Spread Spectrum Communications and Jamming
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Lecture - 31
PN Code Acquisition Fundamentals

Hello students. Today we will start completely new area. And, the discussion will be on the very important activity in the receiver, which is called synchronization. And, related to the spread spectrum communication system, synchronization plays a very major and the crucial role in the receiver design. Synchronization means mainly the alignment of the locally generated PN code with the code that is getting super imposed and transmitted from the transmitter. Synchronization also involves the carrier synchronization.

Please remember for conventional communication system when we talk about synchronization; that talks about either the time synchronization or the frequency synchronization or the phase also the phase synchronization. But, in the spread spectrum communication system the term synchronization is related to two different related to two different aspect. One is the code synchronization; another is carrier synchronization. In conventional communication system, the synchronization is only related to the carrier synchronization. And, in spread spectrum communication system the synchronization consist of code synchronization as well as carrier synchronization.

And when we are talking about the synchronization, we are more interested to learn first about the code synchronization process, which is fundamentally the alignment of the locally generated PN sequence code to the code that is transmitted, and which is super imposed and transmitted from the transmitter; super imposed on the actual data and transmitted from the transmitter. Remember, this code synchronization is having two major part. One is the code acquisition; another is code tracking. Today, code acquisition is the very first part of the code synchronization. Today, we will learn how code acquisition is done inside a direct sequence receiver.

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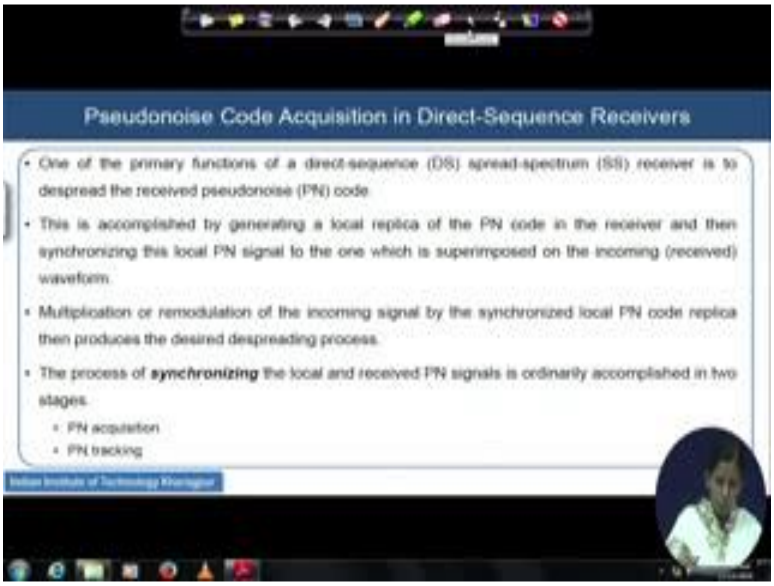

Today, the topic will be understanding the fundamentals of this code acquisition mechanism in the direct sequence receiver. As discussed earlier that code acquisition, code synchronization as well as a code acquisition is the very critical block that is asiding inside the receiver. And, it is a very important signal processing block inside the base band receiver that needs to be devised. And, it is to be designed critically.

And, by means of synchronization and the code acquisition, we are actually defining the, generating code acquisition is having basically generating by, this is accomplished by generating by the local replica of the PN code inside the receiver, first of all. And then, multiplying it with the incoming signal, which consist the PN code transmitted by the transmitter. And after this multiplication or when this multiplication is going on, remember that you have to synchronize the locally generated PN code with the incoming signal code.

And then, actually the desired despreading process can be taken place. So, the synchronization, the term which I already told that locally. It is not only just multiplying the incoming signal with the locally generated PN code. You have to multiply with the synchronized PN code, locally generated synchronized PN code with the incoming signal to make the despreading process faithful. And, hence this synchronization will have the two main parts. One is the PN code acquisition as well as the second part is the PN tracking.

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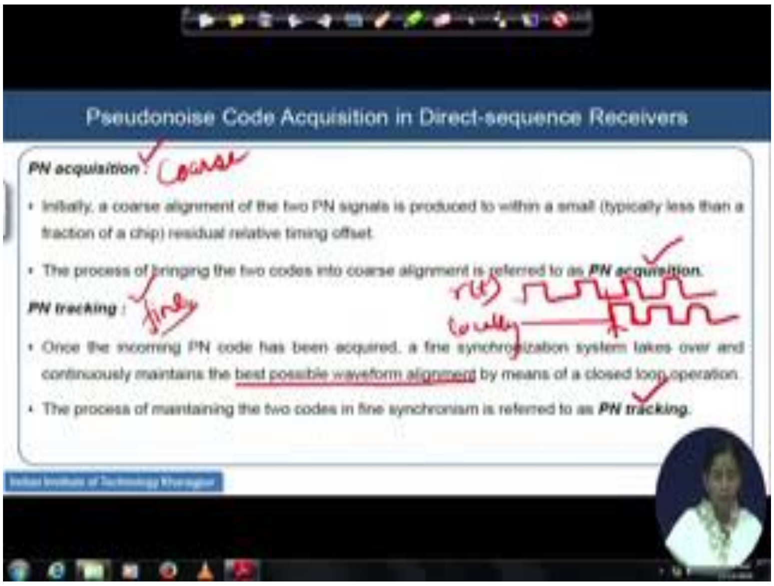

Today, we will enter into PN acquisition. And if you look into the PN acquisition, then we will see the whole synchronization process is a two part mainly. One is actually the coarse synchronization; another is the fast, another is the fine synchronization. In the coarse synchronization, the first task is to; there are two PN signals right now in our hand, you know. Right. One is the incoming signal, which is coming say the rt; another is our locally generated PN sequence. So, we are trying to synchronize the PN code inside the rt and the PN code that is locally generated. So, in the process of this synchronization on this alignment, it is not possible that at the first round you can synchronize both of them hundred percent perfect fashion or with the very minimal error.

So, we do it in two steps. The first step that we do is called the coarse synchronization. And, this coarse synchronization means that you are trying to align this, both of this PN code within a small fraction of a chip duration. So, at least within the chip duration, we try to align them. And, if possible you try to align them within atleast half of the chip duration. So that means, actually the remaining residual error should be less than equal to the chip duration tc or always should be the less than equal to tc. So, if the, it depends upon the complexity and the algorithm you are designing for the coarse synchronization in the coarse alignment process, during coarse alignment process, based on which actually it will be defining whether you will be within actually, whether you are synchronizing within exactly with a residual offset of tc period or within some of it; I mean some part of it. So, you could synchronized within half of the tcp rate, one-fourth of tcp rate or actually you are left with the residual error of full tcp rate. What exactly you are leaving with.

So, error can be something like this. Suppose, this is the incoming rt signal and this is the received PN chip, suppose they are doing. And, what is the target? Let us do once more. Suppose, this is the incoming signal and suppose this is the receiving signal, locally generated PN sequence. So, this is the incoming PN code and this is the locally generated PN code. And, what I mean to say by the synchronization and the offset, it is actually this block aligning this locally generated PN code with that of the incoming PN code. So this, look at this picture. The offset may be of multiple of the chip duration plus actually some fraction of the chip duration also. It depends actually on the coarse alignment process. At least, we try to correct the multiple of the chip duration. And within a chip also, we try to correct at least up to some level.

But, whatever the residual error we are left with, then we will try to acquire it by a continuous observation process, which we call it is the PN acquisition or it is called that, sorry, tracking. So, coarse estimation. When we are trying to align both the codes within the multiple of the chip duration and within the fraction of the chip duration also, I mean should be a n times of tc plus actually some part of within tc, atleast the half part of the tc period, then we call it is the coarse estimation. And, coarse synchronization going on. And also, we call it a PN acquisition going on. It is the coarse alignment we have done.

And, once the coarse alignment is achieved, the coarse aligned signal is (Refer Time: 08:50) to the another circuit, where actually the continuous tracking of this estimated phase offsets are going on and continuously there is a trial and continuously there is a trial going on to realign the remaining offset. So, we need to get the minimal remaining offsets within the chip period. And, we call it a PN tracking. And, it actually remember this PN tracking always actually is having a close loop operation, which tries to maintain the wave form, locally generated wave form, to be best possible aligned with the received signal.

So, any changes in the received signal that happens because of the doppler effect or because of the change of the delay spread inside the channel and because of other issues that are coming from the wireless channel and change of the speed of the velocity, change of the velocity of the vehicle also. So, from all that actually whatever the coarse alignment you are doing, it may be sufficient. But, the residual error portion may keep on changing. And, you are, by continuously observing and accessing, measuring this remaining offsets within the chip and trying to correct it. And, when the locally generated wave form is going on, local wave form is getting generated, to correct the phase of that and trying to best possible way to align it with the incoming signal is called the tracking.

So, we understand now that the synchronization means the combined effect of these acquisition plus tracking, which is the coarse plus fine. And, you have to do the coarse alignment first and then you enter into the fine alignment track.

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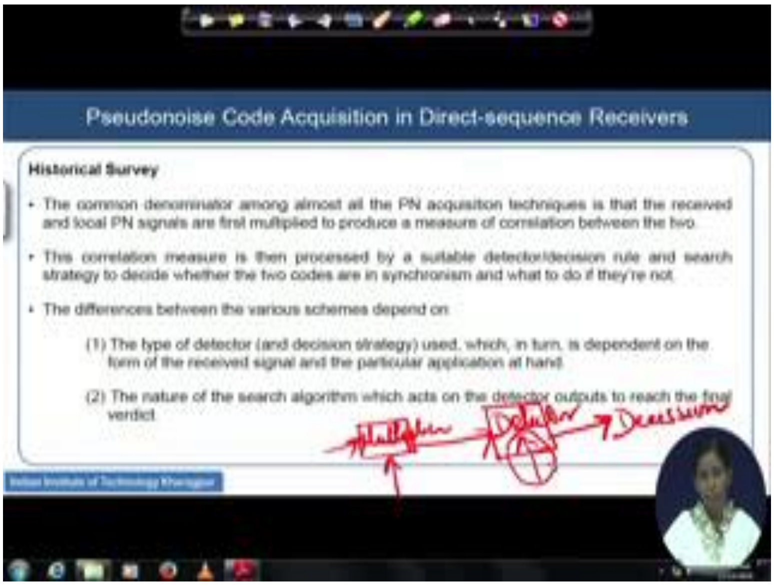

So, let us enter into the available literature going through the (Refer Time: 10:44) literature, what are the different procedure that people follow. Remember this. If you try to follow the structure of this PN acquisition systems, you will find that usually the different methods whatever is proposed is considered a common type of the system model.

This acquisition technique will consist of basically first a multiplier, where actually will take the two different signals. One is locally generated; another is incoming. And, output of this multiplier or basically this multiplier is nothing but a correlation going on between the two. And, we try to see actually the difference of the correlation. And then, we, it is followed by a detector circuit. And, output of the detector circuit is fed to a decision device or some strategy device, which actually this detector, followed by a detector and the strategy decission. Detector and decision can be combined also in some cases. And, this correlation measure, based on this correlation measure and based on some decision rule, based on most probably in most of the cases, based on some threshold set decision rule, we try to find out actually how big this correlation difference is there in between these two signals, whether it is good or too high or too low and what to do next with these difference value of the correlation. And hence, the strategy comes into the picture that what to do, how to device algorithm based on this, on this, on this decision output.

And, difference of the schemes in the acquisition model. We will see the difference is coming due to the design of this detector, due to the change of this detector architecture. The way you are choosing this detector that is actually devising the different kind of the PN acquisition model. And, also the search mechanism based on which the decision is going on. So, that search mechanism is also playing a very important role to vary from the one code acquisition mechanism to the next code acquisition mechanism.

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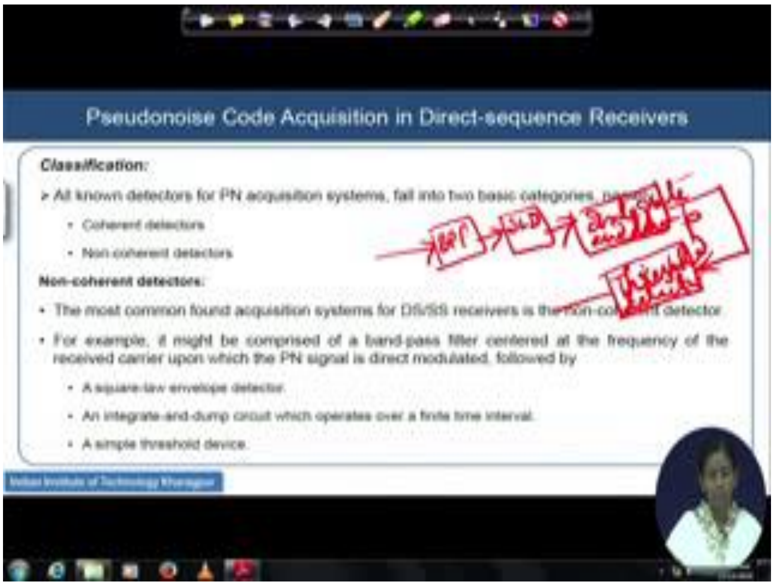

So, we will first look based on the detector how the classification came in the PN acquisition systems. The classification will be mostly based on the coherent detection is going on or a non-coherent detection going on. For direct sequence spread spectrum system, we prefer to go ahead with the non-coherent detector. Remember why because we assume that the carrier; I told that code synchronization and carrier synchronization are two different process that combinely consist the synchronization in the spread spectrum communication system.

While we are doing, dealing with code acquisition and the code synchronization, we assume that the carrier synchronization is not done. That one, that is why we do not know actually. We do not have any information about the phase of the carrier frequency. And hence it is preferable, once you do not know anything about the carrier phase and frequency.

And then, hence it is preferable to go ahead with the non-coherent kind of the detectors. But whatever, however some of the code acquisition system models are there and the mechanisms are there, where actually they which can estimate apriori. Either they have the apriori knowledge or which can estimate also the phase values or the estimate the phase of the carrier frequencies. And, in such a situation also actually the coherent type are there, the coherent type of the detector can be applied.

So, we will prefer to go ahead with the non-coherent detector. And, inside the non-coherent detector we will find that the basically the architecture would look like this. The incoming signal will be entering into after some band pass filter. After some band pass filter, you will see that (Refer Time: 14:50) is entering into square law detector. And, the square law detector output is entering into a intricate and dump circuit.

It is integrate and dump circuit. And, output of this integrate and dump circuit will be entering into a simple threshold detector, where, and remember output of the integrate and dump circuit, there will be a sampler. And, it is, actually it is coming to the threshold and the threshold detector. And this is the combined architecture, the way the non-coherent type of the detector O. And, instead of this band pass filter if I am coming to the coherent detectors, you will get a low pass filter. And, which is basically may be constitute of integrate and dump circuit also. And then, very simple. Either base detector or some threshold detector will be there in the path for the detection process.

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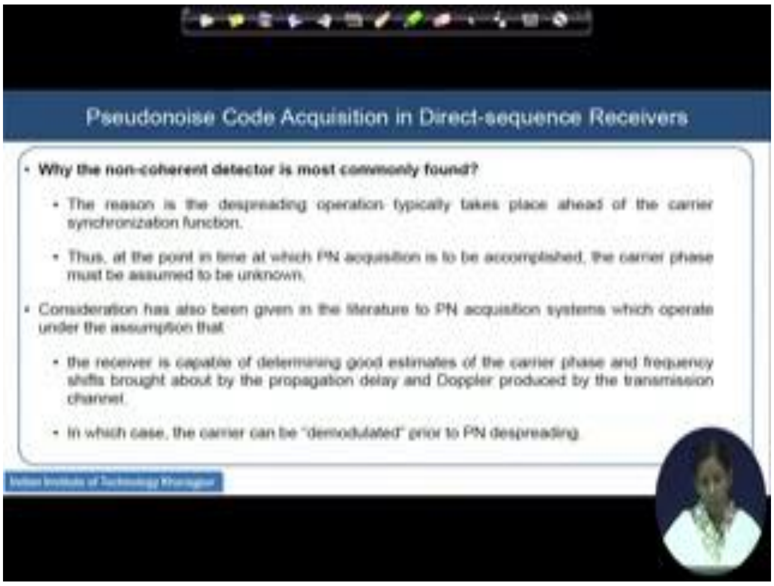

This portion, we have already discussed why we are preferring the non-coherent detector. It is mostly common. Come, coming and change to the practice. But, as I have already told that some of the advanced acquisition system are they may be capable or intelligent enough to estimate the carrier phase frequency chips that are coming up dynamically. Actually that are changing because of the propagation delay as well as the doppler. And, they are capable to estimate that. And, in such situation we prefer to go ahead with the coherent detector.

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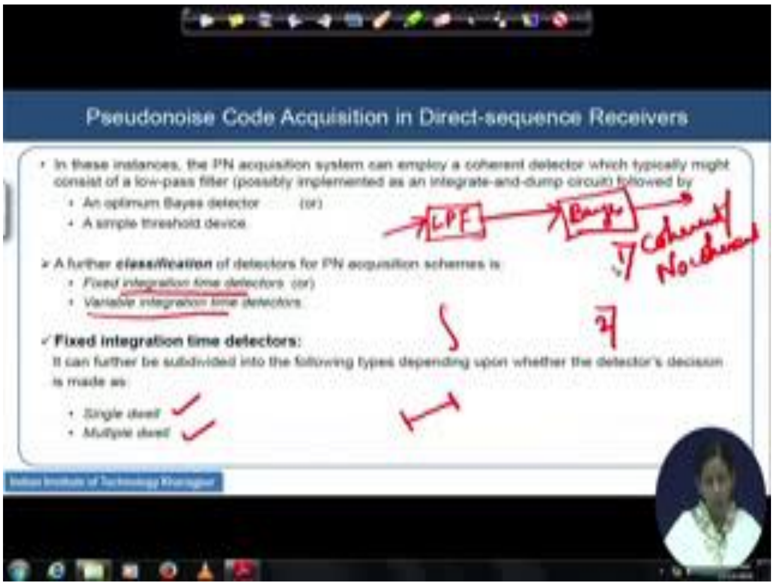

Next slide, we will see actually the coherent detectors. And we, I told that in the case of coherent detector, you will have, it will be employed simply by a low pass filter. And, this low pass filter, you can implement by integrate and dump circuit. And, output will be a simple detector like your optimum base detector or you apply a simply threshold detector also, sometimes. And, here is the decision device at the output.

So, first classification that we have learnt now, based on the detector architecture. And, the detector architecture may be of coherent or non-coherent. So, based on that actually one classification of the PN code acquisition circuits are coming up. The second classification; second classification can come based on the integration time that you are using inside the detector and integration time that you are using inside the detection and decision process. And that integration can be of over the either fixed integration time you are involving with or you can have a variable integration time involved in the process.

Fixed integration time can be further having two different types. Either it is a single dual time or it is a multiple dual time. So, this integration time we call here, the dual. And, this is basically the time duration that is involved. And, if we see that the time duration over which the integration is running is one time, then we call it as single dual time. And, multiple such integration, and taking the decision over the multiple such integration process is involved in the multiple dual time.

So, the fixed integration time detectors, where the integration time is fixed over which the integration and dump circuit is working. That integration interval is fixed, but it may be a single time integration or it may be the multiple time, the stuff is going on. Based on that, it is the single or multiple dual time detectors.

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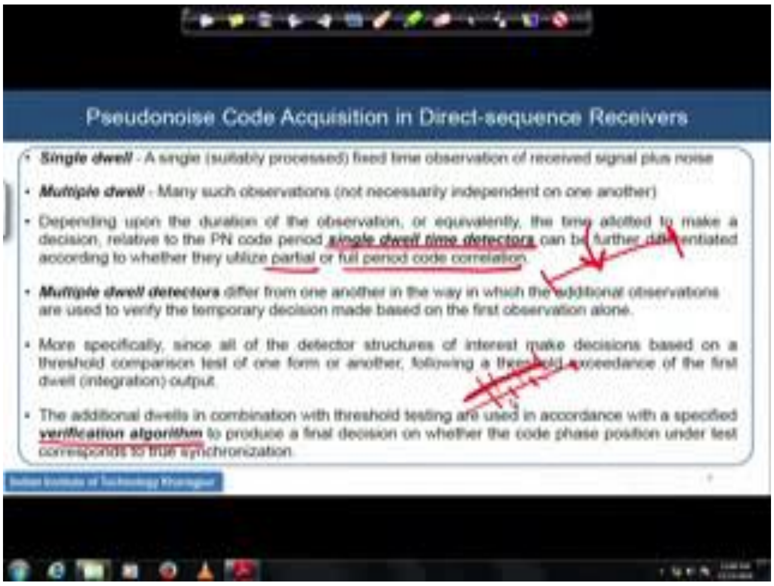

And see this single dual time, when actually we are using it, further actually this single dual time detectors can use, can, it can be further classified based on the fact that whether you are using the full period of the code. Full period of the code means full time period of the code for the correlation or you are using a part of that time period of the code for the correlation and taking decision based on the partial observation of the code duration. And based on that, it is either full period code correlation you are taking or you are taking a partial code correlation. And, hence the single dual time also can be classified further.

And, see multiple dual detectors, they will be varying from one to another based on the fact that how you are relying on the, how you are varying the further decision over the second and the third dual times, based on the observation of the first dual time. So, anyway the multiple dual detectors are taking the decisions and complete observation and decision strategy over the single dual time. And based on that observation, they are taking the, devising the algorithm how to behave, how much extra information needs to be extracted from the second or third or fourth dual times.

You may actually imply some kind of the logic of averaging aactually all the observations over the multiple dual times and give the same weightage on the decision process independently that is going on on each and every dual time. Or, you can actually device some algorithm thinking that if the single dual time output is really very nice, then the second or third real outputs will just be utilize; one or more two mode will be simply utilize over the partial code time. Maybe it can be something like this.

In the single dual time, you can run the correlation over the whole period of the code acquisition and taking a decision. And, the, if you can detect actually the phase very nicely, then in the second dual time you can reduce the length of the correlation period. Hence, it is a multiple dual going on. But, the period of the correlation is not same compared to the single and the multiple. And that decision is based on the observation of the first dual time, wwhatever the estimation on the phase you are you are getting.

And, so the multiple dual detectors can have the several kind of the logics on how you are using the estimation of other dual times, rather than the other dual times, except the single one or the first one. And, the detector structures make some decision that interest, their interest actually may be weighted over the multiple dual, multiple dual observations. And, if the threshold, basically as I told that they are estimating the phase and they are trying to see whether that value is crossing some threshold or not. And based on that, the decision is locked where the synchronization has achieved (Refer Time: 22:00) not synchronized, the decision is locked.

And, so there is a call. There is a algorithm running actually at the output of your detector and the decision device, inside the decision device at the output of detector, which is the verification algorithm. Basically that verification algorithm, the detector is measuring. Right. The correlation difference between these two and then the output of the detector is getting measure with the threshold value, predefined threshold value. And, decision device is saying that over multiple dual interval, how many times actually you are crossing the threshold.

So, decision device; this verification algorithm says that you will take the decision based on the single observation, if it is a single dual system. Or, you will take the further decision whether the synchronization will be declared to be achieved. Fine. Observing the multiple observation, multiple vary observation over the multiple dual time and running the verification algorithm basically over the multiple dual time.

One may run actually verification algorithm in such a way that there is a search going on, right, that how many times the difference has crossed the threshold value or it is below the threshold value. And, once actually the search is going on, where to lock? So, search and lock; that two simultaneous process is involved when the verification algorithm is going on. So, you search and you then lock the device, the logic based on which the locking will be there to declare that hence the synchronization is achieved.

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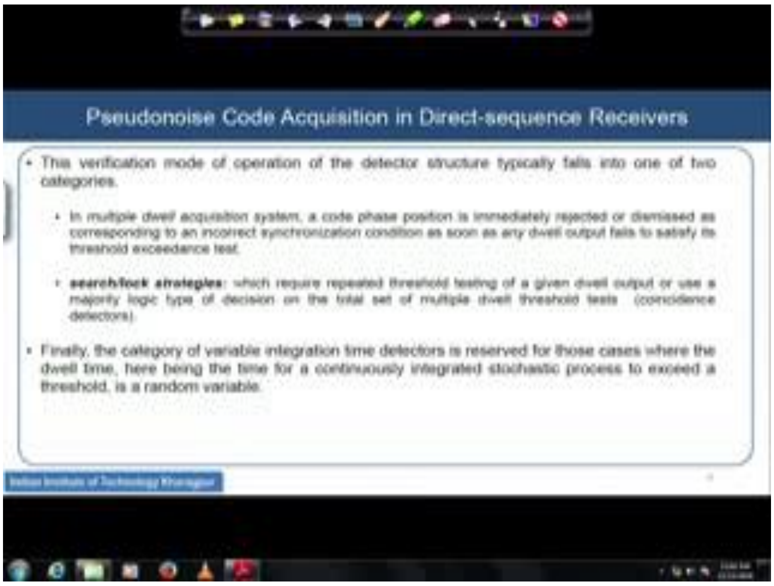

This verification algorithm whatever is existing in practice, as I told it, they are having multiple way or approach to declare the synchronization. One is the search and lock strategy that just now I have explained. That which takes the decision that it is locked, if the majority of the times the difference is crossing that threshold level. And, multiple dual acquisitions system, they locked actually either seeing that any one of this, any one of the dual time, in any one of the dual time, it output fails to cross the limit, you will declare that synchronization is not achieved.

So, it depends actually upon the criteria that you are setting how actually, well, how fine you are in the achieving the synchronization system (Refer Time: 24:36) you designing the system which requires 100 percent or 99.99 percent say code acquisition. That much perfection is required for the design. You are designing a system where actually the synchronization of say around 90 to 95 (Refer Time: 24:52) percent is to go ahead with.

So, 90 to 92 percent kind of (Refer Time: 25:00) can be achieved by this search to lock strategy. If you are really worried about the 99.99 percent of acquisition, in such kind, some kind of the system design, then you have to actually we very strict on this kind of the multiple dual acquisition system kind of. And finally, for all this different kind of the category of the variable integration time, this detector, it is reserved for those cases where actually the dual time can be continuously be varying. For variable integration time detectors, you can actually vary the interrogation time of the integrate and dump receiver on the fly, and hence it is the stochastic process. And, the choice of this integration time itself is the stochastic process. And, hence the whole decision, how many times the decision is the correlation difference is crossing the threshold that is also random variable.

So, completely a very good example of this variable integration time detector is, that is, used in the radar signal processing. And that is the very nice, very good example of this is sequential classical sequential detectors.

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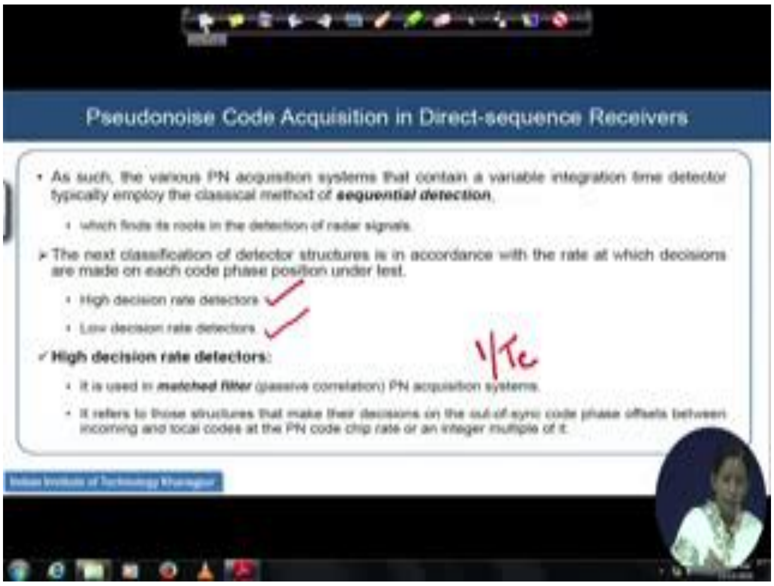

And, next classification of the detector from here onwards depending upon the how fast you are acquiring the code acquisition. And that means, actually how fast your detectors are running. The rate of the decision is the important part to know. So, based on the rate achieved, we get two different category. One is the high decision rate detectors; another is the low decision rate detector. Remember, when we talk about the high decision rate detector, they are the basically passive mass mashed filter based correlator architecture that we find in practice. And, where the decision is made at the rate of the chip rate. So, within a chip duration, the decision is done.

A huge circuit must be these kinds of processor, this kind of the detectors are hardware intense usually. And, they take the decision on the out-of-sync code, phase offsets between the incoming and the local code generation, at the, either at the chip rate or it may be the integrate integer multiple of this chip rate. And, though they are fast enough, their accuracy is under question. And, there are lots of lot of possibility to get a higher rate of false alarm in such detectors. And, hence actually it is also hardware intense circuit design it will be.

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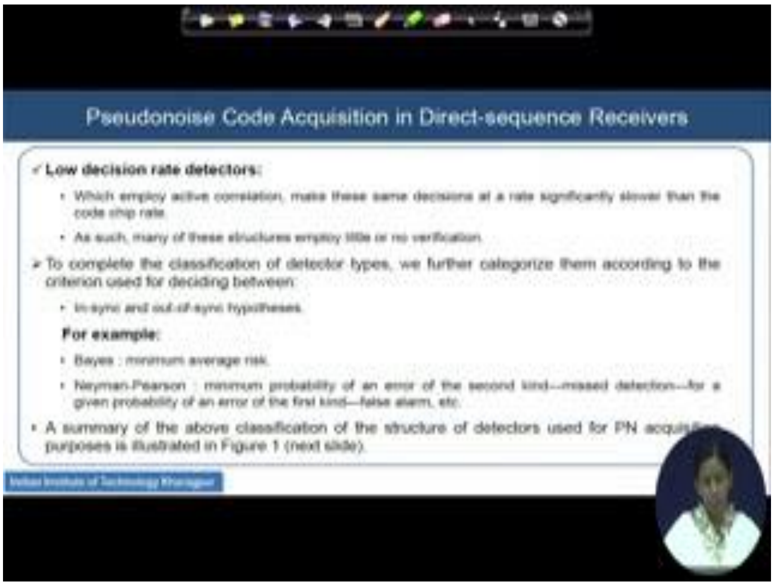

Whereas, the low decision rate detector, they also do the same thing. But, at a very low space. And then, they are slower than the code chip rate. Definitely that is slower than the code chip rate. And as such, many of this structures of this low decision rate detectors, who are the active correlator based architecture will be involved here. And this low decision rate detector, they are not also the hardware intense. Remember, this low decision rate detectors are also give, will give you very high performance in the detection level. I mean, false alarm rate will be less.

And, to complete this whole discussion there is last kind of the detector types which we category in terms of; your in-sync and the out-of-sync hypothesis. I mean, there is a hit or there is no hit, synchronization is achieved or the synchronization is not achieved based on the principal of the Bayes, Neyman-Pearson kind of algorithm, where the minimum probability of an error, of the second kind, miss detection for a given probability of error of the first kind false alarm, they are all involved. And, we will actually go in detail basically in the next module on the match filter based architecture to check also on the non-coherent kind of the detectors. And, let us see how does it work in the next module. And, now the time is to just put the summary on all the kind of the acquisition systems and the detector designs that we have discussed.

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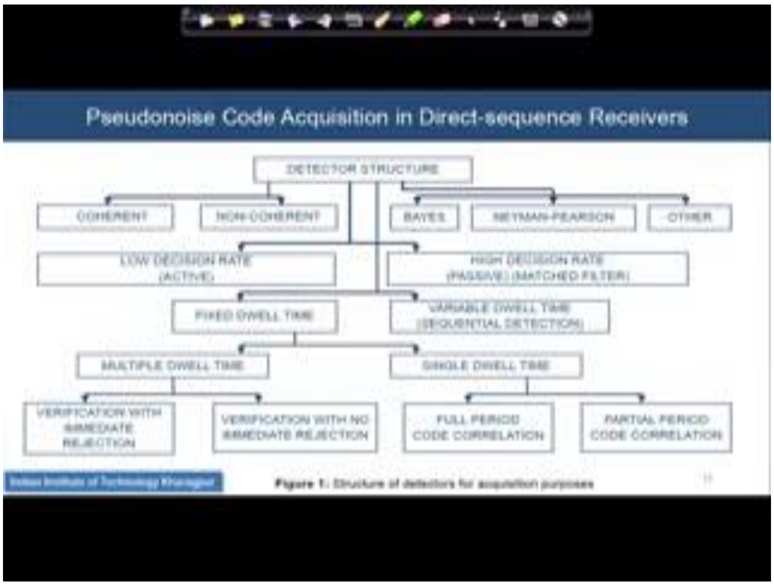

And, here is the tree which will help you to understand the different kind of the PN acquisition system based on the detector architecture, where the classification goes. We saw already that we have, classically we can divide the detectors by coherent and non-coherent detectors. Then, based on the rate at which the detector are performing the acquisition, it can be a low decision rate as well as the high decision rate. (Refer Time: 29:43) usually match filter based passive correlators. And, here the active correlators are involved.

Then, whether you are using a fixed dual time or you are having a variable dual time. If you are having the fixed dual time, then whether you are using a single dual time or a multiple dual time. And further classification, there are over the multiple as well as the single dual time because in the single dual time we have seen, we have the classification based on whether we are using the full period of the code correlation. We are using the full period of the code for correlation or we are not using it, where partially using it. And, multiple dual time are also involved with the verification with the immediate rejection or verification is with no immediate rejection is going on. And another branch, which is based on the in-sync or out-of-sync hypothesis based prediction process, which involves Bayes, Neyman-Pearson or some other kind of the detectors.

So, with this we would like to end here in this module with the understanding of the fundamentals of the PN code acquisition mechanisms available in the literature. For detailed study, one may, if you are interested you may also search for some of the literature.