
무선망에서 Turbo 코드를 이용한 효율적 수신기 설계

석경휴* · 최우진**

Design of effective Receiver
in Wireless Network using turbo code

Gyeong-Hyu Seok* · Woo-Jin Choi**

요 약

본 논문에서는 다중 경로 채널 환경에서 터보 코드를 사용하여 광대역 CDMA 시스템의 수신 신호를 고려하고, 시스템의 성능을 분석합니다. Rayleigh 페이딩 채널 환경에서 터보 코드와 함께 레이크 수신기를 통해 수신된 신호를 전달하여 레이크 수신기의 가지 수에 따라 가변 시스템 대역폭에 대한 성능을 분석한다. 광대역 CDMA 시스템에서 수신기의 디자인을 위해서는 디코딩 및 레이크 수신기의 가지 수를 효율적인 매개 변수를 제시했습니다.

ABSTRACT

In this paper, we considered the received signal of the wideband CDMA systems using turbo code in the multipath channel environments, and analyze the performance of the system. This study is to analyze the performance for the variable system bandwidth according to the number of branches of rake receiver by passing the received signal through a rake receiver with a turbo code in Rayleigh fading channel environments. For the design of receiver in wideband CDMA systems, we presented the efficient parameters for the number of iterative decoding and the number of branches of rake receiver.

키워드

W CDMA, Turbo Code, Rake Receiver
광대역-CDMA, 터보 코드, 레이크 수신기

1. Introduction

The next generation mobile communications systems is discussed in order to transmit at high speed not only the traditional voice service but also data with the high quality like the Internet service or multimedia service. As the standard of HSDPA(High Speed Downlink Packet Access) and HSUPA(High Speed Uplink Packet Access) is completed, the

wideband CDMA system of UTRA TDD(Time Division Duplex) or FDD(Frequency Division Duplex) for IMT 2000 is considered as one of the most efficient radio access technology among various proposals for providing this service[1]. The spread bandwidth of this wideband CDMA system is changed according to the change of data rate. Therefore, depending on the spreading bandwidths of systems, each CDMA system shows different

* 순천청암대학교 의료정보과(dol27@naver.com)
접수일자 : 2012. 07. 27

** 순천청암대학교 컴퓨터정보과(wjchoi7284@naver.com)
심사(수정)일자 : 2012. 09. 05

게재 확정일자 : 2012. 10. 05

multipath characteristics and performance. Over the last few years, many researchers controvert the dependence of the system performance over the different spread bandwidth[2],[3]. Thus, in this paper, the received signal is statistically analyzed in order to design the efficient receiver about the channel bandwidth. And the performance is analyzed while differentiating the number of branches of the RAKE receiver with MRC based on this statistical received signal.

Moreover, in the mobile channel environment, it is applied to a system in the various techniques such as the diversity and channel coding so that the system performance can be improved. In the HSDPA, the HARQ scheme has been proposed as one of the possible techniques to enhance the system performance. The fast decoding occupies attention in the decoding schemes. If the decoding fails on the first attempt, the decoding is immediately stopped and retransmission is automatically requested. Therefore, in this paper, it makes a study of the inappropriate number of iterations of iterative decoding according to the number of branch of the RAKE receiver about the required performance in the wideband CDMA using turbo code as channel coding.

II. Analysis of wideband CDMA

In this paper, the JTC(: Joint Technical Committee) channel model is chosen as the wideband multipath channel model. The JTC channel impulse response is represented by the sum of delayed replicas for the impulse signal weighted by independent zero mean, complex, Gaussian time invariant processes for specific areas, as Eq. (1)[4].

$$h(t) = \sum_{l=0}^{L-1} a_l \delta(t - t_l) e^{j\theta_l} \quad (1)$$

Where, a_l is a Rayleigh distributed random variable representing the envelope of a zero mean complex Gaussian time invariant process, t_l is the time delay, and θ_l is the phase of the process. That is shown in Fig. 1.

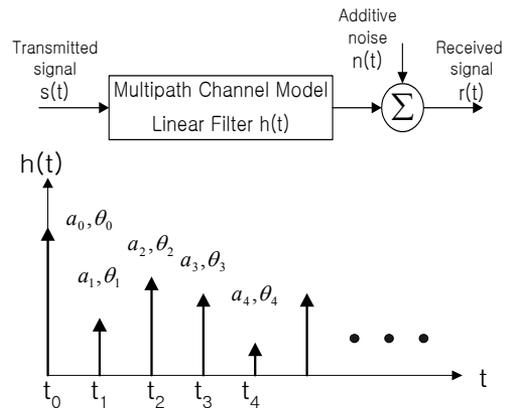


Fig. 1 Wideband multipath channel model

There is no difficulty in assuming that the phase θ_l of the various paths are mutually independent random variables which are uniformly distributed over $(0, 2\pi)$. However, the statistics of path delay t_l and path strength a_l are not so obvious. In this paper, the path strength a_l is assumed to be Rayleigh distribution. This kind of wideband multipath channel model can be used as a theoretical channel model for the analysis of mobile radio system whose bandwidth is less than or equal to that of a theoretical channel model. Thus we could not analyze wider bandwidth system based on narrower bandwidth channel model. The reason is as following. The time resolution of multipath channel is limited by channel bandwidth. Narrower bandwidth channel model has longer time resolution whereas wider bandwidth channel model has shorter time resolution. In other words, even though there are more resolvable paths in a wider bandwidth channel, these can not be represented accurately on a narrower bandwidth channel model. In this paper, we assume the channel bandwidth is

10MHz, which is typical in many measurements. So we can analyze CDMA system whose bandwidth is less than or equal to 10MHz.

Let's assume the general situation for the analysis of W-CDMA signals. Total received signal is composed of K DS waveforms, all of which are asynchronous one another. And coherent BPSK, perfect power control, and synchronization are assumed[5]. Then k th transmitted signal is given by Eq. (2).

$$s_k(t) = m_k(t)c_k(t)\exp(jw_0t) \quad (2)$$

Where $m_k(t)$ and $c_k(t)$ are the data and the spreading sequence of k th user. Then total received signal $r(t)$ can be represented by Eq. (3),

$$r(t) = \sum_{k=0}^{K-1} \sum_{l=0}^{L-1} a_{k,l} m_k(t-\tau_{kl}) c_k(t-\tau_{kl}) \exp[i(w_0(t-\tau_{k,l}) + \theta_{k,l})] + n(t) \quad (3)$$

where K is total number of users, L is total number of multipaths, and $n(t)$ is additive Gaussian noise.

The index $k=0$ represents the signal from a desired user, whereas $k = 1, 2, \dots, K-1$ stands for signals from undesired users. The index $l=0$ represents the first arrived signal while $l=1, 2, \dots, L-1$ stands for second, third, \dots th multipath signal. And $\tau_{k,l}$ represents the delay time of k th & l th indexed signal, while $\theta_{k,l}$ represents the phase shift of k th & l th indexed signal caused by impulse response. Time delay $\theta_{0,0}$ and phase shift $\theta_{0,0}$ can be set as a reference and assumed zero for analytical convenience without loss of generality.

In Eq. (3), $r(t)$ can be grouped into three parts, multipath components from desired user $s_0(t)$, multipath components from undesired user $s_i(t)$, and additive Gaussian noise $n(t)$ [8].

$$r(t) = \sum_{l=0}^{L-1} a_{0,l} m_0(t-\tau_{0,l}) c_0(t-\tau_{0,l}) \exp(j(w_0t + \theta_{0,l})) + \sum_{k=0}^{K-1} \sum_{l=0}^{L-1} a_{k,l} m_k(t-\tau_{kl}) c_k(t-\tau_{kl}) \exp[i(w_0(t-\tau_{k,l}) + \theta_{k,l})] + n(t) = s_0(t) + s_i(t) + n(t) \quad (4)$$

The output of a standard correlation receiver at $t = T$ is given by Eq.(4)[6].

$$z = Re[\int_0^T 2r(t)c_0(t)\exp(-(w_0t + \theta_0))dt] = Re[\int_0^T A s_0(t) + s_i(t) + n(t) c_0(t)\exp(-(w_0t + \theta_0))dt] \equiv S + I + N \quad (5)$$

Where S , I , and N are correlator outputs corresponding to desired user, interference, and noise, respectively. If we assume the desired signal corresponds to transmitting a plus one, and further assume very small delay time compared to bit period ($\tau_{0,l} \ll T$) so that we can ignore intersymbol interference, we have

$$S = \int_0^{TL-1} \sum_{l=0}^{L-1} a_{0,l} m_0(t-\tau_{0,l}) c_0(t-\tau_{0,l}) c_0(t) \cos(\phi_{0,l} - \theta_0) dt = \sum_{l=0}^{L-1} a_{0,l} \cos(\phi_{0,l} - \theta_0) \int_0^T c_0(t-\tau_{0,l}) c_0(t) dt \quad (6)$$

Where $\phi_{0,l} \triangleq w_0\tau_{0,l} + \theta_{0,l}$.

We denote the autocorrelation function of the spreading code, $\int_0^T c_0(t-\tau_{0,l}) c_0(t) dt$ as $R_c(\tau_{0,l})$, and rewrite Eq.(6).

$$S = \sum_{l=0}^{L-1} a_{0,l} \cos(\phi_{0,l} - \theta_0) R_c(\tau_{0,l}) = Re[(\sum_{l=0}^{L-1} a_{0,l} \exp(j\phi_{0,l}) R_c(\tau_{0,l})) \exp(-j\theta_0)]$$

$$= Re \{ |R| \exp(j(\theta' - \theta_0)) \} \quad (7)$$

If the phase of the receiver, θ_0 is adjusted to equal θ' for perfect synchronization then, S becomes^[10].

$$S = |R| = \left| \sum_{l=0}^{L-1} a_{0,l} \exp(j\phi_{0,l}) R_c(\tau_{0,l}) \right| \quad (8)$$

If we make the standard Gaussian assumption for multiple access interference[2],[3], we can have Eq. (9).

$$Var[J] = (K-1)A^2T^2 \frac{W[A_{k,l}^2]}{3G} \sum_{l=0}^{L-1} e^{-2\delta l} \quad (9)$$

We employ a RAKE receiver with MRC (: Maximal Ratio Combining) diversity to use all multipath components. The general RAKE receiver is described in Fig. 2.

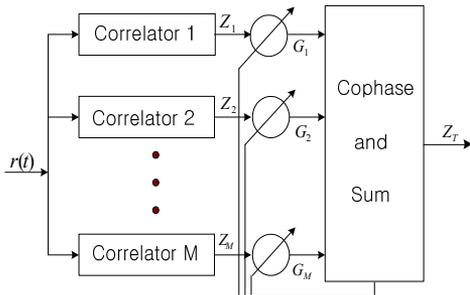


Fig. 2 Rake receiver

Then, after employing MRC diversity, the output of a receiver can be represented by Eq. (10), and the statistics of S_T should be modified as Eq. (11)[7].

$$\begin{aligned} Z_T &= G_1 Z_1 + G_2 Z_2 + \dots + G_M Z_M \\ &= S_T + I_T + N_T \end{aligned} \quad (10)$$

$$S_T = \sum_{i=1}^M G_i S_i \quad (11)$$

Where, G_i is the gain of the j th branch, which is proportional to the ratio of the signal voltage to the noise power of the j th branch, and S_i is the signal component of the correlator output of that branch. Each S_i can be given by Eq. (8) correspondingly. The statistics of I , and N should be modified as follows[9].

$$Var[I_T] = Var[I] \sum_{i=1}^M (G_i)^2 \quad (12)$$

$$Var[N_T] = Var[N] \sum_{i=1}^M (G_i)^2 \quad (13)$$

III. Simulations

In this paper, we consider two different system bandwidths in heavy traffic urban area environments to design effective receiver in wideband CDMA systems using turbo code. Considered channel environments are assumed as maximal excess delay $\Delta = 2.3[\mu\text{sec}]$ and slope $\delta = 0.2$, and considered system bandwidth is 10MHz. The parameters employed to analyze the performance are listed in Table 1.

Table 1. Parameters for simulation

parameter	value
Maximal excess delay	$\Delta = 2.3\mu\text{s}$
Decreasing slope	$\delta = 0.2$
Constraint length	$K = 4$
Channel encoder	$G = (17, 11)_{\text{ocfal}}$
Coding rate	$r = 1/3$
Decoding algorithm	SOVA

We generate the probability density functions, $p(S_T)$, of each CDMA signal over both system bandwidths by generating S_T numerically from Eq. (8) and (11). Those are shown in Fig. 3, where S_T is normalized to have unit power.

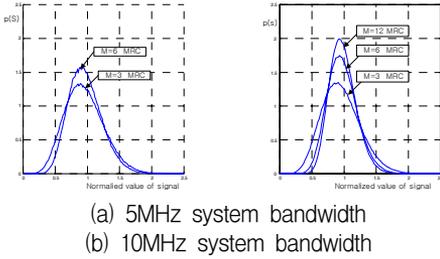
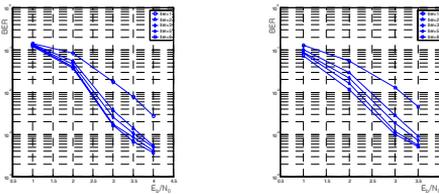


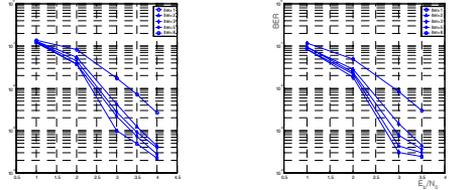
Fig. 3 PDFs of signal statistics S for different bandwidth

This study is to analyze the performance according to the number of branches of RAKE receiver by passing the received signal through a RAKE receiver with a turbo code in Rayleigh fading channel environments. In this simulation, we use the internal interleaver size of turbo code is 192 bits, and maximum 8 times iteration for turbo code decoding. And SOVA(Soft Output Viterbi Algorithm) for iterative decoding is used, because of low complexity and easy implementation. When turbo code is applied to each system whose number of branches of the RAKE receiver are $M=3$ and 6, the BER performance of 5MHz and 10MHz bandwidth system are illustrated in Fig. 4 and Fig. 5, respectively.



(a) Number of branches, $M=3$
(b) Number of branches, $M=6$

Fig. 4 BER performance of 5MHz bandwidth systems



(a) Number of branches, $M=3$
(b) Number of branches, $M=6$

Fig. 5 BER performance of 10MHz bandwidth systems

In Table 2, we present the required E_b/N_0 for a BER of 10^{-3} according to the number of branches of RAKE receiver and the number of iterations for turbo code decoding.

Table 2. Required E_b/N_0 at the BER of 10^{-3} (5MHz / 10MHz)

	# of Iteration=2	# of Iteration=3	# of Iteration=5	# of Iteration=8
$M=3$	3.68 / 3.60 dB	3.55 / 3.45 dB	3.40 / 3.35 dB	3.28 / 3.00 dB
$M=6$	3.46 / 3.17 dB	3.34 / 2.98 dB	3.12 / 2.79 dB	3.00 / 2.71 dB

IV. Conclusion

In this paper, the system performance was analyzed through a computer simulation in order to design the efficient receiver of the wideband CDMA system using turbo code over the wideband multipath channel environment. Firstly, we found the numerically generated statistics of the received W-CDMA signal, and illustrated the performance by applying this signal to the turbo code. In a simulation, PDF of the received signal was shown in case the number of branch of the RAKE receiver was 3, 6, and 12. This signal was applied to the turbo code and the performance was inquired into. The constraint length of the used turbo code was 4. The maximum number of iterations of the iterative decoding was limited within 8 times.

In case the bandwidth of 5MHz was used, it was confirmed as the simulation result to provide the good quality of voice service whenever the iterative decoding more than 2 times was performed, operating at less than 3.7dB of E_b/N_0 . Moreover, in case the bandwidth of 10MHz was used, BER of 10^3 could be obtained with 3.5dB of E_b/N_0 or less.

And the E_b/N_0 value which is required in order to obtain BER of 10^3 according to the number of branch of the RAKE receiver and the number of iterations of iterative decoding organized as the table. As we can see in Table 2, it is shown that the same performance is achieved in case of eight times iterative decoding with $M=6$ in 5MHz system bandwidth, eight times iterative decoding with $M=3$ in 10MHz system bandwidth, and three times with $M=6$ in 10MHz as well at the BER of 10^3 . Also, the same performance is shown in the case of two times iterative decoding with $M=6$ in 5MHz system bandwidth, and three times with $M=3$ in 10MHz system bandwidth at the BER of 10^3 .

As seen in the simulation result, the system bandwidth, the number of branch of the RAKE receiver, constraint length of turbo code, and the number of iterations of iterative decoding affect the performance of the wideband CDMA system. Therefore, it has to be design so that the actual system can be optimized in consideration of a relation between these parameters with bandwidth, cost and a delay time.

Reference

[1] T. Ojanpera and R. Prasad, "Wideband CDMA for Third Generation Mobile Communications", Artech House Boston London, 2001.
 [2] T. Eng and L. B. Milstein, "Comparison of hybrid FDMA/CDMA system in Frequency selective Rayleigh fading", IEEE Journal on

Selected Areas in Communications, Vol. JSAC 12, No. 5, pp. 938~951, June 2004.

[3] C. S. Kim, H. Jeong, and D. J. Oh, "Comparison W CDMA and N CDMA System over Wideband Rayleigh Channel," Proceedings of 10th PIMRC'99, pp. 1007 1011 Osaka, Japan, Sep. 2001.
 [4] H. Suzuki, "A Statistical Model for Urban Radio Propagation," IEEE Transactions on Communications, Vol. COM 25, No. 7, pp. 673 680. July 2003.
 [5] R. E. Ziemer, and R. L. Peterson, "Digital Communications and Spread Spectrum Systems," Macmillan, 2001.
 [6] R. L. Pickholtz, D. L. Schilling and L. B. Milstein, "Theory of Spread Spectrum Communications A Tutorial," IEEE Transactions on Communications, Vol. COM 30, pp. 855 884, May 2002.
 [7] J. G. Prokis, "Digital communications," Third Edition, McGRAW HILL International Editions, 2005.
 [8] 이선근, 정우열, "Binary CDMA 시스템에서 PBS 구조를 가지는 코릴레이터 설계", 한국전자통신학회논문지, 3권 3호, pp. 187-192, 2008.
 [9] 석경휴, 김성홍, "와이드밴드 채널에서 Chase Combining 기법을 적용한 td-cdma 시스템의 성능 분석", 한국전자통신학회논문지, 4권, 1호, pp. 60-65, 2009.
 [10] 박기식, "페이딩 채널에서 MMSE-OSUC 수신기를 적용한 MIMO 시스템의 성능 분석", 한국전자통신학회논문지, 6권, 5호, pp. 723-730, 2011.

About the Author



석경휴(Gyeong-Hyu Seok)

1995년 2월 호남대학교 전자공학과 졸업 (공학사)

1997년 8월 조선대학교 대학원 컴퓨터학과 졸업(공학석사)

2005년 2월 조선대학교 대학원 컴퓨터학과 졸업(공학박사)

청암대학교 병원의료정보과

한국직업능력개발원 통신분야 평가위원

한국의료정보협회 이사

※ 관심분야 : 데이터통신시스템, 병원망, 신경망



최우진(Woo-Jin Choi)

2003년 2월 조선대학교 대학원 컴퓨
터공학과 졸업(공학 박사)

1997년 3월~현재 청암대학교 컴퓨
터정보과 교수

2007년 웹디자인 (지방) 관리 위원

※ 관심분야 : 데이터베이스, 인터넷 정보 보안 & 보호,
광통신