Review of CTU Spark Gap Experiment Electromagnetic Interference

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Penn State and other G-Chaser experiments expressed concerns about electromagnetic interference (EMI) from UMBC's “spark-gap” experiment which is integrated into the CTU payload. On 9 April 2018, a contingent of students and a faculty member (Bilén) from Penn State travelled to UMBC to make measurements of EMI to determine if the concerns were warranted and, if so, to discuss possible mitigation strategies. *A priori* discussion pointed to high-voltage power supply interference as a potential dominant source. Due to the high noise output of the high voltage supply selected by UBMC, system operation would greatly affect the results of any sensitive instrumentation operating anywhere from 1 MHz to 8 MHz (and lower and higher). This is particularly true for Penn State’s TEC system that is part of the PAWSS payload. The TEC system includes a radio receiver sensitive to signals as small as −140 dBm. Interference characterization was conducted at UBMC using a spectrum analyzer, as well as a similar receiver to the SDR-based TEC.

**Spectrum Analyzer Interference Readings:**

The spectrum analyzer was connected to an electric field probe that was placed approximately 10 cm from the high-voltage power supply. The probe is designed to pick up electric fields using a small dipole antenna. Figure 1 shows the ambient power spectrum in this indoor lab environment without the power supply on, which was −61.97 dBm over the frequency range from 1.3 MHz to 7.8 MHz (selected because this is the critical range for the TEC receiver). Figure 2 depicts the noise power spectrum in the environment with the high voltage generator running. When it is turned on, there is an increase of noise across the entire spectrum. Maximum noise is at −30 dBm at 1.3 MHz. The spectrum is awash in closely-spaced peaks that are not deterministic and, as is shown below, changing in frequency.
Figure 1 depicts the spectrum of the noise created in the environment with the spark gap generator off.

Figure 2
The next few measurements were made with the mock-up TEC system. This system consists of a short dipole antenna fabricated from tape measure with each half measuring 30 cm (similar to what will be flown), which was mounted to a board that kept each held 30 cm apart. The antenna was attached to a balun that was then connected to an SDRplay RSP2. To display the data coming from the device, High Definition Software Defined Radio (HDSDR) was used. The display showed an instantaneous spectrum and a waterfall display. Figure 3 shows the display in the environment without the high voltage display on.

Figure 3: Baseline noise of the lab environment shown on HDSDR. Top graph is instantaneous spectrum power and bottom graph is spectrum power over time. Red values depict higher power received while blue depicts lower power received.

In the next few images, the high voltage generator was turned on for a short duration. In Figure 4, the antennas are approximately 30 cm away from the power supply and was on for a short duration. In Figure 5, the power supply is on for a longer period of time in order to get a clear idea of how the frequencies moved with time. In Figure 6, the antennas were around 4 meters away.
Figure 4: HDSDR screen capture. Spark gap turned on for a short period of time.

Figure 5 HDSDR screen capture, spark gap turned on for a longer period of time to show the randomness of frequency fluctuation.
The waterfall spectrum shows that the frequencies of interference are not stable and can shift left and right. This tells us that the operation of the spark gap will interfere with the TEC system as the noise frequency output passes through the TEC frequencies of interest. This prevents the possibility of notching out the interfering frequency. The interference is effectively wide band due to the shifting comb pattern. Hence, this means that there is no possible method to filter out the noise caused by this system.

The TEC is most affected by this because it relies on accurately measuring the signal power as transmitted from the ground. Using these measurements, it can interpolate the faraday rotation of the ionosphere, which then can be used to find the electron content. Other than thermal noise, the bulk of the power picked up by this system needs to be from the ground station, and the effects of the high voltage power supply would be catastrophic. If the high voltage generator employed a fixed switching frequency, the interference coming from it would likely not be an issue because the EMI could be filtered out at those specific frequencies.

The primary issue with the EMI coming from the High Voltage Power Supply selected by UMBC is that it is broad-band. This interference swamps the data collected by the TEC system and has the capability of adversely affecting other data from other scientific experiments as well. Penn State believes replacing this supply with one that operated on a singular fixed switching frequency would mitigate these concerns. This recommendation was made to them during our visit.