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Enhanced Ground Proximity Warning System- Overview

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ABSTRACT

Proximity Warning system have been developed to provide enhanced situational awareness to the pilots such that CFIT accidents which become can things of past. Thus Enhanced ground proximity warning system is used to prevent accidents which can be caused by control flight in to the terrain. Old traditional system used radio altimeter for terrain height. Radio altimeter tells the aircraft height with reference to the Terrence/surface below the Aircraft. In case of rapidly rising terrain it may not react quick enough to issue a warning in time EGPWS corrects this problem by integrating an Aircraft navigational source in to the system. GPS position in conjunction with a terrain database is used to help in prediction of terrain conflict. Any catalogued man made obstructions can be included in the database. This type of system can be used to display terrain profile to the pilot to improve situational awareness.. This paper e deals with detail study of Enhanced Ground Proximity Warning System and how stall warning system, wiper system and decision height option in Aircraft can be connected to enhanced ground proximity warning system to give additional audio warning to the pilot.

Key words: EGPS, CFIT, GPWS, Terrain height, Stall warning system

INTRODUCTION

Enhanced Ground Proximity Warning System uses Aircraft inputs such as position, altitude, airspeed and glide slope Enhanced ground proximity warning system is very important system from the flight safety point of view. The main cause of concern in aviation is loosing of perfectly flyable Aircraft due to flying and hitting in to unknown surface or water and meeting an accident. This type of accidents is referred to as controlled flight in to terrain (CFIT). Statistics show that introduction of the ground proximity warning system (GPWS) in to the aviation industries has resulted in to a dramatic drop in the frequency of the CFIT accidents. Training aids, videos, checklists and procedural recommendations have also been resulted in reduction of CFIT accidents. The Enhanced Ground, which along with internal terrain, obstacles and airport database to predict a conflict between the aircraft flight path and terrain or an obstacle .A conflict will result in the EGPWS providing a caution or warning alert. The EGPWS also provides alerts for excessive glide slope deviation, too low with flaps or gears not in landing configuration and optionally provides bank angle and altitude callouts based on system configuration selection.

EGPWS improves terrain awareness and warning times by introducing the terrain display and the terrain database look head protection. The system can monitor the airplane location, altitude and provides a map type display of surrounding terrain. It also alerts if the airplane approaches too close to terrain, a body of water or tall structure. It protects aircraft from controlled flight in to terrain and approach and landing accidents. The original ground proximity warning system concept relied on information from the air data system and radio altimeter. EGPWS takes it to a higher level by using data from satellite systems and data base containing information on a digital elevation model and an

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aeronautical database. The development of EGPWS has increasingly decreased the risk of controlled flight in to terrain.

Today controlled flight in to terrain accidents continues to be a primary cause of fatalities and airframe losses in aviation. GPWS is the system customized to provide alerts/warning that may not seen by the pilots along the flight path including the range of take off, go around, approach and landing. But, the current GPWS is not perfect yet it is partly because alerts/warning is not provided from GPWS until aircraft has been threatened by terrain/obstacles. EGPWS the new version of GPWS, a passive safety system provides predictive warning of both obstacles and terrain by interchanging a high resolution data base with global positioning system navigators and other sensors. With EGPWS, pilots are available to take measures avoiding threatens timely because the system provides alerts/warning with more than sufficient time to operations.

CAUSES OF CFIT

[1] Air crew error, ATC error, Equipment Malfunction are the main causes of CFIT accidents If the aircraft's navigational equipment is unserviceable or malfunctioned, this could mislead the pilots in reading the wrong data and wrongly fly the plane into terrain also the adverse metrological conditions may result in to CFIT accidents. Lack of information about steep terrain or insufficient warning in case of failures of a system or pilot is not following the Standard operating procedures also may lead to CFIT accidents

OPERATING PRINCIPLE

Compared with GPWS, EGPWS has two more new functions terrain awareness alerting and terrain display. These new functions use the global airport database and global terrain database as well as aircraft position, pressure altitude and flight route to make pilots to have the awareness of the potential controlled flight into terrain. The awareness alerting module of EGPWS Compares these data with the situation of ahead of flight route from terrain database, calculates the speed and height approaching the maximal terrain point. Then this speed and height are compared with the warning envelop, once exceeded, the terrain threat is detected and the alert is triggered.

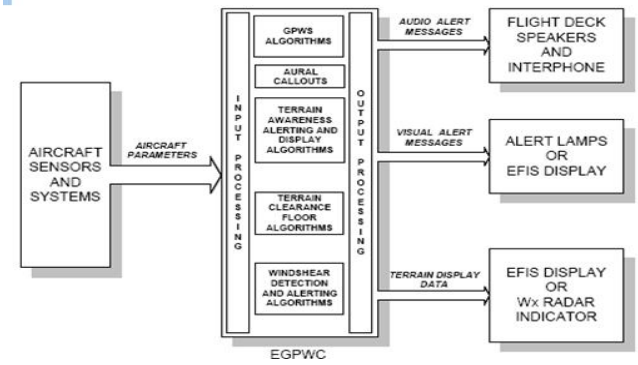

Fig -1 EGPWS Block diagram

The EGPWS uses various inputs signals from other onboard system fitted on Aircraft. Systems providing Altitude, Airspeed, Altitude, Glide slope and position are required for basic and Enhanced functions. Uncorrected and corrected Barometric Altitude, Altitude rate, computed airspeed and static air temperature are provided by air data system. Radio altitude is provided by a Radio Altimeter system. Decision height is provided by a Radio Altimeter system or sub system. Roll Attitude, pitch attitude and magnetic heading information are provided by Automatic Heading Reference System. Latitude and Longitude position of aircraft, true track angle, GPS altitude, and Ground speed are obtained from Global Positioning System. Glide slope information are given by VHF NAV Receiver. Terrain display is obtained on weather radar indicator. Discrete inputs are used for system configuration, signal/status inputs and control input functions. Signal/status discrete include signals such as decision height, landing flap position, landing gear selected and status discrete such as glide slope Valid, magnetic heading Valid and Radio altitude associated with analog signal inputs. Control discrete control EGPWS functions. These includes EGPWS self test, glide slope cancel, flap override, audio inhibit and mod 6 low volume select. Configuration module is used to tell the system the type of aircraft it resides in and its interface. This is defined and established during the EGPWS installation.

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EGPWS output functions are consequently the result of configuration state read each time the EGPWS is powered on. The EGPWS provides both audio and visual outputs. Audio outputs are provided as specific alert phrases and altitude callouts or tones provided by an EGPWS speaker and via the cockpit interphone system for headset usage. Several audio output levels are available; they are established during the installation of EGPWS. These EGPWS audio outputs can be inhibited by other system having higher priorities (stall warning system). Visual outputs provide discrete caution and warning alert and status annunciation. Terrain display video is output to a compatible display system when available and enabled. The discrete visual alerts along with audio caution and warning alerts give optimum terrain alerting capability. Status annunciation provides information to the flight crew about the status of the EGPWS (GPWS INOP). Terrain video is generated by the EGPWS based on the aircraft current position relative to the surrounding terrain. This video is presented on weather radar indicator or terrain display unit.

BASIC FUNCTIONS

[3] Mode 1- Excessive Decent Rate

Mode 1 provides audio and visual alerts for excessive descent rates into terrain. When the EGPWS caution alert envelope is penetrated, the message "SINKRATE" is annunciated and EGPWS alert lights illuminate. Continuing the excessive descent rate into the EGPWS warning alert envelope results in a "PULL-UP" annunciation and EGPWS alert lights illuminated. Mode 1 is desensitized to eliminate unwanted (nuisance) alerts when the EGPWS determines that the aircraft is above a Glide slope beam. In some applications, Mode 1 is also desensitized when Steep Approach or Flap Override is active.

Mode 2a/2b-Terrain Closure Rate

Mode 2 provides audio and visual alerts for dangerously high terrain closure rates. Two sub-modes, referred to as Mode 2A and 2B are defined. Mode 2A is active when flaps are not in the landing position and the aircraft is not on an ILS approach within ±2 dots of glide slope center. When the caution alert envelope is penetrated, the message "TERRAIN, TERRAIN" is annunciated and EGPWS alert lights illuminate. Continuing the high terrain closure rate into the warning alert envelope results in a "PULL-UP" annunciation and EGPWS alert lights illuminated. . Mode 2B is automatically active when the flaps are in the landing position or while on an ILS approach within ±2 dots of glide slope deviation. Mode 2B provides a desensitized alerting envelope to permit normal landing approach maneuvers close to terrain without unwanted alerts

Mode 3 - Descent after Takeoff

Mode 3 provides audio and visual alerts for excessive altitude loss after takeoff, or after a go-around from below 245 feet above ground level (AGL), when flaps and gear are not in the landing configuration. Penetrating the Mode 3 alert envelope causes the voice message "DON'T SINK, DON'T SINK' and illumination of EGPWS alert lights.

MODE 4A/4B/4C - UNSAFE TERRAIN CLEARANCE

Mode 4 provides audio and visual alerts for unsafe terrain clearance with respect to phase of flight, height above ground, and speed. Three sub-modes, referred to as Mode 4A, 4B, and 4C, are defined. Mode 4A is active during cruise and approach with landing gear up. Mode 4B is active during cruise and approach with landing gear down and flaps up. Mode 4C is active during takeoff when either gear or flaps are not in the landing configuration. The aural annunciations for Mode 4A are "TOO LOW TERRAIN" or "TOO LOW GEAR" depending on airspeed. Mode 4B provides "TOO LOW TERRAIN" or "TOO LOW FLAPS" depending on airspeed. Mode 4C provides "TOO LOW TERRAIN". EGPWS alert lights are illuminated during these alerts.

Mode 5 - Descent below Glide slope

Mode 5 provides audio and visual alerts for excessive glide slope deviation when the aircraft descends below the glide slope beam on front-course ILS approaches. Two levels of alerting are provided. If the aircraft is below 1000 feet AGL and gets to or exceeds 1.3 dots glide slope deviation (fly-up), a 'soft'

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(reduced volume) "GLIDESLOPE" is annunciated. Exceeding 2 dots from below 300 feet AGL provides a hard (full volume) *"GL l D E SLOPE"* annunciation. EGPWS alert lights are illuminated during these alerts.

Mode 6 - Advisory Callouts

The EGPWC is programmed to annunciate mode 6 Advisory callouts based Altitude Awareness, Minimum/Approaching Minimum and Back angle type callouts as defined for each EGPWS model. The menu selected advisory callouts are defined and enabled in the installation configuration. Only rural callouts are provided for mode 6.

Excessive bank Angle call out

The bank angle callout feature provides callout annunciation for excessive bank angles based on altitude and bank angle limits defined by aircraft type. It is intended to enhance situational awareness during intentional or unintentional maneuvering and for protection against wing or engine strikes when close to the runway.

Terrain Clearance Floor and Runway Field Clearance Floor

The Terrain Clearance Floor (TCF) alerting function adds an additional element of protection to the standard Ground Proximity Warning System. It creates an increasing terrain clearance envelope around the airport runway to provide CFIT protection against situations where Mode 4 provides limited or no protection. TCF alerts are based on current aircraft location, destination runway center point position, and Radio Altitude (altitude AGL). TCF is active during takeoff, cruise, and final approach. TCF complements the existing Mode 4 protection by providing an alert based on insufficient terrain clearance even when in landing configuration.

RFCF is based on current aircraft location, destination runway center point position, and Geometric Altitude or altitude Above Sea Level (ASL) relative to the destination runway. RFCF provides short landing protection for runways that are significantly higher than the surrounding terrain. When an aircraft penetrates either the TCF or the RFCF alert envelope, the aural message "TOO LOW TERRAIN" will occur. This aural message will occur once when initial envelope penetration occurs, and one time thereafter for each 20% degradation in either Altitude (AGL) or Altitude (ASL) depending on which envelope was violated (TCF or RFCF respectively). EGPWS cockpit alert annunciations remain illuminated until the alert envelope is exited.

Run way Database

The EGPWS Runway Database consists of data records for all airport runways offered for the coverage provided by the Terrain Database. The database provides the means of accessing the records of runways closest to the current aircraft position.

Terrain Alerting and Display

The Terrain Alerting and Display (TAD) function monitors aircraft position with respect to local database cataloged terrain to provide rapid audio and visual alerts when a terrain threat is detected. Terrain threats are recognized and annunciated when terrain violates specific computed envelope boundaries forward of the aircraft path. The terrain database also includes obstacles (when and where available) providing similar annunciations when cataloged obstacles violate the same envelope boundaries.

Terrain alerting outputs (lights and audio) behaves in the same manner as the standard GPWS mode alerts. Either caution or warning alerts will initiate a specific audio alert phrase. The caution aural is "CAUTION TERRAIN" and the warning aural is "TERRAIN, TERRAIN, and PULL UP".

Complementing the terrain threat alerts, the EGPWS also maintains a synthetic image of local terrain forward of the aircraft for display on Weather Radar Indicator. The EGPWS is configured to automatically de-select the Weather Display and pop-up a display of the terrain threats when they occur [4].

TERRAIN AND OBSTACLE DATABASE

The EGPWS Terrain Database is the earth's surface divided into grid sets and cells referenced to the geographic (latitude/longitude) coordinate system of the World Geodetic System 1984 (WGS-84). Elements of the grid sets include the highest terrain

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altitude (above MSL) in each cells respective area. Grid sets vary in resolution depending on geographic location. Because the overwhelming majority of "Controlled Flight into Terrain (CFIT)" accidents occur near an airport, and the fact that aircraft operate in closer proximity to terrain near an airport, higher resolution grids are used around airports. Lower resolution grids are used outside of airport areas where aircraft altitude en route makes CFIT accidents unlikely and for which detailed terrain features are not important to the flight crew.

[5] Digital Elevation Models (DEM's) are available for most of the airports around the world today. In cases where data is not currently available, DEM's are generated from available topographic maps, sectional charts, and airline approach plates. The process of acquiring, generating, assembling, and updating the database is governed by strict configuration controls to insure the highest level of data integrity for generation of the EGPWS Terrain Data base. The Obstacle Database is a separate file included within the terrain database. Both files are loaded into the EGPWS in the terrain database PCMCIA card. The obstacle database is accessed by the EGPWC application software only if obstacle alerting is enabled by installation configuration. [7]

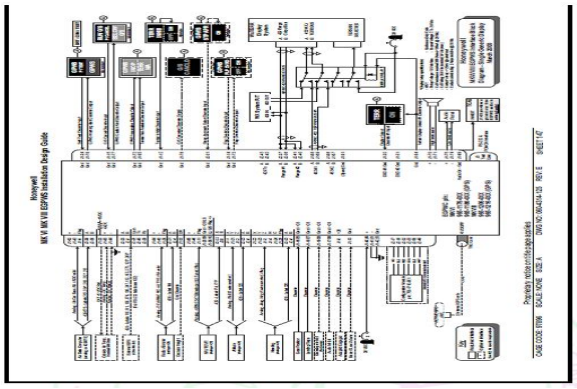

Fig -2 EGPWS system connection diagram

Typical block diagram developed by Honeywell is shown above. EGPWS computer is the heart of the system. All EGPWS functions are performed by this computer. The installation configuration is defined in a programmed configuration module installed in connector of EGPWC.pin connection of basic system like Attitude and heading reference system, landing gear and flaps, terrain awareness and display system and various cockpit indications of EGPWS are mentioned in the diagram. Generally all basic system suggested by Honeywell is being implemented and scope exists for connection of stall warning system, wiper system and decision height option in radio altimeter with enhanced ground proximity warning system. In above diagram optional pin number 36 of Enhanced Ground proximity warning computer has been kept for audio inhibit, same is proposed to be connected to stall warning system.pin number 13 of enhanced ground proximity warning computer is recommended as a optional mode 6 low volume. Same is proposed to be connected to wiper system.pin number 33 of EGPWC is given for decision height option and same can be connected to radio altimeter indicator. Explanation of stall warning system, wiper system and radio altimeter system installed on a multipurpose aircraft used for patrolling is given below

STALL WARNING SYSTEM

[2] (a) Stall Warning System The stall warning system is very important system for aircraft. The system provides an indication of Airplane lift throughout the flight. The main component of stall warning system is:

(I) Lift Transducer (ii) Lift Computer (iii) Reference speed deviation indicator (IV) Flap Position Transmitter (v) Stall Warning Lamp and Horn

System Operation

The purpose of stall warning system is to give an audio and visual warning in cockpit in case aircraft losses its speed. The lift transducer is fitted on the left wing and is electrically heated to prevent icing. If the left piton de-ice switch is switched on , when the Airplane is on the ground, a reduced voltage is supplied to the lift transducer heater via resistor 3FW to prevent overheating, when the Airplane leaves the ground the right main landing gear switch 15 GA closes and completes the ground circuit for the coil of relay 10FW. The relay energizes and its contacts shorts the resistor 3FW allowing the full 28V to supply the transducer heater. The lift transducer detects the airplane wing lift and supplies appropriate

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signal to the lift computer. The flap position transmitter is connected to the flaps and supplies a signal to the lift computer depending upon the position of flaps. The signals from the lift transducer and flap position transmitter are supplied to the lift computer where they are processed in to a reference speed signal for the RSD indicator. During flight the RSD indicator pointer may be anywhere between SLOW and FAST depending upon flight condition. The reference speed (stall speed multiplied by a factor of 1.3) is indicated at the center triangle. If the Airplane speed deviates into the slow range, the lift computer supplies a discrete signal to illuminate the stall warning lamp and sound the stall warning horn from pin M of lift computer.fed to the lift computer.. The line diagram of stall warning system is shown as fig 1.Honeywell suggests pin no 36 of EGPWS as Audio Inhibit .Same pin is proposed to be connected to stall warning system.

Wiper System [6] during heavy rains in order to have a clear vision through Aircraft canopy for pilot, Wipers are used with the help of wiper switch. Wipers blades, wiper Motor, Relay and wiper switch are the main components of Wiper system. .It has been observed that during heavy rains while operating wiper system, a lot of sound being observed in cockpit resulting in

The wipers are driven by a motor via gearboxes which convert rotary motion in to an oscillating angular motion. A flexible shaft links the gearboxes and a further shaft links the RH gearbox to the wiper motor. The wiper motor provides the drive for the windshield wipers. A bonding jumper between the motor and the airframe ensures a good ground connection. The motor is series wound and consists of a suppressor, thermal overload protection and a parking switch. The gearboxes are worm drive gearboxes with a reduction ratio of 155:1. They convert rotational motion from the wiper motor in to an oscillating angular motion. A resistor is located on relay support and is converted in series with the motor when the wiper switch is set to PARK.

The system is supplied from BUS 1 3PP when wiper switch is set to ON, 28V is applied to the relay 3ME. The relay energizes and supplies via contacts A2-A1, the wiper motor. The wipers are driven via flexible shaft by the gearboxes. When the switch is set to OFF, the wiper will stop. Pushing the switch to PARK energizes relay 7ME and applies 28V to the motor via contacts B2-B1 and resistor 4ME. Contacts A2-A1 connects ground to the motor. The motor runs and when the motor PARK position is reached, the built in switch closes and shorts the armature, stopping the motor. The resistor in series with the motor slows down the rotation gradually until the PARK position is reached.

Technical Data Wiper Motor

Type	series wound
Supply	28V DC
Current consumption	5.3A
Power	92 W
Speed	11600 rpm
Weight	1.113 kg
Gearbox reduction ratio	155:1
Angular reduction	60 degree
Resistor resistance	1 OHM
Resistor power rating	50 W +

Honeywell suggested pin no 13 of Enhanced Ground Proximity Warning System Computer As a optional ‘Mode 6 Low Volume’. Pin is grounded and hence normal volume is being heard during flying for EGPWS Warning. This volume is just not sufficient for pilot during wiper motor operation. In order to enhance the volume for EGPWS Warning during wiper motor operation, a 28V DC must be provided at pin no 13 of EGPWS Computer from Wiper system switch.

Radio Altimeter System Presently most of aircraft is fitted with radio altimeter. As the name implies, radio waves are transmitted towards the ground and the time it takes them to be reflected back and return to the aircraft is timed. Because speed, distance and time are all reflected to each other, the distance from the surface providing the reflection can be calculated as the speed of the radio waves and therefore the time

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it takes to travel a distance are known quantities. Aircraft is also fitted with encoding altimeter and counter pointer altimeter. Both these altimeter tells the aircraft height with respect to mean sea level. Altimeters operate on the principle of static pressure applied to it. Radio altimeter tells height of aircraft from the hill or the surface. The drawback of this system is that it detects surface or hill below the aircraft only. Also the alarming time for the pilot is approximately 25 seconds only which may not be sufficient all the time for the pilot for taking appropriate action. The Radio Altimeter System consists of an Antenna, Transmitter and Receiver and Radio Altimeter Indicator. The Existing schematic diagram of Radio Altimeter indication system is shown in fig 3. The radar altimeter system is supplied from the +28V bus via the circuit breaker RAD ALT. The radar altimeter transceiver applies a signal to the transmit antenna. The transmit antenna beams the signal to the terrain and the terrain reflects the signal back to the receive antenna. The returning signal is applied to the receiver section of the transceiver. The altitude of the airplane above the terrain is proportional to the time required for the transmit signal to make a round trip to the terrain and return. The signal is continuous within the maximum range of altimeter, provides constant altitude information which is displayed on the indicator.

The signal from the transceiver drives the indicator pointer via a servo amplifier and servo motor. The altitude scale is marked from 20 to 2000 feet from 20 to 500 feet each scale mark represent 10 feet, and from 500 to 2000 feet each mark represents 100 feet. The decision height (DH) index indicates the altitude below which the DH lamp will light, and is preset by the DH button. The lamp can be extinguished by pressing it in and turned on again by pressing a second time. The indicator and transceiver can be tested by pressing the test push button when the button is pressed the warning flag appears and 50+5 feet are indicated. The warning flag appears when the altitude information is invalid or during self test. The altimeter indicator also supplies the DH signal to the attitude director indicator when the airplane reaches the preset decision height.

CONCLUSION

Enhanced Ground Proximity Warning System is definitely a system which is very useful system and reduces the risk of aircraft accidents caused by controlled flight in to terrain. Study of this paper resulted in a fair knowledge about principle and operation of EGPWS, stall warning system, wiper system and radio altimeter system and how these system can be connected with Enhanced Ground Proximity Warning System. This paper is useful for the technical personnel carrying maintenance on the aircraft electrical system, pilot and for personnel in the field of research.

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