APPLICATION OF RADAR TO AUTOMOBILE CONTROL AND SENSING

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Summary

A description of two new experimental radar driver aids is presented. One adds longitudinal control to existing automobile speed controls to automatically operate both throttle and brakes in response to traffic flow. The second radar system acts as a rear vision aid.

Introduction

The continuing increase in the automobile population, coupled with advances in roadway construction permitting higher speeds, has led to the need for sophisticated methods of automobile control beyond the capability of the human driver. Accidents involving several automobiles are no longer subjects for headlines - they are too common.

Radar, because of extensive use in aerospace systems, is a natural choice for development as a driver aid. Modern solid state technology has progressed to the point where low-cost subsystems are now feasible. Two systems are currently under development at Bendix: Adaptive Speed Control adds automatic headway (or spacing) control to existing speed control devices; Automobile Rear-End Warning provides a radar aid to rear vision.

Headway Control

Speed control devices have been available as options on most American cars for some time. Adaptive Speed Control is a first step toward making the longitudinal control function automatic. The initial use will provide added driver speed control convenience. Later, as car-highway and car-to-car cooperation becomes possible, fully automatic highway control can become a reality.

Figure 1 shows a block diagram of the complete system. The components below the dotted line comprise the basic speed controller. The components above the dotted line are the elements that provide automatic headway control. The driver initiates operation by pushing a speed-set button. The speed controller memorizes this value and signals the actuator to set the proper throttle position. If changing road grade causes speed errors, the throttle is commanded to adjust as required.

In the event a car is overtaken, the radar measures and sends the relative velocity and range to the signal processor. The processor combines this data with an input of own car speed and determines whether throttle or brake actuation is required. The system will continue to follow as long as the lead car stays under the driver-set speed of the radar-equipped car. The car will never exceed the driver-set speed. Of course, the driver can override the system at any time by manually applying the throttle or brakes.

Prior to fabrication of the first system, a detailed mathematical model was developed and used as a design aid. To achieve a near real time model, a hybrid computer was used in the system simulation. Each functional subsystem was modeled.

The headway mode control law defines the points at which commands are sent to the throttle and brakes. A brief discussion of that law is pertinent to understanding system operation. This law is:

$$E = (R - R^*) + 3\dot{R} \qquad (1)$$

$$R^* = 50 + V \qquad (2)$$

where

- E = Control Voltage Level
- R = Measured Range in Feet
- R^* = Desired Range in Feet
- $\dot{R}$ = Measured Relative Velocity in mph
- V = Equipped Vehicle Velocity in mph Expressed in Feet (1 mph = 1 Foot)

The control voltage level is at zero when the system is at desired headway. A positive voltage indicates acceleration is required. A negative voltage initiates throttle back-off; at a high negative level, braking is initiated.

The simulation proved to be a valid representation of the system performance and was of major benefit in design of the experimental system.

The design of a low-cost radar suitable for automobile headway control received considerable study. Both range and range rate measurements are required. A two-frequency CW approach[1] was selected over pulse or other CW modulation techniques after a cost/performance study.

The radar block diagram is shown in Figure 2. The transmitter is switched between two closely spaced frequencies. Each of the doppler-shifted return signals is gated into a separate channel. The range rate is derived from one doppler channel. A third output is a threshold level measurement to assure acceptance by the processors of good signal-to-noise ratio data. The threshold level, therefore, determines the maximum system range.

The selection of a two-frequency radar approach presented two system problems. Since doppler is required to obtain range, no information is available at optimum headway when range rate has been reduced to zero. Also, the system lacks range resolution and can suffer from multiple target affects. Our experience to date has shown that the signal processor can overcome these obstacles when provided with memory and smoothing.

The first radar operated at 16 GHz with 50 milliwatts of transmitter power. The operating range was 200 to 400 feet depending on the size and shape of the car involved. As might be expected, small foreign cars were at the low end of the range.

The antenna and microwave section are shown in Figure 3. A standing-wave waveguide-array antenna was employed to simulate an automobile grille. The remaining components are standard microwave packages including a circulator, mixer, coupler, and isolator. The transmitter is a Gunn oscillator.

Rear End Warning

The second radar application to cars is in a rear vision aid. Dunlap and Associates[2] recently completed a study on motor vehicle rear vision for the National Highway Safety Bureau. The report noted that rear vision is one of the important areas requiring action. The actual proportion of accidents attributable either to lack of adequate rear vision information or to design of the rear vision display was difficult to determine. However, the general conclusion was that blind spots are a contributing factor in many accidents involving cars going in the same direction. Our rear warning system is designed to alert the driver of the presence of traffic in his blind zones.

The system is composed of two lane-changing sensors and a back-up sensor. Each sensor is a CW homodyne radar. The antennas for the lane-changing sensors can be mounted adjacent to the automobile tail lights. The antenna patterns intersect adjacent lanes to illuminate the blind areas and to warn of the presence of approaching automobiles with a light or audible signal. The radars are instrumented to ignore roadside objects. The maximum range of these sensors is 50 to 70 feet on cars, with a minimum range response down to the center door post to cover the entire blind zone.

The antenna for the back-up sensor can be integrated into the rear bumper. The sensor is inoperative until the automobile is in reverse gear. Visual and audible warning is activated in the presence of obstacles such as humans, bicycles, posts, etc. The antenna pattern is centered on the road surface at a distance of 10 feet behind the automobile. The sensor range is 0 to 30 feet.

Figure 4 shows a picture of a car equipped with the three sensors. The engineering tests to date have shown that this type of warning can be a valuable aid to drivers.

References

[1] W. D. Boyer, "A Diplexing Doppler Phase Comparison Radar," IEEE Transactions on Aerospace and Navigation Electronics ANE 10, No. 1, pp. 27-33, March 1963.

[2] Charles R. Kelley, et al., "Motor Vehicle Rear Vision," Final Report, Contract No. FH-11-6951, U.S. Department of Transportation, August 1969.

BLOCK DIAGRAM OF ADAPTIVE SPEED-CONTROL SYSTEM