BER Study of OFDM With Coding And Without Coding Transmission On Nakagami-M Fading Channel

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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, we perform an ce of OFDM-BPSK, QPSK and QAM system by using forward error correcting codes as concatenated codes schemes that are used to encode the data stream in wireless communications Nakagami-m fading channel has been reported here. Our approach is based on decomposition of Nakagami random variable into orthogonal random variables with Gaussian distribution envelopes. Results have been presented by using optimum value of m based on BER and SNR. 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 simulations of double the best BER performance using RS-CC concatenated codes. By concatenating two different codes we can get the effect of improving the total BER due to benefit of RS codes correcting burst errors while convolutional codes are good for correcting random errors that are caused due to noisy channel.

Keywords: AWGN channel, Intercarrier interference (ICI), Multicarrier (MC), RS-CC codes, Orthogonal frequency-division multiplexing (OFDM), Convolutional codes (CC), Reed-Solomon code (RS), Concatenated codes.

1 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 intersymbol 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 multicarrier transmission technique which is being recognized as an excellent method for high speed bidirectional wireless data communication. For wireless, satellite, and space communications systems, reducing errors is critical. Wireless medium is quite different from the counterpart using wires and provides several advantages, for example, mobility, better productivity, low costs, easy installation, flexibility and scalability.

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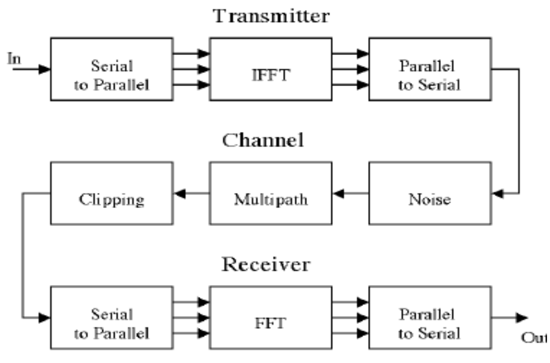
On the other hand, there are some questions and disadvantages of various transmission channels of wireless medium between receiver and transmitter where the transmitted signals arrive at receiver with different power and time delay due to the reflection, diffraction and scattering effects. Besides the BER (Bit Error Rate) value of the wireless medium is relatively high. These drawbacks some time 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 results the higher the SNR and the better communication quality [1].

2. OFDM: The prime idea is that queuing data distribute 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 the 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 highly efficient technique shows favorable properties such as robustness to channel fading and intersymbol 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 flowing channel.



Figure(1) OFDM model

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

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

$$, \quad t_s \le t \le t_s + T \quad (1)$$

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

Where:

Ns is number of subchannels

T is the symbol duration

f_c is carrier frequency

The equivalent complex baseband notation is given by:

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

$$, \quad t_s \le t \le t_s + T$$

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

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.

3 Channel Model: In this paper, the sub-channel spacing $f_0 = {}^{1}/_{T}$ is chosen so that the produced parallel fading sub-channels have flat fading characteristics. So, we have chosen Nakagami-m fading channel with additive white Gaussian noise fading environment, the baseband signal at the input of receiver $y(t)$ is described as follows:

$$y(t) = x(t) * r(t) + n(t)$$

where, $x(t)$ denotes the baseband transmitted signal, $r(t)$ the Nakagami-m distributed channel envelope and $n(t)$ is the additive white Gaussian noise with zero mean. Nakagami-m fading distribution function is given by:

$$P_r(r) = \frac{2m^m r^{2m-1}}{\Gamma(m)\Omega^m} exp\left(-\frac{mr^2}{\Omega}\right), r \ge 0 \quad (5)$$

Where, $\Gamma(.)$ is the Gamma function, $\Omega = \overline{r^2}$ is the average power, m is fading parameter and r is Nakagami distribution envelope.

Since Nakagami distribution encompasses Scattered, reflected and direct components of the original transmitted signal [10], it can be generated using the envelope of the both random signal processes $r_{nlos}(t)$ for non line-of-sight envelope Rician and $r_{los}(t)$ for line-of-sight Rayleigh as per the following expression

$$r(t) = |r_{nlos}(t)| . \exp(1-m) + |r_{los}(t)|. (1 - \exp(1-m))$$

So, this value of $r(t)$ is used as envelope of Nakagami-m distributed channel

4. Error correcting code: There are two different types of FEC techniques, namely block codes Reed-Solomon code and convolutional codes [2]. The Viterbi algorithm is a method for decoding convolutional codes that has been counted as one of good decoding scheme up to date. This algorithm, however is vulnerable to burst errors which means 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 Reed-Solomon (RS) code and a convolutional code (CC), 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.

A. Concatenated Codes: Since the two codes i.e. Convolutional codes and Reed Solomon codes have different characteristic in terms of handling the errors, so their concatenation leads to give benefit in BER performance. More specifically, the CC is good for correcting random errors that are caused due to 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 code is shown in fig 3.

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

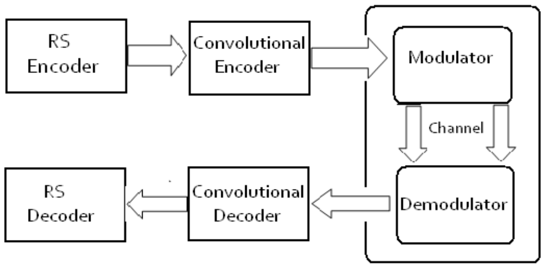


Figure Block dia. Of concatenated code

5. 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 a random data stream of defined length for each of the coding techniques. Here we transmit our data by using OFDM technique in which a 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 the simulations. The encoded data is then passed through Nakagami-m fading channel which adds additive white Gaussian noise (AWGN) to the channel symbols produced by the encoder. In the following figs, Eb/No dB denotes the information bit energy to noise power density ratio and the y-axis we plot the bit error rate (BER). First we run 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 2400 and traceback length as 2. It can be seen that when we move from low modulation scheme i.e. BPSK to high modulation scheme i.e. QAM the BER performance decrease because we combine large no. of bits 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 results come for rate 1/2, for this the absolute BER performance is approx. 2.5 dB better than code rate 3/4 at BER of 10^{-2}.

6. 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 bit goes into the RS encoder and the output of RS encoder is the input to the CC encoder. For comparison of simulation result for without coding with the concatenated codes. The specification of outer and inner code for the two concatenated codes is shown in Table 1.

	Outer code	Inner code
RS-CC	(511,240) RS code	(171,135,140,158) CC code

For different combination of the modulation technique and code rate the Convolutional encoder we have used for the concatenated codes with the Reed-Solomon gives the best BER results for same code rate that we got in our first simulation when we and the RS encoder used is also the best out. From the results that we got after comparing the simulations for different block lengths and different code rates as shown in fig. V of this paper. We used (511,240) RS code in GF(2^9) can be decoded by using Berlekamp-Massey decoding algorithm. The convolutional encoder we used is (171,135,140,158) with Different code rate and 6 memories 7 constraint length. Decoding is done by Viterbi decoding algorithm with trace back length 2 for RS-CC code and 4 for CC-RS code. So here we can say that the concatenation of codes gives the best result that we have got for the single RS and CC code. It clear that the performance of RS-CC concatenated code outperforms that of non concatenated code. It can be seen that RS-CC curve shows less flattening effect and has better performance than the other two codes.

From the above simulation result we can see that BER performance with coding is much better than without coding. We can see from the above plot that the BER curves for concatenated codes are 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. The absolute BER performance of RS-CC code is 3.7 dB better than uncoded at BER of 0.02315 we can easily see that RS-CC code performs better than CC-RS code. RS-CC provides better gain, the absolute BER performance of RS-CC code is about 1 dB better than CC – RS code BER of 10-2. We have illustrated the gains of several decode for different FEC coding techniques as follows

7. Simulation Result

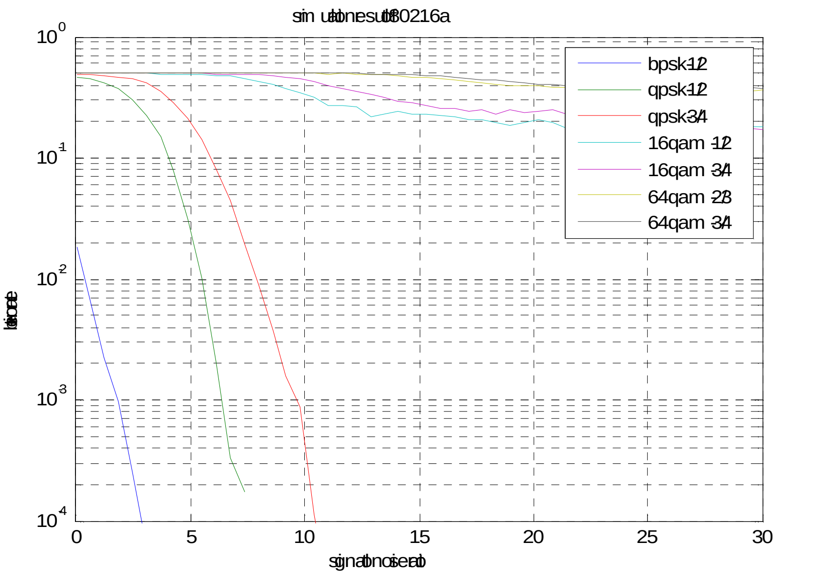


Figure 8 BER Vs SNR graph for uncoded transmission

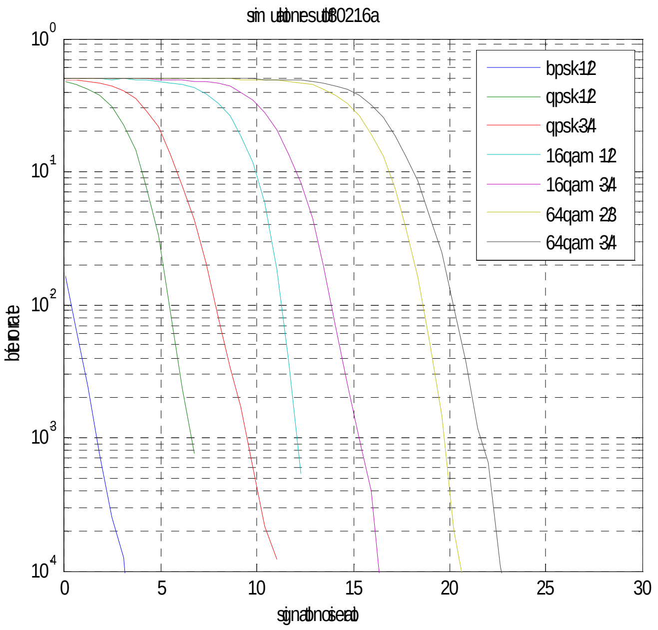


Figure 1V: BER Vs SNR graph with using of concatenation coding transmission.

8. Conclusion : In this paper we compare the performance in terms of BER of concatenated Forward Error Correction codes on Nakagami-m fading channel. We evaluate Bit Error Rate of convolutional codes at different code rates. The best result of each of the two codes were used to model the concatenated codes. We compared the performance of both RS-CC concatenated codes with the uncoded data transmission. The simulation results confirms the outperformance of the concatenated codes RS-CC. RS-CC is no doubt much better than CC and RS codes but the simulation results show clearly that RS-CC is too much better than uncoded data. Due to a good burst error correcting capability of RS codes, the 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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