PROCEEDING

IEEE COMNETSAT 2013

IEEE
INDONESIA SECTION

IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS, NETWORKS, AND SATELLITE

SHERATON HOTEL YOGYAKARTA
3-4 DECEMBER 2013

IEEE Catalog Number : CFP1331S-ART

ISBN : 978-1-4673-6056-2

http://comnetsat.org

IEEE COMNETSAT 2013

2013 IEEE International Conference on Communication, Networks and Satellite

3-4 December 2013

Yogyakarta, Indonesia

IEEE Catatlog Number : CFP1331S-ART
ISBN : 978-1-4673-6056-2

Editors : Arifin Nugroho, Abdul Muis
Publisher : IEEE Indonesia Section
Secretariat : Electrical Engineering, Universitas Indonesia, Depok, West Java, INDONESIA

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Power Control using Fuzzy Genetic to Enhance WCDMA Capacity

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Abstract-The capacity of WCDMA cell is impacted by interference. Power control reduce fading channels and co-channel interference. WCDMA system require quick and exactly power control. Fuzzy Genetic Algorithm (FGA) deliver the good response to the dynamic and random situations. This paper show application of FGA power control on WCDMA. FGA power control able to increase system capacity by 13.25% and can reduce the BER of the system by 13% compared to the use of fixed step power control.

Keywords-Power SIR; Fuzzy; Control; Genetic Algorithm; Capacity; WCDMA

I. INTRODUCTION

The capacity of WCDMA is influnced by the interference[1]. The control of power (PC) can decreases the problem of near-far, fading channels and co-channel interference. Ratio of signal to interference (SIR) power control technique is preferable than power strength power control [2]. In the 3G-CDMA systems, there are four types of power control algorithms namely: open-loop power control, slow power control, inner-loop power control, and the outer-loop power control. Inner PC maintain received SIR according to the targets. SIR target is made by outer PC based on bit error rate (BER) or block error rate (BLER). WCDMA uses fixed step PC (FSPC) to reduce the signaling [3].

Chang [4] were the first to apply the Fuzzy Logic Controller (FLC) to strength-based power control. They showed that FLC is suitable for non-linear and time variant characteristics channels. James stated that algorithm of genetic can improve the capability of fuzzy [5]. Firdaus [6] has done fuzzy genetic to SIR power control using outage probability criteria. Nevertheless, there is no research this mechanism using system capacity and BER criteria.

This study was intended to improve the capacity of WCDMA use FGA-SIR power control. FGA uses fuzzy inference system (FIS) and genetic algorithm (GA).

II. FUZZY GENETIC POWER CONTROL

WCDMA apply Direct Spread-Code Division Multiple Access technology with carrier of bandwidth 5 MHz and 3.84 MCPs chiprate.

WCDMA services multimedia with data rate up to 2 Mbps and uses single carrier. WCDMA have soft handover mechanism to reduce the number of Intercell interference at the cell border, the UE is connected to more than one node-Bs (base stations in WCDMA).

WCDMA uses closed loop (outer and inner) PC. Inner PC manage the transmit power to keep the quality of SIR. The update frequency is 1500 Hz. SIR target depend on Bit Error Rate (BER). Setting the target SIR is adapted to BLER which is the function of the services carried, carried by the outer loop power control. It is a part of the radio resource control layer (layer 3).

SIR required to meet the desired quality requirements depend on the distribution of the SIR itself. Frequency range outer-loop PC is usually from 10 to 100 Hz. Mechanism of action of the outer loop power control begins with quality measurement then the results are compared with the desired quality, if the quality obtained from measurements is better than the desired quality so SIRtarget is lowered, otherwise if the quality of the measurement results is less than the desired quality, then SIRtarget is increased.

To estimate the received SIR, the receiver will estimate the received power from the current connection and the interference. SIR obtained from estimation (SIR_{est}) then used by the receiver to generate power control command according to Algorithm 1 or Algorithm 2 3GPP specification TS 125.214.

Fading is the principal characteristics in mobile radio propagation. Fading can be defined as a change in phase, polarization and or the level of a signal with respect to time. In mobile communication systems, there are two kinds of fading that is short term and long term fading fading. Short term fading is largely due to multipath reflections of a wave transmission by local scattering around a mobile unit. Short term fading due to the phenomenon of the Doppler effect. The movement of the receiver will change frekeuensi received from a source wave.

FIS uses fuzzy set to map inputs to outputs. some of the steps being taken by FIS are as follows: determining fuzzy rules, fuzzifying the inputs, combining the fuzzified inputs pursuant to the fuzzy rules, finding the consequence of the rule by combining the rule strength and the output membership function, combining the consequences to get an output distribution, and defuzzifying the output distribution.

GA is a search heuristic that mimics the process of natural selection. This heuristic is used to generate useful solutions to optimization and search problems.[7] Genetic algorithms generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover.

Each candidate solution has a set of properties (chromosomes or genotype) which can be mutated and altered.[8] The evolution usually starts from a population of randomly generated individuals. It is an iterative process. The population in each iteration called a *generation*. In each generation, the fitness of every individual in the population is evaluated. The more fit individuals are stochastically selected from the current population, and each individual's genome is modified to form a new generation. The new generation of candidate solutions is then used in the next iteration of the algorithm.

2.1 Wideband-CDMA

Power control based on the SIR will be applied on the uplink path. Node-B compared the target SIR with SIR received and make power control decisions. The signal sent to node-B by the UE via the wireless channel (rayleigh fading).

Rayleigh fading signal generation is using a jakes model[9]. On this channel model, a_s and a_c are Gaussian random variable with mean zero and variance σ^2, is determined by:

$$a_c = \frac{2}{N_0}\left(\sum_{n=1}^{N_0}\cos\beta_n \cos\omega_n t + \sqrt{2}\cos\alpha\cos\omega_d t\right) \quad (1)$$

$$a_s = \frac{2}{N_0+1}\left(\sum_{n=1}^{N_0}\cos\beta_n \cos\omega_n t + \sqrt{2}\sin\alpha\cos\omega_d t\right) \quad (2)$$

$$\omega_n = \omega_d\left(\cos\frac{2\pi n}{N_1}\right), n = 1, 2, \ldots, N_0 \quad (3)$$

$$N_1 = 2(2.N_0+1) \quad (4)$$

$$\beta_n = \frac{\pi.n}{N_0} \quad (5)$$

$$\alpha = \frac{\pi}{4} \quad (6)$$

$$\omega_d = 2\pi.f_d \quad (7)$$

Which ω_d is shift doppler, and N_0 is low frequency oscillator which his frequency same with ω_n

AWGN noise is modeled in a Gaussian random distribution pattern with the average value (the mean) is zero, the standard deviation (σ) = 1, the power spectral density (power spectral density) = No/2 (W/Hz), and the power spectral spreadly on an infinite bandwidth.

AWGN noise variance formula is as follows: (Tc is the chip duration, A: Amplitude chip, fs: sampling speed, N_0: noise power spectral density). Energy per *chip*,

$$E_c = A^2T_c \quad (8)$$

If the spreading factor is SF then the energy per bit,

$$E_b = SF \text{ X } E_C = (SF)\, A^2T \quad (9)$$

Noise variance are expressed with:

$$\sigma^2 = \frac{N_0 \cdot f_s}{2} \quad (10)$$

$$\frac{E_b}{N_o} = \frac{(SF)A^2T_c}{2\sigma^2 / f_s} = \frac{(SF)A^2(T_c f_s)}{2\sigma^2} \quad (11)$$

$T_c\, f_s$ is number of sample per *chip*, *m*

$$\frac{E_b}{N_o} = \frac{(SF)A^2m}{2\sigma^2} \quad (12)$$

$$\sigma^2 = \frac{(SF)A^2m}{2(\frac{E_b}{N_o})} \quad (13)$$

So the received signal is

$$r(t) = c(t).s(t) + n(t) \quad (14)$$

r(t) is received signal, *c(t)* is rayleigh channel signal, *s(t)* is send signal, and *n(t)* is Gaussian noise

The parameters in this research is organized as bellow:

Table 1. Sets of Parameters

WCDMA Parameters	Value
Frequency of carrier	2 GHz
Speed of user	70,120, and 200 Hz
Gain of processing	128
Maximum chiprate	3.84 Mega chip per secon
Period of Power control	0.667ms (1500 Hz)
Data rate of voice	120 Kbps (Rb)

Figure 1 is Block of WCDMA transmitter. The data sent is the data distributed uniformly and generated randomly. Because of the uniform distributed the data each have an equal chance of appearing. BPSK mapper is formed bits data into data symbols in accordance with BPSK symbol constellation. Constellation mapping based on gray code.

BPSK mapper output serial data is converted to parallel. The number of bits in each branch depend on the type of modulation signal mapping used. For QPSK modulation, the bits are grouped into 2 bits before modulation or signal mapping process.

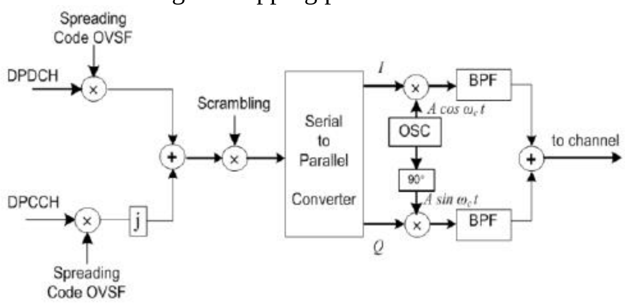

Figure 1. WCDMA transmitter

Spreading code spread the data signal. Its use orthogonal variable spreading factor code. The purpose of the use of spreading code is to provide orthogonality between physical channels in uplink direction (from UE to node-B). The output chip rate is 3.84 Mcps. DPCCH is spread on a branch-Q uses spreading factor (SF) = 256. Spreading factor is also known as the processing gain (GP).

Then each user data bits is multiplicated by one element Walsh-Hadamard code. Leftmost value of each word canalization code is first transmitted chips. Walsh code (length 2^n) can be made by these matrix:

$$H_n = \begin{bmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & -H_{n-1} \end{bmatrix} \quad (15)$$

Matrix H_n with the size 2^n x 2^n is formed using matrix H_{n-1} with the size 2^{n-1} x 2^{n-1} and the size H_2 is in equation 16. Each row of the matrix gives the code for one user. Orthogonalitas test conducted by the multiplication product terms between the two codes (rows of martiks) is zero.

$$H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (16)$$

There are short and long scrambling code on uplink path. This research use last code. Long code is a Gold code formed of 2 long scrambling sequences, they are $C_{LONG,1,n}$ and $C_{LONG,2,n}$. Sequence $C_{LONG,2,n}$ is the shift version 16,777,232 chips of the sequence $C_{LONG,1,n}$. Pulse shaping filter for the transmit is a root-raised cosine (RRC) with roll-off α = 0:22 in the frequency domain. Real and imaginary parts of the signal scrambler S is inserted into the I and Q branches of the modulator and modulated using a sinusoidal with a phase shift of 90 degrees to reach the QPSK modulation.

For channel estimation process, it is necessary to signal 'experiment', the so-called pilot signal, where the signal is known by the sender and the receiver. Pilot symbols per cycle is inserted into the sequence data before pulse shaping. The first symbol of each frame is considered as a pilot symbol, followed by data symbols.

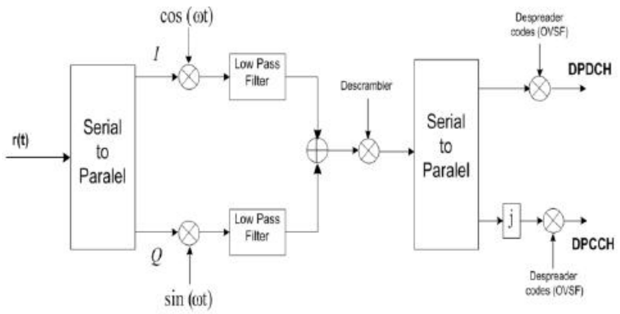

Figure 2. WCDMA Receiver

In the descrambling process, the received signal will be multiplied by a scrambling code that is equal to the scrambling code used by the sender. In the process of despreading, the signal that has been spreaded by previous spreading process, multiplied again by the OVSF code to get the data transmitted. In DPCCH control data, the signal is divided by *j* to eliminate the imaginary value. Block of receiver is in figure 2. Baseband signal containing +1 and -1 transmitted user equipment (UE) to node B is converted to the form of bits 0 and 1 bits returned by the demapping part.

2.2 FGA Power Control Modeling

FGA controller use error 'e' and error change 'de' for the inputs, and the output is a control command 'dp' for power control. Error is the target SIR minus the received SIR, delta error is SIR error now minus the previous error.[10]

Genetic algorithms optimize the fuzzy membership functions. There are 3 membership function to be optimized: 'error', 'error change' and 'dp'. Their shape and number of membership functions are the same, the different is the lower limit value (L), the upper limit (U) and the value of 'x'. L and U values are determined based on the observation of the value of the error, the error value changes and changes in the value of delta p. Delta p is the value of the defuzzification. Chromosome contains the information of e, 'de' and 'dp'. This experiment use 49 rules as shown in table 2. Its mean there are seven membership functions for input and output. Fitness function is the minimum of SIR error.

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{[SIRt - SIRr(i)]^2}{n}} \quad (17)$$

SIRr is SIR received (value of SIR received from UE), SIRt is SIR target or SIR threshold.

Table 2. 49 Based Rules of Fuzzy Logic

de	*e*						
	A	*B*	*C*	*D*	*E*	*F*	*G*
A	A	A	B	B	C	C	D
B	A	B	B	C	C	D	E
C	B	B	C	C	D	E	E
D	B	C	C	D	E	E	F
E	C	C	D	E	E	F	F
F	C	D	E	E	F	F	G
G	D	E	E	F	F	G	G

Which A is large negative, B is medium negative, C is small negative, D is zero, E is small positive, F is medium negative, and G is large positive. The rules in table 2 reads as follows: IF ‘e’ is C and ‘de’ is A THEN ‘dp’ is B. Implication function used is MIN method, this function will cut output fuzzy set. As for the fuzzy inference system used MAX-MIN method (Mamdani). The calculation process using techniques centroid defuzzyfication. These formulations use in FGA power control process

$$e(t) = SIR_{th}(t) - SIR(t) \quad (18)$$
$$de(t) = e(t) - e(t-1) \quad (19)$$
$$dp(t+1) = FGA\ \{e(t), de(t)\} \quad (20)$$

SIR estimation value is calculating with bellow formulation

$$\gamma_k = \frac{|A_k(n)\beta_k(n)|^2}{\frac{1}{M}\sum_{j\neq k}|A_j\beta_j(n)|^2 + \sigma_k(n)^2} \quad (21)$$

A_k is the amplitude of the symbol of the k-th user, $\beta_k(n)$ is the fading channel coefficients and σ_k are the standard deviation of AWGN the k-th user. And M is the spreading factor (SF).

WCDMA system capacity in this simulation can be calculated by the following formula:

$$N = 1 + \frac{W/R}{E_b/N_0} \cdot \frac{\alpha}{(1+i)v} \quad (22)$$

N = Number of user
W = Chip rate = 3,84 Mcps
R = Data rate = 12,2 Kbps (voice)
E_b/N_0 *= Bit energy-to-interference power density ratio*
$\alpha = 1\text{-}10^{-0,1(\eta)}$, η *= Interference margin = 4 dB*
i = Co-channel interference = 0,65
v = Load factor = 0,4

III. RESULT AND DISCUSSION

Fuzzy is used for decision making, and GA optimize the FIS. This paper compares the performance of FGA-PC to FSPC. The parameters are capacity and BER criteria. One user is controlled by power control and the others as interferer for multi-user simulation.

Genetic algorithm optimize the FIS by manage the width of membership functions, and its run offline, once produced the best value then the value is applied to the membership function of fuzzy control. The best value here is the value of the width of each membership function which generates the smallest SIR error. The shape of membership functions are trapezoidal and triangular (Figure3). We have 3 chromosomes [X_1 X_2 X_3], and each variable consist of 5 bits.

Originally fuzzy power control is working, but the results are not optimal, SIRreceived as the results of fuzzy power control is still under SIRtarget. SIRtarget used is 12 dB, in [11] for voice traffic in the WCDMA minimum SIR is 6 dB. For the initial step, width of fuzzy membership function is determined, then Genetic Algorithm run.

Size of population is 15, mutation probability is 0.07, cross over is 0.6, maximum generation is 80. Results of simulation as follows (Table 3).

Tabel 3. Optimization results by Genetic Algorithm

Running	X_1	X_2	X_3
1st	2,0938	3,1875	2,4063
2nd	2,9688	4,9375	3,5313
3th	1,6563	2,3125	1,8438
4th	3,1875	5,375	3,8125
5th	6,9063	12,8125	8,5938
6th	2,75	4,5	3,25
Mean	3,26045	5,520833	3,906283

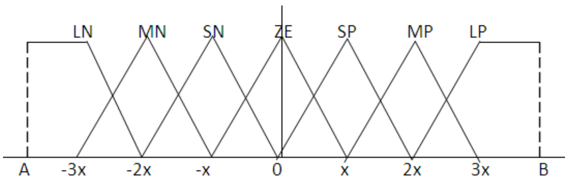

Figure 3. The shape of membership functions

The value of x as GA results show the width of the fuzzy membership functions, in which the membership functions are made permanent (triangles). Each running will be sought value 'best x' based on the smallest of RMSE of SIR error (SIRtarget - SIRreceived) during the running until the specified number of generations. The value of x as results of GA is always changing although GA used fixed attributes (in this study does not address the optimization of GA), this is due to the channel conditions that affect the random of random error SIR values, whereas the reference here to stop the process of GA is number of generation, not minimum RMSE constant value of SIR error. Thus used the average value x results several times running GA. Based on the average value of x then the fuzzy membership functions used are as follows (Figure 4,5,6). Each has a maximum value of membership degree equal to 1, then the lower limit and upper limit is determined based on the maximum value of the error and delta error in the system, while the upper and lower limits on the membership function deltap chosen based on the maximum value at the desired step size power control

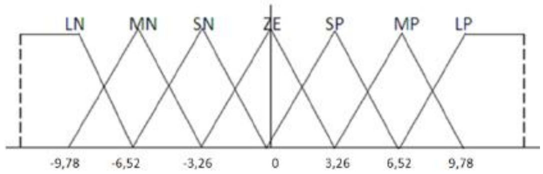

Figure 4. The membership function of *error*

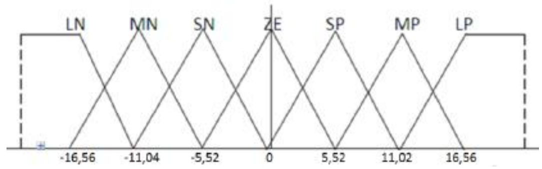

Figure 5. The membership function of *delta error*

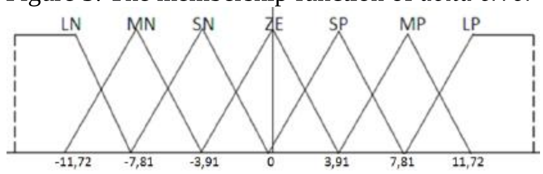

Figure 6. The membership function of *delta-p*

3.1 Analysis of Interference and Capacity System

The main purpose of power control in WCDMA is to reduce interference and increase system capacity. Effect of the interference reduction can be represented by the value of Eb/No, this can be linked to the BER (by looking at the graphs of the relationship between the BER with Eb/No). Figure 7 and Table 4 describe the improved performance of power control by fuzzy genetic power control.

Table 4 Reduction in interference on WCDMA system

Number of User	BER		BER decline
	FGA PC	Fixed PC	
11	0,09896	0,1284	22,9%
21	0,1802	0,2009	10,3%
61	0,3021	0,3219	6,15%

Application FGA power control in WCDMA Up-link systems capable of reducing BER by 13% compared to the use of FSPC

Based on formula number 22, for the WCDMA system, the value of W is 3.84 MCPs and the value of R for voice services is 12.2 Kbps. Value of α, η, i, and v is assumed and made permanent. η value is 4 dB, i = 0.65 and v = 0.4. So that changes the value of N in this experiment is only affected by changes in the value of E_b/N_0. Increasing the capacity of the system by FGA PC seen in Table 5 and Figure 8.

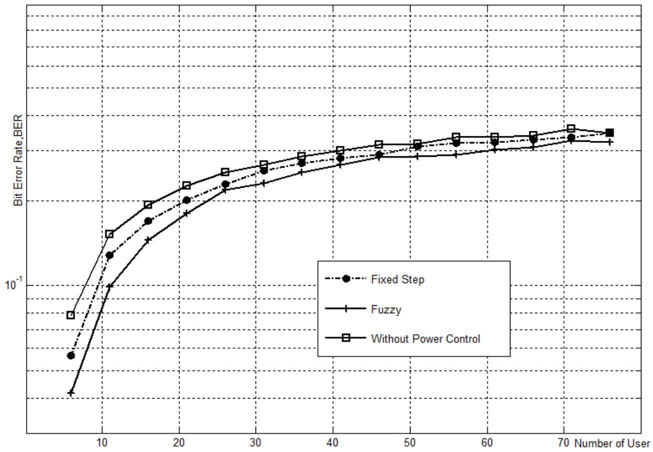

Figure 7. Effect of power control on the BER

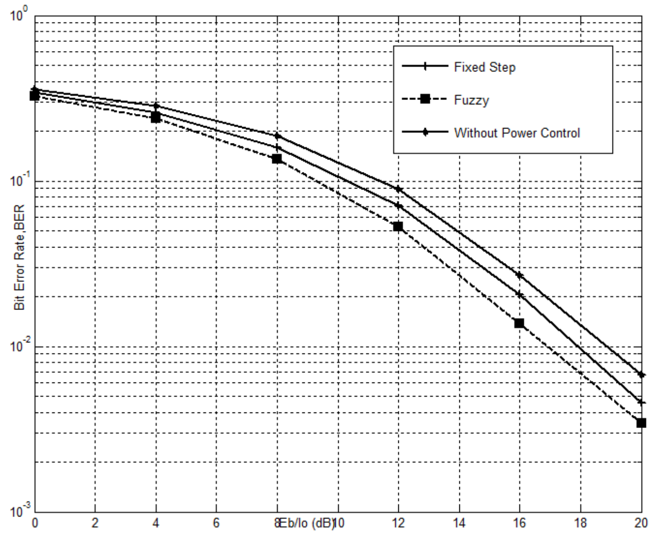

Figure 8. BER to Eb/Io Graphic

Tabel 5 WCDMA capacity

BER	FSPC		FGA Power Control		Capacity enhance
	Eb/Io	N	Eb/Io	N	
10^{-2}	18 dB	16	17.1 dB	18	12,5 %
10^{-1}	10,4 dB	28	9,3 dB	32	14 %

Application FGA power control in WCDMA Up-link systems capable of increasing capacity by 13.25% compared to the use of FSPC.

3.2 Analysis of Power Control Error

Power control errors (PCE) at [12,13] is defined as the difference between the value of the target SIR with the measured SIR at Node B.

$$\mathrm{PCE(i)} = \mathrm{SIR_{true}(i)} - \mathrm{SIR_{target}} \qquad (22)$$

Due to the fluctuating value of PCE and there are positive and negative, then MSE of PCE (MSPCE) is used,

$$\mathrm{MSPCE} = \sum_{i=1}^{n} \frac{[\mathrm{SIRtrue(i)} - \mathrm{SIRtarget}]^2}{n} \qquad (23)$$

Where n is the number of measured data on a running simulation. Based on the simulation, the MSPCE of FSPC is 3.04 dB, and for the Fuzzy power control is 5.9 dB.

IV. CONCLUSION

Shape and width of fuzzy membership function influnce the performance of FGA power control. Application of FGA power control in Up-link WCDMA systems capable of increasing capacity by 13.25% and can reduce the BER of the system by 13% compared to the use of fixed step power control.

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