Digital Communication.
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Lecture-9.
Spectral Properties Of line Codes: Duobinary, Manchester and HDB Codes.

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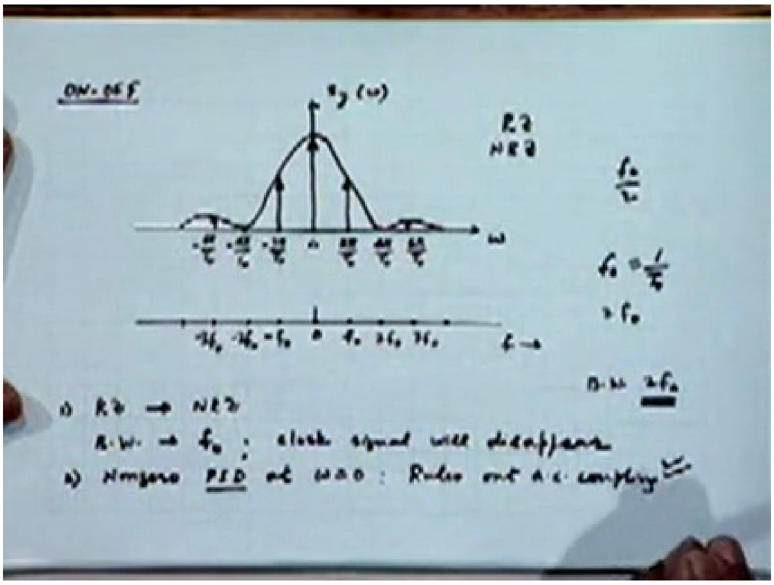

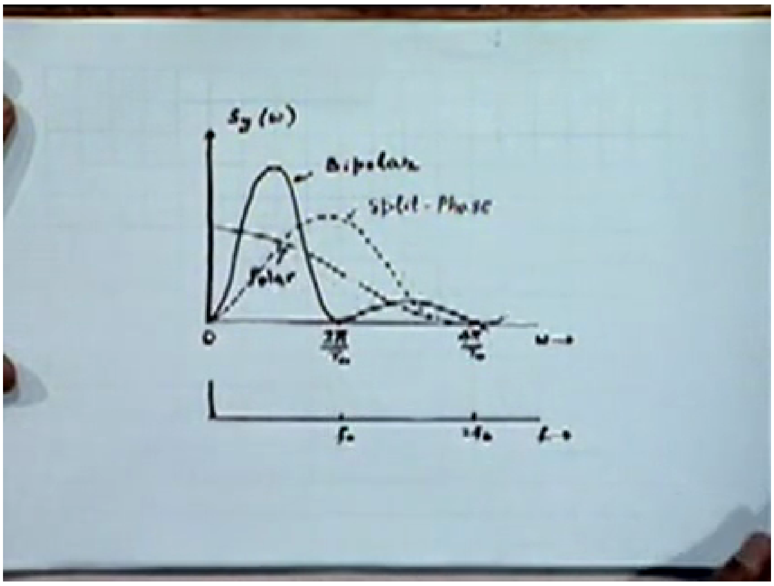

Professor: Let us quickly review what we have done so far in line coding, what we have done so far in line coding. We have seen that if we do simple on-off kind of signalling, we get this kind of power spectrum, right, that you may recollect, which is, which contains both, a continuous part as well as a discrete part. In addition we notice that the bandwidth of this is

2f0, if we consider the main lobe width as the bandwidth, right. I will summarise here and not go through all the things that will discuss about various line coding schemes so far.

Next you may recollect that we considered the polar and the bipolar cases and the kind of power spectrum for the transmitted pulse sequence that we obtained looks like this for polar which has the same bandwidth as the on-off signal, that is 2 f0 but it does not have the discrete spectrum that that displayed, right. + it does not have that strong dc component, impulsive dc component that was also present is the on-off signalling. The bipolar case, in which we did alternate mark inversion if you recollect, in which we have 0 representing, represented by a 0 level, 0 signal, no pulse and 1 is represented by pt or - pt, right, have this kind of spectrum which has surprisingly, it is not that surprising after we looked at the spectrum, i bandwidth only of f0, which is half that of 2f0.

But we may recollect by telling us that even this is twice the theoretical minimum that we can have and therefore its bandwidth efficiency cannot be said to be very good, all right. And we will like to see whether we can improve this bandwidth efficiency further by other kinds of line coding schemes, right. And that is what we will start with today. These are the 3 schemes that we have discussed so far on-off signalling, polar and bipolar. Have we discussed anything else? I think that is what we have done.

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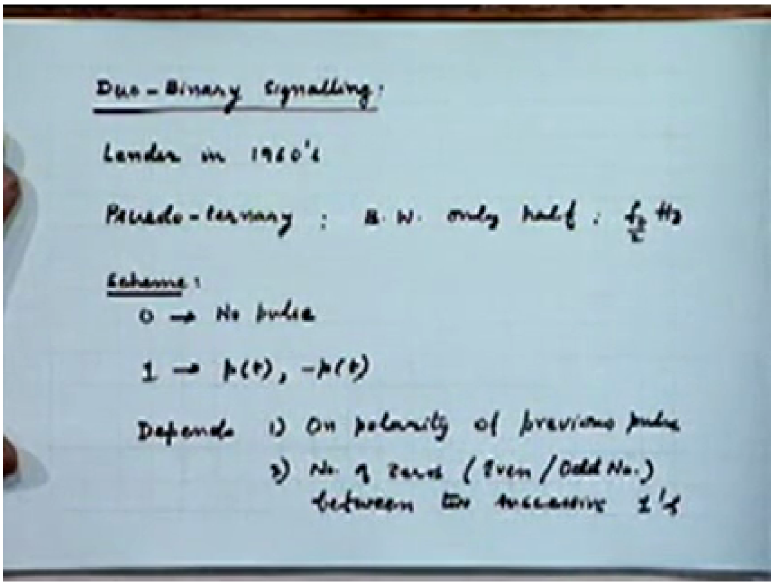

Now i will introduce you 1st a yet another new scheme which we have not discussed so far, we will come to hdb 3 or hdb n a bit later, but before doing that i would like to discuss, introduce to you a new line coding scheme, new to you i mean, it is not really new in the context of historical evolution, it is fairly well-known, that is called duo-binary signalling, okay. This line coding scheme is particularly important because we will see that it helps us to achieve a bandwidth efficiency which is equal to that of the theoretical minimum that we can expect, right.

This was originally proposed by lender, it is a very famous name in this particular line coding schemes, in 1960s, okay. This is also a ternary scheme or a pseudo-ternary scheme of the kind that we use for bipolar signalling. So it is also pseudo-ternary, that is we use no pulse for 0 and pt or - pt for 1 but the difference is as against the bipolar kind of signalling that we have done before, namely ami kind of signalling, the bandwidth required is only half of that. That is instead of 2 f0 we require bandwidth of f0 hertz, sorry, instead of f0, we require f0 by 2 hertz which is half that of bipolar.

The basic scheme is as follows in duo-binary signalling. I have already told you 0 is transmitted by transmitting no pulse, right. 1 is represented by a pulse of shape pt or its negative. Now whether you transmit pt or - pt, this depends on the polarity of the previously transmitted pulse, number-one. So it depends on previous, on polarity of previously transmitted pulse, so previous pulse, that is one thing that determines what will be transmitted next, also it depends on how many zeros have elapsed between the previously transmitted 1 and the one that you are doing now.

We do not actually count the number of zeros, we are only interested in knowing whether the number of zeros is even or odd. Right. So example, if the 2 ones, that is the previous 1 and the current 1 are separated by an even number of zeros, we transmit pt otherwise we transmit a negative pulse, all right. So it depends on number of zeros, more precisely whether it is an even number or an odd number between the 2 pulses, between the 2 words, 2 successive 1s, all right. Okay. Any questions about it? The basic scheme is clear, so let me take an example.

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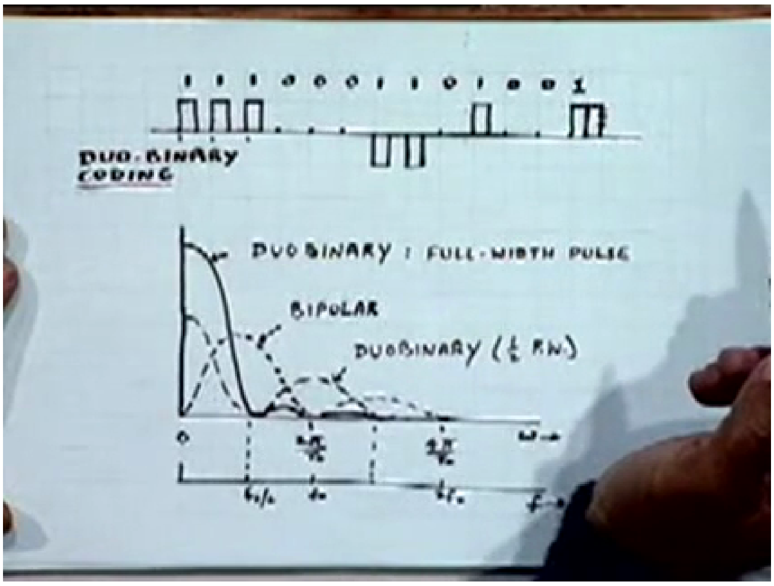

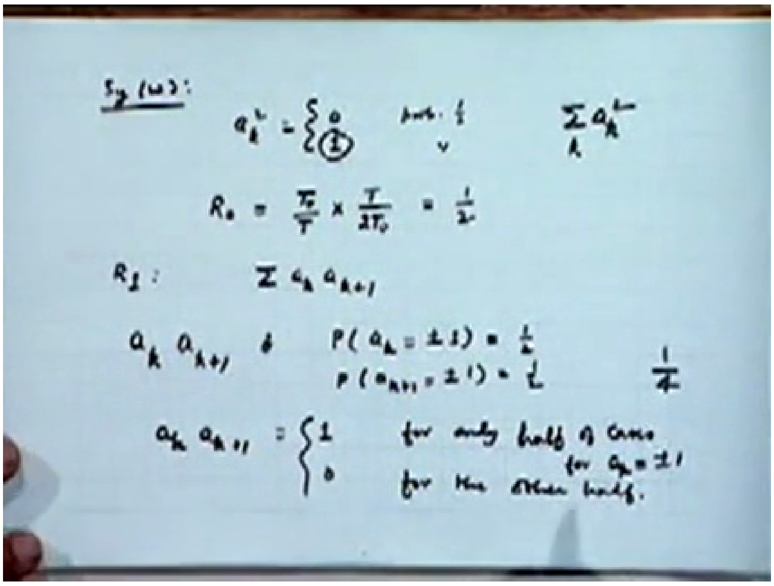

That is the, i think i have it somewhere, yes, i have it done here. Let us say that is the transmitted sequence that you want to transmit on the channel. In the duo-binary coding scheme, this will be a 1, each interval here is like that. This is one transmission interval for one bit, so obviously, since the 2 ones are successively same, there is no 0 in between them, which indicates even number of zeros because we consider 0 also to be an even number. Then the polarity remains the same, same is true here and zeros are transmitted by transmitting no pulse. Since we have the zeros here in between this one and next one here, the polarities reverse.

Now again we transmit with the same polarity, tell we get an odd number of zeros again, right, which is the case here. So we keep on reversing the polarity depending on whether we have an odd number of zeros between 2 consecutive one or an even number of zeros, okay, right. That is it, okay. Here we have even number of zeros, so we transmit the same polarity, again even number same polarity, even number same polarity, odd number, odd number, reverse the polarity. Okay, let us look at the power spectrum of such a scheme.

Let us do a computation of sy omega. And if you remember the steps required to compute the rns, right, that is r0, r1, r2, etc. R0 will be determined by sigma ak square, right. Now aks are 0 for half the time and either +1 or -1 for half the time, right because we are assuming again that ak or the original data sequence contains zeros and ones with equal probability, right. So in any case we are interested in ak square, so ak square will take the value 0 or 1, right, each with probability half, same here. Okay. Which makes it clear that r 0 should be equal to half, 1 by 2. Y0?

It should be, if you remember the expression of t0 by t into the number of 1, the number of values of 1 did you get in ak square because you are looking at sigma ak square over k, those indices k which lie in the interval from - t to + t, that will become t upon 2 t0, half of the pulses, half of the symbols in this interval will contribute a 1 here in this term and therefore that is the value that you will get, half. Consider next the value of r1, which will be determined by sigma ak ak +1, right. Therefore let us concentrate on the behavior of other values ak into ak +1.

It is clear that, it is quite clear, each of them will contribute a nonzero value, only if they are both nonzero, right. That means ak should be + -1 as well as ak +1 should be + -1 and from elementary knowledge of geometric theory, if you assume these 2 symbols are omitted independently of each other, the probability of this to be nonzero and equal to1 or -1 will be 1 by 2.

Student: 1 by 4. (())(12:58).

Professor: I said probability of it being either one or -1 is 1 by 2 but probability of it being either +1 separately and -1 separately will be 1 by 4 each, right. Of course these 2 are exclusive events, that is why they sum up to half.

Student: No sir (())(13:22).

Professor: 1 by 4 of what?

Student: The probability of it being either +1 or -1 is 1 by 4. We can have… (())(13:31).

Professor: Oh yes, yes, absolutely right, you are absolutely right, i have made a mistake. Let me elaborate for the others, those who have said this have said it correctly. Probability of ak equal to + -1 is equal to half, similarly probability of ak +1 equal to + -1 is equal to half independently of each other, right. And therefore probability of both of them being nonzero will be equal to 1 by 4, the product of these 2, right. So we can say that ak into ak +1 is equal to1 for only…

Student: It is independent of ak?

Professor: Because there are assuming, that is an assumption that successive values of binary symbols that are being emitted by the source are being emitted independently of each other.

Student: But in this case if you have got ak equal to1 or -1…

Professor: I am not talking of the coded value, i am talking of the original symbol value, right, the coded values depend on each other, right. So let me put it this way, ak into ak +1 is equal to1 for only half of those cases for which, half of cases for which ak is equal to the -1 and it is equal to 0 for the other half, right. In any case what is really important is the fact that the probability of this being a nonzero is 1 by 4, right, that is what is really important.

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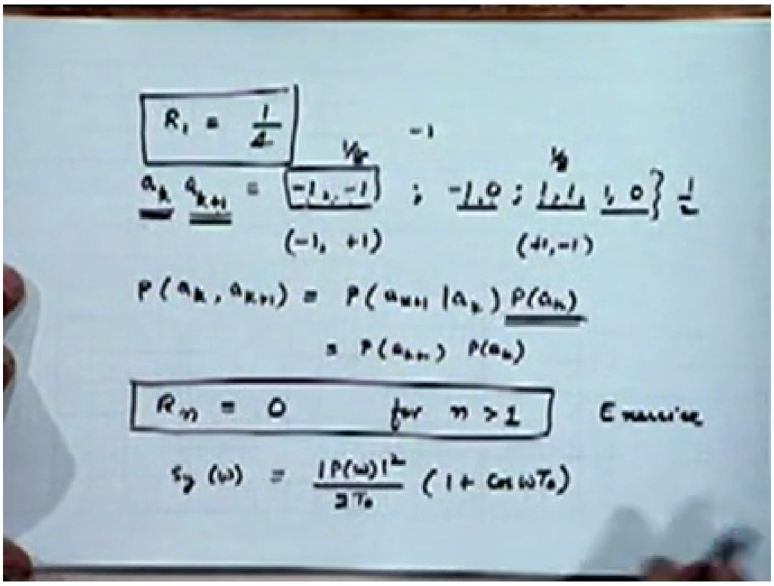

What is the value of r1 then? It is 1 by 4, right. Because if we start with + one, right, i think it may not be clear to everybody. Suppose, i thought there was still some confusion so i should resolve is really. Let us do it here, if ak is 1 or +, just a second. We are looking at ak into ak +1 and suppose you start with ak equal to -1, right. Then we can have the combinations -1 and -1 which will contribute to a nonzero value, similarly -1 and 0 as the 0 value, right, similarly we can start with ak equal to1 and 1 and 1 and 0, right. So we are talking of, 1 and 1 i have taken, 1 and 1, -1 and 0 and 1 and 0, all right, these are the 4 possibilities. So what we see is out of these 4 possibilities which occur with how much probability.

Student: Each as 1 by 4.

Professor: No, each is not 1 by 4, each is 1 by 8 because we are assuming this starting bit to be either -1 or +1, we are not permitting this to be 0, right.

Student: Can be 0,0 possible?

Professor: You can but they will all contribute with half the probability, right. So this total sequence has probability half, right and therefore the probability that you will get a nonzero value will be 1 by 4 which is what we had considered earlier. Not only that, what we notice is that this nonzero value is +1, right, it cannot be -1. That is why r1 has to be equal to1 by 4, okay, is it clear because ak can be +1 or -1. For -1, for ak equal to -1, ak +1 could be either 0 or -1 here, right, and similarly here. I do not know whether i have confused you, please let me know if it is okay.

Student: It is all right. Please repeat.

Professor: Okay, you people want me to repeat, I will do it.

Student: Initially we are not considering the decorative value… (())(18:43).

Professor: Okay, let us consider this question, why we cannot have -1 and +1.

Student: (())(19:02).

Professor: I think i am also slightly confused here, just give me a second. Okay, all right, let me repeat it. This point, we start with the point that we have, let us start with the point that ak can be equal to a + -1 with the probability half, right. So we are ignoring here the value ak equal to 0 because that will not contribute to the product. The next value, next point is what kind of values can we have for ak +1, right. Now the duo-binary rule says that ak +1 must be either of the same polarity or the opposite polarity…

Student: Or 0.

Professor: Or 0, right, these are the 3 combinations, right.

Student: It will not be of opposite polarity (())(20:29) of the opposite polarity.

Professor: Because we are talking of take a +1, right, the number of zeros here is even, so they have to be of the same polarity. If we follow the deo bandwidth rule, 2 successive bits have to be on the same polarity. We have already seen that by the example over here, right. Because 2 successive bits are 1, they have to be of the same polarity. They have to be both, either they are both negative or they are both positive, that is why we did not consider the probability of this be -1 and +1 because that is not possible. Similarly we cannot have +1 here and -1 here, right, so these sequences are not possible.

Now this, total number of these 4 combinations occur with probability half, therefore each of them occur with probability 1 by 8, out of which only 2 of them will contribute a value to the product ak into ak +1 and that product value in which case happens to be +1, right. That is why r1 turns out to be 1 by 4, object is clear now.

Student: When ak is 0, there are only 3 possible values of ak +1, 1, -1 and 0.

Professor: It does not matter what it is.

Student: No, while using that total 7 possible you can make, possible pairs, so how is the probability 1 by 8 of each?

Professor: No, we are just using very basic elementary probability theory here which says that probability of ak and ak +1 together, joint probability, please listen to me, the joint probability of these 2 is, right, out of which we are taking this to be.

Student: These are independent of each other.

Professor: No, if they are independent, they simply become…

Student: (())(22:32) what i am saying is there a total 7 pairs possible, not 8 as you are saying that 8 pairs are possible.

Professor: No, i did not talk of 8 pairs anytime.

Student: You said the probability were ak is 1.

Professor: We are considering, please understand, try to understand, ak can be 0 or + -1, what is the probability of that, half each, either 0 or + -1 will be half each, right. Now given that this event is occurring with probability half, these 4 set of events must have total probability of half, right, that is a point that is being made. And therefore assuming equally likely situations here, we have 1 by 8 here and 1 by 8 here, together they add up to 1 by 4. So whenever starting premises, that we are assuming ak to be nonzero which has a probability half, right.

Okay, i am sorry for the confusion, but i hope it is resolved now. Okay, we proceed further. Similarly, i think i will leave that as an exercise because that is apparently causing a lot of problems here, counting zeros and ones, i think you can do that at leisure yourself. It is comparatively easy to prove that rn for n greater than 1 is 0, okay. Please think about it yourself so that we do not have any more confusion in the class at least, it is very easy to prove that. If you, now if we make use of these results, that is r0 equal to half and r1 equal to1 by 4, and substitute in the expression for sy omega that we had earlier with the, that is the, we get this result. Okay.

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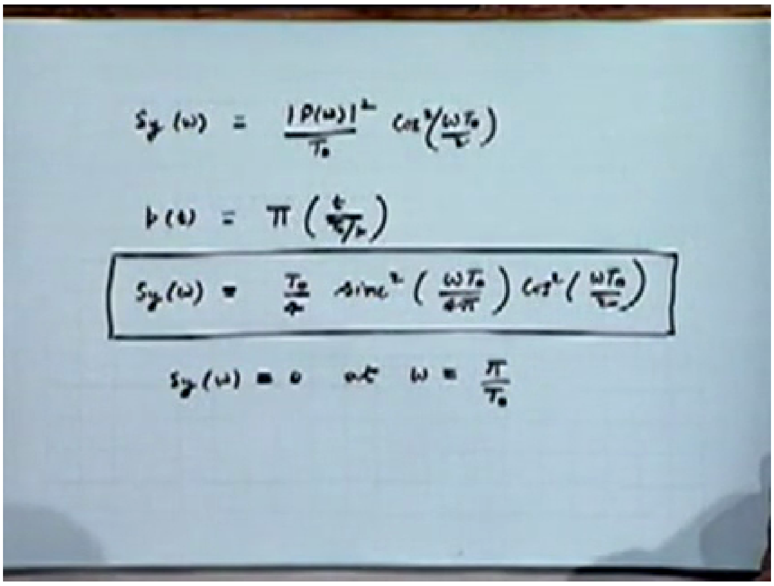

Do i have to show you that expression again or it is okay? All right. Let us simplify that further. 1 + cosine omega t0 can be written as cosine square omega t0 by 2 divided by, multiplied by 2, so this will become p omega mod square upon t0 into cosine square omega t0 by 2, okay. Now if we consider a specific pulse shape like we have been doing, remember the pulse shape that we have been most commonly using for comparison purposes is the half width rectangular pulse.

So we will come back to that again, that is this particular rectangular pulse, then we get the same square function for p omega mod square and the result is t0 by 4 sinc square omega t0 by 4 pie into cosine square omega t0 by 2.

Student: Excuse me sir.

Professor: Yes.

Student: The handwriting is a bit small.

Professor: It is still small? Okay, i am sorry.

Student: The brightness…

Professor: The brightness is small.

Student: The brightness is less and the letters are also very small.

Professor: Okay i will try to write them big, please remind me whenever i forget that.

Student: (())(26:46).

Professor: Let us discuss these suggestions at the end of the class, okay, if you do not mind. At the moment i think i will try to write bigger so that you can see it better. Okay, let us return to this expression here. Is there, is there some other problem? Let us return to this expression here, which is the power spectrum of a duo-binary coded stream, duo-binary coded data signal. Alright, the 1st thing you notice that it has a 0 at, why do you have a 0? Sy omega equal to 0 at omega equal to pie by t0 because that pie by t0 we will get pie by 2, cosines of pie by 2 which is 0, right.

So that is interesting, that is our 1st 0 crossing in the spectral plot will now be at f0 by 2, not at f0. So for all the spectral shapes, all the pulse shape we discussed had their 1st 0 crossing actually determined by the sinc square function, right. We did have a multiplication factor in some other schemes but the 1st 0 crossing always came at either f0 or 2 f0, right, not at f0 by 2. This is the 1st scheme we are seeing, that is the 1st 0 crossing resulting at f0 by2. So we can expect the main lobe to have a width of f0 by 2 on either side of 0 and that is exactly what i got here in this, we can see the plot.

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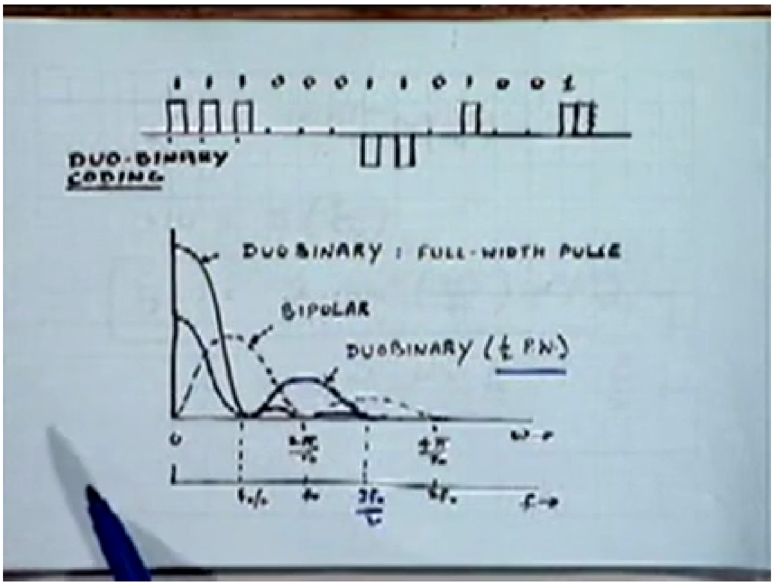

This is your duo-binary scheme. I will show you which is the one. We are considering duo-binary width half pulse width, right, that is shown by the dotted lines here. I think i will draw it with a different colour so that it becomes clear, which is the one i am referring to, that is that duo-binary scheme, okay. Its 1st 0 crossing is that f0 by2 and the next one occurs at 3 f0 by2, this is duo-binary with half pulse width, right. This was the bipolar thing which was occurring, which has the 1st 0 crossing at f0 and this is the duo-binary case.

Student: The black one, it is occurring at 2 f0.

Professor: Well, i am telling you, this is the duo-binary scheme spectrum, this comes from this expression here that we just derived, here, right. This expression here, sinc square function multiplied by this cosine function, that turns out to be this because we get our 1st 0 crossing over here. Now although it seems that we have achieved what we wanted to achieve, there is a small problem you can notice. The 2nd lobe is not all that small as compared to the 2nd lobes of let us say the bipolar or other schemes that we have seen earlier, the polar, right.

Therefore it seems that significant energy still seem to exist between f0 by2 and beyond, right. However that is not a very serious problem. Why, because we have only used one of the things at our disposal, right. Namely the control, we are trying to control the spectral shape by the coding scheme only so far, we can as well also control p omega is the pulse shape, right. Just to show what kind of things we can do by controlling the pulse shape we will discuss that in detail later, soon after we had discussed the basic line coding schemes.

Here i have plotted the duo-binary scheme spectrum, when you take the pulse not to be half width pulse but the fullwidth pulse. What do we notice now, that this black solid line indicates the spectrum in this case, the solid line spectrum drawn here is the spectrum of the duo-binary signals with the full width pulse. That is rectangular pulse of width t0, right. What we find is that the side lobe levels have considerably got reduced and the main lobe width remains the same, right.

The point that is being made here is that not that we should use this fullwidth rectangular pulse, you may or may not used but the important point is that one can control the side lobe through a proper pulse shaping of pt, right. You do not have to use the rectangle pulse of half width, you can use another pulse shape and then control this lobe and therefore maintain the bandwidth essentially in the region f0 by2, okay. All right, so that is as far as the spectrum of a duo-binary coded signal is concerned.

Student: (())(32:40).

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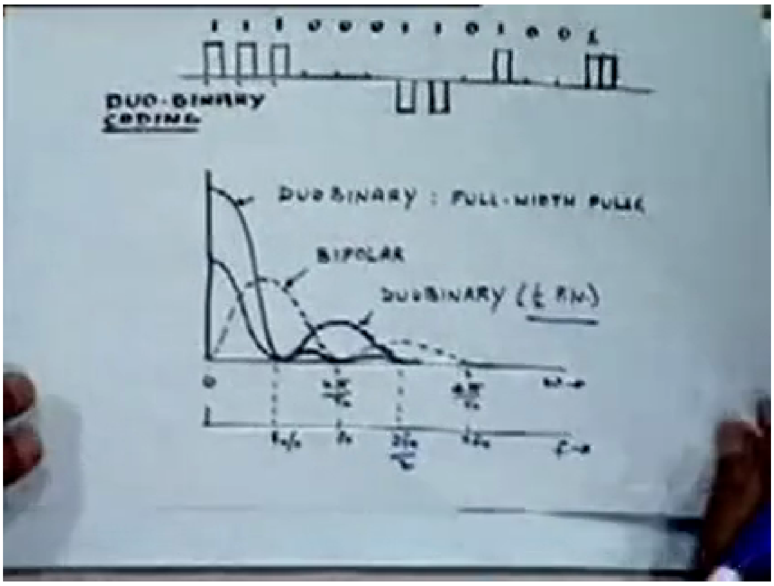

Professor: We will come to the other points, let us discuss the duo-binary scheme in some more detail now, this is only the spectral aspects of it. Can you read this alright or you want still bigger? So 1st thing that we learned just now is that the bandwidth of the duo-binary scheme is half that of bipolar, all right. Considering only on the main lobe basis and that is the only important thing because they can always shape the side lobe of the 2nd lobe down by according to the shaping of the pulse. Now the other properties of the duo-binary scheme are essentially the same as the bipolar signal that we have discussed earlier.

That is quite clear because like the bipolar we do not have considered a component of dc, we do not have a left dc level, dc value that, because of the fact that alternating pulses are, on the whole equal number of pulses are likely to be positive and negative, right. So we have more or less similar properties to that of bipolar, except for one fact. Can you say which one is that? Right. We do not have a spectral null at omega equal to 0, right, except for a missing spectral null, which was very useful if you remember. So like bipolar we have a 3 db disadvantage with respect to, with respect to what? 3 db disadvantage with respect to polar scheme, right.

That is for the same performance either the bipolar or the duo-binary scheme, because they are ternary schemes, they are bought ternary scheme or pseudo-ternary scheme, we will require 3 db more power than the polar scheme, with respect to the polar signalling scheme. Like the bipolar, that is the ami kind of scheme, we also have error detection capability, which is quite obvious, right. Because if 2 successive pulses come with the same polarity, and odd number of zeros between them, we can deduce that there is an error that has taken place somewhere, right and similarly the other way round.

So all the properties that we have seen for bipolar are valid for duo-binary, with the added advantage that the bandwidth is only half of it, right. And the disadvantage that it is, the spectral null that bipolar had at omega equal to 0, right, at this point is missing. So this is, this is the main features of a duo-binary signalling scheme.

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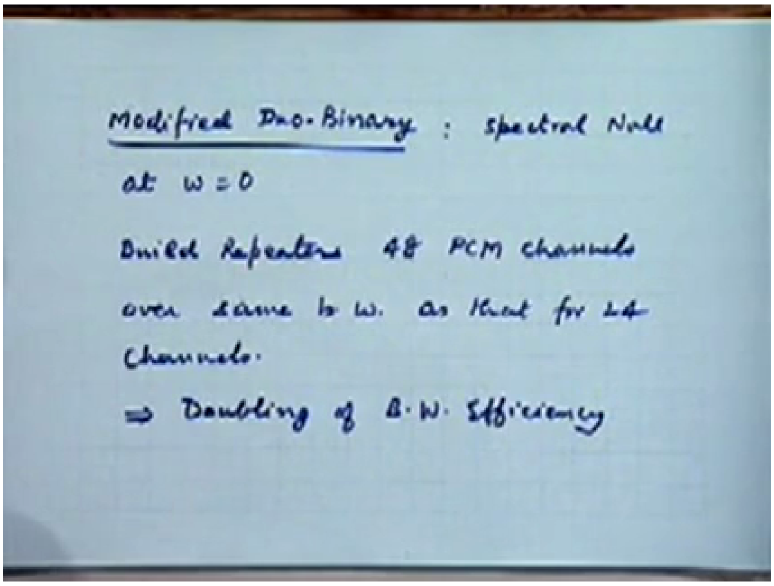

Later lender himself, you remember lender was the person who introduced the duo-binary scheme, he himself came up with a so-called modified duo-binary scheme which eliminates the disadvantage that it has with respect to bipolar. That is which has a spectral null at omega equal to 0. This seemingly simple modification that is, that is inherent in the duo-binary scheme with respect to ami kind of schemes and after its modification to introduce a spectral null at omega equal to 0, made it a very very useful device, useful coding scheme.

In fact soon after this companies came up with systems which would take 2, let us say 2 basic basic units of t1 carrier systems of your time division multiplexing standards which each contains if you remember 24 channels, voice channels. And combine them into a single system with 48 channels with the same bandwidth, right. So one could build repeaters which could transmit 48 channels, 48 pcm channels, we are writing in terms of american context, because lender was and american and he introduced the scheme there. We could introduce, we could use 48 pcm channels over the same bandwidth as that was earlier being used for 24 channels.

That shows the significance of choice of proper line coding schemes. One has doubled the bandwidth efficiency, there is the doubling of bandwidth efficiency here, which is very very significant.

Student: This is for duo-binary or modified deo?

Professor: Well, even duo-binary has the same advantages, except that there is a spectral null, spectral null at omega equal to 0 is missing.

Student: What is the modification…?

Professor: We will discuss that later. I am not discussing the modified duo-binary here, we will discuss it in a slightly different context later. I just wanted to introduce to you the duo-binary concept here which is essentially a small modification of ami in some sense. Next let us come to yet another line coding scheme which is, which follows a slightly different philosophy from the one that we have discussed so far. In all the line coding schemes from bipolar onwards that we discussed so far, we have tried to do the spectral shaping essentially by controlling the manner in which ones and zeros are represented, successive ones and zeros are represented by actual signals, actual pulses, right.

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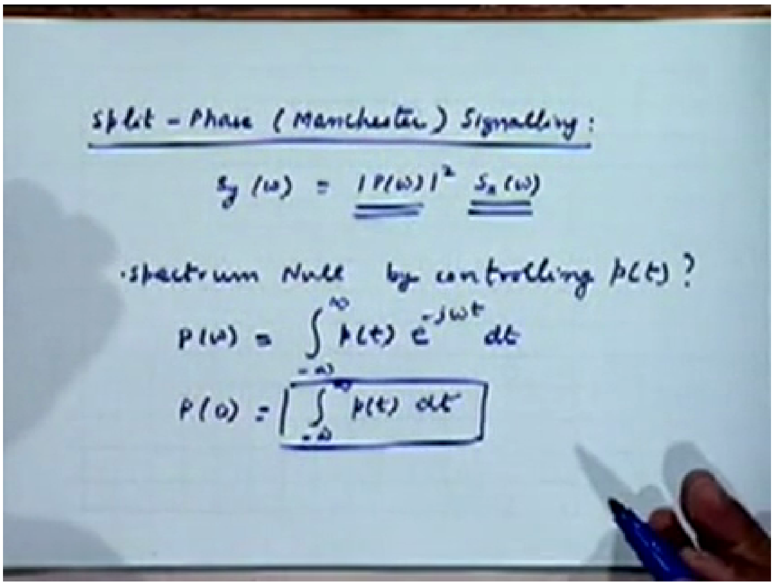

We are not really, we have not done so much with the pulse shape itself, we could also do that and that leads to one more kind of pulse shaping, line coding scheme that we have just briefly discussed here, which is named by the name of split-phase or manchester coding. You may be familiar with this coding scheme. So the point that i am making as we have noticed that we can split our sy omega into 2 parts, namely a part which is contributed by the pulse shape and a part which is contributed by the impulse train with the amplitudes random amplitude ak, right. Sx omega denotes the power spectrum of the impulse train, p omega mod squad indicates the power spectrum of the pulse shape that you use.

So one can do spectral shaping, not only by just controlling sx omega but also by controlling p omega, right. In particular suppose our primary requirement is to introduce a spectral null, right, let us ask the specific questions. Can we introduce a spectral null by controlling p omega or pt? It is very easy to see that yes we can. P omega is the fourier transform of the basic pulse shape pt which is this. As far as the dc value is concerned, that is the value which is determined by the area under the pulse, right. Because if you put omega equal to 0, this factor disappears, so p0 value is essentially given by the area of the pulse.

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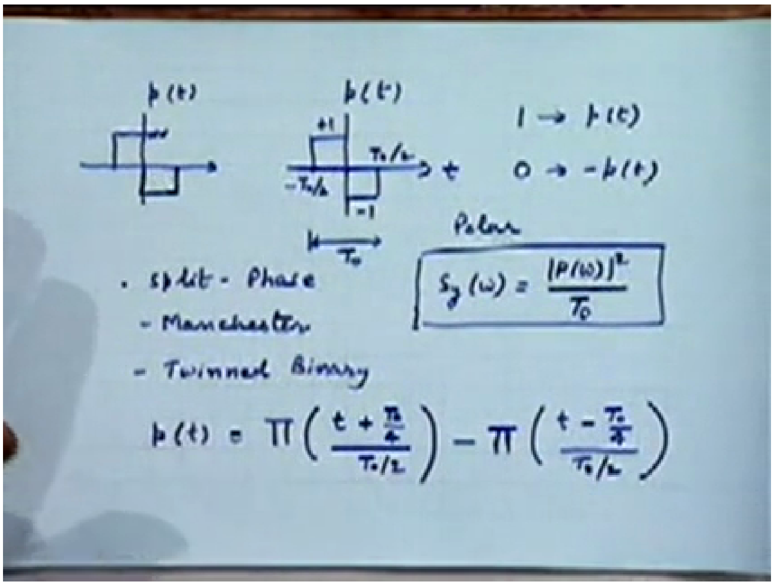

So if we can choose the pulse shape such that the net area under it is 0, we will get a spectral null, right. Manchester coding is one example of, split-phase coding or manchester coding is one example of precisely this kind of coding. So pt is determined by this requirement, i am sorry, right. Let me redraw it, so this is your time axis, half interval of the pulse width, the pulse is having positive amplitude let us say +1 and the other half is having a negative amplitude which is -1. So the overall interval t0 is split into both a positive portion and a negative portion with equal areas so that the net area under the pulse is 0.

And the mapping that you may do, that is what manchester coding does, 1 is represented by pt and 0 by - pt. This is known by the various names split-phase, manchester, and also twin binary, various names for historical reasons.

Student: (())(44:29) is simply 0 level?

Professor: For various other reasons we will like to have it this way. That is what manchester coding does anyway, right. One can always define a new line coding scheme, right, we are suggesting one more but we will have to study what the properties of these are with respect to manchester coding and see that whether it is worthwhile adopting or not. This is what you do in manchester coding. Now as far as power spectral is concerned, it is very simple, essentially what kind of signalling we are finally getting? If we just look at it, if we just look at the final pulse sequence that you will get, what kind of will it be? Will it be ternary or polar, will it be bipolar or polar?

Student: Polar.

Professor: Polar, right. And we have already discussed the power spectrum of polar signals, right. If you remember for polar signal, power spectrum is simply this, equally likely ones and zeros, the 2nd factor completely disappears, we have already done this in the last class, right. So recollect that for a polar signal the power spectrum is given by this expression.

Student: I do not understand that 0 and -1 (())(45:51).

Professor: No, this is just a mapping, both of these will have 0 area. You want both pulses to have 0 area, right, both, the pulse which is being used for representing 1 and the one which is used for representing a 0, right and pt and - pt will both have area 0, that is what we want, okay. So this is the power spectrum. Any questions, any other questions, any other doubts?

Student: This will be different from (())(46:33).

Professor: This code is different.

Student: Altogether different?

Professor: Yes…

Student: We do not have alternate…

Professor: No, there is no further coding rule here. It is just a mapping of 1 and 0 which is done in using this particular kind of pulse shape. The whole idea is that i am now controlling sy omega not through control of sx omega which is what was being done in all those coding schemes, right. But by simply changing my pulse shape, right, one could do some combinations, one can do for a control over pt as well as sx omega, there is nothing stops us from that. Yes?

Student: What will be different, it is almost similar to polar scheme?

Professor: There are similarities and that is why we are saying that the power spectrum is given by basically the same expression but there is an important difference, p omega is different, p omega is different. And if we substitute for p omega, to do that, let us write down an expression for pt. This is actually, both of will to rectangle of pulses of opposite signs, polarity. So mathematically i can write this as a rectangular pulse, let say between - t0 by2 to + t0 which we can think of as being located at - t0 by 4, right. So t + t0 by4 of width t0 by2, with its t0 by2, right, -, - the rectangular pulse which is located at t0 by4 and has the same width, okay, fine. Once i have this we can compute p omega without any problems.

What will be p omega? It will be the sinc square functions corresponding to a pulse width of t0 by 2 which we already know, except that it will have a multiplication factor of e to the power - j omega t0 by4. And this will have, this will will have and this will have -, right.

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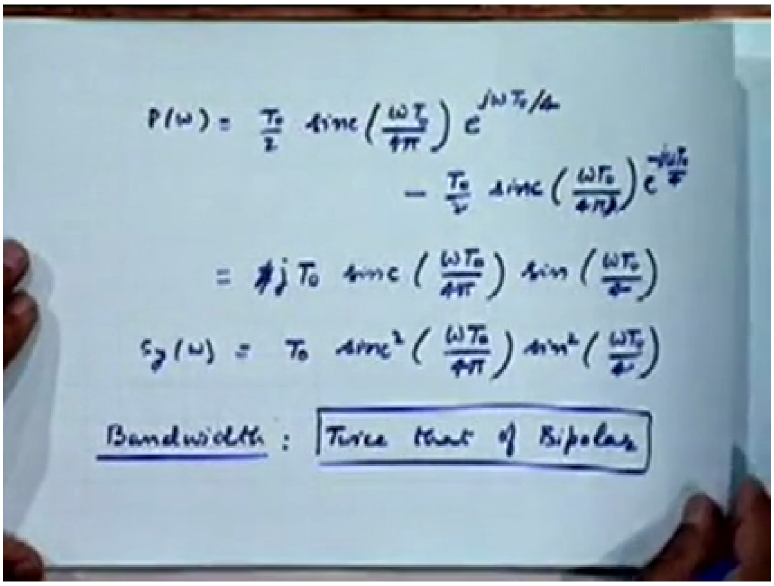

So your p omega is t0 by2 sinc function with the parameter omega t0 by 4 pie corresponding to rectangular pulse of width t0 by 2 into e power j omega t0 by 4 - t0 by2 again the same sinc function omega t0 by 4 pie e to the power - j omega t0 by4. Which we can, we can factor it out, the sinc function we can factor out, we will be left with e to the power j omega t0 by4 - e to the power - j omega t0 by 4 upon 2, right. Which you can write as equal 2 j t0 is saying omega t0 by 4 pie into sin omega t0 by4.

Student: It will be j t0… 2 will not come.

Professor: Right, this will be simply j t0. So sy omega, in fact it will be this whole square, magnitude square of this upon t0 and this will become t0 sinc square omega t0 by 4 pie into sin square omega t0 by4. Which shows clearly that there is a spectral null at omega equal to 0 because we have multiplication by sine function. Right. What is the bandwidth of this spectrum, this signal? Where is the 1st 0 crossing, main lobe which is…?

Student: F0.

Professor: Same as bipolar.

Student: F0.

Professor: Right, because of this, right. The bandwidth is, i am sorry, you are right.

Student: 2f0.

Professor: Now where is the next lobe of this?

Student: This will be omega equal to 4…

Professor: 2 pie, this will be 2 pie.

Student: We will get 2 f0.

Professor: Okay, i am sorry, so bandwidth is twice that of bipolar and that is understandable, right. Can you say why? Because you, you always bound to have 0 crossing at every t0 by 2 seconds, right. So effectively as if your average rate of with transmissions has gone up from every t0 seconds to every t0 by 2 seconds, right. Therefore the bandwidth is doubled, okay. So it makes sense to expect the bandwidth should be doubled with respect to the bipolar schemes. So we are back to the bandwidth that we used as the unipolar scheme, right, with rectangle pulse shape of width half.

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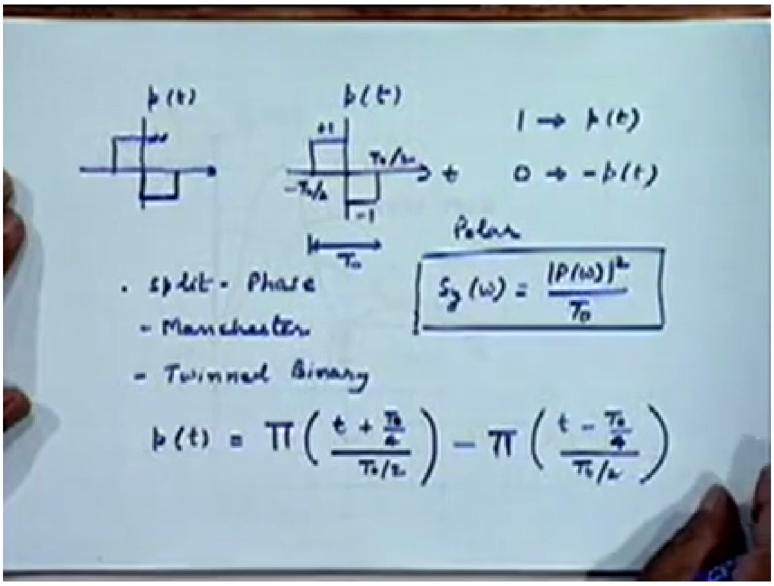

So that is shown in this diagram as far as bandwidth is concerned. This was your polar scheme, just put everything in a proper perspective. This was your polar scheme spectrum. Mind you it might give the impression that the spectrum is 0 beyond this, please remember it is not, right. However we are mainly concentrating our attention on this portion of the spectrum, that is the main lobe portion of the spectrum. For bipolar we will get our 1st 0 crossing at f0 instead of 2 f0, for split phase once again we get it here. So it has some advantages with respect to, at least the polar case, in the sense that we have a spectral null at 0, just like the bipolar what does, right.

But the bipolar spectral null was obtained by coding, the manchester spectral null is obtained by pulse shaping, right, that is the essential difference. Now, so is there any possible advantage of split phase over bipolar whatsoever? We already have seen that it bandwidth is totally not very nice, not very interesting, it is twice.

Student: (())(53:44) 3 db will not be there.

Professor: 3 db advantage, yes, that is there, 3 db advantage is there, it has the same properties in that as far as the polar is concerned. But there is one more advantage it has and that is if you look…

Student: Long string of zeros and ones…

Professor: That is right, it will be absolutely transparent to long string of ones and zeros because no matter whether you are having 0 transmission or 1 transmission, you will always have a change in, there will always be a transmission from 1 to -1 and -1 to1 because of the peculiar shape that we have used, right. Because of the shape of the pulse there is guaranteed to be a transition, right. So any scheme which is manchester coded, any data sequence which is manchester coded will be transparent to long string of ones and zeros. So from point of view of timing extraction and synchronisation, it is a good, good shape to use a bandwidth is not a constraint.

If bandwidth is not a consideration in some applications may be so, one can consider manchester seriously because of this convenience that it gives you. All right. But except for this fact, generally, its other properties are not very desirable properties, particularly the bandwidth 1 and therefore one has to be careful before using it.

Student: Sir.

Professor: Yes?

Student: (())(55:15).

Professor: This word i am just using a bit casually, it means that it does not matter if there is a long string of ones and zeros, we do not lose a work timing synchronisation because we discussed that earlier, we get a long string of ones and zeros, there is a distinct possibility that we may lose our synchronisation for some time. We will have to acquire synchronisation again, we will have to take a, make sure that our loop gets back into recommendations fast as soon as this phase disappears, right. If on the other hand if we do not have this problem, then we say that we are transparent to whether the data sequence as of this type or that type, it does not really matter to us.

Student: This part (())(56:04) long string of ones and zeros in synchronisation.

Professor: I have not, the reason it may not be clear, although i did try to mention something about it is that we have not yet discussed any synchronisation scheme, right. But the essential fact in any synchronisation scheme is that it has to derive timing information, and the clock information from the received data, right. And the clock information, roughly you can imagine will be containing the 0 crossings or bit transitions, right. The more the number of bit transitions, the more regular bit transitions you have, the better it is for the timing rate of the circuit, right.

If on the other hand for a period of time if bit transitions disappear for whatever reasons, because of the kind of data that is being transmitted, we will have problem in extracting the timing, that is what we mean, right. That is why long string of ones and zeros are not good for the timing extraction point of view. So unless we make our coding transparent to this, right, that is it should not matter, even if we have long string of ones and zeros, we continue to get 0 crossings or bit transitions.

Student: (())(57:19).

Professor: That is right, it will be difficult to recover the clock from the received signals which is important for carrying out the demodulation functions, decoding functions, okay. Let us, let us come to hdb coding, time is up, okay. I will just take a few minutes i think, let me complete this because i will not be really going to the details of this. If you will be kindly patient for a few minutes.

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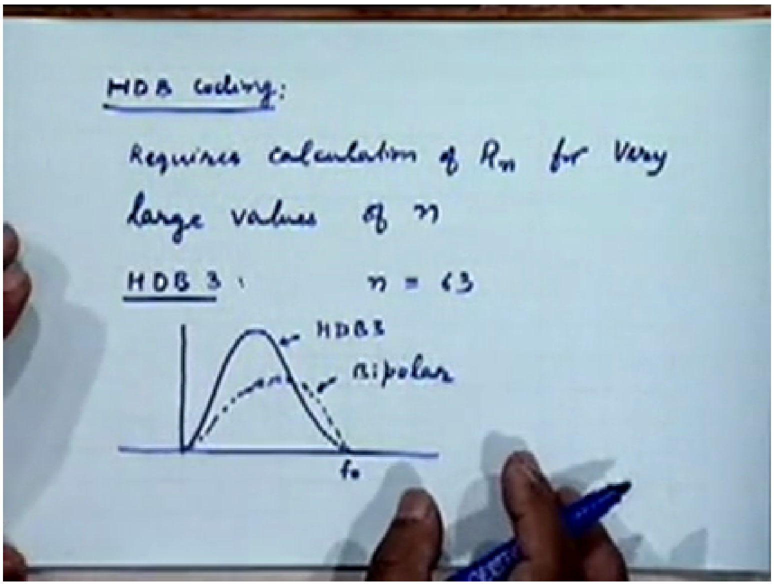

Okay why i am not going to take much time is because i am not going to take the spectral (()) (58:02) of hdb coding in detail. The reason is it is very involved, okay. That is why i am not going to do it here and therefore we can cover this topic quickly and finish off with this. Basically, what turns out is that if we try to do the spectral analysis in the manner that we have been doing so far, the other methods of doing spectral analysis which we have not discussed, right. But the ones which we are discussing require us to calculate the autocorrelation coefficients ris, over whatever period they exist, they are nonzero, right.

1 become nonzero, then okay, then we can go ahead and do the calculations. It turns out that for doing this for hdb coding requires you to calculate rns for very large values of n, right. As an example if you were to consider hdb 3 coding which is the simplest to analyse because n is 3, you need to go up to n equal to 63. So you need to evaluate r0 to r63 to be able to compute the spectrum because it does not become 0 beyond, before that, right. Or it does not become small enough before that.

If it does not become 0, it will at least become small enough to ignore, right. So it so turns out that you require a very large number of terms in that spectrum calculation to be able to compute it reasonably accurately. But obviously such computations have been done and results do exist and i will just give you a feel for the hdb spectrum with respect to the bipolar spectrum. Suppose, both of them if you remember, well bipolar if you remember has a spectral null at, or the 1st 0 crossing at f0, right, so does hdb 3, this is hdb 3, this is bipolar, okay.

As far as the main lobe width is concerned, they are the same but there is a slight difference in detail, in terms of actual shape of the spectrum and its concentration in the main lobe, right, except for that difference they are really very similar, okay. So i thought i will just tell you this and mention the fact that hdb 3 also has the same error detection capability as bipolar does, right. In spite of the fact that we violate those inversion rules, right. We get after 3 zeros, we get, we transmit a 1 with the same quality as the previous 1 rather than opposite polarity.

Can you imagine why we can still use error detection, use this kind of scheme for error detection? Because what i, suppose there is an error, what will it do? It will either delete a violation that we have carried out or introduce a violation of its own, right, these are 2 things it can do. Now each of these facts you can satisfy yourself will be detected at the next violation point, where we expect there should be a violation, we will find that it does not exist.