ANALYSIS OF HYBRID FDMA/CDMA SYSTEMS IN RICIAN FADING

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ABSTRACT

In this paper, a hybrid frequency division multiple access/code division multiple access (FDMA/CDMA) system in a Rician fading channel is described and analysis. The performance of the hybrid system is compared with a wideband CDMA system, which occupies the same total bandwidth. The results show that for DPSK modulation with a RIKE receiver, a hybrid system can have a greater capacity with a strong direct path component or a high signal to noise ratio (SNR). Otherwise, a wideband system remains optimal.

KEY WORDS

Hybrid FDMA/CDMA, CDMA, Rician fading.

INTRODUCTION

Hybrid frequency division multiple access/code division multiple access (FDMA/CDMA) can be used as an alternative to the direct sequence-code division multiple access (DS-CDMA) when the available bandwidth have gaps. Fig.1 shows the spectrum of this hybrid scheme. The available wideband spectrum is divided into a number of subspectras with smaller bandwidths. Each of these smaller sub-channels becomes a narrowband CDMA system having processing gain lower than the original “wideband” CDMA system, for convenience, the bandwidths of each subspectrum are assumed equal. This hybrid system has an advantage in that the required bandwidth need not be contiguous and different users can be allotted different subspectrum bandwidths depending on their requirements.

The performance of hybrid FDMA/CDMA in frequency selective Rayleigh fading is presented in [1], and paper [2] studied the coherent, hybrid FDMA/CDMA in the Rician Multipath fading. Since the channel is time-variant, the channel parameters cannot be estimated perfectly. In such a case, we should consider using DPSK modulation with RIKE receiver.

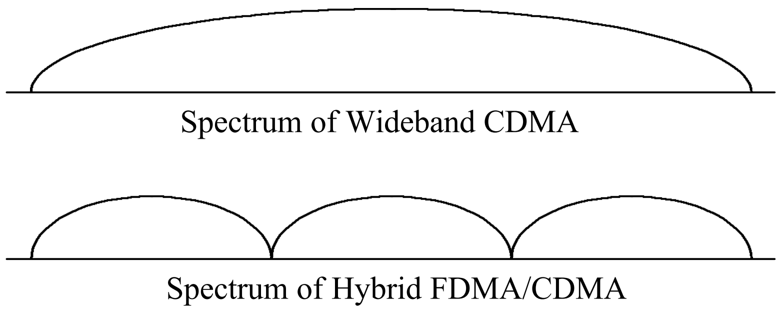

Figure 1. Spectrum of wideband CDMA compared to the spectrum of the hybrid FDMA/CDMA

This paper is organized as follows. In Section II, the CDMA system and channel model is described. In Section III, the bit error rate (BER) expressions for DPSK modulation format are derived. Results and conclusions are provided in Section IV and V, respectively.

CDMA SYSTEM AND CHANNEL MODEL

The system model to be considered consists of K simultaneous transmitters (the zeroth user being the reference user whose performance is to be evaluated). The processing gain is N, the sequences of all users have a common chip rate of $1/T_c$, where $T_c = T/N$, and $1/T$ is the information bit rate. Let $a_k(t)$, $d_k(t)$ denote the code sequence and data siganl (the data bits are differentially encoded for DPSK) waveform of kth user. The transmitted signal for the kth user is

$$S_k(t) = \mathrm{Re}\left[u_k(t)e^{j2pf_c}\right] \qquad (2\text{-}1)$$

where

$$u_k(t) = \sqrt{2P}a_k(t)d_k(t)e^{jq_k} \qquad (2\text{-}2)$$

and where P is the average transmitted power, common to all users; f_c is the common carrier frequency, and q_k is the phase of kth carrier.

A model for a frequency selective multipath channel is a finite-length tapped line. Assume system operates asynchronously, thus the equivalent lowpass signal at the receiver front end of reference user is

$$R_0(t) = r_0(t) + \sum_{k=1}^{K-1} r_i(t - t_k) e^{-jf_k} \quad (2\text{-}3)$$

where the first term is singal component, the second term is multiple access interference component which is approximated to an asymptotically Gaussian random variable (rv) (as the number of users becomes alrge).

For simplicity, perfect power control is assumed. Also, we assume that the fading statistics for each user are identical, and the average received power in each resolvable path is the same. Thus, the equivalent lowpass signal of *k*th user for the L_p path can be expressed in the form

$$r_{kl}(t) = a_l e^{-jf_l} u_{lm}(t) + n_l(t) \qquad l = 0,1,\ldots,L_p - 1 \qquad m = 1,2 \quad (2\text{-}4)$$

where $\{a_l e^{-jf_l}\}$ represent the attenuation factors and phase shifts for the L_p path, $a_0 = b$ is a constant direct path component. All signals in the set $\{u_{lm}(t)\}$ have the same energy, $n_l(t)$ denotes the additive white gaussian noise on the *l*th path with zero mean and spectral density N_0.

The multipath intensity profile (MIP) is assumed to be constant

$$E(a_l^2) = \Omega_0 \qquad l = 1,2,\ldots,L_p - 1 \quad (2\text{-}5)$$

ERROR PROBABILITY ANALYSIS

System employs the RIKE receiver structure for DPSK modulation. When the transmitted signal waveform satisfies the orthogonality property, we have the conditional error probability

$$P_2(g) = \frac{1}{2^{2L-1}} e^{-g} \sum_{k=0}^{L-1} b_k g^k \quad (3\text{-}1)$$

where

$$b_k = \frac{1}{k!} \sum_{n=0}^{L-1-k} \binom{2L-1}{n} \quad (3\text{-}2)$$

where g is signal to noise ratio per bit.

Consider the affection of multipath and multiple access, the g expressed in the form [2]

$$g = s + \frac{s}{b^2} \sum_{l=1}^{L-1} a_l^2 \quad (3\text{-}3)$$

where

$$s = \frac{b^2 / \Omega_0}{\frac{N_0}{E\Omega_0} + \frac{2(K-1)}{3N}\left[\frac{b^2}{\Omega_0} + (L-1)\right]} \quad (3\text{-}4)$$

where E is the bit energy.

Let

$$A = \sum_{l=1}^{L-1} a_l^2 \quad (3\text{-}5)$$

Since $\{a_l\}$ is independent and Rayleigh distributed, then A has a distribution in the form of a chi-squared rv with 2(L-1) degrees of freedom. The expression for the density function is

$$p(A)=\frac{1}{\Omega_0^{L-1}(L-2)!}A^{(L-2)}e^{-A/\Omega_0} \qquad A\geq 0 \tag{3-6}$$

From the (3-3), (3-5), (3-6), we find the probability density function of the g

$$p(g)=\frac{(b^2/\Omega_0)^{L-1}}{s^{L-1}(L-2)!}(g-s)^{L-2}e^{-\frac{b^2}{s\Omega_0}(g-s)} \qquad g\geq s \tag{3-7}$$

Using standard integration techniques to remove the conditioning of g , the final expression for the probability of error is determined to be

$$BER=\frac{\left(\frac{b^2}{\Omega_0}\right)^{L-1}e^{-s}}{2^{2L-1}(L-2)!}\sum_{k=0}^{L-1}b_k s^k\sum_{i=0}^{k}\cdot\binom{k}{i}\cdot(L+i-2)!\cdot\left(s+\frac{b^2}{\Omega_0}\right)^{1-L-i} \tag{3-8}$$

RESULTS

In the follow graphs, L_f refer to the number of CDMAsections formed from the available bandwidth, b^2/Ω_0 is the ratio of the specular power to the average power for the scattered path of the "wideband" system ($L_f=1$), $E\Omega_0/N_0$ is the signal to noise power ratio (SNR). Paper [1] demonstrated that the processing gain and the number of paths of the "narrowband" CDMA sections affected by the bandwidth are reduced.

Fig.2-4 show the average bit error probabilities for each user. Comparing Fig.2, 3 and 4, when direct path component power is lower, the performance of "wideband" CDMA is better, with the increase of direct path component power, the hybrid systems achieve a better performance than a "wideband" CDMA.

Fixing the number of users is 180, fig.5 shows, with the increase of SNR, the performance of hybrid systems will exceed "wideband" CDMA.

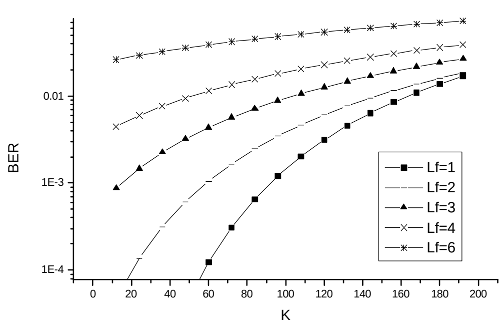

Figure 2. Performance of FDMA/CDMA with $\frac{E\Omega_0}{N_0}=10dB,\frac{b^2}{\Omega_0}=-10dB$

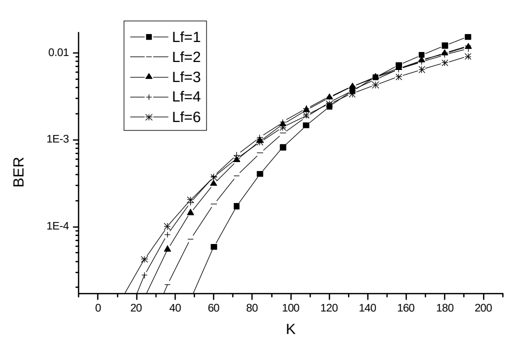

Figure 3. Performance of FDMA/CDMA with $\frac{E\Omega_0}{N_0}=10dB,\frac{b^2}{\Omega_0}=0dB$

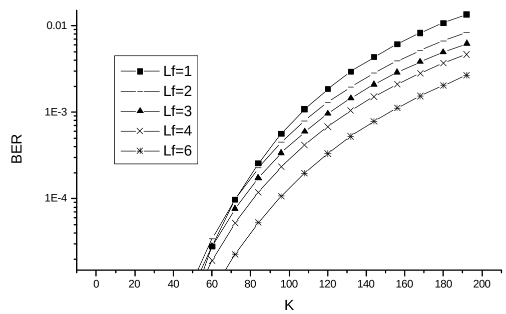

Figure 4. Performance of FDMA/CDMA with $\frac{E\Omega_0}{N_0} = 10dB$, $\frac{b^2}{\Omega_0} = 3dB$

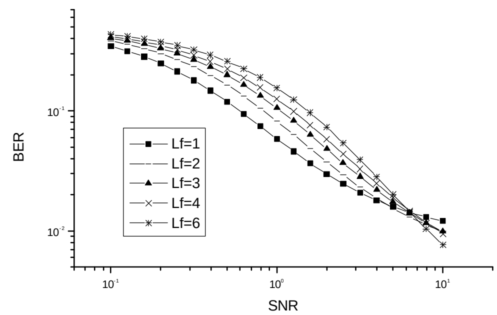

Figure 5. Performance of FDMA/CDMA with $K = 180$, $\frac{b^2}{\Omega_0} = 0dB$

CONCLUSION

In this paper, the hybrid FDMA/CDMA system with DPSK modulation with RIKE receiver in the Rician multipath fading is described and analyzed. The results show, when the direct path component is stronger or the SNR is higher, the hybrid FDMA/CDMA system excells a "wideband" CDMA system. Therefore, differing with coherent modulation, nocoherent demodulation lost signal energy, so the "wideband" CDMA system with DPSK modulation is not optimal.

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