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Title

Explicit Midcourse Guidance Law of Multi-stage Anti-ballistic Missile with Solid Propellant

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Abstract

As the threat of ballistic missiles is growing, the anti-ballistic missiles play a more important role in the defence system. Although the interception altitude of the anti-ballistic missile against the ballistic missile may be different, it has generally been assumed that interception occurs in the exo-atmosphere [1]. To intercept a ballistic missile at a high altitude, the anti-ballistic missile usually has three or four stages. For multi-stage ballistic missiles, the guidance law of the previous stages affects the performance of the guidance for the subsequent stage. If the anti-ballistic missile is not in the proper position with adequate velocity at the beginning of the terminal phase, the guidance command of the terminal phase may be excessive, or interception may even fail. Therefore, a proper guidance law for the middle stage of the multi-stage anti-ballistic missile is essential.

In this study, an explicit guidance law for the middle stage of the multi-stage anti-ballistic missile with solid propellant is proposed. The proposed guidance law is based on powered explicit guidance (PEG) law [2]. Assuming constant gravity, optimal guidance command minimizing time-to-go is constant if only the final position constraint is considered. Therefore, the intercept position of the anti-ballistic missile can be analytically derived by neglecting the aerodynamics. As a result, time-to-go can be calculated that makes the position of the anti-ballistic missile be same as the position of the ballistic missile under free fall with constant gravity assumption. The error resulting from neglecting the aerodynamics and constant gravity assumption can be compensated by computing the time-to-go and guidance command in real-time through the state feedback. Modified zero effort miss (MZEM) [3] guidance law is used for the guidance law of the terminal phase. The performance of the proposed guidance law is demonstrated by numerical simulation for a three-stage anti-ballistic missile. Simulation results show that the guidance command magnitude of the terminal phase is reduced, and the interception is successfully done within the maximum bound of the guidance command.

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