Research on Correction Technology of Radio Wave Propagation Model Based on Adaptive Genetic Algorithm

Yamin Sun, Zhiyong Yu, Chen Pang
Rocket Force University of Engineering, Xi'an 710025, China
Corresponding author’s e-mail: 1348395737@qq.com

Abstract: The modified method of battlefield wave propagation model is analyzed and compared. In the process of improving the matching degree between the wave propagation model and the environment, the least square method has the disadvantages of slow solution speed and easy to fall into the local optimal solution. The adaptive genetic algorithm is used to correct the radio wave propagation model and the experimental verification is carried out. Compared with the previous two algorithms, the correction accuracy is obviously improved, which can provide technical support for accurately describing and predicting the electromagnetic environment in actual combat.

1. Introduction
The radio wave propagation model directly affects the accuracy of the battlefield electromagnetic environment description and prediction[1]. In the current combat scenarios, large-scale radio wave propagation models are often used to predict the monitoring capabilities of monitoring equipment. Since such models have shortcomings that do not match the specific environment, there is a problem that the prediction accuracy is not high. Therefore, in actual combat, the radio wave propagation model needs to be positive. Generally, analytical methods, data statistics and model correction can be used to modify the wave propagation model[2-6]. Analytical calculation methods are difficult to model and difficult to implement; data statistical methods have long test cycles and high costs; therefore, A model correction method with a short test period and a small data processing difficulty corrects the radio wave propagation model. In [7], the model is corrected by the least squares method. Although it can meet the requirements of the correction criterion, due to the inherent defects of the algorithm, the correction accuracy still has a lot of room for improvement. The literature [8] uses the genetic algorithm to the SPM model. Correction is performed, and the correction result is improved compared with the least squares method. However, due to the inherent defects of the algorithm, the correction accuracy can be further improved. Aiming at the defect that genetic algorithm is easy to fall into local optimum, this paper adopts adaptive genetic algorithm, which can improve the global optimization ability and prevent the situation from falling into local optimum by adaptively changing the crossover probability and mutation probability with the fitness value. It can effectively improve the accuracy of electromagnetic environment prediction.

2. Radio wave propagation model correction technique for model correction

2.1. Data collection
The data acquisition methods include continuous wave (CW) test method, pilot test method and ray tracing method[9-11]. The pilot test method has a small test radius, and the RF tracking method has a high cost and a complicated process. Therefore, the continuous wave test method is generally used to correct
the propagation model. In the process of using the continuous wave test method for calibration, in order to improve the test efficiency and shorten the test duration, in the process of the test plan development, the performance of the test equipment and the topographical features of the area to be tested should be combined to select a reasonable position and appropriate quantity (In the densely populated areas, there are generally no less than five, medium-sized cities (about 3, small cities and 1 suburb) test sites, planning the corresponding test routes, using CW waves for testing, detailed recording of test process data. The measurement process is shown in Figure 1.

![Figure 1. Flow chart for the development of the field measurement plan](image)

In order to ensure the representativeness of the measurement data, the following issues should be noted when formulating the measurement plan:

1. In the CW test, its intrinsic length 2L should be 40 wavelength intervals, and 36-50 points are collected within this interval. Thereby achieving the purpose of eliminating fast fading and retaining slow fading;

2. In order to improve the representativeness of the data and reduce the influence of refraction, scattering and diffraction, when the site of the test site is selected, there should be no obvious occlusion around the site and obvious relative height, and there should be sufficient landform around the site. Type, and convenient transportation, the test area must contain typical features in the training plant area;

3. During the test, the vehicle speed is running at a constant speed within the range of 30-60 Km/h. The relationship between the sampling rate of the device and the speed of the vehicle is:

\[
\frac{v_{\text{device}}}{v_{\text{vehicle}}} = \frac{2L}{N} = 0.8\lambda
\]

4. When returning, measure the measurement points again according to the requirements, so as to improve the accuracy of the data and avoid the influence of accidental factors.

2.2. Data Processing Analysis

After obtaining the measured data, the data needs to be further processed, including data filtering, data discretization, geographic averaging and geographic offset correction, thereby improving the accuracy and representativeness of the data. The specific process of data processing is shown in Figure 2.

![Figure 2. Data Processing Flow Chart](image)
(1) Data filtering

Data filtering is to filter out unreasonable sampling points measured by factors such as geographical location and interference during data measurement. For example, data points that are too close or too far from the transmitting antenna, measurement data points with significantly larger obstructions, and data points where the signal strength is significantly higher or lower.

(2) Data dispersion

Because the data sampling frequency is significantly higher than the GPS sampling frequency during the test, the data measurement points are inconsistent with the latitude and longitude coordinates. Therefore, the data needs to be discretized so that the data points are consistent with the latitude and longitude coordinate points.

(3) Geographical average

Geographical averaging is the geographical averaging of data points to obtain the regional mean of a particular length. Its purpose is to improve the accuracy of the data, thereby improving the accuracy of the model correction. In general, take 6m as the geographic average length.

(4) Geographical offset correction

During the data measurement process, due to the certain error of the latitude and longitude acquired by the GPS, the measurement data and the map cannot be completely matched, and the deployment data deviates from the original route, which causes the geographical attribute of the data to be deviated. Therefore, the offset data needs to be corrected to improve the accuracy of the data.

2.3. Correction of radio wave propagation model based on adaptive genetic algorithm

When the calibration of the radio wave propagation model is completed using the measured data, the performance of the correction algorithm directly affects the accuracy of the correction. Based on the defects of the least squares method and genetic algorithm pointed out in the previous section, this section adopts adaptive genetic algorithm, which can improve the performance of correction by preventing the crossover probability and mutation probability from adapting adaptively with the fitness value, and preventing the local optimal situation. The specific process of adaptive genetic algorithm solving is shown in Figure 3. Firstly, analyze the problem to be optimized, determine its objective function and related constraints, set the fitness function and termination conditions, then randomly generate the initial population, determine the number of individuals, encode each individual, calculate the individual's fitness value, and judge whether it meets the termination condition, if it is met, stops the calculation and outputs the individual. At this time, the individual is the optimal solution of the problem. Otherwise, the fitness of the individual is compared with the average value of the previous generation fitness. Value, the probability of crossover and mutation is reduced, and vice versa, the probability of crossover and mutation increases, and then the genetic operation is continued to generate a new generation of population, and it is re-evaluated whether it meets the termination condition, and the output is optimal through repeated iterations until the termination condition is satisfied.

When correcting the radio wave propagation model, the criterion for judging the correction result is:

1. The statistical average error of the signal coverage prediction value and the measured data MeanError<1dB;
2. The standard deviation of the signal coverage predicted value and the measured data is RMSError<8dB;
3. The correlation coefficient between the signal coverage predicted value and the measured data is between 0.6 and 1.
The correction accuracy of the radio wave propagation model is related to the selection of the propagation model, the measured data used in the calibration, and the correction method. Under the premise that the propagation model and the measured data are ideal, the propagation model loss prediction expression is:

\[ L_{\text{test}} = AK \] (2)

Where, in order to predict the value of the wave loss, \( A = (\lg d, \lg h_s, \lg h_u, \cdots) \) is the matrix of the influencing factors of the selected propagation model, \( K = (K_1, K_2, \cdots, K_r)^T \) is the coefficient matrix of each factor, and \( K \) is the required correction coefficient term.

Assuming that the measured loss values at point \( d_i \) are from \( N \) measured data points during the calibration process, the difference between the measured loss value and the predicted loss value is:

\[ g(d_i, K) = L_{\text{act}} - L_{\text{test}} \] (3)

Then the error mean is:

\[ \frac{\sum_{i=1}^{N} g(d_i, K)}{N} \] (4)

The standard deviation is:

\[ \sqrt{\frac{\sum_{i=1}^{N} g(d_i, K)^2}{N-1}} \] (5)

The judgment criterion corrected by the propagation model sets equation (5) as the objective function, namely:

\[ \min J(K) = \sqrt{\frac{\sum_{i=1}^{N} g(d_i, K)^2}{N-1}} \] (6)
The genetic operation is divided into three steps: selection, crossover and mutation, and the genetic optimization function is realized through genetic manipulation. Among them, the roulette strategy is adopted when selecting individuals, and the fitness function of each individual in each generation of population is:

$$f(K) = \sqrt{\frac{\sum_{i=1}^{N} g(d_i, K)^2}{N-1}}$$ (7)

Where, $i = 1, 2, \ldots, N$, $j = 1, 2, \ldots, M$, $N$ is the measured data points, $d_i$ is the i-th measured data point, $M$ is the number of individuals in the population, and $K^j$ is the j-th individual in the population, then the probability of selection for each individual is:

$$P_j = \frac{f(K^j)}{\sum_{i=1}^{M} f(K^i)}$$ (9)

Each time a selection is made, a random number $r$ between 0 and 1 is randomly generated. When $PP_{j,1} \leq r \leq PP_j$ is satisfied, the individual $i$ is selected and a new individual is copied. The larger the fitness value of entering the next generation, the greater the selection probability. After the individual is selected, the pairing can be randomly formed to complete the recombination work of the gene. In order to improve the optimization performance of the algorithm, the crossover probability $P_c$ and the mutation probability $P_m$ are adaptively adjusted to change with the adaptation value, thereby avoiding the case of local optimality, the principles of adaptive adjustment of crossover and mutation probability are as follows:

$$P_c = \begin{cases} P_{ci} - \frac{(P_{ci} - P_{c2})(f - f_{avg})}{f_{max} - f_{avg}}, & f < f_{avg} \\ P_{ci}, & f \geq f_{avg} \end{cases}$$ (10)

$$P_m = \begin{cases} P_{mi} - \frac{(P_{mi} - P_{m2})(f_{max} - f)}{f_{max} - f_{avg}}, & f \geq f_{avg} \\ P_{mi}, & f < f_{avg} \end{cases}$$ (11)

Where $f_{avg}$ is the fitness value of each generation group, $f_{max}$ is the maximum fitness value in the population, $f$ is the larger adaptation value of the two individuals crossing, $f$ is the fitness value of the individual to be mutated, and $P_{ci}$ and $P_{c2}$ are the highest and lowest. Crossover probability, $P_{mi}$ and $P_{m2}$ represent the highest variation and the lowest mutation probability. If $r < P_c$ is satisfied, the individual is cross-generated to generate a new pair of individuals, and if $r < P_m$ is satisfied, the individual is mutated. The optimal solution is output by iterative iteration until the stop rule is satisfied.

3. Test verification
The feasibility of the method is verified by the measured data in a combat drill. Among them, the relevant information of this drill is as follows:

Test area: a suburb of Xi’an City, Shaanxi Province
The test distance range is: 1-15km;
Transmitter performance parameters: the working frequency range is 800MHz-2000MHz, the transmitting power is 30dBm, and the effective height of the transmitting antenna is 30m;

Receiver performance parameters: monitoring receiver sensitivity -144dBm, receiving antenna effective height 1m;

Characteristics of the external environment: the suburbs, the terrain is relatively regular, relatively flat, no large buildings are covered, only a few corners or sharp points, the building density is low, the weather is fine, the air humidity is 23, and the vegetation coverage is moderate.

During the test, the communication equipment transmits a CW signal with a frequency of 900 MHz and a power of 30 dBm.

In order to verify the ability of the adaptive genetic algorithm to modify the radio wave propagation model, the genetic algorithm and the least squares method are used to correct the data under the same measured data, and then the correction results are compared. The correction results of the radio wave propagation model of different algorithms are shown in Figure 4.

![Figure 4. Curve of the correction result of the radio wave propagation model of different algorithms](image)

It can be seen from Fig. 2.1 that due to the scattering, diffraction, multipath effect, external environmental interference and measurement error of the electric wave propagation, the distribution of the measured data points is relatively discrete, but there is still a general trend. Among them, the uncorrected wave propagation model curve has a large deviation from the measured data points, and the theoretical loss of the model is much higher than the actual loss. This is because the wave propagation model used in this paper is an empirical model based on statistical data. The defect is that the environmental applicability is low. In the application process, the measured data of the drilled area is generally used for correction to improve the environmental applicability of the model. The trend of the curve corrected by the least squares method, the genetic algorithm and the adaptive genetic algorithm is in line with the trend of the measured attenuation value, and the deviation is small. Since the measured data in the calibration graph is large, it is difficult to judge the merits of the calibration results from the graph.

The three parameters of MeanError, RMSError and correlation coefficient in the judgment result judgment criterion reflect the degree of agreement between the corrected radio wave propagation model and the measured value. Therefore, it can be carried out from the three criteria data from the judgment result judgment criterion. Analyze and judge the level of correction performance between different algorithms. The specific calibration data results are shown in Table 1.
Table 1. Calibration Results Data Sheet

| Calibration result | Least squares | Genetic algorithm | Adaptive genetic algorithm |
|--------------------|---------------|-------------------|---------------------------|
| MeanError          | 0.8467        | 0.7124            | 0.5481                    |
| RMSError           | 6.8326        | 6.3743            | 5.8100                    |
| Correlation coefficient | 0.6728 | 0.7613          | 0.8243                    |

It can be seen from the data in Table 2.1 that although the correction results of the three algorithms satisfy the requirements, the correction accuracy is different. Among them, the least squares method has the lowest correction accuracy, because the correction result is related to the measured data when the least squares method is used for correction. Since the fluctuations of the measured data fluctuate greatly, and most of the data points are concentrated on the lower side, the calibration curve using this method is low; the accuracy of the correction algorithm is improved compared with the least squares method, but because the crossover and mutation probability in the algorithm is fixed, and the randomness of the algorithm is solved, the solution process is in the process of solving It is easy to fall into the local optimal situation, so in the process of solving this problem, the phenomenon that the calibration curve is high is high; the adaptive genetic algorithm has improved the correction precision compared with the former two algorithms, by the crossover and mutation probability along with the individual The adapt ability changes to avoid the local optimal situation in the solution process. The correction result can more accurately reflect the radio wave propagation law in the exercise area and improve the matching degree between the model and the environment. Among them, the values of MeanError and RMSError between the modified model and the measured data using the adaptive genetic algorithm are reduced by 35.2% and 14.9%, respectively, and the correlation coefficient is increased by 22.5%. Compared with the genetic algorithm correction results, the values of MeanError and RMSError decreased by 23.1% and 8.8%, respectively, and the correlation coefficient increased by 8.2%, which indicates that the modified wave propagation model with adaptive genetic algorithm has higher matching degree. The feasibility of the method is verified.

4. Conclusion
In order to improve the matching degree between the radio wave propagation model and the combat area environment, this paper selects the model correction method to modify the radio wave propagation model based on a large amount of measured data. Aiming at the problem that the least square method solves the slow speed and the genetic algorithm is easy to fall into the local optimum, this paper adopts the adaptive genetic algorithm with faster convergence speed and stronger global optimization ability. The standard deviation of the radio wave propagation model and the measured data is the objective function. The model is modified by the measured data. The experimental results show that the radio wave propagation model modified by the adaptive genetic algorithm has a higher matching degree with the data testing environment, and provides technical support for accurately describing and predicting the electromagnetic environment in actual combat.

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