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Design, Implementation and Comparison of Different QAM Techniques using Cadence 180nm Technology

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***Abstract*—Modulation is one of the fundamental technique required for communication applications. High bit rate, better constellation diagram and effective utilization of bandwidth are the important properties which will be considered in selecting a modulation technique. One such modulation technique which has these properties is QAM technique. Quadrature Amplitude Modulation (QAM) is a combination of two basic modulation techniques amplitude modulation and phase modulation. QAM is widely used in communication applications which come under radio frequency range (such as modems over telephone lines, satellite communications, HD television broadcasting and wireless communications etc) because of its high bit rate, better constellation diagram and effective utilization of bandwidth. Different types of QAM techniques are studied. Designing and implementation of different types of QAMs (16, 32 & 64-QAM) are carried out. In these QAM designs the basic components used are the MOSFETs. The circuit is analyzed at each stage and resulting waveforms are obtained. The bit rate of each QAM is calculated and the comparison is done for different QAMs that are designed. The whole design and implementation of these circuits are carried out using cadence virtuoso software, stimulations are done using spectre circuit simulator and the technology used is CMOS 180nm.**

***Index Terms*— Modulation, Constellation diagram, QAM technique, MOSFETs, Cadence virtuoso software, Spectre.**

I. INTRODUCTION

Communication is the process of sending and receiving information between 2 or more people. Communication is the basic need for every human being. When the exchange of information takes place between 2 or more people who are separated by certain distance is carried out by sending the information in the form of electrical signals through wired or wireless communication devices such as mobile, telephone, internet etc. One of the fundamental system or technique used in communication system is Modulation technique. Modulation is also called as heart of communication system. Modulation is the process of enhancing the signal frequency and it is also defined as varying the properties of carrier signal with respect to message signal. Transmission of message signal over a band-pass communication channel requires a shift of the range of frequency range suitable for transmission, and a corresponding shift back to the original

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frequency range after reception. Modulation has several advantages such as protecting the information signal from loss of information or wrong information due to noise addition, reducing the cost of communication system by reducing the size of the antenna, increasing the rate of transmission of the information signal and so on.

Nowadays QAM is one of the trending modulation technique used in the communication field because of its high bit rate, effective bandwidth utilization and better constellation diagram. QAM stands for Quadrature Amplitude Modulation. QAM has become fast dominant modulation mechanism for high speed digital signals. The QAM technique is the combination of ASK and PSK. QAM performs 2 ASK modulation (with respect to the message signal) using 2 carrier signals which have a phase difference of 90 and the output of these ASK modulators are summed up using a summer, the output of this summer is called as QAM output. Here we can see that the 2 ASK modulation has been performed using phase shifted waves and summed up at the end, hence the summed signal has both amplitude and phase difference. The information signal is split into 2 parts as I-phase and Q-phase data streams. QAM is widely used in practically world. It has many applications in the communication field due to its faster transmission rate and bandwidth efficiency.

II. Block Diagram of QAM

The block diagram of QAM is as shown in the fig. 1, it consist of Information source, splitter & synchronization circuit, carrier source, 90 deg phase shifter, 2 ASK modulators (I-phase modulator and q-phase modulator) and signal summer.

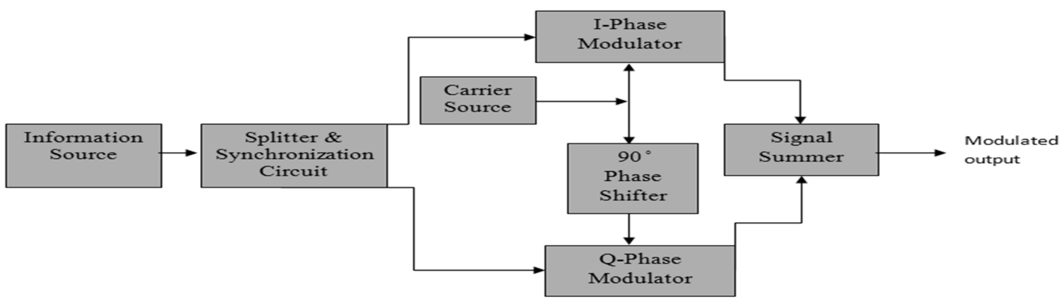

Fig.1: Block diagram of QAM modulator

III. Information Source

Information source produces the message signal which has to be transmitted. The message signal may be a video, audio or a text message. The real world circuit is in analog or continuous form in nature. This signal is converted into digital signal which is actually the input to our QAM circuit (Digital QAM). The analog form signal (voice, video or text) can be converted using Analog to Digital conversion (ADC) block which is used just before splitter circuit. We have made use of V-pulse in Cadence virtuoso software as information source (data input) for our QAM circuit which is already in digital form. Hence we don’t require any ADC for QAM circuit. If analog input is used as information we should use ADC, since it is a digital QAM.

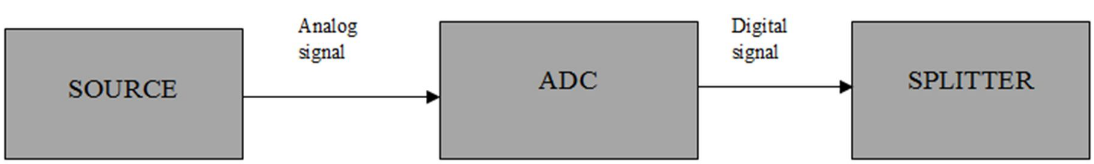

Fig.2: Block diagram of information source

A. Splitter

QAM performs 2-ASK operations simultaneously using 2 different ASK modulators whose carrier wave has 90 degree out of Phase with respect to each other and the output of these ASK modulators are summed up. We have single information source and 2 different ASK modulators (I-phase and Q-phase modulators), hence the information bits are split into 2 parts and are given as input to these Modulators. First the serial bits are converted to parallel form as per order of QAM (for 2^n n parallel bits) and these parallel bits are split as per the order of QAM. Fig.3 shows the block diagram of splitter using D-Flip Flop.

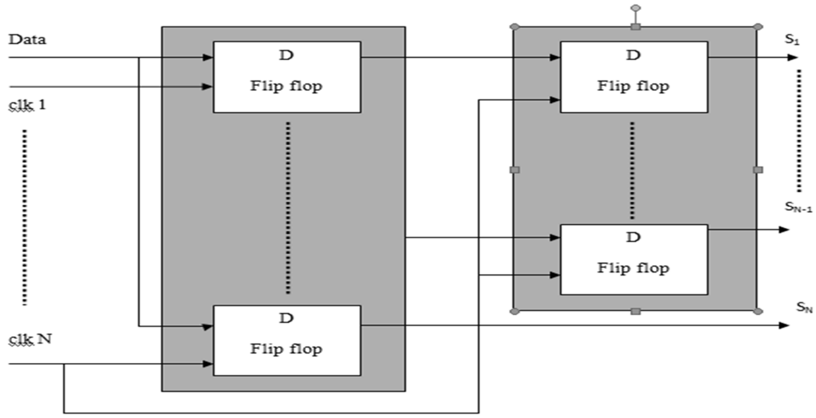

Fig.3: Block diagram of splitterNumber of d-latch usage depends on the order of QAM. Splitter is designed to split the input bits equally or unequally as per the requirement. In 16-QAM and 64-QAM the splitting of the bits takes place equally (since n is even) and in 32-QAM (since n is odd) splitting of the bits takes place unequally. The splitter circuit requires a synchronization circuit since the input bits to selection circuit of I-phase and Q-phase modulators should be synchronized

The splitter circuit is the combination of D-Flip Flops. Synchronization block is also included in the splitter block itself to ensure that process of splitting is been synchronized. Synchronization circuit is also designed using D-Flip Flops. Output from the splitter will be given to the multiplexer (MUX) through selection circuit.

B. Modulator

The modulator is the heart of the QAM. QAM requires 2 ASK modulators. The modulator circuit is a combination of selection circuit and analog MUX. The inputs to the modulator circuit are the message signal and carrier signal.The block diagram of modulator is as shown below in Fig.5.

Fig.5: Internal modulator block diagram

C. Selection Circuit

Modulator task is to send the corresponding carrier wave as output with respect to the input message signal. The selection circuit will help in turning on or triggering any one of the switch of Analog-MUX with respect to the message signal. The selection circuit is a digital circuit. The selection circuit is made up of using AND gates and Inverters. The number of AND gates used (example 2-input, 3-input etc) and number or inverters vary with respect to the order of QAM. The block connection diagram of selection circuit with splitter and MUX is as shown in Fig.4.

Fig.4: selection circuit

D. Multiplexer

A multiplexer (MUX) is a device that selects one signal among several input signals and forwards it to the single output line. A MUX of 2^n inputs has *n* select lines, which are used to select which input line which has to be connected to the output line. Multiplexers are mainly used to increase the amount of data that can be sent over the network within a certain amount of time and bandwidth. In any order of QAM the input Phases of carrier signal will have 4 different phases for all the orders of QAM but number of different amplitude used will change with respect to the order of QAM.

We require two Analog MUXs for the QAM circuit, since we have two different ASK Modulators in QAM circuit. The MUX is designed using op-amp along with MOSFETs as switches. Here we use negative feedback to increase the stability. Over-all gain of the op-amp used is unity.

E. Signal summer

The basic function of the summer is to add two or more signals. The signal summer used here is for analog signals since the output of both the modulators are in the Analog form. Analog summer is designed using op-amp to sum the analog signals. Here we use negative feedback to increase the stability. The output of I-phase modulator and Q-phase modulator is given as input to the op-amp through resistors as shown in the below circuit. Over-all gain of the op-amp is unity. The summer circuit is as shown in fig.6.

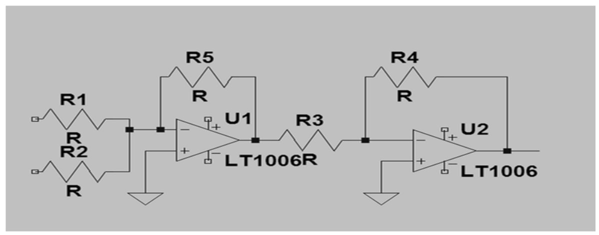

Fig. 6: The signal summer circuit

IV. Implementation of QAM circuits using Cadence gpdk 180nm technology

A. Implementation of 16-QAM

The 16-QAM implemented circuit is as shown in fig. 7. The incoming serial bits are grouped 4 bits at a time and converted to parallel form. These 4 bits are split into 2 equal parts (2 bits each) and these split bits sent to the message inputs of I-phase and Q-phase modulators. Both I-phase and Q-phase modulators are implemented using 4:1 Analog MUX. The Carrier signal inputs for I-phase Modulator are continuous signal having amplitude and phase (5 mV, 0 deg), (5 mV, 180 deg), (10 mV, 0 deg) and (10 mV, 180 deg) and the Carrier signal inputs for Q-phase Modulator are continuous signal having amplitude and phase (5 mV, 90 deg), (5 mV, 270 deg), (10 mV, 90 deg) and (10 mV, 270 deg). The output of 16-QAM consist of 16 different combinations of phase and amplitude.

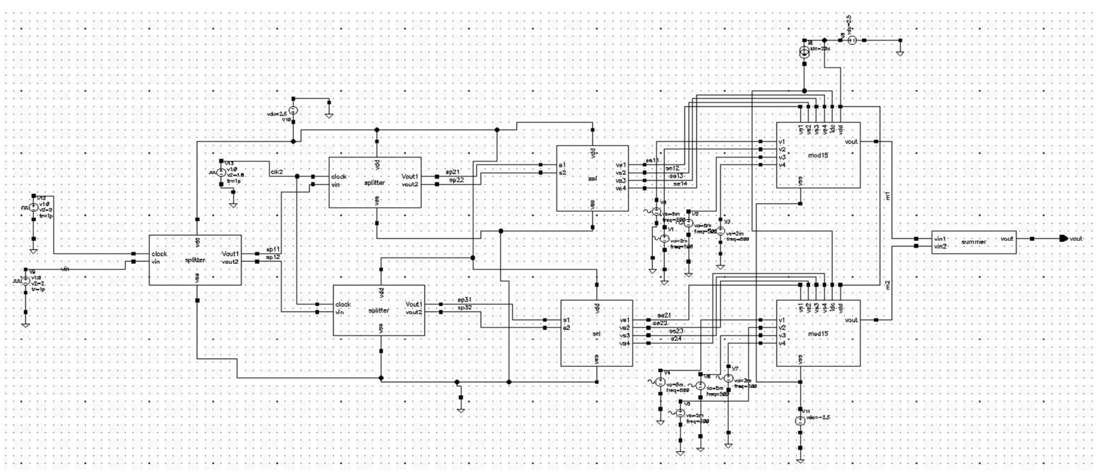

Fig.7: Implementation of 16-QAM circuit

B. Implementation of 32-QAM

The 32-QAM implemented circuit is as shown in fig. 8. The incoming serial bits are grouped 5 bits at a time and converted to parallel form. These 4 bits are split into 2 un-equal parts (3 bits for I-phase modulator and 2-

bits for Q-phase modulator) and these split bits are sent to the message inputs of I-phase and Q-phase modulators. I-phase is implemented using 8:1 Analog MUX and the Q-phase modulator is implemented using 4:1 MUX. The Carrier signal inputs for I-phase Modulator are continuous signal having amplitude and phase (5 mV, 0 deg), (5 mV, 180 deg), (10 mV, 0 deg), (10 mV, 180 deg), (15 mV, 0 deg), (15 mV, 180 deg), (20 mV, 0 deg) and (20 mV, 180 deg) and the Carrier signal inputs for Q-phase Modulator are continuous signal having amplitude and phase (5 mV, 90 deg), (5 mV, 270 deg), (10 mV, 90 deg) and (10 mV, 270 deg). The output of 32-QAM consist of 32 different combinations of phase and amplitude.

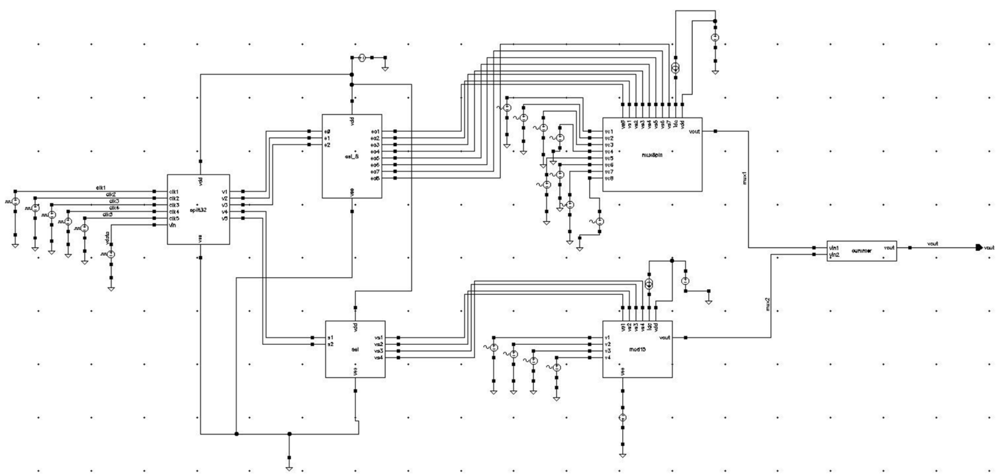

Fig. 8: Implementation of 32-QAM circuit

C. Implementation of 64-QAM

The 64-QAM implemented circuit is as shown in fig. 9. The incoming serial bits are grouped 4 bits at a time and converted to parallel form. These 4 bits are split into 2 equal parts (3 bits each) and these split bits are sent to the message inputs of I-phase and Q-phase modulators. Both I-phase and Q-phase modulators are implemented using 8:1 Analog MUX. The Carrier signal inputs for I-phase Modulators are continuous signal having amplitude and phase (5 mV, 0 deg), (5 mV, 180 deg), (10 mV, 0 deg), (10 mV, 180 deg), (15 mV, 0 deg), (15 mV, 180 deg), (20 mV, 0 deg) and (20 mV, 180 deg) and the Carrier signal inputs for Q-phase Modulators are continuous signal having amplitude and phase (5 mV, 90 deg), (5 mV, 270 deg), (10 mV, 90 deg), (10 mV, 270 deg) (15 mV, 90 deg), (15 mV, 270 deg), (20 mV, 90 deg) and (20 mV, 270 deg). The output of 64-QAM consist of 64 different combinations of phase and amplitude.

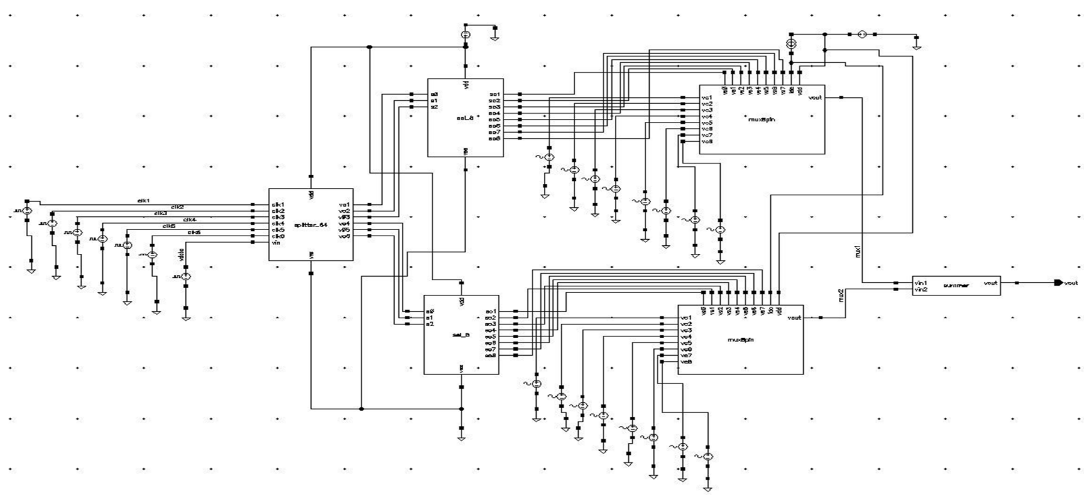

Fig.9: Implementation of 64-QAM circuit

V. RESULTS

A. 16-QAM: Waveform

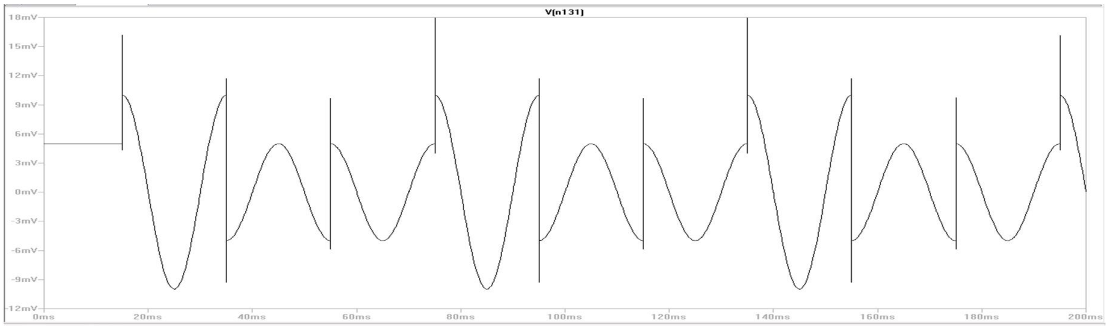

Fig.10: 16-QAM output waveform

Bit rate calculation

The obtained bit rate from the output waveform of 16-QAM

f_c = 10 Mhz.

250k Hz = 4 bits

T = 1/f = 4u

4 us = 4 bits

1 s = x (f_b)

X (f_b) = 1s*4/4u

Bit-rate = f_b= 1 Mbps

Baud rate = f_b/N

N=number of bits per symbol

Baud-rate (f_{b1}) = 250 khz.

The fastest rate of change frequency and highest fundamental frequency at both balanced modulators (f_a) = 125 khz.

Upper frequency = f_c + f_a =10.125 Mhz.

Lower frequency = f_c - f_a = 9.875 Mhz.

Bandwidth = Upper frequency – Lower frequency = 250 khz

f_b(bit rate) in terms of bandwidth.

f_b = Bandwidth*N

f_b =Bandwidth*4

B. 32 QAM: Waveform

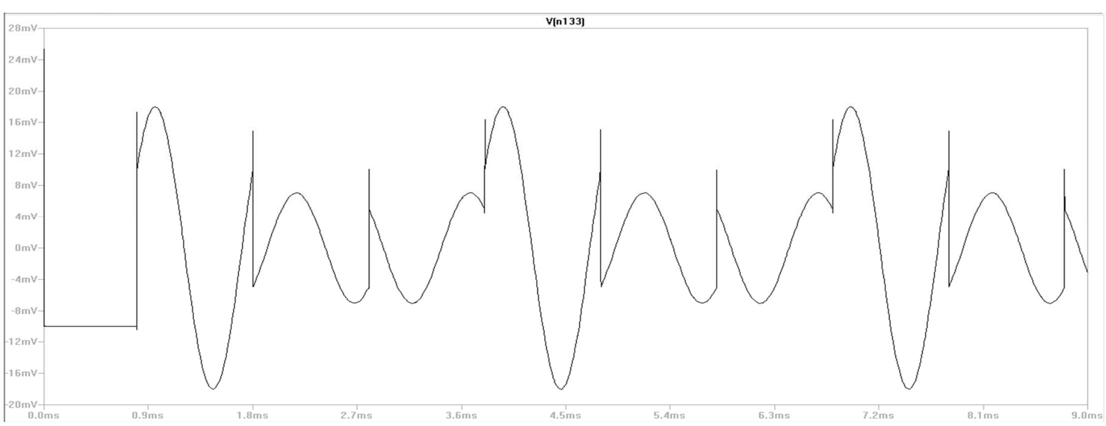

Fig.11: 32-QAM output waveform

Bit rate calculation
The obtained bit rate from the output waveform of 32-QAM
f_c = 10 Mhz.
250k Hz = 5 bits
T = 1/f = 4 us
4 us = 5 bits
1 s = x (f_b)
X (f_b) = 1s*5/4us
Bit-rate = f_b= 1.25 Mbps
Baud-rate = f_b/N
N=number of bits per symbol
Baud-rate (f_{b1}) = 250 khz.
The fastest rate of change frequency and highest fundamental frequency at both balanced modulators (f_a) = 125 khz.
Upper frequency = f_c + f_a = 10.125 Mhz.
Lower frequency = f_c - f_a = 9.875 Mhz.
Bandwidth = Upper frequency – Lower frequency = 250 khz
f_b (bit rate) in terms of bandwidth.
f_b = Bandwidth*N

f_b =Bandwidth*5

C. 64-QAM: Waveform

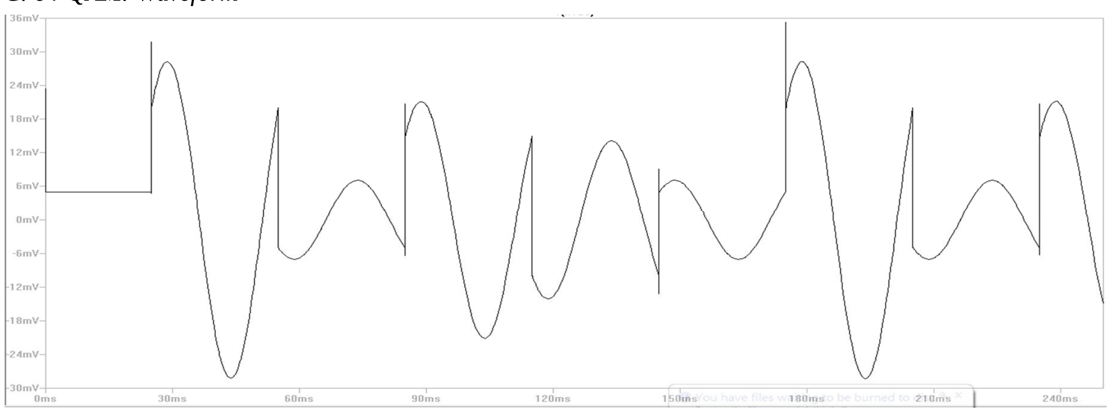

Fig.12:64-QAM output waveform

Bit rate calculation
The obtained bit rate from the output waveform of 64-QAM
f_c = 10 Mhz.
250 kHz = 6 bits
T = 1/f = 4 us
4 us = 6 bits
1 s = x(f_b)
X($f_{b)}$ = 1s*6/4us
bit rate = f_b= 1.5 Mhz
baud-rate = f_b/N
N=number of bits per symbol
Baud-rate (f_{b1}) = 250 khz.
The fastest rate of change frequency and highest fundamental frequency at both balanced modulators(f_a) = 125 khz.
Upper frequency = f_c + f_a = 10.125 Mhz.
Lower frequency = f_c - f_a = 9.875 Mhz.

Bandwidth = Upper frequency – Lower frequency = 250 khz
f_b(bit rate) in terms of bandwidth.
f_b = Bandwidth*N

fb= Bandwidth*6

VI. Comparison of Bit-rate

TABLE I: BIT-RATE COMPARISON TABLE

QAM Technique	Bandwidth in terms of Hz	Bit rate in terms of bits/s	Bit rate in terms of Bandwidth
16-QAM	250 k	1 M	4 * BW
32-QAM	250 k	1.25 M	5 * BW
64-QAM	250 k	1.5 M	6 * BW

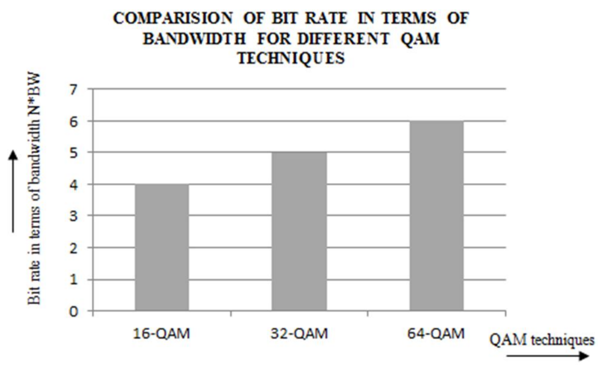

Fig.13: Comparison of bit rates in terms of bandwidth

VII. Conclusion

This work describes the design and implementation of the transmitter part of Quadrature Amplitude Modulation scheme of 16, 32, 64-bits using Cadence Tool. The output at each stage of QAM is analyzed. This design can be practically implemented as it uses MOSFETs for its circuit which minimizes the cost and decrease the size. The efficiency of the circuit is high due to the CMOS technology used. The data rate of each QAM is calculated for a channel frequency. Data transmission rate of each QAM technique is compared and it has shown that as the order of QAM increases, the data rate also increases. The future work can be carried out on the study of SNR (signal to noise ratio) and Shannon's channel capacity formula for these QAM circuits and modifying the QAM circuit for acceptable SNR ratio. The work can be continued to obtain the layouts for the schematics of different QAM techniques. Once the layout is obtained, the fabrication process can be done for these circuits. This will greatly help in many of the communication applications, as QAM techniques play an important role in it.

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