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INTEGRATION OF CDI INDICATORS WITH A FLIGHT SIMULATOR AT VIRTUAL FLYING LABORATORY

Abstract: The article presents design and implementation of CDI (Course Deviation Indicator) gauges conducted as part of the EGALITE project. The software developed served for integration of these gauges with flight simulators of FNTF II class, which are installed at Virtual Flying Laboratory of the Faculty of Automatic Control, Electronics and Computer Science, Silesian University of Technology in Gliwice. This work enabled the use of flight simulators in research on application of satellite navigation in LPV precision approach procedures. The aim of the use of the Virtual Flying Laboratory simulators in EU research projects is to reduce the time and financial resources that are necessary for aeronautic research. It also increases the safety of aeronautic flight research and development studies.

Keywords: LPV procedures, satellite navigation, GNSS, GPS, GALILEO, GLONASS ICAO, EGNOS, SBAS, ABAS, Lateral Guidance, Vertical Guidance, RNAV procedures, SISneT service, FNTF II simulators, FNTF II/MCC, PHS, PAS simulators.

1. INTRODUCTION

Nowadays the generally used navigation system for implementing landing approach procedures is VOR (VHF Omnidirectional Range) [1]. It is the most common angular radionavigation system used in aviation. This system is more versatile and much more precise than the NDB (non-directional beacon) system (VOR permissible error $\pm 2.5^\circ$, along track accuracy $\pm 5.2^\circ$). The system and its principle of operation resemble that of a beacon. The operating frequency range is 108 to 117.9 MHz (with 200 kHz spacing within the range of 108 to 112 MHz, the other channels being used by ILS), whereas the power output is within 100 to 200 W. In particular, the so-called T-VOR radio beacons have a power output of 50 W to account for larger concentration of devices, e.g. around airports. The VOR signal includes azimuth information, which is received and displayed by the on-board part of the system. The aircraft carries only receiving equipment. Due to its structure, the system enables receiving from the radio beacon its bearing in relation to the magnetic north, attaining the desired bearing to or from the VOR beacon, information on passing a radio beacon by the aircraft and a VOR station identifier in Morse code (three-letter string).

Despite the many advantages of the VOR system, approach guidance systems will in future be increasingly based on global navigation satellite systems (GNSS). To prepare for the implementation of precise LPV landing approaches based on this method of navigation [6], it is necessary to carry out several experiments, which usually require performing test flights. However, flight simulators may be used for this purpose, provided that they are equipped with

additional gauges to indicate deviation from proper track when carrying out the approach procedure. Creation of software for implementing CDI (Course Deviation Indicator) gauges and the integration thereof into the flight simulator enabled the application of the Virtual Flying Laboratory to conduct experiments for designing LPV approach procedures [8], to supplement LPV test flights [10]. The results of this work are presented below, preceded by an introduction into the architecture of the Virtual Flying Laboratory.

2. EQUIPMENT OF THE VIRTUAL FLYING LABORATORY

The Virtual Flying Laboratory is a unique professional research and development facility created at the Faculty of Automatic Control, Electronics and Computer Science of the Silesian University of Technology. It is used in the education of the students of the University and for the purposes of research conducted by scientists of the Institute of Computer Science in international cooperation.

The Laboratory was arranged in a room of 100 m² surface area (Fig. 1) and fitted with 12 stationary simulators and 2 mobile simulators installed in special trailers. Two of the stationary devices are training devices, which in terms of overall dimensions resemble aeroplane bodies. FNTP II and FNTP II-MCC stationary simulators are used for instructing pilotage and navigation, they may also be used for acquiring or extending the validity of CPL (Commercial Pilot Licence), ATPL (Airline Transport Pilot Licence), as well as for training flights according to on-board IR (Instrument Rating) indications. These devices enable familiarizing the trainees with the layout of the cockpit, board instruments and aerodynamic model of aircraft such as Cessna 172 RG, Piper Arrow IV, Piper Seneca III, King Air B200. The other 10 simulators, the so-called ground-based computer training devices, are designed for teaching piloting and navigation in aircraft such as: Seneca III, Arrow IV, TB-10, TB-20, C172R, C 172RG, C182, Bonanza, Mooney, Baron and King Air B200.

As mentioned earlier, the Virtual Flying Laboratory also has two large mobile simulators assembled on car trailers. They provide training capabilities for users of single-engined aircraft, such as Cessna 172, 182, 182 RG, and multi-engined aircraft, such as Piper Seneca III, Beech B 58 Baron, Piston R22, R44, Schweizer 300, Estrom 280, FX Turbine MD500, Bell 206. Due to their mobile capabilities, these simulators are also an effective way of promoting the Virtual Flying Laboratory itself, of the Silesian University of Technology, as well as of the Silesian Province or even of Poland. In October 2011 one of the mobile simulators represented our country at the Open Days event in Brussels (Belgium), where it aroused lively interest and attracted many visitors.



Fig. 1. The Virtual Flying Laboratory

At present the Virtual Flying Laboratory is used for educating students in "IT Systems in Aviation" and post-graduate students in "Information and Communications Technology in Air Transport". The process of educating professional flying staff is conducted in collaboration with the Civil Aviation Personnel Education Centre of Central and Eastern Europe at the Silesian University of Technology. In addition to the purpose of educating students, the Laboratory is also used for research conducted by scientists of the Institute of Computer Science in international cooperation. There are now three major projects running, financed under the 7th Framework Programme of the European Union: EGALITE, which is coordinated by the Silesian University of Technology, and HEDGE Next and SHERPA, for which the University is a partner. All the three projects relate to aviation applications of GNSS/EGNOS and also define the areas where EGNOS can be prepared to the operational phase.

The Virtual Flying Laboratory is equipped with flight simulators FNTF II and FNTF/MCC that meet JAR STD-3A requirements [7].

3. DESIGN OF CDI GAUGES

By applying simple geometric functions, using the bearing from a VOR/NDB radio beacon, an experienced pilot is able to steer an aircraft even along an arc. However, VOR/NDB system does not enable controlling the altitude of the aircraft. Therefore the pilot has to read the indications of an altimeter on a separate instrument.

Considering the number of tasks performed by the aircraft pilot, the indications must be clearly legible. Within a second the pilot has to obtain all the necessary information from a gauge or display without overly focusing on the interpretation of the provided visual information. These guidelines have been applied in the design of two gauges that were constructed and integrated with the flight simulator in the EGALITE project, with stress being

laid on readout simplicity and on maximizing the quantity of information readable within a short time. Gauges installed in flight simulators must meet the requirements on flight simulators subject to CSFSTD certification procedures [3][4].

The first of the gauges (Fig. 2a) is based on the design of VOR indicators currently used in aviation [1], representing the position of the aircraft in relation to the radio beacon. Similarly to a VOR indicator, this gauge has a vertical and a horizontal arrow to show the course to the set navigation point. Vertical arrow positioned to the left of the centre of the indicator informs that the aircraft is positioned to the left of the track. Similarly, the arrow shifted upwards shows that the aircraft's position is below the proper course to the set point in space. Diamonds show by how many degrees from the proper direction to the set point the aircraft deviates. In addition on the perimeter of the indicator there is a graphical representation of the aircraft's course, information on the altitude of the aircraft, horizontal velocity of the aircraft and rate of climb/descent in feet per minute. The gauge provides such information as speed and altitude, which additionally facilitates the pilot's operations, as he/she is freed of having to observe more instruments, such as altimeter or IAS (Indicated Air Speed). The system is based on information received from GPS/Galileo system satellites, which enables obtaining information and navigating in any place within the system's reach, even on the oceans, where up to now it was not possible to install radio beacons, and where navigation is based on other systems [2].

The second designed version of the gauge (Fig. 2b) represents a novel approach to data presentation. Similarly to the previous gauge, the information on the direction of the aircraft is given on the perimeter, while current altitude, speed and vertical velocity are displayed inside. Additionally, the information on the aircraft's position is represented by a symbol of an aircraft viewed from the side and viewed from above, presenting thereby the position of the aircraft on the track. The side view may also include information on a selected navigation point and on the distance to that point in nautical miles. Below is also information on the proper course to the navigation point.

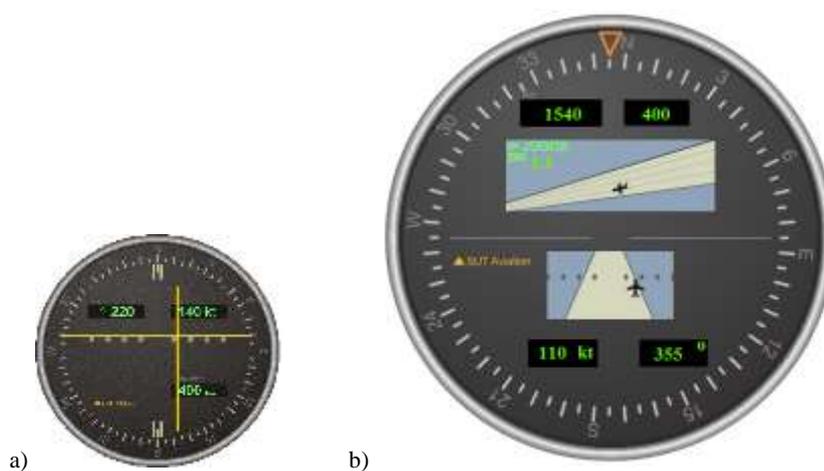


Fig. 2. CDI indicators designed to follow LPV procedures

Fig. 3 shows the gauge integrated into the aircraft simulator cockpit.



Fig. 3. CDI indicators installed in flight simulator

The gauges installed on control panels of PAS and PHS flight simulators are integrated with the system software of the simulator [5]. The variables displayed on gauges, such as rate of climb, flight direction or parameters of keeping the aircraft within the approach path (horizontal and vertical deviation) are computed in an external module of special flight control program, which on the basis of data on the position of the aircraft in the virtual space of the simulator (Virtual World) transmitted via local area network and of a complex mathematical model that describes the behaviour of the aircraft, determines the values of control variables of the CDI indicator which are transmitted back to the control program of the simulator. Research work being part of the EGALITE project included development and implementation of specialized communication protocols for linking simulator programs with the external control module, supplementing the definitions of control variables of the flight simulator to enable controlling the CDI and integrating it with other components of the indicator panel in the simulator cockpit (Fig. 3). The pilot doing the test of completing an approach procedure observes the indications of CDI and makes adjusting manoeuvres to keep the aircraft in proper position in relation to the approach path defined for the given airport. Fig. 4a shows an aircraft that is outside of the approach path, Fig. 4b shows an aircraft which enters the approach path, and Fig. 4c shows an aircraft that is outside of the approach path.

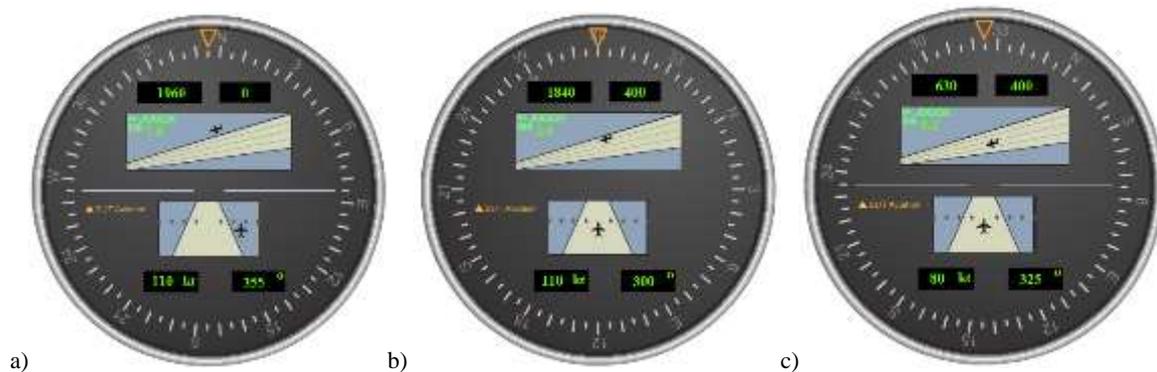


Fig. 4. Position of the aircraft with respect to the approach path on CDI

4. CONCLUSIONS

The basic disadvantages of the currently used navigation systems are their high susceptibility to signal interference caused by terrain obstructions and the high cost of maintaining a ground station. In the case of systems that use satellite navigation there is no need to build ground-based installations. They also provide higher accuracy, as current VOR systems generate errors of up to 5 degrees. It is also not possible to install more VOR radio beacons due to interference problems and excessive concentration of radio equipment, e.g. around airports. The new system can cooperate with ILS, contributing thereby to the accuracy of landing approach. Currently the process of adapting the indicators in flight simulators is under way. The system is able to guide the aeroplane over selected points, displaying both the bearing to the point, as well as correct altitude – features that are lacking in aerial navigation systems currently used. Moreover, owing to the use of information from GPS/Galileo satellites, proper navigation is possible over oceans – the system can be integrated with meteorological systems to enable avoiding harsh weather. In future the system can be integrated with ADS systems to further improve flight safety and eliminate the risk of aircraft collisions in air.

Using flight simulators in research leads to substantial savings in money and time and to improved level of safety in air traffic. Testing new concepts in board instruments prior to installation thereof in real aircraft enables verifying their ergonomics, operating principles and control software without the need to build costly prototypes. This shortens the time required for design and validation, and consequently provides measurable savings and increases the safety of implementing them in civil aviation. Repeated testing in a virtual environment under various approach scenarios adds to the fine-tuning of the final solution.

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