行政院國家科學委員會專題研究計畫　期中進度報告

子計畫三：汽車縱向防撞雷達技術研發(2/3)

計畫類別：整合型計畫
計畫編號：NSC91-2213-E-009-031-
執行期間：91 年 08 月 01 日至 92 年 07 月 31 日
執行單位：國立交通大學電信工程學系

計畫主持人：鍾世忠

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處理方式：本計畫可公開查詢

中　華　民　國 92 年 5 月 28 日

行政院國家科學委員會補助專題研究計畫 □成果報告 ■期中進度報告

智慧型車輛之控制感測與資訊處理技術研發-子計劃三

汽車縱向防撞雷達技術研發（2/3）

Development of A Novel Vehicle Longitudinal Collision-Avoidance Radar (2/3)

計畫類別：□ 個別型計畫　　■ 整合型計畫
計畫編號：NSC－91－2213－E－009－031
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計畫主持人：鍾世忠
共同主持人：
計畫參與人員：鍾卓如、陳南君、施俊仰、蕭智軒
成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

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中　華　民　國 92 年　5　月　13　日

中文摘要（**關鍵詞**：縱向防撞雷達、摺疊反射式陣列天線、窄波束、毫米波電路）

汽車防撞雷達（Collision Avoidance Radar , CAR）為全智慧型運輸系統核心組件之一，其目的在輔助人類感測能力的不足，利用先進的通訊與控制科技，偵測車輛週遭的動態狀況，以適時通知駕駛人採取必要措施。在各種防撞雷達中，縱向防撞雷達(longitudinal collision avoidance radar)在功能需求及技術水準上，均遠較其必他雷達為高，不只要能偵測物體的存在，其方位角、距離、速度、加速度等也須得知，方能在各種路況及車輛環境中應變，防止撞擊情況發生。為達到這些目的，其前端架構必須利用毫米波技術（訊號頻率在 30GHz 以上）實現，才可兼具高精確度、高可靠度及低成本的要求。

本計畫擬以三年時間設計完成一組毫米波縱向防撞雷達。雷達訊號的頻率定為 38GHz，採 FMCW(Frequency-Modulation Continuous Wave) 方式調變，以同時測距及測速。雷達主體包括毫米波天線、毫米波收發電路及 FMCW 控制電路等三部分。在本年度計劃中，我們完成了窄波束天線及前端電路關鍵元件的開發與整合。其中天線為摺疊反射式陣列天線，是由數百個微帶天線組成，有 25dBi 的天線增益，- 15dB SLL 的旁波束差，及 4.6 度的 3dB 波束寬。前端電路包含一 12.7GHz 微波源、12.7GHz-38GHz 三倍頻器、38GHz 濾波器、38GHz 分枝功率分配器、38GHz 功率放大器、及 RF-IF 降頻器。量測結果顯示，毫米波發射電路的輸出功率為 10.6 dB、接收端之轉換損耗為 7dB。

Abstract (Key words: Longitudinal collision avoidance radar, folded reflectarray, narrow beam, millimeter-wave circuits)

Among the various components of the advanced vehicle control and safety system in ITS, the collision avoidance radar (CAR) plays the key function, which utilizes the advanced communication and control technology to sense the environment so as to warn the driver of the potential hazard in his/her path. The CAR is generally grouped into three kinds, that is, the longitudinal CAR, the lateral CAR, and the backward CAR, in which the longitudinal CAR is a long-distance forward-looking radar and serves the most important role for preventing damage collision. This is because that this radar does not only sense the existence of the potential obstacles, but also detect the obstacle's relative directions, distances, and velocities. To achieve these requirements, the millimeter-wave (MMW) technology is the most promising technology to implement the longitudinal CAR due to both high reliability and high position resolution.

The goal of this project is to develop a MMW longitudinal collision-avoidance radar in three years. The radar operates at 38 GHz and adopts the frequency-modulation continuous wave (FMCW) for both distance and velocity

detection. Three major parts are included in the radar, i.e., the MMW antennas, the millimeter-wave transceiver circuits, and the FMCW circuits. In this year, a millimeter-wave (38.1 to 38.4 GHz) transceiver and folded microstrip reflectarray antenna with beam steering are developed for autonomous cruise control (ACC) radar applications. The transceiver has an output power of 10.6 dBm for transmitting and about 7dB conversion loss for zero IF receiving. The folded reflectarray antenna, which is composed of several hundreds of microstrip antennas, has the antenna gain of 25dBi, side-lobe-level of -15dB SLL, and 3-dB beamwidth of 4.6°.

1. INTRODUCTION

In a radar system, a radio signal is transmitted outward from a radar sensor. The radio wave then propagates through the surrounding media and is reflected back to the sensor by objects in its path. The distances and the relative speeds of the objects can then be determined from these echoes. Many different types of radars exist varying from the very basis to multi-million-dollar systems. The beauty of radar is that it allows extension of senses. Vision only works when the environment is lit and clear of smoke, clouds, snow etc. Radar allows one to see or detect objects in the dark or behind clouds or objects that are tens and even hundreds of miles away. In the automotive applications, many radar designs use FMCW technology. The front-end configuration of the radar sensor presented in the paper is suitable for the use of the FMCW technology and fills a niche in the vehicle radar sector.

2. DESIGN AND MEASUREMENT OF THE TRANSCEIVER

In order to design a radar system that is small and cost effective, the design process is broken into modules. The modules are designed individually using commercially available microwave design software (MWOffice 4.2) and then integrated together to form a front-end transceiver. Before assembly, each component is examined by the measurement.

The 38 GHz FMCW radar front-end sub-system presented here is a forward-looking, radar based, detection system for ICW application. Fig. 1. shows the system block diagram. It generates a FMCW waveform using a voltage-controlled oscillator by using a linearizer (frequency locked loop) to stabilize the RF frequency and improve system phase noise. The frequency of the coupled signal is compared to a low frequency linear sweep reference to generate an error signal, which corrects the VCO sweep rate. The 38GHz transceiver for FMCW radar was integrated with micro-strip line VCO and discriminator to form a frequency locked loop, which provide clean souse and high linear sweeping frequency. Fig. 2 to Fig. 4 show the photos of the finished transceiver circuits. The measured output power and conversion loss of the integrated transceiver are presented in Fig. 5 and Fig. 6, respectively. It is seen from Fig. 5 that the output power is around 10.6 dBm from 38.1GHz to 38.4GHz. Also from Fig. 6, it is observed that, for the receiver performance, the conversion loss is about 7 dB This implies that, without a low-noise amplifier (LNA), the noise figure is 7 dB. The performance is well agreement with the gain budget.

3. DESIGN AND MEASUREMENT OF THE ANTENNA

Fig. 7 presents the photo of the finished folded microstrip reflectarray. The antenna structure contains three parts: main-reflector, sub-reflector, and a feed antenna. The main reflector includes hundreds of microstrip antennas used to produce twisted re-radiated fields and provide phase compensation for focusing. The sub-reflector parallel with the main-reflector is made of a substrate printed with high-density metal grid, which is transparent to one polarization but would reflect the other polarization. The feed antenna is a microstrip patch antenna located on the main reflector. The position of this feed antenna is movable so as steering the radiation beam of the antenna. Measured results showed good agreement with the calculated ones. Fig. 8 illustrates the frequency of the measured antenna gain, which shows a maximum gain of 35.4 dBi at 39 GHz. Fig. 9 depicts the measured antenna patterns for different feed positions d. It is seen that the antenna has the antenna gain of 25dBi, side-lobe-level of -15dB SLL, and 3-dB beamwidth of 4.6°. As the feed position d changes from –4 mm to 4 mm, the beam scans over a range of 7.2°.

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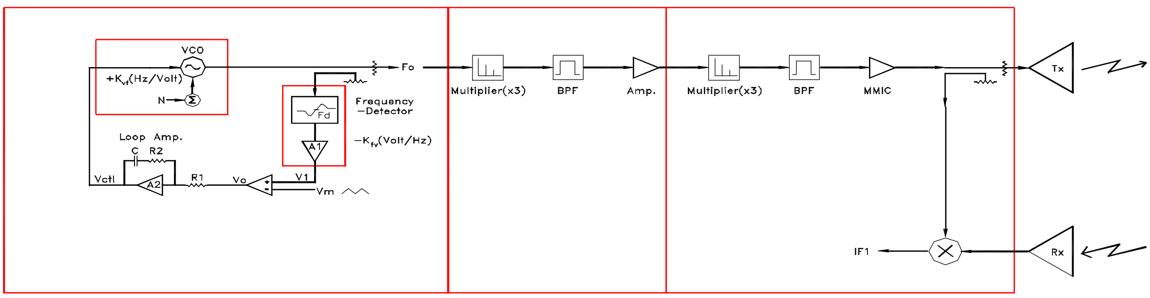

Fig. 1. Block diagram of the front end for FMCW forward-looking radar.

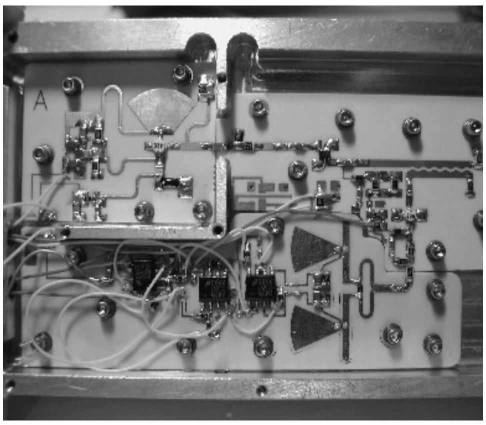

Fig. 2. Frequency locked loop of the 38GHz transceiver. Output frequency is around 4.25GHz.

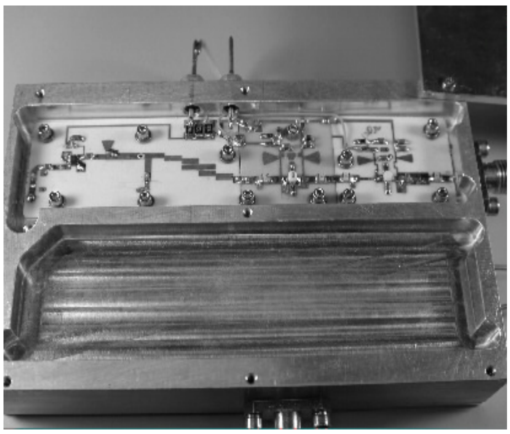

Fig. 3. Tripler and gain stage of the 38GHz transceiver. Output frequency is around 12.75GHz.

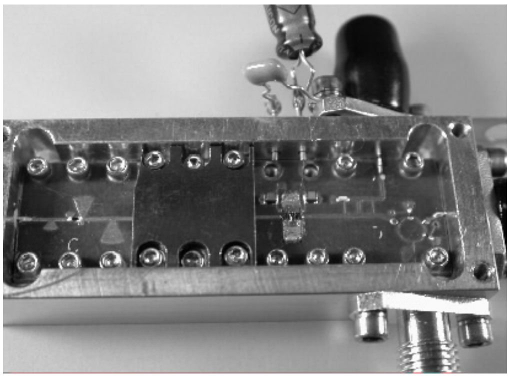

Fig. 4. MmWave module of the 38GHz Transceiver.

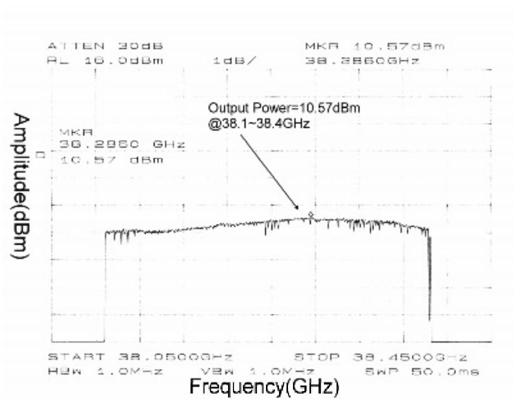

Fig. 5. Output power v.s. frequency for the transmitter.

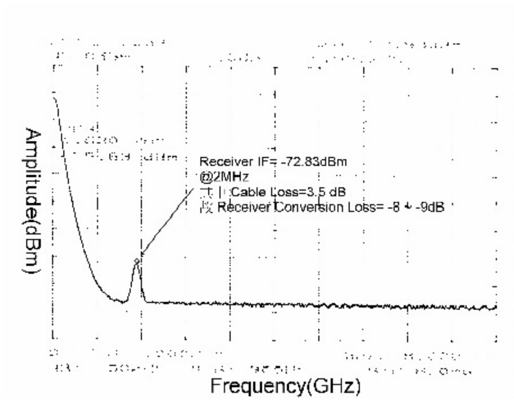

Fig. 6. Conversion loss for the receiver.

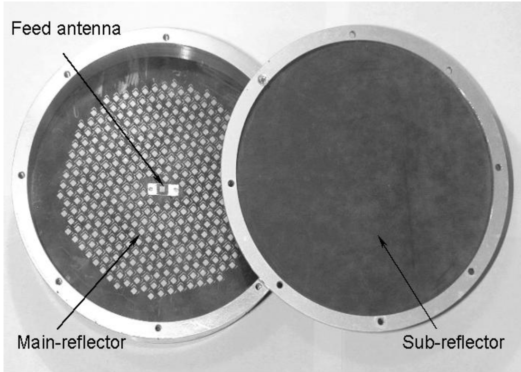

Fig. 7. Folded microstrip reflectarray antenna for the 38GHz radar sensor.

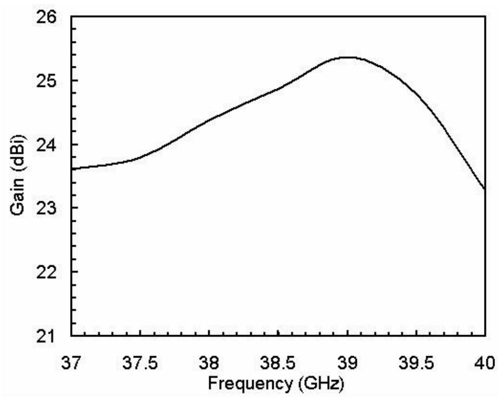

Fig. 8. Measured antenna gain, as a function of frequency, of the folded reflectarray antenna.

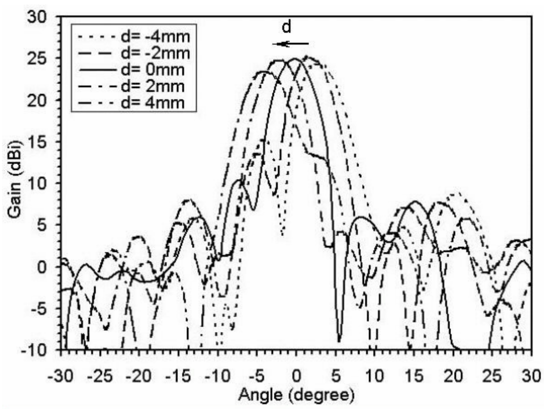

Fig. 9. Measured H-plane pattern of the folded reflectarray antenna.