ISSN 1996-3343

Asian Journal of Applied Sciences

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Asian Journal of Applied Sciences 4 (7): 720-727, 2011
ISSN 1996-3343 / DOI: 10.3923/ajaps.2011.720.727

Concatenated RS-Convolutional Codes for MIMO-OFDM System

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ABSTRACT

In this study, the performance of multi input multi output of orthogonal frequency division multiplexing system will be investigate by using channel coding of concatenated Reed-Solomon with convolutional codes. The system has been tested over additive white Gaussian noise with both of Rayleigh and Rician fading channels. The aim of proposing the concatenated Reed Solomon/convolutional codes is to improve the signal to noise ratio of the orthogonal frequency division multiplexing system. The simulation results shown a significant improvement achieved to the multiple input multiple output of orthogonal frequency division multiplexing system by using concatenated technique against other techniques. The coding gain achieved in the proposed technique was 10 dB at the BER of 10^{-2} compared to the uncoded system over Rayleigh fading with additive white Gaussian noise while it was almost 7 dB at 10^{-2} over Rician fading channel with additive white Gaussian noise. The results showed that, the degradation in the performance of orthogonal frequency division multiplexing system due to Rayleigh fading channel was more than the Rician fading channel. Lastly, the simulation results proved that by using concatenated Reed Solomon/convolutional codes with multiple input multiple output system will achieve more improvement than by using only concatenated Reed Solomon/Convolutional codes with orthogonal frequency division multiplexing system.

Key words: OFDM, MIMO, Reed-Solomon, convolutional, Rayleigh, Rician, fading

INTRODUCTION

The Orthogonal Frequency Division Multiplexing (OFDM) became the common method for the services of wireless indoor short-range like video networking at homes and 4 generation systems that needs to high data rate, high quality of service systems and low of power consumption in addition to the cost (Nyirongo *et al*., 2006; Al-Kebsi, 2008; Kumar *et al*., 2008; Ramesh and Vaidehi, 2006). Meanwhile, the Multiple Input Multiple Output (MIMO) system that uses multiple of antennas in transmitter and receiver has an advantage of spreading the antennas in a multipath intensive scattering environment. This system is performed in different methods to get a diversity gain for struggle the signal fading as well as to increase capacity gain. Commonly, MIMO techniques have three categories. First category uses the increasing of spatial diversity to enhance the power efficiency. While, the other category aims to increase the capacity by using layered method. Lastly, by knowledge the properties of the transmission channel; the third class analyzes the coefficient matrix of the channel and uses these analyzing unitary matrices as filter in transmitter and receiver to improve the capacity (Stuber *et al*., 2004).

A lot of papers have been proposed with OFDM system to improve the performance to mitigate the effect of fading environments and decreases the Bit Error Rate (BER) with increment of Signal-to-Noise Ratio (SNR). The unified method of different OFDM systems has been presented for analyzing the Bit Error Probability (BEP) performance by using an arbitrary linear pilot-assisted channel response estimate. The analyzing is done to estimate BEP for several signal constellation such PSK, BPSK, DPSK and QAM (Chang and Su, 2002). The performance analysis of an OFDM system with different types of coding techniques such as Convolutional codes (CC), Turbo Code (TC), Bose-Chaudhuri-Hocquenghem (BCH) correcting codes, Trellis Code Modulation (TCM) and Reed-Solomon (RS) are presented and compared among them by Van Meerbergen *et al.* (2006), Seddiki *et al.* (2006), Alnuaimy *et al.* (2009) and Lin *et al.* (2000). While Lu *et al.* (2004), Stuber *et al.* (2004), Cideciyan *et al.* (1997), Zhaogan *et al.* (2007), Wang *et al.* (2010) and Salari *et al.* (2008) proposed a combination between OFDM and MIMO systems to achieve high data rates of wireless transmission as well as to improve the system capacity and/or increase the diversity gain. However, the unreliable data is the most important problem in these approaches. A concatenated coding approach presented by Cideciyan *et al.* (1997) for reliable data transmission of CDMA cellular systems. The technique employed outer of Reed Solomon (RS) codes concatenated with inner of Convolutional Codes (CC) and using both of interleavers outer and inner simultaneously. The simulation results proved that the performance by using concatenated coding technique of RS/CC is a powerful scheme for achieving high data reliability. This idea is considered as the best solution for unreliable data transmission. However, it needs to enhance the system capacity and bandwidth efficiency.

In this study, the concatenated of RS/CC with MIMO system has been proposed to achieve improvement of the OFDM system. The proposed system investigated under AWGN with both of Rayleigh and Rician fading channels. This method will be achieve reliable data transmission by using coding technique and enhance the system capacity as well as bandwidth efficiency by using MIMO in OFDM system.

SYSTEM MODEL

Based on IEEE 802.11a specifications we will design an OFDM system. The block diagram that used in this work is presented in Fig. 1. It is an OFDM system using both of coding techniques RS concatenated with CC as well as using MMO system over AWGN with Rayleigh and Rician Fading channel.

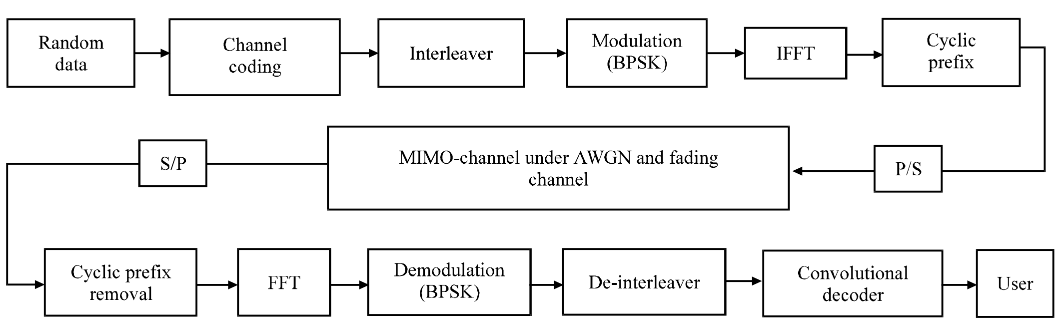

Fig. 1: MIMO-OFDM with concatenated coding block diagram

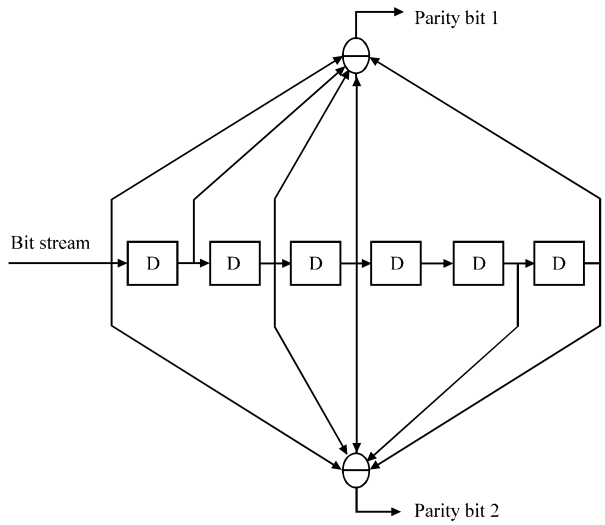

Fig. 2: Structure of (2, 1, 7) convolutional encoder

Channel coding:

Convolutional Codes (CC): The principle of convolutional coding technique depends on the consecutive of shift register stages and uses exclusive OR gates to associated combination logic (Masakawa and Ochiai, 2007). It is represented by CC (n, k, m) where, each of n, k and m are defined as a number of output bits, input bits and the constraint length of the encoder, respectively. The CC employed in this study has 1/2 coding rate, K = 7 and generator polynomials are G1 = 171_{OCT} and G2 = 133_{OCT}. The structure is CC (2, 1, 7) encoder and shown in Fig. 2. The decoding is implemented by hard decision of Viterbi algorithm (Nyirongo *et al*., 2006).

Reed solomon codes: RS codes are block codes operated as several bits (symbols) instead of single bits. An RS represented by RS (n, k, m) code which is utilizes for encoding k of (m-bit symbols) to generate blocks contains of $n = 2^{m-1}$ symbols.

So the encoder contains the input bits of (m×k) and output bits of (m×n). The capability of error correcting in an RS code can be calculated by $d_{min} = (2t + 1)$, since (n-k) = 2t (Nyirongo *et al*., 2006). We will use in this paper RS (7,1,3) that has minimum distance of 7.

Interleaving: An interleaver re request the input bit sequence into nonadjacent way to achieve the robustness versus burst errors in the transmission (Youngsun *et al*., 2010). By using interleaving and deinterleaver processes will guarantee that the most of bursts errors which is produced in the channel are decreased, then the most of burst errors will become single random errors after applying the deinterleaver process (Thibault and Le, 1997).

MIMO channel: The basic concept of MIMO-OFDM system is shown in Fig. 3. By considering N_t, N_r number of transmitter and receiver antenna respectively. It can be implemented in a number of several paths to resist signal fading by achieving diversity gain and/or get capacity gain (Zhang *et al*., 2008).

Fading channel

Rayleigh fading: Consider a mobile antenna receiving a big number N of scattered and reflected signals that are similar to the original signal which is created due to the buildings, hills, bridges,

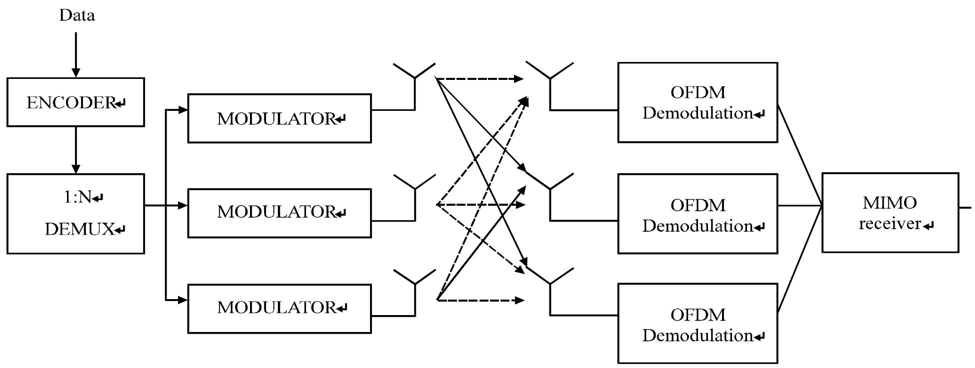

Fig. 3: MIMO-OFDM system

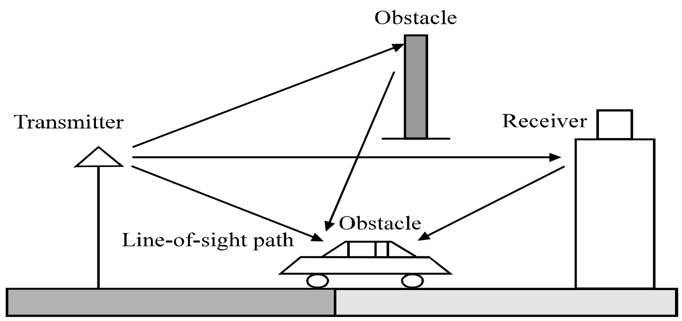

Fig. 4: The paths that may received at the mobile antenna

trees. etc., as shown in Fig. 4. With presence of varying path lengths, the phases of different paths will be random, that makes the instantaneous power receive a random variable. In the case of un-modulated carrier, the transmitted signal frequency ω_c has been passed via a number of ways before arriving to the receiver. The amplitude and phase of the ith path are a_i and φ_i.

If there is no Line-of Sight (LOS) or direct path component, the received signal S(t) will be expressed as:

$$S(t)=\sum_{i=1}^{N} a_i \cos(w_c t+\phi_i) \tag{1}$$

By presence of a proportional motion between transmitter and receiver, the Doppler shift should be considered. If ω_{di} represents the shift for ith component, the received signal will be as following:

$$S(t)=\sum_{i=1}^{N} a_i \cos(w_c t+w_{di} t+\phi_i) \tag{2}$$

The phase φ_i has been assumed to be uniformly distributed over [0, 2π]. If N is big, then the quadrature and in-phase components of received signal will become zero mean Gaussian with standard deviation σ. The Probability of Density Function (PDF) of this received signal envelope given as (Prabhu and Shankar, 2002):

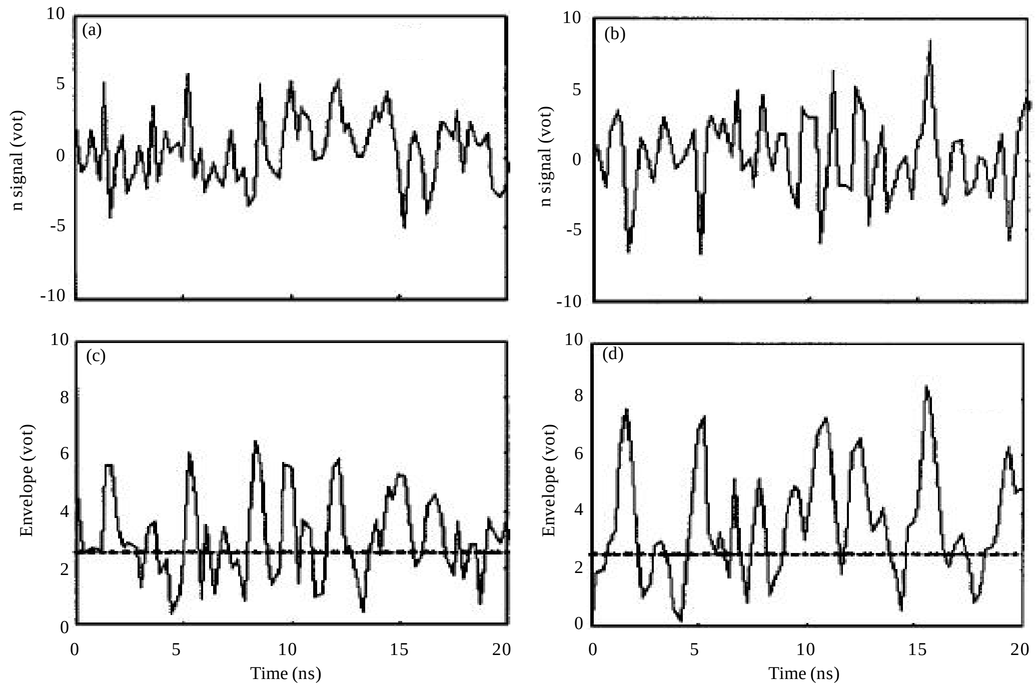

Fig. 5 (a-d): RF signals and envelopes for stationary mobile (a,c) Rayleigh faded and envelope signal and (b, d) Rician faded and envelope signal

$$f(r)=\frac{r}{\sigma^2}\exp\left\{-\frac{r^2}{\sigma^2}\right\}, r\geq 0 \tag{3}$$

Rician fading: The Rician fading is similar Rayleigh fading channel with one difference that it has direct path of (LOS) in addition to the multipath component as shown in Fig. 4. The transmitted signal by the existence direct path (LOS) will be given as:

$$S(t)=\sum_{i=1}^{N-1} a_i \cos(w_c t + w_{di} t + \phi_i) + k_d \cos(w_c t + w_d t) \tag{4}$$

In this case the envelope has a Rician density function as:

$$f(r)=\frac{r}{\sigma^2}\exp\left\{-\frac{r^2+k_d^2}{2\sigma^2}\right\} I_0\left(\frac{rk_d}{\sigma^2}\right), r\geq 0 \tag{5}$$

where, I_0 is the 0th order that modified by Bessel function of the first kind

The relationship between number of paths (N) and the likelihood of signal received is presented in Fig. 5 for stationary mobile unit. With presence of fading, the strength of signal went down the average value (horizontal line) in Fig. 5c and d. In Rician fading, the fluctuation of the received signal in the envelope is much smaller than for the Rayleigh fading as shown in the Fig. 5 (Prabhu and Shankar, 2002).

SIMULATION RESULTS

The MATLAB software utilized to evaluate the performance of OFDM system. The simulation started with un-coded OFDM system then used two coding technique (single and concatenated) and lastly utilized both of MIMO system and concatenated RS/convolutional codes. The OFDM system performance tested under both of Rayleigh and Rician fading channel with AWGN.

The performance of the system is represented by the relationship between BER versus SNR for each case. The system designed in the beginning without coding techniques to show the effect of using coding technique in OFDM system by using BPSK modulation technique over AWGN with fading channel. Then the ½ rate Convolutional Coding technique CC (2, 1, 7) used in OFDM system with generator polynomials $G1 = 171_{OCT}$ and $G2 = 133_{OCT}$ to improve the performance curve. After that, the another coding techniques is RS (7, 1, 8) codes utilized to show the difference of performance between both CC and RS with OFDM system. We also investigated the performance of Concatenated RS (7, 1, 8) and ½ CC (2, 1, 7) with OFDM system under AWGN with fading channel.

In the last, the combination of concatenated RS/CC and MIMO system proposed in OFDM system to achieve more improvement of the performance through AWGN with fading environment. The performance of OFDM system over AWGN with Rayleigh fading channel showed in Fig. 6 and the performance of OFDM system over AWGN with Rician fading channel shown in Fig. 7.

DISCUSSION

The results show that, the worst performance of OFDM system is without channel coding then it improved progressively by adding coding techniques with a little different in the performance between RS and CC over AWGN and both of fading channel. Using concatenated of RS/CC in OFDM system made the performance better than by single coding technique. However, the combination between MIMO system (4Tx, 4Rx) and Concatenated RS/CC in OFDM system gave more improvement to the system as shown in Fig. 6 and 7. Since the coding gain here between uncoded gain and proposed technique is almost 10 dB at 10^{-2} over AWGN with Rayleigh fading channel and almost 7 dB at 10^{-2} over AWGN with Rician fading channel.

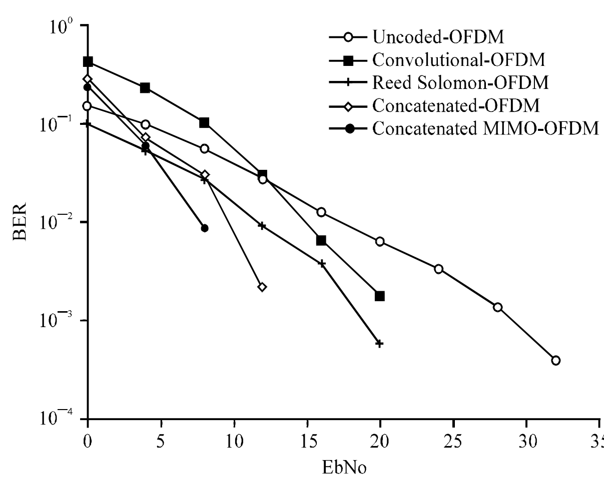

Fig. 6: Comparison among of several techniques with OFDM system over Rayleigh fading channel with AWGN starting with uncoded-OFDM to by using concatenated OFDM

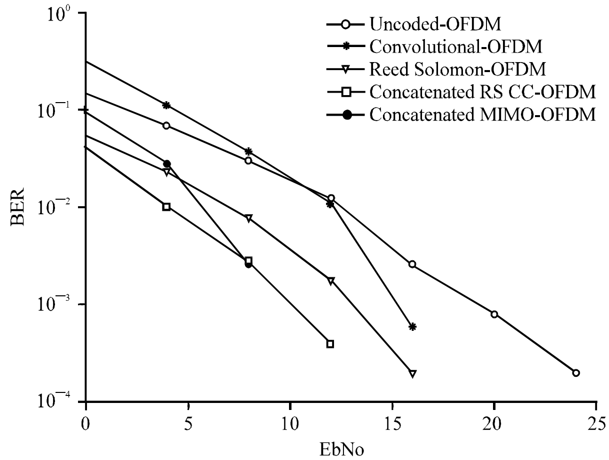

Fig. 7: Comparison among of several techniques with OFDM system over rician fading channel with AWGN starting with uncoded-OFDM to by using concatenated OFDM

By comparing both Fig. 6 and 7, we observe that the proposed technique gave very good results over each of Rayleigh and Rician fading channel with AWGN. In both types of fading channels the concatenated techniques was superior that single technique. However, by combining it with MIMO system we got more improvements of the system performance.

The results showed that the effect of system performance due to Rayleigh fading channel more than Rician fading channel for all of the previous techniques.

CONCLUSION

A concatenated of Reed Solomon and ½ convolutional codes with MIMO-OFDM system over AWGN with Rayleigh and Rician fading channel has been proposed to improve the system performance. The simulation results showed that the concatenated technique performed better than the single codes at high SNR over both of Rayleigh and Rician fading channel with AWGN. The simulation results also showed that by using concatenated of Reed Solomon and ½ convolutional codes in MIMO-OFDM system achieved more improvements of the performance. Lastly, the results proved also that the performance of OFDM system affected due to Rayleigh fading channel more than by Rician fading channel for all of the previous techniques.

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