BER performance of OFDM-BPSK,-QPSK,- QAM over AWGN channel using forward Error correcting code

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Abstract

High bit error rates of the wireless communication system require employing forward error correction (FEC) methods on the data transferred to reducing the error in transmission.

In this paper, the performance of OFDM- BPSK,-QPSK and -QAM system by using forward error correcting codes(convolutional , reed Solomon as well as concatenated coding) schemes that are used to encode the data stream in wireless communications AWGN channel has been reported here . We present OFDM for wireless communications .We address basic OFDM and related modulations, as well as techniques to improve the performance of OFDM for wireless communications (OFDM). we performed various simulations to find out the best BER performance of each of the Convolutional and Reed-Solomon codes and used these best outcomes to model the RS-CC concatenated codes. By concatenating two different codes we can get the effect of improving the total BER due to benefits of RS codes correcting burst errors while convolutional codes are good for correcting random errors that are caused due to a noisy channel.

Keywords- AWGN channel, inter carrier interference (ICI), multicarrier (MC) ,RS-CC, codes. Orthogonal frequency-division multiplexing(OFDM). Convolutional codes (CC), Reed-Solomon codes (RS), Concatenated codes.

I. Introduction

It is increasingly believed that OFDM results in an improved downlink multimedia services requires high data rates communications, but this condition is significantly limited by inter-symbol interference (ISI) due to the existence of the multiple paths. Multicarrier modulation techniques, including OFDM modulation are considered as the most promising technique to combat this problem [4]] OFDM technique is a multi-carrier transmission technique which is being recognized as an excellent method for high speed bi-directional wireless data communication. In wireless, satellite, and space communication systems, reducing error is critical. Wireless medium is quite different from the counterpart using wires and provides several advantages, for example; mobility, better productivity, low cost, easy installation facility and scalability. On the other hand, there are some restrictions and disadvantages of various transmission channels in wireless medium between receiver and transmitter where transmitted signals arrive at receiver with different power and time delay due to the reflection, diffraction and scattering effects. Besides the BER (Bit Error Rate) value of the wireless medium is relatively high. These drawbacks sometimes introduce destructive effects on the wireless data transmission performance. As a result, error control is necessary in these applications. During digital data transmission and storage operations, performance criterion is commonly determined by BER which is simply: Number of error bits / Number of total bits. Noise in transmission medium disturbs the signal and causes data corruptions. Relation between signal and noise is described with SNR (signal-to-noise ratio). Generally, SNR is explained with signal power / noise power and is inversely proportional with BER. It means, the less the BER result is the higher the SNR and the better communication quality [1].

II. OFDM

The prime idea is that all queuing data in buffer are uniformly allocated on small sub- carriers. OFDM efficiently squeezes multiple performance for 4G [2]. The world standard bodies such as IEEE and ETSI have selected the OFDM as their physical layer techniques for the next generation of wireless systems [3]. The growing demand for modulated carriers tightly together reducing the required bandwidth but keeping the modulated signals orthogonal so that they do not interfere with each other. OFDM that is highly efficient technique shows favorable properties such as robustness to channel fading and inter symbol interference (ISI) and is more immune to noise. OFDM system is capable of mitigating a frequency selective fading channel to a set of parallel flat fading channels, which need relatively simple processes for channel equalization OFDM systems have gained an equivalent attention with flat fading environment. In [8], present the method of Channel estimation and Carrier frequency offset to design an OFDM receiver in flat fading environment. However, BER performance of OFDM system in flat fading channel using BPSK modulation technique is studied by Lijun et al. [9]. so our motivation behind this paper is to study the performance of OFDM system using flat fading channel of AWGN channel .

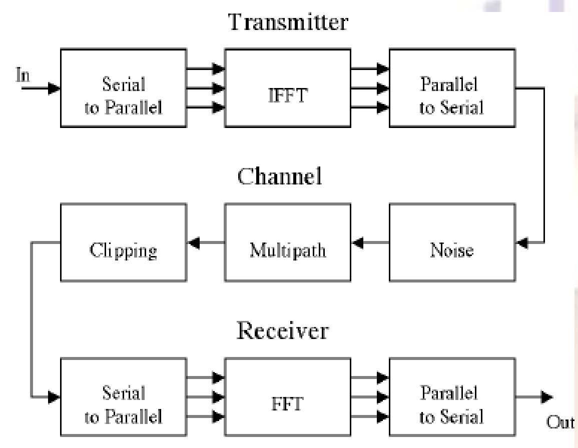

Figure (1) OFDM model

An OFDM signal is a sum of sub carriers that are individually modulated by using phase shift keying (PSK) or quadrature amplitude modulation (QAM). The symbol can be written as

$$S(t)= \quad R_e\{\sum_{i=-\frac{N_s}{2}}^{\left(\left(\frac{N_s}{2}\right)-1\right)} d_{\left(i+\frac{N_s}{2}\right)} \, exp\left(j2\Pi\left(f_c-\frac{i+0.5}{T}\right)(t- ts\}\right.\right.$$

$$, t_s \leq t \leq t_s + T \qquad (1)$$

$$S(t)= 0 \quad , \quad t < t_s \text{ and , t> } t_s + T$$

Where:
Ns is number of sub channels
T is the symbol duration
fc is carrier frequency
The equivalent complex base band notation is given by:

$$S(t) = \sum_{i=-\frac{N_s}{2}}^{\left(\left(\frac{N_s}{2}\right)-1\right)} d_{\left(i+\frac{N_s}{2}\right)} \, exp\left(j2\Pi\frac{i}{T}(t-t_s)\right)$$
$$, t_s \leq t \leq t_s + T$$

$$S(t)= 0 \quad , t < t_s \text{ and , t > } t_s + T \qquad (2)$$

In this case, the real and imaginary parts correspond to the in-phase and quadrature parts of the OFDM signal. They have to be multiplied by a cosine and sine of the desired frequency to produce the final OFDM signal.

Table :1 OFDM specification

NFFT	256
OFDM symbols	192
No. of sub carrier	256
Guard time	28

III. AWGN channel

High data rate communication over additive white Gaussian noise channel(AWGN) are limited by noise .The received signal in the interval 0≤ t≤ T may be expressed as

$$r(t)=S_m(t) + n(t)$$

where n(t) denotes the sample function of additive white Gaussian noise(AWGN) process with power- spectral density.

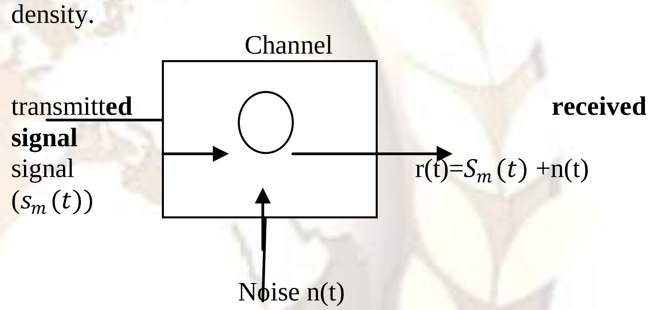

Figure (2) Model for received signal passed through AWGN channel.

IV. Error correcting code

There are two different types of FEC techniques, namely block codes i.e. Reed-Solomon code and Convolutional codes [2]. The Viterbi algorithm is a method for decoding convolutional codes. It has been counted as one of good decoding scheme up to date. This algorithm, however, is vulnerable to burst error which means a series of consecutive errors [3]. Since most physical channels make burst errors, it can be a serious problem.
Furthermore, the complexity increases as the number of memories in the encoder increases, and the increase of the memory causes the increase of computation. To compensate these problems, a new solution can be applied: a concatenation of a Reed-Solomon (RS) code and a convolutional code (CC) i.e., RS-CC concatenated codes. Since RS code is very strong to the burst error, the RS-CC concatenated codes can have good performance than CC and RS itself.
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A. Reed-Solomon Codes (RS)

The RS code is one of linear block code [5]. It is vulnerable to the random errors but strong to burst errors. Hence, it has good performance in fading channel which have more burst errors. In coding theory Reed–Solomon (RS) codes are cyclic error correcting codes. There is a systematic way of building codes that could detect and correct multiple random symbol errors. By adding t check symbols to the data, an RS code can detect any combination of up to t erroneous symbols, and correct up to [t/2] symbols. As an erasure code, it can correct up to t known erasures, or it can detect and correct combinations of errors and erasures. Furthermore, RS codes are suitable as multiple-burst bit-error correcting codes, since a sequence of b+1 consecutive bit errors can affect at most two symbols of size b. Reed-Solomon codes have found important applications from deep-space communication to consumer electronics. They are prominently used in consumer electronics such as CDs, DVDs, Blu-ray Discs, in data transmission technologies such as DSL
& WiMAX.. The Reed-Solomon code is a [n,k,n-k+1] code, in other words, it is a linear block code of length n with dimension k and minimum Hamming distance n-k+1. The error-correcting ability of a Reed–Solomon code is determined by its minimum distance, or equivalently, by n−k, the measure of redundancy in the block. If the locations of the error symbols are not known in advance, then a Reed–Solomon code can correct up to (n − k) / 2 erroneous symbols, i.e., it can correct half as many errors as there are redundant symbols added to the block. A Reed–Solomon code is able to correct twice as many erasures as errors, and any combination of errors and erasures can be corrected as long as the relation $2Er + S \leq n - k$ is satisfied, where Er is the number of errors and S is the number of erasures in the block. For practical uses of Reed–Solomon codes, it is common to use a can be represented as an m-bit value. The sender sends the data points as encoded blocks, and the number of symbols in the encoded block is $n = 2^m - 1$. Thus a Reed–Solomon code operating on 9-bit symbols has $n = 2^m - 1 = 511$ symbols per block. The number k, with k < n, of data symbols in the block is a design parameter [12].

B. Convolutional Codes (CC)

Convolutional codes are extensively used for real time error correction. Convolutional coding is done by combining the fixed number of input bits. The input bits are stored in fixed length shift register and they are combined with the help of mod-2 adders. An input sequence and contents of shift registers perform modulo-two addition after information sequence is sent to shift registers, so that an output sequence is obtained. This operation is equivalent to binary convolution and hence it is called convolutional coding. The ratio R=k/n is called the code rate for a convolutional code where k is the number of parallel input bits and n is the number of parallel decoded output bits, m is the symbolized number of shift registers. Shift registers store the state information of convolutional encoder, and constraint length (K) relates the number of bits upon which the output depends. A convolutional code can become very complicated with various code rates and constraint lengths. A simple convolutional code with ½ code rate is shown in fig.1. Here m represent the current message bit and m1,m2 represent the previous two successive message bits stored which represent the state of shift register. This is a rate (k/n) = 1/2, with constraint length K=3 convolutional encoder. Here k is the number of input information bits and n is the number of parallel output encoded bits at one time interval. In the encoder we observe that whenever a particular message bit enters a shift register, it remains in the shift register for three shifts. And at the fourth shift the message bit is discarded or simply lost by overwriting.

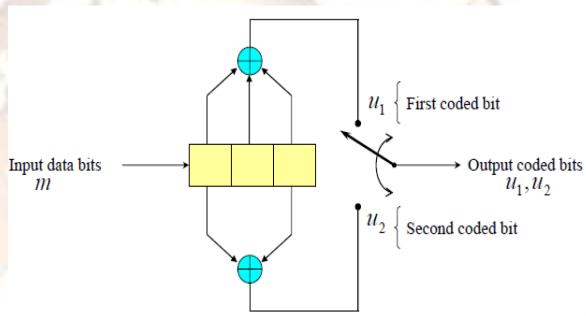

Fig.3 : Convolutional encoder with rate ½, k=1, n=2, K= 4, m= 3.

The constraint length, K, of the convolutional encoder is defined by K= m+1, where m is the maximum number of memories in any convolutional encoder.

A.1 Viterbi Decoding

Viterbi decoding algorithm is mostly applied to convolutional encoder and it uses maximum likelihood decoding technique [4]. Noisy channels cause bit errors at receiver. Viterbi algorithm estimates actual bit sequence using trellis diagram. Commonly, its decoding algorithm is used in two different forms. This difference results from the receiving form of the bits in the receiver. Decoded information is received with hard decision or soft decision. Decoded information is explained with ±1 on hard decision operation while soft decision decoding uses multi bit quantization [4]. Hard decision and soft decision decoding refer to the type of quantization used on the received bits. Hard decision decoding uses 1 bit quantization on the received channel values while soft decision decoding uses multi bit quantization on the received channel values. For hard decision decoding, the symbols are quantized to one bit precision while for soft decision decoding, data bits are quantized to three or four bits of precision. The selection of quantization levels is an important design decision because of its significant effect on the performance of the link [10].

C. Concatenated Codes

Since the two codes i.e. Convoluional codes and Reed Solomon codes have different characteristic in terms of handling the errors, so their concatenation lead to give benefits in BER performance. More specifically, the CC is good for correcting random errors that is caused due to a noisy channel and RS codes can combat burst errors which is caused by convolutional decoder. This is main reason for using concatenated scheme because it reduces overall error rate than single coding scheme. It has been used in deep space communications and digital video broadcasting systems. RS-CC code is a concatenated code of RS code as the outer code and Convolutional code as the inner code [11]. The basic structure for RS-CC concatenated codes is shown in fig. 4.

Fig. 4 shows the basic block structure of CC-RS codes. CC-RS code is a concatenated code of Convolutional code as the outer code and RS code as the inner code. The basic structure for CCRS concatenated codes is `shown in fig.4

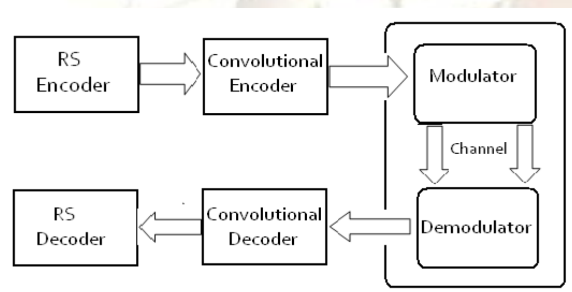

Fig. 4: Basic block structure of RS-CC codes

V. Simulation Results

A full system model was implemented in MATLAB™ according to the above described system for different coding techniques. Performance analysis is done for different code rates by taking random data stream of defined length for each of the coding techniques. Here we transmit our data by using OFDM technique in which large number of closely-spaced orthogonal sub-carriers are used to carry data. Each sub-carrier is modulated with a conventional modulation scheme (such as Quadrature Amplitude Modulation or phase-shift keying*)*.Here we have used BPSK (Binary Phase Shift Keying) and QPSK (Quadrature Phase Shift Keying) phase shift keying modulation and demodulation for all the simulations. The encoded data is then passed through Gaussian channel which adds additive white Gaussian noise (AWGN) to the channel symbols produced by the encoder. In AWGN channel E_b / N_0 dB denotes the information bit energy to noise power density ratio.The simulation is performed between SNR which is derived from E_b/N_0 and modulation technique used and at the y-axis we plot the bit error rate (BER).

A . CC code simulation

When we perform the simulations for only convolutional codes with different combination of modulation technique and code rates . i.e. BPSK -1/2,QPSK-1/2 QPSK-3/4, 16QAM-1/2, 16QAM-3/4, 64QAM-2/3, 64QAM-3/4. The block length (n) taken is 171 and traceback length as 2. From fig.5, it can be seen that when we move lower modulation scheme i.e. BPSK to higher modulation scheme i.e. QAM the BER performance decrease because we combined large no. of bit to form a symbol. For same modulation technique BER performance is different for different code rate. For QPSK-1/2, QPSK-3/4 decrease the code rate the BER performance improves and the best result comes for rate 1/2, for this the absolute BER performance is approx. 2.5dB better than code rate 3/4 at BER of 10^{-2}.

B. RS code simulation

Next we performed the simulations for RS codes for different block lengths and different modulation technique. We can see from fig. 6, as the block length increases the BER performance improves also it can be seen from the graph that the performance also improves for small values of code rate and when modulation complexity increase then BER performance decrease. The RS code, which is well suited for correction of burst errors, shows a poor BER performance for lower SNR values, because of the mainly random errors introduced by the AWGN. Here value of n, k will change according to the modulation.

C. RS-CC Codes Simulations

Then we performed simulation for RS-CC codes. Here the outer code is RS code and the inner code is CC. The information bits go into the RS encoder and the output of RS encoder is the input of the CC encoder. For comparison of simulation results for single RS code and convolution code with the concatenated codes, we have the previous two results which we got from the RS and CC simulations done earlier in this paper. The specification of outer and inner code for the two concatenated codes is shown in Table 1

Table 2: specification of concatenated code

	Outer code	Inner code
	RS code	CC code
RS-CC code	Vary with modulation	(171,133) No. of memory =7
Decoding	Berlekamp-Massey decoding	Viterbi decoding

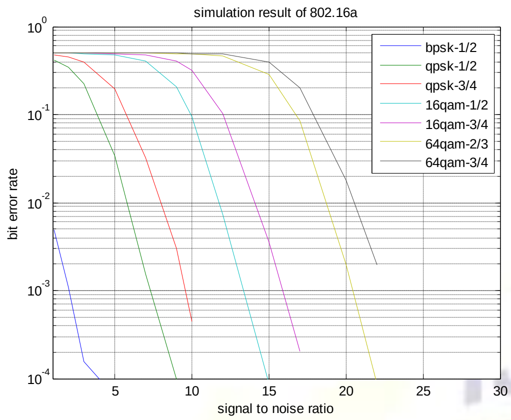

Figure 5; BER performance on AWGN channel using CC FEC.

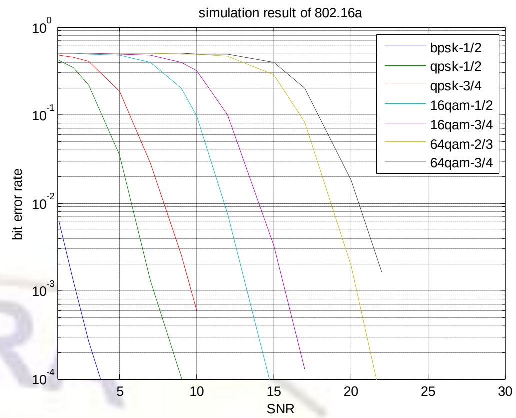

Figure 6: BER performance on AWGN channel using RS FEC.

The convolutional encoder we have used for the concatenated codes is the best BER result for lower code rate that we got in our first simulation (shown in fig. 5) and the RS encoder used is also the best outcome result for different modulation technique. Here we got simulations for different block lengths and different modulation technique as shown in fig.6 of this paper. We used (400, 240) RS code in GF (2^9). It can be decoded by using Berlekamp-Massey decoding algorithm. The convolutional encoder we used is (171, 133) with variable code rate and 7 memories i.e. 7 constraint length. Decoding is done by Viterbi decoding algorithm with traceback length as 2 for RS-CC code. Table 2 gives the achieve coding gain when use concatenated code as compare to single code without coding. We can see from the above plot that the BER curves for concatenated codes are far better than non concatenated codes and too far better than the curve for uncoded data transmission. The flattening effect of the curve keeps on reducing from uncoded curve towards the RS-CC curve.

Table3 : Gain comparison between different FEC technique

Modulation	Switch from RS to RS-CC at BER 10^{-3} . Gain/dB	Switch fro CC to RS-CC at BER 10^{-3} . Gain/db
BPSK - ½	0	0
QPSK- ½	1.5	.5
QPSK- 3/4	.5	.5
16QAM -½	.6	.5
16QAM- 3/4	2	1
64QAM- 2/3	2	1.1
64QAM- 3/4	.4	.6

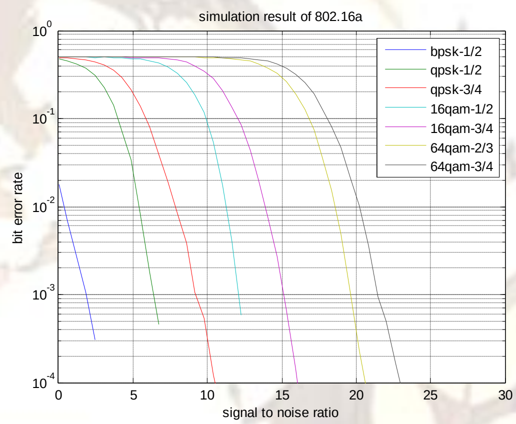

Figure 7 BER performance on AWGN channel using RS-CC FEC.

From fig.7 it is clear that the performance of RS-CC concatenated code outperforms that of non concatenated codes. It can be seen that RS-CC curve shows less flattening effect and has a better slope than the other two codes. It is cleared that BER performance with coding is much better than

VI. Conclusion

In this paper we compare the performance in terms of BER using different Forward Error Correction codes on AWGN channel . We evaluate Bit Error Rate of convolutional codes at different code rates. Similarly we evaluate performance for Reed-Solomon codes for different block lengths as well as code rates. In these case we simulate different combination of modulating technique with the code rate .The best results of each of the two were used to model the concatenated codes. We compared the performance of RS-CC as concatenated codes with the individual codes using data transmission. The simulation results confirms the outperformance of the concatenated codes RS-CC when compared to CC and RS codes give better result on same modulation and code rate . RS-CC much better than CC and RS codes in coding gain also. Due to a good burst error-correcting capability of RS codes, total BER of RS-CC has significant coding gain, and it increases as Eb/No increases. Also the slope of concatenated codes is more strong and has less flattening effect

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