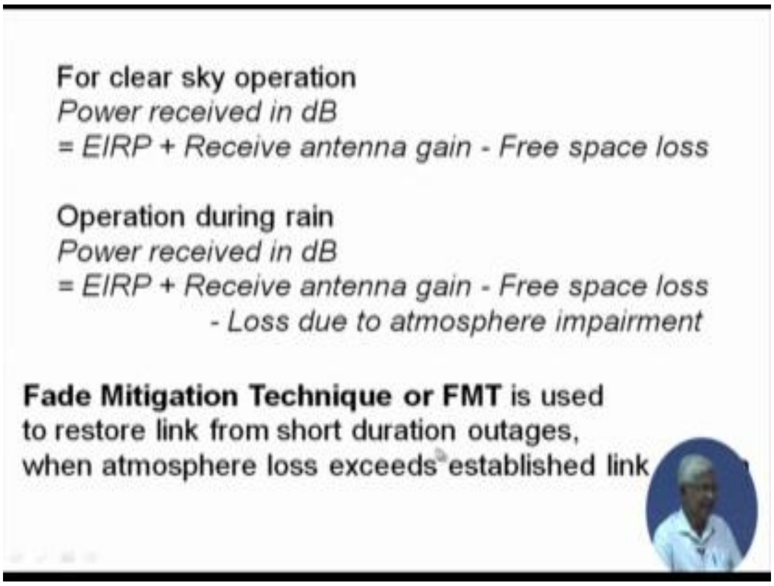

So, let us go little more deeper that is in a clear sky operation really what happens to our signal what happens to our EIRP and G by T, let us see the power received in dB is what is transmitted that is EIRP with the gain of course. So, EIRP and the receive antenna gain and free space loss and this is in the case of clear sky there is no rain and during rain power received in dB will be same EIRP receive antenna gain minus free space loss and minus loss due to atmosphere impairment no this plus minus all these things when we have to talking it is dB you have to remember that.

So, something is adding that is loss due to atmospheric impairment. So, we have to mitigate this that is called fade mitigation technique or FMT that is used to restore the link from the short duration outage, just now we talked about Virat Kohli hitting a six that short duration outage when the atmosphere loss exceeds the established link margin, so that is the fade mitigation technique it could be the longer duration also, but many people are interested in this short mitigation short time mitigation.

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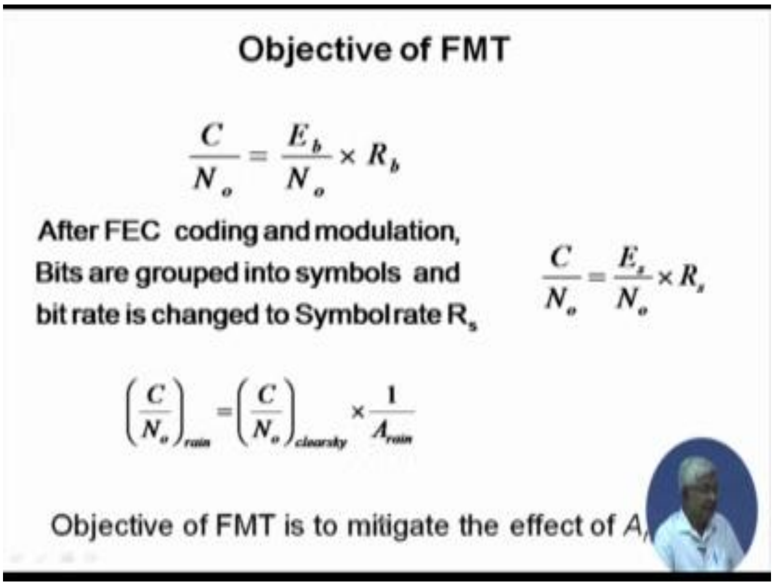

So, objectives of the FMT I put it in a slightly different way you just see C by N naught is C is e b into R b is energy per bit into the bit rate energy per bit into bit rate. So, e b by N naught into R b now after FEC N coding and modulation that FEC is forwarder direction it is forwarder direction coding error control coding which improves the errors after FEC coding and modulation bit's can be grouped into symbols. So, this R b can be called as R s. So, it is a symbol rate instead of bit rate. So, e b by N not be calling as e s by naught and R b can be called as R s. So, C by N naught can be stated as e s by N naught into R s.

Now, let us look at this one very important this is in ratio C by N naught rain is C by naught clear sky reduces by rain attenuation a rain this clear sky is now reduced. So, you get C by N naught rain. So, we have to go back to this.

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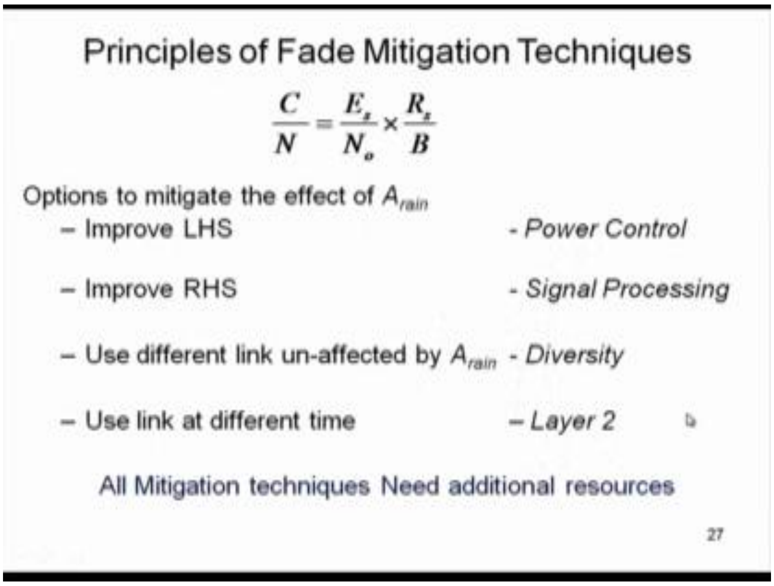

So, were to counter the effect of a rain. So, objective of FMT is to mitigate the effect of a rain. So, fade mitigation can be done in various ways that is again we go back to that C by N instead of N naught C by N is e s N naught into R s by b; b is the band width. So, N naught into b is N options to mitigate the effect of a rain is to improve the left hand side C by N and that is done by power control and you can improve the right hand side that is called signal processing and you can use completely different link which is unaffected by a rain. So, it is called diversity or you can use it in different time then it is layered two that above the physical layer, it is called automatic repeat request etcetera. So, there are various possible techniques to mitigate that will.

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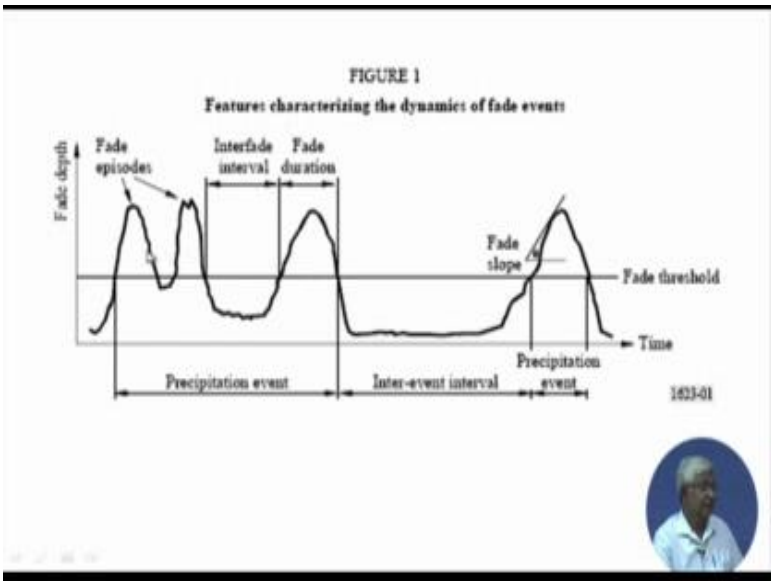

Let us see one by one will see. So, all mitigation techniques need additional resources, we have to remember that any mitigation technique we do additional resource are required how much let us see. Let us see in short term mitigation short term fade there is a fade depth in the y-axis, then these x-axis is the time and this is the plot available from a paper you can see that with time there are some precipitation is occurring and no precipitation that is inter event interval again precipitation event it is occurring.

So, whenever precipitation event is occurring it going above the higher fade depth higher fade depth more attenuation you can see, but this not constant it is varying over times sometimes it come down sometimes goes up. So, these are called fade episodes and there are certain inter fading interval. So, during the precipitation when the rain is occurring there would be small breaks or reduction of the total water content that is falling and this duration is called fade duration when it is above certain fade threshold.

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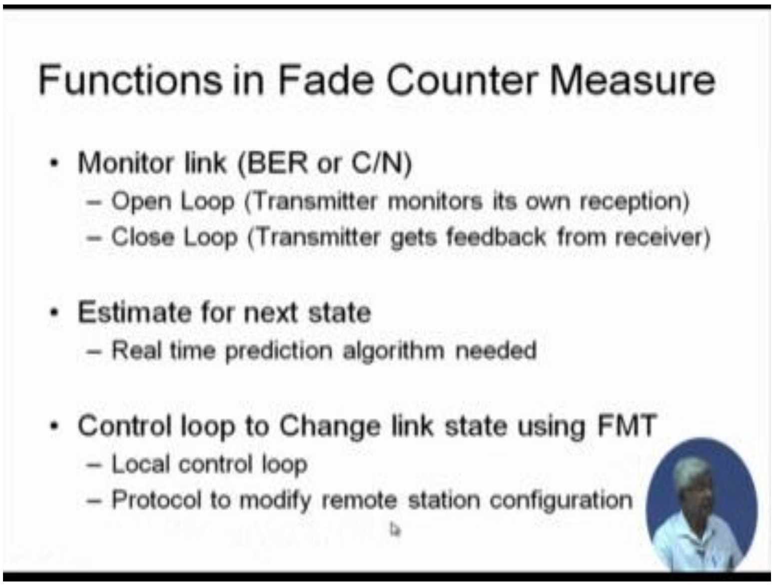

So, up to the fade threshold system is able to operate this much attenuation is able to take beyond that we have to take care. Now, function of fade counter measure or mitigation is first you monitor the BER or C by N then that is possible with the open loop that is transmitter monitors it is own reception the transmitter monitors it is own reception. So, the transmit path is what is happening is knows that is going to satellite and satellite is rebroadcasting back some power is coming back to satellite assuming the transmitter receiver whole thing is both are in the transmit receive antenna gain control of the satellite coverage of the satellite and it could be close loop a transmitter gets a feedback from receiver that how much receiver that means, up link and down link both towards the receiver it is also known to you.

So, you estimate the next state first you monitor and next mate the next state and then real term prediction of the algorithm is needed because real time you are doing and because you have to predict what is going to happen and accordingly you have to take a counter measure or mitigation. So, control loop changes the link state using the fade mitigation technique which could be local control loop or which get be protocol to modify remote station configuration itself because which if it is happening on the down link you have to modify the remote station configuration.

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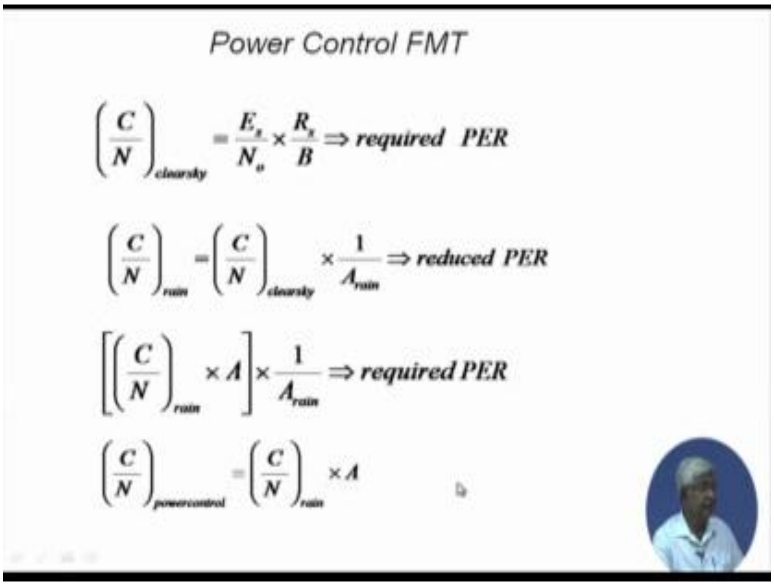

So, power control is done by the by a technique let us say how it is done C by N clear sky is e s by N naught into R s by b that is required PER corresponding to this e s by N naught and during the rain C by N due to be rain is clear sky C by N is attenuated by one by rain it is in ratio is reduced PER because now the C by N is reduced. So, it multiplied by a. So, that you get back the required PER C by N during rain multiplied by so that means, time attenuation which was happening that has to be that C has to be increased by this mainly dB at though it is show in ratio this much amount C has to be increase in the this much amount. So, by C by N power control we mean that C by N power control C by N rain multiplied by A or in dB it will be plus A, A is the attenuation due to rain.

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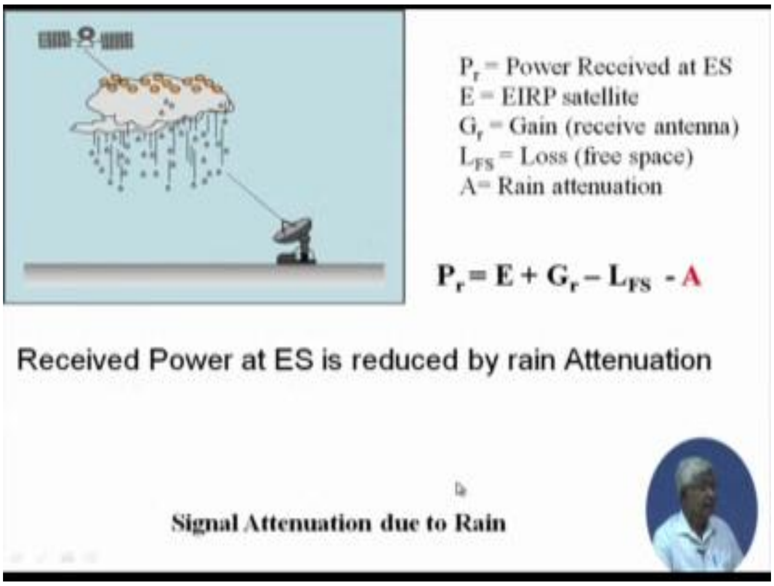

As shown in different way picture that is as if it is a satellite transmitter and ground is C b. So, power received at the station is p R and the same equation p R is e of the satellite plus the gain of the receiver antenna minus path loss free space loss minus the attenuation a and receive power transmission reduced by rain attenuation, but then some more things are happening that is look at it carefully that is rain absorbs microwave signal and it raises the rain water temperature some energy it is absorb.

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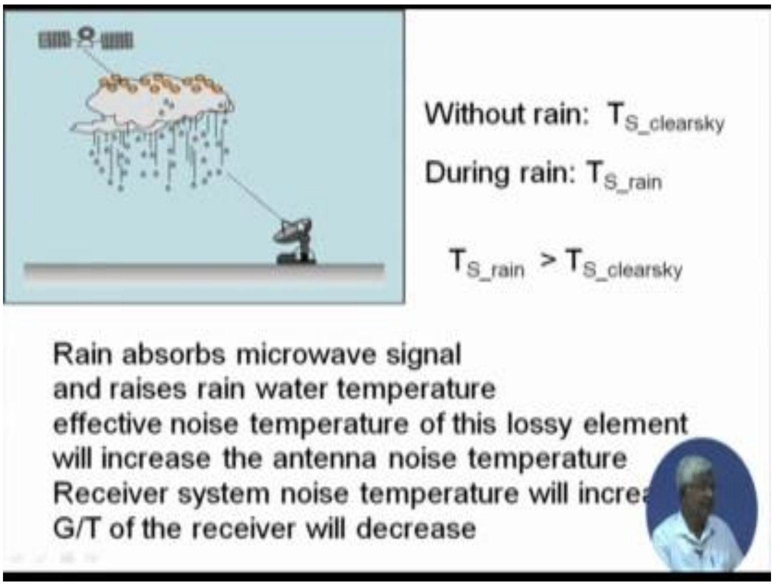

So, rain water temperature has increased slightly we can see the effective noise temperature of this lossy medium because it is absorb absorbing things. So, it is lossy medium. So, this lost element affective noised temperature has increased; that means, this receive antenna temperature which was looking at clear sky only and getting the brightens noise background noise from the clear sky now in addition to that this is also added actually background noise will be reduced by this amount because this a loss, but something will remain and this loss is introducing it has effective noise temperature.

So, it is giving some more noise. So, they effective noise temperature of this element is increasing in that will increase the antenna noise temperature. So, let us see without rain it was. So, antenna temperature increase means receiver noise and antenna temperature together it is system noise temperature of the receiver. So, that is T s. So, without rain let us call T s clear sky and with rain during rain is called T s rain. So, T s rain is more than T s clear sky because temperature has increased effective noise temperature. So, the receiver the receiver effective noise temperature has increased system noise temperature has increased due to during rain.

So, what is happening because of that because of the receiver system noise temperature that is increased and that means, that receiver G by T is decreasing because receiver gain is antenna gain G remains constant and T has increased during it. So, two things are happen one is this signal power has been reduced another is G by T has decreased. So, double effect.

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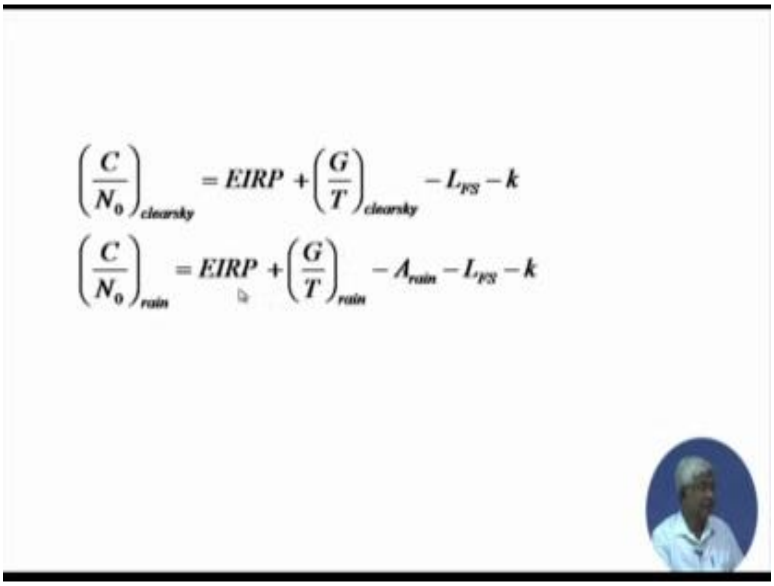

Therefore, your C by N naught in clear sky which is EIRP plus G by T clear sky minus free space loss minus k now it is C by N rain C by N naught rain it is EIRP plus G by T of rain minus a rain minus l f s that is path loss free space loss minus k. So, EIRP reduced by a rain and G by T is also reduced. So, double effect is happening because of that.

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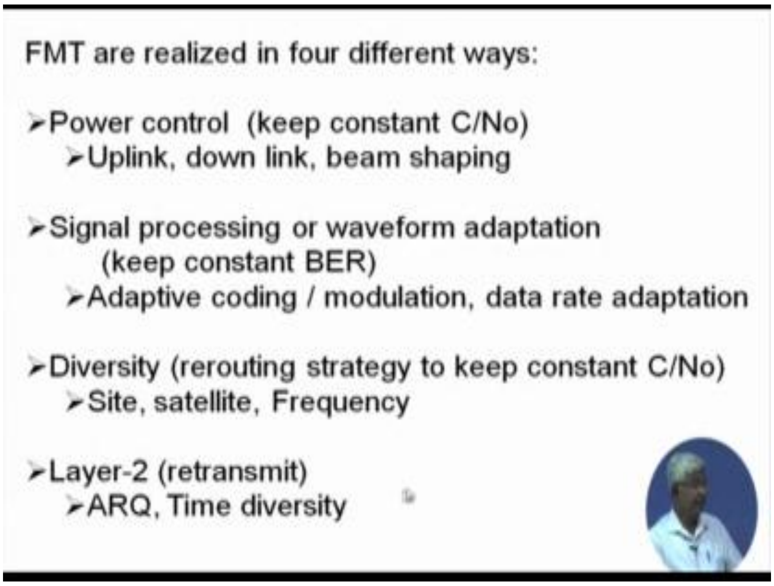

So, FMT is realized that is technique realized in four different ways power control uplink down link and beam shaping and signal processing or waveform adaptation keep the constant BER by changing the coding modulation or data rate will discuss these things as well as there is diversity that is site diversity satellite diversity and frequency diversity and could be layer two this four different techniques we have briefly talk earlier.

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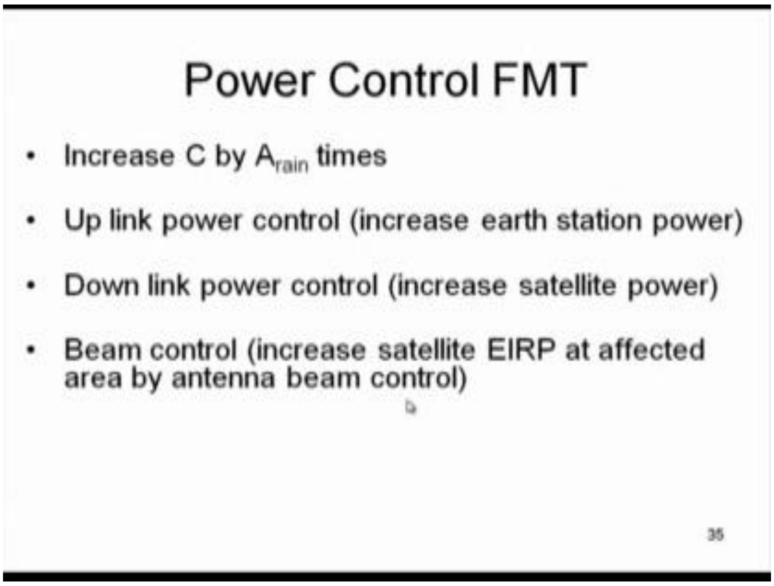

So, let us quickly go through the power control FMT they increase C by rain a rain times that is whatever attenuation due to rain uplink power control increase the earth station power if I increase the earth station power what happens or it will be increasing down link power that is from the satellite power or it could be done by beam control that is increase satellite EIRP at effected area by antenna beam that is the gain of the antenna transmit antenna increase. So, that EIRP increases over that area focused area.

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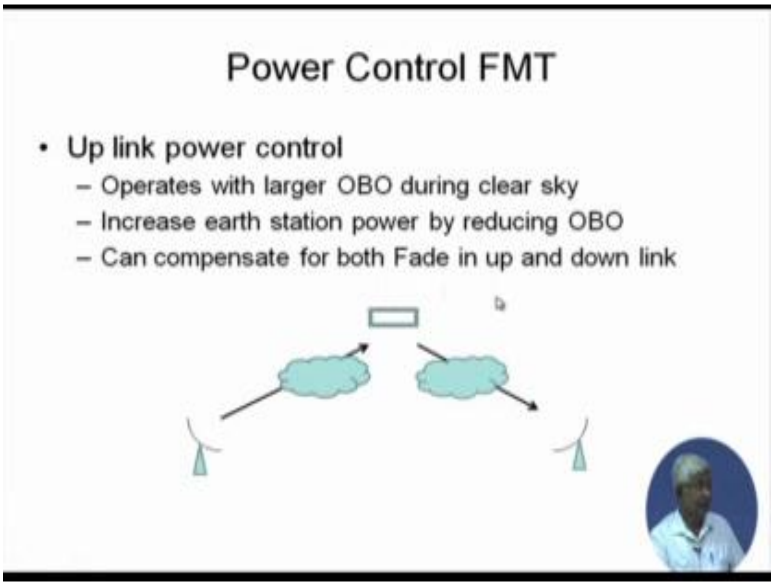

You can see the uplink there is some rain shown here cloud there is rain down link also there is some rain. So, up link power control it operates at larger output back off during clear sky you know output back off if you remember that that was non-linearity is coming you have to operating the non-linear region. So, if we have to increase the increase the EIRP you have you have suddenly getting to the non-linear region. So, therefore, in the clear sky you have to operate with the larger output backup. So, that even during rain when you increase the EIRP it does not exceed the linear region and enter into the non-linear region now they earth station power is increased by reducing the output back off and it can compensate both for fade in up and down link.

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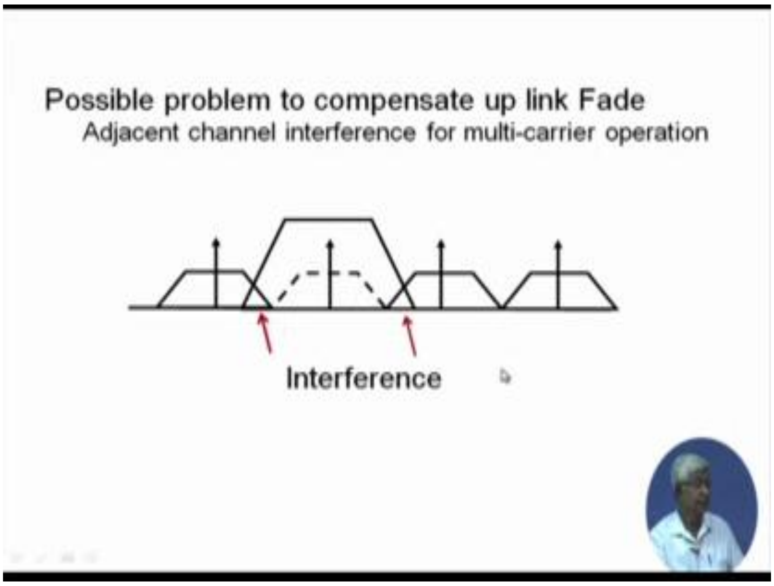

The possible problems because of that is because you are increasing the power adjacent channel interference in the multi carrier operation can take place that can be shown like that that you have this is the different transponders which is adjacent channels this is the frequency x axis and y axis how much is the power you have to operating now this type of segmentation transponded separation we have seen in the space craft discussion.

Now, one of the transponded if I go on increasing the power, it is some of the power will fall more will increase more and fall into the adjacent channels or adjacent transponder band. So, that is call adjacent channel interference pictorially it is shown here. So, similarly adjacent satellite interference can occur nearby satellites.

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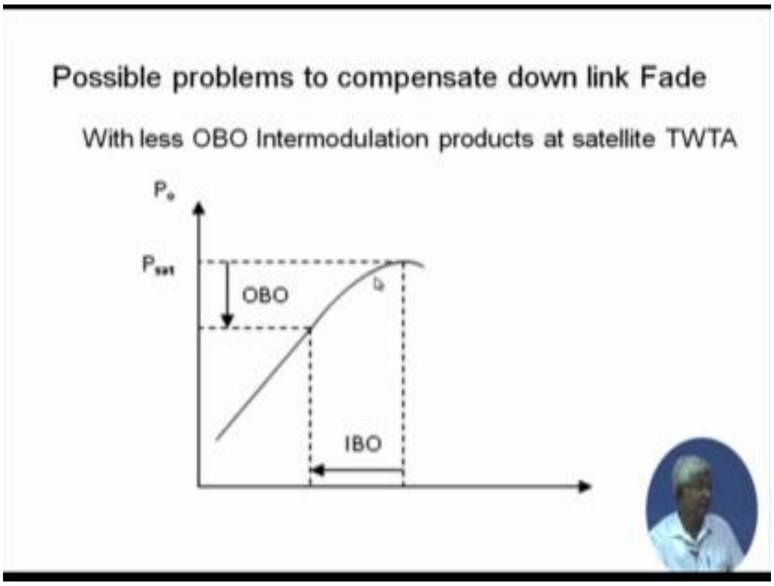

And a possible problem in downlink fade is that non linear curve of satellite. So, you to operate in the linear region you have to give an output back off. So, when you jack up the power this side by increase the input power it should not entering to non-linear region initially you have to operate more and more lower region that means your output power much lower.

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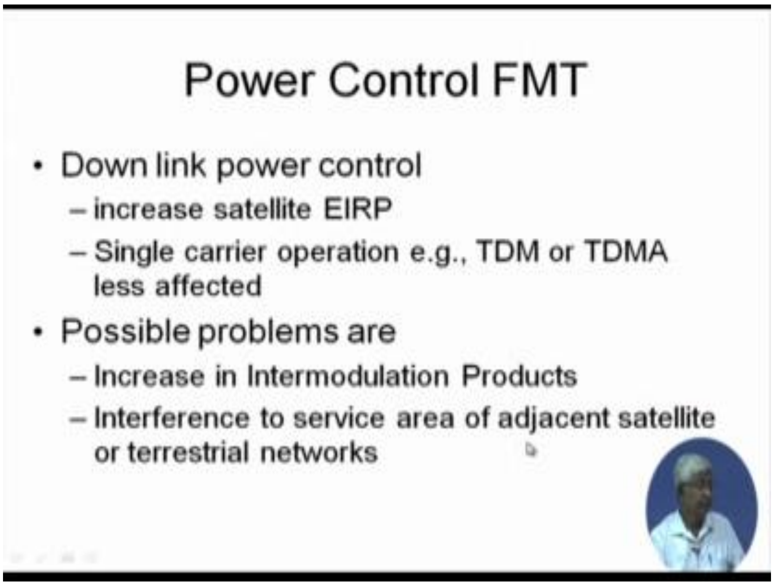

So, with less output back off inter modulation products at satellite I mean if you give it less there will be inter modulation product due non-linearity down link power control increase the satellite EIRP single carrier operation if you increases satellite EIRP, this inter modulation does not occur when it is a single carrier operation that is TDM or TDMA which is less effected or satellite TV broadcast is normally in TDM possible problems could be increase in inter modulation product if there multiple carriers and interference due to service area of the adjacent satellite or terrestrial networks because you increase the power where the rain is not there where there is clear sky the area which is seen clear sky and satellite power is going there here increase satellite power. So, it will have the effect of the terrestrial network or it will act as a C by i to the adjacent satellite operator that C by i, we have discussed earlier.

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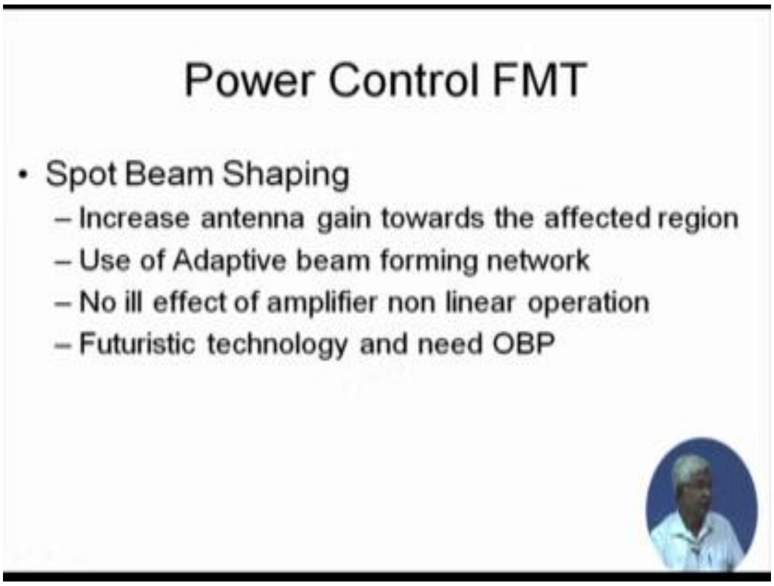

It could be done by spot beam shaping increase antenna gain towards the affected region use of adaptive beam forming network now it will effect of amplifier non-linear region because you are shaping the beam only not the amplifier you are changing your increase the EIRP by linear control of the antenna and futuristic technology you need process etcetera.

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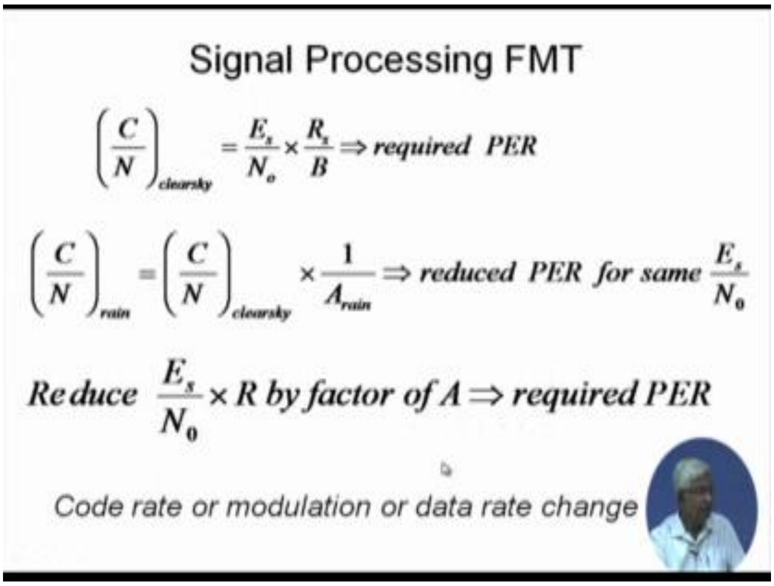

Now, let us go to the signal processing FMT from the power control effect this is a second technique this is done in our regular operation of satellite broadcast this see what it is C by N in the clear sky is we have seen these expression e s by N naught into R s by b that is for the required PER for C by N in the rain C by N in the clear sky into one by a rain this is in ratio. So, this will give reduced per for the same e s by N naught, but same e s by N naught will give the reduced the PER, but if I change this e s by N naught get different PER reduce by e s by N R into R by a factor of a and you get the required PER how that is the code rate or modulation or date rate change.

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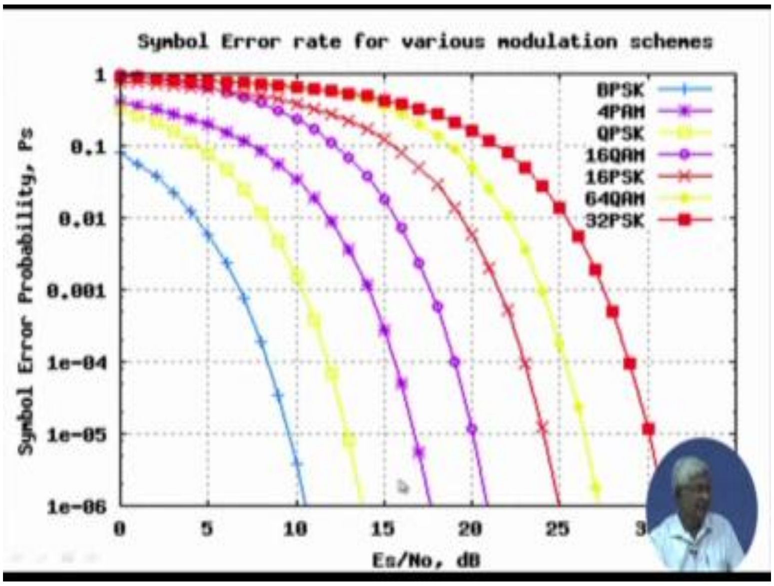

Let us look at it for you are aware of this curve that is e s by N naught versus symbol error rate or e v by N naught verses BER and for different type of modulation say BPSK to higher order of PSK here this is taken from paper which is showing BPSK 4 QPSK 16 form 16 PSK etcetera you can see for a particular BER when you go for higher order of PSK you need a higher e s by N naught that means, you need more power say let us take DER 10 to the power minus 4 or symbol error 10 to the power minus 4 for the BPSK the amount of e s by N naught is required to get this error for QPSK you need more e s by N naught not to get this error to 32 PSK you need much more.

So, this higher order PSK you get the you get the advantage of spectrum efficiency in one symbol period you can push more bits that a advantage bandwidth advantaging bit, but you have to give more power to reach the same BER now what happens that say normally clear sky operation your operating at this with a higher because of the rain you have a attenuation of this much 15 dB attenuation you have. So, instead of increasing 15 dB you start operating at lower PSK lower order of modulation your spectrum efficiency you have to sacrifice, but you will get the same d e R by reducing the e s by N naught or e by N naught by changing the modulation scheme by changing the modulation same thing is for coding channel error coding also you can do same way it is called adaptive error coding and modulation.

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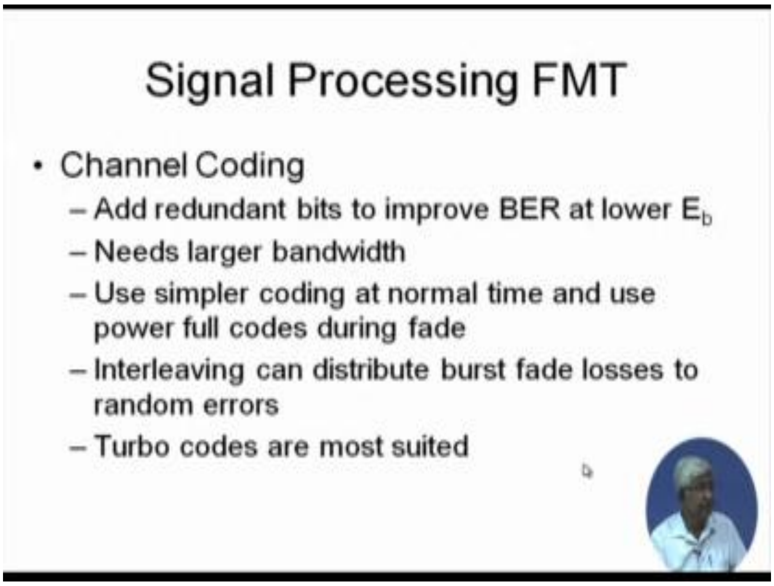

So, channel coding add what is done is additional bits are to improve BER at lower v in need larger bandwidth obviously, and use simple coding at normal time use the full power code during fade. So, you can increase the band width and you can get the more error correction when the fade is occurring. So, that is the way of channel coding. So, interleaving can be distribute can use to distribute the burst fade due to loss say a short fade is there normally this error control techniques they cannot take care of the burst error they can take of the random error. So, distribute the burst error into a random error you can use the technique call interleaving and turbo codes are most suited people are used LDPC coding also.

So, with this we close for the time being and will continue the discussion in the next period.

Thank you very much.