

## **Necessary Bandwidth Description Exhibit**

The necessary bandwidth for both radios seeking experimental authorization was listed as 406 kHz. This is the default setting of the TI RFIC chip radios at the heart of the experimental radios.

An assumption used in calculating the necessary bandwidth is from “Space Mission Analysis and Design”. This source states that for Frequency Shift Keying (FSK) operation, a bandwidth of at least twice the expected data rate is required for proper separation of the Frequency1 and Frequency2 values about the center frequency for digital communication.

Our radios are to be operated at 153,600 bps throughput data rate twice this yields a value of 307 kHz bandwidth.

The product data sheets also state that both the radio units can experience up to 76 kHz deviation from crystal oscillation errors, and an additional 13 kHz due to thermal errors.

Additionally, “Space Mission Analysis and Design” also details how to account for Doppler shift due to the satellites high relative velocity to the Earth. Doppler shift is calculated by multiplying the relative velocity of the spacecraft (6,900 m/s worst case) by the center frequency, and dividing by the speed of light.

For the UHF radio, this yields a Doppler shift of 10 kHz and for the S-Band radio a Doppler shift of 55 kHz.

Summing all of the disturbances for each unit; data rate, crystal deviations, thermal errors, and Doppler shift, the final necessary bandwidth for the 400 MHz band unit is 406 kHz and 451 kHz for the 2.4 GHz unit.

The default setting for channel bandwidth in the TI chip will be acceptable for the 400 MHz radio, and will need to be expanded slightly in the 2.4 GHz radio by programming.

### **References:**

*Larson, W.J., Wertz, J.R., “Space Mission Analysis and Design,” 3<sup>rd</sup> Ed. Boston, Microcosm Press, 2004.*