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Research Article

Performance analysis of WiMAX with BB-BC optimized antenna array

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Abstract

This work discusses the performance analysis of WiMAX system with antenna array optimized by applying Big Bang Big Crunch (BB-BC) algorithm. This algorithm has two phases; Big Bang phase similar to Big Bang Theory and Big Crunch phase similar to Big Crunch Theory. In the Big Bang phase, the randomly generated population of candidates is uniformly distributed over the search space. Then, in the Big Crunch phase these candidates are concentrated to a point using a convergence operator namely centre of mass. Using centre of mass, the new position of each candidate is calculated. This process is repeated until convergence is achieved. Radiation patterns at transmitting side have been obtained. Results show a considerable decrease in side lobe levels at transmitting side.

Keywords: *WiMAX; Big Bang; Big Crunch; side lobe level, antenna array*

1. Introduction

The demand for high-speed broadband internet and multimedia has grown exponentially in last two decades. The IEEE 802.16 group was formed in 1998 to develop an air-interface standard for wireless broadband. The group's initial focus was the development of a LOS-based point-to-multipoint wireless broadband system for operation in the 10GHz–66GHz millimetre wave band. The early WiMAX solutions based on IEEE 802.16-2004 targeted fixed applications, and are referred to as fixed WiMAX [1]. The IEEE group completed and approved IEEE 802.16e-2005, an amendment to the IEEE 802.16-2004 standard that added mobility support. The IEEE 802.16e-2005 forms the basis for the WiMAX solution for nomadic and mobile applications and is often referred to as mobile WiMAX. Nowadays only two standards of WiMAX are prevalent: IEEE 802.16d-2004 also referred to as fixed WiMAX and IEEE 802.16e-2005 also referred to as mobile WiMAX. WiMAX supports various features like adaptive antenna system, multiple antenna techniques and beam forming etc. These features enhance the performance of WiMAX [1-6]. The basic simulation model of WiMAX OFDM system is represented in [7], which is helpful in building a system level model for a WiMAX Orthogonal Frequency Division Multiplexing based transceiver. OFDM technique theoretically saves the bandwidth about 50%.

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On the capacity of cellular system is discussed in [8] which shows that multiple antennas can improve the capacity of cellular systems. It also describes that the mutual information of a single, isolated, multiple transmit and receive antenna array link is exploited by transmitting the maximum number of independent data streams for a flat fading channel with independent fading coefficients for each path. Transmit and receive antenna arrays used in MIMO system is described in [8].

Previous works have shown that antenna array is more efficient when it is optimized using some optimization algorithms. Nowadays metaheuristic algorithms are replacing conventional algorithm like numerical methods, linear programming etc. In [9] antenna array optimization using Genetic algorithm has been described, sidelobe level and null control using particle swarm optimization is shown in [10]. A new optimization algorithm based on evolution of universe, known as Big Bang-Big Crunch (BB-BC) was proposed in [11]. This algorithm has two phases; Big Bang phase similar to Big Bang Theory and Big Crunch phase similar to Big Crunch Theory. In the Big Bang phase, the randomly generated population of candidates is uniformly distributed over the search space. Then, in the Big Crunch phase these candidates are concentrated to a point using a convergence operator namely centre of mass. Using centre of mass, the new position of each candidate is calculated. This process is repeated until convergence is achieved. Most of the applications of BB-BC algorithm in engineering field have been reported for the optimal design of structures. Camp used BB-BC algorithm to minimize the total weight of structures subjected to material and performance constraints [12]. Hybrid BB-BC (HBB-BC) in [13] is shown for the optimal sizing of space truss structures which was later extended for optimal design of Schwedler and ribbed domes. In [14] BB-BC algorithm for parameter estimation of structural systems is described. Genc, BB-BC algorithm is used in bearing only target tracking [15]. Results were found to be superior to classical genetic algorithm in terms of both speed and accuracy. Further BB-BC algorithm is used for voltage stability improvement. In their study BB-BC algorithm determined settings of control variables such as transformer tap, reactive power compensating devices, and generator voltages [16].

The simulations were carried out on IEEE 30 -bus and 118-bus test bus systems. The results of the algorithm were compared with the results obtained by PSO; demonstrate the efficiency of the BB-BC algorithm. Hybridized BB-BC algorithm with local directional moves for target motion analysis in [17] and was found to be more accurate with same computational time. BB-BC algorithm for course timetabling problem is discussed in [18] it has been shown that the BB-BC can produce good quality solutions and comparable with some of the methods applied in the literature. Thus BB-BC algorithm shows better results in some cases as compared to previous well-known algorithms and in some cases has comparable results.

In this paper antenna array optimization algorithm BB-BC is applied on transmitter side of fixed WiMAX system to minimize the sidelobe power.

The rest of the paper is organized as follows: Section II describes of the antenna array. Big bang big crunch algorithm is given in section III, WiMAX OFDM system with BB-BC algorithm is described in section IV. Simulation results are shown in section V and paper is concluded in section VI.

2. Antenna Array

An antenna array is a set of number of spatially separated antennas. Simply, an array of antennas does a superior job of receiving signals when compared with a single antenna, leading to their widespread use in wireless applications. Arrays in practice can have as few as two elements, which is common for the receiving arrays on cell phone towers. In general, array performance improves with added elements therefore, arrays in practice usually have more elements. Arrays can have several thousand elements.

Antennas with a given radiation pattern may be arranged in a pattern such as line, circle or plane to yield a different radiation pattern. In linear array antenna elements are arranged along a straight line while in circular array antenna elements are arranged around a circular ring and in planar array antenna elements are arranged over some planar surface. There are several types of array such as phased array, broadside array and end fire array.

Phased array - an array of identical elements which achieves a given pattern through the control of the element excitation phasing. Phased arrays can be used to steer the main beam of the antenna without physically moving the antenna. Given an antenna array of identical elements, the radiation pattern of the antenna array may be found according to the pattern multiplication theorem

Array Pattern = Array element pattern × array factor, where, array element pattern is the pattern of the individual array element and array factor is a function depends only on the geometry of the array and the excitation (amplitude, phase) of the elements.

Broad side array is the arrangement of identical antennas, which are placed along the axis perpendicular to the direction of maximum radiation. The identical antennas are equally spaced along the line of axis and all the elements are fed with equal magnitude of current with the same phase. This results in array pattern known as broad side array. It is evident that broad side array is bidirectional where maximum radiation is obtained in the direction of axis perpendicular to the array axis. For a broadside array, to have maximum array factor with θ = 90°, the phase angle α must be zero. In other words, all elements of the array must be driven with the same phase. With α = 0°, the normalized array factor reduces to

$$(AF)_n = \frac{1}{n}\frac{\sin(Nkd\,cos\theta/2)}{\sin(kd\,cos\theta/2)} \quad (1)$$

End fire array looks similar to broad side array except that the individual elements are fed with the current that is equal in magnitude but opposite in phase. In other words, the individual elements are excited in such a way that a progressive phase difference between adjacent elements becomes equal to the spacing between the antennas (elements). End-fire arrays are designed to focus the main beam of the array factor along the array axis in either the θ = 0° or θ = 180° directions. Maximum of the array factor occurs when $\Psi = \alpha + k\ d\ cos\theta$. This equation is to be satisfied with θ = 0°, the phase angle α must be $\alpha = -k\ d$. For θ = 180°, the phase angle α must be $\alpha = k\ d$, which gives

$$\psi = kd\ (cos\theta \mp 1) \quad (2)$$

The normalized array factor for an end-fire array reduces to

$$(AF)_n = \frac{1}{N}\frac{sin(Nkd\ (cos\theta \mp 1)/2)}{sin(kd\ (cos\theta \mp 1)/2)} \quad (3)$$

3. Big Bang Big Crunch Algorithm

The BB-BC method as developed by Erol and Eksin [11] consists of two steps: A Big Bang, where candidate solutions are randomly distributed over the search space; and a Big Crunch, where a contraction operation estimates a weighted average of the randomly distributed candidate solutions. The initial Big Bang is identical to other evolutionary methods, in that an initial population of candidate solutions is generated randomly over the entire search space. The random nature of the Big Bang is associated to the energy dissipation or the transformation from an ordered state a convergent solution to a disordered or chaotic state new set of candidate solutions. After the Big Bang phase, a contraction operation is applied during the Big Crunch. In this case, the contraction operator takes the current positions of each candidate solution in the population and its associated penalized fitness function value and computes a center of mass. The center of mass is the weighted average of the candidate solution positions with respect to the inverse of the penalized fitness function values computed as

$$X_{cm} = \frac{\sum_{i=1}^{NC} \frac{1}{f_i} X_i}{\sum_{i=1}^{N} \frac{1}{f_i}} \quad (4)$$

Where, X_{cm} is position of the center of mass, X_i is the position of candidate i in an n-dimensional search space, f_i is penalized fitness function value of candidate i, NC is candidate population size. The positions of the candidate solutions for the next iteration of the Big Bang are normally distributed around the center of mass, X_{cm}, using the following relationship

$$X_i^{new} = X_{cm} + \sigma \quad (5)$$

Where X_i^{new} is the position of the new candidate solution i and σ is the standard deviation of a standard normal distribution. In BB–BC algorithm, the standard deviation is related to a subset of search space which decreases inversely with each succeeding Big Bang

$$\sigma = \frac{r_j \alpha (X_{max} - X_{min})}{k} \quad (6)$$

where r_j is a random number from a standard normal distribution; α is a parameter limiting the size of the search space, X_{max} and X_{min} are the upper and lower limits on the values of the design variables; and k the number of Big Bang iterations. For discrete variables or when index numbers relate to tabular discrete values, the continuous values X_i^{new} are compared to the entire X_i and the nearest value is selected as X_i^{new} Since normally distributed numbers can exceed ±1, it is necessary to confirm and possibly limit candidate positions to the prescribed search space boundaries.

4. WiMAX OFDM System with BB-BC Algorithm

In this paper physical layer of WiMAX OFDM system is simulated. At the transmitting end linear antenna array has been used and the sidelobe levels are minimized using Big Bang Big Crunch algorithm. This algorithm provides optimized value of current being fed to each element through many iterations. These optimized weights are used to null the side lobe levels in antenna array field pattern. The objective here is to minimize the power levels in all side lobes. Radiation field pattern of antenna array is plotted using the following equation.

$$H(\theta) = \sum_{i=1}^{N} e^{j(i-1)(kd\cos\theta)} \quad (7)$$

Where, k = 2π/λ, N = number of antenna elements, Fitness function (cost function) is

$$F = 20\, log_{10}\,(F/max(F)) \quad (8)$$

$$F = abs(H) \quad (9)$$

By using Big Bang Big Crunch algorithm cost function is minimized which minimizes sidelobe levels. The system is simulated for broadside and end fire array of antenna elements and performance analysis of system is carried out in terms of radiation patterns.

5. Simulation Results

For minimizing sidelobes power level BB-BC algorithm is applied at transmitter side of WiMAX OFDM system and for simulation MATLAB is used. Simulation is done under following environment. For simulation Fixed WiMAX is used, number of transmitting antennas are 4, number of receiving antenna is 1, type of antenna array is broadside linear array. Inter-elemental distance is 0.5λ. Frequency of operation is 11GHz and for Optimization BB-BC algorithm is applied to WiMAX system.

In Fig. 3 side lobes can be seen clearly, these side lobes are minimized to a great extent in Fig. 4 by the use of BB-BC algorithm. It can minimize waste of transmitted power and help in interference reduction.

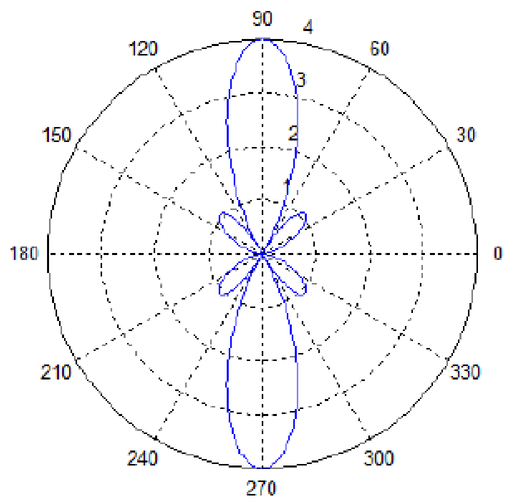

Fig. 3. Radiation pattern without BB-BC

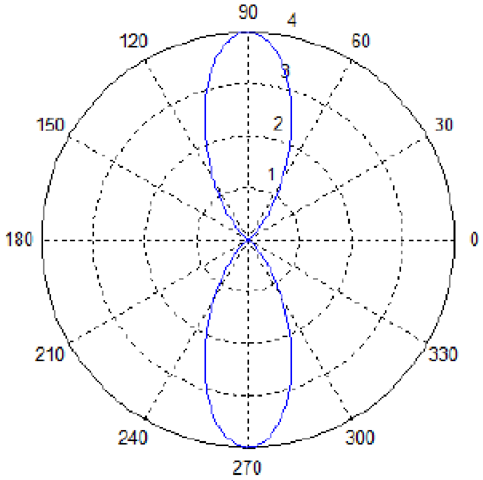

Fig. 4. Radiation pattern with BB-BC

Conclusion

In this work a successful attempt has been made to optimize antenna pattern at the transmitting side in a WiMAX system using BB-BC algorithm. The experimental model has been simulated in MATLAB. Four antennas at the transmitter and a single antenna at the receiving end is used. Big Bang Big Crunch algorithm has been used to optimize antenna weights (current to each element). BB-BC algorithm searches through some iterations over a search space the current vector for the antenna array at the transmitting side to optimize radiation pattern by minimizing side lobe and unwanted lobe levels. Reduced side lobe levels decrease the interference levels and thus help improve Signal to Noise ratio (SNR). Results show that there is a significant decrease in power levels of side lobes and thus minimizing transmitted power. Side lobe level reduction in comparison to non- optimized antenna array.

References

[1] J. G. Andrews, A. Ghosh and M. Rias, Fundamentals of WiMAX- Understanding Broadband Wireless Networking, Massachusetts: Prentice Hall, 2007.

[2] G. Moernaut and D. Orban, "The basics of antenna arrays," [Online]. Available: http://www.orbanmicrowave.com/The_Basics_of_Antenna_Arrays.pdf. [Accessed 30 July 2014].

[3] Y. A and S. Rahman, "WiMAX Broadband wireless access technology:Services, Architecture and deployment models," in *Canadian conference on Electrical and Computer Engineering, 2008 (CCECE, 2008)*, Niagara Falls,ON, 2008.

[4] A. Yarali, B. Mbula and A. Tumula, "WiMAX: A key to bridging the digital divide," in *Southeastcon, 2007*, Richmond, VA, 2007.

[5] M. Khan and S. Ghauri, "The WiMAX 802.16e physical layer model," in *IET international conference on Wireless, Mobile and Multimedia networks*, Chicago, 2008.

[6] Z. Abichar, Y. Peng and J. Chang, "WiMax: The Emergence of Wireless Broadband," *IT professional*, pp. 44-48, 28 August 2006.

[7] O. Abdel Alim, N. Elboghdadly, M. M. Ashour and A. M. Elaskary, *System-Level Model for OFDM WiMAX Transceiver in Radiation Environment,* 2008.

[8] R. Blum, J. Winters and N. Sollenberger, *On the capacity of cellular systems with MIMO,* Communication letters, IEEE, 2002.

[9] A. Tennant, M. Dawoud and A. Anderson, "Array pattern nulling by element position perturbations using Genetic algorithm," *Electronic letters,* vol. 30, no. 3, pp. 174-176, February 1994.

[10] M. Khodier and C. Christodoulou, "Sidelobe Level and Null Control Using Particle Swarm Optimization," *IEEE Transactions, Antenna and wave propagation,* vol. 53, pp. 2674-2679, August 2005.

[11] O. Erol and I. Eksin, "A new optimization method: Big Bang–Big Crunch," *Advance Engineering Software,* vol. 37, no. 2, pp. 106-111, 2006.

[12] C. Camp, "Design of Space Trusses Using Big Bang–Big Crunch Optimization," *J Structural Engineering-ASCE,* vol. 133, no. 7, pp. 999-1008, 2007.

[13] A. Kaveh and S. Talatahari, "Size optimization of space trusses using Big Bang–Big Crunch algorithm," *Computational Structures,* vol. 87, no. 17-18, p. 1129–1140, 2009.

[14] H. Tang, J. Zhou, S. Xue and L. and Xie, "Big Bang-Big Crunch optimization for parameter estimation in structural systems," *Mecanical system signal PR,* vol. 24, no. 8, p. 2888–2897, 2010.

[15] H. Genc and A. Hocaglu, "Bearing only target tracking based on Big bang Big crunch algorithm," in *International Multiconference on Computing in Global Information technology*, Athens, 2008.

[16] Z. Zandi, E. Afjei and M. Sedighizadeh, "Reactive power dispatch using Big Bang-Big Crunch optimization algorithm for voltage stability enhancement," in *IEEE international conference on Power and Energy(PECon)*, Kota Kinabalu, 2012.

[17] H. Genç, I. Eksin and O. Erol, "Big Bang - Big Crunch optimization algorithm hybridized with local directional moves and application to target motion analysis problem," in *Systems Man and Cybernetics (SMC), 2010 IEEE International Conference on*, Istanbul, 2010.

[18] G. Jaradat and M. Ayob, "Big Bang-Big Crunch optimization algorithm to solve the course timetabling problem," in *10th International Conference on Intelligent Systems Design and Applications (ISDA)*, Cairo, 2010.