Millimeter Wave Radar for Automotive Blind Spot Detection System

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Abstract. Considering the problem of rearview mirror blind spot during driving, the paper studied and designed the blind spot detection system based on MMW radar. Radar was installed at an appropriate position on the detection target signal by transmitting, when another car enter the detecting area, the small alarm light beside A pillar would shine or alarm few times, to remind drivers careful change road. And the effect would not effect by weather or time. For the radar sensor application environment, triangle wave LFMCW can effectively solve the speed from the coupling phenomenon. The paper showed experimental and simulation data.

Introduction

Fast, comfortable and safe transportation concept had become the development principle of the field of transportation. The field of transportation had become a carrying artery social development. A variety of means of transport had become a social and economic development of ties\textsuperscript{[1]}. Automobile as the primary means of transport and traffic had become an indispensable part of social life. With the development of China's highways and increasing car ownership, the number of traffic accidents was on the rise. According to the national accident statistics and analytic report\textsuperscript{[2]}, the three aspects of the driver, the vehicle and the road, the driver was the reliability of the worst factors. Driver negligence, drunk driving, speeding, driver fatigue and misjudgments human factors were a direct result of traffic accidents incentives. Another analysis also showed that if the driver was in the 1-2 seconds before the accident, aware of the danger, the vast majority of accidents were avoidable. Therefore, to reduce traffic accidents should strive to improve the reliability of the driver from the start, on the one hand, to strengthen the awareness of road safety with the necessary driver assistance and active collision detection system to improve traffic safety.

Blind Spot Detection System

Automotive blind spot generated from that left side mirror could supply about 12°view and right side mirror could only supply about 5°view. Inner back mirror could only supply about 20°view. So there were blind spots of 37° blind spot when you're driving. In this case, it would cause fatal car accident if you are changing road and passing car.

Blind spot detection (BSD) is a vehicle active safety technology that can detect pedestrians or other vehicles in the vehicle blind spot, and the presence of the driver's risk factors through the alarm, so as to effectively reduce traffic accidents. Get surroundings through the vehicle detection system and target information. Alarm and control in accordance with the evaluation criteria and adjustment requirements. Avoid traffic accidents caused by driver’s fatigue, negligence, misjudgment. The BSD sensors used in the car are mainly laser radar sensors, ultrasonic sensors, infrared and video CCD sensor, millimeter-wave radar sensor.

Millimeter-wave frequency is about 30GHz-300GHz wavelength range between 1-10mm, the millimeter waveband between microwave and infrared. Millimeter wave band had a long study, but has not been given sufficient attention. Later, people recognize the infrared and visual systems
insurmountable difficulties, especially smog and dust environment, microwave band overcrowded, and the beam width, antenna size. Gradually, it got re-awareness and attention to the millimeter waveband. Nineties was a period of rapid development of millimeter-wave technology, and achieved great success in military applications, and precision-guided and interstellar communication. Subsequently converted to civilian markets, as the representative of automotive collision avoidance radar and wireless communications.

The Radar Sensor Design

BSD's radar sensor is for short-range target detection. Due to the poor environment of the use and affected by the roads, fence, trees and traffic signs, the system must have a strong anti-interference ability and very low false alarm rate. At the same time, taking into account the characteristics of the application environment, radar sensors should be of small size, simple structure, low power consumption, and high reliability.

**Work System.** Continuous Wave Radar was used in this paper. Relative to the pulse radar system, continuous wave radar system continuously emits electromagnetic waves, equivalent to 100% duty cycle pulse radar system. Continuous Wave Radar echo, while receiving the transmitted waveform, so there is no blind near zone. Since the emission and receive simultaneously, the continuous wave radar system require separate transmit and receive antennas.

**Work Frequency.** For the field of traffic safety radar sensors, 24GHz or 77GHz millimeter wave band corresponding to the radar antenna area is smaller, high Doppler frequency. Therefore, the millimeter wave band of the antenna size is more suitable to be installed on an automobile.

**Work Waveforms.** Typical continuous wave radar waveforms including: frequency modulation waveform and phase modulation waveform. Triangle wave frequency modulated continuous waveform can achieve better application results in a single target environment. The working principle of the LFMCW radar coherent mixer with a part of the echo signals and transmitting a signal is used to obtain the intermediate frequency signal of the target distance and speed information. Hit the target object when the target object is relatively static, the transmitted signal after reflection back, resulting in the echo signals. The echo signal is the same as with the shape of the transmission signal, but delayed in time of \( \tau = 2R/c \). R is the distance to the target object. \( c \) is the speed of light.

![Fig.1 LFMCW radar stationary target echo signal](image)

The frequency difference of the transmission signal and the echo signal is the frequency of the mixer IF output signal. According to the relationship of similar triangles, formula (1) can be obtained by Fig.1 (a).

\[
\frac{\tau}{f_0} = \frac{T/2}{\Delta F}
\]  

Where, T is the modulation triangular wave cycle, \( \Delta F \) is FM bandwidth. According to \( \tau = 2R/c \), we can get formula (2) by formula (1).
The following conclusions can be drawn from the above formula. IF is proportional to the signal frequency in the case of the modulation period T and the FM bandwidth determined target distance LFMCW radar front-end mixer output. This is the target object is the relatively static case LFMCW radar ranging principle.

When contained in the target object in the relative motion state, the echo signals reflected back from the moving object due to the movement of the target caused by the Doppler frequency shift, as shown in the Fig. 2.

According to Fig. 2, the rising and falling edges of the triangular wave frequency of the IF signal can be obtained as shown below.

\[ f_{b+} = f_0 - f_d \]  
\[ f_{b-} = f_0 + f_d \]  

Where, \( f_0 \) is the frequency of the IF signal in the target object is a relatively static, and \( f_d \) is the Doppler frequency shift. By the formula (2) and the Doppler frequency shift formula \( f_d = \frac{2f_v}{c} \), we can deduce the following formula.

\[ f_{b+} = \frac{4\Delta F R}{cT} - \frac{2f_v}{c} \]  
\[ f_{b-} = \frac{4\Delta F R}{cT} + \frac{2f_v}{c} \]  

By Equation (4) and Equation (5), we can calculate the distance and speed of the target expression as follows.

\[ R = \frac{cT}{8\Delta F} (f_{b-} + f_{b+}) \]  
\[ v = \frac{c}{4f}(f_{b-} - f_{b+}) \]

Although the above two formulas derived in a state of relative motion, but the same applies for a relatively stationary target in the target. Therefore, in practical application, regardless of whether the target is in motion or relatively stationary, as long as the modulation triangular wave are obtained separately in the rising and falling edge of the frequency of the IF signal, can take advantage of the above two formulas to calculate the target's distance and velocity information. This is LFMCW millimeter-wave radar ranging principle.
The Experimental Results

The radar test parameters are shown in Table 1.

| Parameter name | Radar parameters |
|----------------|------------------|
| $f_0$          | 76GHz            |
| $\Delta F$     | 500M             |
| $T$            | 1ms              |

Import sample data. Function call, the sample data import.

```matlab
function data = rd_txt(filename)
    fid = fopen(filename, 'r');
    data = fscanf(fid, '%f', inf);
    Calling the function as follows:
data = rd_txt('data115.txt');
```

Signals in time domain is shown in Fig. 3.

Data Analysis. Since the modulation signal is a triangular wave signal, the by sweep frequency analysis of the modulation triangular wave vertically up and down to sweep the IF signal frequency band, to thereby obtain the target distance and speed information. Therefore, the data can be divided into two parts for processing.

Windowed FFT transform. The beat signals do FFT, the IF spectrum of the beat signal, as shown in Fig. 4. Hamming window calls the following manner: win_ham = hamming (N); The experimental results shown in Fig. 5 after the call.

![Fig.3 Signals in time domain](image1)

![Fig.4 Signals in frequency domain](image2)

![Fig.5 Signals in frequency domain](image3)
The distance and the speed of the calculation target. Analysis were obtained by the spectrum above the rising and falling edge of the frequency of $f_{b+}$ and $f_{b-}$, the distance and speed of the target according to the formula (5) and (6) can be obtained.

Conclusions
From Fig. 3 and Fig. 5, it is concluded that the chirp triangle wave can accurately predict the target spectrum information. From Fig. 4 and Fig. 5, we can draw the to windowing processing effectively improve the accuracy and precision of the frequency domain signal a time domain signal of the radar, in order to optimize the spectrum information of the target.

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