Path Loss Reduction for Multiusers by Different Antenna Arrays

Shu-Han Liao
Advanced Communication System Center, Smart Network System Institute, Institute for Information Industry, Taipei, Taiwan, R.O.C.
shliao@iii.org.tw

Youn-Tai Lee
Advanced Communication System Center, Smart Network System Institute, Institute for Information Industry, Taipei, Taiwan, R.O.C.
lyt@iii.org.tw

Chien-Ching Chiu
Department of Electrical Engineering
Tamkang University
Tamsui, Taipei, Taiwan, R.O.C.
chiu@ee.tku.edu.tw

Chien-Hui Chung
Department of Electrical Engineering
Tamkang University
Tamsui, Taipei, Taiwan, R.O.C.
johnny1987.18@hotmail.com

Abstract- **In this paper, we use the shooting and bouncing ray/image (SBR/Image)[1]-[5] method to compute the path loss for different outdoor environments. Three types of antenna arrays such as L shape, Y shape, and Circular shape arrays are used in the base station and their corresponding path loss on several routes in the outdoor environment are calculated[6]-[8]. Moreover, the genetic algorithm (GA) and Dynamic Differential Evolution (DDE) are employed to optimize the excitation voltages and phases for antenna arrays to form proper antenna patterns[9], [10]. The particle swarm optimization algorithm has better optimization result than genetic algorithm in NLOS case. For antenna arrays Y shape has better optimization result in NLOS case.**

Keywords- ***SBR/Image method, outdoor, antenna arrays, path loss,multiusers.***

I. INTRODUCTION

Obstructions by the buildings in outdoor environments will reduce the received power and increase received data error rate. Different algorithms to predict the affection of obstruction are presented in many literatures [11]. For most papers, omnidirectional dipoles are used for receivers and antenna arrays are employed for transmitters [12]. Applying genetic algorithm (GA) to reduce signal path loss in outdoor communication has been presented in the reference [9]. Compared to genetic algorithms, Dynamic Differential Evolution is much easier to implement and converge faster [13]. In this study, we not only apply other algorithm (DDE) to improve GA but also service for multiusers in outdoor communication. The path loss of wireless communication in the signal is necessary. Due to building obstructions in outdoor environments, the received power will be attenuated and the speed of data transmission will be lowered. Consequently, this study should need to improve performance of antenna arrays in order to make the emergency communication more reliable. In this paper, three different types of antenna arrays are investigated. To synthesize antenna pattern for the lowest path loss [14]-[18], the excitation problems are reformulated as optimization problems. GA and Dynamic Differential Evolution (DDE) , are used to reduce the path loss in the outdoor environment. Section II describes the pattern synthesis by the algorithms. The simulating environment and the design of the proposed arrays are also described. Section III shows the numerical results. Finally, some conclusions are drawn in Section IV.

II. ANTENNA PATTERN SYNTHESIZED BY THE OPTIMIZATION ALGORITHMS

N dipole elements excited by a voltage source are used to form an antenna array. Let V_m and ϕ_m be the amplitude and phase of excitation voltage of the mth element respectively. Then the total current distribution of N antennas can be calculated by the following equation [19].

$$\sum_{n=1}^{N}\int_0^{\ell_n} I_n(z')[K_{mn}(z,z')+K_{mn}(z,-z')]\,dz = -\frac{j4\pi}{\eta_0}\left[c_m\cos\phi_m+\frac{V_m}{2}\sin\phi_m\right] \quad (1)$$

$$0 \le z \le l_m \quad m = 1, 2, \ldots, N$$

$$K_{mn}(z,z') = \frac{e^{-jkR_{mn}(z,z')}}{R_{mn}(z,z')} \quad (2)$$

I_n and ℓ_n are the current and the length of the *n*th element, respectively. η_0 is the free-space impedance. $R_{mn}(z,z')$ is the distance between the point z on the surface of the *m*th element and the point z' on the axis of *n*th element. c_m is undefined coefficient which can be calculated by the boundary condition of $I_1(l_1)=I_2(l_2)=\ldots=I_n(l_n)=0$. For numerical calculation of the problem, the antenna is first divided into sufficient small segments so that current distribution of the antenna over each segment can be considered constant. The moment method is used to solve the current distribution $I(z')$

by equation (1) with a pulse basis function for expanding and the Dirac delta function for testing. Once the current distributions of N dipoles are obtained, the radiation pattern can be computed accordingly.

A. Genetic Algorithm (GA)

We use the genetic algorithm to adjust the antenna pattern in order to minimize the path loss. In the synthesis procedure, the genetic algorithm is used to minimize the following objective function:

$$OF = path\ \ loss \qquad (3)$$

In our problem, the parameter $V_m(or\ \phi_m)$ is given by the following equation:

$$V_m(or\phi_m) = \rho_{\min}^{V_m(or\phi_m)} + \frac{\rho_{\max}^{V_m(or\phi_m)} - \rho_{\min}^{V_m(or\phi_m)}}{2^Q - 1} \sum_{i=0}^{Q-1} b_i^{V_m(or\phi_m)} 2^i \qquad (4)$$

The $b_0^{V_m(or\phi_m)}, b_1^{V_m(or\phi_m)}, ..., b_{Q-1}^{V_m(or\phi_m)}$ is the Q-bit string of the binary representation of $V_m(or\phi_m)$, $\rho_{\min}^{V_m(or\phi_m)}$ and $\rho_{\max}^{V_m(or\phi_m)}$ are the minimum and maximum values admissible for $V_m(or\phi_m)$, respectively. Here, $\rho_{\min}^{V_m(or\phi_m)}$ and $\rho_{\max}^{V_m(or\phi_m)}$ can be determined by prior knowledge of the excitation. Also the finite resolution with which $V_m(or\phi_m)$ can be tuned in practice is reflected in the number of bits assigned to it. The total excitation $V_m(or\varphi_m)$ could be described by a $2L \times Q$ bit string (chromosome). The exciting sources of V_m and ϕ_m are randomly produced by the genetic algorithm and their corresponding antenna pattern can be determined by solving integral equation.

B. Dynamic Differential Evolution (DDE)

Differential evolution (DE) is a population-based, self-adaptive and parallel direct search optimization method that is proposed by Storn and Prince in 1995 [20]. The initial population may be expressed by $\{x_i,\ i = 1,2,\cdots,Np\}$, where Np is the population size. In general, a typical DE optimizer go through the following six procedures:

I. Initialize a starting population: DE is initialized with a population that is composed by a group of randomly generated candidate individuals. Individuals in DE are represented as D-dimensional parameter vectors x_i, $i = 1,2,\cdots,Np$, where D is the number of parameters to be optimized and Np is the population size.

II. Evaluate the population using objective function: After initialization, DE evaluates the objective function (5) for each individual in the population.

$$OF = path\ \ loss \qquad (5)$$

III. Perform mutation operation to generate trial vectors: The mutation operation of DE is performed by arithmetical combination of individual. For each parameter vector x_i of the parent generation, a trial vector v_i is generated according to following equation:

$$v_i^g = x_{best}^g + \varphi \cdot (x_{r1}^g - x_{r2}^g),\ i \neq r_1 \neq r_2 \qquad (6)$$

where $\varphi > 0$, is weighting factor that control the amplification of the differential variation $(x_{r1}^g - x_{r2}^g)$. The indices i, r1 and r2 of individuals are randomly chosen. The subscript g stands for the generation index of the parent generation. The best refer to the optimal individual in the parent population.

IV. Perform crossover operation with probability of crossover CR to deliver crossover vectors: The crossover operation in DE is performed to increase the diversity of the parameter vectors. This operation is similar to the crossover process in GAs. However, The crossover operation in DE just allows to deliver the crossover vector u_i by mixing component of the current vector x_i and the trial vector v_i. It can be expressed as:

$$u_i^g(j) = \begin{cases} v_i^g(j), & if \quad Rand(j) < CR \\ x_i^g(j), & otherwise \end{cases} \quad (7)$$

where CR is the probability of crossover, $CR \in (0,1)$. $Rand(j)$ is the random number generated uniformly between 0 and 1.

V. Perform selection operation to produce offspring: Selection operation is conducted by comparing the parent vector x_i^g with the crossover vectors u_i^g. The vector with smaller objective function value is selected as a member of the next generation. Explicitly, the selection operation for the minimization problem is given by:

$$x_i^{g+1} = \begin{cases} u_i^g, & if \quad OF(u_i^g) < OF(x_i^g) \\ x_i^g, & otherwise \end{cases} \quad (8)$$

VI. Stop the process and print the best individual if the termination criterion is satisfied, else go to step II.

A modified DE namely dynamic differential evolution, DDE, is proposed to speedup the convergence of the DE [21].

III. Numerical Results

The outdoor environment of the buildings in the commercial area in Taipei is shown in Fig. 1. There are seven buildings from A to G in this area. The height of the thickness of the walls in these building is 30cm. The relative dielectric constant and the conductivity of buildings and the ground are assumed to be 8 and 0.0075S/m, and 15 and 0.012S/m, respectively. The heights of each building in alphabetical order are 35, 25, 20, 30, 30, 27 and 20m. L shape, Y shape and Circular shape arrays consisted of 8 half-wave dipoles are used for transmitting antenna arrays. The proposed antenna arrays are set on the top of building B at (50, 5)m with a height of 25m. The receiving antenna is a short dipole antenna with a height of 1.5m. The searching ranges of excitation voltage and phase are 0~1 volt and 0~360 degrees, respectively. The operation frequency is 1.9GHz [22],[23]. LOS and NLOS cases are considered in the followings:

NLOS case:

In this case, we put the receiving antennas (Rx1 and Rx3) at (62, 55)m and (100, -45)m respectively as shown in Fig. 1. There are no obstruction between transmitter and Rx1 but some obstructions between the transmitter and Rx3. Similarly, the path loss with and without algorithms are shown in Table I.

The corresponding radiation patterns with GA and DDE are shown in Figs. 2-3 respectively. In the NLOS case, the transmitting signal can't reach the receiver directly. Nevertheless, it is found that antenna patterns by two algorithms can find the route with the lowest path loss by reflection mechanism. This route avoids the obstructions between the transmitter and receiver, and also shows the direction with fewer obstructions. In the NLOS case, we can observe that path losses of L shape, Y shape and Circular shape arrays with the GA and DDE algorithms are lower. The path loss reduction by GA is 5.28, 5.95 and 2.35dB than the case without the algorithm for the L shape, Y shape and Circular shape arrays, respectively. The path loss reduction by DDE algorithm is 6.46, 8.67 and 3.49dB than the case without the algorithm for the L shape, Y shape and Circular shape arrays, respectively. It is clear that path loss can be reduced by the two algorithms, but DDE algorithm can get lower path loss than GA algorithm. The path losses for the L shape, Y shape and Circular shape arrays with algorithm are reduced about 5-6dB, 6-8dB and 2-3dB respectively. The result of the Y shape array is better than the others. And the Y shape array reduces path loss most. In general, the Y shape array in DDE algorithm is a good choice for NLOS outdoor environments.

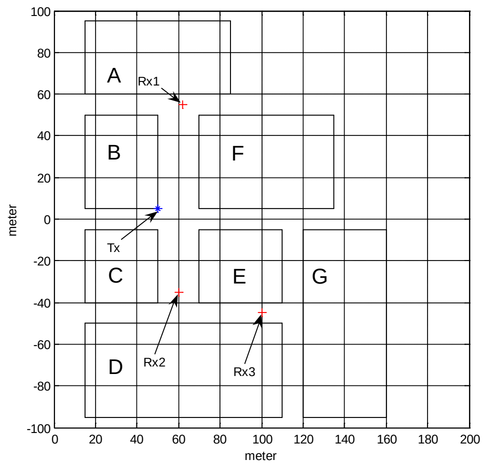

Figure 1. The simplified layout geometry for simulation

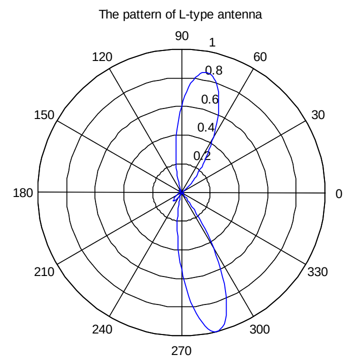

Figure 2(a). Radiation pattern by the GA algorithm in the NLOS case

(a) L shape array

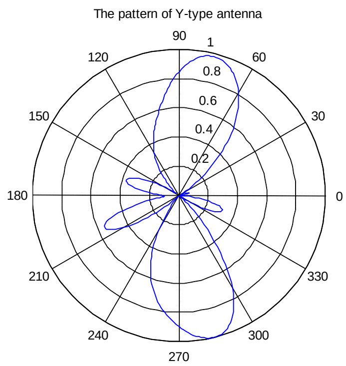

Figure 2(b). Radiation pattern by the GA algorithm in the NLOS case

(b) Y shape array

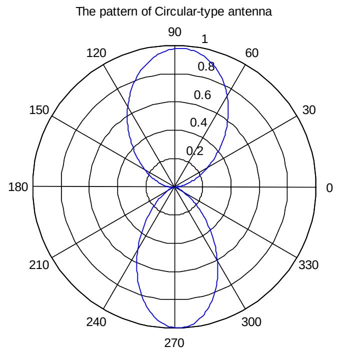

Figure 2(c). Radiation pattern by the GA algorithm in the NLOS case

(c) Circular shape array

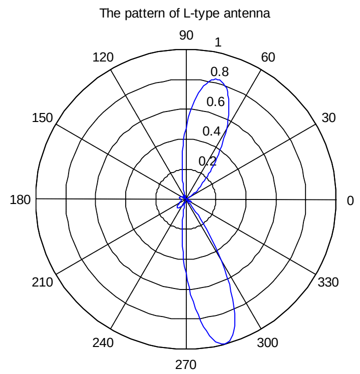

Figure 3(a). Radiation pattern by the DDE algorithm in the NLOS case

(a) L shape array

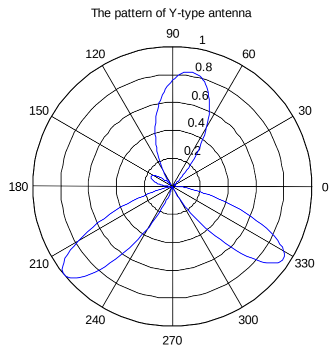

Figure 3(b). Radiation pattern by the DDE algorithm in the NLOS case

(b) Y shape array

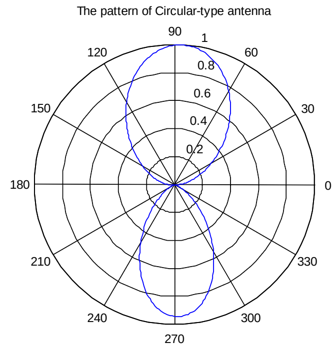

Figure 3(c). Radiation pattern by the DDE algorithm in the NLOS case

(c) Circular shape array

TABLE I The comparison of path loss with and without the two Algorithms in the NLOS case

Antenna arrays / Algorithm	L shape	Y shape	Circular shape
Without Algorithm	92.28	96.36	97.54
GA	87.00	90.41	95.19
DDE	85.82	87.69	94.05

IV. Conclusion

In this paper, three different antenna arrays reducing the path loss in outdoor wireless communication channel for multiusers by GA and DDE are presented. SBR/Image method is used to compute the path loss. Based on the path loss, the synthesis problem can be reformulated into an optimization problem. The algorithms minimizes the object function (path loss) in GA and DDE where we can control the main beam direction, beam width and side lobe level of the radiation pattern. The algorithms avoids the local minimum of the object function and achieves the lowest path loss. By using the algorithms to improve antenna patterns, three different arrays in the outdoor environment are investigated.

Numerical results show that path loss in NLOS cases can be reduced about 2~8dB. It also show that Y shape is a good choice for NLOS in outdoor environments.

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