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Full Length Research Paper

Analysis the effect of Reed-Solomon (RS) coding over WiMAX communication system with transmission of digital colour image

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In this paper an analytical approach is introduced to evaluate the effect of Reed-Solomon (RS) coding over WiMAX wireless communication system with transmission of 16-QAM encoded digital colour image signal over AWGN and fading channel models. Different system configurations including time-domain differential modulation, frequency domain differential modulations, delay spread of channels are considered in the exact BER analysis. Both analysis and simulation results are presented for 16QAM modulation scheme and both AWGN and fading channels. We investigate the performance of RS coding over AWGN and frequency selective fast fading channels. By using RS codes, we can get the effect of improving the total BER due to benefits of RS codes correcting burst that are caused due to a noisy channel. The resulting scheme is tested for the transmission of images over noisy channels.

Keywords: RS coding, fixed WiMAX, colour Image, AWGN and fading channel.

INTRODUCTION

The IEEE 802.16 Working Group created a new standard; commonly known as WiMAX (Wei et al., 2005) (Worldwide Interoperability for Microwave Access) is an emerging wireless communication system that is expected to provide high data rate communications in metropolitan area networks (MANs) (Nichols, 2004). In the past few years, the IEEE 802.16 working group has developed a number of standards for WiMAX. The first standard was published in 2001, which aims to support the communications in the 10–66 GHz frequency band. In 2003 IEEE 802.16a was introduced to provide additional physical layer specifications for the 2–11 GHz frequency band. These two standards were further revised in 2004 (IEEE 802.16-2004). Recently, IEEE 802.16e has also been approved as the official standard for mobile applications (Lu et al., 2001).

WiMAX Standard

To understand the development of the standard to WiMAX current stage, the evolution of the standard is present following: IEEE 802.16-2001, the first standard of the family, was approved in December 2001 and published in 2002. This standard is the result of the activity of hundreds of participants worldwide. The working group of this standard (Air Interface for Fixed Broadband Wireless Access System) focused on providing Wireless MAN access for fixed applications. IEEE 802.16-2001 (LAN/MAN committee, 2001) provides network access to buildings through exterior antennas communicating with a radio base station using point-to-multipoint (PMP) infrastructure design and operating at a radio frequency between 10 and 66GHz with an average bandwidth performance of 70 Mbps and a peak rate up to 268 Mbps. Thus, it is basically an alternative to cabled access networks, cable modems, and digital subscriber line (DSL). However, the IEEE 802.16-2001 standard was not an adequate air interface standard for broadband wireless access. It addressed frequencies in a licensed spectrum that introduces significant challenges to the short wavelength and is limited to line-of-sight (LOS) propagation. It also neglects any conformance with its European counterpart standard, Hiper MAN standard, and supports a single-carrier physical layer. Thus, the initial 802.16-2001 standard was followed by several

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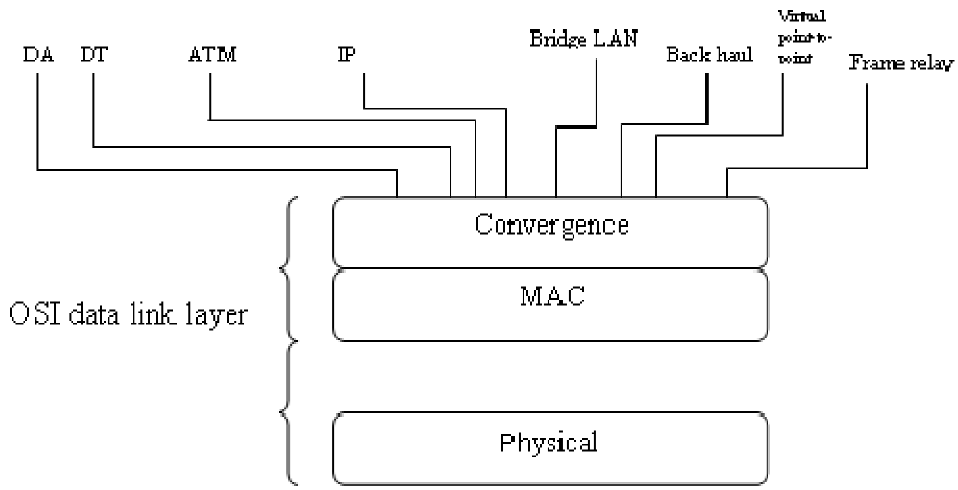

Figure 1. IEEE 802. 16 Protocol Architecture.

amendments.

The first one was IEEE 802.16c (LAN/MAN committee, 2002). The main objective of this amendment was to ensure interoperability among the existing local multipoint distribution service (LMDS) LOS solutions working in the 10–66GHz range. Naturally, since the 802.16c is defined over a wide range of frequency it provides more bandwidth. However, and for the same reason, the maximum coverage of 802.16c does not exceed 5 km. In addition to 802.16c's main objective, it addressed other issues such as testing, performance evaluation, and system profiling, is a vital requirement for interoperability. 802.16c provides guidelines for vendors through mandatory and optional elements of system profiling to ensure interoperability. As for mandatory elements of 2.16c profiling, vendors should support provisioned connections, provide IPv4 support on transport connection, and support fragmentation. As for optional elements, 802.16c allows for different levels of security protocols that allow vendors to provide different functionalities that differentiate their products. As a final remark on 802.16c, it is specified to be network technology independent. Thus it can run under asynchronous transfer mode (ATM), internet protocol (IP), or frame relay. The second amendment was the IEEE 802.16b, also called Wireless HUMAN (Wireless high-speed unlicensed metropolitan area network). This amendment mainly provided for quality of service (QoS) features to ensure differentiated service levels for different traffic types. It extended 802.16-2001 to operate under license-exempt regulation in the 5–6GHz range.

In April 2003, 802.16a, the most eminent among amendments, was published to standardize the lower-frequency multichannel multipoint distribution service (MMDS) solutions in the licensed and unlicensed range of 2–11 GHz. Working at a lower frequency range than 802.16-2001, 802.16a (LAN/MAN committee, 2003) has the advantage of being able to offer non-line-of-sight (NLOS) communication and a cell coverage up to 50km with a bit rate up to 75 Mbps. An additional feature of 802.16a is that it provides for mesh mode operation, which facilitates subscriber-to-subscriber communications.

IEEE 802.16d project was launched to produce interoperability specification and to provide for some fixes for 802.16a. However, the project was transitioned into a revision project for 802.16-2001 and all its amendments. The revision project result is no longer called 802.16d, but it is formally called 802.16-2004 (LAN/MAN committee 2004) (Ahson et al., 2008).

In December, 2005 the IEEE completed the 802.16e-2005 (Islam et al., 2012) amendment, which added new features to support mobile applications. The resulting standard is commonly known as mobile WiMAX (Tran et al., 2008). IEEE 802.16e-2005 was included in the current applicable version of standard IEEE 802.16-2004. This includes the physical and MAC layer enhancement to enable combined fixed and mobile operation in licensed band (Hasan, 2007).

WiMAX Protocol

An 802.16 wireless service provides a communications path between a subscriber site and a core network such as the public telephone network and the Internet. This wireless broadband access standard provides the missing link for the "last mile" connection in metropolitan area networks where DSL, Cable and other broadband access methods are not available or too expensive. The Wireless MAN technology is also branded as WiMAX

IEEE 802.16 Protocol Architecture has 4 layers: Convergence, MAC, Transmission and physical, which can be map to two OSI lowest layers: physical and data link, as shown at Figure 1 (Omerovic, 2003).

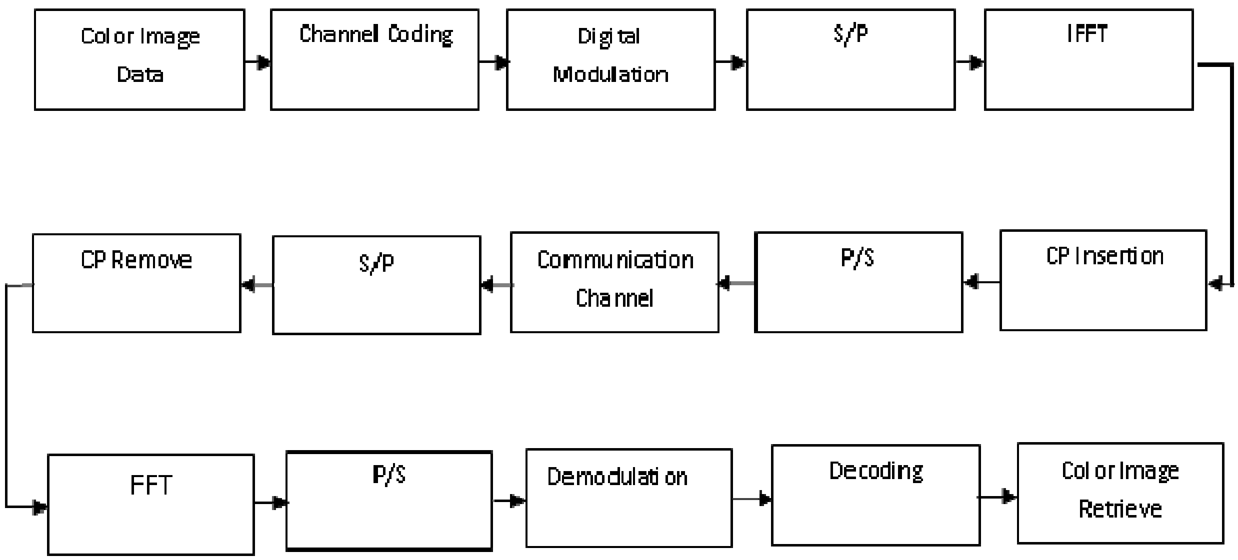

Figure 2. Block diagram of WiMAX Physical Layer.

Simulation Model

The main part of the implemented transmitter and receiver sections of the WiMAX Physical layer are shown in the block diagram of Figure 2. This structure corresponds to the physical layer of the WiMAX air interface. In this setup, we have just implemented the mandatory features of the specification, while leaving the implementation of optional features for future work. The channel coding part is composed of coding techniques i.e. the Reed-Solomon (RS) and Convolutional Code (CC). The complementary operations are applied in the reverse order at channel decoding in the receiver end. We do not explain each block in details. Here we only consider two concatenated encodes namely Reed-Solomon (RS) and Convolutional Code (CC).

The procedures that we have followed to develop the WiMAX physical layer simulator is briefly stated as follows:

At the transmission section:

1. At first we take a colour image and convert it to a random data stream as our input binary data using Matlab R2009a. Then randomization process has been carried out to scramble the data in order to convert long sequences of 0's or 1's in a random sequence to improve the coding performance.
2. Secondly we have performed Reed-Solomon (RS) encoding with the parameters (N = 255, K = 239, T = 8). After this 2/3 rated convolutional encoding is also implemented on the RS encoded. The encoding section was completed by interleaving the encoded data.
3. Then digital modulation techniques, as specified in WiMAX Physical layer namely 16QAM is used to modulate the encoded data.
4. The modulated data in the frequency domain is then converted into time domain data by performing IFFT on it.
5. For reducing inter-symbol interference (ISI) cyclic prefix has been added with the time domain data.
6. Finally the modulated parallel data were converted into serial data stream and transmitted through different communication channels.
7. Using Matlab built-in functions, “awgn”, “rayleighchan” and “ricianchan” we have generated AWGN, Rayleigh and Rician channels respectively.

At the receiving section we have just reversed the procedures that we have performed at the transmission section. After ensuring that the WiMAX PHY layer simulator is working properly we started to evaluate the performance of our developed system. For this purpose we have varied encoding techniques and digital modulation schemes under AWGN and frequency-flat fading (Rayleigh/ Rician) channels. Bit Error Rate (BER) calculation against different Signal-to-Noise ratio (SNR) was adopted to evaluate the performance.

At first, we define the parameters that were used to develop the WiMAX PHY layer simulator. The used parameters are listed in Table 1 as follows:

Reed-Solomon Encoder

Reed-Solomon Codes, abbreviated RS codes, are designed by over sampling a polynomial constructed from the data. The message to send is mapped to a polynomial and the codeword is defined by evaluating it at several points.

The purpose of using Reed-Solomon code to the data is to add redundancy to the data sequence. This redun-

Table 1. Parameter of the Simulator.

Parameters	values
Number Of Bits to be Transmitted and received	61184
Number Of Subcarriers	200
FFT Size	256
CP	1/8
CC	1/2, 2/3
RS	(255,239,8)
SNR	0-25
Modulation	16-QAM
Noise Channels	AWGN, Rayleigh and Rician

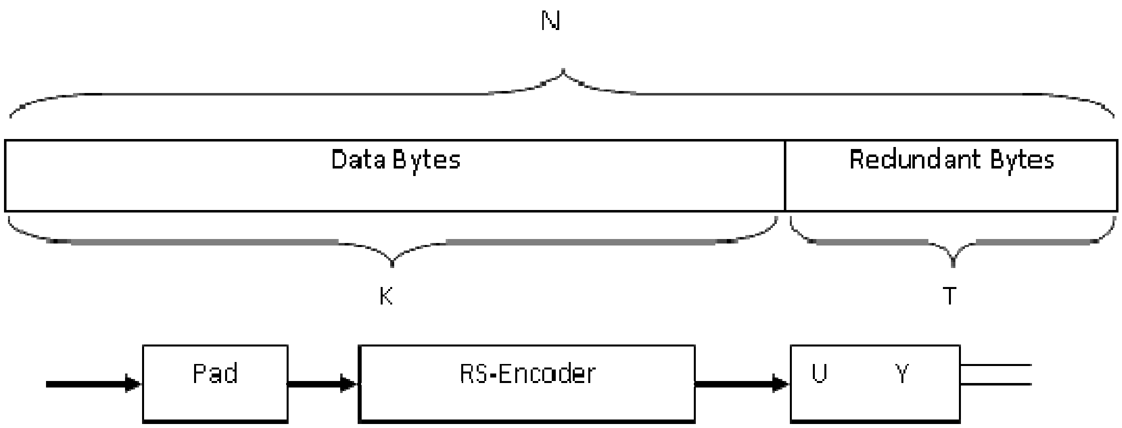

Figure 3. Reed Solomon Encoder.

dancy addition helps in correcting block errors that occur during transmission of the signal.

After randomizer data is passed into the Reed Solomon encoder. The encoding process for RS encoder is based on Galois Field Computations to do the calculations of the redundant bits (36). Galois Field is widely used to represent data in error control coding and is denoted by GF (2^m). (Figure 3)

Where

N= Number of Bytes after encoding

K= Data Bytes before encoding

T= Number of bytes that can be corrected

Eight tail bits are added to the data just before it is presented to the Reed Solomon Encoder stage. This stage requires two polynomials for its operation called code generator polynomial g(x) and field generator polynomial p(x). The code generator polynomial is used for generating the Galois Field Array whereas the field generator polynomial is used to calculate the redundant information bits which are appended at the start of the output data (Crow et al., 1997).

The RS code is derived from a systematic RS (N = 255, K = 239, T = 8) code using GF (2^8). Reed Solomon Encoder that encapsulates the data with coding blocks and these coding blocks are helpful in dealing with the burst errors. The following polynomials are used for code generator and field generator:

$$G(x) = \left(x + \lambda^0\right)\left(x + \lambda^0\right)\ldots\ldots\left(x + \lambda^{2T-1}\right), \lambda = 02_{HEX} \quad (1)$$

$$P(x) = x^8 + x^4 + x^3 + x^2 + 1 \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

The encoder support shortened and punctured code to facilitate variable block sizes and variable error correction capability. A shortened block of k´ bytes is obtained through adding 239k´ zero bytes before the data block and after encoding, these 239-k´ zero bytes are discarded (Hasan, 2007).

In the present research work we have employed the 'rsenc' function available in Matlab to perform Reed-Solomon encoding.

Convolutional Encoder

The outer RS encoded block is fed to inner binary convolutional encoder. A convolutional code introduces redundant bits into the data stream through the use of linear shift registers as shown in Figure 4.

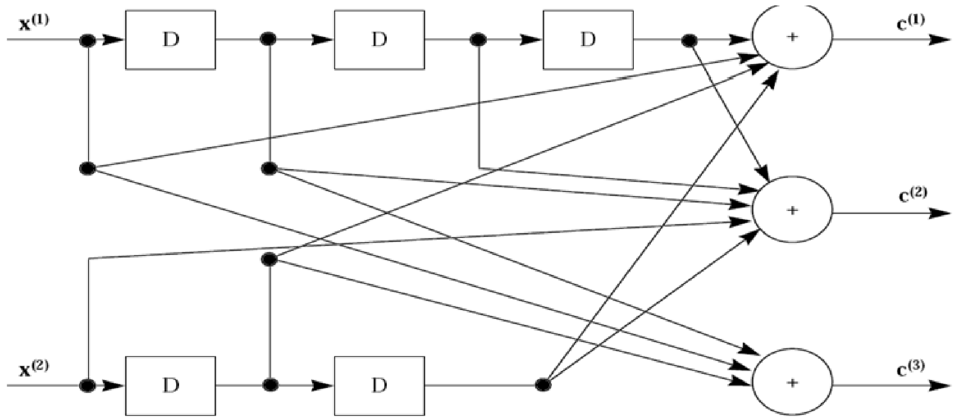

Figure 4. 2/3 rated Convolutional Encoder.

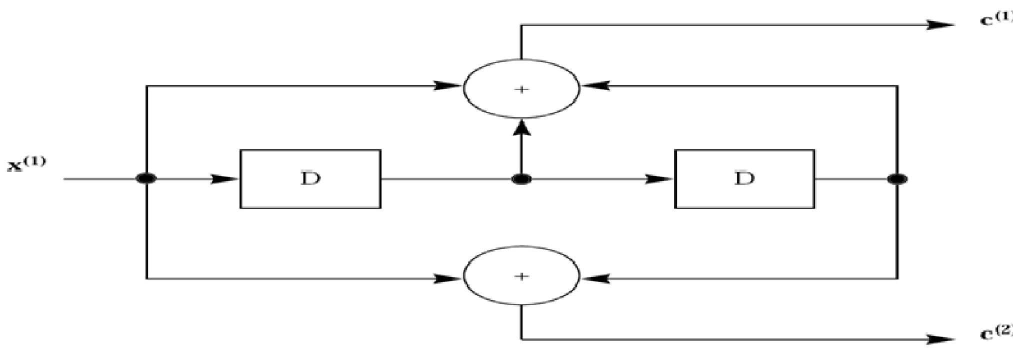

Figure 5. 1/2 rated Convolutional Encoder.

The information bits are input into shift registers and the output encoded bits are obtained by modulo-2 addition of the input information bits and the contents of the shift registers. The connections to the modulo-2 adders were developed heuristically with no algebraic or combinatorial foundation. The code rate r for a convolutional code is defined as

$$r = \frac{k}{n} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(3)}$$

where k is the number of parallel input information bits and n is the number of parallel output encoded bits at one time interval. The constraint length K for a convolutional code is defined as

K=m+1 ………… (4)

where m is the maximum number of stages (memory size) in any shift register. The shift registers store the state information of the convolutional encoder and the constraint length relates the number of bits upon which the output depends. For the convolutional encoder shown in Figure 4, the code rate r=2/3, the maximum memory size m=3, and the constraint length K=4.

A convolutional code can become very complicated with various code rates and constraint lengths. A simple convolutional code with rate of 1/2 and constraint length of 3 describe in Figure 5. Also, the main decoding strategy for convolutional codes is based on the Viterbi Algorithm (Khan et al., 2008). In the present research work we have employed the ‘convenc’ function available in Matlab to perform Reed-Solomon encoding. Here we define two trellises, one for 1/2 rated convolutional encoding and other for 2/3 rated convolutional encoding. For decoding, ‘vitdec’ function is used which are also available in Matlab.

16-QAM

“16-QAM” results when 16 = *M* for *M*-ary QAM. QAM transmits $K = log_2 M$ bits of information during each symbol period. For 16-QAM, there are 16 possible symbols each containing 4 bits, two bits for the I component and two bits for the Q component. The mapping of the bits into symbols is frequently done in accordance with the Gray code which helps to minimize the number of bit errors occurring for every symbol error. Because Gray-coding is given to a bit assignment where the bit patterns in adjacent symbols only differ by one bit (Bateman A, 1999), this code ensures that a single symbol in error

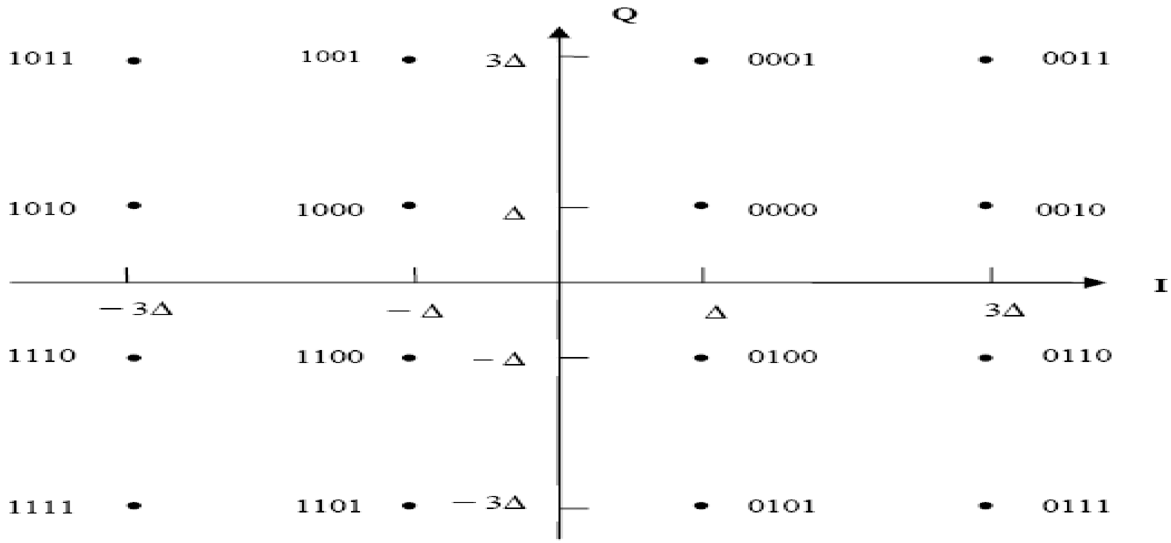

Figure 6. Rectangular constellation of a 16-QAM signal.

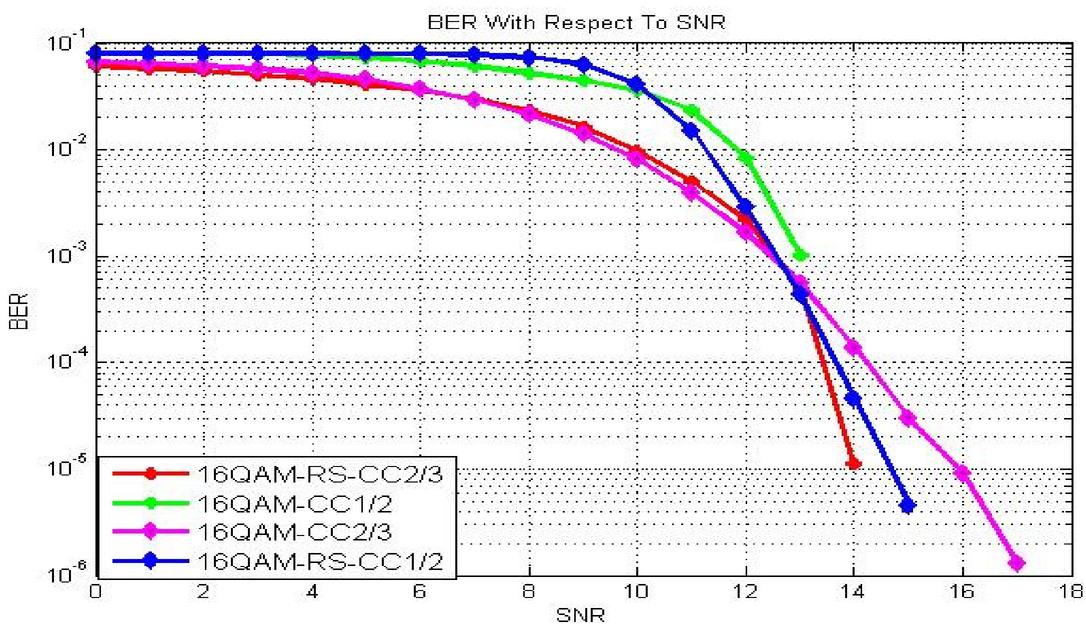

Figure 7. Effect of Reed-Solomon encoding in 1/2 and 2/3 rated 16QAM modulation on AWGN channel.

likely corresponds to a single bit in error. The rectangular constellation of a 16-QAM signal is shown in Figure 6.

The 16 symbols in the 16-QAM rectangular constellation diagram are equally spaced and independent, and each is represented by a unique combination of amplitude and phase (Chen j, 2004).

Here, for modulation, we call the 'pskmod' and 'qammod' function available in Matlab to perform different order of PSK and QAM modulation respectively. Similarly, for demodulation 'pskdmod' and 'qamdmod' are implemented.

SIMULATION RESULT

In this part of our research work, we represent various BER vs. SNR plots to evaluate the effect of RS coding technique of 16-QAM Modulated Fixed WiMAX communication system over different communication channel (AWGN and Rician) with transmission of colour image. Figure 7, 8 and 9 displays the effect of RS coding performance 16QAM modulated WIMAX system on Additive White Gaussian Noise (AWGN) channel models, Rician channel and Rayleigh Channel model respectively.

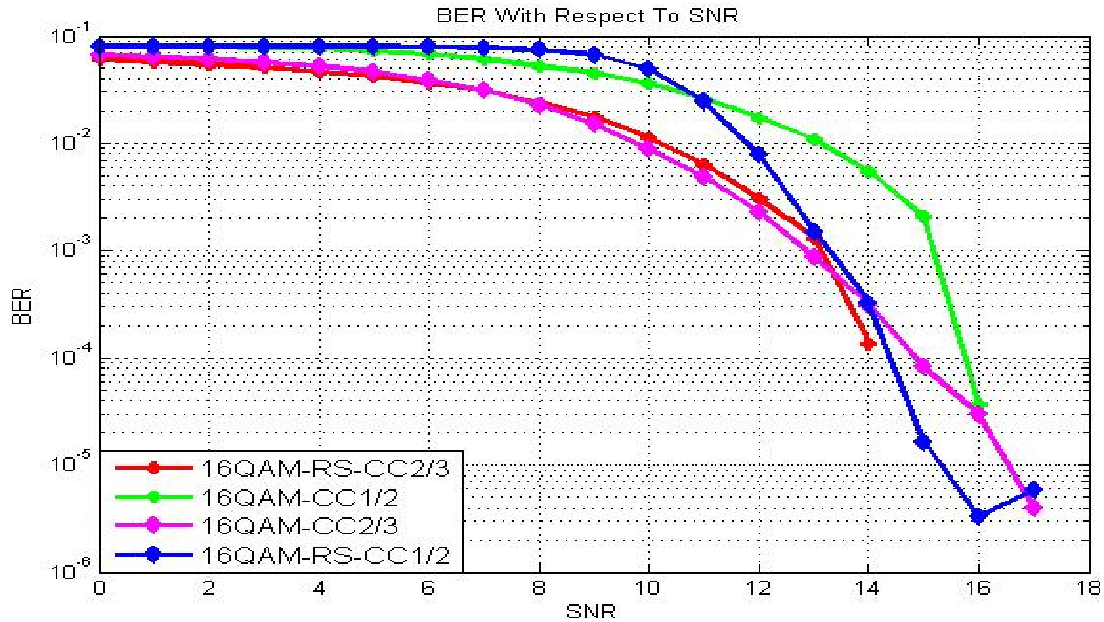

Figure 8. Effect of Reed-Solomon encoding in 1/2 and 2/3 rated QAM modulation on Rician channel.

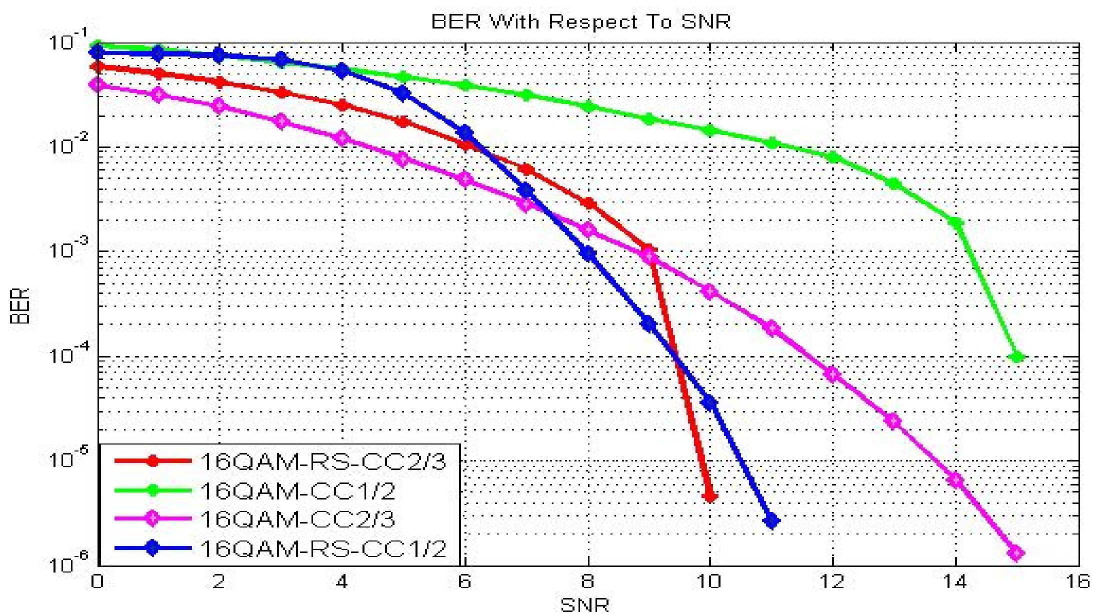

Figure 9. Effect of Reed-Solomon encoding in 1/2 and 2/3 rated QAM modulation on Rayleigh channel.

The Bit Error Rate (BER) plot obtained in the performance analysis showed that model works well on Signal to Noise Ratio (SNR) less than 25 dB.

Figure 7 shows the effect of Reed-solomon encoding over AWGN channel for 1/2 and 2/3 rated 16QAM modulation schemes. For a typical SNR value of 14, the system performance is improved by 10.92 dB when using 2/3 rated CC-RS encoded 16QAM modulation instead of 1/2 rated Convulational encoded 16QAM modulation in AWGN channel. From this figure it is observed that BER performance is improved by 10.92 dB when using Reed-Solomon encoding in concatenated with Convulational encoder.

Figure 8 shows the effect of Reed-solomon encoding over Rician channel for 16QAM modulation schemes. For a typical SNR value of 14, the system performance is improved by 3.65 dB when using 2/3 rated Convulation-Reed-Solomon encoded 16QAM modulation instead of 1/2 rated Convulational encoded 16QAM modulation in Rician channel. From this figure it is also observed that

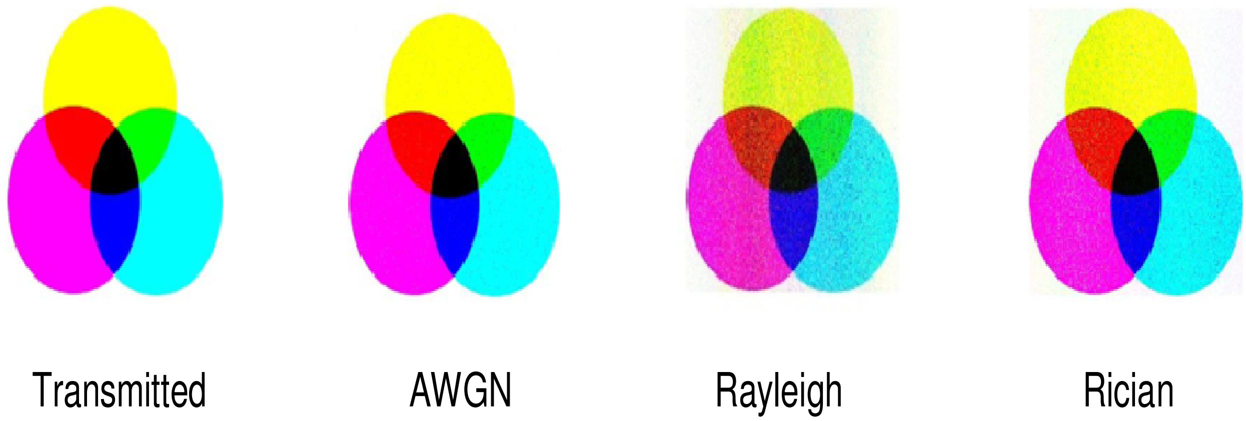

Figure 10. Transmitted and received images for ⅔ rated RS-CC Coded over AWGN, Rician and Rayleigh Channel.

1/2 rated convulational encoded 16QAM modulation can provide better performance for higher SNR value which is unexpected.

Figure 9 shows the effect of Reed-solomon encoding over Rayleigh channel for 16-QAM modulation scheme. For a typical SNR value of 10, the system performance is improved by 19.60 dB when using 2/3 rated Convulation-Reed-Solomon encoded QAM modulation instead of 1/2 rated Convulational encoded QAM modulation in Rician channel. From this figure it is observed that BER performance is improved by 19.60 dB when using Reed-Solomon encoding. Figure 10 shows the colour images is transmitted through the AWGN and Rayleigh and Rician fading channel models with using 16-QAM modulation techniques. The figure also highlights the performance of Reed Solomon and ⅔ rated Convolutional Coded which is to apply the transmitted colour images. It is seen to observe all the images that the performance of 2 /3rated RS-CC coded gives the better performance over AWGN channel.

CONCLUSION

In this paper, we are calculating the BER of ½ and ⅔ rated RS-CC coding schemes based WiMAX wireless communication system in the presence of frequency offset over frequency selective fast Rayleigh fading channels. An analytical BER expression is obtained. The closed formed BER expression can be calculated directly for N=256 number of subcarriers. In the case of ½ rated RS-CC codes, the BER expression was used to analyze the system performance under several wireless channel configurations. Delay spread and Doppler spread will cause significant performance degradation. In these cases, we simulate different combination of modulating technique with the code rate. We compared the performance of RS-CC ½ and ⅔ code rated for colour image transmission, confirms the outperformance of the 2/3 rated RS-CC coding schemes for AWGN channel.

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