EXHIBIT 2

In this exhibit, Caterpillar presents an explanation of the signal formats which are proposed to be used under this experimental license. More detail on the existing GPS signal formats (P-code and C/A-code) can be found in the GPS Interface Control Document (ICD-200), available on the Web at http://gps.laafb.af.mil/y2000/icd200c.pdf.

The GPS system transmits two signals known as the clear/access (C/A-code) signal and the precise (P-code) signal. (The P-code is currently encrypted for broadcast into another code known as Y-code. Caterpillar does not contemplate any use of Y-code under this application.)

C/A-code

The C/A code signal is a spread-spectrum signal produced by binary phase shift keying (BPSK) modulation of a carrier signal by a digital bit stream known as the C/A code. The C/A code is a repeating bit sequence 1023 bits long chosen from a particular family of so-called “Gold codes.” Each GPS satellite transmits a different Gold code from this family as its C/A code. Gold codes are used because the maximum interference (“cross-correlation”) between any two Gold codes from the same family is known to be small. The GPS satellites all transmit their C/A codes on the same frequency, but this cross-correlation property allows each signal to be distinguished from the others. This technique is known as code division multiple access (CDMA).

The C/A code is transmitted using BPSK at a rate of 1.023 Mbps, so that it repeats exactly 1000 times per second. This generates a (sin x)/x type of signal with a main lobe and smaller side lobes. The nulls between the side lobes are located at the center frequency plus or minus N times 1.023 MHz, where N is any integer. The occupied bandwidth of this signal (47 CFR 2.202), computed by direct numerical integration of a mathematically perfect unfiltered signal, is approximately 21.2 MHz. The actual C/A-code signal transmitted by the GPS satellites is transmitted through the same filter used for the P-code signal (described below). The occupied bandwidth of the resulting signal is slightly narrower at approximately 20.5 MHz.

The C/A code signal is further modulated by stream of navigation data bits transmitted at 50 bps. This data bit stream is synchronous with the C/A code so that exactly 20 repetitions of the C/A code are transmitted during each data bit. The data bits are transmitted by inverting the C/A code during data bits equal to “one”.

Although the “necessary bandwidth” (47 CFR 2.202) is part of the “emission designator” (47 CFR 2.201), the method for calculating the necessary bandwidth of the C/A code signal is not obvious from the regulation. Using the occupied bandwidth rather than the necessary bandwidth, the emission designator for the C/A code signal as transmitted by a GPS satellite would be 21M2G1D or perhaps 20M5G1D.

P-Code

The P-code signal is a spread-spectrum signal produced by binary phase shift keying (BPSK) modulation of a carrier signal by a digital bit stream known as the P-code. The P-code is an extremely long pseudo-random bit stream generated by combining the outputs of four feedback shift registers. The P-code repeats once per week because the generator is reset once per week. Further details of the P-code generator are available in ICD-200.

The P-code is transmitted using BPSK at a rate of 10.23 Mbps. Again, this generates a (sin x)/x type of signal with a main lobe and smaller side lobes. The nulls between the side lobes are located at the center frequency plus or minus N times 10.23 MHz, where N is any integer. The GPS satellites filter this signal so that only the main lobe is transmitted. The main lobe is 20.46 MHz wide. Because no filter is perfect, the frequency allocation for each GPS frequency is a total of 24 MHz wide including guard bands. The actual filter characteristic for the GPS satellites is not specified in ICD-200. Reasonable guesses for the occupied bandwidth of the actual transmitted P-code signal range from 20.5MHz to just under 24 MHz.

Split Spectrum

The GPS user community has proposed a signal format for use by pseudolites which combines features of C/A-code and P-code. This new format is known as “split-spectrum” or occasionally “G-prime mode.” The goal of the split-spectrum format is to minimize interference with the existing GPS satellite C/A-code and P-code signals. It does this by moving the signal power of a standard C/A-code signal into the nulls of the P-code main lobe at 10.23 MHz above and below the carrier frequency. This can be accomplished in the analog domain by using the C/A-code bit stream to modulate a 10.23 MHz sine wave and then using this composite signal to modulate the main carrier. Alternatively, the split-spectrum signal can be generated in the digital domain by combining the C/A-code bit stream with a 10.23 MHz square wave and then modulating the main carrier with this composite digital signal. The split-spectrum signal must be filtered with a bandwidth of at least 2.2 times 10.23 MHz, or 22.51 MHz, to preserve both main lobes of the split C/A-code signal. Again using the occupied bandwidth, the emission designator for a split-spectrum signal would be 22M5G1D.

The GPS user community has proposed a modification of the split-spectrum signal for use in certain applications. This modified signal consists of either the high-frequency lobe or the low-frequency lobe of the split-spectrum signal, but not both together. While such a signal could be considered as simply a C/A-code signal transmitted on a frequency 10.23 MHz higher or lower than the nominal center frequency, the GPS user community prefers to think of such a signal as being simply one-half of the more complete split-spectrum signal transmitted at the nominal center frequency.

Pulsed Transmissions

The GPS user community has long proposed that pseudolites transmit in short pulses, to minimize potential interference with the GPS satellite signals. Several pulse patterns have been proposed, but the optimum pulse pattern or format has never been identified. Much experimentation remains to be done.

The previously proposed pulse patterns include:
- Even spacing, 1 kHz pulse rate
- Even spacing, 3 kHz pulse rate
- Pseudo-random spacing, 1 kHz average pulse rate ("RTCM–104" pattern)
- Pseudo-random spacing, 2 kHz average pulse rate ("RTCA SC–159" pattern)
- Pseudo-random spacing, 3 kHz average pulse rate

These pulse patterns (and others to be determined) will be tested with pulse widths which produce average pulse duty cycles from one percent to fifteen percent.