Necessary Bandwidth Description Exhibit

The necessary bandwidth for both radios seeking experimental authorization was listed as 36.5 kHz for UHF frequency transmitters, and 13 kHz for VHF frequency transmitters.

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 1,200 bps and 9,600 bps throughput data rate. Twice this yields a value of 2.4 kHz and 19.2 kHz bandwidths respectively.

The product data sheet for the Kenwood TH-D72A (Spacecraft radios) states that the radio can experience up to 5 kHz deviation from crystal oscillation errors, and an additional 2.25 kHz due to thermal errors.

As the Icom 910h (Ground Station radio) is a large base unit of quality manufacture, all oscillators yield lower values for maximum deviation. For conservative estimation, the values of deviation from the Kenwood radios were used to calculate necessary bandwidth.

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 VHF radio a Doppler shift of 3.4 kHz.

Summing all of the disturbances for each unit; data rate, crystal deviations, thermal errors, and Doppler shift, the final necessary bandwidth for the 440 MHz band units are 36.5 kHz and 13 kHz for the 144 MHz band units.

References:

Larson, W.J., Wertz, J.R., "Space Mission Analysis and Design," 3rd Ed. Boston, Microcosm Press, 2004.