Spread Spectrum Communications and Jamming
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Lecture – 42
FHSS Synchronization Method – I

Hello student, we were discussing the synchronization aspects in the spread spectrum communication receiver. And most of the discussion, we have done with respect to the direct-sequence spread spectrum communication.

In this module, we will try to look into the frequency hopping spread spectrum communication system. We have discussed actually earlier in one of the modules about the FFH - fast frequency hopping, your MFSK system though. But in a concrete fashion, how the acquisition as well as the tracking is done in general in our frequency hopping spread spectrum communication system that was not done. So, in this module, first we will try to see the critical aspect of the synchronization in frequency hopping spread spectrum system, and we would like to view few methodologies of the code acquisition and tracking in FHSS system.

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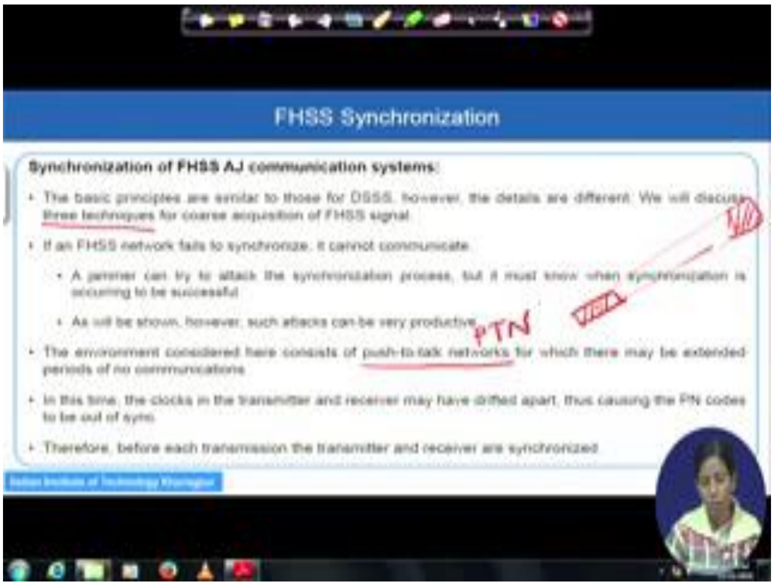

So, synchronization the basic principle of synchronization that we have discussed in DSSS says exactly it holds good actually same for the frequency hopping spread spectrum signal. And why it is required, why it is so critical all those points hold good here. And we will discuss here the basically the three techniques of coarse acquisition for the frequency hopping spread spectrum signal. And remember that for frequency hopping spread spectrum signal, for a jammer to jam you, it needs to then it to know actually before they attack, they need to know that what is a synchronization process, at what point actually the synchronization is occurred in the actual receiver. And that such attacks can be very much productive also in our system designing some cases. And we need to take an example and certain example of a communication network, before we enter into the different kind of the techniques, two different techniques that we have selected here for our discussion today.

And today we would not be able to discuss all these things in single module, we will start with any one of these three techniques, and other two will be consecutively discussed in the next two modules. But remember one thing for the network the communication network and the transceiver system that we will consider for all the discussion of all three techniques will remain same. We consider a push-to-talk network; it is a very popular network we call it a PTN in a way applied widely in a defense application of our country. And this push-to-talk network is the type of the network is such that you transmit to the voice message or you transmit to the voice message or the voice packets over a certain period of the time and after that the one transmission it may happen that the network is silent. I mean there is no communication going on for a certain period of time, and again some message is going over the network.

So, the pattern is such that there is a communication and there is a wide time actually extended period where there is no communication and again the some voice message is going on that is the typical architecture and nature of the PTN - push-to-talk networks. And in this time, the clocks in the transmitter and a receiver may have so when this long gap is happening, so there is high possibility that the clock in the transmitter and the clock in the receiver, they have got drifted apart. And they have been drifted apart and that is causing the PN sequence codes that are getting generated in a transmitter and receiver getting misaligned to a great extent, totally they may be out of sync also.

So, the logic of these PTN network, if every communication of the PTN network is for each and every such was packet that you are receiving, you have to perform the synchronization. Before each transmission or before each reception whatever you say, so it means a for a with respect to the every communication we need to the system I mean transmitter and receiver needs to be synchronized and you have to be establish it.

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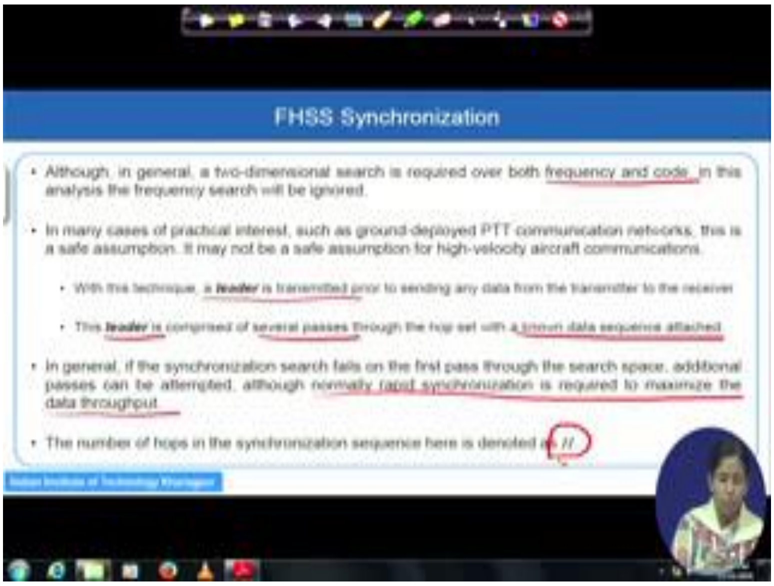

Actually, this logic holds good for any kind of the burst communication, it is the example very very example of burst communication. In burst communication, we a burst of the data is transmitted at one shot over a communication link and over extended period there is a no communication happens. So, data gets accumulated in a typical node over a long time interval and it gets (Refer Time: 05:32) and then over a small packet, the huge amount of the data is packed, and then it is a transmitter and then the communication is stop. This example holds good also for sensor communication, sensor nodes and sensor communication short range in a different kind of the short-range communication, where bust communication is a very important kind of the communication technique. And the communication that goes on in a normal commercial communication system that is a kind of continuous mode of operation, we call that continuous communication. PTN actually falls under the type of burst communication.

FHSS synchronization in PTT appear or PTN push-to-talk kind of communication network hence, it having a very, very important role, because we understand that in the FHSS synchronization, we are having the synchronization and search for a synchronization will be two-dimensional, one is for the frequency and other is for the code. It is equivalent to the DSSS, but here on the addition of that search of the frequency and the code remember that the there is a important phenomena called hopping of the code. So, your code acquisition actually basically means that detection of those hopping pattern that is happening actually in the transmitted signal, and your receive needs to get aligned with that hopping pattern.

In many case of this practical interest such as there is a ground-deployed push-to-talk communication networks, this is the safe assumption that frequency search for the code acquisition sorry for frequency search for the carrier acquisition actually will be ignored, because we hope that actually that is not that much important that would not hamper actually if you do not considering that that is a damaging part in our kind of the code synchronization. That is the safe assumption also, because the frequency of that carrier does not change a lot if it is a ground based PTT communication network, where actually today discussion is center.

But remember if you are moving suppose with a high velocity aircraft, then in high velocity aircraft communications, you this assumption that you are in frequency synchronization carrier, if you are not done that will not have any effect on the codes synchronization of code acquisition mechanism that assumption you cannot hold good for this high velocity aircraft.

But if it is a ground based PTT communication networks, where much lot of actually changes in the velocity or changes in the environment is also not and the Doppler effect is not expected to come. Then we can assume that we can actually changes in the frequency or analysis of the frequency search can be ignored, and it is effect can be ignored on the code acquisition for a FHSS system.

And in the sequence synchronization method, we will start with the concept that we will send first a leader which is the transmitted prior sending any data from the transmitted to the receiver. And this leader is comprised of several passes through the hop set with the known data sequence attached with every pass. And in general, if the synchronization search fails to occur within the first pass, then we keep on searching through the consecutive passes and additional passes can be attempted definitely, although normally the rapid synchronization is required to maximize the data throughput.

So, whether you will go ahead actually if you completely face in the first pass then only you proceed for the second or third. But if the synchronization is already acquired, but not occur as per the perfection level that is expected then whether you will go ahead to the second or third pass that is a call to very typical call where will you straightly compromise with the synchronization percentage of the synchronization already acquired. Based on the fact that more actually you go ahead elapsed time over the synchronization process, it will bring the data throughput, it will minimize data throughput, it will a have a huge impact on the data throughput.

Because multiple search passes to be transmitted from the transmitted to the receiver; and that is in wastage of the bandwidth of transmission that is why actually data throughput is coming down. Now, actually in our analysis, let us considered that the number of the hops, which are associated to the synchronization sequence can be is denoted as capital H.

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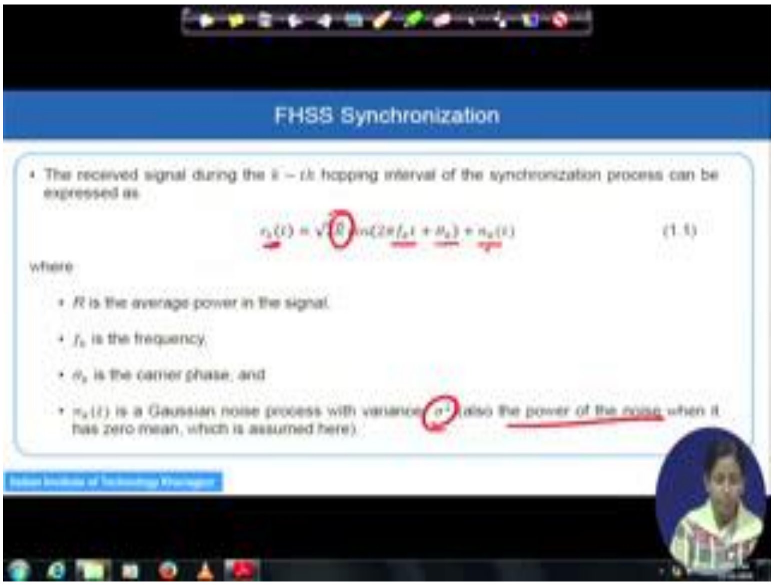

Now, the received signal they for the k-th hopping interval of the synchronization process, it can be given by the equation 1.1. Remember this R is the average power in the signal. If k is a transmission frequency, theta k is the carrier phase, n k is Gaussian noise process with the variance sigma square; it can be also the power of the noise when it has a zero mean, and here we have actually assume that the noise process is having zero mean. So, basically the variance sigma square will be equal to the power of the noise. And this is related to the k-th hopping interval, so the frequency, the phase and the noise all are having a subscript of k.

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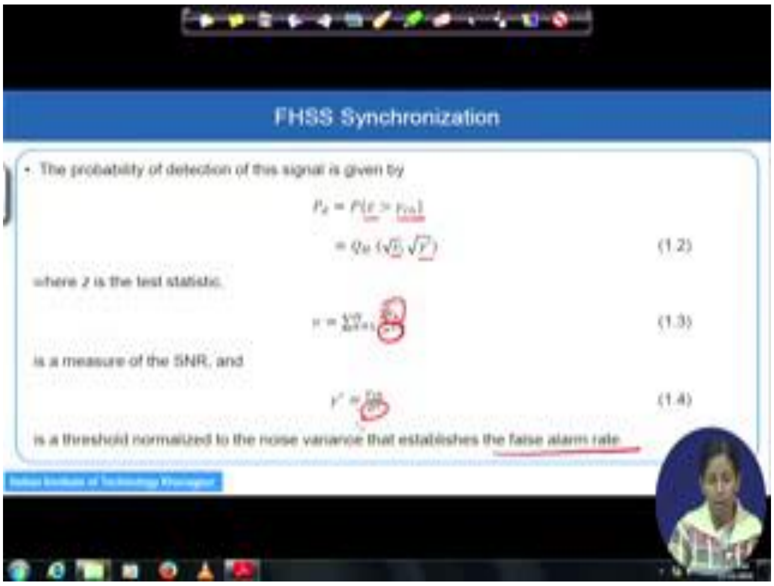

Now, after getting that received signal are came, and accumulating all those k-th hopping interval, now the detection probability statistics will be defined the probability that the test director z process are predefined threshold value gamma t h. It is going by the concept that already we have developed in the last few modules or classes that whenever the test parameter we always inside the coordinator and the detector circuit. You always try to compare the test statistics with respect to predefined threshold value. Whenever the test statistic process the threshold value, we declare that the detection is done.

And all the expression of the probability detection that we have designed, we have to derived in the last module. We have seen that it closed in presence of the additive Gaussian noise the detection probability closely follows the Q function and it can be given by the Q H in this case, where H is a number of the hops, over which the detection probability is defined. And that will be a function of this nu and gamma dash, where this nu is nothing but the sum of all the normalized SNRs. R k is the power of the k-th received signal. So, sigma square, we understand for zero mean Gaussian noise this is the power of the noise.

So, basically your nu is nothing but the total additive power over all the H hops. SNR it is the finally, it is the SNR value of all the H hops. And gamma dash t h is nothing but the normalized gamma value with respect to the sigma square were the noise variance. And remember we have k normalize the gamma dash with noise variance, because we try to establish that we are try to reduce the number of the false alarm. So, for to reduce the false alarm rate, it is essential to normalize the gamma and the SNR with respect to the noise variance that is a method done.

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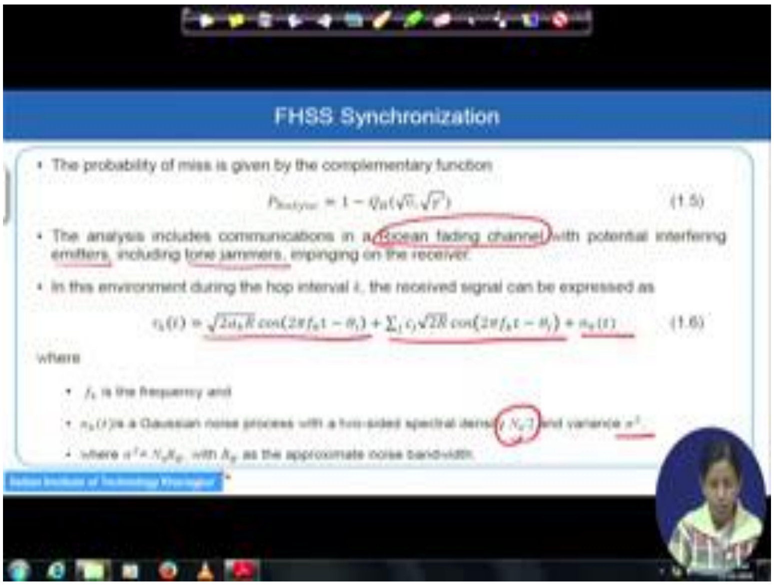

We have also seen that the probability of miss is given by the complementary function, which is a total probability is one detection plus the miss, so 1 minus the detection probability will give you the miss probability of miss. And if we considered that the analysis that we will be now discussing is over Ricean fading channel that is a Ricean fading channel is we will discuss a lot about other fading channels in the wireless communication class.

So, here actually in the Ricean fading, the distribution the fading of the channel actually the signal is the amplitude of the signal as well as the phases of the signal, they are getting changed they are getting having lot of dispersion associated with that. And the received signal, the amplitude of the signal, they are having the fading is contributed by the Ricean distribution and the potential interfering meters with potential interfering emitters as well as that tone jammers they are additive to the whole communication signal model.

So, there are three things that whatever the transmission power is you are not going to expect the same power to be received in the receiver frontend. The total signal will be faded by the Ricean distribution of the channel, and they will have the interfering signals added to it. They will have that tone jammers added to them. And hence in the environment during the hop interval of the k, the received signal can be expressed like this, where actually this is the contribution of the interference signal. This is the noise process as we understand; and this is the intended signal set intended signal portion. We understand f k is the frequency, n k is the Gaussian noise process with a two-sided spectral density of eta 0 by N 0 by 2, variance is having sigma square. Remember this sigma square is equal to N 0 into B IF, where B IF is the approximate noise bandwidth and it is also the bandwidth of our interest.

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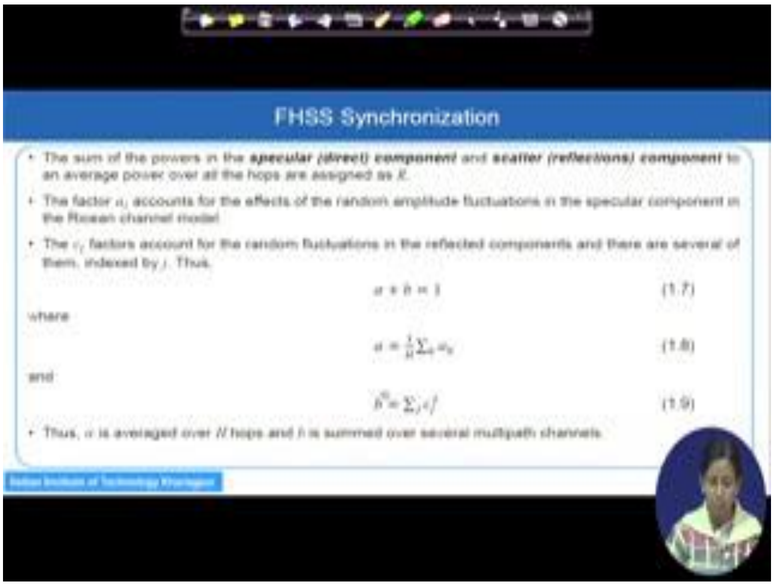

Remember this capital R which is the received power. This power is actually in a multipath environment in Ricean fading channel environment, where you are not going to receive only the line of sight paths, you are going to receive between the transmitter and receiver, you are not going to receive a line of sight path, you are also going to receive lot of the reflected paths, which we call the multi paths in a wireless environment. This is a basically there are a lot of scatters in the environment, the wave electromagnetic waves gets reflected and scattered and refracted by this scatters and scattered waves also are getting are also reaching to the receiver. So, that is why this is called the way that is directly getting received by the receiver antenna is miss called the line of sight - LOS path, others are the multipaths. So, remember this capital R, actually incorporates the power that is getting received by the line of sight as well as the power that is getting received by the dominant multipaths over the environment.

So, here is the direct component as well as the reflected components and the square of the power simulated power for over all the paths including LOS and a multipath is incorporated inside the value capital R. But factor a i here that actually accounts the effects of the random amplitude fluctuations over the direct path and Ricean channel model. And this c j, it is actually basically the random fluctuations and the reflected components. And there are several reflected components for example, the j number of the components that are coming here. So, the phase random phase associated with the direct path will be given us theta i and with the associated, with multiple paths, each of this multiple path is having a different amount of the phases associate with a that is why theta a here actually is varying over the j in the second term.

And remember that this alpha plus b, there is a consideration that we will it will have equal to 1. What is this alpha? Alpha is actually the average value of this a k over all the number of the hops. And this c j is the; b is actually the summation of all the multiple paths the addition of this c j square. So, alpha we can saying is averaged over the H number of the hops all the number of the hops, and this is actually a parameter which is the summed over that several multipath channels. So, it is an average quantity and this is a simple summed up quantity over the multipath channels.

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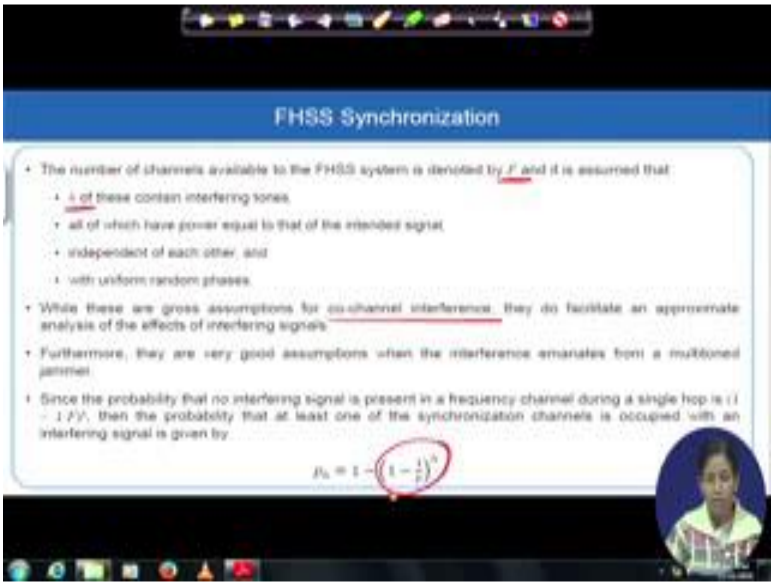

So, now, let us consider that the number of the channels available for this FHSS hopping is denoted by capital F. And we let us assumed that out of this capital F, h number of that tones containing the interfering tones. So, we have total capital F number of the channels to hop, and out of that h number of the channels are h of number of the tones they are already they are containing the interference. And this interfering each of those interfering signals are having the power exactly equal to the intended signal. And all the interfering signals each of their independent of each other also and they are having a uniform random phase associated to them.

These are basically gross assumptions for the co-channel interference, because the interference is now coming from the adjacent channels. And they do facilitate an approximate analysis of the effects of this interfering signals. Furthermore, they are very good assumptions when the interference emanates from the multitoned jammers also. Since, the probability that not having any interference signal present in this whole set of the frequency channel of the capital F, during a single hop can be given as 1 minus 1 by capital F of whole to the power small h. Then the probability that at least one of this tones out of capital F will have the interference is given by the p h is equal to 1 minus 1 minus 1 by capital F into h. So, this is case situation that with the probability that there is not a single channels are getting interfered by the interference, and hence p h is actually at least one of them is having interference.

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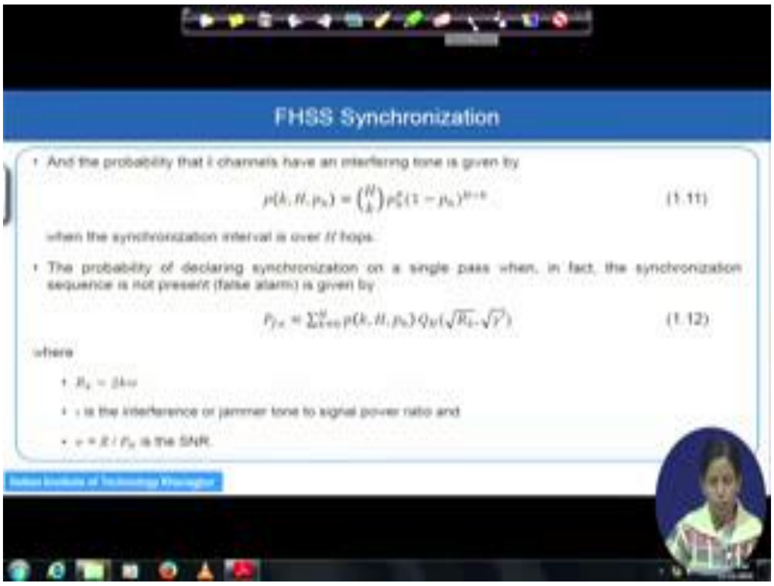

So, now let us consider that the probability that the small k number of the channels having an interfering tone will be given by the equation 1.5 by extending the equation

1.10, this can be given. Because you have total H number of the hops; and out of that you are saying that small k number of the interfering tones are there; and at least small k amount of them are having giving the interference. And actually if we try to extend this concepts slowly, and we try to find out what is the probability of false alarm now, when this is actually the probability of getting interference on small k number of the tones when capital H is the number of the total hopping intervals or hopping tones available or channels available.

Then we see that the probability of false alarm will be given as this equation, where this is actually function of this probability calculated earlier and multiplied with the Q term or the Q function. And this R k and Q function will be a function of R and gamma parameter, where R k is equal to twice k l into u. And this one is the interference jamming tone versus the signal power ratio, jamming tone to the signal power ratio. And this nu this is equal to my capital R by P N where P N is the total noise power. The total noise power means the thermal noise power plus the interference power that we are considering, and this is the SNR that we are talking about.

So, we are seeing here that we are having a term R k, which is considering the interference to jammer tone given by l the number of the tones we are considering the interference. And to this nu is having this R by normalized basically a signal-to-noise ratio. Gamma dash we understand there this is the normalized gamma with respect to sigma square to may be have normalized needs to because we wish to minimize the false alarm rate.

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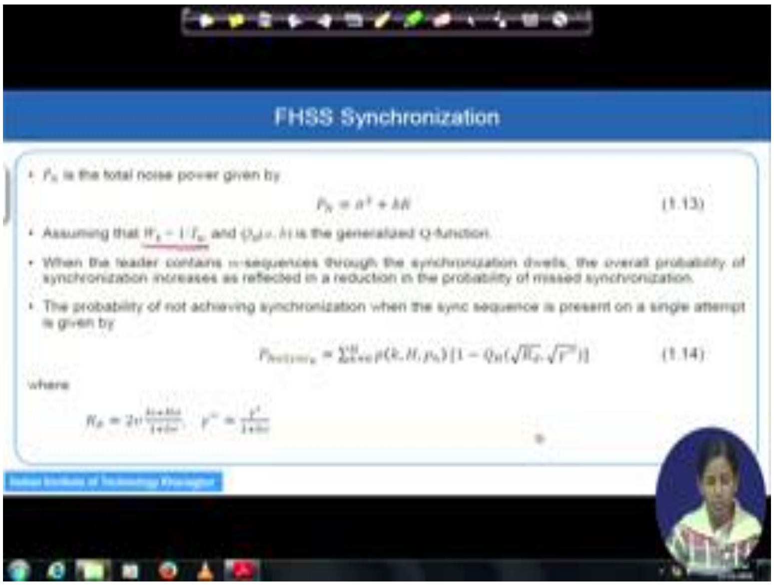

And see that this total noise power P N is given by the thermal noise power plus this b into R. Initial we assume a parameter W F, which is basically 1 by T h, the bandwidth actually T h is the hopping duration, so basically this is the bandwidth total bandwidth of your spreading. And Q H is the generalized Q-function in the equation 1.12. When the leader contains the m-sequences, m-sequences to the synchronization dwells, the overall probability function increases as reflected in a reduction in the probability of missed detection. So, we this is obvious also because if we are increasing the m-sequences, number of what is the m-sequences pseudo synchronization dwells, the overall probability synchronization will be definitely increasing.

And probability that there is no synchronization is going on that will be given by this. Where this R d will be a function of this guy; and gamma double dash will be a function of this. So, this is a condition that probability is not achieving the synchronization when the same sequence is present on a single attempt. So, we call it a missed detection, signal is present, but you could not detect it.

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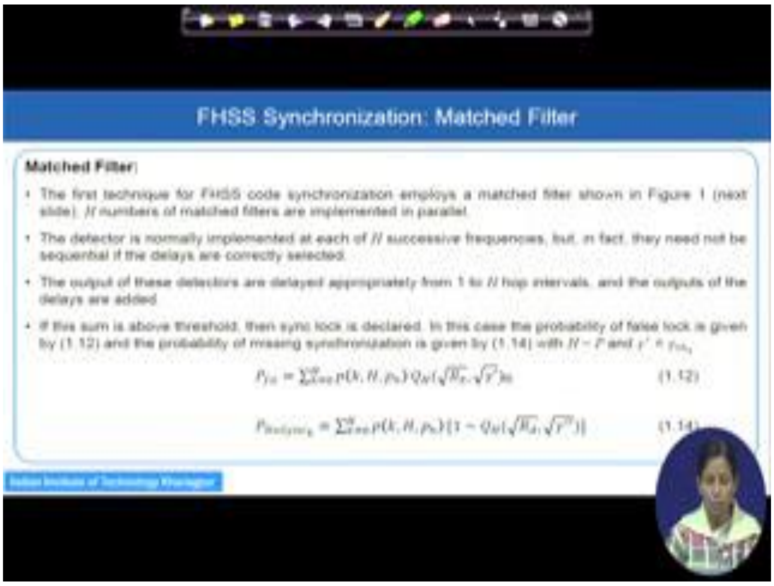

And here comes the first technique of this FHSS code synchronization that employs a matched filter. So, with the concept that how detection probability and missed direction probability. What is the false alarm the expressions are there, based on that we will enter into the matched filter based efficiency synchronization mechanism. We understand that H number of the hops are there that needs to be detected. So, there in the matched filter architecture we deploy H parallel matched filters. And the detected is normal implemented at each of these H successive frequencies.

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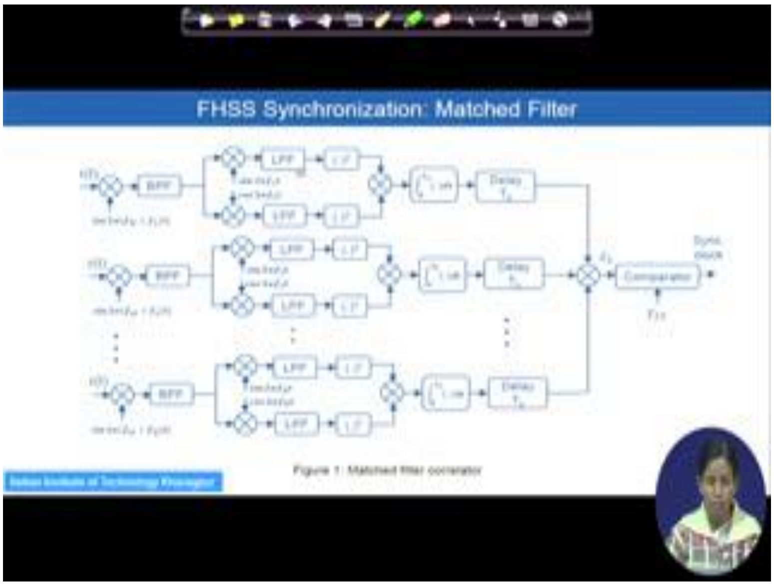

So, the structure will look like this. So, you have H number of the matched filter architecture, each of them are associated with the integration and the delay. So, this is a detector circuits that are accumulate that are associated with each and every path. And question is going on something like this, the output of this detectors will be delayed appropriately from if it is first hops, so it will be delayed by 1; and it is a capital H hop, then it will be delayed by capital H. And addition all the output of the detectors will be added here and then the output of the adder when it is compared inside the comparator with the predefined threshold called gamma t h.

Then depending upon the fact that which output is actually getting crossing the threshold and based on the sum of that is above the threshold then the sync lock will be declared. Now in that case your probability of the false lock will be given by this. And probability of the missing synchronization will be given by this, where capital h will be equal to P - the total power, and then gamma dash will be equal gamma threshold one.

But remember here one thing that here acquisition of the code acquisition will be really very very fast, but false alarm the actually rate at which we will get the false alarm. So, rate of the false alarm definitely will keep on increasing in this architecture. So, this architecture is very good in that case that as you are processing parallel for the H with H matched filters in one of them actually we will give you the acquisition. So, it will have a match with incoming signal. So, code acquisition is very fast in this architecture, but probability getting the false lock that is also really very high.

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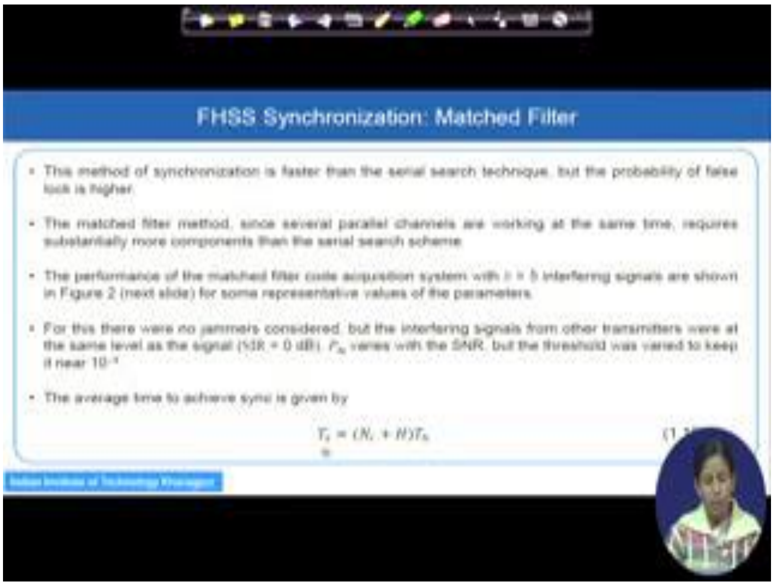

And another important part, as you are parallel implementation H number of the matched filters hence in the whole architecture is very much hardware intense. Power consumption is also very nice; power consumption will be also very high. So, we will take a very quick example to see actually how this code acquisition system will be varying with if I take the small 5 number of the only 5 number of the interfering signals. And if we are having that there is a considered the there is no jammer, but some interfering signals are there the 5 number of interfering signals are there. And the interfering signals from the other transmitter there are at the same level of the signal; that means, at the 0 dB. And probability of false alarm varying with the SNR, but the threshold of this probability false alarm for the signal design system design, it is kept to 0 to the power minus 4.

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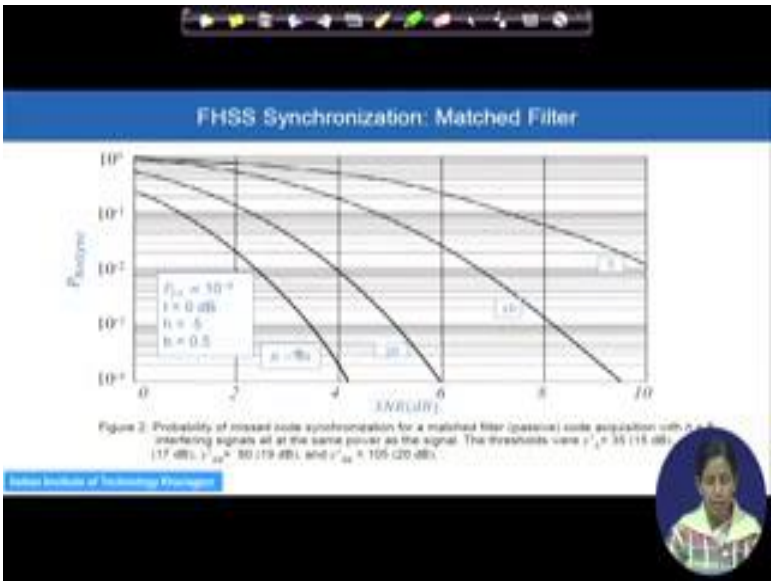

Then you come here and see that if we are varying the number of the hops actually the synchronization probability that is actually performing poor with respect to the SNR, you need basically the high amount of the SNR to reach the same miss detection to keep the same miss detection when the probability of false alarm is predefined. So, that is the situation. And if I quickly look into the average time required to achieve the synchronization by the matched filter process, it will be given by the equation, where the synchronization time is equal to N c plus H multiple by T h. T h is the hopping duration. Capital H is the number of the hops and the number of the chips that you are incorporating inside that design.

So, this is the first method by means of each FHSS synchronization is achieved, but we understand two fundamental points that matched filter based any acquisition technique is really very fast because it is a parallel search going on. And this will be definitely very, very fast they are compared to the serial search technique, but the probability of the false alarm at the same time will be keeping on increasing severely. And it is very much very much hardware intense, but the search your time the acquisition time is minimum compared to any other search techniques. So, if you can actually really effort the higher denser power consumption and higher heavily intense our architecture, so it is always the advisable to go ahead with a matched filter based architecture to minimize your acquisition time and acquisition system.