Spread Spectrum Communications and Jamming
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Lecture – 58
Tutorial – VIII

Hello friends, in this tutorial we shall study the bit error rate for multi user spread spectrum system. That is a DSSS MU BPSK system over a frequency selective fading channel which we are going to modelize the Rayleigh fading channel.

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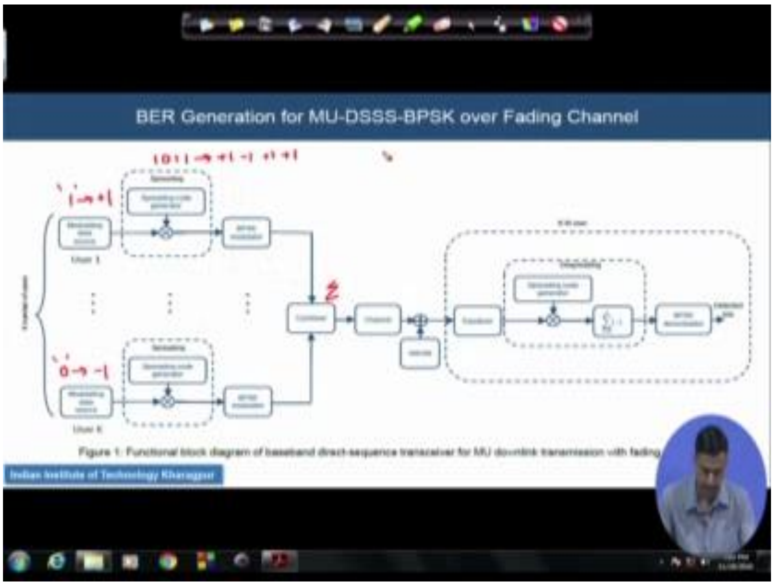

So, as we see, we have multiple users transmitting data to common source that is sorry a common destination and these multiple sources have been labelled as 1 to K. So, there are K numbers of users and each user over here is the data corresponding to each user is spread, using DSS spreading code and which is further modulated and combined and pass through the channel.

The combiner in our case for this the spread signals of these K users is going to be a simple some are as we shall see and the channel which we are going to use is going to be the Rayleigh fading frequency selective channel and the receiver we have the AWGN noise and after performing MMSE equalisation we despread the signal, using the spreading code of that user whose signal we wish to receive or decode. Of course, this block you may be familiar with that is nothing, but taking the inner product of the desired user spreading code with the incoming received signal and summing over all the elements of the result. We further pass this through the BPSK demodulator in order to detect or decode the bits of the user that we wish to now the signal of the user that we wish to decode.

So, once again remember that the modulating data source will emit a binary stream of bits. For example, we could have, let us say if a bit 1 that is a binary bit 1 is sent and this is going to be mapped to a bipolar signal level. Let us say some other user wants to transmit a 0 then, the bipolar representation of this let us say could be minus 1. This spreading code generator will have some spreading code length. Let us say the length is equal to 4 then, in that case we might have some spreading sequence. For example, which may be once again represented in bipolar terms and this multiplication is nothing, but the multiplication of this bipolar input signal to each of this bipolar entities of the spreading code.

So, similarly this will be multiplied by some other unique spreading code which may be orthogonal to the spreading code of the first user. The examples of such codes we have already seen this different unique codes, orthogonal codes with good auto correlation and cross correlation properties. For instance we could have (Refer Time: 04:22) codes and therefore, these codes you consist could be rows corresponding to the Hadamard matrix which we have generated previously in our tutorials where, we showed the MATLAB code for its generation. As I said is combiner in our case will be simply summing up the resultant spread signal that is after multiplication what we had over here. So, we depending on the number of users we will sum up the corresponding elements in order to get the composite signal.

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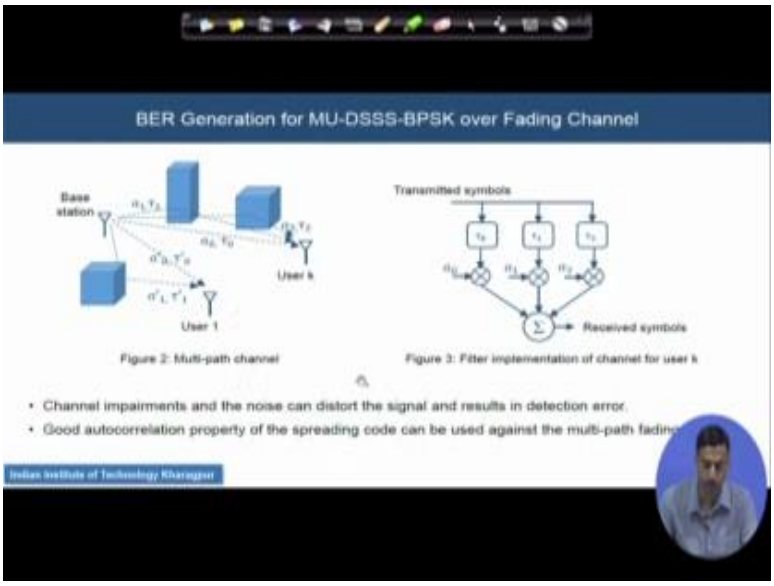

So, let us proceed and see as to what is the concept of multi user communication. So, in our system model we assume down link transmission. So, this is an important point that needs to be noted. We are not analysing this system are not evaluating its performance for uplink. I will come to the problems involved for uplink performance evaluation in a short while, but as of now please note that we are going to down link performance evaluation. So, we have a base station and we could have multiple users from 1 to capital K as was shown before, user small k is some arbitrary user. It is assumed that each of these users' signals at the receiver will be due to multi path effects of the signal which has been transmitted from the base station. For example, user k over here is a direct path line of site path which channel gain a and delay a tau naught and it has two other paths. Similarly user two sorry user one has a direct line of side path and another reflected path.

So, in general we could change the parameters, that is the channel gain the delay etcetera and we could model the entire system. So, we will see what kind of model we have or what are the parameters that we have chosen for simulation? So, that we will see shortly, but as was explained in the previous tutorial as well, for each user we could model these phenomena in terms of linear filter with tap gains corresponding to the channel gains and tap delays corresponding to the path delays.

So, this is a mathematical model for the multi path fading due to each path for a given user and for mobile channel as we know we can if the number of paths are sufficient enough which is an assumption of course, in this case then we could model this the amplitudes or rather the multi path in terms of Rayleigh distributed amplitudes which have uniform phase from 0 to 2 pi. So, that is what we are going to do as we proceed. The tool points which I had also made in the last tutorial that is the detection errors even though we have the right spreading code, code occur due to channel impairments and noise which is the intention or objective of this tutorial and. So, we need to find out the probability of error and another thing is that good auto correlation property of the spreading code and in this case of course, the auto correlation property can be used in order to counter the multi path fading and good cross correlation properties are useful in a multi user scenario.

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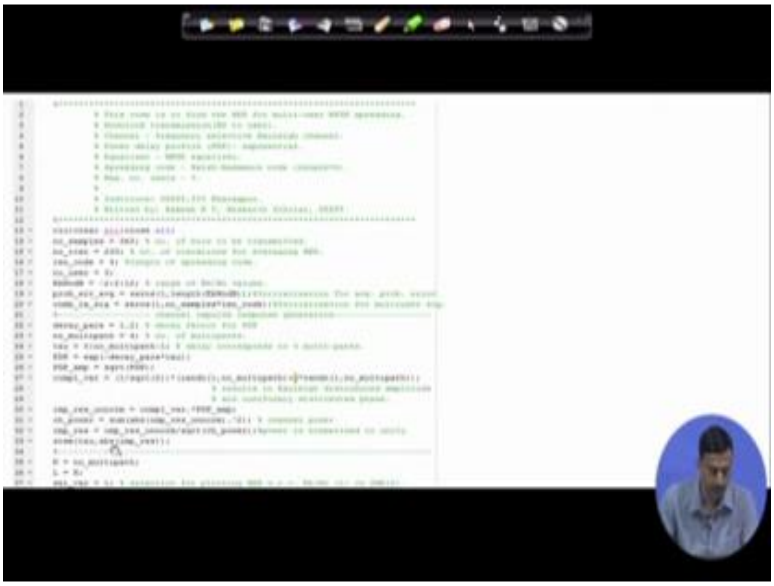

So, let us have a look at the MATLAB code that implements the system model which is described. We have a certain number of samples which is nothing, but the number of bits that we need to transmit. We are going to run this entire simulation over 200 iterations in as Monte Carlo simulation basically. So, we have a length of the spreading code equal to 4, we assume that we have 3 users. So, it is a pretty simple case. We set the uni by n naught range in line number 19 we have and 20 we initialise the variables that we will use to store the average probability of error and the combined signal spread signal due to the 3 users respectively.

We assume a exponential power delay profile, which is not uncommon in mobile communication systems. So, we set the delay parameter to a typical value of 1.2 and we choose the number of multi paths to be 4 for all users. So, this is a simplistic assumption you could change this is an explore in order to see how the performance evaluation looks like. We chose the number of rather the delay corresponding to the multi paths and we generate the exponential power delay profile in line number 25 using the parameters that is the decay parameter and the delay. We find the amplitude for this power delay profile which we use in order to generate the impulse response subsequently. The Rayleigh distributed random variables are generated in line number 27 which is nothing, but a complex Gaussian of entity. As you can see the impulse response of the channel is nothing, but this complex Gaussian quantity multiplied by the PDP amplitude which is exponentially decaying.

So, this is standard procedure in order to generate the impulse response of a Rayleigh fading frequency selective channel. The channel power is found from this impulse response because we need to normalize the impulse response in 30 and we do that in line number 32 and you could then plot this impulse response versus the delay in order to look how it is like? We had done this in the previous tutorial. So, that is why I am not showing the plot over here.

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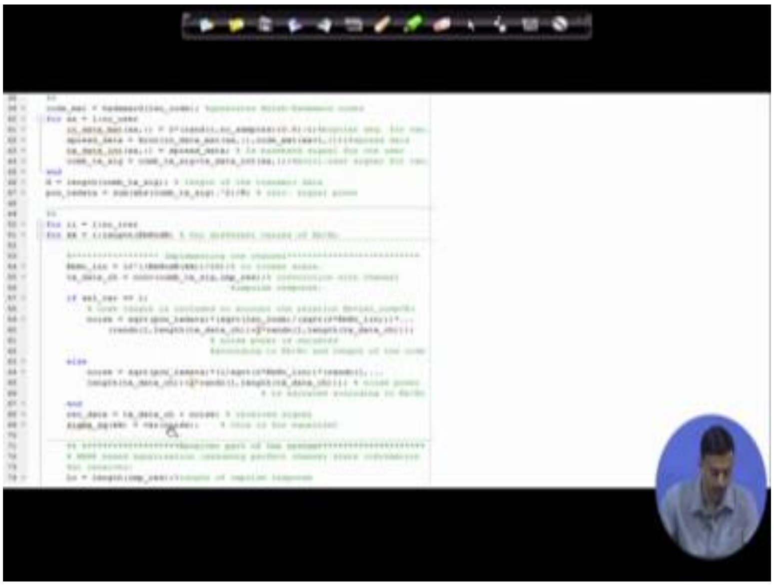

The next part of the code sorry the MATLAB code is to generate the Hadamard matrix. The rows of which are correspond to unique orthogonal spreading codes. So, that is line number 39 and then we use a for loop in order to generate data random data, which will have a length that we have already chosen before; that is in line number 14 as you can see. And we spread the data by finding the inner product as I said, but what is to be noted in line number 42 is that since this is a loop and it runs over the given number of users for each user this variable a will keep changing and so what we are doing is? We are choosing given row of data from that is from this line number 41 which is nothing, but a matrix comprising of rows corresponding to users' data. So, we choose the given row for a given user in this case there are 3 users. So, we choose a given row and multiply it with a row of the Hadamard matrix which again is unique. So, for three users in this case we will have 3 different rows of the input data matrix and 3 different rows of the Hadamard matrix which we have found in line number 31.

So, once this inner product is found, we store it in this variable and then we run the loop again for the next iteration for the next user. So, like this in this manner we complete for these case 3 iterations and we get the composite signal which is the addition of the 3 spread data signal sequences. We store the length of this combined signal which will be the length of the individual spread signal itself because we are adding up the 3. So, the length does not change as such. We calculate the power of the combined composite multiple user spread spectrum signal in line number 47 because we need to use it in order to scale the power accordingly.

And what we notice is that we divide this entire power by the length of the transmit data. So, basically what we are doing in this code? Is that we are assuming that the available transmit power is split into the 3, that is 3 users are sharing the available power. So, we have uniform power allocation scheme. We calculate the noise in this if else part of the code, but before that we convert the E b by N naught to linear scale and then we convolve the combined multi user signal with the impulse response that we had generated in line number 32. So, this takes care of the frequency selective nature of the channel and we generate noise depending on whether we are plotting the E b by N naught for the BER over whether we are plotting the SNR.

So, the difference as was pointed out in the previous tutorial is that when we do it E b by N naught since the energy the same energy per chip in the that is the original signal is spread when we carry out the spreading process. So, we need to do this scaling; however, for SNR the power remains same per chip with or without spreading. So, this square root length code term does not (Refer Time: 16:13) over here. However, we shall plot the results against E b by N naught. The received data is added is nothing, but the addition of the transmitted data from 55 plus noise that is generated and we calculate the variance of the noise because we need to use this parameter for MMSE equalizer which follows.

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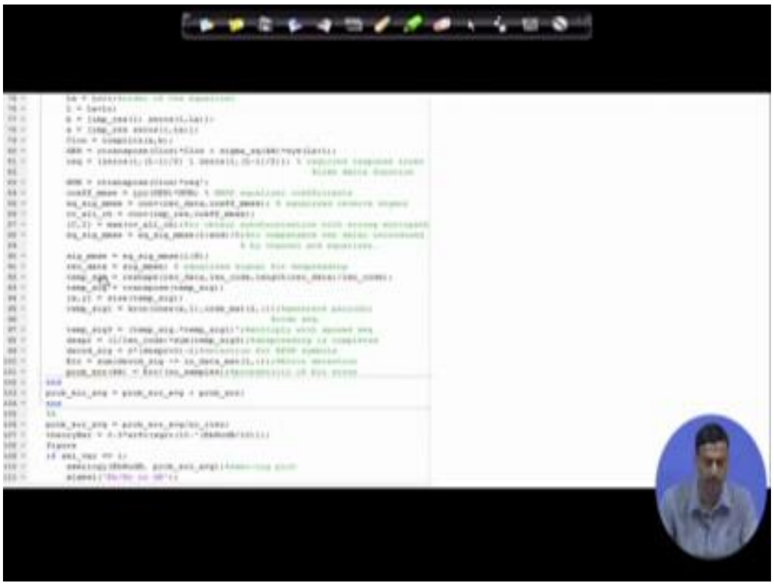

The MMSE equalizer is L c plus 1 tap equalizer. The code of which is shown over here and what we see is that we finally, use this equalizer in order to mitigate the effects of frequency selective fading and once that is done we store the signal and we use the mathematical operations that I had already discussed in the tutorial. So, this part of the code from 74 to I think we have 97 follows the same procedure as we had discussed in the single user case in the last tutorial. So, I am not repeating this part and the decoded signal after dispreading with the code of the desired user, in this case we are using as you can see the code of the second user. So, that is what is to be decoded in line number 95. So, once we do that we find out the error, we sum it up and we average in line number 103.

So, the idea now is to see as to what kind of mere performance a multi user a 3 user in this case system, spread spectrum system yields in the presence of a frequency selective channel.

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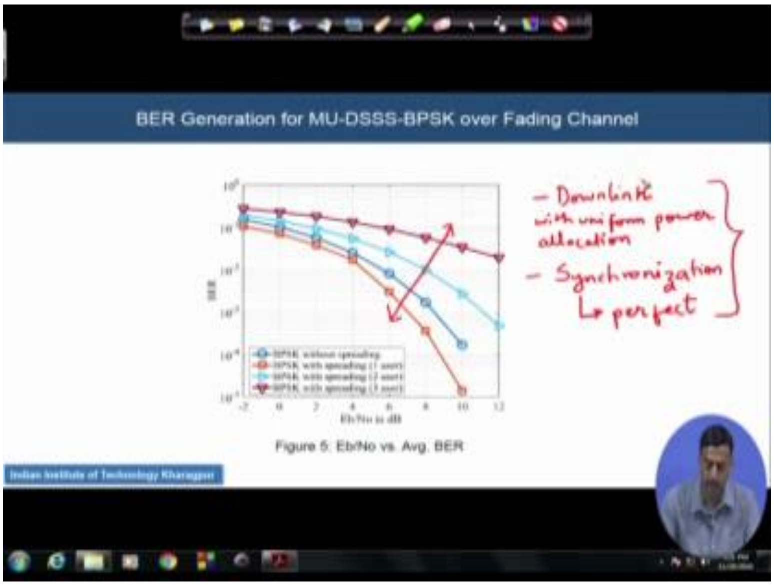

So, what we see here is that we have the performance of BPSK system without spreading in a Rayleigh faded channel which, is given by this circle markers and the performance with 1 user with spreading is given by this square markers. So, this set of curve we already discussed in the last tutorial and we had seen that spreading helps us combat multipath due auto correlation properties of the spreading code. So, it gives us a better performance with spreading as compared to without spreading.

Now please note that BPSK without spreading has been carries out for a single user. So, the comparisons was already discussed in the last tutorial, but now our interest is to see what happens in the multi user scenario and as we see there is a performance degradation. When the number of users increase the BER performance degrades and is poor when the when we have a BPSK with a spreading code of sorry with the 3 number of users.

So, this of course, has been done for a length, code length of 4. You could experiment with higher code lengths, higher multi path numbers by varying the power delay profile parameters etcetera and you could see how the system behaves, but I would like to make two very important points over here and the first point is that this performance evaluation has been done for a down link with uniform power allocation where, equal power allocation for all the users. So, we basically had split the total transmit power of into three components in this case; equal components and we had assigned that power to each user.

So, this was simplistic assumption that we had made. Downlink is important because performance evaluation in the uplink will be more challenging the reason is because usually we need to come up with power allocation scheme which is optimum for uplink. We may not use a uniform power allocation scheme for uplink because the users may be distributed in term. So, proximity from the base station at different locations. So, certain users may be closer to the base station and some users may be at a distance in which case in the uplink the users close to the base station. If we assign equal power to all the users than user close to the base station will act as strong interfere as to users which are at a far away distance from the base station and as such what happens is that the performance for different users will vary and users far away from the base station will see a very significant performance degradation.

So, in that case we will have to come up with some kind of power allocation scheme depending on the location of the users. In a sense what I am trying to talk about is the near far affect that needs to be taken into account before allocating power and so the uplink problem to start with becomes more challenging than the downlink problem. Our evaluation is for downlink and another very important assumption that we have made is regarding synchronisation of the received signal with the codes that we are trying to correlate the received signal with. So, we have assumed this to be perfect.

So, in actual situations, in reality there will some loss in synchronisation inevitably and now it depends upon the correlation properties of the code as to how this will manifest in mere degradation. The reason why I am making these two points is because the performance that we see over here is due to these assumptions is a very optimistic view of things, but generally it the performance of this multi user DSSS BPSK system may be worse than what is shown over here. If we lacks this assumptions and we have models in order to incorporate synchronisation of set errors, timing of set errors etcetera and also if we try and repeat this exercise for uplink by considering near far affect and so on and so forth.

So, this concludes the tutorial for multi user DSSS BPSK system over a Rayleigh fading channel with MMSE equalisation.

Thank you.