AUTOMOTIVE RADARS-DEVELOPMENT STATUS

Rahul Dixit

TRW - Automotive Electronics Group
24175 Research Drive, Farmington Hills, MI 48335

ABSTRACT

This article provides an overview of the advances in developing a mmw radar sensor for automotive applications. While the promise of large business opportunities still exists, there are significant challenges to developing a commercially viable radar based system for the automotive consumer.

The article will cover the issues related from systems configurations, and FCC licensing, through the various components in the radar unit itself, and finally touch on the cost, manufacturability and human factors topics.

INTRODUCTION

There is considerable interest in developing a radar based situation sensing product to enhance driver safety and convenience. However, the wide spread deployment of such products have been awaiting progress on several fronts. This article will cover the systems configurations for a few applications and look at the FCC licensing status. Also discussed are issues and choices related to antennas, RF head, VCOs, and subsequent signal processing. Finally, the larger issues of manufacturability and factory alignment will be discussed, and the article will end with some opinions about cost and human factors.

SYSTEMS

Many radar based automotive products are possible. They range from using forward looking narrow beam radars for autonomous cruise control and collision warning, to side looking broader beam radars for lane change aid and side impact warning, to rear facing wide beam radar for back-up warning. This paper will present system block diagrams for these products, significantly including the other non-sensor components required to provide vehicle control.

While there are many competing electromagnetic phenomologies, including microwave and optical, this article will deal with millimeter wave applications. Similarly, FMCW has been chosen over traditional pulse or time of flight approaches. The FMCW waveform system offers easy modulation, high average power, large bandwidths, permitting very good range resolution and Doppler processing, with good performance at close range yielding high, accurate information on range and closing rate.

TU 4C

SENSOR COMPONENTS

Regardless of the vehicular application, a modern ranging sensor consists of three major subassemblies: the antenna, the transmit-receive subsystem including the modulator, and the signal processing module. For typical

0-7803-3246-6/96/$5.00 © IEEE

forward looking radar applications, a lot of discussion has dealt with the issue of beamwidth. To perform the important functions of correctly identifying the lead-vehicle target, and accurately reporting it's distance and relative speed, high resolution spatial selectivity is required. To cover all vehicle types and weather conditions on US interstate-type highways, general consensus is that 3 degree elevation and 9 degree azimuth field of view is desired. To be incorporated into vehicle styling, W-band frequencies are chosen. The FCC has proposed 4 bands from 47 Ghz. To 140 Ghz., with a (US) consensus forming at 77 Ghz. To minimize errors in measurement accuracy from transmitter leakage into the receiver a bi-static configuration is generally preferred.

Remote sensing technology concepts can be traced back to the 1960's [1], based on novel concepts developed by researchers from the major automobile manufacturers and universities. Advances in Gallium Arsenide monolithic microwave integrated circuit technology, funded substantially by the multi hundred million dollar US Govt. ARPA MIMIC program, has enabled operation at millimeter waves, providing reductions in sensor size, weight, and unit production costs. A typical RF-head consists of a linearized VCO modulator, a RF power stage, and a balanced mixer stage preceded by a high dynamic range low noise amplifier. TRW has developed a single chip homodyne FMCW radar operating at 94 Ghz.

VCO phase noise can also limit the range accuracy by widening the spectrum of the transmitted signals, causing spreading of the beat IF frequency. This error can be reduced by inclusion of a closed loop frequency sweep linearizer. Recent advances in digital technology have resulted in the development of new methods for phase noise reduction [2, 3].

Finally the sensor must function accurately in an environment cluttered with background echoes generated by moving and stationary targets, ground reflections and assorted atmospheric noise [4]. To provide fast update rate of independent vehicle velocity measurements and vehicle range information, a combination of Doppler processing and traditional IF sampling and FFT calculations is required. The presence of a target is determined by an adaptive voltage threshold. Ultimately, to be successful products they must provide robust performance in a complex roadway environment. Inconveniences caused by dropped tracks and nuisance alarms will not be tolerated by consumers, and would likely result in the rejection of these new technologies in the market place [5].

MANUFACTURABILITY

Little has been published in this matter, largely, because this is yet to be demonstrated, and because the solutions are commercial. The problem with making a low cost, but very high performance radar sensor requires that the RF head be generally wire-bond-free. This is not practical, both due to current state of technology (VCO phase noise, and the need to launch the energy into an antenna) and due to the complex multi-beam configurations required. This means, that to accurately place mmw interconnections, manufacturing technologies need to be developed which allow high accuracy/ high repeatability wire-bond placement.

Most realizations use micro strip or low loss dielectric substrate. Direct probe launch onto the waveguide is also a preferred low cost, low RF loss approach. This allows the housing to be two piece, and is compatible with modern surface mount technology. Millimeter wave interconnect circuitry can thus be extensively used in photolithographically etched substrates. This also is compatible with precision PCB manufacturing methods.

Radar sensor installation in the assembly plants, using self aligning techniques, has been proposed, and now needs to be developed for automotive assembly tolerances. Sensor diagnostics and alignment during the vehicle life also need to be addressed, before such products can be commercially viable.

COST AND HUMAN FACTORS

Automotive radars face a very daunting cost target, given the requirement to provide robust performance in a complex roadway (Interstate highway) environment. Typically for large volume applications a price between \$100 - \$300 for the sensor has been discussed, but until there is an award for standard product vehicle applications, likely initial product offerings as options in luxury platforms will not enjoy economies of scale. Companies which are able to credibly meet the automotive industry requirements, teamed with technology leaders will best be able to succeed.

The most challenging issue will be consumer acceptance of such convenience and safety features. The product liability litigation concern further compounds this. Only a minority of us are willing to give up acceleration/ deceleration control, precisely because we know the limitations of the system.

Most vehicle manufacturers are considering limiting the system to accelerator control only and warning the driver about situations where closing distance is inadequate for safe stopping. Industry data shows that approximately 60% of rear-end collisions can be reduced in severity or eliminated, if the drivers had an additional 0.5 seconds to react.

The average consumer will start to depend on the convenience provided by these new situational awareness sensors, and will assign safety decisions to information provided by them. The products thus must work robustly and do so for the life of the vehicle.

SUMMARY

Over the past few years automotive radar sensors have become a viable area for millimeter wave products. There is a huge market potential for automotive application, and impact, are integral elements in future Intelligent Transportation Systems. The maturity of HEMT MMIC technology, coupled with simple radar acrchitecture and robust signal process will enable low cost and small size millimeter wave radar for in-vehicle application.

This paper has provided a status of some of the on-going work on radar based sensors. There are still significant challenges before such a product will be widely deployed in automobiles of the near-future. However, the opportunity is very significant, and many capable entrants are already participating in the field. It is likely that some use of millimeterwave radar products to improve driver safety and convenience will start deployment by (vehicle) model year 1998 or 1999. The issues related to cost and consumer acceptance need to be worked out in the market place.

REFERENCES

1. D. M. Grimes and T. O. Jones, "Automotive Radar: A Brief Review",

Proceedings of the IEEE, Vol. 62, No. 6, June 1974.

2. P. Ganci, S. Potts and F. Okurowski, "A Forward Looking Automotive Radar Sensor", Proceedings of the Intelligent Vehicles 1995 Symposium, Sept. 1995.
3. W. David, "FMCW Sensors for Longitudinal Control of Vehicles", Society of Automotive Engineers, Special Publication, Vol. N. 1106, Nov. 1995.
4. T. Grosch, W. Klimkiewicz, P. Moosbrugger and L. Carpenter, "A 24 Ghz. FM/CW automotive radar designed for collision warning", Proceedings of the International Society for Optical Engineering, Vol. 2344, Nov. 1995.
5. S. Germann and R. Isermann, "Nonlinear Distance and Cruise Control for Passenger Cars", Proceedings of the American Control Conference, Vol. 5, 1995.