MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF AIR NAVIGATION, ELECTRONICS, AND TELECOMMUNICATIONS
DEPARTMENT OF AVIONICS

APPROVED
Head of department
________S.V. Pavlova
‘___’___________2022

GRADUATION WORK

(EXPLANATORY NOTES)

FOR THE DEGREE OF BACHELOR
SPECIALTY 173 ‘AVIONICS’

Theme: ‘Low-altitude fly safety system of airplane’

Done by: __________ (signature) Yu.V. Naumchuk

Supervisor: __________ (signature) O.O. Chuzha

Standard controller: __________ (signature) V.V. Levkivskyi

Kyiv 2022

МІНІСТЕРСТВО ОСВІТИ І АУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ АЕРОНАВІГАЦІЇ, ЕЛЕКТРОНІКИ ТА ТЕЛЕКОМУНІКАЦІЙ
КАФЕДРА АВІОНІКИ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_________С.В. Павлова
«___» ___________2022

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ БАКАЛАВР ЗА СПЕЦІАЛЬНІСТЮ 173 «АВІОНІКА»

Тема: «Система безпеки маловисотного польоту літака»

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Київ 2022

NATIONAL AVIATION UNIVERSITY

Faculty of Air Navigation, Electronics and Telecommunications

Department of avionics

Speciality 173 ‘Avionics’

APPROVED

Department head

S.V. Pavlova

“___” ___________2022

TASK

for the execution of graduate work

Yu.V. Naumchuk

1. Theme of bachelor work: «Low-altitude fly safety system of the airplane »,

approved by order №352/ст of the Rector of the National Aviation University on 04 April 2022.

2. Duration of which is from 16.05.2022 to 19.06.2022.

3. Input data of graduation work: ground proximity warning system, terrain awareness warning system, radio altimeter, flight path prognosticating, profile flight radar, weather radar.

4. Content of explanatory notes: General characteristics and main functions of terrain awareness warning system. Enhanced ground proximity warning systems of modern aircraft. Implementation of the low-altitude fly safety system of the airplane.

5. The list of mandatory graphic material: figures, charts, graphs.

6. Planned schedule

№	Task	Duration	Evaluation of the performance
1.	Selection of literature for performing bachelor's graduation diploma work	16-22.05.2022	
2.	Chapter 1.	23-27.05.2022	
3.	Chapter 2.	28-31.06.2022	
4.	Chapter 3.	01-07.06.2022	
5.	Designing an explanatory note and graphic material	08-11.02.2022	
6.	Preparation for the defence of the diploma	11-19.06.2022	

7. Data of assignment 16.05.2022.

Supervisor ______________________ O.O. Chuzha

(sign)

The task took to perform ______________________ Yu.V. Naumchuk

(sign)

ABSTRACT

The explanatory notes to the graduate work ‘Low-altitude fly safety system of airplane’ contained 42 pages, 15 drawings, 3 tables, 4 flow charts, and 45 reference books.

Keywords: AIRCRAFT, WARNING SYSTEM, ALTIMETER, ALTITUDE, TERRAIN, TRAJECTORY, RADAR, WEATHER RADAR.

The purpose of the graduate work is to study the safety system of aircraft and increase the level of safety of aircraft at low altitudes.

The object of the research is the process of studying and analyzing of Low-altitude flight safety system.

The subject of the research is the low-altitude fly safety system of the airplane.

Research method - probability theory, comparative analysis and processing of literature sources.

Results of the graduate work: recommended for use in research and the practice of avionics engineers and pilots. Recommended in the learning process.

CONTENT

LIST OF CONVENTIONAL ABBREVIATIONS:

CFIT - Controlled Flight Into Terrain;

GPS - Global Position System;

GRWS - Ground Proximity Warning System;

EGPWS - Enhanced Ground Proximity Warning System;

TAWS – Terrain Avoidance and Warning System;

ALA – Approach and Landing Accidents;

TCF- Terrain Clearance Floor;

GCAS- Ground Collision Avoidance System;

RA - Radio Altimeter;

ICAO - International Civil Aviation Organization;

GPWM - Ground Proximity Warning Module;

LRRA - Low-Range Radio Altimeter;

MMRs - Multi-mode receivers;

WXR - Weather radar;

TAD – Terrain Awareness and Display;

ILS – Instrument Landing System;

DEUs - Display electronics units;

DTED – Digital Terrain Elevation Database;

ADIRS - Air Data Inertial Reference System;

FMCS - Flight management computer system;

FLTA – Forward Looking Terrain Avoidance;

PDA – Premature Descent Alert;

FMGC – Flight Management and Guidance Computer;

FWC – Flight Warning Computer

INTRODUCTION

Relevance of the theme. For decades, one of the most popular ideas in the literature has been the idea that flying at low altitudes is dangerous.

One of the reasons for this is the probable collision with the ground. Another idea is that during low-altitude flights, the aircraft can get into point turbulent phenomena or other meteorological obstacles.

Another major disadvantage of flying at low altitudes may be the lack of time for pilots to make decisions during takeoff, descent and landing.

In addition, it should be noted that some reports and scientific publications emphasize the high probability of collisions with birds and drones at low altitudes.

Research related to low altitudes is a relatively new area that has emerged in connection with the flights of private aircraft, small aircraft and more.

As far as we know, no previous study has considered the creation of a reliable security system for such aircraft and low-altitude flights, so this topic is quite relevant and needs further development.

The purpose of the thesis is to study the safety system of aircraft during the operation of the aircraft. Investigation of all possible human, natural and metrological factors that may interfere with the safe landing of the aircraft. That is why the main goal is to increase the level of safety of aircraft at low altitudes.

The object of study is the process of studying and analyzing the aircraft safety system.

The subject of the study is the safety system for a low-altitude flight of aircraft.

Research methods - probability theory, comparative analysis and processing of literature sources.

CHAPTER 1

GENERAL CHARACTERISTICS AND MAIN FUNCTIONS OF THE EARLY PREVENTION SYSTEM

The Ground Proximity Warning System (GPWS) is a system that provides the flight crew with sufficient information and alerts to detect a potentially hazardous situation on the ground, and therefore the flight crew can take prompt and effective action to prevent a CFIT - Controlled Flight into Terrain.

A Controlled Flight into Terrain (CFIT) occurs when an airplane under the full control of a pilot accidentally enters a terrain, obstacle or water. Pilots are usually unaware of the danger until it is too late. Long-term statistics of world flight practice show that CFIT belongs to the type of accidents that most often lead to fatalities.

A large number of CFIT accidents occur during take-off, approach and landing and are often associated with inaccurate approach-and-landing accidents (ALAs).

According to studies examining the occurrence of CFIT accidents, the vast majority of accidents could have been avoided if a warning device called a GPWS approach system had been used.

Thus, if the aircraft is equipped with this system, it may mean that the flight crew will react quickly and perform these actions, for example, starting an "avoidance manoeuvre" to get away from it and avoid an accident.

To reduce the number of CFIT disasters in most ICAO countries for some time, it is necessary to install a system that warns of the aircraft approaching the ground. According to statistics, after the introduction of the GPWS system as standard equipment for turbojet aircraft, the number of CFIT cases on scheduled airlines has decreased significantly.

1.1. Principle of operation of GPWS

The system measures the height of the aircraft above the ground, using information from onboard sensors, which is determined by low altitude radio altimeter (LRRA) or from the air signal system. The computer then monitors these readings, calculates the current position of the aircraft and warns the crew with visual and audio messages that the aircraft is in certain flight modes.

The GPWS system will warn the crew if an aircraft is in a dangerous situation and allow the crew to correct it and avoid an accident.

The scheme of the ground approach warning system is shown in Figure 1.1, which shows the following international abbreviations of information sources for the GPWS system: ADIRS - Air Data and Inertial Reference System; FMGC - Flight Management and Guidance Computer; FWC - Flight Warning Computer.

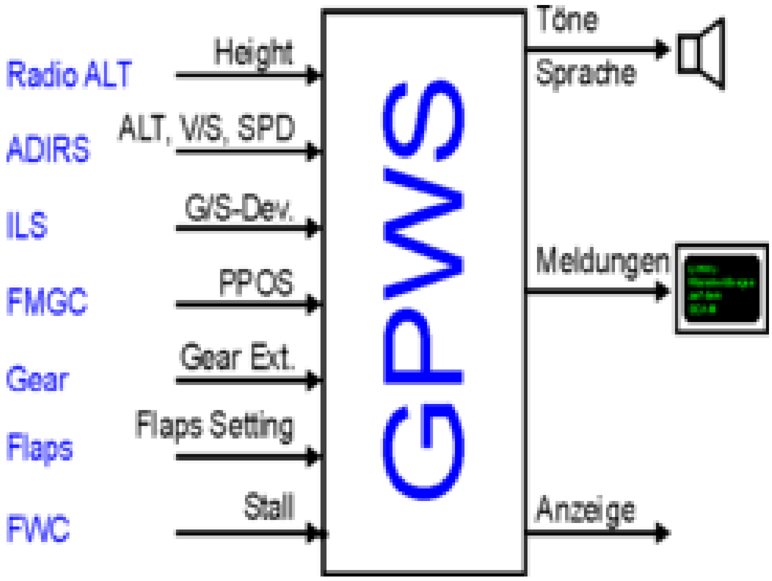


Fig. 1.1. Scheme of the system of approach to the ground

The main component of GPWS is a computer. On which digital data from onboard sensors are fed. The primary GPWS sensors are LRRA, barometric altimeter, electronic landing gear (ILS) parameters, as well as sensors that are sources of information about the configuration of the aircraft, including the position of mechanization of the wing and landing gear.

1.2. GPWS operating modes

There are 5 main modes of the Ground Warning System (GPWS), which are typically active up to 2,500 feet.

1) Mode 1 - When the rate of descent is too high: this is caused by a high rate of descent near the ground (measured at radio altitude) and leads to the warning "Lower speed, lower speed". A related warning, if triggered, is "Pull Up". Mode 1 is active during all phases of flight.

The red arrow indicates the trajectory of the aircraft, and the blue arrow is calculated by GPWS to avoid a collision with the ground (Fig. 1.2., 1.3., 1.4., 1.5., 1.6.).

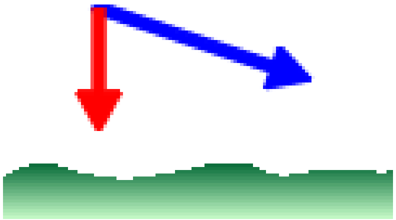


Fig. 1.2. Mode 1 of the Ground Warning System (GPWS)

2) Mode 2 - Excessive speed of approaching the terrain. There are two types of notifications in mode 2: mode 2A (active during altitude, cruise and initial approach) and mode 2B (active during approach and 60 seconds after take-off). When the chassis is raised, the warnings are: "Terrain Terrain" and "Pull Up". When the chassis is lowered, the "Terrain" warning is triggered.

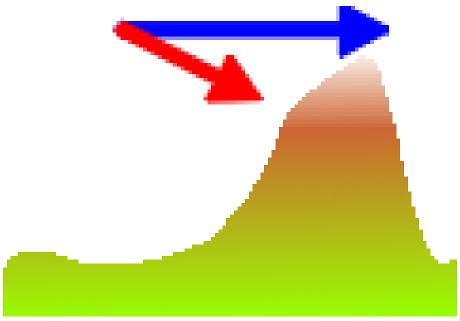


Fig. 1.3. GPWS Mode 2

3) Mode 3 - Loss of altitude after takeoff or landing: Triggered after significant loss of altitude after takeoff or landing - "Don't Sink, Don't Sink".

Fig. 1.4 GPWS Mode 3

4) Mode 4 - Under dangerous landing conditions. Modes 4A and 4B are active during flight and approach, and mode 4C is active during exit. Mode 4A triggers "Too Low Terrain, Too Low Gear" when the chassis is raised, mode 4B

triggers "Too Low Terrain, Too Low Flaps" when flaps are not in the landing configuration (but chassis is lowered), and mode 4C is triggered with non-flaps. in the landing configuration OR raise the equipment: "Too Low Terrain".

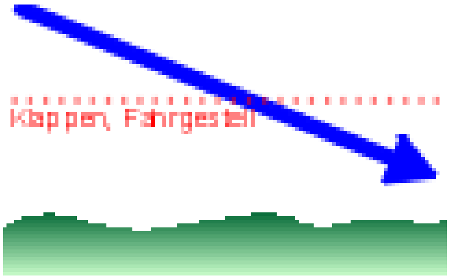


Fig. 1.5 Mode 4 GPWS

5) Mode 5. Excessive descent below the glide path - is triggered when the aircraft falls below the optimal trajectory and triggers a sound notification "Glideslope".

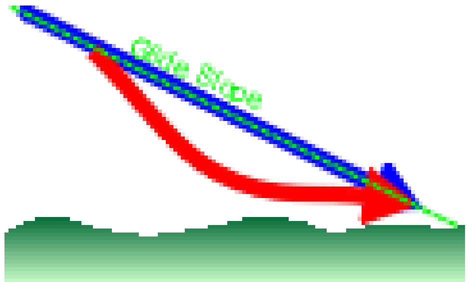


Fig. 1.6 GPWS Mode 5

Basic GPWS modes do not have information about the location of the aircraft - they just work when certain parameters are exceeded, for example, when radio altimeters detect a high speed of connection with the terrain. In addition, GPWS outputs several signals that are generated based on signals from other systems, such as the WINDSHEAR signal and the BANK ANGLE.

The landing height countdown is also a function of GPWS. Signals of 1000 and 500 feet are formed based on relative barometric altitude, and signals of 100, 50, 30, 20 and 10 feet according to radio altimeters.

1.3. Improved GPWS system (EGPWS)

Despite the relatively high efficiency of the practical application of the GPWS system, which has reduced the number of aviation events such as CFIT, it has some drawbacks. Traditional GPWS has a blind spot. Because it can only collect data directly below the aircraft, a conventional GPWS system depends on radio altimeter data, which measures actual altitude above the ground in real time, which can cause problems when detecting landscape elements with a sharp rise in terrain (mountains, hills or artificial obstacles). In addition, the effectiveness of GPWS depends significantly on the speed of the pilot's response to system warnings. Insufficient to avoid an obstacle, and in the event of a collision with a vertical surface at high altitudes, the alarm does not have time to work.

That's why a new Enhanced Ground Proximity Warning System (EGPWS) was developed in 1997, an improved ground-based early warning system that can predict terrain awareness and display (TAD) and warning functions in addition to all GPWS functions. premature reduction at approach (TCF - terrain clearance floor).

Fig.1.7 EGPWS unit from Honeywell

Such an advanced EGPWS system solves this problem by combining the Digital Terrain Elevation Database (DTED) with the Global Positioning System (GPS). The DTED database may also include artificial barriers. The addition of the DTED database enables the advanced EGPWS system to display and predict the terrain near the aircraft, thus providing much better information and warning to pilots when manoeuvring near the ground.

After the advent of EGPWS in the United States, the standard TSO-C151B was adopted, which spelt out the requirements for such systems, this standard is still valid today. This document introduces a classification of ground collision avoidance systems. Systems that include terrain and obstacle database, and therefore have the FLTA function, are classified as TAWS (Terrain Awareness and Warning System). FLTA - Forward Looking Terrain Avoidance. The main role of this function is that the processor analyzes the trends of the aircraft and tries to calculate its (aircraft) location after some time in the future (both coordinates and altitude). The projected location is then compared to the terrain and obstacle database, and if this location is closer to the ground/obstacle than it should be, TAWS will issue a warning. The algorithm is quite complex - in particular, it has different minimum distances to obstacles depending on the current stage of the flight. In other words, EGPWS is a special case of TAWS.

1.4. Terrain avoidance and warning system (TAWS)

There is at least one very fundamental difference between GPWS and TAWS (or EGPWS) - GPWS uses real altitude in real time, and TAWS has a forecasting function, ie it predicts that it will be with the aircraft in some time.

Modern TAWS works using numerical altitude data and instrumental values of the aircraft to predict whether the probable future position of the aircraft will intersect with the ground. Thus, the flight crew receives "an early audible and visual warning of the impending terrain, the ability to orient forward and continue to work in the landing configuration."

TAWS consists of the following main parts:

- terrain relief database (and land obstacles). You need to use the database where the flight is performed, in other cases, this system will not work properly.

- the source of current coordinates. In the vast majority of cases, it is GPS, either built-in or certified external;

- current altitude data source - either barometric altimeter or WAAS GPS. Altitude information may also be supplemented at some stages of the flight by a radio altimeter;

- a processor with a corresponding indication, which processes the incoming information and issues, if necessary, warnings;

Additional sources of information on the condition of the aircraft can be connected to TAWS - landing position and wing mechanization, etc.

TAWS equipment is classified as:

Class A systems, which are required for all but the smallest commercial air transport aircraft,

Class B systems are required for large general aviation (GA) aircraft and are recommended for small commercial or GA aircraft.

• TAWS Class A equipment shall guide unavoidable ground contact under the following conditions:

- Excessive descent

- Excessive terrain

- Negative speed or loss of altitude after takeoff

- Flight to the terrain when not in the landing configuration

- Excessive deviation from the instrument landing system (ILS) glide path, localizer performance and vertical guidance (LPV) or global navigation satellite system (GNSS) glide path (GLS).

- Five hundred voice messages when the plane descends to a height of 500 feet above the ground or the nearest runway.

- Required: TAWS Class A installations must provide a terrain awareness display that shows the surrounding area or obstacles to the aircraft, or both.

Class B TAWS is defined by the US FAA as an Equipment class as defined in TSO-C151b and RTCA DO-161A. At a minimum, he will provide notice in the following circumstances:

- Excessive descent

- Negative speed or loss of altitude after takeoff

- Five Hundred Voice Call as the plane descends to a height of 500 feet above the nearest runway.

- Optional: A TAWS Class B installation can provide a terrain awareness display that shows the surrounding area or obstacles to the aircraft, or both.

Class C defines voluntary equipment for small general aviation aircraft that do not require the installation of Class B equipment. This includes minimum performance standards for reciprocating and turbine-powered airplanes if they are configured with less than six passenger seats, except for any -what pilots' seats. TAWS Class C equipment shall meet all TAWS Class B requirements with minor modifications to the FAA. The FAA has developed the C-Class to facilitate the voluntary use of TAWS for small aircraft.

TAWS class A is installed on large aircraft, class B or C on slightly smaller aircraft. Naturally, the higher the class, the more functions (situations when a warning is issued) are supported by the system.

Another feature of TAWS - PDA, is Premature Descent Alert. During TAWS operation, the PDA function determines that the aircraft is approaching directly (closer than 15 miles from the end of the runway) and begins to monitor whether the aircraft has dropped below the glide path above the allowable limit. Again, in order not to generate false alarms, the PDA shuts down closer than half a mile from the lane.

The TAWS (Terrain Avoidance Warning System) provides the crew with information on:

1) unacceptably high rate of decline,

2) dangerous proximity to the ground,

3) loss of altitude after takeoff,

4) deviations below the glide path,

5) the nature of the dangerous relief of the earth's surface in the direction of flight,

6) dangerous wind shift.

The TAWS function is implemented in a separate independent module, which is part of the TCAS collision warning system and is called the ground collision warning module (GCAM). The GCAM module provides a complete forecast for alarms and warnings to prevent a catastrophic collision with the ground of a serviceable aircraft in controlled flight, as well as all modes of the conventional ground collision warning system by TSO C151a.

The purpose of TAWS is to provide the flight crew with timely information on potential hazards in the direction of the flight route that could lead to a collision with the ground. TAWS generates a ground approach alarm, an altitude warning or a detour warning depending on the position of the aircraft relative to the ground.

The TAWS system performs the following tasks:

- processes input signals from aircraft systems;
- establishes the relationship between the location of the aircraft and the terrain databases and airports;
- assesses the risk of collision with the ground in the direction of the flight path of the aircraft;
- determines the predicted envelope of the predicted height gain to prevent a collision, using data from the workstation module;
- generates appropriate voice and visual alarms and warnings to the flight crew on the selected indicator.

1.5. TAWS Hazard Warnings and Ranges

GCAM module - ground collision warning module. The GCAM module provides a complete forecast for alarms and warnings to prevent a catastrophic collision with the ground of a serviceable aircraft in controlled flight, as well as all modes of the conventional ground collision warning system by TSO C151a. This module generates both predicted and reactive warnings.

Forecasted warnings are warnings that occur when the safe level of the intended position of the aircraft and the terrain at the projected point of the route is reduced. This warning is implemented through the CPA prediction feature, which uses the topography of the earth's surface and predicts dangerous situations of collisions with the earth and generates voice, visual and graphical alarms.

The CPA function displays to the flight crew a predicted ground collision warning in all phases of flight from take-off to landing:

- the exact location of the aircraft is determined;
- available data on the characteristics of the aircraft;
- all characteristics obtained from the surface database, intact and serviceable;
- the airport zone database is working;
- all necessary input signals are working;
- the terrain is not blocked.

Reactive warnings include 5 modes and include voice and visual messages about reaching the set heights and warnings about reaching the roll limit. Reactive wind shear warning mode (optional) is also considered to be the reactive mode of the GCAM module.

Areas of alarm are formed in both horizontal and vertical planes (Fig. 1.8).

In the horizontal plane, the area of action for the determination of conflict situations in the course of rectilinear horizontal flight is a narrow field of view, with an angle of 1.5 ° on both sides of the flight path in front of the aircraft. This narrow overview ensures that the ground on either side of the flight path will not generate unnecessary warnings and warnings. As soon as the aircraft starts to reverse, the CPA function uses the aircraft's reversal speed to extrapolate the conflict detection to the entire ground surface located in the reversal direction up to 90 ° from the aircraft's current trajectory.

In the vertical plane, the warning CPA range extends along the flight path from a distance of 20 seconds in front of the aircraft to the predicted trajectory of altitude at a distance of 132 seconds in front of the aircraft. The zone of 20 seconds provides enough time for the pilot to react to perform a standard set of altitudes.

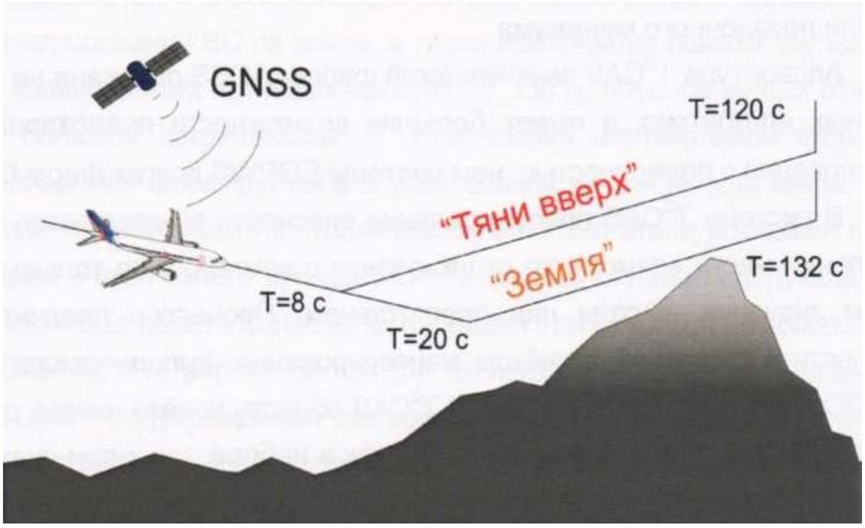


Fig. 1.8. Vertical danger warning area

This is determined from the maximum value of the altitude gradient for the aircraft model confirming the fact that the crew and the aircraft can start the set of departures from the ground. The altitude gradient is defined as the best ascent speed using the actual altitude gain characteristics of the aircraft taking into account weight, barometric altitude, air temperature, aircraft configuration, engine failure and set data for the airplane model.

The range of predicted hazard warning signals (CPA function) is the same in structure as the warning area, except that it begins on the flight path 8 seconds ahead of the aircraft from the starting point of the climb 120 seconds ahead of the aircraft. The interval of 8 seconds represents the maximum expected time for the pilot's reaction to start manoeuvring. If the range of the CPA warning signals is dangerous, two types of warning signals can be generated. The type of warning signal is determined depending on CPA calculations: the aircraft has or does not have sufficient altitude gain capabilities to ensure elevation above the terrain due to the standard manoeuvre:

- PULL UP warning - is generated if CPA calculations determine that the aircraft can fly over the terrain.

- AVOID TERRAIN warning - is generated if CPA calculations determine that the aircraft is unable to fly over the terrain.

1.5. TAWS operating modes.

In addition to the 5 main GPWS modes mentioned earlier, the TAWS system includes three main operating modes, such as:

Mode 6 "Exceeding the threshold value of the difference between the geometric and relative barometric height".

Figure 1.9. Mode 6 "Exceeding the threshold value of the difference between the geometric and relative barometric height".

Mode 6 is designed to generate an audible alarm with a significant difference between the readings of the altimeter and the relative barometric altitude (Fig. 1.9). The mode is active only when the landing gear and flaps are seated. A warning signal is issued in the alarm area: the yellow "EARTH" board lights up and the "HEIGHT CHECK" language message lights up.

Mode 7 "Estimation of terrain in the direction of flight".

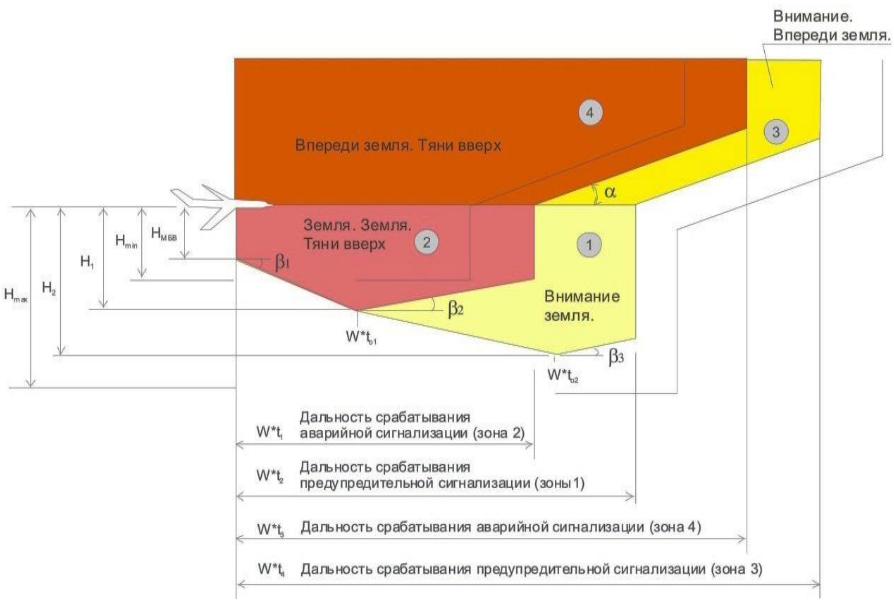


Fig. 1.10. Mode 7 "Estimation of terrain in the direction of flight" vertical profile

The mode is active at all stages of the flight, including turns (Fig. 1.10.). It is used to check the absence of relief elements and artificial obstacles within the established working space, the shape and size of which are calculated and depend on the stage of flight, location of the aircraft and its spatial orientation angles, flight speed, etc.

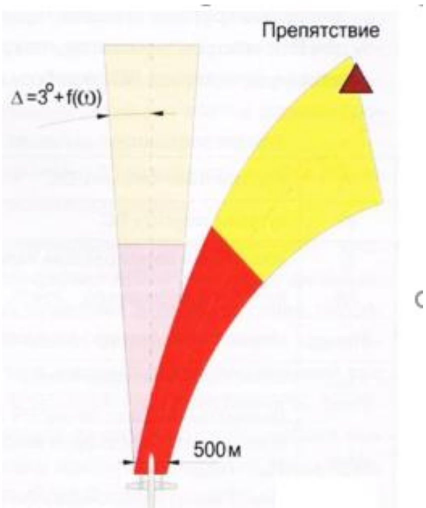


Fig. 1.11. Mode 7. Horizontal profile

Workspace is limited:

- the estimated range in the direction of flight of the aircraft, which depends on the ground speed of the aircraft and the stage of flight;

- an area of obstacles on both sides of the flight trajectory, depending on the manoeuvre (straight flight, reversal)

- distance down, depending on the stage of flight, vertical trajectory, and dynamic characteristics of the aircraft.

Mode 8 "Premature decline when approaching landing"

Fig. 1.12. Mode 8 "Premature decline when approaching landing"

The mode is active at all stages of the flight, except for the stage of takeoff and exit to the second circle (Fig. 1.12). The safety assessment of the position of the aircraft in the terrain in the aerodrome area is carried out based on information on the location of the aircraft, true altitude and aerodrome information from the TAWS aeronautical database. It has two sub modes 1 and 2.

Submodel 1 "Warning of insufficient true height".

In this mode (Fig. 1.13) it is checked whether the aircraft is dangerously below the allowable approach trajectory (by comparing the current true altitude with the altitude at which it is permissible at the current distance from the runway threshold). When the aircraft enters the alarm area, the yellow "EARTH" board is turned on and the message "LOW EARTH" is periodically issued.

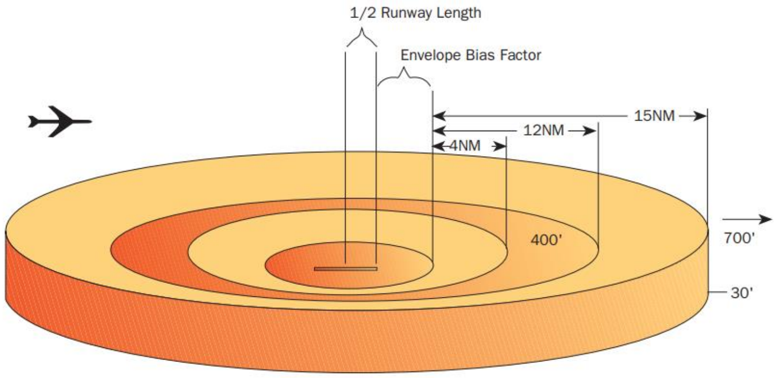


Fig. 1.13. Sub-mode warning limits 1

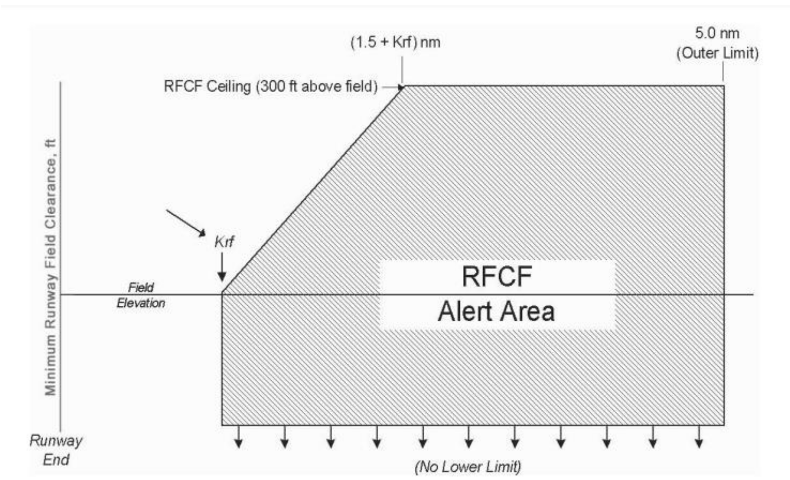


Fig. 1.14. Limits of the warning alarm mode 2.

In mountainous areas, the elevation of the runway may be greater than the excess of the terrain under the trajectory of the approach to landing (Fig. 1.14). In this case, the altitude reading on the radio altimeter can be significant, while the aircraft will be below the runway. Using the boundaries of the true altitude check mode does not give normal results. To issue an alarm in this situation, the mode of checking the excess over the runway threshold is used. Within the alarm area, the system generates a warning alarm: the yellow "EARTH" board lights up and the message "low earth" is periodically issued. When the parameters of the aircraft are in the alarm zone, a voice message "Low Ground" and a warning light signal are issued.

1.6. Display TAWS system information

Thus, many modern land-based warning systems also include a terrain database. This class of systems is designated EGPWS. In them, the indication of the relief synthesized from the database serves, first of all, not for navigation, but to warn the pilot about the danger of collision with the ground. (Fig. 1.15).

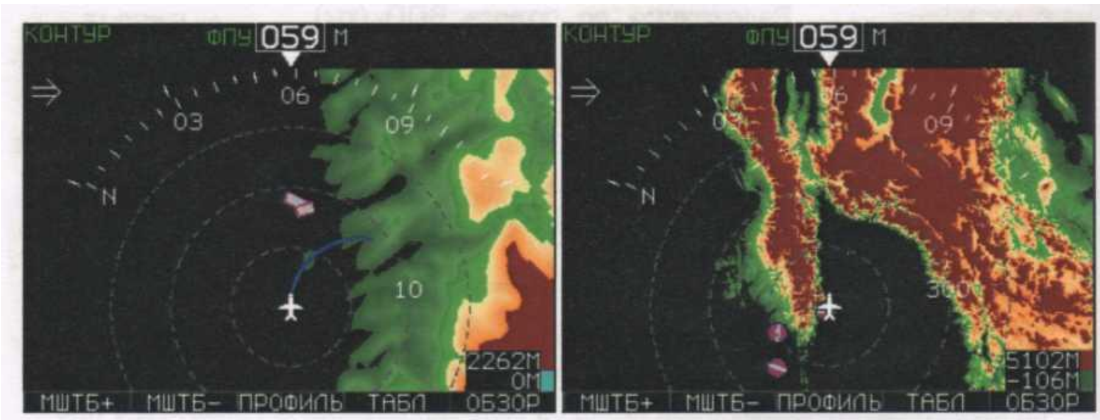


Fig. 1.15. Relief display on the TAWS indicator

If the aircraft rises to a great height, the relief image disappears. EGPWS information is displayed on the pilot's pilot and navigation indicators. On the aerobatic indicator, it is depicted in the version "view from the window", and the horizon line does not look like a straight line, as in the traditional air horizon, but a broken line, which repeats the relief profile. Symbols common to the aerobatic format are superimposed on this image - scales, digital counters, badges and texts. The navigation indicator highlights areas of the surface that pose a danger at a given altitude. The degree of danger is coded by the colour of the area:

- red - obstacles that are directly on the course with an altitude exceeding the current flight altitude;

- yellow - the same obstacles away from the current course with a lower altitude than in the LA;

- green or grey - elevations that are below the current height, but must be taken into account;

- areas of the surface that are much lower than the flight altitude are not induced at all.

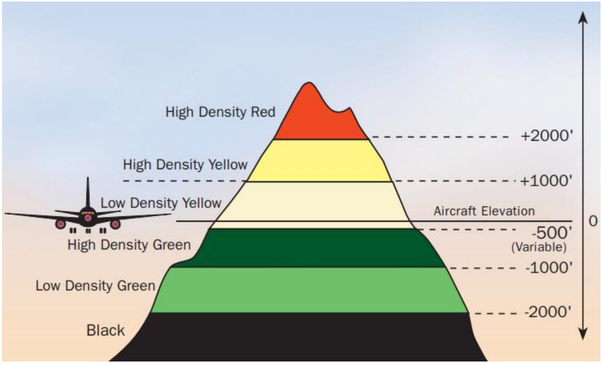


Fig. 1.17. Display the degree of danger by the colour of the area

EGPWS systems can contain not only a database of terrain but also a database of high obstacles - skyscrapers, masts, towers. Then they are also depicted on the map.

The system of early warning of proximity to the ground SRPBZ (VNIIRA-navigator) provides the crew with information: unacceptable rate of descent, dangerous proximity to the ground, loss of height after takeoff, unacceptable deviation below the glide path, reaching a given height when approaching landing, dangerous obstacles and terrain in direction of flight. Extensive built-in SRPP control allows not only to test systems on board aircraft but also to assess the performance of onboard sensors and systems used.

SRPPZ does not require control and verification equipment for ground inspection on the plane and in ATB. It has a built-in "black box", which allows you to quickly assess the operation of aircraft equipment and the actions of the crew after each flight. The crew receives information from SRPP visually (according to the degree of danger green, orange, and red colour of the image and alarms) and by ear - to make a decision is pronounced in a female voice in Russian or English, language messages "Dangerous descent", "Pull up", " Low chassis "," Check height

", etc. Extensive built-in control of SRPPZ allows not only to test systems on board aircraft but also to assess the performance of onboard sensors and systems used.

CHAPTER 2.

SYSTEMS OF PREVENTION OF APPROACH TO THE EARTH ON THE EXAMPLE OF MODERN AIRCRAFT

2.1 Boeing 747 collision warning system.

The GPWS system of the Boeing 747 wide-body long-haul passenger aircraft is designed to warn the crew of dangerous flight conditions when approaching the ground, as well as to warn of flying in gusty winds. These warnings are provided by visual and audible alarms.

GPWS consists of:

1. Engine Indication and Crew Alerting System (EICAS)
2. Ground Proximity Warning System computer
3. Takeoff Configuration Warnings
4. Landing Configuration Warnings
5. Stall Warning System
6. Overspeed Warning System
7. Traffic collision avoidance system (TCAS)

The ground approach control elements (Fig. 2.1) consist of a glide path lock switch, a ground proximity flap switch and a ground approach configuration switch, the switches are located on the co-pilot panel.

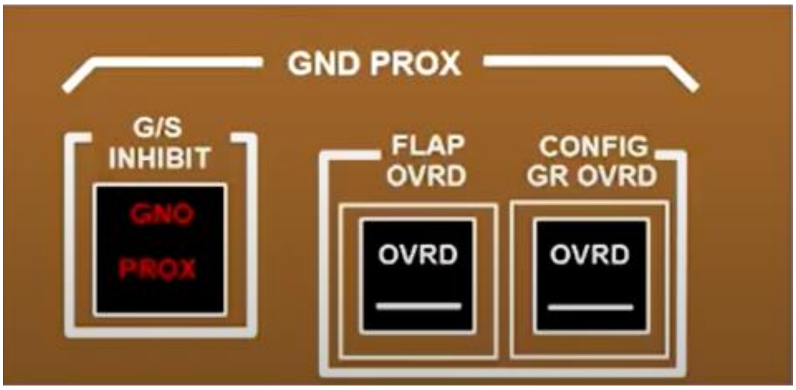


Fig. 2.1 Ground Approach System Panel

GPWS, which is installed on the Boeing 747 has 7 modes of operation.

Mode 1 - Excessive and severe barometric descent rates

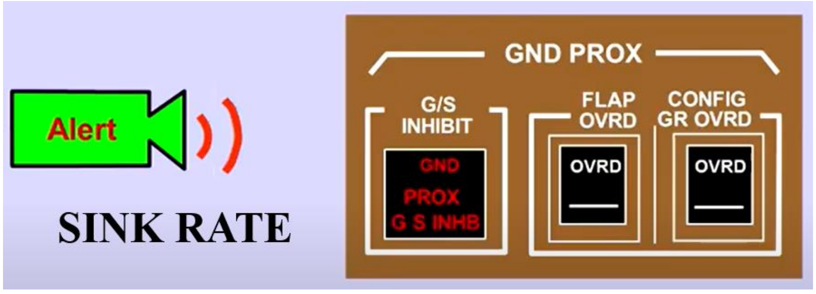


Fig. 2.2 System panel in mode 1

Pilots hear a voice warning: SINK RATE. GND PROX board glows. If the deceleration rate does not change and the ground is close, the PULL-UP voice command sounds, the GND PROX board goes out, the MASTER WARNING button flashes, and the PULL-UP command appears on the main display. When the position starts to correct, the PULL-UP command will change to SINK RATE. This mode does not depend on the position of the flaps or gears.

Mode 2 - Excessive terrain closure rate

Fig. 2.3 System panel in mode 2

Provides alerts and alerts when the closure speed is too high. Pilots hear TERRAIN twice, then PULL UP. GND PROX board glows.

Mode 3 - Altitude loss after take-off or go-around

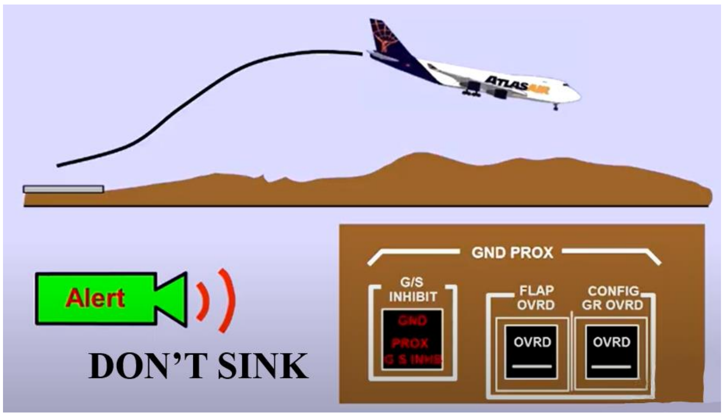


Fig. 2.4 System panel in mode 3

Gives notifications of large loss of altitude during takeoff or in anticipation when the flaps are not in the landing configuration or the chassis is not lowered. Pilots hear: DON'T SINK. GND PROX board glows.

Mode 4 - Unsafe terrain clearance while not in the landing configuration

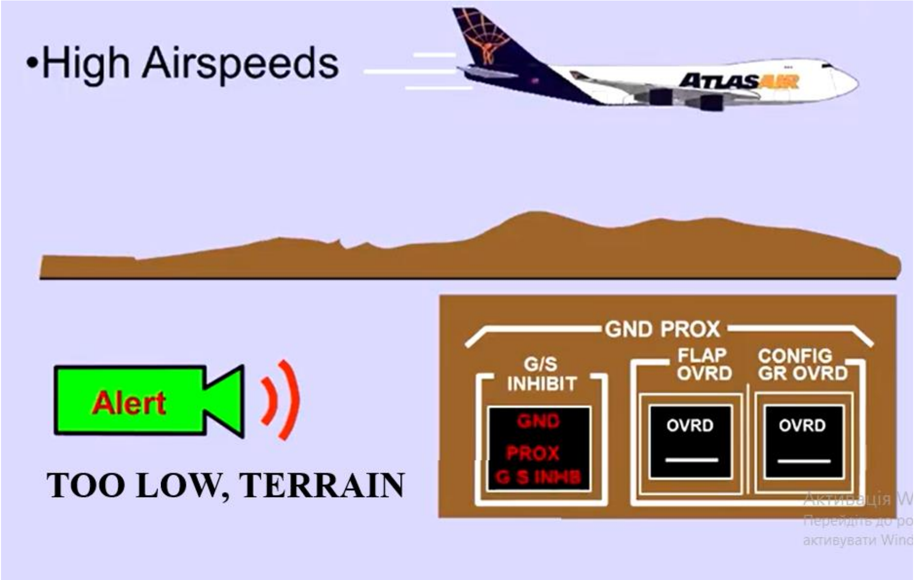


Fig. 2.5 System panel in mode 4a)

a) If the road speed is high, the pilots hear: TOO LOW, TERRAIN. GND PROX board glows.

Fig. 2.6 System panel in mode 4 b)

b) If the track speed is low and the chassis is not released, the pilots hear TOO LOW, GEAR. GND PROX board glows. If you press the CONFIG GR OVRD button, the voice command will be disabled.

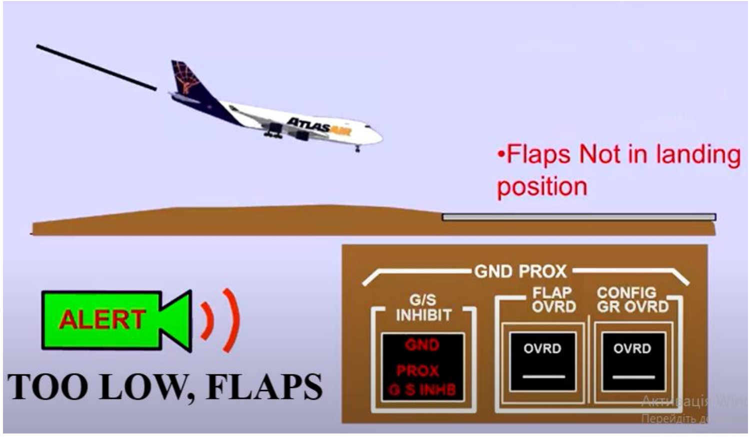


Fig. 2.7 System panel in mode 4c)

c) If the road speed is low, the chassis is released, but the flaps are above the landing configuration, the pilots hear: TOO LOW, FLAPS. G / S INHIBIT GND PROX board illuminates. If you press the FLAP OVRD button, the voice command will be disabled.

Mode 5 - Deviation below glideslope

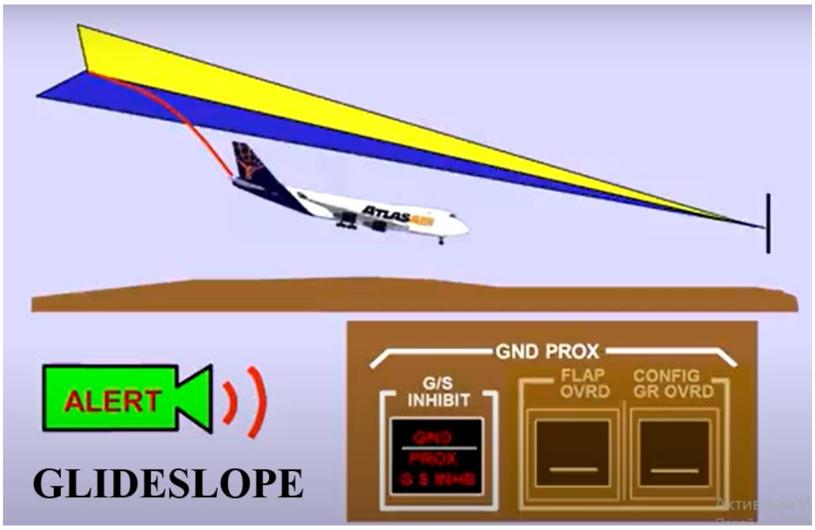


Fig. 2.8 System panel in mode 5

Pilots hear GLIDESLOPE. G / S INHIBIT GND PROX board illuminates. If the deviation from the glide path increases and the altitude on the radio altimeter decreases, the voice command becomes louder. Pressing the G / S INHIBIT button mutes the sound.

Mode 6 - Altitude advisories

GPWS reports the current altitude:

100 feet - ONE HUNDRED

50 feet - FIFTY

30 feet - THIRTY

10 feet - TEN

Mode 7 - Windshear

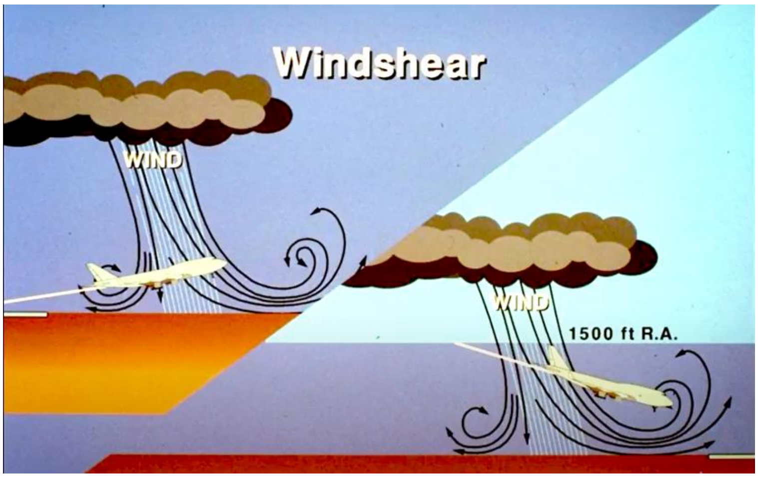


Fig. 2.9 Mode 7 - Windshear (intensive descending air currents)

If immediately after take-off or at any other time when the altitude is less than 1,500 feet on the RV, the aircraft finds itself in intense downward air currents, or there is a strong accompanying wind, a two-tone siren and voice: WINDSHEAR. The same - WINDSHEAR - appears on the main display, and then the MASTER WARNING board lights up.

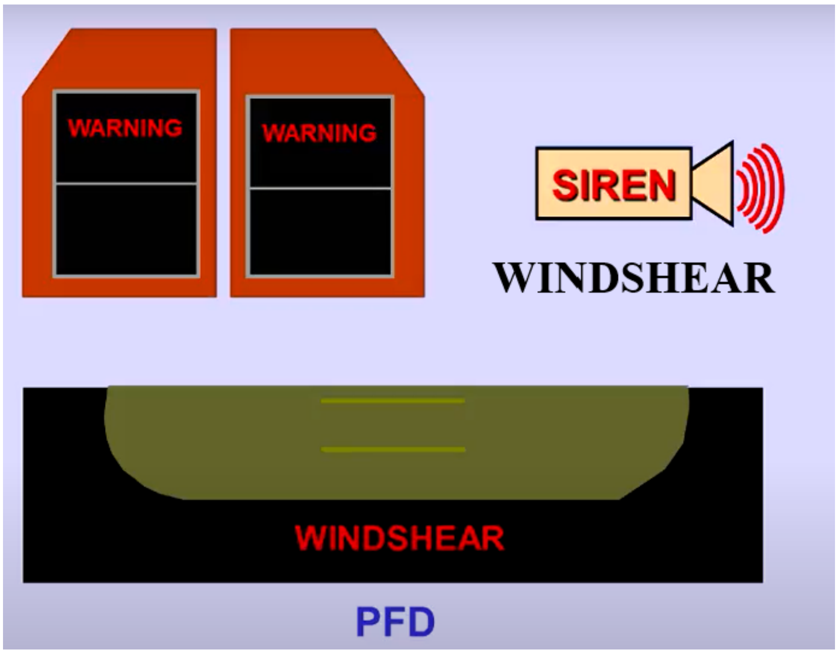


Fig. 2.10 System panel in mode 7

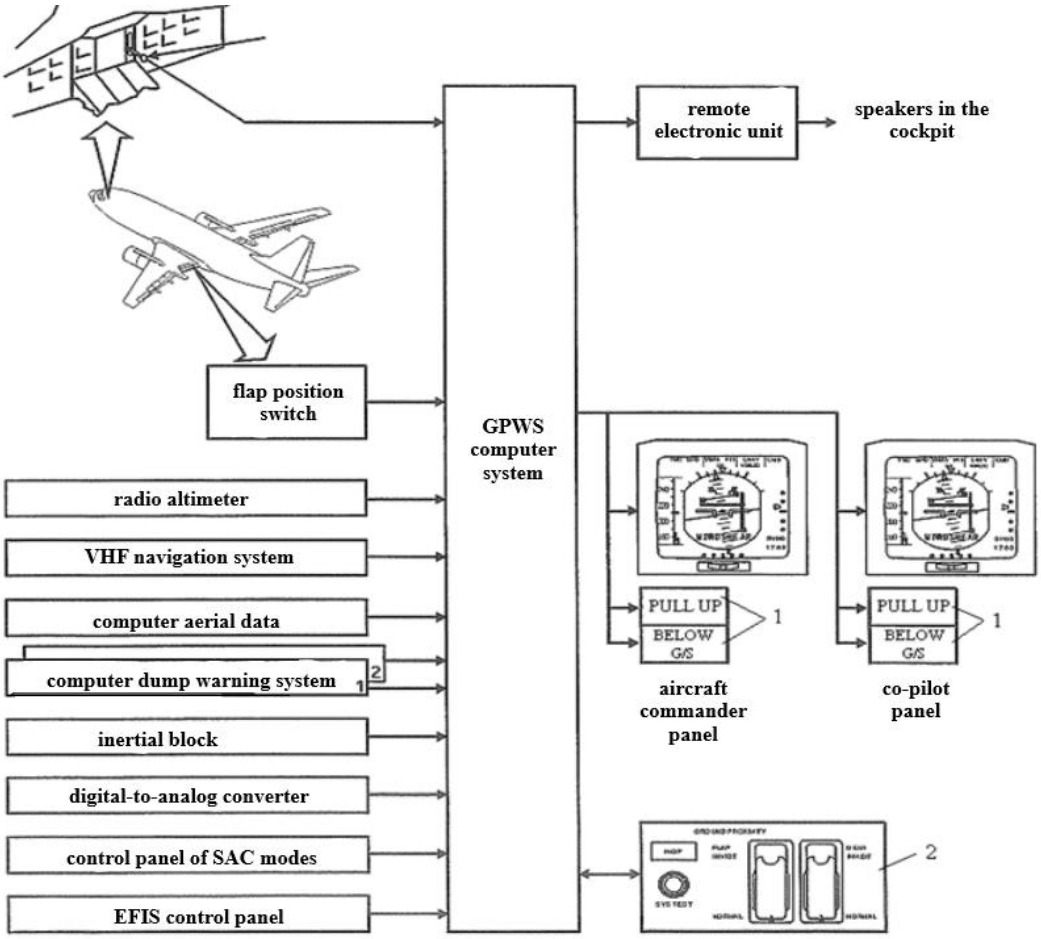


Fig. 2.11 Voeing 747 GPWS functional diagram:

1 - light alarms;

2 - remote control system to prevent the approach of the earth.

2.2 Airbus A320 EGPWS system

The EGPWS system uses many aircraft parameters to provide: - notifications, - visual alerts - audible crew alerts, - displays. The system is designed to be compatible with normal aircraft operations. The likelihood of unwanted notifications during the flight is unlikely.

Functions integrated into the EGPWS system:

- GPWS: basic ground approach warning system (six modes),

- Advanced EGPWS modes: wind shear detection and alerts, excessive tilt warnings, ground clearance, terrain warnings and obstacles.

The EGPWS system of the Airbus A320 aircraft operates in the following operating modes:

Mode 1. Excessive descent speed (radio height less than 750 m).

The SINK RATE language message is issued, or (if the situation further develops) the PULL-UP language message is issued.

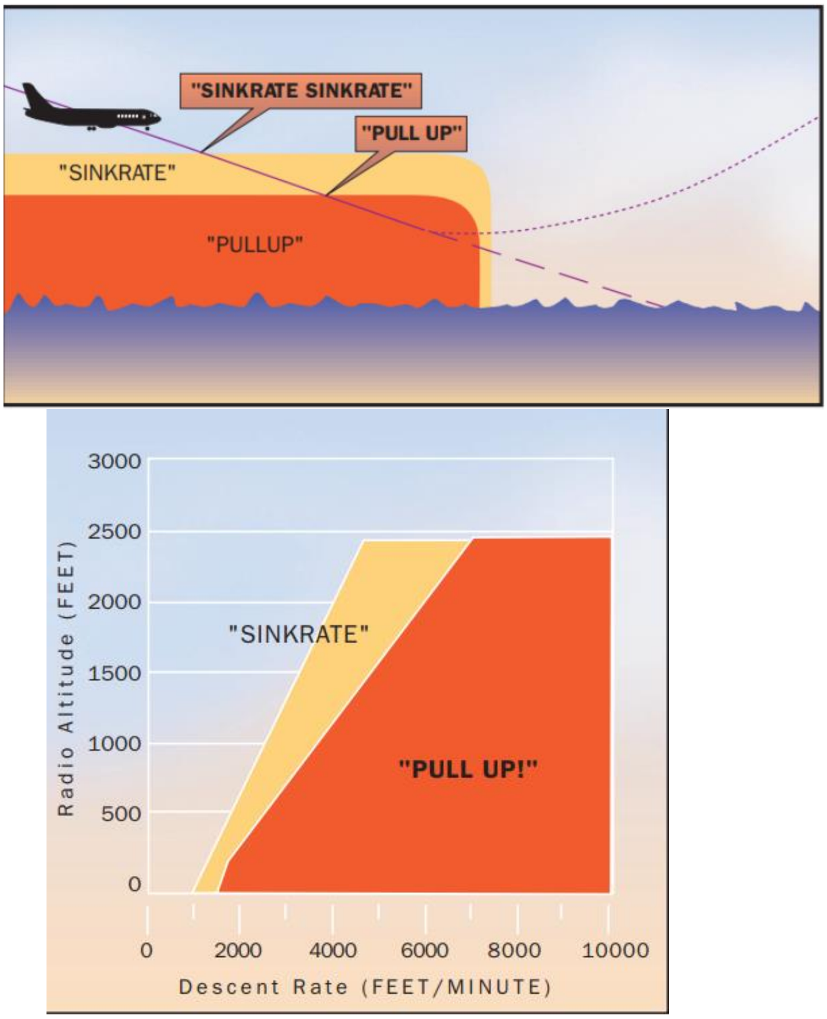


Fig. 2.12 Mode 1 (Excessive rate of descent) of the EGPWS system of the A320 aircraft

Mode 2. Excessive speed of convergence with the earth's surface.

The mode activates the alarm when there is a potential threat that the ground is rising rapidly relative to the aircraft.

Mode 2A. The mode is active during the initial ascent, approach and cruise flight. The language message TERRAIN, TERRAIN is issued, at the same time on the indicator the text of yellow colour EARTH.

If the distance to the ground continues to decrease, the PULL-UP language message appears and the same text message is displayed.

Voice messages will remain until the aircraft rises above 100 m barometric altitude or until the flaps are in the landing position.

Mode 2B provides a normal approach without unwanted signals. It is chosen at the landing position of flaps or at the performance of landing on ILS at a deviation from a course and glide path zones of more than 2 points. However, if the chassis is not in the landing position, the language message TERRAIN, TERRAIN (EARTH, EARTH) must be issued, and the yellow text EARTH appears at the same time. If the chassis and flaps are in the landing position, only the language warning TERRAIN, TERRAIN is issued.

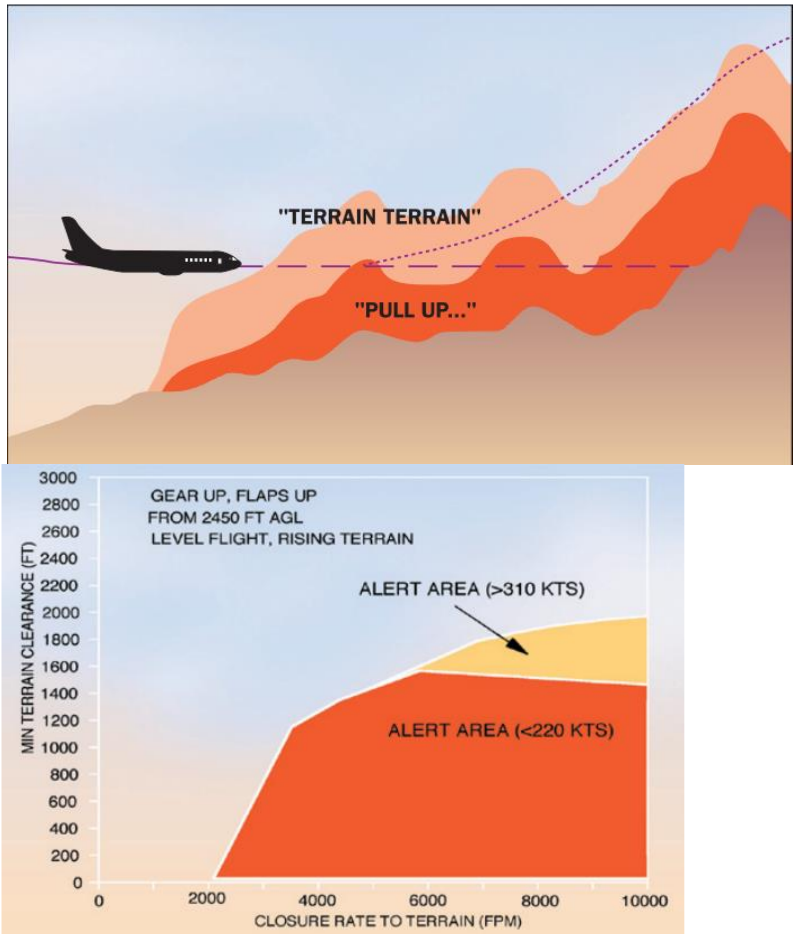


Fig. 2.13. Mode 2. Excessive speed of convergence with the earth's surface

Mode 3. Loss of altitude on takeoff or landing on the second lap.

Radio height less than 450 m, chassis and flaps not in the landing configuration. The DO NOT SINK language message appears.

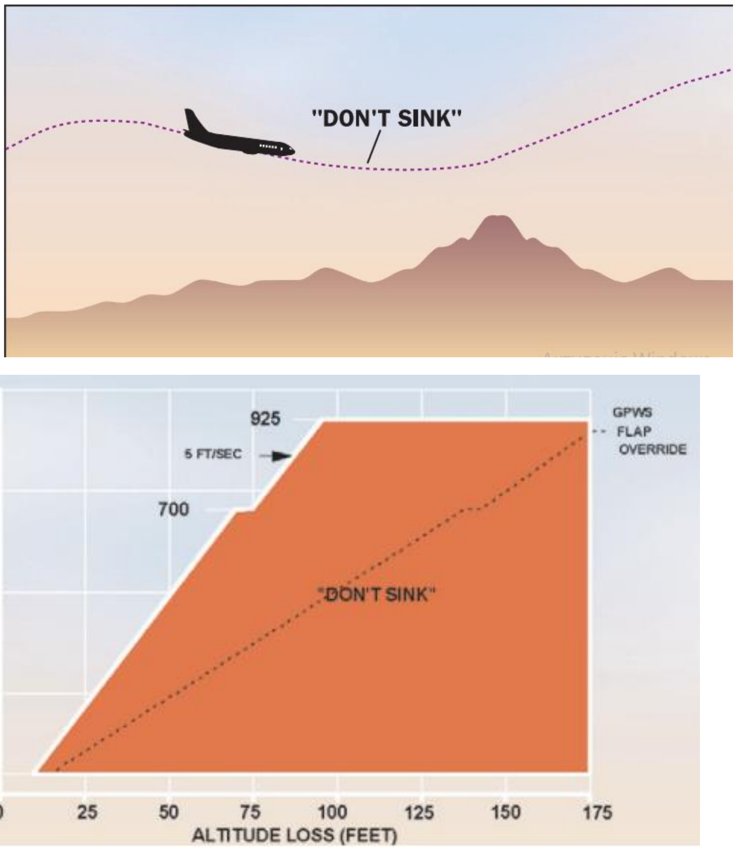
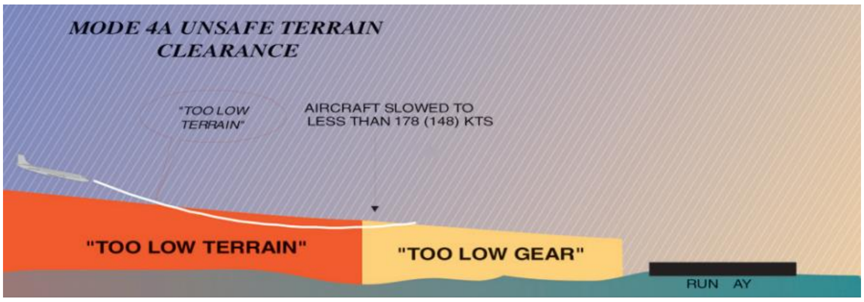


Fig. 2.14 Mode 3. Loss of altitude on takeoff or approach to the second lap.

Mode 4. Flight near the ground with flaps not in the landing position and the chassis not released.

Mode 4A. Cruising flight and landing, chassis removed, flaps not in landing position. Radio altitude less than 300m, speed more than 350km / h: TOO LOW TERRAIN language message is issued. Radio height less than 150m speed less than 350km / h. TOO LOW GEAR language message is issued.



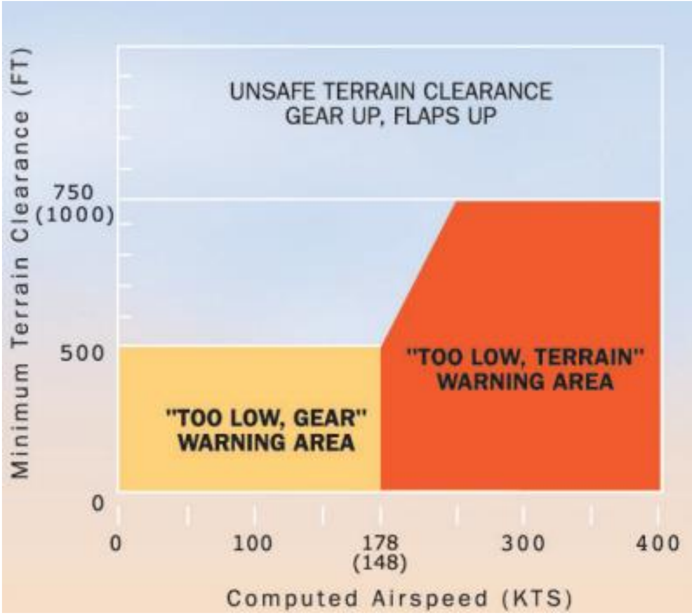


Fig. 2.15 Mode 4A.

Mode 4B. Cruising flight and landing, chassis released, flaps not in landing position. Radio altitude less than 300 m, speed more than 295 km / h: Language message issued: TOO LOW TERRAIN (LOW LAND). Radio altitude less than 75 m speed less than 295 km / h. TOO LOW FLAPS language message is displayed.

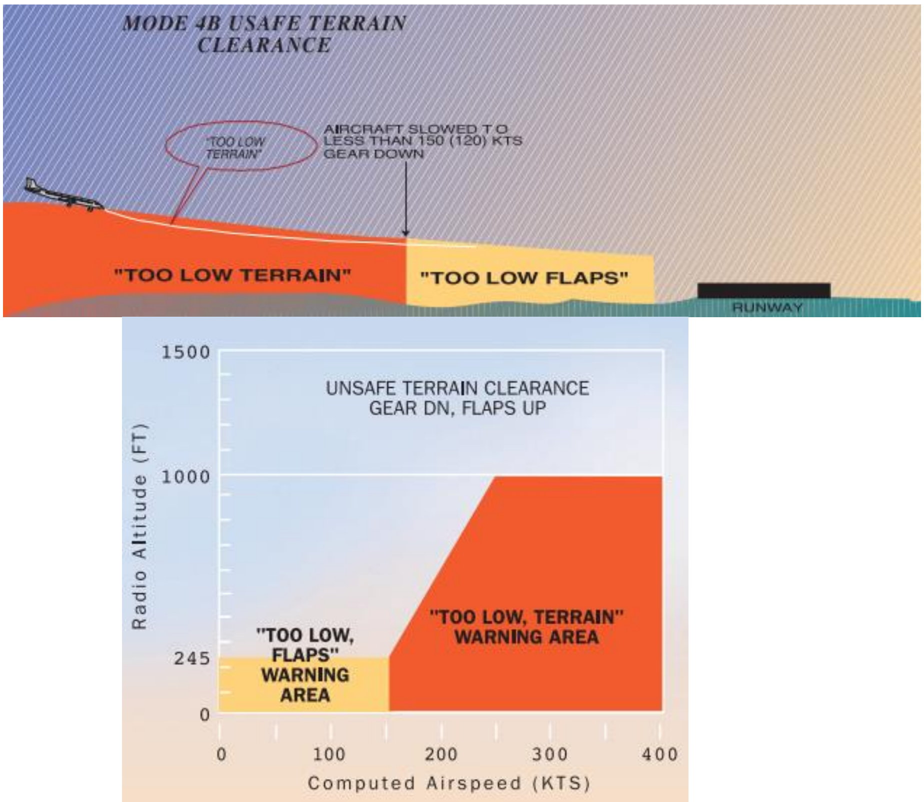


Fig. 2.16 Mode 4B.

Mode 5. Unacceptable deviation down from the glide path when approaching landing

Provides two levels of alarm.

Level 1 signals occur when the radio altitude is less than 300 m and the deviation of the aircraft below the glide path along the position bar is 1.3 points or more. A GLIDESLOPE language warning is issued.

Level 2 signals occur when the radio altitude is less than 100 m, and the deviation of the aircraft from the glide path zone on the bar position is 2 points or more. At the same time, voice messages sound louder and are issued every 3 seconds.

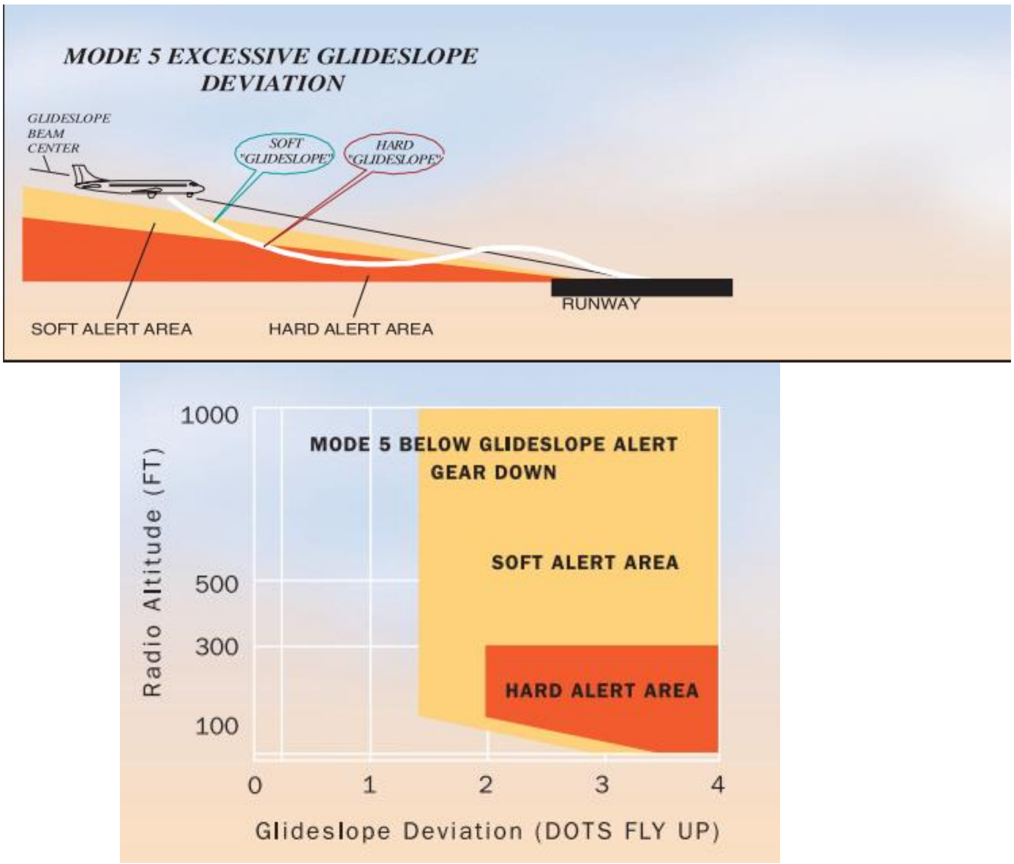


Fig. 2.17. Mode 5. Unacceptable deviation from the radio glide path when approaching landing.

Mode 6. Issue a warning signal at an altitude of 500 feet.

This function uses the global terrain database entered into the system and the database in aerodrome areas.

Notification of premature reduction (in the aerodrome area), is a notification of reduction below the permissible level of the underlying surface. When the aircraft enters the alert area, a TOO LOW TERRAIN language message is issued.

For EGPWS control units in the Airbus A320 aircraft, there is a dashboard (Fig. 2.18) and switches "TERR ON ND" and "GPWS G / S".

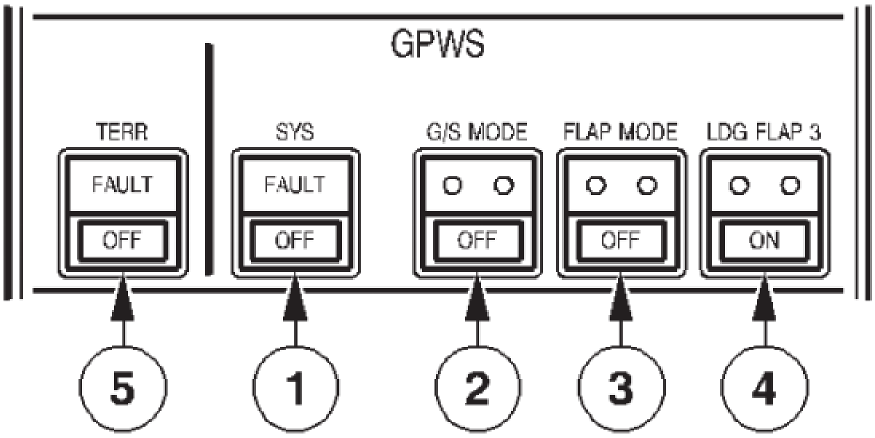


Fig. 2.18 Dashboard of EGPWS "Airbus A 320"

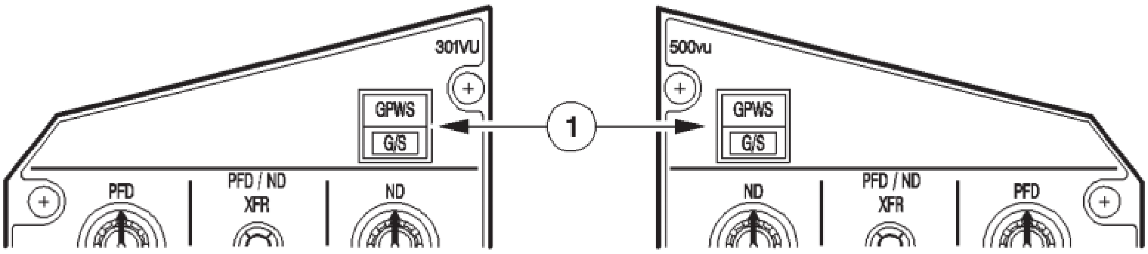


Fig. 2. 19. Dashboard of the A320 aircraft

2.3 Early warning system for approaching the ground SRPPZ-2000, aircraft An-148.

The SRPPZ-2000 system, when working with electronic equipment on board the An-148 aircraft, is designed to identify potentially dangerous situations in flight, the development of which can lead to critical consequences such as unintentional collisions with the ground or water surface, ie CFIT accidents. But the priority function of the system is to warn the crew about such a situation and provide all possible recommendations to avoid such a situation.

The warning signal is implemented by providing voice and light alarms, as well as by visually displaying information about the nature of the underlying surface on the BFI, over which the flight. The basis for displaying visual information is an electronic database of the terrain, artificial obstacles, and airfields in the direction of flight.

Warning alarms occur in the following cases:

- exceeding the allowable vertical rate of descent (mode 1);

- exceeding the allowable speed of approach to the ground or water surface (mode 2);

- loss of altitude during takeoff or departure to the second lap (mode 3);

- Insufficient height above ground with flaps and/or chassis that are not in the landing configuration (mode 4);

- approach to landing and deviation from the radio glide path more than the allowable value (mode 5);

- if an unacceptable difference between the true height and the relative barometric height is detected (mode 6);

- when passing pre-known values of heights during the approach (landing 7);

creation of language messages;

- exceeding the allowable value of roll near the ground (mode 8);

- detection of potential danger in the direction of flight;

- with premature decline;

The SRPP-2000 unit is a structurally and functionally complete device that performs all the functions of the SRPPZ system, collects, processes converts information from connected systems, and issues warning signals to the crew.

On the front panel of the unit is mounted: a connector designed to connect, if necessary, to a PC to diagnose SRPPZ; two LEDs "Contr. 1 »,« Contr. 2 », and « Contr. 3 "are closed by lenses and fuse holder. An electrical connector is located on the back of the unit to connect the unit to the aircraft feeder. The unit is fixed and mounted on the chassis (frame). To ensure grounding, special busbars are provided.

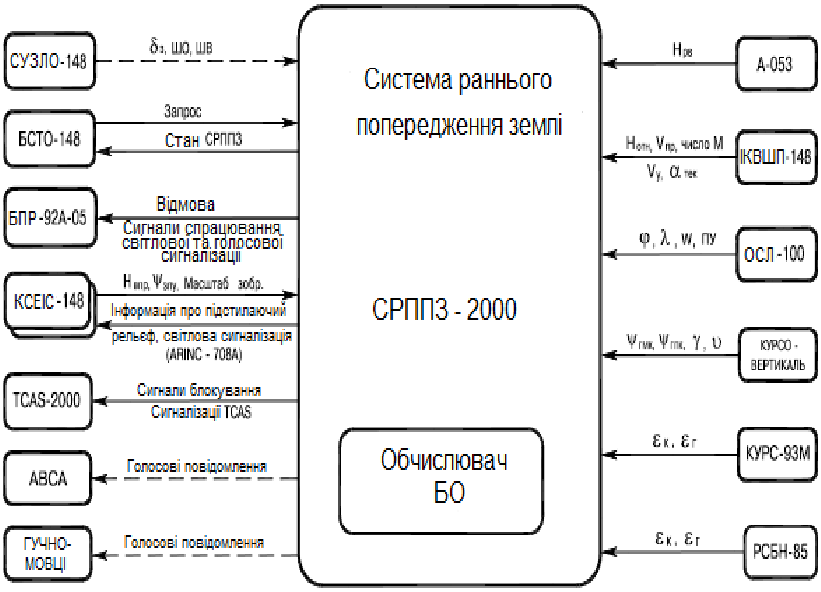


Fig.2.20 Structural scheme of SRPPZ

Primary information sensors send signals to the SRPPZ, where they are received and analyzed. If there is a signal at the input of the signal corresponding to the dangerous situation, the onboard computer (BO) generates danger signals, which in turn are sent to KSEIS, the intercom system and the onboard recorder. Light signals are received by the crew through the phones of the pilots' headsets, as well as on the KSEIS indicators.

The SRPPZ system is powered by a 27 V DC mains bus from the bus W1 of the left RU 27 V through the SRPPZ circuit breaker.

In fig. 2.21 shows the control and management bodies of the system SRPPZ-2000.

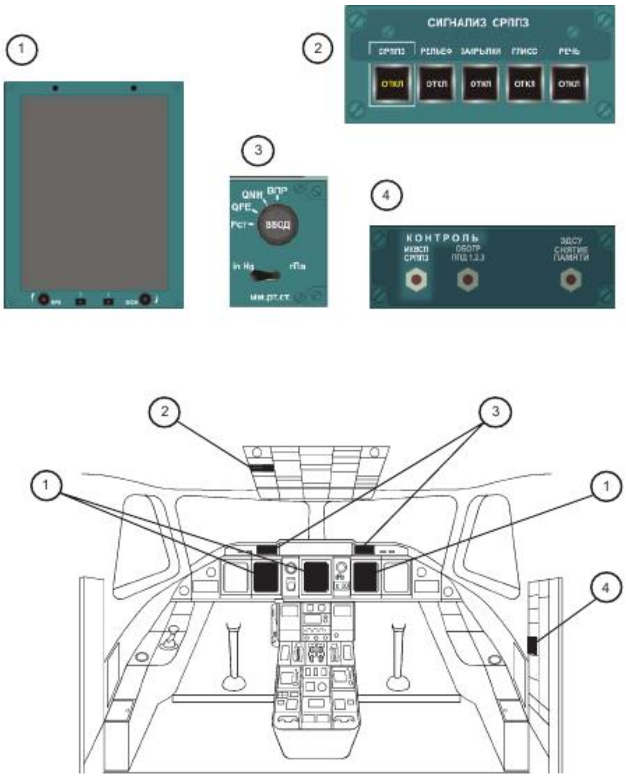


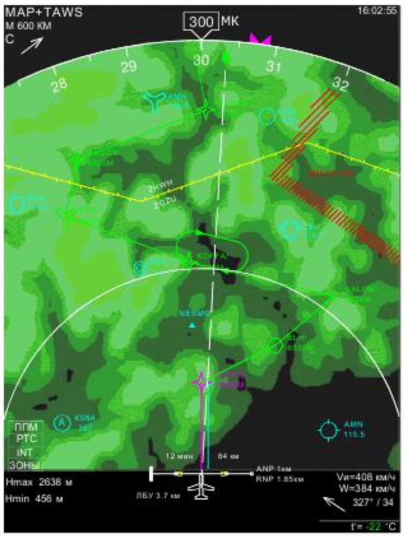
Fig.2.21 Management and control bodies SRPPZ-2000 aircraft An-148

Signals from primary information sensors are analyzed by a computer. If the input signal has a value equal to the level of the dangerous situation, the onboard computer generates a danger signal, which is sent to the SPU, on the board and on-board recorder.

Built-in controls provide:

- formation of the signal "SRPPZ RIGHT";
- blocking of the warning signal if the system of SRPPZ is faulty;
- conducting a pre-flight inspection without the use of inspection equipment.

In fig. 2.22 can evaluate examples of visual reproduction of aerobatic information. The frame is displayed on the BFI.



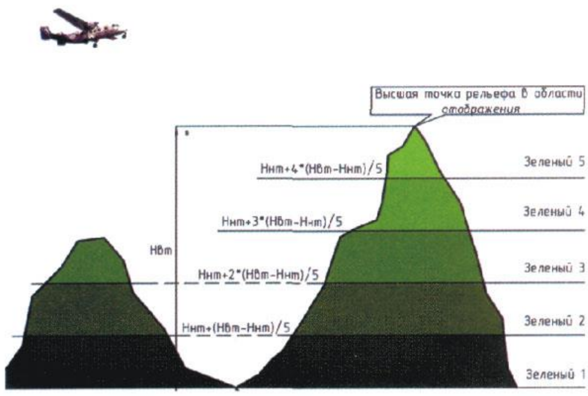
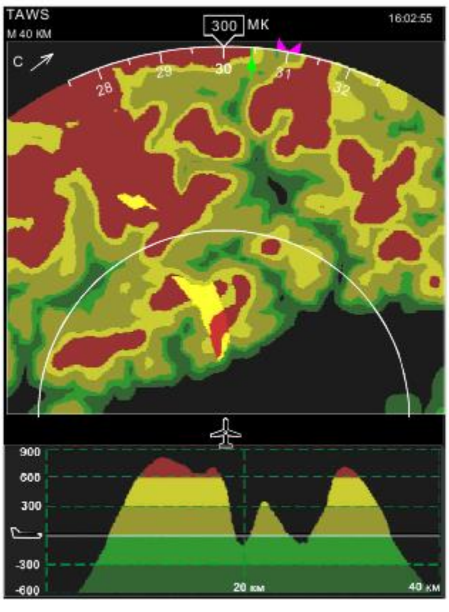


Fig.2.22a FRAME “MAR + TAWS” (absolute heights)



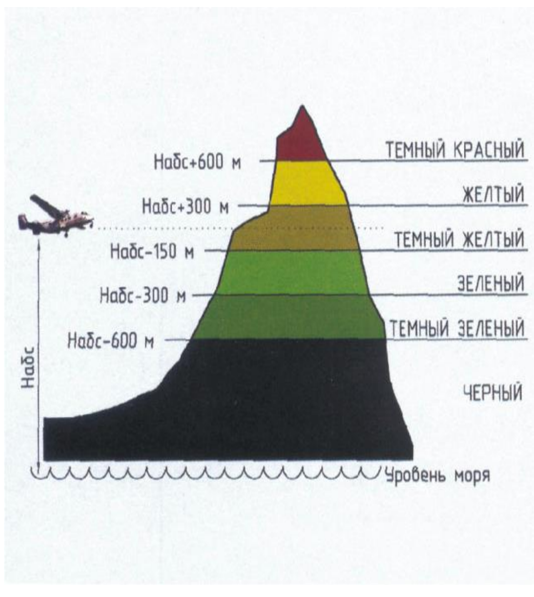


Fig. 2.22b. TAWS FRAME (relative heights)

CHAPTER 3.

USE OF A PROFESSIONAL FLIGHT RADAR AS A SENSOR OF THE EARLY WAR APPROACHING SYSTEM

3.1. Flight with a bend in the terrain

The use of early approach systems (hereinafter - GCC) increases the time given to the crew to make decisions and correct piloting errors. The main sensor of the SRPPZ which directly measures the distance to the earth's surface is a radio altimeter of small altitudes, but it can only measure the true altitude (H0) under the aircraft. At low-altitude flights, it is necessary to predict the flight trajectory of the aircraft and to anticipate the possibility of its approach to the ground at critical altitudes.

Today, the SRPPZ is engaged in such forecasting. The forecast is based on the known coordinates of the aircraft, which are measured by the Computational Aircraft Control System (OSL) based on a known course, which is determined using the course vertical system. The result of such a prediction is some point in the airspace on the flight path of the aircraft at a certain biased distance, which is sufficient to manoeuvre to avoid collision with an obstacle. Predicting the possible approach of the trajectory of the flight to critical altitudes to the ground surface is performed by calculating the true altitude of the trajectory at some point according to the digital relief model of the earth's surface, which is in the memory of the computer computing system.

Thus, the work of SRPPZ is to determine the true altitude of the flight path of the aircraft at some biased point, to avoid collisions with the ground. This forecasting system has certain shortcomings, the main of which are errors in the coordinates of the aircraft location, and inaccuracies in the map of the absolute altitudes of the earth's surface due to natural and artificial changes in terrain and course measurements. It is necessary to use sensors for direct measurement of the intensity of changes in the relief of the earth's surface to reduce the impact of inaccuracies on the results of forecasting.

The aircraft must manoeuvre at low altitudes in the vertical plane while bypassing the terrain in compliance with the safe true altitude H0 and maintaining the specified course, to avoid collisions with the ground. Such a flight is called a profile flight.

Low-altitude flight with manoeuvring in the vertical plane is carried out in such a way that the height of the flight trajectory was greater than specified (Fig. 3.1). The flight is performed on the shortest trajectory in the areas between the tops of obstacles.

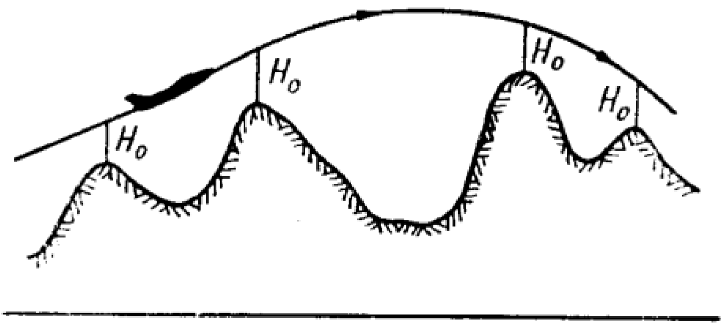


Fig. 3.1. Flight over the envelope of obstacles

During the flight with the bending of the terrain, there is the greatest convergence of the trajectory to the vertical profile of the terrain. (Fig. 3.2.)

Fig. 3.2. Flight with a bend in the terrain

A flight with manoeuvring in the horizontal plane, in which the avoidance of obstacles occurs at a constant altitude of the flight is called a flight bypassing obstacles (Fig. 3.3).

Fig. 3.3. Flight around obstacles

Performing a low-altitude flight in the manual control mode significantly increases the risk of collision with ground obstacles, water bodies or elevations. The pilot does not have enough time to react to the obstacle and avoid it, which is why it is necessary to automate the control of aircraft at low altitudes or to provide adequate signalling of changes in the terrain safety to ensure safety of the earth's surface.

Perception of terrestrial objects and obstacles changes during low-altitude flight. And the viewing area of the earth's surface is decreasing (some elements of the aircraft structure may overlap the view of the area). It is necessary to take into account the fact that the pilot has a very limited time to recognize the obstacle. Also, a very important factor is the terrain and visibility conditions that affect the detection range of a dangerous threat. Therefore, this stage should be subject to automation to increase the level of flight safety.

During the flight with the avoidance of obstacles, the manoeuvring of the aircraft in the vertical plane must be provided with a constant safe height of H0 relative to the earth's surface (Fig. 3.4).

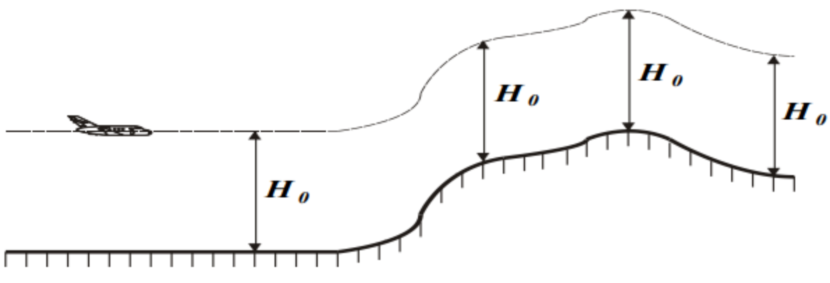


Fig.3.4 Scheme of low-altitude flight with obstacle avoidance

To perform this type of flight, ground-based anchor sensors are required, ie a profile flight radar station (RLP) is required to warn the crew of possible obstacles in the flight path. Such systems have the range and biased altitude information for all weather and lighting conditions. RLPP are long-range and angular.

The biased height H_y above the point of the earth's surface in front of the aircraft at a safe range D is determined from the triangle AOB (Fig. 3.5):

$$H_y = D\sin\beta,$$

where D is the range measured to the biased point;

β is the angle of inclination of the beam by the patterns of the direction of the antenna (DNA) relative to the velocity vector.

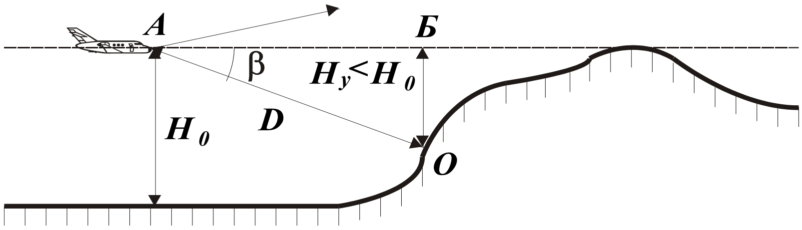


Fig. 3.5. Scheme of bias of biased height

In long-range RLPP, the antenna is fixed, and the DNA beam is fixed at an angle to the axis of the aircraft. To overcome the obstacle, the distance to the biased point is measured. During the flight, the manoeuvre is performed in the vertical plane so that the measured range D is equal to the safe reference range D_0. In this case, the biased height Hy will be equal to the reference height H0 (Fig. 3.6).

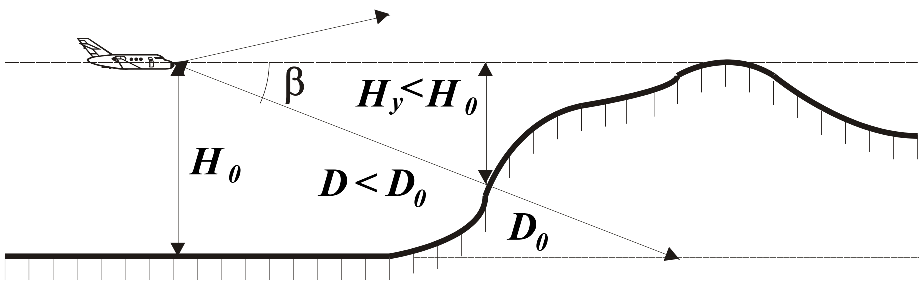


Fig. 3.6. Scheme of operation of the long-range RPP

The value of the measured range ($D = D_0$) is fixed on the RPM of the protractor type due to the movement of the antenna in the vertical plane. To avoid an obstacle, it is necessary to measure the angle of inclination of the DNA beamβ, and then the pilot will be able to manoeuvre the vertical plane (Fig. 3.7).

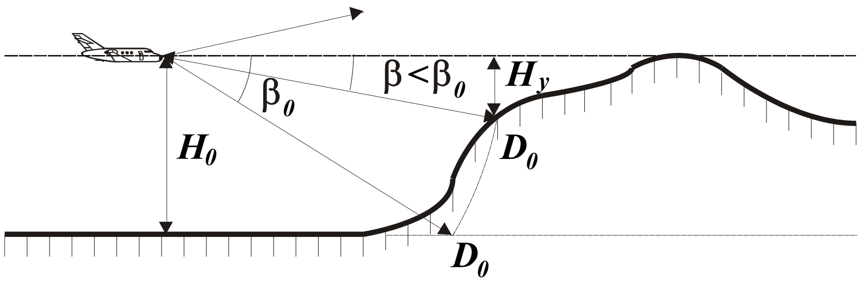


Fig. 3.7. Scheme of operation of an angular RPP

It follows from the above that the profile flight radar must ensure the flight of obstacles at distances that are sufficient to manoeuvre the vertical plane.

3.2. Meteorological and radar stations

Multifunctional meteorological radar stations (MNRLS) are an autonomous source of meteorological information. In the mode of a survey of the earth's surface, MNRLS is an autonomous means of navigation. MNRLS are installed on the aircraft to indicate to the crew the angular position, range and degree of danger of hydrometeorological formations (GMOs), the position of the aircraft relative to landmarks, as well as the angle of wear of the aircraft. MPR information is displayed on the electron beam indicator in the cockpit. In modern MPR provides for the issuance of information to the navigation complex.

The vast majority of MNRLS is a pulsed radar, the principle of which is based on the use of secondary (reflected) radiation of radio waves by various objects (inhomogeneities) encountered in the propagation of the probe.

In fig. 3.8. a simple scheme of the onboard radar is presented. This is one of the variants of the traditional scheme of pulse radar, which takes into account the peculiarities associated with the installation of radar on board the aircraft. This scheme is not a real block structure of the MNRLS, but only explains the principle of operation of the onboard radar.

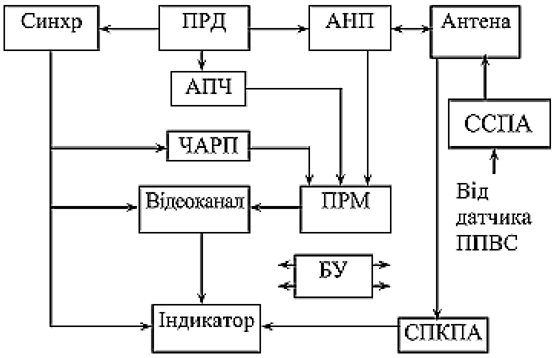


Fig. 3.8. Simplified MNRLS scheme

MNRLS functions:

1. Detection, determination of coordinates and degree of danger of hydrometeorological formations

2. Obtaining an even-contrasting image of the earth's surface and determining the coordinates of terrestrial objects.

3. Navigational survey of the earth's surface using symmetric DN and determining the coordinates of terrestrial objects

4. Measurement of the angle of wear of the aircraft

The transmitter (PRD) generates powerful pulses of microwave energy of the required duration and shape. A synchronizer (Sync.) Is required to coordinate the time of operation of all radar units and the formation of calibration range marks.

The antenna is designed to form a DS of the required shape, radiate the energy of probing pulses and receive energy reflected by objects.

There is a receiver to detect signals reflected from objects against the background of noise and to obtain useful information from them.

An antenna switch (ANP) is designed for the automatic gradual connection of the antenna to the output of the transmitter or to the input of the receiver (at another time). The switching frequency is equal to the repetition frequency of the probe pulses.

The indicator is intended for the reproduction of radar information, in polar coordinates azimuth-range, and also auxiliary information. The deployment scheme contained in the indicator unit provides the deviation of the electron beam in its tube and together with the system of synchronous transmission of the angular position of the antenna (SPKPA) forms a radial-sector scan.

The Automatic Frequency Tuning (AF) system provides automatic tuning of the receiver to the frequency of the transmitter signal. The time-of-life automatic gain control (TAC) device automatically changes the gain of the receiver in such a way as to ensure uniform amplification of signals, reflected objects, and which are located at different distances from the Russian Federation. To monitor how this happens, while receiving signals reflected from nearby objects, the receiver is amplified to a minimum. And then gradually increases. And when receiving signals reflected from the most distant targets, the gain reaches the highest value.

Recently, the world's leading companies have started the production of coherent-pulse on-board radars, the scheme of which is characterized by additional connections that provide the receiver with a reference signal that carries information about the phase.

In modern digital radars, the signal is converted into digital form, and the node, designated on the scheme as "Video Channel", implements digital signal processing, and all communications between units are made in digital form except for high-frequency inter-frequency communication. Fig. 3.9).

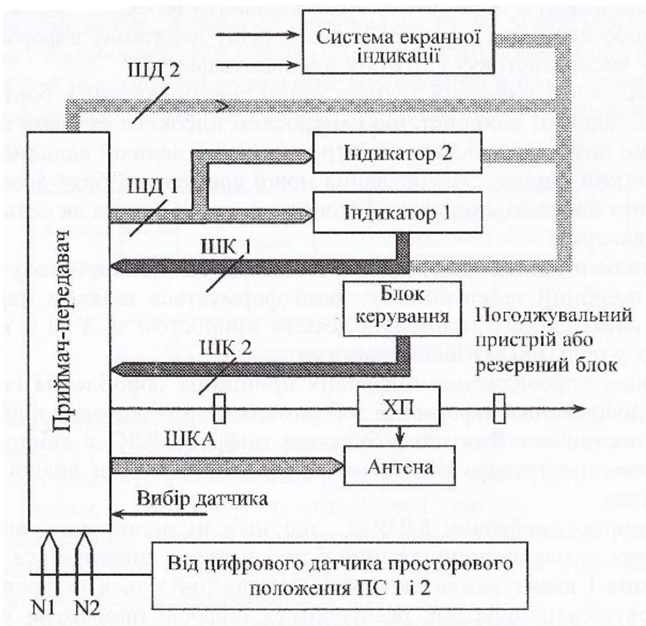


Fig. 3.9. The structure of digital MNRLS

The indicator unit together with the signals on the data bus receives information about:

- the angular position of the antenna;
- time of radiation of the probing pulse;
- selected range scale;
- tilt changes antennas;
- selected mode of operation, etc.

Onboard radars have a block design. The main units of modern MNRLs are usually the antenna, transceiver and indicator with the remote control. The appearance of the main blocks of the MNRLS is presented in Fig. 3.10, 3.11.

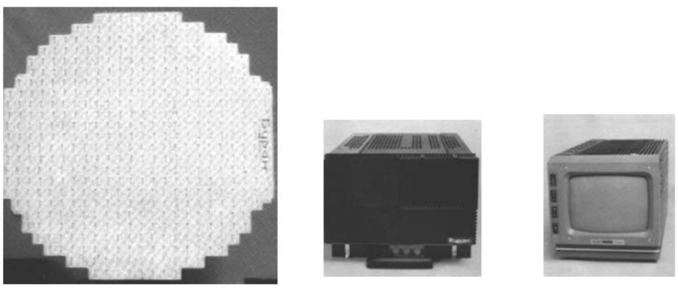


Fig. 3.10 Antenna, transceiver and MNRLS-85 indicator

The transceiver is located in the lower nasal compartment behind the ceiling on which the antenna is mounted. In traditional designs, transceivers are connected to the antenna by waveguides (feeders). However, such cases are known when monoblock constructions in which the antenna and the transceiver are structurally a single unit. This avoids the wave-like path with a rotating joint, which is a source of energy losses and disturbances. The monoblock design is applied in MNRLS "Buran-A".

Consider the MNRLS "Storm-A" aircraft An-148.

Meteorological and navigation radar station "Buran - A" was created to solve the following tasks:

1. Survey the airspace (in the horizontal and vertical planes) to obtain and display on the screen the indicator information about the meteorological formation, certain areas of heavy rainfall, areas of high turbulence and the degree of their danger.

2. View the vertical section of meteorological formation in a given direction.

3. Survey land and water surface to perform navigation on typical land and water landmarks.

4. Identification of mountain peaks and high-rise buildings.

5. Determination of coordinates (inclination and course angle) of the observed radar objects.

The range of detection of radiocontrast objects depends on the flight altitude and characteristics of the irradiated object, for example:

- centres of clusters of thunderstorms .... 150-400 km.

- large industrial cities .... up to 350 km.

- background of ordinary terrain and the shore of reservoirs. 100-150 km.

- industrial facilities, bridges .... 40-80 km.

- turbulent zones in the middle of meteorological formations 10-60 km.

The main modes of operation of MNRLS "Buran-A" are:

1. "Control",

2. "Earth",

3. "Meteo" and sub-modes -

    1) "Profile",

    2) "Turbulence",

    3) "Stabilization",

    4) "Tilt-automatic".

The "Control" mode is designed to check the functionality of the MNRLS and its channels of communication with the built-in control means.

The "Earth" mode is used to form a radar map of the area and radar survey of land and water surface.

The Meteo mode is intended for radar inspection of the airspace in front of the aircraft to detect hydrometeorological formations, analyze them and assess the degree of their danger.

The "Profile" submodel is intended for viewing meteorological formations in the vertical plane (at distances ≈ of 40 km).

The "Turbulence" sub-mode is used to detect dangerous turbulence zones in meteorological formations and is activated automatically in "Meteorological" mode if the observation range is set to 40 km and/or less.

Sub-mode "Stabilization" is designed to stabilize the direction of the antenna beam during the evolution of the aircraft (roll ± 20 ° and pitch ± 10 °). The sum of the angles of pitch, roll and inclination of the antenna is limited to ± 30 °, in the horizontal plane, the movement of the antenna is limited to ± (85 ± 3) °.

Tilt-automatic sub-mode is used to automatically control the tilt of the antenna during the evolution of the aircraft in height. The sub-mode operates in the "Earth" or "Weather" mode at the "Dialogue" level, for which the "N / A OFF" symbol must be moved to the "N / A ON" position on the radar control panel or vice versa.

The angles of the antenna in the "Earth" mode are presented in the table. 3.1,

Table. 3.1

Angles of inclination of the antenna in the "Earth" mode

Set range, km.	Flight altitude, km				
	1.0	2.0	4.0	6.0	10 0
	Antenna angle, degree				
600	-	-	-	-	-2,75
320	-	-1,5	-2,25	-2,5	-4,5
160	-1,25	-2,5	-4,25	-5,5	-7,0
80	-3,5	-4,75	-6,5	-7,5	-12,5
40	-5,0	-10,5	-10,5	-15	
20	-9,0				

Therefore, to determine the distance to the radiocontrast point in the "EARTH" mode or dangerous meteorological formation in the "METE" mode, any MNRL must have the function of a rangefinder with an active location and have a subsystem for measuring range.

Measurement of range by radar methods is based on the assumption of rectilinear propagation of radio waves at a constant speed. Therefore, to measure the range to the target, it is sufficient to measure the delay time of the signal reflected from the target relative to the emitted radar signal.

$$R = \sqrt[4]{\frac{P_{\text{ïð}} \cdot G_a^2 \cdot \lambda^2 \cdot c \cdot \tau \cdot D^2}{512\pi^2 \cdot P_{\text{èçë}}}}$$

where $P_{изл}$ – is the radiated power; $P_{пр}$ - received power; λ – is the wavelength; G_a – gain; τ – a resolution to the target; c – is the pulse duration; ψ – filling on purpose; D – is the diameter of the target; γ – is the fill factor for the target.

Methods of measuring range depend on which of the parameters of the received radio signals is used to measure the delay time and are:

- amplitude,
- frequency
- phase.

Among radars with amplitude range measurement methods, pulse stations are the most common. The principle of their operation is shown in the diagram in Fig. 3.11.

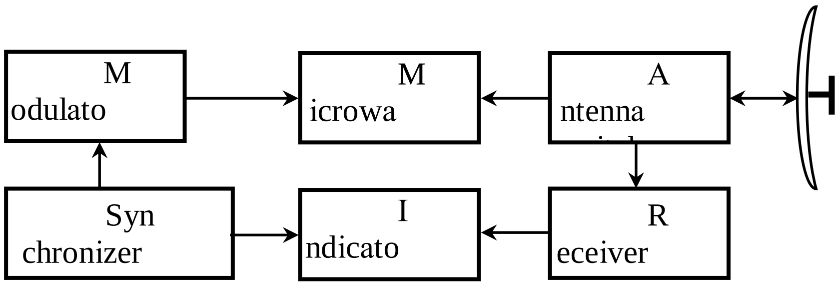


Fig. 3.11. Functional diagram of a pulsed radar rangefinder

The high-frequency generator, controlled by a pulse modulator, emits short high-frequency pulses (probing signals) with a given periodic repetition.

The sounding signal can be written as follows:

$$u_{зен}(t) = U_0 \cos(\omega_0 t + \psi_0) \quad \text{при } t_0 \leq t \leq t_0 + \tau_u,$$

where t_0 is the start of the reference on the time axis, which coincides with the beginning of the pulse; τ_i - pulse duration; U_0 - amplitude of oscillations; ψ_0 is the initial phase of oscillations.

3.3. The use of MNRLS as a radar profile flight.

As a sensor for measuring the change in the terrain in some biased area in front of the aircraft, it is most correct to use a meteorological radar in the mode of measuring the distance to the ground with a narrow beam.

Because the main advantages of using MNRLS as RPP are:

- the presence of the range measurement function (D);
- high resolution in range (ΔD), azimuth (Δα) and angle (Δφ);
- the ability to change the power of the emitted signal.
- narrow pattern (λ_RLS);
- the ability to stabilize the beam during the evolution of the aircraft (roll, pitch);

- the ability to change the angle of the beam (β);
- digital processing of parameters with the possibility of automatic transmission of signals to the means of collision prevention;

To date, on-board MNRLS is already used in practice as a means of preventing collisions with obstacles. But only with the participation of the crew.

During the survey of space with the help of symmetrical narrow DN antennas detect ground obstacles (mountain peaks, hills and high-rise buildings). Due to this, the probability of observing interference reflections from the earth's surface at all flight altitudes exceeding a certain altitude (1000 m) is reduced. When bypassing obstacles, the survey sector mustn’t change its position in space when the aircraft is stepping and rolling. Therefore, the DN axis of the antenna must be stabilized in space.

In the case of approaching a mountain peak, when the aircraft is flying at a constant altitude of H and is far enough away from the obstacle, the horizontally directed divergent beam of the radar irradiates a large part of the mountain. The area of exposure to the obstacle decreases as you approach the mountain. Therefore, the backlight on the screen becomes smaller.

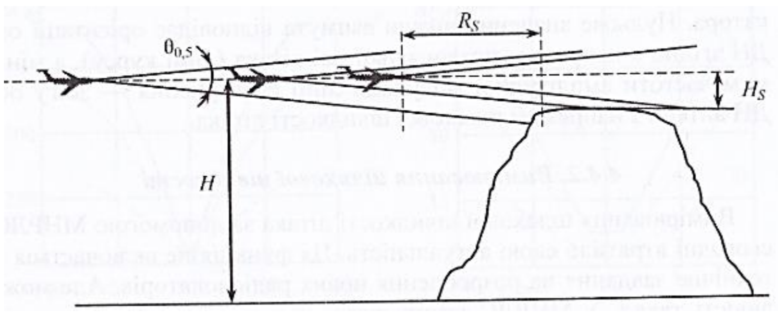


Fig. 3.12. Safety circuit method

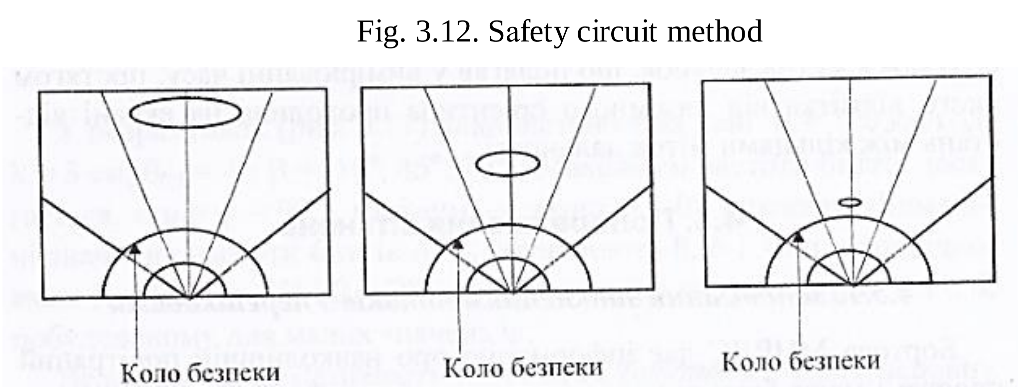


Fig. 3.13. Decrease the light from the mountain as you approach it

However, if the illumination from the obstacle crosses the safety circle, it is necessary to gain height to ensure the required excess. The safety circle can be marked on the light filter of the MNRLS indicator.

Therefore, the paper proposes the automated use of MNRLS complete with the TAWS system as a radar profile flight.

After analyzing the principle of operation of MNRLS and modes of its operation, we can conclude that in addition to the existing modes and sub-modes of operation programmatically possible to enter in the mode "Earth" additional sub-mode of MNRLS such as "Relief". In this sub-mode, depending on the flight altitude of the aircraft, the antenna MNRLS switches from scan mode to beam lock mode. This will make it possible to inspect the topography of the earth's surface at a distance of about 25 km in front of the aircraft, which is enough to manoeuvre in the event of an obstacle along the flight route.

The IRRS can implement the rangefinder or angular function of the profile flight radar, as it can accurately measure the distances and angles of the antenna.

When implementing the long-range method of profile flight MNRLS will constantly measure the distance to the earth's surface and compare the change in terrain in front of the aircraft with a digital model stored in the memory of the computer system or TAWS. That is, in addition to performing the function of safe flight, there is a real opportunity to implement a survey-comparative method of navigation of the crew.

One of the main modes of TAWS - "Assessment of terrain in the direction of flight" - is designed to check the absence of terrain elements and artificial obstacles within the established working space by predicting and modelling possible dangerous situations. With the use of MNRLS in the "Relief" mode, the forecast will be much more accurate, because there are a priori further to calculate the characteristics of the relief of the earth's surface.

In addition, during reversals, the MNRL antenna may also deviate further in the direction of reversal to analyze the area over which the aircraft will fly.

For modern aircraft, it is recommended to use the digital coherent-pulse MNRLS "Buran-A" regional aircraft An-148 as a profile flight radar.

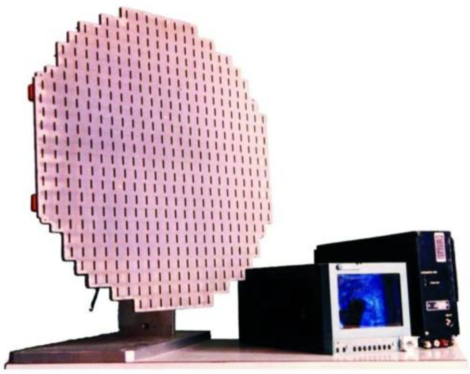


Fig. 3.14.

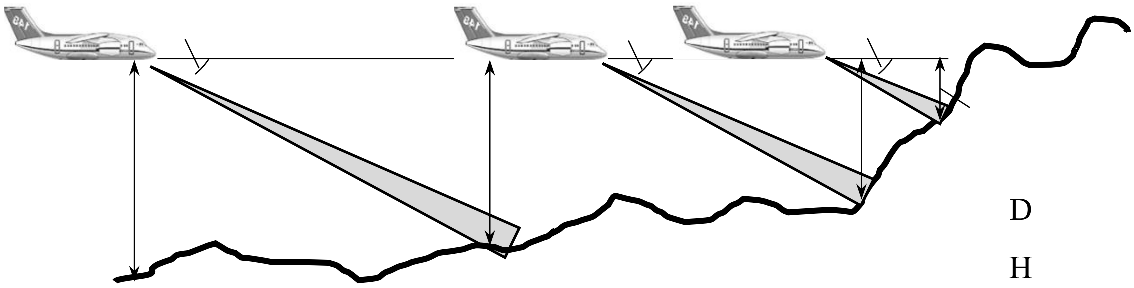


Fig. 3.15. Implementation of MNRLS An-148 to assess the terrain

Automated use of MNRLS complete with the system SRPPZ-2000 as a radar profile flight involves the creation of a new sub-mode of MNRLS "Relief" and the implementation of some algorithms for information exchange.