ALTITUDE DEPENDENCE OF THE DIFFERENTIAL SIGNAL ALT

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The aim of this paper is to delineate the implementation of the issues regarding the altitude difference signal depending on a radio altimeter with focus on the software solutions in Matlab. The paper includes mathematical model of a radio altimeter together with necessary mathematical tools. It also focuses on the specific creation of the software solution including the termination of impulses. The applications of the obtained results is in applying the created program for simulation and modelling of various types of radio altimeters.

K e y w o r d s: radio altimeter, frequency modulation, impulse creation, impulse termination

1 INTRODUCTION

The continued progress in science and technology, rapid and intensive development of aerospace technology puts ever more demanding requirements on navigation in terms of their simplicity, price, their reliability, accuracy, autonomy, fault tolerance and of course, their longest service life. These requirements are even stricter if we talk about aviation technology.

The need for accurate and current information on the actual altitude of an aircraft is one of the most important information especially in risky situations such as take-off and landing. This puts constant pressure on manufacturers to produce radio altimeters with the greatest possible accuracy**.**

Computer simulations are a very suitable method for understanding the issues concerning radio altimeters. They give us an opportunity to graphically display various parameters without the need to actually measure the physical parameters. In general, we only need to know the mathematical relationships that characterise technical device behaviour in terms of physics while using the knowledge of other sciences. We can then, by an appropriately selected program, simulate the real situation, and we can also create extreme situations that occur in the real world only exceptionally, if at all.

2 MATHEMATICAL ANALYSIS OF A RADALT

A radio altimeter of small altitudes is a radio navigation device, which works with a frequency modulation using differential frequency dependence between the direct and the reflected signal, based on the altitude of an aircraft. A radio altimeter receiver compares the current value of the transmitted and received signal. The signal received after the reflection from the ground is time-delayed to the broadcasted signal by the value τ given by the Formula 1:

$$\tau = \frac{2H}{c} \qquad (1)$$

The changes in regularity of a frequency modulated transmitted signal can generally be any periodic function of time. From the perspective of mathematical analysis, the simplest change is the sinusoidal frequency modulation. The high-frequency frequency-modulated signal of a radio altimeter can be described by the formula:

$$u_v(t) = U_v \sin\left(\omega_0 t + \frac{\Delta\omega_0}{\Omega_M}\sin\Omega_M t\right) \qquad (2)$$

, where:

ω0 = 2π f0	– mean value of the carrier frequency
ΩM = 2π FM	– angular modulating frequency
Δω0 = 2π Δf0	– rise of the carrier
f0	– mean freq of the transmitted signal
Δf0	– frequency rise of the transmitter
FM	– modulating frequency

The signal reflected from the Earth's surface, which is received by the radalt antenna, has the same waveform as the transmitted signal. It is however time-delayed by the time "τ" and its amplitude is lessened due to the scattering and absorption of the electromagnetic energy:

$$u_p(t) = U_p \sin\left[\omega_0(t-\tau) + \frac{\Delta\omega_0}{\Omega_M}\sin\Omega_M(t-\tau)\right] \qquad (3)$$

For a typical radio altimeter of small altitudes such as the Russian RV-5, which has a frequency modulation FM = 150 Hz and H_{max} = 750 m, the value of the expression for phase change changes only slightly in the range of 1 to 0.99 with changing altitude. This makes it possible to consider that the amplitude of the received signal is more or less equal to the amplitude of the transmitted signal. This mathematical conclusion corresponds to the reality.

The amplitude of the resulting signal changes in time t_1 as follows:

$$U(t_1) = U_v + U_p\cos(\varphi_0 + \varphi_M\cos\Omega_M t_1) \qquad (6)$$

After some deeper analysis we can conclude that the resulting signal is not only frequency modulated, but also amplitude modulated with modulation period of:

$$T_M = \frac{2\pi}{\Omega_M} \qquad (7)$$

The information about current altitude is present in the amplitude of resulting signal, which is obtained by mixing the transmitted and the received signal.

3 SHAPING THE PULSES OF A RADALT

The pulses are formed from the modulation envelope of the resulting signal and then counter determines their occurrence per second. To create these pulses, the resulting difference signal has to be amplified by the low-frequency amplifier and band-passed by a limiter. This creates rectangular pulses from the original signal; the number of created pulses is proportional to the altitude of the aircraft, so the scale of the pulse counter can be directly calibrated in meters. That means that the device that generates pulses resulting from the modulation envelope signal and also counter of these impulses are both essential elements of the measuring circuit of a radio altimeter. The impulses originate or terminate at the moment when the envelope of the resulting signal passes through zero. This conclusion can be mathematically written in the form:

$$U(t_1) = U_v + U_p \cos[\varphi_0 + \varphi_M \cos \Omega_M t_1] = U_v \quad (8)$$

The alternating emergence and disappearance of the pulses is caused by the unequal values of the phase change $\varphi(t)_{max}$ and $\varphi(t)_{min}$, which represent the sum and the difference of the initial phase φ_0 and of the variable phase φ_M by the change of the altitude in the ΔH interval. The critical altitude can be determined as:

$$\Delta H = \frac{\lambda_0}{8\xi} = \frac{c}{8\Delta f_0} \quad (9)$$

The altitude interval ΔH corresponds to the change in the number of pulses per pulse over one modulation period T_M. The ΔH value is called the critical altitude, which is the minimum change in altitude that the radio altimeter can register. It follows that if the aircraft changes its fly altitude of a value less than the value of ΔH, the radio altimeter will not change its infotmation, since it does not change the number of pulses per modulation period.

3 PROGRAMING THE PULSES IN MATLAB

The specific program code can be found in the Annex B of the thesis [1]. The process was divided into two main parts; creation of the pulse by the so-called function *H_vzniku(deltaf, f0, k)* and the termination of the pulse by the function *H_zaniku(deltaf, f0, k)*. Their parameters are:

deltaf – frequency rise of the radalt
f_0 – carrier frequency of the radalt
k – number of the pulse

For further calculations, the function to calculate the number of pulses for a specific number of pulses called *numOfImpulses (H, deltaF, f0)* was created. This function calculates the corresponding discrete number of pulses for a given altitude. Demonstrational output of the impulses function of a RV-5 radalt is displayed in Fig 1.

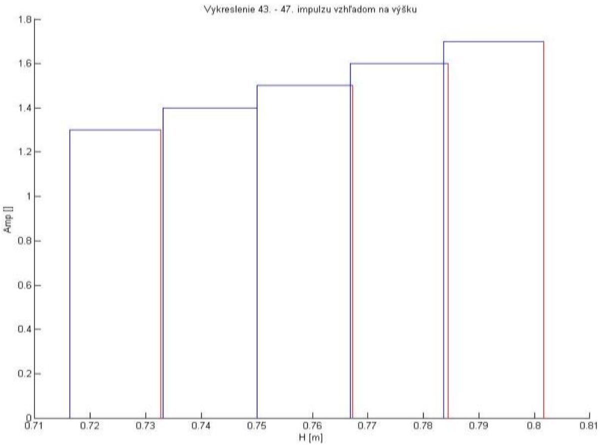

Figure 1. Demonstrational output of the impulses

5 CONCLUSION

Aim of this work was to create an algorithm for graphical display of the pulses creation of a radio altimeter with the frequency modulation. The main benefit of the created program is the fact that the algorithm can be used to compare different types of radio altimeters. All we need to know is the value of the carrier and the Δf frequency of the radio altimeter. This makes it possible to compare the accuracy of different types of radio altimeters and graphically display the resulting value of their methodological errors.

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