THE PILOT-HELICOPTER-ENVIRONMENT PROPERTIES IN SAFETY TERMS

Tadeusz DĄBROWSKI[1], Wiktor OLCHOWIK[1], Sławomir AUGUSTYN[2]

[1] Military University of Technology, Electronics Faculty, 2 gen. Kaliskiego Str., 00-908 Warsaw; tadeusz.dabrowski@wat.edu.pl, wiktor.olchowik@wat.edu.pl
[2] National Defence University, Management and Defence Faculty, Aviation and Air Defence Institute, 103 gen. Chruściela Av., 00-910 Warsaw; s.augustyn@aon.edu.pl

Summary

This paper is devoted to deliberations on transmittance measurement system properties and potential Pilot-Helicopter-Environment (P-H-E), in the security context of this system. Based on the operator's transmission of the Pilot-Helicopter (P-H) and the results of the stability studies, it is possible to obtain the answer about the scope of acceptable - for safety reasons - changes the operator's transmission coefficients. On the other hand, the potential recognition allows the inference about the properties of the P-H-E system in safety and reliability areas. The basis of this interference is the assumption concerning the system which is suitable for the safe implementation of tasks in certain conditions and if the P-H system has a required stability supply at the specified time.

Key words: stability item, potential of safety, potential criterion of airworthiness safety

WŁAŚCIWOŚCI SYSTEMU PILOT-ŚMIGŁOWIEC-OTOCZENIE W ASPEKCIE BEZPIECZNOŚCIOWYM

Streszczenie

Artykuł poświęcony jest rozważaniom na temat transmitancyjnych oraz potencjałowych miar właściwości systemu pilot-śmigłowiec-otoczenie (P-Ś-O), w kontekście bezpieczeństwa tego systemu. Opierając się na transmitancji operatorowej układu pilot-śmigłowiec (P-Ś) i na wynikach badania stabilności tego układu, możliwe jest uzyskanie odpowiedzi na temat zakresu dopuszczalnych – ze względu na bezpieczeństwo systemu - zmian poszczególnych współczynników transmitancji operatorowej. Z kolei ujęcie potencjałowe pozwala na wnioskowanie o właściwościach systemu P-Ś-O w aspekcie niezawodnościowym oraz bezpiecznościowym. Podstawą tego wnioskowania jest założenie, że system jest zdatny do bezpiecznego zrealizowania zadania lotniczego w określonych warunkach i w określonym czasie jeśli układ P-Ś posiada wymagany zapas stabilności.

Słowa kluczowe: zapas stabilności, potencjał bezpieczeństwa, kryterium zdatności bezpiecznościowej

1. INTRODUCTION

The system of a pilot - P, helicopter - H and the environment - E (e.g. climatic environment understood, geographical, administrative, military etc.) can be regarded as a fairly typical antropotechnical structure. Starting from this perspective, it can be assumed that to describe the performance of this structure it is useful inter alia shot transmittance [1, 3, 4, 6, 7, 8] and potential [2].

An illustration of transmittance shot the pilot-helicopter (P-H) is a transfer functioning in a control theory about specific factors (e.g. strengthening and constant time). Analysis and study on the stability of the agreement based on the transmittance to get answers about the scope of allowable changes to each item as a function of system stability and factors in these changes.

The recognition of potential allows you to request a commercial properties of P-H-E in terms of airworthiness and safety. The basis for this request is the adoption of the assumption that the system is suitable for the safe implementation of productive tasks (i.e., is fit to perform the specified air mission under defined conditions and within a specified time) if the P-H has a required item stability. This article contains a development and refinement of this reasoning.

2. THE ASSUMPTIONS

These assumptions are creating by following aspects:

a) the airworthiness usable safe system area P-H-E is determined by a specific supply of the stability of P-H;
b) the stability properties of the agreement P-H describe its operator's transmittance;
c) the characteristics of amplitude modulated-phase of P-H are the basis for the designation of the item layout stability;
d) the destabilizing force in the P-H has the form of a stroke unit;

e) the energy and information supply, **which can be used** in the antropotechnical P-H-E system in order to eliminate the negative effects of destabilising factors (internal and external) is called **disposal safety potential** $\mathbf{F_{b\text{-}dis}}$ (equivalent to **safe potential** of the system $\mathbf{F_B}$);

f) the energy and information supply, **which must be used** in the antropotechnical P-H-E system in order to eliminate the negative effects of destabilizing factors (internal and external) is called **required safety potential** $\mathbf{F_{b\text{-}req}}$ (equivalent to **the hazard potential** of the system $\mathbf{F_N}$);

g) the applied criterion of airworthiness safety fitness takes the form of inequality:

$$\mathbf{F_{b\text{-}dis} \geq F_{b\text{-}req}} \tag{1}$$

3. ANALYSIS OF THE SUPPLY STABILITY OF THE PILOT-HELICOPTER SYSTEM

Suppose, as a basis for reflection, a simple transmittance system of pilot-helicopter (fig. 1), in which the $G_p(s)$ means the transmittance of the pilot and $G_s(s)$ the transmittance of the helicopter.

Fig. 1. The pilot-helicopter system

where,

$G_p(s)$ – transmittance of the pilot; $G_s(s)$ – transmittance of the helicopter; $X(s)$ – transform of references quantity; $Y(s)$ – transform external quantity; $Z(s)$ – transform of disruptions.

The empirical study of dynamic properties of pilots (crews) have made it possible to determine the approximate mathematical pilot system, during the execution of a task in the form of air operator's transmission [1,6,7]:

$$G_p(s) = \frac{K_p(T_d s + 1)}{sT_I} e^{-sT_p} \tag{2}$$

where:

K_p – the strengthening coefficient pilot;
T_p – the delay time of the initial reaction pilot;
T_d – the advance time;
T_I – the constant of integration;

Similarly, based on literature data [6,7] it can be assumed that the transfer function in a control theory the helicopter has the form:

$$G_s(s) = \frac{K_s}{(T_{1s}s + 1)(T_{2s}s + 1)} \tag{3}$$

where:

K_s – the strengthening coefficient, determines the level of helicopter pilot control signal response in steady state;
T_{1s} – time constant helicopter, specifies the time to wait for a response from the helicopter to boost inflicted on the control stick of swash-plate of the mail rotor;
T_{2s} – time constant helicopter, specifies the time to wait for a response for helicopter by collective pitch control lever inflicted on blades of mail rotor and adjustment lever the engine power.

In the above system (fig. 1) stability analysis can be performed on the basis of Nyquist criterion.

For the measurement of the potential safety P-H-E system can be regarded as a supply of amplitude and a supply of phase (fig. 2). A supply of phase $\Delta\varphi$[°] shows the relationship (4).

$$\Delta\varphi = 180 + \varphi_{(A=1)} \tag{4}$$

where: $\varphi_{(A=1)}$ – the phase shift in degrees at individual strengthening of the pilot-helicopter system.

The supply of the amplitude in decibels ΔL [dB] is presented by the relation (5).

$$\Delta L = -20 \log A_{(\varphi=-180)} \tag{5}$$

where: $A_{(\varphi=-180)}$ – the strengthening of the P-H system with the phase shift φ = -180°.

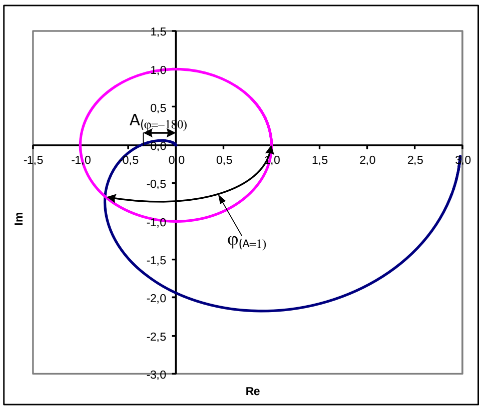


Fig. 2. Graphic of phase shift at individual strengthening $\varphi_{(A=1)}$ and strengthening $A_{(\varphi=-180)}$ with the phase shift φ = -180° [*own source*]

The indicative parameter values transmittance set out in the average helicopter based on information obtained from the experimental pilots helicopters Mi-2, Mi-8, Mi-17, Mi-24, W3A Falcon, and on the basis of the instructions concerning producers for using the helicopters indicated in table 1.

Table 1.

Flight conditions	K_s	T_{1s} [s]	T_{2s} [s]
W_{min}	7,0	6,0	3,0
W_{opt}	8,0	1.0	2,0
W_{max}	24,0	0,5	1,0

For the above particular system antropotechnical pilot-helicopter analysis was made the impact of certain parameters simulation pilot and flight conditions of the potential of the security system, the yardstick be expressed in the form of supply the amplitude and phase.

Case 1. The illustration of an item depending the amplitude and a phase on constant advance T_d - for the fixed value of other parameters (strengthening pilot transmittance coefficient $K_p = 5$; an initial delay time of the pilot's reaction to change the flight conditions $T_p = 0.28$) and agreed parameter values transmittance helicopter corresponding to the optimum conditions flight ($K_s = 8$, $T_{1s} = 1s$, $T_{2s} = 2s$). The calculation has been carried out for the continuing advance T_d amending: 0,2÷3.0. The graphs characteristics amplitude – phase shifters system opened presents figure 3, and graphs the amplitude supply and phase supply figure 4.

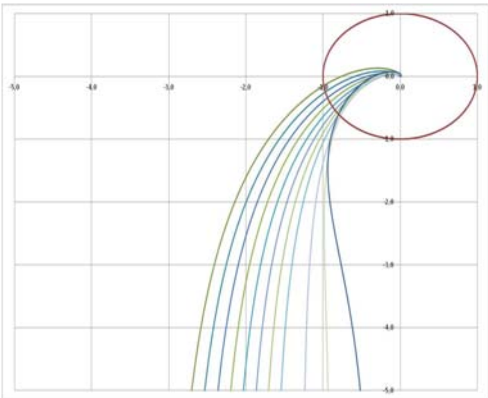
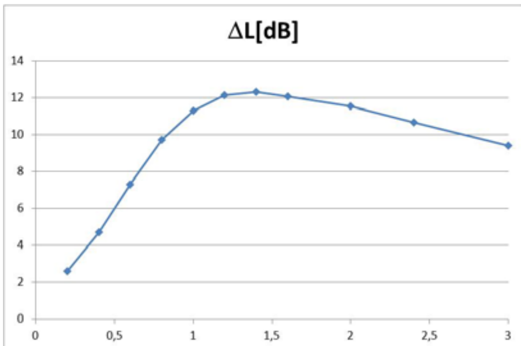
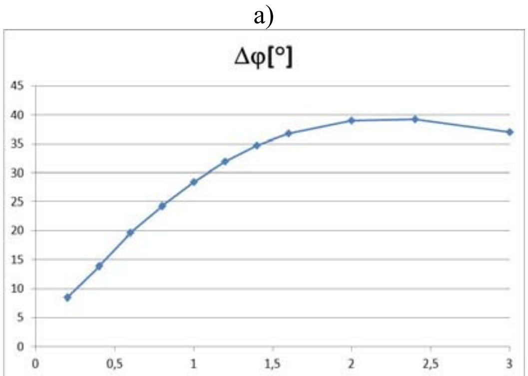


Fig. 3. Characteristics of amplitude-phase of pilot-helicopter system with a fixed lead time T_d [*own source*]



a)



b)

Fig. 4. The amplitude supply (ΔL) and phase (Δφ) the pilot-helicopter system as functions advance time T_d [*own source*]

Case 2. The illustration of the dependence the amplitude supply and phase supply from strengthening coefficient of the pilot K_p - for predefined values other parameters (fixed advance pilot transmittance $T_d = 0.38$; the delay time $T_p = 0.28$), and agreed parameter values transmittance helicopter optimum conditions corresponding to the flight ($K_s = 8$, $T_{1s} = 1s$, $T_{2s} = 2s$). The calculation has been carried out for the strengthening coefficient of the pilot K_p amending: 3÷7. The graphs characteristics amplitude – phase shifters system opened presents figure 5, and graphs the amplitude supply and phase figure 6.

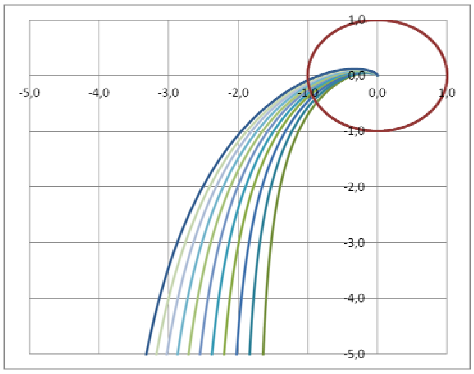
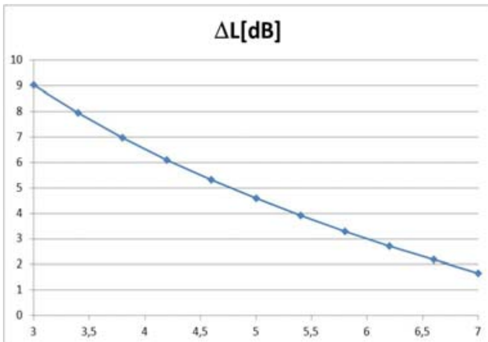
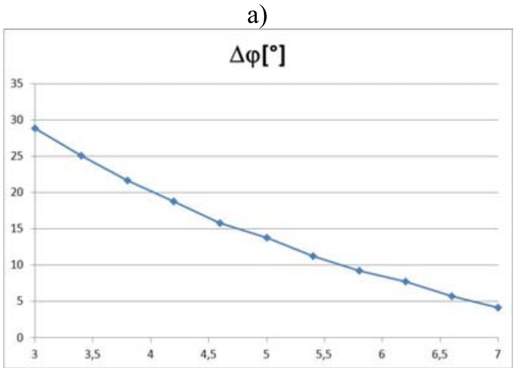


Fig. 5. Characteristics of amplitude-phase of pilot-helicopter with a fixed the strengthening coefficient pilot K_p [*own source*]



a)



b)

Fig. 6. The amplitude supply (ΔL) and phase supply (Δφ) the pilot-helicopter system as functions the strengthening coefficient pilot K_p [*own source*]

Case 3. The illustration of the dependence of supply the amplitude and a phase pilot-helicopter system from the flight conditions W - when fixed parameters transmittance pilot (strengthening coefficient $K_p = 5$; the advance time $T_d = 0.38$; the delay time $T_p = 0.28$) and parameters helicopter transmittance values corresponding to each of the flight conditions – in accordance with table 2. The calculation has been carried out for the flight conditions changing from the conditions of the minimum W_{min} through an optimal W_{opt} to extreme W_{max}.

Table 2.

W	Flight conditions	K_s	T_{1s} [s]	T_{2s} [s]
0	W_{min}	7,0	6,0	3,0
1		7,2	3,0	2,8
2		7,4	2,1	2,6
3		7,6	1,6	2,4
4		7,8	1,2	2,2
5	W_{opt}	8,0	1.0	2,0
6		9,0	0,9	0,8
7		11,0	0,8	1,6
8		14,0	0,7	1,4
9		18,0	0,6	1,2
10	W_{max}	24,0	0,5	1,0

The graphs characteristics amplitude – phase shifters system opened presents figure 7, and graphs supply the amplitude and phase of figure 8.

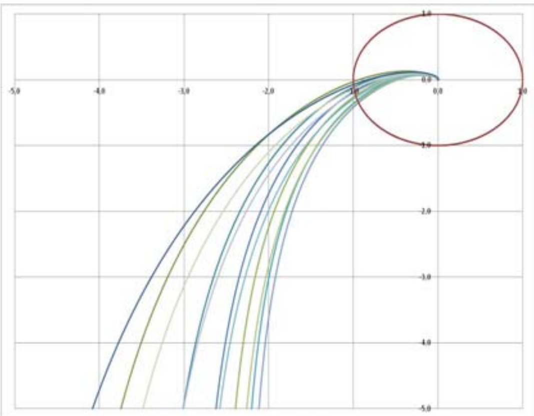
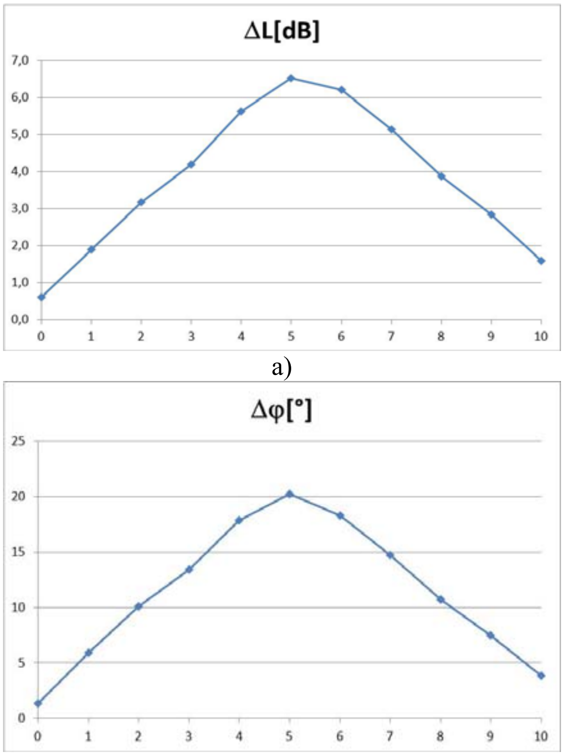


Fig. 7. Characteristics of amplitude-phase of pilot-helicopter system from the changing flight conditions W [*own source*]

4. A SYNTHESIS OF THE AIRWORTHINESS AND SAFETY PILOT-HELICOPTER-ENVIRONMENT SYSTEM

Taking into account the above (especially the graphs in figures 4, 6 and 8) it allows to engage in deliberations about the P-H-E system in safe terms. There can take it that the security system is dependent on the stability of the stock ZS as item stability. When examining a stash of fabric structure always stability: as item amplitude and the phase of the supply, the aim should ensure the remote control transmittance and the helicopter transmittance parameters of these stocks at the appropriate level.



a)

b)

Fig. 8. The amplitude supply (ΔL) and phase supply (Δφ) the pilot-helicopter system as functions the flight conditions W [*own source*]

Recognition is illustrated by fig. 9. The adoption of criteria item values stability (e.g. on the basis of in service experience) allows relatively easy to present what is the level of security of the P-H-E system for a specific value of the selected parameter transmittance system or with specific conditions of flight.

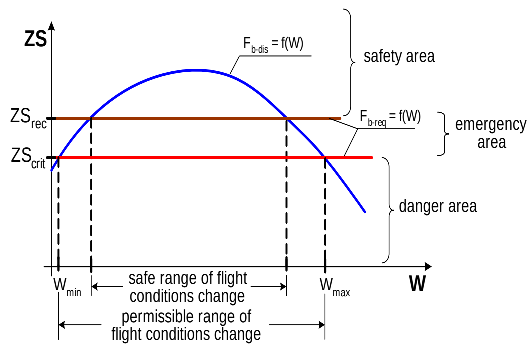


Fig. 9. The potential interpretation of the item as stability as function of the flight conditions [*source own*]

Indications: ZS-item stability, ZS_{rec} - recommended item level stability, ZS_{crit} - critical item level stability, $F_{b\text{-}dis}$ - disposal uplift stability (disposal the level of safety potential), $F_{b\text{-}req}$ - required item stability (the required level of safety potential).

It is depending on the approved level of the required stability supply (it is influence on strict helicopter properties and pilot skills) there can be highlighted three areas of the P-H-E state system:

- safety area when:

$$\mathbf{F_{b\text{-}dis} \geq F_{b\text{-}req\,(rec)}} \tag{6}$$

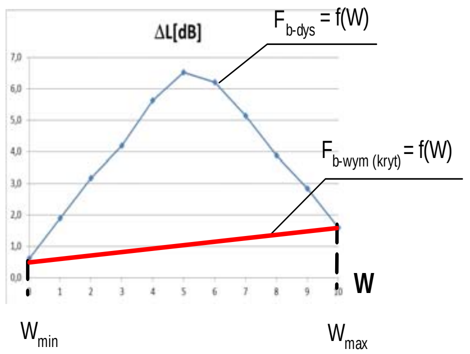
- emergency area, when:

$$\mathbf{F_{b\text{-}req\,(crit)} \leq F_{b\text{-}dis} < F_{b\text{-}req\,(rec)}} \tag{7}$$

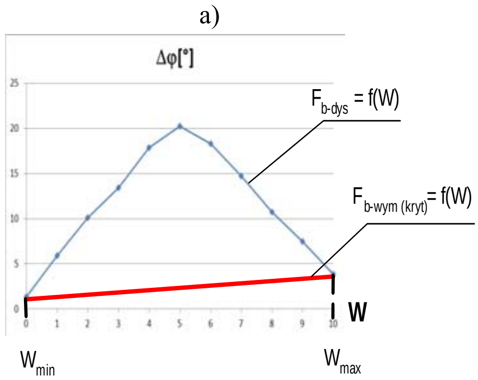
- danger state area, when:

$$\mathbf{F_{b\text{-}dis} < F_{b\text{-}req\,(crit)}} \tag{8}$$

The admission to reduce the item below the disposal stability ZS_{crit} results in a safety transition state in an area of danger which in turn leads, on the whole, to an accident or air crash. For detail of this interpretation of the security issues of the P-H-E let's analyze dependencies of figure 8 by showing relation on figure 9. The results show in figure 10.



a)



b)

Fig. 10. Illustration potential interpretation of the amplitude supply (ΔL) and phase supply (Δφ) as a function of the flight conditions W [*own source*]

The value of the amplitude supply (ΔL) and phase supply (Δφ) with lying above the level designated by required potential safe $F_{b\text{-}req\ (crit)}$ are the favouring values of P-H-E system in the area of the security situation. This means that, e.g. for minimum flight conditions is required – due to the safety of the system – supply of the amplitude not less than 0.5dB, and supply of the phases of not less than 2^0. In turn for the maximum flight conditions of those supply should be not less than: the supply of the amplitude of the 1.5dB, the reserve of phase of the 4^0.

The analogous analysis of the drawings submitted to the figures no 4 and no 6 leads to the conclusion that the desired range of values constant time T_d advance is the scope of: 1.2÷2.0, and the value of the pilot strengthening K_p should not be greater from 7.

5. CONCLUSIONS

The stability of the agreement pilot-helicopter is a basic prerequisite for the proper implementation of the processes and maintain the ability to control safety of P-H-E system. The results of the analysis presented above stability – safety which is shown significant practical amenities of this recognition.

On the basis of the results of this analysis there can be, for example, made a matching assessment of the properties especially for helicopter pilot properties. It can also identify desirable controllers, the actuators and correction algorithms, affecting the supply stability of the system.

It should also draw attention to the stability of the process control. Although it is the basis of safety system but may not be the only criterion. For example, stability supply are greater in the value of the coefficient of strengthening pilot (figure 6).

However, it is important to remember that a small coefficient of strengthening to give slower investigation to the desired trajectory flight, which may impede e.g. driving alongside obstacles.

In addition to the analysis of stability there should be parallel analysis the qualitative indicators of the regulatory process optimization, which may be equally important from a safety point of view. Generally, parameters transmittance shall be selected so that to maintain in a rational compromise between the quality requirements and stability supply.

It seems that technically it is possible in the current track to have changes amplitude-phase supply stability of pilot-helicopter system. In result by comparing designated values with the values required recommended and required critical synthesis *on-line* of diagnosis safety system. Informing the pilot about that the system is located in the area of the hazard state or it has a tendency coming into the area of the danger state is of vital importance for maintenance and operation.

BIBLIOGRAPHY

[1] Augustyn S.: *Żywotność lotniczego systemu antropotechnicznego*. Wyd. AON 2013. Rozpr. hab.
[2] Dąbrowski T.: *Diagnozowanie systemów antropotechnicznych w ujęciu potencjałowo-efektowym*. Wyd. WAT 2001. Rozpr. hab.
[3] Pełczewski W.: *Teoria sterowania*. Wyd. N-T. Warszawa 1980.

[4] Krasowski A., Pospiełow G.: *Podstawy automatyki i cybernetyki technicznej*. Wyd. N-T. Warszawa 1965.
[5] Lewitowicz J., Kustroń K.: *Podstawy eksploatacji statków powietrznych – własności i właściwości eksploatacyjne statku powietrznego*. T.2, Wyd. ITWL, Warszawa 2003.
[6] Lindsted P.: *The effect of pilot's work quality on technical conditio of propeller engine bearing system*. Vibromechanika. Journal of Vibroengineering. p. 6-10, vol. 8, No, 2, 2006.
[7] Lindsted P.: *Automatyka lotnicza. Podstawy teoretyczne dla pilotów*. Wyd. WOSL Dęblin 1981.
[8] Niziński S., Wierzbicki S.: *Zintegrowany system informatyczny sterowania pojazdów*. Diagnostyka, nr 30 t.2/2004. s. 47-52.

Tadeusz DĄBROWSKI Assoc. Prof. PhD, Eng.
He works for Institute of Electronic Systems, Faculty of Electronics MUT.
Specialisation: operating theory, especially technical diagnostics of men-machine systems.

Wiktor OLCHOWIK, PhD, Eng.
He works for University of Information Technology in Warsaw and Institute of Electronic Systems, MUT.
His professional interests include: automatics, computer measurement and diagnostic systems, digital signal analysis.

Col. **Sławomir AUGUSTYN** Assoc. Prof. PhD, Eng.
Head of the Department of aviation, The Aviation and Air Defence Institute at National Defence University Warsaw, Poland.
Specialisation: technical advice, engineering, management project and operation research. Several publication in field.