ASEC Exhibit H: **Supplemental Details Regarding Upper Frequency, Lower Frequency, and Necessary Bandwidth**

The transmitter has a tunable center frequency from 395.5 MHz to 399.5 MHz.

The center frequency is fixed prior to operation and cannot be changed during operation.

Regardless of center frequency, the instantaneous occupied bandwidth is 130.8 kHz.

- Lower Frequency: **395.5 MHz** (spectral edge of **395.4346 MHz**)
- Upper Frequency: **399.5 MHz** (spectral edge of **399.5654 MHz**)
- Modulation Scheme: **BFSK 54kbaud**
- Necessary Bandwidth: **130.8 kHz**
- Emission Designator: **130K8F1D** (BFSK used for telemetry/data transmission)

Supporting Calculations

The NTIA Redbook Manual of Regulations for Federal Radiofrequency Spectrum Management, Appendix J[1], Table A, Fixed and Mobile Services (Data) Binary FSK (BFSK or 2FSK) provides direction on how to calculate the necessary bandwidth for the modulation scheme being used in this application.

$B_n = R/Log_2 S + 2KD$, when $0.5R \leq D \leq 10R$, and it is assumed that $K \approx 1.2$

For the equation above:

$B_n =$ Necessary Bandwidth
$D =$ Peak deviation, i.e., half the difference between the maximum and minimum values of the instantaneous frequency.
$K =$ An overall numerical factor which varies according to the emission and which depends upon the allowable signal distortion.
$R =$ Total bit rate, which includes data, encoding, and any other overhead bits.
$S =$ Number of equivalent non-redundant signaling states.

The document also references Section 5.1.5 of the Redbook regarding expectations for occupied bandwidth as it relates to necessary bandwidth. Section 5.1.5 simply states:

> *All reasonable effort shall be made in equipment design and operation by federal agencies to maintain the occupied bandwidth of the emission of any authorized transmission as close to the necessary bandwidth as is reasonably practicable.*

[1] https://www.ntia.gov/sites/default/files/2023-11/j_2021_edition_rev_2023.pdf

The radio associated with this application has been designed and tested in laboratory environments to meet this goal.

For this radio design:

$$D = 32{,}000\ Hz$$

$$R = 54{,}000\ bps$$

$$S = 2$$

Checking for an appropriate relationship between D and R, which requires:

$$0.5R\ \leq D\ \leq 10R$$

$$0.5(54{,}000)\ \leq 32{,}000\ \leq 10(54{,}000)$$

$$27{,}000\ \leq 32{,}000\ \leq 540{,}000$$

The condition is True and the equation applies as follows:

$$B_n = R/Log_2 S + 2 \cdot K \cdot D$$

$$B_n = 54{,}000/Log_2(2) + 2 \cdot 1.2 \cdot 32{,}000$$

$$B_n = 54{,}000 + 76{,}800$$

$$B_n = 130{,}800 \approx 131kHz$$

This Necessary (Occupied) Bandwidth holds true for all center frequencies.

Using a median tunable center frequency of 397.5 MHz and the Necessary (Occupied) Bandwidth calculated above, the lower and upper frequencies when operating at 397.5 MHz can be determined as follows:

$$F_{lower} = F_{center} - B_n/2 = 397.5MHz - 0.1308MHz/2 = \mathbf{397.4346\ MHz}$$

$$F_{upper} = F_{center} + B_n/2 = 397.5MHz + 0.1308MHz/2 = \mathbf{397.5654\ MHz}$$

The absolute lower edge is encountered when the center frequency is set to 395.5 MHz.

$$F_{lower\_spectral\_edge} = F_{center} - B_n/2 = 395.5MHz - 0.1308MHz/2 = \mathbf{395.4346\ MHz}$$

The absolute upper edge is encountered when the center frequency is set to 399.5 MHz.

$$F_{upper\_spectral\_edge} = F_{center} + B_n/2 = 399.5MHz + 0.1308MHz/2 = \mathbf{399.5654\ MHz}$$