Instrument Landing System

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Abstract

The Instrument Landing System (ILS) is an internationally normalized system for navigation of aircrafts upon the final approach for landing. It was accepted as a standard system by the ICAO, (International Civil Aviation Organization) in 1947. Since the technical specifications of this system are worldwide prevalent, an aircraft equipped with a board system like the ILS, will reliably cooperate with an ILS ground system on every airport where such system is installed.

The ILS system is nowadays the primary system for instrumental approach for category I.-III-A conditions of operation minimums and it provides the horizontal as well as the vertical guidance necessary for an accurate landing approach in IFR (Instrument Flight Rules) conditions, thus in conditions of limited or reduced visibility. The accurate landing approach is a procedure of permitted descent with the use of navigational equipment coaxial with the trajectory and given information about the angle of descent.

The equipment that provides pilot instant information about the distance to the point of reach is not a part of the ILS system and therefore is for the discontinuous indication used a set of two or three marker beacons directly integrated into the system. The system of marker beacons can however be complemented for a continuous measurement of distances with the DME system (Distance measuring equipment), while the ground part of this UKV distance meter is located co-operatively with the descent beacon that forms the glide slope. It can also be supplemented with a VOR system by which means the integrated navigational-landing complex ILS/VOR/DME is formed.

INTRODUCTION

An ILS provides the pilot or autopilot of a landing aircraft with the guidance information.

The information's provided to the aircraft by the ILS are:

- Its position relative to the centre line of the runway (lateral or azimuth guidance)-LLZ.
- Its position relative to the defined angle of descent (elevation guidance)- GP.
- Its distance from the point of threshold or touch down- LP DME/Markers.

Categories of operation minimums:

Category I

- A minimal height of resolution at 200 ft (60.96 m), whereas the decision height represents an altitude at which the pilot decides upon the visual contact with the runway if he'll either finish the landing manoeuvre or he'll abort and repeat it.
- The visibility of the runway is at the minimum 1800 ft (548.64 m)
- The plane has to be equipped apart from the devices for flying in IFR (Instrument Flight Rules) conditions also with the ILS system and a marker beacon receiver.

Category II

- A minimal decision height at 100 ft (30.48 m)
- The visibility of the runway is at the minimum 1200 ft (365.76 m)
- The plane has to be equipped with a radio altimeter or an inner marker receiver, an autopilot link, a raindrops remover and also a system for the automatic draught control of the engine can be required. The crew consists of two pilots.

Category III A

- A minimal decision height lower than 100 ft (30.48 m)
- The visibility of the runway is at the minimum 700 ft (213.36 m)
- The aircraft has to be equipped with an autopilot with a passive malfunction monitor or a HUD (Head-up display).

Category III B

- A minimal decision height lower than 50 ft (15.24 m)
- The visibility of the runway is at the minimum 150 ft (45.72 m)
- A device for alteration of a rolling speed to travel speed.

Category III C

- Zero visibility

ILS (Instrument Landing System) is a radio beam transmitter that provides a VHF/UHF radio signal on the air in order to help the pilot to perform a precision approach. There are four main elements (Figure 1) in the complete ILS:

- A localiser radio beam to furnish directional guidance to and along the runway
- A glide path radio beam to furnish vertical guidance at the correct descent angle to the runway touchdown point
- Fan markers (outer marker and middle marker). In some cases DME has been authorised for use when markers are not available or cannot be installed.
- A suitable radio navigation aid is provided on most installations to assist in interception of the localiser and holding procedures. At some locations two of these aids are provided. This aid can be either a VOR or a low-powered NDB (Locator).

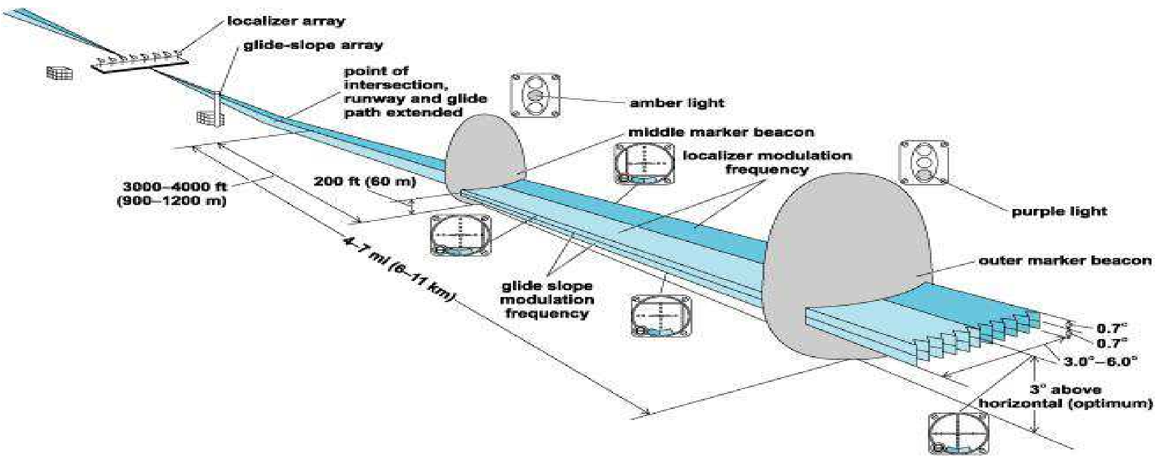


Figure 1. The description and placement of the individual parts of the ILS system.

Ground Equipments

(a) Localiser

One of the main components of the ILS system is the localizer which handles the guidance in the horizontal plane. The localizer is an antenna system comprised of a VHF transmitter which uses the same frequency range as a VOR transmitter (108.10 – 111.95 MHz), however, the frequencies of the localizer are only placed on odd decimals, with a channel separation of 50 kHz. The transmitter or antenna (Figure 2) is in the axis of the runway on its other end, opposite to the direction of approach. A back course localizer is also used on some ILS systems. The back course is intended for landing purposes and it's secured with a 75 MHz marker beacon or a NDB (Non Directional Beacon) located 3-5 nm (nautical miles) or 5.556-9.26 km before the beginning of the runway. The course is periodically checked to ensure that the aircraft lies in the given tolerance.
The aerial localiser is on the runway extended centreline at the opposite end to the approach end, at a distance which ensures that it lies below the runway take-off obstruction clearance plane. The transmitter building is usually located 100–120 metres to the side of the aerial. The field pattern radiated by the localiser is illustrated with the course line lying along the extended runway centreline. The localiser beam 'width', as it is interpreted by the travel of the localiser needle on the aircraft cross pointer indicator from full deflection in the blue sector (150-hertz) to full deflection in the yellow sector (90-hertz) is normally 5° for uncategorised systems and all other systems are adjusted to 210 metres wide at the landing threshold. Total width in terms of degrees will depend on position of aerials and length of runway. The equipment is designed to provide a usable on-course signal at a minimum distance of 25 nautical miles from the runway at a minimum altitude of 2.000 ft above the threshold. Each localiser is identified aurally by a coded designator consisting of three letters, the first of which is the letter 'I'. The transmitters are usually duplicated, with an automatic changeover facility from primary to secondary equipment in the event of failure or malfunction.

Figure 2. Antennas of the localizer system

The transmitted signal

The localizer or VHF course marker emits two directional radiation patterns (Figure 3). One comprises of a bearing amplitude-modulated wave with a harmonic signal frequency of 150 Hz and the other one with the same bearing amplitude-modulated wave with a harmonic signal frequency of 90 Hz. These two directional radiation patterns do intersect and thus create a course plane, or a horizontal axis of approach, which basically represents an elongation of the runway. (1)
For an observer – a pilot, who is situated on the "approaching" side of the runway (therefore in front of the LLZ antenna system) predominates a modulation of 150 Hz on the right side of the course plane and 90 Hz on the left. The intersection of these

two regions determines the on-track signal. The width of the navigational ray can span from 3° to 6°, however mostly 5° are used. The ray is set to secure a signal approximately 700 ft (213.36 m) wide on the borderline of the runway. The width of the ray magnifies, so at a distance of 10 nm (18.52 km) from the transmitter is the ray about 1 nm (1.852 km) wide. The range of the localizer can be even 18 nm (33.336 km) in the 10° field from the center of the ray (on-track signal) and 10 nm (18.52 km) in the field 10°-35° from the center of the ray, because the main part of the signal is coaxial with the middle of the runway. The localizer is identified by an audio signal added to the navigational signal. The audio signal consists of letter "I", following with a two-letter addition, for example: "I-OW".

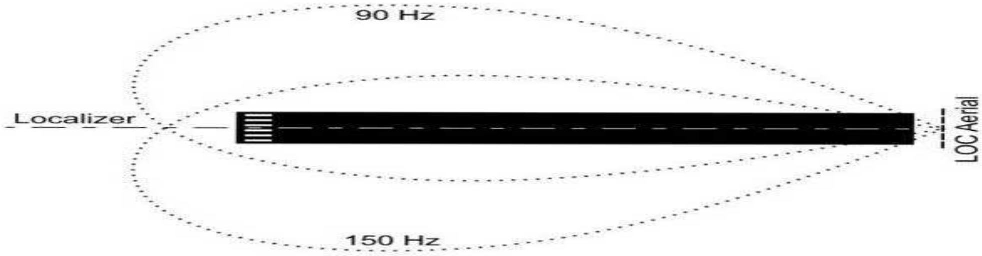


Figure 3. Radiation pattern of the localizer's VHF transmitter

(b) UHF descent beacon – glide slope

The glide slope or angle of the descent plane (Figure 4) provides the vertical guidance for the pilot during an approach. It's created by a ground UHF transmitter containing an antenna system operating in the range of 32930-335.00 MHz, with a channel separation of 50 KHz.
The transmitted is located 750-1250 ft (2286-381 m) from the beginning of the runway and 400-600 ft (121.92-182.88 m) from its axis. The observed tolerance is ±0.5°. The UHF glide slope is paired with the corresponding frequency of the VHF localizer.

Figure 4. The UHF descent beacon draws a glide slope in the area

Like the signal of the localizer, so does the signal of the glide slope consist of two intersected radiation patterns, modulated at 90 and 150 Hz. However unlike the localizer, these signals are arranged on top of each other and emitted along the path of approach. The thickness of the overlapping field is 0.7° over as well as under the optimal glide slope (Figure 5).

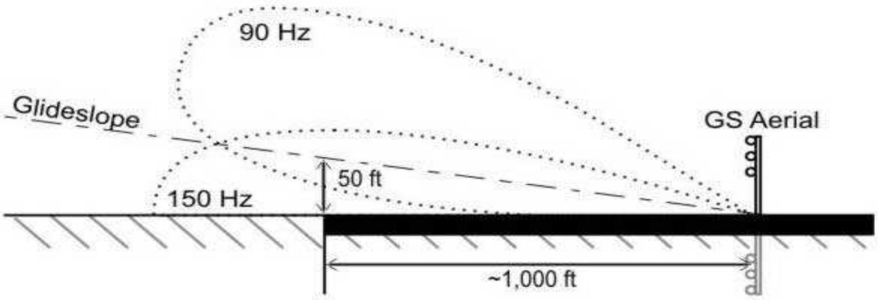


Figure 5. The radiation pattern of the UKV descent beacon forming the glide slope

The signal of the glide slope can be set in the range of 2°-4.5° over the horizontal plane of approach. Typically it's a value of 2.5°-3°, depending of the obstacles along the corridor of approach and the runway's inclination. False signals can be generated along the glide slope. It's happening in multiples of the angle that‘s formed by the glide slope and the horizontal plane. The first case arises at approximately 6° over the horizontal plane. These false signals are inversive, which means that the directions to climb or descend will be swapped. A false signal at 9° will be oriented the same as the real glide slope. There are no false signals under the glide slope.

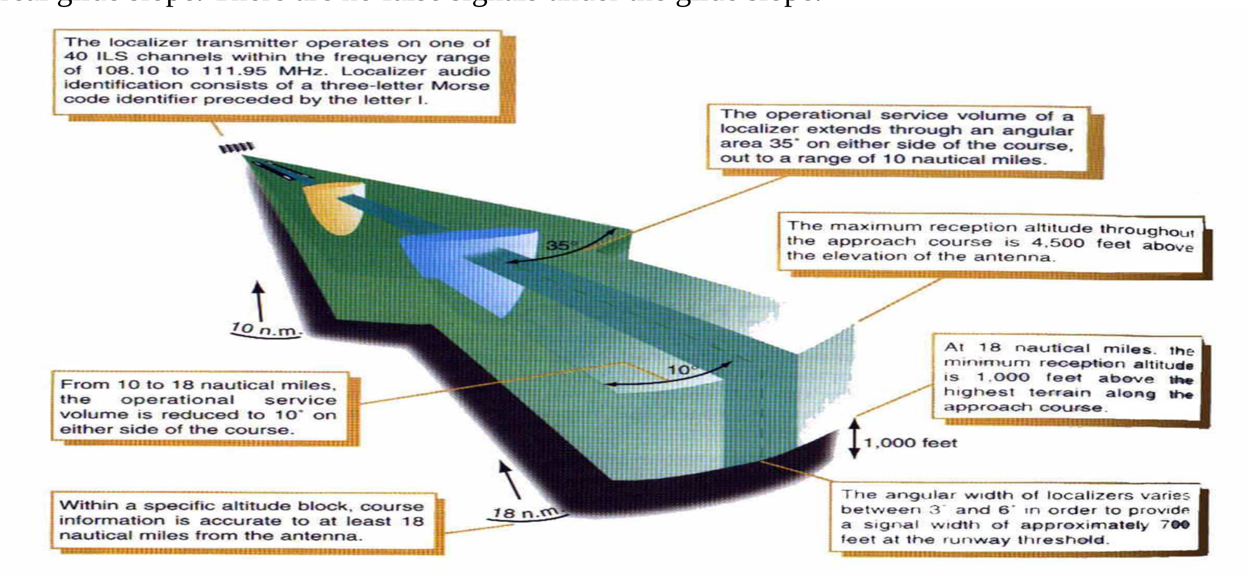


Figure 6. Range of localizer, glide path and markers on a runway.

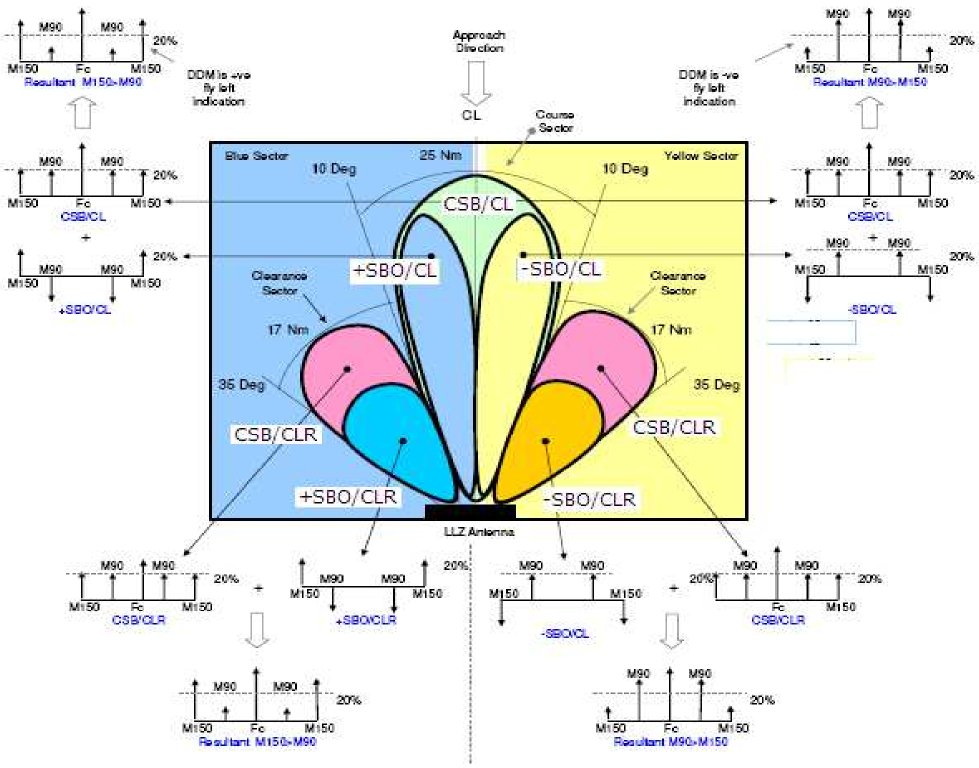


Figure 7. The phase variation of SBO and CSB.

Generation of CSB and SBO signals (Figure 8):

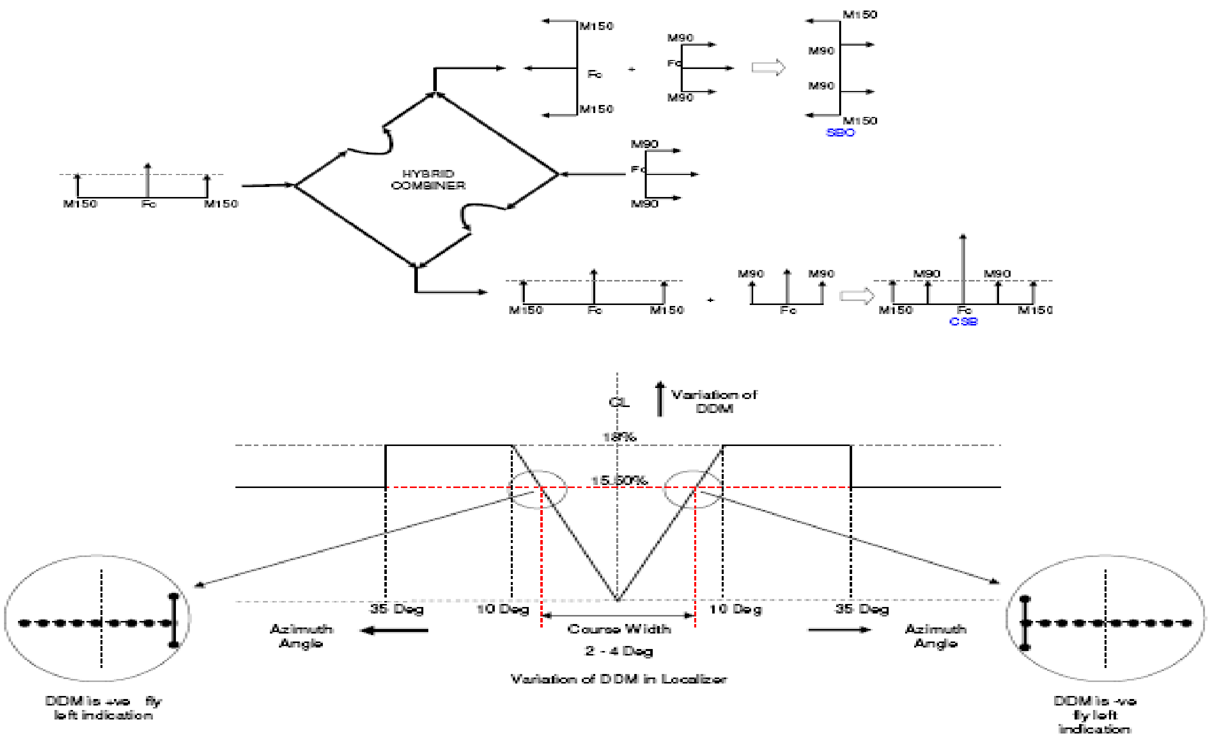


Figure 8. Generation of CSB and SBO signals.

Onboard equipments:

Localizer receiver

The signal is received on board of an aircraft by an onboard localizer receiver. A simplified block scheme of the onboard receiver of the localizer's signals is displayed in. The localizer receiver and the VOR receiver form a single unit. The signal of the localizer launches the vertical indicator called the *track bar* (TB). Provided that the final approach does occur from south to north, an aircraft flying westward from the runway's axis is situated in an area modulated at 90 Hz, therefore, the track bar is deflected to the right side (Figure 9 and Figure 10/a 10/b b).

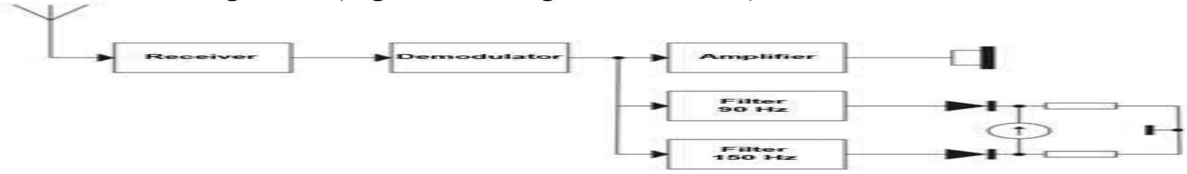
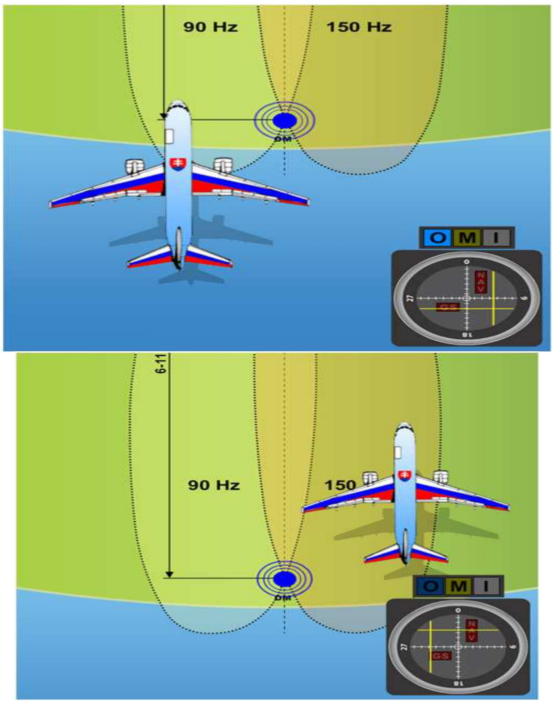


Figure 9. Block scheme of the onboard course beacon's signal receiver



a) b)

Figure 10. a) A plane flying approximately along the axis of approach, however partially turned away to the left; b) A plane flying nearly in the approach axis slightly leaned out to the right.

On the contrary, if the plane's positioned east from the runway's axis, the 150 Hz modulated signal causes the track bar to lean out to the right side. In the area of intersection, both signals affect the track bar, which causes to a certain extent a deflection in the direction of the stronger signal. Thus, if an aircraft flies roughly in the axis of approach leaned out partially to the right, the track bar is going to deflect a bit to the left. This indicates a necessary correction to the left. In the point where both signals 90 Hz and 150 Hz have the same intensity, the track bar is in the middle, meaning that the plane is located exactly in the approach axis (Figure 11).

When the track bar is used in conjunction with a VOR, a lean out of 10° to one or the other side from the signal causes a full deflection of the indicator. If the same pointer is used as an indicator of the ILS localizer, a full deflection will be induced by a 2.5° diversion from the center of the localizer's beam. Therefore the sensitivity of the TB is roughly four times greater in the function as an indicator of the localizer as at the indication of information from the VOR.

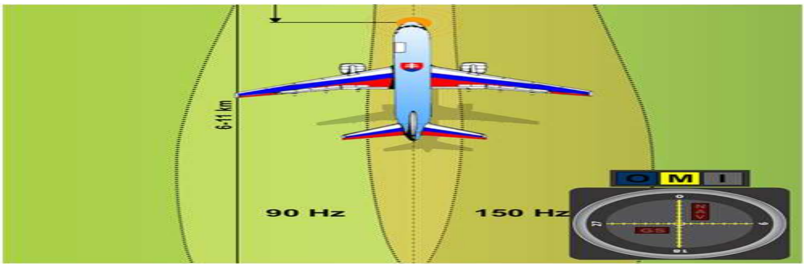


Figure 11. A plane flying exactly in the axis of approach

In case that a red NAV bat appears in the upper right section of the onboard ILS indicator, it represents that the signal is far too weak or out of the receiver's reach and for that reason the pointer's deflection cannot be considered to be accurate. The vertical pointer will return to the neutral position, meaning to the center of the indicator. A momentary display of the NAV bat, short deviations of the TB, or both instances happening at once can occur in the case that an aircraft flies between the receiver's antenna and the transmitter, or some other obstacle gets into their way (Figure 12).

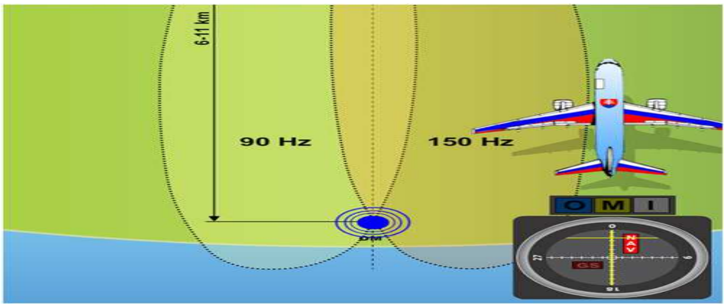


Figure 12. A plane situated out of reach of the VKV course beacon's signal

Glide Slope Receiver

The glide slope's signal is on board of a plane received by means of a UHF antenna. In modern avionics are the controls for this receiver combined with the VOR's controls, so the correct frequency of the glide slope beacon is tuned in automatically at the instant when the localizer's frequency is selected. The glide slope's signal puts the horizontal pointer of the glide slope into operation which intersects the TB(2). This indicator has its own GS bat which lights up whenever the glide slope beacon's signal is too weak or the onboard receiver, hence the whole aircraft is out of the signal's reach (Figure 13).

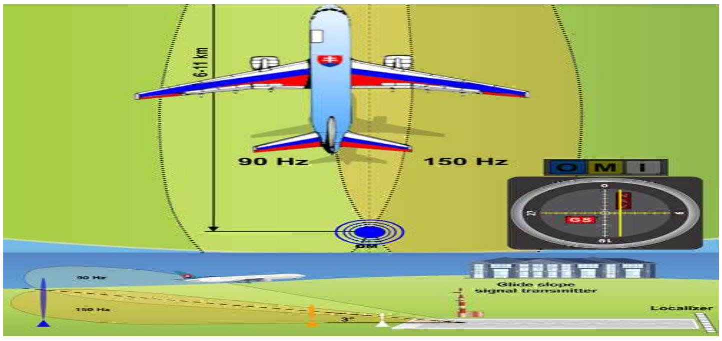


Figure 13. An example of the displayed GS pointer notifying a diversion from the glide slope, a too weak received signal, or an obstacle on the way.

The onboard indicator of the ILS system can be used by a pilot to determine the exact position because it provides vertical as well as horizontal guiding. It portrays both indicators in the middle, which means that the aircraft is located in the point of intersection of the course plane (horizontal) and the glide slope. The event pictured indicates that the pilot must descent and correct the flight course to the left in order to acquire the correct course and glide slope level. The case shows a necessity to ascend and adjust the flight course to the right. With a 1.4° overlapping of the beams is the area around 1500 ft (457.2 m) wide at a distance of 10 NM (18.52 km), 150 ft (45.72 m) at a distance of 1 NM (1.852 km), and less than one foot (0.3 m) at the instant of touch down. The apparent sensitivity of the instrument increases as the aircraft closes in to the runway. The pilot has to watch the indicator with attention so that he can keep an overlap of both needles of the pointer in the middle of the indicator. Thereby he'll achieve a precise homing all the way to the touch down (Figures 14, 15, 16).

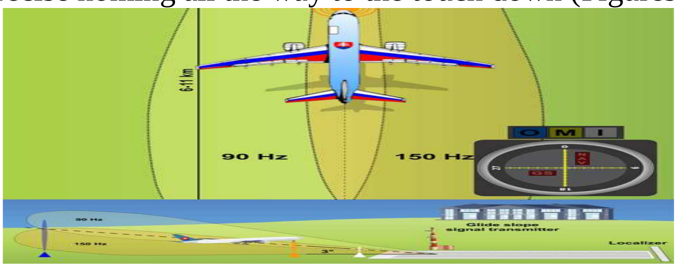


Figure 14. Both pointers in the middle – the aircraft is located in the point of intersection of the course and descent plane.

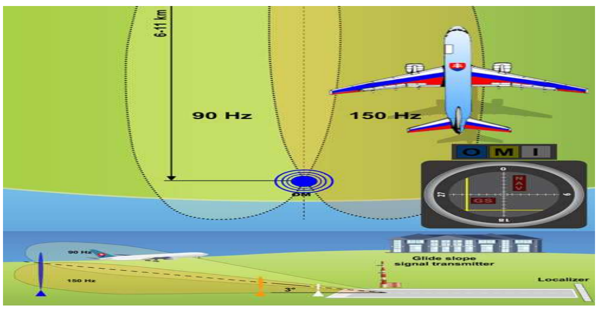


Figure 15. A case when the aircraft is located right of the runway's axis and too high over the glide slope.

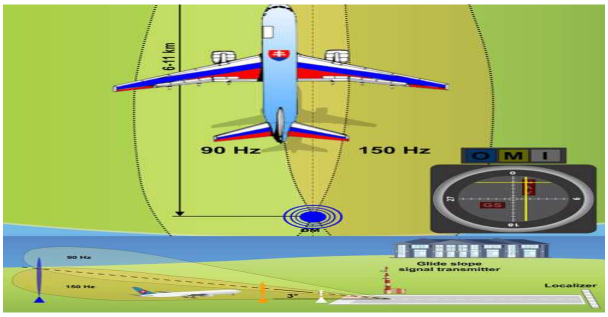


Figure 16. A case when the aircraft is located left of the runway's axis and too low under the glide slope.

Marker beacons

For the purpose of discontinuous addition of navigation data with the value of a momentary distance from the aircraft to the runway's threshold, the following marker beacons are used:

Outer Marker (OM)

- The outer marker is located 3.5-6 NM (5.556-11.112 km) from the runway's threshold. Its beam intersects the glide slope's ray at an altitude of approximately 1400 ft (426.72 m) above the runway. It also roughly marks the point at which an aircraft enters the glide slope under normal circumstances, and represents the beginning of the final part of the landing approach.
- The signal is modulated at a frequency of 400 Hz, made up by a Morse code – a group of two dots per second. On the aircraft, the signal is received by a 75 MHz marker receiver. The pilot hears a tone from the loudspeaker or headphones and a blue indicative bulb lights up. Anywhere an outer marker cannot be placed due to the terrain, a DME unit can be used as a part of the ILS to secure the right fixation on the localizer.
- In some ILS installations the outer marker is substituted by a Non Directional Beacon (NDB) (Figure 17).

Figure 17. The outer position marker (blue)

Middle Marker (MM)

The middle marker is used to mark the point of transition from an approach by instruments to a visual one. It's located about 0.5-0.8 NM (926-1482 m) from the runway's threshold. When flying over it, the aircraft is at an altitude of 200-250ft (60.96-76.2) above it. The audio signal is made up of two dashes or six dots per second. The frequency of the identification tone is 1300 Hz; passing over the middle marker is visually indicated by a bulb of an amber (yellow) colour. It was removed in some countries, e.g. in Canada (Figure 18).

Figure 18. The middle marker (yellow).

Inner Marker (IM)

The inner marker emits an AM wave with a modulated frequency of 3000 Hz. The identification signal has a pattern of series of dots, in frequency of six dots per second. The beacon is located 60 m in front of the runway's threshold (3). The inner marker has to be used for systems of the II and III Category (Figure 19).

Figure 19. The inner marker (white).

CONCLUSION:

Instrument Landing System (ILS) is one of the most important CNS facilities available for an aeroplane to have a safe landing.

The instrument landing system is the primary precision approach facility for civil aviation, a precision approach being one in which both glide slope and track guidance are provided. The ILS signals are transmitted continuously and provide pilot interpreted approach guidance. When flying the ILS approach, the pilot descends with approach guidance to the decision height (DH), at which point he makes the final decision to land or go around. Any installation must conform to the standards laid down in ICAO Annex 10 and an appropriate performance category will be allocated to it. Any exception to these standards will be published in NOTAMs.

The localiser transmitter supplies approach guidance in azimuth along the extended runway centre line. The glide path transmitter provides approach guidance in the vertical plane. Marker beacons provide accurate range fixes along the horizontal plane. Many ILS installations use an associated DME to provide a continuous ranging facility than that provided by the markers. ILS installations may also be complemented with a low power NDB, known as a locator beacon. The function of the locator is to provide guidance, during intermediate approach, into the final approach path, which is marked by the ILS.

The ideal flight path on an ILS approach is where the localiser and the glide slope planes intersect. To fly this flight path, the pilot follows the ILS cockpit indications.

References

1. Airport Authority of India, CNS Facility: ILS system- Localizer material. Pg: 25.
2. Airport Authority of India, CNS Facility: ILS system- Glide path material. Pg: 49.
3. Airport Authority of India, CNS Facility: ILS system- Marker material. Pg: 63.