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Analysis & Error Performance of Multicarrier DS-CDMA System over Rician Fading Channel

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Abstract: -In this paper, a multicarrier signalling technique is applied to a direct-sequence CDMA system, where a data sequence multiplied by a spreading sequence modulates multiple carriers instead of a single carrier. This type of signalling suppresses the narrowband interference & it is very robust to multipath fading without requiring the use of either a RAKE structure or an interference suppression filter. Multicarrier DS systems can be categorized into two types, a combination of orthogonal frequency division multiplexing (OFDM) and CDMA, or a parallel transmission scheme of narrowband DS waveforms in the frequency domain. In the former system, a spreading sequence is serial-to-parallel converted, and each chip modulates a different carrier frequency. In the latter system, the available frequency spectrum is divided into M equal-width frequency bands, where M is the number of carriers, and each frequency band is used to transmit a narrowband DS waveform. The system described in this paper belongs to the second group. The error performance of this multi carrier DS CDMA system was carried out for rician fading for an AWGN channel.

***Key words:* CDMA, Multicarrier, Direct Sequence, OFDM, Rake Receiver, Rician Channel**

I. INTRODUCTION

The most important issue in the design and investigation of broadband wireless system in the future consist of support to a wide range of services and high data bit rates. A variety of multiple access techniques can be employed to accomplish these purposes. CDMA system based on spread-spectrum signalling has become a significantly attractive multiple-access technique, especially the advanced techniques of OFDM (orthogonal frequency division multiplexing) schemes. Since the orthogonality exists between subcarriers, it is the principal feature enabling a CDMA system to combat the channel-fading phenomenon and to avoid narrowband interference in multiple-access schemes [1]. MC-CDMA (multi-carrier CDMA), generated by OFDM signalling are now being explored. One of the most important types of MC-CDMA systems is the MC-DS-CDMA (multi-carrier direct-sequence CDMA), in which data sequences multiplied by a spreading sequencer modulate disjointed multiple carriers [2]. The receiver provides a correlator for each carrier, which at each output is combined with MRC (maximal ratio-combining) diversity. A multicarrier DS SS system proposed, in which a data sequence multiplied by a spreading sequence modulates M carriers, rather than a single carrier. The receiver provides a correlator for each carrier, and the outputs of correlators are combined with a maximal-ratio combiner. A multicarrier system requires a lower speed, parallel-type of signal processing, in contrast to a fast, serial-type of signal processing in a single carrier RAKE receiver. The multicarrier DS systems have already been proposed and these proposed techniques can be categorized into two types, a combination of orthogonal frequency division multiplexing (OFDM) and CDMA , or a parallel transmission scheme of narrowband DS waveforms in the frequency domain. Here M adaptive gain amplifiers in the maximal ratio combiner, which may simplify the receiver. In a multicarrier system, carrier frequencies are usually chosen to be orthogonal to each other, i.e., carrier frequencies satisfy the following condition:

$$\int_{0}^{T_c} \cos(\omega_i t+\phi_i).\cos(\omega_j t+\phi_j)dt = 0$$

for i≠j

(1.1)

Where T_c is the chip duration, w_i and w_j are, respectively, the i^{th} and j^{th} carrier frequencies, and φ_i and φ_j are arbitrary carrier phases, respectively. This is done so that a signal in the j^{th} frequency band does not cause interference in the correlation receiver for the ith frequency band. Band limited multicarrier DS waveforms is used, to minimize such unnecessary self-interference, and so orthogonality among carriers is not required. Also, this signalling scheme prevents narrowband waveforms from causing interference to all frequency bands.

II. MULTIPATH FADING

A. *Causes of Multipath Fading*

Fading is the variation of the amplitude, phase and angle with time, between the sent signal and the received signal. Fading in wireless channels is due to multipath effects and is also referred to as multipath fading. The implication of this is that the receiver receives more than one image of the signal and there is also a time difference between them. There are a few factors that contribute to this multipath effect, namely shadowing, diffraction, reflection and refraction [3]. These effects also cause another phenomenon known as attenuation. Attenuation is the decrease of power contained within a signal between the times it is transmitted to the time it is received. Shadowing happens when an object blocks the path between the transmitter and receiver entirely. It is most severe in built-up areas where builds are in the direct path of the signal. The receiver is still able to pick up the signal because it is reflected and refracted around the buildings. The power in the signal will be weaker; however, than if there was no scattering. Reflection occurs when a signal hits a smooth, solid surface, like the side of a building. The higher the frequency, the higher the reflection will be, this effect can be observed with microwave signals, they are high frequency signals and need line-of-sight for adequate strength at the receiver. Diffraction is the effect that occurs when a signal comes into contact with an irregular surface such as the leaves on a tree. The signal is reflected in many different directions, contributing to the attenuation and the multipath effects. It is also known as the scatter effect. Refraction occurs when a signal passes through a medium other than air. These effects can be seen in figure 1.

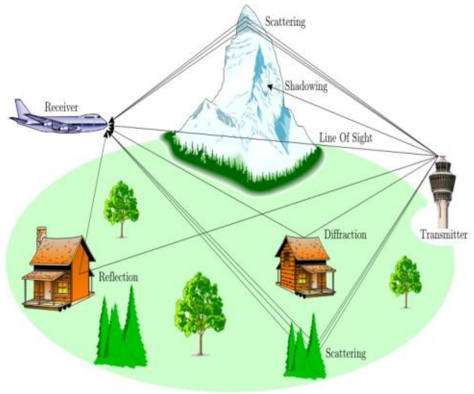

Fig.1 Causes of Multipath fading.[4]

Wireless communication channels are generally time-varying multipath channels. In some cases, there is a direct path between transmitter and receiver, as well as other paths. This line-of-sight path would be dominant and would cancel out some of the effect caused by the other paths. The normal case is that there is no line-of-sight path, and the signal received has been reflected or scattered a number of times. Each of the paths that the different components of the signal take has a different physical length. This makes the signal harder to reconstruct at the receiver.

B. Rayleigh Fading Model

The Rayleigh Fading Model is primarily used for modelling an environment where there are many objects that cause the signal to scatter or diffract. There is no direct line-of- sight between the transmitter and receiver. The signal is still able to be recognisable at the receiver if the scatter is sufficient enough that many of multiple paths combine to produce a workable signal. Because there is no dominant path, the process will have a zero mean with the phase distributed evenly between over a range of 2π. Therefore, the channel response will be Rayleigh distributed. If we let the A and B is two zero mean Gaussian random variables, each with a variance of σ^2, and let P=**Error! Reference source not found.**, the probability density function is given by,

$$P_R(r) = \frac{2r}{\omega} e^{\frac{-r^2}{\omega}}, r \geq 0 \tag{2.1}$$

Where ω = E (R^2). In some models the gain and the phase are represented as a complex number. In such a case the real and imaginary parts are modelled by independent, identical distributed random Gaussian processes.

The statistical averages of R are given by

$$E(R^k) = (2\sigma^2)^{\frac{k}{2}} \ \tau(1+\frac{k}{2}) \tag{2.2}$$

Where τ is the gamma function, it is a function which extends the factorial function to complex and non-integer numbers.

The variance of the channel is given by

$$\sigma^2 r = (2 - \frac{1}{2\pi})\sigma^2 \tag{2.3}$$

If a channel is not time-varying, it does not fade and will remain at a constant level. As such, the channel will be uncorrelated. Whereas, if there is a relative velocity between the transmitter and receiver then the signal is correlated and becomes time-varying. Correlation means that components in the signal at time t have an effect on components occurring after time t. The equation for normalized autocorrelation of a Rayleigh fading channel with a constant velocity is

$$R(\tau) = J_0(2\pi f_d \tau) \tag{2.4}$$

with a delay of τ and a maximum Doppler shift of f_d.

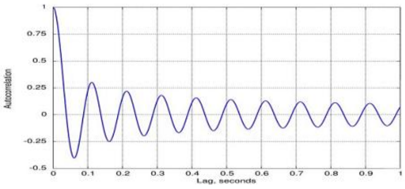

Fig.2. Expected Autocorrelation of the amplitude of a Rayleigh fading channel

C. Rician Fading Model

The major difference between Rayleigh fading and Rician fading models is that with Rician fading there is a dominant line-of-sight path between the transmitter and the receiver. This causes the statistical modelling of the channel to vary in certain ways. For instance, the overall multipath effect is not as prevalent as in Rayleigh fading,

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since the line-of-sight path helps drastically when receiving and decoding the signal. To examine the Rician model by consider a narrow-band propagation channel with a carrier signal of

$$s(t) = \cos(\omega_c t) \tag{2.5}$$

The received signal over the Rician multipath fading channel will be

$$v(t) = C.\cos(\omega_c t) + \sum_{n=1}^{N} \rho \cos(\omega_c t + \phi_n) \tag{2.6}$$

Where C is the amplitude of the line-of-sight component and ρ_n and φ_n are the amplitude and phase, respectively, of the multipath components of the signal. The Rician K-factor is the ratio of signal power in the dominant component over the mean of the multipath components. It is measured in dB. If we let C = 0, then the Rician model degrades to a Rayleigh fading model, making K = 0.

III. SYSTEM MODEL

A. System Overview

In recent years, several wideband CDMA systems have been proposed either to realize an overlay system, where DS CDMA waveforms are overlaid onto existing narrowband signals to enhance the overall capacity, or to combat multipath[5].A multicarrier system can be considered as one realization of such a wideband DS system[6]. Figure 3 shows a band limited single-carrier wideband DS waveform in the frequency domain, where the bandwidth, BW1, is given by

$$BW_1 = (1+\alpha)\frac{1}{T_c} \tag{3.1}$$

Where, $0 < \alpha < 1$, and T_c, is the chip duration of the single carrier system.

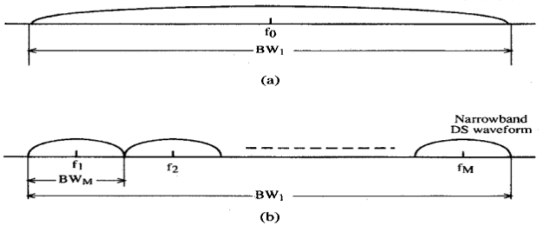
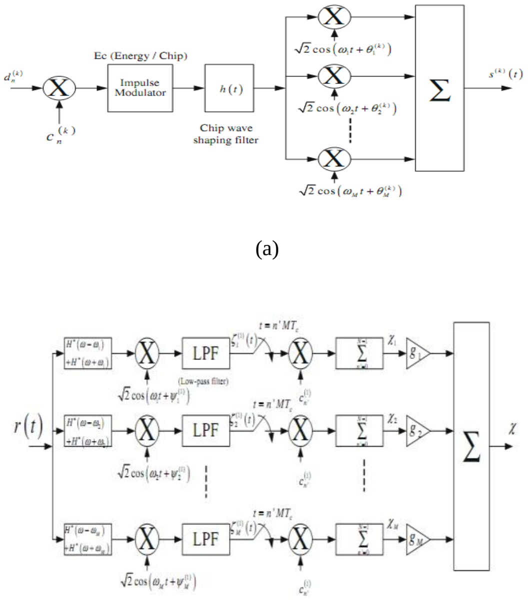


Fig 3. Power spectrum densities of DS waveforms. (a) psd of a single-carrier DS waveform. (b) psd a multicarrier DS waveform.

In a multicarrier system divide BW_1 is divided into M equal-width frequency bands as shown in Figure 3 (b), where all bands are disunite. Then the bandwidth of each frequency band, BW_M, is given by

$$BW_M = \frac{BW_1}{M} = (1+\alpha)\frac{1}{MT_c} \tag{3.2}$$

Note that $M.T_c$ is the chip duration of the multicarrier system and M is the number of carriers.



(a)

(b)

Fig. 4 Transmitter and receiver block diagrams. (a) Transmitter for kth use (b) Receiver for the first user.

B. Transmitter

The transmitter for the kth user is shown in Figure 4, where $d_h^{(k)}$ is a random binary sequence representing data, and $c_n^{(k)}$ is a pseudo-random spreading signature sequence. Assume that there are N chips per symbol, and that each user has a different signature sequence. The sequence $d_h^{(k)} c_n^{(k)}$ modulates an impulse train, where the energy per chip is E_c. After passing through a chip wave-shaping filter, the signal out of the filter modulates the multiple carrier signals and is transmitted.

C. Channel

The channel is assumed to be a slowly varying frequency selective Rayleigh channel with delay spread of T_m. suppose the first M symbols out of the source modulate the M carriers in the first time interval. In the second time interval, the same M symbols modulate the M carriers, but cyclic shifted by one symbol. In the ith interval, $1 < i < M$, the (i - 1)th cyclic shift modulates the M carriers. At the receiver, a deinterleaver is employed. In what follows, assume independence is achieved without the need to employ the interleaving [7]. Then the complex low pass equivalent impulse response of the ith channel can be written as

$$c_i = \zeta_i' \delta(t)$$

(3.3) Where the { ζ I', i = 1,2,M} are i.i.d., zero-mean, complex Gaussian random variables. Under the above assumptions, the transfer function of the ith frequency band for the kth user is given by ζ i' Ξ $\alpha_{k,i}$exp (j$\beta_{k,i}$), where $\alpha_{k,i}$ and $\beta_{k,i}$ are, respectively, an i.i.d. Rayleigh random variable with a unit second momentand an i.i.d. uniform random variable over [0, 2π]. The received signal is then given by

$$r(t) = \sum_{k=1}^{K} \{\sqrt{2E_c} \sum_{n=-\infty}^{\infty} d_h^{(k)} c_n^{(k)} h(t - nMT_c - \tau_k) \sum_{m=1}^{M} \alpha_{k,m} \cos(\omega_m t + \theta'_{k,m})\} + n_w(t) + n_J(t)$$

(3.4)

Where h = [n/N], h(t) is the impulse response of the chip wave-shaping filter

$$\theta'_{k,m} = \theta_{k,m} + \beta_{k,m}$$

(3.5)

n_w(t) is AWGN with a double-sided psd of η0/2, and n_J(t) is partial band Gaussian interference with a psd of S_{nJ}(f).

D. Receiver

The receiver of the first user (k = 1) is shown, where the following characteristics for the chip wave-shaping filter is assumed:

$$X(f) \equiv |H(f)|^2$$ Satisfies the Nyquist criterion

(3.6)

$$F^{-1}|H(f)|^2 \equiv x(t)$$

(3.7)

$$\int_{-\infty}^{\infty} |H(f)|^2 \, df \equiv 1$$

(3.8)

Also, assume that |H (f) $|^2$ is band limited to W', where W' < BW_M/2 = (f_{i+1} - f_i)/2, and f_i is the ith carrier frequency. This implies that the DS waveforms do not overlap.

IV. SIMULATION RESULTS

The below plot shows how P_e varies with SNR for SNR values varying from 0 to 9. As it can be inferred that P_e is more for Nc=512, M=1 case in comparison with the other cases. The same is shown in terms of numerical values in the table.

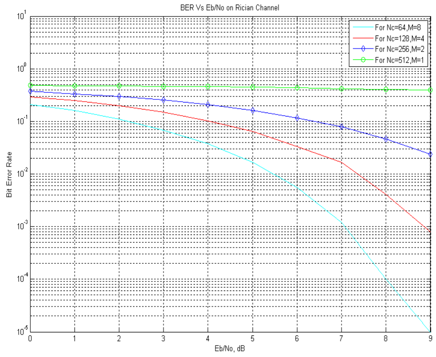


Fig 5 Error Performance of MC DS CDMA System

SNR (in dB)	Nc=64, M=8	Nc=128, M=4	Nc=256, M=2	Nc=512, M=1
0	0.21	0.29	0.3717	0.4852
1	0.1599	0.2469	0.3328	0.4779
2	0.113	0.1974	0.2985	0.4733
3	0.0685	0.1487	0.254	0.4639
4	0.0378	0.1020	0.2072	0.4556
5	0.0165	0.0652	0.1618	0.4454
6	0.0056	0.0336	0.1155	0.4342
7	0.0012	0.0165	0.0783	0.4211
8	0.0001	0.0041	0.0463	0.4083
9	0	0.0008	0.0236	0.3970

Table .1

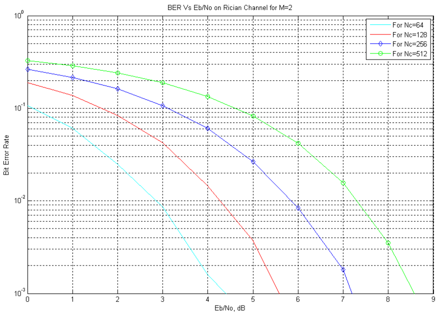


Fig 6 Plot for M=2

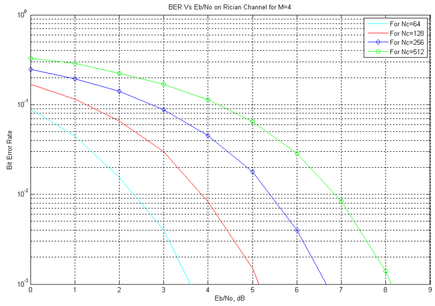


Fig 7 Plot for M=4

The above two plots are for M=2 and M=4. As it can be seen that the almost same type of response is obtained for Nc=64,128,256 and 512. A comparison for M=2 and M=4 is given in table below.

SNR(in dB)	M=2,Nc=512	M=4,Nc=64
0	0.3291	0.3167
1	0.2875	0.2739
2	0.2411	0.2224
3	0.1882	0.1686
4	0.133	0.1134
5	0.0823	0.0649
6	0.0420	0.0287
7	0.0156	0.0084
8	0.0035	0.0014
9	0.0004	0.0001

Table 2

From the table above it can be concluded that for M=4 for a given SNR the Pe was observed to be less. As 'M' increases the probability of error reduces.

V. CONCLUSION

We discussed a new way of realizing a wideband CDMA system. The system has a narrowband interference suppression effect, along with robustness to multipath fading. The BER performance of the generalized MC DS-CDMA is presented for transmissions over Rician fading channels. The results show that the Multi carrier scheme can combat ISI more effectively in comparison with single carrier CDMA scheme.

REFERENCES

[1] J. Proakis, Digital Communications. New York McGraw-Hill, 1989.

[2] S. Kondo and L. B. Milstein, "Multicarrier CDMA system with co channel interference cancellation," in Proc. VTC '94, Stockholm, Sweden, June 1994, pp. 164C-1644.

[3] Physics, Chapter 37: Reflection and Refraction Henry Semat City College of New York Robert Katz University of Nebraska - Lincoln, rkatz2@unlnotes.unl.edu

[4] Tele-information.com/2012/12/single-frequency-network-sfn/

[5] M.Schwartz, W.R.Bennet, and S. Stein, Communication Systems and Techniques. New York: McGraw-Hill, 1966.

[6] S.Kondo and L.B.Milstein, "On the use of multicarrier direct sequence spread spectrum systems," in Proc. IEEE MILCOM '93. Boston. MA Oct. 1963, pp. 52-56.

[7] E.Sourour and M.Nakagawa,"Performance of orthogonal multi carrier CDMA in a multipath fading channel," IEEE Trans. Communication, submitted for publication.

[8] G. L. Turin, "Introduction to spread-spectrum anti multipath techniques and their application to urban digital radio," Proc. IEEE, vol. 68, Mar 1980.

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