Research on target detection technology of MIMO technology in vehicle collision avoidance

Jieqiong Zeng¹, Cuilin Zhong²

¹ College of Electrical and Mechanical Engineering, Guangdong Polytechnic of Industry and Commerce, Guangzhou, China.
² College of Automotive Engineering, Guangdong Polytechnic of Industry and Commerce, Guangzhou, China.

E-mail: 123682131@qq.com, E-mail: zhzhongcuilin@126.com

Abstract: MIMO (multiple input multiple output) vehicle anti-collision radar refers to the application of MIMO system radar in vehicle anti-collision. MIMO radar is a new type of radar which has been put forward in recent years and attracted great attention. It is a kind of radar with multi transmitting and multi receiving. The characteristics of wave form diversity make it have many performance advantages, such as strong anti-jamming ability and strong resolution, compared with traditional radar. In recent years, many researchers have studied the application of MIMO Radar in the field of aviation and land transportation and made remarkable achievements. Compared with the traditional radar, the advantage of MIMO radar is due to the orthogonal performance of the transmitting waveform. The related problems of the pattern are deeply related to the resolution. As an important reference index in radar, the resolution is worthy of further study. In view of the above problems, the main work of this paper is as follows.

1. Introduction

People from the ancient form of hiking, using horse, donkey, bamboo raft mode of transportation, embarked on the modern society of car, ship, aircraft mode of transportation. The improvement of the means of transportation makes people's way of travel more and more convenient, but the occurrence of traffic accidents is more and more frequent. The number of deaths caused by traffic accidents every year is shocking. As a very important means of transportation in modern society, with the development of transportation in modern society, the incidence of traffic accidents is also increasing year by year. Traffic accidents have become a problem to be solved all over the world. As the speed of the highway is very fast, once the accident happens, the situation will be extremely serious. In order to ensure the safety of driving on the highway, automobile anti-collision system plays an important role. Automobile anti-collision measures are divided into active preventive measures and passive protective measures. The common passive protective measures are safety belt, air bag, etc. The active preventive measures are mainly automobile anti-collision system. According to the data released by the transportation department, it is found that the application of automobile anti-collision system can greatly reduce the probability of traffic accidents. The common automotive anti-collision systems are ultrasonic, passive infrared, anti-collision radar, etc. Although the cost of ultrasonic and passive infrared is low, they are easily affected by weather conditions and other external factors. The infrared response time is very long, which can not play a role of warning the driver. So the research of
automobile anti-collision radar is one of the hot spots among automobile manufacturers, which has great practical significance and economic benefits[1].

Considering the reflection of the scattered signals of different parts of the target by the environment such as ground objects, radar targets provide rich scattered signals in different scattering directions. The signal received by the radar is the superposition of various signals. It has similar characteristics to angular expansion, so the signals received by two receiving antennas spaced apart at a certain interval can be independent of each other. In addition, the radar target has obvious flicker characteristics. Small changes in the attitude and direction of the radar target will cause severe fluctuations in the radar echo, which can reach 10-25dB. The fluctuation of this echo signal is very similar to the signal fading of mobile channels, which will seriously affect the detection performance of conventional radars. It can be seen that radar echo signals have certain characteristics similar to mobile communication channels. The concept of MIMO has been deeply studied in mobile communications, it is an interesting attempt to solve the problems of radar signal reception and target detection.

The traditional vehicle anti-collision radar system has the disadvantages of mutual interference and slow search speed in the use process. In addition, in the complex traffic environment, the traditional radar has high requirements for the stability of the system front-end frequency, the dynamic range of the receiver, the system spurious, and the phase noise. The above problems make the design of traditional radar system extremely complex. MIMO radar is a new type of radar, which is developed in recent years. Each transmitting antenna can produce different isotropic detection signals at the same time. These characteristics make the MIMO radar have a larger detection range, which can basically cover the dead angle of the previous vehicle borne radar; it has a stronger anti-jamming ability, which makes the vehicle borne anti-collision radar work well in more and more complex traffic environment; it has a stronger weak target detection ability; it enables the car to detect the emergency earlier, and the driver can have a more sufficient response time to avoid danger. It has better dynamic target display ability. This makes the application of MIMO radar to vehicles become a research hotspot[2].

2. Design and Simulation of MIMO radar quadrature phase coded signal

2.1 The basic principle of genetic algorithm
As we all know, when we optimize the solution of a problem, we usually need to determine the objective function, feasible solution space, initial solution and other elements. Guided by the objective function, the optimal solution is searched in the feasible solution space. When genetic algorithm is used to solve the problem, the solution of the problem is composed of "chromosomes", that is, individuals. The solution space of the problem is composed of several individuals to form a group or to become a group (all possible solutions). At the beginning of genetic algorithm, the initial population (initial solution) can be randomly generated in the population that meets the existing conditions or can be obtained by other optimization algorithms. Then, the initial population will be selected by nature according to the principle of survival of the fittest and survival of the fittest (size of objective function value). Individuals with strong adaptability (good objective function value) will be preserved, and they will be regarded as the parent generation, and the population (current solution) will be updated by recombination through crossover and variation. Because the individuals in this generation inherit some excellent characters of the previous generation, they are better than the previous generation in performance. In this way, good characters can be accumulated from generation to generation, so as to find the optimal solution[3].

2.2 The basic principle of hybrid genetic algorithm
Hybrid genetic algorithm (HGA) refers to that after the traditional genetic algorithm runs, the optimization result of the traditional genetic algorithm is used as the initial value in the new algorithm, and then the new algorithm runs to get the final optimization result. Its purpose is to optimize the local minimum points that have fallen into a relatively bad state to a relatively good local minimum point or minimum point. The first step is to set the parameters of traditional genetic algorithm, such as
crossover rate, mutation rate, population size, evolution algebra and so on. The second step is to run the traditional genetic algorithm to get the proper solution and the optimal population. In the third step, the optimal solution obtained by the traditional genetic algorithm is used as the initial solution of the new algorithm. The fourth step is to run the new algorithm to see whether the optimal solution is due to the current solution. If it is better than the current solution, the optimal solution is used to replace the current solution and update the most population. If the optimal solution is not due to the current solution, the current solution is kept unchanged and the optimal species group is kept unchanged[4].

2.3 Implementation of hybrid genetic algorithm
The minimum cost function is a nonlinear multivariable NP problem. Hybrid genetic algorithm is used to optimize the coding sequence in this paper. The next step of the hybrid genetic algorithm is to continue to optimize the design results with the optimization algorithm function. The optimized phase sequence is substituted into the optimization algorithm function as the initial value. If the fitness function is worth the optimization, the sequence result is updated. When the fitness function value no longer changes, it stops running and outputs the corresponding optimization sequence value. Step 1: initialize the population (randomly generate population S0). Set the coefficient factor manually according to the design requirements. For example, if the autocorrelation sidelobe and the cross-correlation peak are equally important, we can construct W1 = 1w2 = 1 first, so we may as well give w = [1, 1, 1, 1]. Step 2: substitute the initial phase sequence value and coefficient factor into the cost function), calculate the function value to select the individual in the population that makes the cost function value optimal, update the coefficient factor W, because the order of magnitude generated by each part of the cost function is different, the update coefficient factor reaches the order of magnitude of eliminating each part of the cost function. Later, the coefficient factor W is updated according to the optimization requirements. Step 3: select the population, mainly using roulette selection algorithm. Step 4: Cross and mutate the selected excellent individuals to produce new individuals. The cross rate was 0.95 and the variation rate was 0.035. Step 5: terminate the operation when the fitness function (cost function) reaches the optimum(Fig. 1)[5].

Fig. 1 MIMO Technology

3. MIMO waveform design for automotive anti-collision radar
Millimeter wave radar is one of the indispensable sensors to realize intelligent driving and further automatic driving. Compared with ultrasonic, image, laser and other detection methods, millimeter wave radar has its own advantages, such as good adaptability to the environment, its measurement accuracy is less affected by severe weather factors such as rain, snow, fog, etc., and its cost is relatively low, so it has a good market prospect. In order to ensure the safety of driving, the millimeter wave radar is required to measure the distance, angle and speed of multiple targets simultaneously and accurately, so the measurement accuracy and resolution are put forward higher requirements. Classical radar theory points out that the range resolution of radar system depends on the frequency bandwidth of the signal used. Therefore, compared with 24GHz, more and more manufacturers choose 77GHz with wider available frequency band, and the working waveform is mainly LFMCW. Doppler resolution can be improved by increasing the time of measurement accumulation. The angle resolution depends on the beam width, which is proportional to the wavelength of the transmitted signal and
inversely proportional to the equivalent aperture of the antenna; under the same equivalent aperture, the 77GHz radar has a narrower beam width than the 24GHz radar, so that a higher angle resolution can be obtained\cite{6}.

Multiple input multiple output (MIMO) radar can effectively increase the virtual aperture of the antenna, so it is gradually used in the automotive anti-collision radar. For MIMO radar, all waveforms in the transmitted waveform set are required to be orthogonal, that is, to have the lowest cross-correlation level possible, and to have a lower autocorrelation sidelobe and a higher Doppler tolerance. In other applications, a variety of MIMO radar waveform design schemes have been proposed, such as frequency coding waveform and phase coding waveform. The former includes sub pulses with different carrier frequencies, while the latter includes sub pulses with different initial phases. In the automotive radar, when only two transmit antennas are configured, the ideal transmit waveform scheme is: one antenna transmits LFM sawtooth wave with up frequency modulation, while the other antenna transmits LFM sawtooth wave with down frequency modulation; the cross-correlation level between up and down frequency modulation signals is determined by the time bandwidth product of the signal. However, if the number of transmitting antennas is more than two, the scheme is no longer desirable. According to the above requirements, a new design scheme of MIMO radar waveform is proposed in this paper. Firstly, the time-frequency characteristics of the designed waveform are described, and then the range velocity map and range Doppler map after signal processing are given through simulation experiments, which verify the effectiveness of the scheme\cite{7,8}.

4. Conclusion
The application of MIMO radar technology in vehicle anti-collision radar can improve its anti-jamming capability in increasingly complex traffic environment. Compared with traditional radar, the performance of MIMO radar is waveform diversity. This paper mainly focuses on the orthogonal waveform design, one of the key technologies of MIMO radar, and the problem of radar pattern. In this paper, based on genetic algorithm, hybrid genetic algorithm and convex optimization method, the cost function and constraint function of waveform design and pattern suppression are modeled and improved, and several factors that affect waveform design and pattern suppression are simulated and analyzed. In the background of wave shape design and pattern suppression, the intercept error model of floating-point number is established.

ACKNOWLEDGMENTS
This research was supported by Guangdong Young Innovative Talents Project (NATURAL SCIENCE) under Grant No.2018GkQNCX101.
References
[1] Peng Zhangyou, Zhu Jinghua, Ma Xiaoying, et al. Estimation method of arrival angle of MIMO reflection wave in anti scratch radar [J]. Electronic measurement technology, 2017, 40 (9): 99-103.
[2] Shen Yafei, Yin Yang, Bai Jie. Application of compressed sensing in space domain in vehicle borne radar target location [J]. Journal of Tongji University (NATURAL SCIENCE EDITION), 2017, 45 (z1): 43-46, 62.
[3] Jiang Haitao, Bai Jie. Application of digital beamforming in vehicle borne millimeter wave radar [J]. Journal of Jiamusi University (NATURAL SCIENCE EDITION), 2018, 36 (1): 111-113130.
[4] Li Hui, Chen can. A multivariable system identification method and its application in evaporation process [J]. Computer engineering and application, 2016, 52 (12): 221-226.
[5] Jiang Panpan, Dou Dongdong, Zhu Shilei, et al. Multi antenna group parallel detection algorithm based on QRD-M [J]. Application of electronic technology, 2013, 39 (6): 92-95, 99.
[6] Tian Zhiling. 5g technology and test and measurement challenges [J]. Computer fan, 2018, (35): 139.
[7] Sadi. MU-MIMO technology applied to Wi Fi to innovate and optimize spectrum utilization [J]. Integrated circuit application, 2014, (5): 16-16.
[8] Chen Ming, Li shaolei, Yan Hui. Modal test technology under MIMO test system [J]. Automotive engineer, 2012, (11): 32-34.