논문 2011-06-36

Short Range Rear Obstacle Detector for Automobile Using 24GHz AM Radar Sensor

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Abstract : FMCW Radar sensor is commonly used for an automobile collision avoidance system for rider's safe. Systems using FMCW radar, however, would be one of expensive solutions for just simple rear obstacle detection purpose due to its high cost. In this letter, a short range rear obstacle detector using novel 24GHz AM radar sensor is presented. It can be implemented at significantly lower cost than FMCW radar for practical commercialization. The proposed AM radar sensor module is fabricated in a single aluminum housing to reduce the overall size while using single power supply voltage of 12V with 1200mA current for automotive applications. The measured detection range is up to 210cm with 10cm of distance resolution, which is suitable for a parking assistance system for automobiles.

Keywords : AM radar sensor, Rear obstacle detector, Vehicle parking assistance system

Ⅰ. Introduction

As the number of automobile is increased, the chances of accidents also increase significantly. TV and radios broadcast children's car accidence in daily news. When children play or sit in a blind spot, especially in the rear side of automobile, it's not easy for drivers to recognize the existence of children in the rear. To avoid these unwanted accident, a number of obstacle detector is being introduced [1].

Ultrasonic sensor is one of the most commonly used detectors for automobile, which is attached at rear bumper body. Due to the angular limit of ultrasonic sensors, at least four ultrasonic sensors are placed directly on the bumper [2]. For aftermarket users, at least four places on the bumper need to be drilled out, causing the increase in labor cost while aesthetically ruining the automobile.

Other alternative one is a detector using infrared rays. It is one of the cheapest solutions, but their performance declines under various weather conditions. Thus the detection range reduces significantly on rainy day due to the beam attenuation from raindrop.

Most reliable and universal solutions recently reported are FMCW radar sensor, and several makers release commercial products for automobile collision avoidance system recently [3-4]. In spite of its reliable performance, it usually costs over thousands of dollars, which is not affordable for most automobile owners.

In this paper, a short range rear obstacle detector using a novel 24GHz AM radar sensor is presented demonstrating the possibility of implementation of a reliable detector at low

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Manuscript received : 2011. 04. 13.,
Revised : 2011. 05. 06., Accepted : 2011. 06. 13.
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cost. Comparing the phase difference between a reference and a reflected signal from target, the module outputs a voltage level in proportion to the range to an obstacle. Using the output voltage, an alarm device can be activated to alert driver for obstacle being. AM radar can achieve the required selectability for rear parking assistance with two sensors at reasonable cost making it preferable choice over ultrasonic sensors for aesthetic purpose.

Ⅱ. Implementation of 24GHz AM Radar Sensor

1. Operational Principle

In order to detect an obstacle, transmitter module radiates an amplitude modulated signal to a target through transmission antenna, and the reflected signal from the obstacle is sensed at the receiver. Comparing the phase differences of the received signal with its original reference signal, the distance to the target can be calculated [5].

To generator a stable carrier of 24GHz frequency, a phase locked loop (PLL) was used. Amplitude modulation (AM) signals are being generated at AM modulator with the 10MHz TCXO reference, which is attached at bottom side of the module housing. The AM modulated signal is radiated to an obstacle through Tx amplifier and antenna with center frequency of 24.128GHz.

At the receiver section another PLL was used with a center frequency of 23.744GHz, which is apart from Tx carrier by 384MHz. The generated Rx carrier is mixed with the received signal at mixer stage, which results in 384MHz IF signal. Finally the received signal is demodulated using single ended mixer, and the detected signal is compared their phase differences with the reference signal.

2. Block Diagram

Fig. 1 shows the block diagram of proposed 24GHz AM radar sensor. The transmitter consists of PLO, AM modulator, reference signal using TCXO, and amplifier. The receiver consists of LNA, down mixer, PLO, and demodulator. To enhance the isolation between Tx leakage and received signal, which is very weak signal reflected from a target, a leakage cancellation circuit was used. Note that some part of the AM modulated signal is branched using power divider, and is used at leakage cancellation circuits at receiver. The circuit generates a signal with an opposite phase with respect to the leakage so that the leakage can be canceled to improve the detection range.

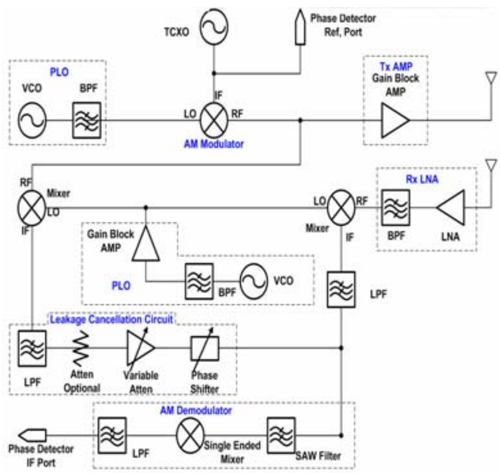


Fig. 1. Proposed 24GHz AM radar sensor block diagram

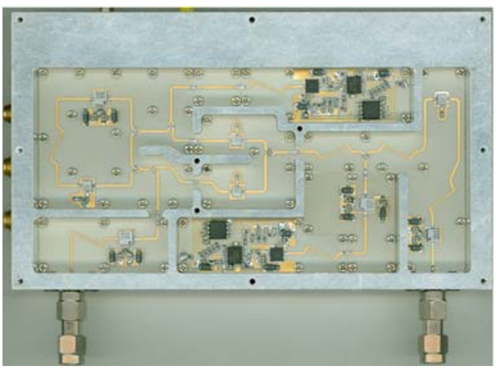
3. Implementation of AM radar sensor

Fig. 2 shows the photograph of implemented obstacle detector with its inside view. Transmitter and receiver are all designed using microstrip circuit on a single 0.4mm thickness of Teflon substrate with permittivity of 2.2. The designed module housing is divided by two layers internally. Upper layer is for RF circuit of 24GHz frequency range, and bottom layer is for IF circuits including demodulator, detector, leakage cancellation circuits, and voltage regulator circuits for power supply. For vehicle application, the module uses a single

12V power supply. For both effective radiation and reception, two 4 x 4 patch array antennas with 15dBi gain, beam width of 30 degree, and 34 mm x 36 mm size were designed and attached at Tx and Rx port respectively.

As a reference source, FOX924 TCXO from FOX Electronics with +/-1.5 ppm frequency stability was used to compare the phase differences with the reflected signal from an obstacle or target. To carry the modulation signal of 10MHz reference, 24.128GHz of phase locked oscillator was designed. Note that several metal walls are used to isolate each section not to interfere each other. Input and output ports are SMA(f) type coaxial connector, and the size of implemented radar sensor module is 143 mm x 82 mm x 24 mm.

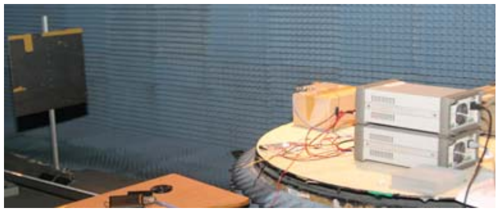
(a) Outside view



(b) Inside view

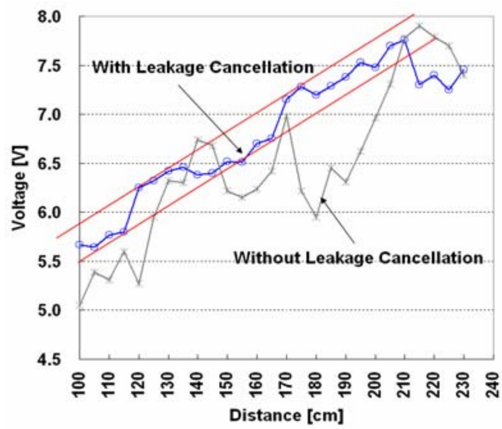
Fig. 2. Implemented obstacle detector using 24GHz AM radar sensor.

Ⅲ. Measurement Results



(a) Target reflector

(b) Measurement setup



(c) Measurement results

Fig. 3. Test setup and measurement results

Fig. 3 shows the test setup with flat rectangular metal reflector to verify the performances of the implemented 24GHz AM radar sensor as a short range rear obstacle detector for automobile application. The radiated Tx signal is reflected at the metal plate, and the reflected signal is sensed at the receiver. A phase detection circuit compares the phase difference of the demodulated signal with its original reference, and then, the module produces a voltage output in proportion to the distance, which represents the range to the target, or reflector.

The test was conducted moving the

reflector along to the straight line of path up to 230cm with every 5cm step, and its measured voltage output is depicted at Fig. 3. Without the leakage cancellation circuit, the measured result was fluctuated along to the distance due to the interference caused by the Tx leakage, which is relatively higher enough than the reflected weak signal what we want to detect. To solve the problem, the leakage cancellation circuit was used, and the interference was cleared effectively so the output voltage showed relatively linear characteristics up to 210 meters.

required to operate the designed radar module for practical automobile application.

The transmitted power is 10dBm, and the center frequency is 24.128GHz to meet the general regulation for an obstacle detector with modulation signal of 10MHz. The distance resolution is around 10cm, and the phase noise of Tx signal is less than -91dBc/Hz at 100kHz offset. DC bias of 12V/1200mA single power is required to operate the designed radar module for practical automobile application.

IV. Conclusion

In this paper, a low cost simple structured short range rear obstacle detector was presented using 24GHz AM radar sensor for automobile applications. Even though the FMCW type radar sensor is generally considered as a higher performance solution for automobile collision avoidance, it also makes things difficult for wide usages for most vehicles due to the higher cost. The implemented AM radar sensor has a detection range up to 210cm with 10cm resolution, which is sufficient performance for commercial products. The module uses a center frequency of 24.128GHz with less than 10dBm output power for general compliance of regulation so it is expected to be adopted in a parking assistance system for vehicle.

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