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High-performance GPS - System 500

*A high-performance, easy-to-use
GPS surveying system*

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Leica

MADE TO MEASURE

A high-performance, easy-to-use GPS surveying system

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Designed for today and for the future

The last decade has seen a tremendous change in GPS surveying. Whereas 8 to 10 years ago GPS was still used almost exclusively by specialists for geodetic networks and scientific measurements, it has now become a standard tool for almost every survey application and can be used by technicians as well as professional surveyors.

In the past, users were mainly concerned about the accuracy of receivers and post-processing results. Today, many users expect a black box and take it for granted that GPS will work and deliver the results they need. Surveyors now demand powerful but easy-to-use systems that can be used for any job, with seamless data flow, full field coding and easy interfacing to CAD and mapping systems.

System 500 from Leica Geosystems AG meets all of the needs of the modern surveyor. Powerful, flexible, yet very easy to use, it is a highly-efficient production tool designed for speed, efficiency, accuracy and reliability.

Six main requirements

When designing System 500, major emphasis was placed on six main areas:

- Easily upgradeable, modular hardware
- New ClearTrak™ receiver technology
- High-speed RTK with integrity monitoring
- Comprehensive, easy-to-use MMI (man-machine interface)
- On-board application programs
- SKI-Pro office software and easy interfacing to other systems

Easily upgradeable modular hardware

The more versatile the GPS receiver, the better value and the more economical it is. Because System 500 receivers are small, light and modular in design, they can be set up anywhere, operated in any way, and used for any task. With a detachable terminal, plug-in batteries and slot-in PCMCIA cards, the receiver can be operated on a tripod or pole, used in a minipack or vehicle, set up on a pillar or at a reference station. It can be used for almost every application from static control networks to kinematic detail surveys to GIS mapping.

The System 500 range comprises three receivers: SR510 single frequency, SR520 dual-frequency, and SR530 dual-frequency RTK receiver. As all three units have a common design, hardware can be upgraded easily at any time. A user can opt to start with single-frequency and upgrade later to dual-frequency and RTK. As nothing is discarded, there is no waste of material and invested capital.



Fig.1 Rover, with pole and minipack



Fig.2 Rover, all on pole



Fig.3 GIS rover, all in minipack



Fig.4 Static measurements on tripod

New ClearTrak™ receiver technology

Today's users demand that GPS receivers should measure accurately and reliably anywhere under any conditions. A top-class receiver has to have fast acquisition times, work perfectly under Anti Spoofing, track low-elevation satellites, measure well under light foliage, and be as immune to multipath and resistant to interference signals as possible.

ClearTrak™ is the term for a suite of technologies that assures that System 500 receivers have the best possible performance. The basis of ClearTrak™ is the patented Code-Aided Tracking, with fully-independent L1 and L2



Fig.5 SR530 RTK receiver, with radio in housing

tracking loops, that has been employed in a series of Leica receivers and has now been improved and enhanced still further with new multipath-mitigation and interference-rejection techniques.

The true measure of a dual-frequency receiver is how well it tracks L2 under AS and adverse conditions. Code-Aided Tracking provides full-wave L2 carrier-phase measurements with a huge signal-to-noise advantage over the conventional cross-correlation technique used in some other receivers plus high-accuracy L2 pseudoranges. The SR520 and SR530 receivers have the best L2 signal quality in the industry. There is no perceivable difference in performance whether AS is on or off.

A new Multipath Mitigation Correlator (patent applied for) coupled with state-of-the-art antennas reduces the effects of multipath signals to levels much lower than previously achievable. In practical terms this translates into code (pseudorange) measurements of far higher accuracy than could be achieved in the past. With differential-code measurements providing position accuracies of 30cm, System 500 receivers are ideal for GIS mapping and similar applications. These high-accuracy code measurements also aid RTK for faster, more reliable ambiguity resolution.

A GPS receiver is essentially a radio receiver designed to receive signals from GPS satellites. As these signals are very weak, it is important that a receiver is as resistant as possible to interference signals. Interference is most likely when measurements are carried out close to transmitters

and microwave stations, or when receivers are used in the vicinity of navigation and radar systems at airports and harbours. The new Leica ClearTrak™ receivers have excellent anti-jamming characteristics with sharp cut-off SAW filters eliminating out-of-band interference and adaptive, multi-level sampling minimizing any in-band interference. Tests have shown that Leica System 500 receivers provide clean phase and code measurement data at sites where other receivers are often jammed.

Full details of System 500 ClearTrak™ technology are contained in the paper by Stansell and Maenpa (reference 1).

High-speed RTK with full integrity monitoring

With the steady development of RTK systems over the last 5 years, GPS surveying has progressed from being a special technique for experts to a standard survey tool for almost everybody. Today, RTK systems make up a significant portion of the GPS survey market and the trend to RTK is increasing rapidly. It is quite conceivable that, in a few years time, nobody will purchase a GPS survey system that is not capable of RTK.

Leica Geosystems AG introduced RTK with System 300 in 1995 and improved the performance steadily over the next four years.

System 500 has a completely new RTK technology. The Real-Time Kinematic mode built into the new SR530 receiver is based on new algorithms, new ambiguity-resolution strategies and a new self-checking technique. These new techniques together with the new ClearTrak™ receiver technology and high-speed processors provide much better RTK performance than anything that was available in the past:

- Ambiguity resolution in 30 seconds
- Ambiguity resolution on longer lines
- Ambiguity resolution in difficult environments
- Accuracy 5 to 10mm + 2ppm
- Reliability better than 99.99% on short lines
- Reliability better than 99.9% on long lines
- Update rate 5Hz
- Latency less than 0.05 seconds

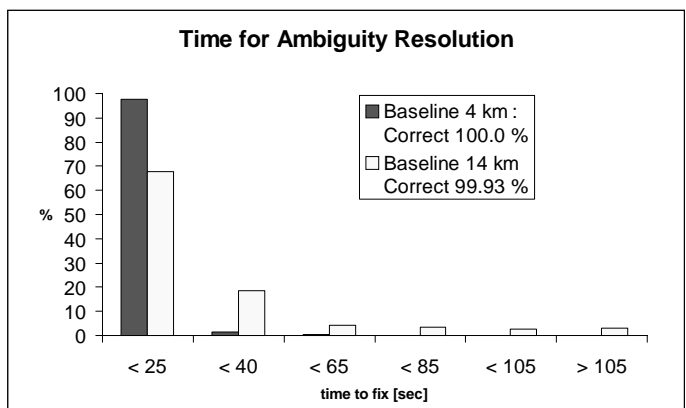


Fig.6 RTK long-duration tests on 4km and 14km baselines.

Fast and reliable ambiguity-resolution on-the-fly is a MUST for a modern RTK system. Static initialization and initialization on a known point are simply too inconvenient for high-speed production work. In a good environment with 5 or more satellites, the SR530 will initialize on-the-fly within 30 seconds on short and medium lines up to about 5 to 10km. Even on long lines over 10km, at least 50% of fixes will usually be made within 30 seconds and the rest well within a minute.

As ClearTrak™ helps the receiver to track amongst trees and obstructions, there is a tendency for surveyors to try to measure with the SR530 in situations where they would not have trusted former RTK systems. Even in an unfavourable environment, ambiguity resolution rarely takes longer than 60 seconds. After initialization, the SR530 will hold the ambiguities and provide positions in the centimetre range as long as at least 4 satellites are tracked on L1.

For the surveyor in the field, reliability is the most important aspect of RTK. In System 500, every initialization is the result of two completely independent ambiguity resolutions. After initialization is made, the ambiguity-resolution process continues to run computing independent position fixes every 15 seconds and checking the updated position displays. This continuous, integrity-monitoring process guarantees the highest degree of reliability.

For stake-out and positioning tasks, a high update rate with low latency is required. The SR530 displays centimetre-accuracy positions every 0.2 seconds (5Hz) with less than 0.05 seconds delay with no degradation in accuracy. This high performance is the direct result of proprietary techniques for phase prediction and the transmission and reception of data. As each 0.2-second position fix is computed completely independently there is no loss of accuracy. This contrasts favourably with other systems in which 5Hz positions are simply extrapolated and accuracy degradation occurs.

The new System 500 RTK is an exceptionally efficient production tool. Further details can be found in the paper by Ziegler and Euler (reference 2).

The user environment

The first part of this paper dealt with ClearTrak™ and RTK, the “measurement engine” of System 500. The second part covers the operating system, application programs, outputs and inputs, and SKI-Pro software. As users begin to take for granted that “GPS works”, their interest changes from pure technology to the entire user environment. They want systems that are easy and efficient to use for the jobs they have to do.

Easy-to-use MMI

A modern GPS survey system has to be capable of being used for almost any task (geodetic control, detail and topographic surveys, engineering and stake out, seismic work, GIS, hydrographic survey, monitoring, etc.) and has to meet the individual requirements of users all over the world. It has to be powerful and versatile, yet very easy to use.



Fig.7 Main menu



Fig.8 Survey panel

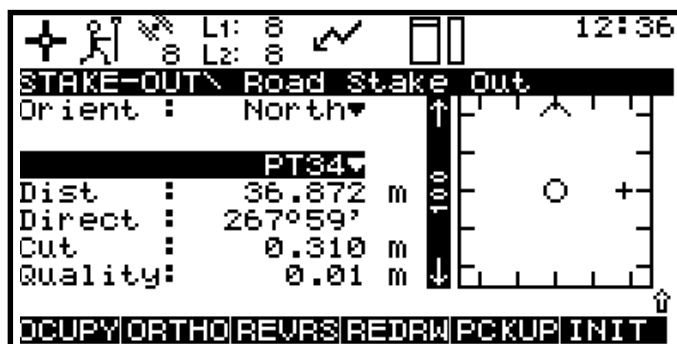


Fig.9 Stake out panel

The operating system of System 500 receivers consists essentially of a series of menus and sub-menus, function keys and user-definable keys. Access is easy and straightforward for all standard operations such as data logging for post processing, RTK surveying and RTK stake out. Special functions and advanced settings are accessed through sub-menus and key strokes in such a way that they are not immediately apparent and will be of no concern to the normal operator. There are also two operating modes: standard for first-time users and normal work, advanced for experienced operators and demanding applications.

Although the receiver is delivered with a series of standard settings for all routine data logging and RTK work, an advanced user can also configure (program) it to operate (track, record, transmit/receive, survey, stake out) in any way according to his/her requirements. Once configured, the receiver can be used by any technician after only a few minutes of instruction. For many standard applications, single key-stroke operation is all that is needed.

There are on-board libraries for antenna information, ellipsoids, projections, geoidal models etc. Transformation parameters can be computed for results in local coordinates.

Point identifiers can be entered or set to increment automatically. Three different code/attribute/annotation systems are supported. Thus data acquisition with System 500 provides all of the flexibility needed for subsequent input into almost any surveying or mapping software.

Data is arranged in user-definable jobs and recorded on PCMCIA cards or optional internal memory. A series of utility functions is provided for formatting cards, transferring jobs, and for downloading and uploading data, coordinates, coordinate systems, code lists, firmware, almanacs etc.

Even the language can be chosen. As field operators in many parts of the world often speak little English, the MMI is also available in several language versions. Two languages can be loaded, English plus a local language. Just a single keystroke is needed to switch from one to the other.

The terminal, with 12-line 32-character display and full alphanumeric keyboard, will normally be used with the receiver for standard survey work, field-data acquisition, and stake out. For certain special applications, however, the receiver can also be used without a terminal. Once configured, it will power up, track, record, transmit/receive, compute RTK positions, and power down at preset times. Sequences can be repeated automatically.

On-board application programs

Many of today's users of RTK systems demand more than simple point coordination and stake out. They want to use the data in the field, for computation, analysis, positioning etc. They want computation routines and application programs in the receiver itself rather than on a separate PC. System 500 receivers have a series of standard application routines and programs. Other specialized programs are optional.

Standard routines and programs include:

- Survey for field-data acquisition
- Averaging for points measured more than once
- Survey of "hidden points" where GPS cannot be used
- Stake-out of points, lines, grids, slopes
- Stake out of "hidden points" where GPS cannot be used
- Measurement and computation of areas
- Calculator functions
- Coordinate geometry routines
- Computation of transformation parameters

Three options, RoadPlus, QuickSlope and DTM Stakeout, are powerful, sophisticated programs designed for applications in civil engineering, earthworks and mining.

With RoadPlus, the field surveyor can use SR530 RTK to stake out roads and railways based on user-defined horizontal and vertical alignments and cross sections. Horizontal alignments can consist of straights, circular and spiral curves; vertical alignments of straights, circular and parabolic vertical curves. Distances (chainage) along the alignment and offsets from the alignment can be defined.

Road-design files in GSI format have to be created and loaded into the receiver. When staking out in the field, the required intervals along the alignment and offsets to the alignment can be selected. The standard stake-out display

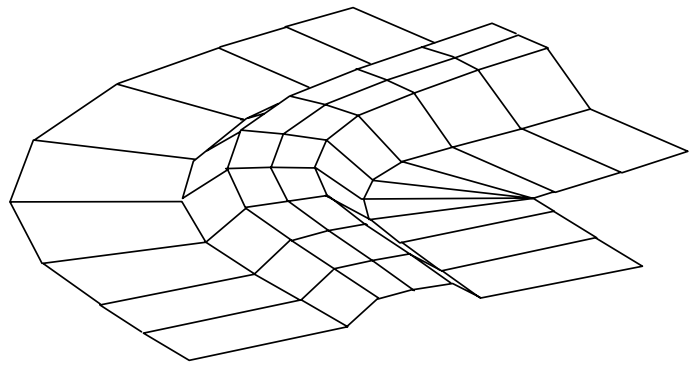


Fig. 10 Roadplus for horizontal and vertical alignments and cross sections

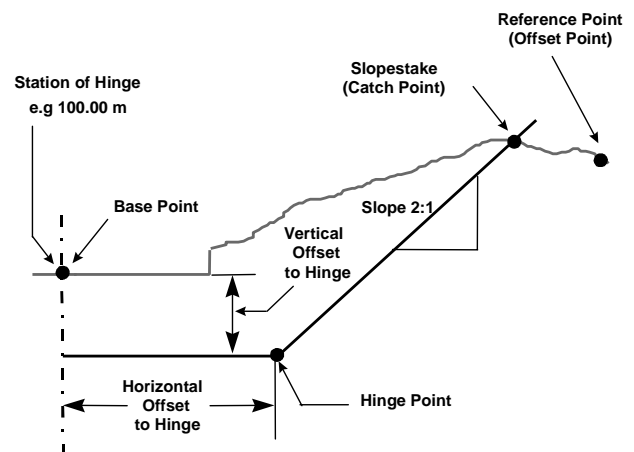


Fig. 11 Quickslope for locating catch, hinge and base points

shows bearing and distance or distance and offset to the required points as well as cut and fill. The flexibility and convenience of RoadPlus combined with the power and speed of SR530 RTK provide an impressive production tool for road construction.

QuickSlope is a program that runs on the SR530 receiver for locating and setting out points with RTK in road construction, site grading, earthworks and mining. It is particularly useful for locating the position of catch points (slope stakes), setting offset points, and determining horizontal and vertical offsets to catch, hinge and base points.

With the DTM Stakeout program running in the SR530, the field surveyor can determine the difference between a required design surface and the actual ground surface. A DTM (Digital Terrain Model) file for the required surface has to be generated and stored in DXF or GSI format. The RTK display shows coordinates and cut and fill values for all points occupied within the area of the DTM. The program is used to stakeout design surfaces for earthworks, landscaping and mining.

With the SR530 and on-board programs, computations and stakeout are combined into just one real-time process.

The fourth option is the GIS application program. With this program loaded, the SR530 can be used for GIS data acquisition in exactly the same way as the GS50 GIS receiver but with full RTK centimetre accuracy.

SKI-Pro office software and easy interfacing to other systems

SKI-Pro is a completely new office-support and post-processing software designed to complement System 500 receivers. Market requirements for software show a similar trend to those for receivers with emphasis shifting from measurement and data processing to applications and the entire user environment. A modern GPS software has to be easy to-use and have all the support functions, routines and sub-programs that are needed for efficient production work.

SKI-Pro has an intuitive graphical interface within a standard Windows™ (95, 98, NT) operating framework. All components have a uniform appearance, common operating procedures, and interact in a multi-tasking environment. The result is that SKI-Pro is easy to learn and use and yet very flexible. The user can move effortlessly from one component to another, working in the way that is the most suitable for the current job.

The post-processing component will process all types of data taken in all measuring modes. Although automatic processing with default settings and automatic selection of baselines will normally be used for routine work, the SKI-Pro operator can always take full control of parameters, windows, satellites used, processing sequences etc. in case of special baselines and non-standard applications.

Almost the first thing that a user will notice about SKI-Pro is that both the data flow and interaction between components is seamless. Jobs can be created, data imported, viewed, verified and edited, baselines processed and adjusted, coordinates transformed, and results exported in what is essentially one fast and easy process. Real-time coordinates can be imported and combined with post-processed results.

This paper touches on only a few selected components of SKI-Pro that are of particular interest for production work.

SKI-Pro has libraries for ellipsoids and projections and will compute and apply transformation parameters between WGS84 and local systems. Geoidal models can be accessed and applied. Results can be in the WGS84 and/or local-coordinate system; heights can be ellipsoidal and/or orthometric. For use with RTK, coordinate systems can be transferred from SKI-Pro to the receiver and from the receiver to SKI-Pro.

Code lists can be created in SKI-Pro and transferred to the receiver. Code lists used and modified in the receiver can be transferred to SKI-Pro. Point identifiers, coordinates, codes and attributes are exported to mapping and CAD systems.

One of the most useful and impressive features of System 500 and SKI-Pro is the ease by which data can be imported from and exported to other systems. The SKI-Pro import wizard facilitates the input of coordinates lists. The SKI-Pro export wizard allows the user to define ASCII files in any format for the transfer of results to surveying and mapping software. The SKI-Pro DXF wizard creates export files in DXF format for immediate use in CAD and GIS systems.

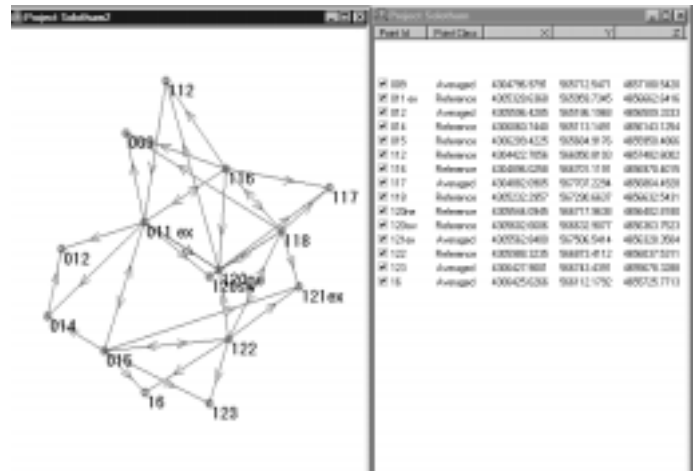


Fig. 12 SKI-Pro GPS network

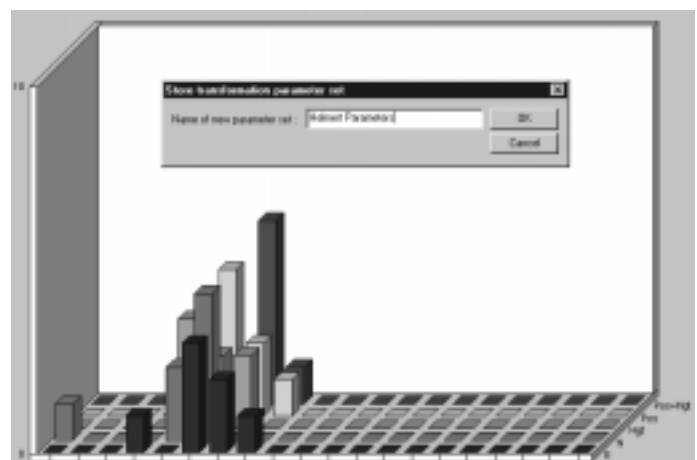


Fig. 13 SKI-Pro graphical display

With System 500, it is even possible to import to and export from the receiver without using SKI-Pro. After setting an import-file mask, coordinate lists of control points or points to be staked out can be read directly by the receiver. By means of export-file masks, RTK results can be exported directly from the receiver in any required format for input into other software packages.

Summary

System 500, with state-of-the-art measurement engines embedded in future-oriented user interfaces, is designed to meet the needs of GPS surveyors well into the 21st century.

The new ClearTrak™ technology, high-speed RTK and SKI-Pro processing kernel ensure rapid measurements and high-accuracy results. The receiver MMI, on-board programs and the support routines in SKI-Pro software provide the power and flexibility needed for fast and efficient work and easy interfacing to other systems.

System 500 is an easy-to-use, high-performance production tool for every type of application from geodetic survey to engineering and stake out.

References

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2. C. Ziegler, H-J. Euler: "New Ambiguity Resolution Strategies, Improved Reliability in Difficult Environments, Shortened Ambiguity Resolution Times, Low Latency Results". Technical paper published by Leica Geosystems AG, March 1999.

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