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Cruise Control Operation from Zero to Preset Speed-Simulation and Implementation

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Abstract—**Controlled & safe cruise control operation is one of the major constraints faced by today's automotive industry. Adaptive cruise control (ACC) with Stop & Go scenarios is the most important research topics in the field of intelligent transportation systems. This paper deals with the development of an ACC controller supporting stop & go function. The main feature of this controller represents adaptation to a user-preset speed and, if necessary, speed reductions can be done to maintain a safe distance from the lead vehicle in the same lane on the road, irrespective of whatever speed it is moving. The extreme case is the stop and go operation in which the lead vehicle stops and the vehicle at the rear must also do so. The main concern of the system is about the inter-distance control in highways where the vehicle velocity mainly remains constant & it also deals with the vehicle circulating in towns with frequent stops & acceleration. In both situations, goals of safety and comfort are to be achieved. The main aim of the paper is to design a model for adaptive Cruise Control system which works efficiently under the STOP & Go scenarios using Matlab and validate it with physical design architecture incorporating safety features. The paper also deals with various lane changing strategies to enforce an overall control of the vehicle.**

Keywords- **Adaptive Cruise Control, Stop & Go scenario, Zero speed, fail-safe features, Lane changing.**

I. Introduction

Number of accidents can be avoided through timely threat recognition and appropriate collision avoidance. This may be achieved by suitable warning to the driver or by automatic support to longitudinal or lateral control of the vehicle. Adaptive Cruise Control (ACC) is an automotive feature that allows a vehicle's cruise control system to adapt the vehicle's speed to the traffic environment but the driver remains responsible for steering & collision avoidance. If deceleration of the ACC is not sufficient enough to avoid a collision, the ACC warns the driver with a warning sound. The ACC was often used during free driving & busy traffic (i.e.., speed between 70 & 90 km/hr on the high ways) & was hardly used during congestion. When the ACC is active, it was concluded that the time-headway in car-following situations was around 0.2 seconds higher than without the ACC. The normal ACC doesn't work under the speed below 30 to 50 kmph thus causing driver inconvenience to drive. To overcome this, ACC with Stop & Go is designed to work even at zero speed.

The cruise control operation using radar sensors is the most vulnerable technology used for automotive control [1]. The advantage that radar sensors have over other types of sensors, such as optical or infrared sensors, is that they perform equally well during the day, the night, and in most weather conditions. Radar sensors will undoubtedly be an integral part of any multiple sensor system or sensor fusion used to achieve a true autonomous vehicle. The use of ultrasonic sensors [2] and laser sensors [3] which are reasonably cheap and work for ranges of up to a few meters but problems arise regarding both their accuracy and their behavior in noisy open-air and dirty conditions. A passive optical [4] can be an alternative to commonly used active sensors like radar or laser. Though it is able to detect traffic on the road and obstacles at distances up to 200 meters, it has less accuracy at greater distances.

II. Methodology

Currently numerous models are available in market with Adaptive cruise control (ACC) feature. Mitsubishi was the first automaker to offer a laser-based ACC system whose control mechanism did not apply the brakes and only controlled speed through throttle control and downshifting. Later Toyota incorporated radar based ACC. Mercedes lined up next on introducing ACC system which completely halts the car if necessary which was further adopted by Bosch and Audi. BMW's Active Cruise Control system implemented Stop-and-Go system. These cruise control techniques have faced lot of set-backs in issues pertaining to unsafe operation. The major problems left un-attended in these vehicles were, initially the shooting-up of accelerator un-controllably under certain conditions of cruise control, cruise control not cancelling when the brakes were applied,vehicle accelerating beyond the set speed, vehicle resuming to cruise control on its own resisting the applied brakes, faulty brake problems and speed control issues. So in order to overcome these faults, this paper presents additional sensors to ensure complete safety. It also incorporates fail-safe features.

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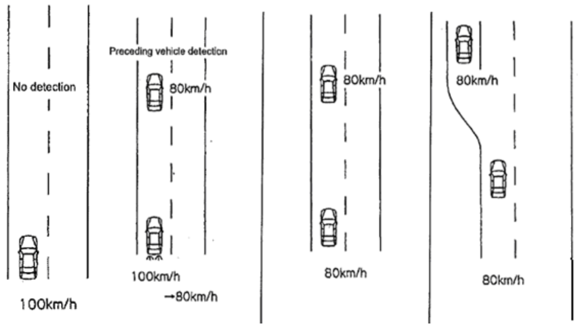

Figure 1. Cruise control operation

The operation of ACC with Stop & Go manages speed to a complete stop and resumes the set speed based on driver input such as touching the pedal or resume button. In the cruise scenarios in which two vehicles are involved, the front one is called lead vehicle and the following vehicle is called the host vehicle for the longitudinal controller. A sensing system attached to the front of the vehicle is used to detect whether slower moving vehicles are in the host vehicle’s path. If a slower moving vehicle is detected, this system will slow the vehicle down and control the clearance, or time gap, between the host vehicle and the lead vehicle. If the system detects that the forward vehicle is no longer in the host vehicle's path, the system will accelerate the vehicle back to its set cruise control speed. This operation allows the host vehicle to autonomously slow down and speed up with traffic without intervention from the driver. The method by which the host vehicle's speed is controlled is via engine throttle control and limited brake operation. The system is divided into 2 modules, namely Vehicle model, ACC with Stop & Go model.

A. Vehicle model

The vehicle model is just like a representation of a car. It consists of all the blocks that a car has. The main components of a vehicle model are:

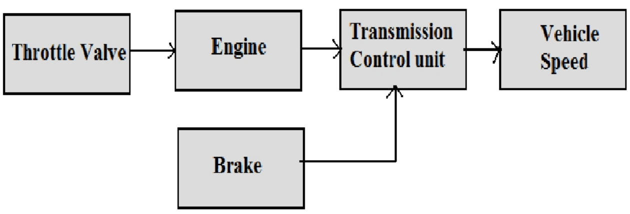

Figure 2. Vehicle design

The Throttle valve and brake circuit are designed as follows:

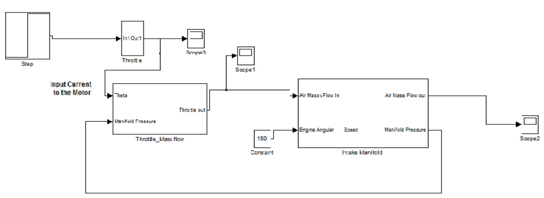

Figure 3. Throttle Valve

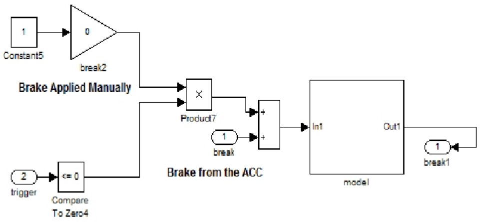

Figure 4. Brake circuit

Transmission control unit: The main purpose of vehicle dynamics is to convert the engine speed (in rpm) to the vehicle speed in terms of Miles/ hr or Km/hr. The vehicle speed tells us how fast the vehicle is moving.

B. ACC with Stop & Go model

The primary function of this module is to process the distance information from the sensing unit and determine if a lead vehicle is present. When the system is in time gap control, it sends information to the Engine Control and Brake Control modules to control the clearance between the host Vehicle and the Target Vehicle. Stop and Go Adaptive Cruise Control is an automotive feature that allows a vehicle's cruise control system to adapt the vehicle's speed.

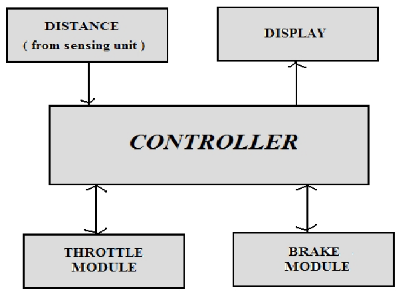

Figure 5. ACC Block diagram

Distance: The distance here is the distance between the lead vehicle and host vehicle. The distance is one of the major inputs to the controller. We get the distance value using the sensing units like Range estimation Image processing technique, radar communication e.t.c.

Display: The display is present on the Dash board of the car. Here it ind icates the distance range, warning messages and so on.

Throttle module: The throttle module here sends the controller the throttle position & also adjusts its position when the controller says to do.

Brake module: The brake module here sends the controller the amount of brake applied its position & also adjusts its position when the controller says to perform.

Speed Calculation: The speed of the lead vehicle is calculated using the distance difference method. The formulae used for this is:

$$\text{Speed} = d1 - d2 \qquad (1)$$

d1 → distance at time t=1 sec, d2→ distance at time t= 2 sec.

Hence, both the vehicles are maintained at a safe-distance from each other.

Speed Required for Host Vehicle: The speed required for the host vehicle is set based on the speed of the Lead vehicle. Here we set the speed as (if the distance between the vehicles is in safe inter-distance range):

Host Vehicle Speed = Lead Vehicle Speed (2)

III. SIMULATION

The modelling is done using simulink model in MATLAB.

A. Algorithm

START

Step1: Start the Engine.

Step2:Operate the vehicle manually using the acceleration and brake pedal.

Step3: Check whether Acc is turned on.

Step4: If the acc is turned off goto step 2.

Step5:Check whether any object is detected.

Step6: If no object is detected that the host vehicles speed = set speed.

Step7: After the object is detected calculate the distance using

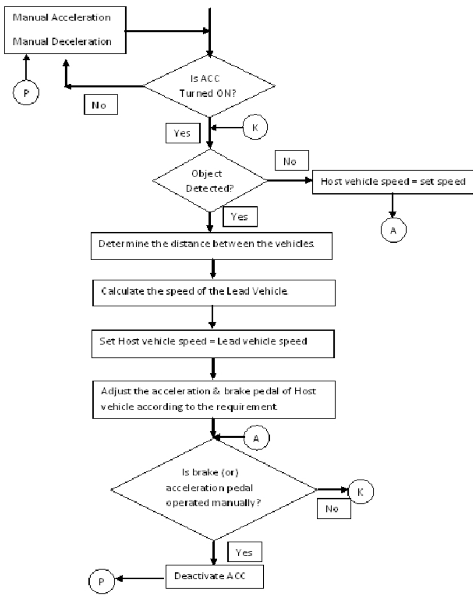

Figure 6. Flow chart

the time difference technique.

Step 8: Get the Host vehicle speed.

Step 9: Set Host vehicle speed = Lead vehicle speed.

Step 10: Adjust the acceleration & brake pedals in order to achieve the safe speed required.

Step 11: If user manually presses the acceleration or brake pedal, then deactivate the ACC.

Step 12: Display user that ACC is deactivated

Step 13: Repeat process continuously.

STOP

B. Modes of driving

1) *Manual Driving*: In the manual driving mode, the user presses the acceleration pedal in order to move the vehicle at a desired speed. The gain is fed to a slider, which represent a throttle valve.

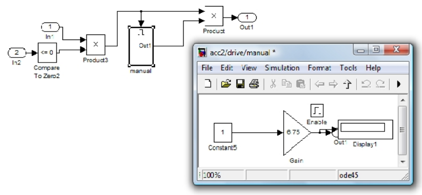

Figure 7. Manual driving circuit

2) *Cruise Control*: The control enters into cruise control mode when there is no obstacle present for host vehicle to drive for a certain speed. Here the cruise control is set to a set speed of 90. If user triggers the manual switch, then cruise control mode is deactivated.

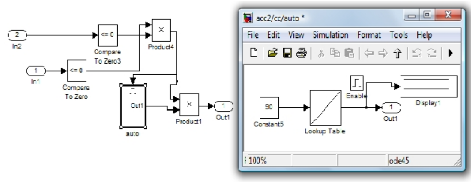

Figure 8. Cruise control model

C. Circuit components

1) *Adaptive Cruise Control*: The control enters into ACC when there is an obstacle present in front of host vehicle. Here we are going to calculate the amount of acceleration & brake required.

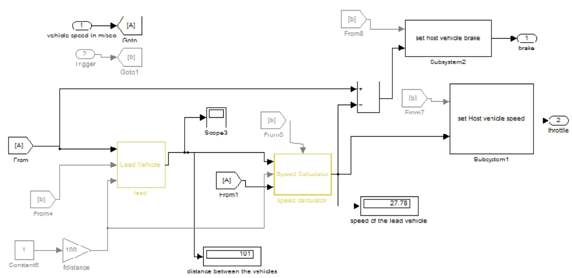

Figure 9. ACC circuit

2) *Speed calculator*: The speed calculator block calculates the speed of the lead vehicle based on the distance between the cars.

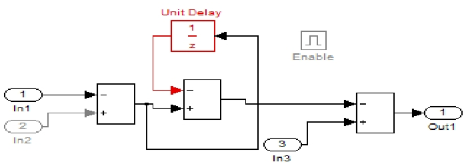

Figure 10. Speed calculator

3) *Vehicle Found*: Here when we select vehicle found, the distance between the cars is set by default as 100. The vehicle found is activated when the car is running in CC mode.

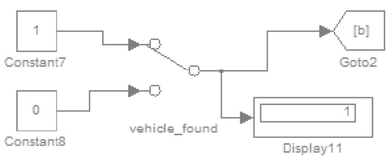

Figure 11. Vehicle found

4) *Manual Switch*: This switch is used to select the ACC active & inactive

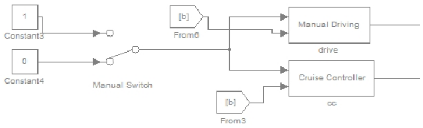

Figure 12. Manual Switch

IV. Design Implementation

A. Cruise Control Operation

- The various sensors used in the cruise control operation are radar sensor, throttle position sensor, Brake pedal sensor, positions sensor, speed sensor, engine rpm sensor and fuel injection ratio sensor.
- This physical model uses the current millimeter-wave radar systems operating at 76–77 GHz frequency range to measure the inter-distance between the moving vehicles up to 200m ahead and upto a relative motion of 250Kmph. The radar sensor sends signals and these beams are reflected back from the vehicles ahead. The sensor picks up the reflection and sends them to the micro-controller. This is done using three overlapping radar beams, the sensor network provides range and closing-rate information to the cruise control system, which can control the brakes and also the throttle of the vehicle.
- The micro-controller immediately calculates whether the car's speed needs to be adjusted, or if the road ahead is clear. This is done based on a simple calculation of safe inter-distance between vehicles to avoid collision using current speed of the two vehicles and response time to stop the vehicle on pressing the brakes as parameters. If the distance between the vehicles > safe inter-distance, then the controller triggers the ECM to adjust the speed of the host vehicle by either accelerating or decelerating corresponding to lead vehicle. If the distance between the vehicles < safe inter-distance, then the controller communicates to the brake system to completely halt the vehicle and disengage the cruise control system.
- Based on the input signal, ECM decides the car's speed. The speed is controlled by fuel ejection parameter and throttle position sensor which converts the throttle valve angle into electrical signals. As the throttle opens, signal voltage increases and vice-versa. Hence the system adapts the speed of the vehicle according to the speed of the vehicle ahead, in order to maintain a separation time-interval between the two vehicles.
- When the brake control system gets activated for distance less than safe inter-distance between the vehicles, the controller automatically triggers the braking system using the brake pedal sensor and ABS. The wheel is prevented from locking by a mechanism that automatically regulates braking force to an optimum for any given low-friction condition. In addition to the normal brake components, including brake pedal, master cylinder, vacuum boost, wheel cylinders, calipers/disks and brake lines, this system has a set of angular speed sensors at each wheel, an electronic control module and a hydraulic brake pressure modulator (regulator). Hence the vehicle is brought to complete halt avoiding collision and accidents.
- The model also uses other sensors like rear position and engine rpm sensor, crankshaft sensor, camshaft position sensor which constantly helps calculate data on wheel revolutions and levels of vehicle pitch and centrifugal force to the controller. On the basis of the car's current path and the data supplied, the controller can calculate the approaching curve path.

B. Lane Changing Strategies

Increasing traffic on highways leads to more dangerous situations during lane changes. Generally, the Lane Change system monitors the area behind and beside the own vehicle by vision and radar sensors. If a dangerous object is detected in the neighboring lane, the speed is controlled automatically to permit lane change. By using the signals from the radar sensor, the control unit judges whether the lane change can take place or not. It also works out its lateral position on multi-lane roads. If there are several vehicles within the sensor's field of coverage at the same time, this information is used to select which of the vehicles the system should track. For this purpose, the radar sensor is placed in the rear bumper of the car and detects vehicles along side as well as behind the car. If detected, the system informs the driver until the vehicle has moved out of range. Firstly, it alerts the driver regarding the presence of the other vehicle and secondly adjusts the speed of the vehicle correspondingly so that collision is avoided during lane changing.

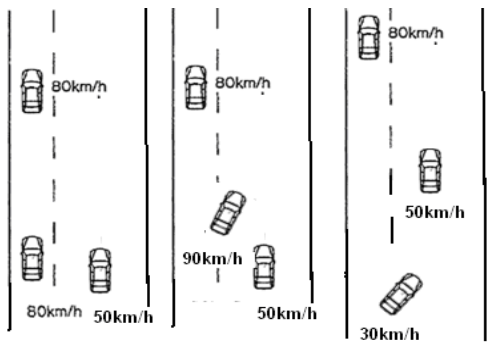

Figure 13. Lane changing strategies

While changing lanes, the safe zone parameter influences the speed of the host vehicle. On changing lanes, the satellite radar sensor senses whether the car is in safe zone thereby disengaging the cruise control and allowing the driver to change lane. But when the car is not in the safe zone, the sensor triggers an alarm which creates a sound signal in order to warn the driver to avoid lane change and so the driver will have to decelerate in order to change the lane. But if the driver forcefully changes the lane, a momentary torque will be triggered by the control unit which will influence the steering control and stop the driver from accelerating while changing the lane.

V. Results And Discussion

A. Simulation

For the Input Current of 0 to 6.75 volts, the throttle angle shifts from 0 to 90 deg.

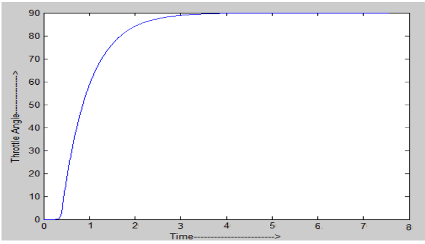

Figure 14. Input current Vs throttle angle

The amount of air flow through the intake manifold w.r.t throttle angle is shown below:

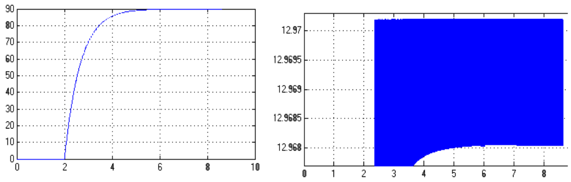

Figure 15. Air flow through intake manifold

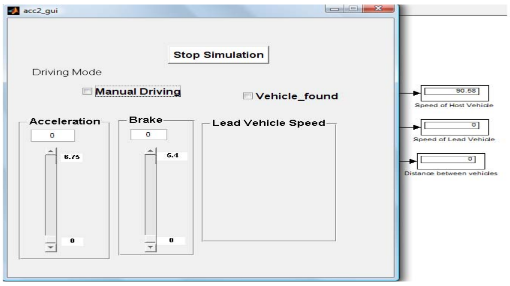

Figure 16. Output Environment when automatic driving is activated i.e. CC

The output environment shown below is achieved when user activates the ACC, then the vehicle gets out of manual driving mode. Here as there is no vehicle present in front of Host vehicle. The host vehicle moves at a set speed of 90 km/hr.

The output environment shown below is achieved when user selects that a vehicle is present then the ACC calculates the Lead vehicle speed using the distance between 2 vehicles, then sets host vehicle to lead vehicle speed.

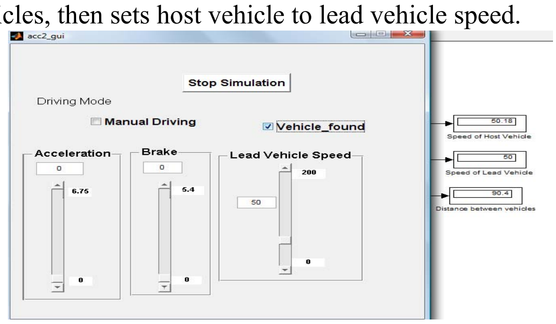

Figure 17. Output Environment when Lead vehicle is present

B. Physical Design- Issues And Solutions

1) Braking issues:

When depressing the brake pedal, the auto's hydraulics engages and slow or stop the vehicle. In addition, two other functions can also occur, one of which is critical to the operation of the vehicle- disengaging of the cruise control. The other function is to switch on the brake lights to alert other vehicles that the car is slowing down and/or is going to stop [5]. In the past, these items typically used electromechanical sensors to sense the brake pedal motion but failed to disengage the cruise control, allowing the engine to continue its race forward increasing the possibility of a potentially dangerous collision.

*Solution:*When the brakes are applied a sensor must be activated that in turn, disengages the cruise control, automatically reducing gasoline flow to the engine, allowing the vehicle to slow or stop. The sensors are of a single pole normally open and a single pole normally closed type.In the second case, when the brake pedal is depressed, the normally closed contact will open automatically disengaging the cruise control.

2) Acceleration issues:

There are cases, where in the vehicle faces the problem of un-controllable acceleration. During such conditions, the vehicle is prone to accidents. To avoid this, we have defined a preset speed parameter which is embedded in the micro-controller. When the host vehicle acclerates beyond the preset speed, the micro-controller communicates with the ECM via throttle position sensor and influences the throttle angle with respect to the fuel ejection parameter.Thus the speed of the host vehicle is controlled gradually and brought to rest.

3) Acceleration limitations:

If approaching a slower vehicle ahead or if another vehicle cuts in front, the automatic distance control slows down the car by initiating corrective controls in the engine management and, if necessary, in the braking system too. We have defined the various modes of Preset speed in order to suit the different kinds of road traffic. During peak traffic conditions the distance between the cars will be minimal, in such cases the pre-set speed (0-20Kmph) is activated and hence the driver will not be able to accelerate beyond 20Kmph.During normal traffic conditions there will be mediocre distance between the cars and hence the pre-set speed of (10-50Kmph) is activated, thus setting the maximum speed limit to 50.In highways the distance between the cars gradually increases and hence the pre-set speed of (50-Max.Speed) is activated , thus giving the driver an option of increasing the acceleration upto the Max.Speed limit. If the rate of deceleration exceeds the vehicle's maximum stopping power, visual and audible warning signals will prompt the driver to apply the brakes manually.

C. ADVANTAGES

- Incorporated a dead man's switch which is a switch that is automatically operated in case the human operator becomes incapacitated. The switch usually stops a machine, and is a form of fail-safe.
- In order to avoid skidding during braking, hydraulic systems with electronic enhancement such as an ABS brake system is used.
- Incorporating Road Characteristics: Driving over "rolling" terrain, with gentle up and down portions, can usually be done more economically (using less fuel) by a skilled driver viewing the approaching terrain, by maintaining a relatively constant throttle position and allowing the vehicle to accelerate on the downgrades and decelerate on upgrades, while reducing power when cresting a rise and adding a bit before an upgrade is reached. Cruise control will tend to over throttle on the upgrades and retard on the downgrades, wasting the

energy storage capabilities available from the inertia of the vehicle. In order to complement the different roads, we define the road characteristics as follows:

1: Vehicle going UP on an inclined road

-1: Vehicle is getting DOWN from an inclined road

0: Vehicle on a plain Road

- The advantage that radar sensors have over other types of sensors, such as optical or infrared sensors is that they perform equally well during the day, the night and in most weather conditions. Radar can also be used for target identification and for detecting road conditions by making use of scattering signature information. Radar sensors will undoubtedly be an integral part of any multiple sensor system or sensor fusion used to achieve a true autonomous vehicle. The same radar sensors used for ACC can also be used in pre-crash sensing, parking aid and collision avoidance and assistance (CW/A) systems. When used in a CW/A application, the radar sensors allow for warning signals to be given and for air bags to be activated. CW/A systems can also be designed to take control of a vehicle when a collision is anticipated ACC, multiple radar sensors must be used in conjunction with the long-range forward-looking 76–77 GHz ACC radar.

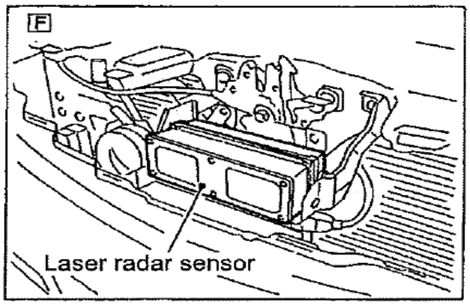

Figure 18. Laser radar sensor

VI. Conclusion

The project demonstrated the longitudinal vehicle model via simulation. Using the distance between the vehicles, the speed was calculated. Different modes of driving were also shown. This model is validated by a physical design along with the corresponding sensors and actuators. Hence, the complete implementation of the concept is done. Also the variuos issues involved during implementation and the corresponding solution were discussed.

VII. Future Enhancements

The distance & speed calculation can be modified and validated by using techniques and algorithm like ant colony, GA, nueral network. Enhanced safety features and indication mechanism can be incorporated in the system design at the event of failure of cruise control mode of operation. These features can be activated depending upon the distance between the vehicles. The project can be further enhanced by using effective methods to detect the front vehicle in all road conditions & weather conditions using image processing techniques or Radar or some wireless techniques.

Acknowledgement

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