Digital Communication
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Lecture – 18
Passband Digital Modulations – II: Offset QPSK

We were talking about binary passband signalling right and as a slightly more general case of binary signalling than the primary PSK we are actually looking at what we can actually call 4-ary scheme although we are under the general title of binary scheme at the moment that is the quadrature phase shift keying right, it is because we thought that each of the two quadrature carriers when modulated in BBSK manner in a anti-podal manner gives rise to the quadrature phase shift keying that we talked about.

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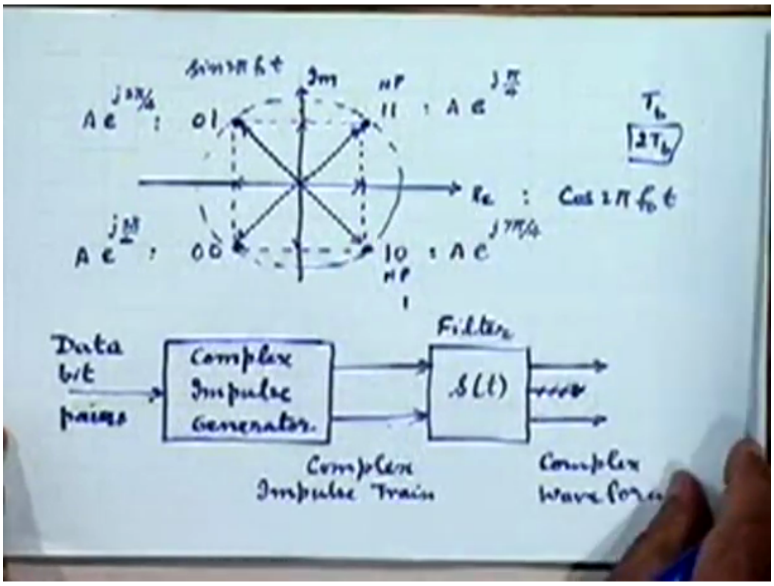

And this was the picture that I think I showed you at that time this constellation diagram corresponds to QPSK to recapitulate for you we have two quadrature carriers in QPSK, each modulated by possibly one or the two bits that either we can think of these two carriers being independently modulated by two streams, two bit streams or on a block basis that is we take two bits at a time and use one of this points as a signal for representation of those two bits.

As far as the modulation is concerned therefore you can think of this being the cosine part of the carrier and this being the sine part of the carrier so you are doing an anti-podal modulation in the cosine component as well as in the sine component on the quadrature component right, so depending on what which sequence you have for example if two bits have 1 1 then we have cosine 2 pi f0 t and you also have sine 2 pi f0 t being simultaneously represented right.

That is this will be represented by this amplitude of this carrier and this amplitude of the sinusoidal carrier right and the resultant phaser that you will get is this point right similarly you have many have 0 1 your quadrature the in-phase carrier is minus cosine 2 pi f0 t and the quadrature carrier is plus sine 2 pi f0 t and the resultant of these two is this phaser this is the net signal that you end up sending and so on for each of the 4 possible phases that you can have right, corresponding to the 4 bits that you can have.

Now how you allocate these bits to the corresponding waveforms or the corresponding phases is somewhat arbitrary except that it is useful to follow a certain pattern for example if you might notice in this diagram I got this point representing a 1 1, this point representing a 0 1, 0 0 and 1 0 do you notice any pattern in this scheme of things in this representation of these 4 points on the constellation by this respective bit pairs.

The gray code transformation that is as you go from 1 point on the constellation to its neighbouring point on either side of the neighbourhood right you only change 1 bit in the representation that is I am representing this as a 1 1 and this as a 0 1 where as this one has gone through a transition, similarly as I go from here to here this represents a 1 0 can you guess a reason as to why this will be useful to do that? Any suggestion on that why do we (()) (05:15) Can you elaborate how? Yes that is a good answer but

Student: (())(05:26) Not like that

Professor: Okay it is really very simple now when you are of course we are going to talk about it in detail when we talk about demodulation but roughly you can see that error in this case refers to the event that I might confuse or wrongly decide when I really transmitted this point on the constellation I might wrongly decide that the transmitted point was this or this or this, these are the likelihoods, when you are making your decision at the receiver in the presence of noise you make one of this wrong decisions if ever you make a wrong decision right.

Now the most probable wrong decisions would be those which correspond to adjacent symbols or adjacent points in the constellation because they are the ones which one can easily go to between noise right so therefore when that happens we would like to make its impact as small as possible on the original binary bit pattern right and therefore you want to make sure that you may be symbols do not differ from each other for more than 1 bit.

So if it all there is a symbol error at the receiver it gets converted to only a single bit error rather than multiple bit errors so that is the advantage of using gray coding representation or gray code mapping on the constellation diagram, so are these points clear? Now also to further recapitulate for you we had discussed certain disadvantages of the QPSK waveform right and the specific disadvantage was we could easily have incoming bit pattern which takes us from seceding bit pairs going from 1 1 to 0 0 or 0 1 to 1 0 right.

In which case we can expect 180 degree phase transition should take place in the waveform right for example we had first pair as 1 1 and the next pair as 0 0 they are going from this phase to this phase which is 180 degree opposite to the previous phase or similarly I might go from here to here so it is quite possible that at various stages in the waveform you will have a 180 degree phase shift transitions which are undesirable.

Particularly when you finally band limit this waveform such 180 degree phase shift variations will cost the envelop of the signal to go through zeroes so essentially you will get a non uniform amplitude or a non constant envelop waveform right after filtering if you have infinite bandwidth it will not create any problem, if you have rectangular pulses but we know that finally we are not going to have rectangular pulses.

And therefore these 180 degree phase shifts transitions really mean that you have to go through an envelope variation which goes through zeroes right it becomes zeroes in between the amplitude does not remain constant throughout after filtering. Now to offset that effect let us see what we can do let us return to this constellation diagram again, in this constellation diagram I had represented this point as say let us say corresponding to incoming with pair of 1 point and how did I generate this incoming bit pair 1 1?

I looked at two successive bits coming in right and then mapped those two successive bits onto this point, now this is actually a slightly artificial way of doing things if you may notice because I have to wait for two bits look at what the bit pair was and then carry out this mapping, I could as well carry out mapping as in when each bit is coming along and each bit is coming along at let us say specific interval T sub b right.

And you are doing this mapping as we have talked about at intervals of 2T sub b right because you are going to wait for 2 but intervals to look at this sequence or the sequence or this sequence and decide which of the constellation points needs to transmitted, now what I could do was I did not wait up to the second bit to come along and then decide as in when each bit comes along I let it decide now what the next ways will be right.

So as if your choice on the constellation is decided by not the two bits by not looking at the complete pair first and then deciding but it keeps on making your transition every T b seconds you are still looking at T bits right, you had a previous let us say you had a previous phase here somehow right now at the next, after T b seconds one of these bits is going to change, one is going to remain constant. Because every T b seconds only 1 bit will be changing right let us say one of them changes and you come here.

Student: We cannot come here.

Professor: It has to come here because only one of the bits is changing at a time.

Student: Sir there is difference between, this one is 1 so (())(10:57)

Professor: Let me first explain then you please ask you doubts let us say this corresponds to previous and this corresponds to new right now after T b seconds, after T sub b seconds this will disappear right this will be become previous and you will get one new bit.

Student: Sir that means you cannot come down anyway.

Professor: No okay depends on what the new bit is you will either go down or go up now, now okay, right okay you are absolutely right, yes because the new one, because the previous one now is 1 you will come here right, I think I will have to wait further on this point, main point is yeah so either you will stay there or you will go in this side, is it clear, so either there will be no phase transition or there will be phase transition of how much, you have gone from here to here, 90 degrees right. Similarly if you are here again this 0 will move here right and therefore you should be either moving here

Student: No sir one will move right, 180 and 90 both they will stay there or go up.

Professor: This is previous, this is new, this becomes 1 here by depending on whether it is 0 or 1 either it will move up

Student: Or 180 degrees.

Professor: No we will not have 180 degrees, I can have 180 degrees, no I thought 180 was out of the question

Student: Sir but it is

Professor: Okay we return to this point although

Student: Sir the incoming bit is 0 then it will move to left and then 1 then move to right then wait for next bit and then move to this one, it is 0

Professor: See to start with you had 1 0 and we are interpreting this to be the previous bit and this to be the new bit right.

Student: Sir it will ignore 1 surely it does not have to be take into consideration that a previous one.

Professor: Yeah the previous one will disappear and a new one will come which could be either 0 or 1 right.

Student: So if it is 0 then it should move to left, if it is 1 to move to, no no no.

Professor: I think I am making some mistake in explaining it is actually should be quite obvious that you are only changing one bit right and therefore you can only go to one of the neighbouring points because you are only changing one of the two bits.

Student: Sir I think 1 0 and 0 1 change, 1 is the previous bit sir, in 1 0, 1 is the previous bit, sir 1 is the previous bit. 1 is the previous bit because you move to, from 0 0 you move to 1 0.

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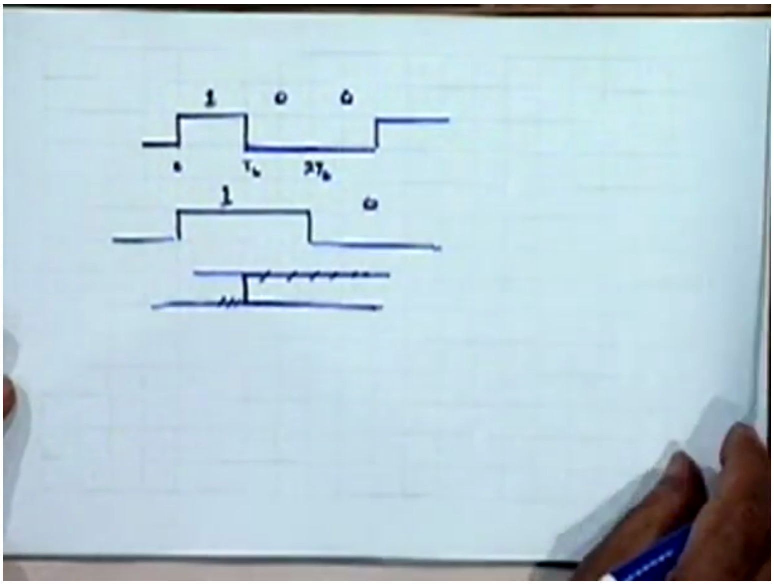

Professor: I think I will try to explain it in a different way first and then comeback to this diagram maybe we will ignore this confusion for a time bit. Yes I think better finish this explanation otherwise this will only create trouble, I took it for granted that it will be very easy to explain now let us try waveform, corresponding to this so let us say the point is that every T b seconds, T sub b seconds you are going through a, can we have some quite please.

Every T sub b seconds we are going through a bit transition right so let us say we are resolving it into basically what we are doing is we are extending each bit to really to an interval which is twice this I think this is the mistake which is that constellation diagram is not everything in the case of this particular scheme that I am talking about now, we are really extending this to twice this interval right.

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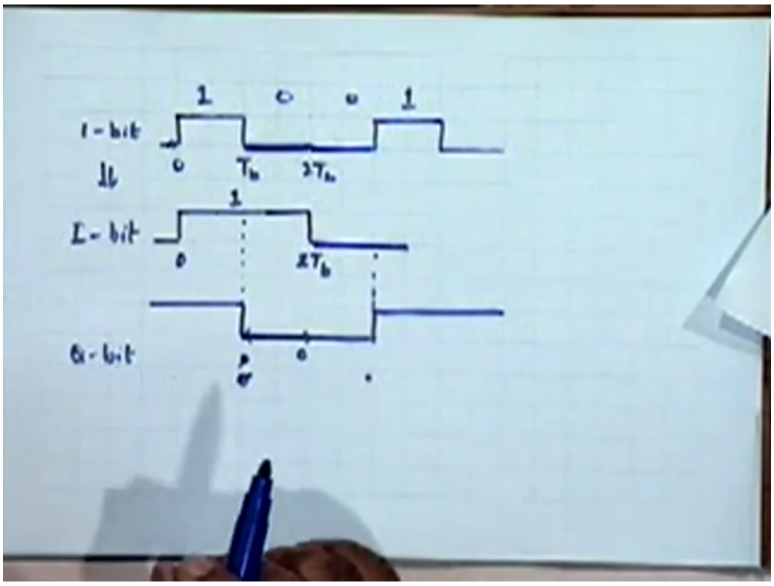

Similarly the next one will come along and the transition is here, I am sorry it should have been, right this bit is extended up to here and the next bit goes up to here so this is 0 this represents this 1 here and this 0 is represented by this right, let me (())(17:14) take a fresh page, you have an incoming bit stream corresponding to 1 then 0 let us say again 0 right and let say then 1 and so on right what we are really doing is, we are now looking, the change is being made.

I think the reason why we are making, we are getting confused there is because the change is being made only by 1 bit every T b seconds where as the change is retained for a duration of 2T seconds, 2T b seconds, so we have these are you bit intervals, what I really do is, actually this is the point I should have first explained before I go to the phaser diagram, we need to look at two bits in interval of 2T seconds but the way we are doing that looking a slightly different from what we are doing earlier.

Since we are looking at 2T seconds we really let this bit extend up to interval of, so I am converting this one bit stream into two bit streams, the I bit stream and the Q bit stream right you can think of this process as follows, I am converting this into two quadrature bit streams one I am calling the I bit stream the other I am calling the Q bit stream right, the image of this bit stream basically I have half T bit rate right.

I take alternate bits of each let us say that even bits going to the I bit stream and the odd bits can go into the Q bit stream right, so the even, let us the first one, the 0 th one is 1 is extended over in interval of 2T b seconds and this how it is represented, the next even bit is this 0 right and this is how it goes right and now let us see what happens to the Q bit stream to start with you have a 0 let us say before that suppose this was 1, I have not show that.

So at this point you have a 0 and this 0 will possessed up to this point and the next one is a 1 so it will posses up to this point right and now actually this is the important thing what you will see is that the transitions in the two bit streams are really offset with respect to each other by a bit interval right they are not occurring together this was a mistake we were making when we are looking at the constellation diagram without regard to the physical processing that we are carrying out right.

When you regard them as occurring together basically that is what QPSK is, you just look at these two bits together and then decide a point in the constellation right now what we will do is we look at what is happening at each of these point right so as you can see either in a particular interval of T b seconds whichever you might take the previous one of the bits will remain constant and one of them is going to a transition right.

No matter which interval of T b seconds you take right so you can only go from the present bit pair value to one of the neighbouring bit pair values is it clear now and therefore you can only move from any point in this constellation to one of the neighbouring points of the constellation right that clears you.

Student: The last state sir, last state.

Professor: Suppose you have 1 right this one of this I streams is going to remain at 1 now this 1 may change or may not change depending on what you had here right but no matter how it happens whether it changes or not only one of the bit, two bits is changing right if only one of the two bits is changing and you have a gray code mapping you can only go to a neighbouring point because of gray code mapping right, is it clear.

Because you had a gray code mapping and only one of the two bits is changing after T b seconds so every T b seconds you are moving from any point in the constellation to one of a neighbouring points that is the whole point right so I think the explanation that we have given earlier was faulty because it was not taking into account this particular mechanism by which we were creating the phase transitions, is it clear?

So therefore this kind of quadrature phase shift keying it is still quadrature because we will still have at any time four possible phases right but you are only going to go through phase transitions of 90 degrees by a mechanism of offsetting of the bit streams in the I and Q streams, the bit patterns in the I and Q streams are offset with respect to each other by a bit interval or by half the symbol interval if you call 2T sub b, a symbol interval then we are offsetting these two bit streams by half the symbol interval.

If you can address your question this way please I think others will also benefit whatever doubts you may have, Deepankar speak out, is it clear? Anybody Vivek, is it fine, is it really clear, you can speak out if it is not clear I may explain again it does not really matter if you slow process a little bit because it is a fairly important point to understand. (())(23:09)

Okay I have what is really important is to realize that two bit stream is based on this I mean this 0 here corresponds to this 0 here right the next 0 here will come after, sorry this 0 here is there, this 1 here, every bit is therefore being extended to twice its duration because you are looking at new bit every T b seconds but the processing is done on a symbol basis where symbol is two bits.

Right, you can think of the gray code basically remember each of the quadrature carrier is being modulated by you can think of as a I and Q bit streams right so it is either being modulated by I stream which is modulating the cosine carrier and the Q stream is modulating sinusoidal carrier right so depending on where you are on this and where you are on this you will be on one of this force. (())(24:31)

No way transmitting the signal continuously but now the transitions will occur every T b seconds in the QPSK the transitions were occurring every 2T b seconds so what we have really done is they have traded off the points of transition which were earlier occurring at a slower rate right by the magnitude of transition, the transition themselves are now occurring more frequently every 2T b seconds in this manner right.

Earlier we were looking at these two things together as a bit pattern 1 0 and transmitting this phase then we were waiting for 2T b seconds looking at the next bit pattern 0 1 and transmitting this fifth phase right, now I will go through many more transition, I will go through a transition here another transition here and so on and so forth.

Student: Sir in the early case the energy relation would have been not there (())(25:34)

Professor: No the Nm section, there is no Nm section even now the gray coding advantage you still posses (())(25:41) not as one bit as one single

Student: As one signal, so then the concept of having a change from only the one point to other is (())(25:55) in this case we can say that you can go only (())(25:58) 90 not 180 between that.

Professor: That is the point it is not the question of error correction it is a fact that earlier in our earlier signal things we could have 180 degree phase shift or transitions in our new scheme of things we could only have 90 degree phase shift (())(26:16) transitions but the transitions will now occur every bit interval basis rather than every pair of bit interval basis right, this scheme of QPSK is called offset QPSK in which the incoming bit stream is first split into two streams I and Q and then each of them modulates one of the two quadrature carriers and then they are added together right.

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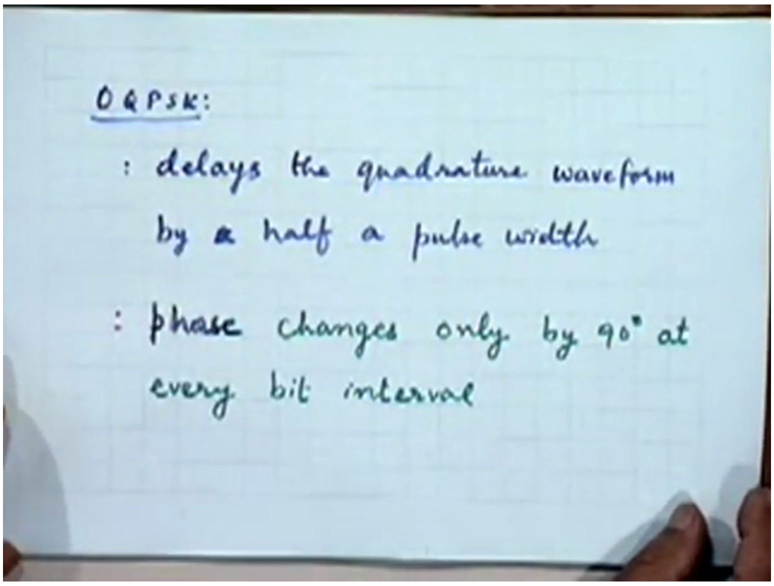

So that is offset quadrature phase that the two pulse is in the two string pattern, two bit patterns offset with respect to each other by an interval of one bit interval or half the symbol interval right so I hope this is now sufficiently clear even though I have had to rather explain it rather painfully it was actually a very simple thing, let us therefore talk about OQPSK mathematically now, if you have physically understood what is happening here.

Let us go through a mathematical characterization of the offset QPSK so basically what we have seen is that offset QPSK delays the qudrature waveform by half a pulse width okay and way I am defining the pulse width as that corresponding to a pair of pulses, a pair of bits and then result is that the phase changes, can you see this colour alright, that is the writing very smoothly.

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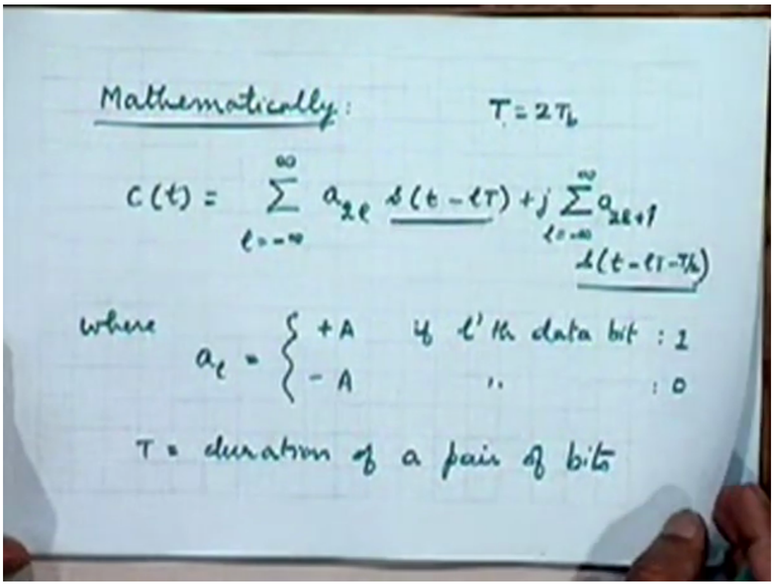

Let me try this, yeah I think I will try green okay I will change that colour no problem, phase changes, this you can see clearly only by 90 degrees at every bit interval right fine so mathematically we can say something like this if you want to write my modulated waveform you can think of this as actually a sum of two modulated waveforms in which the I stream modulates that to the in-phase carrier and the Q stream modulates the quadrature phase carrier right.

It is one way of looking at it or the even bits modulate one of the carrier and the odd bits represents analogue carrier and the even and odd bits have pulse shapes associated with each other which are essentially offset with respect to each other by half T bit interval half T pulse width or half T symbol interval not bit, half T bit interval so you can think of this even bits being represented by A sub 2l and associated pulse shape being s t occurring at, not 2 lt because you are having a new pulse every T seconds.

Okay let it be right right you are absolutely right but this T here I am, this T is 2T sub b plus j times I am taking the odd bits here which are (())(30:47) a 2l plus 1 into a pulse shape s t minus lT minus T by 2 okay so this pulse is offset by this pulse by T by 2 where T by 2 is equal to T sub b right, so this is one way of representing mathematically the modulation process of offset QPSK right.

Student: Sir in the previous phase you said that the series changes by 90 degree at every bit interval.

Professor: We change, I am sorry if I made that impression it is wrong it may change in fact the better the phase changes or not will depend on the bit pattern that is coming along right that the magnitude by which it may change is at the most 90 degrees right, where a sub l is going to be either plus a or minus a depending on whether the l th data bit is 1 or it is 0 right and T is here the duration of pair of bits.

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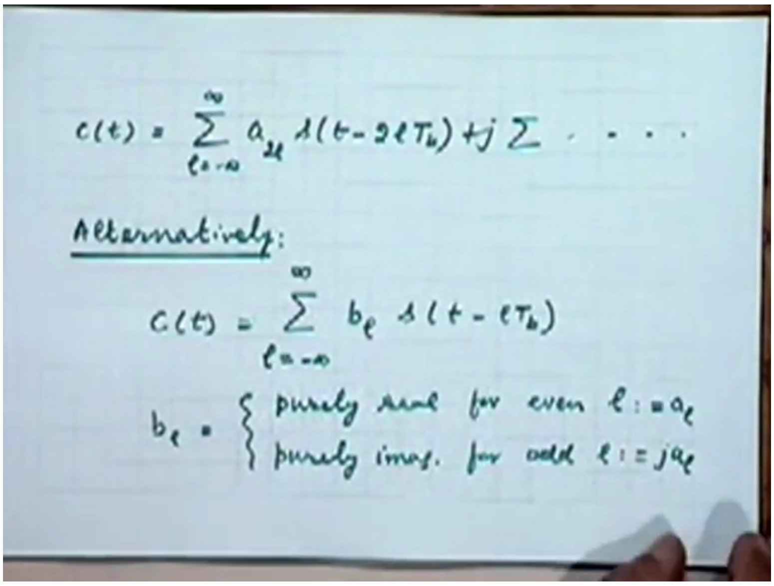

I have already given that up over there duration of it pair of bits fine. Alternatively as one of you wanted to write it in terms of T b you can do that T sub b then this will become minus 2 l T sub b and so on (())(32:42) sure, remember that the duration of each of this s t is how much this pulse shape has a duration of 2T b equal to T right but a new pulse is coming and interfering with the previous pulse every T b seconds right and deciding on the new phase right.

They are going from the previous phase to a new phase every T b seconds right so therefore is it alright can I remove this now, we can also alternatively write this modulation process as follows, I can write C t is equal to incidentally these are all baseband expression I am writing as far as the passband expression is concerned you know how to go from a complex baseband representation to the corresponding passband representation.

You multiply this with e to the power j omega c t and take the real part of that right that will give you this modulating the cosine component and this modulating the sine component that is standard so I am only writing the baseband complex envelop representation yeah coming back to this alternate representation you can also write this as b l s t minus lT b right where if you were to see you can think of these as a complex number right this b l will be now what? No this is the point

Student: (())(34:36) for even and odd.

Professor: Very good that is the point that I expected you to respond with, d l will be purely real for even bits for even l right and the value will be equal to A sub m and be purely imaginary for all l and the value will be again let us say j times a sub l right basically that same I Q bit stream concept right that even times you are only changing the real part of the carrier right changing that to either plus amplitude to minus amplitude or vice versa right.

At odd bit intervals when the Q stream becomes active you are changing the quadrature carrier that is all that is the physical picture behind this statement, so any questions about the OPQSK representation? So one thing you will therefore appreciate is that unlike QPSK where I just have to specify a constellation diagram that was a complete specification of QPSK right.

In the case of OQPSK just giving constellation diagram is not enough right I know these are the four phases but I no longer can just say that how this 4 phase phases are going to be invoked there is no immediate way by which I can associate with the incoming bit stream the face sequence that will finally come out of the modulator right in the OQPSK case right so, yes please.

Student: Sir in this upper one you know you are adding the two at c at a particular instant was some real plus imaginary, there it is either real or imaginary how can you equate the two (()) (36:50)

Professor: This is another way of looking at what is being done right that is all, there are two ways to explain that again let me go back to these diagrams right, every bit in, every even bit intervals let us say this is an even bit right nothing is going to happen to the I mean the new pulse that is coming along is this one right the previous one stays this expression does not say that the previous one has disappeared the one which was active at the previous bit interval is still there in the sum.

And to that to adding a new pulse right corresponding to this so this previous one this one is continuing but to that we are adding a purely real component here you are adding a purely imaginary component in the next bit interval while the previous one is still there right so at any point the number is still complex, it has to be because you are going to have to work

Student: Sir now did you say that b l is purely real (())(38:01) sir you have written down there b l is purely real and purely imaginary.

Professor: That is true, it is true is not it? It is the s t that is overlapping right every T b seconds there is a new s t coming in while the previous s t is still active right so at any stage therefore you are getting contributions from 2 of these s t right the previous one and the present one think about it a bit carefully this something that you can easily understand right okay.

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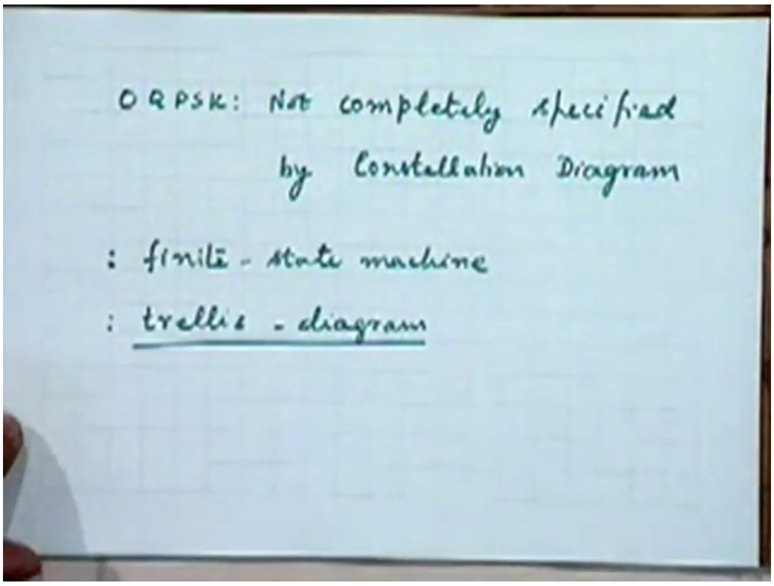

Now the point that I was making was that because of the time offset OQPSK not completely characterized by a single constellation you require something more than that for its characterization not completely specified or characterized by a constellation diagram you need to specify rules which need to be impose to constraint the phase transitions right because certain rules have been followed right and that is how you are going from 1 point in a constellation to the any other point in the constellation.

And this transitions are now governed by certain rules in the QPSK there were no rules at random you could go from one point in the constellation to another point in the constellation but now we can, we have to follow certain rules and this is best explained by viewing the modulation process of OQPSK as if you are working with a finite state machine with which you are familiar with your sequential logic and all that.

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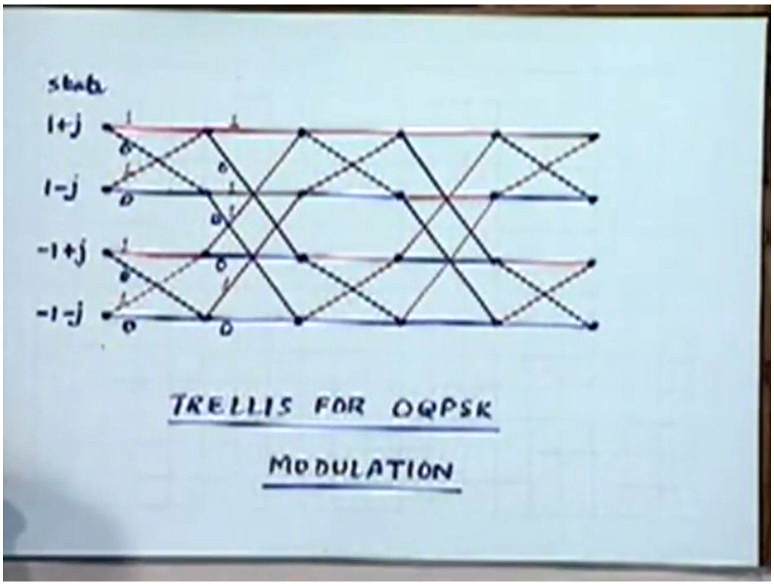

And in the digital modulation context it is conventional to represent this finite state machine action by means of a diagram called the trellis diagram so I am going to introduce to you what is a trellis diagram the concept of it trellis diagram, this is a trellis diagram for OQPSK modulation now first what is a trellis diagram basically a trellis diagram consist of a set of loads which represents that different possible states in which your machine can be right.

Our constellation diagram has four points so we can be in one of these four states corresponding to 4 points in the constellation and you know these states are 1 plus j, 1 minus j, this 1 plus j, 1 minus j refers to your constellation diagram right you can think of these point as a 1 plus j, this as 1 minus j this is minus 1 plus j and this is minus 1 minus j right, so these are the four possible states.

So you start with having this notes corresponding to these four possible states now these notes are replicated every bit interval right along time so you have one, you have a set of 4 nodes at this time, a set of 4 nodes again after one time interval and so on and so forth right, now so therefore at each time you can be in one of these 4 nodes right and as you step through the trellis you are really going through a particular bit sequence and therefore a particular phase pattern on that constellation diagram.

Now let us say you are now let us discuss our QPSK trellis diagram let us say you are in state 1 plus j right now where can you go, let us these are the even bit times and these are the odd bit times, at even bit times what is going to happen you are only going to change the imaginary components because your real component is going to stay the same is it clear? At even bit times the real component is going to stay the same, come back to this diagram, right. So what is really changing is it depends on what you are calling even or odd right.

Student: Odd will change (())(43:29) alternate.

Professor: It is the matter of definition it really does not matter, okay it is a matter of definition it does not really matter I have taken it to be that way right if we take this to be, this alternate intervals to be even and odd it does not matter how you start right so here I have only allowed a change into the state of the imaginary components so 1 plus j can thus become 1 minus j or it can stay 1 plus j right so depending on let us say whether incoming bit stream is, incoming new bit value is 1 or 0.

So 1 I have indicated but the transition that will take place this connections show the transitions right in from the first set of nodes to the next set of nodes and so on, so as a new bit is 1 you go to 1 plus j if it is 0 you can go to 1 minus j right similarly if you are initially in 1 minus j if it is 0, you stay there, if it is 1, you change to 1 plus j right and so on so basically you will see that in this interval you will have these are the various possible parts to which you can go depending on where you initially are.

If you are in this node you can either go here or here, if you are in this node you can either go here or here, if you are here you can either go here or here, here this way or that way right these are the only ways in which you can progress from time, this time to the next bit time, at the next bit time which you can regard as odd bit times right you will only be changing the real part of the component right.

So you can go from 1 plus j to minus 1 plus j or stay there right this 1 may change to either plus 1 remain plus 1 or you may change to minus 1 similarly 1 minus j can stay at 1 minus j or become minus 1 minus j right so these are the possible transitions you can have at this time again you can progress like this so the sequence of states through which you go will of course depend on your initial state and the specific bit pattern that comes along later so as a particular bit pattern comes along you will be following through the particular path in this trellis right.

So as you trace your path through the trellis you are specifying a specific bit (())(46:30) so a complete specification of a modulation scheme like OQPSK requires you to specified by means of a trellis diagram like this right it is not only the fact that you have four phases that is four points in the constellation space but also the mechanism by which this (())(46:54) transitions occur is best depicted in this kind of a diagram, you will notice, we will see later that this kind of a diagram is useful in depicting many kinds of modulation scheme which have memory in it right where the next phase depends on what the previous phases were.

There is a particular phase trajectory that you follow and therefore if there is a particular path through which you have to trace the trellis, so is the concept of a trellis diagram clear and what it can do for us? So basically a specifying sequence of complex numbers right, suppose you are following this path specifying sequence of complex numbers and what is the sequence of complex numbers specifying for us? Come on?

The phase, the successive phases of the carrier that you will be transmitting right so you start from this suppose you start from here and let us say you go here and then you go here but you know that these phases, you cannot possibly go from here to let us here this is the constraint imposed by our modulation scheme right so if we are here then we can either go here or here that is all, if you are here we can either go here or here right.

So anyway once we given a pattern we can follow a specific path in predictor, sequence of complex numbers which would be finally used to modulate your carrier okay, so that is the concept of a trellis diagram, incidentally even if you are not able to draw this here it is available in books and maybe I will Xerox some portion of this and give you this material, if you are able to draw it, it is fine.

I have to tell you that there is going to be with this is not last we have heard of OQPSK, a small variation of OQPSK can give rise to further improvement properties what is the improvement in properties we have got in OQPSK as compared to QPSK let us quickly just capture onto this point, the improvement is in the waveform that will result, the phase transition will be of smaller magnitude plus minus 90 degrees rather than plus minus 180 degrees right.

Now still we will still have the trouble when we filter this waveform because we are still having phase transitions right and therefore we are going to go through variations in the envelop magnitude, it is not going to stay constant after you band limit this waveform right because many do band limitation sharp phase transitions where they are of plus minus 180 degree kind, plus minus 90 degree kind are not going to be admissible, they are going to be smoothen out and therefore amplitude variation are going to come in.

And remember amplitude variations are not good if there are non-linearities in your system which are typically the case in channels like the supply communication channels, they are going to be not love non-linearities you have to work with for example the TWT amplifiers travelling to amplifiers that use at the satellite end are essentially non-linear devices, if you operate at a particular amplitude they will work fine but if you allow amplitude variation to take place you no longer show that again you will be going to a linear function of the amplitude right.

So it is best to keep the gain, I mean to work at a small neighbour in the operating region amplitude variations not permissible also these amplitude variations are not good from the point of view of transmitter efficiency we talked about that last time so it there is still need for looking for other variations of OQPSK which will not have any amplitude variations whatsoever.

Fortunately it is possible to do so and we will discuss one such scheme next time, it is called minimum shift keying and we will think of this in two different ways, one in which it is regarded as an extension of OQPSK and in the other in which it is regarded as special case of FSK so it is a very interesting modulation scheme, they are two different ways of looking at it, I think I will stop here and we will meet tomorrow.