Spread Spectrum Communications and Jamming
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Lecture - 62
IS95 and CDMA - Part I

Hello students. Today we will start discussing about commercial spread-spectrum communication network, and which was the very successful first time worldwide. And the system is IS-95 and CDMA 2000. We will quickly a review and go for the later on go for the detailed description of the system both the system and we will try to learn that what exactly is the transmission frequency, what is the uplink frequency, downlink frequency, the channel, the codes that are used here how the communication setup is built for this commercial network.

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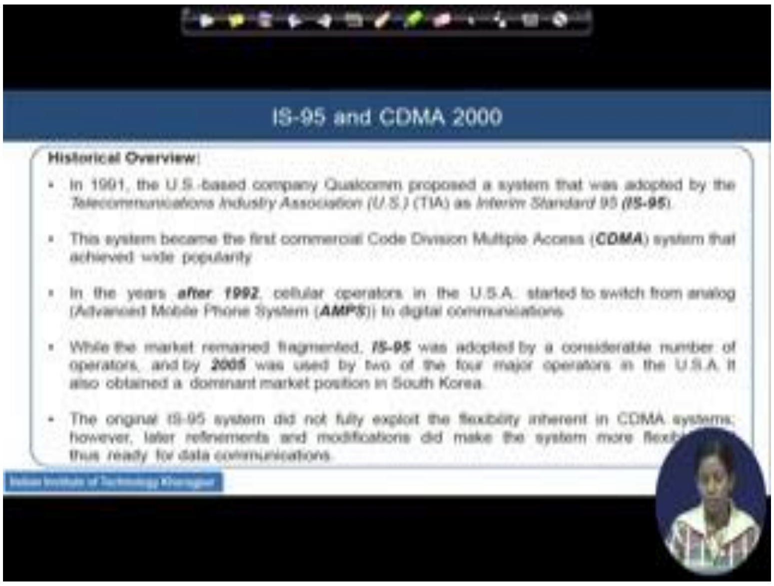

We will start with historical overview. This interim standard 95, which is in short call IS-95 it was the system was the brainchild of Qualcomm. And in early 1990s basically 1991 Qualcomm came up with this spread-spectrum communication based basically it is a code division multiple access based communication system, and this proposal they named as IS-95. Very soon within very short duration IS-95 become very popular system I mean communication system for the mobile communication in USA. In 1992 in USA, there was a migration happening of shifting the mobile communication from analog domain to digital communication domain. And already the IS-95 was proposed from Qualcomm, and there IS-95 was a very nice fit for all kind of the communication demands of those 90s in the decade of 90s. And that is why the first generation of the mobile communication which we called the 2G communication in the digital domain, the first generation of the digital domain basically. Actually it was very famous based on this code division multiple access communication technique.

By 2005 major two operators in the USA, they obtained IS-95 to be their communication mechanism; and it was a very popular very popular communication system for the South Korea also. This original IS-95 system actually, it was a first generation system design. So, it was not fully exploiting the complete flexibility, which was inherent in the code division multiple access communication.

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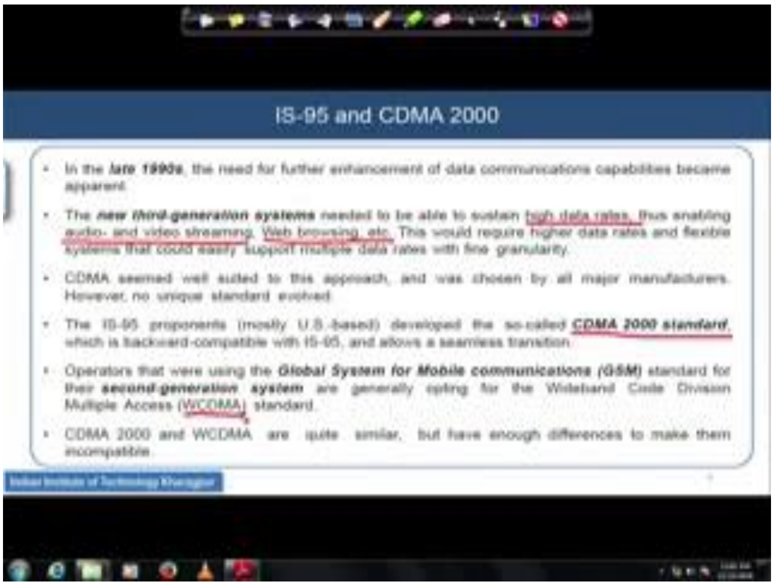

And later on when the demand for the high data rate communication came for the next decade I mean late 1990s then automatically the development started happening on the top of the basic standard developed for IS-95. The third generation mobile communication or 3G mobile communication actually they started late 1990 with the demand of very high data rates. And enabling the audio video both streaming, enabling the web browsing etcetera this demand started giving at the earliest of that 2000. And that is why the people who generated the IS-95 standard, they further developed IS-95, and they come up with the proposal which they named as CDMA 2000.

And when they did it they also made the new standard CDMA 2000 compatible with IS-95 so that means, the existing infrastructure of the communication network who was using IS-95 or the mobile handsets who was working over IS-95 standards they all can be actually backward they all can be now be operated over CDMA 2000 standards. So, CDMA 2000 can be give support of all the kind of the data rate demands of IS-95 network.

And CDMA was very well suit approach at that moment when the new demand for web browsing, audio-video streaming apart from the high data rate communication came up in the early 2000. And not only the Qualcomm, the other operators they came up with the new standard which was called the global system for mobile communication, it is a basically a GSM standard. And for the second generation system they came up with that; and this GSM actually was also based on a code division multiple access, but it involves a very wideband of the operation, and that is why the system was named as wideband code division multiple access standard, and it was also called a WCDMA.

So, the parallelly two standards came up one is from the Qualcomm side, which was the modification of IS-95 named as CDMA 2000; and parallelly other operators came up with a new standard call the global system for mobile communication which is called GSM. And fundamentally the GSM is based on a CDMA network and so GSM was also renowned after the name of WCDMA. And if you see closely the spec of both CDMA 2000 and WCDMA, we will find lot of similarities between these two spec. But still they are a lot of differences between these two between because of the wideband operation involved in WCDMA. And we today we will quickly look into the spec of CDMA 2000 standard, and try to find out what are the typical parameters set was parameter value set for the communication in IS-95 and the CDMA 2000.

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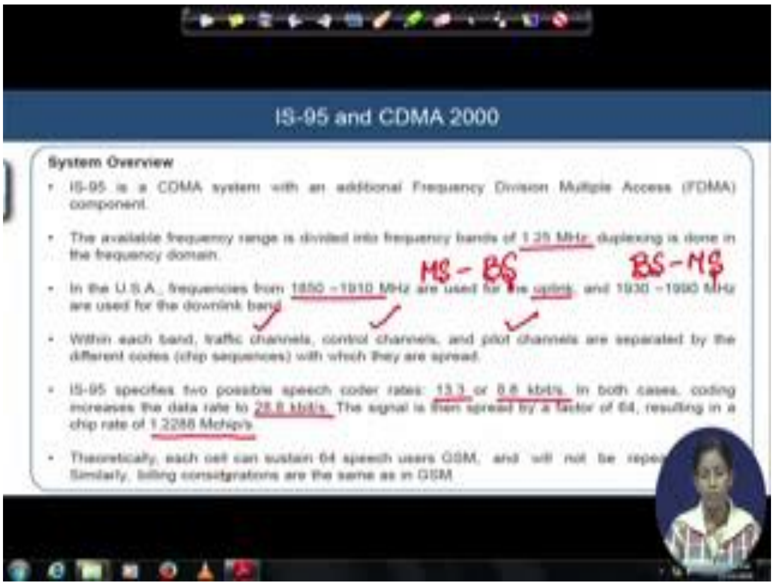

We will start with IS-95 as I told IS-95 is basically a CDMA system, but it has an additional feature of frequency division multiplexing access or FDMA. And the total available bandwidth for this IS-95 actually is divided over the smaller frequency bands because the multi-user support will be provided by frequency division multiple access here. So, you need multiple frequency bands and here the frequency bands where of the width of 1,25 five megahertz. And when for the duplexing operation for the duplexing operation I mean for your transmission and reception when simultaneous transmission and reception will be required for that that they utilize the frequency band also.

So, one of the frequency band will be dedicated for the uplink communication, another will be going for the downlink communication. And for that the total available frequency range from 1850 to 1990, they divided into two halves. The first half is 1850 to 1910 megahertz which was used for the uplink; uplink means you are going from the communication is going from the mobile station to the base station. And the remaining frequency 1930 to 1990, the remaining 60 megahertz was utilized for the downlink communication which is from the base station to the mobile station.

And there was there are several channels involved inside both in the uplink and downlink and which are named as traffic channel, control channel, pilot channel, synchronization channels and management channels also, but all these channels are coded by the different kind of the codes to separate out these channels both in the uplink as well as in the downlink. And in every frequency band was you need to separate them out. So, the separation mechanism is provided by the chip sequences the difference sequences involved.

And if I try to see what is IS-95 system, IS-95 is basically communication system which supports only the voice communication, and hence it is has a speech coder rates different basically two is it supposed to different speech coder rates one is 8.6 kilobit per second range another is 13.3 kilobit per second. And this speech coder rates, they are this data rates are enhanced by incorporating the coding and this coding helps them to go up to 28.8 kilobit per second for both of them that means, the code rate are different for each and then the signal will be spread by a factor of 64. So, you need a 64 length chip sequence for availing a chip rate of 1.2288 mega chips per second.

Remember, if 64 separate orthogonal sequences are available to us, then we can at least suppose 64 users it seems at a particular time in the network. But in practice we see we can hardly supports 12 to 18 numbers of the users with a successful quality of and satisfactory quality of service rate and with successful communication. This is because the orthogonality of the codes in between the codes they are really not sustained. And there is a lot of issues related to the power control, there are lots of issues related to the channel involved. And hence it is the experience says that hardly 12 to 18 users at a particular time can be actually accommodated in IS-95 kind of network, which is really pretty low compared to the number of the codes available in hand.

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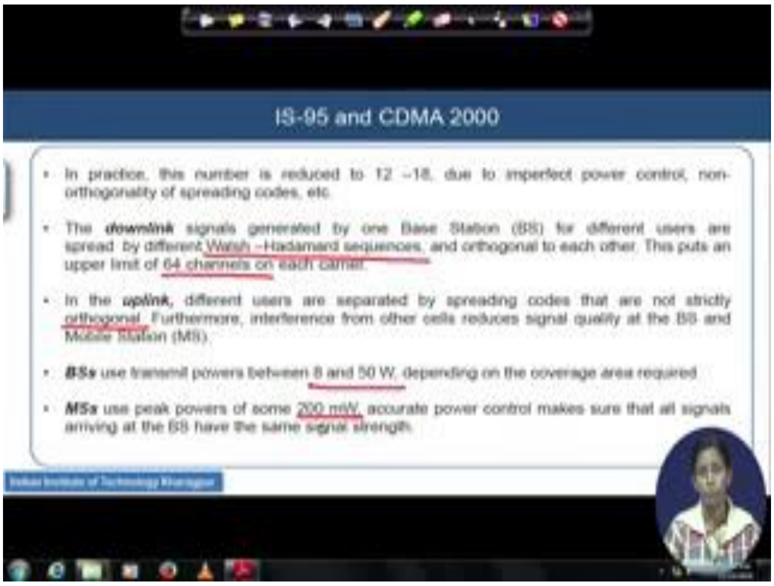

The downlink signals that are generated by the base station, and for the different users, they used for spreading the Walsh Hadamard sequences, and they are all the orthogonal to each other and you can have a 64 different users or channels on each carrier or each frequency. In the uplink, different users are separated and they are separated by the spreading codes that are not strictly orthogonal because you cannot make it, because time of the uplink transmission is not synchronized. And furthermore the interference from other cells the interference that are coming from the other cells they reduces the signal quality at the base station and in between the mobile stations.

The base stations that used a transmit power is varies between 8 to 50 watt and depending upon what will be the coverage area of the typical base station. While the mobile stations they use the peak power of some around 200 milliwatt, and the accurate power control is essential in such kind of the communication systems because otherwise there will be huge interference we will further restrict to accommodate large number of the users in at a particular time in the network.

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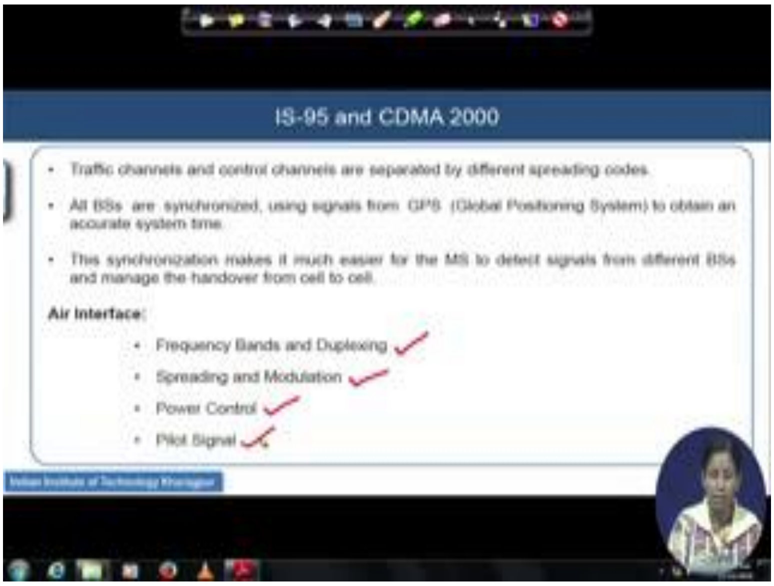

So, the other different channels that are the traffic channels, and the control channels that are getting used here they will be again separated by the different spreading codes. So, definitely you are not going to use the same length of Walsh Hadamard code for your data communication, for your pilot channel transmission control channel as well as the traffic channels. Remember that when the base stations are doing the downlink transmission and the base stations for to do the effective handover and the power control as we have discussed earlier, it is essential that the base station should be in sync. And this synchronization is provided in the IS-95 network by means of global positioning system or by GPS.

And this synchronization is actually very very helpful to establish the MS to establish a very good synchronization not only during the downlink, but also it enables the mobile stations to detect the timing information of all the users of the whole system on a whole network itself. And aligned himself according to that global time. And it also helps to detect the signals that are coming from the different base stations and approximately it helps the mobile station to initiate the process of the handover from the cell to cell.

If we look at clearly into the air interface, the critical parts that will be interested in to understanding IS-95 will be the frequency bands and the process of the duplexing, the spreading and modulation techniques, the power control mechanism and the kind of the pilot signals that are utilized here for the uplink and downlink communication.

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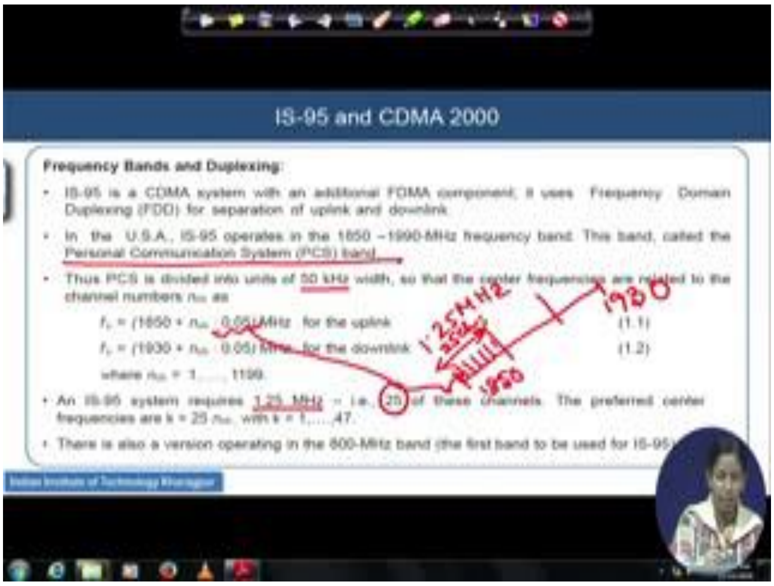

We will start with a frequency bands and the duplexing. We understand that IS-95 is a CDMA technique; on the top of that it uses frequency division multiple access for duplexing and as well as the multi-user support. And frequency division duplexing means for uplink and downlink, you will have separate channels dedicated channels, and as we have already seen that 1850 to 1990 is a total allocated band for the communication of IS-95. This band is also named as a personal communication system band. And remember inside that band PCS is divided by fundamentally into some channels that channels are called the 50, the all the channels are 50 kilo hertz wide and the channel numbers that the way we give it something like this.

You start with 1850 - the lowest one, and you give (Refer Time: 15:29) number of the channel multiplied by 0.5 for where the number of the channel varies from 1 to 1199 numbers. And if you go like that you will slowly start with 1850 onwards and will reach up to 1990. And remember for the uplink, it will start with 1850 for downlink as a starting frequency is 1930; you have to start channeling numbering the channels in the downlink starting with the 1930 center frequency. And as we understand then we have to understand what is the difference between a channel and the frequency band, definitely a frequency band as we have already discussed is having a bandwidth of 1.25 megahertz. So, it means that you need at least 25 numbers of such channels to construct a frequency band of 1.25 megahertz.

So, if I see like this, so I have a in uplink say, I have the frequency band 1850 to 1930 for transmission for my communication in the uplink; and in that I have the several frequency bands each of them are 1.25 megahertz wide. And if I try to see within the mega 1.25 megahertz band, there are several channels, and these channels each of these channels are 0.5, they are 50 kilohertz wide. And such 25 number of the channels are there within 1 frequency band, so that is the relation between your frequency band and the channels utilized for the IS-95. And remember one other thing that there are also the several versions which are operating in a 800 megahertz band also for this IS-95 that is not a point of our discussion here in this module; if you are interested, you can check it out.

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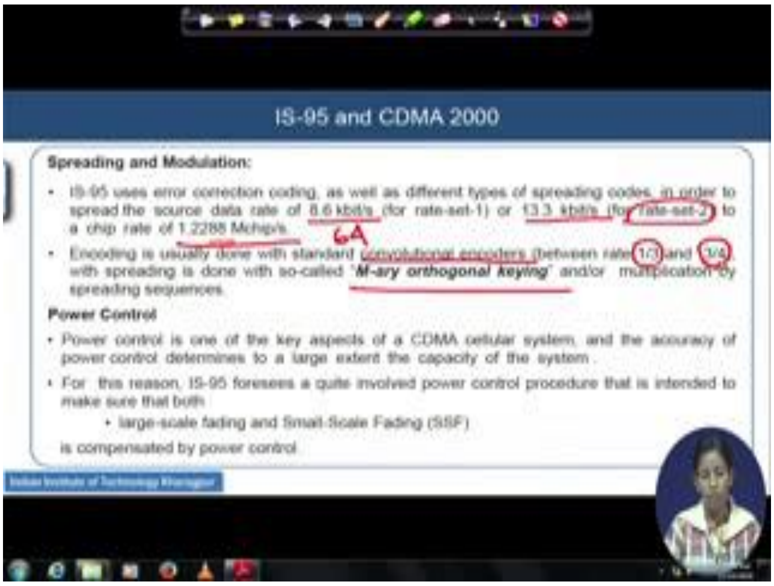

Then is the kind of spreading and modulation let us quickly visit; what does it do. We understand that it is a voice communication mainly and for your transmission of that voice. It uses actually it is supposed to different type of the data rate one is 8.6 kilobit per second for we call it a rate-set-1; another is the 13.3 kilobit per second which call we call it rate-set-2. It is not a peak set we will see later that there is a variable rate support within this zone, but all are combinedly say called a rate-set-1. And similarly the supportable there variable supportable rates in the zone of 13.3, we call it rate-set-2.

And we understand that we will be using the 64 chip length codes and that is will help us to finally leads to a chip rate of one point double two double eight mega chips per second for transmission, so that is about the spreading and the modulation that we use is the M-ary orthogonal keying. And remember we need actually the error correcting codes to be deployed before releasing the data in air; and this error correction codes are deployed as we have already studied in the rake receivers that error control codes are essential to come back with the errors that are happening or the fading that is happening inside the channel. So, they are the channel codes, they are the channel correction codes to minimize the errors in the received signal; and the errors that are originated because of defade of the channel to avoid that we utilize the error correcting codes. IS-95 deploys the convolution encoders; and the code rate with which they operate is basically one-third and 3 by 4.

Next come to the power control. If it is a CDMA network we understand that the power control is a very important issue which will help us to maintain the interference profile of the whole network under control. And you can expect actually in uplink all the mobile users signal are received in the base station with the almost same power it is not dependent on it is corresponding location. I mean the received signal power at the base station is not going should not vary with respect to the mobiles location. You should control the power in such a way that the received signal power from all the mobile station irrespective of the location should be at the same level, so that is the motto of the power control. And here also we do the power control to come back to the effect of the large scale fading as well as a small scale fading.

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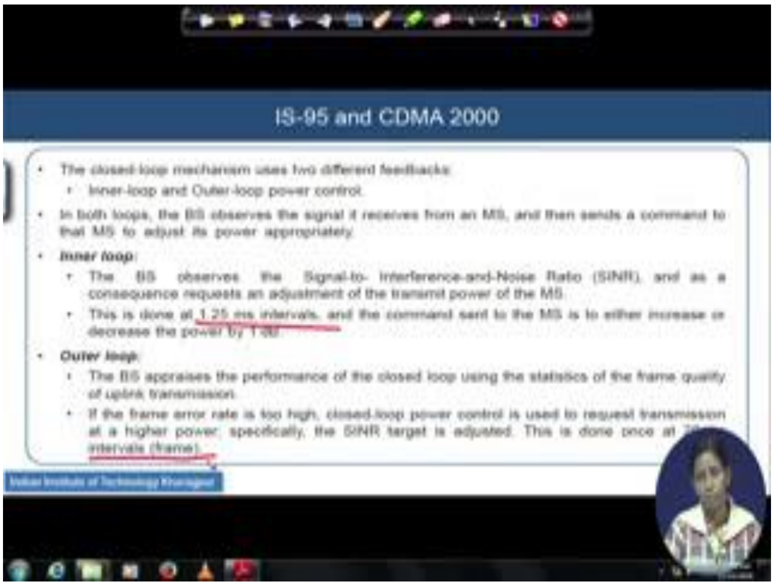

And for to in order to achieve each in a IS-95, we proceed with both that open-loop mechanism as well as the closed-loop mechanism that we have already learnt for the near for problem and the power control mechanism in the CDMA. And there are two measures of this power control in this IS-95, the measures are how accurate you are in the power control and what is that what speed you are doing the control. So, accuracy basically indicates that how much received power deviates from the ideal level under the steady state situation where the received power changes very slowly and almost not it is in sometime cases. And the speed of the power control basically determines how quickly the power control can be achieved adaptively; and as I told that IS-95 ops both the open-loop as well as the closed-loop mechanisms.

We understand that the open-loop mechanisms will be incorporated by the mobile stations at the mobile station without taking any help or any intimation from the base station. And is it happens in the downlink mobile station measures the power received in the downlink from the base station. And hence it tries to adjust the power for the next interval when he is going at for the uplink communication that means, it measures the power received in the downlink channel, but he tries to apply it over the uplink channel communication. And by doing that remember that open-loop power control can control over the shadowing and average path loss, it can mitigate both of them, but it cannot do justice with the small scale fading. And for that we need to go ahead with a very close observation and that is why the closed-loop mechanism will be better to control the SSF.

And the only available methods for their controlling the mobile station power at the start of the call is this is done by the open-loop mechanism only, where the receiver is having a no information from the mobile station it from the base station at the beginning of a call. He measures the incoming signal power received power, and he adjust some of it is transmission power for the immediate next session.

The closed-loop mechanism as we have studied it can be capiases to two different power control feedback path; one is the inner-loop feedback, another is the outer loop feedback. And inside the inner-loop feedback, what base station does base station observe the signal-to-interference-noise ratio over the short interval. He just he has a predefined SINR value or threshold value, and he tries to see whether the received signal-to-noise ratio is below that or above that if it and according to that it gives the instruction to the mobile station to adjust the transmit power. And remember the duration over which the inner-loop runs in IS-95 is approximately over a duration of 1.25 milliseconds only, and the command sent to the mobile station to either increase or decrease it will be at the gap of 1dB at least.

So, once the instruction comes from the base station to mobile station at the end of the inner-loop after checking the received signal power in the base station with respect to the signal threshold of the predefined threshold, if it is actually less then he will dictate to the mobile station to increase the transmit power level by around 1 dB or the vice versa. Whereas, the outer loop to control the outer loop the base station appraises the performance of the closed-loop and he actually continues this observation of the inner-loop over a longer time duration of 20 milliseconds. Where these 20 milliseconds is actually the frame interval; and then the base station competes the frame error rate.

It is not only the signal-to-interference-noise ratio measured in the inner-loop top of that he computes the frame error rate. If the frame rate is under control then he does not send any further information to the mobile station, but if it is not if the error is high then it gives instruction to the mobile station to increase the power. But remember actually the instruction will come at the end of the frame which is at the gap of 25 milliseconds.

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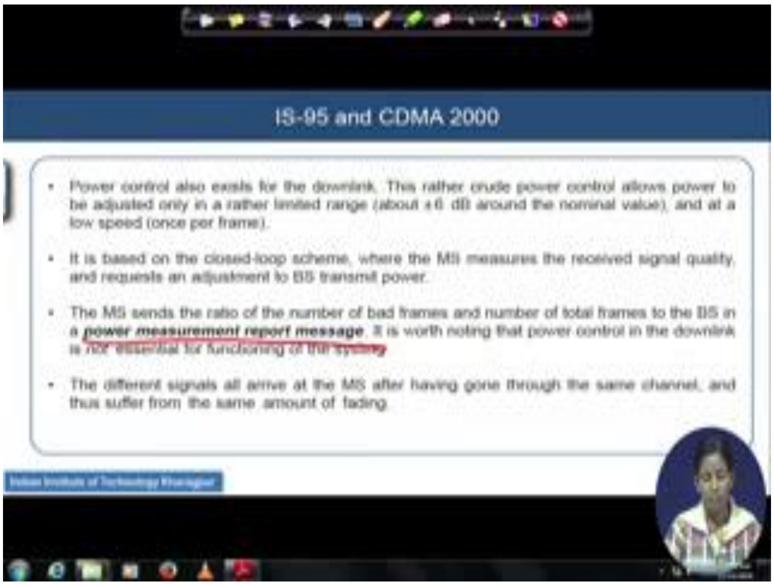

So, mobile station actually tries to see whether at the gap of a 25 milliseconds whether some further information is coming from the base station or not regarding the power control; if it is no then he continues with the same power level; otherwise he tries to adjust. So, power control as we have also seen that the power control is very crucial for the uplink, but there exists the power control and the downlink also. It is not that much crucial, but this power control will allow you to adjust only the rather limited range and it is based on the again closed-loop scheme, where the mobile station measures the received signal and then its quality and then it request to adjust a base station to control his power.

So, when during the hand shaking and the message exchange basically mobile station sends the ratio of the number of the bad frames to the total number of the frames of the base station received in the downlink, and then he prepares the power measurement report message we call it. And for that with that he actually requests the base station to adjust its power for the next downlink. And the different signals that arrive all that arrive at the mobile station after having gone through the same channel thus suffer from the same amount of the fading and that is why we say that in the downlink the power control is not that much critical for the communication.

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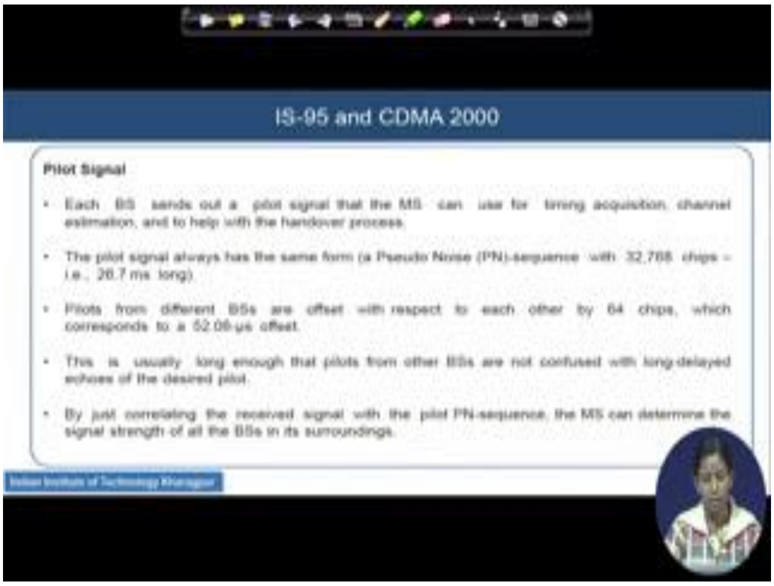

Next come to the pilot signals. We understand that each base station sends some pilot signals to the mobile station for timing acquisition, channel estimation and to accomplish the handover process also. And to do that it sends same some form of the PN-sequences, and the length of the PN-sequences will be 26.7 milliseconds corresponding to 32, 768 chips and the chip length, and this base stations pilots from the different base stations they will be having some amount of the offset with respect to each other we should not go beyond 60 length of 64 chips definitely and basically which translates into 52.08 microsecond maximum.

So, each of the base stations are actually having correlation time correlation after 50 or over a time relation after a 52.08 microsecond. And we think that we it is practically also experimented that this duration of 52 microsecond is long enough such that the pilots from other base station would not be able to reach to the existing to the current base station pilot data. And they would not confuse the extraction of the pilot that means, the delay is delayed enough to extract the desired pilot. And that is actually after getting the pilot PN-sequences mobile station gets lot of information related to the synchronization and estimation that needs to be done performed in the handset.

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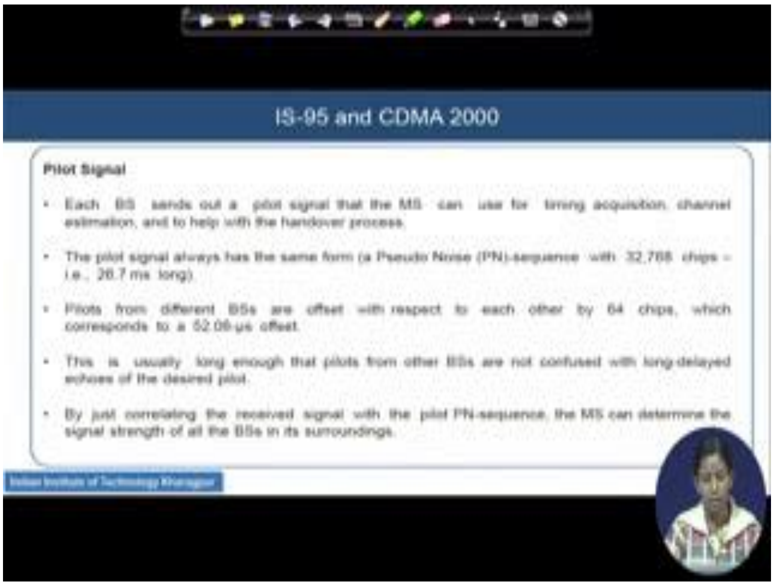

Coding, if I try to see we understood that two different kinds of the codings are there. And before a speech signal is can be transmitted, it needs to be coded we call it as speech coders; and we also provide the error correction coding for the channel at to handle the defads again inside the channel. Spreading modulation where portion we have already discussed and the coder the speech coder that is designed to basically it has to be designed in such a way that the speech coder should be able to support the variable code rate that is the demand from the practice. And we actually see that for the uplink always is a for the uplink actually the coder is always should be output of the coder should be

28.8 kilo bit per second in IS-95, whereas for your downlink you have the limit up to 19.2 kbps.

There are famous speech coders developed already for the practice; one is the IS-96A coder. This IS-96A coder actually is vocoders, and it gives a data rate up to 8.6 kilo bit per it works nicely with 8.6 kilo bit per second rate.

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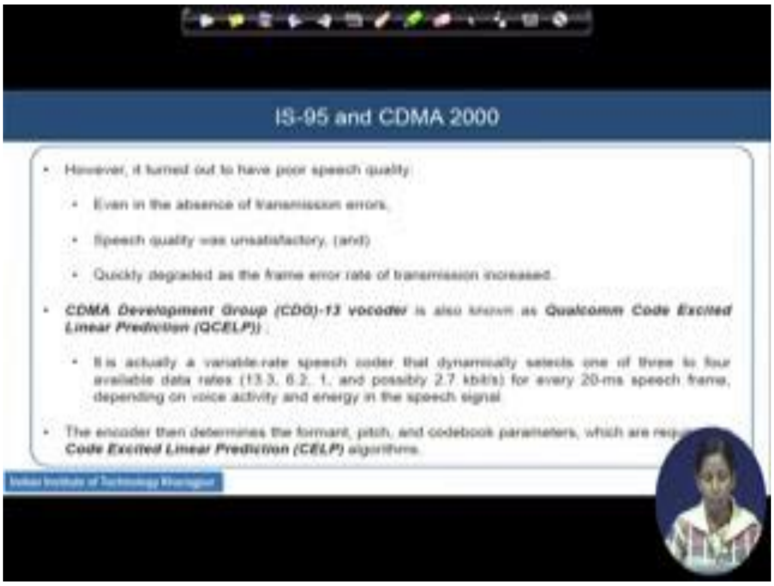

But the main problem of this IS-96A is that in absence of this transmission error is quality of the it produces a very poor quality; it produces very poor quality of the speech at the receiver end. Hence it is unsatisfactory and it is quickly degrades as the frame error rate of the transmission is increased I mean the performance of that coder. So, the people developed the second version of this IS-96A which is called the CDG 13 vocoder, and this is a preparatory algorithm that was developed by the Qualcomm again and Qualcomm called it the QCELP, it is the coded excited linear prediction based coding schemes.

And basically it is again a variable speech coder which can provide the variable data rates starting from 13.3 to 2.6 kilo bit per seconds, it is the range, over which you can have for every 20 milliseconds, it picks up this coder picks up of any one of this code rate based on the some kind of the voice activity, the energy in the speech signal by observing lot of stuff. He will pick up any one of this. And this encoder then determines the format, the pitch, the codebook parameters everything which are required for this code excited linear prediction algorithm.

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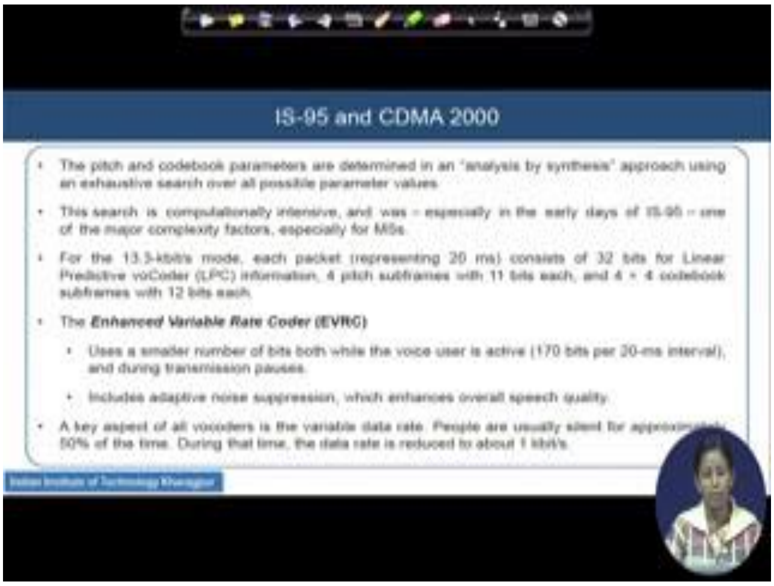

And remember this pitch and the codebook parameters they will be determined in an analysis by synthesis mechanism, extracting will be the basically the parameter values all the possible parameter values. And this search is very much complexity in a high huge complex, it is computationally intensive and computationally complex. And specially for early days of IS-95, this was a major complexity factor specially for the mobile stations which restricted the operation of this CLP further. And hence people develop the further development on the variable rate coder which is called enhanced variable rate coder, and that uses a very small number of the bits at the beginning for both the voice users for bits both while the voice user is active as well as the transmission pauses are going on. And in that situation, we start with the data bit of 170 bits for 20 milliseconds interval and then includes adopted noise suppression techniques and enhances overall speech quality a lot.

The key aspects of this vocoders is that it should support the key aspect is that they should support the variable data rate. And usually the continuously people cannot speak. So, usually over a conversation you will see that 50 percent of the time one person is silent; and during that time the data rate comes down to be 1 kilo bit per second. So, when you are talking either you are talking at the rate of 8.6 kbps or 13.3 kpbps or when you are silent the data rate is coming down to 1 kbps. So, for both the situation the variable rate coder should be able to support the communication system that is the fundamental demand of the design. And I am not the IS-96A, but we are see could support all this demand very nicely after designing to some extent.

In the next module, we will see some for some more features mainly the error correcting codes error that are used for this uplink downlink in IS-95 and some other features related to the channels.