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STUDIES OF SMART ANTENNA SYSTEMS IN AGRICULTURAL APPLICATION AND PERFORMANCE OF NOVATEL'S SMART-V1 AND SMART-V1G ANTENNAS

1. Giriraj Prajapati* 2. Dr. Rajiv Trevedi 3. Dr.Gulzar Ahmed
Email- girirajp@yahoo.com, rajeev.trivedi80@gmail.com, gulzar ahmed61@gmail.com
1.Research Scholar, Mewar University Chittorgarh, (R.J.)
2. Professor, Organization : alpine Institute of technology ,Ujjain (M.P.)
3. Professor, Organization Mewar University Chittorgarh, (R.J.)

ABSTRACT

This paper discusses the agricultural application and performance of NovAtel'sSMART-V1 and SMART-V1G antennas. In this paper, the results of field tests are presented. This paper also introduces Nov Atel's newest enhancement to positioning algorithms, GL1DE™. This test was designed to resemble a typical agricultural environment. NovAtel's SPAN technology was used to collect the GPS and IMU data during the dynamic vehicle testing. Components included a NovAtel Propak-V3 and a Honeywell HG1700 IMU AG58. Data collected during dynamic vehicle testing was post-processed using NovAtel's Inertial Explorer technology to obtain an antenna trajectory solution. The trajectory solution for each antenna accounted for appropriate lever arm corrections from the INS to the antennas. The expected accuracy of the trajectory was 2-3cm.

Key words: Antennas, Agricultural application

INTRODUCTION

SMART antennas, with integrated GPS and L-band receivers and a rugged form, offer high level L1 GPS capabilities that can be used in a variety of environments. Additionally, SMART antennas with GPS plus GLONASS capability offer increased solution availability. This paper examines the design of NovAtel's SMART-V1, and SMARTV1G antennas and investigates their performance during field tests.

Common Features

Both antennas support RS-232 or RS-422,USB or CAN, as well as API. The antennas also support NovAtel's innovative RT-20 technology for decimeter-level positioning. The SMART-V1 and V1G are compliant with the European ROHS directive. Currently the SMART-V1G is available in a dual RS-232 and USB configuration. the latest product configurations available for the SMART-V1 and SMART-V1Gantennas. The antennas feature:

• 14 GPS L1, 2 SBAS, plus 1 L-band or 12 GLONASS L1 • Carrier phase tracking for improved positioning accuracy and reliability
• Position, velocity, and time (PVT) output at rates up to 20 Hertz and raw carrier phase measurement data at rates up to 20 Hertz
• 1PPS accuracy of 20 nanoseconds (typical)
• RT-20 (GPS or GPS+GLONASS)

SMART-V1 Features

The SMART-V1 antenna incorporates NovAtel's OEMV-1 card. This means that the antenna is GPS only. It also has L-band capability for VBS (with an Omni STAR subscription) or Canadian Differential GPS (CDGPS, which is free for all users). Omni STAR provides a high-quality corrections link that eliminates the requirement for a ground-based correction signal. The Government of Canada's CDGPS, provides a sub-meter correction signal for use in Canada and the northern USA. The SMART-V1 antenna allows users to take advantage of the improved positioning accuracy provided by L-band technology. For users within North America, free CDGPS L-band corrections provide sub-meter accuracy with a data signal that performs well in difficult conditions, such as in heavy foliage.

SMART-V1G Features

The SMARTV1GantennaincorporatesNovAtel's OEMV-1G card, allowing the antenna GPS+GLONASS capabilities. This interoperability is a huge asset for the agricultural and machine control Positioning using *GL1DE* in an Agricultural Environment.

Fig.1 NovAtel's SMART-V1 Antenna

***GL1DE* Overview**

The SMART-V1 and V1G antennas feature the *GL1DE* algorithm, which is NovAtel's latest enhancement to its positioning algorithms for single frequency GPS applications. *GL1DE* is particularly helpful in improving single frequency positioning for products with limited space for a ground plane. One such product would be a small SMART antenna, see Table 2. Generally, a SMART antenna of that size would be more susceptible to multipath (reflected) signals. Multipath signals tend to induce time-varying biases and increase the measurement noise on the L1 pseudo range measurements.

Channel Configurations
SMART-V1 SMART-V1G
14 GPS L1 14 GPS L1
1 L-band 12 GLO L1
2 SBAS 2 SBAS
Position Accuracy (Horizontal RMS, no GL1DE)
L1 1.8 m
SBAS 1.2 m
CDGPS 1.0 m
Omni STAR VBS 0.9 m
DGPS 0.7 m
RT-20 0.2 m
Measurement Precision
L1 C/A Code 18 cm RMS
L1 Carrier Phase 1.5 mm RMS
Data Rate
Measurements 20 Hz
Position 20 Hz
Time to First Fix (TTFF)
Cold Start 65 s
Hot Start 35 s
Signal Reacquisition
L1 0.5 s (typical)
Accuracy
Time Accuracy 20 ns RMS
Velocity Accuracy 0.03 m/s RMS
Dynamics Velocity 515 m/s
SMART-V1 and SMART-V1G
Specifications
Size 115 mm diameter x 90 mm height
Weight 575 g
Power Input Voltage +9 to +24 VDC
Power
Communication
2 RS-232 or RS-422 Serial ports
1 CAN Bus or USB 1.1 port
1 PPS
Input/ Output Connectors
18-pin plastic bulkhead connector
Mounting
1" - 14 UNS threads for centre mounting
3 x 10-32 UNF screws for plate mounting
Temperature
Operating -40° to +75°C
Storage -55° to +90°C
Waterproof/Immersion
MIL-STD-810F 512.4, Procedure l
Shock MIL-STD-810F 516.5

Testing Introduction

Testing was conducted in RT-20 mode evaluation. The second test was a dynamic vehicle test designed to test the antennas for agricultural use.

RT-20 Testing Overview

The RT-20 test was further split into two components: RT-20 mode convergence and RT-20 mode steady state with no filter resets. The goal of the first RT-20 test was to evaluate the horizontal and vertical convergence for both the SMART-V1 and the SMART-V1G. The goal of the second test was to evaluate the steady-state positioning performance. Equipment used during the RT-20 evaluations included a NovAtel DL-V3 receiver with a GPS-702-GG antenna, as a base station. A SMART-V1 antenna and a SMART-V1G antenna were used as stationary rovers, mounted to a house.

RT-20 Convergence

During this test, a software reset of the RT-20 filter was conducted every 3200 seconds. This was repeated over approximately 50 cycles. The 50 plus cycles were used to compute horizontal and vertical errors after "*n*" seconds of convergence. The data were then sorted by the magnitude of horizontal and vertical errors to determine the 50th and the 95th percentile errors. For both the SMART-V1 and the SMART -V1G, it took approximately 5 to 7 minutes to achieve a horizontal position accuracy of less than 20 centimeters (50th percentile) and 16 to 20 minutes to achieve a position accuracy within the 95th percentile. It took both antennas less than 4 minutes to achieve a vertical position accuracy of less than 20 centimeters (50th percentile) and 15 to 20 minutes to achieve a position accuracy within the 95th percentile. A notable observation regarding the SMART-V1G was that using the antenna's GLONASS capability, there appeared to be a greater improvement in the reduction of vertical position error. The SMART-V1G still tends to improve horizontal accuracy at the 50th percentile and shows a comparable accuracy at the 95th percentile.

RT-20 Steady-State

The same base station and rover configuration was used to evaluate the performance of the RT-20 in steady state mode. The SMART-V1 and SMARTV1G receivers each computed a real time RT-20 solution that was logged at 1Hz. No resets of the filter were conducted and the data were collected for approximately 12 hours, 8 of which are presented in the following solution. See Figures 4 and 5 below to see horizontal results typical for RT-20 steady state mode for both SMART-V1 and SMART-V1G. Both SMART-V1 and SMART-V1G converge to a position accuracy of less than 10 centimeters in under approximately 10 minutes. The antennas maintained that position accuracy for the 12 hour duration of the test. During the 8 hours of the test that are depicted in this paper, horizontal position errors were consistently less than 5 centimeters. See Figures 4 and 5 for more information.

Figure2 Dynamic Vehicle Test in Overview

Figure 3: Antenna Location

Agricultural Environment

The evaluation was conducted in a dynamic vehicle. The vehicle collected data for the agricultural test. The vehicle travelled on a simulated "AB" line with a vehicle velocity of 5 to 10 km/h. See Figure 9 for an example of the vehicle's path. Two SMART-V1 antennas were located on the roof of the van. See Figure 8. Data evaluated included single-point, SBAS, CDGPS and VBS with results for SBAS and CDGPS tests presented in this paper.

The right plot shows the errors for the same SMART-V1, but with the pseudo range and carrier phase measurements used by the *GL1DE* algorithm. The *GL1DE* solution is very effective in mitigating the "noise" inherent in the least-squares solution. The *GL1DE* solution also reduces the effect of multipath, to generate a reasonably smooth and consistent position solution. Results for this test were simila r to test results from the SMART-V1 running in

CDGPS mode, shown in Fig

figure4 **Figure : Open-field test environment**

Note that the CDGPS errors currently include a bias in the northing of approximately -0.5m and a bias in the easting of approximately+1 m due to a datum difference between WAAS and CDGPS, which is taken into account for the least-squares solution but not currently for the *GL1DE* solution. A future release of *GL1DE* will account for this and eliminate the bias. For agricultural pass-to-pass applications that rely on relative positioning, this will be a non-issue. For both the SMART-V1 and the SMART-V1G antennas, the pass to- pass repeatability was on the order of 30 cm or less. See Figure 10 on page 5 fot the pass-to-pass Google Earth output generated in Inertial Explorer.

Figure. 5 Pass to Pass Google Earth Output

Conclusion

This testing has shown that the SMARTV1 and the SMART-V1G are suitable antennas for agricultural applications. With the addition of NovAtel's *GL1DE* positioning algorithim, noisy solutions are smoothed easily and single frequency positioning is improved. antennas offer great value for versatile positioning in a rugged package. The SMART-V1 and SMART-V1G antennas incorporate NovAtel's field proven OEMV-1 or OEMV-1G cards and offer: high quality code and phase measurements, reliable pass-to-pass positioning using GL1DE technology, or decimeter level positioning using RT-20. The antennas offer a wide range of positioning modes including single-point, SBAS,VBS, CDGPS, DGPS and RT-20.

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