Principles of Digital Communications
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Lecture - 49
Quadrature Phase Shift Keying - III

In quadrature phase shift keying that is QPSK, the input data bit stream which is a polar waveform corresponding to the binary information bit sequence is input to a demultiplexer which splits this stream into two streams; even stream and odd stream.

The even stream is generated by the even bits which are located at even bit time intervals in the input data stream that is at t equal to 0, t equal to 2 T b, t equal to 4 T b and so, on; where T b is the bit interval in the input data stream.

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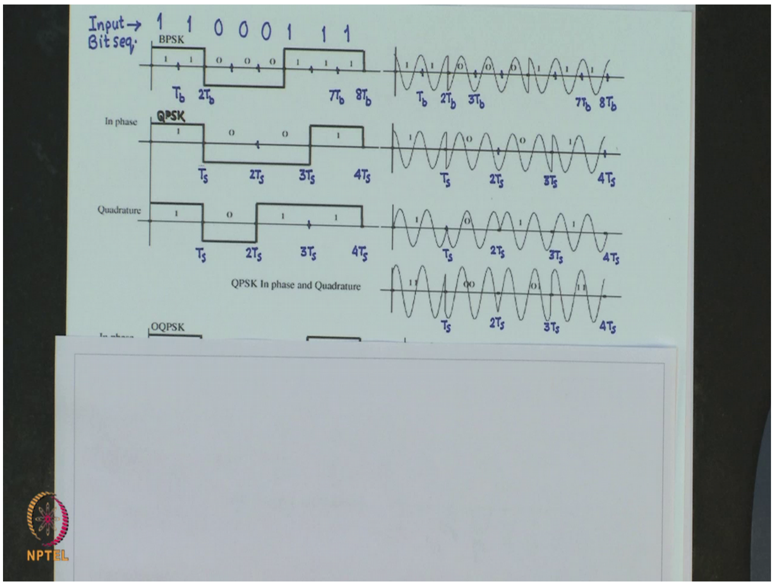

So, this figure out here depicts what I said just now, that I have the input information bit and we get the polar waveform for this. This polar waveform after inputting to the demultiplexer gets split into two waveforms one is even waveform and the other is the odd waveform. The even waveform is obtained by taking the even bits from the polar waveform given here. So, if you select 1 0 0 1 so, you generate even bit waveform here.

Similarly, the odd stream is generated by the odd bits located at the odd times located at the odd bit time intervals in the input stream that is at t equal to T b, t equal to 3 T b and so, on. The even stream modulates the carrier cos 2 pi fct and therefore, it is also known as in phase stream or component of the QPSK signal, bits in this stream are known as i bits and the odd stream modulates the carrier sin 2 pi fct and therefore, this is also known as the quadrature stream or component of the QPSK signal.

So, bits in this stream are known as q bits. So, the modulation is as shown in the figure here. So, this is a BPSK modulation and this is the modulated signal which we get from the in phase part of the QPSK and this is the quadrature component of the QPSK signal where the quadrature component has modulated sin 2 pi fct. So, the QPSK signal is shown here and this is the sum of this two modulated signals.

Now, please note that the data bit interval in both this in phase and quadrature streams are twice the bit interval in the input data stream. So, we will denote the bit interval in this in phase and quadrature component as T s, then T s is equal to twice T b. The two streams form to BPSK modulated channels which are independent; since the input bits are independent from one bit interval to the other bit interval.

Now, both of these data streams are in synchronization what this means; that the changes in phases in both these streams can occur only at the multiple of bit interval T s which is twice the T b and this changes are independent. So, you see that in phase at T s there is a change and the quadrature component also there is a change. Then again here at 2 T s this changes but, this remains the same.

Now, the carrier phase will change by plus minus 180 degrees when both in phase and quadrature components of the QPSK signal changes sign. So, here it changes sign, here it changes sign. So, here the QPSK signal will go 180 degrees phase shift and the carrier phase of the QPS that is the QPSK signal phase will change by plus minus 90 degrees, whenever one of the in phase of quadrature component of the QPSK signal changes sign.

So, if you look here these proceeds as it is, but there is a change. So, you will get a 90 degrees change in the QPSK signals phase and the carrier phase will not change when neither in phase or quadrature components of the QPSK signal changes sign. So, as long as the phase changes are gradual amplitude variations in QPSK are smooth and more or less maintain a constant envelope from one state to the other.

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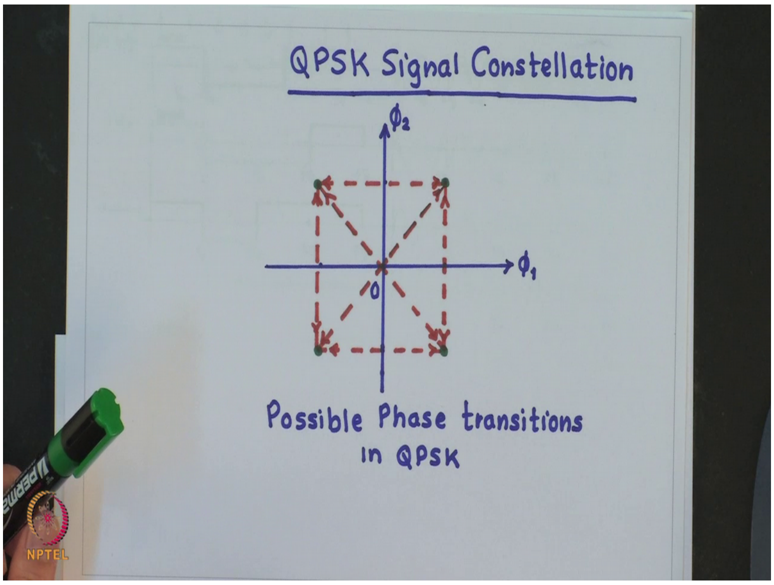

If you look at the QPSK; so if you look at the QPSK signal constellation. We see that there are four states, corresponding to the four message symbols being transmitted and here we show the possible phase transitions that can take place in QPSK. So, if you are in this state then it can either go here, it could go either here or it could go here and similarly if we are in this state it could travel in any of this dotted paths.

So, it is reasonable to assume that on an average a phase change of 90 degrees per state will occur, but when the 2 bits each in the i phase component and q phase component change simultaneously; this will happen when this point goes here. Then the carrier experiences a phase shift of 180 degrees, 180 degree phase change; however, causes the envelope of the QPSK signal to invert and this abrupt change in the envelope introduces spurious high frequency components in the QPSK spectrum.

And in a practical implementation to reduce inter symbol interference that is ISI, when the rectangular pulse is passed through a pulse shaping filter say a raised cosine filter. These high frequency components are attenuated.

However, this also causes heavy fluctuations in the envelope of the signal and this is an undesirable quality in communication systems. So, in order to prevent this high frequency components and the consequent envelop fluctuation that we use what is known as offset or staggered QPSK. In offset QPSK popularly known as OQPSK the i and q bits are offset by half a symbol period that is 1 bit period of the input data stream.

And this ensures that both the bits do not change the state at the same time. Thus, limiting the maximum phase change to 90 degrees and preventing any spurious high frequency components. So, the idea is something like this the OQPSK signal constellation is similar to what we have for QPSK, but we see that the transition from this state is only to either this state or this state, but it cannot be to this state.

So, it does not go through 0 and similarly when it is in this state or this state it cannot go either this side or that side correct. This is what is achieved in offset QPSK ok; to understand this more in detail let us look at the this figure.

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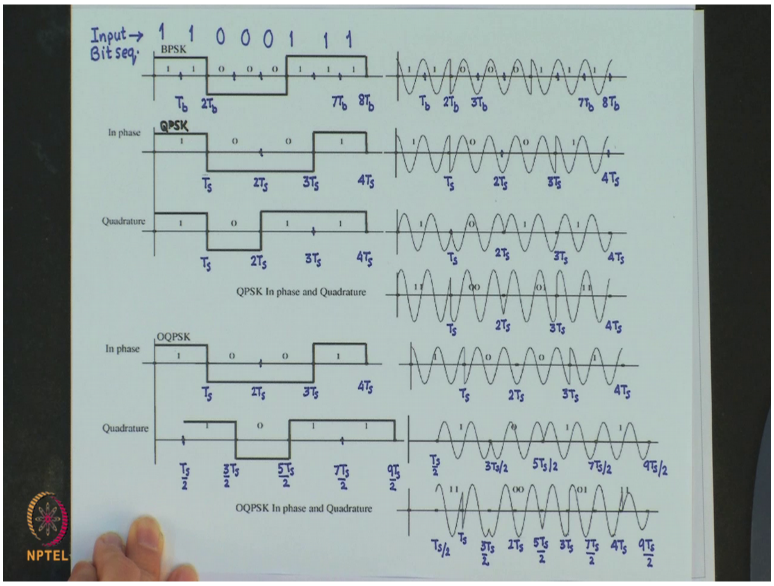

So, in offset QPSK our in phase wave remains the same as we had for the QPSK case and the quadrature wave for the offset QPSK is just shifted by a delay of T s by 2 or T b duration. So, this portion out here is shifted to the right and then this signal modulates cos 2 pi fct and this signal modulates sin 2 pi fct and the sum of these two modulated waveform gives us, what is known as offset QPSK.

Now, when we do this you can see from this diagram that during any bit interval say, if we with reference to the original bit duration; the phase can change now. Earlier this was not allowed in QPSK it could occur only at 2 T b that is at T s, but now here because of this offset of the quadrature component the phase of the carrier can change every T b seconds and, but both the waveform cannot change the sign simultaneously.

So, in this case you can never have 180 degrees phase shift in the modulated signal. The maximum phase change you can have is only 90 degree because at a time only one of this waveform is allowed to change the sign correct and that is how this 180 degrees phase shift is avoided. Let us take another example; I have another example out here.

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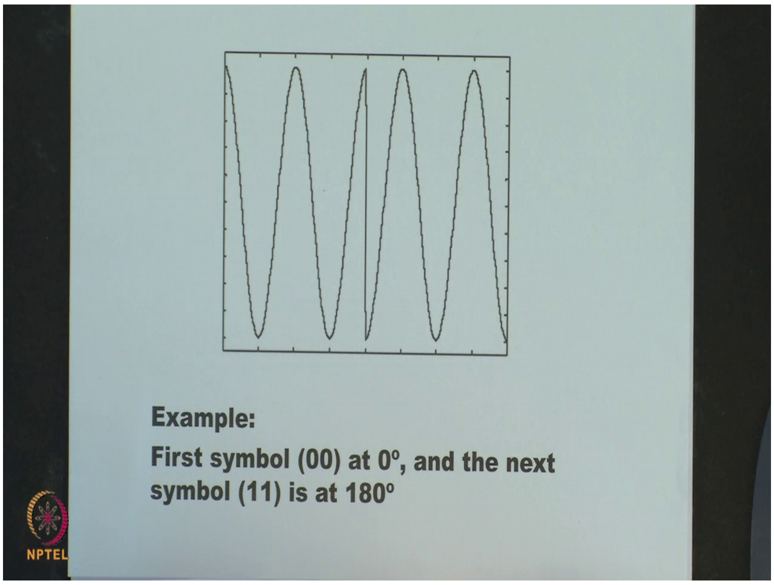

So, this figure out here shows that if I transmit symbol 0 0 and then transmit symbol 1 1 using the QPSK; then this is the output which I will get correct because remember 0 0 would be located at this point in the signal constellation and 1 1 is located in this point.

So, when you go from 0 0 to 1 1 state there will be a jump of 180 degrees; you see the jump out here correct. So, there is a discontinuity of the phase and this discontinuity in the phase gives rise to spurious high frequency which we want to avoid. Now, the same thing if we were to do it with the help of offset QPSK; the figure would be something like this.

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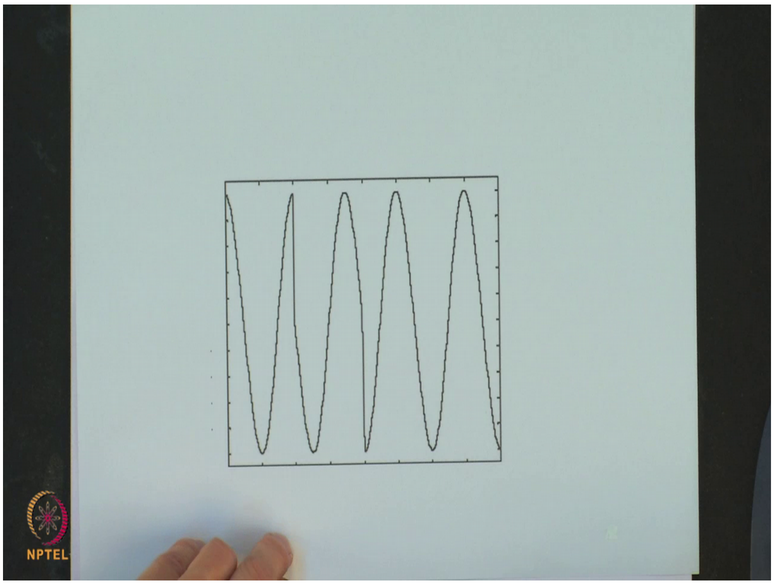

Here you will see that using an offset approach for symbol 0 0 at 0 degree, then an intermediate symbol will come at 1 0 which will be at 90 degrees, then the next full symbol 1 1 at 180 degrees.

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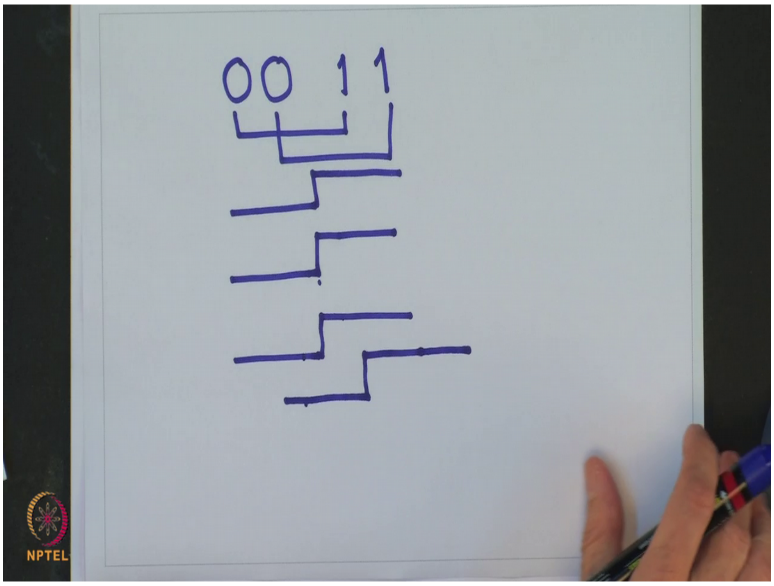

So, this is simple to see I have 0 0, I have 1 1. So, this corresponds to the in phase and this corresponds to the quadrature phase. So, in the earlier case I would have like this. So, it would be the in phase would be this and then it would go to the 1 and for the quadrature it would be like this and then it would go to like this, this not to the scale. So, at this instant both of them change, but now with the offset qs what will happen this will remain as it is and this will shift by 1 unit not to the scale again please.

So, you see basically during the T b duration this is 0 0 then it goes to 1 0 and then it goes to 1 1 correct.

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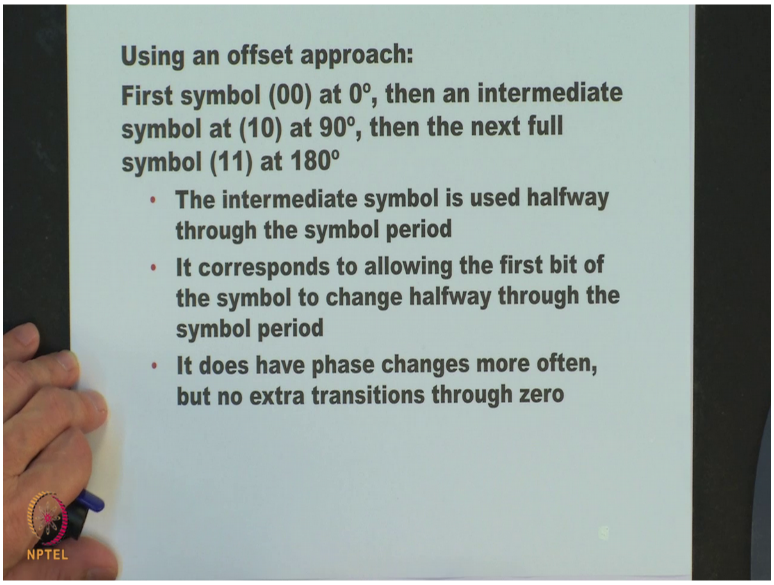

So, using this approach the intermediate symbol which is 1 0 is use halfway through the symbol period. So, this corresponds to allowing the first bit of the symbol to change halfway through the symbol period. So, it does have phase change changes more often, but no extra transitions through zero correct.

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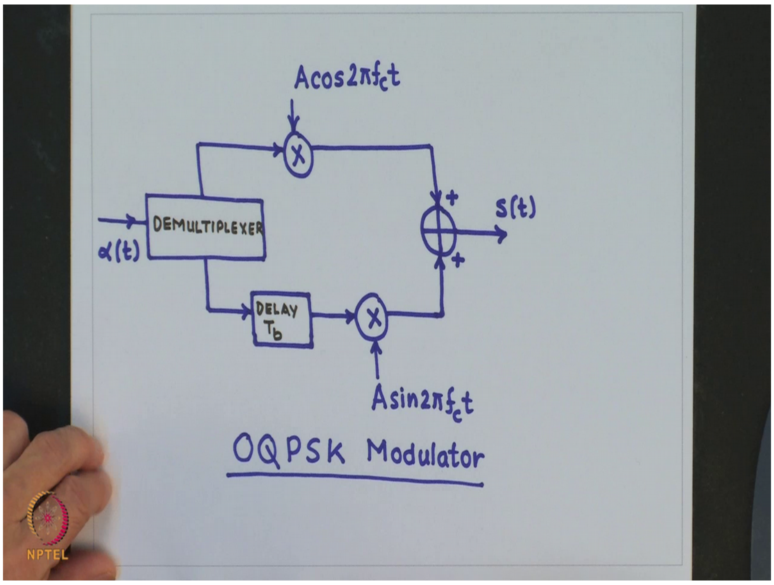

Now, the offset QPSK modulator would looks as shown in this figure. You have the input stream put a demultiplexer, we get the in phase component of the QPSK signal modulating cos 2 pi fct and this the odd stream is delayed by T b units that is T s by 2 and this modulates the sin 2 pi fct and the output is the QPSK, OQPSK signal correct.

Now, the optimum receiver for this can be easily obtained as follows, if we recognize that we can choose the two orthogonal signals phi 1 t and phi 2 t to be of this form remember; it is important to note that two streams are displaced by T b seconds.

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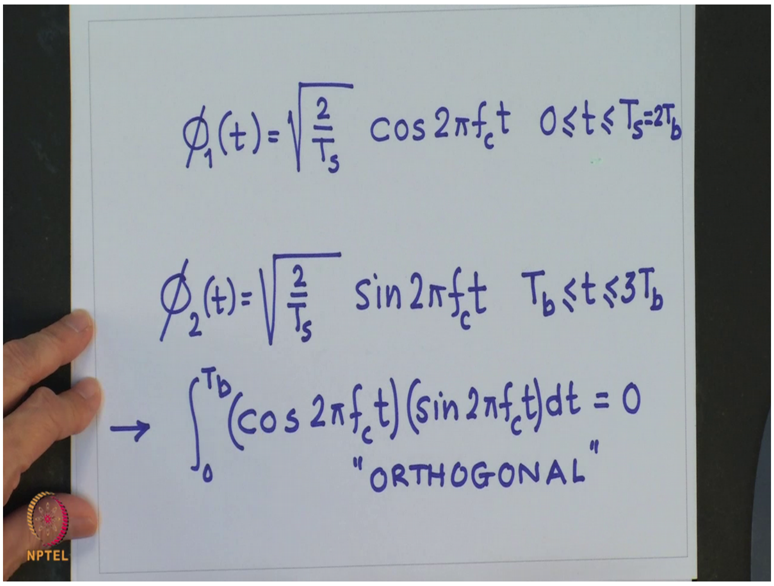

So, your orthogonal basis signals are accordingly displaced by T b second and it is also important to note that cos 2 pi fct and sin 2 pi fct; they are still orthogonal over the duration 0 to T b. This is important thing to note ok.

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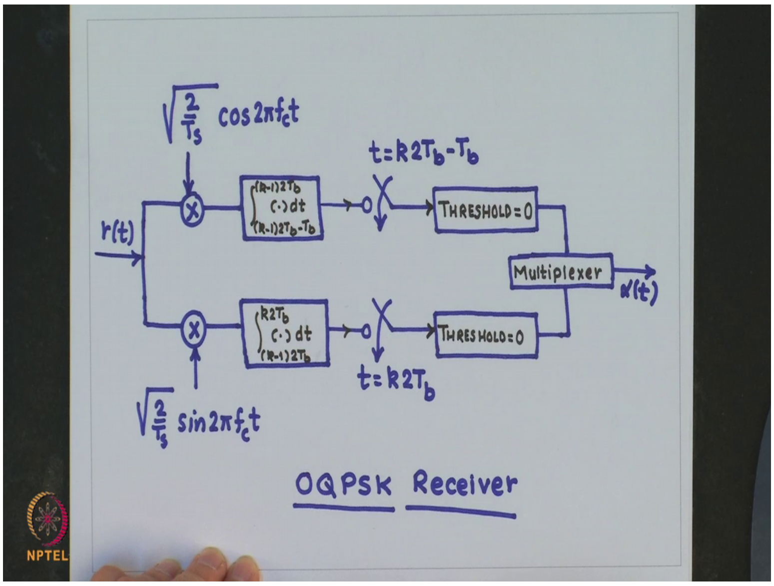

Given this, now we can find out the optimum OQPSK receiver which will looks something like this; you have the input signal, you take its projection on cos 2 pi fct and you take its projection on sin 2 pi fct and then you integrate this over this bit duration. Both the integration are over to be duration, but this integration is offset by T b duration.

And then each of this basically besides the bit which have been transmitted and then it is multiplex here and then we get the final signal alpha t. As far as the probability of error for this receiver is concerned, it will be the same as what we got for the optimum QPSK receiver because these two channels are still independent and it will not make any difference to the calculation of the probability of error.

Now, there is another version of QPSK; what is known as pi by 4 shifted QPSK.

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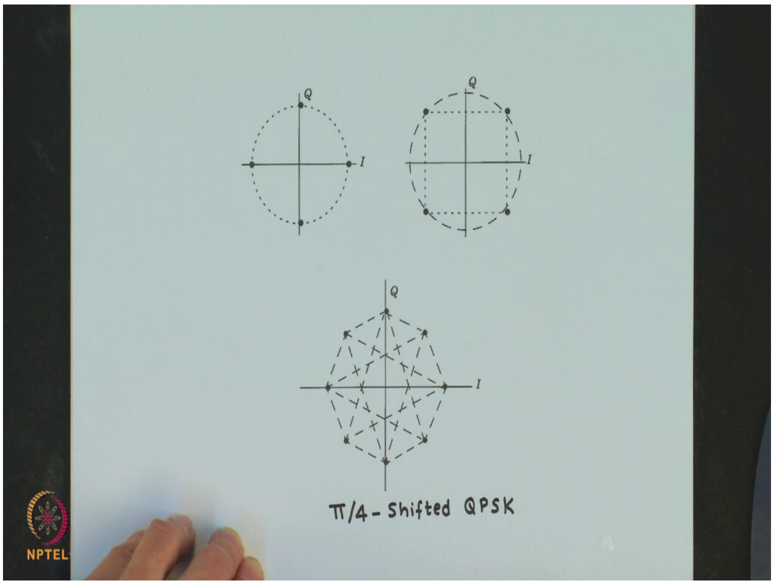

Now, an ordinary QPSK signal may reside in either one of the two commonly used constellations which are shown in this figure here correct. This is shifted by pi by 4 radians with respect to this; there is another variant of QPSK known as pi by 4 shifted QPSK. So, in this the carrier phase used for the transmission of successive symbols is alternatively picked from one of the two constellation shown in this figure.

So, one time it is picked from this constellation and the other time it would be picked from this constellation. So, it follows therefore, that a pi by 4 shifted QPSK signal may reside in any one of eight possible states as indicated in this figure correct. So, it is important to know that if I am in this state which corresponds to the state from this constellation; then next time I can move from here to either this state which is this state in this constellation or to this state which is here or it could be here correct.

So, if I am here the next time I am going to move from here either to this point or to this point or to this point or it could be this point correct. So, it is this point correct. So, from this state there are 4 dash lines emanating from each possible message point in this figure and this define the phase transitions that are feasible in pi by 4 shifted QPSK.

So, this version of QPSK will give phase changes in the modulated carrier signal which are plus minus pi by 4 and plus minus 3 pi by 4, but since it is not going through 0, 180 degrees phase shift is avoided.

So, we can say that pi by 4 shifted QPSK is in between QPSK and offset QPSK system. Now, with this we complete our study on the QPSK system. We have studied BFSK system and in the coherent detection of BFSK signal, the phase information contained in the received signal is not fully exploited other that to provide for synchronization of the receiver to the transmission.

But by making a proper use of the phase when performing detection; it is possible to improve the noise performance of the receiver significantly and this improvement is; however, achieved at the expense of increased receiver complexity. There is a version of frequency shift keying known as minimum frequency shift keying or just minimum shift keying which is a special type of continuous phase frequency shift keying; where the frequency changes occur at the carrier 0 crossings.

So, there is a continuity of the phase; unlike what happens in the BFSK case. So, MSK is a particularly spectrally efficient form of coherent binary FSK and MSK signal also can be thought of as a special form of offset QPSK, the difference being that the base band rectangular pulses which are use in offset QPSK are replace with half sinusoidal pulses. And this will study next time.

Thank you.