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A Review on Digital Modulation Techniques in Wireless Communication

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Abstract

This paper analyses the various digital modulation techniques used in the present Wireless communications which has become the need of today. Here we see the various digital bandpass modulation schemes like the phase shift keying, frequency shift keying, amplitude shift keying and the M- ary signalling used most widely in wireless communications these days.

Keywords: *Digital Modulation Techniques, WC.*

1. Introduction

Wireless communications had come to the rescue when long distance wired communication was not a feasible idea, especially in difficult terrains like marshy area, mountainous and landslide prone area, oceans glaciars and various topographical constraints. Due to its seamingless advantages, it also started being used in short range communication applications. It is fastly growing field in our modern life and creates enormous impact on nearly every feature of our daily life. A great technological changeover during the past two decades has offered a potential growth in the domain of digital communications and a host of applications and various technologies are coming up every day due to these valid reasons. Digital modulation schemes help in the evolution of mobile communications by increasing capacity, speed as well as the quality of the wireless system. Three basic constraints which must be taken care of are bandwidth, power and noise level of the system while developing the communication systems. Becauseof the error-free capability offered in digital modulation, it is preferred over the analog techniques for modulation. The Worldwide interoperability for Microwave Access (which is Wi-Max) uses combinations of different modulation schemes and is a reliable technology offering high speed voice, video and data services which are contemporary requirements. In this paper the literature review on the different digital modulation techniques which are generally used for the wireless communication is presented forward.

2. Digital Modulation Techniques

In digital modulation schemes, binary code modulates the analog carrier signal. The digital modulator device acts an interface between the transmitter and the channel. The digital modulation schemes are categorized basically either on their detection characteristics or in terms of their bandwidth compaction characteristics. The main criteria for best modulation scheme depends on Bit Error Rate (BER), Signal to Noise Ratio (SNR), Available Bandwidth, Power efficiency, better Quality of Service, cost effectiveness [8]. The performance of each modulation scheme is measured by estimating its probability of error with an assumption that system are operating with Additive White Gaussian Noise [9]. Modulation methods which are capable of transmitting more bits per symbol are more immune to error caused by noise and interference induced in the channel [10]. The delay distortion can be an important measure while deciding modulation scheme for digital radio [11].

There are various digital modulation schemes which are used in the telecommunication system. The basic types of digital modulation scheme are Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK) respectively [12,13,14]. The ASK, FSK and PSK with nyquist pulse shaping at the baseband form the basic technique of digital modulation, but other methods are also possible by incorporating two or more basic digital modulation techniques with or without introducing pulse shaping. Thus, hybridized modulation can be designed depending upon the type of signal and the application. The implementation of ASK is simple but they are limited to deliver low amount of power and achieve low data transmission rates. The PSK modulation technique have steady envelope but discontinuous phase transitions from symbol to symbol. DPSK, QPSK and MSK are the derivatives modulation schemes of the Phase Shift Keying. A better digital modulation scheme is to be contemplated over by the designer which has an ability of exploiting the existing transmitted power and the bandwidth to its full coverage [48]. In paper [15], author have presented the characteristics of modulation techniques and determined the figure of merit for each particular modulation. The comparative study of Digital Modulation schemes that can used in OFDM which is main part of WI-MAX model is presented in [16]. The designs of BASK, BFSK and BPSK modulators using Field Programmable Gate Arrays employs the minimum number of block necessary for their implementation [17]. Binary Phase Shift keying (BPSK), Quadrature Phase Shift keying (QPSK), Eight-Phase Shift keying (8-PSK) and Sixteen- Phase Shift keying (16-PSK) are the types of M-ary modulation schemes [18]. The BPSK, QPSK, 16-QAM and 64-QAM modulation schemes has been investigated for performance according to their BER values in [19]. The energy efficient schemes such as BPSK or QPSK are used when channel conditions are poor whereas when the channel quality improves, 16-QAM or 64-QAM is to be used [20]. The BPSK, QPSK and QAM has been analyzed to reduce the error performance of the signal and to compare which scheme is better through Rayleigh Fading Channel in the presence of Additive White Gaussian Noise [21]. Performance evaluation of an wi-max system under different combinations of BPSK, QPSK, 4-QAM, 16-QAM digital modulation and different communication channels AWGN and fading channels is presented in [22]. The BER performance of wi-max physical layer with the implementation of different concatenated channel coding schemes under QAM and 16-QAM digital modulations over realistic channel conditions is disussed in [23]. The performance of various modulation schemes in AWGN channel is investigated in [24]. The paper given in [25] is based on Wi-Max physical layer to understand the effect of various modulation techniques, coding rates, cyclic prefix factors and OFDM symbol on the system performance.

Binary Amplitude Shift Keying (BASK)

In BASK scheme the resultant is obtained by changing the amplitude of the carrier according to the digital signal.. The BASK is a coherent modulation scheme hence the concept of the co-relation between the signals , number of basis functions, the I and Q components and the symbol shaping are not applicable here.

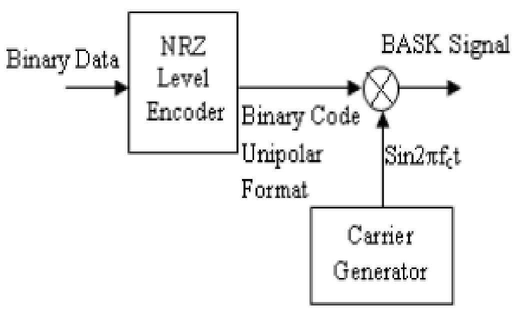

Fig.2 BASK modulation block diagram

In the block diagram of BASK modulator, the output of multiplier is modulated by binary code. The input binary sequence is converted into suitable format for product modulator by the NRZ level encoder.

The bandwidth efficiency is very poor in BASK. The implementation of the BASK is simple but it is highly vulnerable to noise and the performance is good only in the linear region which does not make it suitable for mobile or wireless applications. QAM and M-ary ASK which have much significant applications with improved parameters can be obtained by combining BASK with PSK. The FPGA based modulator is presented for BASK and BPSK modulation techniques in [26] .

Binary Frequency Shift Keying (BFSK)

In the BFSK, the two different frequencies mark and space are used to represent the two different symbols [27]. Depending upon the separation between the two carrier frequencies, BFSK can be categorized as wideband or a narrowband digital modulation technique. FSK has a poorer error performance than PSK or QAM and thus is seldom used for high performance digital modulation systems [28]. Because of the separation in the carrier frequencies, it is not a bandwidth efficient scheme and generally not used because of the receiver design complexities.

Binary Phase Shift Keying (BPSK)

In BPSK digital modulation scheme is referred as the simplest form of phase modulation and in this scheme only two phase states are represented by the the carrier phase.

A Coherent BPSK system is characterized by having a one dimensional signal space with a constellation diagram consisting of two message points.

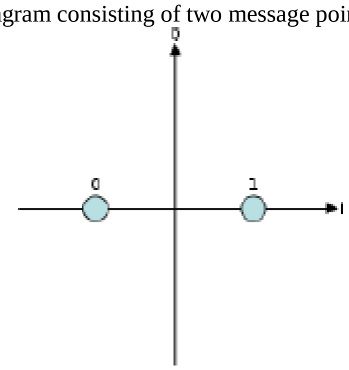

Fig.3 Constellation diagram of BPSK

The two phases which are separated by 180° and can also be referred as 2-PSK. In BPSK, a single carrier is modulated by controlling its polarity according to the binary data signal to be transmitted. The magnitude of the modulated BPSK signal is kept constant, thus increasing the maximum power to be delivered.

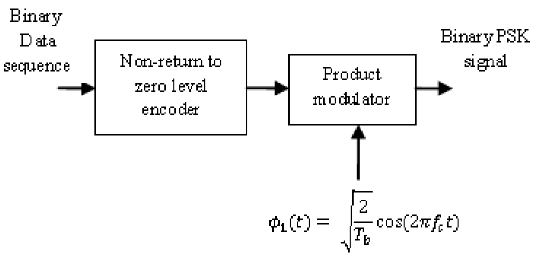

Fig.4 BPSK modulator

To produce a BPSK signal, the binary sequence in polar form with symbol 1 and 0 are represented by fixed magnitude levels of + (Eb)1/2 and - (Eb)1/2 respectively. The resulting binary wave in polar form and a sinusoidal carrier ϕ1(t), whose frequency is given by fc = (n c/T b) for some fixed integer nc are applied to the product modulator. The carrier and timing pulses used to obtain the binary wave are generally extracted from a common master clock. At the output of modulator the desired PSK waveform can be obtained.

The BPSK modulator is basically a two positional switch, controlled by the data stream [29]. The high level in data allows 0° phase and the low level in data permits the 180° phase introduced in the output. The prime advantage of Binary Phase Shift Keying is that it provides a suitable modulation format for downlink data transmission in inductive biomedical telemetry systems, because it achieves high data rates and power efficiencies. BPSK modulation is simple to design and less complex when compared to QPSK, which is almost double the complexity of BPSK design [30]. The BPSK digital modulation technique is generally used in the application of high speed data transfer. It is simple in implementation and gives a 3dB power improvement as compared to BASK modulation technique. The BPSK modulation consists of a phase modulation with two possible states of the intermediate frequency by a serialized numerical signal [31]. The Bit error rate (BER) of BPSK in AWGN channel can be estimated as in [32].

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

As the transmitted signal per energy bit, Eb is increased for a particular noise spectral density No, then the message points corresponding to symbols 1and 0 move further apart and the average probability of error will be reduced.

There is only one bit per symbol in BPSK , this is also termed as symbol error rate. The BER is the number of bit errors divided by the total number of transmitted bits during an observed time interval [33]. The BER is a unitless quantitiy and is often expressed in percentage. The BER measurement is a standard figure of merit in high speed digital systems [34]. The figure shown below explain the process of BPSK demodulation.

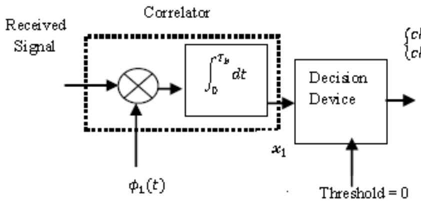

Fig.5 BPSK demodulator

To demodulate the original binary sequence of 1s and 0s, the noisy PSK signal x(t) is applied to a correlator, which is also supplied with a locally produced coherent reference signal ϕ1(t). The correlator output x1 is compared with a threshold of zero volts. If x1 > 0, the receiver output will be symbol 1. On the other hand, If x1 < 0, the receiver decides in favor of symbol 0. If x1 = 0, then the receiver makes a random decision in favor of 0 or 1.

Differential Phase Shift Keying (DPSK)

For the demodulation of a phase modulated signal, it become noticeable that the receiver needs a coherent reference signal but if differential encoding and phase shift keying are combined together at the transmitter station then the resulting modulating technique is termed as Differential Phase Shift Keying [6]. In this, the phase is unchanged for the transmission of the symbol 1, whereas the phase of the signal is advanced by 180° for the transmission of symbol 0. The track of the phase change information which becomes mandatory in determining the relative phase change between the transmitted symbols. The complete process is based on the assumption that the alteration of the phase is very slow to an extent that it can be considered to be almost constant over two bit intervals [35].

Quadrature Amplitude Modulation (QAM)

The QAM is a modulation scheme where its amplitude is allowed to vary with phase [36]. This technique can be viewed as a combination of ASK as well as PSK [37].

QAM is widely used in many digital data communication applications , where data rates beyond 8-PSK are needed by a radio communication system then QAM modulation scheme is extensively used because QAM achieves a greater distance between adjacent points in the I-Q plane by distributing the points are more distinct and data errors are reduced [38]. The QAM modulation is more

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useful and efficient than the others and is almost applicable for all the progressive modems [39].

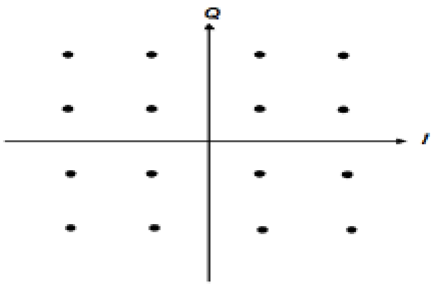

Fig.6 Constellation diagram of 16-QAM

In the 16-QAM, the four different magnitude levels are used.The combined stream would be of 4*4=16 states. In this scheme, each symbol represents four bits.

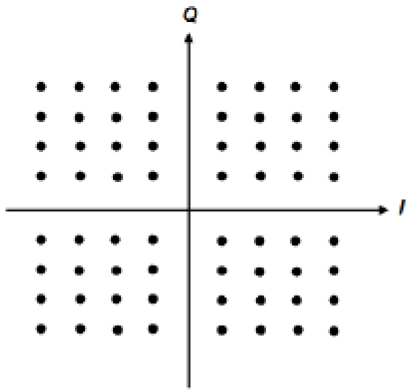

Fig.7 Constellation diagram for 64-QAM

This is same as 16-QAM except that it has 64 states where each symbol represents six bits. It is a complex modulation technique but with a greater efficiency. The mobile Wi-Max technology uses this higher modulation technique when the link condition is high.

Quadrature Phase Shift Keying (QPSK)

In QPSK digital modulation scheme, the division of the phase of the carrier signal is designed by allotting four equally spaced values for the phase angle as $\pi/4$, $3\pi/4$, $5\pi/4$ and $7\pi/4$, thus providing a major advantage over BPSK by having the information capacity double to it.

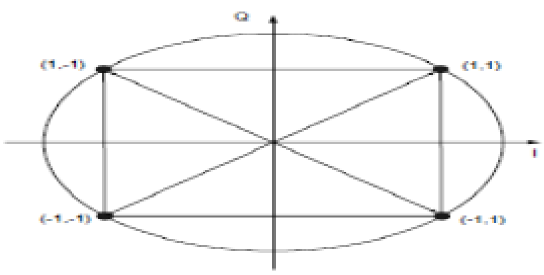

Fig. 8 Constellation diagram of QPSK system [21]

The QPSK becomes a highly bandwidth efficient digital modulation technique because in its constellation diagram, there are four message points. In QPSK the data bits to be transmitted are combined into symbol, each containing two bits each symbol can take on one of four possible values which are 00, 01, 10 or 11 [40]. In QPSK the bandwidth requisite and power requirement is less because more data can be transmitted using different phases and single carrier [41]. QPSK technique may be used either to double the data rate compared to a BPSK modulation system while maintaining the bandwidth of the signal or to maintain the data rate of BPSK but half the bandwidth requirement [42]. The performance of QPSK system in the presence of system impairments may be determined by its bit error rate or symbol error rate [43].

Offset Quadrature Phase Shift Keying (OQPSK)

By offsetting the I and Q modulations by T_s/ 2s, then there is an assurance that aI_n and aQ_n can not change polarity at the same time [44]. The maximum fluctuation in instantaneous amplitude is now restricted to that corresponding to a 90° phase reversal. The resulting modulation is termed as Offset- Quadrature Phase Shift Keying.

The OQPSK is also called Staggered Quadrature Phase Shift Keying. This modulation technique is a variant of phase shift keying using four different values of the phase to transmit. The fluctuations in amplitude in the OQPSK are lower as compared fluctuations in the Non-OQPSK because OQPSK limits the phase shift to no more than 90° at a time. The OQPSK signal does not regenerate the high frequency side-lobes as that of in QPSK modulation scheme. It provides the reduced spectral occupancy and thus allowing more efficient RF amplification. The OQPSK modulation scheme is extensively used for satellite and CDMA applications.

Minimum Shift Keying (MSK)

MSK is a modulation scheme having characteristics of performing well in Gaussian channels and Fading channels [45]. It is an updated form of continuous phase FSK. For keeping the two frequency states orthogonal, the minimum spacing between the two carrier frequencies should be equal to half of the bit rate. The information capacity of an MSK signal is equal to that of QPSK signal but bandwidth requisite is lesser than that needed by QPSK due to the 1/2 cosine pulse shaping. An MSK signal can be obtained from either an OQPSK signal by substituting a square pulse by 1/2 co-sinusoidal pulse or from an FSK signal alternatively. An MSK technique is spectrally more efficient than the QPSK technique because an MSK has lower out of band power. The demerits of this modulation technique are that it comes in the category of linear modulation and resulted spectrum is not enough compact to realize data rate approximating RF channel bandwidth.

Gaussian Minimum Shift Keying (GMSK)

Variety of digital radio communication systems uses GMSK modulation technique. This modulation is based on MSK, which is itself a form of continuous-phase frequency shift keying [46]. An MSK signal is obtained by applying a half sinusoidal pulse instead of the square pulse. If a Gaussian pulse shape is applied instead then the resulted digital modulation scheme is an enhanced version of the MSK modulation technique in the terms of bandwidth and spectral efficiency and is known as GMSK

This technique can be seen as frequency or phase modulation scheme, even though the rate of change of phase is restricted by the Gaussian response but the phase carrier can still advance up to 90° over the track of the bit period. The sternness in pulse shaping lies on the bandwidth time product because obtained phase change over a bit period may fall short by $\pi/2$ which will have a scrupulous impact on bit error rate [47] but it still provides improved bandwidth efficiency over MSK. The relationship between the pre-modulation filter bandwidth B and the bit period Tb gives the bandwidth of a GMSK system [48]. The linear approximated GMSK is presented in Software Defined Radio environment because it provides a common I/Q modulator that can be used for all second generation systems [49]. The GMSK permits class-C non-linear amplifiers to be used, however even with a low BT value its bandwidth competency is less than the filtered QPSK [50]. In GMSK, the side lobe levels of the spectrum introduced in MSK are further reduced by passing the modulating NRZ data waveform through a pre-modulation Gaussian pulse-shaping filter [51]. The performance of GMSK can be enhanced by using optimum filters, Viterbi-adaptive equalization and soft decision Veterbi decoding.

3. Conclusion

In this paper, the review on digital modulation techniques for wireless communication presented shows that the choice of digital modulation technique is completely application specific and should be chosen carefully. Some applications need a higher precision rate, while some schemes focus on effective utilization of available bandwidth and permissible power for the given application. The quality of service offered by wireless communication systems can be greatly improved by correctly selecting the modulation scheme. Thus, proper selection of digital modulation technique needs to be done to increase radio coverage and power consumption.

As some of the technique involve lesser complexities in the modulation and demodulation system design and prove cost-effective like the BASK, BPSK ,BFSK and DPSK modulation schemes and can be visualized for the systems which do not need high amount of precisions or when financial budget is the foremost aspect and the BER performances can be tolerated. The QAM techniques are exclusively used for top boxes , Microwave Digital radio, Broad band set , Digital video, and in Modems. In the area of mobile communication, GMSK has proved its performance over the QPSK and MSK because of the better spectral efficiency. But the search for a better modulation scheme doesn't end here as the criterion for higher data rate communication is taking the lead role in almost every field of communication and thus the Inter Symbol Interference and Bit Error Rate calculation become very crucial and important aspect for any ultramodern digital modulation scheme.

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