Characteristic Mode Analysis of Unmanned Aerial Vehicles with Realistic Shapes and Material Composition

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Small unmanned aerial vehicles (sUAVs) perform wide range of applications that include surveillance, product delivery, emergency care, and defense-related applications. Quantifying the electromagnetic response of sUAVs is essential for developing effective communication schemes with sUAVs, optimal sensor placement on a sUAV, radar detection of sUAVs, and the development of electromagnetic-based countermeasures. Quantifying the electromagnetic response of sUAVs is complicated by their permutations of shapes, sizes, and material compositions. In this work, Characteristic Mode Analysis (CMA) is evoked to quantify the coupling of electromagnetic fields to sUAVs over the L-band and S-band. The main advantage of CMA is that it decomposes the total surface currents on a UAV in terms of a set of fundamental modes and it provides the relative significance of each mode at a certain frequency. Therefore, within a frequency band of interest, we can only focus on the modes that are significant, neglect the other modes, and use these modes to quantify and compare the electromagnetic response of sUAVs with different properties.

UAV are typically composed of many different components with each component contributing to the overall electromagnetic response. Modeling the entire UAV, will leads to a convoluted electromagnetic response due to mutual coupling and neighbor induction. Therefore, we break down the sUAV into discrete components, simulate each component individually, and combine the components progressively until the full sUAV structure is simulated to attack the (de)convolution problem. We also vary the material composition of each component to study the commonly used materials for sUAVs and delineate the effect of material composition on the characteristic modes of the structure. Our analysis shows that sUAVs with point group symmetry substructures, such as quadrotors, possess modes that are degenerate. Degenerated modes have identical modal significance at every frequency, but their current distributions are rotated. Furthermore, we will show that sUAV with semi-hollow frames possess additional modes that are absent in sUAVs with solid frames. Using these conclusions, we will present rules-of-thumb to optimize electromagnetic coupling to a sUAV and a framework to compare the electromagnetic response of sUAVs of different properties.