Spread Spectrum Communications and Jamming

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Lecture – 54
Interference Handling Mechanism in CDMA Networks

Hello students, today we will discuss the interference handling mechanism in a CDMA network. Interference is main bottle neck for deploying the CDMA Networks and today we will learn; what are the ways of handling, what are the different mechanisms are there to handle this interference inside the actual practical network.

Top of that actually the source of the interference, we have to understand actually that; how they are coming into. Mainly you know various environment we understand that in a spread spectrum communication system, we understand that there is a perfect orthogonality preserved when the course are designed and the course are generated in the transmitter, but once actually the spread signal is transmitted over the year because of the presence of the multi path propagation and different kinds of the fading.

Fading means the effect of the various channel on that transmitted signal in terms of amplitude, phase, frequency and because of all that fading the perfect orthogonality between the codes, which are may be given to different users does not hold good, does not prevail and because of that there is a huge interference is expected to come in the receiver; both in the uplink communication; that means, when mobile station to base station the communication is going as well as in the down link communication, when the base station to mobile station the communication is going on.

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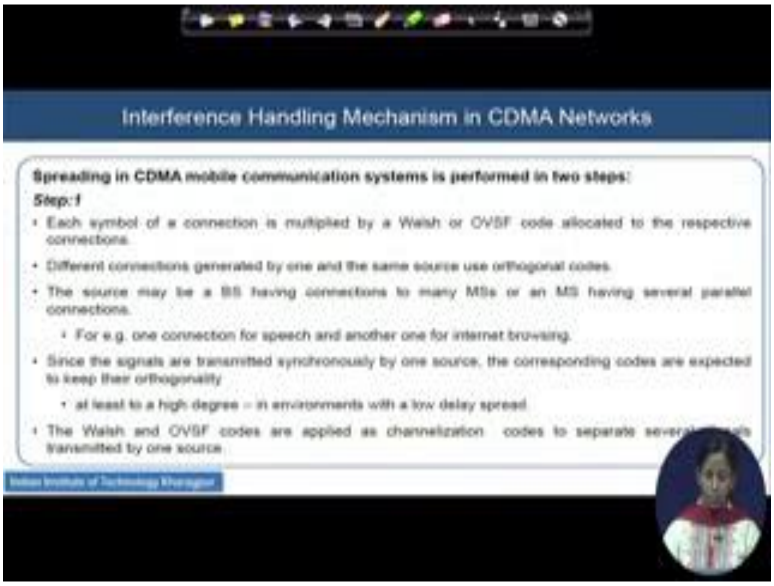

So, let us see the different methods. Spreading, let us see how we do spreading in a CDMA mobile network. There are two steps; in step one each symbol of a connection we spread it using a Walsh code or a OVSF code and the different connections generating by one source. For example, when BS both base station generates a signal for different users or actually the same source having a different kind of the applications. For example, one connection is there for your speech transmission, another connection is there for the video transmission, the third may be for some something else or multimedia or may be internet browsing. So, you are spreading different kind of applications with different kind of the spreading codes and in such situation, fundamentally when your source is same and you are using for multiple connections and in such situation, this is a step one where; actually one set of the codes are preferred. Where, your Walsh or OVSF will be the main application.

At least, in such cases we assume that high level of the synchronous communication is going on. At least a very high level degree in the environments, so at least with a very low delay, where the environment with a very delay low spread channels, such kind of the high degree of the synchronisation is expected to happen. And these corresponding courses are expected to keep their orthogonality. And Walsh and OVSF codes they both are applied for the channelization in such system and they are actually different sources or the different signals from the same sources can be separated out. Once they are utilizing for the channelization, they are the codes to separate the several signals. So, where the same source I mean the base station to the mobile station, so same source. You are or actually from the multiple connections of the same mobile station that you wish to separate them out. For that you are using the step 1.

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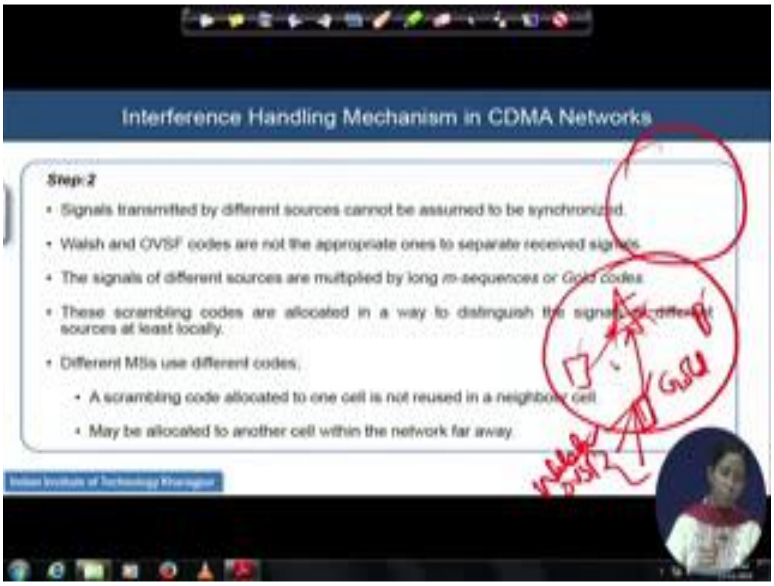

Step 2, the signals transmitted by the different sources are now cannot be assumed synchronized. Consider a same consider a cell where, actually the different mobile stations with their different locations they are trying to communicate at the same time to the base station. So, how will you confirm that all this mobile stations will be time synchronized fashion? This is not possible. So in the uplink the synchronization is a very big issue and in such situation interference is very very several situation is for having the interference and to avoid the situation we will try to choose a code who is having the very low cross correlation values and we prefer hence the either m sequences or the Gold sequences to be applied in the step number two to identify the different source cells.

By means of different sources actually it may happen that two different base stations actually who were may be in the bigger cell it is there. So, to identify both of them and definitely in the uplink to identify the different mobile users, you are using the different Gold codes.

So, suppose you think that you are a mobile source and you are having separate connections. One for internet browsing, one for your speech communication and another is for video transmission. See we are using a set of Walsh code or your OVSF codes for spreading the signal and top of that you are using the Gold code to spread them once more because you wish to separate them out from the neighbouring mobile stations. So, this is the situation that we are calling as step 1 and step 2 different kind of the spreading.

And usually we use a scrambling code also on the top of this, which help us to allocate to one cell. Where, which actually the scrambler that is utilized in one cell and the scrambler that is utilized in your net cell, that is never equal and they are chosen in such a way that the intra cell, not only the intra cell interference the inter cell inference also actually is minimized. So, when we are talking about the multiple users within a cell it is called the intra cell interference and inter cell interference, the interference that we are getting from the neighbouring cell transmission.

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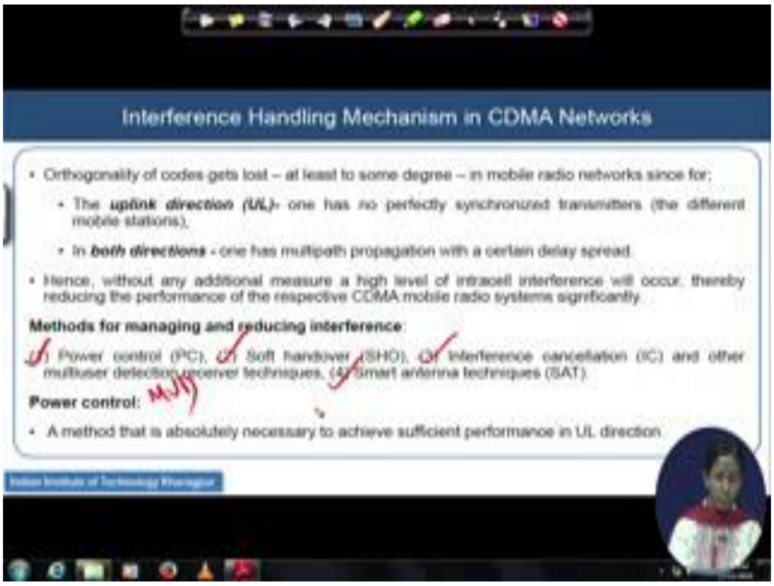

So, these are the mainly two different state of the codes utilized for a CDMA Network. Now, which is more critical that we need to understand? The orthogonality of the codes gets lost we understood to some degree in mobile networks and in the uplink direction as well as in the downlink direction. In uplink direction it is because that perfectly synchronous situation within different mobile users we cannot confirm. Downlink direction because you have a multi path propagation and depending upon the situation the multi path profile gets changed, contributing to your received signal and hence there are different delay spreads involved for every path of the multiple paths and it is actually your location dependent where you get all this different kind of the spreading and you get the received signal differently.

Hence, without any additional measure of this high level of intra cell interference that will occur there by reducing the performance of the respective CDMA mobile radio systems. It reduces significantly the performance. If you see the performance graphs without any control on this interference, it with a huge effect you will see their probability is very very high.

So, after understanding that interference handling is required. Let us revisit what are different mechanisms that we will discuss here. The first one is the power control, the most powerful one and without which the fascination of mobile network could not be deployed even until today it is a mandatory step kind off. Then, the another one is the soft handover, third is a interference cancellation scheme; inside that mud multi user detection or the mud receivers and forth is the smart antenna techniques. We will quickly visit inside the power control mechanisms.

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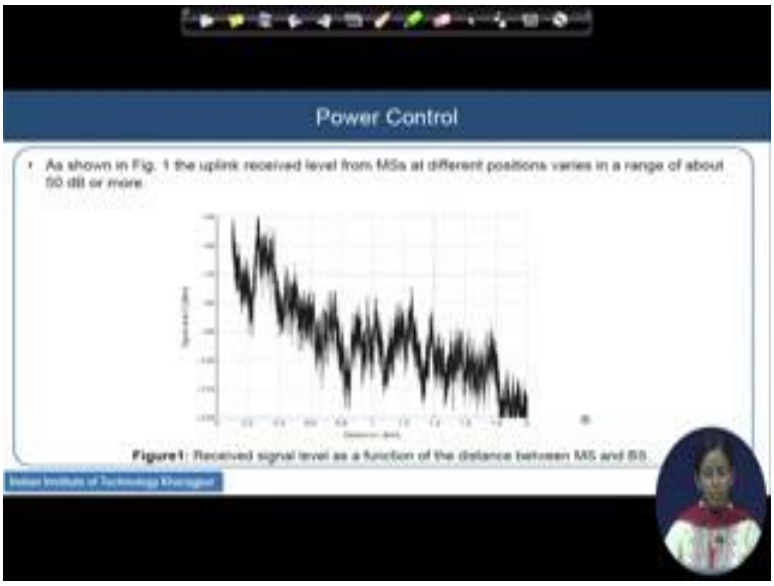

So, that is usually found in the uplink situation. So, before entering into the mechanism, let us see that how much power you are really getting, really you are losing in the uplink direction, if you are varying your distance from the base station.

This is a graph of distance changed versus the variation of the received signal level. So, as shown in this figure that the as uplink received level from the mobile station at the different position if it you are varying. So, if you are closed to the base station say up to 0. 1 Kilometre away from the base station, you will be receiving; base station will receive minus 50 dBM. That you are away from him around 1.5 kilometres, he will receive close to the minus 100 dBM. So, around 50 dBM power is getting lost, if you are over the distance.

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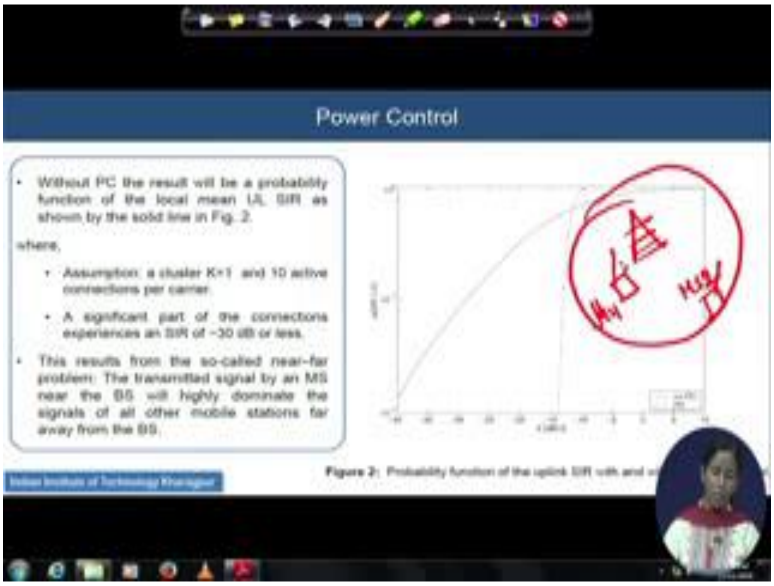

Hence, power control is required. So, how this power control is coming from is the fact is something like this. See before coming to that typical problem let us see what is happening. Suppose you have, we are showing here a power control without power control the probability graph, probability function of the local mean uplink signal to interference ratio. We are thinking the signal to interference ratio will be less than equal to certain pre defined level. What is a probability of getting that? Assumption is suppose I have the cluster and 10 active connections are their per carrier and they are separated by definitely separate orthogonal codes and a significant part of this connection we can see that they are experiencing the signal to interference ratio around minus 30 dB or the less, but this is resulting from the fact that there is a so called nice problem in the CDMA network which we know, which is known as a near far problem.

What is this? Let us see. Suppose this is a cell, this is the base station of interest and suppose they are at two mobile stations; one is very close to the base station and another is around the boundary and both of them are simultaneously transmitting in the same power. Because of the distance issue the power that is received from the mobile station 1, will be heavily high compared to the mobile station 2 and there by dominating actually the decision of that base station.

So, mobile station 2s signal will be completely buried almost and because of the very very low signal power received by the base station. So, we call it a near far problem. This happen mainly because of their corresponding location. So, if both of them contrasted by the same power levels. So, this kind of problem will happen, but if we can do something, if we can control the power means something like this; the guy who is having low, who is having nearby position from the base station he should uplink, he should send the signal with a controlled low power compared to the guy who is far from the base station and wish to get connected at the same time.

So, the power transmission for both of them can never be same and based on their relative distance they should control their own power to not to interfere their neighbours within a cell. So, to control the inter cell this is called a near far problem and to control the inter cell interference coming from the near far problem we need to do the power control. See this graph is showing that if you do the power control. So, almost you will be gaining an amount of, SIR can be controlled or within a 14 dB up to 14 dB we can control it.

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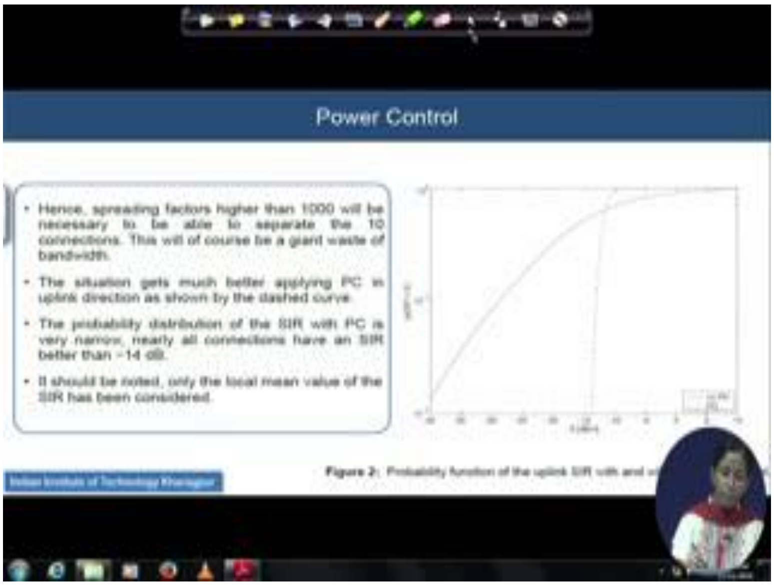

So it should be noted that this whole discussion and this graph that we are doing it is a basically on the local mean value only.

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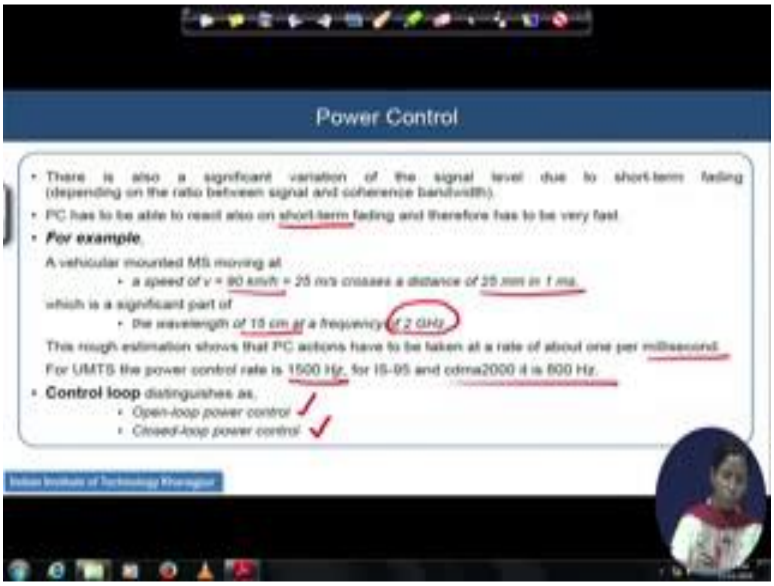

So, significant variation of the signal level we are expected to get due to also the short time fading. The fading actually is the loss of the signal power and mainly the loss of the signal power and also the changes affected on that signal phase and the frequency over the very short duration, when the signal is passing through the various channel. We will learn a lot about the different kind of the fading in a typical class, but here we will understand actually the effect of the short term fading. The term is short term always is indicating you that you will have a affect on the variation on the signal level, rapid variation on the signal level over a very short duration and therefore, it has to be I mean the power control is expected to be have very fast nature.

For example, vehicular mounted on a mobile station, a vehicular mounted mobile station who is moving actually at a rate of say 90 Kilometre per hour and crossing a distance of say 25 Millimetre per Millisecond and having a significant part on the wavelength of 15 Centimetre at the frequency of say 2 Giga Hertz. Avery rough estimation shows that the power control action has to be taken at a range of your 2 Milliseconds or even at least one power control needs to be done within Millisecond s because that is the fast range the channel is changing. And here are few examples actually the way the rate if we, with which we do the power control in the IS 95 and in CDMA 2000, the famous two CDMA networks and this part of the loop; the control loop there are two different types of the power control loop.

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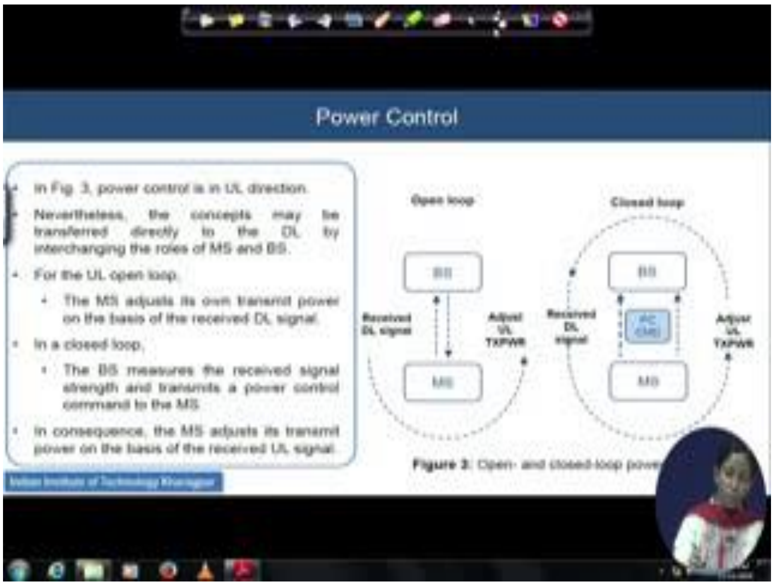

We will discuss now. One is the open loop power control and another is the closed loop power control. Let us visit.

See the diagram 3, we have shown the open loop as well as the closed loop power control here. And in the open loop power control the decision goes like this. So, base station is transmitting something some signal and mobile station has received that signal in the downlink. So, while receiving this signal he has measured the received power. From the received power and with the application with the straight forward calculation power received it can be directly related to the distance covered. So, more the distance is power received will be less. So, he can calculate the distance his respective distance from the base station based on the received power level and also he can adjust or he can assume that, what will be the approximate channel condition he can also from the received signal he can also do the channel estimation.

So, understanding the condition of the channel and received power level and measuring the distance, now what he can do is, he can now change his transmit power. If the channel condition is really good he would not transmit at do at high level. If the channel condition is bad and he needs to put more power to get the transmission something like that and so he will adjust the transmit power level in the uplink, the next transmission in the uplink and remember in the open loop we do not have any instruction from the base station. How to do go ahead with it? Whereas, in the closed loop base station; when mobile station is transmitting something in the uplink, base station is receiving that and he is measuring the condition of the channel in the uplink as well as a received power level. And after that he is giving the instruction during the down link channel about the all the information of the channel characteristics, the received power, the distance measured to the mobile station and then the mobile station is managing, is utilizing that information to adjust the uplink transmit power level during the next transmission and all.

So, see actually this is more correct compared to this because downlink and uplink channel conditions are never same in the Walsh domain. This guy assumes that as if the channel is remaining constant for the whole process to get completed, which is highly unlikely to happen. Whereas, this one is much more likely to happen because the channel is measured, the actual uplink channel is measured by the base station and that information is just sent to mobile station and if the channel is not expected to change for a very fraction of the time, very fast change is not expected to happen. So, mobile station can utilize those information to have the control of the transmit power for the next onwards.

As the loop is open here without involving the base station so, the name is open loop and as the both base station and mobile station is involved in the two power control mechanism; this is called the closed loop power control.

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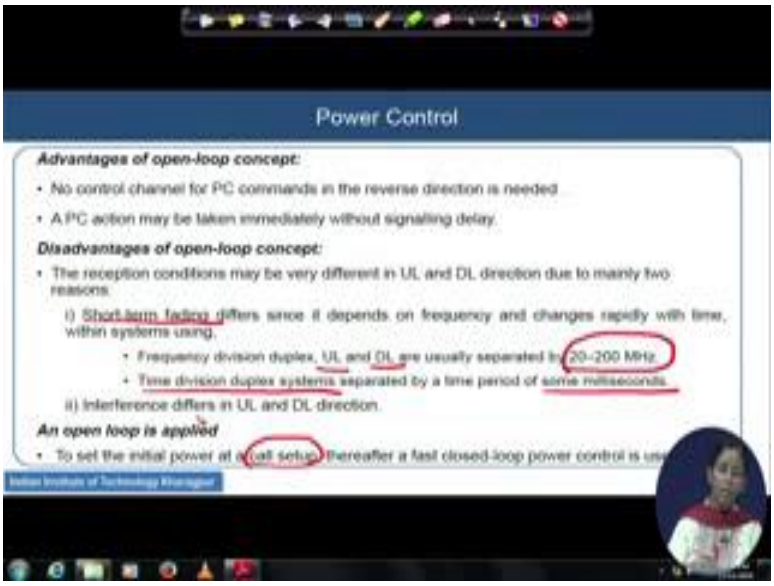

There are few advantages and disadvantages. Remember in the open loop the advantage is there is no control of the base station on the decision of the mobile stations. So, there is no involvement, no signal processing involved in both the cases. It is only the signal crossing in the mobile station. So, the decision can be very fast and can be implemented immediately, but disadvantage is what? Several disadvantages are there. Number one, the uplink and downlink channel condition. The way we communicate is such that either the changes, either the channels so, either we do actually the frequency division duplexing or we do the time division duplexing. There are two different kind of the systems available in practice.

Frequency division duplexing means that for the uplink and the downlink you use two different channels; the uplink channel and the downlink channel. They are completely different for the transmission and they are usually separated by around 20 to 200 Mega Hertz from each other. They are separated around 20 to 200 Mega Hertz from each other. There is another stub which is called the Time division duplex systems where, the channels are separated where the transmission has separated over time.

So, downlink transmission, uplink transmission they are going on over the separated different time periods and this separation is over some Milliseconds. So, neither you can expect the channel to be same for downlink and uplink for frequency division duplex nor you can think that they are supposed to be constant, when the time division duplex system is going on. So, short term fading is definitely having a very big effect in both kind of the systems where, the open loop power control seems not to be good, But still we apply it which, we apply it for the initial power at a call setup and after that we switch it to the closed loop power control.

Remember not only the short term fading. Even the interference also the interference profile differs for the two different channel and interference profile will keep on changing, if you observe the interference profile over the time.

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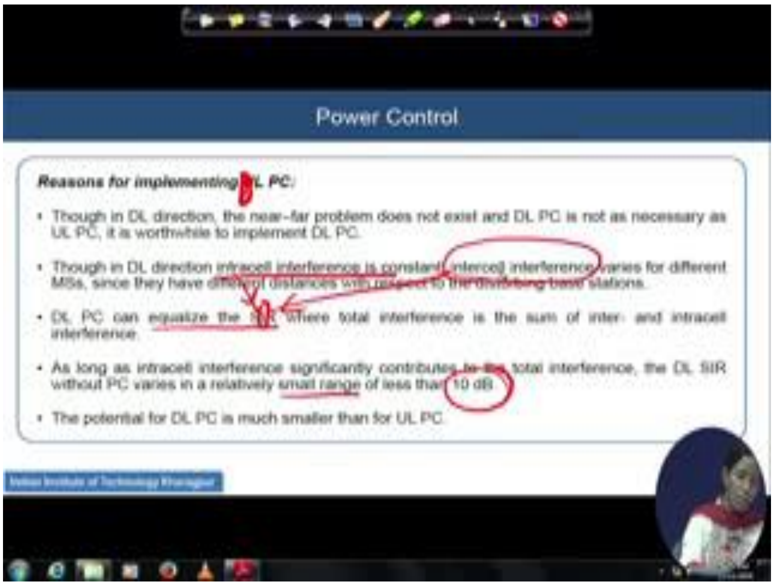

So, now these are the reasons for implementing the power control in downlink. This is not uplink, this is now reason for downlink. Already we have covered the uplink situation. So, this is the downlink. So, in the downlink actually the situation is not that much critical like the uplink because near far problem is not there. In the downlink means you are coming from the base station to the mobile station. So, base station to mobile station there is no near far problem kind of stuff right. But still we have the directions different mobile stations are at different directions and there are the concept of the intra cell interference as well as the inter cell interference; you may think that intra cell interference is constant. But inter cell interference they vary largely and they affect the mobile stations to a great extent and that is why actually the different distances with respect to the distributing base stations and all you are going to get a huge effect of the inter cell interference in that situation.

So, the downlink power control also can equalize to some extent the signal to interference ratio where, the total interference here we consider as a inter cell interference plus the intra cell interference both. And as long as this intra cell interference is significantly contributing to the total interference, the downlink SIR without the power control it varies relatively over a very small range say 10 dB kind off. But if this intra cell interference is varying largely as well as the inter cell interference is also again showing here a huge variation, downlink power link control also needs to be very fast in that situation.

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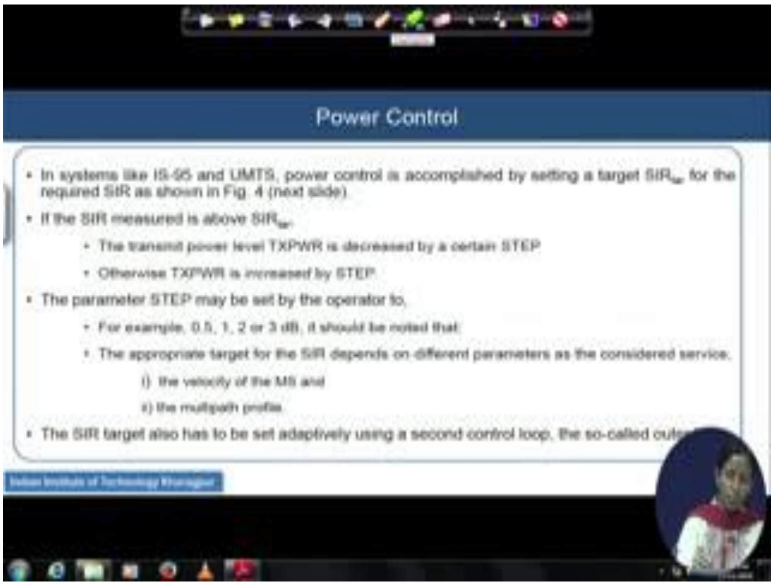

But whatever it is compared to the uplink power control the hazard related to the downlink power control is much easy and it is much less and can be easily controllable. So, the system like your IS 95, UMTS they do the power control, in a power control mechanism in two steps.

The steps I will show in the next slide, but finally, there are there is a target SIR set first and if the target SIR measured is, if the SIR that we are measuring in the receiver; it is above the target SIR then, the transmit power level which keep on decreasing and otherwise it will be increasing by a small step. And how the step will be? It depends upon the operator to operator. In some operator it may vary see, it may vary from 0.5 to maximum 3 dB and the appropriate also actually this SIR target is not a fixed target always because it needs to be changed, varied based on the velocity of the mobile station with which it is moving as well as the multi path profile of the channel the way it is varying and. So, setting up of this SIR target is required to be adaptively changed.

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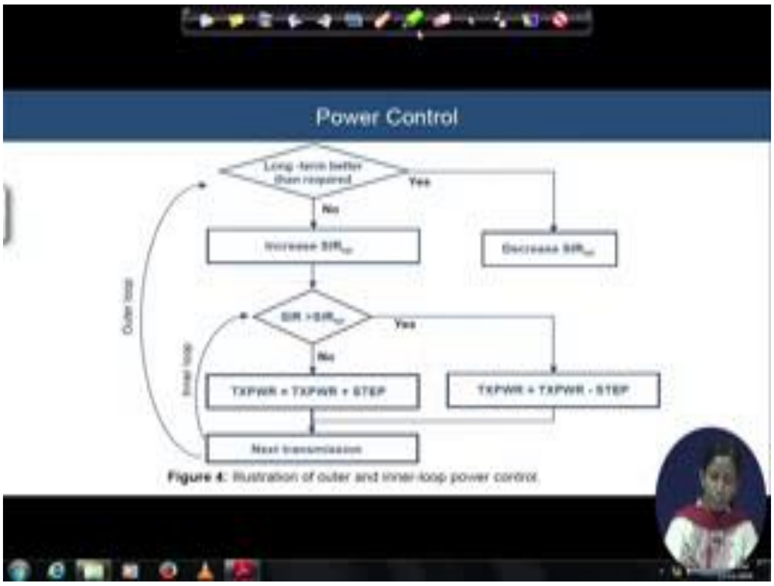

Now, let us see the whole part. So, this is the figure it has having as discussed earlier it is having two loops; one is the inner loop another one is the outer loop. I can tell that inner loop is observing over the short duration and outer loop is showing it over the long duration and within the short duration as I told that whether the measured SIR is increasing is crossing the target SIR. If it is no, it is not crossing then you keep on increasing the transmit power slowly one by one, one by one, one by one the step size is varying from your 0.5 to 3 dB and do the next transmission.

And after the transmission and if it is actually yes, then you please decrease it, do the same thing by decreasing it in the step; and once that part is done then, you do this new set with the next transmission will be with a new set of the transmit power either by the decreasing available one with a step or by increasing it with a available step.

In the next transmission you do the outer loop. In the outer loop it is a long term better than it is required and we check it over a long term and you check whether it is the signal to interference ratio, it is better than whatever is required or not. If it is better yes then, you can decrease the SIR target signal to interference ratio it will be down and otherwise you increase it the signal to interference ratio and then you run the inner loop. So, before measuring the SIR for each and every cycle you first check the outer loop. Once the outer loop is done then you come here.

So, actually this SIR after increasing the SIR tar the increased value or the decreased value also you may actually run the part. Here we have shown the whole stuff with increased one. Similarly with the decreased one also the same part actually the lower inner loop will run. So, this is a replica of the increase SIR tar.

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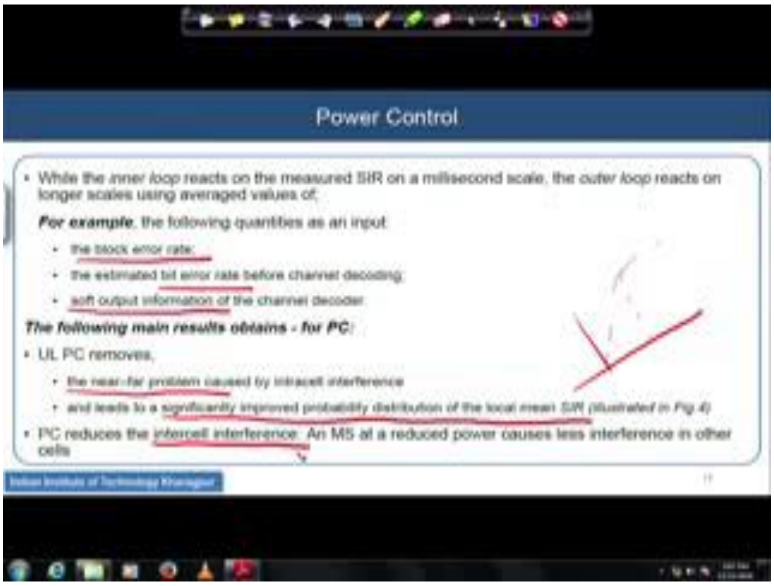

So, see when the inner loop reacts on the measurement of the signal to interference ratio on a Millisecond scale, the outer loop is expected to operate over longer scales using the averaged value of. For example, suppose the following quantities he can take as an input; this outer one. He can take the block error rate. So, over the long time of the transversal several packet transmission for each and every packet he can actually calculate the block error rate and over that he can keep on checking whether the symbol error interference ratio whether, it is improving or decreasing. If it is decreasing no then, the error rate will be decreasing and the other I mean it is improving.

So, error rate will decrease is the SIR has improved and it will increase if the SIR has decreased. So, the affect of the channel will be definitely and the interference profile will be definitely affecting the block error rate. Say that the checking at that he can have assume that whether, what is the condition of the received signal and then he can automatically adjust.

The estimated bit error rate also he can check before the channel decoding or he can take the soft output information of the channel decoder itself. So, based on all this the outer loop can start thinking the how to adjust the SIR? And the following at the main results that we obtain once we do the uplink the uplink power control.

This uplink power control it will remove completely; the near far problem that we have already understood. It leads to significantly improve probability distribution of the local mean signal to interference ratio. That also we have seen by the graph like this which was earlier like this and we could improve around 14 dB kind off and the power control also reduces not only the intra cell, it also helps us to reduce the inter cell interference because the mobile station with a reduced power he can he cannot create interference to the neighbouring cell mobile station also. So, you are improving the both the intra cell as well as the inter cell interference by doing the power control.

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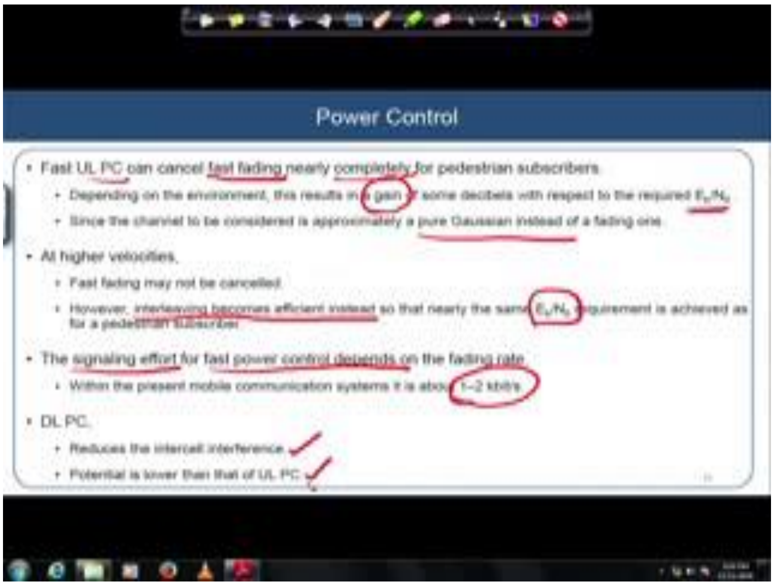

If you do the very fast uplink power control it can cancel the fast fading, very fast fading. Fast fading means actually the fading or the change in the signal amplitude level and all the other affects on the signal is going very fast over the time axis. That is called meaning of a very fast fading. For the time being just go ahead with this explanation. We will detail it later on in the fading class. So, when actually the fast fading is there in the channel uplink power control cancel it also almost completely for the pedestrian subscribers.

So, depending on the environment that results some gain of some decibels with respect to the required E b by N naught. If you can give the or control, see it will give you a gain, central power of the gain in the dB level and since the channel to be considered is approximately a pure Gaussian instead of the fading one in that situation. When actually the gain is there so you approximate it by the pure Gaussian channel instead of what exactly is the Rayleigh distributed channel or Rician distributed channel.

So, what we are finally, find that for first fading cases the uplink power control can completely remove the effect of the fast fading for the pedestrian speed or if you are moving with a very high velocity then, fast fading we cannot cancel by the uplink power control, but; however, some inter leaving comes into picture and as an efficient and instead. So, that the nearly almost the same E b by N naught requirement, we can carry out and it is achieved for the same pedestrian subscribers. And how good actually I mean how fast we can do this uplink power control I mean the signalling effort for this fast power control it totally depends on the fading rate.

For approximately within the present mobile communication system, we see that 1 to 2 Kilo Bit per second actually it is now currently. Inside the downlink power control, it completely we learnt that it reduces the inter cell interference completely and it has a potential to control this interference both in the intra cell as well as the inter cell that we has already discussed. That its potential is low compared to the uplink power control. So, the task that the uplink power control can do as having much more effect on the total individual user throughput as well as the total network throughput.

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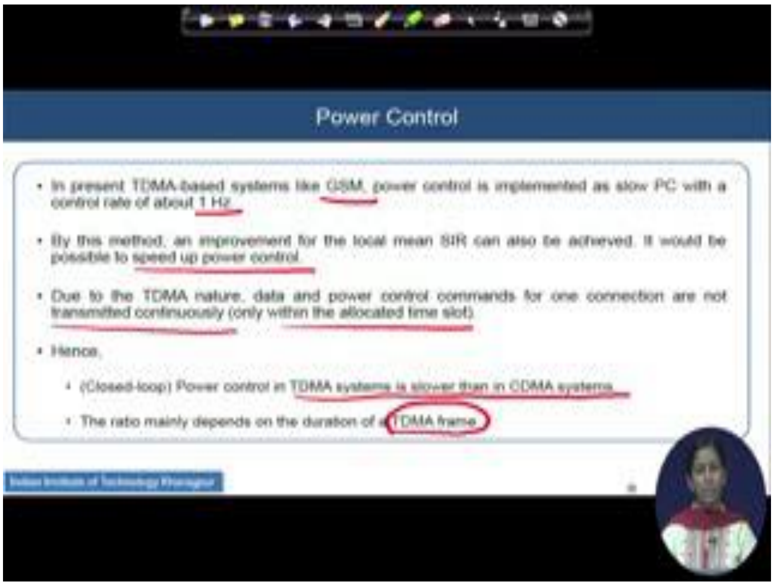

At present, so TDMA based systems like your GSM, the power control are implemented which is slow power control and the control rate is about 1 Hertz for GSM. And by this method and improvement for the local mean of SIR can be achieved that we have already discussed and it would be possible to speed up the power control also. Due to the TDMA nature this data and the power control commands for one connection and not transmitted continuously, only within the allocated time slot you are allowed to go ahead with and so, the close loop power in the TDMS system it is slower than the CDMA system.

The ratio mainly depends on the duration of this TDMA frame mud structure and what you are trying to understand from this whole is from the last two slides is, it is basically the summarization of the effect of this power control and we understand that the uplink power control is absolutely essential to control the inter cell interference, intra cell interference and to mitigate the problem of near far problems; and to mitigate also the fast fading effects for the pedestrian users, and compare to uplink in some cases we also do the downlink power control, but the downlink power control is not having that much effect to improve the total scenario to total performance of the CDMA network.