Ultra Wideband Two-Way Time-of-Flight Distance Measurement Provides Sub-Centimeter Range Measurement Accuracy

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Wireless distance measurement technologies are an increasingly important technology. This is especially true where GPS is not available. Furthermore, high accuracy measurements are critical for in-building applications such as autonomous robotic navigation. In these cases, users are requiring ever greater levels of accuracy. This abstract describes how Ultra Wideband (UWB) Two-Way Time-of-Flight has been used to achieve sub-centimeter accuracy. These tests indicate that millimeter accuracy is also possible.

Two key factors enabled this accomplishment. First, since accuracy is proportional to RF bandwidth, the bandwidth was maximized by using UWB RF transmissions. These links provide over 1 GHz of bandwidth. Second, the received waveform was recorded with a resolution of 61ps. Such high resolution waveforms make it possible to develop a correlation-based indication of the time of the first arriving energy.

The accuracy of the technique was confirmed in the lab on a 4.5m linear displacement test apparatus and in the field using laser survey equipment. Both reference systems provided sub-centimeter accuracy. The results are tabulated below.

Linear Displacement (meters)	UWB Measurement (1 standard deviation) (mm)
0.5	8.6
1.0	6.4
1.5	6.5
2.0	5.8
2.5	9.5
3.0	4.2
3.5	9.0
4.0	13.6
4.5	4.8

Range (meters)	UWB Measurement (1 standard deviation) (mm)
40	4.6
80	2.2
120	13.5
160	4.6
200	3.5
240	2.5
280	1.9
320	1.8
360	3.5
400	2.1
500	3.1
550	3.0
600	4.4

Figure 1: Lab results with linear displacement reference (l) and field results with laser(r)

The paper will describe the test results and discuss obstacles which affect accuracy. These effects include: signal compression, operation in Fresnel nulls, robustness issues with algorithms, interference, distortions due to second order algorithmic side effects, proper calibration and bias elimination. It was also observed that range errors had a Gaussian distribution. Therefore averaging subsequent readings will improve system accuracy by the square root of the number of readings averaged.