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Precision Positioning Technologies and Trends at Topcon

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ABSTRACT

Topcon is committed to the development of innovative, cutting-edge positioning technologies and products which form the foundation for delivering the best customer solutions in the precise positioning industry. Topcon is focused on integrating existing technologies and on developing new technologies capable of providing uninterrupted high precision positioning 24 hours a day 7 days a week. This is our “24/7 SQ” concept, SQ standing for “Standardized Quality”. The key to the success of our 24/7 SQ concept is the seamless integration of all technologies driven by intelligent and easy-to-use software, delivering the best integrated hybrid solutions for our customers’ needs.

Topcon’s R&D is focused on the development and seamless integration of GPS-GLONASS-Galileo(G3)-GNSS, optical, laser, inertial navigation, imaging, scanning, automation&control, computer-vision, communications, and software technologies. This paper will discuss how these technologies are utilized and developed at Topcon to create products covering the entire spectrum from high accuracy 3D-surveying(e.g., mmGPS) to the automation and control of the job construction, mining, and agricultural sites and equipment(e.g., SiteLINK Total Job Site Management System).

The mmGPS technology combines the advantages of laser and GNSS technologies to create a hybrid-system capable of providing mm-level of

accuracy within the “Laser-Zone”. The SiteLINK Total Job Site Management System combines mesh network technology with the latest short-range communication technologies to create the foundation for the automation of job sites.

KEYWORDS: mmGPS, Laser-Zone, 24/7 SQ, G3, GNSS.

1. INTRODUCTION

Topcon was incorporated in Tokyo Japan in 1932. Over its long history of 75 years, Topcon has developed many “World’s First” products and technologies. One of Topcon’s primary missions is to be “The Primary Source” of superior value positioning systems that significantly improve the productivity and quality of work performed in civil engineering, agricultural and mapping industries.

Topcon is the premier manufacturer of precision positioning products offering the most complete positioning product portfolio in our industry. These products cover the entire spectrum from machine control and automation to the high-end optical and the most advanced GNSS products and services. Topcon is also one of the major manufacturers for vision testing instruments, retinal cameras, surgical and electron beam microscopes, and one of the world’s leading suppliers of optical lenses for reading CDs, DVDs and for camera phones. This paper will focus on the technology trends within Topcon’s Positioning business.

In the last five years the emergence of massive multi-core chips able to perform one trillion operations per second (i.e., 1 teraflop), distributed computing, wireless broadband communications, Micro-Electro-Mechanical Systems (MEMS) and advances in image processing and artificial intelligence are revolutionizing the precise Positioning business. Topcon is taking advantage of the latest advances in all these technologies to develop products and offer unique solutions to our customers ranging from machine control and automation to advanced software GNSS receivers.

2. Technology Trends at Topcon

Topcon’s core technology was originally the optical technology. In the early eighties Topcon started organic development of laser and image processing technologies. In 1994 Topcon initiated the strategy to start the acquisition of companies providing superior technologies complimentary to Topcon’s optical, laser and image processing technologies. As part of this strategy Topcon acquired AGTEK in 1994, Javad Positioning Systems (JPS) in 2000, and KEE Technologies in 2006. AGTEK provided the foundation and the initial technology for the machine control business, JPS for the GNSS business, and KEE technologies for the agricultural business.

In the last 10 years Topcon has advanced the state of the art and integrated all these technologies to offer superior products and solutions for the surveying, construction, machine control, Geographic Information Systems (GIS) and agricultural industries.

2.1 Optical Technology

Topcon offers a wide range of conventional and Robotic Total Stations for the general construction and surveying industries. In 2005 Topcon introduced Digital Imaging technology into the Total Stations allowing the surveyors to perform 3D close range

photogrammetry (Fig. 1).



Fig. 1. GPT7000i Imaging Total Station

To support the imaging Total Stations, Topcon is offering software tools for close range photogrammetric 3D modelling, feature extraction, image triangulation and image rendering.

The robotic Total Stations have revolutionized surveying and stakeout operations worldwide. Topcon's latest Robotic Total Station Technology incorporates Quick-Lock and Infrared (IR) communication, built-in 2.4 GHz radio, X-TRAC Prism Tracking, Ultra-Fast Servo Motor and integrated Bluetooth. This robotic technology provides the capability to track a simple prism of up to 1Km away, measure with mm level accuracy to a single prism of up to 3Km distances, and provide non-prism high accuracy measurements of up to 2Km distances.



Fig. 2. Cable-Free Robotic Total Station

Topcon's robotic Total Stations have the ability to perform automatic 3D scanning and image rendering using either internal or external digital cameras.

Topcon's research and development in this area is focused on providing the best tracking, quick-lock and measuring technology for the robotic Total stations.

2.2 Laser Technology

Topcon offers a reach set of laser products ranging from level and slope control for the general construction, interior construction (i.e., green lasers) and utility (i.e., pipe lasers) industries to the machine control and agricultural industries.

Topcon's mm-GPS N-Beam technology provides the ability to determine mm Level heights by combining the N-Beam vertical angle with the GPS measurements as shown in Fig.3.

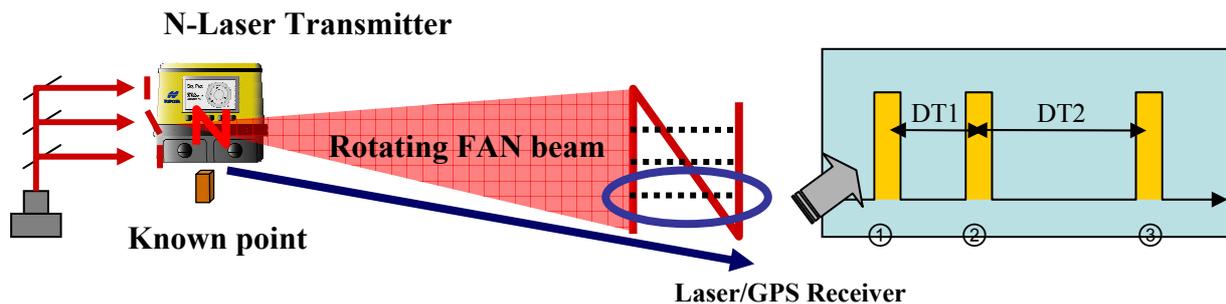


Fig. 3. mmGPS N- Beam Technology

At the transmitter the rotating fan beam generates a N-shape Laser (i.e., two vertical and one inclined laser planes). The Laser/GPS receiver detects the three laser-crossing times T1, T2, and T3 of the vertical-slant-vertical beams and computes the elevation angle through the time crossings ratio $DT1/(DT1+DT2)$. The height difference between the N-Beam laser transmitter and the Laser/GPS receiver is computed from the measured vertical angle and the horizontal distance computed from the GPS positions of the N-beam Laser transmitter and the Laser/GPS receiver.

This hybrid laser/GPS technology provides mm level accuracy within a 300 meter radius from the laser transmitter. Fig. 4 shows the operational area of the mmGPS technology which is referred to as the "Laser-Zone".

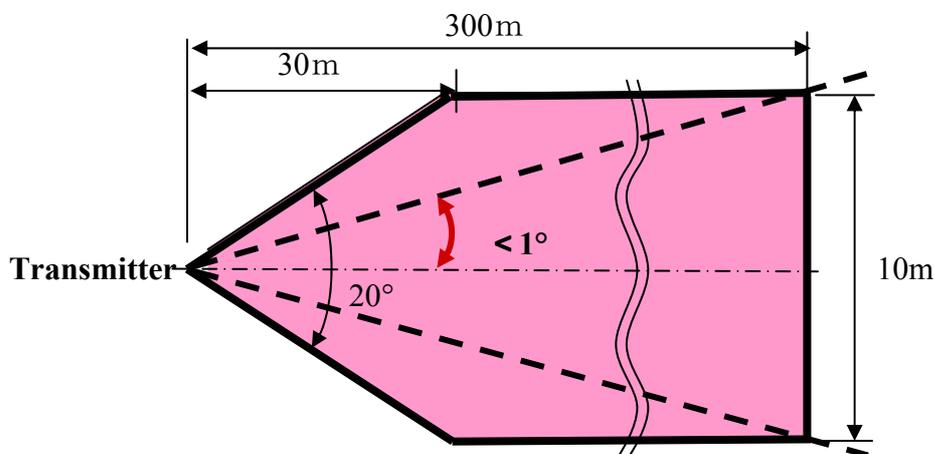


Fig. 4. mmGPS Operational area

This year Topcon introduced the GLS-1000 laser scanner which incorporates Topcon's latest state of the art laser scanner technology. Fig. 5. shows a picture of the GLS-1000 scanner.



Fig. 5. Laser Scanner GLS-1000

This scanner utilizes a invisible eye-safe Class 1 pulsed laser and is able to collect 3000 points per second with a range accuracy of 4mm at a distance of 150m. The GLS-1000 laser scanner provides 360 degrees horizontal angle view with up to 70 degrees elevation angle extent and is equipped with a 2 megapixel color digital camera. To support this scanner Topcon has developed 3D point cloud modelling and image rendering software with the capability to generate CAD drawings for 3D modelling and design.

Topcon is focusing the research development efforts on improving the laser technology to increase the range of application while maintaining the mm level accuracy.

2.3 GNSS Technology

Until 2006 Topcon was offering a variety of single and dual-frequency GNSS receivers capable of tracking both the GPS and GLONASS satellite signals. In 2006 Topcon introduced the G3 chip technology and the GR-3 and Net-G3 receivers based on this technology. Both of these receivers use 72 "universal" channels to track all GPS, GLONASS, and Galileo satellite signals. Topcon's micro-tuned precision antennas are capable of tracking all GPS, GLONASS, and Galileo signals, and the patented center-mount radio antenna provides excellent radio communications with superior interference reduction. Fig. 6 shows the GR-3 and Net-G3 receivers.



Fig. 6. Rover GR-3 and network Net-G3 Receivers

The GR-3 rover receiver includes a unique dual communication system capable of receiving both cellular (i.e., CDMA or GSM/GPRS) and radio signals. The internal radio can be configured either as a 915 MHz Spread Spectrum internal Tx/Rx or digital UHF radio. The digital UHF radio is using DSP technology and delivers better flexibility and reliability than the older analog UHF technology.

The Net-G3 receiver offers full network system connectivity. Its USB, Ethernet and four serial ports combined with the 20Hz data rates offer all the functionality and flexibility required for network reference receivers.

One major component of Topcon's GNSS network technology is the TopNET network software. TopNET is configurable and scalable to support Continuously Operating Reference Station(CORS) networks as well as Single-Base RTK and modelled RTK networks. TopNET's modelled network RTK modules support network operations based on Area Correction Parameters (FKP), Virtual Reference Station(VRS) measurements and Master-Auxiliary network Corrections(MAC). As the network needs increase TopNET offers the scalability to support as many stations as needed to cover an extensive area of network operations.

Topcon's GNSS research and development is focused on providing the best GNSS tracking technology in challenging environments including urban canyons, heavy canopy, and heavy interference environments. For the network support Topcon's research and development efforts are focused on providing state of the art modelling for tropospheric and ionospheric errors and on providing flexible, reliable, and scalable network software solutions.

2.4 Machine Control Technology

In the last ten years Topcon has been the leader in the development of 3D integrated automatic control systems for the construction and agricultural industries. Topcon's 3D integrated automatic control solutions provide the "missing link" in the automation from the survey and design phases of a job to stake out and execution.

The heart of a machine control system is a computer providing the user interface and the primary intelligence to control the entire system. This computer is tightly integrated with all positioning devices (i.e., GPS/INS, Lasers, sonar sensors etc), attitude devices (i.e., slope sensors, gyroscopes/accelerometers, dual GPS antennas etc.) and the hydraulic valves of the machine. The construction or agricultural job designs are loaded into the computer memory. The application software running in the control computer compares the current position and orientation of various machine components (e.g., bulldozer blades, scraper blades, excavator buckets, section sprayers etc.) and adjusts automatically these components and the machine's steering system to follow the design surface and design objectives to the required level of accuracy.

Fig. 7 shows a typical machine control configuration, and Fig. 8 shows the User Interface for Topcon's System Five-3D computer-controller box. The System Five-3D computer-controller box is running on Windows CE Operating System and the application software provides a rich interface to display grade information, machine-setup, system status and job site information (i.e, plan view, cross-section, profile views etc). Topcon provides a similar product for agricultural land levelling applications.

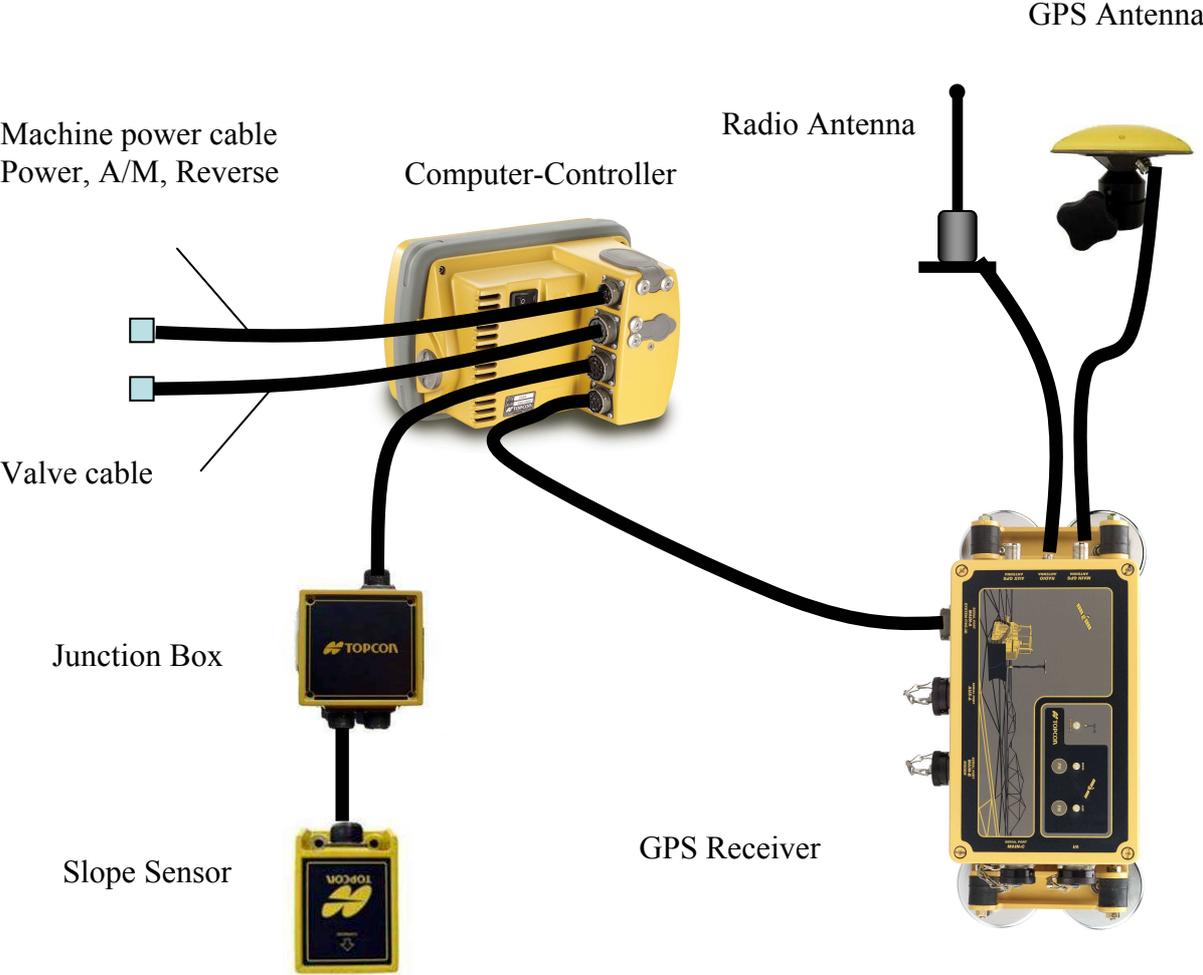


Fig. 7. Machine Control Configuration



Fig. 8. Topcon System Five-3D control Box

Early this year Topcon introduced the SiteLINK Total Job Site management System which provides complete machine tracking, asset management, theft control and reporting functionality. SiteLINK utilizes Mesh Network Technology built on top of a standard Wi-Fi environment and linked over the Internet for off-road equipment tracking and remote job site monitoring.

For the precision agricultural markets Topcon offers the computer-controller X20 box shown in Fig. 9.



Fig. 9. Topcon Precision Agriculture and Control System

The X20 Precision Agriculture and Control System is running on Windows XP and provides full functionality for guidance (visual and auto-steering), mapping and variable rate control, spraying, planting, spreading, and fertilizing.

Topcon's research and development efforts for machine control are focused on developing and providing end-to-end control, automation and monitoring for construction, agricultural, and mining on-site and off-site operations.

2.5 Field Controller and Software Technology

Topcon is manufacturing CE (CE.Net and Windows Mobile) field controllers to support all surveying, construction, and GIS field operations. Fig. 10 shows Topcon's current field

controller offerings (i.e., GMS-2, FC-200, FC-100, and FC-2000).



Fig. 10 Topcon Field Controllers (GMS-2, FC-200, FC-100, FC-2000)

The GMS-2 controller is an integrated single frequency GPS+GLONASS CE field computer powered by Topcon's TPSCORE GPS/GLONASS chip technology able to track all available GPS/GLONASS satellites. It features an integrated digital camera, and it is paired with the BR-1 beacon receiver for mapping and GIS applications.

The FC-200 controller is designed as an integral part of the GPT-9000 series robotic total stations. Built on a 520 MHz processor, with built-in Bluetooth wireless communications, the FC-200 provides cable-free connection to RC-3 quick-lock system or GPS receiver. The FC-200 provides wireless Wi-Fi LAN connectivity and 2.4 GHz spread spectrum radio connectivity to the GPT-9000 Robotic Total Stations.

The FC-100 and FC-2000 are Topcon's CE based general purpose field controllers providing Bluetooth wireless connectivity to all of Topcon's optical instruments and GNSS receivers.

Topcon is also focused on the development of intelligent surveying/GIS controller software which automates most of the surveying field operations. TopSURV is a powerful and easy to use controller software automating all the surveying field tasks including data collection, advanced roading layout functionality, full robotic Total station support, GPS RTK setup and control, and network communications. Pocket-3D is a powerful controller software running on Windows CE devices specifically designed for the contractor's data collection (i.e., check cut/fills, layout points etc.) in the job site. TopPAD is a field mapping and management software which combines the functionality of ESRI's ArcPAD field software with user Interface and hardware support specifically designed for Topcon's GIS mapping systems.

Topcon Tools is a powerful GPS post-processing, network analysis and adjustment software offering a rich user Interface for importing data from all of Topcon's field controllers and instruments. Topcon Tools includes an extensive set of modules for analysis, design, and image processing. The PI-3000 PC software provides a reach set of functionality for 3D photogrammetric modelling, surface analysis and design.

For the support of the Machine Control operations, Topcon offers three PC software products TopSITE, 3D-Office, and AgForm-3D. The TopSITE application software is a CAD-based software program offering full design capability for an entire site as well as 3D site simulation. The 3D-Office software provides the functionality required to create, edit, import/export, design and prepare all inputs required for System Five-3D controller box and the Pocket 3D field controller software. The AgForm-3D software provides the post-processing functionality for land levelling and agricultural surveying operations.

Topcon's software development efforts are focused on providing intelligent easy-to-use software delivering the best integrated solutions to our customers' needs.

3. CONCLUSIONS

Thought internal development and through external acquisitions Topcon has in the last ten years advanced the state of the art in the optical, image processing, laser, machine control and software technologies. Topcon's research and development efforts are focused on providing technological breakthroughs and innovative solutions which will help our customers to automate as many tasks as possible and give them the competitive edge for building and establishing profitable businesses.

Topcon is fully committed to develop the technologies that will provide full end-to-end automation and will meet the constantly changing demands facing the surveying, construction, and agricultural industries.

All these efforts have been rewarded as it is evident in the last several years by Topcon's accelerated offerings of innovative products and unique solutions for the precise positioning industry. Topcon has introduced more "world's first" products than any other company. Among them

- World's First dual-frequency GPS plus GLONASS receivers for surveying (Legacy E)
- World's First auto focus total station (GTS-600AF)
- World's First satellite-directed automatic 3D machine control system
- World's First integrated GPS receiver, antenna and radio (HiPer+)
- World's First integrated GPS receiver, controller and radio (HiPer+)
- World's First wireless total station (GTS-230W)
- World's First cable-free RTK system (HiPer Lite)
- World's First electronic self-leveling laser under \$900 (RL-H3C)
- World's First value-priced (under \$1,500) totally self-leveling laser with SmartLine (RL-VH3D)
- World's First robotic total station with instant beam lock system (GTS-800)
- World's First robotic total station with optical communication link (GTS-800)
- World's First satellite receiver chip (Paradigm G3) allowing users to track all GPS, GLONASS, and Galileo signals.
- World's first integrated GIS data collection and land survey system (GMS-110)

Topcon is the largest company in the world focused exclusively on precise positioning, machine control hardware products and software applications for the surveying, construction, and agricultural industries. Topcon is committed continue on the accelerated path of bringing innovative products and intelligent solutions that best address our customers' needs.

4. REFERENCES

www.topconpositioning.com