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RESEARCH ON APPLICATION OF TRAFFIC INFORMATION COLLECTION BASED ON MILLIMETER WAVE RADAR

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ABSTRACT

This paper proposes a new type of traffic information collection equipment—millimeter wave radar based on ground sensing coils, video detection, microwave detection and other traffic collection equipment; the purpose of the research is to collect road traffic information parameters at intersections through millimeter wave radar. , Such as traffic volume, traffic flow density, time average speed, interval average speed, headway time, vehicle queue length, etc.; introduced the working principle of the frequency modulated continuous wave (FMCW) millimeter wave radar traffic monitoring system modulated by triangle wave, using the Doppler effect to get The speed of the vehicle; the speed-distance formula and the combination of numbers and shapes are used to obtain the queue length of the vehicle; the triangular wave radar can detect the position information of multiple vehicles at the same time, and can obtain real-time traffic volume and traffic flow density; use the speed of a single vehicle and The position information of multiple vehicles can obtain time average speed, interval average speed, headway time and other parameters; compared with existing research, the results obtained in this paper have certain practical significance.

KEYWORDS: FMCW Millimeter Wave Radar, Doppler Frequency, Traffic Information Parameters.

1. INTRODUCTION

Common data collection methods include coil, microwave, ultrasonic, video, vehicle GPS, electronic tags, etc. [1-3]. Xiaodong Zhang et al. used a video monitoring system to set a virtual "vehicle detector" on the display to complete the collection of dynamic traffic parameters [4]; Zuo Zhang et al. analyzed the data collection standards and The characteristics of trajectory data, the collected information is stored in the form of snapshots, and the processing methods of trajectory data are: single vehicle trajectory reconstruction, full-time-space trajectory reconstruction, microscopic and macroscopic traffic parameter extraction, etc. [5-6]; Fangyu Wu et al. use high-space-time The resolution panoramic camera tracks and shoots dynamic vehicles. The general process of the camera extracting vehicle trajectory data is: background estimation, object recognition, object tracking, and noise reduction. Free-flow traffic and phantom traffic waves in specific environments are studied [7]. Weifeng Xu et al. introduced the fusion collection method of automobile electronic sign collection, video and coil, and ERI-based traffic parameter acquisition methods, and proposed data acquisition methods such as section flow, interval speed, and OD traffic [8-9]. Ping Wang et al. used the toll data of the highway toll network system to predict the unknown traffic volume of the specified road section cross section. The specific method is: first obtain the average driving speed of the vehicle on the shortest path, and then estimate the driving time of each road section, And finally get the historical traffic volume of the designated road section [10]. Haiqiang Liu et al. obtained traffic queuing characteristics based on the temporal and spatial driving status information of CVIS intelligent vehicles, and used a Markov model to estimate the number of queuing vehicles at critical parking times[11]. This paper proposes a new technical method, using Frequency Modulated Continuous Wave (FMCW) millimeter wave radar to collect traffic information and obtain real-time traffic parameters in the monitoring area.

2. OVERVIEW OF RADAR TRAFFIC MONITORING SYSTEM

Radar is also called a radio detection and ranging system. Radar consists of four parts: antenna (transmitting antenna and receiving antenna), signal processor, terminal display device, and servo system. It has detection range,

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speed, angle and target shape information. And other functions. The antenna has the function of transmitting signals and receiving echoes. The basic components of the radar are shown in Figure 1.

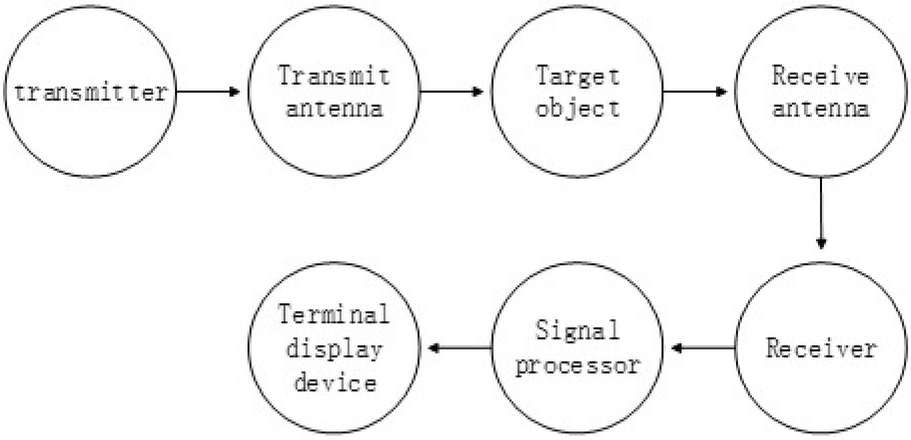

Figure 1. Basic components of radar.

Generally speaking, electromagnetic waves with a wave length of 1-10mm are called millimeter waves. According to the difference of electromagnetic wave radiation methods, millimeter wave radars are divided into two types, pulse system and continuous wave radar; continuous wave radar can be divided into: CW constant frequency wave Radar, FSK frequency shift keying wave radar, FMCW frequency modulation wave radar, CW radar can only be used for speed measurement, FSK radar cannot measure multiple targets at the same time, and cannot meet the requirements in the process of traffic information collection.

FMCW millimeter wave radar can design internal circuits, set relevant parameters such as frequency modulation and antenna control according to specific needs, and select an integrated transceiver antenna or other forms of antenna, which can ensure the accuracy of traffic information collection data[12-13]. FMCW millimeter wave radar mostly uses sawtooth wave and triangle wave modulation. Sawtooth wave radar can only measure distance in most cases. Triangle wave radar can measure distance and speed at the same time, and can track the target continuously, and is not susceptible to interference from other clutter, The system has high sensitivity and other advantages [14].

3. WORKING PRINCIPLE OF FMCW RADAR TRAFFIC MONITORING SYSTEM MODULATED BY TRIANGLE WAVE

The working principle of the triangular wave modulated FMCW millimeter wave radar is: first a constant voltage is delivered from the power supply, adjusted to different power outputs by an oscillator (VCO), the triangular wave pre-adjuster roughly outputs continuous triangular wave power, and then the triangular wave modulator output Stable continuous triangle wave power. At this time, the triangle wave power is small. After transmission, the received echo signal power is smaller, which is not conducive to detecting the echo. Therefore, the RF signal power needs to be amplified by the RF power amplifier. Radio frequency signal is emitted. When the radio frequency signal encounters the detection object, an echo will be generated. The equipment that receives the echo detection target signal is the receiving antenna, which filters out some abnormal clutter through the filter to protect the received echo signal. The frequency of the received signal is relatively small, and the power of the received signal needs to be amplified by a high-frequency amplifier. In the mixer, the high-frequency echo signal is mixed with the local oscillator voltage, and after the mixed signal is obtained, the echo signal frequency is reduced to the intermediate frequency. The clutter is filtered out through the filter, and the intermediate frequency signal is amplified by the intermediate frequency amplifier in order to obtain a relatively large output signal-to-noise ratio. After that, the required intermediate frequency echo signal is obtained through the detector and AD sampling, and then the signal is processed. The intermediate frequency signal is visualized by the video amplifier, and finally

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displayed on the display device for easy observation. Through this entire process, FMCW radar completes the process of transmitting signals and receiving echoes, and after signal processing, obtains the data information of the detection target. The working principle of the FMCW millimeter wave radar modulated by the triangle wave is shown in Figure 2.

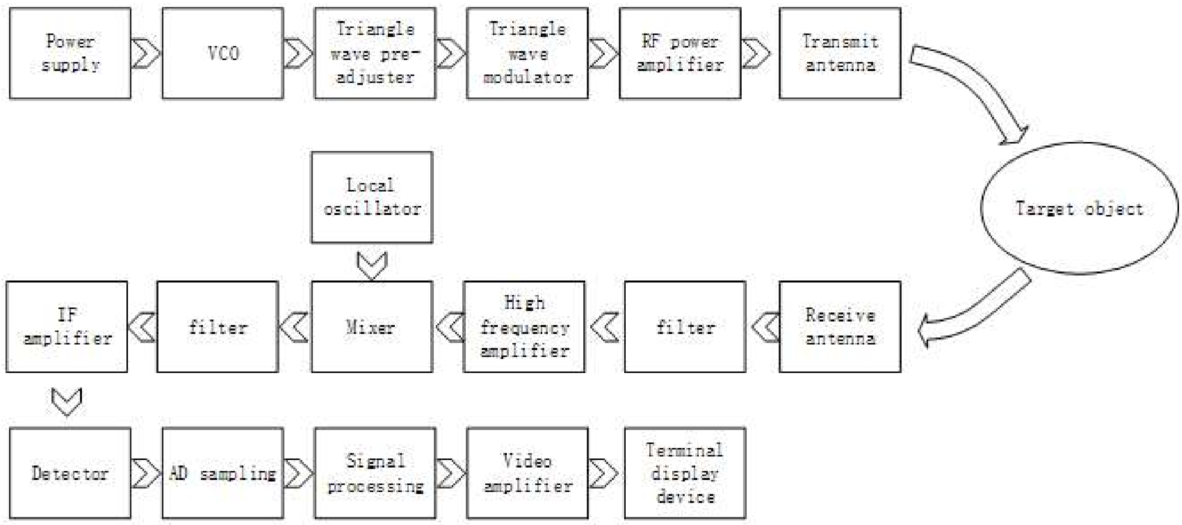

Figure 2. Working principle diagram

4. COLLECTION METHOD OF TRAFFIC PARAMETERS

(1) The method of radar speed measurement [15]
Radar emits signals by emitting electromagnetic waves. After encountering obstacles, reflections occur. After a period of time, the radar can receive the reflected signals.

The expression of the transmitted signal is:

$$S_t(t)=l\sin(2\pi f_0 t+\varphi) \tag{1}$$

The expression of the received signal is:

$$\begin{aligned} S_r(t)&=lS_t(t-t_r) \\ &=l\sin(2\pi f_0(t-t_r)+\varphi) \end{aligned} \tag{2}$$

Due to:

$$ct_r=2(R_0-V_r t) \tag{3}$$

And so:

$$S_r(t)=l\sin(2\pi f_0(t-\frac{2(R_0-V_r t)}{c})+\varphi) \tag{4}$$

$$\begin{aligned} \alpha &= 2\pi f_0(t-\frac{2(R_0-V_r t)}{c})+\varphi \\ &= 2\pi f_0 t+\frac{4\pi f_0 V_r t}{c}-\frac{4\pi f_0 R_0}{c}+\varphi \end{aligned} \tag{5}$$

$$\frac{d_\alpha}{d_t} = 2\pi f_0 + \frac{4\pi f_0 V_r}{c} \tag{6}$$

Due to:

$$S_r(t) = 1\sin(2\pi f_1 t + \varphi) \tag{7}$$

And so:

$$2\pi f_1 = 2\pi f_0 + \frac{4\pi f_0 V_r}{c} \tag{8}$$

$$f_1 = f_0 + \frac{2 f_0 V_r}{c} = f_0 + \frac{2V_r}{\lambda} \tag{9}$$

From this, the radial speed of the object detected by the radar can be obtained, and then the traveling speed of the vehicle can be obtained, which is the horizontal speed.

(2) Calculation of traffic volume
In the radar monitoring area δ, the usually set monitoring area is a rectangular area, and all driving vehicles can be detected at the same time.

$$Q_1 = \sum_{i=1}^{n} q_i \tag{10}$$

The traffic volume detected in unit time m is:

$$Q = \sum_{i=1}^{m} Q_i \tag{11}$$

(3) Calculation of area density of traffic flow
Traffic flow density refers to the number of vehicles per unit length on the road at a certain moment. The surface density of traffic flow refers to the number of vehicles in a unit area of a road at a certain moment.

In the radar monitoring area δ, the surface density of traffic flow is:

$$\rho_q = \frac{\sum_{i=1}^{n} q_i}{\delta} \tag{12}$$

(4) Calculation of time average speed
In the radar monitoring area δ, the speed of all vehicles can be detected.

$$\overline{v_t} = \frac{\sum_{i=1}^{n} v_i}{n} \tag{13}$$

(5) Calculation of interval average speed
The interval average speed is the ratio of the total distance traveled by all vehicles to the total time traveled by all vehicles in the radar monitoring area.

$$\overline{v_s} = \frac{\sum_{i=1}^{n} v_i t_i}{\sum_{i=1}^{n} t_i} \tag{14}$$

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(6) Calculation of headway
In the radar monitoring area, the radar can leave the driving track of the detected vehicle in the front-end display device during the detection of the vehicle. Because the lanes are clearly divided at the urban road intersection, the vehicle basically moves in the same straight line, so it is easy to detect and record.

At a certain time t_1, the driving position of a certain driving vehicle on the entrance road is recorded as P, and the time when the following vehicle travels to this position is t_2. Therefore, the headway of the two moving vehicles is:

$$\Delta t = t_2 - t_1 \qquad (15)$$

(7) Calculation of vehicle queue length
Calculation of the length of the vehicle queue, that is, when the red light at the intersection is on, the calculation of the length of the vehicle queue on the lane. In the case of ensuring that the queue length of an intersection will not affect the normal driving of vehicles at the adjacent intersection, the radar can detect the vehicles in the entrance lane, and it can be displayed on the display device. Suppose the number of closely connected vehicles is N. In this convoy, the radar detects the distance R_1 from the first vehicle in the convoy and the distance R_2 from the radar to the last vehicle to judge the length of the queue of the convoy waiting to park.

As shown in Figure 3 below, let O point be the radar installation position, B and C are the positions of the first and last vehicles in the fleet, and the distance of OA is a fixed value.

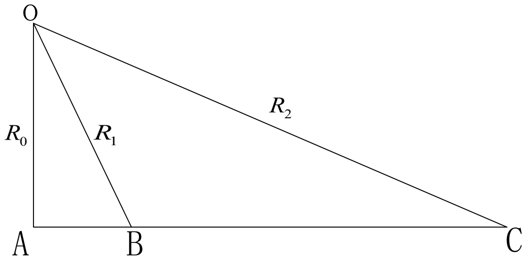

Figure 3. Geometric structure.

The calculation formula of radar distance is:

$$2R = \mathrm{c}t \qquad (16)$$

$$R_1 = \frac{\mathrm{c}\Gamma_1}{2} \quad R_2 = \frac{\mathrm{c}\Gamma_2}{2} \qquad (17)$$

Γ_1 —The time required for the radar to return to the radar after launching to B;

Γ_2 —The time required for the radar to return to the radar after it is launched to C.

The distance of AB and AC is:

$$l_{AB} = \sqrt{R_1^{\,2} - R_0^{\,2}} \qquad (18)$$

$$l_{AC} = \sqrt{R_2^{\,2} - R_0^{\,2}} \qquad (19)$$

Therefore, the distance of BC is the length of the queue of vehicles:

$$l_{BC} = l_{AC} - l_{AB} \qquad (20)$$

5. CONCLUSION

FMCW millimeter wave radar has the advantages of all-weather, unaffected by harsh environment, light, temperature, etc., light weight, and low price. Therefore, FMCW millimeter wave radar is applied to the collection of traffic information at intersections will gradually become a trend. This article mainly studies the composition

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of the radar monitoring system, the working principle of the FMCW millimeter-wave radar with triangular wave modulation, and the method of traffic information acquisition, and obtains real-time road traffic information parameters. Compared with the existing research [4], the results obtained in this paper are reliable.

(1) According to the characteristics of the triangular wave radar that can detect multiple target positions at the same time, the real-time traffic volume in the detection area can be known, and then the traffic flow density can be calculated; at the same time, the headway data can be obtained;

(2) According to the speed-distance formula and the combination of number and shape, the length of the vehicle parking queue at the intersection can be obtained;

(3) After detecting the driving speed of each vehicle, the time average speed and interval average speed in the detection area can be obtained.

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