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Performance of Wideband Mobile Channel with Perfect Synchronism BPSK vs QPSK DS-CDMA

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ABSTRACT
Direct-sequence code-division multiple access (DS-CDMA) is currently the subject of much research as it is a promising multiple access capability for third and fourth generations mobile communication systems. The synchronous DS-CDMA system is well known for eliminating the effects of multiple access interference (MAI) which limits the capacity and degrades the BER performance of the system. In this paper, we investigate the bit error rate (BER) performance of a synchronous DS-CDMA system over a wideband mobile radio channel. The BER performance is affected by the difference in path length ΔL and the number of arriving signals N. Furthermore, the effect of these parameters is examined on the synchronous DS-CDMA system for different users' number as well as different processing gain G_p. In this environment and under the above conditions the performances of the BPSK (Binary Phase Shift Keying) and the QPSK (Quadrature Phase Shift Keying) modulations are compared. The promising simulation results showed the possibility of applying this system to the wideband mobile radio channel.

General Terms
Mobile Channel Synchronization.

Keywords
Synchronism, Direct Sequence CDMA, BPSK, QPSK, Complex Gain, Bit error rate.

1. INTRODUCTION
Direct-sequence code-division multiple access (DS-CDMA) using multicarrier modulation has been extensively studied recently. It is a promising multiple access capability for third and fourth generations wireless systems [1- 4]. The advantage of the Quadrature Phase Shift Keying (QPSK) modulation versus the Binary Phase Shift Keying (BPSK) one is well known. It has the possibility to transmit in the same frequency band twice more information, while the number of errors and the ***Eb***/***No*** relation are the same.

We introduce the wideband mobile radio channel developed in [5]. Particularly, we derive its impulse response, and investigate the bit error rate (BER) performance of a synchronous DSCDMA system over this wideband channel. In this environment, the performances of the BPSK (Binary Phase Shift Keying) and the QPSK (Quadrature Phase Shift Keying) modulations are compared. In the DS-CDMA system, the narrowband message signal is multiplied by a large bandwidth signal, which is called the spreading signal. The spreading signal is generated by convolving a pseudo-noise (PN) code with a chip waveform whose duration is much smaller than the symbol duration. All users in the system use the same carrier frequency and may transmit simultaneously. By assigning a specific spreading signal to each user, which is approximately orthogonal to the spreading signals of all other users, it is possible to allow many users to share the same carrier frequency and channel simultaneously. Therefore, the receiver performs a correlation operation to detect the message addressed to a given user and the signals from other users appear as noise due to decorrelation. The synchronous DS-CDMA system is presented for eliminating the effects of multiple access interference (MAI) which limits the capacity and degrades the BER performance of the system [6]. MAI refers to the interference between different direct sequences users [7]. With increasing the number of users, the MAI grows to be significant and the DS-CDMA system will be interference limited. Also, in indoor and mobile radio communication channels, the system performance is significantly degraded by multipath fading channels. The effective method to overcome the degradation in the performance due to multipath fading is diversity combining. The goal of diversity is to reduce the fading effect by supplying the receiver with several replicas of the same information signal transmitted over independently fading paths [8, 9]. In this paper, we investigate the BER performance of the synchronous DS-CDMA over a wideband transmission channel, the urban multipath fading channel, by using specific parameters as proposed in [5].

2. SYSTEM AND CHANNEL MODELS
In this section, we provide a mathematical description of the DS-CDMA system, in which an orthogonal spreading sequence is used. Also, we will derive the channel model impulse response from the power spectrum density (PSD) of the wideband channel.

2.1 Transmitted Signals
Let us assume that there are k independent users transmitting signals in the DS-CDMA system. Each of them transmits a signal as described in [9]. The transmitted signals are simply expressed as

$$S^{(k)}(t-\delta^{k}) = \sqrt{P^{(k)}}u^{(k)}\left(t-\delta^{(k)}\right)a^{(k)}\left(t-\delta^{(k)}\right)$$

Where $P^{(k)}$ is the power of the transmitted signal, $u^{(k)}$ is a binary data (information) sequence, $a^{(k)}$ is a spreading signal (pseudorandom sequence), and $\delta^{(k)}$ is the time offset of the k^{th} users. These time values characterize asynchronism between different users. In our case, we assumed that the receiver is delay and phase synchronized.

The k^{th} user's data signal is a sequence of unit amplitude rectangular pulses of duration T_b; the pulses' values can be either -1 or +1 with equal probability. Each pulse represents an information bit for user k. This sequence is given by

$$u^{(k)}(t) = \sum_{j=-\infty} u_j^{(k)} g_{T_b}(t - jT_b)$$

Where,

$$g_{T_b} = \begin{cases} 1 & for \quad 0 \le t \le T_b \\ 0 & otherwise \end{cases}$$

The spreading signal $a^{(k)}$ (t) is a sequence of unit amplitude rectangular chips of duration T_c and can be expressed as

$$a^{(k)}(t) = \sum_{i=-\infty}^{\infty} a_i^{(k)} \Psi(t - T_c)$$

Where $\psi(t)$ is a chip waveform that is time limited to $[0, T_c]$ and normalized to have energy T_c , and $a_i^{(k)}$ is the i^{th} chip value of the k^{th} user. The chip value can be either -1 or +1 with equal probability. There are G chips per bit, and thus $G = T_b / T_c$ is the processing gain or spreading factor for user k. Also, we assume that the desired user is $k = 0$ and all other contribute to MAI.

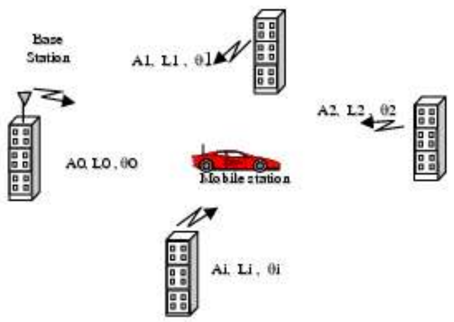

Fig. 1: Wideband propagation Model

2.2 Wideband Channel Model

The propagation model is used to evaluate the wideband transmission as shown in figure (1). It assumes that multipath waves arrive at a receiver point under these conditions as follows [5]:

1) The number of arrival signal is N; each signal has amplitude A_i (f) and path length L_i. These amplitude and path lengths are independent of each other and are distributed uniformly within a fixed range.

2) $A_o(f)$ is a line of site (LOS) direct signal amplitude and the amplitude of non-direct signals as reflected or refracted is $A_i(f)$ (i ≥). Also, L_o for LOS is defined as the minimum distance (path length) of arriving signals.

3) The angles of arrival (θ_i) of the signals are distributed over 2π uniformly in a horizontal plane.

4) The amplitude of each signal is constant over $(f_c + \Delta F)$ and centered at a transmission radio frequency of f_c.

5) The bandwidth of the receiver is $(2\Delta f)$ and centered at f_c, where $\Delta f < \Delta F$.

The power spectrum density (PSD) of the received signal is expressed as a function of the bandwidth $(2\Delta f)$ as follows [5]:

$$P(f) = 2\Delta f\{\sum_{i=0}^{N} A_i^2(f) \; + \; \sum_{i=0}^{N}\sum_{j=0}^{N} \frac{A_i(f)A_j(f)}{K\Delta L_{ij}\Delta f} \; \times \; [\cos\left(K\Delta L_{ij} f\right).\sin\left(K\Delta L_{ij}\Delta f\right)] \qquad \textbf{(4)}$$

Where,

K = 2π / c, and c is the velocity of light. Also, $\Delta L_{ij} = L_i - L_j$ and ∑∑ means i≠ j.

The ratio of power spectrum density a'^2 is denoted as $a^2 = \frac{A_0^2(f)}{A_i^2(f)}$ where $a = 20LOG(a')$

Equation (4) shows the received signal level for wideband transmission. The first term represents the mean valued (LOS signal) and the remaining term represents the instantaneous signal variation (multipath signal) as the receiver moves along the street. The wideband multipath channel is modeled as in figure (2). s_i (t) and τ_i represent direct (LOS) and the non-direct signals, and the time delay respectively; where i = 0: N, N is the total number of arrival signals.

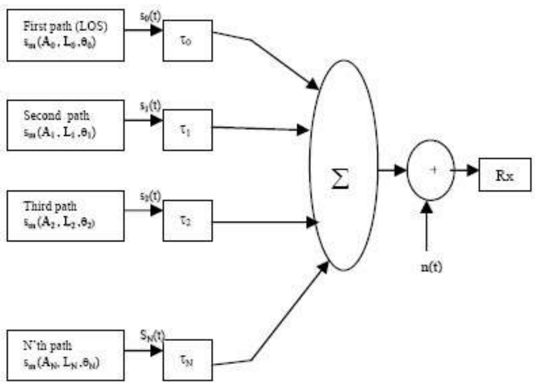

Fig. 2: The Model of the wideband channel

After verifying the power spectrum density (PSD) of the received signal function as shown in equation (4), we derive the channel transfer function by taking the roots of the PSD function. Then, by applying the inverse fast Fourier transform (IFFT) to the transfer function, we get the impulse response of the wideband multipath channel, *h(t).*

$$h(t) = F^{-1}\left(\sqrt{P}(f)\right)$$

2.3 Received Signals

The total received signal, *r(t),* which convolved the transmitted signal, *s(t),* with the impulse response of the wideband channel, *h(t),* plus the Additive White Gaussian Noise (AWGN), n(t), having a double-sided power spectral density (PSD) $N_o/2$ can be written as

$$r(t) = \sum_{k=0}^{k-1} \sum_{j=0}^{L-1} \sqrt{p^{(k)}} s^{(k)}\left(t - \delta^{(k,L_k)}\right) X\, h^{(k,L_k)}(t) + n(t) \qquad \textbf{(7)}$$

From equation (7), the signals from many users arrive at the input of the correlation receiver, which is typically used to filter the desired user's signal from all other users' signals that share the same bandwidth at the same time. Thus, the total received signal contains both the desired user's signal and K-1 undesired users' signals as well as the channel noise. Also, there are the multipath components of both the desired and interfering users.

3. SIMULATION RESULTS

In this section, we present and discuss the results of the BER performance of the synchronous DSCDMA system over a wideband multipath channel as presented in [5]. The physical parameters of this channel model that were used in Equation (4) for addressing the simulation results are based on the following values:

1. The number of arrival signal is N = 20.
2. The carrier frequency f_c = 1.9 GHz.
3. The difference distance between the arrival signal and the one just next to it is varying from (0:15) and is defined by path length difference $abs(\Delta L_{ij})$.
4. The bandwidth of the received signal is denoted as Δf, and it equals 90 MHz, whereas it is a wide band transmission.

After numerous testing times of the channel for different N and ΔL_{ij}, we found that the channel fade depth becomes shallower when the number of arriving signals N and path length difference ΔL_{ij} are increased. So, the impulse response of the channel level depends on both N and ΔL_{ij} which agrees to [5]. Further, we found the suitable values, N and $\Delta L_{ij,}$ for the synchronous DS-CDMA system are 20 arrival signals and (0:15) meter(s), respectively.

For the validation of the simulated result with the theory, the well-known formula of the probability error [10]

$$P_e = T\left(\frac{K-1}{3G_p} + \frac{N_0}{2Eb}\right)^{\frac{1}{2}}$$

It is adapted for DS-BPSK system where K is the number of users, G_p is the processing gain, E_b is the Energy per bit and N_o is noise spectral density. T is the tail function defined as

$$T(x) = \int_x^{\infty} \frac{1}{\sqrt{2\pi}} exp\left(-\frac{y^2}{2}\right) dy$$

The probability of error of DS-QPSK (10) is similar to (8) for DS-BPSK case except for the extra factor 2 which indicates that the DS-QPSK system behaves as having twice the number of the number of users and is given as:

$$P_e = T\left(\frac{2(K-1)}{3G_p} + \frac{N_0}{2Eb}\right)^{\frac{1}{2}}$$

At first time, it can be seen that theoretically for the same number of user, (1) gives higher P_e than (10). This result (10) is in worse performance due the doubled data and to the increased inter-user interference. The DS-QPSK can be viewed as two DS-BPSK transmitters operating on the odd and the even data bits separately but transmitting this data streams together.

3.1 Performance of DS-BPSK-CDMA

Based on the BER performance of DS-BPSK-CDMA presented in [11] and regarding the comparison to DS-QPSK system in the next subsection, the results are presented again in this paper. In this case, a randomly real code sequence consisting of -1 and 1 and randomly real additive noise are generated for the simulation of the bits error rate of DS-QPSK and compared to theoretical computation as shown in Figure (3). we illustrate the average BER for the different number of active users, 4, 8, 16, 32 with G_p = 128, processing gain. It can be seen that, with the same N andΔL_{ij} , there is difference in BER performance between 4 users and 32 users by 3.5 dB at 7*10e-3 due to MAI. Also, the performance decreases with the increasing number of users when the E_b/No is larger than 5 dB. In addition, the simulation, solid lines, and theoretical, dotted lines, results approach each other with increasing E_b/N_o for different users, 4, 8, 16, 32.

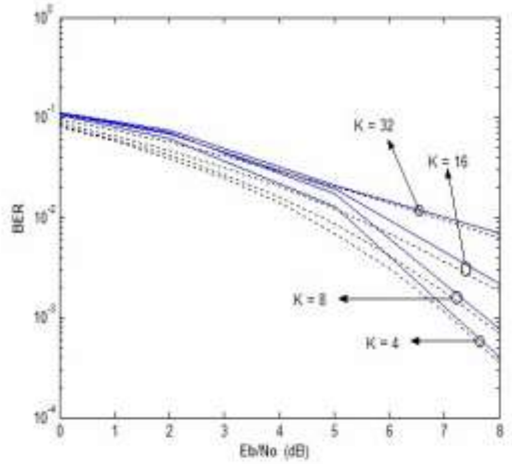

Fig. 3: G_p=128, N=20 arrival signals, ΔL_{max} = 15 m, DS-BPSK simulation curves, solid lines, and theoretical curves, dotted lines.

3.2 Performance of DS-QPSK-CDMA

For the simulation of DS-QPSK over wideband multipath channel a randomly complex spreading sequence is implemented to generate the even and odd code sequences. Consequently, to carry out correctly the operating simulation, a randomly complex additive noise is generated too. This leads to the doubling of the generated data rate, compared to the DS-BPSK. All other parameters are identical to DS-BPSK system and under the above presented conditions.

Figure (4) shows the simulated BER performance of DS-QPSK over wideband channel under the above conditions. The BER decreases with larger E_b/N_o. There is no significantly performance difference for different users for the given interval E_b/N_o between 0 and 8 dB, but decreasing with smaller number the users. In Figures (5) to (8) the comparison of the simulated and theoretical BER performances in DSQPSK are presented. The simulated curves are closely similar to the theoretical ones. The equation (10) was adapted and applied for the QPSK performances and found to be satisfactory for most cases.

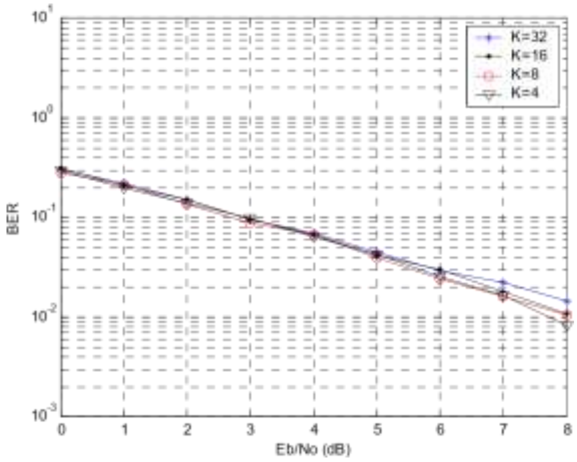

Fig. 4: DS-QPSK simulation curves. G_p=128, N=20 arrival signals, ΔL_{max} = 15 m.

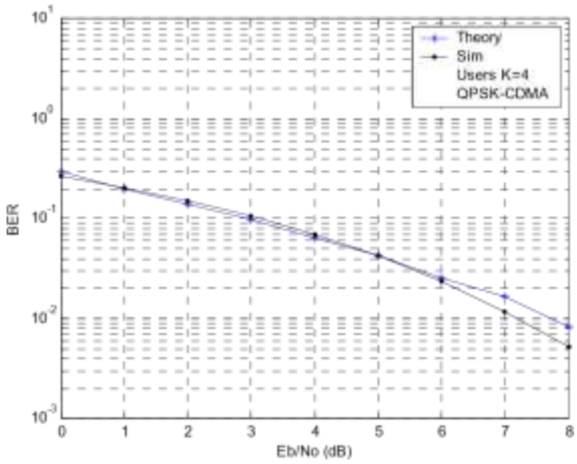

Fig. 5: DS-QPSK simulation and theoretical curve for K= 4 users, G_p=128, N=20 arrival signals, ΔL_{max} = 15 m.

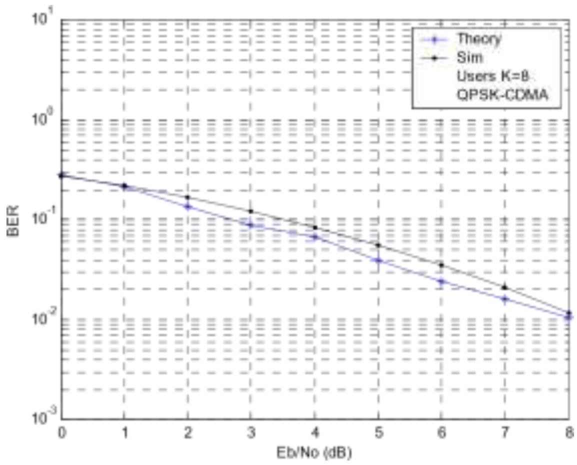

Fig. 6: DS-QPSK simulation and theoretical curve for K= 8 users, G_p=128, N=20 arrival signals, ΔL_{max} = 15 m

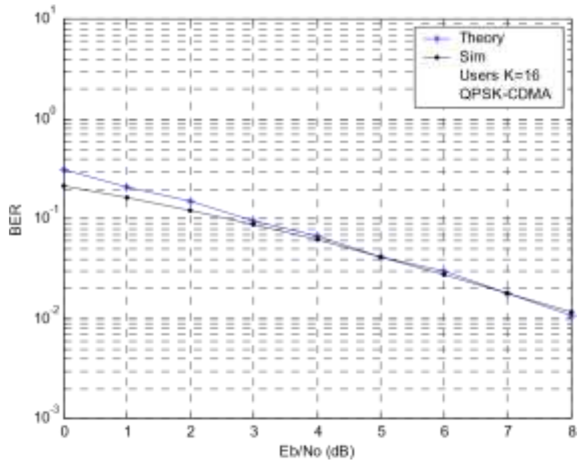

Fig. 7: DS-QPSK simulation and theoretical curve for K= 32 users, G_p=128, N=20 arrival signals, ΔL_{max} = 15 m.

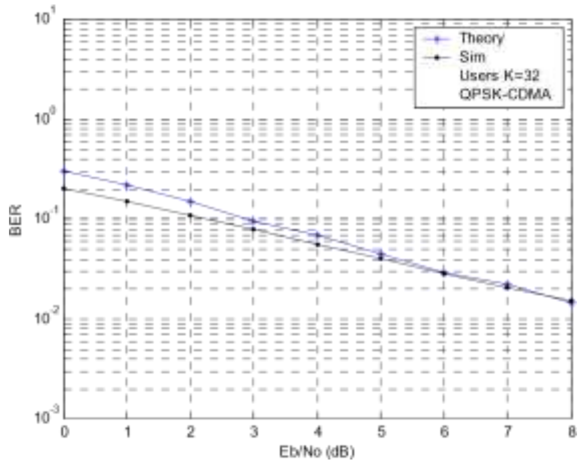

Fig. 8: DS-QPSK simulation and theoretical curve for K= 32 users, G_p=128, N=20 arrival signals, ΔL_{max} = 15 m.

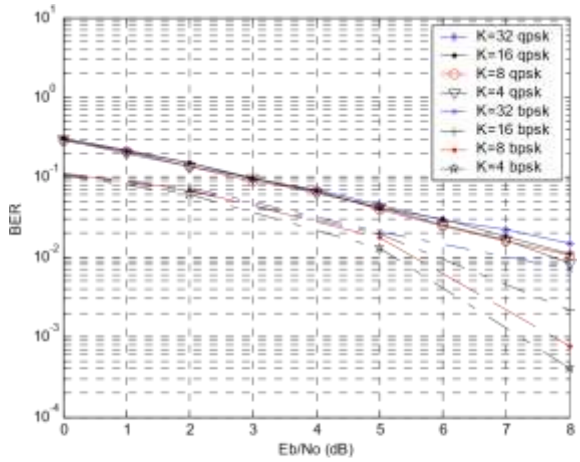

Fig. 9: Comparison between DS-BPSK and DS-QPSK BER simulation, G_p=128, N=20 arrival signals, ΔL_{max} = 15 m

3.3 Comparison of DS-BPSK vs DS-QPSK

Figure (9) shows the comparison between simulated BER performances of DS-BPSK vs DS-QPSK over wideband channel. DS-BPSK performs better than DS-QPSK in all considered cases. The difference of BER between both systems varies approximately between 2*10e-2 and 7*10e-3 for all cases. The higher BER values of DS-QPSK are due principally to the doubling of data rate.

4. GAIN EFFECT

Figure (10) shows the BER performance over a wideband multipath channel, as a function of the processing gain (Gp = 32, 64, and 128). The arrival signals N, the maximum path length difference, and Eb/No are set to 20, 15 m, and 8 dB, respectively. We note that the performance of the system depends on Gp. It is noteworthy that Gp has a negative effect on the number of users, K. As Gp increases, the probability of error decreases. Hence the bigger the processing gain Gp, the greater is the effective power advantage of the wanted signal over the interference power [12].

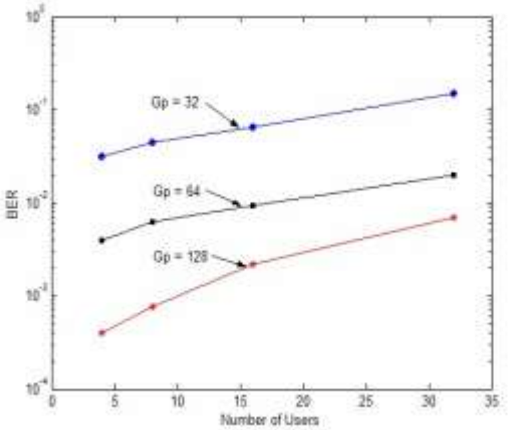

Fig. 10: BER performance for different processing gains, Gp, with different users at N=20 arrival signals and $\Delta L_{\max}$ = 15 m

5. CONCLUSION

In this paper, we evaluated the bit error rate (BER) performance of the synchronous DS-CDMA system over a wideband mobile radio channel. DS-BPSK vs DS- QPSK are compared. The channel power spectrum density (PSD) is introduced and its impulse response is derived. In order to demonstrate the potential of this work, various simulation results have been presented.

After several tests of the channel for different N and ΔL_{ij} to be applied to the DS-CDMA system, we found proper values (N = 20 arrival signals and $\Delta L_{\max}$ = 15 m) to achieve better performance. DS-BPSK compares favorably to DS-QPSK due the doubling of the generated data rate, and users interferences.

Furthermore, BER improvement is achieved with increasing the G_p and decreasing the number of users. Also, we note that the simulation BER performance for different users approaches the theoretical BER performance. Finally, we can see that the wideband transmission channel yields very good performance for synchronous DS-CDMA at specific propagation parameters, N and ΔL_{ij}, DSQPSK shows higher BER values than DSBPSK due principally to the doubling the data rate.

6. REFERENCES

[1] L.-C. Wang, On the Performance of multicarrier DS-CDMA with Imperfect Power Control an Variable Spreading Factors, IEEE J. on Sel. Areas in Comm. vol. 24, No 6, June 2006.

[2] S. Hara and R. Parsad, Overview of multicarrier CDMA, IEEE Comm. Mag. vol. 35, No 12, December 1997.

[3] L. Loyola and T. Miki, A new transmission and multiple access scheme based on multicarrier CDMA for the future highly mobile networks, Proc. IEEE Int. Symp., Pers. Indoor and Mobile Comm. , vol. No 2, September 2003.

[4] D. K. Kim and S.-H Hwang, Capacity analysis of uplink synchronized multicarrier DS-CDMA system, IEEE Comm. Letter, vol. No 6, Mars 2002.

[5] S. Kozono, Received Signal-Level Characteristics in a Wide-Band Mobile Radio Channel, IEEE Trans. Veh. Tehnol., vol. 43, no. 3, pp. 480-486, August 1996.

[6] S. H. Hwang and L. Hanzo, Reverse-Link Performance of Synchronous DS-CDMA Systems in Dispersive Rician Multipath Fading Channels, Electronics Letters, vol. 39, no. 23, November 2003.

[7] Z. Guo and K. Ben Letaief, An Effective Multiuser Receiver for DS/CDMA Systems, IEEE J. Select. Areas Commun., vol. 19, no. 6, pp. 10191028, June 2001.

[8] M. A. Do and S. Y. Wu, Hybrid Diversity Combining Techniques for DS-CDMA over a Multipath Fading Channel, Wireless Networks 3, pp. 155-158, 1997.

[9] K. S. Zigangirov, Theory of Code Division Multiple Access Communication, IEEE, 2004.

[10] M. B. Pursley, Performance Evaluation for Phase-Coded Spread Spectrum Multiple Access Communication – Part 1: System Analysis," IEEE Trans. Comm., pp. 795-799, Aug. 1977.

[11] H. Al-Sharari, Performance of Wideband Mobile Channel on Synchronous DS-CDMA, 6th WSEAS International Conference CSECS'07, Cairo, Egypt, Dec. 29-31, 2007.

[12] T. Timotijevic, System Level Performance of ATM Transmission over a DS-CDMA Satellite Link, Ph.D. Dissertations, University of London, 1999.