9. Modulation

9.1 General Description

The modulation is a form of differential Quadrature Phase Shift Keying (QPSK) where each successive symbol is shifted in phase from its predecessor by 45 degrees ($\pi/4$ radians). The receiver of this modulation is intended to be compatible with any transmitter which accomplishes this phase shift of the carrier, of which at least two types are available. A transmitter which modulates the phase but keeps the amplitude of the carrier constant will generate a constant envelope frequency modulated waveform which will be denoted C4FM. A transmitter which modulates the phase and simultaneously modulates the carrier amplitude to minimize the width of the emitted spectrum will generate an amplitude modulated waveform which will be denoted CQPSK.

Other forms of differential Quadrature Phase Shift Keying modulation (for example $\pi/4$ DQPSK) will be studied for possible inclusion in this document.

9.2 Symbols

The modulation sends 4800 symbols/sec with each symbol conveying 2 bits of information. The mapping between symbols and bits is given in Table 9.2-1.

Table 9.2-1 Dibit Symbol Mapping to Modulation Phase or Deviation

Information Bits	Symbol	CQPSK Phase Change	C4FM Deviation
01	+3	+135 degrees	+1.80 kHz
00	+1	+45 degrees	+0.60 kHz
10	-1	-45 degrees	-0.60 kHz
11	-3	-135 degrees	-1.80 kHz

9.3 Nyquist Raised Cosine Filter

The modulation symbols are filtered with a Raised Cosine Filter which satisfies the Nyquist criterion minimizing intersymbol interference. The input to this filter consists of a series of impulses, scaled according to paragraph 9.2, and separated in time by 208.33 microseconds (1/4800 sec). The group delay of the filter is flat over the passband for $|f| < 2880$ Hz. The magnitude response of the filter is given approximately by the following formula.

f = frequency in hertz

$|H(f)|$ = magnitude response of the Nyquist Raised Cosine Filter

$|H(f)| = 1$ for $|f| < 1920$ Hz

$|H(f)| = 0.5 + 0.5 \cos(2 \pi f / 1920)$ for $1920 \text{ Hz} < |f| < 2880$ Hz

$|H(f)| = 0$ for $|f| > 2880$ Hz

9.4 C4FM Modulator

The C4FM modulator consists of a Nyquist Raised Cosine Filter, cascaded with a Shaping Filter, cascaded with a frequency modulator. The Nyquist Raised

Cosine Filter is described in paragraph 9.3. The Shaping Filter has a flat group delay over the passband for |f| < 2880 Hz. The magnitude response of the Shaping Filter is given approximately by the following formula. The response of the filter above 2880 Hz is not specified because the filter H(f) should cut off above 2880 Hz.

$|P(f)|$ = magnitude response of the Shaping Filter

$|P(f)| = (\pi f/4800) / \sin(\pi f/4800)$ for $|f| < 2880$ Hz

Figure 9-1 C4FM Modulator

9.4.1 C4FM Deviation

The C4FM modulator must have the deviation set to provide the proper carrier phase shift for each modulated symbol. The deviation is set with a test signal consisting of the following symbol stream.

... 01 01 11 11 01 01 11 11 ...

This test signal is processed by the modulator to create a C4FM signal equivalent to a 1.2 kHz sine wave modulating an FM signal with a peak deviation equal to: $\pi/2$ x 1800 Hz = 2827 Hz. The method of measurement for this test signal and the tolerance on the deviation are specified in references [4] and [5], respectively.