Spread Spectrum Communications and Jamming
Prof. Debabrati Sen
G S Sanyal School of Telecommunications
Indian Institute of Technology, Kharagpur

Lecture - 15
Generation Mechanism and Properties of OVSF and Barker Codes

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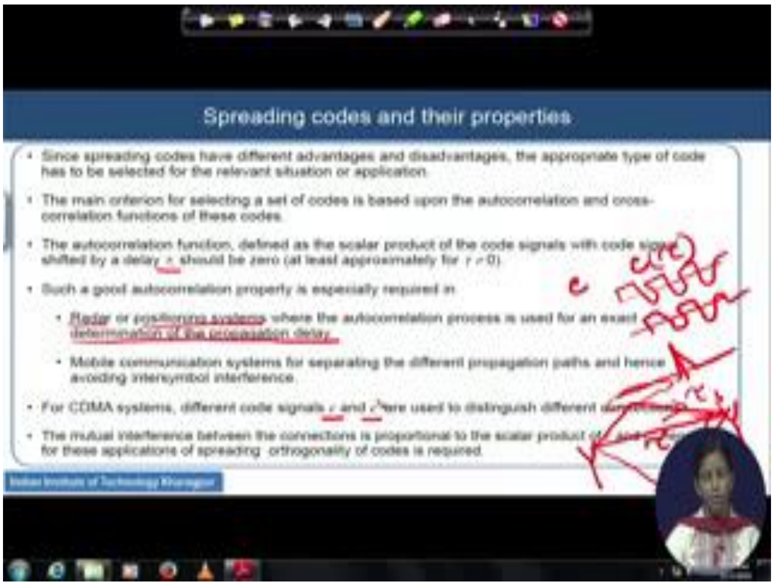

Hello students, so in continuation of the code generation mechanisms and their properties, today we will continue with the OVSF and barker codes. Remember one thing that when we choose codes in practice for a typical kind of application, we see different kind of the advantages and disadvantages involved in a different kind of their codes. And the choice of the code for a typical application is largely depends on their two basic properties; one is a autocorrelation and another is a cross correlation properties.

The autocorrelation function as we have already discussed with respect to a random binary sequences. We will be revisited and will be recalled. And the autocorrelation function is defined as a very scalar product of the code signals, where actually the signal may be shifted by amount of the delay tau. And remember if I am shifting it by an amount of the delay tau and the autocorrelation function for all the tau apart from tau equal to 0 should give us the 0 value. So, I should get if I auto correlate one sequence c, I mean PN spreading sequence c with delayed version of this c which you are emitted writing as c tau, tau is talking about the delay of that sequences. So, suppose this is a first frequency c and this is the delayed version of that sequence c.

So, if tau is not equal to 0, so for all those cases, I should get to the auto correlated value to be exactly. So, I should get basically, but the demand is for tau equal 0, you would get a very good autocorrelation value and for the rest of the part you should get a complete 0 value. So, this is a ideal situation of the demand to have a to declare that the code is having a very good autocorrelation property. Such a good kind of autocorrelation property is required in what kind of the scenario let us see.

Suppose in radar or in any positioning system localization designing a system for localized precise localization, where the autocorrelation this kind of autocorrelation process is utilized to detect the location and where the autocorrelation process is utilized to extract the propagation delay for radar. And positioning system also to use to understand actually the typical delay value from where you will extract the location information. The high autocorrelation value and the low and the very approximately 0 autocorrelation other values for tau not equal to 0 will be earnestly required.

In a mobile communication also for separating the different propagation path for example, I have a transmitter and I have a receiver here, and I am transmitting from the transmitter to the receiver and via different paths, the signal received gets received in the receiver. And the point who are actually helping to scatter the signal in the environment we call them the scatterers. So, the way the movement is going on is like this propagation is going on is like this. The same signal its get scattered by the scatters who are located at different position, and they are also reflecting the scattered there, they are scattering the wave and they are reaching to the receiver frontend. So, you are not only getting the direct line of sight path, you are receiving the signal via the scattered paths.

So, if you wish to understand the delay enhanced, the delay associated with the direct path and all other scattered paths they are not same. If we wish to segregate the paths multi paths actually the signals which are received in the multiple paths, if there is a requirement to segregate all of them, we have to actually estimate the corresponding delays independently. For such kind of the situation also the high autocorrelation peak is spreading sequence with high autocorrelation peak and the perfect having perfect autocorrelation property is required.

Think about a CDMA system where the different code signals that we already have already discussed during Walsh Hadamard code analysis that in a multiuser scenario bark code division multiple access is utilized, where actually different users are given the independent codes orthogonal codes. And they are separated out they are segregated in terms of all those unique codes allotted to them. And if the different code signal c and c prime we are denoting here is utilized then they will utilize to distinguish between the different connections. And also the mutual interference in such a situation when the connection is done, the mutual interference from c to c prime which is proportional to the scalar product of the c and c prime. And for the orthogonality to maintain all this, we need perfectly actually the codes to be orthogonal to each other.

So, good autocorrelation property is there and good cross correlation property will be in demand when my two codes, two different codes assigned to two different users, and they when they are having a scalar product, the total product output of the product we are expecting to be exactly 0. So, the codes who are having this two kind of the properties are the theoretically speaking is the best code of the demand, but unfortunately the codes so simultaneously having a very good auto correlation property and a very good cross correlation property. Simultaneously having both of them is almost impossible actually and that is why sometimes we will find that we need to compromise actually in between the selection of the very good either very good autocorrelation properties codes or very good cross correlation properties based on the kind of the application for which they will be used for.

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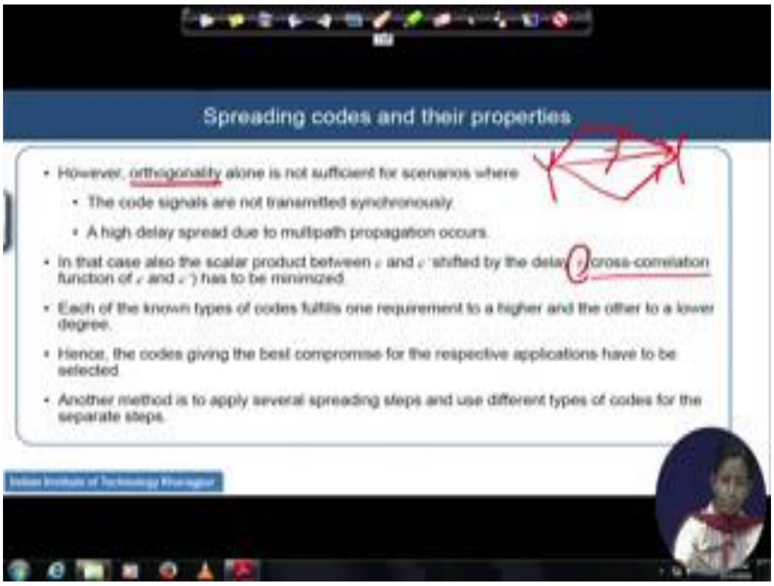

See that when we are talking about the code division multiple access systems, and we are thinking that multiple users will be there in the network. And each of them will be given dedicated orthogonal codes. So, and if you think that then their interference between the users, the multiuser interfere will be nullified only because of the orthogonality maintaining the orthogonality of the codes itself that is not the exact case. Because as I have explained in the last slide that when the signal is propagating via wireless communication medium, actually to not only traverse the line of sight path it traverse from the multiple scattered path or the multi paths. On the top of that whenever hence the code signals that you are trying to transmit, they are not transmitted always now also some synchronous fashion.

So, because of the loss of the synchronization and also because of the delays involved in the multipath propagation, so both of the cases, you will be receiving the signals who are delayed by certain amount in from the generated signal at the transmitter. And hence you will be always demanding for multiuser environment, it will be also demanding that the cross correlation value should be minimized.

So, in case of multi user interference diminishing the multi user interference, there are the two demands for the code in the code should be orthogonal, it is chosen such a way that we will get a set of the orthogonal codes. And the cross correlation property within the set should be also minimized. And each of these known types of the codes, they full fill one requirement to higher and the other to a lower degree if. Your autocorrelation is very good cross correlation would not be actually satisfactory and if cross correlation is really very good autocorrelation only satisfactory in such a way.

And for your kind of the application for which you are selecting the code you have to choose the code who gave the great compromise between the kind of the demand you are having and. So, choice will be application dependent and the service requirement dependent, and another method to apply the several spreading steps and use different types of the codes for the separate steps maybe another good assumption.

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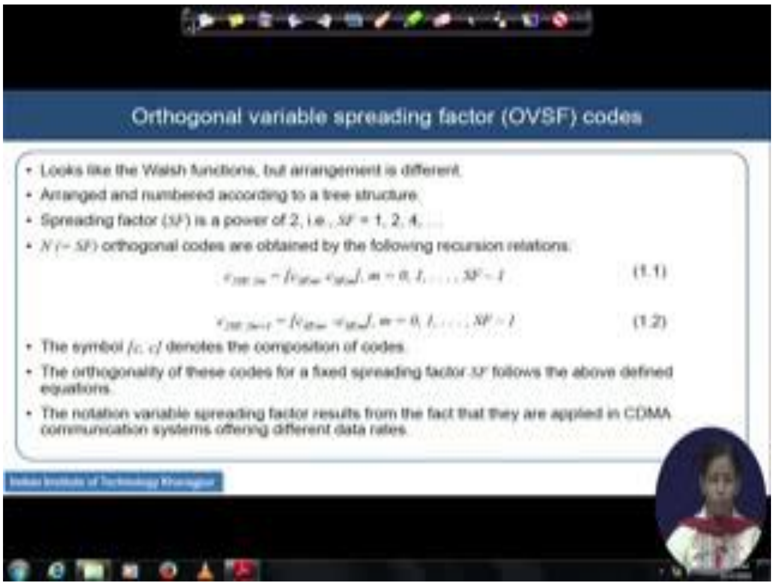

For example the type of the codes you are utilizing for minimizing the inter channel interference may not be actually go to minimize the inter symbol interference. So, you may actually utilize the different kind of the codes to go ahead with. So, that will be the design with the multiple codes. So, concatenation of the multiple codes training codes for the design.

Today as I mentioned today our discussion point is for orthogonal variable spreading factor codes. If you looked the structure of these orthogonal variable spreading factor code, you will see a lot of similarity with the Walsh Hadamard code, but the arrangement is little bit different. And we will be arranging here we be seeing here are as some tree structure getting form for the orthogonal OVFS codes based on the spreading factor. The spreading factor is usually a power of 2, so you will get the spreading of either 1 or 2 or 4, 6, 8 like that. So, the way the code is generated it is in the following recursive process.

Suppose, you are generating a code of twice spreading factor where spreading factor values varying from 1 to the higher numbers. And it is of 2 m, and m can be having varying from 0 to SF minus 1, he will be constructed by c SF m and c SF m c SF m is the previous one, hence it is divided by 2 and I mean it means actually the previous page values of the codes. And the next stage value of the codes will be constructed by the same previous step value and its second position on the second location will be in the matrix will be of just the conjugate of that.

We will take an example to have an idea how the codes is how the typical code is getting generated. But remember this is the composition of the code c comma c here inside the square bracket the composition of the codes. The orthogonality of this kind of code for a fixed spreading factor SF follows above the defined equation. And the notation variables spreading factor results from the fact that they are applied in the CDMA communication systems offering different data rates.

So, very good part of this kind of the code is you can generate the several codes several codes under this family, who are having the different value of the spreading factor. Based on the spreading factor you are basically varying the data rate offered to the users. So, if you wish to generate and design a circuit, where multiple data rate support is required and the orthogonality is also very important issue in association with the protection against the jamming and a difference controller OVSF support find lot of applicability in that sense.

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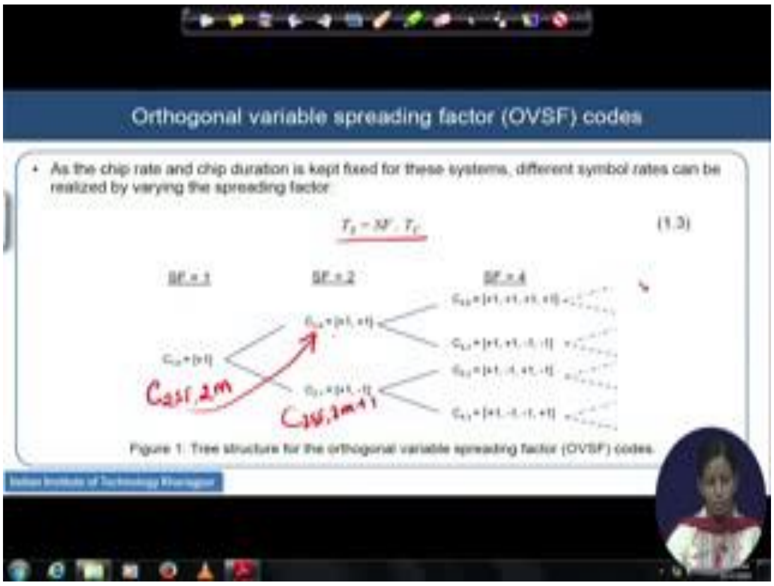

So, we will take an example here. Remember the total symbol as we are not changing the chip duration and the number of the chips, so that symbol duration of the generated code will be governed by this equation where the symbol duration is equal to spreading factor multiplied by the chip duration. Let us take an example we will start with a spreading factor one. So, the code will be how, the code will be the nomenclature will be c 1 comma 0 because we understand we write the nomenclature as 2 SF comma 2 small m. We are started with m is equal to 0.

Here as a bit is equal to just 1, SF value is equal to 1; and this is equal to SF value sorry SF is equal to just 1. So, if we are starting with the not 2 SF, it will be starting at least a first one should start with a just SF. So, this is the SF is equal 2; and from SF equal to 1, you are generating a SF equal to 2. So, here it will be working like this twice into SF for 1 comma 2 s m. And the way you will be generating it like this. So, this plus one will be repeated for 2 comma 0, but 2 comma 2 m plus 1 this is to 2 SF 2 m plus 1, the code will be repeated from the 2 s from the SF and then the second entry will be the complement of the last data entered.

If I go ahead further, so from to next generated SF will be definitely 4, because it is the power of 2 you are proceeding. Here again this first two will repeated; and the second location you have the same repetition. For one will be as it is therefore, you will run from 0, 1, 2, 3 because in every cases whatever the value of the SF you are having m is varying from 0 to a maximum that number, it is a SF minus 1 up to that n can vary as we have seen in the question number 1.2.

So, when SF was equal to 2 n has two values 0 and 1. For SF equal to 4, m has four values 0, 1, 2, 3 for every SF equal to 4. So, c 4 comma 0 is generated by repeating the c 2 comma 0; c 4 comma 1 will be the repetition of the previous one and the complementary last entry will be complement of that c 4 2 will be the repetition of the previous one which one 2 1. And the last entry will be that it will be the complement of the remaining section. So, this way you can proceed. So, this is the tree structure you are generating. Good part is that there is a data rate variation possible because you are within a symbol duration, the number of the chips that you are utilizing they are varying how see.

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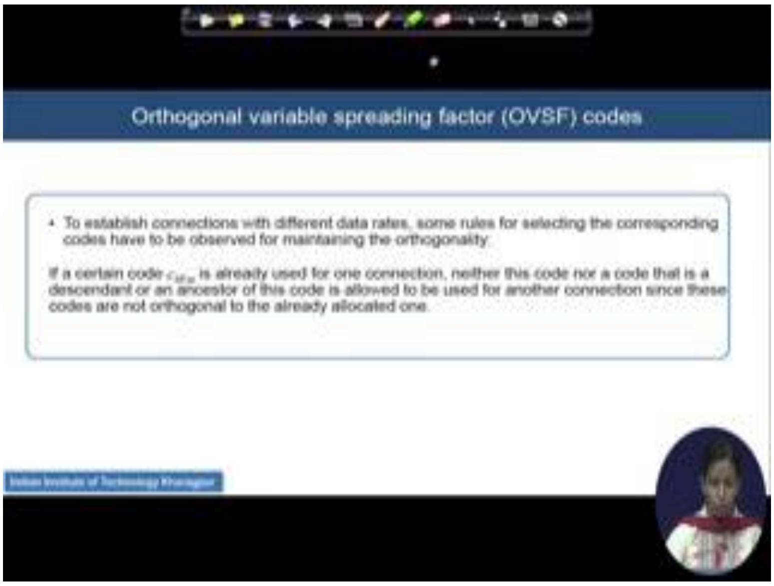

And remember one thing to establish some connections with the different date rates. So, some rules we have to follow here. And also to maintain the orthogonality, we in order to maintain that there will be an interference from the one kind of the user to the next kind of the user, so the codes that we are generating that should follow certain rule. What are those rule better to go to the next slide to understand the rule.

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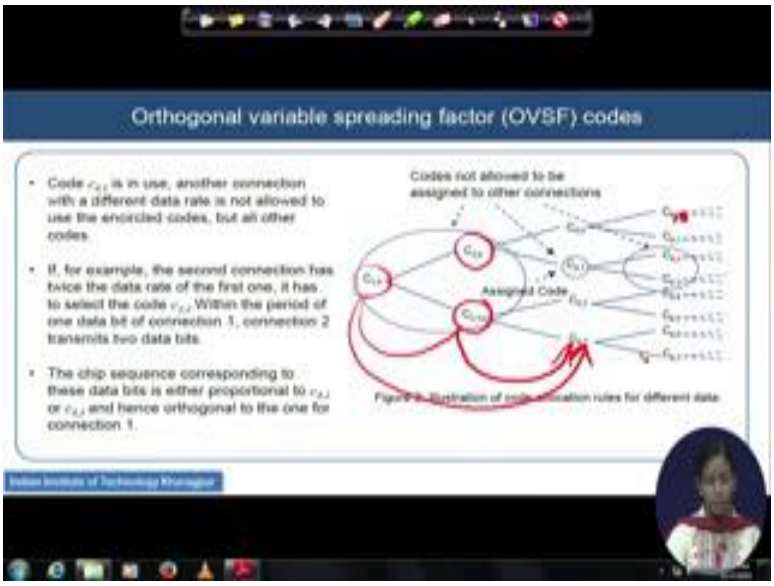

So, we generated the sequences like this from c 1 0, c 2 0 generator; from c 2, 0 c 4 0, c 4 1 generated; and from c 2, c 4 2 and c 4 3 generated. So, from each parent 1 1 set of the new child processes are child codes are getting generated. Remember if c 4 1 is already allotted to some user in order to keep the orthogonality, and in order to keep that minimal interference property from the other user, you should not allow the code which are the child codes of this c 4 1 are all the parents codes from where actually c 4 1 is linked to the user, new user.

So, give for this example for c 4 1 - c h 2, c h 3, these are the child codes they cannot be allotted as well as his mother is c 2 0 whose mother is c 1 0 and c 2 1 also. So, c 4 1 is heavily correlated with 2 0, 1 0, 2 1, 8 2 and 8 3. So, this is his whole family, this family or can none of the members from this family none of the code members from this family can be allotted to second user, if c 4 1 is in use. But you can allot any other codes from say c 8 9 1 2 this 7 and c 4 0, this will be 0, this is not 9. So, this is c 8 comma 0. So, anybody actually you know other guys from the child section or any other guys from the peer section can be chosen for allotting it to the second user.

And how the data rate can be varied by using the different kind of the codes or something like that, for such example suppose some second connection which is having some twice the data rate requirement needs to be provided needs to be supported and then it has to select if I have started already given the code c 1 0, and if the second data second user is demanding double the data rate corresponding to the compared as compared to the first user connection, then I have to give either c 2 1 or c 2 0. Because within a period about one data bit of connection one connection two can transfer two bits, because the structure if you see he is here actually a transmitting 1 0 and if you are you are transmitting one and here you are transmitting 1 1. So, within the same bit duration, here you are transmitting twice the bits, here you will be transmitting four bits.

So, the data rate if you are trying to see from here to here it is double from here to here it is double. So, from here to here it is four times. So, the data rate variable data rate support in a CDMA network is heavily possible if we allot the OVSF codes and we choose the OVSF code in such a way that along with the data rate support, the interference cancellation to some extreme level is can be can be provided heavily provided.

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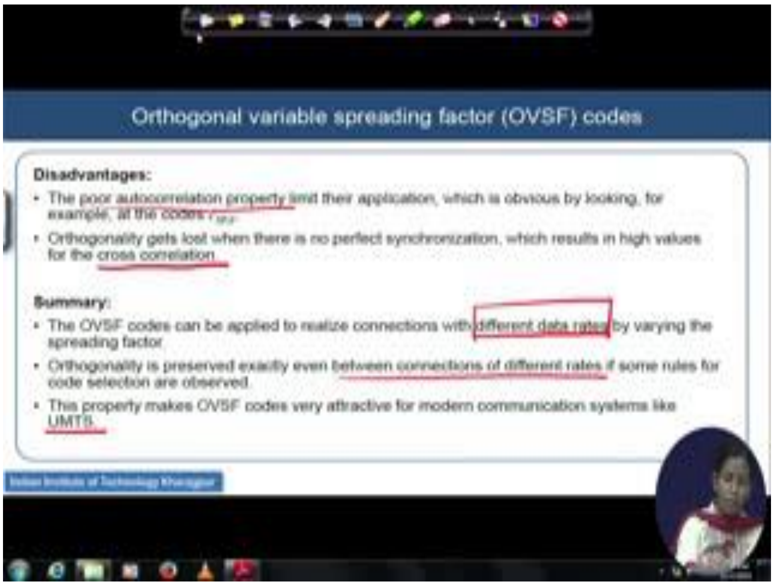

So, the advantages, disadvantages of this kind of the code. The disadvantage of OVSF code is that if the orthogonality of the code, so it is lost then there is a and there is no perfect synchronization. The cross correlation values of the code increases heavily which is not a very good situation for a kind of the CDMA network, where for a multiple user support is required. And it has also very poor autocorrelation property that limits its applications sometimes for kind of the application, where your high synchronization precise localization is required and in the radar kind of situation where your precise estimate of the delay is to be done.

So, neither it has a very, I cannot say it is a very good auto correlation property and with the minimal with no synchronizing, no perfect synchronization situation you can provide your very good cross correlation also. The summary something like that the OVSF codes can be applied to realize the connections with different data rates by varying spreading factors. So, different data rate is the main gain or main advantage of this kind of the codes, which is not supportable by any other codes that we will discuss today in the family of the codes. Orthogonality preserved to exactly when between the connections of the different rates. So, if you are that orthogonality that you are talking about if the under the perfect synchronization situation definitely. And this two properties of this OVSF codes have made them attractive for the modern communication systems like you UMTS and IS 95. And with that we will end our discussion with OVSF and we will try to see some new family of the code.

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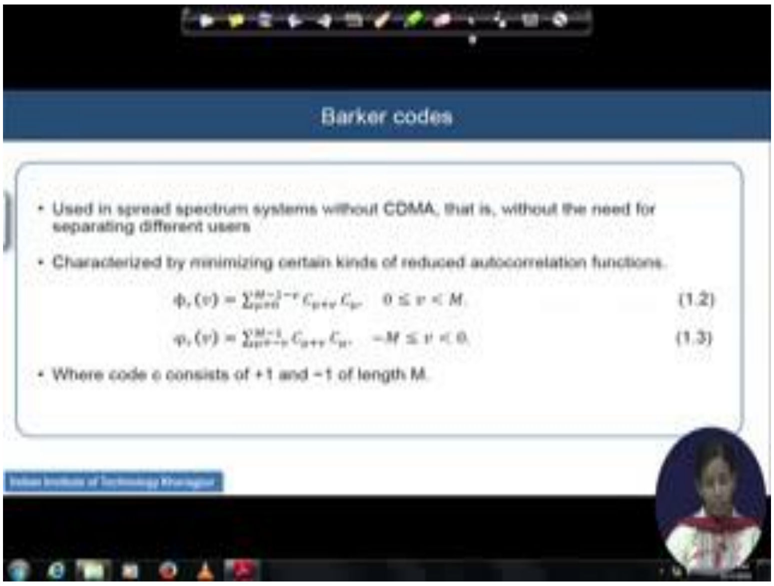

Our next discussion will be on the barker codes. Barker codes you will see they are utilizing the spread spectrum communications because but for some definite kind of application. Barker codes are mainly utilized for the synchronization purposes inside the spread spectrum communication. Because we will see that the codes available codes in the barker is not much they are very few in numbers available, because of which they cannot be used utilized for mobile communication systems where dense number of the user support is possible; not actually the length of the codes. Even not only the number of codes are less the length of the codes that are available that are also not remarkably high. So, they cannot be utilized for the code keying purpose or they cannot be utilized for the spreading sequence purpose to avoid the jamming effect and all, but this codes are very, very useful for synchronization purpose, so that is why we will go to revisit its property.

Barker codes are characterized by minimizing the certain kinds of the reduced autocorrelation function. So, the autocorrelation function that barker code has to follow has to satisfy to declare a code to be a barker code. The two auto correlation functions are this. So, the delay that you are having if the nu is the delay or the shift the lag over these are the autocorrelation you are computing, if the log is high positive lag between 0 to m then the competition will go like this the equation 1.2. And for the negative lag and capital N is the length over which actually you are doing this autocorrelation performing this autocorrelation the length of the whole sequence. And its autocorrelation property for minus M to the 0, I mean with the negative lag values that will be governed by the equation 1.3.

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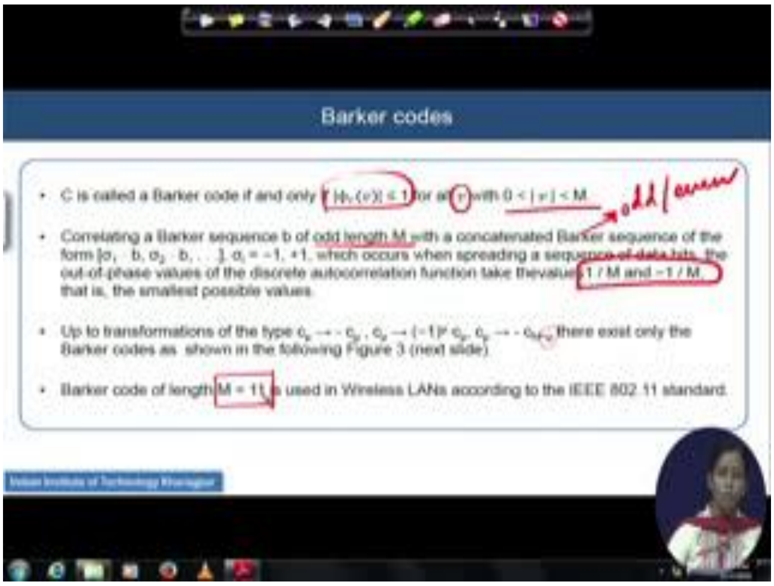

The code here always consists of plus 1 and minus 1 and its length is assumed here to be capital M. The code can be said barker code with all these autocorrelation property if and only if this relation holds good that is the auto correlation value should be always less than equal to 1 for all the lags, where the lag is varying from mode of the lag varying from 0 to m. So, for both the equations that we have discussed earlier in the last slide for equation 1.2 and 1.3; both the cases actually the output of the autocorrelation computation should be less than or equal to 1 to declare the code is a barker code.

Correlating a barker sequence b of length odd length m, so length of the barker sequences remember that they can be odd or even. So, if I try to go ahead with the correlation of the barker sequence of odd length with a concatenated barker sequence of the form something like this, where alpha i is equal to minus 1 and plus 1. So, what we have done is we have concatenated the barker sequences and which and they are trying to confirm the correlation property and which occurs when the spreading sequence of the data bits the out of phase values of the dispute autocorrelation function. It happens actually this kind of autocorrelation happens when I spread the sequence of the database and we are getting actually the raw barker codes in the receiver, and we are trying to find out the autocorrelation property of it.

Then the out of phase values of this discrete autocorrelation function, I mean I can call it as a cross correlation also. I just the out of phase values which is not exactly means of exactly actually here tau equal to 0. So, when this guy is going on then the out of phase values for this autocorrelation function will be turned down to 1 by M and minus 1 by M, these are the smallest possible values that a barker code can give you. So, the transformation is something like this either c mu to minus c mu or c mu equal to minus 1 to the power mu into c mu. And c mu to minus c m minus mu where mu is the delay that with which we are dealing with. The barker codes are available barker codes on the generation of the codes are very, very small; and length number 11 barker code length 11 is widely used in the WLAN sequence WLAN standard is 802.11 standard. And not only in the LAN standard in a several spread spectrum communication system design this barker length of 11 is widely used for the synchronization purpose.

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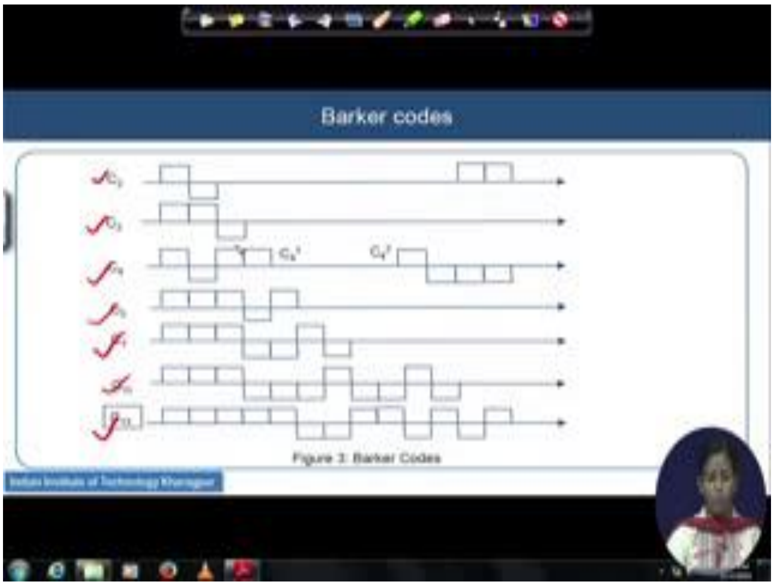

These are the few barker codes that I was saying that is possible to generate and there are no other barker codes available with the kind of property that we have already stated related to the autocorrelation and the cross correlation of this kind of the codes. If I follow all that we will be able to find only the code with length 2, length 3, length 4, length 5, length 7, length 11 and length 13. So, hardly 7 number of the barker codes you will be able to find for practice. And remember the barker code number of very short length c 2 and c 3, and c 4 even they are not having much use in practice because even for the synchronization at least some certain length of the codes are will be required to provide the extract the to a estimate the parameter of our interest.

And if it is the timing and if it is a timing extra mostly for the timing extraction, the timing information extraction we try to utilize this barker codes. And then also actually you need a self sufficient length of the chips such length of the codes in the name of the chip over which actually, the estimation needs to be average out. So, very small length of the codes like c 2, c 3 or c 4 would not give you a very good estimate because averaging cannot be done over large number of the chips the available chips are so less. So, a very good kind of the synchronization is not visible because the estimate will be very poor. If utilize the very small length of the barker codes that is why I was telling that length number 11 length number 13 even length number 11 to some extent for a for a short distance kind of communication barker codes are utilized. For WLAN, this c 11 has already mentioned c 11 barker code is utilized for the synchronization purpose.

So, barker is not a unusual unlike the other kind of the applications, what we have discussed at the beginning of the Walsh Hadamard code discussion that codes are mainly utilized for the code keying or multiuser support and mainly for these two purposes and also for giving the protection against the jamming. So, environment at the interference cancellation barker is not getting utilized for any one of them. Barker is showing that code can be utilized also for the synchronization purpose, which is really very, very important that we need to do for a successful reception of a spectrum communication system, where code acquisition and the code tracking is of earnest importance to for successful reception, and the and retrieval of the data in the receiver. We will discuss it later, but the code that will be utilized now we have already discussed barker is that code.