Spread Spectrum Communications and Jamming
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Lecture – 08
Hybrid Spread Spectrum System and Time Hopped SSS

Hello students, today we will learn two more different kind of the frequency hopping apart from the direct sequence spread spectrum and the frequency hopping spread spectrum. Today, we will learn two more different kind of the spread spectrum techniques, one will be the hybrid spread spectrum system and another technique another will be the time hopping spread spectrum technique.

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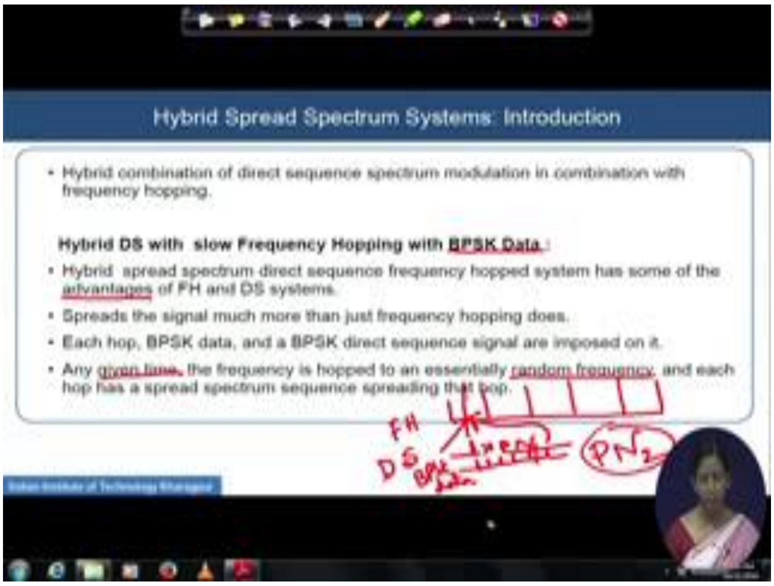

We will start today, with the hybrid spread spectrum technique. As the term is hybrid, so, you understand that there will be a hybrid combination of two different kind of the spread spectrum system; one is your direct spread spectrum system, another is the frequency hopping spread spectrum. So, today all the understanding of our earlier direct sequence spread spectrum and the frequency hopping spread spectrum we will combine today. The signal model will be combined, the advantages will be combined, and also the disadvantages, the corresponding disadvantages of DSSS as well as FHSS will be addressed.

So, the hybrid direct sequence, let us start with the slow frequency hopping system, because it is easy to track and we will also consider only the BPSK data modulation, because this is also very easy to understand. This direct sequence hybrid spread spectrum system and which has already I have told that this has the advantage of both frequency hopping as well as the direct sequence system and remember in case of the processing gain calculation, in the case of you understanding the frequency spreading that is happening for signal that will be obviously, much more than just the frequency hopping does or just the direct sequence spread spectrum technique does.

Here fundamentally for each and every hop, what we learnt in the frequency hopping? We have a wide channel available, we have divided it over number of the smaller channel and we will hop over the channel for every data symbol. If it is, then this is the frequency hopping system. And here, for the spread spectrum come direct sequence spread spectrum what we understood is we will take each and every symbol and then we will multiply it with a, the PN sequence chip and PN sequence code it is and then the PN sequence code will help me to spread it over the time access.

So, if it is something like this, then the combination of this direct sequence spread spectrum with the frequency hopping spread spectrum will lead meet work situation, where for each and every hop there will be A BPSK data stream coming into and there will be a PN sequence BPSK signal, that will also coming in, PN sequence will be coming in, and for each and every hop this BPSK data will be now, spread by this PN sequence. So, in an every hop each and every data, in every hop will be spread by the PN sequence. If I can change also the sequence, so, that the spreading these varying over the different hop, but that will be complicated one usually for each and every hop we try to keep that PN sequence constant and later on you can change the sequence also, after several such symbols.

So, at a given time, the frequency will be hopped to an essentially some following, some random frequency. Remember you are getting one PN sequence to spread the data that will be another set of the PN sequence, so PN sequence numbers two; I am saying here, who will actually tell you how to hop over channel to channel. So, the combination of these two PN sequence will lead the signal design. So, at a given time the frequency will be hopped essentially by this PN two and in each hop that the data will be spread over that hop frequency by the first set of the PN sequence.

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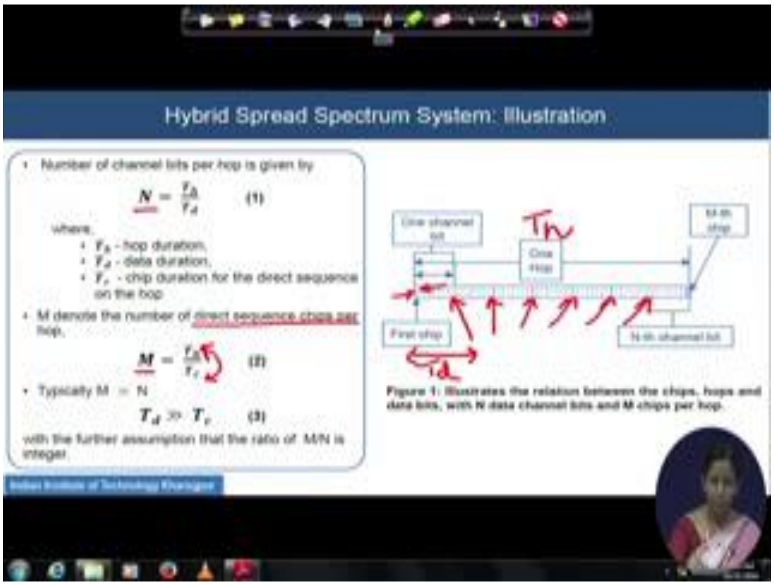

So, in a hybrid spread spectrum system, we are whatever I was explaining, in the last slide, it is something like this, this is the total channel available, for a particular hop and this is one hop. Suppose, in this one hop, if are you getting here, these are the channels. Bits are equivalent to me; equivalent to the symbols they are available. So, here is 1 bit and 1 second bit and third bit and fourth, fifth and the sixth. So, I have here around 6 channel bits to transmit and inside that every channel bit, now you see they are getting spread over the direct sequence, by direct sequence spread spectrum by a PN sequence code number 1. So, 1 bit for a particular hop, when I am sending 6 channel bits. So, definitely I am in under the domain of slow frequency hopping and in the slow frequency hopping each and every channel bit. Now, I have spread using a second PN sequence which is PN sequence 2. So, I have also utilized the direct sequence spread spectrum communication system.

So, if I ask that what is the number of the channel bits I am getting over the total hop duration? Hop duration will be from here to here which is given by T h and then T d is the channel bit duration, which is given by the duration of 1 bit and hence, the T h by T d will give me what will be the number of the channel bits available in that one hop. In this situation, I will have 6 number of channel bits, and so, now, similarly, I can also find out how many number of the direct sequence chips are available inside that 1 hop, which will be governed by capital N and that will give us the T h by T c given by T h by T c, what we see is that chip duration T c is the one chip duration from here to here.

So, this T h by T c and T h by T d they are giving actually to different time concept, and remember as the number of the chips that are available inside a hop, they are much bigger than the number of the bits that are available within a hop. So, definitely your duration of the bit duration of a bit which should be much larger than the duration of a chip or oppositely the duration of a chip, will be much less than the duration of a bit.

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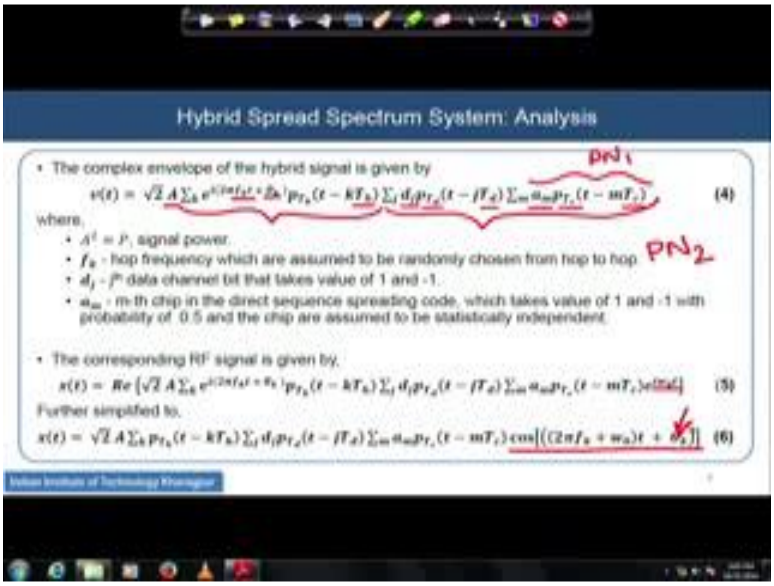

So, now this is the time to look into the mathematical model of the signal. We will start again from here, A is that signal amplitude and a square is the signal power to be transmitted. F K is as usual half frequency, which we assume that the randomly it is getting chosen by the PN C from hop to hop and here is the PN sequence number 2, who is actually randomly generated, sequence is generating, this hopping frequency. According to the PN sequence 2, the hopping frequency is getting determined. Theta K, this is the random phase associated with the BPSK modulation P T h is the (Refer Time: 08:44) associated with the final hopping pulse and T h is the hopping duration.

D J is the symbol the transmitted channel bit I should say and randomly it can take a value of either plus 1 or minus 1. The associated pulse shipping is done by P T d, T d is T d, D E T d is the duration of that BPSK symbol. Come here A M is the M H chip of the direct sequence spreading code. Here actually, the concept of the spreading code number 1 is coming, and the corresponding chip duration is given by T c, P T c is the related (Refer Time: 09:24).

So, this is the first spreading going on, by direct sequence spreading. Spreading over the each and every channel bit is going on, and of this spread, D S spread signal, now it is getting hopped over the different frequency. So, here is the frequency hopping, here is the direct sequence spread spectrum, so combinely it is the hybrid signal, hybrid spread spectrum system.

From here, from equation number 4, easily we can come to the corresponding RF signal generation, where we are multiplying it with the RF frequency omega naught T and which can be further simplified to the equation number 6 where we expand the exponential terms by cos plus a sin and then taking the real part of the year ending with the simplest form of cos of 2 pi F K cos omega naught into T plus theta K, where theta K is a completely random and from hop to hop, it is a completely independent from hop to hop the generation of this theta K.

So, as the we have already discussed that for the direct sequence spread spectrum system, timing is a very important information that needs to be retrieved in the receiver, without which actually successful data retrieval, data detection would not be visible. So, we are really very keenly interested to understand how the timing estimation and timing synchronization will become critical for this hybrid spread spectrum system.

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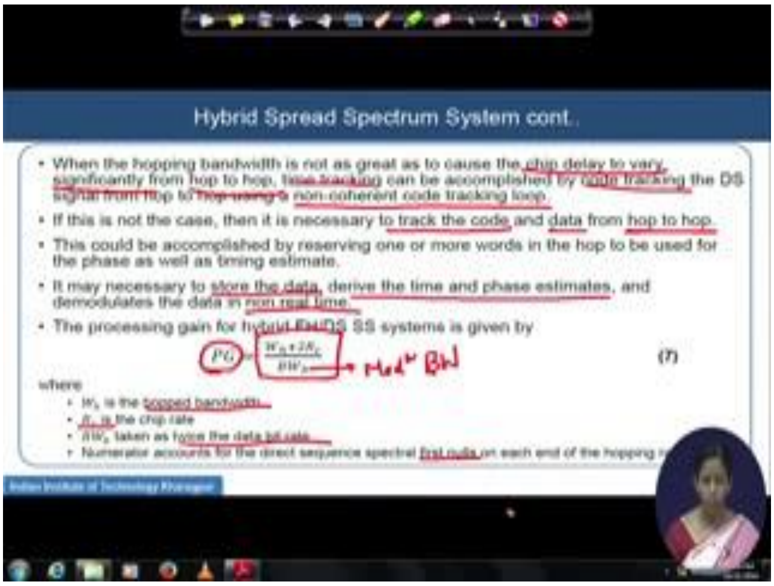

The good part of this system design is that, if we think then the when the hopping bandwidth the total W, as we have seen in the last slide, it is not as great as to cause the chip delay from that will vary from hop to hop that will vary significantly from hop to hop, then we can apply the hop tracking for the ready sequence from the hop to top, using a non-coherent code tracking loop. So, when you can add it is, when actually the chip delay, that will load not vary significantly from hop to hop. So, then the time tracking can be easily done by the, so, time tracking can be done easily by the code tracking, and the method that can be utilized is a simplistic non coherent code tracking loop, but if this is not the situation you mean to say that, when the chip delay is really significant from hop to hop, then it is necessary that you track the code and the data for each and every hop. So, for each and every hop then the signal process load in the receiver will be definitely increasing.

So, as you were seeing that the spread spectrum, hybrid spread spectrum system is giving you the highest spreading bandwidth, it we will also give you the (Refer Time: 12:28) complexity and the signal processing load like this in the receiver.

We will be really interested to know actually, how this tracking and that its compensation will keep on going it can be online, it can be offline and also, but it will be very hard to do it online, if there is a need for tracking it on the for each and every hop. So, then that situation, we may need to store the data and we can derive the time phase estimates and then you demodulate the data on the non-real time. So, this is the offline transmission that, offline estimation and offline correction technique that, we prefer to go ahead with.

As frequency, the hybrid spread spectrum system has not only given the higher bandwidth with respect to the frequency hopping spread spectrum or direct sequence spread spectrum. It also gives you the higher processing gain the P G is definitely relatively very high as compared to your direct sequence spread spectrum and frequency hopping. You see actually here we get the total effect of the spreading gains, spreading gain that are coming from the frequency hopping and the total gain that is coming from the direct sequence spread spectrum system. W H is the hopped bandwidth; R C is the chip rate and remember this B W B. We take that twice the data bit rate.

So, finally, it is A W H plus to R C divided by the B into W B. This is the modulation bandwidth that, we have seen earlier. This was the hopping bandwidth and this two R C is the chip rate and this total bandwidth what we are talking about, it is actually for the direct sequence spread spectrum that is the first nulls on each side of the hopping range, we will consider.

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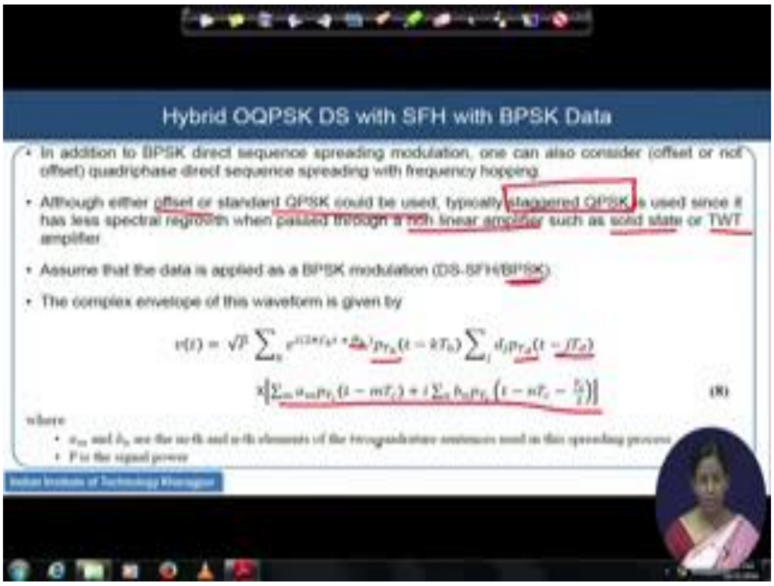

So, processing gain wise, we have gained a lot and similarly, in addition to the BPSK direct sequence spreading modulations, some people also prefer, to utilize QPSK direct sequence spreading with this frequency hopping, where actually the fundamental data modulation will be going on via BPSK, but spreading will be powered, will be covered by the QPSK signals and remember for we can utilize the both the offset or non-offset standard QPSK modulation techniques for this spreading, but we prefer to go ahead with the staggered QPSK. Reason is that, it has very less spectral regrowth. When the signal is passed through the non-linear amplifiers, which are the essential path of the front end receiver design and all the solid state or the T W T kind of the amplifier is to avoid the extra spectral regrowth. We prefer to go ahead with the staggered QPSK for this kind of the, when we are utilizing the QPSK based spreading.

And remember, now we are going to go ahead like this, we will have a QPSK based QPSK based spreading and fundamental data modulation we will be followed by the BPSK modulation and the whole system is there slow frequency hopping system.

Here, this A M and this B N they are the mth and the nth element of the two quadrature phase, 2 quadrature phases, used for the spreading process because if it is a QPSK know, you would not get actually the only the I phase, kind of spreading sequence you will get the spreading sequence is both on the I phase, as well as on the Q phase. So, B N is on the Q phase, and A N is actually the that associated with the I phase, T c is as usually the chip duration, T d is the bit duration, F K is the hopping frequency, theta K is the random phase associated with the BPSK modulation, and PTH and PTD, PTC both the PTCs. Here, they are all the related pulse shaping, corresponding pulse shaping for the frequency hopping for the data modulation and for the spreading techniques.

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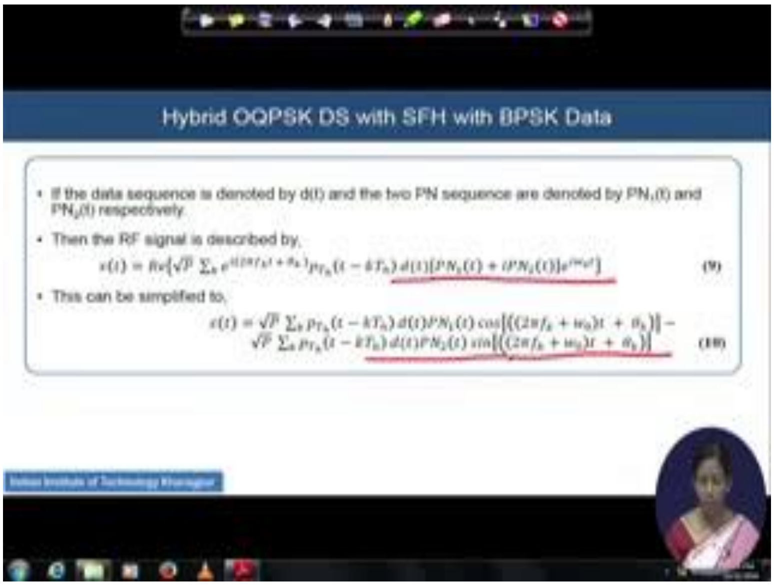

So, we are seeing two different things, we are having that the PN sequence is here are two types actually the data sequence if we are denoting it by D 2 D T, then fundamentally for this QPSK based PN sequences, we can actually tell that the PN sequences which is applied on the I th on the I phase and the P S sequence which is also already there on the Q phase they may be denoted as PN 1 and PN 2 say, these are this PN 1, PN 2 are not same actually. What I said earlier that PN 1, PN 2 will be for the spreading on by the direct sequence and spreading, then spreading by the hopping spreading sequence for hopping. So, if PN 1 and PN 2 are there for the direct sequence then PN 3 is running here for your frequency hopping it is such like.

So, going to the next slide, considering that concept of this PN 1 and PN 2 related to the QPSK PN sequence for spreading, we are ending up with the equation. This is the simpler one, compared to the equation number 8. Remaining part are the same and you are taking real part of each for to construct the RF signal and for the simplification can be ended up like this. It is very easy one, you just expand the exponential part here and then you take the multiplication of the both of them and this sin term will come this time, because i is end here cos theta plus J sin theta, will be ending up and this multiplication with this sin theta with this I will lead to the minus term and minus sin theta will be remaining in the whole expression.

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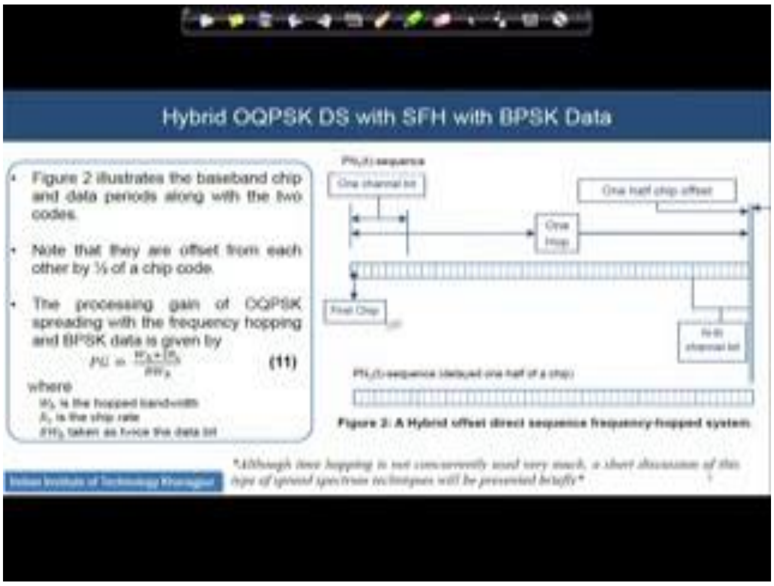

This is that hybrid orthogonal QPSK based direct sequence with slow frequency hopping with the BPSK data modulation combinedly shown here. See this is my PN 1 sequence, which is the in phase sequence for spreading this is my PN 2; this is the Q phase sequence for spreading. Though they have generated simultaneously, it is very hard to keep both of their phases exactly same highly synchronized and in this situation, we are seeing that there is a delay of a half of chip between both of them. As usual actually the they are these are the boundary of the channels, these are the boundary of the channel bits, these are the boundary of the channel bits and within each channel bit there is a spreading going on.

So, this is the PN 1, PN 1 sequence which has spread the sequence something like this all the in phase chips or the in phase bits they have got spread and all the Q phase bits they have got spread by the PN 2 sequence. And definitely the processing gain will be ending up with this W H plus 2 R C divided by B into W B, which is not having any kind of the change because you are coming up with a high phase and full phase spreading.

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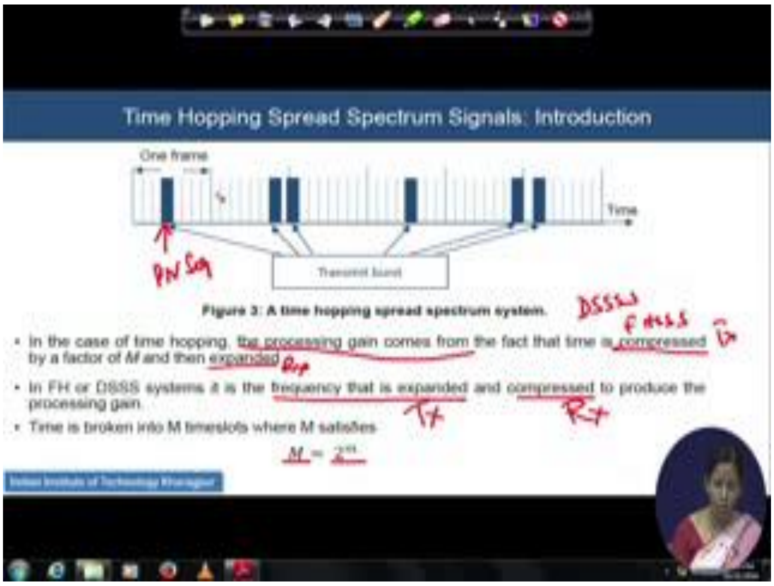

With that concept of frequency hopping and the direct sequence base hybrid spread spectrum communication system. Now, this is the last one that we are entering is a time hopping spread spectrum systems and signals. Time hopping spread spectrum signals are little bit having the concept very little bit different compared to the direct sequence spread spectrum as well as frequency hopping and the hybrid. Here, we will play there we played with the frequency and the bandwidth, here we will play with the time allotted.

Concept is such that given the whole time frame, we will divide the total time frame into several smaller frames and within that smaller frame, we there will be further, there will be further division or subdivision of the time frames and whatever the data that you have collected in the earlier frame, we will be transmitted in any one of the sub frame of this one frame in a burst mode. So, I said what? I said that, this is a total time period for your transmission available. The total time you have first this is the super frame, time frame I should say super time frame has been first divided into smaller time frames and the each of this time frame smaller time frame, they are subdivided into the sub time frames. So, the bits that we have collected earlier, the earlier time frame. We will transmit in one of those sub frames, sub time frames within a frame.

Now the choice of in which sub frame you are transmitting this burst, that is the question and that will be selected by a PN sequence. So, PN sequence will help you to choose the sub frames, any one of the sub frames randomly within a frame. So, the bits that are transmitted here, they are collecting here, the bits that are transmitted here, they are getting collected here. So, every frame is basically, transmitting the accumulated bits of the earlier frame.

So, basic difference between a time hopping processing gain that comes from and the way the processing gain comes from the data sequence spread spectrum and the frequency hopping as spread spectrum system, the basic gap is here. In the time hopping the processing gain comes from the fact that the time is first compressed, it is compressed and then it will be expanded in the receiver, but in other two cases the frequency that is expanded first and then it is compressed in the receiver. So, we this, process wise also it is completely opposite not only you are playing with a time you are fast compressing the time in the transmitter and then expanding it in the receiver whereas, in the time frequency hopping cases and the direct sequence cases we are playing with frequency you first expanded the frequency by spreading in the transmitter and then you compressed it in the receiver to get the gain, completely opposite in all the sense.

Let us start understanding some of the notations here. Let us think that we have divided the total available time in the by capital M time slots and the time slots are divided in such a way that it will be 2 to the power small m. So, 2 to the power small m, we will consider 1 frame actually. So, we are having this 1 frame and 1 frame is broken into capital M slots and such a way that it is equal to 2 to the power small m.

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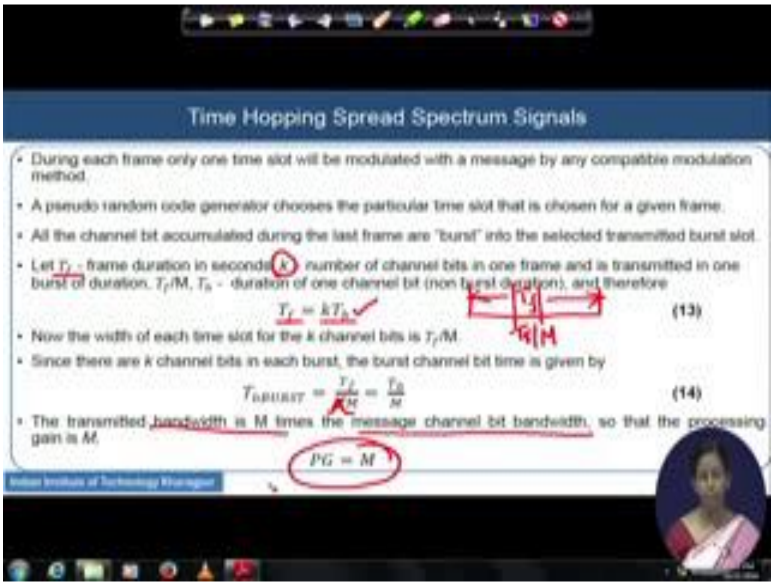

And so, during each frame only one time slot, we will be modulated with a message by an compatible modulation method, that we have understood. There is no restriction of choice of your modulation technique. So, BPSK, QPSK or any other hand modulation technique you can consider the random code as I have already told he will select the slot and that will be a burst transmission going on.

Now, let us consider the time associated with this burst transmission, let us consider that T F is the total frame duration in the seconds and there are K number of the channel bits that needs to be transmitted within that frame duration. If there is no burst transmission going on, so what will be the situation? Situation is that the whole T F by N when there is no burst transmission, then the T F the total time period for the frame duration will be given by K multiplied by T B, where T B is your bit duration of the one channel bit. So, you have the total time period T F allotted for the frame and you have K number of bits to be transmitted, if there is no burst transmission going on. So, you will do K into T B if T B is my bit duration. So, K into T B will give me T F.

Now, if I am now, if I am doing the burst transmission so, I am compacting all those K number of the channel bits over a duration of T F by capital M, because I have M number of the smaller time slots for each and every time slot I am having T F by capital M. And if there is a burst transmission going on so, I will get the time is equal to T F by K into M, K is the number of the channel bits so it is small k, k into capital M and hence, if I do the substitution here the T F by K is basically, from this equation 13, it is equal to T B. So, I can put it is T B by M. So, finally, the burst time is equal to T B divided by the capital M. In terms of the bandwidth, basically this message it is transmitted bandwidth will be in times higher, than the message bandwidth channel bit bandwidth. So, fundamentally M is processing gain you are ending up with.

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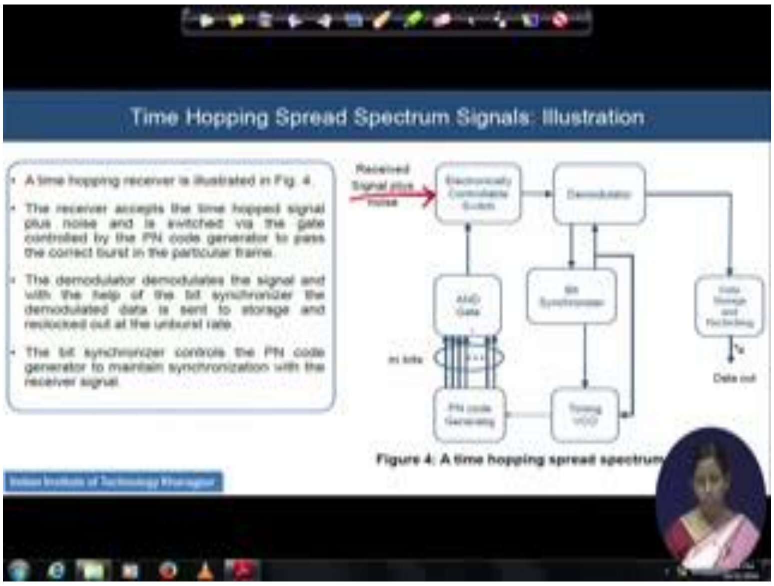

This is spread spectrum time hopping, spread spectrum signal generation and the receiver circuitry the way it works is like this. You have received the signal plus the noise time hopped received signal and this is the first block which is the electronically controllable switch, the switch is getting operated by and gate which is finally, driven by the PN code generator. This is the code generator which is actually the same code generated, the same code it is generating, which is used for the transmitter for time hopping. The code is generated and the AND gate is allowing actually to choose the typical words period and that signal within that burst period is allowed to enter into the demodulator, that is the way.

Once actually it is entering into the demodulator, the bit synchronizer is helping to provide the synchronization information so that demodulated is demodulating the signal and it is data storage and it is reclocked, because now, it is dehopped, also it is reclocked. The bit synchronizer is driving the timing VCO, which is actually trying to keep the bit synchronizer and the PN sequence code generator in sink. So, thing is something like this the signal has deceived your bit synchronizer and timing VCO will actually begin sync and it will trigger the PN code generator. He will generate the code, the AND gate will help to choose based on the code generated and will allow actually the incoming signal, the selected burst section to enter into the demodulator. Demodulator will demodulate it. Basically, it is getting dehopped also and prior to that the synchronization should be on and synchronized signal is (Refer Time: 28:38), dehopped signal is demodulated and it is stored in this data.

And once actually the stored data, whenever is required the stored data can be taken out, that is the dehopped spread spectrum deceiver, the way that dehopped spread spectrum (Refer Time: 28:53) and receiver works like.