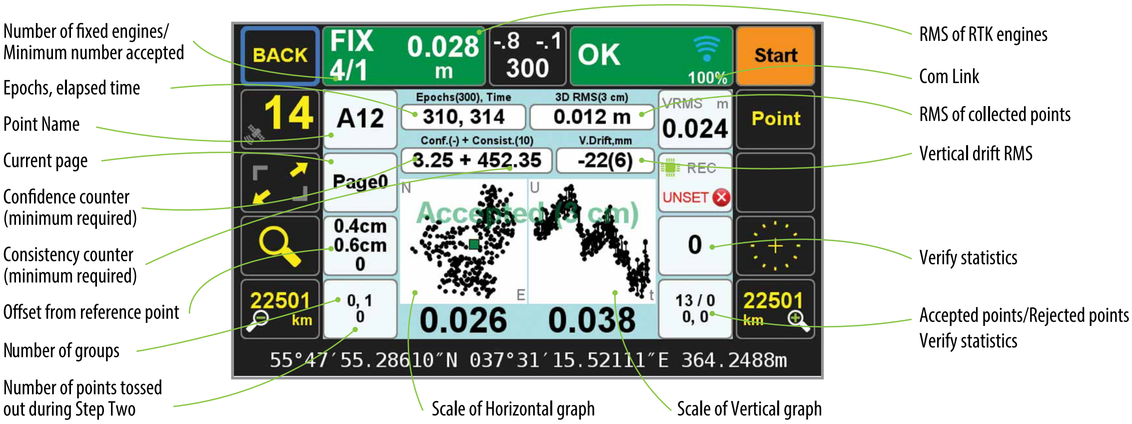
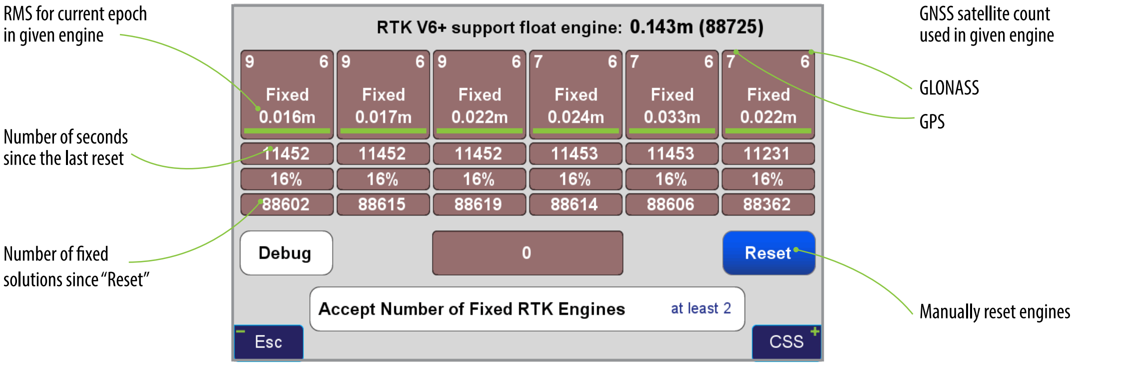
RTK V6+ six engines plus one support



Auto Verify... Auto Validate...



This vigorous, automated approach to verifying the fixed ambiguities determined by TRIUMPH-LS gives the user confidence in his results and saves considerable time compared to the methods required to obtain minimal confidence in the fixed ambiguity solutions of other RTK rovers and data collectors on the market today. The methods required by other systems are not nearly so automated, often requiring the user to manually reset the single engine of his rover, storing another point representing the original point and then manually comparing the two by inverse, all to achieve a single check on the accuracy of the fixed ambiguities. Acquiring more confidence requires manually storing and manually evaluating more points. Conversely, J-Field automatically performs this test, resetting the multiple engines, multiple times (as defined by the user), provides an instant graphic display of the test results, and produces one single point upon completion.

Read details inside and compare with other receivers that require Multiple Point survey, Manual Evaluation, Single Engine, and Single Ambiguity Check per Point.

With TRIUMPH-LS you need Single Point survey, Automated Evaluation, Multiple Engines, and Multiple Ambiguity Checks per Point.

JAVAD

Continue reading pages 3-6

Cluster Averaging

Many jurisdictions dictate that surveyors using RTK revisit critical cadastral points several times in order to demonstrate the results of the survey are reliable. These sorts of mandates are meant to trap inevitable errors encountered while pushing GNSS technology to the limits of operability under canopy or nearby obstructions. Producing the same bad coordinate multiple times (such as three observations, separated by several hours) is still possible considering that the base coordinates could be mis-entered, the base receiver could be setup on the wrong point and possible centering and leveling errors at the base and the rover. With Javad's J-Field, VB-RTK using DPOS, and the Base/Rover Setup procedure the risk associated with the base coordinates being mis-entered or the base receiver being setup on the wrong point are substantially reduced, proving that smart technology can help surveyors minimize commonly encountered blunders.

The rigorous verification process found exclusively in J-Field, uses the six RTK engines of the TRIUMPH-LS to quickly fix and then force a loss of fix for a user defined number of times to prove the point being collected was not the result of a bad fix. In as little as a few seconds, J-Field's verification process provides confidence to surveyors that their positions are defensible and reliable. Other systems require numerous manipulations by the user to perform a fraction of what J-Field does automatically. Consider that most RTK users today, desiring to prove RTK results are valid, must collect a point, then manually reset the RTK engine, collect a second point and then compare the first to the second to determine if there is acceptable agreement. This is a tedious and time consuming process that provides one single check on the fixed integer ambiguities.

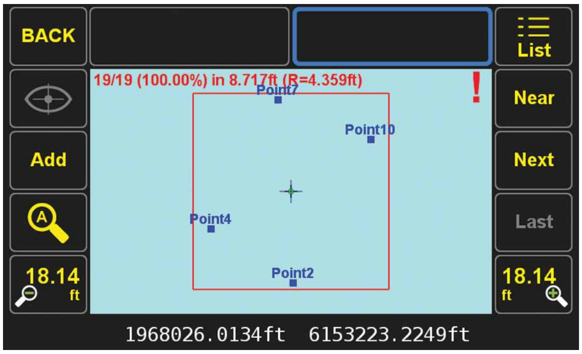
Even with the exhaustive verification procedures in J-Field, the legal obligation in some locales for surveyors to revisit a point hours later remains. J-Field's newest feature, Cluster Averaging makes evaluation of these repeat visits automated and simple. Once a surveyor has collected a point several times, he can initiate Cluster Averaging which searches the points that are visible in the database and finds all occurrences of points that are within a user defined horizontal range of one another. These occurrences are referred to as "Clusters". Next the user is notified of the number of clusters found in the database with the option to create an average point for each cluster. A graphic representation of each cluster is provided, along with the extreme spread of the points in the cluster expressed in North, East and Up. Finally, a rich report is provided with vital statistics of each point used to create the cluster and for the resulting average point. All of this is done automatically, with minimal user involvement, with staggering speed and detail.

It is also possible to manually produce Cluster Averaging, one cluster at a time from the Review Screen. (Home>Collect>Review). First let's look at the one at a time, manual approach in Review:

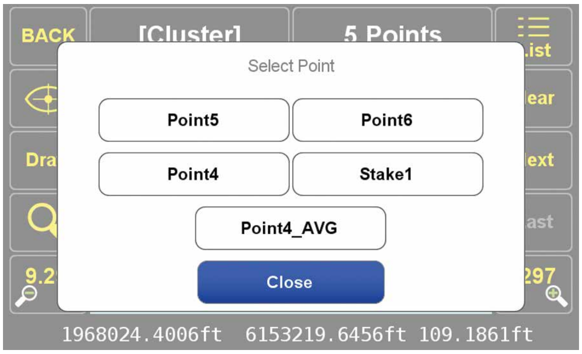
Here are (pic. 1) four groups of surveyed points (notice the dots are bold squares indicating each dot is composed of more than one point).

Pressing the selection button (shown in blue here) shows that there are 19 points (pic. 1) within this red square.

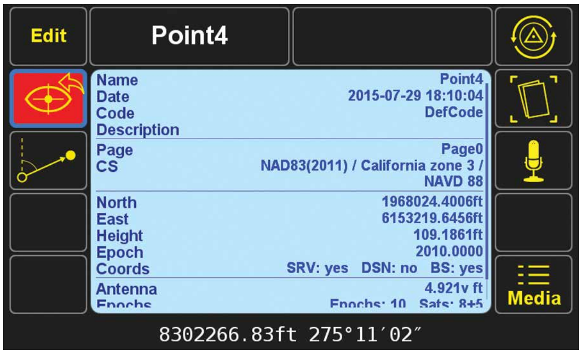
Dragging the cursor over one of the Clusters of points



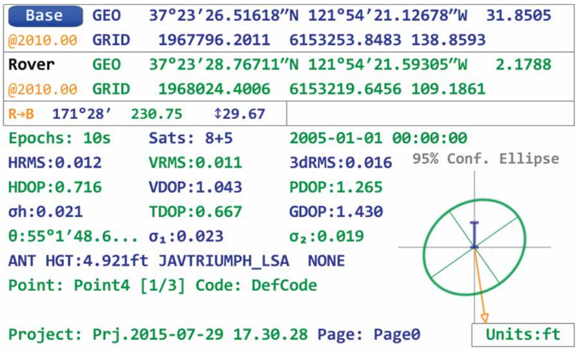
pic. 1 | Four groups of surveyed points



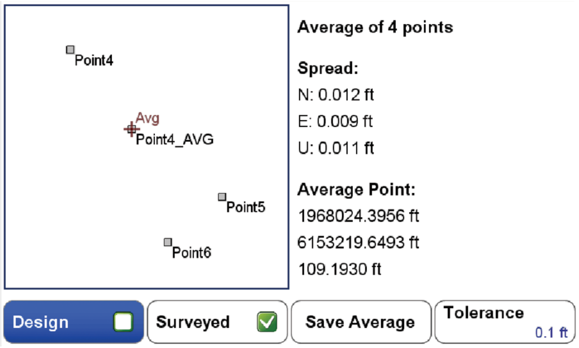
pic. 2 | Points within the Cluster



pic. 3 | Statistics about the selected point



pic. 4 | Base/Rover Statistics screen



pic. 5 | Cluster Average Statistics

Concepts Behind RTK Verification

Fundamental in the determination of GNSS solutions is calculating the correct number of full wavelengths (so-called ***fixing ambiguities***) in order to figure out the distances from the satellites to the receiver. In doing Real Time Kinematic (RTK) surveying, we need it fast and we need it to be correct.

Multipath, the reflections of GNSS signals from ground and nearby objects and structures create their own indirect measurements from the satellites to the GNSS receiver. It's as if your measuring tape is bent around an obstacle such as a tree instead of a free and clear line of sight between two points. No calculator is going to improve this result.

TRIUMPH-LS has sophisticated hardware to distinguish between the direct and indirect signals and remove most of the indirect signals. It also reports the amount of indirect signal that has been removed. The worst case is when the receiver doesn't see the direct signal at all; e.g., the satellite is behind a building, but it's still receiving the signal reflected off of the nearby structure. It is the task of the RTK engines to isolate such indirect signals and then exclude them from the calculations.

If too many of the signals are affected by severe multipath or indirect signals, no solution may be found. Remember, indirect signals are analogous to the bent measuring tape! When you're preforming RTK surveying, observe your environment and come to recognize that the structures around you are like mirrors for GNSS signals.

The other aspect impacting the veracity of a fixed solution is when there are weak GNSS signals. Frequently, weak signals are due to their penetration directly through tree canopy.

While **TRIUMPH-LS** can't move the obstacles that are creating multipath out of the way, its sophisticated hardware has advanced multipath reduction sub-system, its tracking software is designed to handle even the weakest signals, and its **J-Field** software provides reliable RTK solutions like no other system with its **Automatic RTK Verification System** (patent pending). J-Filed also has ample tools to demonstrate the reliability of the solution or warn against questionable results. You can readily see that without such tools other systems can provide you wrong and misleading solutions.

J-Field uses six RTK engines (Figure 1) running in parallel plus a support engine to monitor and aid the six engines. Each engine uses a different criteria and mathematical method tailored to resolve ambiguities in different conditions. These six parallel engines not only verify robust solutions but also maximize the possibility of providing solutions in all conditions.

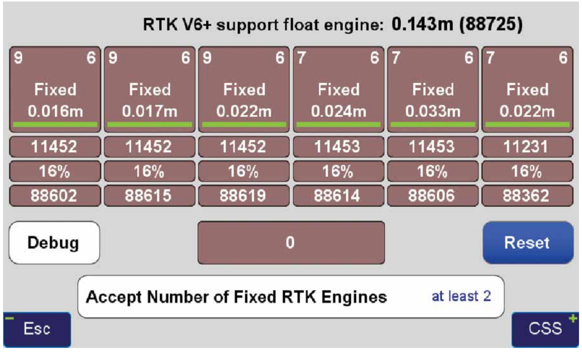


Figure 1 *V6+ six RTK Engines*

User Defined Verification Tools

J-Field provides the option for you to specify the **Minimum Number of Fixed RTK Engines** in verifying solutions **N** times before a position is automatically accepted where **N** is a user defined value.

J-Field employs two metrics to evaluate the performance of its RTK system of six engines: **1) Confidence Counter, and 2) Consistency Counter.** (Figure 2)

Confidence Counter

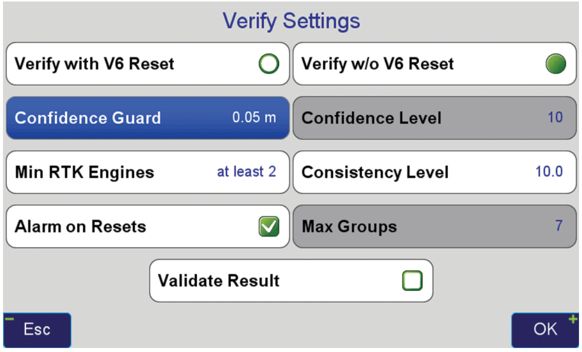


Figure 2 *Verify Settings*

This metric is incremented each time an engine is reset, ambiguities are recalculated, and the solution is in agreement with the previous ones (as defined by the **Confidence Guard (CG)**, default value 5 cm) is achieved. The Confidence Counter increments by 1, 1.25, 1.5, 1.75, 2.0, and 2.5 depending on the number of reset engines that fix in that epoch.

Consistency Counter

The Consistency Counter is incremented each time a solution is in agreement with the previous ones (as defined by the Confidence Guard) irrespective of engines being reset or not. The Consistency Counter is incremented by 0.0, 0.1, 0.25, 0.5, 1.0 and 1.5 depending on the number of fixed engines used in that epoch. Note that one fixed engine gets no credit and 6 fixed engines gets a **Consistency Credit** of 1.5.

Using these Confidence and Consistency verification tools, J-Field has two options to achieve reliable RTK solutions: **1) Verify With Automatic RTK Engines Resets** and **2) Verify Without Automatic RTK Engines Resets.**

Verify with Automatic RTK Engines Resets

This method has two steps: **1) Confidence Building** and **2) Smoothing and verifying.**

• **Step One**

In Step One, fixed engines are reset and solutions are collected into groups. Each group contains all the epochs located within a specified radius (the CG value) from its center and new groups are created as necessary so that all epochs fall into at least one group. Each group has its own Epoch Counter, Confidence Level and Elapsed Time. A point may fall into more than one group. The current best group is shown within [ ] and others within ( ). Step One continues until a group reaches the Confidence Level. (Figure 3)

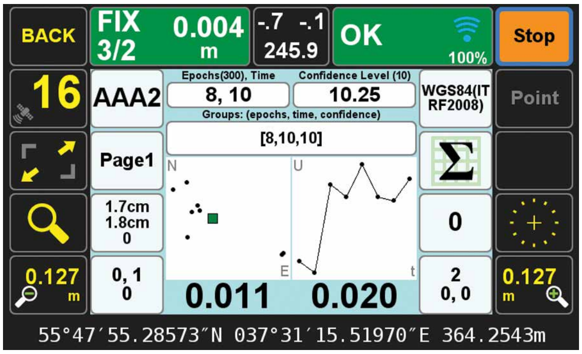


Figure 3 *End of Step one*

• **Step Two**

In Step Two, engines are not reset and solutions which are inside the CG of the selected group are added to that group for the remaining number of epochs that user has requested (Epoch Number, EN). Solutions that are outside the CG of the selected group, will be ignored but counted and on each such epoch, the RTK engines will reset. If the number of ignored points reaches 30% of EN, the whole process will restart. J-Field has 6 parallel RTK engines. You can specify the minimum number of engines required to be fixed to provide an epoch solution in Step Two. If the number of groups exceeds the Max Group the process restarts at Step One. This is to reduce the possibility of creating too many groups and rare false solutions in difficult environments. (Figure 4)

In both steps the Consistency Counter is also incremented as mentioned earlier.

You can manually reset all RTK engines via the V6-RTK engines screen (Figure 1), or assign this reset function to any one of the U1 to U4 hardware

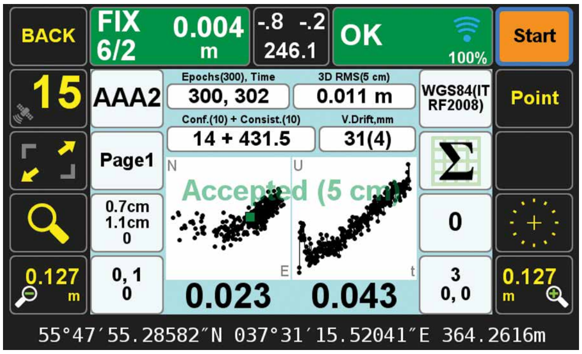


Figure 4 *End of Step 2*

buttons in front of the TRIUMPH-LS for easy access.

Verify without Automatic RTK Engines Resets:

In this method we don't force the RTK engines to reset but rely mostly on the Consistency Counter. There will be only one group as selected by the first epoch. Solutions that are not within the Guard band of the current average will be thrown out. If more than 30% of solutions are thrown out, the process will restart.

The horizontal and vertical graphs presented in both approaches also help the surveyor to evaluate the final solution. The linear drift of the vertical solution and its drift RMS are also shown above the vertical graph. A high linear drift (more than few centimeters) reveals severe multipath or, in rare cases, a wrong ambiguity fix. Pay close attention to the vertical drift and the horizontal and vertical scatter plots of epochs. Consider the scatter plots as doctors examine X-rays to determine anomalies.

The desired **Confidence Level** and **Consistency Level** are user selectable. Default values are 10. These parameters along with the desired number of epochs must be reached before a solution is provided.

In either case there is also a **Validate** option which, when selected, will reset all engines at the end of the collection and continues with 10 more epochs to validate if the solution is within the desired boundary of the Confidence Guard. (Figure 2) Minimum number of engines for the Validation Phase is user selectable.

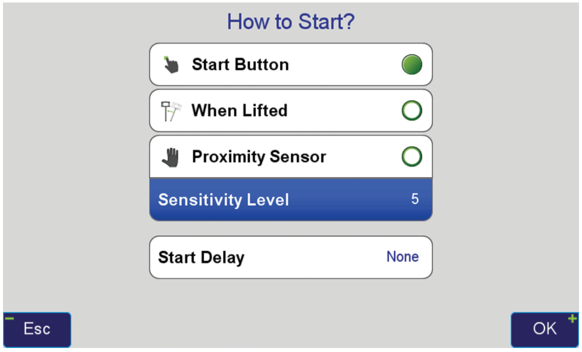


Figure 5 *How to Start*

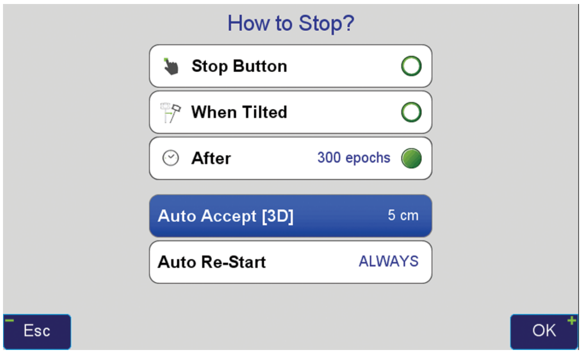


***Figure 6** How to Stop*

In either case, if Auto-Accept is activated, the position will be automatically accepted if the RMS of the final solution is less than what user has selected in the Auto-Accept screen. (Figure 6)

You can also use **Auto-Restart** if you want to monitor structures or test the RTK system unattended. (Figure 6)

Screen Shots of Action Screen

Action Screen shows detailed information about each point collected. Screen shots can automatically be attached to each point and saved at the end of each collection (Figure 7). In **Verify with Automatic RTK Engines Resets** screen shots at the end of both Step One and Step Two are saved (Figures 3 and 4). In Action screen there are 8 white boxes that selected items can be viewed on them.

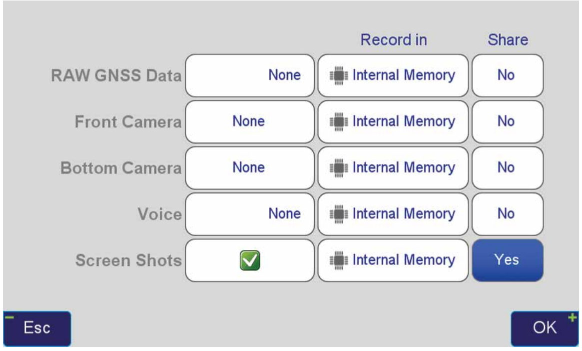


***Figure 7** What to record screen*

Review Screen

View cluster of all points. Select the desired point to see its point cluster (Figure 8). Click the icons to see additional details about that point (Figure 9) including the distance and direction to the current point (Figure 10).

The effects of multipath, ionosphere, orbit, and other sources of problems somewhat exponentially increase as the baseline length increases. In a VRS/RTN scheme your **actual** baseline length is the actual distance to the nearest base station. The **virtual** base station that is mathematically created is not the actual length. We strongly recommend using your own base station near your job site in a

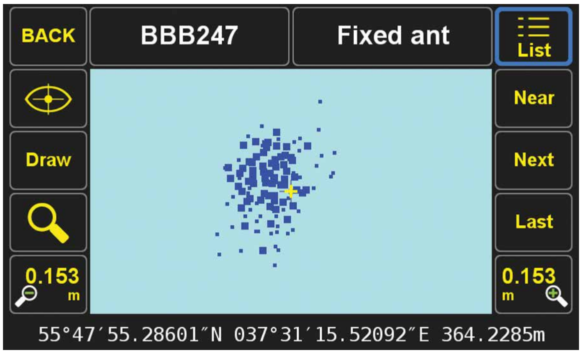


***Figure 8** Review screen shows cluster of 386 points*

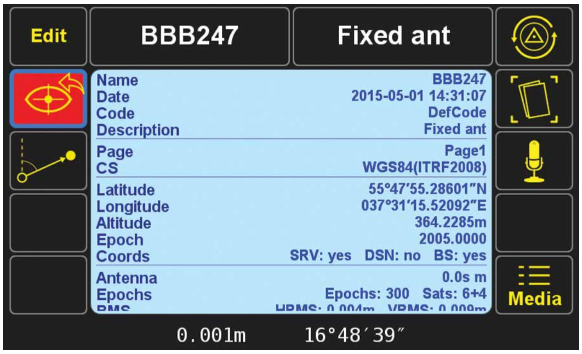


***Figure 9** Detailed information on selected point (scroll to see all information)*

***Figure 10** Distance and direction from the current point to the selected point*

Verified-Base RTK (VB-RTK) scheme.

In addition to providing you with the most reliable RTK solutions (especially true in remote areas where cell coverage is hit or miss), using your own base receiver allows you to easily tie your solutions to well-established IGS/NGS spatial reference systems through Javad's exclusive Data Processing Online Service (DPOS) and J-Field's user-friendly Base/Rover Setup. Note that post-processed results returned to the Triumph-LS using DPOS are dependent on the availability of orbital data from NGS and may require several hours. For further reading about DPOS, its integration into J-Field and the streamlined approach developed by Javad for setting up the base and rover, please check out Shawn Billings' excellent article on VB-RTK on our website. Point your browser to: *http://www.javad.com/jgnss/javad/news/pr20150219.html*

Alternatively, if you don't have access to IGS-type stations to use DPOS, you can select an open area near your job site and use TRIUMPH-LS to obtain its position via RTN networks for about 5 minutes. You may repeat a couple of times for assurance. Then transfer this position to the TRIUMPH-1 or TRIUMPH-2 to use as the base station near your job site. The Base-Rover setup screen in the TRIUMPH-LS makes this job very easy.

Instantaneous Multipath charts

TRIUMPH-LS removes most of the multipath instantly on every epoch. Click on the Satellite icon to see the Signal Strength of satellites and then click the "+" key to see the multipath charts.

Figure 11 shows the amount of code phase multipath that TRIUMPH-LS has removed; relative to a fixed level. That is why negative numbers are in this figure. Units are in centimeter. Noting the signs in this figure, the amount of multipath in some satellites is in excess of 5.6 meters.

Figure 12 shows the amount of carrier phase multipath that TRIUMPH-LS has removed relative to a fixed level. Units are in millimeter. Noting the signs in this figure, the amount of multipath in some satellites is in excess of 4 centimeters.

SAT	EL	L1	P1	P2	L2C	L5	SAT	EL	L1	P1	P2	L2C	L5
GPS2	29↑	273	281	-76	--	--	BDU11	75↑	362	--	--	--	305
GPS6	44↑	55	201	-60	-5	189	BDU12	36↓	288	--	--	--	200
GPS12	70↑	183	190	-90	-94	--	GPS3	10	--	--	--	--	--
GPS14	25ˆ	281	317	-97	--	--	GPS29	3	--	--	--	--	--
GPS17	23↓	332	364	-74	6	--	GPS32	3	--	--	--	--	--
GPS24	53↓	117	566	67	-64	124	GLN7	3	--	--	--	--	--
GPS25	30↑	243	218	-42	-50	-34	GLN19	12	--	--	--	--	--
GLN1	10↑	305	229	-126	-404	--							
GLN8	16↓	26	87	-484	-617	--							
GLN9	32↑	359	301	-246	55	--							
GLN15	31↓	276	203	-93	-2	--							
GLN16	84↑	235	309	-133	-109	--							
GLN17	39↓	52	-84	-156	-52	--							
GLN18	69↑	190	168	-177	-184	--							
GAL12	68ˆ	680	-121	246	--	32							
SB127	25ˆ	469	--	--	--	319							
SB128	15ˆ	206	--	--	--	322							
QZ193	13↑	550	513	--	56	55							
BDU2	16ˆ	299	--	--	--	275							
BDU5	25ˆ	269	--	--	--	230							
BDU8	25↓	145	--	--	--	143							

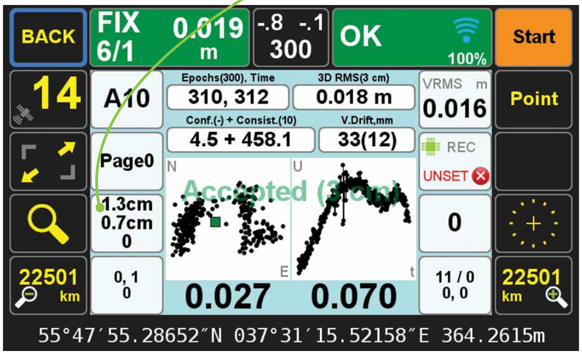
Figure 11 *Code Phase multipath removed (cm)*

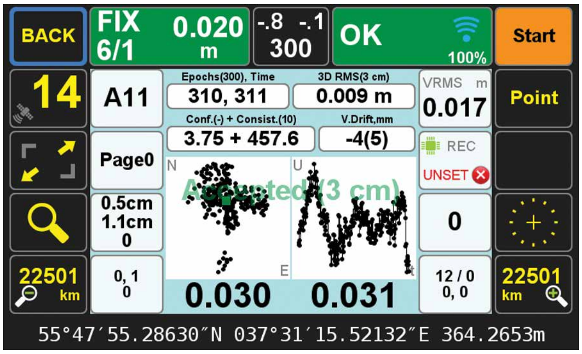
SAT	EL	AZ	L1	P1	P2	L2C	L5	SAT	EL	AZ	L1	P1	P2	L2C	L5
GPS2	29↑	154	7	7	2	--	--	BDU11	75↑	158	-6	--	--	--	-5
GPS6	44↑	98	11	9	2	2	-13	BDU12	36↓	60	-6	--	--	--	-14
GPS12	70↑	282	7	8	-2	-2	--	GPS3	10	26	--	--	--	--	--
GPS14	25ˆ	302	5	8	-4	--	--	GPS29	3	229	--	--	--	--	--
GPS17	23↓	58	6	9	-6	-2	--	GPS32	3	346	--	--	--	--	--
GPS24	53↓	196	1	4	13	1	-12	GLN7	3	297	--	--	--	--	--
GPS25	30↑	282	4	8	7	1	-32	GLN19	12	210	--	--	--	--	--
GLN1	10↑	34	1	4	-15	-23	--								
GLN8	16↓	344	12	15	17	25	--								
GLN9	32↑	316	0	2	-3	-6	--								
GLN15	31↓	142	5	5	0	1	--								
GLN16	84↑	266	2	2	-11	-18	--								
GLN17	39↓	44	-1	-4	-12	-10	--								
GLN18	69↑	188	-1	3	-1	-6	--								
GAL12	68ˆ	108	0	-26	0	--	-14								
SB127	25ˆ	160	7	--	--	--	-4								
SB128	15ˆ	130	9	--	--	--	-11								
QZ193	13↑	68	-3	-1	--	1	-19								
BDU2	16ˆ	132	-7	--	--	--	-17								
BDU5	25ˆ	154	-4	--	--	--	-7								
BDU8	25↓	54	-10	--	--	--	-20								

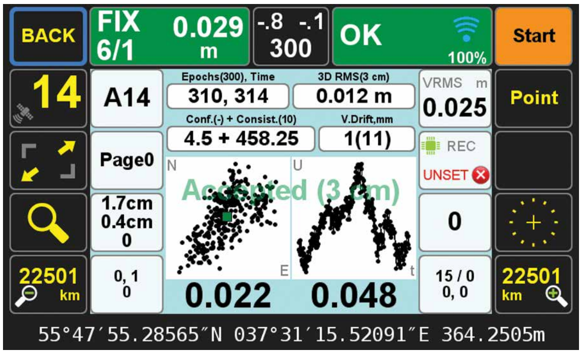
Figure 12 *Carrier Phase multipath remove (mm)*

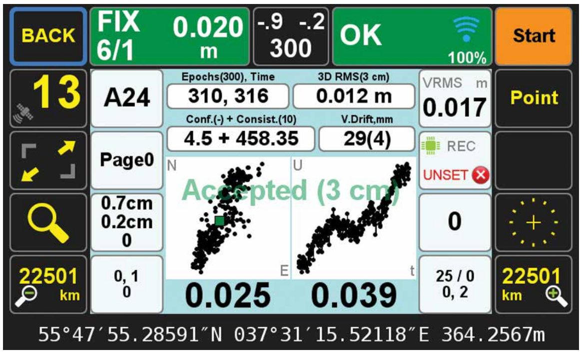
Multipath Showcase

Graphs in the following examples show multipath effects in a 13.8 km baseline where about 1/3 of the rover sky was blocked by a tall building. This box shows horizontal (top) and vertical (bottom) offsets from the actual coordinates of the point (earlier surveyed for test).

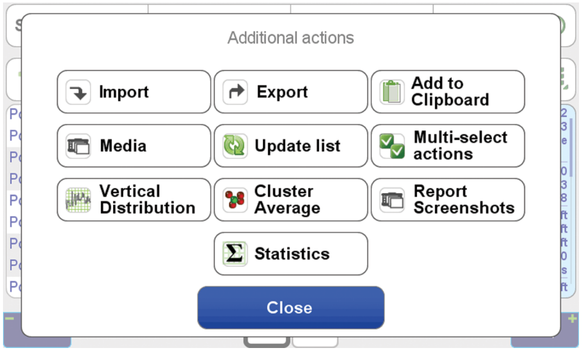




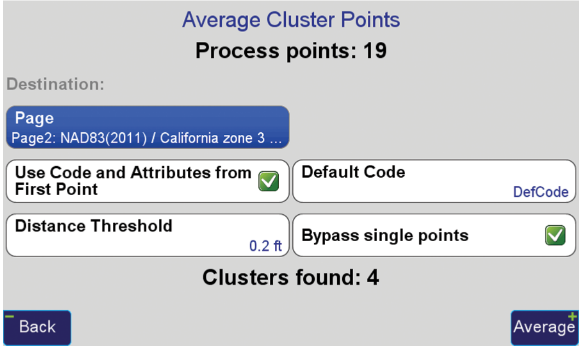




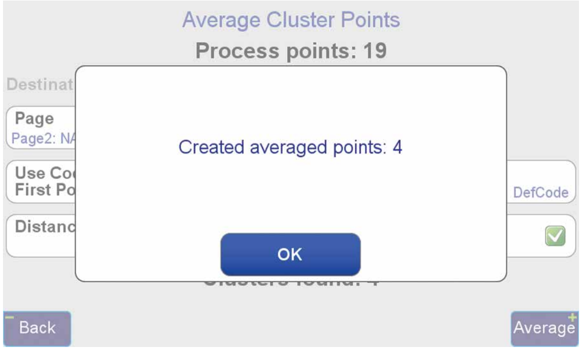
Javad Ashjaee, Ph.D.



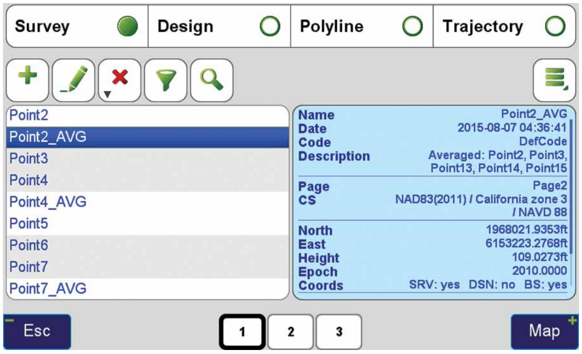
pic. 6 | Option for Cluster Average



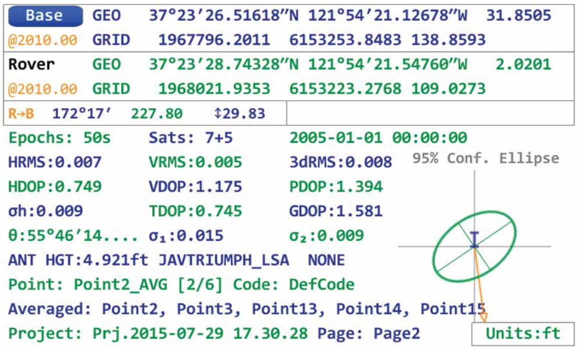
pic. 7 | Cluster options



pic. 8 | Number of Cluster Averaged



pic. 9 | Points lists



pic. 10 | Base/Rover Statistics screen

and pressing the Eye/Crosshair icon presents a options for points within the Cluster radius. In this example (**pic. 2**), Point4, Point5 and Point6 are individually surveyed points. Stake1 is a design point, created from entering coordinates. Point4_AVG is an average point created previously created from Cluster Averaging.

After selecting a point from the cluster, press anywhere on the blue field to see additional statistics about the selected point (pic. 3).

With the Base/Rover Statistics screen (pic. 4) visible, pressing the UP arrow hardware button shows the Cluster Average Statistics screen. Here the user is given the extreme spread of the cluster of points, the average coordinates (weighted by the error estimates in the case of survey points), with the option to include only surveyed points or only design (imported/calculated) points or a combination. The Tolerance value sets the radius used to define what falls within a cluster (pic. 5).

Pressing Save Average displays the Average Tool in COGO for final acceptance of the average.

The process described above creates averages from clusters one at a time as the user selects a point in a cluster and initiates the average command from the review screen. However, J-Field can also create averages from clusters automatically from the Additional Actions button

found in the Points Screen. With this command all possible clusters are identified from the points currently visible in the points list (excluding any points that have been filtered from view).

A Pop-Up screen appears (pic. 6) with the option for Cluster Average.

Selecting Cluster Average, J-Field detects all occurrences in the visible database of points within the user defined tolerance (pic. 7-8).

If, Average is selected, the average point of each detected cluster will be created automatically. The name of the point, by default, is [PointName]_AVG, with [PointName] being the name of the first point detected in the cluster. For example the averaged point from a cluster of points named Point4, Point5 and Point6, will be named Point4_AVE (pic. 9).

For efficiency, the Code and Attributes from the first point in the cluster can be assigned to the average point using the appropriate check box.

Once the points have been created from the Cluster Average Utility, they are visible in the Points Screen. If all of the points used in the Cluster are surveyed points, the resulting Average point is also created as a survey point, having the same number of epochs as the combined epochs from the points in the cluster. The error estimates are modified according to the combination of the errors of the individual points, generally resulting in much improved precision in the Average point.

Now there is no longer a need to manually determine how to handle redundant observations of the same point. Store a point as many times as you wish and let the Cluster Averaging simplify your processing time and improve the precision of the your surveys. J-Field's new Cluster Averaging takes only seconds to accomplish and can be done easily while still in the field.

Shawn Billings, PLS

Collecting Points in Difficult Environments

Fundamental in the determination of GNSS solutions is resolving the correct number of full cycles of the carrier signal (so-called fixing ambiguities) in order to determine the distances from the satellites to the receiver. These distances contain errors caused by inaccuracies in the satellite clock and by the ionosphere and troposphere. When a base station is used, these errors and errors in the satellite orbits are nearly identical to both the rover and base station receivers when the baseline distance is short. By removing these common errors through RTK processing, centimeter level accurate vectors can be calculated between the base station and the rover.

Multipath, the reflection of GNSS signals from nearby objects and structures create their own indirect measurements from the satellites to the GNSS receiver and is the most critical source of inaccuracy in precision GNSS applications. The worst case is when the receiver doesn't see the direct signal at all; e.g., the satellite is behind a building, but it's still receiving the signal reflected off of the nearby structure. Such indirect signals are usually strong, unhelpful and misleading.

The other aspect impacting the veracity of a fixed solution is when there are weak GNSS signals. Frequently, weak signals are due to their penetration directly through tree canopy. While the TRIUMPH-LS can't move the obstacles that are creating multipath out of the way, its sophisticated engineering is designed to handle even the weakest signals like no other system with its RTK Verification System (patent pending).

When located in difficult environments and under tree canopy, all GNSS receivers are prone to give bad fixed solutions that may be appear to be acceptable if they are not verified. Existing methods to verify GNSS solutions include "dumping" the receiver, turning it upside down to cause the RTK engines to reset, and re-observing the point at a later time.

The TRIUMPH-LS automates these processes with its built-in software features of Verify and Validate. Verify automatically resets the RTK engines after every fixed epoch is collected in the first step of its process. Epochs are sorted by distance and placed into groups during the first step. Once a group has built up a set level of confidence the RTK engines are allowed to collect the remaining epochs without resetting. If epochs fall too far away from the best selected group from the first step, they are rejected and the RTK engines are reset. Validation is the final step of the process. With this feature enabled the RTK engines will reset one final time at the end of the observation and collect 10 additional epochs. Allowing sufficient time between the first step and the final validation step will guarantee a bad solution is not allowed to be accepted. From extensive testing of these features in the worst of multipath environments, a bad solution has yet to be accepted when the Verify and Validate features are used and 120 epochs are collected.

Matt Johnson, PLS

See Verification Video at **www.javad.com**

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