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Enhanced ground proximity warning system

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In this paper the main characteristics and functionality of the Honeywell MK VI Enhanced Ground Proximity Warning System are given. The System, intended for the modernization of the Antonov 26, predicts a potential conflict between the aircraft flight path and terrain or an obstacle. A possible conflict will result in the system providing a visual and audio caution or warning alert.

Key words: **aircraft, cargo aircraft, flight security, avionics, Ground Proximity Warning System**

Introduction

ENHANCED Ground Proximity Warning System (EGPWS) Honeywell MKVI is terrain awareness and alerting system. The EGPWS uses aircraft inputs including geographic position, attitude, altitude, airspeed and glideslope deviation. These are used with respect to internal terrain, obstacles, and airport database to predict a potential conflict between the aircraft flight path and terrain or an obstacle. A possible conflict will result in the EGPWS providing a visual and audio caution or warning alert.

Basic functions

The system provides six basic functions:

- excessive descent rate, mode 1,
- excessive closure to terrain, mode 2,
- altitude loss after takeoff, mode 3,
- unsafe terrain clearance, mode 4,
- excessive deviation below glideslope, mode 5,
- advisory callouts, mode 6.

Mode 1 provides alerts for excessive descent rates with respect to altitude and is active for all phases of flight. This mode has inner and outer alert boundaries (Fig.1).

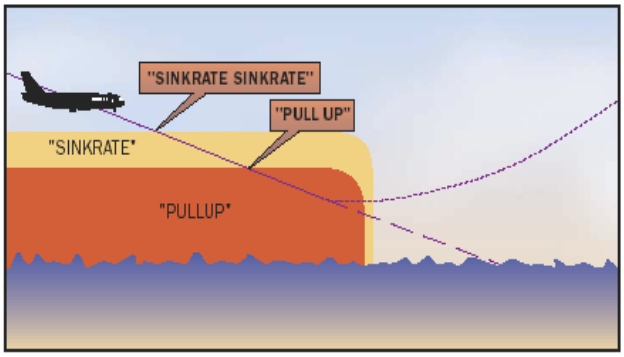

Figure 1. Excessive descent rate, mode 1

Penetration of the outer boundary activates the EGPWS caution lights and "SINKRATE, SINKRATE" alert enunciation. Additional "SINKRATE, SINKRATE" messages will occur for each 20% reduction of the time of impact. Penetration of the inner boundary activates the EGPWS warning lights and changes the audio message to "PULL UP" which is repeated continuously until the inner warning boundary is exited.

Mode 2 provides alerts to help protect the aircraft from impacting the ground in cases of rapid terrain rising, with respect to the aircraft, is detected. Mode 2 is based on the radio altitude and the speed with which it is decreasing (closure rate). Mode 2 exists in two forms, 2A and 2B.

Mode 2A (Fig.2) is active during climbout, cruise, and initial approach (flaps not in the landing configuration and the aircraft not on glideslope centreline). If the aircraft penetrates the Mode 2A caution envelope, the aural message "TERRAIN, TERRAIN" is generated and cockpit EGPWS caution lights will be lit.

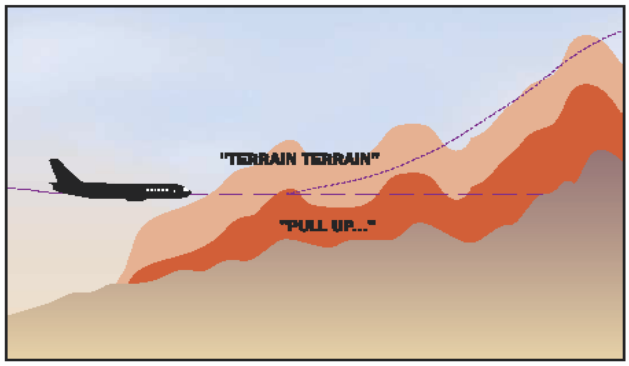

Figure 2. Excessive closure to terrain, mode 2

If the aircraft continues to penetrate the envelope, the EGPWS warning lights will be lit and the aural warning message "PULL UP" will be repeated continuously until the warning envelope is exited.

Mode 2B provides a desensitized alerting envelope to permit normal landing approach manoeuvres close to terrain without unwanted alerts. It is also active during the first 60 seconds after takeoff.

Mode 3 (Fig.3) provides alerts for significant altitude

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loss after take off or low altitude go-around 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. 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". Upon establishing a positive rate of climb, the EGPWS caution lights will extinguish and the aural alert cease.

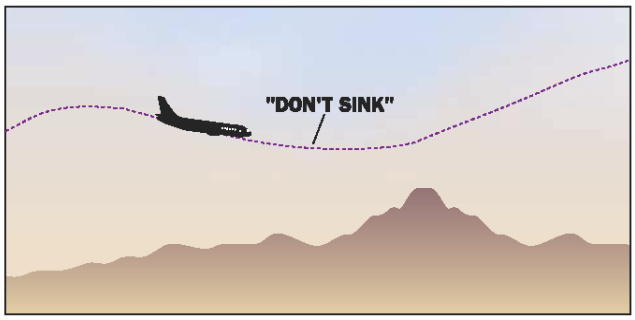

Figure 3. Altitude loss after takeoff, mode 3

Mode 4 provides alerts for insufficient terrain clearance with respect to the phase of flight, aircraft configuration (gear and flaps configuration), and speed. Mode 4 exists in three forms, 4A, 4B, and 4C.

Mode 4A (Fig.4) is active during cruise and approach with the gear not in the landing configuration.

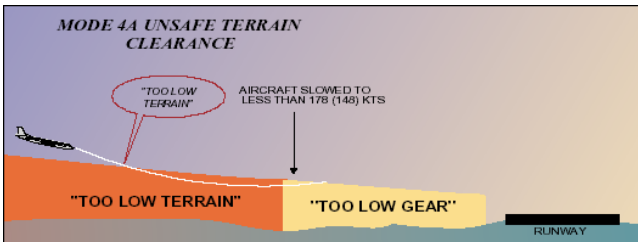

Figure 4. Unsafe terrain clearance, mode 4A

Figure 5. Unsafe terrain clearance, mode 4B

Figure 6. Unsafe terrain clearance, mod 4C

Mode 4B (Fig.5) is active during cruise and approach with the gear in the landing configuration and flaps not in the landing configuration.

Mode 4C (Fig.6) is active during the takeoff phase of the flight with either the gear or flaps not in the landing configuration.

Mode 5 (Fig.7) provides two levels of alerting when the aircraft descends below glideslope.

The first level alert occurs below 300m (1000 feet) radio altitude and the aircraft is 1.3 dots or more below the beam. This turns on alert lights and is called a "soft" alert because the audio message "GLIDESLOPE" is enunciated at half volume. Twenty percent increase in the glideslope deviation causes additional "GLIDESLOPE" messages enunciated at a progressively faster rate.

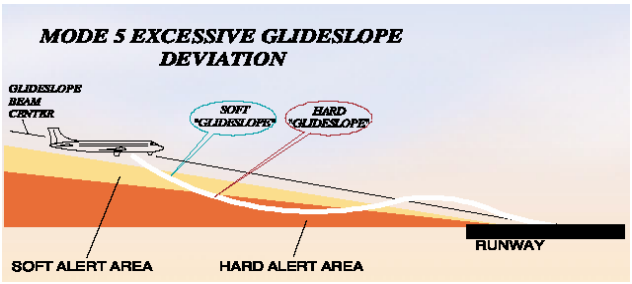

Figure 7. Excessive deviation below glideslope, mode 5

The second level alert occurs below 90 m (300 feet) radio altitude with 2 dots or greater glideslope deviation. This is called a "hard" alert because a louder "GLIDESLOPE, GLIDESLOPE" message is enunciated every 3 seconds continuing until the "hard" envelope is exited.

Mode 6 provides EGPWS advisory callouts based on the menu-selected option established at installation. These callouts consist of predefined radio altitude based altitude and excessive bank angle voice callouts. There is no visual alerting provided with these callouts.

The callout "BANK ANGLE, BANK ANGLE" advises of an excessive roll angle (Fig.8). The EGPWS provides excessive bank angle limits based on the aircraft altitude above the ground (radio altitude) and if the autopilot is engaged.

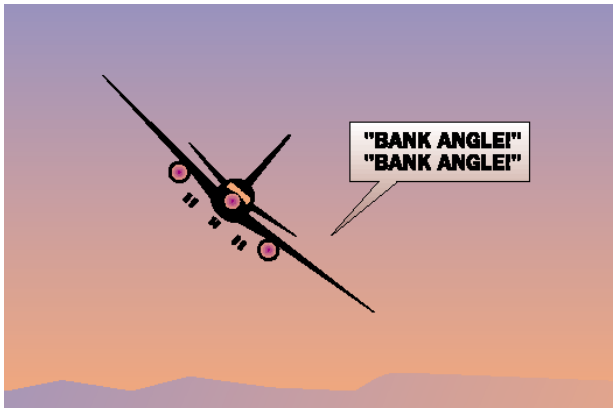

Figure 8. Excessive roll angle, mode 6

Enhanced functions

EGPWS also provides a lot of enhanced functions, which contribute significantly to the security of flight.

Geometric altitude

Based on GPS altitude, geometric altitude is a computed pseudo-barometric altitude (above sea level - ASL)

designed to reduce or eliminate errors potentially induced in corrected barometric altitude by temperature extremes, non-standard pressure altitude conditions and altimeter miss-sets. Geometric altitude ensures an optimal EGPWS terrain display and alerting capability.

Envelope Modulation

Due to the terrain features at or near specific airports worldwide, normal operations have resulted in nuisance or missed alerts at these locations in the past. With the introduction of accurate position information and terrain and airport databases, it is possible to identify these areas and adjust the normal alerting process to compensate for the conditions. The EGPWS envelope modulation feature provides improved alert protection and expanded alerting margins at identified locations throughout the world. This feature is automatic and requires no flight crew action.

Terrain clearance floor

The terrain clearance floor (TCF) function (Fig.9) enhances the basic GPWS modes by alerting the pilot of descent below a defined "Terrain clearance floor" regardless of the aircraft configuration. The TCF alert is a function of the aircraft's radio altitude and distance (calculated from latitude/longitude position) relative to the centre of the nearest or destination runway included in the database (all runways greater than 600 m (2000 feet) in length).

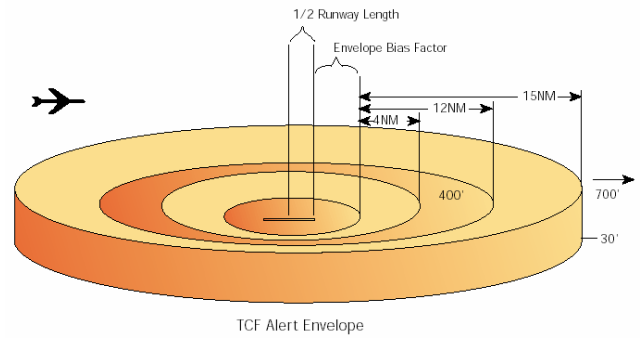

Figure 9. Terrain clearance floor

Runway field clearance floor

A runway field clearance floor (RFCF) feature is similar to the TCF feature except that RFCF is based on the current aircraft position and height above the destination runway, using geometric altitude (in lieu of radio altitude). This provides improved protection at locations where the runway is significantly higher than the surrounding terrain. TCF and RFCF alerts result in illumination of the EGPWS alert lights and the aural message "TOO LOW TERRAIN". The audio message is provided once when initial envelope penetration occurs and again only for additional 20% decreases in Radio or Geometric Altitude. The EGPWS alert lights remain on until the TCF/RFCF envelope is exited.

Terrain alerting and display (TAD)

The system looks ahead of the aircraft and detects terrain or obstacle conflicts. This is accomplished based on aircraft position, flight path angle, track, and speed relative to the terrain database image forward the aircraft.

EGPWS generates caution and warning ribbons (Fig.10).

A terrain conflict intruding into the caution ribbon activates EGPWS caution lights and the aural message "CAUTION TERRAIN, CAUTION TERRAIN" or "TERRAIN AHEAD, TERRAIN AHEAD", Fig. 11. An obstacle conflict provides a "CAUTION OBSTACLE, CAUTION OBSTACLE" or "OBSTACLE AHEAD, OBSTACLE AHEAD" message. The caution alert is given typically 40-60 seconds ahead of the terrain/obstacle conflict and is repeated every seven seconds as long as the conflict remains within the caution area.

When the warning ribbon is intruded (typically 30 seconds prior to the terrain/obstacle conflict), EGPWS warning lights are activated and the aural message "TERRAIN, TERRAIN, PULL UP" or "OBSTACLE, OBSTACLE, PULL UP" is enunciated with "PULL UP" repeating continuously while the conflict is within the warning area (Fig.12).

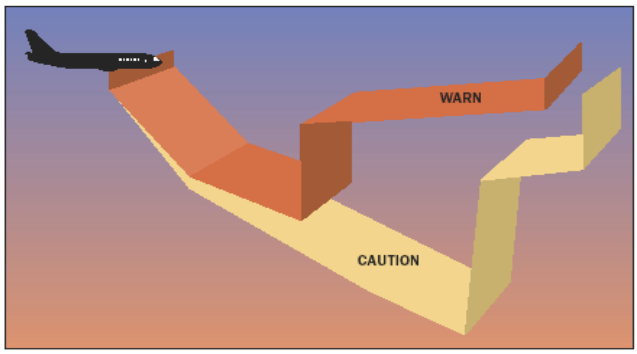

Figure 10. Caution and warning ribbons

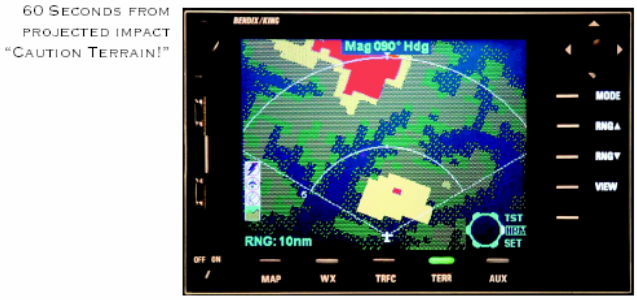

Figure 11. EGPWS display when caution alert is issued

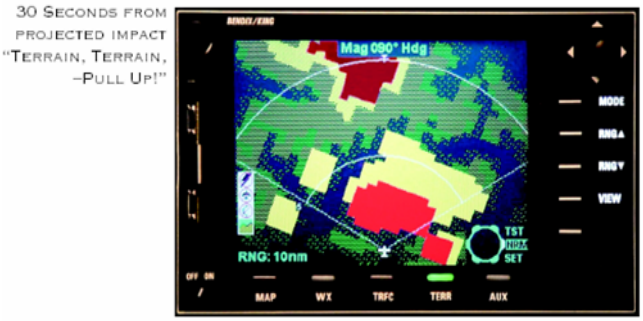

Figure 12. EGPWS display when warning alert is issued

System inputs

The EGPWS utilizes signals from the following systems:

- Air data: uncorrected and corrected barometric altitude, altitude rate, computed airspeed, static air temperature,
- Radio altitude and decision height,
- Roll attitude, magnetic hading.

- GPS data: latitude and longitude position, true track angle, GPS altitude, groundspeed, horizontal and vertical figure of merit (VFOM/HFOM), horizontal integrity limit (HIL), and sensor status,
- Navigation data: glideslope and localizer,
- Display range,
- Discrete signals: signals for system configuration, status and control signals such as decision height, landing flap position, landing gear selected, glideslope valid, magnetic heading valid, and radio altitude valid, test signal
- An EGPWS Configuration module is utilized to tell the system the type of aircraft and interface that it is in. This is defined and established during the EGPWS installation. EGPWS output functions are consequently the result of the configuration state read each time the EGPWS is powered on.

System outputs

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 and are established during the installation of the EGPWS. These EGPWS audio outputs can be inhibited by other systems having higher priority (i.e., windshear) or cockpit switches in some cases. The EGPWS also has the ability to inhibit other system audio outputs such as TCAS.

Visual outputs provide discrete caution and warning alert and status annunciations. Terrain display video is output to a compatible display system.

System constraints

If terrain data is unavailable for a particular area (within the region for a regional database), then terrain and obstacle alerting is not available for that area.

The display of terrain and obstacle information is intended to serve as a situational awareness tool. It does not provide the accuracy as the sole source for deciding terrain or obstacle avoidance.

TAD/TCF functions should be manually inhibited when within 28 km (15 NM) and on approach to an airport that is not in the airport database to avoid unwanted alerts. TAD/TCF functions should be manually inhibited for ditching or other off-airport landings.

Conclusion

EGPWS significantly contributes to the security of flight by increasing the pilot's situational awareness. One of the conditions to the Antonov 26 airplanes to join European civil cargo traffic is to build in EGPWS.

References

[1] www.egws.com
[2] www.honeywellaerospace.com

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Sistem za upozoravanje o približavanju tlu

U radu su opisane karakteristike i funkcionisanje sistema za upozoravanje o približavanju tlu predviđenog za modernizaciju aviona Antonov 26. Sistem procenjuje putanju aviona i moguć konflikt putanje i terena, odnosno veštačkih prepreka (oblakoderi, tornjevi ...) U slučaju mogućeg konflikta daju se vizuelni i zvučni alarmi upozorenja odnosno uzbune.

Ključne reči: **avion, transportni avion, bezbednost leta, avionska oprema, sistem za upozoravanje o približavanju tlu.**

Система для предупреждения о приближении со Землёй

В настоящей работе описаны характеристики и функционирование системы для предупреждения о приближении со Землёй, предусмотренной для модернизации самолёта Антонов Ан-26. Система оценивает траекторию самолёта и возможное несоответствие (столкновение) траектории и почвы, а именно искусственных препятствий (небоскрёбы, вышки...). В случае возможных столкновений, даются визуальные знаки тревоги и включаются звуковые сигналы тревоги, то есть сигналы предупреждения.

Ключевые слова: **Самолёт, транспортный самолёт, безопасность полёта, самолётное оборудование, система для предупреждения о приближении со Землёй.**

Système avertisseur de la proximité du sol

Les caractéristiques et le fonctionnement du système avertisseur de la proximité du sol, prévu pour la modernisation de l'avion ANTONOV 26, sont donnés dans ce papier. Le système prédit la trajectoire de l'avion et le conflit potentiel entre la trajectoire et le terrain, c'est-à-dire les obstacles artificiels (gratte-ciel, tours, etc). Dans le cas du conflit possible, les alarmes visuelles et sonores ainsi que les alertes sont données.

Mots clés: **avion, avion de transport, sécurité du vol, avionique, système avertisseur de la proximité du sol.**