A MICROWAVE RADAR FOR VEHICULAR APPLICATIONS

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ABSTRACT

A Commercial Side Detection System (SDS) sensor based on microwave radar technology for commercial vehicular applications is introduced. The design, manufacture, and function of the SDS sensor are described. Some important aspects of the use of microwave radar on vehicles are discussed and the benefits to the vehicle operator are summarized.

INTRODUCTION

The Side Detection Sensor is intended to operate as a driver aid. Through the innovative application of microwave technology and radar signal processing, the sensor is able to significantly reduce the ambiguity associated with lane change maneuvers. The cost of the sensor is in line with commercial expectations. The sensor is mounted on the side of the vehicle, an LED is mounted on the side view mirror, and a chime box is mounted in a standard gauge in the dashboard. The sensor is able to detect objects in a predetermined detection zone. When the presence of an object moving in the same direction as the platform vehicle is detected (a "hazardous" object), the system provides an indication to the vehicle operator through the LED in the side view mirror. If the vehicle turn signal is active, the system provides an additional indication of the presence of the object with a chime. The shape of the detection zone, and the location of the sensor on the vehicle, are optimized to provide effective coverage of the "blind zone". The microwave radar provides effective performance in poor weather, not afforded by other technologies.

THEORY OF OPERATION

The SDS Sensor is a K Band Multi-zoned Radar. The radar uses a complex waveform to estimate the range and velocity of moving objects, while discriminating stationary (relative to the ground) objects which are considered to be of non-interest. The radar tracks objects through zones of coverage, and provides an indication to the vehicle operator when a potentially "hazardous" object is present in a region called the detection zone. The detection zone approximates a box 4.5 meters orthogonal to the vehicle, 5 meters parallel to the vehicle (centered at the sensor) and 2 meters high (Figure 1). The system is designed to provide an indication to the platform vehicle operator when objects with a radar cross section of $1.0\ m^2$ or greater are present in the detection zone. Platform vehicle speed is required for sensor operation and is acquired through an external speed pickup device.

The detection zone is defined by the azimuthal pattern of transmit/receive pairs of antennas. Instrumented range cutoff truncates the antenna pattern so that the radar reports objects primarily in the adjacent lane. The detection zone is customized for the type of vehicle platform. In the application for both large articulated trucks, and smaller trucks, the "blindzone" has been determined to be an area extending from slightly in front of the bumper (because of the high hood obstruction in conventional cabs) to an area behind the cab (because of the sleeper cab or cargo obstruction). The elevation pattern is designed for effective coverage of objects of interest, while mitigating the impact of road clutter. The detection zone for an automobile

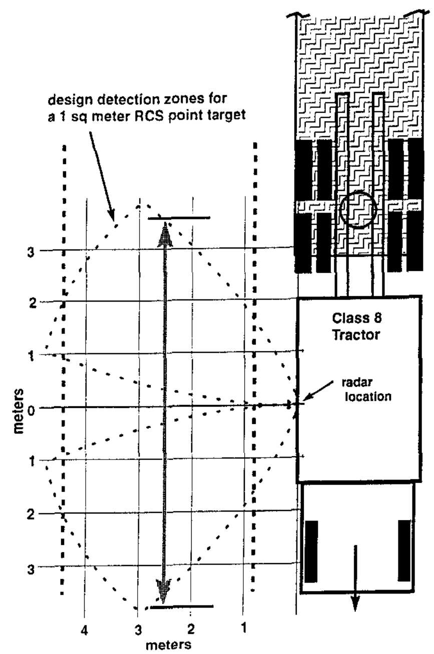

Figure 1 - Sensor Detection Zone

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may be significantly different from the detection zone applicable to a truck, depending on body style and sensor location.

The sensor operates in the Industrial, Scientific and Medical (ISM) band at 24.000 GHz to 24.250 GHz. A 24.225 GHz Voltage Controlled Oscillator (VCO) is swept to provide the radar waveform. Frequency modulation and control is provided by waveform shaping circuitry within the sensor. The potential for sensor to sensor interaction is minimal because of the complexity of the radar waveform, and because the antennas are designed to be cross-polarized in those situations in which the sensors are likely to be in close proximity.

SENSOR DESCRIPTION

The fundamental objective in the design of the sensor is the minimization of manufacturing and assembly costs. The resulting design is described below. The SDS sensor microwave front-end consists of a multilayer microwave board with printed patch antennas and corporate feed, and a transmit and receive MMIC set mounted on this board. The microwave board is mounted in a plastic radome assembly. The radar signal processing, and radar waveform alignment and control, is performed on a signal processing card. The interface between the signal processing card and microwave assembly is through a commercial pressure fit connector which mates at final sensor assembly. Connection to the vehicle for power and vehicle interface is provided through a filtered pair of product connectors. Figure 2 shows the major subassemblies of the radar. The assembly minimizes piece parts, and does not employ microwave connectors. The assembly is designed to be compatible with automated manufacturing processes. Bonding materials and adhesives are dispensed with automated dispensers and the die attach is performed on a precision robotic work cell.

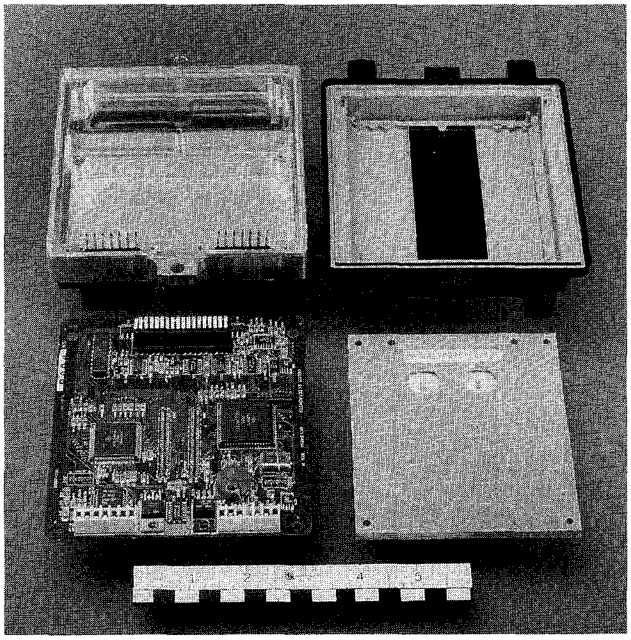

Figure 2 - Radar Assembly

MICROWAVE SUBASSEMBLY

Most of the microwave circuitry is implemented on a Monolithic Microwave Integrated Circuit (MMIC). This approach was selected over other approaches because it minimizes discrete microwave interconnects. The parasitic effect of interconnects was determined to be so detrimental that the MMIC approach was considered the only viable approach, both for cost and performance reasons. Additionally, the multi-channel aspect of this system dictates a MMIC approach to minimize the difficulty of routing power and control voltages across the microwave board. A 4" Multilayer Self Aligned Gate (MSAG) process was selected as the lowest cost approach [1]. The MMIC is mounted directly onto the microwave board to eliminate the need for a carrier. Substantial attention is directed towards the interface between the MMIC and the microwave board because of thermal expansion effects and parasitic ground inductance. The bonding material and thickness is optimized for this application. Additionally, the size of the MMIC is constrained because of thermal expansion. Prior to die attach, the multilayer microwave board is laminated to an aluminum enclosure. This aluminum enclosure isolates the transmit and receive MMICs from each other and from undesired radiation from the antennas. After the MMICs are attached to the board through openings in the enclosure, lids are placed over the openings so that the MMICs are enclosed in a moisture resistant package.

The 24.225 GHz system frequency is derived from a MESFET VCO. Frequency tuning for temperature compensation and radar waveform modulation is achieved by employing varactor diodes in the tank circuitry of the oscillator. These tuning voltages are generated in the signal processing card. The microwave signal then passes through a buffer amplifier and a sequence of gain stages. The zone of coverage is selected by enabling the final gain stage in each channel. The LO for the receiver is also coupled from this oscillator. The receiver function is performed by several high gain stages and a diode ring. The LO from the transmitter MMIC is buffered on the receiver MMIC. As with the transmitter, the zone of coverage is selected by enabling the receiver gain stage of the channel desired.

The antenna board is a multilayer dielectric system comprised of a low dielectric constant antenna plane, a ground plane, and a high dielectric microstrip plane. The zones of coverage are defined by fixed squinted antenna patterns generated by printed patch arrays. The frequency of operation provides for adequate zone definition using antennas which are reasonably sized. This factor is particularly critical in automotive applications, since the externally visible portion of the radar is defined by the size of the antennas. Automotive platform applications require keen attention to the size and cosmetic appearance of the radar.

The patch arrays are fed by microstrip corporate feeds. The corporate feeds are coupled to the MMIC transmit and receive ports by small slot couplers in the antenna ground plane. The slot couplers prevent unintentional radiation from emanating through the sensor, while allowing the intended radar signal to be efficiently radiated.

RADOME

The radome is a plastic material with a metal plating on the interior. Only the region immediately above the radiating elements is unplated. The plating extends from the perimeter of the edge plated antenna board to the aluminum housing, creating a continuous electromagnetic box around the sensor. The plating minimizes the radiation of the corporate feed, thereby permitting the antenna patch and corporate feed to be realized completely in microstrip, rather than stripline, circuitry. This control of undesired radiation from the corporate feed by the radome eliminates the requirement for an additional dielectric layer in the microwave board (as required by a stripline corporate feed) and minimizes microwave board cost. The radome over the corporate feed also permits the antenna dielectric substrate to be selected for efficient antenna element radiation.

For this commercial application, the radome is required to provide robust environmental protection. The radome material and structure provides remarkable resistance to caustic vehicle fluids and gravel bombardment, while remaining cosmetically attractive and electronically functional. This feature is particularly important in automotive platform applications.

SIGNAL PROCESSING

All baseband and digital signal processing occurs on the multilayer Signal Processing Card (SPC). Also, radar waveform generating voltages and frequency alignment voltages are generated on the signal processing card. The radar algorithms are capable of rigorously discriminating between potentially "hazardous" objects, and objects of non-interest (telephone poles, guard rails, oncoming traffic, etc.)[2]. The radar algorithms minimize false alarms, while maintaining high confidence in detection of viable "blindzone" objects.

Target tracking and discrimination is especially challenging in this vehicular application. The close proximity of targets, highly specular nature of reflection, and apparent disparity in RCS of different vehicles creates dramatic variations in target return. Unlike distant airborne aircraft return, which has been thoroughly studied, close proximity road vehicle radar return is a field where limited information is available [3].

Natural power, gain, frequency, and transmitter leakage drift in the microwave assembly are compensated by processes in the SPC. Rather than invoking traditional microwave feedback and control mechanisms, the burden of alignment is substantially placed on digital processing. The availability of sophisticated digital signal processors and low cost memory makes this technique, not viable until very recently, a very attractive solution.

VEHICLE MOUNTING

Figure 3 shows a typical vehicle mounting (the fuel tank is visible below the sensor, the sleeper cab is above the sensor). Because of the diverse body structures of different trucks, the mounting bracket is designed to properly position the radar in each application. The wiring harness which connects to the back of the sensor is routed to the sideview mirror LED and to the gauge in the dashboard.

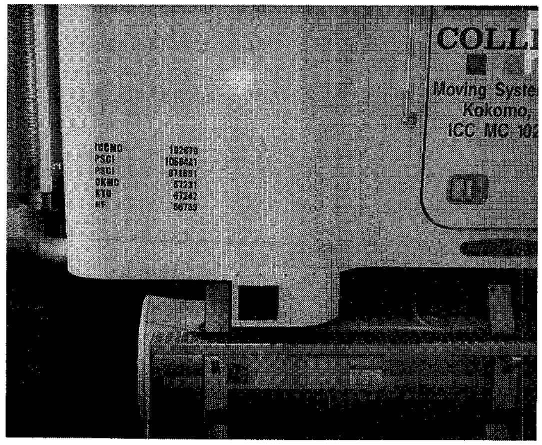

Figure 3 - Typical Vehicle Mounting

CONCLUSION

A commercial side detection system as a drivers aid has been presented. The low cost sensor assembly has been described, and important system considerations have been discussed. The sensor operation at 24 GHz allows for effective all weather performance using reasonably sized antennas. The availability of powerful digital signal processors allows for the implementation of complex radar algorithms which effectively minimize false alarms while providing for high confidence "blindzone" object warning. The availability of 4" MSAG MMIC technology enables cost effective implementation of microwave circuitry. The use of a multilayer microwave/ antenna board precludes reliance on expensive microwave connectors, launches, or waveguide.

REFERENCES

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[3] W. Parnell, F. Copeland, A Unique Government Capability for Supporting ITS Technology Development, Proceedings of the Intelligent Vehicles '95 Symposium, Sept. 25-26, 1995