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MOBILE RADIO COMMUNICATION WITH VARIOUS DIGITAL MODULATION TECHNIQUES

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ABSTRACT: *This paper describes various modulation techniques that are used in mobile communication system. Since digital modulation offers numerous benefits and is already being used to replace conventional analog systems, the primary emphasis of this paper is on digital modulation techniques. Here , the coverage focus on the modulation and demodulation as it applies to mobile radio systems. A large variety of modulation techniques have been studied for mobile radio communication systems and the further research is ongoing for future development. While designing a modulation scheme the hostile fading and multipath conditions that is resistant to mobile channel impairments is a challenging task. Since the ultimate goal of a modulation technique is to transmit a message signal through a radio channel with the best possible quality while occupying the least amount of radio spectrum , new advances in digital signal processing continue to bring about new forms of modulation and demodulation. This paper describes many practical modulation schemes, receiver architectures, design tradeoffs, their performance and comparison among them under various types of channel impairments, especially in AWGN channel to choose the suitable one in all these transmission functions.*

Keywords: Analog Modulation, Digital Modulation, AWGN channel, Mobile communication, MATLAB.

1. INTRODUCTION

Now a day, most people are familiar with a number of cellular radio communication systems used in everyday life. Mobile radio communication industry has grown by orders of magnitude, fueled by digital and RF circuit fabrication improvements, new large scale circuit integration, and other miniaturization technologies which make portable radio equipment smaller, cheaper, and more reliable. Digital switching techniques have facilitated the large scale deployment of affordable, easy-to-use radio communication networks[1].

Modern digitalized age is based on the communication system which in turn is based on the data transmission, receiving and proper processing to convey throughout the world. New system solutions should also take care of all new subscribers and their demands. The users do not just want their mobile phone for speech, but they also want the possibility to send and receive fax, e-mail and data without delay. The rapid worldwide growth in cellular telephone subscribers has demonstrated conclusively that wireless communication is a robust, viable voice and data transport mechanism. However, the wide-spread success of cellular has led to the development of newer wireless systems and standards for many other type of telecommunication traffic besides mobile voice telephone calls. However, several techniques are under consideration for the next generation of digital phone systems, with the aim of improving cell capacity, multipath immunity and flexibility. These techniques could be applied to provide a fixed wireless system for rural areas.

2. MOBILE COMMUNICATION

Mobile radio communication began with Guglielmo Marconi’s and Alexander Popov’s experiments with ship-to-shore communication in the 1890’s. Radio systems have increased in importance since that time for both voice and data communication. Modern mobile systems mostly use high frequencies (UHF and above) because of the larger available bandwidth at these frequencies. In the United States this includes cellular telephone systems operating at 800-900 MHz and personal communication systems (PCS) at 1800-2000 MHz, and a variety of unlicensed devices, including wireless LANs, in the ISM bands at 902-928 MHz and 2.4-2.4835 GHz[2]. Additional high speed, short-range digital communications will use the unlicensed national information infrastructure (U-NII) bands at 5.15-5.35 GHz and 5.725-5.825 GHz.

3. WIRELESS COMMUNICATION

The rapid worldwide growth in cellular telephone subscribers has demonstrated conclusively that wireless communication is a robust, viable voice and data transport mechanism. Many formidable obstacles stand in the way of achieving reliable and very high data communications. The requirements for capacity and speed in the network entail that today's systems have to be developed further or replaced by new ones. However, the wide-spread success of cellular has led to the development of newer wireless systems and standards for many other type of telecommunication traffic besides mobile voice telephone calls.

For example, next generation cellular networks are being designed to facilitate high speed data communications traffic in addition to voice calls. New standards and technologies are being implemented to allow wireless networks to replace fiber optic or copper lines between fixed points several kilometers apart (fixed wireless access)[3]

The current commonly used mobile telephone system all over the world is the GSM-system being applied to fixed wireless phone systems in rural areas. It is mainly designed for speech and some drawbacks have shown up, mostly in terms of capacity and speed. It uses Time Division Multiple Access (TDMA) which has a high symbol rates leading to problems with multipath causing inter-symbol interference. However, several techniques are under consideration for the next generation of digital phone systems, with the aim of improving cell capacity, multipath immunity and flexibility.

A wireless communication link as shown in the figure 1 includes a transmitter, a receiver, and a channel, as shown in figure 1[1]. Quantization, coding and decoding are only performed in digital systems. Most links are full duplex and include a transmitter and a receiver or a transceiver at each end of the link.

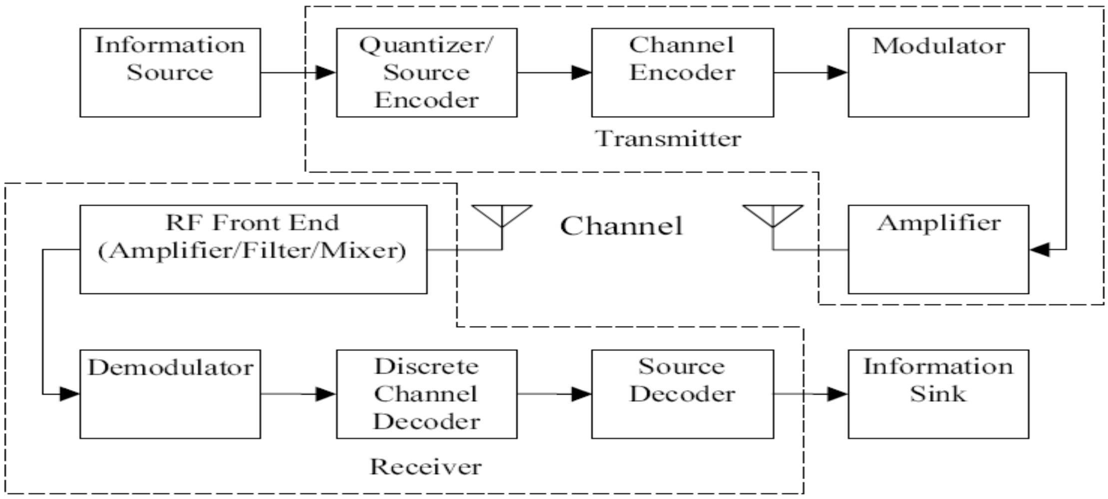

Fig. 1: Block diagram of a wireless communication link.

4. MODULATION TECHNIQUES

The purpose of analog modulation is to impress an information-bearing analog waveform onto a carrier for transmission. FM –AMPS (Analog Frequency Modulation Technique) is an example of modulation scheme used for wireless application. In the other hand, the purpose of digital modulation is to convert an information-bearing discrete time symbol sequence into a continuous-time waveform (perhaps impressed on a carrier). Similarly, wireless networks have been increasingly used as a replacement for wires within homes, buildings, and office settings through the deployment of *wireless local area networks* (WLANs).

Here, the main purpose is to cover **'Digital Modulation Techniques'** which serve a considerably better performance to wireless applications. But the major concerns while dealing these modulation schemes are bandwidth efficiency and implementation complexity. These terms are mainly affected by the following factors which can accounted for in the basic conception and analysis of these modulation schemes–

- Base band pulse shape
- Phase transition characteristics
- Envelope fluctuations(channel nonlinearities)

5. DIGITAL MODULATIONS

Digital Modulation Techniques are used to transmit binary data over a band-pass communication channel with fixed frequency limits set by the channel. For wireless data transfer, several digital modulation techniques are incorporated like BPSK, QPSK, DPSK, OQPSK, BFSK, QAM etc. Among these schemes PSK and QAM are considered to be the most widely used and efficient schemes applied for wireless technology.

5.1 BINARY PHASE SHIFT KEYING (BPSK)

BPSK or binary PSK is the simplest version of PSK, in which the carrier assumes one of two phases. This scheme has only two signal elements, one with a phase of 0 & the other with phase of 180 (π). A logical 1 is encoded as 0 phase, and a logical 0 is coded as a phase of π. A bipolar base band signal is treated as the input to the modulator which is then multiplied by a carrier of frequency f_c from a local oscillator. If the sinusoidal signal has an amplitude of A and energy per bit $E_b = \frac{1}{2} A^2 T_b$, the BPSK transmitted signal is ,

$$S_{BPSK}(t) = m(t)\sqrt{\frac{2E_b}{T_b}} \cos\left(2\pi f_c t + \theta\right)$$

; $0 \leq t \leq T_b$ (binary 1) ………………… (1)

Where, T_b is the period of transmitted signal, θ is the phase of the unmodulated carrier & m(t) is the data signal.

The modulated signal is multiplied by the recovered carrier, and this product is integrated over a bit interval. If the integration result is positive, the received bit is deemed to be 1; if the integration result is negative, the received bit is deemed to be 0

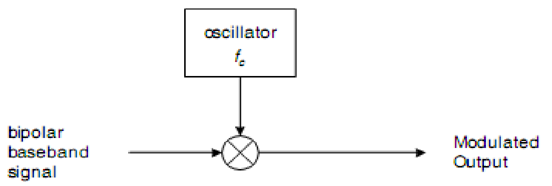

Fig. 2: BPSK Modulator

The probability of bit error in an AWGN channel is found using the Q-function of the distance between the signal points and is given by the generalized equation,

$$P_b = Q\left(\frac{d_{min}}{\sqrt{2N_o}}\right); P_b = Q\left(\sqrt{\frac{2E_b}{N_o}}\right)$$

$$= \frac{1}{2} erfc\sqrt{\frac{E_b}{N_o}} \qquad \text{…………………………(2)}$$

5.1.1SIMULATION RESULT

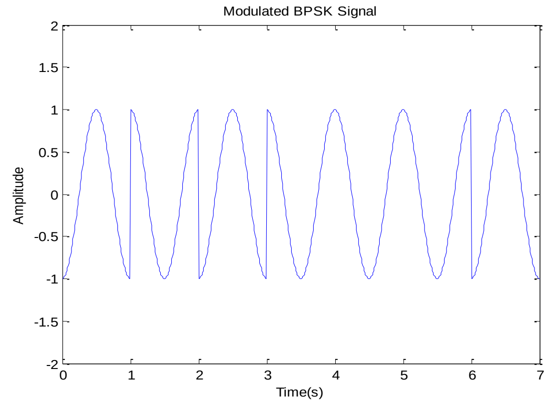

Fig. 3: Modulated BPSK Signal

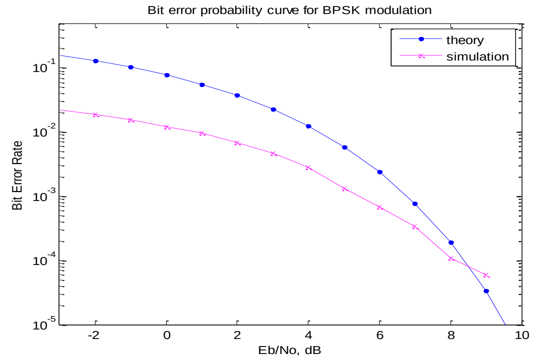

Fig. 4: SNR (in dB) Vs. BER of BPSK

5.2 QUADRATURE PHASE SHIFT KEYING (QPSK)

Quadrature Phase Shift Keying (QPSK) is another example of M-ary PSK with M=4 where one of four possible signals is transmitted during each signaling interval, with each signal uniquely related to a dibit (pair of bit). In QPSK the phase of the carrier takes one of four equally spaced values, either $0, {}^{\pi}/_{2}, \pi \;\&\; 3\,{}^{\pi}/_{2}$ or ${}^{\pi}/_{4}, 3\,{}^{\pi}/_{4}, 5\,{}^{\pi}/_{4}, \&\; 7\,{}^{\pi}/_{4}$ where each value of phase corresponds to a unique pair of message bits.

The QPSK signal may be given by,

$$S_{QPSK}(t) = m(t)\sqrt{\frac{2E_s}{T_s}} \cos\left[2\pi f_c t + (2n+1)\frac{\pi}{4}\right]$$

; $0 \leq t \leq T_s$, n =0, 1, 2, 3, 4………………….. (3)

The unipolar binary message stream has a bit rate R_b and and is first converted into a bipolar non- return-to-zero (NRZ) sequence using a unipolar to bipolar converter. The bit steam m(t) is then split into two bit streams $m_I(t)$ and $m_Q(t)$ known as I (In- phase)channel and Q(Quadrature) channel each having a bit rate $R_s = R_b/2$. These two I channel and Q channel modulated signals input to the summer can be represented by the following mathematical expressions[1]:

$$S_I(t) = m_I(t)\sqrt{\frac{2E_s}{T_s}}\cos\,[2\pi f_c t + \Phi] \qquad \ldots(4)$$

$$S_Q(t) = m_Q(t)\sqrt{\frac{2E_s}{T_s}}\sin[2\pi f_c t + \Phi] \qquad \ldots(5)$$

Where Ts is the symbol duration and is equal to twice the bit period T_b. The modulated and noisy filtered QPSK signal is received by the receiver and after the carrier recovery. This demodulated signal is then filtered by a lowpass filter to remove out of band noise and adjacent channel interference

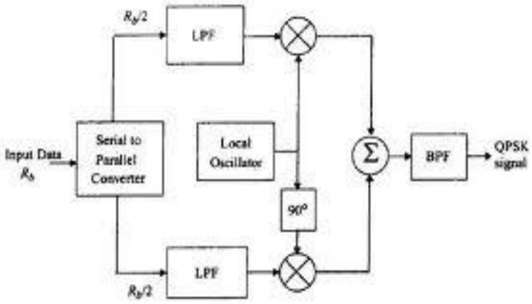

Fig. 5: QPSK Modulator

The probability of bit error or bit error rate (BER) of QPSK in an AWGN channel is obtained as[2],

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_o}}\right) = \frac{1}{2}erfc\sqrt{\frac{E_b}{N_o}} \qquad \ldots\ldots\ldots\ldots(6)$$

As a result, the probability of bit-error for QPSK is the same as for BPSK. If the signal-to-noise ratio is high (as is necessary for practical QPSK systems) the probability of symbol error may be approximated:

$$P_s = 2Q\left(\sqrt{\frac{E_s}{N_o}}\right) \qquad \ldots\ldots\ldots\ldots\mathbf{(7)}$$

5.2.1 SIMULATION RESULT

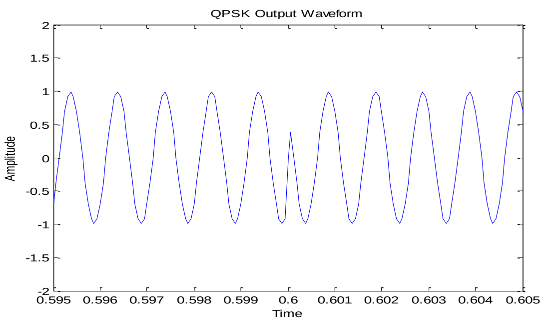

Fig. 6: Modulated QPSK Signal

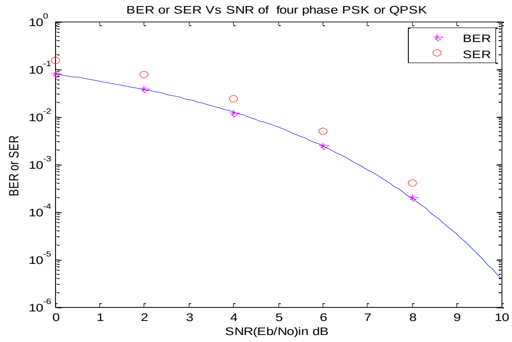

Fig. 7: BER or SER Vs SNR (in dB) of QPSK

5.3 DIFFERENTIAL PHASE SHIFT KEYING (DPSK)

A signaling technique that combines differential encoding with phase shift keying is known as *'Differential phase shift keying'* (DPSK).This is a no coherent form of phase shift keying which eliminates the need for a coherent reference signal at the receiver and hence, avoids the requirement of coherent detection unlike the conventional PSK detection technique. No coherent receivers are easy and cheap to build, and hence are widely used in wireless communications[3].

It is the signaling method where the digital information content of a binary data is encoded in terms of signal transitions. In DPSK, the carrier phase is changed only if the current bit differs from the previous one.

For example, symbol 0 represents transition and symbol 1 represents no transition in a given binary sequence with respect to the previous encoded bit. A reference bit must be sent at the start of message which includes an extra initial bit in the differential encoded sequence (and hence the DPSK signal).

$$d_i = \overline{m_i \oplus d_{i-1}}$$

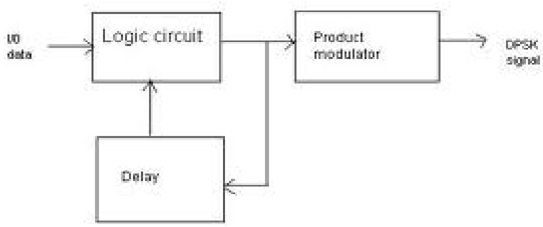

Fig. 8: DPSK Modulator

The average probability of error for binary DPSK in Additive White Gaussian Noise (AWGN) is given by

$$P_{e,DPSK} = \frac{1}{2}\,exp\left(-\frac{E_b}{N_0}\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

5.3.1 SIMULATION RESULT

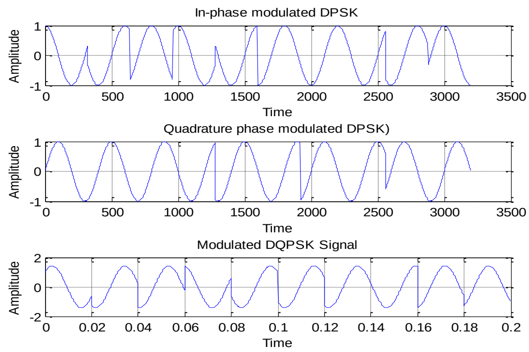

Fig. 9: Modulated DPSK Signal

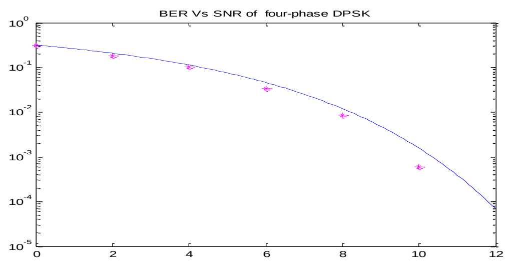

Fig. 10: BER or SER Vs SNR (in dB) of DPSK

5.4 BINARY FREQUENCY SHIFT KEYING (BFSK)

In BFSK, the binary signal is used to *frequency modulate* the carrier. Frequency modulation encodes information bits into the frequency of the transmitted signal. In this method, the frequency of a constant amplitude carrier signal is switched between two values according to the two possible message states corresponding to a binary 1 or 0. In other words, in this method the frequency of the carrier is changed to two different frequencies depending on the logic state of the input bit stream-one frequency being used for a binary 1 and another for a binary 0.

It can be shown that, the probability of error for a coherent FSK receiver is given by,

$$P_{e,FSK} = Q\left(\sqrt{\frac{E_b}{N_o}}\right) \qquad \text{..................(9)}$$

Again, the probability of error of an FSK system employing noncoherent detection is given by[4],

$$P_{e,FSK,NC} = \frac{1}{2}\exp\left(\frac{-E_b}{2N_o}\right)\ldots \qquad \text{................(10)}$$

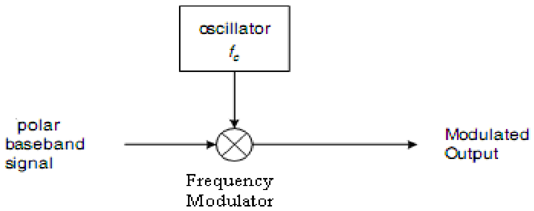

Fig. 11: BFSK Modulator

5.4.1 SIMULATION RESULT

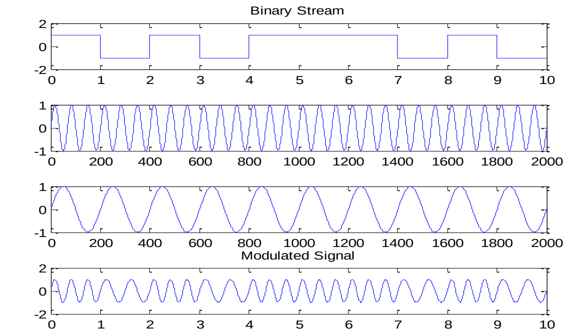

Fig. 12: Modulated BFSK Signal

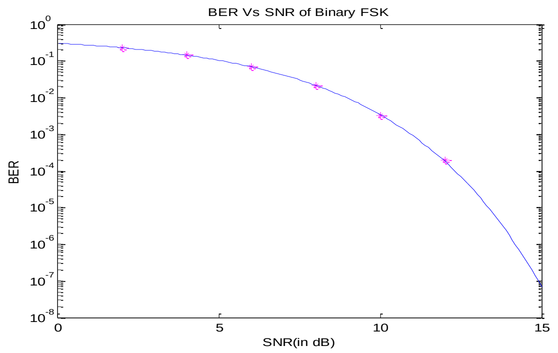

Fig. 13: BER or SER Vs SNR (in dB) of BFSK

5.5 QUADRATURE AMPLITUDE MODULATION (QAM)

Quadrature Amplitude Modulation (QAM) is a modulation scheme which is carried out by changing (modulating) the amplitude of two carrier waves. The carrier waves are out of phase by 90 degrees, and are called quadrature carriers[5] - hence the name of the scheme.

For QAM, the information bits are encoded in both the amplitude and phase of the transmitted signal. Quadrature amplitude modulation is a combination of ASK and PSK[6]. Thus, whereas both MPAM and MPSK have one degree of freedom in which to encode the information bits (amplitude or phase), MQAM has two degrees of freedom. As a result, MQAM is more spectrally efficient than MPAM and MPSK, in that it can encode the most number of bits per symbol for a given average energy.

It can be shown that the average probability of error in an AWGN channel for M-ary QAM, using coherent detection, can be approximated by

$$P_e \cong 4\left(1-\frac{1}{M}\right)Q\left(\sqrt{\frac{3E_{av}}{(M-1)N_0}}\right), \qquad \text{............(11)}$$

Where Eav /No is the average signal to noise ratio.

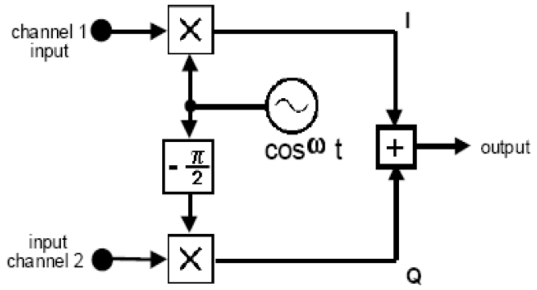

Fig. 14: QAM Modulator

5.5.1 SIMULATION RESULT

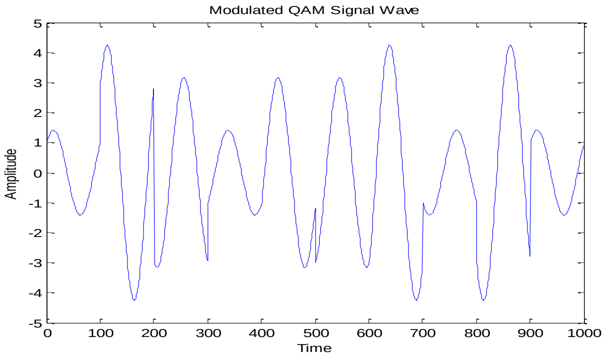

Fig. 15: Modulated QAM Signal

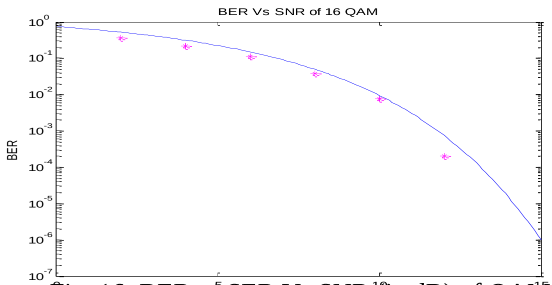

Fig. 16: BER or SER Vs SNR (in dB) of QAM

6. CONCLUSION

In this paper, we discussed various modulation techniques for their performance analysis. These techniques posses interesting characteristics that differ from the others and consequently, the schemes perform differently from each other from many aspects. The major criteria considered for the performance analysis of different modulation techniques are: BER performance, Spectral efficiency, Adjacent channel interference, Power efficiency (esp. at mobile), Implementation complexity/cost (may require dual-mode mobile) etc. But, so far, we see that QPSK and QAM are two of them which offer better performance than the others in regard of bit error probability (BER), bandwidth efficiency, power efficiency, adjacent channel interference, constant envelope amplitude and reduced cost and complexity of the receiver and transmitter all together. The most interesting feature of these schemes is that they are more bandwidth and power efficient and provide the data transmission without a lesser amount of distortion and deviation from the actual data. Moreover, they show less susceptibility to the deleterious effects of regeneration of side lobes and spectral widening.

Consequently, observing and taking each and every factor related to the safer transmission of data into consideration, we may conclude that, QAM and QPSK are the most desired and suitable choice for the application in cellular radio communication system as they impose the most significant effects accounted for the performance.

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