TRIMBLE EVEREST PLUS MULTIPATH MITIGATION TECHNOLOGY

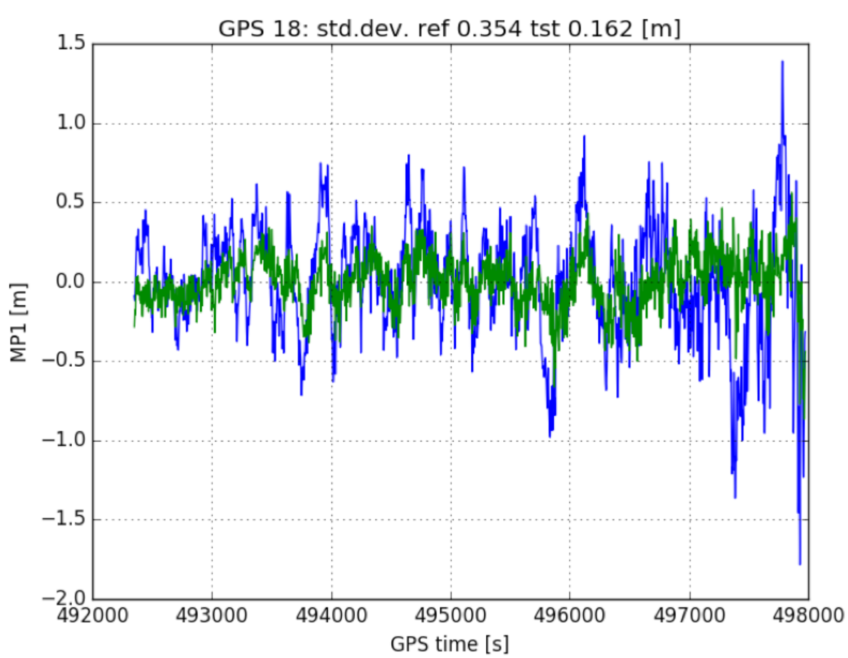
A dominant error source on satellite measurements is caused by a phenomenon known as multipath. This is where a signal reflection is superimposed on the desired direct signal, causing distortion. Reflective surfaces for GNSS signals are all around us, and include: metallic surfaces such as vehicles, buildings, water, trees, fences and walls. In the mid-1990s, Trimble introduced the patented Everest™ multipath rejection technology based on advanced digital signal processing. Within the satellite signal tracking loops, the reflected multipath signals were processed and ultimately rejected. This allowed sub-meter DGPS positioning and faster more reliable RTK initializations.

With the introduction of Maxwell™ 7 Technology, Trimble has significantly improved the multipath mitigation performance. This patent pending technique is known as Everest Plus and has several components contributing to the resulting improvements:

- An improved tracking discriminator which inherently reduces the amount of multipath on the raw measurement
- Additional information is extracted from the hardware to go into a multipath estimator
- A neural network has been added that takes data from the hardware and derives an improved multipath estimate which is removed from the pseudorange observables
- Improvements in code/carrier filter for PVT solution to better handle challenging environments
- For example, driving in a built up area, around trees and freeway applications

Figure 1 shows these improvements, derived from the raw pseudorange without the code/carrier filter. The data shows the well-known MP1 estimate, filtered with a 10 second time constant. The blue curve shows the pseudorange multipath on L1 from legacy Everest, the green shows the multipath from Everest Plus. In this example the multipath reduction is over 50%.

Figure 1



Evaluating all GPS satellites from the same data set in a roof top environment yields an average multipath reduction of 31% with the new technique (Figure 2).

Figure 2

MP1 (cm)			
PRN	**Everest**	**Everest+**	**Reduction**
1	21.6	20.2	6.48%
3	33.0	31.1	5.76%
8	27.4	21.5	21.53%
10	20.5	11.9	41.95%
11	23.4	15.0	35.90%
14	12.1	13.3	-9.92%
18	35.4	16.2	54.24%
21	41.1	22.3	45.72%
22	23.6	20.7	12.29%
24	41.1	19.5	52.55%
27	27.8	16.4	41.01%
31	21.6	18.7	13.43%
32	13.4	9.7	27.61%
Average	**26.3**	**18.2**	**30.85%**

To evaluate the positioning improvements of Everest Plus, dynamic tests were performed compared to a high precision GNSS/INS post processed truth reference.

Data was collected in the following environments:

- Freeway
- Downtown San Jose
- Open Parking Lot
- Trimble Campus – walking pace
- Urban

The data included mostly dynamic data, but also static sections such as stops at gas stations, traffic lights, stop signs and covered a variety of traffic speeds. The summary statistics are tabulated below. The Time column provides the total duration for each environment classification. Overall we get an improvement in the 2D 95 percentile of between 15% and 30% in the SBAS pseudorange solution depending on the environment. Sub-meter 95% performance was delivered in all environments except downtown San Jose and the Trimble campus where the vehicle was driven very close to buildings and trees.

	Time		Everest (cm)		Everest+ (cm)		Reduction	
Environment	**Seconds**	**Hours**	**68%**	**95%**	**68%**	**95%**	**68%**	**95%**
Freeway	33,164	9.2	55	98	39	71	29.09%	27.55%
Downtown SJ	18,669	5.2	84	252	73	215	13.10%	14.68%
Open Lot	11,039	3.1	41	74	37	52	9.76%	29.73%
Trimble Campus	4,406	1.2	83	182	54	134	34.94%	26.37%
Urban	21,572	6.0	67	123	44	90	34.33%	26.83%
	Total	**24.7**						
SBAS GNSS only solution - Horizontal Error relative to GNSS/INS forward/backward truth								

While this test has focused on SBAS, the DGNSS solution will also benefit as will the RTK/RTX engine which uses the pseudorange in the initial integer ambiguity search.

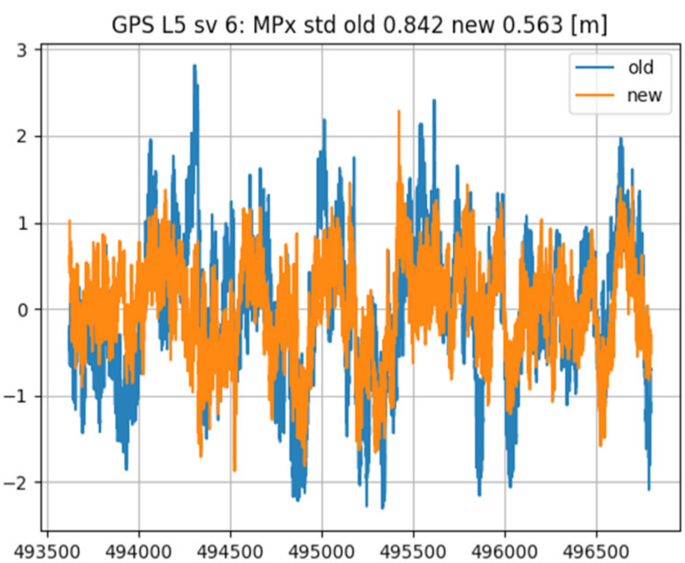
The original Everest technology was only for narrow band GNSS signals. Specifically it operates on:

- GPS & QZSS L1 C/A & L2C
- GLONASS L1 & L2 C/A
- BeiDou B1 & B2
- Galileo E1
- IRNSS L5

With the introduction of Everest Plus this has been extended to the following wideband signals:

- GPS & QZSS L5
- GLONASS L1 & L2 P
- BeiDou B3
- Galileo E5A & E5B

The following figure provides an example of the legacy method of tracking "old" compared to the "new" method of tracking which enables Everest Plus. The data was collected on a building roof with relatively high multipath.



Trimble's new Everest Plus Multipath Rejection Technology promises to contribute significantly to the positioning performance of Maxwell™ 7 based receivers.