Millimetre Wave RADARS for Automotive Applications

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ABSTRACT

This paper discusses recent developments in RADAR technology specifically in the Automotive area.

The concept of Intelligent Cruise Control ICC is introduced and the application of millimetre wave sensors is discussed.

FMCW and Pulse Coded RADARs are described and details of novel quasi-optical antennae and mixers are presented.

INTRODUCTION

Increasing traffic volumes bring congestion to cities and increased risk to motorway (freeway) drivers. Many automobile manufacturers now believe that Intelligent Cruise Control (ICC) Systems go some way to alleviating these problems and that high definition RADARs operating in the millimetre wave bands are the ideal distance sensors for these Systems.

The concept of producing mm wave distance measuring RADARs using both pulsed and Frequency Modulated Continuous Wave (FMCW) techniques is by no means new. REFs [1] [2]. The important change is the area of application and hence the pressure on technologists to conceive <u>LOW COST</u> techniques to enable vehicle mounted RADAR to become a production item.

Market information indicates that the term "Low Cost" means less than $500 selling price for a Sensor module operating at 77GHz having DC/Digital interfaces to the vehicle "Body Management" and "Engine Management" computers.

This paper will describe the work on various parts of the Sensor System that has taken place in order to meet the performance and production cost targets.

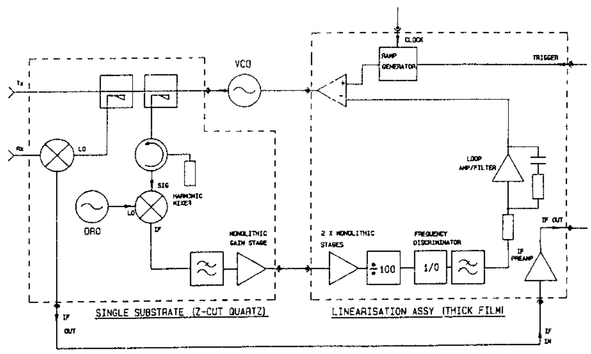
1. RADAR System Concepts

Two types of RADAR systems are currently being investigated for the ICC application.

1.1. FMCW RADAR

A schematic diagram of a linearised FMCW RADAR system is shown in Figure (1).

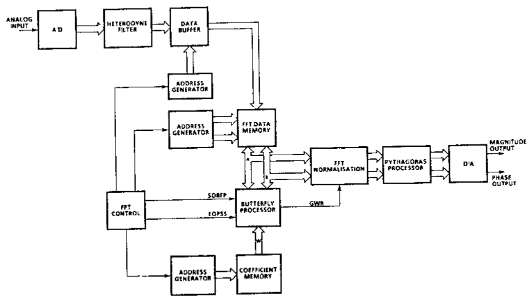
Figure 1
Linearised Transceiver Schematic



The RADAR measures range using the swept frequency technique see REF(3). The frequency sweep must be linear for accurate ranging and the RADAR makes use of "frequency feedback" to linearise the transmitter VCO.

The RADAR presents range information in terms of the frequency of the IF output of the transceiver mixer. A Fast Fourier Transform (FFT) frequency analyser system is used to convert the frequency data to a digital word which is fed to the ICC management computer. See Figure (2).

Figure 2 - FFT System

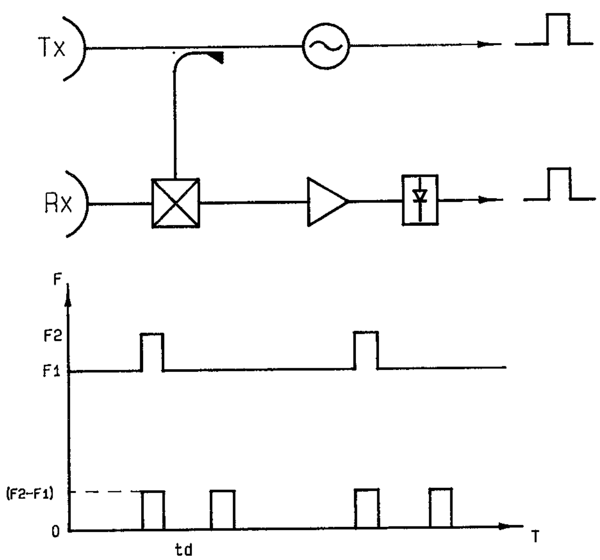


The FFT is realised as a Large Scale Integration (LSI) CMOS digital integrated circuit.

1.2. Pulse Coded RADAR

A very simple RADAR system has been developed which makes use of Pulsed Frequency Modulation (PFM) to measure range. See Figure (3).

Figure 3 - PFM RADAR



The oscillator frequency is pulsed from its rest value to a higher frequency for a very short time ≈20nS. Energy at the pulsed frequency is transmitted and reflected from a target. Some energy returns to the transceiver after a time delay $t_d = \frac{2R}{C}$

where t_d = time delay
R = Range to target
C = Speed of light

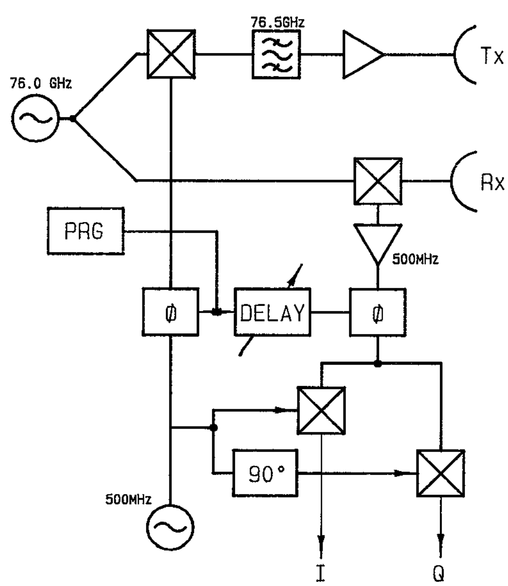
The received energy will be of the same frequency as it was during transmission (assuming a stationary target) but the transmitter has now returned to its rest frequency. An IF signal will therefore be produced where frequency will be the difference between the pulsed and rest frequencies of the oscillator. The IF burst will occur a time t_d after the transmit pulse and the range may be calculated by measuring this time delay.

This type of RADAR is very simple in construction and uses few millimetre wave components but it is very in-efficient since energy transmitted in the interpulse period is wasted; also the power transmitted is very low ≈10mW.

However tests have shown that the simple PFM RADAR is sensitive enough to detect a car 150m away in rain conditions.

A more sensitive but more complex system uses phase coding. See Figure (4).

Figure 4 - Phase Coded RADAR



A millimetre wave oscillator is used to drive an upconverter mixer, this is also fed with a VHF signal which is bi-phase modulated by a Pseudo Random Code Generator (PRG). The resultant output from the upconverter is therefore also bi-phase modulated. This signal is amplified and fed to the transmit antenna.

The receive antenna feeds a downconverter mixer whose Local Oscillator (LO) drive is derived from the millimetre wave oscillator. The Intermediate Frequency IF) output is amplified and fed to a bi-phase modulator which is driven with a delayed version of the Pseudo Random Code that drives the transmitter. The VHF output from the bi-phase modulator is fed to an In phase and Quadrature (I and Q) baseband detector System.

When the inserted delay is equal to the target delay t_d then maximum correlation occurs. The system may therefore be made automatic with the inserted delay being indexed by a controller which stops when correlation is at a maximum.

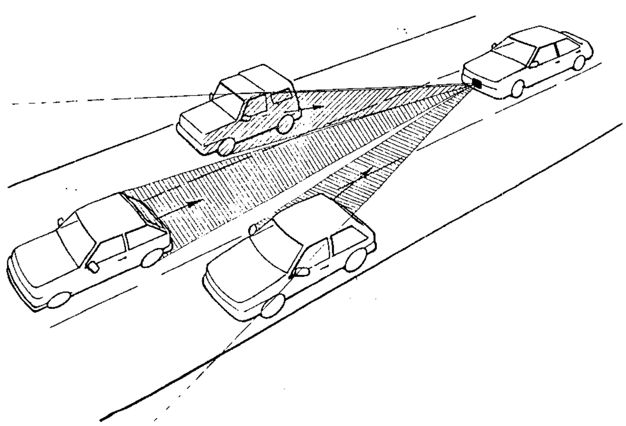
2. Antenna Design

Antenna systems for vehicle RADAR applications must fulfil various criteria.

a) Beamwidth

The antenna must be capable of discriminating vehicles in lanes in front of the RADAR equipped vehicle. It is not sufficient to illuminate the entire area ahead of the RADAR and the antenna must actually switch beams in order for the Sensor to build up a picture of the highway "scene". Figure (5).

Figure 5 - The Highway Scene

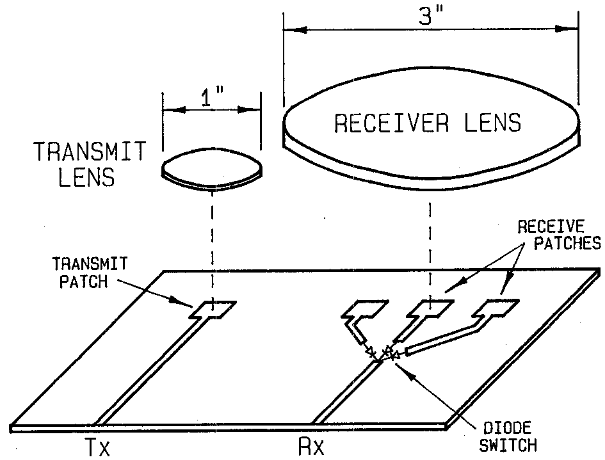


b) Cost

A beam switching antenna has been produced which uses quasi-optical principles in its design. No machined metal parts are required which makes the antenna suitable for high volume manufacture and offers the promise of low cost.

The Antenna is depicted in Figure 6.

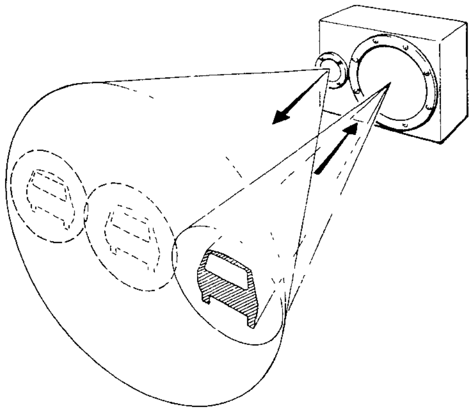
Figure 6 - Quasi Optical Antenna



Plastic Lenses (High Density Poly-ethylene) are mounted above patches formed on microstrip.

The small lens (1" diameter) forms a single beam approximately 10^{o} wide to flood the highway. The large lens (3" diameter) acts as the receiving antenna and focuses received energy onto one of three patches which may be selected to produce three receiver beams (each approximately 3^{o} wide) to scan the highway. Figure 7.

Figure 7 - Switched Beam Attenna



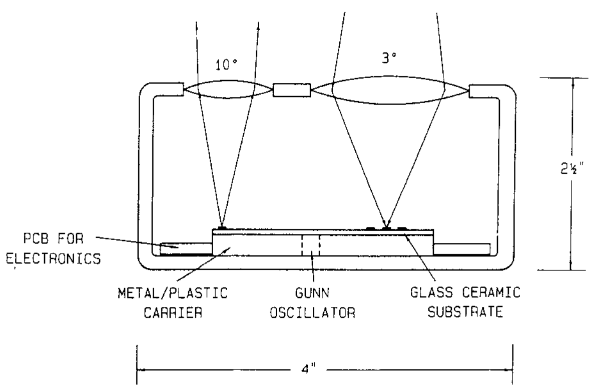
3. Millimetre Wave Circuits

All the RADAR systems described in this paper are very simple and use very few components.

All the millimetre wave circuits are built using conventional microstrip techniques.

A Cruise Control Sensor unit is being developed. See Figure 8.

Figure 8
Proposed Structure of Cruise Control Unit



The glass ceramic substrate carries all the functions required for FMCW or PFM RADAR operation i.e. patch antennae, balanced mixer, coupler and oscillator feed.

The Sensor uses an external Gunn effect oscillator at present but it is hoped that this may soon be replaced with a HEMT based planar source.

4. Conclusions

In order for millimetre wave RADAR to be used as a Sensor for Intelligent Cruise Control it must be designed to be affordable. The RADARs described in this paper together with the simple quasi-optical antenna system show that this is now a practical possibility.

REFERENCES

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[3] A Highly linearised mm-wave voltage controlled oscillator for FMCW RADAR applications. Proc. MIOP88 conference March 1988.