Comparison of Different Antenna Arrays with Various Height

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Abstract. In this paper, we use the shooting and bouncing ray/image (SBR/Image) method to compute the path loss for different outdoor environments in the residential area. Their corresponding path loss of the outdoor environment for the non-line-of-sight (NLOS) cases are calculated. Numerical results show that the performance in reduction of path loss by DDE algorithm is better than that by GA. Besides, the path loss for the circular shape antenna is lower than that for the cross shape antenna array both in NLOS case.

Keywords: SBR/image method · Antenna height · Antenna patterns

1 Introduction

In recent years, the development in the wireless communication is promising. In the wireless outdoor communication [1–3], the heights of buildings are tall in modern cities to make the outdoor communication more difficult and complex. Obstructions by the buildings in outdoor environments will reduce the received power. Various heights of transmitting antenna will lead different path loss [4, 5], due to the different reflection and the diffraction of waves [6, 7]. To reduced the path loss, antenna arrays are usually employed for transmitters. Applying GA to reduce signal path loss for the array in outdoor communication has been presented in the references [8–10].

Section 2 describes the pattern synthesis by the algorithms. The simulating environment and the design of the proposed arrays are also described. Section 3 shows the numerical results. Finally, some conclusions are drawn in Sect. 4.

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2 Antenna Pattern Synthesized by the Dynamic Differential Evolution Algorithm

2.1 Calculation of Antenna Current and Pattern

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 m-th element respectively. Then the total current distribution of N antennas can be calculated by the following equation.

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

$$0\leq z\leq l_m \quad m=1,2,\ldots,\mathrm{N}$$

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

2.2 SBR/Image Method

The SBR/Image method is used to calculate the path loss for any given antenna pattern. The SBR/Image method can deal with radio wave propagation in the outdoor environments. It conceptually assumes that many ray tubes are shot from the transmitting antenna and each ray tube bouncing and penetrating in the environments is traced. If the receiving antenna is within a ray tube, the ray tube will contribute to the received field and the corresponding equivalent source (image) can be determined. By summing all contributions of these images, we can obtain the total received field at the receiver. As the result, we can calculate the path loss. GA and DDE are used to find the excitation voltages and phases to minimize the path loss.

2.3 Dynamic Differential Evolution (DDE)

DDE algorithm starts with an initial population of potential solutions that is composed by a group of randomly generated individuals which represents excitation voltages and phases. Each individual in DDE algorithm is a D-dimensional vector consisting of D optimization parameters. The initial population may be expressed by $\{x_i : i = 1, 2, \cdots, Np\}$, where Np is the population size. After initialization, DDE algorithm performs the genetic evolution until the termination criterion is met. DDE algorithm, like other EAs, also relies on the genetic operations (mutation, crossover and selection) to evolve generation by generation.

3 Numerical Results

The layout of the buildings in the residential area is shown in Fig. 1. There are nine buildings from A to I in this area. The height of these buildings are all in 10 m and the wall thickness is 30 cm. Cross shape and circular shape arrays consisted of 8 short dipoles are used for transmitting antenna arrays. The proposed transmitting antenna arrays are set for six different height at the position by triangle mark. The receiving antenna is a short dipole antenna with the height of 1.5 m. There are 36 receiving points distributed with equal space in NLOS area. Each transmitting height has 36 receiving point in the area. The final path loss of each height is the average value of total receiving data. The searching ranges of excitation voltage and phase are 0–1 V and 0–360°, respectively. The operation frequency is 5.9 GHz. For fair and comparison, GA and DDE algorithm's cross over probability (0.6), mutation probability (0.025), population size (30) and termination generation (700) are the same. Note that the total number of generations is set equal to 700. i.e., $g_{\max} = 700$. NLOS case are considered respectively in the followings:

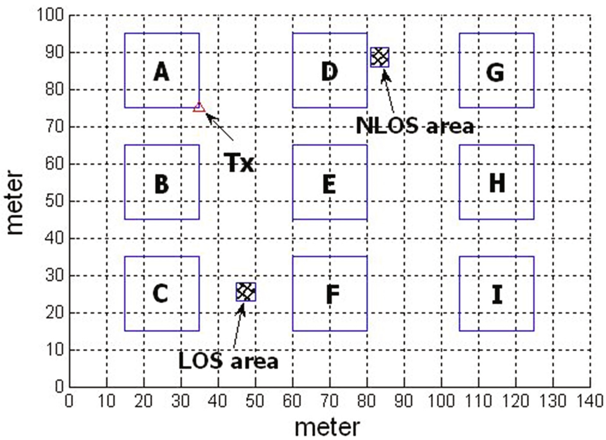

Fig. 1. The simplified layout geometry for simulation

NLOS case:

There is an obstruction between the transmitter and receiver for NLOS case. Some transmitting ray is diffracted by different way in various transmitting height. The path losses with GA and DDE, and without algorithms for the cross and circular shape arrays are shown in Figs. 2 and 3 respectively. In Fig. 2, it is observed that path losses of cross shape arrays for transmitting antenna height of 1.5, 5, 10, 12, 15 and 20 m by GA are lower 1.6, 4.3, 2.9, 2.5, 4.6 and 4.7 dB than the case without the algorithm, respectively. The path loss by DDE for transmitting antenna height of 1.5, 5, 10, 12, 15

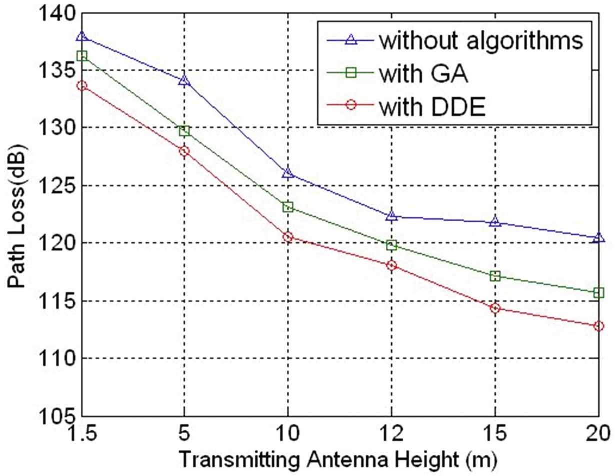

Fig. 2. Path loss of cross shape array with different algorithms in NLOS case

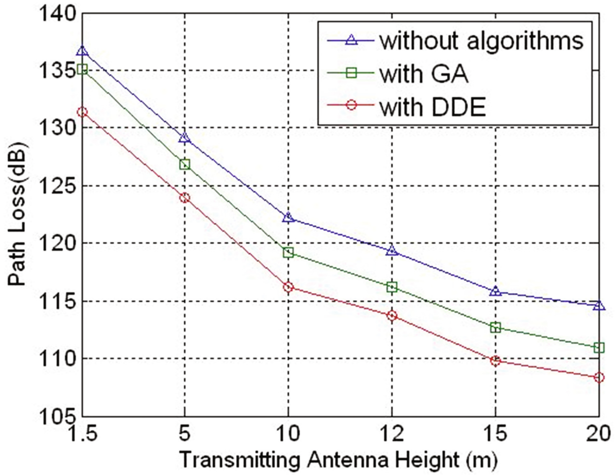

Fig. 3. Path loss of circular shape array with different algorithms in NLOS case

and 20 m are lower 4.2, 6, 5.4, 4.1, 7.4 and 7.5 dB than the case without the algorithm. In Fig. 3, path losses of circular shape arrays for transmitting antenna height of 1.5, 5, 10, 12, 15 and 20 m by GA are lower 1.5, 2.2, 2.9, 3, 3 and 3.6 dB than the case without the algorithm. The path loss by DDE for transmitting antenna height of 1.5, 5, 10, 12, 15 and 20 m are lower 5.2, 5.2, 5.9, 5.5, 5.9 and 6.1 dB respectively than without algorithm. It is clear that the path loss by the DDE algorithm is lower than

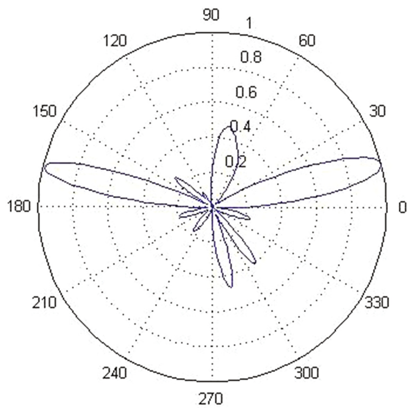

Fig. 4. Radiation pattern of cross shape array of transmitting height at 20 m by the GA algorithm in the NLOS case

those by GA. It is also seen that the path loss for the circular shape array are better than that for the cross shape array in NLOS case. Figure 4 shows the radiation patterns of cross and circular shape arrays by GA and DDE at transmitting height 20 m. In the NLOS case, the transmitting signal can't propagate directly to the receiver. Nevertheless, it is seen that antenna patterns by algorithms can find the route with the lowest path loss by reflection and diffraction. The radiation pattern by DDE is more directional than that by GA. Moreover, the power for circular shape antenna array is more focused than that by cross shape antenna array (Figs. 5, 6 and 7).

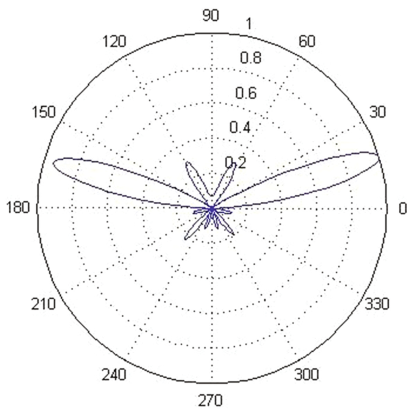

Fig. 5. Radiation pattern of cross shape array of transmitting height at 20 m by the DDE algorithm in the NLOS case

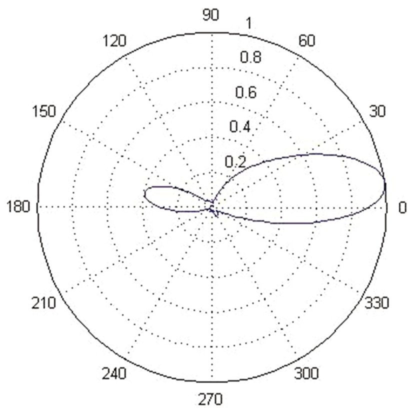

Fig. 6. Radiation pattern of circular shape array of transmitting height at 20 m by the GA algorithm in the NLOS case

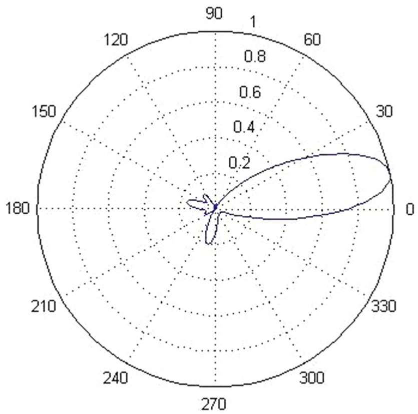

Fig. 7. Radiation pattern of circular shape array of transmitting height at 20 m by the DDE algorithm in the NLOS case

4 Conclusion

Two different antenna arrays and six kind of transmitting heights for reducing the path loss in outdoor wireless communication channel by the GA and DDE algorithm 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 GA and DDE are used to regulate the antenna excitation voltages and phases of each array element to minimize the path loss. Numerical results show that path loss in LOS case can be reduced 3–6 dB by using algorithm. The path losses for the NLOS cases can be reduced about 3–7 dB by using algorithm. It is also found that the path loss reduction by DDE is better than that by GA. Two algorithms in same condition (cross over, mutation, population and generation) shows that DDE's optimization is better than GA. It is found the path loss for circular antenna array is lower than that for cross antenna array. It is worth noting that in these cases the present work provides not only comparative information but also quantitative information on the performance reduction.

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