Spread Spectrum Communications and Jamming

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Lecture - 01
Introduction to Spread Spectrum Communication

Hello students, today is the first module of this Spread Spectrum Communication course. So, we will start with the Introduction of Spread Spectrum Communications. In this module, we will try to understand; what is the meaning of spread spectrum communications, whether and what kind of communications system is it what is the basic difference of this spread spectrum communications from the narrow band communication systems or conventional communication systems, with respect to the block diagram of a digital communication system.

We will try to understand; what are the basic difference of this block level understanding that is the basic difference of this spread spectrum block diagram, from the conventional block diagram of a semi conventional communication systems. We will also try to understand brief history of this spread spectrum communications and we will also learn the key benefits of designing such kind of communication systems and we will end up with the different types of such communication systems which are useful for the practical implementation, let us start.

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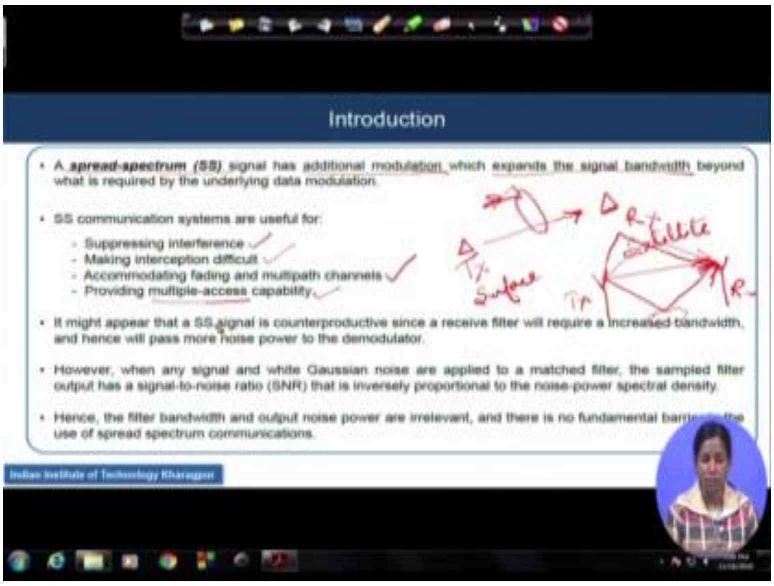

As the name suggests, it is a Spread Spectrum Communication System. Please check the term Spread Spectrum minutely. So, we are designing a system, where we are playing with a spectrum of a signal and as the name suggests we are spreading the spectrum of a signal. The spreading means it had a under underlying path of it is you are having an additional modulation involved in the signal processing; first reading your signal and this modulation additional modulation helps you to expand the signal bandwidth and the bandwidth, this expanded bandwidth is beyond the minimum required bandwidth for the data modulation. So, for example, if I take A D C S K signal and if it is minimal required data, if it is a 1 m b p s signal and suppose, 1 m b p s is the data rate required and we require 1 mega hertz bandwidth at least to transmit this signal.

For spread spectrum communication systems we require a bandwidth which will be higher than this1 megahertz bandwidth. So, in the spread spectrum we will transmit the same 1 m b p s signal, but with higher bandwidth that is the minimal spread signal itself. Lot of questions immediately starts. Why should we communicate with a bandwidth which is more than the required bandwidth? Are we getting some key benefits by doing this and what are those? If yes, what are those benefits? So, let us first understand what are the benefits because, of which we are intentionally spreading the signal and some redundant bandwidth we are utilizing to transmit data, for which the data modulation bandwidth is really far below than the spread bandwidth.

The Spread Spectrum Communication system is basically, very useful for certain cases; 1. By meaning of spreading the signal, by doing the spread spectrum signal, we can actually separate the interference. Remember, whenever we are talking about the interference, we are talking about the narrow band interference. The bandwidth of the interference will be much less than the spread spectrum signal or the spread signal. So it may be the bandwidth of the interference may be in the order of the actual data modulation, but it is far less compared to the spread bandwidth.

We will see later that how this separation of interference will happen only because of spreading the signal bandwidth in the due course. It also helps us for making interception difficult interception means suppose, you are you are a communicator and you are communicating with an intended receiver. So, this is a intended transmitter receiver and communication needs to be established between these two. And take an example of a satellite communication going on somewhere on the ground surface to the intended satellite receiver, and there is a flight going on and which is actually the enemy flight and he is having a communication system inside and his task is to detect whether, actually some communication is actually going on from the surface to satellite or not.

So, he will always try to intercept what is there in air and whether, if he understands what the frequency of your transmission is? He will try to also detect whether actually in that frequency whether there is some communication going on or not. If it is my enemy flight he will also try to jam my signal. So, now, you see we are talking about a communication system, where we are trying to design the communication system which will be vigilant of having any interception from the enemy, which will also be actually a very stout and robust in the signal design in such a way, such that the low probability of intercept is in-built in the signaling system itself and that an radio design itself.

So, spread spectrum modulation or spread spectrum communication and moduling giving, an additional modulation by spreading the spectrum of the data underlying data modulation will help you to make the interception very difficult for the enemy, how it is we will see. It also helps the spreading of signal it also helps to accommodate the spreading of multipath channels. What is these two terms? I should state little bit. In a valid communication scenario, we know that when the signal gets transmitted, with an transmitting antenna to a receiving antenna.

This is a free space actually, it is a space between which the electromagnetic waves will propagate between the transmitter and from the transmitter to receiver and the path is not always a guided path through which the signal flows from the transmitter to receiver. The signal also flows via the multiple paths, it gets started or reflected from the different scatterers present in the environment and it reaches like this. So, like this a multiple paths cross over, multiple paths the signal reaches to the receiver. This is a very common phenomena that happens in a wireless domain and we call it a multipath propagation.

And because of this multipath channel concept and the spreading which is basically the accumulation and changes in the phase, accumulation in the amplitude and change in the phase of the transmitted signal with which you receive the signal at the receiver. You receive the signal at the receiver with that, whole concept of the spreading and the multipath channels. Your received signal needs to be clarified, needs to be cleaned up before your detection demodulation and detection process proceed in the receiver circuit.

A spread spectrum communication helps us to mitigate the spreading and the spreading due to the multipath channels in the received signal alone.

It also helps us for the multiple access capability. What is this multiple access? Now is suppose, you are in a wireless environment and you are using a typical technology to communicate with your receiver and then like you, there may be multiple users who are at a time trying to access the radio environment or radio channel to transmit the corresponding data to their own receivers. So, it is the multiple users simultaneously, trying to access the various channels to transmit their data.

So, then it is the multiple access of the same wireless channel is a very common phenomena in a wireless environment. So, how will you do it, you can understand that if lot of us, trying to send our data simultaneously, using the same frequency at the same time, and this we use the same bandwidth. So, there is high possibility that the signals from me and from my neighbor will collaborate, and they will overlap with each other, and they will also create interference to each other. If some extra measure is not taken during the due process and. So, you need to take some preventive measures, to segregate the signal from the different users.

The technique by means of which we can do it, there are lot of techniques available for this multiple access, and to reduce the interference from the multiple users, in the when the communication is going on, and spread spectrum actually gives the very nice facility, provides a very nice facility, to provide this multiple access in the multi-user environment. It enables the multiple using multiple access capability, because it inherently uses different codes for the transmission it different uses different codes to spread the signal of the different user data. We will see little bit some detail of this capability later on again. In the due course we will also address the different multi-user interference handling techniques, in the receiver with respect to the c d m a technology.

So, these are basically the four different use cases for, which the spread spectrum communication systems are found to be useful for. There are some more also we will see in the coming slides. Now see one thing that when we are, one may ask a question that that when we are using, the spread spectrum signal. So, suddenly the signal bandwidth has increased than the minimum required bandwidth; so in the receiver design. So, I need to the wider bandwidth filters to filter the signal, I need to filter the signal after the antenna. So, once the filter bandwidth here is increased. As if am I not allowing the larger noise power to my demodulator and the detector circuit later on, it may seem that we are allowing right, but remember if I am thinking that the signal is following the Gaussian process, and the Gaussian noise is also applied on the top of it.

Then we understand from the fundamentals of the matched filter that matched filter cancels filtered output will give you maximum s n r. It will be inversely proportional with the power spectral density of the noise. So, hence the output power of this filter, will be here the noise power of the output of the filter, will be irrelevant, and hence there is a fundamental limit for us to use that spread spectrum communication.

So, remember there is no fundamental barrier. There is no question at all to think that the noise power will be increased in such kind of the systems, and it will put a fundamental barrier in the implementation, it is really not. Thanks to matched filter concept.

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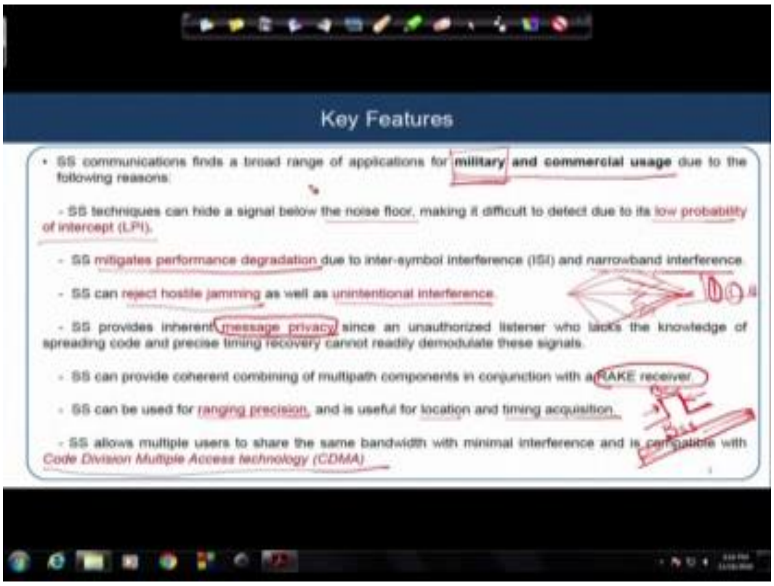

So, let us come back to revisit the key features of spread spectrum communication systems. Please remember you may already got the idea that spread spectrum communication is very useful to give you a secure communication. So, I think that communication system will be implemented only in the military purpose, it is no. The application may be in the military purpose, as well as the commercial usage; though it started with the military purpose; definitely yes, but later on it has got a very big success in the commercial network also, commercial mobile communication network. So, there are of different reasons for which a spread spectrum communication became so popular, actually spread spectrum communication gives you or hide your signal below the noise floor. So, it makes you very difficult to detect, whether there is communication or there is not. So, it gives you very poor detectability, we call it the low probability of intercept, we cannot detect whether communication is going or not.

Number two, it mitigates the performance degradation, because of any inter symbol interference; that is going on and also the narrowband interference already I had mentioned, that when some narrowband interference will be there, we will get a gain on the top of it, it is that. It also rejects all the hostile jamming, and it is an all unintentional interference, may be actually interference coming from your other networks, who are unknowingly trying to give interference from you, and it still may be somebody intentionally trying to send high power in your transmission security band, and trying to jam you and disturb your communication. So, it rejects the both, it rejects intentional jamming, and it also helps in to reject the unintentional interference.

Spread spectrum this provides the inherent message privacy. If you cannot detect what the communication is about, if the signal is buried in noise, and you are unable to detect something, the privacy of the message transmission is really very high. So, spread spectrum communication is the first step, is the first move by means of which it provides security in the physical layer.

Today, you might have heard lot a lot about the five layer security systems spread spectrum communication is very fundamental step towards that. So, it would not allow any unauthorized listener to lag, who is not having any knowledge, what kind of typical code, or the scheme you are using for spreading your signal .They would not be able and if he is not having any timing information, timing information of your signal, he cannot recover at all what you are transmitting, if he cannot crack that is definitely.

So, spread spectrum also, provides a very coherent combining of the multiple path signals, by means of a typical receiver which we call a rake receiver and it helps us to provide a huge gain of the received signal to noise ratio, because of the successful combination over multiple path signals. So, what I mean to say here is, I showed you that in the trans wireless channel. Your receiving signals not only over the line of sight path you are also receiving signal over the multiple reflected path these are called the multipath. So, once actually the signals are received and these multiple paths the signals of the multiple paths are received by the multiple delays associated to it.

Once the these signals are there and you are receiving those signals and if you can capture those signals over their corresponding delay points, and if you can successfully combine them, you call that software as a receiver architecture if you can do that then definitely actually all those multipath signals will help you to increase noise signal to noise power. And this capacity is there in spread spectrum communication system and. So, coherent combination of the multipath signals can enhance our S N R in a rake receiver.

Spread Spectrum Communication can be useful in ranging and precision. What is this about? So, let me one thing that suppose from earlier we understand from 1 m b p s transmission of A D T S S signal and suppose, 1 megahertz bandwidth in the conventional maritime communication system in spread spectrum system 10 times of this bandwidth. Suppose 10 mega hertz of the bandwidth we are now utilizing. So, one actually one way we are using the spread spectrum bandwidth. Suppose, this is the bandwidth V H F and this is the conventional bandwidth B C.

So, when actually the bandwidth has increased. So, you now see that in terms of the timing whenever the bandwidth is really very high, it is a wide band transmission going on, and whenever the wideband transmission goes on actually, in the time domain you can actually utilize this signal wideband signal, for a precise localization, because the timing domain signal corresponding to the wide bandwidth is much less corresponding to the compared to the time duration or time signal of this D T.

So, now you can have a fine resolution over the time access. You can locate the information; you can get the information over smaller time access, over the smaller time duration. So, it improves the precision of ranging it can improve the useful information of the location and also the timing acquisition. So, anything related to localization, receive engine precision, timing acquisition; all those activities which are very important tasks in our commercial communication systems. They can be now be performed by Spread Spectrum Communication.

Spread Spectrum also allows then multiple users to sustain within a within a given interference within minimum interference, with minimum interference, in a zone of, the geographical zone of communication and hence, it is very, it became actually a key factor to develop the very famous communication technology, which is the C D M A.

So, we have got the very key features of this Spread Spectrum Communications in this slide. And remember one thing we have already been discussed. I hope, you have got in a Spread Spectrum Communication System.

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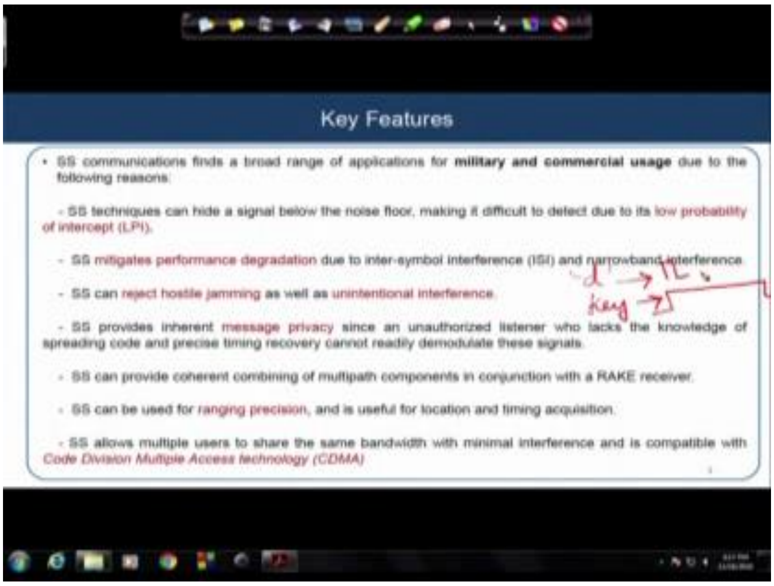

We have first of all, we have a data signal, and we have some key and this key is helping us to spread the bandwidth of this data signal, in such a way that we can get a lot of benefits listed here, but remember one thing So, once you are increasing the bandwidth of the signal here the key is a specific space signal bandwidth. So, once you are using the bandwidth you increasing the bandwidth of the transmitted signal remember that the gain of the transmitted signal is decreasing keeping the gain bandwidth product constant in the transmission system. We will revisit this concept, once I show you the block diagram of that Spread Spectrum Communication system in the next few slides.

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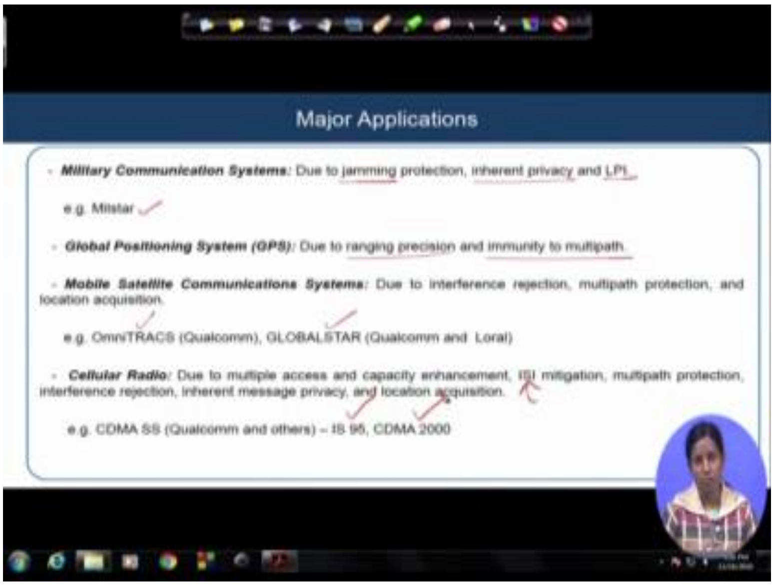

Before entering into the detail of the mathematical expression of the Spread Spectrum Communication or block diagram, let us also revisit what are the major application scenarios of such design systems. Military is definite really, definitely the important part because, we need the secured communication for military and the defense applications and as the spectrum communication gives us actually protection against the jamming and it has inherent privacy. It has low power, low probability of intercept. So, military communication system has got the maximum application for spread spectrum communication, very good example of such system is milstar.

It is also used in the global positioning system, because global positioning G P S is very famous for giving us the ranging precision, giving us the timing alignment for the multiple users and it gives is immunity to the multipath also. So, G P S based, timing G P S localization, we use D T in our day-to-day lives spread. Spectrum communication is the key parameter to enable the system, another high ranging and high precision inside that system.

Mobile Satellite Communication System, due to the interference rejection multipath protection and location acquisition. So, my satellite communication system also prefers the spread spectrum communication. Very good examples are; the milstar designed by QUALCOMM, the global star designed by QUALCOMM and Loral. And finally, comes the Cellular Communication or our famous Mobile Communication, due to the multiple access capability, capacity enhancement, here inter symbol interference this stands for inter symbol interference mitigation property, here multipath protection, interference rejection and your inherent message privacy location acquisition, because of loss of the good paths that are, there in the spread spectrum communication in cellular media also it has got a very good grip and the example is I S 95 C D M A 2000 systems, W C D M A systems, which are very famous actually in the of today's C D communication systems in wireless.

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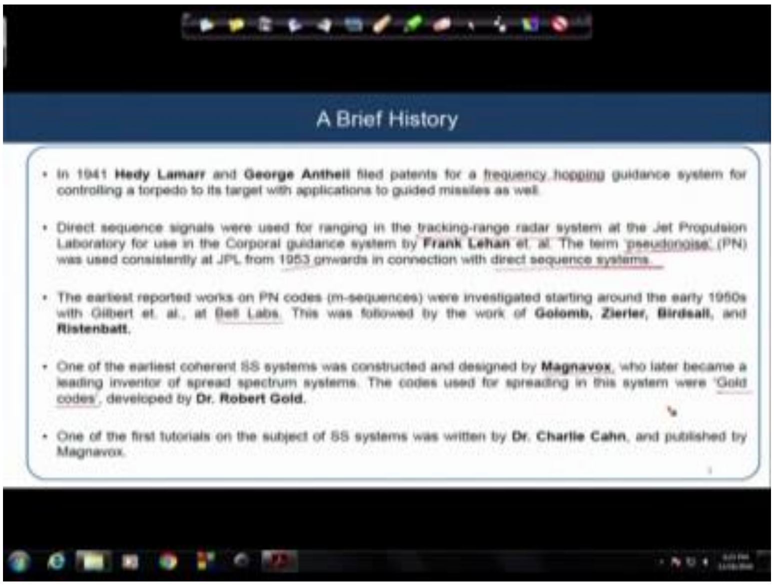

Let us have a very brief overview of the history; who started who were there at the start point of this spread spectrum communication. Who did it first and who are the legendary people who led this spread spectrum communication based research, especially the finding out the different keys, designing the keys who are the, so, main people, at the end a very famous people, who have done and designed all these keys for us.

It was 1941, when Hedy Lamarr and George Antheils, they filed a patent on the frequency hopping spread spectrum communication systems and this is the first time actually somebody, something use in pen and paper, prior to that if even if something has happened we are unaware of it. And we get the applications to the, for it was having a target with applications to guided missile as well as. And the direct sequence signals here they were used for ranging and tracking, a radar, which is called a tracking range radar system and it was used in the jet propulsion laboratory and in the (Refer time: 25:23) laboratory and it is the J P L who gave the term as psuedonoise to the direct sequence spread spectrum systems from 1953.

So, the first types on the systems, which were actually got very big deed. One was the frequency hopping system; another was the direct sequence spread spectrum systems. The earlier reported works on this P N C C N systems or the M sequences were investigated in early nineteen fifties in the bell labs, and these are the group of the people Goulomb and Goulomb et al few (Refer Time: 25:00) who had worked a lot over the designing of the sequences later on. And finally, it is really the earliest coherent spread spectrum systems were first constructed and designed by Magnavox and it was the code that used inside that was the gold code and the code was the inventor was that Robert Gold.

So, the gold code, this code we will learn a lot and its property. We will learn a lot in one of the modules in this whole course. We will also learn what are the other codes possible are getting used in practice or spread spectrum communication systems including my N sequence also, and the first tutorial on the spread spectrum communications in the lecture series, you will find it was written by Doctor Charlie Cahn and it was published by Magnavox.

So, this about the brief history, actually to know who filed the first patent right from the design of the sequences system, then the first such system was designed and remember Gilbert was took a pioneer role to do the research in this field.

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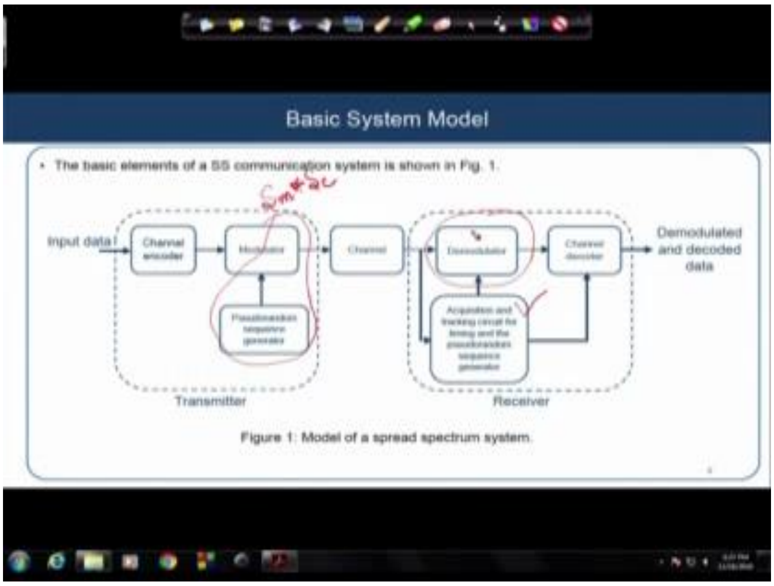

This is the block diagram level of the basic system model of spread spectrum system, and we will try to just identify, what are the basic difference between the conventional digital communication system block diagram and the spread spectrum system block diagram. So, we understand that, this is the input data and prior to that we have done input data, that is coming and this is channel encoding prior to that the source encoding and all has been done. I am guessing this is the channel encoder which helps us to encode the data to give protection against the channel fading, various channel fadings.

And this channel, we are considering here, to be mostly wireless channel, it can be any other thing also the dual coiled cable or an optical fiber cable channel also in that cases the channel encode encoding will be different for them. If it is a wireless channel we know lot of the channel encoding techniques. For example, the convolutional code the and also the conventional convolutional code or the L D P C code or actually the combined coders, I mean concatenated codes where the R S and the convolutional codes are combined and so on.

We need not incite the module it here, we mean that we are having both the data modulation, as well as the extra modulation, that is coming because of the spreading of the signal. So, data modulation and spread spectrum modulation, both are actually incorporated inside this modulator. And for what you need for the spreading of the wave fronts you need a pseudo-random sequence here. So, we have spread our sequence here which is helping me to spread that signal. So, basically the modulated signal here is coming in, and if it is a modulated signal we are actually and basically, multiplying with each, code signal, we call it as S C and then finally, the S M multiplied with the S C is the spread signal, that is coming out of this modulator box; the output of the channel when it is entering into a receiver, when it is entering into the demodulator block.

Remember, this demodulator corresponds to the only spread spectrum demodulation process, but this demodulation needs a very high and accurate information about your timing of the signals and tracking is also an important part that continuously needs to be going on, to acquire the pseudo random sequence so along the pseudo random sequences of the receiver to that of the transmitter. Remember, one thing we have assured, assumed here that the receiver and transmitter are in they know both of them, know your that what exactly is the key getting used for a typical transmission at that moment. So, key is already shared.

And this demodulator does not encompass the data demodulator. After this spread spectrum demodulation, the actual data demodulation goes on and data detection channel decoding data detection everything goes on. So, the basic difference that we are seeing from the conventional block is that we have a modulator spread spectrum modulator which along with there actually the pseudo random frequency generator it is reading out and this is the extra section in the transmitter and in the receiver.

We have the acquisition tracking circuit board and a unit and also the demodulation unit an additional demodulation unit for the spread spectrum communication, additively coming apart from your additively coming on the top of your data modulation de modulation in the conventional communication system. So, these are the two blocks in the transmitter as well as corresponding in the receiver, we will be seeing in addition in this communication system.

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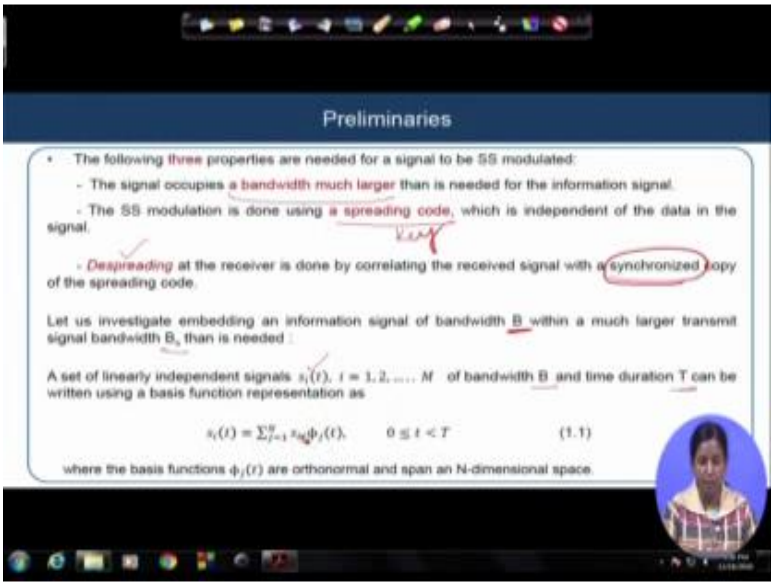

And remember that tracking acquisition we have got acquisition, means the time sequence acquisition of the codes as well as the signal, as well as the carrier we need to do in the receiver, but remember we also need to do a tracking. Tracking means you continuously, when the data communication is going on you have to keep on track the any changes whether any changes has happened on the phase frequency or time or not. If it is there no the successive demodulation would not be happening in the receiver. So, the s n r gain that we are talking about from the beginning itself, it means that very nice tracking should be going on in the receiver of such system that needs to be ensured.

So, there are basically three properties of a that needed for the signal to be declared as the spread spectrum signal, that we have learnt already number one should be it is a very bandwidth be very much larger compared to whatever is declared minimum it should use the spreading code which we also sometimes call our key and it should have a dispreading process at the receiver which is done by correlating the receiver signal with the synchronized copy of the spreading code remember it is synchronized copy; that means, your tracking your acquisition time at the acquisition is correct it is ideally done.

And let us quickly review this, the mathematical formula of such communication system we will try to investigate, how the information signal, which is having a bandwidth of B is embedded in a larger transmitter signal, which is having a bandwidth of B S. So, suppose there are set of linearly independent signals S I T, then I can have one to capital

M, and these independent signals, S 1 S 2 S 3 S 4 to S M. They are of bandwidth capital B and they will have time duration of capital T. So, you can write this S I T in the form of S I J and phi J in forms of the basis function.

Where the phi, J T are the orthonormal basis functions and they have a span over m dimension dimensional space. So, I can represent any signal by means of the orthonormal basis function and this will span over the m dimensional space. We have learnt it actually in the digital communication system. If you recall that we can write any signal that is transmitted over the space, you know it is by now, in terms of this orthogonal basis function over A M dimensional space. So, this is the same thing there is nothing to do with the spread spectrum yet.

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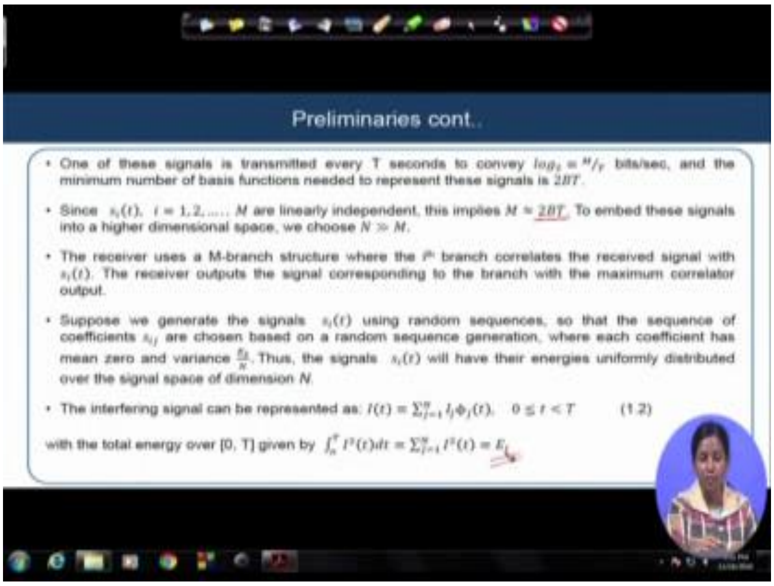

Next one of the signals we transmit over the time duration T every time duration, and remember, actually the minimum number of the basis function, that you need to represent all these signals will be actually twice B into capital T. and since actually this, all these signals S I T, where I belongs to 1 to capital M they are linearly independent of each other. It also implies that this capital M should be almost equal to this 2 D T, and this is embed this signal into a higher dimensional space, with the space is suppose capital N, we need that this capital N should be very large compared to capital M. So, the receiver now, uses only the N branched structure where the I th branch correlates the received signal with the known signal S I T, and received signal with the S I T and the receiver outputs the signal which corresponds to the maximum correlated output definitely.

So, suppose we have to generate the sequence S I T is in a random sequence. So, that the sequence of coefficient S I J are chosen and they are chosen based on some random sequence generation once again, and each coefficient they are having some mean 0 and now, the variance will be the total signal or S divided by capital N because N is the, N dimensional space over which you will actually express the signal.

And, so, now, the interfering signal also B E written as 1.2 in terms of the same orthonormal basis function over the N dimensional space and the total energy we are interested actually only over the duration of this of this interference unless, it is it is having a duration of 0 to capital T. So, the energy can be re easily obtained by the calculation where the energy, let us define it as E J.

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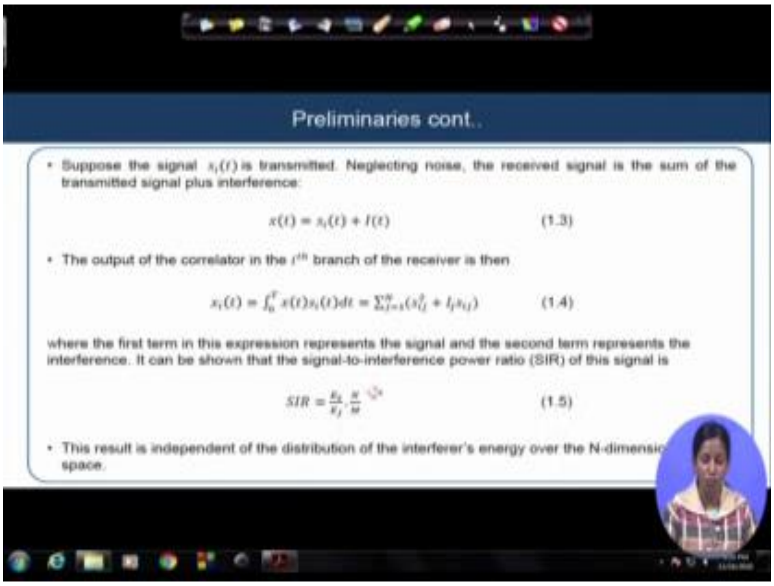

So, we are having the signal as well as the interference. Let us now consider that at the input of the receiver. We are receiving a signal where the original signal clubbed with the interference is entering we for the sake of the analysis. We can consider that there is a noise path associated with it and now the when the I th branch is correlating this input signal with the known signal S I T. Then this will be correlated output over the duration of capital T and we will be receiving the, we will be ending up after the correlation we will be ending up with square of the intended signal plus some part of the interfering signal as we can show that now the obtained signal to the interference ratio because, you are now ending up with the signal plus interference. So, signal to interference ratio will be given by E S by E J into N by capital N as given in equation 1.5.

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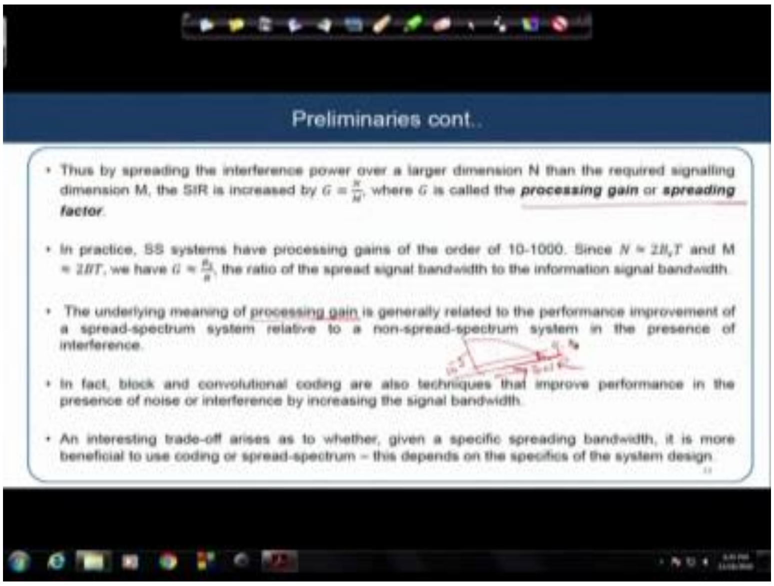

Remember, this result is independent of the distribution of the interfering signals definitely, because it is nowhere the distribution of the interfering signals are coming, controlling the S I N R S I R. It might be well you have to compute the S I N R. Now remember one thing in the previous slide if you notice that as my N is much larger than M. So, there is a gain involved from the signal to the interference ratio in the spread spectrum communication. That gain, that is increased the signal to interference ratio is increased, now by an a factor of capital N by M which we have referred here as the capital G and which we will call as the processing gain or the spreading factor, it is a very famous term that we will keep on using in the whole syllabus.

Remember, this is the processing gain. So, whenever you spread some signal you end up with the gain in the signal to noise power and we call it a processing gain, but we are losing somewhere, we are losing the redundant amount of the bandwidth at the cost of extra bandwidth .We are gaining over the signal to interference ratio the signal power, at the end of the receiver is much increased corresponding to the interference power. And in the bandwidth domain also it can be equivalently written in terms of the spread spectrum bandwidth divided by the actual bandwidth required for the data modulation.

To give you an idea, for visually interactive system design, we keep this gain factor 20000 around. So, what is the underlying meaning of this gain? So, the underlying meaning of this processing gain is that that now the bit error rate of any modulation schemes with respect to my E D Y N naught. Suppose, it is with respect to S N R data schem if I go ahead with that and whatever the bit error performance, we were getting and suppose, we were getting 10 to the power minus 5 bit error rate, at a speed at A S N R of say 9.6 or 9.8 D B for my D B S K kind of communication systems.

So, now, week actually the spread spectrum communication depending upon the factor G, that is actually involved here will you get the same 10 to the power minus 5 with a much higher increased S N R. So, that gives the same 10 to the power minus 5 bit error rate. We will be able to get with much less value of the S N R. So, that is the meaning that the gain is getting reflected on the performance of the system. So, always the spread spectrum communication system, will give you the better B E R performance in a physical layer compared, to the any conventional communication system, but remember all that gain is coming at the cost of your extra bandwidth involved in the system design.

So, question which comes like this. So, we understand that when we give the convolution code or the block coding for the channel encoding process, it also improves the performance of the of the whole system in the five layer and it gives us that in the presence of noise as well as interference we get enhanced performance over the bit error rate they also work by including the signal bandwidth then whether will it be fine to go ahead with block or convolution coding channel coding or you will go ahead with the spread spectrum communication.

So, to choose between these two, if you if you ask me right now, that whether we shall be go ahead with the error control coding or we shall go ahead with the spread spectrum communication system, who will be good who will be bad, how to choose all that the answer is it depends on the specifications of the system design itself, and the requirements of the system which will give you this answer.

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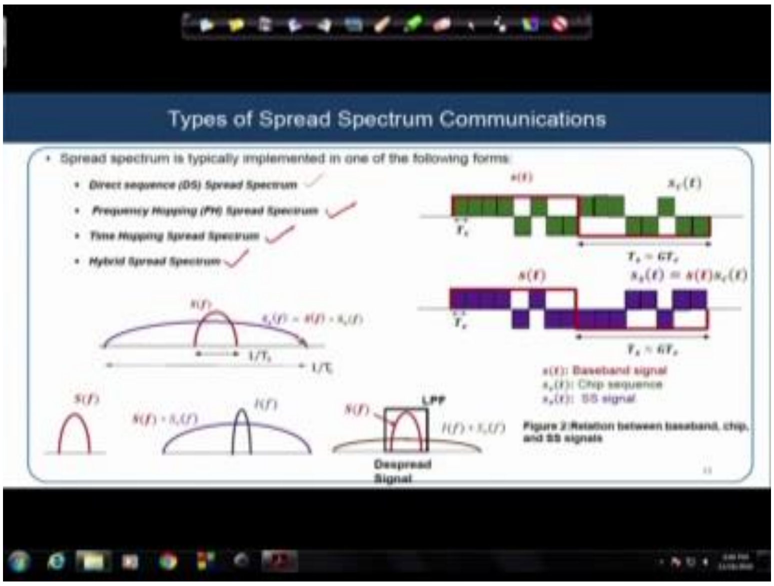

And the first and lastly actually we will end up with telling that what are the different kind of the spread spectrum communications used in practice.

We have mostly the four types; one is the first one is the direct sequence spread spectrum system, second one is the frequency hopping spread spectrum system, third is the time hopping spread spectrum system, and four is the hybrid combination of any three of these kinds and we have given a simple example, we will this detail and discuss in detail in the corresponding modules for each and for them and we will see what actually the meaning of those spread spectrum communication systems mean, but here we will try to see the glimpse of, what is the first one the direct frequency spread spectrum communication mean.

We were telling from the beginning that we have a data, the S T, here the red line is the data, that is supposed required to be transmitted and this data is having duration of T S and this smaller green graph that you are showing going inside, this is the pseudonoise or this is the key or this is the actually the code sequence, that will actually help me to modulate my signal S T. So, the S T T is the code sequence, S T is the data sequence, S T T is the code sequence, S T T is having time duration of T C. So, now, see actually we are considering if we consider that T S and T C is chosen such that, T S is G times larger of T C then the G the gain, which is actually given by T S by T C further.

So, once these two signals are multiplied with each other, you will be ending up with these blue signals which is actually spread spectrum signal, where which is ending up with this by multiplication of S T and S T T therefore, the positive where the positive part of the signal is there we will not see any change of the phases of this S T where as in the negative during the negative part actually you will see lot of changes correspondingly happening for the for the pulses and finally, once this multiplication is done no between the red and this green graph, green graph and green signals, these two signals once they are multiplied and you are ending up with a spread signal, there is no existence of this T S, finally we are ending up with a spread spectrum signal with that individual duration of the pulses give oven by the T C.

So, if I see try to see this. So, we have given the expression for all these three and if come back here and try to see the frequency domain what is going on basically. So, this is a spectrum of the mod data modulation signal which is corresponding to S T it is S S and it is having a bandwidth of 1 by T S definitely. Because, T S is the time duration of this signal and after the multiplication, we are ending up with the spread signal. So, it will be governed by 1 by T T roughly.

And so, this S S is equally the converged signal of S S into S C F. Now, this is transmitted finally. So, this was your S S signal was the actual signal you started with, we end with the spread signal which is called F S F. We have transmitted this F S F through a transmitting antenna. So, this is a wide band signal transmitted through a transmitting antenna finally. At the receiver end here we will be receiving the signal S P F into S C F and we understand that this was my S F section, and this was the bandwidth was 1 by T S I need to get it back. Remember, when it was travelling over the channel there was an interfering signal called I F, whose narrowband interfering signal which had also entered into the receiver frontend and see the situation the power of this interfering signal is higher than the power of the spread signal.

Another important part to notice when the signal was transmitted, when the signal was spread that bandwidth of this F S and the power of this total F S, then the bandwidth has got increased the power is reduced. So, you are ending up here with the situation, where the interfering signal clubbed with the spread signal has entered in the receiver. We again multiply the signal this spread signal with their own known keys. I mean the same S T T once we do it the by default of the signal processing itself that spread signal actually, comes back it goes gets back our original signal process, which will be filtered out by addressing by putting a low pas filter, but what is happening with this I th there, that S C T is also getting multiplied with I T. So, once that multiplication happens. So, now, this signal is spread over a very wide bandwidth. So, now, if you compare the signal received signal power, after the modulation, demodulation in the receiver the signal power is much enhanced compared to the interfering power.

So, this is pictorially and with the help of a graph this is the first level of understanding the way, the spread process communication works, how it can reduce the effect of an interfering signals, but we will be discussing this topic in detail with corresponding to the each of these spread spectrum communication systems in the coming modules.