SIMULATION OF DYNAMIC FLIGHT ALTITUDE CHANGE FOR RADAR ALTIMETER

Marek Češkovič – Ján Labun – Marián Miľo – Viktor Képeši

The article addresses the issue of low altitudes radar altimeters. The topic is focused on the possibility of simulation and measurement of low altitudes in small enclosed laboratories or in rugged terrain. It works via the evaluation of the dynamic change of the altitude by the adequate dynamic change of the distance. In the article the method is described, which can truly reproduce the change of the altitude in static, but also in dynamic behaviour and thus makes it possible to eliminate the influence of parasitic reflections of transmitted electromagnetic energy from the surrounding environment and also from the ground. By using this method we do not have to execute the flight measurements. Besides the significant economic saves it also creates the space for the realisation of ongoing research in the improvement of the accuracy of low altitudes measurements by the radar altimeters.

K e y w o r d s: radar altimeter, altitude simulation, depolarization panel

1 INTRODUCTION

To assure the maximum safety of the flight of the plane, there are plenty of assistant systems used on-board. Their first task is to inform the crew about the threat of dangerous situation, respectively to make an advice for the crew to secure them. Digital processing allows creating the complex systems of monitoring the flight parameters and other systems in so much that the modern aircraft systems are able to autonomously recognize the different dangerous situations and subsequently to offer the best solution for avoid such situation. In case of crew fail are even more able to take the plane under the control for the necessary time. In case of solving the crises or emergency situation, for example the engine failures, these kinds of systems are a huge support for the pilots. We can mention for instance the emergency landing of the Airbus on the Hudson River in the New York.

The systems which we mentioned are unfortunately not possible to install into small planes and helicopters. It is mostly due to economic, construction and operational reasons. Especially endangered group of the aircrafts are mostly helicopters, which are able to take-off and landing also in urban built-up areas and thanks to that are massively used for rescue missions and other works. Equally as in case of civilian transport planes, also in that segment the CFIT (controlled flight of the plane or helicopter into the terrain) type of accident happens relatively often. To avoid that kind of accident the EGPWS generation 22 device was developed by the Honeywell Company, but any massive distribution to aircrafts was still not realized.

The way how to improve the safety of the flights of small aeroplanes and helicopters should be done by installation of some kind of relatively cheap and simple system, which could be connected to the circuits of common FMCW radar altimeter. By that modification it should be possible to warn the crew before the danger of the collisions with the ground. For the purposes of further developing and experiments was necessary to simulate the dynamical change of the altitude for the radar altimeter. That simulation has brought also its drawbacks and complications and it is almost impossible to avoid them in laboratory conditions. The article presents the new method which has been developed, which allows the imitation of the altitude change in static and dynamic regime, with reliable elimination of parasitic reflections of electromagnetic energy from the surrounding environment, objects and from the ground.

2 LOW ALTITUDES RADAR ALTIMETER

Radar altimeter Works basically as a radar distance measurer. Its block diagram consists of transmitter, receiver, evaluation circuits and antennas circuits. The transmitter radiate frequency modulated HF signal via transmitting antenna directly to the ground or terrain. That signal is reflected from the ground back towards the plane, where it is received by the receiving antenna and subsequently that signal is leaded to the receiver block. The time delay between transmitted and received signal is proportional to the flight altitude. The FMCW type radar altimeter is using for the evaluation of the altitude the comparison of the instant value of the frequency between emitted and received signal from the ground. The instant value of the change of the frequency is caused by frequency modulation of carrying signal. The result of the comparison of that two, high frequency signals equals to the differential frequency. The differential frequency directly depends to measured altitude – the vertical distance between the plane/helicopter and the ground.

Common types of radar altimeters are built to measure the altitude in the range usually from 0 to 750 meters. The typical transmission power reaches the values from 0,5W to 1W. If we use the radar altimeter in closed laboratory or in the other special room with the emitting high – frequency energy via antennas we come across with a problem of unintentional reflection of electromagnetic energy. Due to that fact are the input and evaluation circuits of radar altimeter oversaturated by those reflected signals. By that way it is impossible to ensure even the basic proper functionality of the radar altimeter during the measurements of very small altitudes. On the base of these facts, we and the members of the department of avionics have tried to find the way and method how to create such kind of environment, where the reflections will not affect normal operation of the radar altimeter. The results reached in a new form of progressive method which allows making non reflected measurements not only in closed places but also in exterior environment by elimination of reflection from the close buildings, threes and from the ground. In that case is possible by the simple way to simulate the dynamical change of the altitude with real values of vertical elements of the speed.

3 DEPOLARIZATION PANEL AS A REFLECTION SURFACE FOR THE RADAR ALTIMETER

Depolarization panel represents a device, which is able to reflect and change the polarity of signal which was transmitted towards it. It consists from two main parts - polarization filter and the reflector. The distance between the filter and the reflector depends on the wavelength of the radio wave of the signal which is used. By the suitable setting up it is possible to create the band pass with demanded wide. The result is the fact, that the panel will not only rotate the polarization of impacting waves but even more it will significantly supress/not reflects undesirable signals which work at other frequency band. That panel represents almost ideal reflection surface, which can create the artificial terrain surface for the measurements of radar altimeter. By the using of that panel it is possible to totally supress the effect of parasitic reflections of electromagnetic energy. The only special issue towards the original configuration is the necessity of adjusting the polarization of receiver antenna to wave polarized by panel.

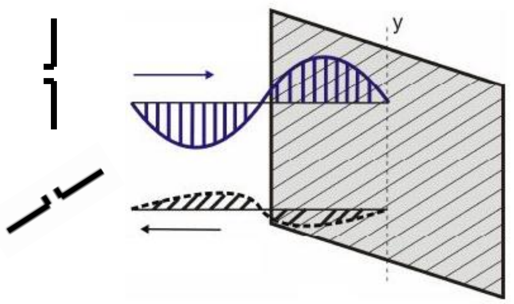

Figure 1: Change of the polarization of transmitted radio wave (blue – emitted wave, black – reflected, polarized wave)

4 CREATING OF WORKSTATIONS WITH THE POSSIBILITY TO CHANGING ALTITUDE

At the department of avionics is underway the continuing research of improvement the accuracy of measurement of the altitude by the FMCW type radar altimeter as a precautionary device, which could warn the pilot against the possible terrain collision. For that purposes we need to build –up two measurement workstations. At first place we have needed to simulate the change of altitude in static mode and at the second we have needed to change the altitude dynamically. By the static regime is meant the situation when the altitude is changed by the exactly determined steps. In dynamic regime is necessary to change the altitude quickly, similarly as plane or helicopter flies against the obstacle or towards the ground.

4.1 WORKSTATION FOR STATIC REGIME

Thw workstation consists of these parts:

- Stend of radar altimeter RV5
- Movable antenna system tripod
- National Instruments DAQ converter
- PC with LabView and Matlab software
- Fixed depolarization panel

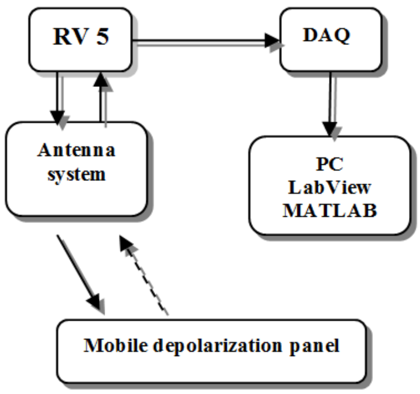

Figure 2: Block diagram of workstation


Figure 3: Mobile depolarization panel

4.2 WORKSTATION FOR DYNAMICAL REGIME

The measurements are conducted as follows: imitation of the height change is performed by moving the antenna system in respect to the depolarization panel. The result of this change is differential frequency that is converted by DAQ converter to a numerical signal. It is subsequently displayed using virtual instrument panel in LabView program. This program also captures and stores the measured data so that they can be analysed and displayed later, as well as processed using Matlab program. This type of measurement allows simulation of altitude change within the range of 0 to 6 meters. In order to increase this range the measurement sequence has to be modified as follows: the antenna system would become stabile and depolarization panel will be movable. In order to do so the panel had to be installed on mobile platform, as it is shown on the Figure 3. Moving from the lab to the hallway of the Department of Avionics allows simulation of static height change within the range of 0 to 64 metres. However, the work-station was unable to imitate dynamic height change, so that the measurement sequence had to be adequately modified.

The main reason to simulate the dynamical change of the altitude of radar altimeter is to create such conditions, which allows examining the creation of Doppler frequency shift. This shift depends on the approaching or moving the altimeter away from the ground. If we are capable to find out the value of that Doppler shift, the proportion of real altitude of the flight to the value of Doppler frequency shift determines the time, when the real height will be equal to zero - so it means the collision with the terrain. This idea also allows realizing the simple warning system against the terrain collision.

The FMCW radar altimeter compares directly emitted high frequency modulated signal with the reflected signal and the result of that comparison is value of differential frequency. Differential frequency is directly depending on the height of the plane above the terrain. By progressive amplification of that frequency, terminating, formation and by detection process of the signal the sequence of pulses of positive polarity is created. These pulses are integrated and transformed to an DC voltage, also with positive polarity, which is proportional to the real flight altitude. It is just the Doppler effect, which causes that the number of pulses in the one modulation half – period of received signal is nto the same as in second half-period. By the monitoring of number of these pulses it is possible to identify if there is Doppler frequency shift present. On its base it is also possible to define if the plane is approaching or moving away from the ground.

The workstation for imitation of dynamical change of the altitude demanded the reverse approach, than in static regime. The stand of radar altimeter RV5 had been necessary to install on some kind of movable object, able to achieve relatively high speeds, due to the creation of the Doppler shift effect. After the short deciding we had decided to install overall stand to classic passenger car.

Figure 4: The sight on the RV 5stand including the power supply and PC

That kind of modification had demanded the problem of power supply, however the voltage could not be plugged by the fixed cables from the buildings in the university. Due to this purpose we made the autonomous supply composing of serial connection of 2 pieces of car batteries, it means 2 x 12V = 24V and of the static convertor which converts 24V to the 115V/400Hz. The current consumption of the overall set-up was 3,5 A. During the tests, after the 30 minutes of demo operation of the radar altimeter, the terminal voltage of batteries did not decreased under the 24,3V.

The last obstacle was to build up the antenna system, capable to be carried by the car. The roof of the car was chosen as a best position for it so we put it on the roof rack. We mounted it on the next holder with antennas and coaxial cables. The vertical axis is settable by the adjustment screws. By that operation we can ensure the direct position between the antennas and the reflection surface - to the depolarization panel.

Measurements were done at the roads, which lay inside in the faculty campus, of course with respect of safeness for operators, other people and also for other environment.

Figure 5: Antenna system

Figure 6: Segments of the measurement system

After the first measurements with positive response, when the expectations were confirmed, we moved to the proper work. For the confirmation of the creation of positive or negative Doppler frequency shift we have done the series of measurement, firstly towards to the deplorazitaion panel and then away from the panel. The resulted difference in the count of pulses in a frame of halfperiods is shown in following graphs (dependency of the different count of pulses to speed). From the graph it is clear, that simultaneously with the increasing the speed of the car, was also the difference of count of differenc increasing. The practical measurements had confirmed all of theoretical conclusions, which we said before we took the building of the workstation.

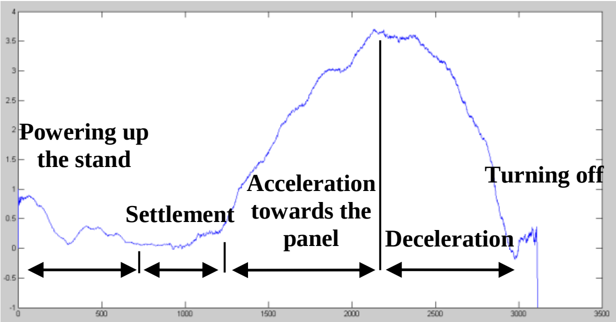

Figure 7: The dependence of change of pulse count in the time

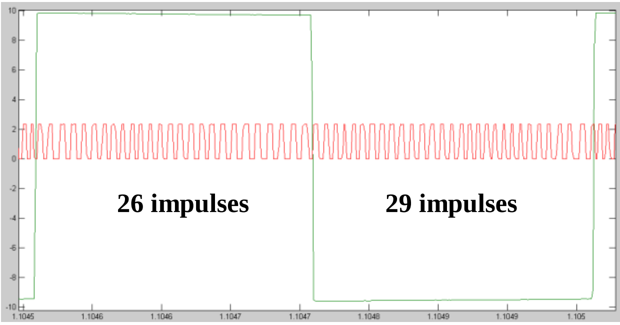

Figure 8: The difference in count of pulses due to Doppler shift effect while moving towards to the panel

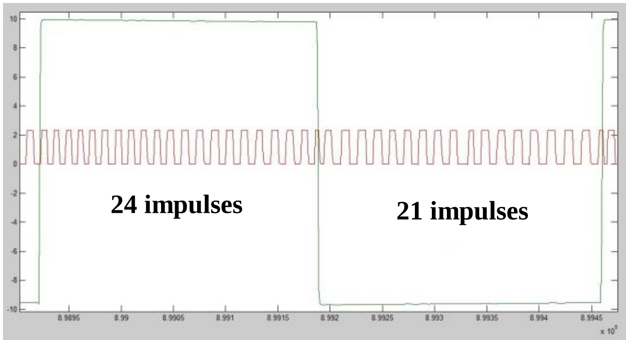

Figure 9: The difference in count of pulses due to Doppler shift effect while moving away from the panel

5 CONCLUSION

The first experimental measurements confirmed correctness of the measurement workstation's set-up and met the expectations of their authors. The use of the depolarization panel creates prerequisites for further research of radio altimeters as it reliably suppresses the influence of parasitic reflections of electromagnetic energy from surrounding environment. Besides this, the workstation is also capable of imitating dynamic altitude change in the same way as it is on real airplane or helicopter and this fact allows us to realise the patent of anti-collision warning system.

BIBLIOGRAPHY

[1] SOTÁK, M., LABUN, J.: The new approach of evaluating differential signal of airborne FMCW radar-altimeter. Aerospace Science and Technology 17, 2012

[2] LABUN, J.: Zvýšenie presnosti merania malých výšok u leteckých rádiovýškomerov, dizertačná práca, Košice, 1998

[3] LABUN, J. - SOTÁK, M. - KURDEL, P. Technical note innovative technique of using the radar altimeter for prediction of terrain collision threats. In: The Journal of the American Helicopter Society. Vol. 57, no. 4 2012, ISSN 0002-8711

[4] Ing. Miroslav Procházka CSc., Antény, BEN – technická literatúra (2005)

AUTHORS´ ADDRESSES

Marek Češkovič, Ing,
Technical university of Košice
Faculty of Aeronautics
Rampová 7, Košice
e-mail: marek.ceskovic@tuke.sk

Ján Labun, doc. Ing, PhD.
Technical university of Košice
Faculty of Aeronautics
Rampová 7, Košice
e-mail: jan.labun@tuke.sk

Marián Miľo, Ing.
Technical university of Košice
Faculty of Aeronautics
Rampová 7, Košice
e-mail: marian.milo@tuke.sk

Viktor Képeši, Ing.
Technical university of Košice
Faculty of Aeronautics
Rampová 7, Košice
e-mail: viktor.kepesi@tuke.sk