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Author: Ms. Jiao Wang
National Key Laboratory of Aerospace Flight Dynamic, Northwestern Polytechnical University, China

Prof. Yuan Jianping
National Key Laboratory of Aerospace Flight Dynamics,Northwestern Polytechnical University,Xi'an, China

Prof. Ruonan Zhang
Northwestern Polytechnical University, China

RELATIVE STATES DETERMINATION FOR SMALL SATELLITES FORMATION USING VIRTUAL SATELLITE BASED ON ANTENNA ARRAYS

Abstract

For small satellite formation, the high-precision position and attitude of a deputy satellite relative to a chief satellite is crucial as they are the fundamental information for consensus control and collision avoidance which thereby increases fuel efficiency and the mission lifetime. However, the traditional relative navigation systems that are comprised by a lot of sensors have usually large volume and high cost. Considering the miniaturization of small satellites and their highly integrated functional modules, cost-effective relative navigation method is required.

In this paper, a novel approach is proposed, called Relative states Determination using Virtual Satellite based on Antenna arrays (RDVSA). The existing communication systems and antenna arrays on flying vehicles are utilized in this approach, and a virtual satellite is defined, the position and attitude of which are determined using orbit and attitude deduction. We consider the scenario of two-vehicle formation where the relative position and attitude of the deputy vehicle needed to be determined. In RDVSA, the deputy vehicle broadcast probing signals which can be received by the chief vehicle. The signals are transmitted and received using planar antenna arrays. Thus the angle-of-arrival (AoA) and angle-of-departure (AoD) of the line-of-sight (LOS) signal propagation path from the deputy to the chief vehicle can be estimated using the array signal processing. Then based on the geometrical relations of the chief and virtual satellites, the corresponding AoA and AoD between the deputy and virtual satellites are also deduced. Based on the measured AoAs and AoDs of the LOS paths from a deputy to the chief and virtual vehicles, the rotation matrix and equations can be established. According to the TRIAD algorithm, the attitude of the deputy vehicle relative to the chief vehicle can be determined. Furthermore, its relative position is estimated by the LOS path directions. The method of RDVSA is theoretically proved and also validated by the simulation results in this paper. The signal transceiver architecture for inter-vehicle communications and the RDVSA method is also presented for its implementation in a real vehicle.

Without the need of extra sensor components, the RDVSA method takes full advantage of the existing on-board communication systems. Thus it can save space, weight, and cost for a flying vehicle significantly. Additionally, the navigation accuracy can be improved by the employment of the virtual satellite. In particular, it is adequate for small satellites with miniature sizes in formation flying.