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POSSIBILITY OF ANTIMISSILES GUIDANCE ACCURACY  
ENHANCEMENT AGAINST BALLISTIC MISSILE  

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Abstract:  
In this paper are presented some simulation results of antimissile guiding process on attacking short-range ballistic missile. In simulations, laws of antimissile guidance were defined using classical proportional guidance method or Bellman dynamic programming and optimal quadratic criteria of guidance process. It is evident, from comparing simulation results obtained by using both ways of antimissile controls, that usage of modern automatic control methods supported by digital technologies is the way how to significantly improve accuracy of missiles guidance process, even on targets such as ballistic missiles.

1. Preface  
Modern weapon systems, including missile means of mass destruction, are more and more available not only for official governments, but also for other political subjects. Especially clear implication of proliferation of ballistic and guided cruise missiles is increasing risk of accidental unauthorized or deliberate attack of mid and long range ballistic missiles against the territory of Europe. The territory of the Czech Republic is also potentially threatened by midrange ballistic missiles which are possessed by some Near and Middle East countries and countries of northern Africa. The Czech Republic can be threatened by short-range ballistic missiles, e.g. also from
the territory of former states of Yugoslavia. Therefore the term of defence against ballistic missiles or missile defence is very frequent at the present [7].

At NATO summit in Prague in 2002 there was agreed on the study of practicability of missile defence „NATO MD“ (NATO Missile Defence). The goal of this study is a complex appreciation of possibilities of NATO member countries territory defence against a whole spectrum of missile threats. This study refers to an already worked out study of NATO missile defence systems of battlefield, which has led to a NATO project of active layered missiles defence of battlefield, and is supposed to ensure defence of allied forces against missiles with range up to 3000 km. This system is supposed to achieve initial operational capability in the year of 2010. One of discussed thoughts is the connection of NATO MD with alliance integrated air defence systems NATINADS (NATO Integrated Air Defence System). The Czech Republic, as a NATO member country, is also engaged in solving NATO missile defence of battlefield [7].

The United States of America has started realization of USA missile defence project „NMD“ (National Missile Defence) on the basis of the law accepted in the year of 1999. The purpose of NMD project itself is to create an effective integrated worldwide system, which would protect USA territory against limited threats of mid and long range ballistic missiles. It is about stationary ground non-nuclear missile defence system using satellite detector systems. In the context of discussion about NATO missile defence, USA offers possibility of American missile defence enlargements activity for the whole alliance.

The American ground mobile missile system THAAD (Theater High Altitude Area Defence) designated to C3-protection of battlefield against mid and long range ballistic missiles is in the stage of advanced development. Furthermore, two naval versions of missile defence systems are also in the stage of advanced development. In frame of project ABL (Airborne Laser), US researches highly efficient lasers placed on board of highflying Boeing 737 designed to destroy ballistic missiles. American – Israel missile defence system ARROW-2, which is designated to defend against short range or midrange ballistic missiles, is in the stage of operational employment in Israel. All of mentioned missile defence systems are designed to destroy offensive ballistic missiles in the middle part of exoatmospheric phase of flight in higher atmosphere.

Besides above-mentioned studies and projects there have been already anti-aircraft missiles systems capable quite successfully counteract short or midrange ballistic missiles, namely on their final, down going part of flight. Here it is possible to name American PATRIOT PAC-3 with antimissiles ERINT, French-Italian SAMP/T and Russian series S-300 and S-400.

German-Italian MEADS is under development, which assumes usage of ASTER missile. S-200VE VEGA and S-75M3 VOLCHOV have partial capability of counteracting against short-range ballistic missiles which were also in the Army of Czech Republic [3].

Capability of anti-aircraft and antimissile systems to effectively counteract against ballistic missiles is conditioned by their capability to guide counter missile on a very
fast target accurately and by their capability to destroy the target. Therefore, this paper discusses conditions and ways how to achieve required accuracy of missile guiding.

2. Accuracy of missile guiding process

For antimissiles guidance on ballistic missiles it is optimal to use some variants of two point guidance methods [1], [2]. Accuracy ratio of guidance in this case is so-called „miss of target \( h_0 \)“ - see figure 1.

Fig. 1 Kinematic relations for „miss of target“

„Miss of target“ \( h_0 \) is defined as minimal vertical distance between missile trajectory and target, if from a definite moment, e. g. after interrupting activities of onboard control missile system as a result of loss of its stability [1], [4], the missile and the target will move equally and in a straight way toward themselves. Relation of this miss (for simplicity only in vertical plain) was derivated in [1] or in [4] as follows:

\[
h_0 = \frac{r_0^2}{|\dot{r}|} \tilde{c} = \tau_k^2 |\dot{r}| \tilde{c},
\]

where

\( r_0 \) ……distance between missile and target, when guidance process is interrupted;
\[ \tau_k \ldots \text{time remaining to missile and target hit after interrupting onboard missile control system;} \]
\[ |\dot{r}| \ldots \text{missile and target convergence velocity;} \]
\[ \dot{\epsilon} \ldots \text{angular rotation velocity of missile-target connecting line.} \]

While quantities \( r_0 \) and \( \tau_k \) are given mainly by missile technical characteristics and its control system [4], quantity \( \dot{\epsilon} \) can be affected by guidance method selection so that the quantity is minimal. Theoretically, the most suitable guidance method, from this point of view, should be a method of parallel convergence [1], whose guidance equation (in vertical plain) has the form of
\[ \dot{\epsilon} = 0. \quad (2) \]

According to the realization of parallel convergence method by relation (2) it is possible to guide missile only on equally and straight-lined moving targets (which ballistic missile isn’t), it seems the best consideration is some modifications of proportional guidance method [2]. A suitable method is especially its optimized version; its procedure and way of usage were mentioned in [5] and [6].

Optimization of missile proportional guidance method, done by the usage of Bellman dynamics programming and optimal quadratic criteria, minimizes normal missile acceleration mainly in the final (terminal) phase of its flight. Simultaneously the method also minimizes angular rotation velocity \( \dot{\epsilon} \) of the connecting line of missile-target and in the final consequence also “miss of target” by the missile. It appears efficient to verify the effectivity of the method by simulating antimissile guidance process on a ballistic missile using [5] presented a optimized method of surface-to-air missile guidance on a maneuvering airplane.

3. Results of guidance process simulations

To check effectiveness of selected antimissile optimizing guidance process method on ballistic missile it was selected a situation, where a missile complex with tactical – technical parameters corresponding to S-300PMU2 with missiles of 48N6E type, deployed c 10 km ahead of defended object, and applied near upper boundary of effective action area against short-range ballistic missile (up of 500 km) with tactical-technical parameters derived from missile of SCUD B type (or 9K72), on its final, downgoing part of flight, is used for active missile defence [3]. Simulation of antimissile guidance process on a selected ballistic missile was made partly by using a standard proportional guidance method [1], [2], partly by using optimized guidance method [5].
Simulation results show progress of antimissile normal accelerations $a_y$ and angular rotation velocity $\dot{\epsilon}$ of connecting line of missile-target in final phase of antimissile guidance process in figure 2 and figure 3, and in figure 4 they shows partly final parts of ballistic missile and antimissile trajectories, partly processes of miss of target $h_0$ depending on time $\tau_k$, which has left from the moment of interruption of onboard antimissile control system activities to the hit of antimissile and target.
From the presented graphs, a considerable reduction (c by 3 ranks) and positive progress of the antimissile necessary normal acceleration in the critical final phase of its guidance when using optimized guidance method [5] in comparison with the standard guidance method [1], [2] are evident.
Fig. 4. Terminal phase of missile trajectories and process of missing of antimissile with target.

Fall of level (c by 1 rank) of angular rotation velocity of connecting line of missile – target is also visible when using optimized guidance method in comparison with standard guidance, and especially its progress during the approaching of the antimissile to target is positive.

Change (i.e. value reduction) of both mentioned parameters, which occurs by using optimized guidance, is further manifested in the accuracy of the guidance of antimissile on target, as the graph shows in figure 4. Miss of target (i.e. of ballistic missile) by antimissile was counted by relation (1) for the most likely values of quantity $\tau_k$, which are within interval (0.5 ÷ 1.5), as results from [1] or [2] and [4].
4. Conclusion

Simulation results clearly point to fundamental advantages of optimized antimissile guidance process on an attacking ballistic missile. They are in correspondence with declared goals of this optimization, significant decreasing of necessary antimissile normal acceleration and angular rotation velocity of connecting line missile-target at guidance on extremely fast target in the critical terminal phase of guidance process. That results in creating a presumption for achievement of necessary accuracy of antimissile guidance on an attacking ballistic missile.

Furthermore, simulation of antimissile guidance process on ballistic missile has shown that guidance results, optimized by Bellman’s dynamic programming method, are very little dependent on initial conditions of this guidance (e.g. on aiming antimissile during launching to supposed collision point), as well as on possible maneuver of target. So this method is predetermined for use against modern short-range ballistic missiles, maneuvering at terminal flight phase.

On the contrary it was shown that antimissile guidance results when using standard proportional guidance method are significantly dependent on both initial conditions and possible maneuver of target.

Simulation of the guidance process only in one plane fully suffices, because missile’s spatial motion is controlled by means of two identical and separate control circuits in two mutually orthogonal planes [1], [2].

Presented partial simulation results of antimissile guidance process on attacking ballistic missiles and conclusions formulated on their basis point not only to a necessity to continually evolve closely specialized problems of guidance missile, but also to a necessity of its interdisciplinal enrichment.

References:
Introduction of Authors:

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