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INSTRUMENT LANDING SYSTEM AS AN EXAMPLE OF A PRECISION APPROACH SYSTEM

Summary. This paper presents basic information about an instrument landing system (ILS). An ILS operates as a ground-based instrument approach system, which provides precision lateral and vertical guidance to an aircraft approaching and landing on a runway, using a combination of radio signals. Additionally, it contains a description of data gathered during an ILS approach and compares it with nominal values.
Keywords: approach system, instrument landing system, precision approach

1. INTRODUCTION

The approach system is a set of a technical radio devices, allowing for approaches to be made in reduced visibility. There are two main types of approach system and procedure: the precision approach and the non-precision approach. The type of approach is determined by the approach system used. A precision approach involves an instrument approach and landing using precision lateral and vertical guidance with minima, as determined by the category of operation. The instrument approach procedure is a series of predetermined manoeuvres for the orderly transfer of an aircraft under instrument flight conditions from the beginning of the initial approach to a landing, or to a point from which a landing may be

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made visually. Approach procedures are based on available navigation aids. Other vital factors are:

- landform in the vicinity of aerodrome,
- types of aircraft operations which are going to be anticipated,
- types of aircraft for which the procedures are going to be developed.

2. INSTRUMENT LANDING SYSTEM

The ILS is an example of a precision approach system, which is used when there is reduced visibility or a low ceiling. The original ILS was established in 1929 and its first operational use took place in 1938. The ILS gives both vertical guidance (the glideslope) and horizontal guidance (the localizer).

The localizer generates a signal, which provides course guidance, allowing it to determine the deviation of an aircraft from an extended runway centre line (as an angular deviation, for example, 2° to the right). The localizer transmitter produces a flat vertical beam, which sets the direction for landing. The localizer (LLZ or LOC) operational frequency is 108.1-111.9 MHz with 200 kHz of spacing. The LOC emits two beams of amplitude-modulated radio waves with frequencies at 90 Hz and 150 Hz. The direction line, compliant with an extended runway centre line, is determined by the equal modulation depth of both signals, as shown in Figure 1.

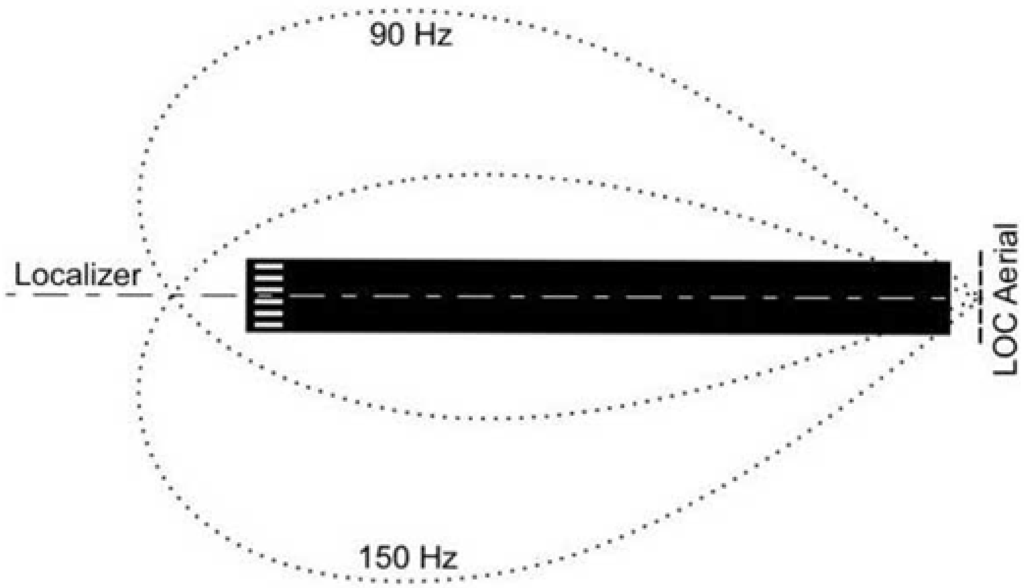

Fig. 1. Modulation of localizer signals

The modulation depth is 18-22% for ILS CAT I or II and 19-21% for ILS CAT III. The accuracy of guidance is on the level of 15 arc minutes. The transmitter also emits the identification signal, which is a combination of three characters in Morse alphabet.

The required ranges are:

- 25 NM - in sector +/- 10°,
- 12 NM - in sector +/- 10 to +/- 35°,
- 10 NM - in sector +/- 35°.

Some LOCs are able to transmit a back course signal, which is very helpful in go-around situations.

The localizer is also able to provide different types of approach, defined as a localizer directional aid (LDA) or a simplified directional facility (SDF). However, it is a non-precision approach because it does not ensure horizontal guidance. The localizer antenna is located behind the end of the runway, as shown in Figure 1.

The glideslope is the second part of the ILS system. It provides vertical guidance. The operational frequency is 328-335 MHz. The glideslope signal is transmitted using a technique similar to that for the localizer. The equal modulation depth of both signals, 90 Hz and 150 Hz, arranges a glideslope (glide path or GS), as shown in Figure 2. The glide path is set approximately 3° above the horizontal (it depends on many circumstances). The required range of the glideslope signal is 10 NM in sector +/- 8°.

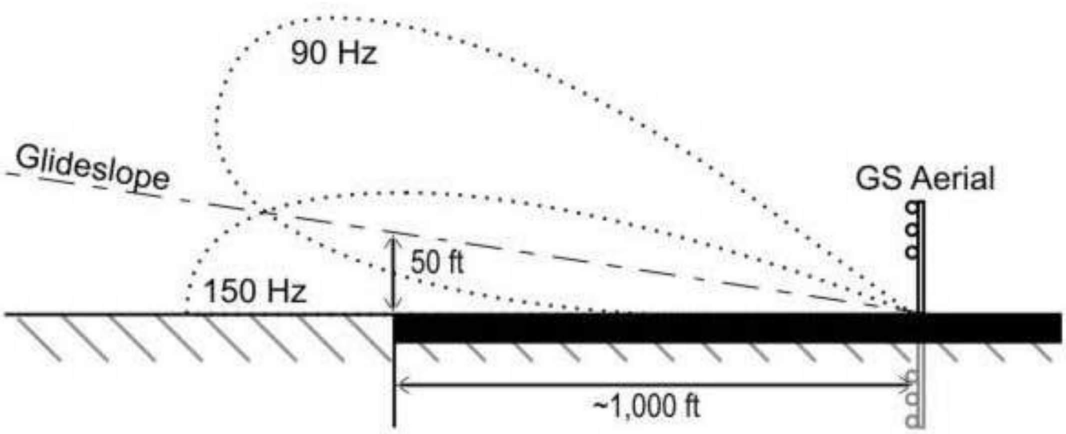

Fig. 2. Modulation of glideslope signals

The glidepath antenna is located at the side of the runway of the aiming point (the place where landing aircraft should touch the ground).

To ensure the necessary information about distance in order to touch down, the ILS is frequently combined with distance measuring equipment (DME), which is replacing markers in many installations.

There are three categories of ILS equipment, which support similarly named categories of approach/landing operations:

- CAT I - with a decision height of 60 m (200 ft) above the runway level with a runway visual range of 550 m (with exceptions),
- CAT II - with a decision height of less than 60 m (200 ft) and more than 30 m (100ft) above the runway level with a runway visual range of 300 m,
- CAT IIIA - with a decision height of less than 30 m (100 ft) and more than 15 m (50ft) above the runway level with a runway visual range of 200 m,
- CAT IIIB - with a decision height of less than 15 m (50 ft) above the runway level with a runway visual range of 50 m,
- CAT IIIC - no limitations.

2.1. Description of GPS data achieved from the tracker during an ILS approach

For test approaches, Diamond DA42 Twin Star was used. Flight data were recorded by HawkEYE HE7200. The result was a flight trajectory in the Receiver Independent Exchange System format. For further processing, conversion to WGS-84 was required. The conversion was conducted using the RTKPOST program. The received data consisted of the time of measurement, the actual position coordinates and the altitude of the aircraft. Examples of received data are shown in Table 1.

Table 1.

Example data received from HE7200

Measurement time	Latitude	Longitude	Altitude
09:33:08,00	50,47332564	19,2525192	925,949
09:33:09,00	50,47333406	19,25154111	925,0143
09:33:10,00	50,47334225	19,25056167	924,5494
09:33:11,00	50,47335188	19,24958055	925,5397
09:33:12,00	50,47336624	19,24860003	926,4705
09:33:13,00	50,47338076	19,2476202	926,2664
09:33:14,00	50,47339283	19,24664021	924,1948
09:33:15,00	50,47340501	19,24565776	921,4592
09:33:16,00	50,47341978	19,24467182	918,9965
09:33:17,00	50,47343759	19,24368241	916,8366
09:33:18,00	50,47345597	19,24269032	914,4574
09:33:19,00	50,47347422	19,24169637	911,3859
09:33:20,00	50,47349249	19,24069939	908,1087
09:33:21,00	50,47351108	19,23969777	904,191
09:33:22,00	50,47353034	19,23869116	900,349
09:33:23,00	50,47355071	19,23767957	896,6332

The aircraft performed an ILS approach procedure for runway 27 of Katowice-Pyrzowice Airport. A comparison of the data gathered during the test approach with a nominal approach path was made for the localizer as well as the glideslope.

The geographical coordinates given in decimal degrees were converted into the distance from equator and the prime meridian. The circumference of the great circle was r_z = 6,371,000,000 m, while the distance between two consecutive parallels was determined according to the following formula:

$$N[m] = \frac{2\pi r_z}{360}$$

The gained outcome was multiplied by the latitude values.

For the longitude conversion, calculations were made for the latitude 50º according to the following formula:

$$r_{50^\circ} = cos50^\circ * r_z$$

Given that the radius at the given latitude was known, the distance between successive meridians could be determined thus:

$$E[m] = \frac{2\pi r_{50^\circ}}{360}$$

The longitude defined as the distance from the meridian 0° was a product of X [m], with subsequent values indicated by GPS tracker.

The model approach was designated by two reference points used to determine a straight line. To determine the position of the aircraft with regard to vertical guidance, geographic coordinates of the runway threshold in the opposite direction was used, while FAP27 was the point of known location as described in the ILS procedure chart. The glide path was determined by a straight line with the beginning at the touchdown zone and the reference datum height being the point described on the ILS procedure chart.

To simplify the analysis of the achieved results, the descend trajectory was inclined by an angle equal to the nominal glideslope in relation to the X-axis. It was made by using the formulas for the rotation point by an angle in a perpendicular coordinate system, as below:

$$x_1 = xcos \propto - ysin \propto$$
$$y_1 = xsin \propto + ycos \propto$$
$$\propto = atan2(e, n)$$

where:
e, n = coordinates of the last point of the nominal approach path.

As a result, on the vertical guidance chart, the X-axis coincides with the extended centre line of the runway. Additionally, for horizontal guidance, the X-axis is the reference that helps to assess the descent profile of an aircraft performing an approach procedure.

The descent profile is presented in Figure 3. The fact that the touchdown occurred at an altitude of 303 m confirms the elevation of the runway.

Figure 4 shows that the aircraft was established on the localizer approximately 8,000 m from touchdown. The width of the runway was 60 m, which means that the deviation from the runway centre line is not greater than its width.

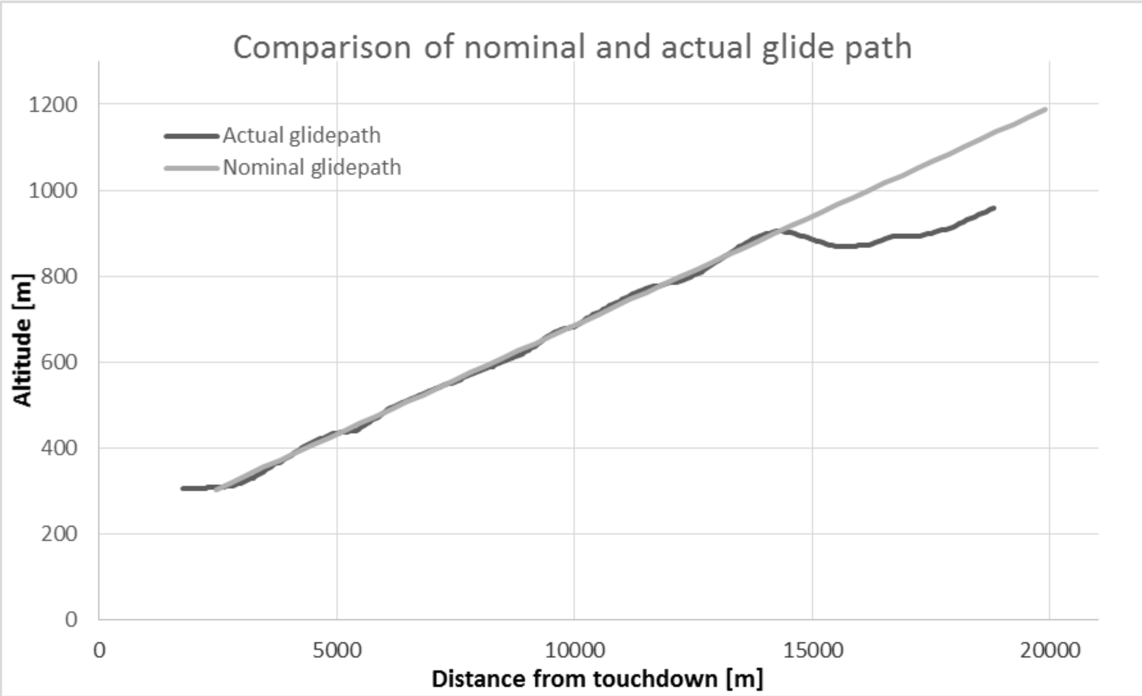

Fig. 3. Comparison between the nominal and actual glide paths

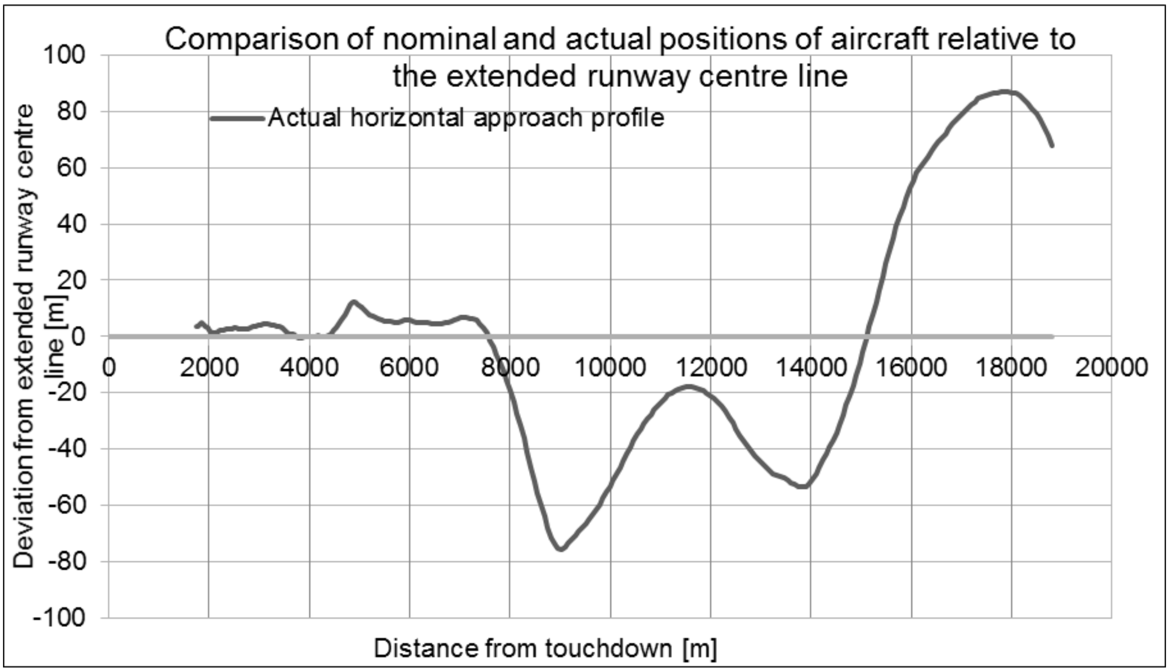

Fig. 4. Comparison of nominal and actual positions of aircraft relative to the extended runway centre line

3. CONCLUSION

For a long time, the ILS has been a standard precision approach system used in the context of instrument meteorological conditions. Until 1995, it was recommended by the ICAO. Despite constant improvements of the design and technological advances, the ILS ceases to cope with the increasing density of air traffic. Radio navigation is still an essential element in ensuring the safety of air transport.

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