# EEP3010

Communication System Lab

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**Study of 8-Quadrature Amplitude Modulation (8-QAM) and Demodulation**

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**By:**

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# Experiment #5

## Abstract:

Digital data can be transmitted across a wired or wireless communication channel using the digital modulation technology known as 8-QAM (8 Quadrature Amplitude Modulation). It is a type of quadrature amplitude modulation (QAM), which combines two in-phase and quadrature analog Impulses into a single digital signal. Data is encoded using B-QAM into 8 distinct signal states, each of which is represented by a different arrangement of in-phase and quadrature amplitudes. Typically, a digital-to-analog converter (DAC) and a quadrature modulator are used to create 8-QAM signals. The in-phase and quadrature signals are modulated using discrete voltage levels that are created by the DAC and then converted into digital data. The combined signals are then sent over the communication channel after being modulated.

Digital communication systems use differential encoding as a technique to encrypt signals so that only the difference between the current and prior values is conveyed, In this instance, an XOR gate is employed. Differential encoding has the benefit of reducing the quantity of data that must be communicated, which can lower the need for transmission bandwidth and data storage. The ability to apply differential encoding to lessen the transmission system's sensitivity to random noise and other types of interference is another benefit.

An illustration of the potential signal states in a digital modulation technique is called a constellation diagram. The image is a scatter plot, with the real and imaginary components of the signal being represented by the x- and y-axes, respectively. The diagram's dots stand in for various signal states, and the space between them denotes the energy of the signal.

## Objective:

In this experiment our main objective are:

- In the first part, we will be observing the Even bit, the Odd bit, and the C bit while we conduct tribit data encoding techniques for the NRZ-L data format.
- Following this, we perform Differential encoding of data. If we apply the data stream d(t) to one input of an Ex-OR logic gate and the output of the Ex-OR gate b(t) is applied to the other input of the gate, we get the Ex-OR of the input signal, written as b(t-Tb)d(t).
- Now, we examine the bandwidth efficiency of QAM and the CONSTELLATION diagram for the incoming data stream in the third portion.
- Study of bandwidth efficiency in Quadrature Amplitude Modulation techniques.
- Study of Carrier Modulation and demodulation Techniques by Quadrature Amplitude method

## **Experimental Procedure:**

The necessary equipment required for this part of experiment is :

- Experimental Kit DCL-QAM
- 20 MHz Dual Trace Oscilloscope
- Connecting Chords
- Power supply

**Tribit Data Coding Technique of NRZ-L Data Format:**

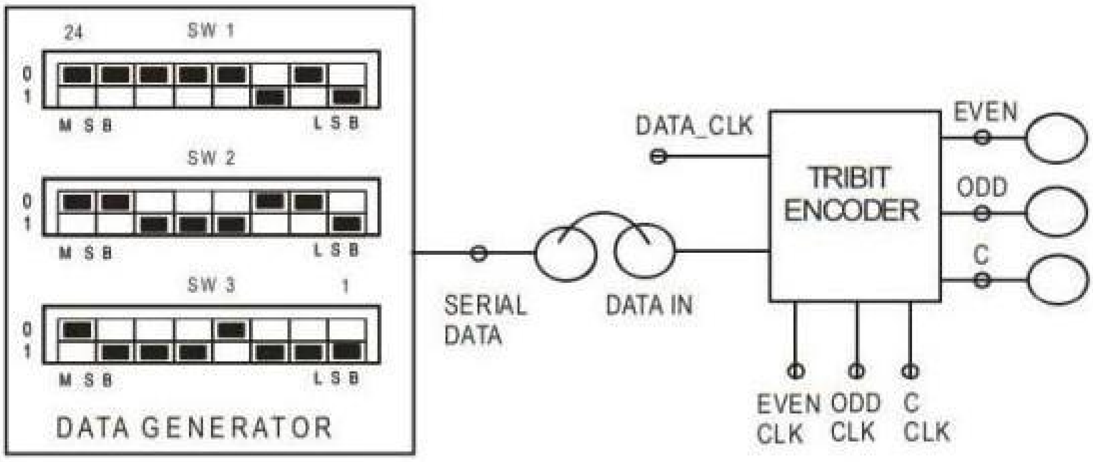
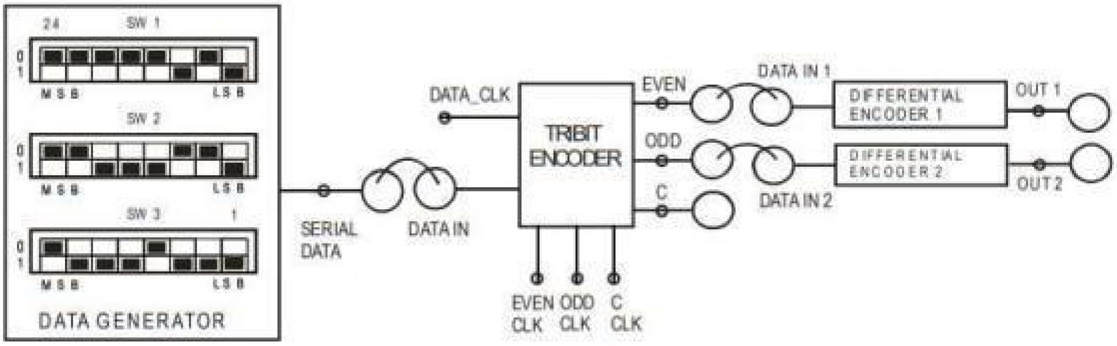



FIG 1.1 BLOCK DIAGRAM FOR TRIBIT ENCODING OF NRZ-L DATA

The procedure to do this part of experiment is:

1. Connect the components of the DCL-QAM kit as shown in the figure above and turn on the power.
2. The switches SW1, SW2, and SW3 are set up using the data generator in the manner depicted.
3. The output serial data is connected to the DATA IN of the TRIBIT ENCODER.
4. Oscilloscope display of tribit clock created at EVEN CLK, ODD CLK, and C CLK in relation to serial data.
5. Watch the waveforms on the Oscilloscope display.
6. Have a look at the various waveforms shown here. Radio wave oscillator
7. Even clock with regard to odd clock and anticlockwise, even data with respect to even CLK, odd data with respect to ODD CLK, and anticlockwise with respect to C CLK.

**Differential Encoding of Data:**




The procedure to do this part of experiment is:

1. Connect the components of the DCL-QAM kit and tum on the power.
2. The switches SW1, SW2, and SW3 are set up using the data generator in the manner depicted
3. The output serial data is connected to the DATA IN of the TRIBIT ENCODER
4. Link the resulting EVEN and ODD information to DATA IN1 and DATA IN2 on your DIFFERENTIAL ENCODERS.
5. Check out the OUT1 and OUT2 ports on the DIFFERENTIAL ENCODERS for a glimpse of the original data and the encoded EVEN&ODD values.
6. Look at the waveforms of the differentially encoded data OUT1 in relation to the coded data EVEN and the differentially encoded data OUT2 in relation to the coded data ODD on the oscilloscope screen

**Observation Of Constellation Diagram for QAM and study of Bandwidth Efficiency Of QAM:**

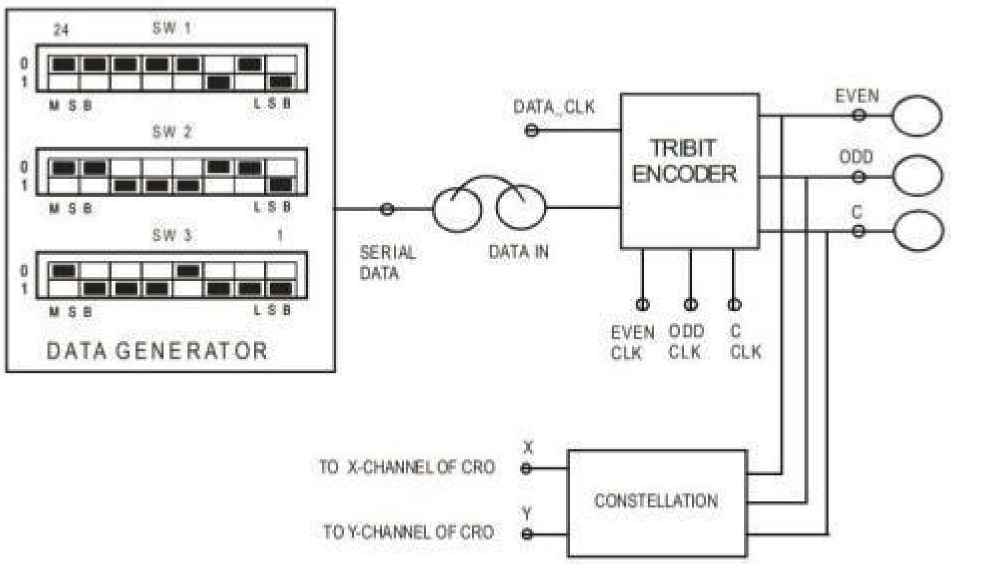
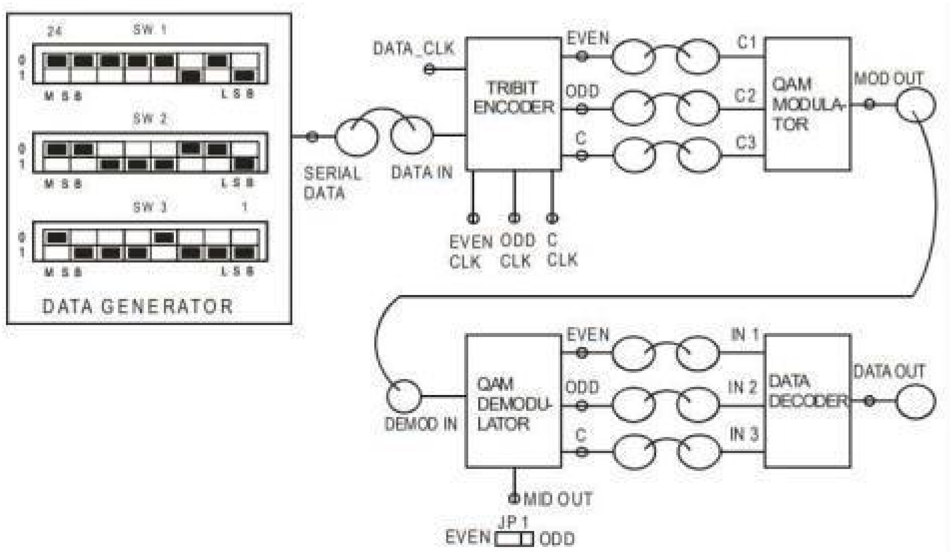



FIG 3.1 BLOCK DIAGRAM FOR OBSERVATION OF CONSTELLATION DIAGRAM

The procedure to do this part of experiment is:

1. Connect the components of the DCL-QAM kit and turn on the power.
2. The switches SW1, SW2, and SW3 are set up using the data generator in the manner depicted.
3. The output serial data is connected to the DATA IN of the TRIBIT ENCODER.
4. Join the X and Y inputs of the CONSTELLATION BLOCK to the corresponding inputs of the CRO.
5. Have a look at the waveforms for SERIAL DATA in relation to DATA CLK, EVEN DATA in relation to EVEN CLK, and ODD DATA in relation to ODDCLK on the Oscilloscope screen. Data in C relative to the C CLK and a Constellation diagram of CRO showing the distribution of the data under various circumstances.
6. Since we know that the transmission clock is 256KHz (based on our measurements in the DATA CLOCK post), we can divide this by the observed value of 3 bits per transmission.
7. The modulator bandwidth is equal to the transmission clock divided by the number of bits conveyed.

**<u>Quadrature Amplitude Modulation and Demodulation Techniques:</u>**




The procedure to do this part of experiment is:

1. Use the diagram to connect the components of the DCL-QAM kit. Once everything is wired up,tum on the power.
2. The switches SW1, SW2, and SW3 are set up using the data generator in the manner depicted.
3. The output serial data is connected to the DATA IN of the TRIBIT ENCODER.
4. The QAM MODULATOR's control inputs C1, C2, and C3 must be connected to the EVEN, ODD, and C tribit data, respectively.
5. To create a QAM modulated signal, link the QAM modulator's MOD OUT to the QAM demodulator's DEMOD IN.

6. Move the jumper (JP1) to the EVEN and ODD positions to see the multipliers' output at the QAM DEMODULATOR'S MID OUTpost.
7. EVEN, ODD&C demodulated data from the QAM DEMODULATOR should be connected to IN1, IN2, and IN3 of the DATA DECODER, respectively.
8. Check out the deciphered information at the DATA OUT terminal in DATA DECODER.
9. Check the deciphered information against the SERIAL DATA.
10. Look at the modulated signal (QAM MOD), serial data, and data output on the Oscilloscope's screen.

## Test Results:

### Tribit Data Coding Technique of NRZ-L Data Format:

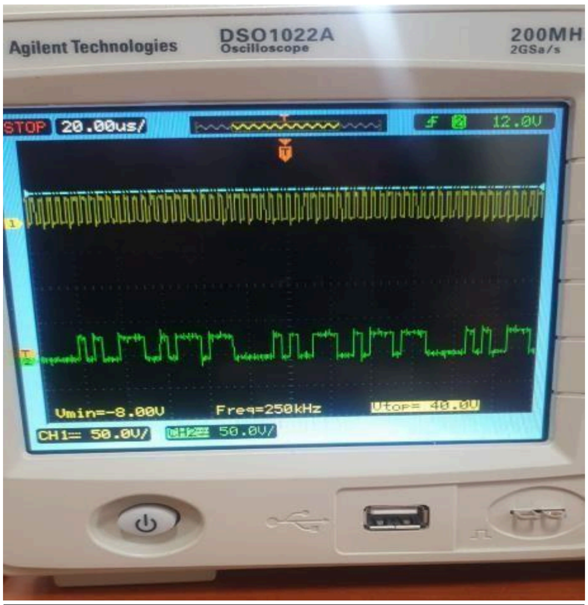



Fig 1.1 Data Clock vs serial Data

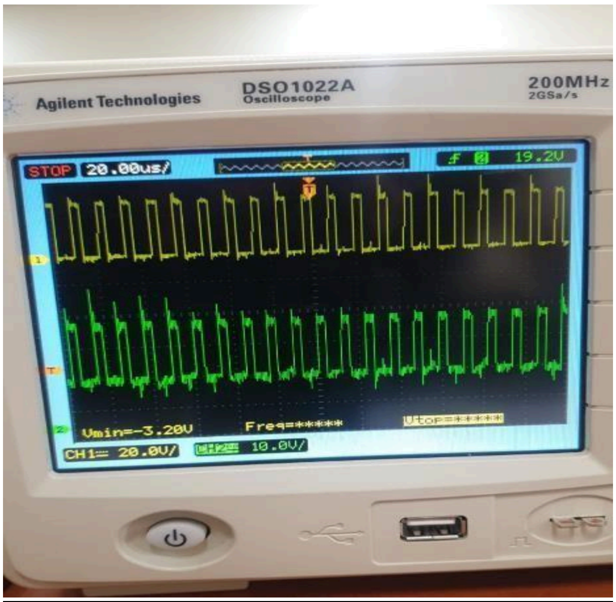



Fig 1.2 Even Clock vs Odd Clock

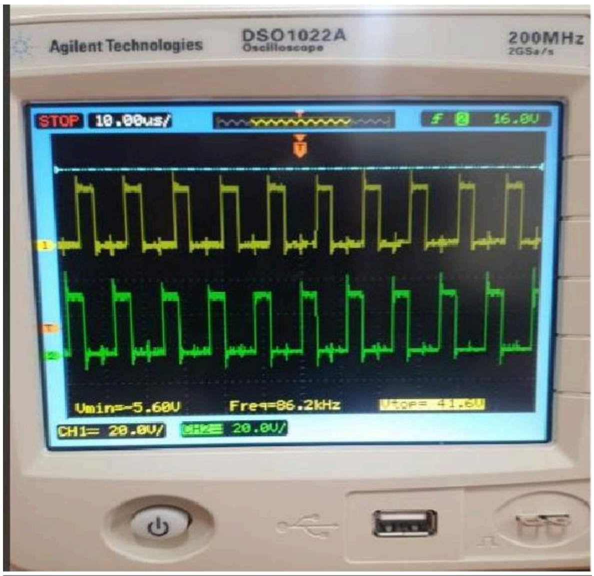



Fig 1.3 Even Clock vs C clock

In the above Fig 1.1 the yellow signal represent the clock signal and the green signal shows the serial data bits.In Fig 1.2 the yellow signal is even clock and the green signal is odd clock. In Fig 1.3 the yellow signal is even clock and the green signal is C clock.

The comparison between the respective clocks and bits are shown below:

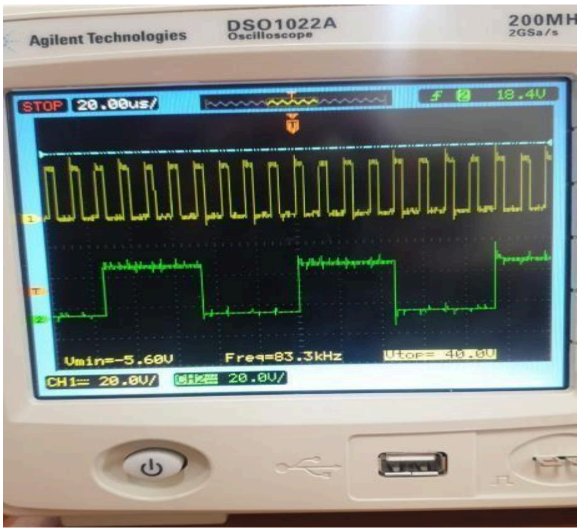



Fig 1.4 Even Clk and Even (Tribit Encoder)

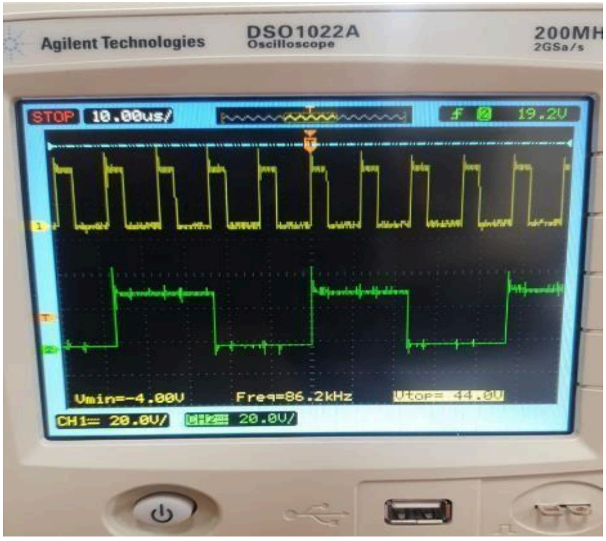



Fig 1.5 Odd Clk and Odd(Tribit Encoder)

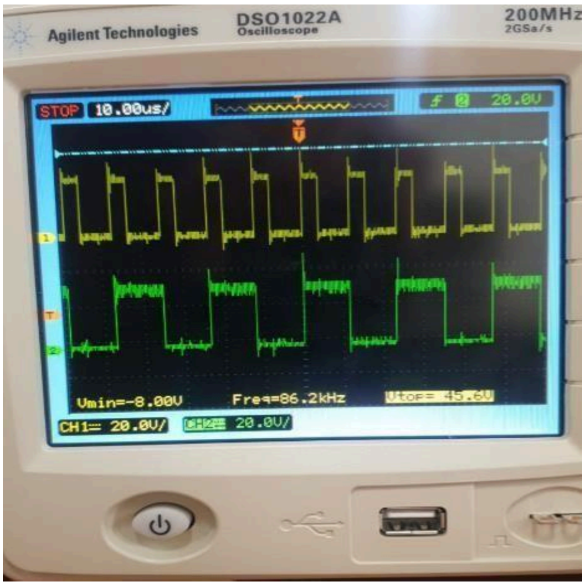
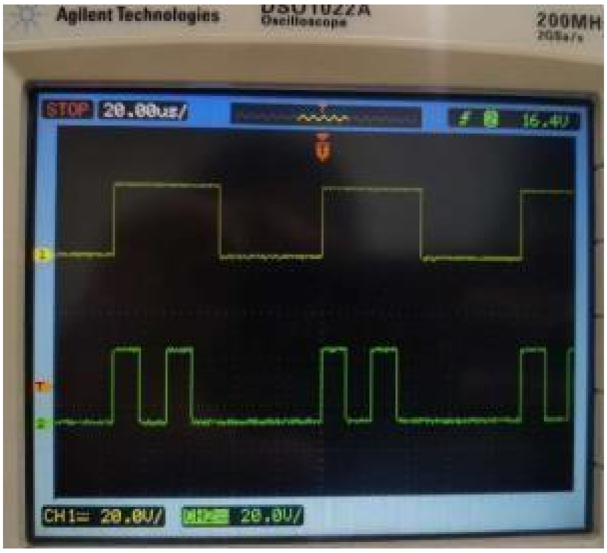



Fig 1.6 C Clk and C (Tribit Encoder)

**<u>Differential Encoding of Data:</u>**

On passing the Even , Odd and C bits from the tribit encoder to the differential encoder we get the following waveforms as Out 1 and Out 2 corresponding to Even and odd bit.



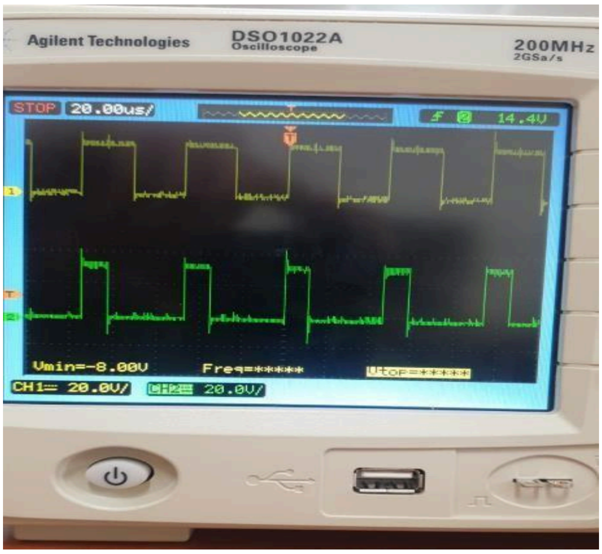




Fig 2.1 Even Bit vs OUT1

Fig 2.2 Odd Bit vs OUT2

In fig 2.1 the green signal shows the output of the differntial encoder for the Even Bit and the yellow signal shows the Even bit.

In fig 2.2 the green signal shows the output of the differntial encoder for the Odd Bit and the yellow signal shows the Odd bit.

**Observation Of Constellation Diagram for QAM:**

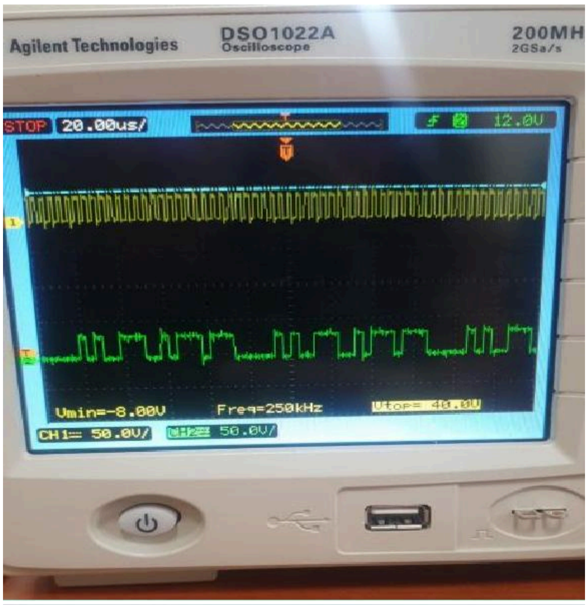



Fig 3.1Data Clock vs serial Data

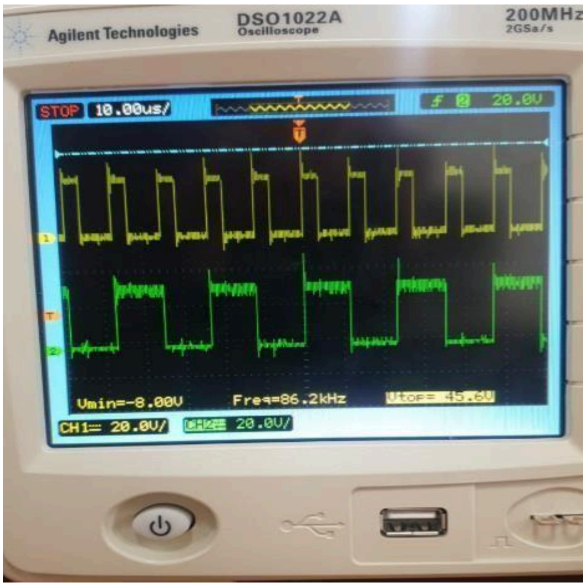
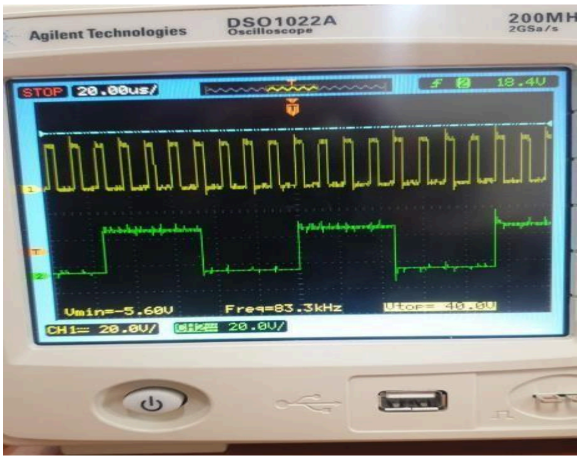



Fig 3.4 C Clk and C (Tribit Encoder)



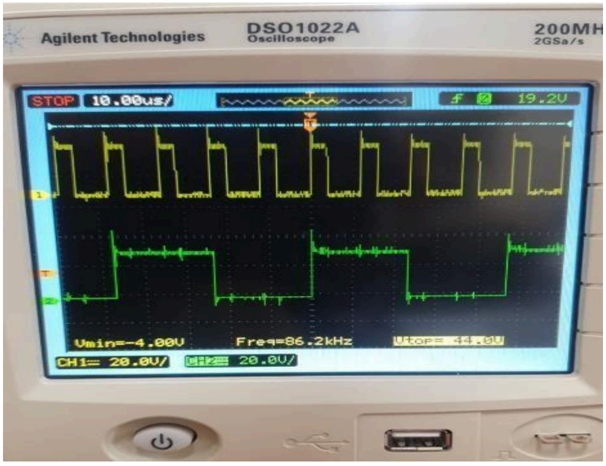




Fig 3.2 Even Clk and Even (Tribit Encoder)

Fig 3.3 Odd Clk and Odd(Tribit Encoder)

In the above Fig 3.1 the yellow signal represents the clock signal and the green signal shows the serial data bits.


Here we are able to visualize all the 8 symbols in the input stream as 4 symbols. The data stream for the above figure is "000001010011100101110111." For the input data stream "101010101010101010101010" we got the constellation plot as:

Here 7 symbols are plotted in the Constellation plot.

"000000000000000000000000” we got the constellation plot as:


Here 1 symbols are plotted in the Constellation plot.

"111111111111111111111111” we got the constellation plot as:


Here 1 symbol is plotted in the Constellation plot.

**Bandwidth efficiency Calculation:**

Bit transmission speed = 256KHz

Bandwidth of modulator = clock/no, of bits transmitted = 256KHz/3

Bandwidth Efficiency = Fb/Bw = 256/(256/3) = 3

## Quadrature Amplitude Modulation and Demodulation Techniques:

For QAM modulation and demodulation we took the input data stream as shown:

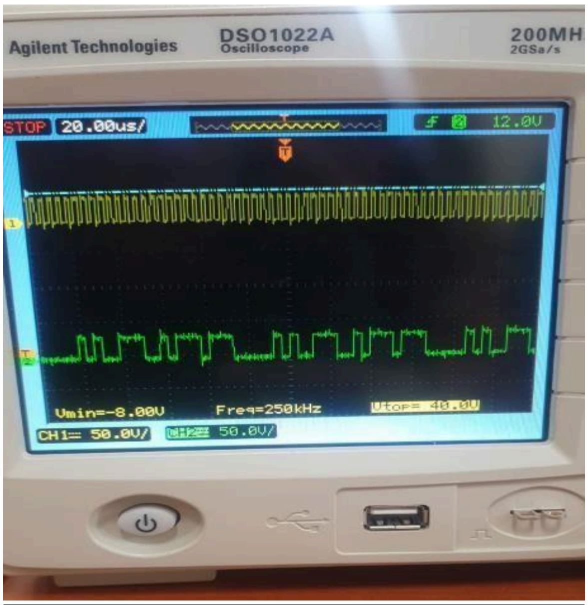



Fig 4.1 Data Clock vs serial Data

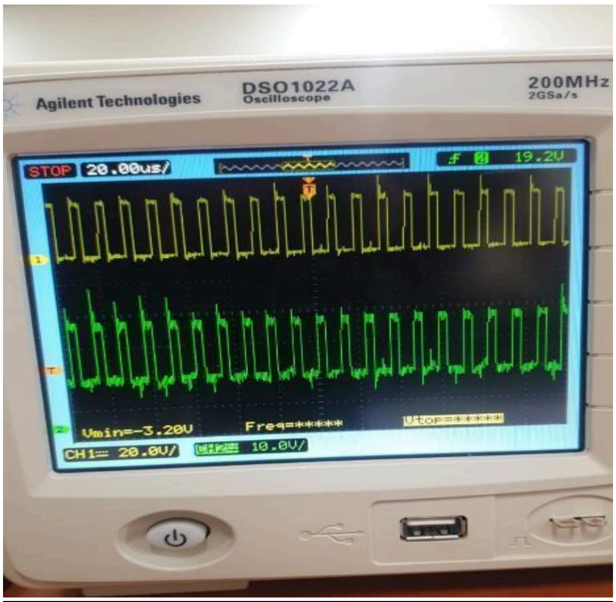



Fig 4.2 Even Clock vs Odd Clock

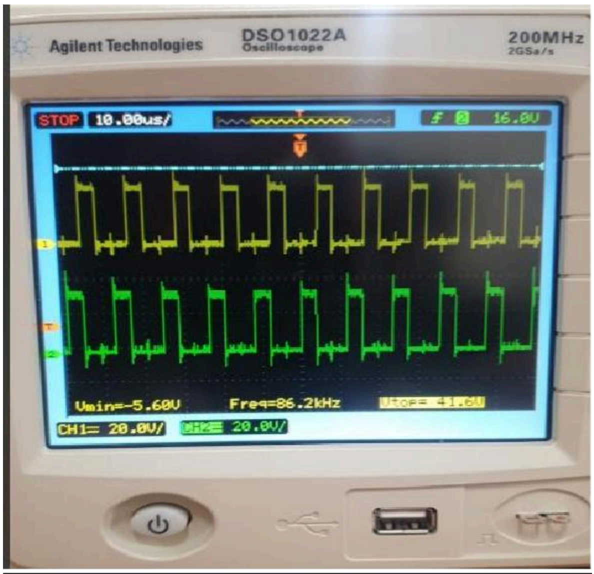
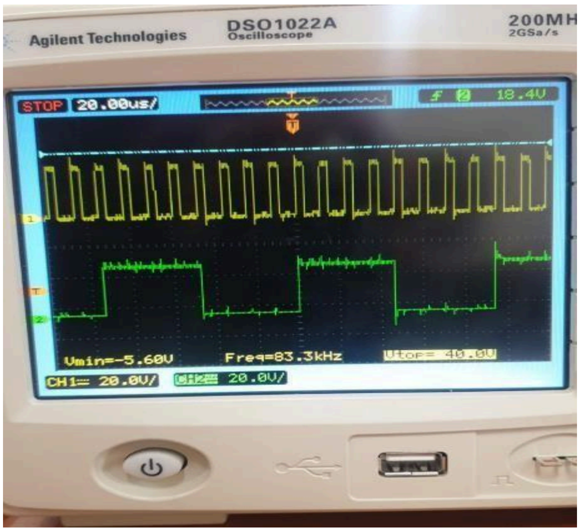



Fig 4.3 Even Clock vs C clock

In Fig 4.2 the yellow signal is an even clock and the green signal is an odd clock. In Fig 4.3 the yellow signal is even clock and the green signal is C clock.

The comparison between the respective clocks and bits are shown below:



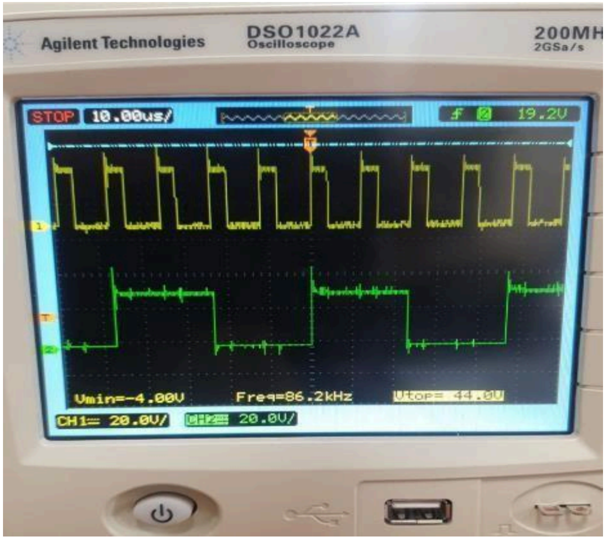




Fig 4.4 Even Clk and Even (Tribit Encoder)

Fig 4.5 Odd Clk and Odd(Tribit Encoder)

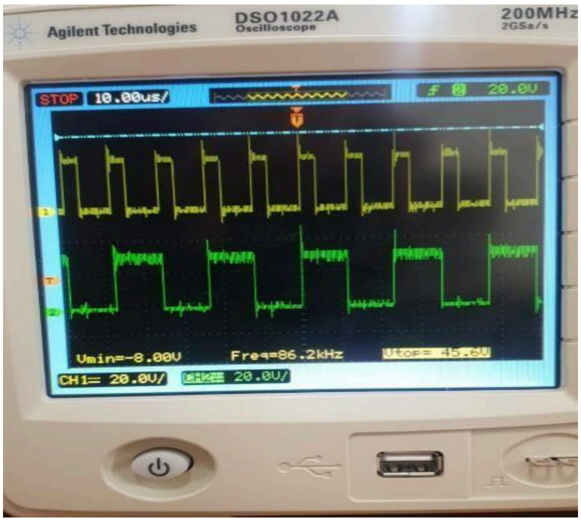
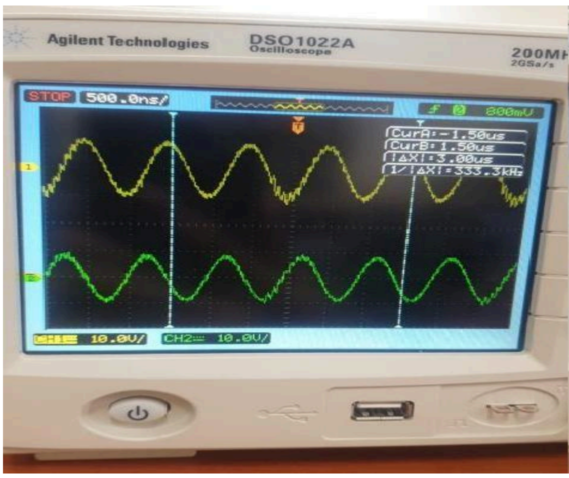



Fig 4.6 C Clk and C (Tribit Encoder)

The phase component shown as below:



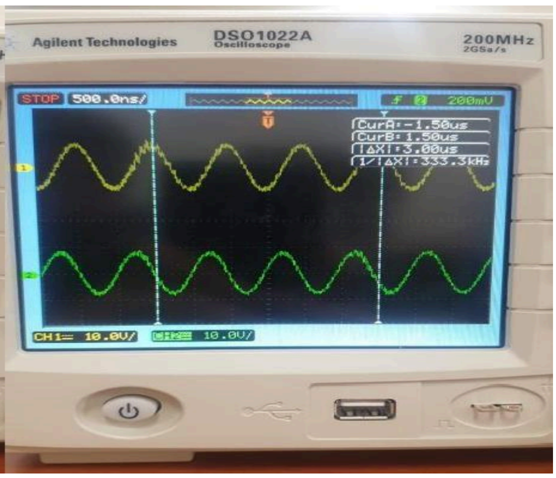
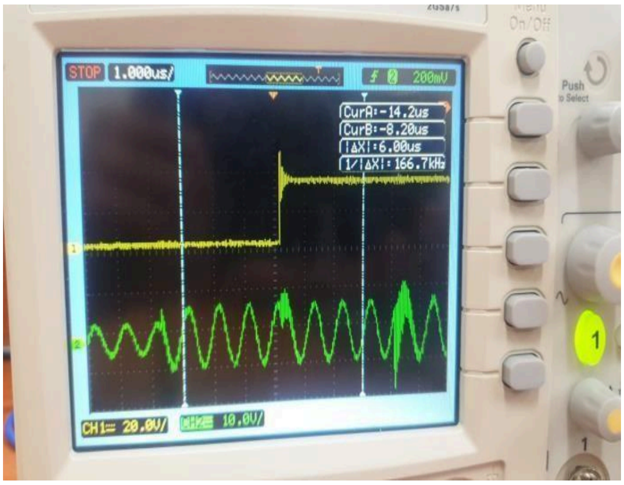




Fig 4.7 SIN 1 (0) vs SIN 2 (90)

Fig 4.8 SIN 1 (180) vs SIN 2 (270)

The obtained modulated output as shown below:



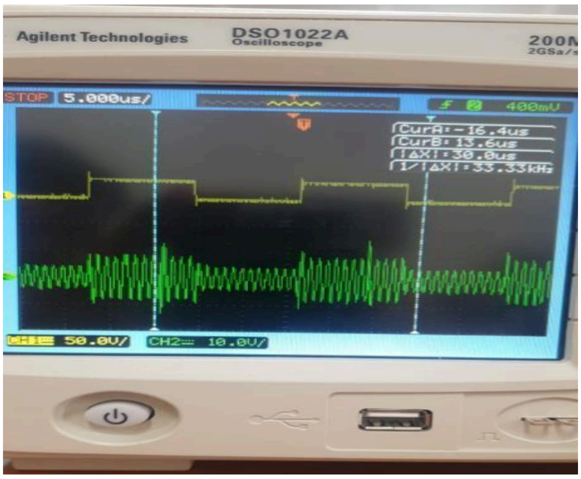
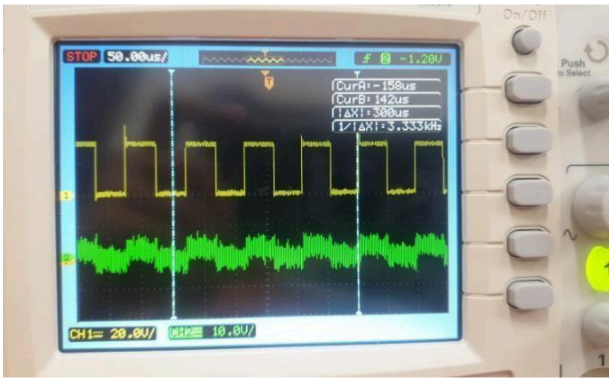




Fig 4.9 EVEN (TRIBIT ENCODER) vs MOD OUT

Fig 4.10 C (TRIBIT ENCODER) vs MOD OUT



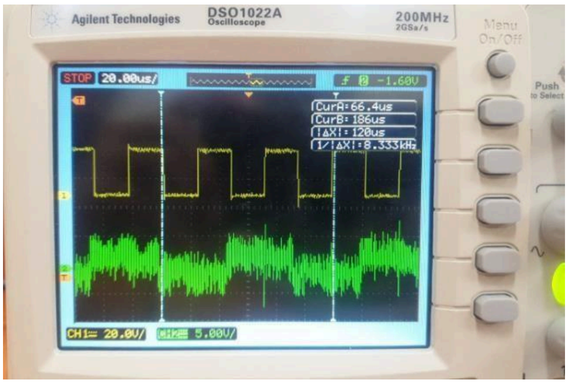




Fig 4.11 EVEN (TRIBIT ENCODER) vs MID OUT

Fig 4.12 odd (TRIBIT ENCODER) vs MID OUT

In Fig: 4.9 the yellow signal shows the Even bit from the tribit encoder and the green signal shows QAM modulated output.

In Fig: 4.10 the yellow signal shows the C bit from the tribit encoder and the green signal shows the QAM modulated output.

In Fig: 4.11 the yellow signal shows the Even bit from the tribit encoder and the green signal shows the Demodulated Output.

In Fig: 4.12 the yellow signal shows the Odd bit from the tribit encoder and the green signal shows the Demodulated Output.

The demodulated Even, Odd bit obtained is as shown below:

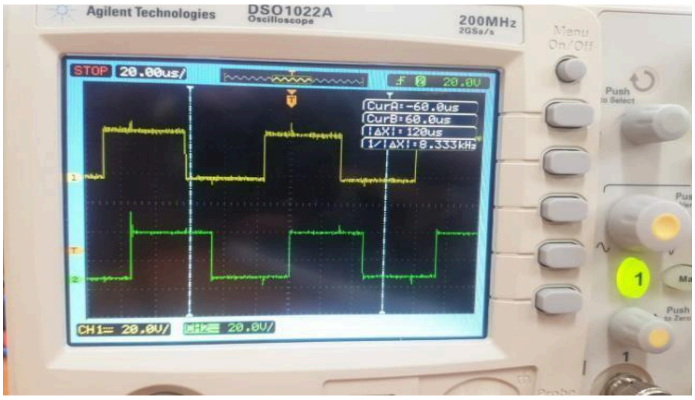



Fig 4.13Even(Tribit Encoder)vsEven(Demodulated )

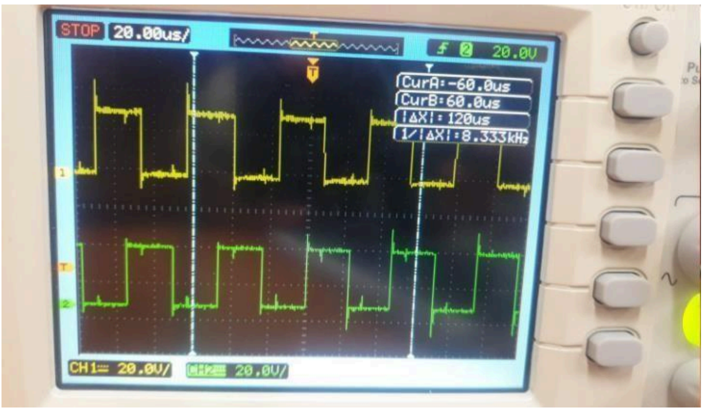



Fig 4.14Odd(Tribit Encoder)vsOdd(Demodulated)

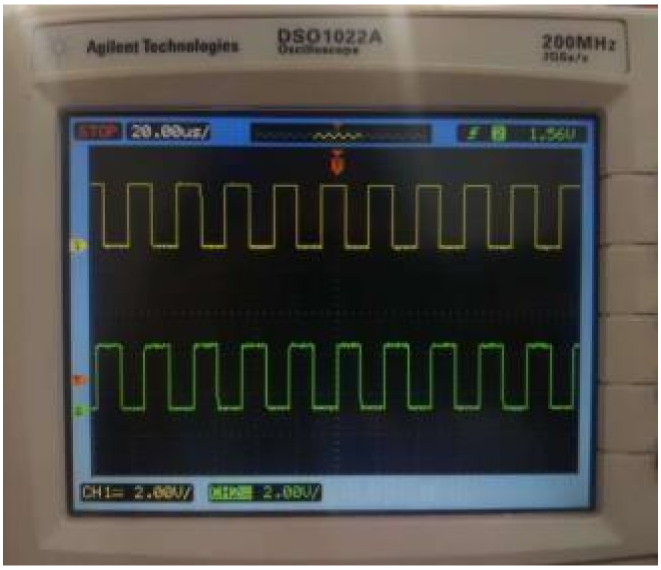



Fig 4.15C(Tribit Encoder)vsC(Demodulated)

After passing the demodulated output through the tribit decoder , we obtain data out as shown:

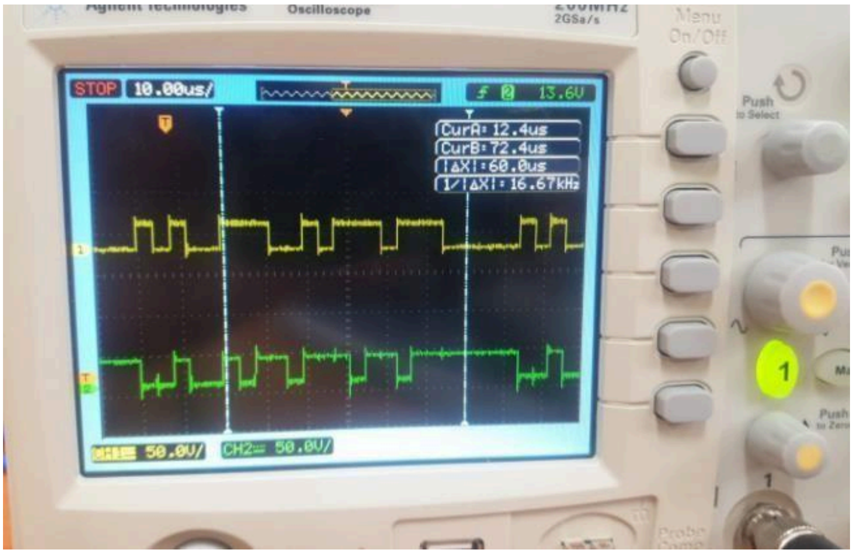



Fig 4.16 Serial Data vs Data Out

In the above figure Serial Data is shown in yellow and the green signal shows the reconstructed data out after demodulation.

## Discussion:

### Tribit Data Coding Technique of NRZ-L Data Format:

- The given data stream is encoded into 3 bits using clock pulses having different duty cyLes. The duty cycle of pulses can be seen in the images in test results.
- The data is encoded using ODD, EVEN and C dock into ODD, EVEN and C signals.
- The encoding is in such a way that if the serial data is high at some instance and clock pulse is high, the corresponding encoded data remains high until the next clock pulse. This process continues.
- The C bit is responsible for changing the amplitude of the QAM and the Odd and Even bit combination are used to select the phase component.

### Differential Encoding of Data:

- Differential encoder is a circuit consisting of XOR gate taking inputs, a data stream and time delayed (by Tb) output.
- In this experiment ODD and EVEN signals after the tribit encoded are sent into differential encoder.
- We can observe that if input is 1, the output data makes transition in its state. If the input is 0, the state remains the same.
- Differential encoding prevents inversion of signals and symbols from affecting the data.

### Observation Of Constellation Diagram for QAM and study of Bandwidth Efficiency Of QAM:

- Constellation diagram is representation of states of modulated signal on a graph, It displays signal as a 2d plot. The distance between the origin and the point

determines the amplitude of the carrier signal at that state. The angle between 2 states with respect to origin determines the phase difference.
- In the plots made in the results section we can say that the possible states are 8 and they are divided in 4 phases and 2 amplitude levels.
- Each of these 4 phases are at a minimum phase difference of pi/2
- The maximum ratio of amplitude of states is 2.
- We can observe that in the first figure, we can see all the states in the constellation diagram. This is due to the presence of all the states in the input bitstream.
- In the other figure, only few states are present in the constellation diagram.

**Quadrature Amplitude Modulation and Demodulation Techniques:**

- Four carrier waves are used for modulation, each having a phase difference of 90 Degrees.
- The ODD, EVEN and C data is sent into the QAM modulator. Output is an analog signal which is modulated.
- It is observed that ODD and EVEN data decide the change in phase whereas C data change in amplitude. We can see this through the plots in the test results section, when ODD, EVEN and C data are plotted with respect to the modulated signal.
- The modulated signal is sent into a demodulator which produces 3 data streams, that are ODD, EVEN and C data.
- We can observe some delay in these signals when compared to the original data.
- This data is then sent into a tribit decoder to obtain the final signal (input signal). Even this signal is time delayed by a few units.

## Conclusions:

For 3-bit intervals, tribit encoding generates an EVEN(in phase) signal, an ODD(in quadrature) signal, and a C data signal, respectively. The voltage levels of these signals correspond to the values of the first, second, and third bits.

Every time the input data contains the digit "1," the differential encoder's output will change states. The differential encoder's output will remain unchanged if the input data contains the value "0"

The constellation diagram shows that the symbol produced by the EVEN, ODD, and C bits has eight different values, which are equally distributed across the four comers of the page. We may also determine how far apart the two symbols are using the constellation diagram. The phase shift in the broadcast signal, if any, will be 90 degrees. In contrast to BPSK, which uses a 180 degree angle, the angle is extended by 180 degrees, from zero to 360 degrees.

In QAM, a SYMBOL is created by combining three bits. Each signal is represented by a single symbol and three bits at the receiving end.

For instance, when using BPSK, the signal adjusts as data is transferred according to the bit rate The symbol rate, which is one-third of the bit rate, is the rate at which symbols are transmitted. Ts=3Tb

In conclusion, Quadrature Amplitude Modulation (QAM) is a digital modulation scheme that allows for the transmission of high-speed digital data over communication channels, The key advantage of QAM is its ability to transmit more bits per symbol, which leads to higher data rates and increased spectral efficiency. The demodulation process involves detecting the amplitude and phase of the received signal and mapping it back to the original digital data, The use of coherent detection and error correction techniques helps to improve the accuracy and reliability of the demodulation process, QAM is widely used in modern communication systems such as satellite, cable, and digital terrestrial television, as well as broadband internet access. With the increasing demand for high-speed data transmission, QAM remains a crucial modulation technique for modern communication systems. Overall, QAM provides a cost-effective and efficient way of transmitting digital data over communication channels, and its continued use and development will play an important role in shaping the future of communication systems.

## References:


- Lab Manual For Experiment #5.
- Principles of communication systems – S.Haykin.
- Communication system Notes.