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MINIMISING COMMUNICATION EFFORTS IN SELF-ORGANISED RELATIVE ATTITUDE CONTROL FOR FORMATION FLIGHT SCENARIOS USING DIRECTION OF ARRIVAL METHODS

Abstract

Formation flying missions open doors for innovative distributed Earth observation (EO) tasks, requiring coordination of instrumentation. The related control schemes in Attitude and Orbital Control Systems (AOCS) involved rely on the accuracy of the positioning and attitude sensors of each formation agent. Typically AOCS tasks are governed by formation control (like MPC or H^{∞}), leading to communication overhead between chief and deputy satellites. An upcoming mission of the University of Würzburg evaluates and demonstrates different approaches to minimize this overhead using highly-directional Inter-Satellite Links (ISL). In addition decentralised attitude and orbital control schemes shall be developed and their minimum information overhead be analysed. Furthermore, decentralisation shall lead to self-organising controls acting to minimise the overall control effort in the formation.

As a precursor this paper analyses approaches minimizing the communication overhead of such control schemes, focussing on possible sensor data available to every agent. One promising approach is depicted and showcased with on-ground verification. In this approach agents are controlling themselves, but acquiring knowledge about attitude of their own and their communication partner by mere monitoring of non-control related communication. Hence, even if the partner is not providing attitude data, estimations on attitude is possible. The proposed approach decouples a portion of incoming RF signals and phase/magnitude discriminates it against a second local transceiver acting as reference signal source. This transceiver is synchronised with the remote transceiver. Additional measurements can be conducted in time domain by innovative use of filter topologies affecting the frequency and phase correlation of the signal. Thus, the timespan the affected lies within thresholds to the unaffected frequency-phase discriminated envelopes can be dithered by different filters and refined. Given certain commercial modulation schemes and packet format coming with them, repeating non-payload symbol sequences of these protocols are modified to orthogonal codes, further enhancing phase discrimination accuracy. With utilisation of multi-antenna systems like phased-array patch antennas an augmenting beam forming pattern to the transmitting and receiving transceiver is defined. The correlation between time-domain measurements, frequency-phase domain and beam-forming effects is analysed and reported with respect to transceiver induced jitter. This jitter has been empirically modelled. An observer based on this analysis and model has been developed and is evaluated by turn-table experiments.

An improvement of the best case 1% phase and 5% magnitude accuracy of COTS phase discriminator solutions has been achieved. An approach applying dithering technique in frequency-phase domain for timespan measurements has been critically considered.