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DISTORTION SOLUTION OF THE ILS LOCALIZER COURSE LINE BY PC SUPPORT

INTRODUCTION

On a normal flight, an aircraft flies at cruising altitude to its destination, where it begins its descent and intercepts the projected runway centreline, then makes a final approach with an accuracy of a few feet in each axis at touchdown. Land-based military and civil aircraft rely on the instrument-landing system (ILS), a low-altitude approach system that does not provide guidance signals all the way to touchdown. The ILS consists of a glide-path (GP) beam and localizer (LLZ) beam installed on the runway (RWY) area.
The GP provides vertical steering signals for landings in front course on the RWY. The localizer provides lateral steering signals approaches on the RWY. Two 75 MHz marker beacons provide spot checks of positioning at 1,05±0,15 kilometres range and 7,2 kilometres along the front course. The marker beacons unable to determine of the aircraft altitude by means of the airborne radio altimeter. In the special case the ILS can be extended by Distance Measuring Equipment (DME) for continues measuring of the aircraft range to the touchdown point.
The glide-path antenna establishes a radiation pattern in space from which a signal is derived proportional to the vertical displacement from the glide path. The glide-path angle is usually 2,5° to 3,0°. This signal drives the up-down cross-pointer needle or flight direction.
The localizer establishes a pattern in space whose signal is proportional to lateral displacement from the vertical plane through the runway centreline. This signal drives the left-right cross-pointer needle or flight direction.
Because the localizer and glide path transmissions of the continuous-wave type, reflections to the aircraft from surface irregularities, hills, vegetation, bushes, snow cover and other aircraft will cause bends in the course and path line. Consequently that received signal is the vector sum of all energy arriving at the aircraft's antenna, including both from direct and reflected. At sites that do not have flat land in front of the runway, the reflected signals from the surface irregularities cause the course and glide line distortion.
In the case of the GP system the glide line distortion can be suppressed by means of the special antenna system. But in the case of the localizer antenna system it is impossible. For suppressing the course line distortion, we have two possibilities:

— *Firstly:* to smooth the terrain before the localizer antenna;
— *Secondly:* to calculate the course line distortion, alternatively how the distortion is also called - waviness of the course line, by PC support. In this way to determine the course line distortion.

This work is oriented at the ILS/Localizer course line distortion calculation by means of PC support.

DESCRIPTION OF THE ILS LOCALIZER

The localizer is the lateral guidance portion of the instrument landing system. The course line is aligned with the projected runway centreline.

The radiation from the antenna system produces a complete pattern that is amplitude modulated by 90 and 150 Hz navigation tones with 20% depth of modulation for both tones. The difference in depth of modulation (DDM) of 90 and 150 Hz in the localizer coverage area changes in accordance with the azimuth angle. On the left-hand side of the runway, looking from the antenna down the length of the runway, the depth of modulation of the 150 Hz navigation tone is higher than the 90 Hz navigation tone. On the right-hand side of the runway, the 150 Hz navigation tone predominates. On course line both navigation tones have the same depth of modulation, resulting in a DDM equal to zero. Hence, the DDM gives information of the correct course line and on which side of the course line the aircraft is positioned.

The aircraft localizer receiver measures the DDM. The left-right cross-pointer indicator shows the aircraft position in the localizer covering area.

The localizer antenna is located within 300 and 500 meters beyond the stop end of the runway, centred on the runway centreline (Fig. 1. The localizer antenna).

Fig. 1. The localizer antenna

The localizer horizontal antenna patterns enable to evaluate the aircraft position in the approach area.
Because the radiations are of continuous-wave type, reflections from terrain, buildings, aircraft (taxiing), and ground vehicles will reflect spurious energy to the approaching aircraft to the landing, resulting in a bend, distortion and waviness, in the course line.

MATHEMATICAL ANALYSES OF THE ANTENNA PATTERN SOLUTION BY PC SUPPORT

Firstly the horizontal antenna pattern values and characteristics are calculated. The calculation can be realized both to measure that in the real conditions on the airfield and to calculate them from the function of the antenna radiation. Because, there have not been any antenna pattern measured values available, the PC calculation is used from the real part of the antenna radiation function. The antenna radiation function is given by [1, 2]:

$$F_{(\vartheta)L_1,L_2,R_1,R_2} = \frac{\pi^2 \cos[\frac{kl_1}{2}\sin(\vartheta \pm \Theta)]}{\pi^2 + \sin(\frac{kl_1}{2}\vartheta \pm \Theta)^2} \tag{1}$$

Where:

k = 2π/λ;

l_1 – is the antenna size;

Θ – is the misalignment of the antenna axis;

υ – is the independent variable angle.

The left and the right antenna patterns of the localizer is given by the following equation

$$F_{(\vartheta)_{Localizer_{Left}}} = F_{(\vartheta)_{L_1}} + F_{(\vartheta)_{L2}} \tag{2}$$

$$F_{(\vartheta)_{Localizer_{Right}}} = F_{(\vartheta)_{R_1}} + F_{(\vartheta)_{R2}} \tag{3}$$

For calculation of the localizer coverage a standardized antenna pattern is needed. It means, the maximum value of the left and right antenna patterns $F_{(\upsilon)Left\text{-}max}$ and $F_{(\upsilon)Right\text{-}max}$ are calculated, and then the standardized antenna pattern will be calculated as follows:

$$F_{(\vartheta)s\tan dard} = \frac{F_{(\vartheta)}}{F_{(\vartheta)\max}} \tag{4}$$

The difference in depth of the modulation is given by the following equation

$$DDM = \frac{m.(F_{(\vartheta)_L} - F_{(\vartheta)_P})}{F_{(\vartheta)_R} + F_{(\vartheta)_L}} \tag{5}$$

Where m is the amplitude modulated signal depth and m = 0,2 or 20%.
Displacement sensitivity of the localizer is expressed

$$S_{localize} = \frac{\Delta DDM}{\Delta \vartheta} \ [\% /°] \tag{6}$$

The antenna radiation function values and the graphic presentation have been calculated particularly in the EXEL-97 and MATLAB version 5.1.3. The statically computed mode has been selected.

MATHEMATICAL ANALYSES OF THE COURSE LINE WAVINESS SOLUTION BY PC SUPPORT

As already mentioned, the radiations are of continuous-wave type, reflections from terrain, buildings, aircraft (taxiing), and ground vehicles will reflect spurious energy to the approaching aircraft to the landing, resulting in a bend, distortion, waviness, in the course line. The reflexion characteristics of the terrain object are diffusion in the localizer covering area. The direct signals with the reflected signal add on the airborne receiver antenna, which results in waviness of the course line (Fig. 2. Composing of the direct and reflected wave).

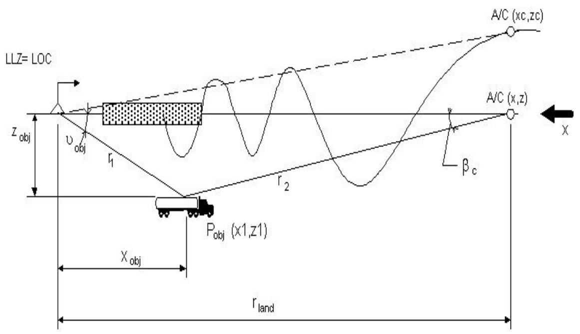

Fig. 2. Composing of the direct and reflected wave

Difference trajectory propagation of the reflected and direct electromagnetic wave results in phase changes $\Delta\varphi$ of the received signal [1, 2]. The $\Delta\varphi$ depends on the

$$\Delta R = R_{reflected\ signal} - R_{direct\ signal} = (r_1 + r_2) - r_{lend} = (r_1 + r_2) - x \tag{7}$$

$$\Delta\varphi = k.x.\cos(1 - \cos\beta_c) \tag{8}$$

The resulting difference in depth of modulation is

$$DDM_{result} = DDM_{direct\ wave} + DDM_{coused\ by\ reflection} \tag{9}$$

The $DDM_{direct\ wave} = 0$ at the course line. The result $DDM_{result} = DDM_{coused\ by\ reflection}$ then

$$DDM_{result} = \eta\left[\frac{F_{R}(\vartheta_{object}) - F_{L}(\vartheta_{object})}{2.F_{(\vartheta=0)}}\right].\sin\left\{kx\left[1-\cos\left(atg\frac{z_{obj}}{x - x_{obj}}\right)\right]\right\} \tag{10}$$

The object coordinates can be changed according to true conditions.
Angular deviation of the course line from the RWY axis (correct course line) is the result of the reflected transmitted signals from the terrain surface is given by

$$\Delta\beta = \frac{\eta}{S_{localizer}}\left[\frac{F_{R}(\vartheta_{object}) - F_{L}(\vartheta_{object})}{2.F_{(\vartheta=0)}}\right].\sin\left\{kx\left[1-\cos\left(atg\frac{z_{obj}}{x - x_{obj}}\right)\right]\right\} \tag{11}$$

Lateral deviation of the aircraft from extension lengthwise axes RWY is the result of the reflected transmitted signals from the terrain surface is given by

$$\Delta Z_{aircraft} = x.tg\frac{\eta}{S_{localizer}}\left[\frac{F_{R}(\vartheta_{object}) - F_{L}(\vartheta_{object})}{2.F_{(\vartheta=0)}}\right].\sin\left\{kx\left[1-\cos\left(atg\frac{z_{obj}}{x - x_{obj}}\right)\right]\right\} \tag{12}$$

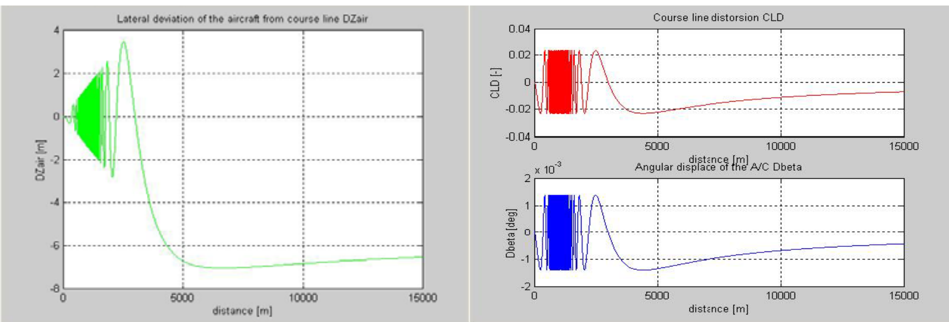

Fig. 3. Left: Lateral deviation of the A/C from the course line; Right: Course line distortion and angular displacement of the A/C

Elongation of the cross indicator pointer depends on the supply current ΔI_{CPI} value coming from the airborne localizer evaluation equipment. This current value is given by the following equation (Fig. 4. Cross point indicator current).

$$\Delta I_{CPI} = S_{A/C\ receiver}.\Delta\beta \tag{13}$$

$$\Delta I_{CPI} = \eta \frac{S_{A/Creceiver}}{S_{localizer}} \left[\frac{F_R(\vartheta_{object}) - F_L(\vartheta_{object})}{2.F_{(\vartheta=0)}} \right] .\sin\left\{ kx\left[1 - \cos\left(atg \frac{z_{obj}}{x - x_{obj}} \right) \right] \right\} \tag{14}$$

The calculated values show the frequency of the ΔI_{CPI} increasing in dependencies on the decreasing distance of the approaching aircraft from RWY threshold. The frequency of the oscillations determines the following equation

$$f_{Waviness} = \frac{V_{A(C}}{\lambda} \left(1 - \cos\left[atg \frac{z_{obj}}{x - x_{obj}} \right] \right) \tag{15}$$

Where $V_{A/C}$ is the speed of the approaching aircraft. When the $f_{waviness} > 3$ Hz is suppressed by the board evaluation system.

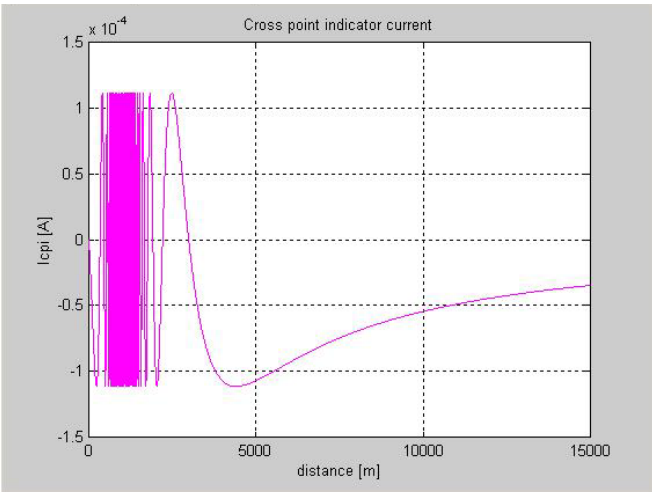

Fig. 7. Cross point indicator current

CONCLUSION

The presented work is oriented at the determination of the Localizer course line in the real airport environment. Programming solution results consist in the detection of the terrain surface to the ILS activity. Program on the basis of the object coordinate solves analytically and graphically the aircraft deviation both from the course line and the cross pointer indicator current depending on distance of the aircraft from the runway thresholds. The results of this work are applicable both in the teaching process, and practically in true condition of the airfield.

REFERENCES

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