BASIC MATLAB SIMULATION OF ADAPTIVE CRUISE CONTROL SYSTEM FUNCTIONING, AND IT'S SAFETY ANALYSIS.

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***Abstract* - Adaptive Cruise Control System (ACC) is one of the safety critical embedded systems. This is an automotive sector driver assistance system which can help to prevent accidents by reducing the workload on the driver. Adaptive Cruise Control (ACC) is an advanced automotive feature that allows a vehicle's cruise control system to adapt the vehicle's speed to the traffic environment. A radar system attached to the front of the vehicle below bumper of vehicle is used to detect whether slower moving vehicles are in the ACC vehicle's path. If a slower moving vehicle is detected front of it, the ACC system will slow the vehicle down and control the time gap, between the ACC vehicle and the forward vehicle. If the system detects that the forward vehicle is no longer in the ACC vehicle's path, the ACC system will accelerate the vehicle back to its set cruise control speed. This basic functionality and working of this Adaptive Cruise Control System (ACCS) was simulated using MATLAB-Simulink software. In this paper we showed results i.e. speed of opposite vehicle and controlled speed of the vehicle. Both software and hardware safety analysis methods such as FMEA and FTA have also discussed.**

Keywords - Adaptive Cruise Control, Driver assistance system, MATLAB-Simulink.

I. INTRODUCTION

A critical system is any system whose 'failure' could damage in human life, the system's environment or which can control entire equipment with its command in operation [8].

There are three types of Critical Systems:

- Safety Critical Systems –Failure may injure or kill people, damage the environment –Example: nuclear and chemical plants, aircraft – (Example: Weapon industry. People will be killed if the systems work.)
- Business Critical Systems –Failure may cause great financial loss –Example: information system. Customer information cannot be lost, or hacked.
- Mission critical system –Failure may cause a mission to fail –Large values potentially wasted –Example: Space probe. Large sums of money, many years of waiting [9].

The loss in ACCS also results in severe damage to the human life or environment. Adaptive cruise control system (ACCS) is one of the Safety Critical Systems in automotive field.

Scientists and Researchers always have a most never ending question about safety and reliability of Heavy Vehicles in the real world traffic. They came out with a solution called Advanced Driver Assistance Systems (ADA) such as Adaptive cruise Control System (ACCS). This is an optional cruise control system and an advanced vehicle safety control system for road vehicles that automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead [1].

Adaptive cruise control is also called active cruise control, autonomous cruise control, intelligent cruise control, radar cruise control, or traffic-aware cruise control. Adaptive Cruise Control (ACC) is an automotive feature that allows a vehicle's cruise control system to adapt and adjust the vehicle's speed to the traffic environment. A radar system attached to the front of the vehicle down the bumper is used to detect whether slower moving vehicles are in the ACC vehicle's path. If a slower moving vehicle is detected, the ACC system will slow the vehicle down and control the time gap, between the ACC vehicle and the forward vehicle. If the system detects that the forward vehicle is no longer in the ACC vehicle's path, the ACC system will accelerate the vehicle back to its set cruise control speed. This operation allows the ACC vehicle to autonomously slow down and speed up with traffic without intervention from the driver. The method by which the ACC vehicle's speed is controlled is via engine throttle control and limited brake operation [2].nModern cruise control (also known as a speedostat or tempomat) was invented in 1948 by the inventor and mechanical engineer Ralph Teetor [1]. For the driver safety level Carsten and Morello mention a restricted definition, which mainly focuses on the appropriate design of the human machine interface (HMI) of an advanced driver assistance system (ADAS) in order not to distract the user from the driving task (European Transport Safety Council, 1999), and by that go into the needs of the user for the particular ADAS. However, Heijer and Wiersma (2001) argued that this level should also incorporate adequate choice of measures in order to support the user in performing a safe trip. During the development, ACC was regarded as a tool with potential for increased traffic safety. ACC is currently marketed as a convenience system rather than a safety aid. According to some authors (Marsh, 2003) this is done out of fear of potential lawsuits following accidents. Still the system should be regarded in its effect on traffic safety, either positive or negative [3].

II. OVERVIEW

"Adaptive cruise control is the first system in a network of sensors," said John Vaughan, vice president of business development at M/A-Com Inc. (Lowell, Mass.), which supplies sensors for the Mercedes system. "In time you will have a sensor field around the car which will be used by the vehicle's intelligence. It's the beginning of the microwave era in automotive electronics."

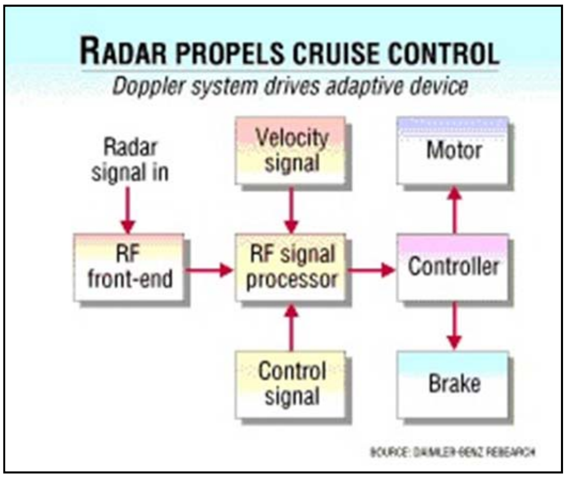


Fig.1: Overview of ACCS with RADAR linked.

ACCCS is an embedded Safety critical system which has both hardware and software embedded in it. The Mercedes-Benz system uses a 77-GHz Doppler radar linked into the electronic control and braking systems to maintain a safe distance between a car with the system and the vehicle in front of it. Most of the new S-class vehicles are expected to ship with the radar, which carries a premium of about $1,500.
At European Microwave Week — which pulled together three previously separate conferences on GanAs, microwaves and wireless techniques — automotive radar came across as one of the hot areas in what is already an upbeat sector of the semiconductor industry [4].
The high range of RADAR and its efficiency made it more popular. This is costlier compared to the sensors or wireless techniques but when safety is the main criteria for us, we must use it.

III. BASIC MATLAB SIMULATION OF ADAPTIVE CRUISE CONTROL

In this paper we have done a Basic Functioning of Adaptive Cruise Control System (ACCS) in MAT-LAB Simulink. In this model of ACCS the radar input time is given manually by us and it takes by own when it is connected to a RADAR. ACCS should be enabled automatically when the opposite vehicle is moving slower than our vehicle and if the situation continues it may collide and accident may takes places. RADAR is used to find out at what speed does the opposite vehicle moving by the transceiver which emits and receives the waveform by the wave reflection.

In this ACCS there are four main Situations:

1. If opposite vehicle moves slower than our vehicle, if it is near to our vehicle then automatically our vehicle must get adjusted to that speed and move on.
2. If opposite vehicle stops then our vehicle should eventually slow down and finally stops our vehicle.
3. If the opposite vehicle is moving faster than us and it is beyond the range of our RADAR our vehicle should move in a normal speed.

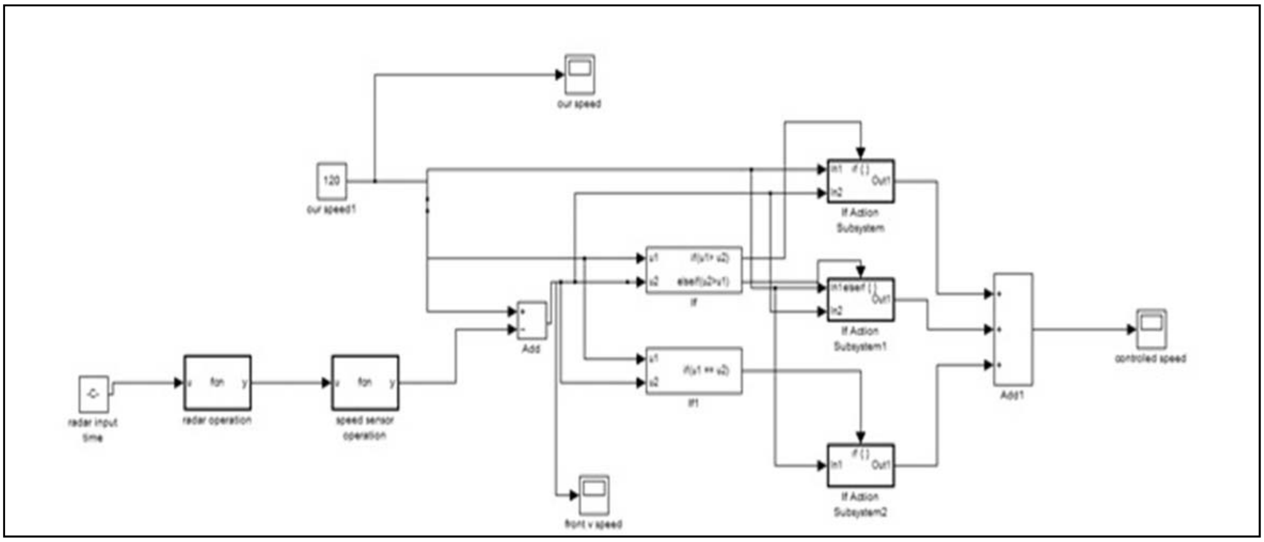


Fig 2: Basic Functioning of Adaptive Cruise Control System (ACCS) in Mat-LAB Simulink.

In the above model we have used 3 If Action Subsystems for the three above situations and conditions such as speed of the 2 vehicles of same speed or more speed or less speed based on the distance. Once the input from the radar is taken and then it calculates the speed of the opposite vehicle using the constant value and stores in the front v speed parameter. We will give the input in our speed parameter manually and both the speeds of the vehicles will be compared and checks whether the opposite speed is in the range of the RADAR or not. ACCS will be enabled automatically only when the vehicle is in RADAR range. Once the opposite vehicle is out of range ACCS will be disabled.

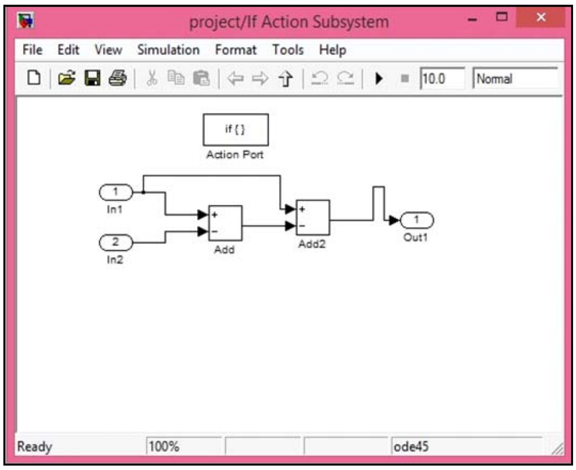


Fig.3: Circuit Diagram for If Action Subsystem when our speed is more than front v speed

In the model of ACCS there are 3 If Action Subsystems and each one should be given an inbuilt condition to satisfy those 3 specifications above. Fig.2 is the design if our speed is more compared to the opposite vehicle i.e., front v speed. Then the action to be performed is sent to the Adder named Add1 in the model.

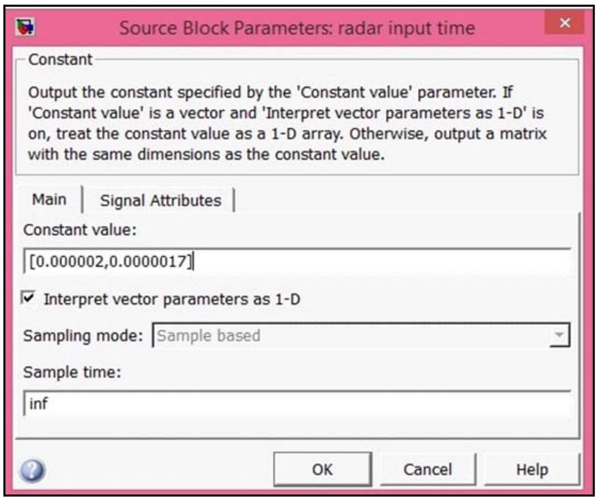


Fig 4: Manually given Radar Input Time Values and our speed value in Constant value Parameter.

The radar bands below 300 MHz have a long historically tradition because these frequencies represented the frontier of radio technology at the time during the World War II. Today these frequencies are used for early warning radars and so called Over the Horizon (OTH) Radars. Using these lower frequencies it is easier to obtain high-power transmitters. There are many types of radars such as UHF (Ultra High Frequency), VHF (Very High Frequency), and LF (Low Frequency). We should use different types of Radars for our usage and criticality. We have given two values in the Constant value parameter as the RADAR inputs. By calculating these inputs the distance of the opposite vehicle from our vehicle and speed of the opposite vehicle can also be calculated. RADAR takes the values for every second in the waveform by a transceiver. It is also fixed to a specific range and intimates to the driver when there is any obstacle in that range. We must give the Constant value i.e., speed of our vehicle in this our speed window parameter.

IV. RESULTS

The following are different results obtained by the model functioning of ACCS.

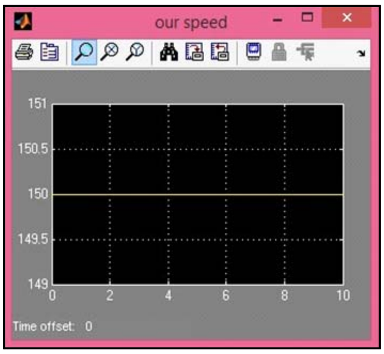


Fig 5: The result graph in mat lab showing our speed vehicle in km

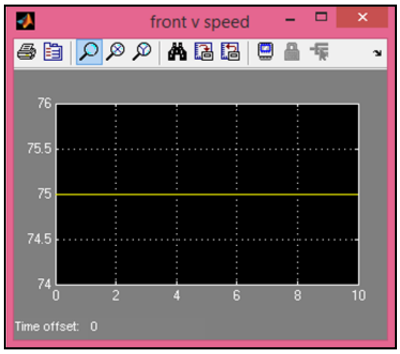


Fig 6: The result graph in mat lab showing opp. vehicle speed in km

The above 2 graphs are the results of two vehicles, our speed is vehicle with ACCS and it shows the speed it was travelling. The front v speed is the vehicle opposite to the vehicle with ACCS. By using RADAR we get the speed of the opposite vehicle. Here, the model calculates the speed of the opposite vehicle as 75 km/hr. by taking the inputs from the RADAR.

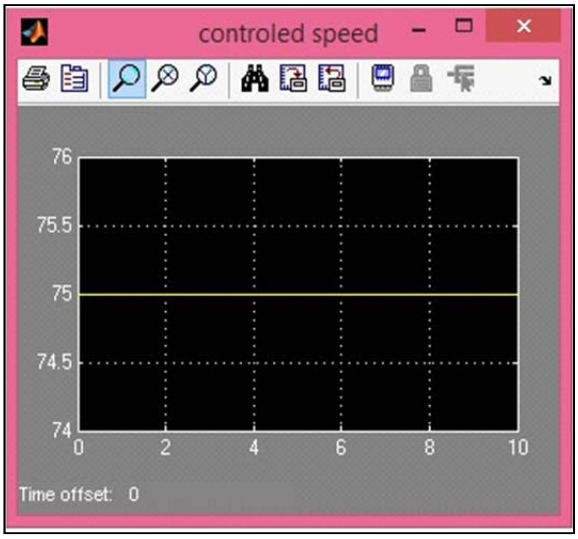


Fig.7: The result Graph in MATLAB showing the speed of controlled speed in km.

Fig.7 shows us the result of the entire model i.e., Controlled speed of ACCS vehicle. As observed the controlled speed will be same as the opposite car speed i.e., front v speed so that both the vehicles travel in same speed and thus accidents will be avoided.

V. SAFETY ANALYSIS OF ACCS

Safety is an emergent system property, and one component cannot make a system safe. Computers and software add an unpredictable element to the system, but there are a number of ways to deal with safety issues. First, it is important to consider safety from the very beginning of system design and a safety team, responsible for system safety issues, should be created. Second, extensive safety analysis should be done to try and come up with as many safety issues as possible. This analysis should better prepare the system designers to deal with safety issues, and it might make it easier to figure out which system functions are safety critical. More effort can be spend on making those identified functions safe and correct. Finally, it is important to use diverse safety mechanisms to increase the chances that one will catch the safety hazard. Although these are not fool proof methods, they are a good starting point for safe system design [6].

There are two safety assessment methods mostly used in the safety analysis. One of the methods is failure mode and effective analysis (FMEA). In FMEA, trained engineers or system designers team analyses the cause consequence relationships of component failures on system hazards. Second method is Fault tree analysis (FTA), serves as an effective method in reducing component level testing effort and also plans an effective integration and system testing [5].

Tests that are available for hardware:

a) Functional analyses
b) Detailed failure analyses (FMEA, FTA, Error Sequence Analysis, quantification etc.) [7].

Both FMEA and FTA can be done in RAM Commander Software which is intensively used for Safety Critical Systems. For ACCS there are 3 critical components. They are Radar, Speed Sensor, and brake sensor. We can do Failure Mode Effect Analysis to each of it.

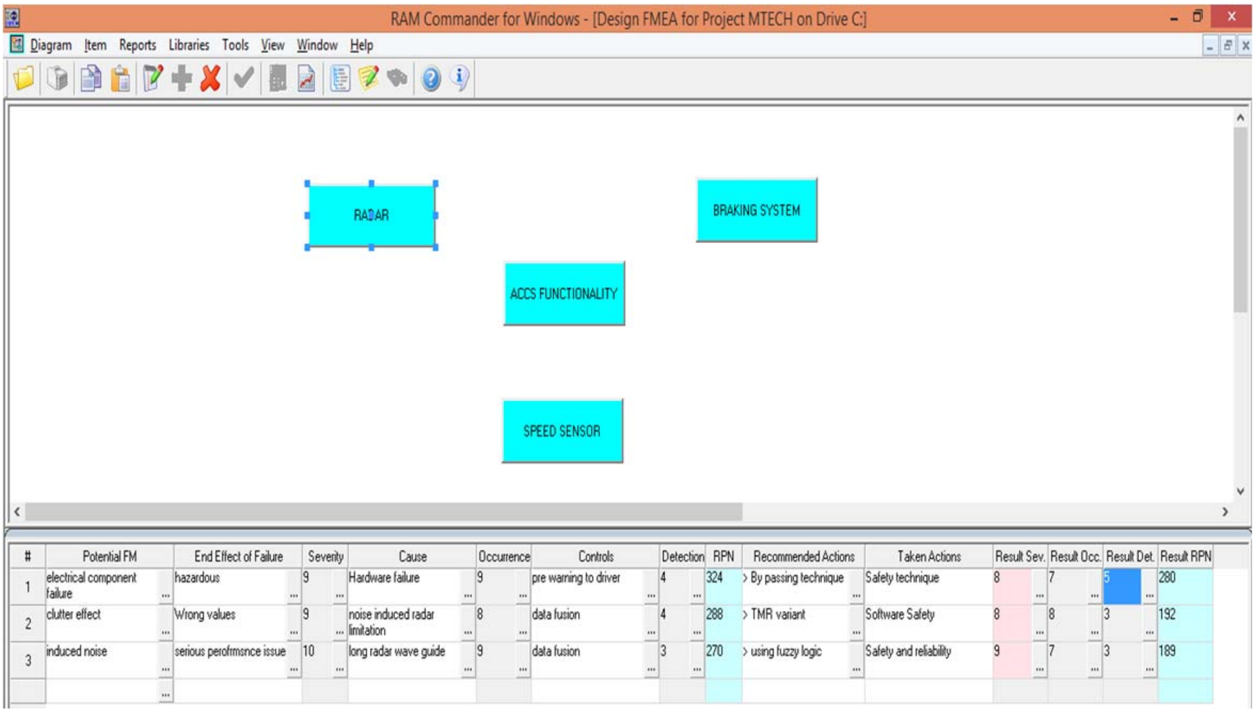
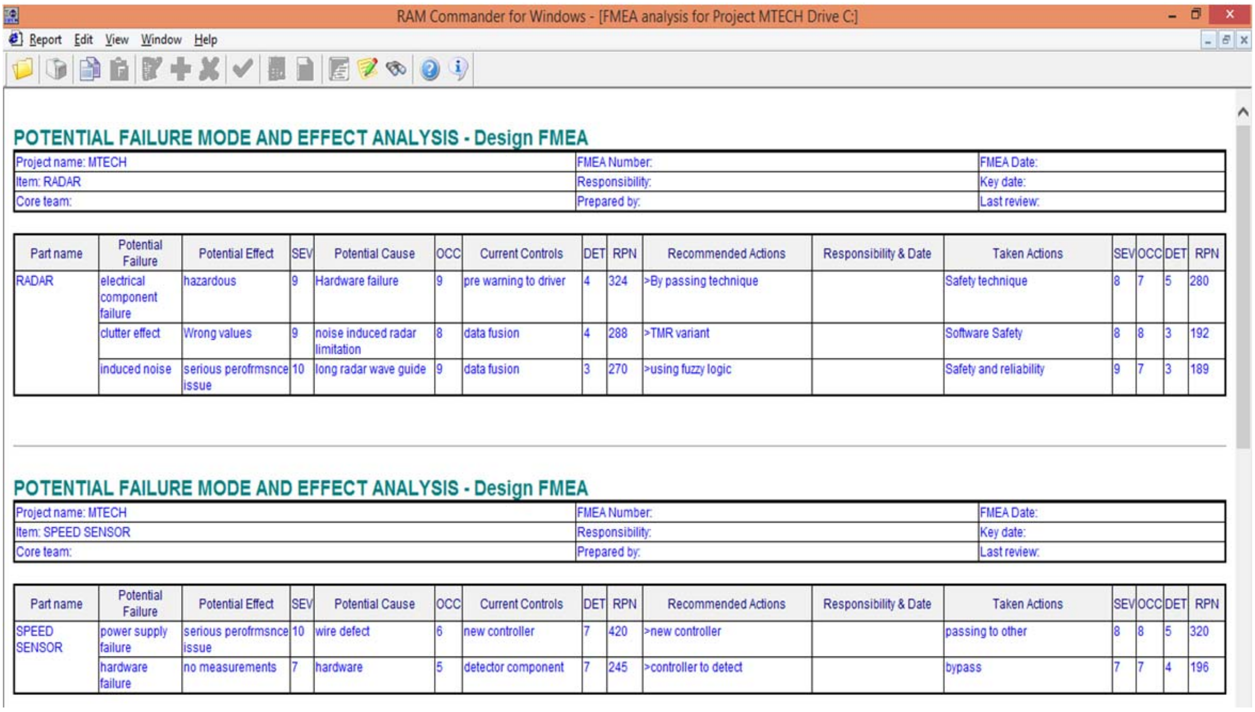


Fig. 8. FMEA analysis for RADAR in ACCS

In RADAR there are 3 potential failure modes and we have taken causes of these failure modes, effects of it, and also some control actions to be taken and after the feasibility calculation we get RPN (Risk Priority Number). The Failure Mode with highest RPN is to be resolved with techniques primarily.



POTENTIAL FAILURE MODE AND EFFECT ANALYSIS - Design FMEA

Project name: MTECH	FMEA Number:	FMEA Date:
Item: RADAR	Responsibility:	Key date:
Core team:	Prepared by:	Last review:

Part name	Potential Failure	Potential Effect	SEV	Potential Cause	OCC	Current Controls	DET	RPN	Recommended Actions	Responsibility & Date	Taken Actions	SEV	OCC	DET	RPN
RADAR	electrical component failure	hazardous	9	Hardware failure	9	pre warning to driver	4	324	>By passing technique		Safety technique	8	7	5	280
	clutter effect	Wrong values	9	noise induced radar limitation	8	data fusion	4	288	>TMR variant		Software Safety	8	8	3	192
	induced noise	serious perofrmsnce issue	10	long radar wave guide	9	data fusion	3	270	>using fuzzy logic		Safety and reliability	9	7	3	189

POTENTIAL FAILURE MODE AND EFFECT ANALYSIS - Design FMEA

Project name: MTECH	FMEA Number:	FMEA Date:
Item: SPEED SENSOR	Responsibility:	Key date:
Core team:	Prepared by:	Last review:

Part name	Potential Failure	Potential Effect	SEV	Potential Cause	OCC	Current Controls	DET	RPN	Recommended Actions	Responsibility & Date	Taken Actions	SEV	OCC	DET	RPN
SPEED SENSOR	power supply failure	serious perofrmsnce issue	10	wire defect	6	new controller	7	420	>new controller		passing to other	8	8	5	320
	hardware failure	no measurements	7	hardware	5	detector component	7	245	>controller to detect		bypass	7	7	4	196

Fig. 9. Design FMEA for RADAR and SPEED SENSOR

This is the Feasibility Calculation for both radar and speed sensor. In recommended actions if we want reports to be taken for FMEA then the report with the above details can be shown.

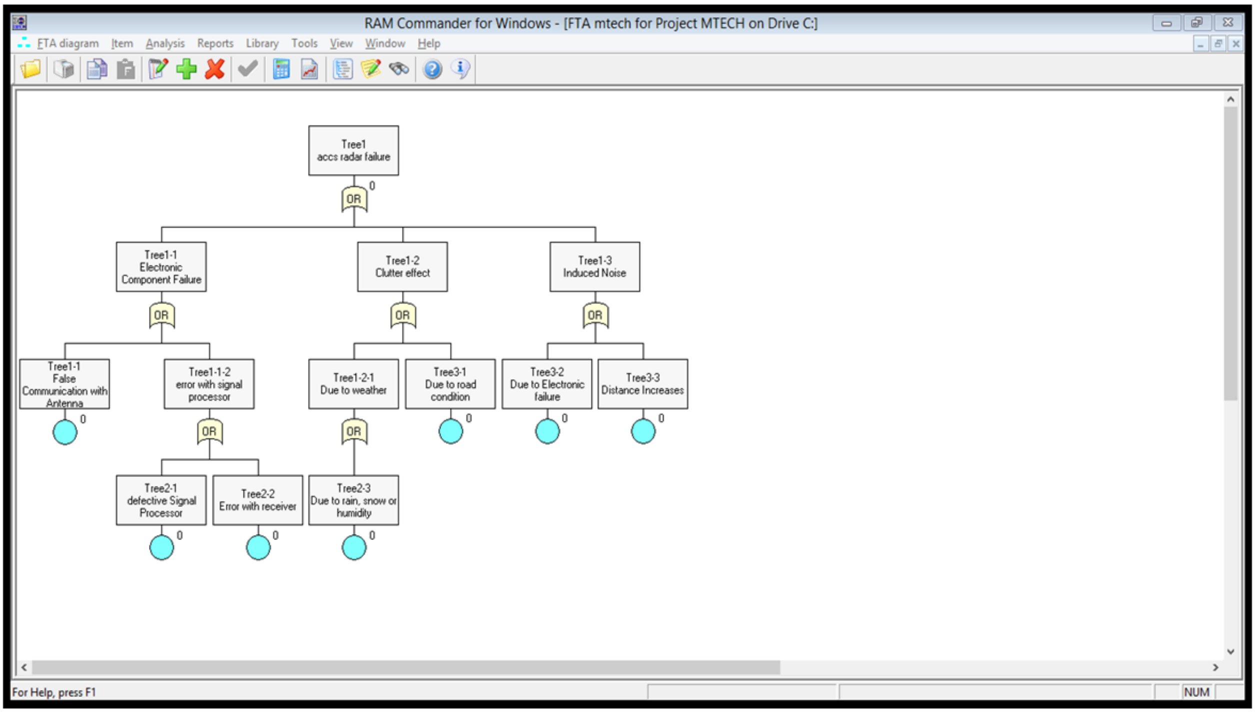


Fig. 10. FTA Analysis for RADAR in ACCS

This Fault Tree Analysis (FTA) can also be generated using FMEA in a RAM Commander. This is used to show the graphical representation of the entire Tree diagram. We can do MCS (Minimal Cut Set) calculation using FTA Analysis. We use logical gates in this FTA which are connected with events from parent nodes to child nodes.

VI. CONCLUSION

Adaptive Cruise Control system was developed for the purposes of driving with both safety and comfort. It reduces the number of brake and switch operations that are required of the driver. As a result, the system reduces the driving burden so that the driver can drive in comfort. In this paper we have shown a basic functionality of an Adaptive Cruise Control system done in MATLAB Simulink Software. When the input value are given to the Radar and our speed, the calculation of front v speed and controlled speed came as a result. The effects and causes of these ACC parts were identified by using Failure Mode Effective Analysis (FMEA) and root causes of these failures were analysed by using Fault Tree Analysis (FTA). The combined results of FMEA and FTA provide input for analysis of temporal or causal justification for prioritization of verification or validation test systematic approach from system down to subsystem.

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