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ANALYSIS OF SMART ANTENNA FOR CELLULAR COMMUNICATION

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ABSTRACT

In this paper, the performance evaluation of Switch Beam Smart Antenna (SBSA) is investigated. The relation of Bit Error Rate (BER) for DS/CDMA system is extended within the case of software of SBSA in base station. As result shows, the range of energetic users for any suitable BER can be extended depending on the windowed feature carried out to antenna aperture.

KEY WORD: *Smart antenna, communication & Radiation pattern .*

INTRODUCTION

Currently, a massive growth of users in 3rd generation mobile technology has been reported [1-3]. That is due to an expanded number of customers as well as new high bit rate data services being added. This increase in users placed a demand to provide sufficient capability within the networks. One of the top promising techniques for increasing the capacity in mobile structures is smart antenna. The generation of smart antennas is based on array antennas. Here the radiation pattern is altered by adjusting the amplitude and relative phase on the new array elements. It is feasible to use these techniques in 3G cell systems within the frequency range 1-2 GHz.

The signals from customers communicating through the same base station historically are separated by using frequency (IDMA), through time (TDMA) or with code (CDMA). The smart antennas add a new possibility of person separation via space through SDMA (space division multiple access), which means that customers within the same cell can use the same communication channel that is defined as a combination of carrier frequency, time slot and spreading code. Similarly, the SDMA principles are legitimate for each TDMA system (e.g. GSM and CDMA) systems (e.g.Is-95 and UM1S) [4-6].

The base station antenna is 120 sectored. For that reason, most of the electromagnetic pollution energy is radiated in different directions than towards the marked user. Moreover, the energy radiated in different directions is experienced as interference by means of other users.[7-8] The smart antenna uses the base station antenna patterns directing a beam toward the user interest only. Therefore, smart antenna will provide the more efficient energy and spectrum for cellular communication systems .

SWITCHED-BEAM SMART ANTENNA AND SIGNAL MODEL

SBSA creates a group of overlapping beams that together result in omnidirectional coverage. The overlapping beam patterns pointing in slightly different directions are presented in Figure 1. The SBSA creates a number of two-way spatial channels on a single conventional channel in frequency, time or code. Each of these spatial channels has the interference rejection capabilities of the array depending on side lobe level (γ).

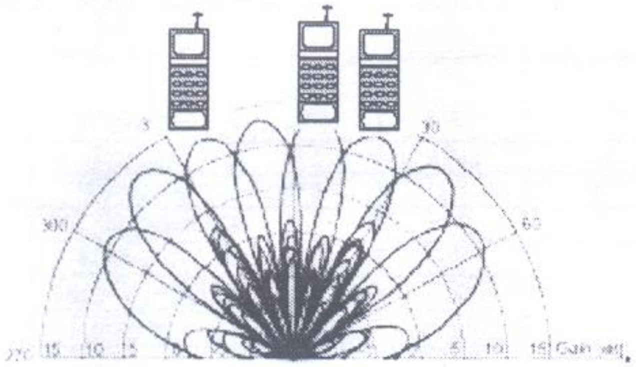

Figure.1 Switched beam array pattern

Because of the cellular actions, beam-switching algorithms for each name determine whilst a specific beam should be selected to preserve the very best signal sign and the system constantly updates beam selection, making sure that person receives the best. The system scans the outputs of every beam and selects the beam with the largest output energy as well as suppresses interference coming back from directions far away from the active beam's center.

SIGNAL MODEL AND DECISION RULE OF SBSA

The input signal of N antenna elements from N spatial channels is given by

$$U = |U_1, U_2 ....U_i ....U_N|. \quad (1)$$

Where $U_i(t) = \sqrt{\wp}\,|1, e^{-1\varphi}, e^{-12\varphi} .....e^{-1(n-1)\varphi i}|^T$ is *i*-th user signal. $\varphi_i = 2\pi(d/\lambda)\sin\phi_i$ ϕ_i is *i*–th user angle of arrival signal. $\wp_i$, is power user *i*-th signal and. $\wp_i = 0$ if i>K.

where K is a number of active resolved in space users. The steering matrix for N spatial channels has a form

$$\Phi = |a_1, a_2 ....a_1 ....a_N|. \quad (2)$$

where $a_i = |1, e^{-1\psi i}, e^{-12\psi i} ....e^{-1(N-1)\psi}|^T$ is the steering vector. $\psi_i = 2\pi(d_\lambda / \lambda_0)$ sin θ_i. θ_i is *i*-th reference angle. The matrix Φ forms the spatial filters (see Figure 2) with orthogonal properties $a_i^H a_k = N.i = k$ and $a_i^H a_k = 0$, i $\neq$k.

Taking into account eq. (1) and eq. (2) the output of switch beam antenna is

$$S = \Phi^H U = |S_1.S_2 .....S_i ......S_N| \quad (3)$$

If all users are located exactly in directions of reference angles $\phi_i = \theta_i$ the vector S_i = $|0,0.......\sqrt{\wp_i}........0|^T$ But if $\phi_i \neq \theta_i$ we need to evaluate the maximum element of each vector to detect active users. Really, in practice the signals S_1..... S_2..... S_i..... S_N are not available separately and the output of the antenna is

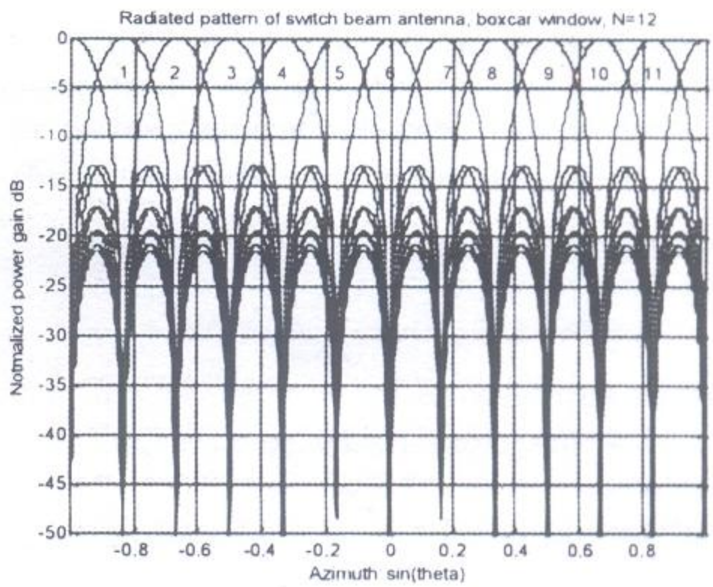

Figure 2. The spatial switched pattern for number of antenna elements N=12

$$N = \sum_{i=1}^{N} S_i + n(t), \qquad (4)$$

Where *n(t)* is zero-mean thermal noise that is presented at the input of the receiver.
The next decision rule is applied. If $|x_i| \geq \alpha$, there is an active user in *i*-th channel where i = 1.2,.......N.....α is threshold and x_i, is *i*–th element of vector X.

WINDOWED BEAM FORMER

The parameters of windowed beams for various windows as calculated and presented in Table 1, the comparison of beam width for boxcar window (e.g. no windowed antenna) and Chebyshev window with parameters N=20, γ = -50dB is presented in Figure 3.

Table 1. Main parameters of windowed beams

Window	N	Δ	γ (db)
Boxcar	12	1	-13
Hamming	18	1.5	-40
Triangular	17	1.42	-26
Blackman	23	1.92	-58
Gauss (a=3.0)	22	1.83	-56
Chebyshev	20	1.58	-50

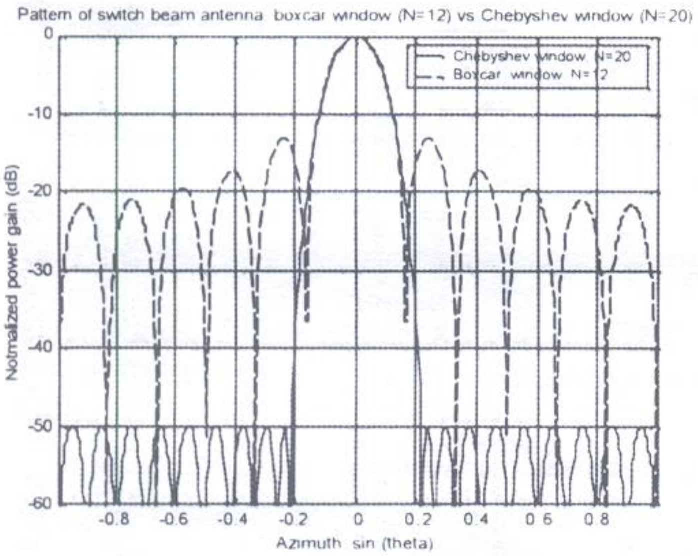

Figure 3. Comparison of spatial beam width for rectangular (N=12) and Chebyshev (N=20, γ = –50dB) windows

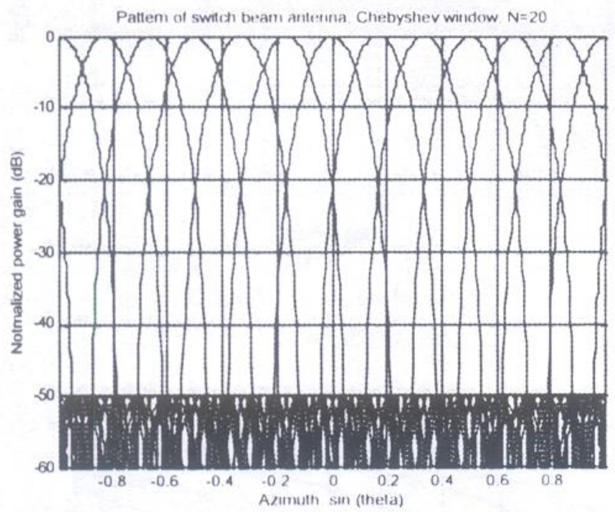

Figure 4. The spatial switched pattern with Chebyshev (N=20, γ = –50dB) windows

As can be seen, the same beam width is achieved with 12 and 20 elements respectively. The switch beamformer with Chebyshev window and the number of spatial channels is 12 (the same as for rectangular window in the Figure 2) is presented in Figure 4.

PERFORMANCE ANALYSIS AND SIMULATION RESULT

We consider the DS/CDMA system model presented in [9-12]. The *k*-th user's received signal by

$$S_k(t-\tau_k)=\sqrt{2P}b_k(t-\tau_k)a_k(t-\tau_k)\cos(\omega_c t+\theta_k) \quad (5)$$

where $b_k(t)$. and $a_k(t)$ are the data and pseudo noise (PN) code rectangular signals respectively. P is the received power and ω_c carrier frequency, t_k and θ_K are the time delays and phase shifts of the signal propagation.

The received signal *r*(t) is given by

$$r(t)=\sum_{k=1}^{K} S_k (t-\tau_k)+n(t) \tag{6}$$

where K is the total number of simultaneous active users and *n(t)* is the thermal noise, which we neglect in this paper.

If the received signal *r(t)* is the input to a correlation receiver matched to $s_i(t)$, the output is

$$y(t)=\int_0^{T_b} r(t)a_1(t-\tau_1)\cos(\omega_e t-\hat{\theta}_1)dt \tag{7}$$

where T_b is the data bit period. $\hat{\tau}_1$ and $\hat{\theta}_1$ are the estimates of time delay and phase shift of the desired signal.

As shown in [9-12] the Bit Error Rate (BER) for DS-CDMA system is given by

$$P_e=Q\left\{\sqrt{\left(\sum_{k=2}^{k}\frac{E_b^{(k)}/N_0M}{3E_b^{(1)}/N_0}+\frac{1}{2E_b^{(1)}/N_0}\right)^{-1}}\right\} \tag{8}$$

Where $E_b^{(1)}/N_0$ is relation of signal energy to noise power spectral density for user of interest (#1). $E_b^{(k)}/N_0$ is the same for interfering users. *M* is PN-code length. Q (y) is the tabulated function.

We extended eq. (8) to switch beam antenna

$$P_e=Q\left\{\sqrt{\left(\sum_{k=2}^{k_1}\frac{E_b^{(k)}\gamma/N_0}{3E_b^{(1)}/N_0}+\sum_{k=2}^{k_2}\frac{E_b^{(k)}/N_0M}{3E_b^{(1)}/N_0}+\sum_{k=2}^{k_1}\frac{E_b^{(k)}\gamma/N_0M}{3E_b^{(1)}/N_0}+\frac{1}{2E_b^{(1)}/N_0}\right)^{-1}}\right\} \tag{9}$$

Where K_1 is the number of interfering users in the same PN-code like user # 1. Affected side lobes: K_2 is the number of interfering users with the different PN–codes affected main lobe: K_3 is like K_2 but affected side lobes.

We assume that the data is modulated using binary phase shift keying (BPSK) format. The pulse and PN-code amplitudes are all independently and identically distributed random variables. All odd channels, as well as even ones (See Figure 3) have the same PN –codes length *M*-128 we assume that the power of each mobile station (MS) is perfectly controlled by the same BS. MSs of a cell are uniformly distributed. The decision statistics was evaluated for desired 1 and given K–1 interfering transmitters.

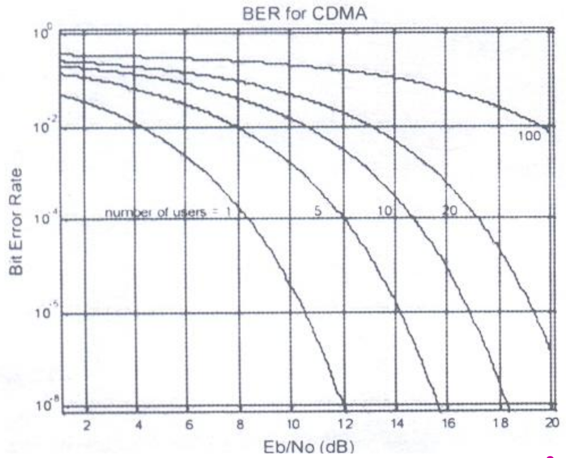

Figure 5 The BER performance of DS- CDMA system and 120^0 sectored antenna

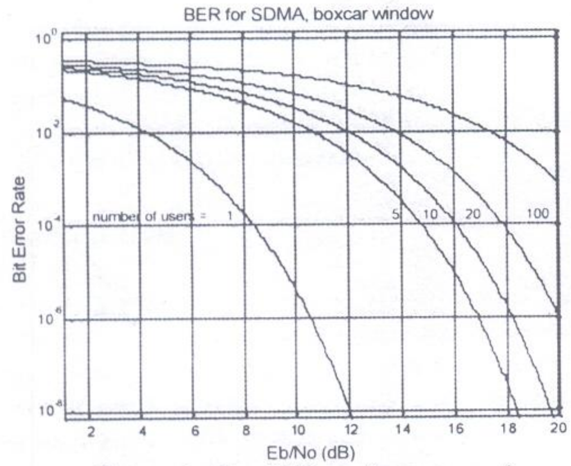

Figure 6. The BER performance of DS-CDMA/ SDMA switched beam no windowed antenna

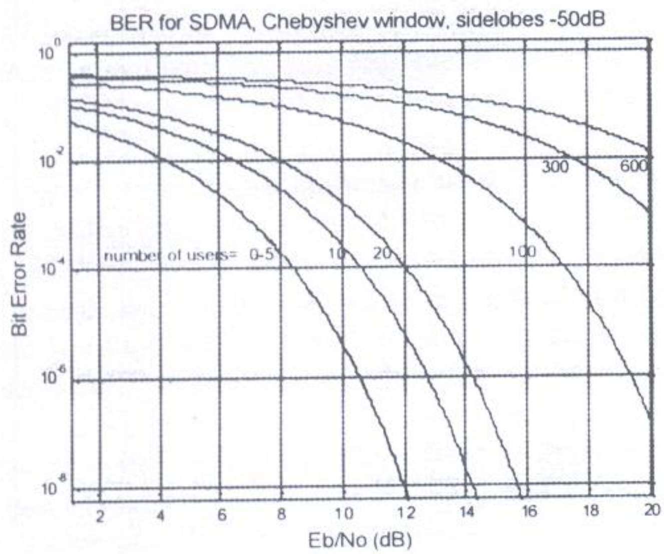

Figure 7. The BER performance for DS- CDMA and switched beams Chebyshev (N=20,γ=-50 dB) windowed antenna

The simulation results are presented in Figure 5, 6 and 7 where BER as a function of E_b/N_0 and number of active users in the service area is plotted. Figure 5 presents DS-CDMA system with conventional 120^0 antenna. Figures 6 presents no windowed SBSA (N=12) system and Figure 7 presents Chebyshev windowed SBSA (N=20, γ = –50 dB). As follows from Figures 5, 6. and 7 for the fixing of BER (for example for 3G communication acceptable BFR is $P_e = 10^{-4}$) the application of SBSA can increase the number of active users up to 1.5 times for no windowed antenna and up to 8 times for Chebyshev windowed antenna without losing the performance quality.

CONCLUSIONS

Recently smart antenna has brought enormous changes in the field of mobile communication systems. The predominant motive for applying smart antennas is the possibility for a big boom in potential and to introduce new services. The purpose of this paper is to give a overall performance evaluation switch beam smart antenna (SBSA) and its comparison with conventional CDMA systems.

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