Comprehensive Testing Procedures for Robust Avionics

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Mei Qi Tang
McGill Rocket Team, Montreal, Quebec, H3A0E9

INTRODUCTION

Testing procedures and standards are a key aspect to developing reliable avionics, and have been lacking in the design process for the McGill Rocket Team (MRT) until this year. It is very difficult to predict the rocket's behavior in-flight, and even more difficult to simulate that behavior on the ground. As such, it is important to develop a wide variety of tests to both guide the avionics design, and to validate the final product. These sort of tests are the building blocks of avionic system development, and are required to ensure the success of continuously more complex SRAD systems. The testing procedures presented divide into two categories: configuration and integration testing. Configuration testing is meant to drive design choices for the most optimal performance of an individual subsystem. On the other hand, integration testing validates the design choices of an individual subsystem with respect to its neighbouring subsystems through interference analysis, aiming to optimize the overall system performance. Both types of tests were applied to RF Radios and COTS Antennas to validate the telemetry design for MRT's 2019 SAC submission *Caladan.*

CONFIGURATION TESTING

Configuration testing was done entirely indoors, inside an anechoic chamber, which allowed repeatable measurements to be taken in an ideal test environment without any outside interference or RF reflective sourroundings. First, a preliminary exploration on the ideal placement of radios in the rocket was conducted. It was already known that carbon fibre, a material used for many structural elements in *Caladan*, is somewhat conductive and therefore will act as a ground plane reflecting signals[1]. However, due to assembly and other design considerations, the COTS patch antennas had to be in proximity to the carbon fiber material. Therefore, preliminary configuration tests in the anechoic chamber were conducted to study the effect of antenna orientation and placement with varying distances to the carbon fiber material. These preliminary tests were not only easy to setup, but were also designed to be remote-controlled with automated data recording and post-processing. These allowed for efficient preliminary optimization of the most performant configuration of antenna placement around RF reflective materials.

Once the top desired configurations were selected, the team then conducted more precise, but also more time consuming, antenna radiation pattern tests using NSI-MI Technologies Near-Field test equipment in the anechoic chamber. With the rocket's flight behavior in mind, the configuration with a radiation pattern that showed the highest potential of maintaining a stable link was selected.

INTEGRATION TESTING

Although a best-performing, or at least functioning, configuration is important, it does not prove that the subsystems won't interfere with each other or that the system will work under real flight conditions. To gain that confidence, MRT ran indoor spectrum analyzer tests, as well as short-range and long-range outdoor tests. By displaying the magnitude power level of an input signal over a specified frequency range, the spectrum analyzer gave insight on potential interference effects such as intermodulation between the radios. To see how the system would perform closer to in-flight settings, the AV bay was lastly studied outdoors. Due to simpler logistics and setup, the preliminary tests occurred at a short range (15-100 meters), simulating long range with added attenuators. Once these preliminary short range tests showed the ability of the system to communicate at the imposed "long distance", a true long-distance test was carried out. Separating the receivers and transmitters for all of our telemetry systems by a distance of first 10km (about apogee distance), and subsequently 15km (potential recovery distance), signal strength, throughput, and interference were measured and a final system validation was performed. The distance tests were carried out with different orientations of the rocket, including a spin test where the rocket spun around its primary axis for several minutes, to account for the different orientations expected in flight. This concluded the testing procedures with a confirmation that, not only are the on-board radios and antennas positioned in the optimal spot, but also that they perform as expected in the field, under different applied stressors.

CONCLUSIONS, AND FOLLOW-ON WORK

These testing procedures will continue on to serve as the basis of all of MRT's avionics development in the future. The need to have quantitative analysis to back up design decisions for rocket electronics cannot be overstated, and is absolutely necessary when looking ahead at creating any type of SRAD system. In tangent with testing, MRT has been developing SRAD antennas over the past year. This is the goal of MRT's short-term follow-on work, and the tests, now proven to work on COTS modules, will be used to improve SRAD modules in the coming year to the point where a reliance on COTS will no longer be necessary.

REFERENCES

[1] Mckenzie, A. B., and White, S., "Characterization Of Electrical Conductivity Of Carbon Fiber/Epoxy Composites With Conductive Afm And Scanning Microwave Impedance Microscopy," University of Illinois, 2015.