“TUNA CAN” ANTENNA DESIGN FOR CUBESAT MISSIONS

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1. Abstract:

ELFIN, a University Nanosatellite Program 3U CubeSat, will use the “Tuna Can” bonus volume (CubeSat Design Specification draft revision 13) to store magnetically clean VHF and UHF canted dipoles. While steel carpenter’s tape has been a popular antenna choice on micro and nano-satellites for decades, its magnetic permeability of is unsuitable for use near sensitive magnetometers.

Therefore, our antenna design utilizes fiberglass booms from AFRL’s VPM CubeSat, which is inlaid with beryllium copper conducting elements. Similar in size to carpenter tape antennas, these are bi-stable, allowing them to be stowed without restraint. This requires a ‘kick’ to make the antennas translate from their fully stowed state. While advantageous for a number of deployables, our storage design bypasses this kick requirement need by stowing the antennas in a transition state.

These antennas will deploy into a canted dipole, which based on their position on the end of the chassis should provide near omnidirectional coverage. They are secured by conventional nylon lines and deployed with burn resistors. Preliminary mechanical and storage testing has been completed, and RF testing is currently in progress to verify our theoretical models.

2. Design:

2.1 Individual Antenna Holder:

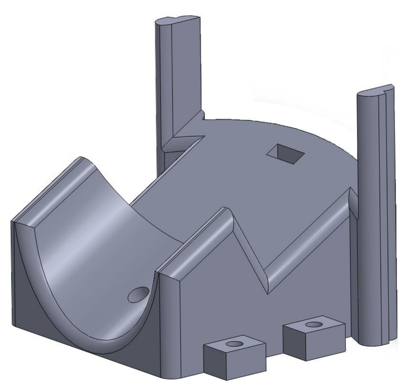

Figure 1: Antenna holder

Three design requirements drive the holder design. They need to be compact to fit in the tuna can, withstand vibration stresses, and allow the antennas to freely deploy without catching. The small size of the conducting element (pictured below) allows one screw hole to secure the antenna. To provide more strength, the holder is curved to match the antenna design. A flat section has been included to hold the coiled, flat, antenna. This holds the antennas in their "transition state“, providing strain energy and automatic deployment.

2.2 Antenna Holder Assembly:

The completed assembly has five parts: four antenna holders, and the "tuna can“. The tuna can is a hollowed out cylinder, 2 cm high, and 6.1 cm in diameter, which bolts to a PCB on the spacecraft. The raised sections help constrain the stowed antennas laterally, preventing them from expanding under vibration.

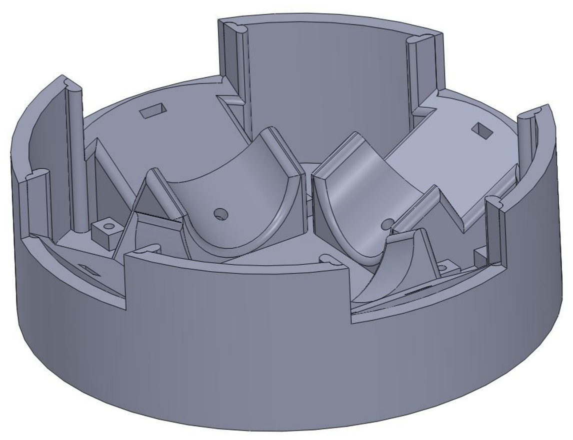

Figure 2: Antenna holder full assembly

2.3 Antenna Release Mechanism:

The antennas are secured with a fishing line, one for each pair. Each fishing line wraps around and below the tuna can through a small notch in each holder. The fishing line runs under the tuna can, across the PCB, and across a pair of small resistors. These resistors will be overdriven on command to melt through the fishing line, deploy the antennas. Once the fishing lines are cut, the antennas will self-unfurl due to their bi-stable nature.

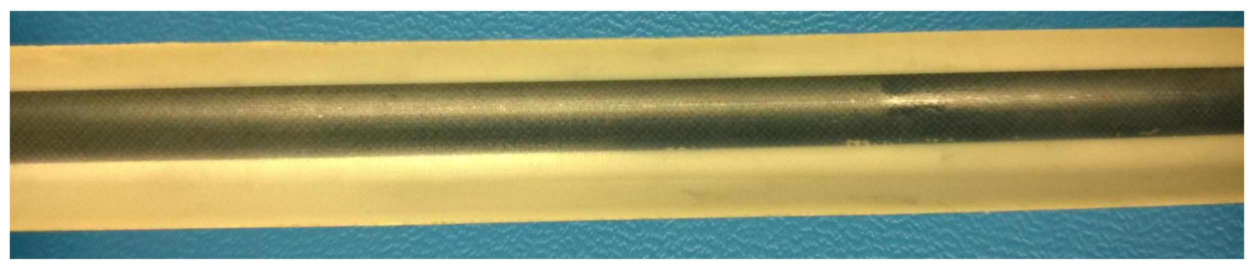

Figure 3: Closeup on antenna section with conductor element

3. Full Model Assembly:

These models display the antenna assembly attached to the full model.

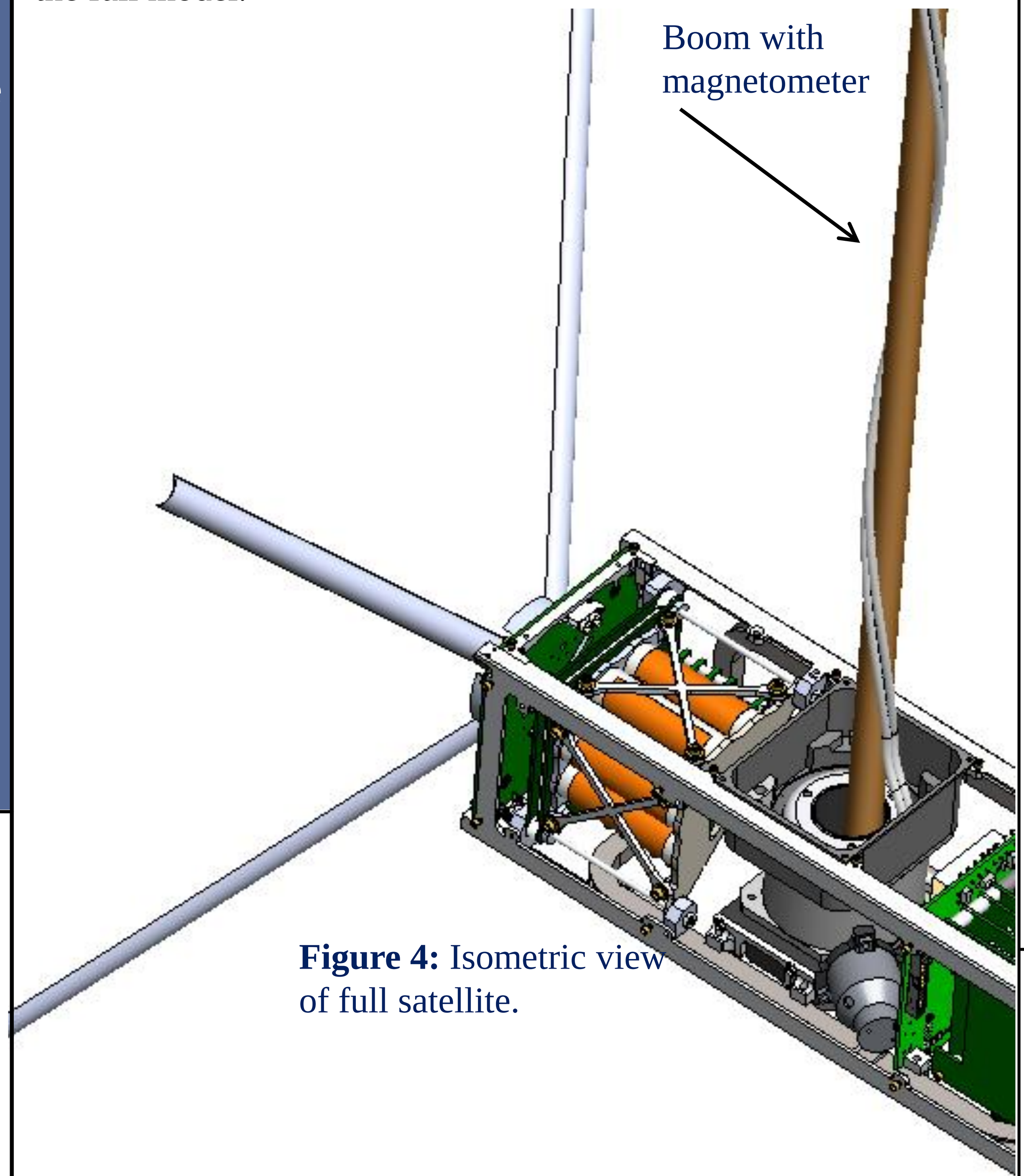

Figure 4: Isometric view of full satellite.

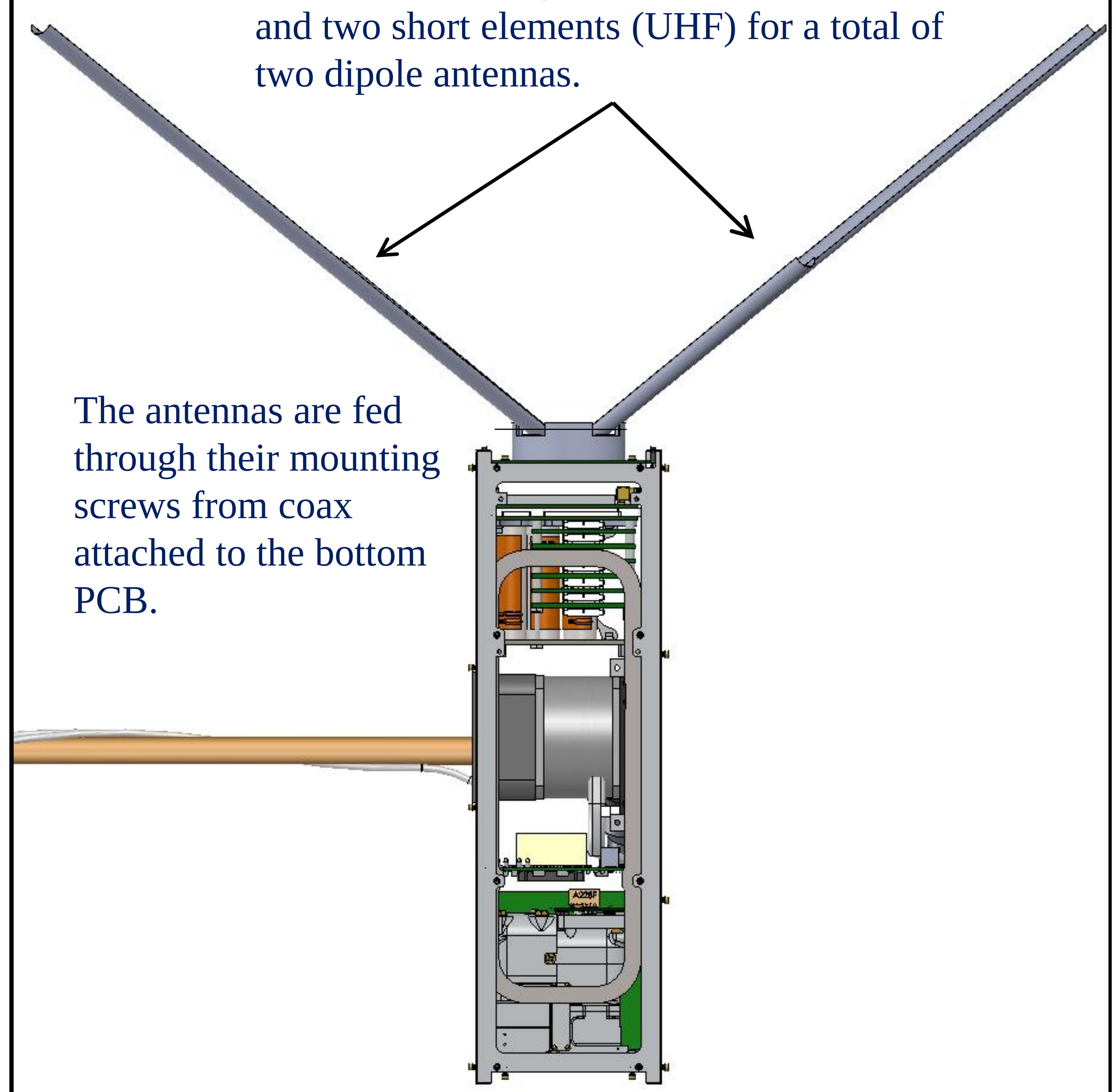

Figure 5: Side view of full satellite showing how the tuna can antennas are secured.

4. Mechanical Test Data

Tests have been done on a 3D printed prototype of the full antenna holder assembly, made out of ABS plastic. While lacking the mechanical strength of aluminum, it allows repeated testing of the deployment. The antennas are rolled up one pair at a time, and secured with a single fishing line running across both elements. For simplicity, the majority of tests were conducted by cutting the fishing line from beneath with shears. However, tests have been conducted using the resistors in a slightly different geometry.

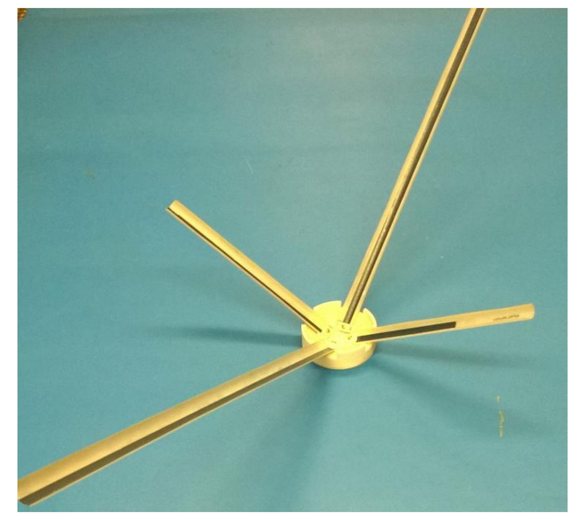

Figure 6: Deployed antennas

Preliminary tests are promising. As soon as the lines are cut, the antennas immediately spring into their deployed position. Each fishing line is independent, so each pair can deploy no matter the state of the other pair. The notches constrain the fishing line so there is a very low probability of the lines losing contact with the antennas, and deploying before commanded.

Vibration testing is the first priority in further tests. Excessive shaking during launch can cause the lines to snap, or the coiled antennas to expand. Also under investigation is the proper not to tie in the antenna. In addition, we are working to ensure that burning through the lines will not cause excessive heat blooming.

Figure 7: Stowed antennas

5. RF Optimization

Our spacecraft doesn’t have the control authority to track the ground during communications. As a result, the orientation and angle must be optimized so that the gains are equal magnitude in every direction.

The first orientation placed the antennas parallel to the plate where they are attached. However, as evidenced in figure 8, this configuration caused a severe dip in signal strength at 135º on the X-Y plane. The antennas were reconfigured, angled 30º away from the top plate, and twisted 45 degrees along the long axis.

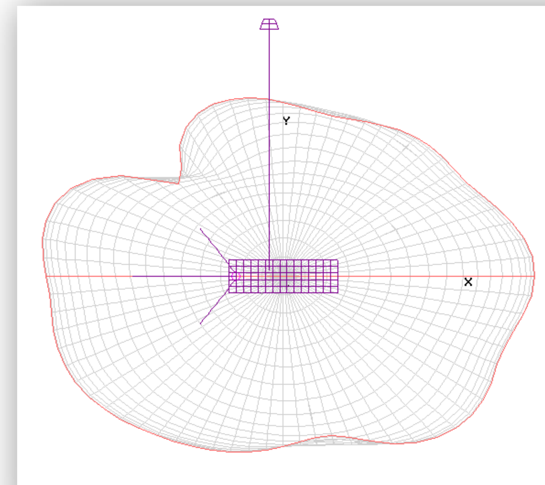

Figure 8: Old RF data

The goal is to obtain a decibel level as close to zero or above in all directions. The plot in figure 9 shows our current configuration, significantly better than figure 8. Additionally, Our link budget shows that the link will be completed in every orientation, with the shown configuration.

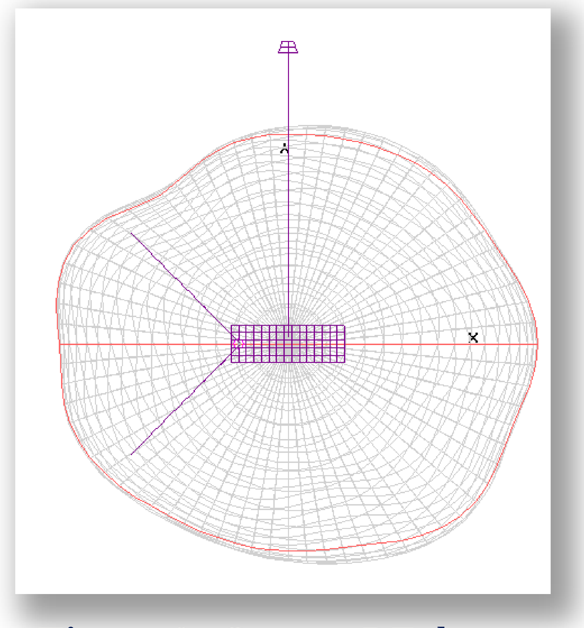

Figure 9: Current RF data

6. Conclusions

There are a number of aspects of the design that require further testing. Testing the antennas after vibe will be an important validation of our design. It is necessary to ensure that the antennas do not expand and catch when the CubeSat is deployed from the PPOD.

A PCB must be fabricated to test deployment using the burn resistors, and feed the antennas electrically. The previous tests conducted using burn resistors were on a larger PCB, incompatible with the tuna can, but they determined the burn profile which achieves best results.

The antennas are being tested to see how well simulation results compare with reality. Tests are being conducted on a dry lakebed to simulate how the antennas perform in space.

Figure 10: Field testing configuration