3. GENERAL MEASUREMENT METHODOLOGIES

In principle, interference testing is straightforward. To wit, an interference test is performed by applying a "foreign" signal to an operating receiver while monitoring receiver performance. Any degradation in receiver performance, beyond what can be expected under normal operating conditions, is then attributed to the interference.

Thus, for our tests, the interfering UWB signal must be fully characterized, GPS receiver operation must be defined in a way that can be measured, and receiver performance must be monitored in a way that is meaningful with respect to its intended application. This section explains these measurement methodologies.

3.1 Interference Characterization

In real life, UWB and GPS signals are radiated through space and summed within the GPS receiver antenna. In the laboratory, it is easier to control power levels, outside interference, and measurement repeatability if the signals are conducted through cables and added with a power combiner.

However, if conducted signals are used, it is imperative that conducted and radiated signals are characterized and compared to insure that systematic errors are not introduced. Thus, as part of our testing methodology, spectra and waveforms of radiated and conducted UWB signals were measured and compared. The radiated UWB signal was transmitted within an anechoic chamber and received by a GPS receiver antenna while the conducted UWB signal was transmitted through a coaxial cable connected to a power combiner. Results of this comparison, given in Appendix A, show that differences between radiated and conducted UWB signals are negligible.

There are many different types of UWB signals. The one characteristic they all possess, however, is wide bandwidth. Band-limiting by the GPS receiver significantly alters the characteristics of an already diverse signal set. In the past, engineers have found that the amplitude statistics of the interfering signal have the most bearing on whether it will be benign or destructive to the performance of a victim receiver. Thus, as part of our testing methodology, the amplitude of the UWB signals was sampled and statistically analyzed. Two bandwidths were used, corresponding to the bandwidths of two classes of GPS receivers. Results of this test are provided in Appendix C.

3.2 Operational Testing

An operating GPS receiver must be frequency-locked onto the modulated and Doppler shifted carrier frequency, delay-locked onto the C/A code, and phase-locked onto the message. Thus, at a bare minimum, an operating GPS receiver is frequency-, delay-, and phase-locked to a GPS signal.

Two testing methodologies are used to measure the effect UWB interference has on receiver operation or locking. The break lock (BL) operational test determines the BL point defined to be the minimum amount of interference that causes a receiver to lose lock. The reacquisition time (RQT) operational test determines the amount of time it takes a receiver tracking a GPS signal to reacquire the signal after it has been momentarily removed.

The RQT test does not identify an "RQT point" as the BL test identifies a BL point. It is left to others to determine a reasonable RQT and corresponding RQT point for their application. Once this point is established, the BL and RQT operational tests bracket a region of GPS receiver performance degradation. The RQT point sets the lower bound where the interference begins to have a detrimental effect on the operation of the receiver. The BL point sets the upper bound where operation is impossible.

The BL point may differ significantly from receiver to receiver. For example, surveying receivers require flawless carrier phase-lock. General purpose navigation receivers, however, allow imperfect carrier phase-lock but demand stable C/A code delay-lock, and consequently are more tolerant toward some types of interference.

3.3 Observational Testing

An operating GPS receiver calculates user position through the measurement of GPS "observables." Performance degradation of an operating GPS receiver is commonly evaluated through its observables which include pseudorange, carrier phase, Doppler frequency-shift, clock-offset, signal-to-noise ratio, and carrier cycle-slippage. Observables can usually be obtained from the receiver, in real time, through a computer interface.

Various range estimates are computed from these observables, and errors in the range estimates are subsequently statistically analyzed to determine performance degradation. It is not our intent to use results of this analysis to establish precise range-error budgets. Rather, these statistics are intended to support other trends of UWB interference such as RQT degradation. In addition, range error statistics are useful for isolating performance degradation to C/A code delay-locking or carrier phase-locking functions.