To: *Dr. Oman and whom it may concern*

From: *Kaitlyn Barr (Team D1)*

Date: *October 20, 2017*

Re: *Individual Analytical Analysis*

Introduction

This document will discuss the analytical vibration analysis for the D1: Unmanned Aerial Vehicle (UAV) Antenna. The team was provided with a RA-23K model antenna from the Dynamic and Active System Lab (DASL). This is the antenna that DASL uses to record data from wildlife tagged with archival telemetry tags. The RA-23K allows the DASL to locate where the strongest signal from the tags are coming from to hone in on the location of the animals. Since the antenna is not a device that the team has control over changing the design of, it imposes limitations on the team that must be accounted for such as its size and weight. This report goes further into the analysis to account for vibrations in the antenna that may be caused during flight, to determine how the team can avoid resonance. Resonance occurs when the imposed frequency on a system matches the natural frequency of the system ($f = f_n$). When resonance occurs, the oscillatory motion allows for the system to reach maximum deflection. In this case, if the antenna dipoles deflect too much during flight, they could come into contact with the rotors of the UAV, causing unstable flight, or even lead to loss of flight. This is especially of concern to the team since the dipoles have a very low spring constant and are extremely flexible, higher chance of large deflections. Even if the location of the antenna is moved to avoid entering the path of the rotors, data is more accurate if the vibrations of the antenna are minimized, so it is up to the team to prevent resonance to reduce the deflection of the dipoles.

Details of Physical Modeling:

The RA-23K Antenna is shown in Figure 1. After taking measurements, the team created a SolidWorks model and drawing, Figure 2, which labels important dimensions (in inches) needed for the vibrational analysis described in this report. The team's objective is to mount the antenna to the bottom of a UAV and give it rotational movement up to 60°. During the data collection process the team must try to minimize vibrations in the antenna dipoles and avoid resonance.


Figure 1: RA-23K Antenna [1]

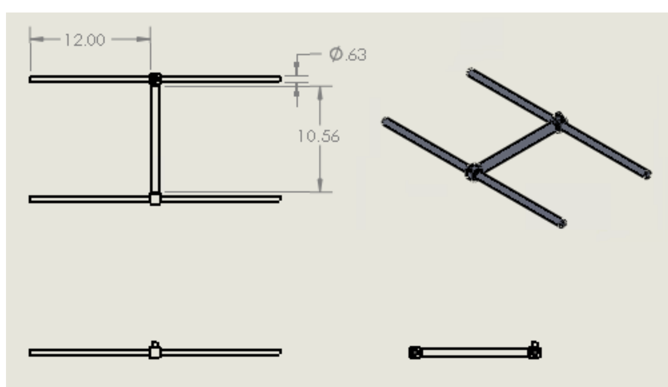

Figure 2: RA-23K Antenna Drawing

Analysis and Assumptions:

To begin the vibrational analysis, it is first assumed that during data collection (when the vibrations of the antenna are of interest) the UAV will be stationary in the vertical direction, hovering in the air. This eliminates vibrations coming from the motion of the base. Assuming this condition, the main source of vibrations in the antenna during data collection would be due to vortex shedding around the dipoles. Vortex shedding is a result of air or other fluid moving around a cylindrical object. As the fluid circles the back of the object, is sticks then slips off in an uneven pattern resulting in vortices behind the object seen in Figure 3. The unbalanced fluid movement of the vortices lead to vibrations in the object. In the case of the UAV antenna, fluid flow around the dipoles could be caused by sideways movements of the UAV, the wind, or the rotation of the gimbal.

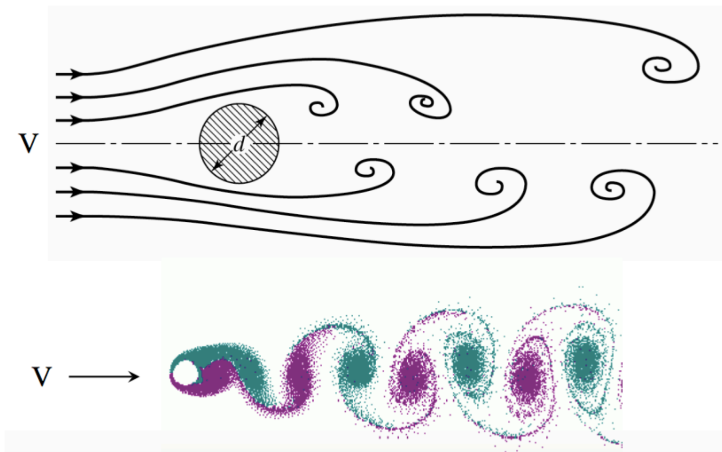

Figure 3: Diagram of Vortex Shedding [2]

To avoid vortex induced resonance, the team will ensure that the speed of the UAV (with respect to the wind) or gimbal will not match a speed that may cause resonance. The equations and calculations to measure the critical speed begin with the Equation 1 for vortex shedding [2].

$$St = \frac{fd}{\vec{v}} \tag{1}$$

Where St = Strouhal's number = 0.21, f = frequency of vortex shedding, d = diameter, and $\vec{v}$ = velocity. If resonance occurs, the natural frequency, f_n, is met, and $f = f_n$, forming Equation 2 [2].

$$St = \frac{f_n d}{\vec{v}} \tag{2}$$

Since St is already a defined value, and d is known from the system, the only variable to solve for is f_n, which is shown in Equations 3 and 4 [2].

$$f_n = \frac{\omega_n}{2\pi} \tag{3}$$

$$\omega_n = \sqrt{\frac{k_{eq}}{m_{eq}}} \tag{4}$$

Where ω_n = natural angular velocity, k_{eq} = spring constant equivalent, and m_{eq} = mass equivalent. Since the actual k_{eq} of the spring is unknown, an estimated 0.5 N/m will be assumed until a more accurate value can be produced. Substituting values with $k_{eq} = 0.5\ {}^{N}/_{m}$, $m_{eq} = 0.055\ kg$ (the mass of one end of the dipole), $d = 0.016\ m$, and $St = 0.21$, it is found that:

$$\omega_n = 3.015\ {}^{rad}/_{s}$$

$$f_n = 0.479\ Hz$$

$$\vec{v} = 0.0365\ {}^{m}/_{s}$$

The next section will further analyze the results of these calculations.

Results:

Vortex shedding around the antenna dipoles may be caused by translational motion from the base or wind, as well as rotational motion from the gimbal. To help minimize deflection of the dipoles, the team must avoid resonance. This means that when controlling the rotational speed in the team's gimbal system, the antenna must be rotated faster or slower than 3.015 rad/s. This will be important to note when choosing motor for the system as well as programming the rotational movements of the device. The next important piece of information is to let the user know that during data collection, the UAV velocity combined with wind velocity should not match 0.0365 m/s. The UAV may move through, but not linger at this velocity.

Works Cited

[1] T. Inc., "RA-23K VHF Antenna," RA-23K VHF Antenna | Telonics Inc. [Online]. Available: http://www.telonics.com/products/vhfAntennas/RA-23K.php. [Accessed: 19-Sep-2017].

[2] F. Penado, 'Self Excited Oscillations and Instability.' Northern Arizona University, 2017.