The Concatenated Coding Scheme for OFDM system over burst noise channel

Byung-Hyun Moon*, Jong-Soo Park**, Sang-Min Choi*

Abstract In this paper, a concatenated RS and Turbo code is proposed for OFDM system over burst error channel. The concatenated code used in this study is a RS(255,202) code and a rate 1/2 turbo code. The turbo code uses 2 recursive systematic convolutional (RSC) code as the constituent codes and the parity bit are punctured to get the desired code rate. It is shown by simulation that the conventional OFDM system fails when there exists burst noise. The concatenated RS and turbo code obtains at least 5dB gain over the turbo code at the bit error probability of 10^{-3}.

Key Words : Concatenated Code, RS and Turbo Code, OFDM, Coded OFDM

1. INTRODUCTION

Recently, there have been increasing attempts to extend the services available through wired public telecommunication networks to mobile/movable non-wired telecommunication-network users. These attempts have raised expectations that the development of broadband mobile communications is likely. For broadband multimedia mobile communication systems, it is necessary to use high bit rate transmission of at least several megabits per second. However, if digital data are transmitted at a rate of several megabits per second, the delay time of the delayed waves exceeds 1 symbol time. To overcome such a multi-path fading environment, it is possible to use an OFDM transmission scheme.[1]

OFDM is expected to be used in future broadcasting and wireless LAN(WLAN) systems For example, ETSI BRAN in Europe [2]* IEEE802.11 in the United States [3]* and ARIB MMAC [4]*in Japan have already adopted the OFDM transmission technology as a physical layer for future broadband WLAN systems.

In this paper, the concatenated Reed Solomon and turbo code is proposed for OFDM transmission system over the bursty noise channel. The performance of the proposed system is compared with the one with turbo code only.

2. OFDM SYSTEM MODEL & INTERFERENCE SIGNAL MODEL

Digital multimedia applications as they are getting common lately create an ever increasing demand for broadband communication systems. Although the technical requirements for related products are very high, the solutions must be cheap to implement. Whereas for the satellite channel and for the cable channel such cost-efficient solutions already exist for the terrestrial link, the requirements are so high

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that the standard solutions are no longer feasible or lead to sub optimal results. OFDM is a method for the Europan radio(DAB) and TV (DVB-T) standard. Due to its numerous advantages it is under discussion for future broadband application such as wireless ATM a well.

Fig. 1 shows basis structure of OFDM system. [1][5] In the transmitter, the transmitted high-speed data is first converted into parallel data of N sub-channels. Then, the transmitted data of parallel sub-channel is modulated by PSK-based modulation. The modulated data are fed into an invrse fast Fourier transform(IFFT), and an OFDM signal *S(t)* is generated. This OFDM signal is fed into a guard time insertion circuit to reduce ISI.

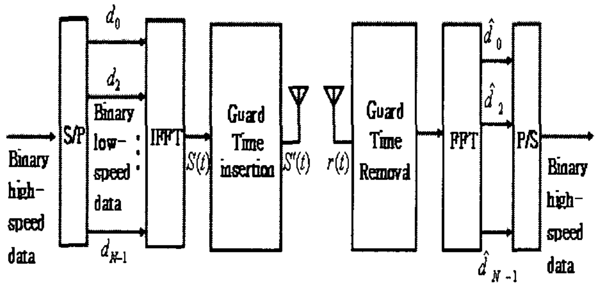

Fig. 1. Basic Block diagram of OFDM System

The received signal *r(t)* is represented in equation (1) where *n(t)* is the background Gaussian-noise component and *I(t)* is the burst-noise component.

$$r(t) = S(t) + n(t) + I(t) \quad (1)$$

Channels exhibiting error bursts have been modeled by Markov processes [6][7], by impulse noise [8], and by bursty noise [9]. The bursty noise model allows for arbitrary rate of noise burst occurrence, arbitrary but fixed burst length, arbitrary error probability during a burst, and arbitrary error probability when no burst occur. For example, the tracking and Data Satellite(TDRS) suffers from Radio Frequency Interference (RFI) characterized by randomly occurring noise bursts of fixed duration [10].

In this paper, the burst noise is modeled as Figure 2 and 3 such that the burst noise is ranging from 20% to 80% of the frame length. The length of a frame in Fig. 2 is 960 bits when rate 1/2 turbo code is used. Thus, 20% of a frame would be 192 bits long burst noise. Similarly, the length of a frame in Fig. 3 is 5120 bits long when a concatenated RS and a turbo code is used. Thus, 20% of a frame would be 1024 bit long burst noise..

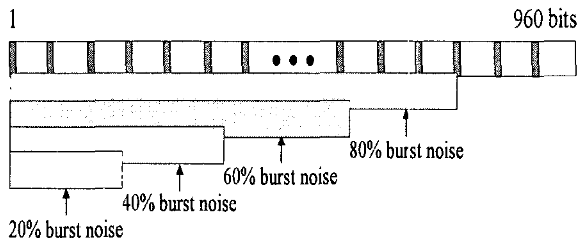

Fig. 2. Length of the burst noise when turbo code is used

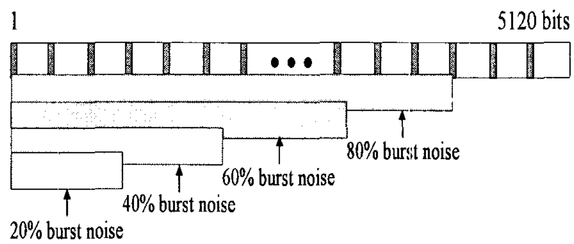

Fig. 3. Length of the burst noise when concatenated code is used

3. REED-SOLOMON CODE & TURBO CODE

3.1. Reed-Solomon Code

Reed-Solomon code is a special subclass of q-ary BCH codes. RS codes have been widely used for error control in both digital communication and storage systems. Among the various types of nonbinary linear block codes, the RS codes are some of the most important for practical applications. RS codes are described by the parameters

$$N = q - 1 = 2^k - 1$$
$$d_{\min} = N - K + 1 \qquad (2)$$
$$t = \frac{d_{\min} - 1}{2} = \frac{N - K}{2}$$

where N is the length of the non-binary code, K is the length of the information symbols and $d_{\min}$ is the minimum distance of the code. The RS code used in this paper is RS (255,202) code.is the length of the information symbols and is the length of the non-binary code,

3.2.Turbo Encoder

A typical turbo encoder is shown in Figure 4. The turbo encode consists of two recursive systematic convolutional (RSC) encoders that are fed the same set of data in parallel. The two encoders RSC encoders are usually the same. The coefficients of generator polynomial representing a RSC can be represented by equation (3).

$$g^{(0)} = 1 + D + D^2$$
$$g^{(1)} = 1 + D^2 \qquad (3)$$

$g^{(0)}$ is feedback generator polynomial, and $g^{(1)}$ is feed-forward generator polynomial. Also, it can be represented by octal number by $g^{(0)}$=7, $g^{(1)}$=5. The interleaver block is denoted by α and its output is $\overline{m}_i$.

The overall code rate of a turbo code is 1/3. As with convolutional codes, this rate can be increased by puncturing th parity bits. In particular, a rate 1/2 turbo code can be obtaind from the rate 1/3 turbo code by puncturing one of the parity bits.

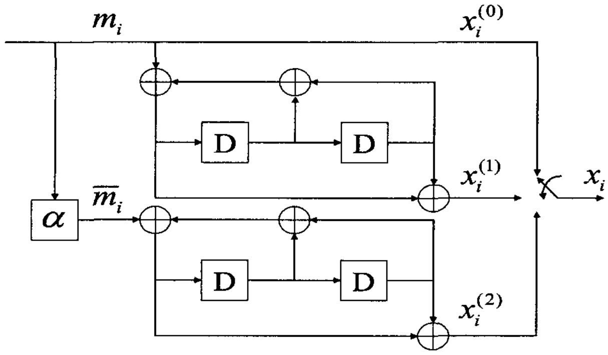

Fig. 4. Turbo Encoder

3.3. Turbo Decoder

The problem of decoding turbo codes involves thte joint estimation of the two Markov processes, one for each constituent code. Turbo decoding proceeds by independently estimating the individual Markov processes. Since the two Markov processes are driven by the same data, the estimate can be improved by sharing the information between the two decoders in an iterative fashion. The output of one decoder is used as a priori information by the other decoder. Figure 5 shows the schematic of turbo decoder.

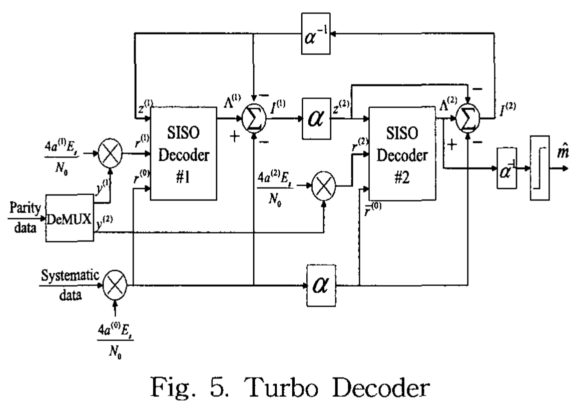

Fig. 5. Turbo Decoder

3.4. MAP Algorithm

Soft-input/Soft-output(SISO) decoder is the main ingredient of the iterative decoding algorithm. Maximum a posteriori probability(MAP) criterion is used to provide soft-output. In principle, the MAP algorithm is able to calculate precise estimate of the posteriori probability of each message bit. However, the MAP algorithm suffers from two practical problems. First, it is computationally intensive. Second, it is sensitive to the round-off errors that occur when representing numerical values with finite precision. These two problems can be alleviated by performing the algorithm in log-domain. There are two classes of MAP algorithm that work in the log domain. In this paper, log-MAX algorithm is used in the simulation.

4. ERROR CORRECTION SCHEME OF CONCATENATED CODE

Fig. 6 is concatenated code system architecture that use proposing RS code and turbo code. A RS code is used as outer encoder, and turbo code is used as an inner code.

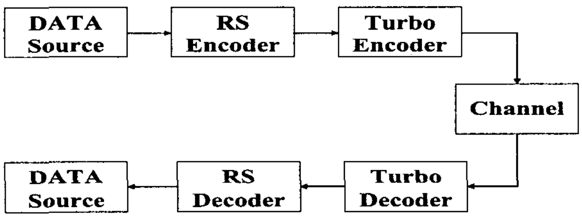

Fig. 6. Proposed Concatenated Coding Architecture

Fig. 7 shows the detailed proposed OFDM system block diagram with concatenated RS and turbo code in this paper. The input data is RS encoded by outer RS Encoder and then turbo encoded by inner Turbo Encoder. And an inter-leaver is placed between the outer encoder and inner encoder in order to exclude the interrelationship between encoders. Then, the transmitted data of each parallel subchannel is modulated by PSK-based modulation. These modulated data are fed into an inverse fast Fourier transform(IFFT) circuit, and then the guard interval is added. The structure of a receiver is the reverse of the transmitter. The data after removal of the Guard interval fed into the BPSK demodulator. The parallel subchannel is data is serially fed into the turbo decoder and. The deinterleaved turbo decoder output is fed into RS decoder.

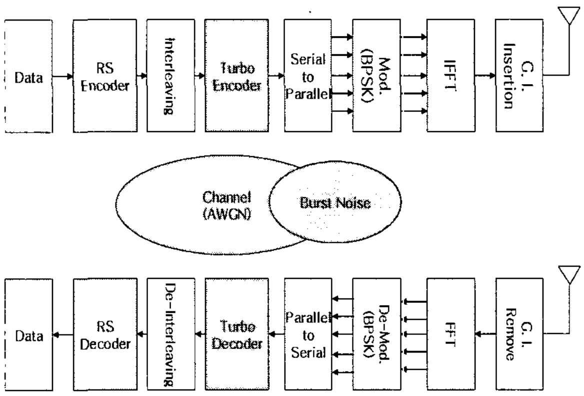

Fig. 7. Block diagram of Concatenated Coded OFDM System

5. SIMULATION RESULT

Computer simulations are performed in order to measure the performance of the concatenated RS and turbo code. The outer RS code used in this simulation is RS(255,202). And rate 1/2 turbo code is used as the inner code. Thus, the overall rate of the concatenated code is 0.396.

The performance of the OFDM system without coding is shown in figure 8. As shown in figure 8, OFDM system with 4 kinds of burst noise does not improve as the signal-to-noise ratio increases. In figure 9, the performance of the turbo code is shown when the OFDM system suffers with 4 kinds of the burst noise is present. When there is 20% of the channel is contaminated with burst noise, the bit error rate is close to 10^{-3} as the signal to noise ratio increases. When there is 40% of the channel is contaminated with burst noise, the bit error rate is close to 10^{-2} as the signal to noise ratio increases.

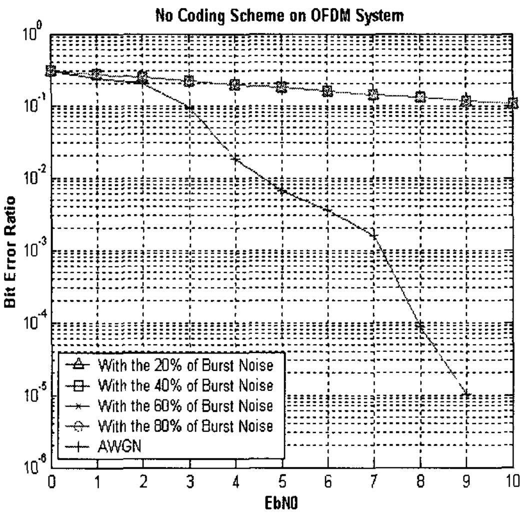

Fig. 8. BER of OFDM system without coding

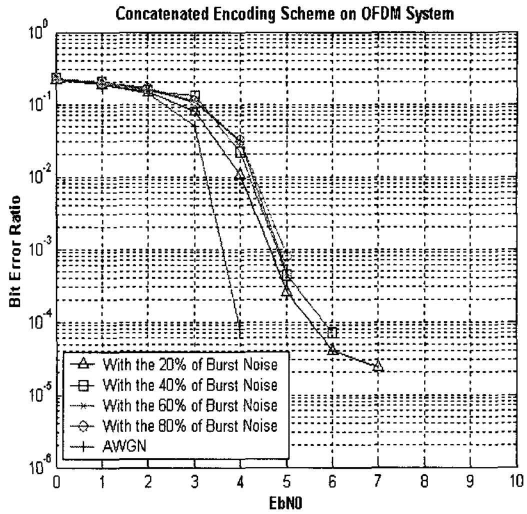

Fig. 10. BER of OFDM system with proposed coding scheme

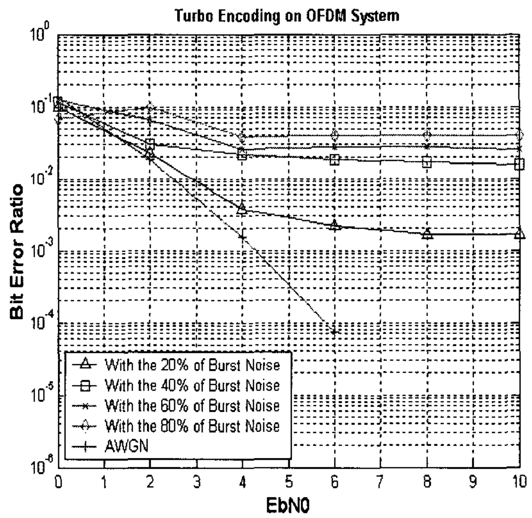

Fig. 9. BER of OFDM system with rate=1/2 turbo code

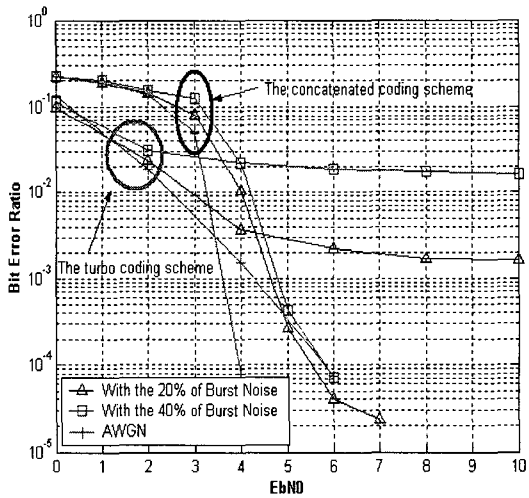

Fig. 11. BER of the proposed system

The performance of concatenated RS and turbo code for OFDM over burst noise is shown in figure 10 and 11. When there exists 20% of burst noise, the proposed coding scheme obtains a bit error rate of 10^{-3} with signal to noise ratio of 4.6dB. On the other hand, the performance of the turbo code unable to obtain a bit error rate of 10^{-3} with signal to noise ratio of 10dB. Similar results are obtained with 40% of burst noise. The bit error rate of 10^{-4} is obtained for the proposed coding scheme when the signal to noise ratio is 5.5dB. However, bit error rate of the turbo coding scheme saturates to 10^{-3}

6. CONCLUSION

In the case of OFDM system, it is shown that BER doesnt improve as the signal to noise ratio increases when the burst noise exists. When the BER is 10-4, the proposed coding scheme requires signal to noise ratio of 5.5 dB. However, BER of the turbo encoded OFDM system approaches to 10^{-3} as the signal to noise ratio increases.

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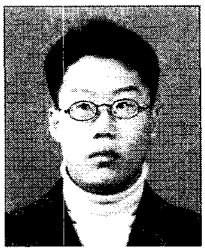

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