J. Tanskanen, J. Mattila, M. Hall, T. Korhonen, and S.J. Ovaska, “Predictive closed loop power control for mobile CDMA systems,” in *Proc. IRC Workshop'97*, Espoo, Finland, Sept. 1997, pp. 41–42.

PREDICTIVE CLOSED LOOP POWER CONTROL FOR MOBILE CDMA SYSTEMS

Jarno M. A. Tanskanen[1], Jari Mattila[2], Michael Hall[2], Timo Korhonen[2], and Seppo J. Ovaska[3]

[1]Helsinki University of Technology
Institute of Radio Communications
Laboratory of Signal Processing and Computer Technology
PO Box 3000, FIN-02015 HUT, Finland
E-mail: jarno.tanskanen@hut.fi

[2]Helsinki University of Technology
Institute of Radio Communications
Communications Laboratory
PO Box 3000, FIN-02015 HUT, Finland

[3]Helsinki University of Technology
Laboratory of Electric Drives and Power Electronics
PO Box 3000, FIN-02015 HUT, Finland

Abstract—In this paper, a predictive closed power control loop for mobile communication systems is simulated employing actual multiuser interference. It is shown that when the estimates of the received power level are noisy, and the control loop response is inherently delay-limited, predictive lowpass filtering can be applied to improve the received power level estimates and overall system performance. In this paper, comparative bit error rates and relative transmitter power consumptions between a predictive and a conventional control scheme are presented.

I. INTRODUCTION

As the CDMA systems are inherently interference limited, it is of paramount importance in the uplink transmission (from mobile to base station) to keep the *received power level* from each mobile unit constant in the average [1]. The need for power control has been widely studied, and the capacity of a CDMA system is found to greatly depend on the power control function [1], [2]. In this study, the mobile transmitter power control, used to counteract Rayleigh fading, is achieved through a closed power control loop for which it is necessary to estimate the received power level.

II. CLOSED LOOP POWER CONTROL SIMULATOR

To clearly demonstrate the effects of the predictive power controller, simulator components are kept as simple as possible. Simulation parameters are derived from those presented for the Qualcomm CDMA system in [3]. Some parameters are adjusted for simulation purposes. Both data and spreading code are random binary sequences produced by maximum length shift registers with periods of $2^{31}-1$ and 127, respectively. 127 is also the number of chips per bit. The carrier frequency is 1.8 GHz and the chip frequency 1.2288 MHz, as in [3]. To clarify power control effects, and to reduce simulation execution time, the power control frequency is double that given in [3], i.e., transmission power is controlled every 6 bits. At each control instant, the transmission power is either increased or reduced by 1 dB.

In the simulations, there are altogether 5 or 10 identically power controlled users which are connected to a common base station and interfere with each other. The observed mobile experiences a total control loop delay of either 2, 50 or 127 chip durations while all the other interfering users have their loop delay set to 2 chip durations. Mobile speeds v_i, i=1, …, 9, of the interfering users are set to $v_i=i\cdot 5$ km/h, in the 10 user simulations, and to $v_i=i\cdot 10$ km/h in the 5 user simulations. The observed mobile is moving with the speed of 10 km/h or 30 km/h. Also, a white Gaussian noise (WGN) interference model is used for comparisons. The complex WGN used has zero mean and component variance of 1 or 5.

The transmitter applies differential encoding and binary phase shift keying (BPSK) to the data before applying the spreading code, and sets the power level. In the channel, Rayleigh fading is applied to the transmitted signal. The average fading power is set to 0 dB in all the users’ channels. Complex additive white Gaussian noise (AWGN) of component variance 0.05 is added to simulate receiver noise. The receiver model is exactly synchronized, and the spreading code is perfectly known. From the receiver, the despread and integrated, but not yet differentially decoded, signal is fed to the controller as the input. The control is based on the estimated received signal power level originated from the mobile being controlled, and aims to maintain the constant desired received power level irrespective of the fading and interference. The predictive filtering is independently applied to the in-phase and quadrature components of the controller input. After prediction, average signal power is calculated, and the power control command bit is send to the mobile transmitter accordingly. The non-predictive reference controller is exactly identical with the predictive controller, except that the predictors are omitted. In the predictive controller, the first degree lowpass Heinonen-Neuvo polynomial predictor [4] of length 15, analyzed in [5], is applied. Results for a single user system have been presented in [6].

III. SIMULATION RESULTS

A little surprisingly, the prediction does not have much effect on the achieved bit error rates, given in Table 1. Varying the loop delay also makes little difference. The same simulations were also run with the total power control loop delays of 50 and 127 chip durations, and the BER results differ at most by $0.1\cdot10^{-3}$ from those given in Table 1. In all the cases with actual multiuser interference, cumulative power consumptions, Table 2, are consistently a little lower when employing predictive received power level estimation, though the improvement is actually only marginal. Employing the WGN interference model, power consumptions of the predictive systems are equal or a little higher than those with the reference system. Although the variance of the user’s radio channel output is not the variable that is actually controlled, it directly affects the interference experienced by the other users. The variance reductions achieved though applying the prediction are listed in Table 3.

Table 1. BERs from the simulations of 100000 bits with the total control loop delay of 2 chip durations. In the WGN interference simulations the mobile speed was 10 km/h.

Controller	5 users, 10 km/h	5 users, 30 km/h	10 users, 10 km/h	10 users, 30 km/h	WGN var = 1	WGN var = 5
reference	$7.6\cdot10^{-3}$	$13.6\cdot10^{-3}$	$5.2\cdot10^{-3}$	$9.5\cdot10^{-3}$	$9.6\cdot10^{-3}$	$22.8\cdot10^{-3}$
predictive	$7.6\cdot10^{-3}$	$13.6\cdot10^{-3}$	$5.1\cdot10^{-3}$	$9.6\cdot10^{-3}$	$9.6\cdot10^{-3}$	$22.6\cdot10^{-3}$

Table 2. Power savings achieved employing the prediction from the simulations with the total control loop delay of 2 or 127 chip durations. In the WGN interference simulations the mobile speed was 10 km/h.

Loop delay	5 users, 10 km/h	5 users, 30 km/h	10 users, 10 km/h	10 users, 30 km/h	WGN var = 1	WGN var = 5
2 chips	0.3 %	1.3 %	0.3 %	1.3 %	0.3 %	-0.4 %
127 chips	0.2 %	1.1 %	0.3 %	1.2 %	0 %	-0.6 %

Table 3. Channel output variance reductions achieved by applying the prediction. In the WGN interference simulations the mobile speed was 10 km/h.

Loop delay	5 users, 10 km/h	5 users, 30 km/h	10 users, 10 km/h	10 users, 30 km/h	WGN var = 1	WGN var = 5
2 chips	4.0 %	2.3 %	-0.2 %	4.1 %	3.2 %	3.3 %
127 chips	1.8 %	3.2 %	0.2 %	4.5 %	2.2 %	0.0 %

IV. CONCLUSIONS

In this paper, it is shown by simulations that the predictive filtering can be successfully applied to the as pre user received power level based closed loop power control. The results show that in most cases transmitter power consumption may be slightly reduced, and the channel fading is slightly better counteracted with the predictive control, while maintaining the same BER as with the non-predictive control.

ACKNOWLEDGMENT

This work has been funded by the Technology Development Centre of Finland, Nokia Corporation, Telecom Finland, and Helsinki Telephone Company. The work of Jarno Tanskanen has also been supported by the Päijät-Häme Fund under the Auspices of the Finnish Cultural Foundation, and by Foundation of Technology, Finland.

REFERENCES

[1] K. S. Gilhousen, I. M. Jacobs, R. Padovani, A. J. Viterbi, L. A. Weaver, Jr., and C. E. Wheatley III, “On the capacity of a cellular CDMA system,” *IEEE Trans. Vehicular Technology*, vol. 40, pp. 303–312, May 1991.

[2] O. K. Tonguz and M. M. Wang, “Cellular CDMA networks impaired by Rayleigh fading: system performance with power control,” *IEEE Trans. Vehicular Technology*, vol. 43, pp. 515–527, Aug. 1994.

[3] “An overview of the application of code division multiple access (CDMA) to digital cellular systems and personal networks,” Qualcomm, Inc., USA, 1992.

[4] P. Heinonen and Y. Neuvo, “FIR-median hybrid filters with predictive FIR substructures,” *IEEE Trans. Acoustics, Speech, and Signal Processing*, vol. 36, pp. 892–899, June 1988.

[5] J. M. A. Tanskanen, A. Huang, T. I. Laakso, and S. J. Ovaska, “Prediction of received signal power in CDMA cellular systems,” in *Proc. 45th IEEE Vehicular Technology Conference*, Chicago, IL, July 1995, pp. 922–926.

[6] J. M. A. Tanskanen, J. Mattila, T. O. Korhonen, and S. J. Ovaska, “Predictive Closed Loop Transmitter Power Control,” in *Proc. 1996 IEEE Nordic Signal Processing Symposium*, Espoo, Finland, Sept. 1996, pp. 5–8.