Mitigation of Signal Diffraction Effects on Precise GPS-Positioning

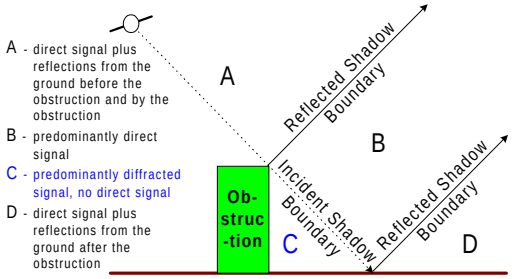
Lambert Wanninger, Volker Frevert, Steffen Wildt
Geodetic Institute, Dresden University of Technology, D-01062 Dresden, Germany
Lambert.Wanninger@mailbox.tu-dresden.de

Signal diffraction is a common error source in precise GPS positioning if obstructions exist above the antenna horizon. It occurs whenever the direct signal is obstructed but nevertheless a diffracted signal is received and processed. The longer propagation time of a diffracted signal causes carrier phase errors of up to several cm. A common characteristic of all diffracted signals is their weak signal power as compared to a direct signal received under the same elevation angle.

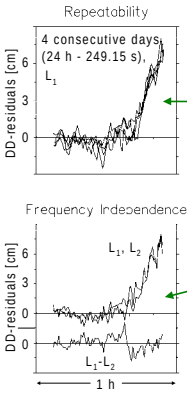
In the case of Trimble GPS-receivers, the signal strength is given as SNR (signal-to-noise values of the L_1 and L_2 phase observations) in arbitrary, i.e. Trimble-specific, units. In order to be able to process these secondary observables, we extended our post-processing software Wa-Soft:

... to include Trimble-SNR values in the RINEX observation files according to RINEX version 2.1,

... to include weighting functions which are based on SNR values.

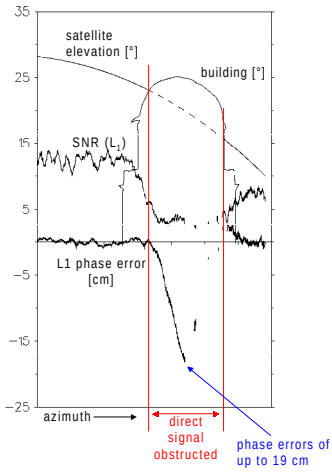


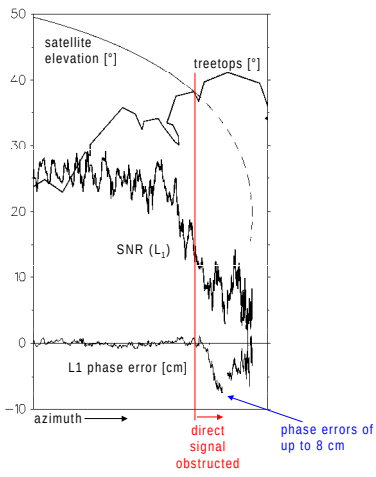
Comparison: Diffraction Effects, Multipath Effects



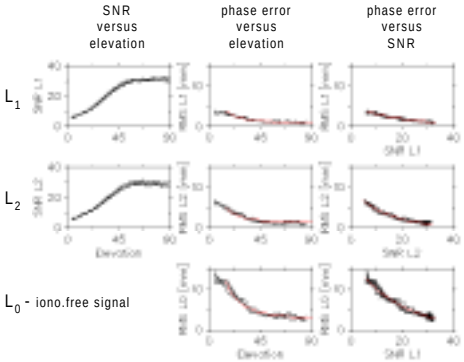
	Diffraction Effects	Multipath Effects
Common Features	• depends on local environment of receiving antenna, • repeats with identical satellite constellation and unchanged environment, • no mitigation by relative positioning, • the effect on coordinate estimation is reduced with increase of observation time (static observations), • in kinematic mode rapid changes of the local environment and thus rapid changes of diffraction effects: mitigation by filtering.	
Differences	• no line-of-sight signal, only diffracted signal received, • independent of signal frequency: geometry-free linear combination not affected, • maximum errors: in the order of decimeters, • signal strength reduced.	• superposition of direct and reflected (indirect) signals, • frequency-dependent: detection in geometry-free linear combination, • maximum errors: 4.8 cm L1, 6.1 cm L2, 21.4 cm iono-spheric-free combination, • fluctuating signal strength

Examples of diffraction effects on phase observations and signal strength





Analysis of Trimble phase data / Weighting functions



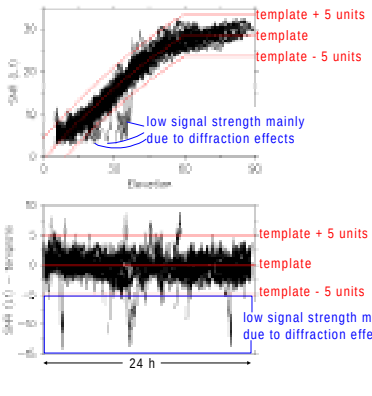
Elevation-dependence of Trimble-SNR-values:

Trimble 4000 SSE / 4000 SSi / 4700 / 4800 - receivers: SNR given in arbitrary units (receiver-dependent)

template(el) = $a_0 + a_1 * el + a_2 * el^2$ for 0° < el < 60°
$a_0 + a_1 * 60 + a_2 * 60^2$ for el > 60 °

iterative calculation with elimination of SNR-values < template - 5 units,

individual templates for each receiver-antenna pair: differences up to 10 units

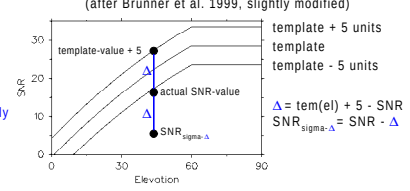


weighting functions
(best fitting functions shown in red):

elevation-dependent weighting:
$w(e) = \sin^2(e)$
for e > 10 deg

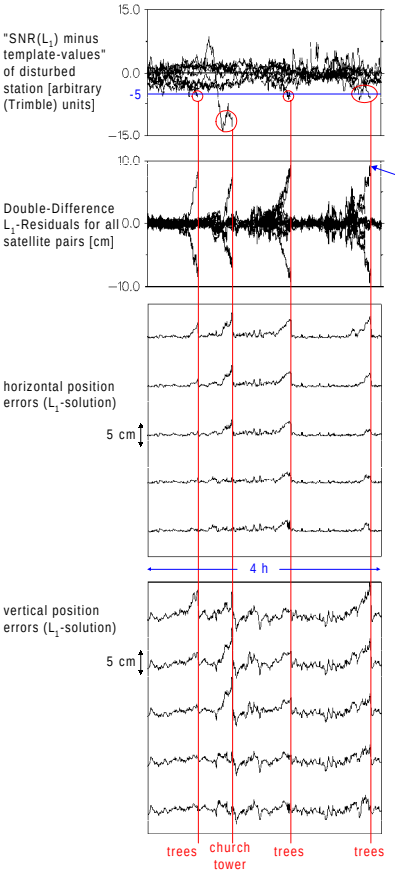
SNR-dependent weighting:
$w(SNR) = e^{SNR / A}$,
with $A(L_1) = 10$,
$A(L_2) = 6$,
$A(L_0) = 9$

sigma-Δ weighting: SNR-dependent weighting using SNR
(after Brunner et al. 1999, slightly modified)



Kinematic Processing of a Static Baseline

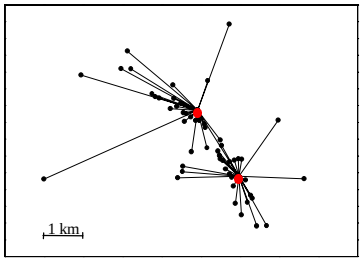
baseline length 3 km, one station affected by signal diffraction



Algorithm	RMS [cm]	
equal weights	1.3	
elevation-dependent weighting	1.1	35 % improve-ment
SNR-dependent weighting	0.9	
sigma-Δ weighting	0.7	
elimination of obs. with SNR < template-5, sigma-Δ weighting	0.7	
equal weights	1.5	
elevation-dependent weighting	1.4	40 % improve-ment
SNR-dependent weighting	1.3	
sigma-Δ weighting	0.9	
elimination of obs. with SNR < template-5, sigma-Δ weighting	0.8	

Rapid Static Positioning

network of 55 stations, 5 km x 6 km , two independent determinations, session lengths 10 minutes with minimum of 5 SVs, two permanent stations, rural area: signal obstructions by trees, buildings etc.



Algorithm	all 55 stations		11 stations with diffraction effects	
	horizontal	vertical	horizontal	vertical
equal weights	1.6	2.2	2.4	1.9
elevation-dependent weighting	1.3	1.9	2.1	2.1
SNR-dependent weighting	1.2	1.8	1.9	2.0
sigma-Δ weighting	1.0	1.6	1.4	1.7
sigma-Δ weighting + cleaning	0.9	1.5	1.3	1.6

20 ... 40 % improve-ment

RMS of coordinate differences [cm] between two independent network determinations.

cleaning - elimination of those 5 % of observations which cause the largest double-difference residuals (applicable to static observations only).

Results and Conclusions:

Phase errors due to signal diffraction can reach several cm. Most diffraction events are detectable in the signal-to-noise (SNR) values, if the elevation-dependence of SNR values are taken into account.

A slightly modified sigma-Δ weighting algorithm (after Brunner et. al 1999) improves kinematic and rapid static positioning results by 20 to 40 %.

Kinematic positioning can be further improved by elimination of those observations whose SNR values indicate large diffraction effects. Rapid static results gain by elimination of those 5 % of observations which cause the largest double-difference residuals.

Presented at the XXII. General Assembly of the IUGG, Birmingham 1999