ANALYSES OF VHF/UHF AND GPS ANTENNAS ONBOARD AN UNMANNED AERIAL VEHICLE HELICOPTER

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Abstract

Major advances in technology have put the use of unmanned aerial vehicles (UAVs) at the forefront in commercial and military applications. Such UAVs are being used for weather, reconnaissance, aerial mappings, and military operations. UAVs come in different sizes, shapes, and forms. The two most common types of UAVs are fixed wing and rotary. In this effort, the latter is referred to as a UAV helicopter (UAVH).

At the heart of a UAV mission's success are the antennas onboard. These antennas are used to perform many tasks such as: Manual takeoff, flight, or landing a UAV; relay of messages or data; and other mission specific tasks. This effort concentrates on the modeling and analysis of three VHF/UHF antennas and two GPS antennas onboard a UAVH. Two of the three VHF/UHF antennas are 14-inch blades, and the third is a 9-inch blade, each operating in the 30-400 MHz frequency range. The GPS antennas are dual-stacked circular patches, operating at 1575.42 MHz (L1) and 1227.6 MHz (L2) frequencies. However, only the analysis at L1 is provided in this effort. The majority of the UAVH model preparation is performed in GiD, a commercial CAD and meshing software. The computational electromagnetics (CEM) modeling and analysis effort is carried out using WIPL-D, a Method of Moments (MoM) software.

1. General Description. The VHF/UHF antennas analyzed here are of the widely used blade types, commonly used on fixed wing and rotary aircraft, each operating in the 30-400 MHz frequency range. The antennas will be referred to as Blade #1, Blade #2, and Blade #3 throughout this effort, in order to distinguish them from one another. Blades #1 and #2 are 14-inch blades, referring to their slightly more than 14-inch physical height. Blade #3 is a 9-inch blade, referring to its slightly more than 9-inch physical height. All three blade antennas are placed on the UAVH in such a way that one or more of the blades will be capable of maintaining 360^{o} coverage at all times. The blade antennas are shown in their respective locations on a UAVH model as shown in Fig. 1.

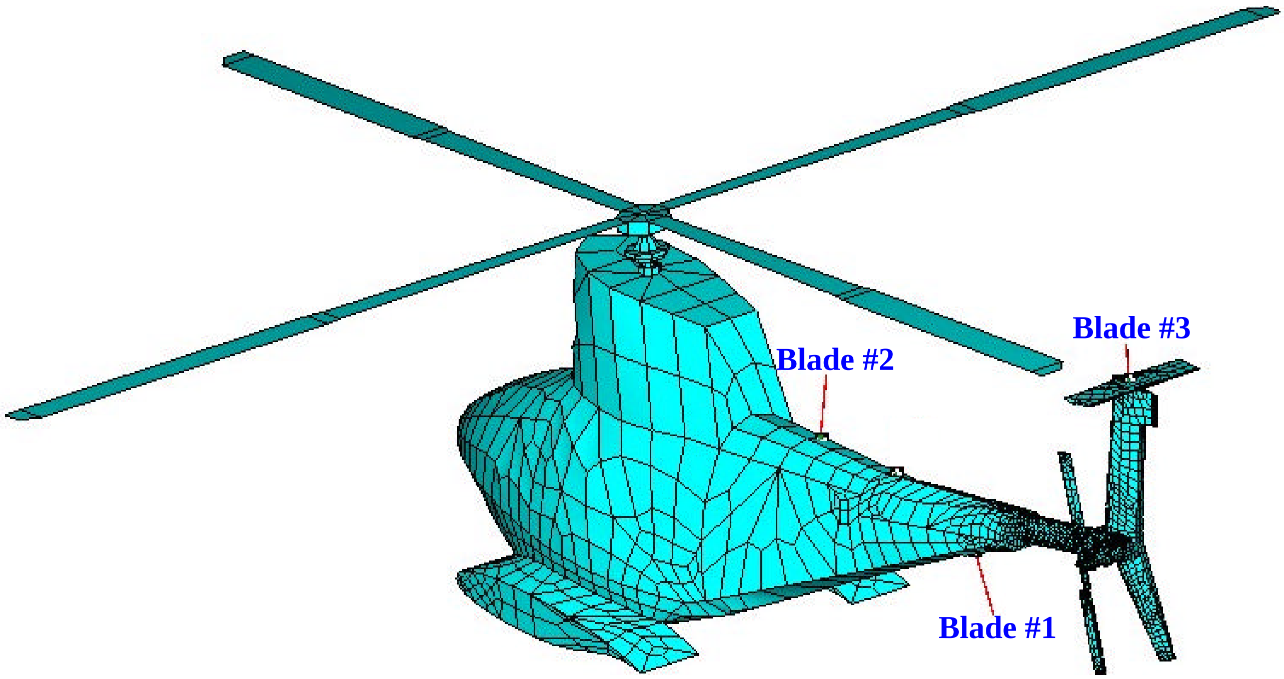


Fig. 1. VHF/UHF Antennas Mounted Onboard a UAVH Model.

The GPS antennas used in this study are circular dual-stacked patches with right hand circular polarization. Physical antenna details of the GPS antennas are provided in [1]. The GPS antennas operate at both the 1575.42 MHz (L1) and 1227.6 MHz (L2) frequencies. However, only the analysis at L1 is provided in this effort. The two GPS antennas will be referred to as GPS #1 and GPS #2 throughout this effort, in order to distinguish them from one another. The GPS antennas are shown in their respective locations on a UAVH model as shown in Fig. 2. The UAVH model in Fig. 2 had to be reduced in order to fit the model within the maximum number of unknowns allowable on a standalone workstation. The eliminated portions of the fuselage are ones assumed to have minimal to no effects on the GPS antennas' radiation patterns (RPs).

2. <u>WIPL-D Models.</u> Since the internal design of the blade antennas are not available, simplified wire models are chosen. Blade #1 and Blade #2 are treated as "fat monopoles" of 14.3 inches in height, and Blade #3 is treated as a "fat monopole" of 9 inches in height. Such a simplification of the antenna model generates a wide range of antenna mismatch loss (MML) values, as the frequency is varied from 30 MHz to 400 MHz.

The GPS antennas modeling details are provided in [1]. The antennas adhere to a known physical antenna in size, shape, feed locations, and dielectric material properties. MML values for the GPS antennas are of no importance, since they are receive-only antennas.

The quad-mesh models of the UAVH, shown in Fig. 1 and Fig. 2, are prepared in GiD (a commercial CAD and meshing software) and converted into WIPL-D format models using an internally prepared MATLAB conversion script. The antenna models are added directly in WIPL-D. Moreover, simplified models of the rotor mount and the main rotor of the UAVH have been built directly in WIPL-D as well, since their CAD models were too complex to mesh in GiD. This significantly reduces the total number of unknowns required for this modeling effort.

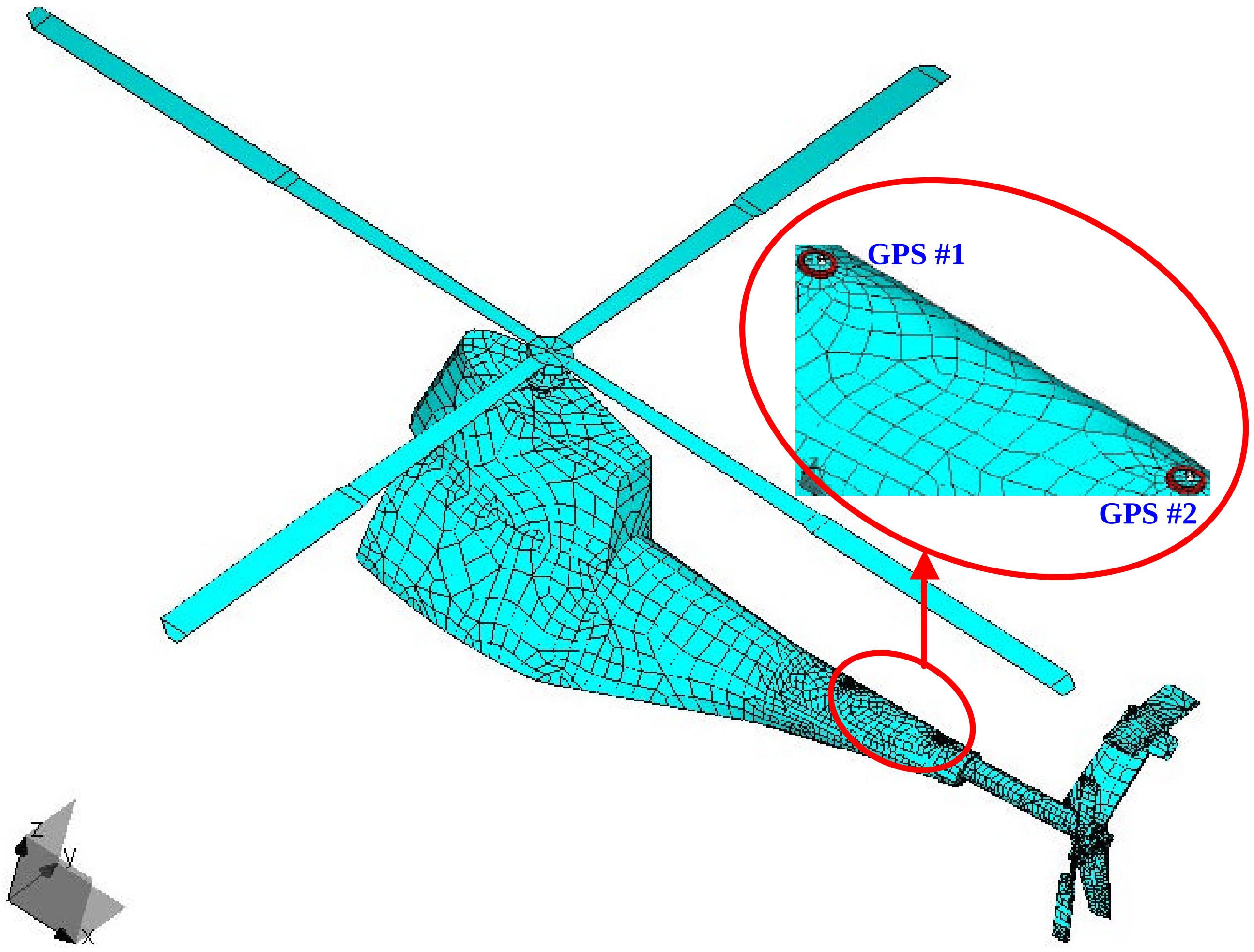
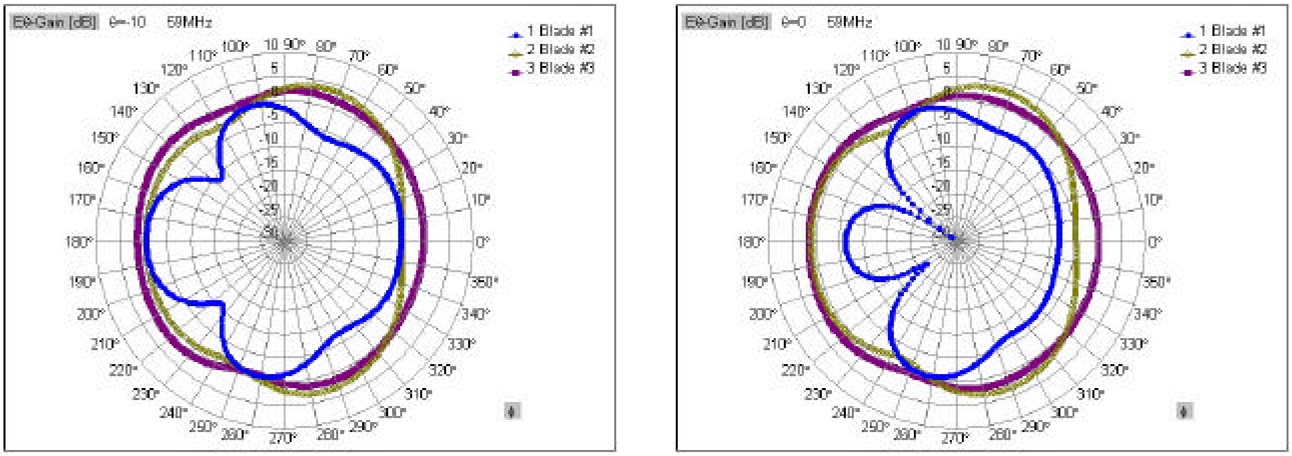


Fig. 2. GPS Antennas Mounted Onboard a UAVH Model.

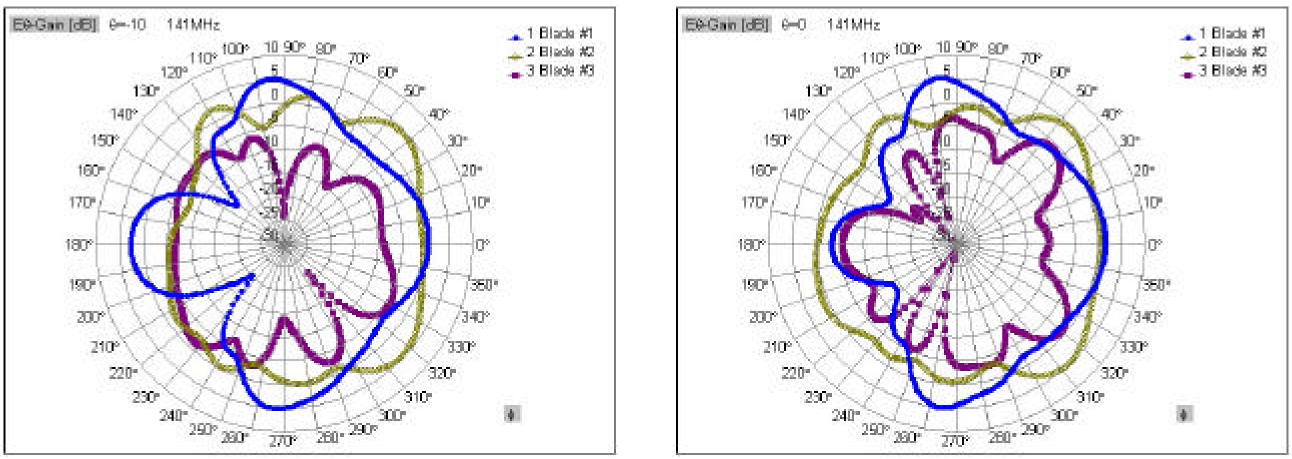
3. <u>Results.</u> As mentioned earlier, the VHF/UHF antennas operate in the 30-400 MHz frequency range. Within this frequency range there are three sub-frequency ranges of interest, they are: 30-88 MHz (VHF low); 108-174 MHz (VHF high); and 225-400 MHz (UHF). Furthermore, in each of the three sub-frequency ranges, the analysis is performed at the lowest, midpoint, and highest frequency. However, only conic RPs at the midpoint frequencies (59, 141, and 312.5 MHz) will be provided here, and are shown in Fig. 3, Fig. 4, and Fig. 5, respectively. Figs. 3, 4, and 5 contain sample overlays at the -10^{o} and 0^{o} conics. The blade antennas MML data are shown in Table 1, which would be used to generate the corrected gain of the antennas.

For the GPS antennas, since satellites are normally positioned at 10^{o} above the horizon and higher, only three dimensional (3-D) RPs are presented. Fig. 6 shows a set of two 3-D RPs for the GPS #1 antenna, providing full 360^{o} coverage in the azimuth orientation. Similarly, Fig. 7 shows a set of two 3-D RPs for the GPS #2 antenna.



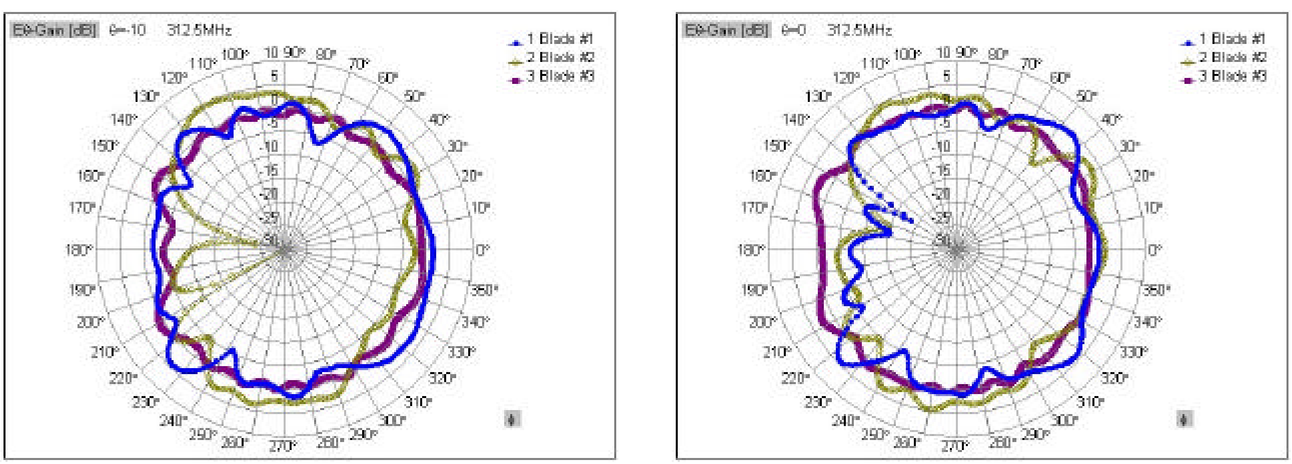
-10^{o} Conic 0^{o} Conic

Fig. 3. RPs of VHF/UHF Antennas Mounted on a UAVH at 59 MHz.



-10^{o} Conic 0^{o} Conic

Fig. 4. RPs of VHF/UHF Antennas Mounted on a UAVH at 141 MHz.



-10^{o} Conic 0^{o} Conic

Fig. 5. RPs of VHF/UHF Antennas Mounted on a UAVH at 312.5 MHz.

Table 1. Blade Antennas MML Data.

Antenna	Frequency (MHz)	MML (dB)
Blade #1	**59** **141** **312.5**	**-18.83** **-6.03** **-3.21**
Blade #2	**59** **141** **312.5**	**-22.53** **-4.64** **-3.78**
Blade #3	**59** **141** **312.5**	**-18.96** **-15.10** **-0.03**

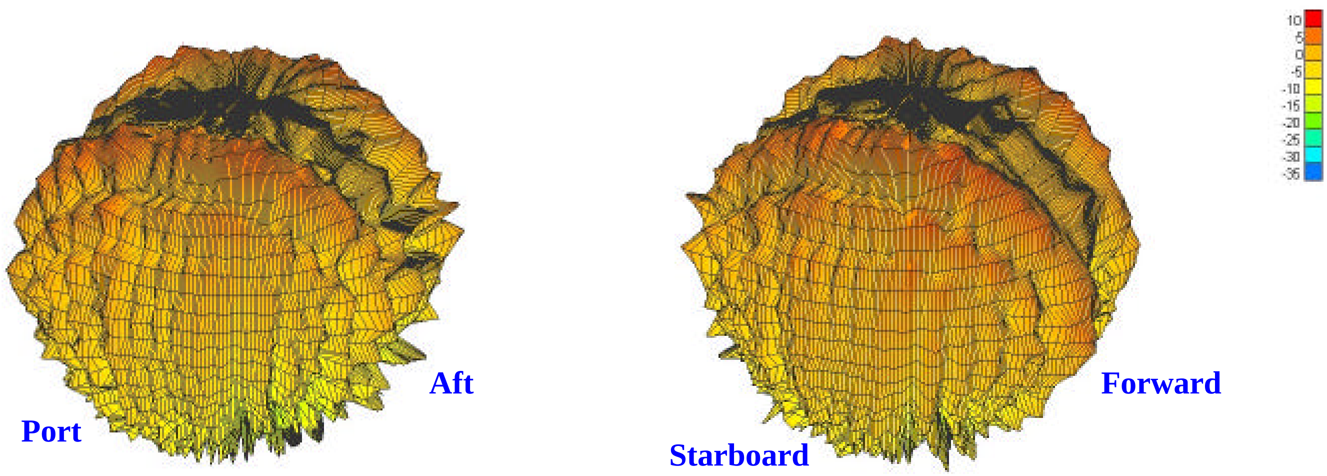


Fig. 6. GPS #1 Antenna 3-D RPs Mounted on a UAVH.

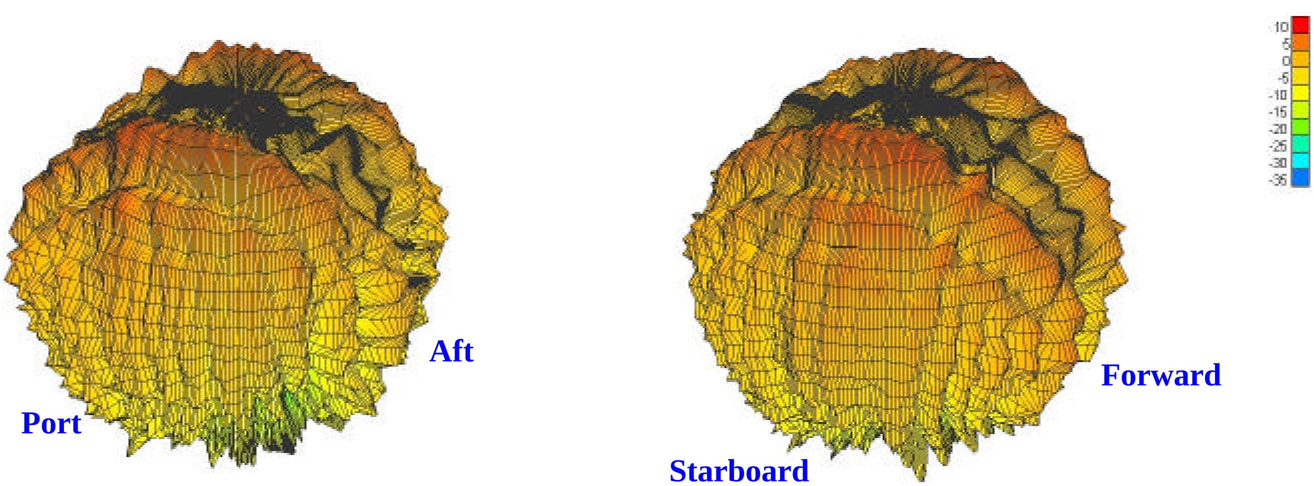


Fig. 7. GPS #2 Antenna 3-D RPs Mounted on a UAVH.

4. Conclusions. The RPs in Figs. 3, 4, and 5 show that the blade antennas, in their selected locations, do collectively provide 360^{o} coverage, from a pattern-shape perspective. However, the antenna gain values in those plots do not account for antenna MML. Hence, the MML data in Table 1 play a significant role in gain correction. Table 1 shows that the wire models used for the blades do (as expected) exhibit extremely high MML values at the low end of the frequency range, due to their extremely short electrical length in that region. To the contrary, the MML of the 9-inch blade (Blade #3) at 312.5 MHz is negligible, since the electrical length of the antenna is slightly more one-quarter of a wavelength at that frequency.

Figs. 6 and 7 provide a 3-D view of the GPS antennas RP performance. For both antennas, as expected, the main pattern degradation occurs over narrow strips in the forward and aft directions, due to structural blockages from the doghouse and the vertical stabilizer and tail rotor. However, since the RPs in the port and starboard directions are relatively unaffected, either GPS antenna has an ample number of satellites in their field-of-view. Finally, both GPS antennas' zenith coverage does not seem to be significantly affected by the main rotor blades, even for the worst case scenario of a blade positioned directly overhead (the case used in this effort.)

5. References.

[1] S.N. Tabet, "GPS Antenna on Mounting Rings Over a PEC," Proceedings of the 18th Annual Review of Progress in Applied Computational Electromagnetics, Monterey, CA, pp. 607-613, April 18-22, 2002.