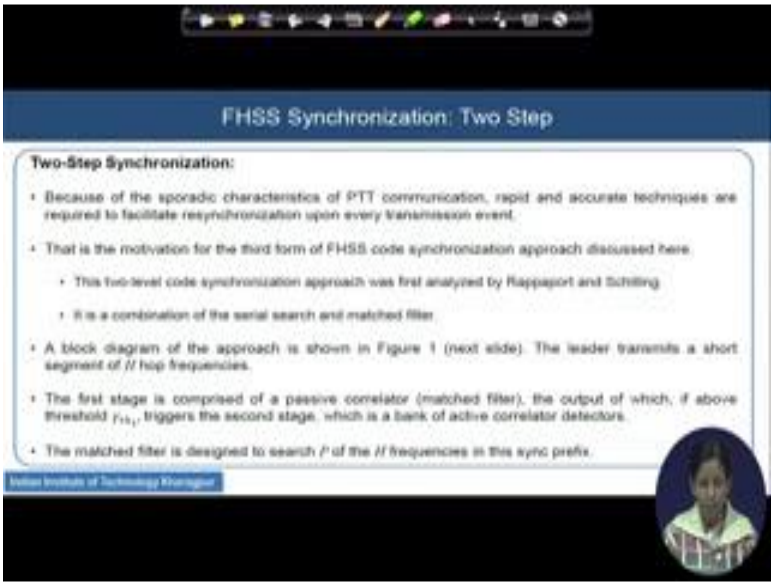
**Spread Spectrum Communications and Jamming**
**Prof. Debarati Sen**
**G S Sanyal School of Telecommunications**
**Indian Institute of Technology, Kharagpur**

**Lecture - 44**
**FHSS Synchronization Method – III**

Hello students, as discussed in the last slide in the last module that in this module we are going to combine both the matched filter based approach and the serial search active correlated based serial search architecture. To see whether we can give the advantage of both of them in a new one; and that one we call a two-step mechanism that we will be discussing today. So, fundamentally we are going to club the match filter based passive for correlator architecture with the active correlator based serial search architecture.

And we understand that matched filter gives as a very fast acquisition at the cost of high probability of false alarm and high complexity. And the contrast serial search mechanism gives us very high detection probability lowering the false alarm, and at the cost of long acquisition time. So, target is what final target is to get the high detection probability, low false alarm with reasonable time of acquisition.

(Refer Slide Time: 01:42)

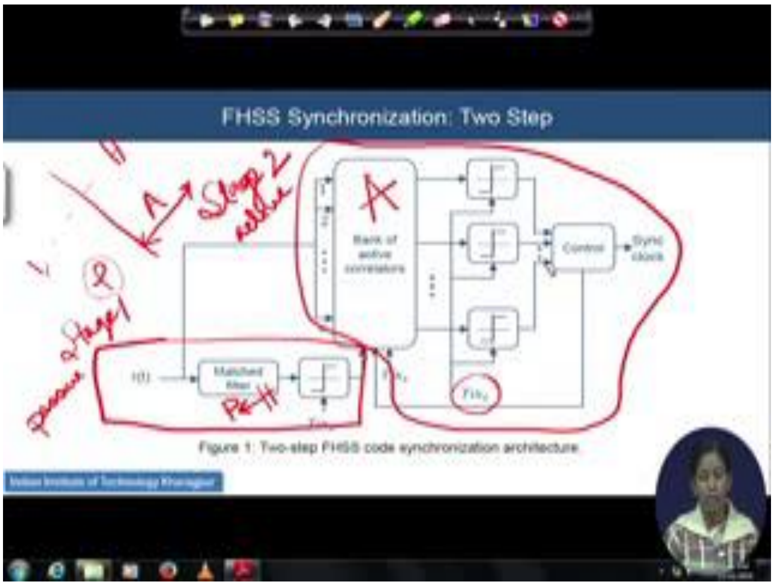



So, here we are the mechanism is called a two-step synchronization mechanism. And we understand that there are communication in the push-to-talk network on which all this schemes we are continuously discussing. The communication there is a burst type we call it as sporadic characteristics of the communication. And rapid and accurate techniques are required really to facilitate resynchronization on each and every transmission packet, so that is the main motivation of this third form that actually fast acquisition is required also very good acquisition I mean accurate rate accurate acquisition is also will be the most important part. And this two level synchronization mechanism of FHSS approaches of it was the first analyzed by Prof. (Refer Time: 02:45). And this is a basically combination of this matched filter plus a serial search technique.

Let us see the next slide to understand what exactly is going on here. But remember here also we will consider that there are capital H number of the half frequency is involved in the synchronization sequence. We will send the leader for each the way we send the leader for the matched filter as well as the serial search. And there are two stages the first stage is having one set of the threshold call the gamma t h 1; and second stage uses the another stage of the threshold which call it gamma t h 2.

And remember there are searching is also divided into these two-steps. The first step find suppose p capital P number of the searchers capital P number of the tones out of the capital H to be searched and the remaining capital A number of the tones will be searched in the second step. Such that capital P plus capital A the number of that tones searched by the stage 1 and the number of the tones searched by the stage 2 totally combined gives the total number of the tones over which the hopping is going on.

(Refer Slide Time: 04:07)




So, this is a block diagram of that two-step architecture. As I said the first stage ends here. The second stage consists of this stage 1 and stage 2. The first stage consists of a matched filter. So, stage 1 is passive correlator based architecture; and stage 2 is active correlator based architecture consisting of. And as I told that threshold value also of the first stage and the second stages are not same, they are different. The philosophy is what you know the whenever the signal is received here, the matched filter starts working. So, in the matched filter, we are having actually say its task is to find out say capital P number of the tones out of your capital H number of the tones. So, out of capital H, it is targeted to find out the capital P number of the tone.

So, you need not to actually build up a matched filter architecture here, where the number of the stage is parallel stages involved will be capital H. You need to put here now the very less number of the parallel chains of the matched filters, which is equal to capital P. But philosophy is that if the matched filter output for all those capital P number of the searches, if you will search maybe actually for overall the capital P and out of this, if we can find actually for all the capital P number of the stages, there is a sufficient number of amount of the statistics such that the statistics is crossing the predefined gamma value or the threshold value. Then there is an indication that matched filter is giving an indication that there is a chance of getting synchronized tones within this received block.

So, the received block is fed to the matched filter, and see received block is also fed to the active correlator bank of correlators, but active correlator bank never starts working without getting a trigger input from the matched filter output. So, what matched filter finds that the output of the threshold comparators, at the output of the matched filter is really high that means the matched filter output is crossing the predefined threshold; then actually it means that there is a chance that if you search over the same period over the same set of the incoming chips, there is a chance that you can be able to find out the synchronization point. Then the active correlator is activated.

And here is we are having a bank of active correlators and any one of that bank of active correlator is activated. Suppose, I have capital C number of the correlators here, so out of capital C any one of the correlators will be activated by the output of this stage 1. And he will try to do the serial search the mechanism that we have discussed in the previous one, and his task is now to find out the remaining capital A number of the tones. And in finding out the remaining capital A number of the tones. And this search actually is a very means long lengthy process and with serially its keeps on searching. And once we searching, we understand that the output of the every step, output of the every tone when it is searching, it should be sufficiently large, it should be most of the cases if it is actually well tuned then only the output statistics z will be high. And then any one of these bank of the threshold two comparators, comparators are having a second level of the thresholds the output will be high.

Now, if the output is high then the control will give based on where you are in. And based on that control will either declare that the sync is completely lost; if it can find all the capital A position or if it is not then he will readjust the clock slowly such that it can get aligned with that capital A number of the path. So, the situation is such that I understand that if serial search for all capital H number of the tones needs to be done then it is a very lengthy process that the correlator cannot do, because it will take huge time. To reduce the time the partial search is performed by the matched filter by parallelizing the whole architecture. And by parallelizing each we choose actually efficiently those capital P number of the tones, the presence of whom also confirms that there is a chance that that this is a chunk of within this chunk of the bits the synchronization points will be able to be searched by the active correlators then only we trigger the active correlators.

Now, remember one thing if my active correlator does not find actually the sufficient amount of the z value - the test statistic value, then what you will do he will actually means declared that he could not find, and he will actually be pulled he will be drawn in the pull of the correlators. Where actually matched filter will assign him some job at certain other point of time. And see maybe the second correlator some other correlator maybe assign the same job by the matched filter. But whether matched filter have the time to assign the job to the second or the third correlator that depends upon remaining time of the total acquisition time the within which you need to complete the search.

So, and if the situation is such that all the correlators are busy at a particular point of time, when the matched filter has found some kind of the pre-sync message that he could actually get a by comparing his output with this gamma t h 1. When all the correlators are busy at that moment even if actually matched filter is trying to say that there is a chance to find out some synchronization point within this capital A within this set of the received chips, the correlator none of the correlators will take the input will none of the correlator will take the job. And in such situation that request is totally discarded. So, see what we have done in this combined architecture is acquisition long huge acquisition time required by the serial active correlators is reduced and reduced by a great extent by partially implementing the matched filter.

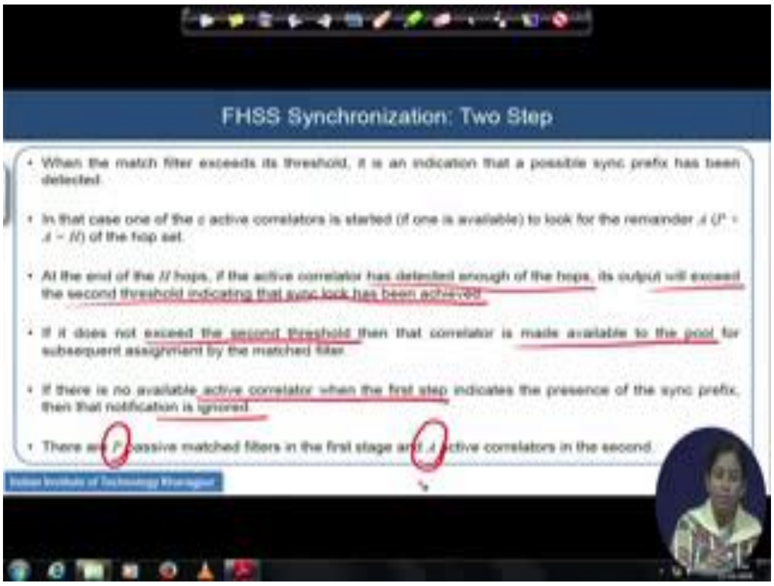
So, the totally h number of the tones, we have divided into P plus A. The P number of the tones will be searched by matched filter and A number of the tones will be searched by the remaining active correlators. The P is choosen in such a way that for those tones there may be scattered means they are not required to be sequential one, there may be actually some rapid number of the tones. But if that random tones out of capital H matched filter is able to find out that will be done at very fast speed. But with possibility that the probability of the false alarm is also high and that is why actually next stage the serial search is very, very essential. And for all those remaining one actually if you are doing I understand that for this capital A time, for capital A number of the tones, the serial search will be done in such a way that the detection probability will be very high.

Here the false alarm probability is high detection probability is less, but here the detection probability is very high. So, in average, it will be a balanced detection probability for A plus P number of the tones actually guaranteed by the active correlators if it can find the capital A number of the tones. At the same time, actually the time the higher time that is consumed by the serial architecture I mean the serial active serial search active correlators architecture that is counterbalanced by the very fast acquisition that is occurred to avail this P number of the tones by the matched filter.

So, one way actually the detection probability is getting balanced by the serial active correlator; another way the acquisition time is taken care of by the matched filter. So, combinely you it is expected that with a low noise situation, we will be able to detect both the P and A number of the tones and with a reasonable time of the acquisition and very with a reasonable time of acquisition and satisfactory level of the detection probability, so that is a gain of this whole architecture where the disadvantages of both the techniques are nicely combined to get pretty good and satisfactory performance of the detection probability as well as the acquisition time.

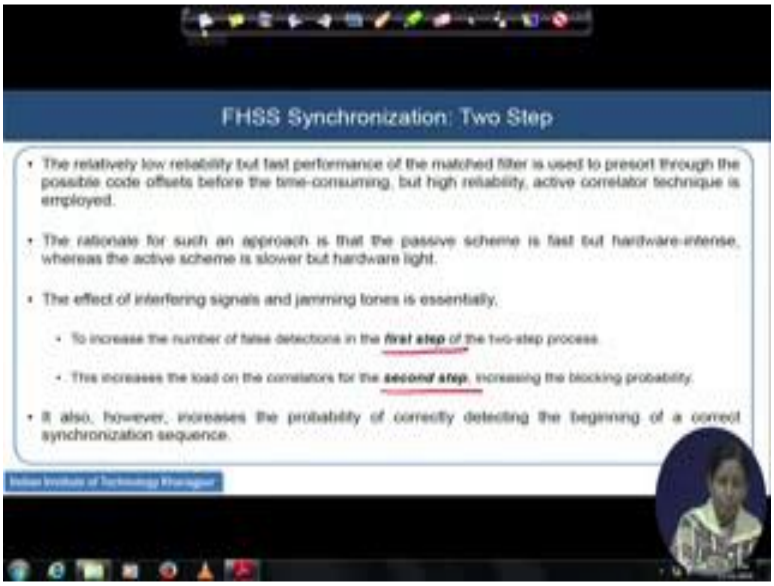
So, this two-step mechanism proposed by Prof. (Refer Time: 14:00), they are very popular and they are widely used also in the PTT network. But remember as we have incorporated both the matched filter as well as the active bank of active correlator architecture, complexity wise actually you have not gained much because matched filter anyway matched filter is a hardware complex hardware intense, and the this guy is also having a several other architectures and hardware components associated with it. So, we could not actually do much over the hardware complexity, but with that that is the cost function of this architecture, but with respect to that we have gained a lot in the performance in terms of detection as well as the acquisition. Both has been improved by combining the earlier two mechanisms, so that is the plus point of this two-step one.

(Refer Slide Time: 14:58)




In this slide, the same stuff is explained. And remember at the end of this capital H number of the hops, if the active correlator has detected in half of the hops, its output will exceed as I told. And the second threshold indicating the sync lock has been achieved. But if it does not exceed the second threshold then the correlator is made available to the pool. And for a new assignment, we done by the matched filter. And if there is no active correlator available when the matched filter output has detected some part of the capital P number of the tones then actually the whole notification will be completely ignored, because nobody is free to take the charge or take the assignment to find the remaining capital A number of the tones. So, you have a P number of the passive for matched filters in the first stage, and capital A number of the active correlators in the second stage.

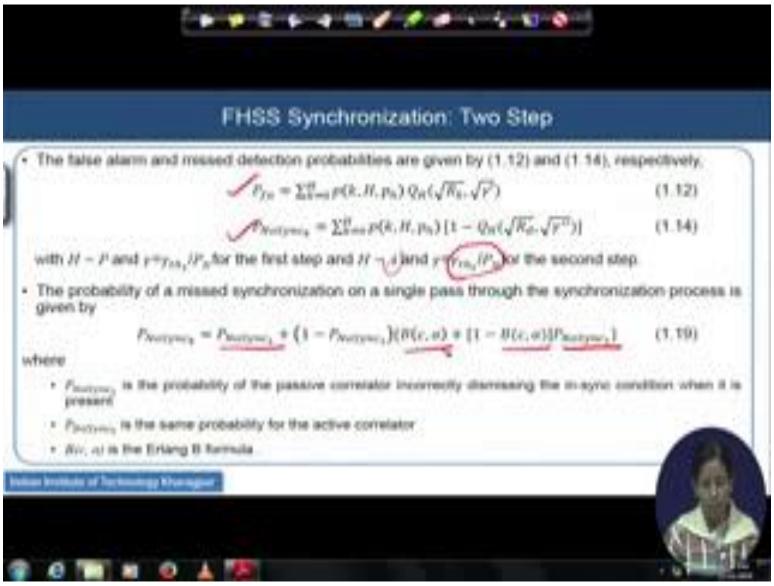
(Refer Slide Time: 16:09)




How will you divide this capital P versus capital A that is the design choice. And it will actually largely affect the acquisition time constant within which you are trying to complete the design and the detection probability. What is the minimum required detection probability of yours? Now, the relatively low reliability, but the fast performance of this matched filter, we have used to present through the possible code offsets before the time consuming, but highly reliability active correlators are coming next to deploy to improve the detection probabilities I have already told. But hardware intense and hardware light that are also getting combined; and effect of the interfering signals and jamming tones is essentially will be up to fold.

See to increase the number of the false detection actually that jammers can increase the fault detection probability in the first step of the two-step process. And if it is really high then it increases the load of the correlators in the second step, because it increases the blocking probability also. And however, there is a increases; however, increases in the probability of the correctly detecting the beginning of a correct synchronization sequence also is possible because of this whole architecture. We will see actually in the next few slides, how this blocking probability is coming into picture if we are having a large number of the false detection coming from the first stage to the next.

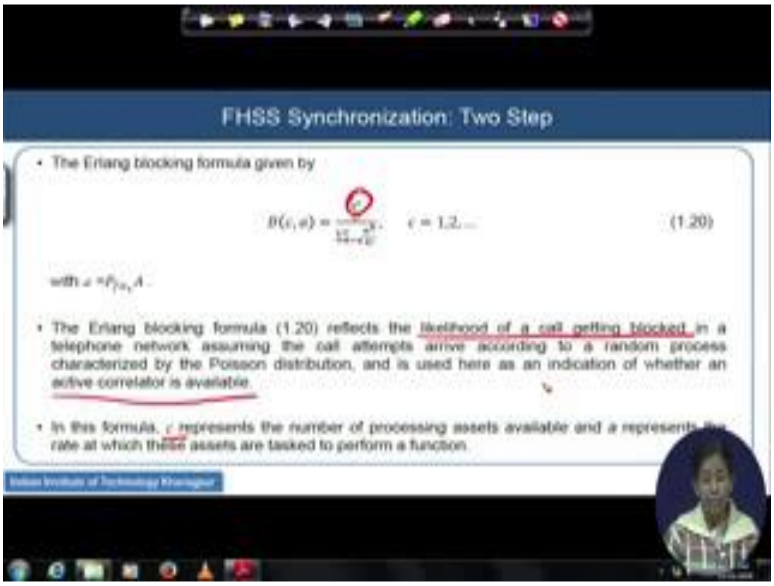
(Refer Slide Time: 17:47)




The false alarm and the missed detection probabilities, the expression we have seen earlier also. They are given repeated once again. And where actually this capital H will be equal to P and this gamma will be given by your gamma t h 1 by the total noise power for the first step. For the second, step capital H will be equal to capital A, because A is the number of the step tones over which you are searching. And gamma will be basically gamma t h 2 by the normalized tone power normalized sorry total noise power. Probability of the missed synchronization on a single pass through the synchronization process will be given by this expression is the newly developed one where we consider that there is a total missed detection.

So, total missed detection means for missed synchronization means, it should be a combination of the first stage plus the second stage. So, this is a first stage missed detection and this is the second stage missed detection B, c, a this is the Erlang B formula of the blocking probability it is talking about. And how this is a Erlang B formula, so the total missed detection is the function of not only the missed detection of the first stage and the second stage, it is also a function of the blocking probability coming into picture.

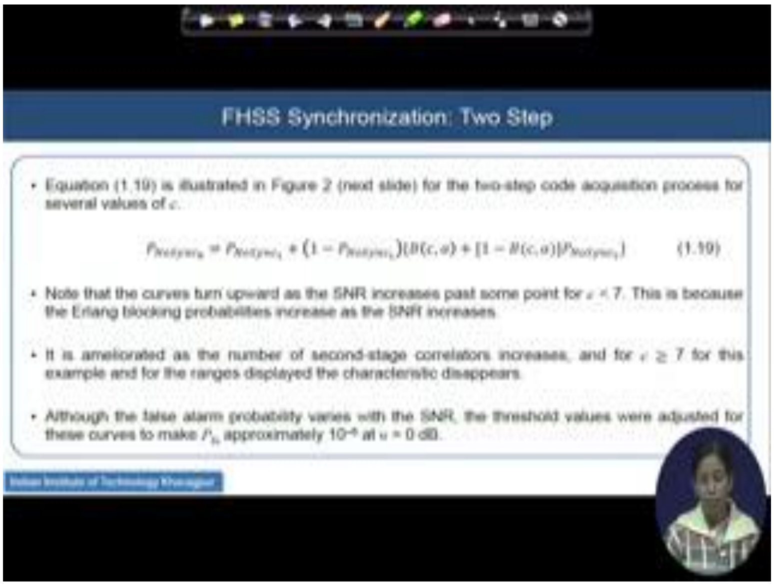
(Refer Slide Time: 19:20)




What is blocking probability or the Erlang B formula is given by this. And remember with where this a the value of this a is given by the false alarm of the stage number 1 and multiplied by the number of the tones assigned to the stage 2. And why this Erlang B formula is coming here is because it is basically formula that reflects the likelihood that are called will be blocked in a normal telephone network. And the call attempts to arrive according to, if we consider that the call is attending it is arriving as a random process and its arrival process is given by a Poisson distribution. And it is an indication that here it is an indication that as an indication of whether I active correlated is available or code arrival code that active correlated is not available. It has some similarity with the telephone line actually the call is dropped if your line is not free kind of. So, here actually the request from the matched filter is getting dropped, if your correlators are none of the correlators are free

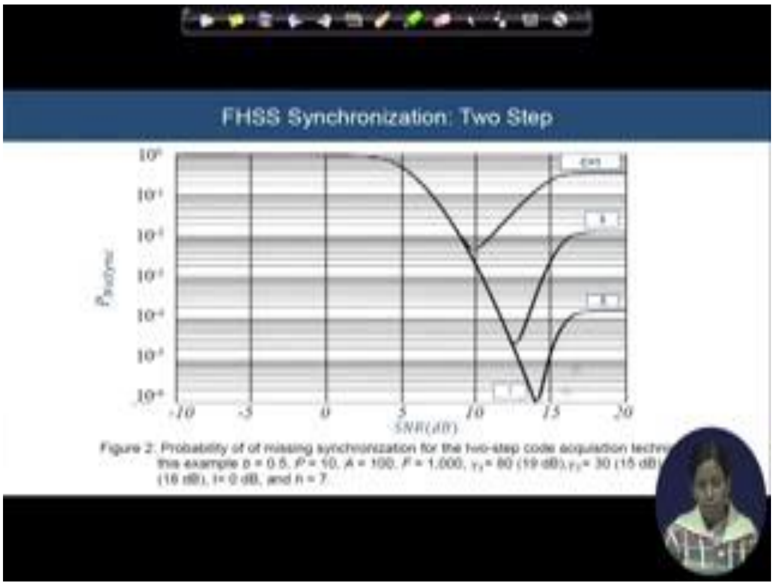
The formula this blocking of formula Erlang blocking formula, the c represents the number of the processing assets that are available you mean the number of the active correlators available in the second stage. And the a - this guy, he is representing the number of the what is the tasked performed it represents the rate at which way the each of the correlators are given a typical tasked to perform. So, basically we can map the normal blocking called blocking probability of telephone network can be mapped here with the availability of a correlator in the second stage and the job assigned to each of them. Based on that whether there is a chance that even if actually the matched filter output of the stage number one is delivering something or requesting something to proceed the second stage is discarding that effect and discarding that request. That is why actually you are seeing that the detection probability as well as the no-sync missed detection is a function of this blocking also.

(Refer Slide Time: 21:45)




So, that is why it is like this. We have reproduced the formula once again. We will try to plot this now in the second slide. We will try to plot this as a function with several values of the c. And let us see if I plot it and this is a blocking probability, remember this blocking probability is a function of this c right - the number of the asset available in the stage 2 or the active correlator number of the active correlators are available. So, we can find a very nice result that if the value of the c is less than seven, the blocking error probability will turn up, and this is because that blocking probability will be increasing with as the SNR increases. But if you cross the number of the correlators greater than equal to 7, then this typical characteristics totally disappear.

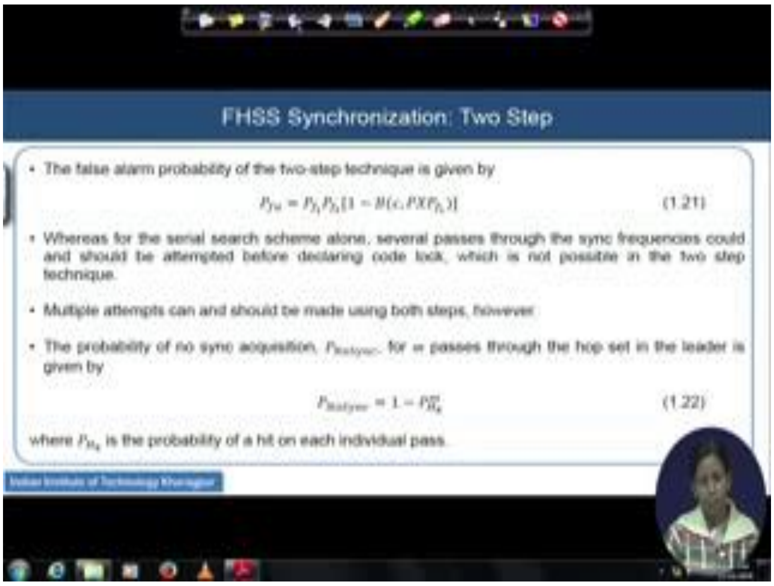
(Refer Slide Time: 23:04)




And let us see, how does it go. In the next slide, let us see the blocking probability actually, it is a no sync there is no sync of the missed detection probability actually it improves if I keep on increasing the value of the correlators in the active stage. But it will always also goes up actually if you increase the SNR, because the blocking probability Erlang B formula, the Erlang formula that is there if you look that if you look inside that we see that you will see that if the SNR is increasing the blocking probability slowly increasing.

And if the blocking probability is increasing, so hence the missed detection noise again will be increasing. So, with the increment of the SNR faster missed detection will be decreasing, and then based on a typical value of the c and the point after central point that values also on the number of the based on the number of the correlators utilized for the active stage. The blocking probability suddenly starts increasing with this SNR and hence the SNR hence the detection probability also decreases and the less detection increases slowly. So, beyond seven actually at this kind of the graph, this issue is not there at all.

(Refer Slide Time: 24:37)

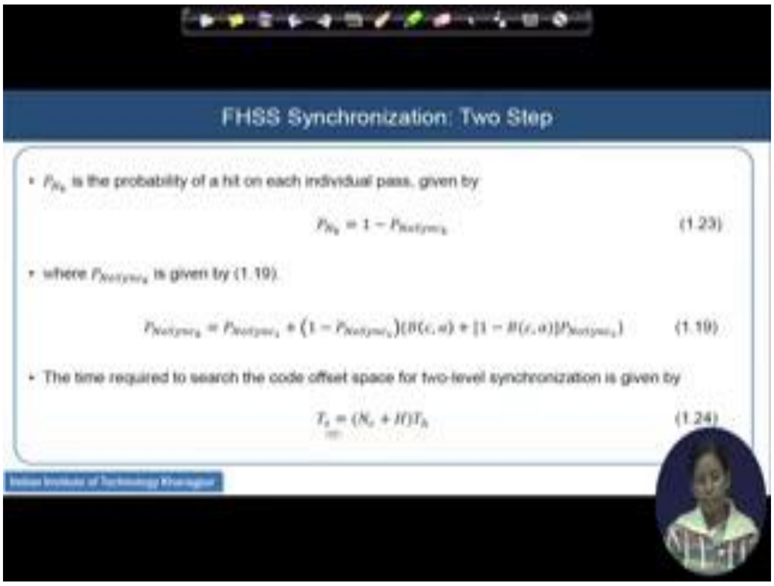



And though the false alarm probability, it varies with the signal to noise ratio a lot, the threshold values we can adjust for this curves to make the probability of the false alarm approximately 10 to the power minus 5 at 0 dB SNR for this kind of the cases. Now, if I try to understand what is the false alarm of the two-steps jointly going on, so false alarm probability of joints of false alarm probability at the end, it should be given by the false alarm probability of the stage 1, false alarm probability of stage 2, and also the allowing the number of the times actually the second stage or the correlator serials correlator stages is running actually, so 1 minus the blocking probability.

And whereas, for the serial search mechanism alone, the several passes through the sync frequencies could and should be attempted before declaring the code lock, which is not possible really for your two stage statement. Because if you are trying to see the actual serial search mechanism, we take multiple iterations over the multiple dwell time before declaring there is a sync lock. Here if you try to do that you cannot do it alone over the serial search methods over the serial search portion, you have to do it over the whole architecture. So, we do not prefer to go that way.

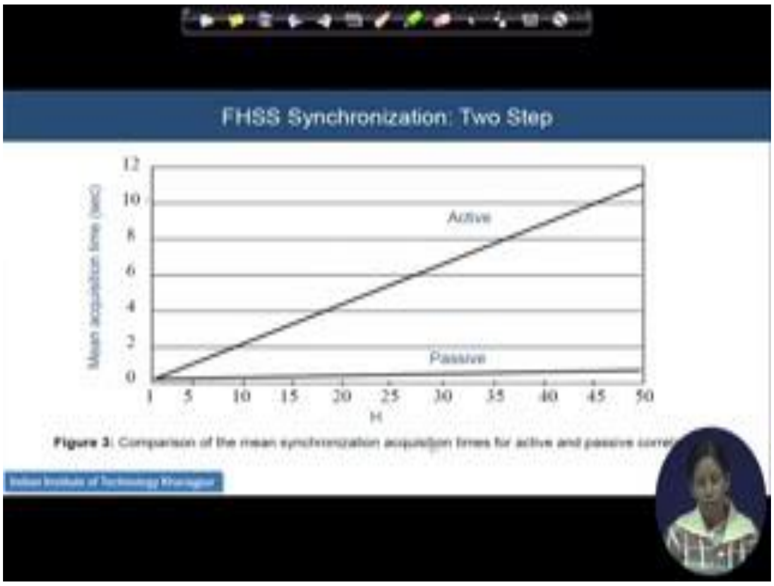
Multiple attempts here you can make of, but you have to actually then run here on the first stage as well as in the second stage. And in such a situation you have to then or the whole false alarm probability will be increased and also the detection probability and the time acquisition of the acquisition everything will be under tie. So, probability that there is no sync acquired that will be finally, 1 by the minus of P H k of m where P H k we understand the probability of a hit on each and every individual pass. So, if I am going over the small m passes, so it will be raised to the power m; and no sync means, if there is no detection at all happening that will be a 1 minus the total one.

(Refer Slide Time: 26:43)



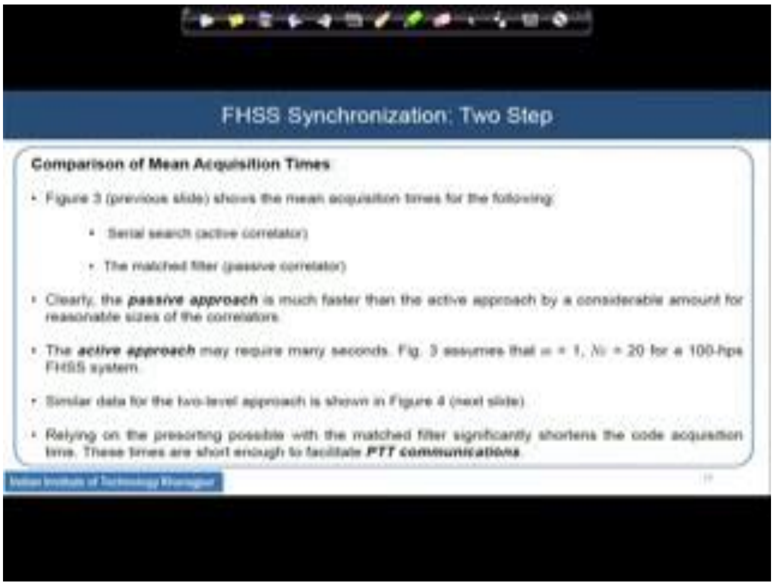

Where is a expression for the P H k the hit for each and every search. And no sync a hence actually finally will be given by this expression we have seen earlier. The total time required now which is the most important part for which we did all this. We realize at the detection probability has increased, but we have not understood here to (Refer Time: 27:08) actually we are good in acquisition. In acquisition time the acquisition time, you do you remember we saw a small m here in the acquisition time of the serial search; now that m is vanished because we understand that we are not really going to repeat it over the m number of the period, and there is a acquisition time which will be ending up with.

(Refer Slide Time: 27:28)



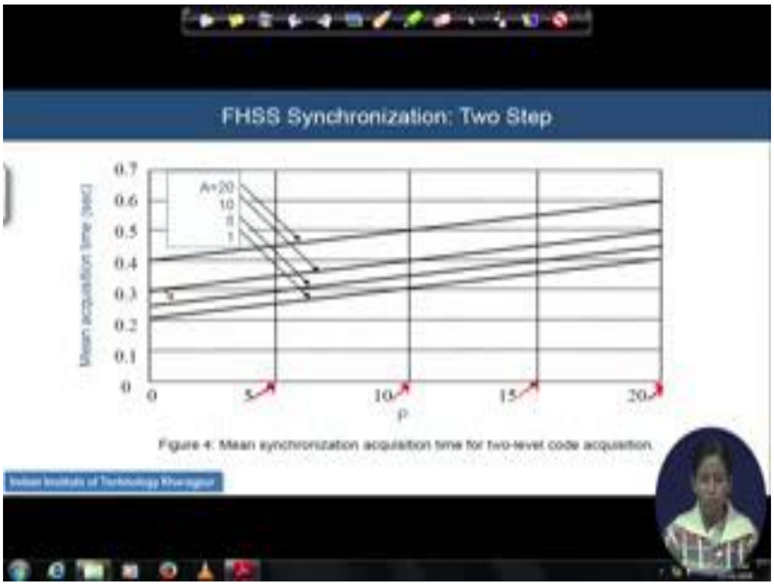

If I compare the active and the passive search techniques, the mean acquisition time here will be a function of your, this number of the hopping. If your hopping is more, then you are active serial search techniques they will keep on actually increasing the mean acquisition time that is obvious; and passive is far better compared to that because passive is parallelly implementing all that. So, there is no large increment over the; if your H is increasing, it is obvious we understand now.

(Refer Slide Time: 28:03)



And now if I try to compare the serial search and the matched filter based mean acquisition times that I have shown in the last slide, we refer the passive approach to go head and if it is an acquisition time based.

(Refer Slide Time: 28:31)




And of two level approaches, if I am trying to see for the PTT communications, then here we are. So, A is equal to 20 means in the serial search process the 20 number of the tones are remaining to search; 10 number of the tones remaining to search; 5 number of the tones remaining to search, and 1 number of the tone remaining to search. So, if your P is increased definitely if your number of the if with the fixed number of P let us first understand with the fixed number of P say equal to 6 something like that it should be 5. This 5 is for here, this number 5 is for this point, 10 is for this point, 15 is here hence and 20 is here

So, say first stage is the number of the tones that your matched filter searching is equal to 5; if that is the situation then if I am keeping only single tone to be searched in the serial active search technique then your acquisition time is around 0.25 second. And more and more actually you are increasing the number of the tones to be searched by the serial search technique keeping the capital P value the number of the tones to be searched by matched filter fields. Hence you see the acquisition time is increasing, and if I do miss a some structure like this that we have increased the P up to this and then only one total suppose 6 numbers of stuff is needs to be done or total say 10 number of the tones needs to be search. So, you can actually increase it to be 7 or 8, and then you do it by 1 or increase by 9 and then you do it by 1. So, you can avail it by a very low amount of the acquisition time.

So, how you are going to choose the word segregation of P and A, it is not only a function of your acquisition time only, it is also there is a hardware complexity involved, and it is a restriction from that point is also needs to be done. And the detection probability what is the target detection probability of yours, so that is a crucial choice between these two tone distribution between the two stages architecture.

So, with that we are ending with this frequency-hopping spread spectrum code acquisition techniques. We have learnt three different techniques. First one was the matched filter based giving us a very fast acquisition and very better cost of very high probability of false alarm detection probability is less. We then learnt a serial search active for a correlated based mechanism where we have got a very high detection probability at the cost of a very large acquisition time which is not acceptable.

Then we have learnt to combine both the techniques which is a two-step technique, where we have divided the search mechanism between these two. And we have we could improve the acquisition time to a reasonable one and detection probability also was improved by taking care of the it is a balanced actually some part balanced that there some section balance the detection probability and some section balance the acquisition. So, as a whole the detection probability as well as acquisition was improved, that is all about the code acquisition mechanism of the frequency-hopping spread spectrum communication.

Next module, we will discuss about the frequency-hopping code tracking.