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INPUT REQUIREMENTS OF ILS MAPPER PROGRAM

ABSTRACT

A new computer program for mapping scatterers that disturb ILS was completed by the Author 1½ years ago and is available. It works with Windows 95, 98 and NT and is fast and easy to use. It produces a map often indispensable to the airport authorities for negotiations aiming at the removal of a disturbing obstacle or at the improvement of ILS antennas. In principle normal digitised ILS inspection flight recordings form good input as such but for best results some additional requirements should be taken into account when improving existing or designing new data acquisition systems. The costs incurred are of minor order. Requirements include termination of the approach sufficiently near the antenna, high enough data acquisition rate, sufficiently accurate distance measurement, not too high a time constant during recording, and above all, recording of localiser receiver output in parallel with the glide path when analysing the GP with ILS mapper. The results obtained so far are both interesting and useful and can help the interpretation of new "radio maps" in similar cases. Repeatability of ILS maps is remarkable in comparison to mere plotted records.

GENERAL

Regular inspection flights are necessary to verify compliance of ILS with requirements set by ICAO and are performed either by authorities or by other providers of flight inspection service. Their records are useful as such in graphic form (although digitally recorded) for their purpose of verification of essential parameters of ILS. However, with small additions these records provide for excellent input data for location by ILSmapper program of reflecting objects near the localiser and glide-path antennas in case of excessive interference caused by various structures, trees, etc. Location of scatterers requires knowledge of the position aeroplane accurately enough, e.g. its distance from the antenna and its lateral shift from the centreline. The elevation affects the results only minimally but in the GP case the also the elevation record is necessary in order to exclude the flight track from the receiver output.

SCATTER OF ILS RADIO WAVES

Radio wavelengths of roughly one metre create a fuzzy "optical" picture, like the 2nd world war metre wave radar where the aeroplanes appeared as large blobs. However, even their type could be estimated due to their propeller modulation and other behaviour. Likewise the relatively coarse ILS maps can be interpreted more and more accurately with the wisdom gained by cumulative experience.

Only large surfaces (walls) can direct reflecting metre waves appreciably. As the mapping occurs in the relatively narrow front sector of the approaching aeroplane, many scatterers behave like points in that narrow sector i.e. the magnitude of the scattered wave does not vary wildly.

The interference caused by scatter gives rise to a rhythmic wave disturbance (bends) that appear in the inspection flight record. The bend waves become shorter as the distance to the scatterer decreases (except in some GP approaches far from the antenna).

PRINCIPLE OF ILS MAPPER

ILSmapper performs a series of transforms of a kind (e.g. Fourier Transform) that it annexes side by side to produce a map. The transform is obtained by cross correlation between the unified flight record and waveforms created by a point scatterer as correlating functions (whereas Fourier transform uses sinuous waveforms). A similar method is used in wide base interferometry of radio astronomy but in the ILS case the base (the flight track) is at an end-fire aspect in relation to the area of interest, not broadside as in the astronomy. The input data (already subtracted by theodolite data) shall be unified i.e. the data interval shall be made constant, the time factor of the receiver be compensated for and the track be corrected (for each side separately) to represent an approach along the centreline of the runway. The program accepts any decimal separator being used in the host computer. The program steps are in short as follows:

Unification of input data and calculation of curve forms:
- RC correction i.e. emphasis of short bend waves
- Cancellation of theodolite residue (the receiver is often delayed, the theodolite is not)
- Calculation of Path and interpolation to 12m distance steps
- Low-pass filtering of Path values
- Quadratic Off CL phase correction
- Linear shift of distance of data due to Path and interpolation to 16.67m distance steps
- Linear phase angle correction due to Path involving a filter effect of 1:9 bandwidth
- Additional fine adjustment of Path phase (limits: LOC ±50m, GP ±29m)

Cross correlation transforms and display:
- Cross correlation, results to 40x301 array, tapering of short bend wave ends
- Calculation of results and display as plots plus provision with suitable scales
- Interpolation and painting of Map (6 pixels per array value), level of black contour
- Calculation of co-ordinates of Map point and display of them with array value by click of mouse
- Marking of chosen points and their values on Map if so desired
- Maximised/Normal window states

In two-frequency installations the ILSmapper program detects scatterers of the main beam only. The program is not suitable for analysis of disturbance caused by scatter on the clearance frequency.

INPUT CONSIDERATIONS

Length of approach

Normally the inspection is limited just to the essential part of the approach and terminated near the threshold, far from the transmitting antenna. However, rapid scalloping, the most useful part of the bends for positioning of objects, is often confined to the neighbourhood of the antenna simply because objects there cause the strongest scatter. Consequently the approach should not be terminated prematurely.

On the other hand, large structures, e.g. buildings, can be farther away and still cause noticeable disturbance. The ILS mapping program in question uses given bend frequency band for location of scatterers. It requires e.g. a Localiser record spanning nine times the distance of the scatterer from the centreline plus its distance from the antenna. For instance a building situated 1km off the centreline and 10km away from the antenna would require the approach to begin at 29km from the antenna in the localiser case.

Data rate

A non-constant input data rate will do fine because the ILSmapper will create constant data rate by interpolation. For best results the distance between samples should be preferably 0.012km (0.00648NM) or less and not greater than 0.0167km (0.0090NM). If there are some short breaks in data communication to the inspecting aeroplane, the data will still be useful because the program can interpolate over such gaps in distance (although it cannot create missing data). The crucial data is most often near the antenna as mentioned above so the data shall be arranged in ascending order of distance for input to ILSmapper.

Distance measurement

Just for obtaining essential parameters of ILS installation the accurate distance from antenna is not important. Sighting of two known points and assumption of constant speed between and beyond them suffice in such cases. However, the ILS mapping program requires distance values more accurate than those based on just an assumption. The true distance is namely the time integral of speed and can accumulate considerable errors because of speed variations. Any direct distance measurement, e.g. DME, will do. Measurement based on GPS is sufficient. Distance shall be given from the antenna and the values shall form a continuously growing series i.e. they shall be suitably filtered if necessary. Otherwise the program will jump to next higher values and discard lower values in between, thus seriously impairing the effective data rate. On the other hand, this property allows large shift of effective starting point of data by just copying and suitably modifying one row of data onto the top of the record.

Tracking

The flight path or track is important for object positioning. Normally the flight path is tracked by theodolite and its reading is transmitted by a radio link to the aeroplane to be recorded along with the ILS receiver output. For object positioning the lateral component of the track is by far more important than the vertical one. Consequently the localiser inspection flight data is sufficient as is whereas the glide-path data often lacks the most important track component because of the solely vertical tracking of the aeroplane. The lateral data exists, however, in the localiser receiver output. It just has to be recorded. The record of this additional component during GP approaches is absolutely necessary for mapping of scatterers (the program contains a filter that removes excessive roughness from the LOC data in the GP case). In LOC approaches considerable accuracy is required from the theodolite record if the scatterer is far from the antenna; for best results the lateral error should not exceed a couple of metres. (N.B. the swath for path correction by ILSmapper is only ±50m wide in LOC case.)

The input data mentioned above is fed into the program as a text file comprising three or four columns: 1) the distance; 2) the CDI reading minus theodolite; 3) the lateral deviation (theodolite in the LOC case or the LOC CDI reading in the GP case); 4) the elevation (theodolite), if any.

Time constant

In inspection flights often a time constant typical for normal approach is used. Such filtering causes delay and attenuates the high frequency end of the bend spectrum, the most important frequencies for the object positioning. However, ILSmapper can correct the frequency response afterwards but with the cost of increasing noise. So the data should rather be recorded with a small delay, if any, but could of course be presented to the pilot with a time constant convenient for flying.

The theodolite reading shall be subtracted from the receiver output in order to present just the interference caused by the terrain and various objects there. However, the two series of data do not match in case of the receiver output being delayed because the delay of the theodolite record is very small. The delay leaves a residue of the track in the difference. The residue easily swamps the wanted difference near the antenna if the track oscillates rapidly that is often the case in GP records. However, the ILSmapper program is able to fairly suppress the residue caused by the delay difference.

The residue caused by the delay mismatch is clearly visible in **Figure 1**.

Bend wave bandwidth

Scattering from the terrain converts the otherwise straight flight record along the centreline to an oscillating curve, consisting of repetitive waves called bends. Oscillations near the antenna have generally shorter wavelength than oscillations farther away. The bend wavelengths used to calculations in ILS-mapper are about 50 to 450 m in the localiser case; the bend frequency bandwidth would be from 0.11Hz to 1.0Hz when approaching with a speed of 100 knots. In the glide-path case the wavelengths are somewhat longer due to a correction depending on the offset of the GP antenna. The ILS receiver used should not strongly attenuate these bend frequencies during data recording.

Lack of sign convention

There is no international agreement on the signs of outputs of the ILS receiver and of the theodolite. The default used in the ILSmapper is 150 Hz side being positive, also in case of the theodolite. Signs differing from this rule are taken care of by using minus signs in front of certain parameters in the program. Such signs do not generally turn those parameters negative; they rather act as switches.

Because the polarity of receiver outputs and theodolite readings has not been internationally agreed, the program utilises as default the Finnish custom (150 Hz is positive). Anyhow, any opposite sign can be complied with by providing certain input values with minus signs, see the following tables:

LOC

What is of opposite sign	Where to put minus sign
Theodolite	DR 1/s (data rate)
CDI minus theodolite	DR 1/s and LOCw
Theo. and CDI - theo.	LOCw. (LOC width)

GP: If LOC CDI is of opposite sign, provide LOCw. with minus sign. In addition:

What is of opposite sign	Where to put minus sign
Theodolite	GPwidth
CDI minus theodolite	GPwidth & GPangle
Theo. and CDI - theo.	GPangle

Site and other parameters

The size and layout of various airports as well as the parameters of their ILS installations differ, so certain distances, angles and angle widths, the side of interest etc. form an important group of input data and shall not be forgotten. The program contains some choices for input and output units of distance as well.

The program has also controls for the adjustment of the time constant, the map area displayed and the value at the contour of the black blip visible on the map.

Figure 2 displays an overall view of the ILSmapper window and the various parameters involved.

CONCLUSION

Several requirements have been imposed on inspection flight records if used as input for the ILSmapper program that is available and working. The requirements do not stem so much from the very program that has been described than from the need of all co-ordinates of the position of the aeroplane that would apply to any such calculation program. In addition some requirements derive from the likely area of strongest scatter that is relatively near the antenna. The importance of high bend frequencies to positioning of scatterers has been explained. Lack of international agreement on signs has been dealt with. All data required is generally available but perhaps not always fully recorded. Anyhow, the requirements mentioned do not generally involve costly improvements in the flight inspection equipment currently in use.

REFERENCES

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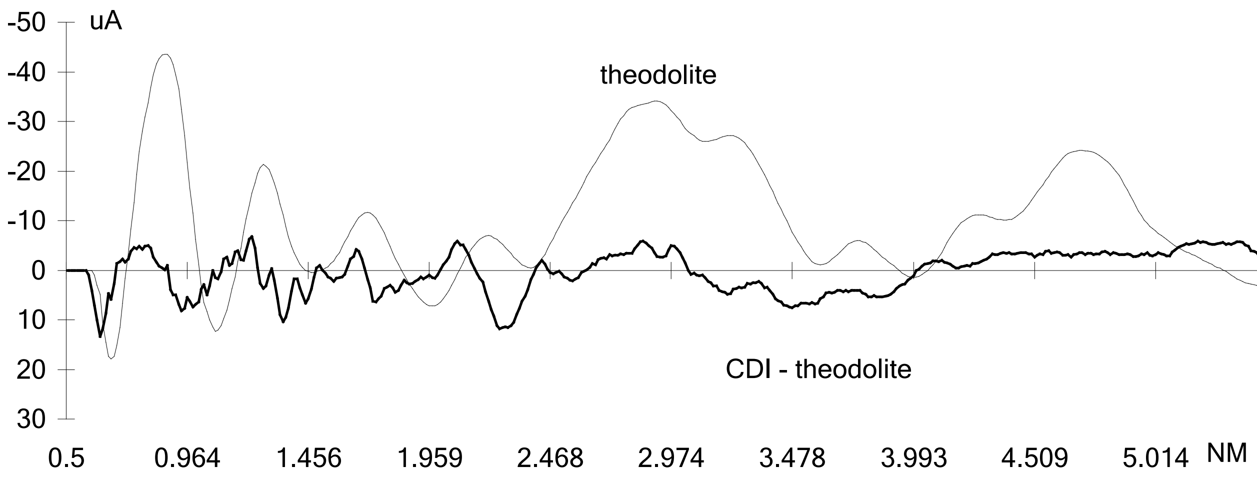

Figure 1. Residue caused by delay mismatch in GP record.

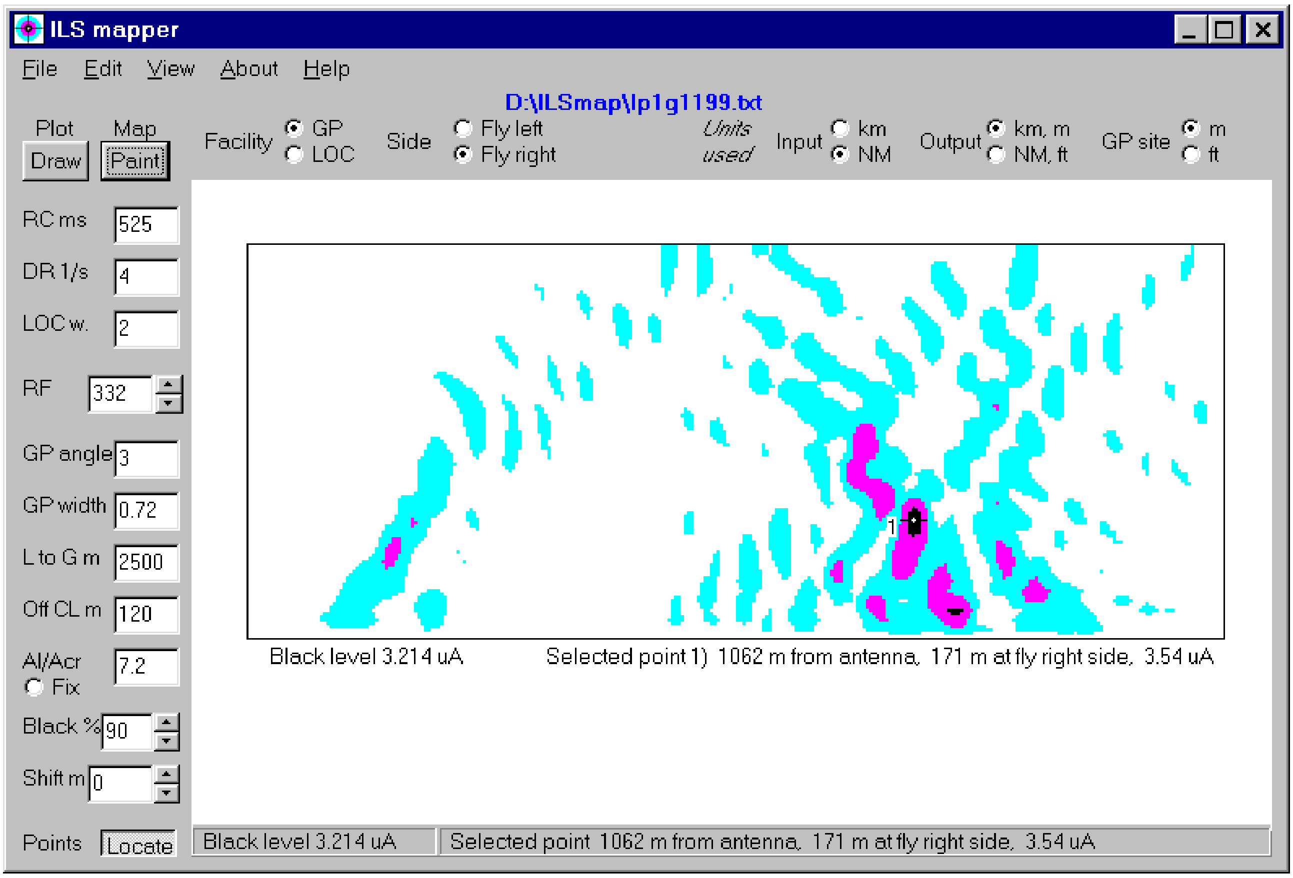

Figure 2. Overall view of the ILSmapper window.