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RATE COMPATIBLE PUNCTURED TURBO-CODED HYBRID ARQ FOR OFDM SYSTEM

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Abstract— Now a day's orthogonal frequency division multiplexing (OFDM) is under intense research for broadband wireless transmission because of its robustness against multipath fading. A major concern in data communication such as OFDM is to control transmission errors caused by the channel noise so that error free data can be delivered to the user. Rate compatible punctured turbo (RCPT) coded hybrid ARQ (RCPT HARQ) has been found to give improved throughput performance in a OFDM system. However the extent to which the RCPT HARQ improves the throughput performance of the OFDM system has not been fully understood. HARQ has been suggested as a means of providing high data rate and high throughput communication in next generation systems through diversity combining transmit attempts at the receiver. The combination of RCPT HARQ with OFDM provides significant bandwidth at close to capacity rates of channel. In this paper, we evaluate by computer simulations the throughput performance of RCPT code HARQ for OFDM system as compared to that of conventional OFDM.

Keywords- *OFDM; hybrid ARQ; rate compatible punctured turbo codes; mobile communication; multipath fading*

I. INTRODUCTION

Orthogonal frequency division multiplexing has been considered as one of the strong standard candidates for the next generation mobile radio communication systems. Multiplexing a symbol data serial stream into a large number of orthogonal sub channels makes the OFDM [1] signals spectral bandwidth efficient. Recently, high speed and high quality packet data communication is gaining more importance. A major concern in wireless data communication is to control transmission errors caused by the channel noise so that error free data can be delivered to the user. For successful packet data communication, hybrid automatic repeat request (HARQ) is the most reliable error control technique for the OFDM systems as in HARQ schemes, channel coding is used for the error correction which is not applied in the Simple ARQ schemes. In HARQ, the advantage of obtaining high reliability in ARQ system is coupled with advantage of forward error correction system to provide a good throughput even in poor channel conditions. Turbo codes, introduced in 1993 by Berrou et al., have been intensively studied as the error correction code for mobile radio communications. Rate compatible punctured turbo (RCPT) coded HARQ (RCPT HARQ) scheme was proposed in [2] and shown to achieve enhanced throughput performance over an additive white Gaussian noise (AWGN) channel. In [3] it is shown that the throughput of the RCPT hybrid ARQ scheme outperforms other ARQ schemes over fading and shadowing channels.

In this paper, we evaluate the throughput performance of RCPT coded HARQ for OFDM system over additive white Gaussian noise channel. When the number of allowable retransmissions is unlimited, transmitting minimum amount of redundancy bits with each transmission would result in the highest throughput as unnecessary redundancy is avoided. However in a practical system, [4] the number of retransmissions allowed is limited to avoid unacceptable time delay before the successful transmission. When the number of retransmissions is limited, the residual bit error is produced.

II. RCPT ENCODER/ DECODER AND RCPT HARQ

The RCPT encoder and decoder are included as a part of the transmission system model shown in fig.1. RCPT encoder consists of a turbo encoder, a puncture and a buffer. Turbo encoder /decoder parameters are shown in Table 1.

TABLE 1. TURBO ENCODER/ DECODER PARAMETERS

Encoder	Rate	1/3
	Component encoder	RSC
	Interleaver	S-random (S = K $^{1/2}$)
Decoder	Component decoder	Log-MAP
	Number of iterations	8

Turbo encoder considered in this paper is a rate 1/3 encoder. Turbo encoded sequences are punctured by the puncturer and the different sequences obtained are stored in the transmission buffer for possible retransmissions. With each retransmission request, a new sequence (previously unsent sequence) is transmitted. Turbo decoder consists of a depuncturer, buffer and a turbo decoder. At the RCPT decoder, a newly received punctured sequence is combined with the previously received sequences stored in the received buffer. The depuncturer inserts a channel value of 0 for those bits that are not yet received and 3 sequences, each equal to the information sequence length, are input to the turbo decoder where decoding is performed as if all 3 sequences are received. In this paper the type I HARQ is considered. For type I HARQ, the two parity bit sequences are punctured with P = 2 and the punctured bit sequence is transmitted along with the systematic bit sequence. If the receiver detects errors in the decoded sequence, a retransmission of that packet is requested. The retransmitted packet uses the same puncturing matrix as the previous packet. Instead of discarding the erroneous packet, it is stored and combined with the retransmitted packet utilizing the packet combining or time diversity (TD) combing effect.

III. TRANSMISSION SYSTEM MODEL

The OFDM system model with RCPT coded HARQ is shown in Fig 1.

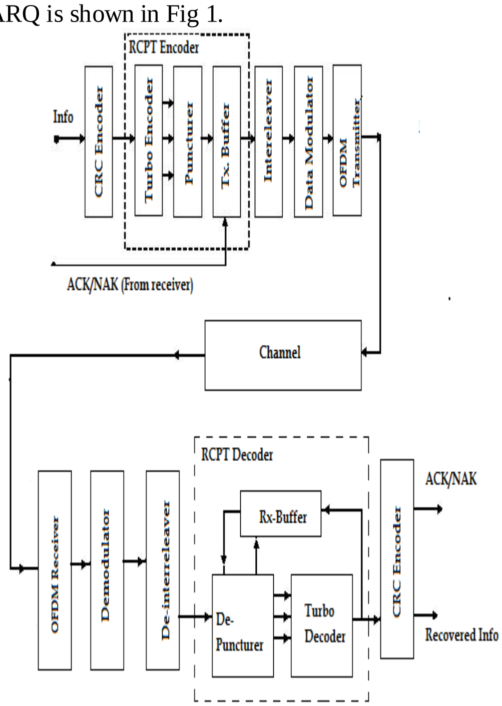

Fig. 1. OFDM with HARQ system model

At the transmitter a CRC coded sequence of length K bits is input to the RCPT encoder where it is coded, punctured and stored in the buffer for possible retransmissions. The parity sequences are punctured before transmission based on adopted HARQ scheme. The punctured sequences are of different length for different puncturing periods. The sequence to be transmitted is block interleaved by a channel interleaver and then transformed into PSK symbol sequence. The N_c data modulated symbols are mapped onto N_c orthogonal subcarriers to obtain the OFDM signal waveform. This is done by applying the inverse fast Fourier transform (IFFT). After the insertion of a guard interval (GI), the OFDM signal is transmitted over Additive white Gaussion noise channel and received by multiple antennas at the receiver. The OFDM signal received on each antenna is decomposed into the N_c orthogonal subcarrier components by applying the fast Fourier transform (FFT) and each subcarrier component coherently detected to be combined with those from other antennas based on maximal ratio combining. The MRC combined soft decision sample [5] sequence is de-interleaved and input to the RCPT decoder which consists of a de-puncturer, a buffer and a turbo decoder. Error detection is performed by the CRC decoder which generates the ACK/NAK command and recovers the information in case of no errors.

IV. SIMULATION RESULTS

The turbo encoder/decoder parameters are as shown in Table 1. The computer simulation conditions are summarized in Table 2.

In this paper, the information sequence length K = 1024 bits is assumed. The turbo encoded sequence is interleaved with a random interleaver. The data modulation scheme considered is BPSK modulation and the ideal channel estimation is assumed for data demodulation at receiver. We assume OFDM using N= 512 sub-channels, number of pilots P= N/8, total number of data sub-channels S=N-P and guard interval length GI=N/4. In our simulation, we assume channel length L=16, pilot position interval 8 and the number of iterations in each evaluation are 500. A rate 1/3 turbo encoder is assumed and a log-map decoding is carried out the receiver. The numbers of frame errors to count as a stop criterion are limited to 15.

TABLE 2. SIMULATION CONDITIONS

Information sequence length	$K = 2^{10}$ □ 2^{14} bits	
Channel interleaver	Block interleaver	
Modulation / demodulation	BPSK	
OFDM	No. Of subcarreiers	Nc = 256
	Subcarrier spacing	$1/T_s$
	Guard interval	$T_g = 8/T_s$
ARQ	Type	Type I
	Max. No. Of tx.	Ω
Propagation channel	Forward	Additive white gaussion noise
	Reverse	Ideal

The throughput in bps/Hz is defined as

$$\eta = \frac{Bits\ transmitted\ successfully}{Total\ number\ of\ bits\ transmitted} \quad .....(1)$$

Fig. 2 shows the bit error rate as a function of average bit energy- to- additive white Gaussian noise (AWGN) power spectrum density ratio. The throughput in bps/Hz is defined as [6] the ratio of the number of information bits over the total number of transmitted bits, where the throughput loss due to GI insertion is taken into consideration. In fig.2 the blue line indicates the bit error rate of conventional OFDM for a given range of signal-to noise ratio (SNR) while the red line shows the bit error rate (BER) for turbo coded type I HARQ for the same range of given SNR. From graph (fig. 2) below it can be seen that the bit error rate of turbo coded HARQ decreases with the increase in SNR however the BER for the conventional OFDM remains as it is for the entire range of SNR, hence we can get improved throughput for turbo coded HARQ as compared to that of conventional OFDM. Fig. 3 shows the bit error rate as a function of given range of signal to noise ratio. Here the BER decrease is shown in between 0 to 1, where the BER changes rapidly for the lower SNR and we can get a very low BER even for higher SNR.

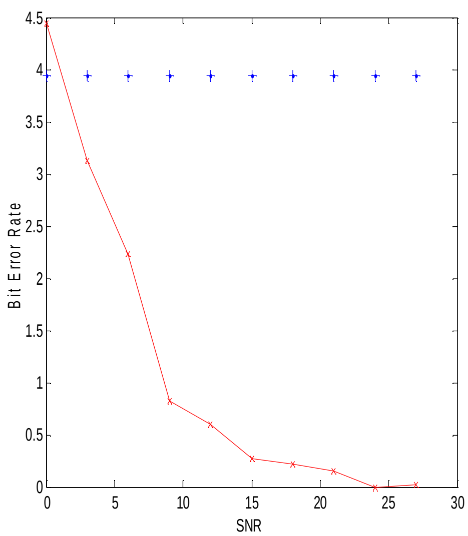

Fig. 2. BER of conventional OFDM (+) and turbo coded HARQ (x)

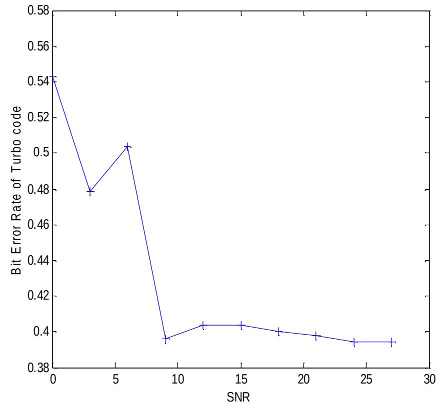

Fig. 3. BER of turbo code

V. CONCLUSIONS

The throughput for the RCPT coded HARQ for an OFDM system was evaluated. It is shown that the bit error rate of turbo coded HARQ decreases with the increase in signal to noise ratio, and hence we can get a improved throughput for the OFDM with turbo coded HARQ as compared to that of conventional OFDM. It is shown that the throughput is almost insensitive to the information sequence length.

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