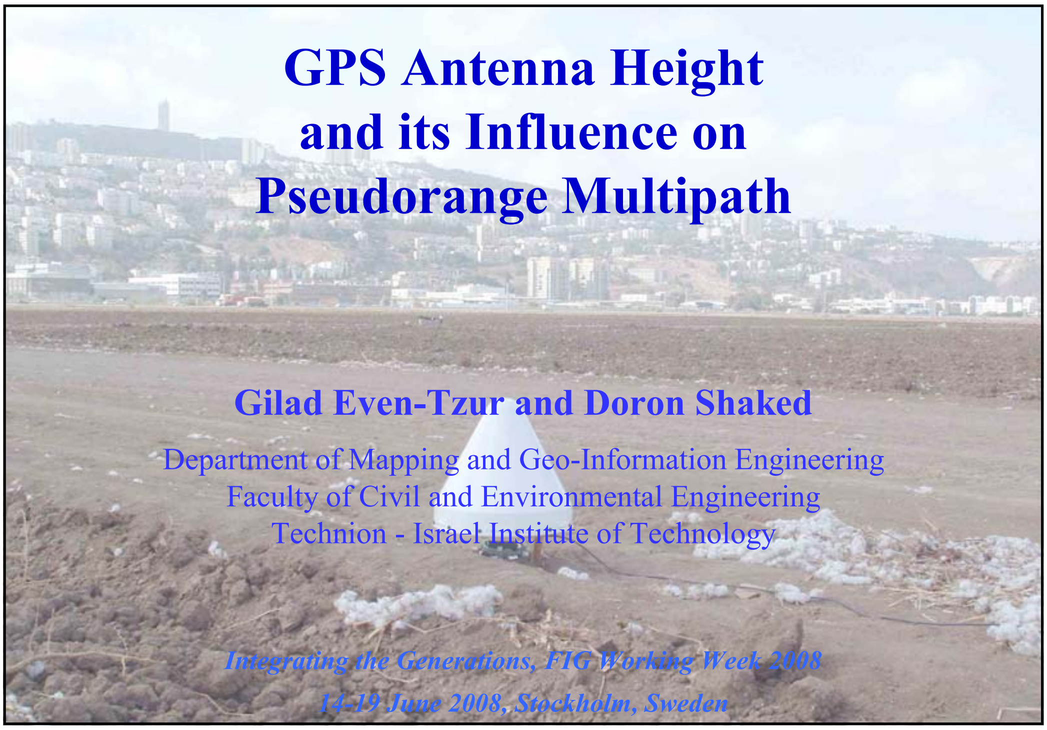

GPS Antenna Height and its Influence on Pseudorange Multipath

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Some Facts about Multipath

Multipath error is a dominant error source connected with GPS positioning.

Positioning the antenna away from nearby objects can minimize the multipath effect.

Multipath arising from below the antenna can be reduced by using ground planes.

Some Facts about Multipath

Multipath distorts the C/A-code and P-code modulations, as well as the carrier phase observations.

Pseudorange multipath behaves similarly to that of carrier phases, except that the variation is larger by several orders of magnitude.

Some Facts about Multipath

The impact of multipath signals on the pseudorange and carrier phase observation is dependant upon a variety of factors:

► the distance of the reflecting object from the antenna.
► the antenna attenuation characteristics.
► the capacity of the receiver to mitigate multipath.

Research Motivation

Permanent GNSS sites are usually located on open field. Therefore, the ground is the only source of multipath.

We would like to examine the effects of the antenna height on pseudorange multipath in a variety of GPS antenna types.

The Multipath Computation

$$MP_{P1} = P1 - 4.0915\Phi_1 + 3.0915\Phi_2 + \left[4.0915(\lambda_1 N_1 + MP_{\Phi_1}) - 3.0915(\lambda_2 N_2 + MP_{\Phi_2})\right]$$

$$MP_{P2} = P2 - 5.0915\Phi_1 + 4.0915\Phi_2 + \left[5.0915(\lambda_1 N_1 + MP_{\Phi_1}) - 4.0915(\lambda_2 N_2 + MP_{\Phi_2})\right]$$

MP_{P_1}, MP_{P_2}	- Pseudorange multipath (+ receiver noise)
P1, P2	- Pseudorange data
Φ_1, Φ_2	- Carrier phase data
N_1, N_2	- Integer ambiguity
λ_1, λ_2	- Carrier phase wavelength
MP_{Φ_1}, MP_{Φ_2}	- Carrier phase multipath

The Multipath Computation

$$MP_{P1} = P1 - 4.0915\Phi_1 + 3.0915\Phi_2 + \left[4.0915(\lambda_1 N_1 + \cancel{MP_{\Phi_1}}) - 3.0915(\lambda_2 N_2 + \cancel{MP_{\Phi_2}})\right]$$

$$MP_{P2} = P2 - 5.0915\Phi_1 + 4.0915\Phi_2 + \left[5.0915(\lambda_1 N_1 + \cancel{MP_{\Phi_1}}) - 4.0915(\lambda_2 N_2 + \cancel{MP_{\Phi_2}})\right]$$

The impact of the multipath on the carrier phase is insignificant in comparison to the multipath pseudorange, and can therefore be ignored.

The Multipath Computation

$$MP_{P1} = P1 - 4.0915\Phi_1 + 3.0915\Phi_2 + \left[4.0915(\lambda_1 N_1 + \cancel{MP_{\Phi_1}}) - 3.0915(\lambda_2 N_2 + \cancel{MP_{\Phi_2}})\right]$$

$$MP_{P2} = P2 - 5.0915\Phi_1 + 4.0915\Phi_2 + \left[5.0915(\lambda_1 N_1 + \cancel{MP_{\Phi_1}}) - 4.0915(\lambda_2 N_2 + \cancel{MP_{\Phi_2}})\right]$$

Constant biases, if there is no cycle slip.

The results are the pseudorange multipath, which can be seen as a series of residuals with metric unit values.

Comparison of Pseudorange Multipath

When the g… …the
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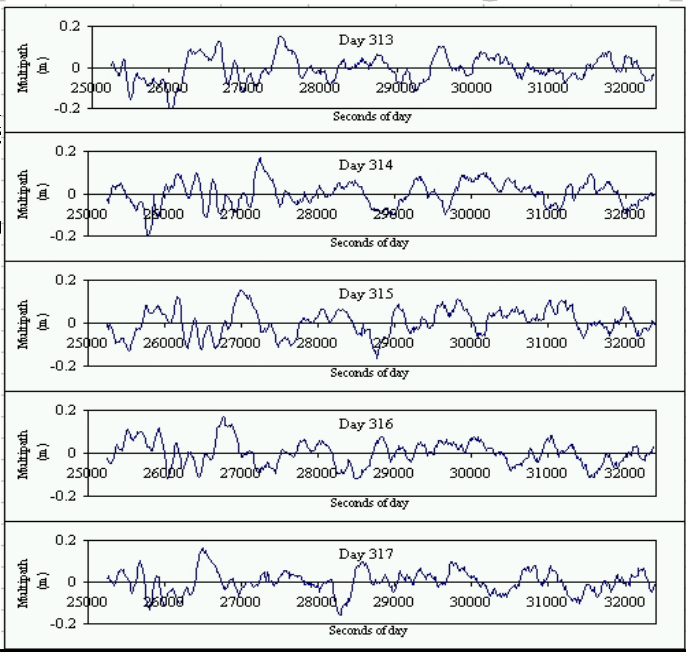
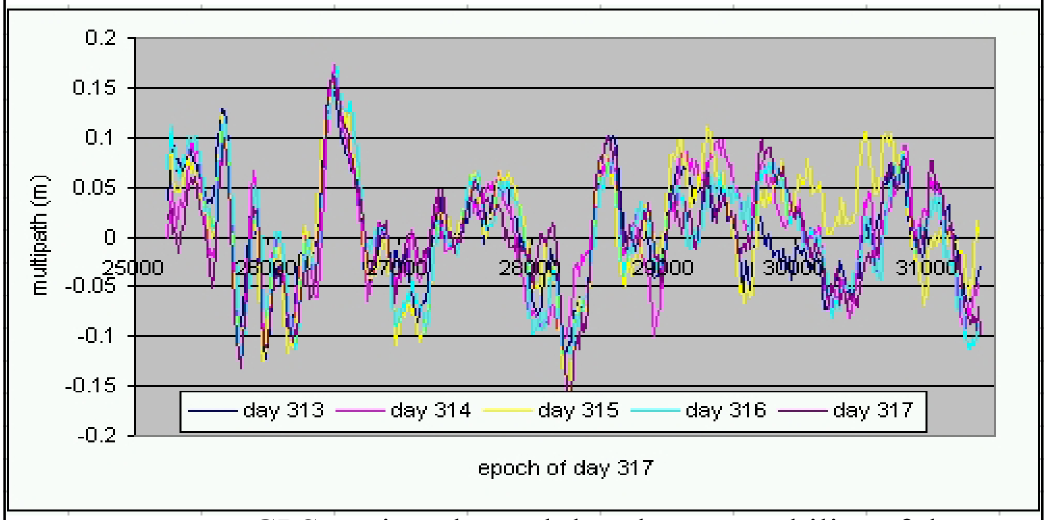


Comparison of Pseudorange Multipath



permanent GPS station showed that the repeatability of the pseudorange multipath is at the level of 75%-80% due to changes in uncorrelated noises between days.

Experiment Description

► The same antennas was set in three successive days (GPS day 301 to day 303 in 2007) at the same time over the same point, and each day the antenna phase center was positioned at different heights –

about 1.60m, 0.9m and 0.2m.

► The selected station was located on a flat open field.

► Three types of GPS antennas were examined:

* Ashtech DM Choke Ring
* Ashtech Geodetic L1/L2
* AeroAntenna Geodetic L1/L2

► Three Ashtech Z-Surveyor receivers were used in all the experiments.

► The observations (C1, P1, P2, L1 and L2) were measured during the same time every day.

The Examined Antennas

• ASH DM Choke Ring - a high cost antenna, designed to mitigate multipath efficiently, standard in permanent GPS sites.

• ASH Geodetic L1/L2 – microstrip patch antenna, with a medium size ground plane, typically used for geodetic surveying.

• AER Geodetic L1/L2 – geodetic antenna with a small sized ground plane, typically used for RTK surveying.

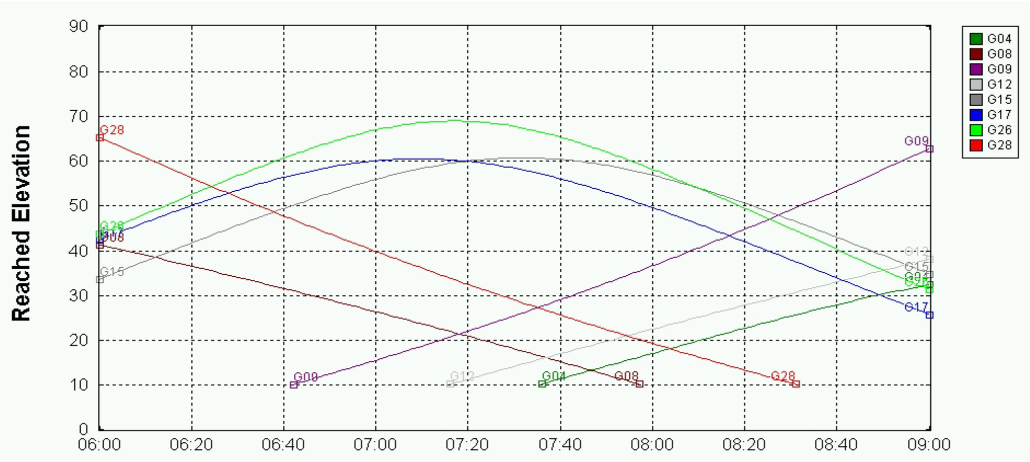
The Field Test

GPS day 301(2007), three GPS antenna types set up on a flat open field at a height of approx 1.6m.

The Data Analysis Process

- ► The analysis was carried out on RINEX files using TEQC software.
- ► Three types of pseudorange multipath were calculated: MP_{C1}, MP_{P1} and MP_{P2}, for each of the satellites in view.
- ► Day 303 was used as basis for common time scale.
- ► The common time was 152 minutes.
- ► 8 satellites were used.

The satellites elevation angels:



The Data Analysis Process

Since the pseudorange multipath is a series of residuals, the total effect of pseudorange multipath can present by using the quadratic form:

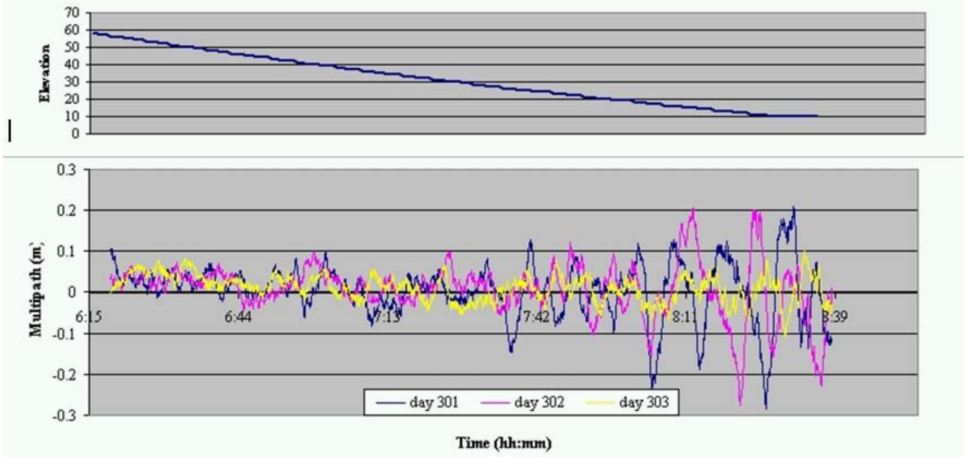
$$\varphi = \sum (MP_{P1})^2$$

As φ becomes smaller the effect of the pseudorange multipath on the code observations is reduced, and vice versa.

Therefore, testing the quadratic form of the same satellite in the same time on different days enables a numerical comparison of the pseudorange multipath effects.

The Results

Pseudorange C/A code multipath on PRN28 in common time scale – Ashtech DM Choke Ring.

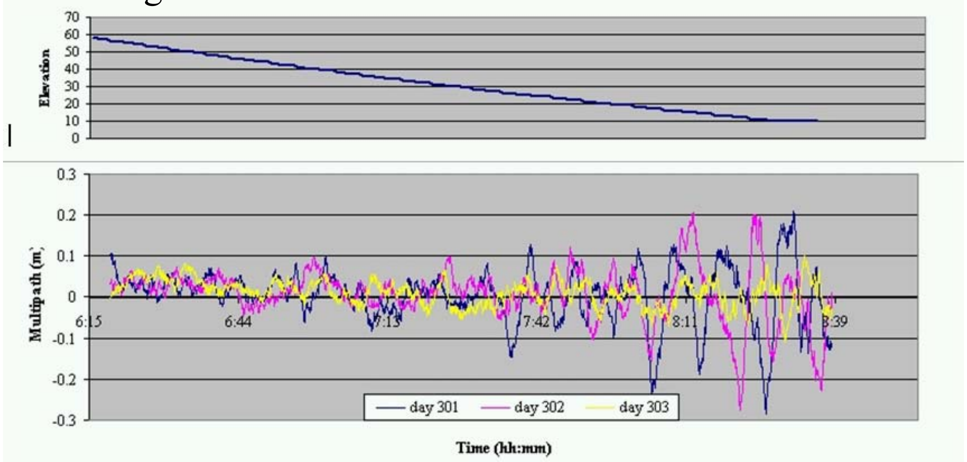


The antenna heights: 1.56m (at day 301), 0.97m (302) and 0.20m (303).

The Results

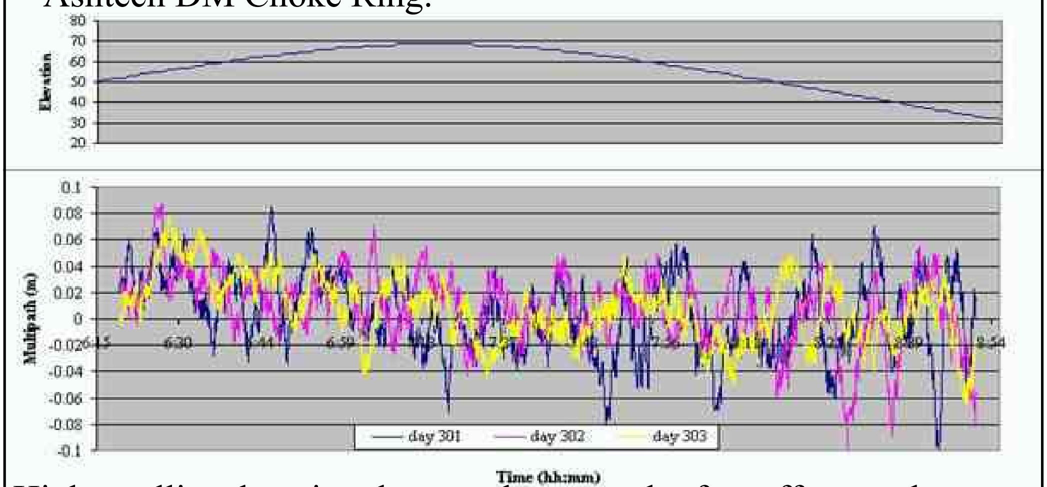
► Multipath effects are highest at lower elevations and lowest at higher elevation.

► Pseudorange multipath residuals grow smaller as the GPS antenna height decreases.



The Results

Pseudorange C/A code multipath on PRN26 in common time scale – Ashtech DM Choke Ring.



High satellite elevation does not have much of an effect on the multipath, even at different antenna height set ups.

The Results

► The quadratic form of the multipath residuals on the C/A code for eight GPS satellites in common time scale, in square meter units.

		GPS day									
PRN		301	302	303	301	302	303	301	302	303	common time
	height	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	
	Ant.	Ash. DM Choke ring			Ash. Geodetic L1/L2			Aer. Geodetic L1/L2			[minutes]
4	C/A code	3.64	2.99	1.10	3.74	3.10	0.90	16.36	8.45	1.41	79
8		10.18	2.41	1.77	6.44	6.55	1.72	13.10	5.89	2.13	99
9		8.60	4.14	1.92	8.29	6.67	1.16	14.72	9.39	2.44	123
12		4.05	2.69	1.47	11.10	7.53	1.61	17.26	6.54	1.54	92
15		1.41	1.23	1.36	3.04	3.18	1.88	2.42	2.19	0.88	149
17		1.22	1.58	1.25	2.77	2.25	1.41	4.95	2.52	1.45	152
26		1.70	1.45	1.26	3.40	3.44	1.76	5.32	2.94	1.16	152
28		7.58	7.18	1.94	11.73	11.67	2.30	18.62	9.47	1.83	139

The Results

► There is a dramatic reduction of φ between higher and lower antenna set ups for PRN28.

		GPS day									
PRN		301	302	303	301	302	303	301	302	303	common time
	height	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	
	Ant.	Ash. DM Choke ring			Ash. Geodetic L1/L2			Aer. Geodetic L1/L2			[minutes]
4	C/A code	3.64	2.99	1.10	3.74	3.10	0.90	16.36	8.45	1.41	79
8		10.18	2.41	1.77	6.44	6.55	1.72	13.10	5.89	2.13	99
9		8.60	4.14	1.92	8.29	6.67	1.16	14.72	9.39	2.44	123
12		4.05	2.69	1.47	11.10	7.53	1.61	17.26	6.54	1.54	92
15		1.41	1.23	1.36	3.04	3.18	1.88	2.42	2.19	0.88	149
17		1.22	1.58	1.25	2.77	2.25	1.41	4.95	2.52	1.45	152
26		1.70	1.45	1.26	3.40	3.44	1.76	5.32	2.94	1.16	152
28		7.58	7.18	1.94	11.73	11.67	2.30	18.62	9.47	1.83	139

The Results

► There is a minor reduction of φ between higher and lower antenna set ups for PRN26.

		GPS day									
PRN		301	302	303	301	302	303	301	302	303	common time
	height	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	
	Ant.	Ash. DM Choke ring			Ash. Geodetic L1/L2			Aer. Geodetic L1/L2			[minutes]
4	C/A code	3.64	2.99	1.10	3.74	3.10	0.90	16.36	8.45	1.41	79
8		10.18	2.41	1.77	6.44	6.55	1.72	13.10	5.89	2.13	99
9		8.60	4.14	1.92	8.29	6.67	1.16	14.72	9.39	2.44	123
12		4.05	2.69	1.47	11.10	7.53	1.61	17.26	6.54	1.54	92
15		1.41	1.23	1.36	3.04	3.18	1.88	2.42	2.19	0.88	149
17		1.22	1.58	1.25	2.77	2.25	1.41	4.95	2.52	1.45	152
26		1.70	1.45	1.26	3.40	3.44	1.76	5.32	2.94	1.16	152
28		7.58	7.18	1.94	11.73	11.67	2.30	18.62	9.47	1.83	139

The Results

► The table shows the clear influence of GPS antenna height on pseudorange multipath residuals without correlation to the antenna type. The multipath residuals level grows smaller when the antenna height is lower.

		GPS day									
PRN		301	302	303	301	302	303	301	302	303	common time
	height	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	
	Ant.	Ash. DM Choke ring			Ash. Geodetic L1/L2			Aer. Geodetic L1/L2			[minutes]
4	C/A code	3.64	2.99	1.10	3.74	3.10	0.90	16.36	8.45	1.41	79
8		10.18	2.41	1.77	6.44	6.55	1.72	13.10	5.89	2.13	99
9		8.60	4.14	1.92	8.29	6.67	1.16	14.72	9.39	2.44	123
12		4.05	2.69	1.47	11.10	7.53	1.61	17.26	6.54	1.54	92
15		1.41	1.23	1.36	3.04	3.18	1.88	2.42	2.19	0.88	149
17		1.22	1.58	1.25	2.77	2.25	1.41	4.95	2.52	1.45	152
26		1.70	1.45	1.26	3.40	3.44	1.76	5.32	2.94	1.16	152
28		7.58	7.18	1.94	11.73	11.67	2.30	18.62	9.47	1.83	139

The Results

► As expected the choke ring antenna had the best performance. It mitigated multipath signals reflected from the ground in a better way, relative to the two other antennas.

		GPS day									
PRN		301	302	303	301	302	303	301	302	303	common time
	height	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	
	Ant.	Ash. DM Choke ring			Ash. Geodetic L1/L2			Aer. Geodetic L1/L2			[minutes]
4	C/A code	3.64	2.99	1.10	3.74	3.10	0.90	16.36	8.45	1.41	79
8		10.18	2.41	1.77	6.44	6.55	1.72	13.10	5.89	2.13	99
9		8.60	4.14	1.92	8.29	6.67	1.16	14.72	9.39	2.44	123
12		4.05	2.69	1.47	11.10	7.53	1.61	17.26	6.54	1.54	92
15		1.41	1.23	1.36	3.04	3.18	1.88	2.42	2.19	0.88	149
17		1.22	1.58	1.25	2.77	2.25	1.41	4.95	2.52	1.45	152
26		1.70	1.45	1.26	3.40	3.44	1.76	5.32	2.94	1.16	152
28		7.58	7.18	1.94	11.73	11.67	2.30	18.62	9.47	1.83	139

The Results

► For high and medium antenna heights the RTK antenna had the poorest performance.

PRN		GPS day									common time [minutes]
		301	302	303	301	302	303	301	302	303	
	height	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	
	Ant.	Ash. DM Choke ring			Ash. Geodetic L1/L2			Aer. Geodetic L1/L2			
4	C/A code	3.64	2.99	1.10	3.74	3.10	0.90	16.36	8.45	1.41	79
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17		1.22	1.58	1.25	2.77	2.25	1.41	4.95	2.52	1.45	152
26		1.70	1.45	1.26	3.40	3.44	1.76	5.32	2.94	1.16	152
28		7.58	7.18	1.94	11.73	11.67	2.30	18.62	9.47	1.83	139

The Results

► For the low antenna height the RTK antenna performance, surprisingly, was equal to that of the choke ring and geodetic antennas.

PRN		GPS day									common time [minutes]
		301	302	303	301	302	303	301	302	303	
	height	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	1.6m	0.9m	0.2m	
	Ant.	Ash. DM Choke ring			Ash. Geodetic L1/L2			Aer. Geodetic L1/L2			
4	C/A code	3.64	2.99	1.10	3.74	3.10	0.90	16.36	8.45	1.41	79
8		10.18	2.41	1.77	6.44	6.55	1.72	13.10	5.89	2.13	99
9		8.60	4.14	1.92	8.29	6.67	1.16	14.72	9.39	2.44	123
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15		1.41	1.23	1.36	3.04	3.18	1.88	2.42	2.19	0.88	149
17		1.22	1.58	1.25	2.77	2.25	1.41	4.95	2.52	1.45	152
26		1.70	1.45	1.26	3.40	3.44	1.76	5.32	2.94	1.16	152
28		7.58	7.18	1.94	11.73	11.67	2.30	18.62	9.47	1.83	139

Conclusions

► The clear influence of GPS antenna height on the pseudorange multipath residuals, with no correlation to the antenna type was shown.

► For all codes, the multipath residuals level grows smaller as the antenna height decreased.

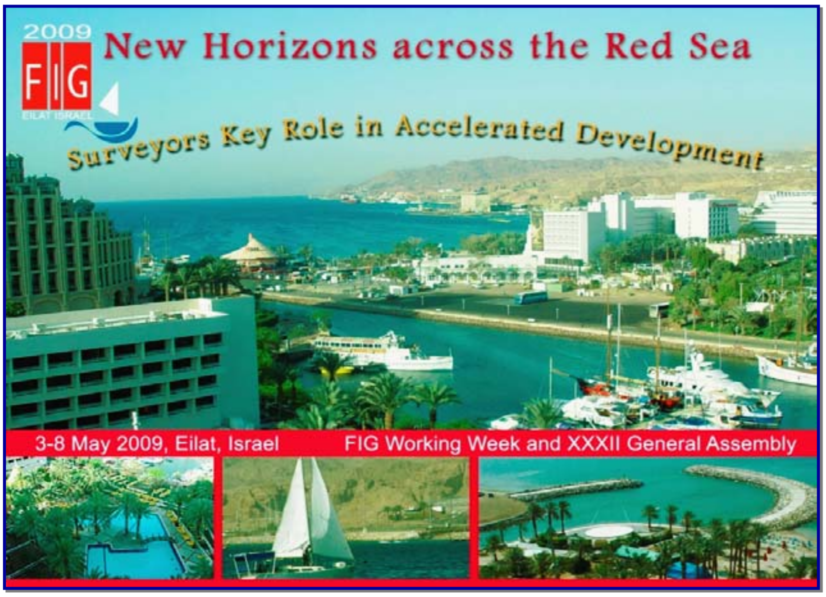
► The choke ring antenna had the best performance in mitigating multipath signals reflected from the ground.

► For high and medium antenna heights, the RTK antenna had the worse performance among the antennas examined.

► For the lower antenna height the RTK antenna performance equaled that of the choke ring and geodetic antennas.

Conclusions

► The data obtained in this research proves that the optimal height for positioning the GPS antenna in order to reduce pseudorange multipath is at ground level.



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