Electromagnetic Analysis of Unmanned Aerial Vehicles Using Characteristic Mode Analysis

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Abstract— A study of the electromagnetic response of small-unmanned aerial vehicles (sUAVs) is performed using characteristic mode analysis. Characteristic mode analysis calculates the fundamental modes that can be supported by sUAVs facilitating the interpretation of their electromagnetic response. sUAVs with realistic shapes and material compositions were studied and the characteristic modes supported by the structure are quantified over a wide frequency range.

Keywords- Characteristic mode analysis; UAV

I. INTRODUCTION

Characteristic mode analysis (CMA) has been widely applied to perfectly conducting bodies for antenna design and optimizations [1]. The main advantage of CMA is that it decomposes the total surface currents on the object in terms of a set of fundamental modes and it provides the relative significance of each mode at a specific frequency. However, applying CMA for complex shapes, composed of one or more dielectric materials, is still under development [2]. Since UAVs are typically composed of a wide range of dielectric materials and composites, in this work, we are adapting CMA to UAVs with a wide range of shapes and material compositions. Calculating the modes of a UAV will facilitate the prediction of the electromagnetic response of UAVs.

II. UAV Characteristic Mode Analysis

A simple example of a quadcopter UAV is shown in Figure 1. It consists of different components with each component contributing to the overall electromagnetic response of the structure. However, the frame will dominate the electromagnetic response of the UAV at low frequencies since it is the largest component of the structure. Therefore, as a starting point we will focus on the frame of the UAV. For the sake of simplicity, the frame will be modeled as two intersecting bars as shown in Fig.1 (b) where each bar is assumed to be 0.2 m × 0.028 m × 0.024 m and to be composed of Teflon. Figure 2 shows the equivalent surface current distribution of the first three modes of the frame. Mode 2 is identical to Mode 1 but its currents are rotated by 90°. Mode 3 represents a hybrid mode combining the current patterns of Mode 1 and Mode 2 and it resonates at a slightly higher frequency.

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We also used an Artec EVA 3D scanner to get a better approximation of the geometry of the UAV as shown in Figure 3. We will use this geometry to update our characteristic mode analysis to study the effect of the UAV's shape and material composition on the fundamental modes of the structure. Moreover, wires will be added to the UAV frame and the electromagnetic coupling to these wires will be quantified.

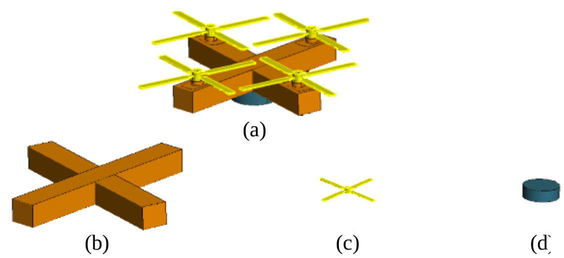

Figure 1. (a) UAV design, (b) UAV frame, (c) UAV blades, and (d) UAV transmitting and receiving system.

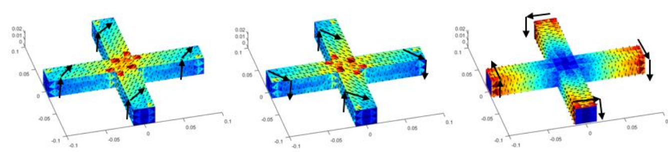

Figure 2. First 3 modal currents of a Teflon UAV frame.

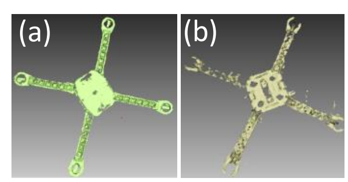

Figure 3. (a) Scanned UAV frame bottom view, (b) scanned UAV top view.

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