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Data Communication using Pulse Shaping techniques in wireless signal processing approach-In depth review

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Abstract

One of the most challenging issues facing deployment of 3G technology is how to make the network architectures compatible with each other. New signaling techniques are being designed specially to enhance today's 2G networks, deliver unprecedented functionality for 3G, and successfully derive the future generation of wireless systems, thus delivering immediate and long term benefits to subscribers. With the architecture of each generation of wireless devices addressed in the development of advance technologies, subscribers can easily evolve their systems without additional network modification, significantly reducing cost and implementing time. The present paper provide the in depth review of Data Communication using Pulse Shaping techniques in wireless signal processing approach.

Keywords*: Data communication pulse shaping, signal processing, WCDMA*

Introduction

The First Generation (1G) and Second Generation (2G) of mobile telephony were indented for voice transmission. The Third Generation (3G) is meant for both voice and data applications. The thirst for effective communication and higher bandwidth has led to the evolution of the next generation wireless systems, and newer technologies are being deployed to provide the user with information and entertainment anywhere and anytime. The third generation mobile radio systems (IMT-2000 globally and UMTS in Europe) are becoming a reality today. The network infrastructure is currently being deployed in many countries. Manufacturers, network operators and service providers are now focusing on the development of new services and applications as well as suitable business models to make third generation mobile communication an economic success. One important lesson to be learnt from the development of 3G is that the potential future services and applications, including the expected user behavior should be taken into account from the very beginning to derive the technical requirements. This approach is essential to enable the economic success of future system.

Currently, different wireless technologies (e.g. GSM, CDMA, and TDMA) are used throughout the world for 2G, 2.5G, and eventually 3G networks. Researchers are continuing their ideas for the development of an undefined wireless world, which could become operational by 2010 [17]. The next generation systems based on the DS-CDMA, FDMA/TDMA and GSM concepts are projected to provide transmitting high speed data, video and multimedia traffic for both indoor and outdoor systems, new technologies like Wideband Code Division Multiple Access (WCDMA), already in service, are providing users with high data rate services options like they have never experienced previously.

Wireless Communications Systems

The first systems for cellular telephony (referenced as first generation systems) were introduced in the early 1980, and were based on analogue modulation techniques using Frequency Division Multiple Access (FDMA). In the early 1990, the first digital systems using Time Division Multiple Access (TDMA) were launched, referred to as second generation (2G) systems 40]. Since then, the number of mobile subscribers has grown explosively as shown in Figure 1. The most widespread 2G system today is the Global System for Mobile communications (GSM),

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which in several west European countries has reached a penetration rate exceeding 70%. The 2G systems not only made voice communications become wireless on a large scale, but also introduced low-rate data services, improved security and roaming between networks [7,8].

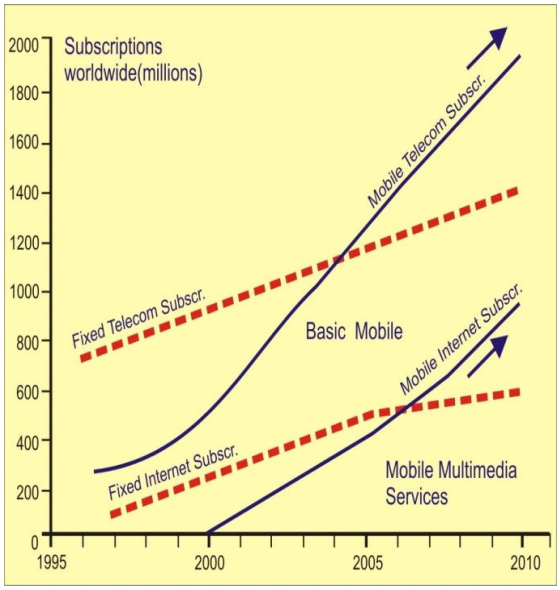

Figure 1 Forecast for the future growth of both fixed and mobile subscribers. The internet will boost mobile services. UMTS forum [7].

The common air-interface enables, for the first time, world-wide compatibility of mobile systems as shown in Figure 2.

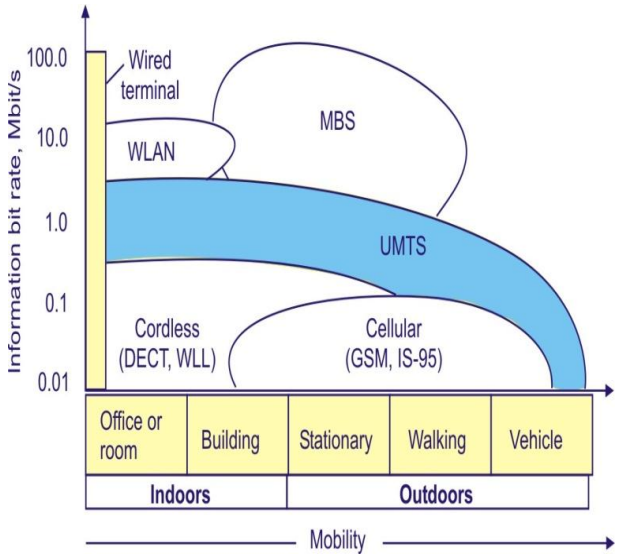

Figure 2 The information bit rate versus the user mobility for different wireless communication systems [9].

Wideband CDMA

Wideband Code Division Multiple Access (WCDMA) technology has emerged as the most widely adopted 3G air interference. Its specification has been created in the 3rd Generation Partnership Project (3GPP), which is the joint standardization project of the standardization bodies from Europe, Japan, Korea, the USA and China [9,10].

WCDMA is considered to be wideband technologies based on the direct sequence spread spectrum transmission scheme, where user information bits are spread over a wide bandwidth by multiplying the user data with quasi-random bits called chips derived from CDMA spreading codes. In order to support very high bit rates (upto 2 Mbps), the use of a variable spreading factor and multicode connection is supported. The chip rate 3.84 Mcps used to leads a carrier bandwidth of approximately 5 MHz. The relatively high bandwidths occupied by CDMA systems are responsible for the significant advantages of CDMA over traditional narrowband systems.

Signal processing in wireless communication

Signal processing techniques, such as Equalization, Detection, and Fast Fourier transform, have been successfully used in communication systems to improve the quality of communication. The applications of signal processing techniques to wireless communication is an emerging area that has recently achieved dramatic improvement in results and holds the potential for even greater results in the future as an increasing number of researchers from the signal processing and communication areas participate in this expanding field [1-5]. From an industrial viewpoint also, the advanced signal processing technology cannot only dramatically increase the wireless system capacity but can also improve the communication quality including the reduction of all types of interferences. As an example, a recent field test by Lucent Technologies demonstrated that adaptive signal processing for antenna arrays can be effectively used in mobile communication systems to mitigate the co-channel interference and increase the system capacity, setting a milestone for signal processing in wireless communications.[10]

Signal Processing Techniques are being employed in the field of wireless communication to enhance the performance of the system. There are many areas varying from First Generation(1G)to Fourth Generation (4G). The recent trends in the Research and Development are in the cutting edge technologies such as IS-95,GSM,CDMA,CDMA 2000,WCDMA,MIMO,SDR etc and the commonly employed different air interface techniques such as TDMA, FDMA ,WCDMA etc.[1,7-16]

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Pulse Shaping in Wireless Communication

The rapidly increasing popularity of mobile radio services has created a series of technological challenges. One of this is the need for power and spectrally efficient modulation schemes to meet the spectral requirements of mobile communications. Linear modulation methods such as QAM, QPSK, OQPSK have received much attention to their inherent high spectral efficiency However for the efficient amplification of transmitted signal, the Radio Frequency Amplifier is normally operated near the saturation region and therefore exhibit non linear behavior. As a result significant spectral spreading occurs, when a signal with large envelope variations propagates through such an amplifier and creates large envelope fluctuations. Pulse shaping plays a crucial role in spectral shaping in the modern wireless communication to reduce the spectral bandwidth.

Pulse shaping is a spectral processing technique by which fractional out of band power is reduced for low cost, reliable, power and spectrally efficient mobile radio communication systems. It is clear that the pulse shaping filter not only reduces inter symbol interference (ISI), but it also reduces adjacent channel interference. To satisfy the ever increasing demands for higher data rates as well as to allow more users to simultaneously access the network, interest has peaked in what has come to be known as wideband code division multiple access (WCDMA).The basic characteristics of WCDMA waveforms that make them attractive for high data rate transmissions are their advantages over other wireless systems. It emphasizes that how the choice of spread bandwidth affects the bit error rate of system [11-14]

Survey of the literature

This section provides the in depth review work of earlier research workers as collected from international/national journals as well as conferences from 1993 to 2010.

Fred Harris (1993) implemented matched filter in DSP based modem, which was followed or preceded by additional analog filtering. It has been reported that non uniform gain and phase of these analog filters caused filter mismatch and lead to undesired ISI. A technique to design digital matched filters, which include spectral gain and phase compensation required to equalize the known characteristics of analog filters in transmitter and receiver paths has been discussed. [15]

Jun He Colin etal (1993) discussed the differential detection of OQPSK signals in mobile radio environment. Two implementation schemes, SRRC Filter ODQPSK and constant envelope ODQPSK (CE-ODQPSK) were evaluated using computer simulation. It was demonstrated that a compact spectrum and low envelope variation of modulated signal were achievable using SRC-ODQPSK. The good spectral and envelope properties, superior error performance and simple receiver configurations make SRC and CE_ODQPSK attractive for use in power and bandwidth limited mobile radio communications. They advantages of small envelope fluctuation, compact spectrum and better BER performance than $\pi/4$ DQPSK and GMSK in hard limited and Rayleigh fading environments. [16]

Xiang Gen Xia (1997) described the family of pulse shaping filters with ISI free matched and unmatched filter properties. The raised cosine pulse shaping filter plays an important role in digital communications due to its ISI free property that holds after matched filtering is performed. In this letter author proposed a new family of pulse shaping filters and using these new pulse shaping filters ,the computational load and therefore the hardware cost in demodulation for modern design might be reduced in some applications, where low pass (band pass) filtering is performed before the matched filtering.[17]

Ye Li,KJ RayLiu (1998) reported that signal processing techniques such as equalization, detection and fast fourier transform had been successfully used in communication systems to improve the quality of communications. With recent exploding research interest in wireless communication, applications of signal processing to this area became increasingly important. Indeed it was the advancement in signal processing technology that made most of todays wireless communications possible and held the key to future services.[18]

Andrey V. Kisel (1999) presented a simple alternative approach to pulse shaping filters with ISI free matched (white noise case) and unmatched filter properties Author reported that Nyquist 1 filter in closed form proved to be ISI free with or without matched filtering when its complex transfer function was derived from an initially given Nyquist 1 filter. Such signals might not only reduce the hardware cost in designing modern systems but might also open wide optimization prospects for data transmission systems..[19]

N .S. Alagha (1999) reported that data transmission over bandlimited channels required pulse shaping to eliminate or control ISI. Nyquist filters provided ISI free transmission. Phase compensation can be applied to square root of any zero phase band limited nyquist filter with

normalized excess bandwidth less than or equal to one. The resulting phase compensated sq root filter was also nyquist filter.In case of raised cosine spectrum, phase compensator had simple piecewise linear form. Such a technique was particularly useful to accommodate two different structures for receiver, one with a filter matched to transmitting filter and one without a matched filter.These generalized raised cosine filters offered more flexibility in filter design. For instance the rate of asymptotic decay of filter impulse response might be increased or residual ISI introduced by truncation of impulse response might be minimized..[20]

CC Tan, NC Beaulieu(1999) studied the transmission properties of Xia,s pulses. and reported that a family of pulses suggested by Xia's that are intersymbol interference (ISI)-free with and without matched filtering.The transmission characteristics of these pulses are compared to the more commonly used raised cosine pulse for three different receiver scenarios. Comparisons between the two families of pulses are made with eye diagrams and by determining the average probability of bit error accounting for noise, intersymbol interference (ISI), and timing error. given, the family of linear phase and widely used raised cosine and root raised cosine pulses generally have a lower probability of error than the family of Xia pulses..[21]

Laurence B. Milstein (2000) reported that in order to satisfy the ever increasing demands for higher data rates as well as to allow more users to simultaneously access the network interest peaked in what came to be known as WCDMA. The author discussed the basic characteristics of WCDMA waveforms that made them attractive for higher data rate transmissions over the wireless channel. The author emphasized how the choice of spread bandwidth affected BER of system as well as how it affected the reliability of various subsystems, such as those that perform coarse acquisition and adaptive power control. Finally author discussed other potential enhancements to WCDMA systems such as the use of interference suppression at receiver or multiple antennas at transmitter..[22]

Jiangzhow wang etal (2000) reported that WCDMA is emerging as a predominant wireless access technology for 3G systems. WCDMA was designed to flexibly offer wideband services such as wireless internet services and video transmissions. Wideband was essentially about data rate. The physical limitations and impairments to the radio channels (BW constraints, multipath fading, noise and interference) presented a fundamental technical challenge to the goal of reliable high data rate communications.[23]

A.Silvaetal (2000) presented a technique for reducing ISI in underwater coherent communications using the time reversal acoustics. The paper introduced a "virtual time reversal mirror that was implemented electronically at the receiver array and simulated a kind of processing that would be done by actual TRM during reciprocal propagation stage. In both the cases the probe pulse sent by transmitter/receiver located at the physical/virtual focal point and received at array provides a template impulse response for undoing the effects of multipath by straightforward linear filtering. [24]

R.Veljanovski etal (2001) studied the characteristics of pulse shaping FIR filter, which has been used for TDD-WCDMA transmitter. The comparison between TDD and FDD schemes for communication between mobile terminal and the base station was made.TDD a new duplex method for WCDMA,whereby uplink and downlink transmissions are carried over the same radio frequency by using synchronized time intervals. In TDD time slots in a physical channel are divided into transmission and reception part. Information on uplink and downlink were transmitted reciprocally. In FDD uplink and downlink transmissions used two separated radio frequency bands.TDD was able to handle up to sixteen users per time slot, whereas one WCDMA cell contained fifteen time slots. Two pulse shaping FIR filters attenuated the adjacent channel from in phase and quadrature phase components. The sampling frequency and filter complexity depend upon interpolation factors. Various interpolation factors produced different filter characteristics. It affected sampling frequency, complexity and attenuation of filter. [25]

Behrouz etal (2001) reported that designing matched transmit and receive filters such that their combination satisfies nyquist condition was a classical problem in digital communication system. A novel method has been presented for designing such filters. The proposed method was based on a cost function whose minimization lead to the designs that can strike a balance between stops band attenuation, residual ISI, robust sensitivity to timing jitter and reduced peak to average power ratio.[26]

H Gharavi etal(2001)presented a twin class unequal protected video transmission system over wireless channels. Video portioning based on separation of variable length coded (VLC) Discrete cosine transform coefficients within each block were considered for constant bit rate transmission. In the splitting process the fraction of bits assigned to each of the two partitions was adjusted according to the requirements of unequal error protection scheme employed. [27]

SF Lin (2001) presented a novel approach for implementing power efficient finite impulse response filters that require less power consumption than traditional

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FIR filter implementation in wireless embedded systems. The proposed schemes were imposed to direct form and achieved certain reduction in the power consumption.. In several wireless handheld systems FIR filters are indispensable parts among various image/video communication applications to reduce noise and enhance the specific features. So low power architecture for dedicated linear phase FIR filter was proposed [28]

Kal Kalbasi (2002) reported that the increasing use of digital IF and direct conversion architectures are the trends in the design of multimode phones. For digital IF designs, simulation of RF, analog and baseband signal is a key part of the design process along with the tradeoff study of different channel selection filtering.[29]

Ken Gentile (2002)reported that that pulse shaping filter plays a critical part in maintaining the signal integrity. It has been reported that in modern data transmission systems, bits or group of bits (symbols) are typically transmitted in form of individual pulses of energy. A rectangular pulse is probably the most fundamental. Fourier transform of the pulse yields its spectral characteristics pulse of width τ has bulk of its energy contained in the main lobe, which spans the one sided bandwidth of $1/\tau$ Hz which implies that frequency span of data transmission channel must be at least $2/\tau$ Hz wide. Thus the challenge in the data transmissions systems is to obtain the highest possible data rates in the bandwidth allotted with least number of errors[13]

Woo-Jinoh (2002) introduced a simple design method for root squared type raised cosine filter with equiripple characteristics. Through some design examples author showed that proposed filter has much better performance in ripple than conventional Square root cosine filter at the expense of small increasing of ISI. In addition the proposed filter is compatible with conventional SRCF. [30]

Song-Ling Tsai (2003) considered the DSP implementation of some 3GPP WCDMA transmissions. Signal processing elements and DSP simulation of equivalent baseband wireless channel. The transmission signal processing elements include spectrum spreader, transmission filter and receiver filter where spectrum spreader and transmission filter together constitute baseband modulator and receiver modulator was sometimes referred to as matched filter. For wireless channel several different models were considered. There are still several possible extensions that would enhance the performance and functionality of the realized system. for example in a practical system , base station would adjust the power of each user according to BER and SNR[31]

Massimiliano Laddomada(2003) presented" Digital Pulse shaping FIR filter design with reduced ISI &ICI. An important requirement in the design of data transmission filters is the minimization of intersymbol interference, which is zero if the overall impulse response (transmit filter, channel and receive filter) satisfies the first nyquist criterion. In this context, an important class of transfer functions, satisfying the nyquist criterion, is the raised-cosine filter family. In order to guarantee low interference between adjacent channels, the transmit and receive filters must have a high value of stopband attenuation, so as to reduce the interchannel interference as much as possible. [32]

Hamizi Bin Zamzuri(2003) in his paper on Simulation on WCDMA for 3G mobile systems described the multiuser effects and calculation of BER in 3G mobile systems using Simulink MATLAB. The model for system was constructed using block diagrams in Simulink library that fulfilled the characteristics of system.Gaussian approximation is used to define the bit error rate in CDMA, multiple access and communication systems.BER is calculated by comparing between transmitting data and receiving data.The multi user effect and BER are evaluated at different data rates. [33]

Dongsong Zeng(2003) in his paper of pulse shaping filter design in UWB system, optimal pulse shaping filter has been discussed that minimizes UWB signal interference to existing or legacy narrowband signals, such as global positioning system, satellite communication systems, etc. Ultra wide band signal is defined as one whose bandwidth over center frequency ratio is greater than 0.25 or one whose bandwidth is over 500 Mhz. [34]

Nicholas J Bass and DP Taylor (2004) investigated the influence of transmit and receive filtering on the design and associated performance of wireless communication systems. Based on the derivations using power series models of time or frequency selective channels they had presented the pulse shaping filters which can be matched to characteristics of the channel. The choice of filter parameters allowed some degree of control over received signal. Peak to average power ratio requirements in the transmitter are determined. OFDM represents an alternative method of achieving some of the stated objectives of pulse shaping methods developed. [35]

Pal Orten and Arne Svensson(2004) described that DS-CDMA is evaluated for rectangular pulse shaping and square root raised cosine pulses with different roll off factors. Rectangular pulses are found to be better even with close adjacent channels. With synchronization error in order of 10% of a chip interval, square root raised cosine pulses outperform the rectangular pulse The effect of

square root raised cosine chip shaping on the BER of a system with and without adjacent channels for additive white gaussian noise (AWGN) channels and for Rayleigh fading channels has been studied. [36]

C. Tan ,N C Beaulieu(2004) discussed about the transmission properties of conjugate root pulses. A family of pulses have recently been adopted by Xia that are intersymbol interference free with and without matched filtering. The transmission characteristics of these pulses are compared to the more commonly used raised cosine pulse for the three different receiver scenarios. However the work reported here based on the fuller examination of transmission behavior of new pulses indicates that the conventional (root) raised cosine pulse shaping is almost always superior to conjugate root pulse shaping. This conclusion is drawn on the basis of investigations of eye diagrams, maximum distortion and average symbol error probabilities in the presence of symbol timing errors. Raised Cosine Pulse shaping is most suitable for applications in the three system scenarios investigated. [37]

Antonio Assalini and A M Tonello (2004) proposed two new Nyquist(ISI free) pulses that exhibit better error probability performance in the presence of sampling errors than the popular raised cosine and proposed pulses by Beaulieu, Tan and Damen. The new pulses are also robust to root and truncation operations. Two new Nyquist pulses have been proposed that asymptotically decay as t^{-3} and as t^{-2}.they both exhibit a small error probability than the popular raised cosine pulse. The latter pulse also behaves better than a recently proposed pulse by Beaulieu, etal. Next, authors have considered the equivalent pulses that are obtained by auto convolution of a truncated root version. For very small timing errors, the proposed t^{-3} decay pulses exhibit better performance than t^{-2} decay pulses. For larger timing errors, the proposed t^{-2} pulse still exhibits a much wider eye opening, a smaller maximum distortion and improved BER than other pulses[14]

Gianluca Setti(2004) in his paper on the performance of chaos based asynchronous DS-CDMA with different pulse shapes, described a general framework to assess the joint effect of pulse shaping and spreading sequence statistics on asynchronous DS-CDMA. With this the effect of three possible pulse shapes(rectangle, band limited rectangle and square root raised cosine) associated with three possible spreading sequences(i.e. chaos based and optimum) has been analysed. So overall performance is obviously degraded by band limitations.[38]

Lingwen Zhang(2006)discussed digital up converter system module for WCDMA base station based on SDR was constructed and the optimum filters used in the system were designed and simulated which indicate that the filters designed were with appropriate frequency properties and lower steps which could help to reduce computation complexity and storage space. [39]

DS Waldhauser et al (2006) reported that multicarrier systems such as OFDM are already established in lot of current communication standards. Moreover they are very prominent candidates for future systems in mobile communications. Filter bank based multicarrier systems can be designed to provide a better spectral shaping than OFDMA systems. They have some advantages over OFDM, which will further motivate research in direction of channel equalizers with low complexity. So optimum adaptability to time and frequency selectivity of propagation channel is crucial for mobile communication systems. **[**40**]**

Chia Yu Yao (2007) presented the design of SRRC FIR filters by an iterative technique. A pair of matched square root raised cosine filters in transmitter and receiver in a band limited digital communication system has been analysed that can theoretically achieve zero ISI. In reality ISI cannot be zero when both SRRC filters are approximately implemented because of some numerical precision problems in the design phase as well as in the implementation phase. An iterative method to design the coefficients of SRRC FIR filter has been proposed.[41]

Mohd Al Eshtawie(2007) reported that finite impulse response (FIR) filters have the advantage of linear phase, guaranteed stability, fewer finite precision errors, and efficient implementation. In contrast, they have a major disadvantage of high order need (more coefficients) than IIR counterpart with comparable performance. The high order demand imposes more hardware requirements, arithmetic operations, area usage, and power consumption when designing and fabricating the filter. Therefore, minimizing or reducing these parameters, is a major goal or target in digital filter design task for optimum performance. [42]

Greg Berchin(2007) introduced the practical design and implementation of signal processing algorithms. Filter Design Least Square(FDLS) based filter approximation was based on the review of pseudo inverse, transfer function and frequency response and also that output was a combination of present and past input and output values with each scaled by a set of coefficients. [43]

M. Arif etal (2008) described the design and implementation of IIR filter for wireless communication of a occupied channel. When a user of a mobile occupies a channel, it assigns a range of frequencies for the same channel. So for this purpose, an IIR filter used at the base station to select a particular frequency range assigned to a

particular channel was designed. In the design author has designed appropriate type of band pass filter to implement the operation. Digital filters are very important in signal processing because they allow distortion free transmission of waveforms. [44]

Fumiyuki Adachi(2008) discussed about Wideband DS-CDMA for Next Generation Mobile Communication systems. Wideband wireless access based on direct sequence code division multiple access aimed at third generation mobile communication systems is reviewed. WCDMA is designed to flexibly offer wideband services which cannot be provided by present cellular systems with various data rates as high as 2Mbps.[45]

CJ Kikkert (2008) investigated the Bit Error Rates (BER) obtained using different filter types for RF front ends for WCDMA-UMTS mobile radio systems. Most Base Stations uses Chebychev or Cauer-Chebychev filters. This paper compares the use of Bessel, Butterworth and Chebychev filters for use as single channel filters in a WCDMA-UMTS radio system. It is shown that even though Bessel filters pass more adjacent channel interference, they result in a significantly lower Bit Error Rate (BER) and insertion loss than the other filter types.It has been emphasized that group delay is an important parameter for WCDMA based communication system.[46]

M.Renu(2009) described that with increase in demand for faster communication systems, the rate of data transfer over the channel is increasing. As the channel consists of interferences and various other parameters which affects the transmitted bits hence resulting in corruption of message bits. From the analysis on such short wireless channel for data communication it can be observed that Bit Error Rate drops down with increase in SNR. In most of the mobile or cellular systems, message travels through various paths and reach to the receiver unit giving rise to multipath communication The BER performance of the system for different fading parameters as well as roll off factor have been evaluated.[47]

A. S. Kang and Vishal Sharma(2009 and 2010) Studied the analysis of Square Root Raised Cosine filter for WCDMA at 5Mhz.The effect of variation of Roll Off Factor, Group Delay and Interpolation factor have been studied. The same study has been carried out for flipped exponential family, flipped secant hyperbolic family and flipped secant inverse hyperbolic family. The simulation model has been developed for the simulation study of pulse shaping filter using simulink library from Matlab7.3. The simulation study has been carried out at 64 kbps data rate for WCDMA at 5 MHz using different values of Group Delay. The optimum value of Group Delay D=6, is found as an optimum value with Interpolation Factor M=5 and Roll off factor 0.22. [48-58]

Conclusion

The application of signal processing techniques to wireless communications is an emerging area that has recently achieved dramatic improvement in results and holds the potential for even greater results in the future as an increasing number of researchers from the signal processing and communication areas participate in this expanding field. Due to intensive use of FIR filters in video and communication systems, high performance in speed, area and power consumption is demanded. Digital Signal processing techniques are being used to improve the performance of 3G systems WCDMA (Wideband Code-Division Multiple Access), an ITU standard derived from Code-Division Multiple Access (CDMA), is officially known as IMT-2000 direct spread spectrum. W-CDMA is a third-generation (3G) mobile wireless technology that promises much higher data speeds to mobile and portable wireless devices than commonly offered in today's market. The present paper has provided the in depth review of Data Communication using Pulse Shaping techniques in wireless signal processing approach. The study has impact in wireless communication as given below:

1. The study is useful to improve the performance of WCDMA Network.
2. In the planning of WCDMA Network.
3. To achieve the flexibility in use of data rates in different environments.
4. Design of future cellular mobile communication network.
5. The proposed WCDMA Simulator can be used for optimization of parameters in various environments, with various mobile distributions and different services.

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