NEW APPROACH TO NONLINEAR GUIDANCE LAW DESIGN

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ABSTRACT. This paper presents a new approach in nonlinear guidance law design. The new guidance law is developed based on partial stability theorem and enables the missile to intercept highly maneuvering targets with zero-miss-distance within a finite interception time. The approach is advantageous from practical view-points since it leads to classification of state variables of the guidance system dynamic with respect to their required stability properties and tries to adapt with practical situations. Effectiveness of the proposed guidance law in achieving zero-miss-distance within a finite interception time is demonstrated analytically and through computer simulations.

Keywords: Nonlinear guidance law, Partial stability, Interception time

1. Introduction. The Proportional Navigation (PN) guidance law and its generalizations have been used widely in tactical missiles because of their simplicity and ease of implementation [1,2]. However, increased maneuvering ability of new generation of targets had a huge adverse effect on the performance of these guidance laws.

   For highly maneuvering targets, the optimal guidance laws (OGL), derived based on optimal control theory [3] or differential game theory [4], can theoretically result in a significant performance improvement. However, these laws lead to a two point boundary value problem, which is too complicated for real-time implementation. Moreover, the performance of OGL depends on estimation of interception time, which is commonly approximated [3,4]. In practice, especially for unpredictable maneuvering targets, the accurate approximation is impossible.

   Recently, nonlinear control theories have been used in design of robust guidance laws. Methods, such as Lyapunov-based nonlinear guidance laws [5,6], first-order sliding mode guidance laws [7-9] and nonlinear $H_{\infty}$ guidance laws [10,11], were considered in this regard. All these guidance laws were designed based on asymptotic or exponential stability of all states, which is shown in this paper that, in practical situation, such a behavior is not realistic for all states of guidance system.

   In this paper, it is shown that, in a practical approach to guidance problem, each state must have a specific behavior and there is no need for asymptotic convergence of all states. It is in contrast to conventional methods in nonlinear control theory that try to force all states to asymptotically converge to the origin (equilibrium point). The proposed guidance law is based on the principle of partial stability, which is stability with respect to a part of state variables [12].

   In this method, the states vector of the guidance system, i.e., $(x)$, is separated into two parts: $x_1$ and $x_2$, where $x_1$ consists of states whose asymptotic stability behavior is desirable. For components of $x_2$, stability behavior is not desirable; however, they should satisfy some constraints. Moreover, target acceleration vector is assumed as an