Lecture - 45
Introduction to CDMA

Good morning. We begin lecture 45. Again thank you very much for the cooperation extended yesterdays that we would cover lecture 43 and 44. So, since we have covered more material than a typical lecture, I thought it could be good for us to summarize the key concepts. But as you are seeing in CDMA it is several simple concepts that have been put together to build a very complex very efficient system.

So, maybe even to begin with if I were to ask you to draw the block diagram of a spread spectrum system, multiuser spread spectrum system based on the concepts that we have already studied so far, I think that would be a very good exercise. So, this is how it would go.

(Refer Slide Time: 01:03)
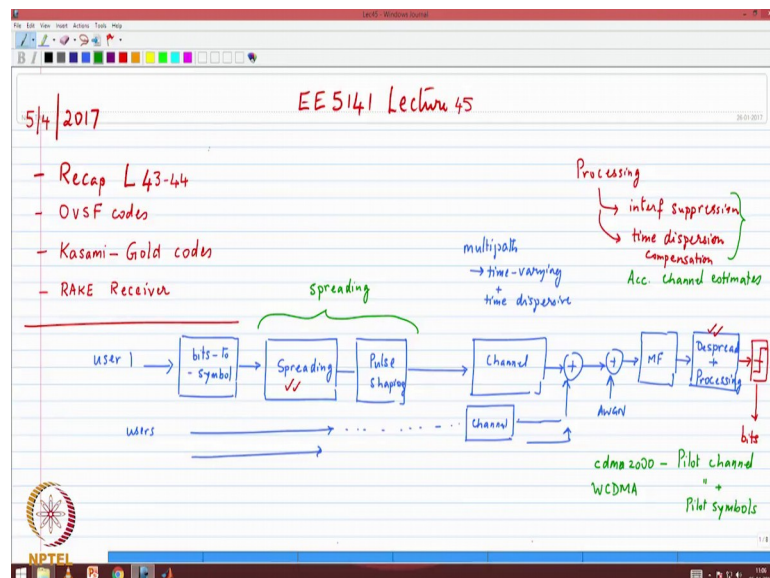
So, for user 1 you would have the information bits, this is user 1 and you would map it on to a symbol that would be exactly as you would do for a narrowband system bits to symbol mapping depending upon what the constellation modulation using, we have been looking at the binary as a simple form, but you do not have to limit yourself.

Then would come the process of spreading. So, the introduction of chips let us assume that it is a binary modulation. So, the process of spreading introduces more signal transitions and then after that you will do the pulse shaping and we have combined these 2 operations quite often to refer to this as our spreading operation, but that is there is a bit level spreading and then there is a pulse shaping that is associated with that ok.

So, this can also be broadly classified as the spreading process. So, at this point our signal will enter the channel, the channel can be a multipath channel; so multipath. So, it could be time varying and time dispersal. So, that is part of our now where does the interference from other users come in. So, our signal has experiencing some channel add to it, the signals of other users. So, basically you would have several of them, each of them will if they are spread spectrum they will go through similar operations, they will go through their own channel and then we will get added on to our.

So, basically you will have several of these interfering signals that are getting added to that, and to all of this we have the AWGN that will always be present AWGN is present. So, here is a system where there is signal which has been spread many user signals which have also been spread that are mixing together in the channel, causing potentially causing interference and AWGN also present, ok.

Now, at the other end the first step will be the match filter and this would be a chip level match filter, because that is how we would be we want to be able to separate after these chip level match filter, then you can do the despreading operation, but because we have also encountered other impairments such as time varying dispersion and other. So, we would also write down here in addition to dispreading, we would probably do some form of processing ok.

The processing would be in the form or processing would include interference suppression I need to be able to handle all of the interfering signals, interference suppression. I would also need to worry about the time dispersion, time dispersion compensation because only then I can apply the decision device and if once I have done all of that then comes the stage where I will do a decision and then take out the bits. So, at a high level, I do not want you to miss the where exactly is the spreading despreading operation. So, what we have been studying deals with spreading and despreading operations.

Now, these operations do not require you to know the channel, but you need to be able to synchronize because you are spreading and despreading must be applied at the corrected points at the cur in a synchronized manner.

Now, these 2 operations interference suppression and time dispersion it is not time dis it is time dispersion compensation. So, some form of equalization, these will require you to have channel estimates. So, they will require accurate channel estimates, channel estimates would mean the complex channel gains. So, basically magnitude amplitude and phase are is required.

So, you are building a coherent receiver channel estimates and this is usually done in the case of CDMA 2000 the coherent channel estimates are obtained through a pilot channel which is not transmitting any information, but is only transmitting an m sequence so that you can do the channel estimation. So, there is a pilot channel and in WCDMA it is a combination there is a pilot channel plus pilot symbols. Pilot symbols are nothing, but known symbols that are inserted in your traffic sequence ok.

Now, in today's terminology when we in design a coherent receiver, you have to transmit known symbols right typically you would have called it known symbols why do you call it pilot symbols you know the terminology is always pilots symbols OFDM these are the pilot symbols in the OFDM system, and the history comes from because in the CDMA system there was a channel which was dedicated for channel estimation called the pilot channel.

So, anything associated with pilot channel estimation, now seems to have the name pilot associated with they call it pilot symbols or a pilot. So, basically there is a need for you to do very as accurate as possible channel estimation and that is what we have seen, ok.

(Refer Slide Time: 07:44)
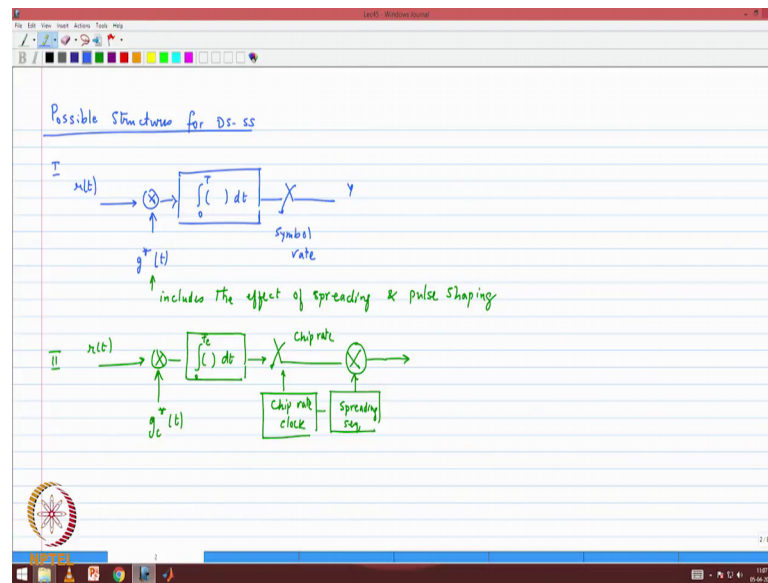
So, the I thought there was a question, the form of the receiver that we would like to work with is the chip max sequence followed by the despreading operation and of course, along with that whatever additional processing that we would need to do ok.

(Refer Slide Time: 08:03)
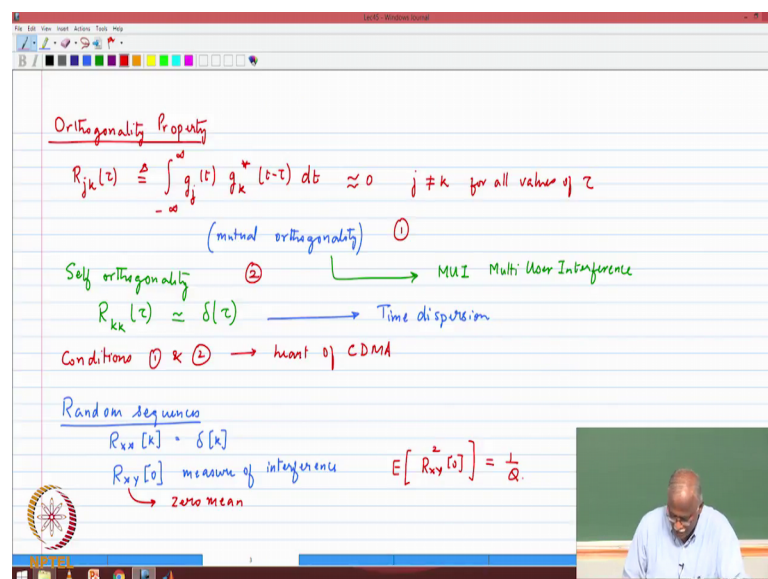
The 2 properties that are very important for us, one is mutual orthogonality that makes me robust against other users codes and self orthogonality and both of these are necessary for us to build a CDMA system. So, maybe just to reemphasize the mutual orthogonality is what helps me be robust against multi user interference. The common

notation is a MUI multi user interference this is the interference caused by other users who are on the same channel, multi user interference and self orthogonality this is the one that helps me deal with the multipath time dispersion.

So, those are the 2 impairments as you can see if you went to see go back to the first channel the things that we are worried about is the channel impairments and the interference impairment. So, both of these must be handled in the despreading and the processing operations, which is important for us. So, this is important the 2 parts.

Then we also said that the we studied the properties of random sequences let me just write down the other key results, random sequences as a starting point for our understanding of choice of spreading sequences and we showed the following the following properties and basically we said that if we can achieve this type of performance it is its very good.

So, the random sequences R_{xx} of k autocorrelation, this comes out to be delta of k and that is a property of (Refer Time: 09:58) and cross correlation R_{xy} of 0 this we said was a measure of the interference because that is what comes in when I try to despread my desired signal, I will get a cross correlation between my sequence and the sequence of the interfering signal. So, this is a measure of the interference and we want to keep this quantity in mind and we did a quick statistical characterization, this one we showed because of the information bits being independent, this one turns out to be zero mean the property of the of the of the bit sequence, that that represents the random sequence and, but more importantly we were interested in the energy.

So, R_{xy} of 0 squared and this we showed was equal to 1 over Q; and this is the one that tells us that if I can use something that that has the properties or behavior like a random sequence, I get a suppression of my interference by a factor 1 over Q. So, if there are 2 users 2 interfering users, the net interference that I will see is approximately 2 over Q. If I have ku uses it will be k over Q that is the net interference.

So obviously, you do not want your k 2 become larger than Q because your protection against your interference is primarily dependent on q. So, the way to start to think about the system is that this is a system that is very good and extracting your signal, in the process of extracting your signal if you have good correlation properties. It will suppress the unwanted signals and it can suppress any number it suppresses multiple unwanted

signals at the same time the single operation will suppress them and it suppresses them by a factor of 1 over Q and that is what makes the system robust.

(Refer Slide Time: 12:10)
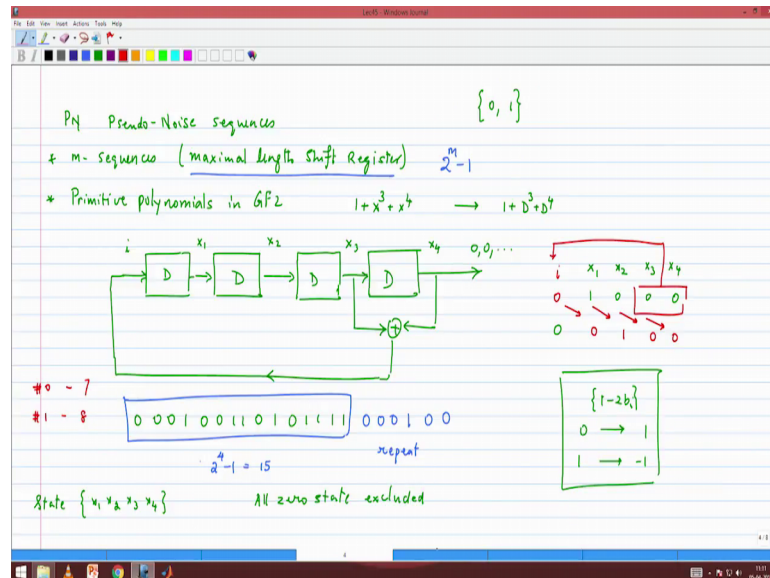
We did spend some time talking about the properties of PN sequences, again these are basic shift register operations. So, I am assuming you would not have any difficulty to generate this sequence of 6 16 or15 values.

(Refer Slide Time: 12:25)
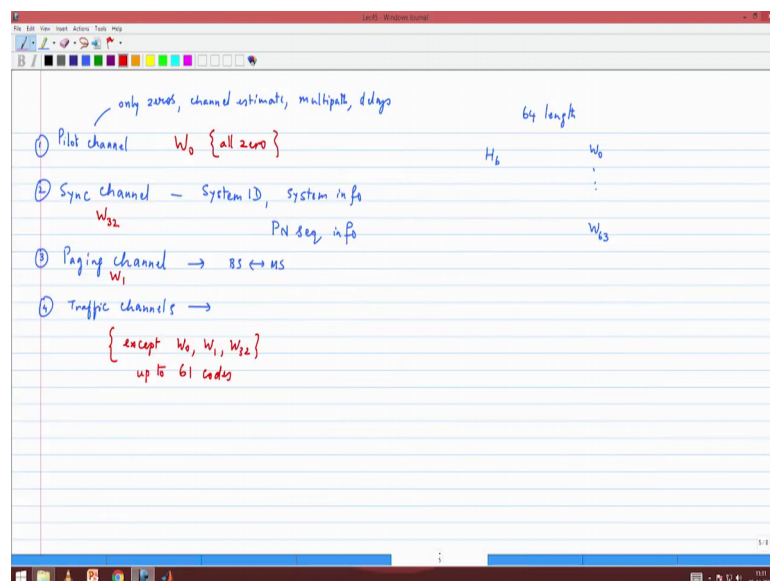
Let me just summarize the properties and I think that will be that will be very useful for us because even if you have studied m sequences before, these are a very crucial for us to understand CDMA 2000 and white when wideband CDMA.

(Refer Slide Time: 12:42)
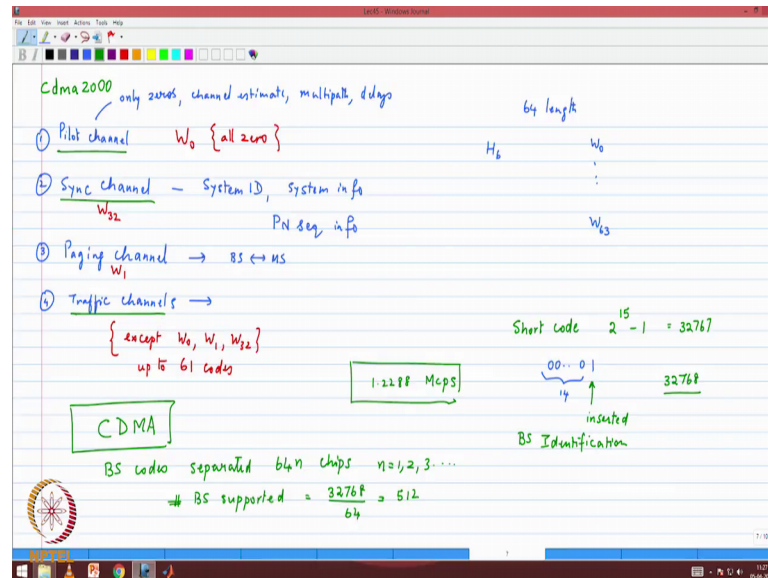
So, the properties of m sequences, again just a quick summary since these are basic concepts if I have m shift registers; that means, I have a primitive polynomial in gf 2 which is of order m, m shift registers. So, this will lead to a sequence of length 2 m minus 1 and interestingly this also happens to be the period of the sequence, because after that the sequence repeats itself. So, very interestingly what we call as a PN sequence happens to be a periodic sequence. Actually if there is nothing not nothing random, but it is a very predictable sequence after you have gone passes 1 period ok.

So, a very interesting so, but it has all the properties that we are looking for, what are some of the other properties that we are by the way in the shift registers we may be dealing with zeros and ones, but the mapping that we are using a 0 will map to a one a one will map to a minus 1. So, please whenever we interpret the results especially when you are doing correlations, we have to be careful are you doing it in the bipolar values or the binary values, if it is binary you are doing a modulo 2 addition if it is the bipolar values you are actually doing the multiplication.

So, again keep that picture in my keep that point in mind. So, that there is no confusion about the interpretation of the results. These m sequences have got the following

properties again just interesting for us to observe balance property. The number of zeros and ones are almost the same and there actually there is a very precise relationship there are 2 m 2 power m by 2 ones and 2 power m by 2 minus 1 zeros. So, once they get mapped there is one extra minus 1 compared in the overall sequence, once they get to the bipolar values otherwise this is this is a good picture because when I add any of these m sequences the answer will be

Student: (Refer Time: 15:00).

A it because of this property I will always get the value. So, there is a important indication of how this these things are going to play out for us. So, basically the ones and minus ones will start to cancel each other and I will be left with a minus 1 at the end, if I add this any of these m sequences in the bipolar representation.

The other interesting property is that when I take a m sequence and do a modulo 2 addition of the of itself with a cyclic shift of k units cyclic shift, I produce another cyclically shifted version of the sequence. So, all the properties are still preserved the balance property the run length property all of that are still preserved. So, basically it is just a cyclic shift of that.

So, this is again a very useful property as you will see in today's lecture. A run length property I would not rewrite that it just says that the probability of having a sequence of identical digits 000 or 111 becomes less and less probable. So, long runs are less probable that is all nothing more to add, probably the most important let me use a different color that is going to be the autocorrelation property and this is what we will leverage anytime we work with m sequences.

So, this basically says R x of k this is a cyclic autocorrelation one defined as 1 over Q summation L is equal to 0 through Q minus 1 x of L x conjugate we are dealing with the real values are conjugate really does not matter L minus k mod Q and this is what we showed yesterday as minus 1 over Q, and this is a very useful property because this is what will be the strength of the m sequence when we work in a environment where there are multiple users and multipath as well. This also led us to some observations that m sequences basically all the different m sequences that are available are cyclically shifted versions of it.

So, there are some limitations for m sequences, there are limitations when there are multiple users because then I have to you give them all different codes and that actually these codes are not they are all cyclically shifted versions. So, therefore, there is confusion when you have multiple users and multipath. There is a possibility that we will not be able to tell the difference whether it is a new other user or it is a multipath component

So, this basically says that I if I assign one of them m sequences, then I cannot assign several cyclically shifts. So, that is a limitation. So, we also said that if I take sequences from different generator polynomials, m sequences from different generator polynomials there is there are good sequences available by the way you can get good correlation, but you know you want large number you want to have let us say 32 users, and in order to find 32 sequences from different generator polynomials all of which have good correlation properties is going to be the challenge.

So, different generator polynomials here there is no guarantee of the cross correlation. So, you have to check the cross correlation. So, you have to check and see if the cross correlation is check the cross and there are cases where you will see poor cross correlation as we mentioned yesterday cross correlation. So, that is a quick summary of what we have said as far as the m sequences are concerned.

Now, the applications of m sequences we said yesterday are primarily in scrambling because the spreading part may not be we have not yet found a solution to that.

(Refer Slide Time: 19:24)
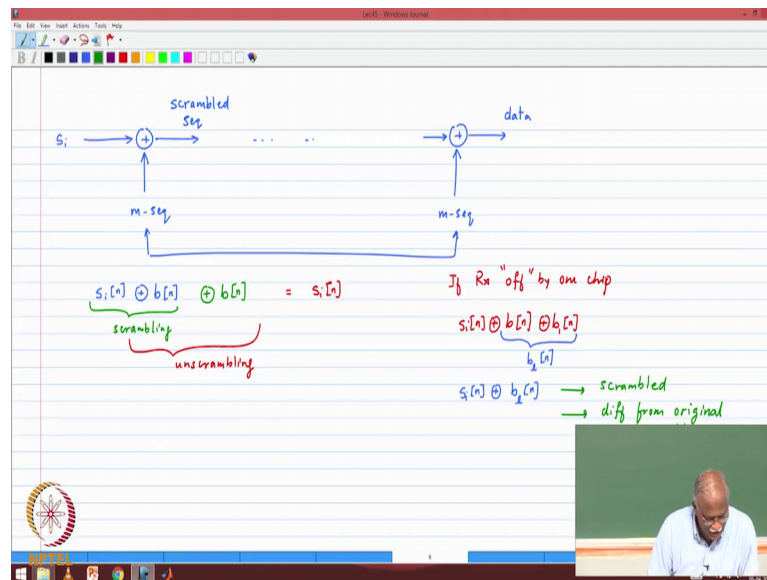
So, now how does the scrambling work if I have a input information sequence si binary, I can do a modulo 2 addition with my m sequence which is also represented in the binary form modulo 2 addition, and this will come out to be a scrambled sequence, ok.

So, the a transmitter has to generate m sequence now you know and then you do the rest of the processing. At the receiver let us say that you have received a scrambled sequence you have to be able to unscramble it and the unscrambling process is basically a modulo 2 addition with the m sequence itself. So, the receiver must also be able to see generate the same m sequence and m sequences can be very long, yesterday we saw that the long code used in CDMA 2000 is 2 power 42.

So, you know where in the m sequence where do I where do I start. So, these 2 must somehow be synchronized you at the receiver must know at this point and time what is the m sequence what is the phase of the m sequence that that is being used for scrambling that same m sequence values should be added at this point and this is what gives us the data once again ok.

This is a and I just want to write down something very simple, but I want make sure I want you to think about this. So, s i of n is a binary value, I do the operation with the m sequence let me call that as b of n. So, this is the scrambling operation then at the other end I do exclusive or with bn, bn exclusive or with itself will remove the scrambling. So,

this is the unscrambling operation and what comes out of this is s i of that is what we have written down here ok

So, again a simple operation, but it is good for us to know in the context. So, in a CDMA system you have to be synchronized at the chip level, you it is its much more stringent than a narrowband system because the in a narrowband system you must be synchronized at the symbol level. Chips are much smaller in terms of time duration compared to a symbol. So, therefore, a synchronization at the chip level is critical ok.

Now, an interesting question what happens if for some reason your estimation of the synchronization is slightly off and you are off by one chip. If you are off by one chip if the r u not urx the receiver is off by one chip. If Rx is off means it is synchronization is slip it is you know one off by one chip what happens by one chip, ok.

So, what we have is s i of n modulo 2 b of n, modulo 2 b 1 of n am I correct you are off by one it is a it is shifted to the one and we know that b of n plus b 1 of n is some other cyclically shift version b L of n. So, what I actually will get is s i of n scrambled by b L of n actually I mean deep trouble, because now what happened. Now I do not even know what these scrambling sequence is because it if the combination of the original sequence plus a cyclically shifted version now I actually must figure out what is the shift in order to undo this.

So, this is where the problem is coming. So, this means that the scrambling is still present it is still scrambled and the problem is it scrambled by a sequence that I did not use right it says it is a new sequence. So, it is and the scrambling is different from the original scrambler. So, it is it is a important point to keep in mind. So, though it may seem like oh it is just trivial just do modulo tradition at the transmitter modulo 2 addition; addition at the receiver no this core synchronization is very very important just a observation ok.

Now, this is CDMA 2000 goes by the name CDMA, CDMA is lowercase that is the trade trademark officially code division multiple access actually has a acronym uppercase CDMA, the system the first system that was used using code division multiple access was CDMA and then eventually became called CDMA 2000, 4 types of logical channels that need to be supported one is a pilot channel used for channel estimation, second is a sync channel then a paging channel for all the exchange of information between the

mobile and the base stations. And then finally, the users traffic and we saw how all of these are all will eventually be create or will be transformed into a sequence which has this magic number 1.2288 mega chips per second.

All these channels eventually must produce 1.2288 and at that rate of 1.2288 they get combined and then pulse shaped and then transmitted using an IQ transmitter. So, in the process we notice that there were 2 PN codes or m sequences that were utilized and the 2 PN sequences the official names given the one is called the short code or the short a PN sequence, this is the one with 2 power 15 as the basically the 15 order polynomial, ok.

So, this is will produce a sequence 2 to the power of 15 minus 1 and in the, but basically the this number is 3 2 7 6 7 it is slightly awkward number if it had been to power 15 that have been much easier. So, they actually make it a 2 to the power 15 sequence in the implementation.

Now, what is it that that basically mean that insert one bit, and that one bit comes there is one occurrence of the following sequence 0 0 0 0 14 run length, there is one run length basically somewhere in these in the sequence there will be a length 14 zeros, 15 zeros can never occur 14 zeros. So, after these 14 zeros you insert a plus 1.

So, this is the bit that is inserted and. So, you know you know exactly where the additional bit has been inserted. So, that is after when you see 14 zeros as a. So, this with this insertion it becomes 32768 and this is used for base station identification do a simple calculation regarding this, because of multipath I cannot use successive cyclic shifts, we said that we are going to use the cyclic shifts by 64 units.

So, basically base station codes these base station codes that are used for identification are separated by multiples of 64 chips 64 n chips. So, n equal to 1 2 3 and so on So, how many base stations can be supported number of base stations that can be supported it has to be this 32768 divided by 64 32768 divided by 64 that comes out to be 512, and they thought that no cellular system or no individual deployment or in a one location will have will require ever need more than 512 base stations. So, they say oh this is pretty good we will build a system that is fine whether that is. So, that is a little bit of history ok.

(Refer Slide Time: 28:09)
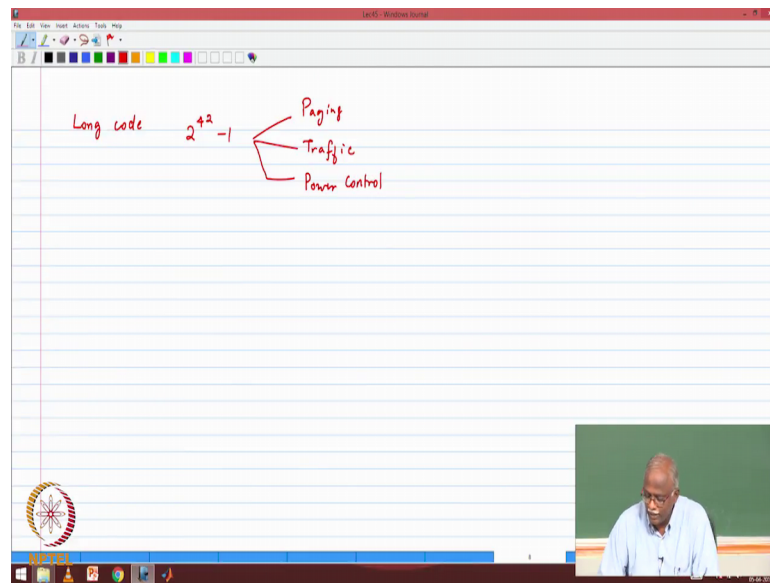
What about the I said there are 2 codes, one is the short code the other one is the long code. The long code consists of a 42 shift register 2 power 42 minus 1, this is used in the paging channel to scramble it is also used in the traffic channel with a user specific mass. So, it is not just the m sequences some additional modification and this is also used to tell you where to insert the power control bits.

So, this longs long code is it is plays a very important power control bits, which of those you have to insert 800 of them per second which where do you puncture and insert the power control bits. The locations are determined by the long by the long code and of course, what value you would insert depends on whether the base station wants you to increase the power or decrease the power ok.

(Refer Slide Time: 29:00)
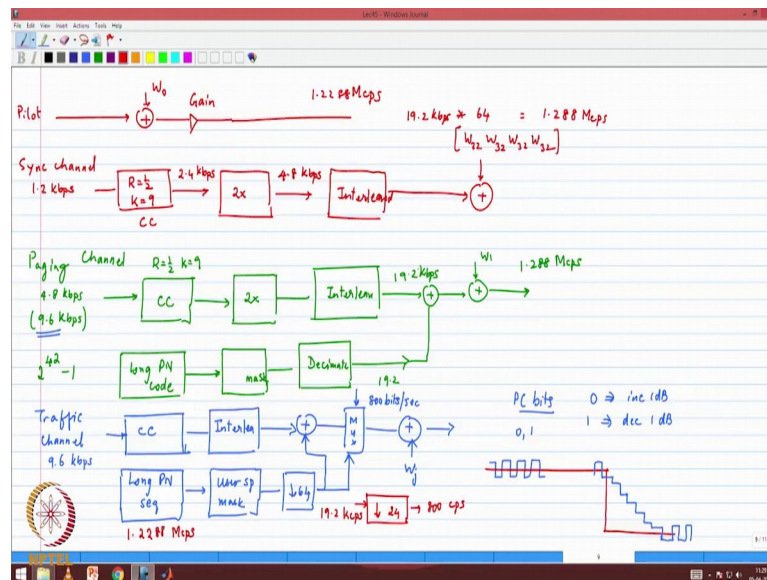
So, again, now, we if you go back and look at this information the this hopefully is a useful and these numbers also are important. So, if you go along this in this branch. So, this is coming at this is being generated at 1.2288 mega chips per second, when it when you down sample it by 64 you get 19.2 kilo chips per second k cps it should not should not write bits and then if I further down sample by 24, down sample by 24 that is what gives me 800 chips per second ok.

So, the ultimately there is this down sampling all of these numbers are done using simple operations like down sampling up sampling and they all are in the way they are chosen has a very specific structure and a purpose behind that.

Now, this is CDMA 2000 and any CDMA system more or less will have similar types of information, it must have a way for you to estimate the channel either a pilot channel or pilot symbols, it must have a paging channel it must have the traffic channels.

(Refer Slide Time: 30:28)
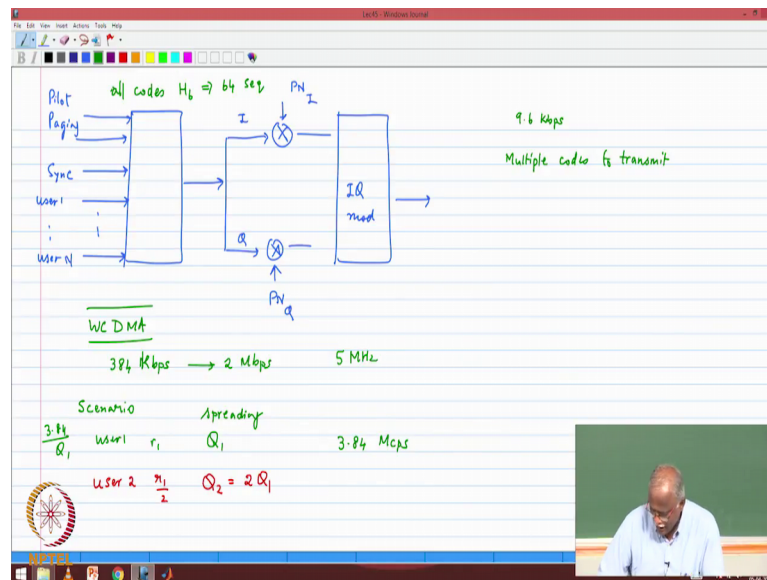
So, wideband CDMA has a following difference with respect to a CDMA 2000 and that difference is that all the spreading codes for a CDMA 2000. All the codes are from Walsh Walsh Hadamard; I think I used the notation H 6, H6 which means they are length 64 sequences all of them whereas, here we are not constrained by the length 64 and there are differences.

(Refer Slide Time: 31:08)
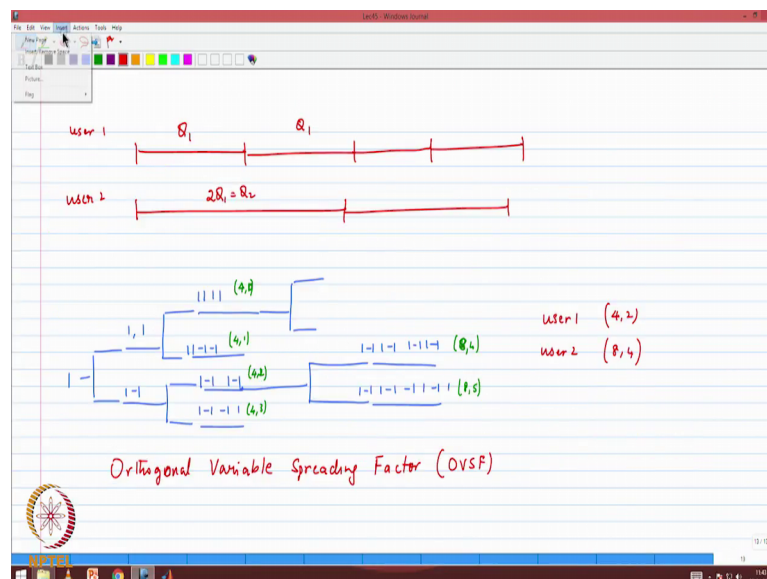
So, let us quickly build on this and see how to understand this system. So, let me quickly spend a few minutes on the wideband CDMA system introducing for you they one of the key elements of wideband's of the wideband CDMA system.

(Refer Slide Time: 31:30)
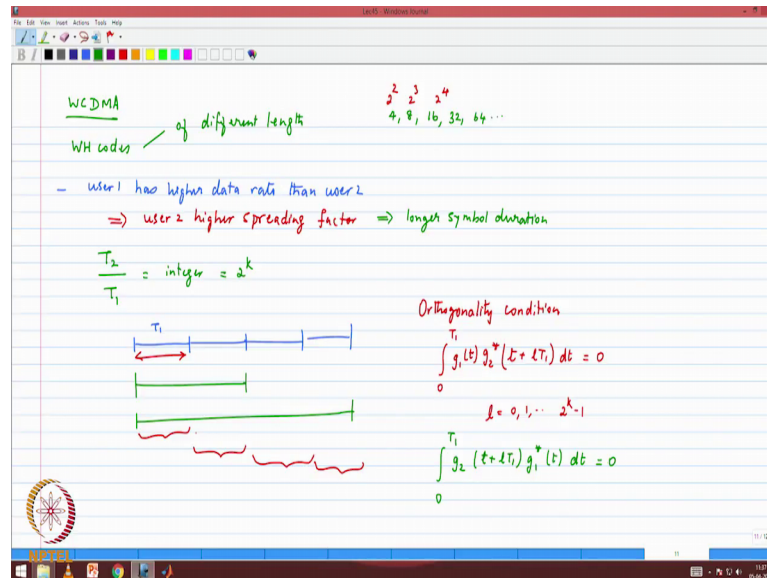
So, wideband CDMA also uses Walsh Hadamard codes, but it uses Walsh Hadamard codes of different lengths not just a fixed length of different lengths, we make some assumptions about the possible lengths that can be used. So, Walsh Hadamard codes you can have are 4 8 16 I have left of 2, but basically starting. So, basic you get powers of 2, 64 and on this is 2 squared this is 2 squared, 2 cubed 2 power 4 and so on So, basically powers of 2.

So, the wideband CDMA does the following, let us say that there are 2 users one of them has got a higher data rate. So, user 1 has higher data rate than user 2 higher data rate than user 2. Now user 1 and user 2 cannot have arbitrary data rates. So, this because the spreading factors are restricted just one more line before we go to that point.

So, this will also mean which of them has got a higher longer spreading code? User 1 has got a higher data rate.

Student: (Refer Time: 33:00).

So, we will have a shorter spreading code the user 2 will have. So, user 2 this also is another way of saying that user 2 has got a higher spreading factor. If you have a higher

spreading factor and the chips are always fixed in terms of their duration, then the symbol duration of user 2 is longer. So, user 2 has higher spreading factor, if you have a higher spreading factor that automatically leads to because your chips are of constant duration of longer symbol duration, I hope just sort of the lengths between that symbol duration, ok.

And. So, now, the condition is the symbol duration of user 2 divided by the symbol duration of user 1 has to be an integer and it has to be a power of 2 that is that is what will be allowed because of these different spreading factors. So, when I take the ratio. So, typically as an example supposing user one has got the following spreading this is T 1 user ones symbol after spreading, user 2 can have this or user 2 can have this because it is got a lower rate it can be a factor of 2 or a factor of 4 and so, basically this is very important for us to maintain we do not allow arbitrary spreading factors, but gives you enough flexibility.

But now very important how will you construct the receiver? Receiver for user one will say I am going to require the following orthogonality condition what am I orthogonality what am I going to do? I am going to do a matched filter receiver what will I use as my duration of my waveform; it will be of duration T 1. So, again the keep in mind that this is where it is a very simple step, but important that you are following this.

So, the orthogonality condition when I have different lengths it is its very important for me to capture. So, orthogonality condition says that I can go from 0 to T 1 that will be my it will be g 1 of t, g 2 star of L t plus L T 1, dt should be as close to 0 as possible. Now what am I saying? I have this portion of the waveform and I want to correlate with respect to that. Now if this portion of the waveform must be orthogonal to this then shift the spreading sequence of user 2 by how much T 1, then you have to show that it is orthogonal to this portion after your shift then it just shows orthogonal to this portion it is orthogonal to this.

And how many such shifts will you get? 0 1 2 all the way to 2 power k minus 1, because that is the number of possible shift. So, this is the essence of the orthogonality condition why because the receiver to in order to detect this symbol, we will take this portion of the received waveform and apply the correlation based receiver and therefore, it will have to correlate with this it will get the desired data this is some unwanted portion, but

this correlation segment waveform must be orthogonal must look orthogonal to this portion.

Then this portion does not affect my decision, then I move my receiver to this portion and then I try to do the correlation basis even then, but at this point in time it has to show orthogonality with this part of the user twos code and that is how the whole thing emerges. May be it is may find it a little bit intuitive to write it in the following fashion 0 to T 1 instead of shifting instead of writing it like this, you can write it as g 2 star t plus lt one times g 1 sorry.

Student: G 1.

G 1 star maybe this is more intuitive for us to write because that is how the. So, this we want to be as close to 0 as possible these 2 are exactly the I am I just rewritten that ok.

So, now we also in the last class we did a quick you know saying if I have a assigned a code I cannot assign the any successor and other things. So, I want to this technique of preserving orthogonality at different lengths, has got a specific name which was introduced for wideband CDMA it is called orthogonal variable spreading factor codes OVSF and it is an interesting concept because it for the first time we started to think saying- hey always it was always thought of as all users having this same spreading factor.

Now, you may have a voice application which has got certain spreading factor you may have a high data rate data application, which is got a different spreading factor and both of them can be supported on the same CDMA system. So, OVSF is a very powerful concept and that has been introduced in wideband CDMA.

So, let me just h quickly give you an introduction or basically.

(Refer Slide Time: 39:03)

So, OVSF the concept says that we can use codes of different lengths codes of length and the lengths are constrained to be powers of 2, 2 power k. So, starting from k equal to 2 onwards we can go and we still have to maintain orthogonality. Orthogonality maintained even with the codes of different lengths, orthogonality must be maintained and that is the feature of OVSF, orthogonality maintained you can please I do it saying that for codes of different lengths.

So, the rule is a very simple one OVSF rule, the rule says that if a code is assigned then you cannot assign any of it is successors that is the first thing that is forbidden, you cannot assign any of the successors, you not assign a successor; that means, a code of longer length that is derived from this code. So, this is a code of longer length a successor will have longer length predecessor will have shorter length and you cannot assign a predecessor either because both of them will violate a predecessor, this is a code of shorter length, ok.

So, this is the basic rule you can assign everything else, all other codes any other code can be assigned. Now when you have codes of length 4 or 8 it is easy to do it by hand, but usually the spreading factors in wideband CDMA go up to 512, you can go up. So, basically these codes it is you have to have a systematic way of numbering the codes.

So, the convention that is used in terms of the notation this will help us in the next example that we are going to. So, OVSF L comma n means this is the nth code length L

where L is some power of 2 and n itself can be 0 1 all the way to L minus 1; so l L-th code of sorry L-th code of a of length L ok.

Now, the Hadamard way of generating longer length sequences from the shorter length is captured by the following. So, OVSF length L comma 2 i; that means, I am looking at some the length L the 2 i-th code, this would have come from an OVSF of length L by 2 and it would have come from the i-th code of length L by 2, because when I go to the next level I will get 2 2 for each of those showing this is. So, and this is and how was this generated? I got it by repeating OVSF L comma L by 2 comma i. So, that was how I got OVSF L comma 2 i, now OVSF L comma 2 i plus 1 that is obtained by OVSF L by 2 comma i minus of the flipped version of OVSF L by 2 comma i ok.

So, I hope if you just try of few example I mean write it down it is not difficult at all to see. In fact, especially if you go back to the tree that we drew, it will become very clear to see that 4 comma 2 will generate 8 comma 4 and 8 comma 5 you can see that and then you can verify this ok.

So, just as a quick example as always let us say OVSF 2, if OVSF 4 comma 2 let me just see what OVSF 4 comma 2 is 4 comma 2 it is 1 minus 1, 1 minus 1 OVSF 4 comma 2 is 1 minus 1 1 minus 1 this will give me OVSF 8 comma 4, that will be 1 minus 1, 1 minus 1 and then that repeated 1 minus 1, 1 minus 1 and it will also give me OVSF 8 comma 5 which would be 1 minus 1, 1 minus 1, 1 minus 1, plus 1, minus 1, plus1 basically the that sequence are flipped. So, again from here we have obtained this set using the formula that is given on the left.

(Refer Slide Time: 44:23)
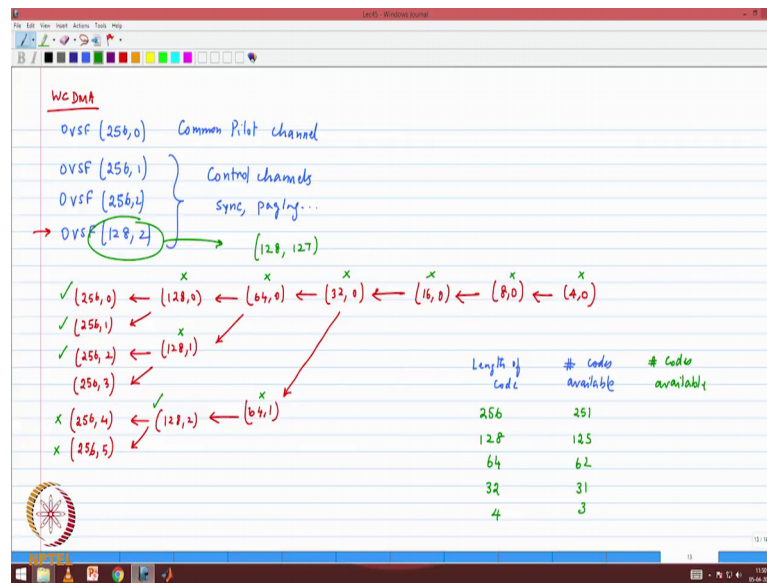
Now, comes the design of the system, wideband CDMA system just like CDMA 2000 has follows certain conventions for assigning. So, OVSF 256 comma 0 is always dedicated for the common pilot channel. OVSF 256 comma 1 is dedicated for control channel. So, is OVSF 256 comma 2 and OVSF 128 comma 2, these three are dedicated for what we call as the control channels. Control channels include synchronization channel, it includes the paging channel and so on dot dot dot several control information has to flow.

Now, why would somebody use a spreading factor of length 256 and a spreading factor of length 128, what does this tell you. This particular channel has got higher data rate. So, in order to accommodate the higher data rate they said instead of keeping or adding more and more channels I am going to I am going to use 128 comma 2 and then send it in a more compact fashion, ok.

So, this is structure now how do you how do you visualize this. So, this is how we visualize. So, 256 comma 0, the predecessor was 128 comma 0 and it is predecessor was 64 comma 0, predecessor 32 comma 0, predecessor 16 comma 0, predecessor 8 comma 0, predecessor 4 comma 0. So, and of course, 128 comma 0 also is the predecessor for 256 comma 1, and 256 comma 2, the predecessor is 128 comma 1 and the this one has got 256 comma 3 and so on.

Now very important to note you have when you assign 256 comma 0 when you say that is for the common pilot channel, that automatically eliminated all predecessors x it means that they cannot be used in that system in the wideband CDMA system that is the OVSF rule right.

Can 256 comma 1 we used?

Student: (Refer Time: 47:08).

Why, because it is neither a predecessor nor a successor. So, this is 256 comma 2 can be used. So, 128 comma 1 cannot be used what is the predecessor of 128 comma 1? 64 comma 0 that the anyway that was already blocked out.

Now, 128 comma 2 is 128 comma 2 has been used. So, 128 comma 2, 128 comma 2 has got 2 successors that will be 256 comma 4 and 256 comma 5 the predecessor of 128 comma 2 happens to be 64 comma 1 as a predecessor, and the predecessor of that will be 32 comma 0.

So, we assign 128 comma 2 that was the fourth code, that we have assigned as part of the system design. So, which means that I have blocked 64 comma 1 and all the predecessors I have also blocked 256 comma 4, and 256 comma 5. So, this is the wideband CDMA code allocation scheme. So, now, comes the application of this. So, this is the length of the code and this is the number of codes available.

Now, if I tell you I am interested in length 256 codes, how many if 256 codes are available? So, I go down the length the line of 256 and if there is a either a tick mark or an into mark; that means, it is gone either it is been assigned or it is been blocked

So, 5 of them have been blocked. So, the number of codes available will be 251 5 of them. So, if I go down to 128, I see that 3 of them have been blocked. So, 125 codes are available. So, go down the list 64 lengths, you get 62 of them available because 2 of them have been blocked, 32 I can have 31 codes used and for 4, I can have 3 codes used. So, this is what is available.

So, if a user comes and says that I want length 256 no problem I have got 251 of them available. I can assign to you want length 32 I have so many codes available. So, you are constantly mapping or managing the allocation of these codes, at any time if you have

assigned one code you must block out all the successors and the predecessor that is the most important thing, because if you do not do that then you will violate orthogonality and the performance of your system will go down ok.

So, managing the and once you have a map like this and it is all you have to do is put the tick marks and the x match and then you can even you actually write it as a program this is very easy to handle ok.

Now, just for you to try out if this particular code had been replaced by instead of 128 comma 2. Let us say that I had assigned 128 come out 127 instead of can you please redo this calculation new with this green allocation what are the number of codes available. It is just a slightly different calculation a different set of codes will get blocked especially if you do 128 comma 127, some other codes will get blocked and interesting for you to see which ones will get blocked.

So, please try that we will pick it up from here in tomorrow's lecture.

Thank you.