International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

Available at http://inpressco.com/category/ijcet

Research Article

Simulation of Enhanced Ground Proximity Warning System using VHDL

Raghavender.V [Ȧ*], Rambabu Mokati [Ȧ], Anil Kumar.V [Ȧ] and H.Jeevan Rao [Ȧ]

[Ȧ] Department of Aeronautical Engineering, Vardhaman College of Engineering, India

Accepted 10 January 2014, Available online 01 February 2014, **Special Issue-2, (February 2014)**

Abstract

The "Enhanced Ground Proximity Warning System (EGPWS)" is designed to alert pilots when the aircraft is in one of the defined hazardous situations, by generating visual and audio warnings/alerts. Controlled Flight into Terrain (CFIT) is an accident where the aircraft is flown into the ground while the aircraft is completely airworthy. EGPWS integrates terrain situational awareness with respect to current airplane position and predicted trajectory with an advanced Ground Proximity Warning System. EGPWS provides alert information to the flight crew both visually and aurally. A terrain map database will be used, which provides EGPWS a means to estimate a flight-path or selected changes thereof for approaching high grounds. Based on the aircraft's position, terrain that is above or within 2,000 ft below the aircraft is presented on the system display. It is also included along with the basic functionality, to alert pilots in advance, so that they have sufficient time to overcome hazardous situations. For example situations like steep rise of terrain/obstacle in the path of aircraft won't give sufficient time to crew to overcome. In this paper all the required features that enable to generate proper alerts at proper time are implemented. The VHDL language is used to write code for the EGPWS functionality. It is also designed to provide various defined colors on the display, which enable the crew to know terrain height variations in the surrounding area through which aircraft is moving.

Keywords: *Terrain, Steep, CFIT, VHDL, Flight path.*

1. Introduction

The two major causes of eighty percent of commercial aviation fatalities in the 1980s were controlled flight into terrain (CFIT) and approach-and-landing accidents (ALAs). CFIT occurs when an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew. This type of accident can occur during most phases of flight, but CFIT is more common during the approach-and-landing phase.

*1.1 **CFIT***

When all of the different causes of the aircraft accidents are classified by type, CFIT remains the number one cause type. In the analysis of worldwide accidents in aviation, it is found that the CFIT (controlled flight into terrain) accidents are considerably more in number. (It was seen that out of 2500 world airline accidents between 1988 and 1995 around 2219 are CFIT accidents) CFIT only occurs during poor visual conditions – pilots do not fly an airworthy aircraft into terrain that they can see. [Hanson, Howison, Chikos, and Berson, "Aircraft Alerting Systems Standardization Study, Phase IV: Accident Implications on System Design",

*Corresponding author: **Raghavender.V**

1.2 EGPWS

The EGPWS is a Terrain Awareness and Alerting system providing terrain alerting and display functions with additional features. EGPWS integrates terrain situational awareness with respect to current airplane position and predicted trajectory with an advanced Ground Proximity Warning System. EGPWS provides alert information to the flight crew both visually and aurally. A terrain map database will be used, which provides EGPWS a means to estimate a flight-path or selected changes thereof for approaching high grounds. Based on the aircraft's position, terrain that is above or within 2,000 ft below the aircraft is presented on the system display. Terrain situational awareness may be provided up to 30 minutes before a potential terrain conflict. The terrain map database also comprises geographic data on virtually all airports available and will therefore be very effective in preventing premature/incorrect descents. EGPWS is able to determine the aircraft's position and flight path based upon information from the embedded Global Positioning System and FMS, Air Data System, Radio Altimeter and VOR/ILS systems. The EGPWS computer compares aircraft altitude with its internal terrain data base. If there is a potential threat of collision with terrain, the EGPWS computer generates a warning, well before the classic GPWS would do. This enables the pilot to take appropriate actions. The EGPWS monitors the aircraft flight path and generates visual and audio warnings/alerts when the

DOI: http://dx.doi.org/10.14741/ijcet/spl.2.2014.122

aircraft is in one of the defined hazardous situations. The purpose of the EGPWS is to detect inadvertent flight toward terrain and alert the flight crew so that they may take appropriate action. In addition to conventional GPWS, EGPWS has some additional protections like forward looking wind shear protection, bank angle protection etc.

With multi-sensor accuracy, plus a massive terrain database, the EGPWS can provide seven modes of capability:

1. Excessive descent rate, offering alerts and warnings for excessive descent with respect to altitude above ground level (AGL);
2. Rising terrain, to prevent impacting hills and mountains;
3. Descent after takeoff, to prevent "sinking" after initial climb;
4. Terrain clearance, to assure the aircraft simply remains safely above ground;
5. Excessive glide slope, to assure the aircraft does not approach the runway too high or too low;
6. Advisory callouts, for when the aircraft descends through predefined altitudes below 2,500 feet AGL or a decision height set on the radio altimeter, or when bank angles become too steep; and
7. Reactive wind shear.

1.3 Working of EGPWS

Basically, EGPWS works as follows: It uses data from the GPS and other navigational aids, the FMS, and the air data sensors to determine the aircraft position both longitudinally and vertically (lat/long). Then it adds that information to data from the terrain/runway database to form a display showing the terrain elevations around the aircraft. The EGPWS provides both horizontal and vertical look-ahead. With the horizontal look-ahead, the airplane can "see" at least a quarter mile on each side of the aircraft. So, if the aircraft enters into a bank turn, the EGPWS can "anticipate" the turn and warn against possible CFIT. The crewmen receive from the EGPWS an aural alert and a visual warning from a multicolor image. The green color on the image indicates terrain safely below the aircraft. Yellow represents a cautionary alert of 60-seconds prior to the predicted time of impact and is accompanied by a "caution terrain" aural message. And red indicates terrain that the aircraft could impact within 30 seconds; it is accompanied by an aural "terrain, terrain, pull up." What Peaks Mode offers is a depiction of the terrain below in various shades of green to denote ground elevations. The crew can view the terrain on their display even while 2,000 feet above the terrain. This predictive terrain hazard equipment is known as enhanced GPWS (EGPWS) or ground collision avoidance system (GCAS).

These GPWS features along with enhancements are implemented on a single chip (FPGA) by using VHDL (Very High Speed Integrated Circuit Hardware Description Language) in this dissertation.

2. Modes of Operation

EGPWS has different modes of operation to detect each type of CFIT. Each mode is processed by comparing the current values of certain flight parameters with pre-set limits. When triggered, each mode outputs a unique voice warning.

Mode 1 –Loss of Altitude After Takeoff

“Descent after takeoff, to prevent "sinking" after initial climb” Mode 1 provides warnings for significant altitude loss after take-off, or low altitude go-around (less than 245 ft AGL) with gear or flaps not in landing configuration. Mode 3 is active during first, second and third segment climb-out. Mode 1 warnings activate the **GND PROX** display on the PFD and aural message “DON’T SINK”. The aural message is only repeated twice unless altitude loss continues to accumulate.

Mode 1 – Altitude loss after takeoff – Provides warnings for excessive altitude loss after takeoff or go ground from less than 245 AGL, with gear or flaps not in the landing configuration. The amount of altitude loss that is permitted before an alert is given is a function of the height of the aircraft above the terrain as shown below. This protection is available until the EGPWS determines that the aircraft has gained sufficient altitude that it is no longer in the takeoff phase of flight. Significant altitude loss after takeoff or during a low altitude go-around activates the EGPWS caution lights and the aural message **“DON’T SINK, DON’T SINK”**

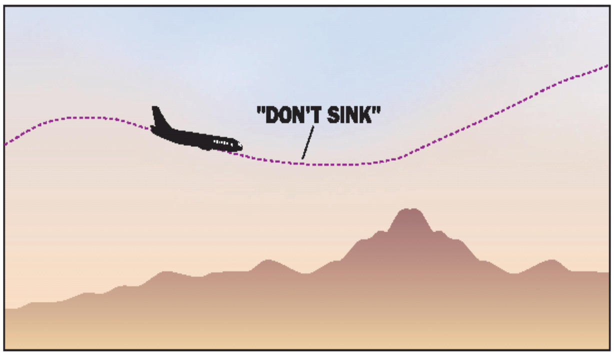

Fig.1 Altitude loss after takeoff turbofan (jet)

Mode 1 is active only when the aircraft is above 30 AGL and below 1500 AGL, the gear or flaps are up, and the GPWS is in the takeoff mode.

The aural message is enunciated twice for each 20% de-gradation of altitude. Upon establishing a positive rate of climb, the EGPWS caution lights extinguish and the aural alert will cease.

If the Aural De-clutter feature is disabled, the warning is enunciated continuously until positive climb is established.

Mode 1 looks at radio altitude terrain clearance and altitude rate. Altitude rate is either an inertial vertical speed, if available, or barometric altitude rate. Mode 1 is desensitized with elapsed time from take off. Mode 1 is affected by the Aural De-clutter option. On entering the mode 1 envelope the voice warning, "Don't sink" is given. The warning will continue until a positive rate of climb is activated.

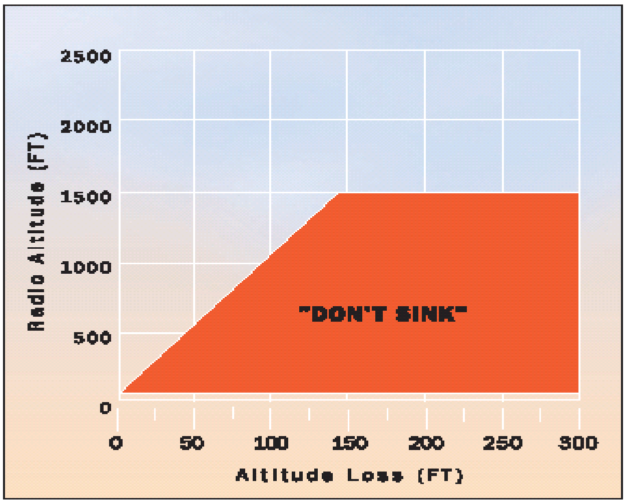

Fig.2 Altitude loss after takeoff turbofan

Mode 2 –Excessive Descent Rate

"Excessive descent rate, offering alerts and warnings for excessive descent with respect to altitude above ground level (AGL)".This mode has an inner and outer warning boundary. Penetration of the outer warning boundary activates the yellow **GNDPROX** display on the PFD and a minimum of 2 "SINKRATE" voice alerts. Further penetration to the inner boundary leaves the red **GNDPROX** display on the PFD, but changes the message to "PULL UP".

Mode 3 – Flight into Rising Terrain

Mode 3 provides alerts and warnings to help protect the aircraft from impacting the ground when rapidly rising terrain with respect to the aircraft is detected. Mode 3 is based on radar altitude and on how rapidly radar altitude is decreasing (closure rate). Mode 3 exists in two forms, 3A and 3B.

Mode 3A

Mode 3A is active during climb out, cruise and initial approach (Flaps not in landing configuration and aircraft not on glide slope centerline). If the aircraft penetrates the Mode 3A alerting envelope, the message "TERRAIN, TERRAIN" is generated and the **GND PROX** display on the PFD comes on. If the aircraft continues to penetrate the envelope, the warning message "PULL UP" is repeated continuously until the warning envelope is exited. Upon exiting the warning envelope, if terrain clearance continues to decrease, the message "TERRAIN" will be given until the terrain clearance stops decreasing. In addition, the visual alert will remain on until the aircraft has gained 300 ft of barometric altitude, 45 seconds has elapsed or the flap override switch is activated.

Mode 3B

Mode 3B is selected with flaps in landing configuration or when making an ILS approach with Glide slope deviation more than ± 2 dots. Warnings for Mode 3B activate the **GND PROX** display on the PFD and the continuous aural message "TERRAIN" until the terrain closure rate falls below warning levels.

Mode 4 –Lack of Altitude Awareness During Cruise Flight

"Terrain clearance, to assure the aircraft simply remains safely above ground".

Mode 4 provides alerts and warnings for insufficient terrain clearance with respect to phase of flight and speed. Mode 4 exists in three forms, 4A, 4B and 4C.

Mode 4A

Mode 4A is active during cruise and approach with gear not in landing configuration. Warnings for mode 4A activate the **GND PROX** display on the PFD and the aural message "TOO LOW GEAR", or if airspeed is greater than 190 KIAS, "TOO LOW TERRAIN". These messages will only be repeated twice unless terrain clearance continues to decrease.

Mode 4B

Mode 4B is also active during cruise and approach, but with gear in landing configuration. Warnings for Mode 4B activate the **GND PROX** display on the PFD and the message "TOO LOW FLAPS", or if airspeed is greater than 159 KIAS, "TOO LOW TERRAIN". These messages will only be repeated twice unless terrain clearance continues to decrease.

Mode 4C

Mode 4C is active after take-off or low altitude go-around (less than 245 ft AGL) with gear or flaps not in landing configuration. Mode 4C is active during first, second and third segment climb-out. Warnings for Mode 4C activate the **GND PROX** display on the PFD and the message "TOO LOW TERRAIN". These messages will only be repeated twice unless terrain clearance continues to decrease.

Mode 5 – Descent Below Glide slope on Landing

"Excessive glide slope, to assure the aircraft does not approach the runway too high or too low".

For normal descent rates above 500 FPM, Mode 5 Glide slope alerts are provided when the aircraft is below 1000 ft AGL with gear down and the deviation exceeds 1.3 dots below the ILS Glide slope. For descent rates between 500 FPM and 0 FPM (level flight or descent rates), Mode 5 glide slope alerts are linearly reduced from 1000 ft to 500 ft AGL. For level flights or climb rates, Mode 5 glide slope alerts are enabled at 500 ft AGL or with some deviation is required to give an alert below 150ft AGL. The alert becomes more frequent and louder (hard alert) if the condition worsens. Alerts for Mode 5 activate the "GLIDESLOPE" message and **GNDPROX** display on the PFD.

Mode 6 – Altitude Awareness During Final Approach

"Advisory callouts, for when the aircraft descends through predefined altitudes below 2,500 feet AGL or a decision height set on the radio altimeter, or when bank angles become too steep". The Mode 6 function provides callouts for descent through predefined altitudes AGL, including descent through DH. The Mode 6 callouts function is active during the final approach phase of flight. Each callout is only annunciated once per approach

Mode 7 – Microburst Wind shear

In flight the system provides wind shear warnings and alerts under the following conditions:

Mode 7 wind shear warnings and alerts are provided between 10 and 1500 ft AGL during take-off and final approach phases of flight, when the level of wind shear exceeds predetermined threshold values. The actual wind shear value which is measured represents the vector sum of inertial vertical speed air mass accelerations along the flight path and perpendicular to the flight path. These shears result from vertical winds and rapidly changing horizontal winds.

2.1 Simulation Results

MODE 2: Sink Rate Results

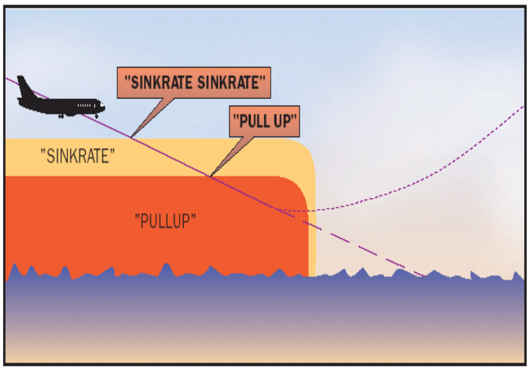

Fig.3 Excessive Descent Rate

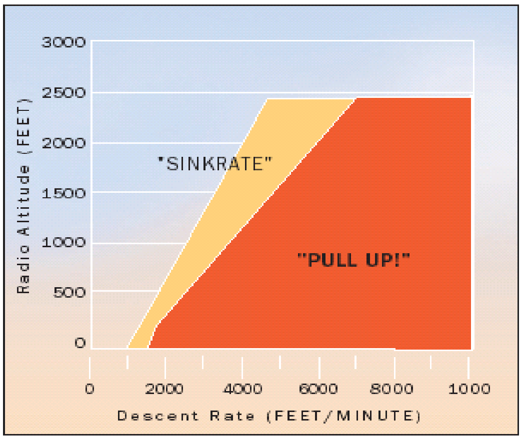

Fig.4 Excessive Descent Rate Turbofan (jet)

MODE 3: Terrain Clousure Rate

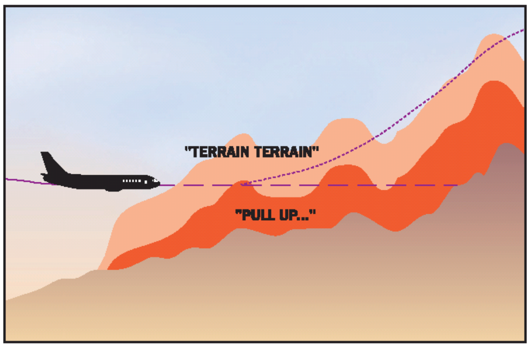

Fig.5 Terrain Closure Rate

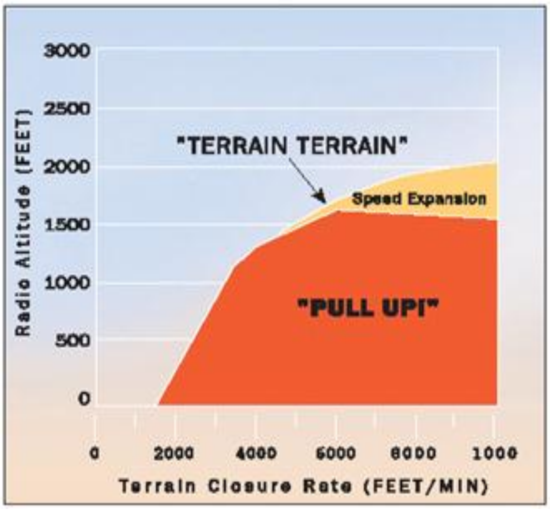

Fig.6 Terrain Closure Rate

MODE 4: Low Terrain

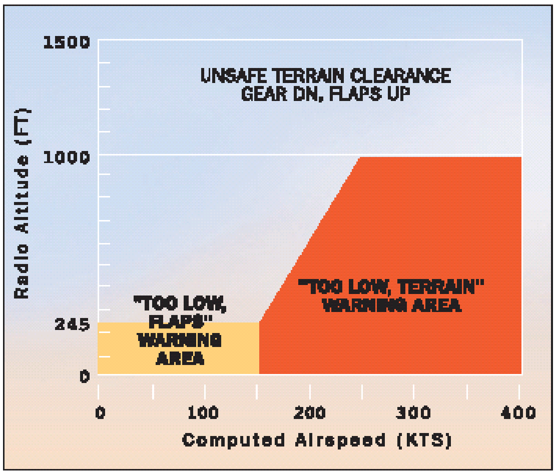

Fig.6 Low Terrain

MODE 5: Glide Slope

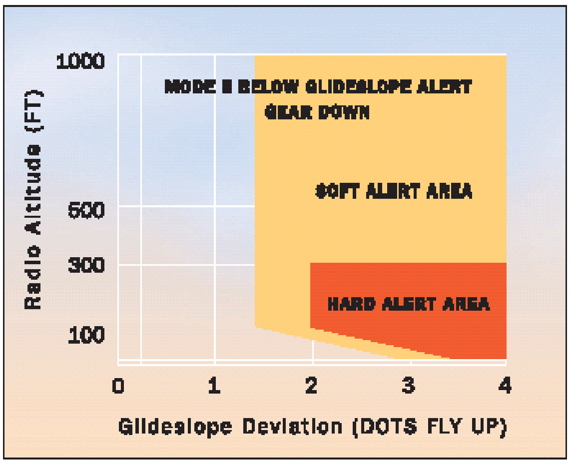

Fig.7 Glide Slope

MODE 6: Bank Angle

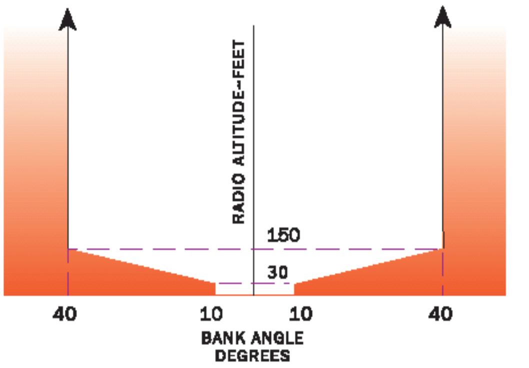

Fig.8

Bank Angle

MODE 7: Wind Shear Alert

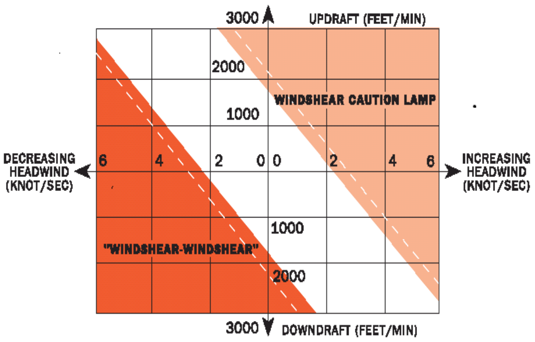

Fig.9 Wind Shear Alert

Syenthesis Results Pin Diagram of Mode 1:

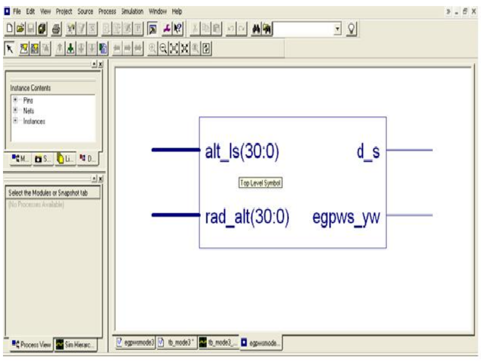

Fig.10 Pin Diagram

RTL Schematic:

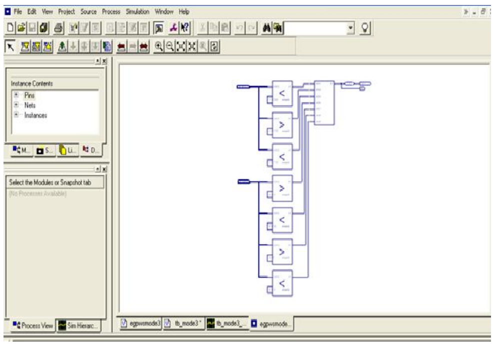

Fig.11 RTL schematic

Conclusion

The aircraft was equipped with an enhanced ground proximity warning system (EGPWS). Apart from the basic GPWS functions this system also performed functions including "Terrain look- ahead" alerting.

As no FDR or QAR data was available EGPWS flight history data, obtained from the EGPWS computer, was examined. Access to the data stored in the EGPWS computer non-volatile memory assisted the investigation significantly. The accessibility of non-volatile memory data has provided another tool for the investigation of accidents and incidents.

References

Albert Hel Frick,(2000), Principle of Avionics, Avionic communications Inc

J.Powell,(1998), Aircraft Radio systems,, Pitman Publishers

Don Bateman, (2000), "Enhanced Ground Proximity Warning System (EGPWS) and Flight History Stored in Non-Volatile Flash Memory", Honeywell. Presented at the ANZSASI Conference June 2000 in Christchurch NZ

R.P.G. Collinson, Introduction to Avionics Systems, Kluwer academic publishers, Second Edition.

Ian Moir, Military Avionics Systems, AIAA Education.

MK VI and MK VIII,(2004), Enhanced Ground Proximity Warning System (EGPWS) Pilot's Guide, Honeywell International Inc.