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Design of Effective Receiver in Wideband-CDMA Systems Using Turbo Code

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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.

Key Words : W-CDMA, Turbo Code, Rake Receiver

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 HSIPA(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 bandwidth of systems, each CDMA system shows different 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

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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.

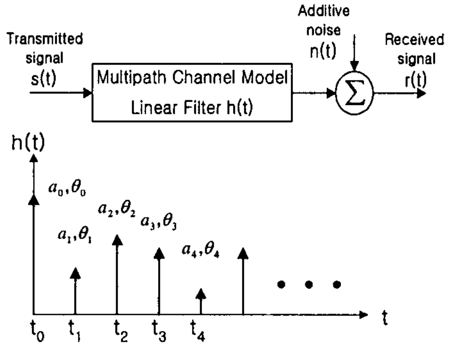


Fig. 1. Wideband multipath channel model

2. 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 responseis 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].

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

Where, αl is a Rayleigh distributed random variable representing the envelope of a zero-mean complex Gaussian time-invariant process, tl is the time delay, and θl is the phase of the process. Fig. 1 shows that.

There is no difficulty in assuming that the phase θl of the various paths are mutually independent random variables which are uniformly distributed over (0, 2π]. However, the statistics of path delay tl and path strength αl are not so obvious. In this paper, the path strength αl 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 10[MHz], which is typical in many measurements. So we can analyze CDMA system whose bandwidth is less than or equal to 10[MHz].

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).

$$s_k(t) = m_k(t)\, c_k(t) \exp(jw_o t) \tag{2}$$

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

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

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, ⋯, K-1 stands for signals from undesired users. The index $l=0$ represents the first arrived signal while $l=1$, 2, ⋯, L-1 stands for second, third, ⋯-th multipath signal. And $\Omega_{k,l}$ represents the delay time of kth & lth indexed signal, while $\theta_{k,l}$ represents the phase shift of kth & lth indexed signal caused by impulse response. Time delay $\Omega_{0,0}$ and phase shift $T_{0,0}$ 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 s0(t), multipath components from undesired user si(t), and additive Gaussian noise $n(t)$.

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

The output of a standard correlation receiver at t = T is given by Eq.(5)[6].

$$\begin{aligned} Z &= Re[\int_0^T 2r(t) c_0(t) \exp(-(w_0 t+\theta_0))dt] \quad (5) \\ &= Re[\int_0^T 2\{s_0(t)+s_i(t)+n(t)\} c_0(t) \\ &\quad \cdot \exp(-(w_0 t+\theta_0))dt] \\ &\equiv S+I+N \end{aligned}$$

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

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

Where, $\phi_{0,l} \equiv -w_0\tau_{0,l}+\theta_{0,l}$

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).

$$\begin{aligned} S &= \sum_{l=0}^{L-1} a_{0,l}\cos(\phi_{0,l}-\theta_0) R_c(\tau_{0,l}) \quad (7) \\ &= Re[(\sum_{l=0}^{L-1} a_{0,l}\exp(j\phi_{0,l}) R_c(\tau_{0,l}))\exp(-j\theta_0)] \\ &= Re[|R|\exp(j(\theta'-\theta_0))] \end{aligned}$$

If the phase of the receiver, θ_0 is adjusted to equal θ' for perfect synchronization then, S becomes

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

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

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

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.

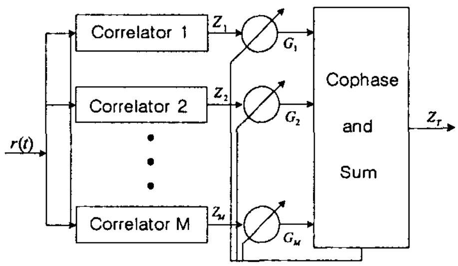


Fig. 2. Rake receiver

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

$$\begin{aligned} Z_T &= G_1 Z_1 + G_2 Z_2 + \cdots + G_M Z_M \\ &= S_T + I_T + N_T \end{aligned} \tag{10}$$

$$S_T = \sum_{i=1}^{M} G_i S_i \tag{11}$$

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

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

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

3. 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 $\Delta = 2.3$[Osec] and slope $\delta = 0.2$, and considered system bandwidth is 10[MHz]. The parameters employed to analyze the performance are listed in Table 1.

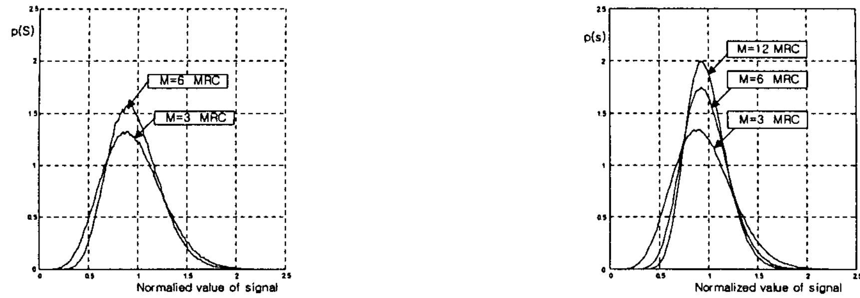
Table 1. Parameters for simulation

parameter	value
Maximal excess delay	Δ = 2.3μs
Decreasing slope	Ω = 0.2
Constraint length	K = 4
Channel encoder	G = (17, 11)octal
Coding rate	r = 1/3
Decoding algorithm	SOVA

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

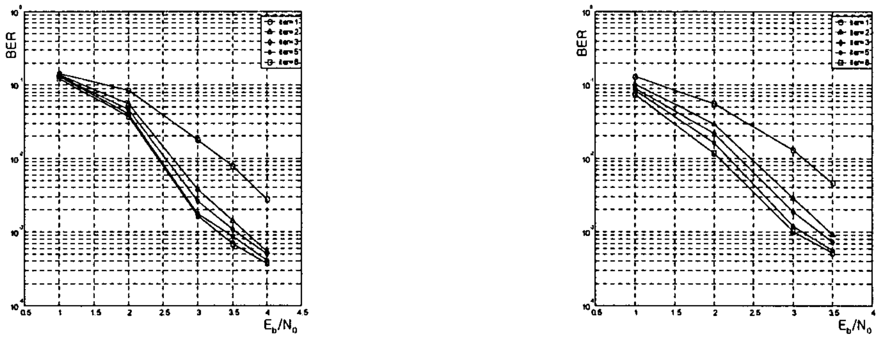
This study is to analyze the performance according to the number of branches of RAKE receiver by passing the received signal through a RAKE receiver with a turbo code in Rayleigh fading channel environments. In this simulation, we use the internal interleaver size of turbo code is 192 bits, and maximum 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 5[MHz] and 10[MHz] bandwidth system are illustrated in Fig. 4 and Fig. 5, respectively.

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



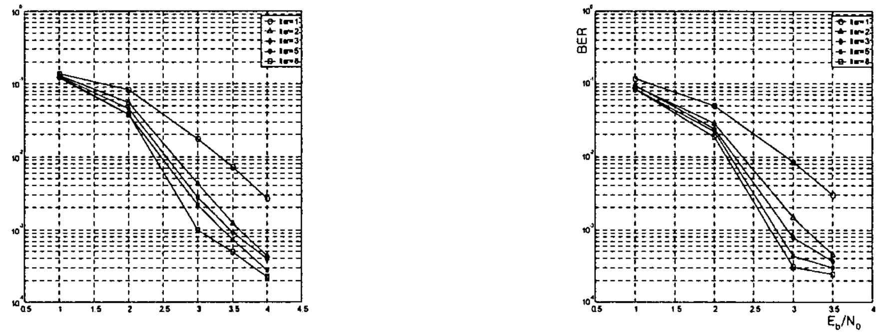
(a) 5[MHz] system bandwidth (b) 10[MHz] system bandwidth

Fig. 3. PDFs of signal statistics S for different bandwidth



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

Fig. 4. BER performance of 5[MHz] bandwidth systems



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

Fig. 5. BER performance of 10[MHz] bandwidth systems

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

	the number of iteration			
	2	3	5	8
M=3	3.68/3.60	3.55/3.45	3.40/3.35	3.28/3.00
M=6	3.46/3.17	3.34/2.98	3.12/2.79	3.00/2.71

([dB])

4. 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 5[MHz] 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 then 3.7[dB] of E_b/N_o. Moreover, in case the bandwidth of 10[MHz] was used, BER of 10^{-3} could be obtained with 3.5[dB] of E_b/N_o or less.

And the E_b/N_o 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 5[MHz] system bandwidth, eight times iterative decoding with M=3 in 10[MHz] system bandwidth, and three times with M=6 in 10[MHz] 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 5[MHz] system bandwidth, and three times with M=3 in 10[MHz] 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.

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Biography

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