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Radio-Frequency Positioning for Airborne Wind Energy Systems

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Despite the promising outlook in terms of economical feasibility, AWE technology is currently at an intermediate development stage, with challenges yet to be overcome before it can reach the market. One of these challenges involves obtaining a reliable estimate of the aircraft position and velocity in space. Since these variables are used for flight control, accuracy in their estimation plays a crucial role for both optimizing the power output of the AWE system and for ensuring operational robustness. Due to its simplicity, the usual approach within the AWE community is to combine measurements of the tether angles and length obtained by rotary encoders on the ground unit. Estimators utilizing these measurements have been proven effective when the tethers are kept highly taut, which typically occurs during the reel-out phase. However, during the reel-in phase, when the traction force is lower, estimation results based on the assumption of taut tethers degrade. Other popular strategies make use of a standalone GPS or a GPS associated with an IMU and a barometer. However, GPS signal loss has been reported in situations in which the aircraft is subject to high accelerations or flying at low altitudes. Furthermore, signal quality can vary depending on meteorological conditions and location, which makes it not reliable enough for AWE applications. Finally, industrial grade GPS receivers and IMUs compatible with the AWE requirements can be costly. Another investigated alternative has been the use of cameras and computer vision techniques.These approaches, however, do not seem to address real-world situations such as changes in lighting and weather, occlusion, and the presence of extraneous objects in the images, and, therefore, are not suitable for a system which is expected to work uninterruptedly and, to some extent, be independent of environmental conditions. More recently, an approach combining range measurements from ultra-wideband devices and readings from an IMU was proposed. In this approach, the distances between a radio transceiver fixed to the aircraft and a number of beacons scattered on the ground are measured, resulting in a larger accuracy than encoder-based schemes, specially when the tethers are not highly taut. However, to the best of our knowledge, no experimental results validating this setup are available in the literature. Lateration of range information obtained through time-of-flight measurements has several advantages over more conventional positioning techniques. It is simple, inexpensive, weather independent, and does not rely on any strong assumption about the system. Moreover, it allows for all computations to take place on the aircraft, eliminating communication delays which could jeopardize the performance of the automatic controllers. Motivated by these characteristics, this work presents a setup based on 2.4 GHz radio-frequency devices and on an Extended Kalman Filter for the real-time position and velocity estimation of a tethered aircraft. These variables are validated against line angle and length data obtained from rotary encoders at the ground station, demonstrating a good performance of the implemented measurement system. Furthermore, it is shown that the same setup can be used as a communication infrastructure, allowing for cost and complexity reduction.