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AntennAlign Alignment Tool Accuracy

- The AntennAlign Alignment Tool (AAT) uses three technologies for measuring antenna alignment
 - GPS subsystem for azimuth
 - Augmented with onboard gyroscope
 - Inclinometers/Accelerometers for Tilt and Roll
 - LASER Rangefinder for Height (AGL)

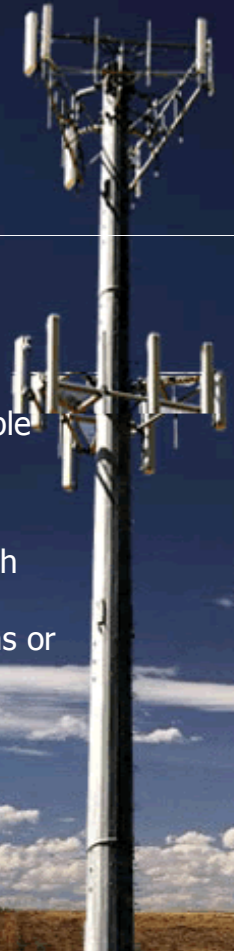




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Azimuth - GPS Subsystem

- The AntennAlign incorporates a GPS subsystem with the following specifications:
 - GPS Sensor Specifications
 - Receiver Type: L1, C/A code, with carrier phase smoothing
 - 12-channel, parallel tracking (10-channel when tracking SBAS)
 - SBAS Tracking: 2-channel, parallel tracking
 - Horizontal Accuracy: <60 cm 95% confidence (DGPS1)
 - Azimuth Accuracy: <0.3° RMS, < 1.0° R99.9
- Azimuth accuracy quantified
 - +/- .3 degrees RMS (63-68% probability)
 - +/- .53 degrees R95 (95% probability)
 - +/- 1.0 degrees R99.9 (99.9% probability) when AntennAlign Quality Index >90
- The AAT averages several measurements to minimize any single wild reading and can be used in multiple simple capture modes to capture more samples to raise the probability of a very accurate reading if desired.
- The AAT uses an embedded tilt sensor to minimize the time taken to acquire GPS for measuring azimuth
- The AAT has an embedded gyro that can be used when GPS azimuth is not available due to obstructions or interference

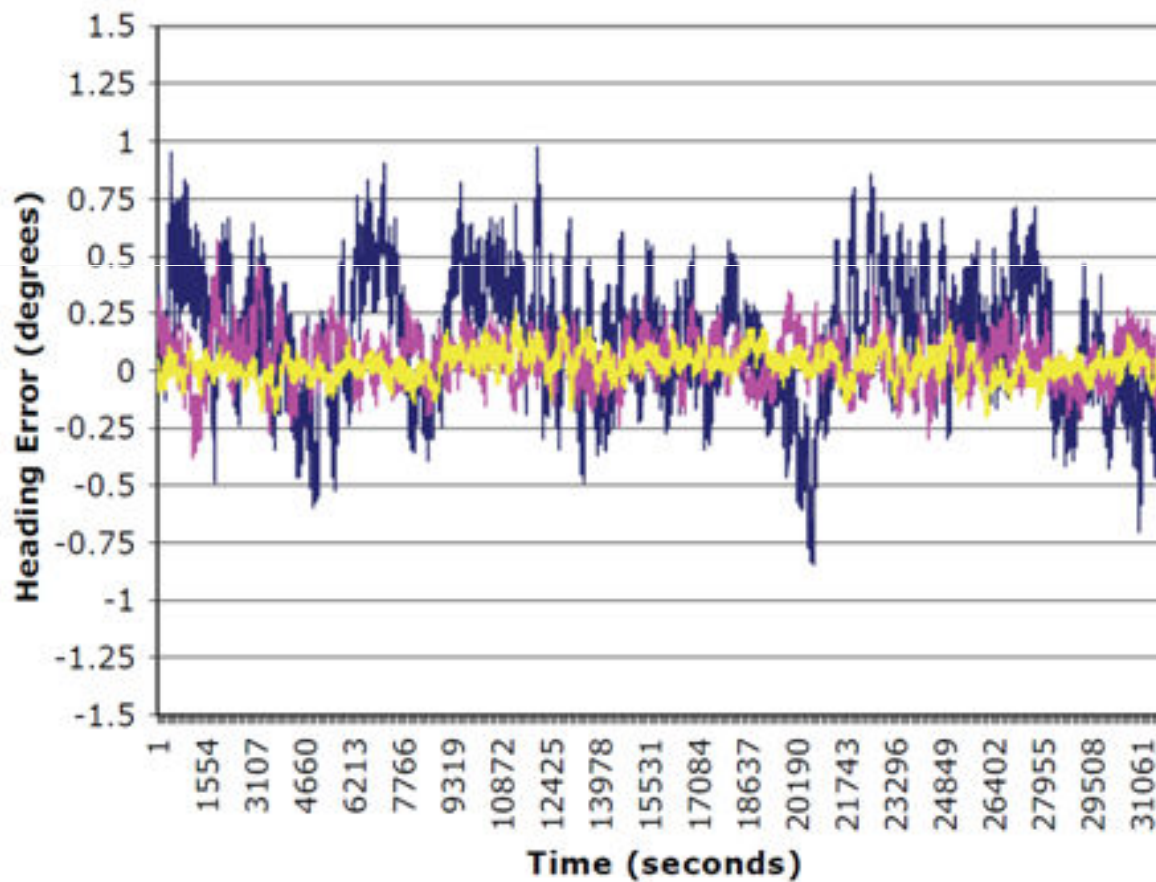




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GPS Subsystem Accuracy

The azimuth accuracy of the AAT is represented by the dark blue line in the graph



GPS Subsystem Accuracy (cont.)

- Obtaining azimuth near RF sources is difficult. GPS performance varies dramatically with the number of available satellites, their signal strength, the quality of the GPS signals, and the surrounding environment (multipath).
 - The available signal strength of GPS is typically 1/1,000,000 of the RF signal strength in the vicinity of a hot cell antenna.
 - GPS frequency is 1575.42 MHz. This is right in the middle of the cell bands (850MHz and 1900MHz) which makes receiving a GPS signal difficult due to RF interference due to high gain and harmonics
- To combat these issues, the AAT uses:
 - DoD GPS antennas with tight tolerance band pass filters and special amplifiers.
 - Used on missile ships to operate near high power communication equipment, radar, targeting systems.
 - Multiple types of RFI shielding
 - Optical grade wire mesh shielding (100 threads/in²)
 - EMI sheet noise absorbing materials on critical signal paths
 - Critical components are housed in complete brass shield
 - Housing panels are all shielded using wire oriented RFI resistant gasket material
 - Multiple options to give the user tools to work with in difficult environments
 - Hi/Lo multipath filter
 - Quality Indicator
 - Gyro capability
 - Control over GPS subsystem inside AAT

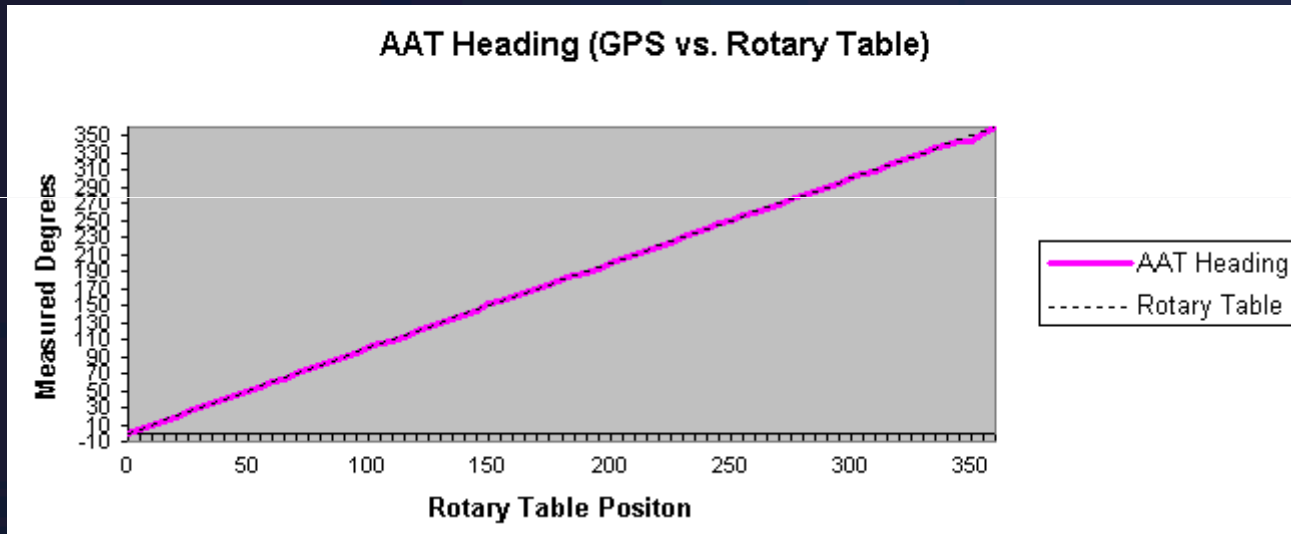




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Azimuth Accuracy Testing Results

Testing results excerpted from Sunsight specification SD 5003-1, ISSUE 4, THEORY, DESIGN AND TEST MEASUREMENT OF ANTENNALIGN ALIGNMENT TOOL ACCURACY (document available on request with active non-disclosure agreement)



The primary testing of the AAT azimuth system has been performed by finding true north using solar noon. The AAT was then rotated on a machinists rotary table to take measurements at 5 degree increments. Results are represented in the graph above.





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Tilt and Roll Subsystem Accuracy

- Measuring device chosen
 - Range: +/- 60 degrees
 - Resolution: .001 degree
 - Linearity:
 - 0 to 10 degrees is +/- 0.1 degree
 - 10 to 45 degrees is +/-1% of Angle
 - 45 to 60 degrees is Monotonic
 - Null Repeatability: .05 degrees
 - Cross Axis Error: <1% to 45 degrees
 - Typical Accuracy: +/- 0.25% FSO Temperature:
 - Operating temperature -40 to +85 degrees Celsius
 - Tc of Null: 0.008 arc-degrees per degree Celsius
 - Tc of Scale: 0.1% per degree Celsius
 - Time Constant: 0.3 Sec Freq Response: 0.5 Hertz





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Tilt and Roll Accuracy (cont.)

Excerpts from Sunsight specification SD 5003-4,, THEORY, DESIGN AND TEST MEASUREMENT OF ANTENNALIGN ALIGNMENT TOOL ACCURACY:

The AAT tilt and roll accuracy are much more difficult to measure in the field environment due to tower movement, mounting alignment, etc. Tilt and Roll accuracy has been tested in laboratory environments using a standard angle measuring scheme incorporating a granite surface plate, sine plate, gauge blocks, and a machinist level. The following picture shows the accuracy setup for testing and calibrating tilt and roll.





Tilt and Roll Accuracy (cont.)

- The specifications of the measuring environment were:
 - Granite Surface Plate (GGG-P-463C certification).000005 inch
 - Gauge Blocks (Grade AS-2)+ .000004, -.000002 inch
 - Sine Plate .003 inch
 - Machinist Level .0005 inch

This measurement station described above was used to certify the accuracy of the tilt and roll characteristics of an AAT with the following results.

**All values in degrees, measurements taken at approximately 80F degrees, 75% humidity

Tilt				
Standard	Measured		Delta	
1.433	1.48		-0.047	
2.866	2.93		-0.064	
5.739	5.82		-0.081	
11.537	11.56		-0.023	
17.458	17.38		0.078	
23.578	23.48		0.098	
1.433	-1.46		-0.027	
2.866	-2.9		-0.034	
5.739	-5.8		-0.061	
11.537	-11.52		0.017	
17.458	-17.43		0.028	
23.578	-23.54		0.038	
			0.098	Max Positive Deviation
			-0.081	Max Negative Deviation





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Tilt and Roll Accuracy (cont.)

⊕ **All values in degrees, measurements taken at approximately 80F degrees, 76% humidity

Roll			
Standard	Measured	Delta	
1.433	1.52	-0.087	
2.866	2.94	-0.074	
5.739	5.77	-0.031	
11.537	11.59	-0.053	
17.458	17.5	-0.042	
23.578	23.66	-0.082	
-1.433	1.4	-0.033	
-2.866	2.86	-0.006	
-5.739	5.65	-0.089	
-11.537	11.51	-0.027	
-17.458	17.52	0.062	
-23.578	23.53	-0.048	
		0.062	Max Positive Deviation
		-0.089	Max Negative Deviation

The conclusion of this testing is that the AAT meets the published specification of +/- .25 degrees of accuracy for tilt and roll measurements.

Sunsight conservatively chose +/- .25 degrees for a tilt and roll specification to assure meeting specifications in all types of environments.



Height Measurement - LASER Rangefinder

Display: In-scope LCD

– Units: Feet, Yards, Meters, and Degrees

Measurement Range:

- Distance: 0 to 3280 ft (1000 m) typical; 6560 ft (2000 m) max to reflective target
- Inclination: +/- 90 degrees
- Accuracy:
 - Distance: +/- 1 ft (+/- 30 cm), high quality target
+/- 1 yd (+/- 1 m), low quality target
 - Inclination: +/- 0.25 degrees

– Measurement Modes / Features:

– Horizontal distance, vertical distance, slope distance and inclination measurements

