L-band Antenna Performance Improvements

NovAtel Inc.

ABSTRACT

NovAtel's GPS-702L provides combined L1/L2 and L-band reception in a single antenna. Designed for use with the OmniSTAR and Canada-wide Differential GPS (CDGPS) correction services, the GPS-702L is a replacement for NovAtel's GPS-600-LB antenna. The difference of the GPS-702L over its predecessor is its ability to improve on RTK while maintaining L-band performance.

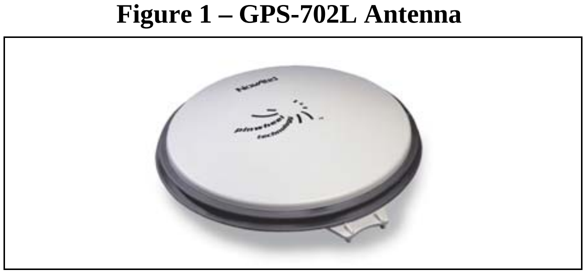
The performance of the GPS-702L, both on its own and as compared to the GPS-702 and the GPS-600-LB, was evaluated by collecting system level measurements under a variety of conditions. Three of the tests were designed to simulate typical applications in which the GPS-702L is often used. The first is a high multipath environment. The second is driving back and forth with 180-degree turns, as encountered in precision agriculture applications. Thirdly, the ambiguity resolution time, important for RTK applications, was assessed. To complete the analysis, the antenna gain patterns and phase centre variations were plotted.

The test results collected show that the GPS-702L offers comparable performance to the GPS-702 and consistently outperforms its predecessor, the GPS-600-LB. As a result, the GPS-702L is considered an ideal solution for high precision, real-time applications using L-band technology and for users who operate in both L-band and RTK modes with a single antenna.

ANTENNA OVERVIEW

NovAtel's GPS-702L, part of NovAtel's GPS-700 antenna series, offers access to the GPS L1 and L2 frequencies, as well as the L-band frequencies used by the OmniSTAR and Canada-wide Differential GPS (CDGPS) correction services.

Figure 1 – GPS-702L Antenna



When combined with NovAtel's ProPak-LB*plus* receiver, the GPS-702L 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 structured to perform well in difficult conditions such as heavy foliage. Worldwide, OmniSTAR's subscription-based service offers real-time DGPS positioning with meter- to decimeter-level accuracy.

Figure 2 – ProPak-LB*plus* Receiver

Features and Benefits

In addition to superior L1, L2, and L-band reception, the GPS-702L features improved RTK performance for high-accuracy, real-time positioning applications. Closely located L1 and L2 phase centers combined with high phase center stability ensure optimal RTK operation, even over long baselines.

In addition, the GPS-702L meets the European Union's directive for Restriction of Hazardous Substances (RoHS). As one of the first RoHS compliant GPS products, integrators can be confident that the GPS-702L can be used in system designs for years to come.

For extended life, the GPS-702L also features a waterproof housing and meets the vibration and salt spray standards as shown in *Table 3* on *Page 2*. Sharing the same form factor as the other antennas in the GPS-700 series, the GPS-702L is compact and lightweight, making it a highly portable and rugged antenna suitable for a wide variety of environments and applications.

Pinwheel Technology

The GPS-702L features NovAtel's patented Pinwheel technology with its aperture coupled slot array design. This unique configuration offers superior amplitude radiation pattern roll-off near the horizon, in effect eliminating multipath-generated replicas of the original line-of-sight (LOS) signal. It also exhibits excellent sensitivity to right-hand circularly polarized signals over a wide range of elevations and in all azimuth directions. The Pinwheel design results in an excellent axial ratio as well, ensuring that a high quality signal is received. It also provides enhanced immunity against EMC/EMI and electromagnetic pulse interference.

Specifications

Specifications for the GPS-702L antenna are provided in the tables that follow.

Table 1 – GPS-702L Performance Specifications

Pass Band	
L1 (3 dB)	1575 ± 20 MHz (typical)
L2 (3 dB)	1228 ± 20 MHz (typical)
L-band (1 dB)	1543 ± 20 MHz (typical)
Out-of-Band Rejection	
L1, L-band	
1555 ± 75 MHz	30 dBc (typical)
1555 ± 100 MHz	50 dBc (typical)
L2	
1227 + 50 MHz	25 dBc (typical)
1227 - 50 MHz	30 dBc (typical)
1227 ± 100 MHz	50 dBc (typical)
LNA Gain	27 dB (typical)
Gain at Zenith (90°)	
L1	+5.0 dBic (minimum)
L2	+1.5 dBic (minimum)
L-band	+5.0 dBic (minimum)
Gain Roll-Off [1]	
L1	13 dB
L2	12 dB
L-band	13 dB
Noise Figure	≤ 2.5 dB (typical)
VSWR	≤ 2.0 : 1
L1-L2 Differential Propagation Delay	15 ns (maximum)
Nominal Impedance	50 Ω
Altitude	9,000 m

[1] From zenith to horizon.

Table 2 – GPS-702L Physical and Electrical Specifications

Diameter[2]	185 mm
Height	69 mm
Weight	500 g
Input Voltage	+4.5 to +18 VDC
Current Consumption	33 mA (typical)
Connector	TNC female
Regulatory	FCC Class B, CE

Table 3 – GPS-702L Environmental Specifications

Operating Temperature	-40°C to +85°C
Storage Temperature	-55°C to +85°C
Humidity	95% non-condensing
Random Vibration	MIL-STD-810F, 514.5, 7.706
Sinusoidal Vibration	ASAE 5.15.2, Level 1
Shock	IEC 68-2-27, Ea
Bump	IEC 68-2-29, Eb
Salt Spray	MIL-STD-810F, 509.4
Waterproof	IEC 60529 IPX7
RoHS	EU Directive 2002/95/EC

TESTING OVERVIEW

To evaluate the performance of the GPS-702L, a variety of measurements were taken:

- Code minus carrier standard deviation under high multipath conditions
- L-band signal to noise ratio during 180-degree turns
- Percentage of ambiguity resolutions over time after an RTK reset
- Antenna gain over elevation and azimuth
- Phase centre variations

For comparison, the same data was collected for the GPS-702, NovAtel's L1/L2 antenna, and the GPS-600-LB, the predecessor to the GPS-702L. Where applicable, the antennas were connected to receivers of identical model, software load, and configuration.

TEST RESULTS

Multipath Performance

To gauge an antenna's resistance to multipath, the amount of variation in the code minus carrier measurement can be examined. As the pseudorange code is much more susceptible to noise than the carrier, when the difference between the two is taken,

[2] Not including tape measure tab. Full diameter with tape measure tab is 195 mm.

what remains is largely the noise found on the code. Large variations in the code noise can typically be attributed to multipath. As a result, the multipath susceptibility of an antenna can be shown by plotting the standard deviation of the code minus carrier.

To evaluate the multipath performance of the GPS-702L, GPS-702, and GPS-600-LB, the antennas were placed on the edge of the roof at the NovAtel offices, a high multipath environment. Each antenna was connected to an identical receiver and the code minus carrier standard deviations at various satellite elevations were calculated. The data for all three antennas is shown for the L1 and L2 frequencies in *Figure* 3 and *Figure* 4, respectively.

Figure 3 - L1 Code Minus Carrier Standard Deviation vs Satellite Elevation

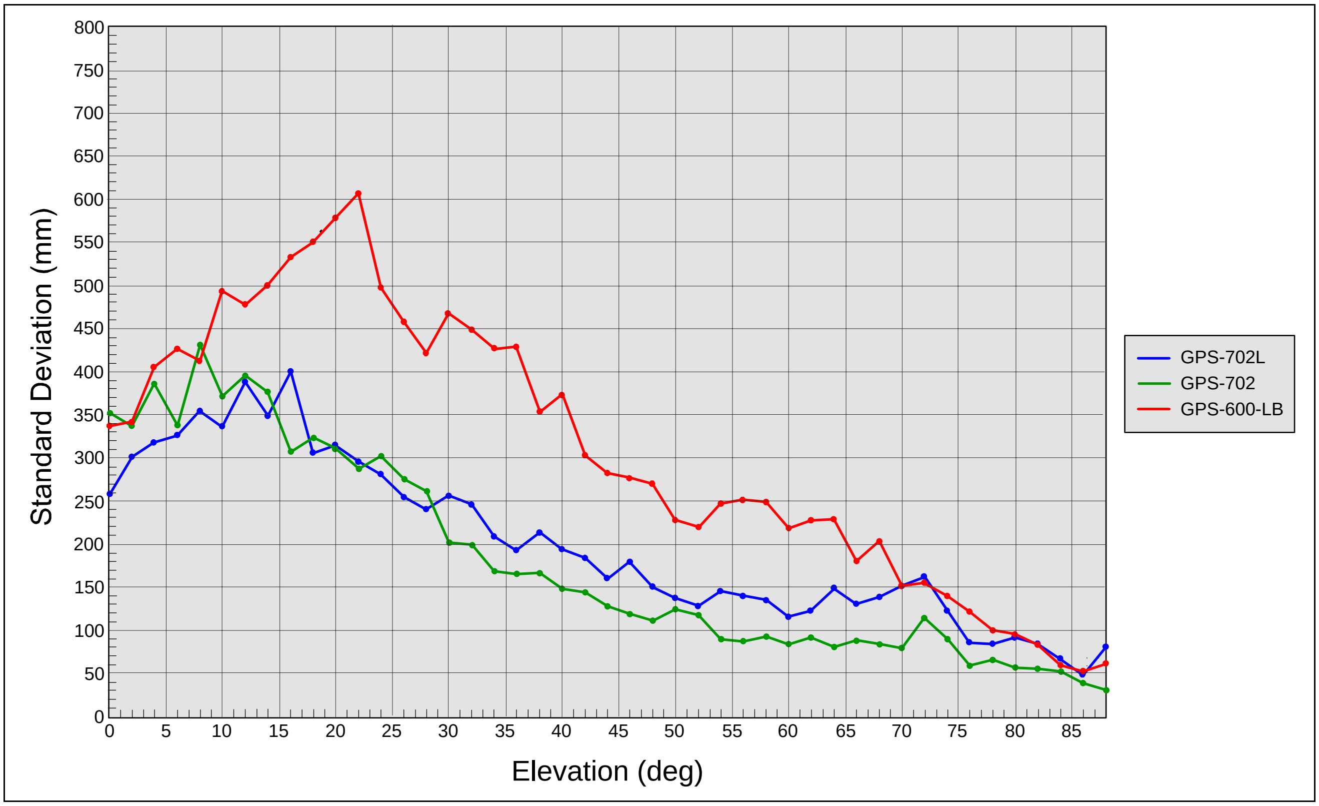
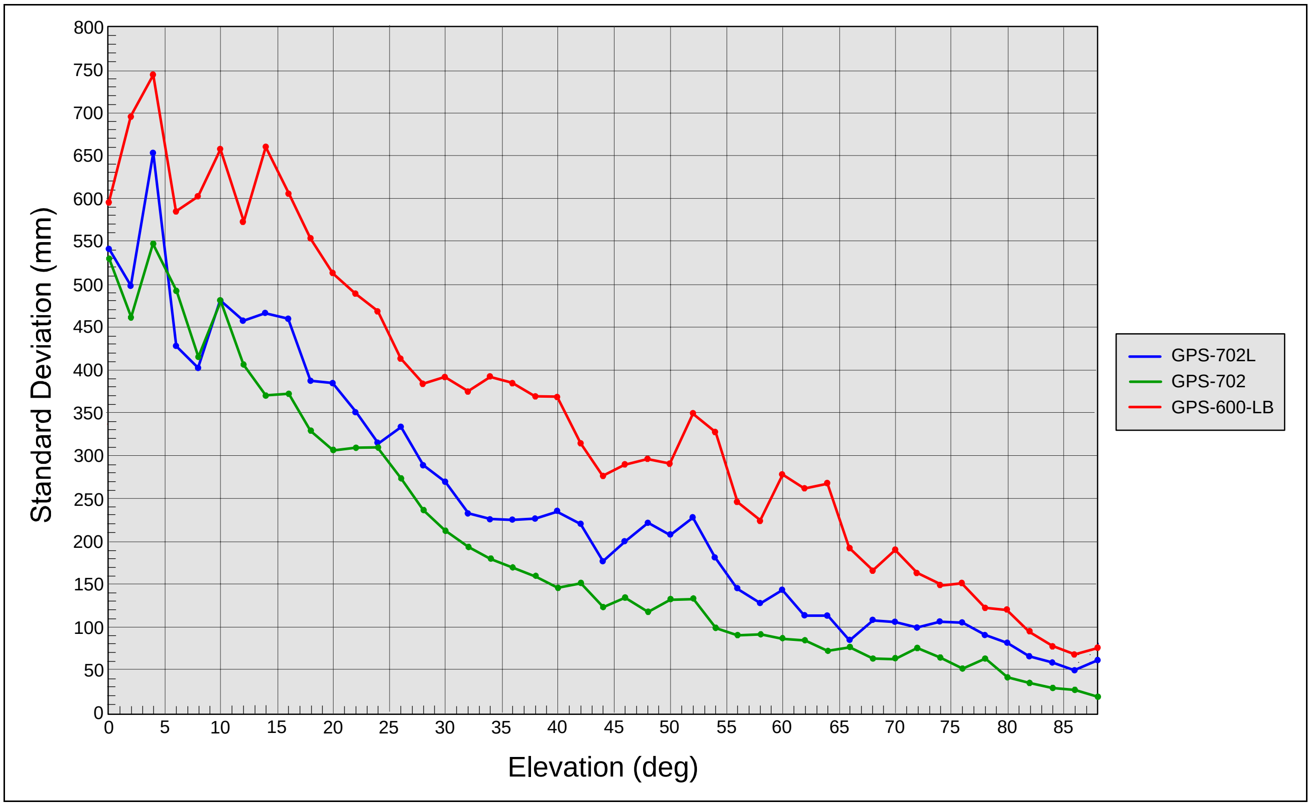


Figure 4 – L2 Code Minus Carrier Standard Deviation vs Satellite Elevation

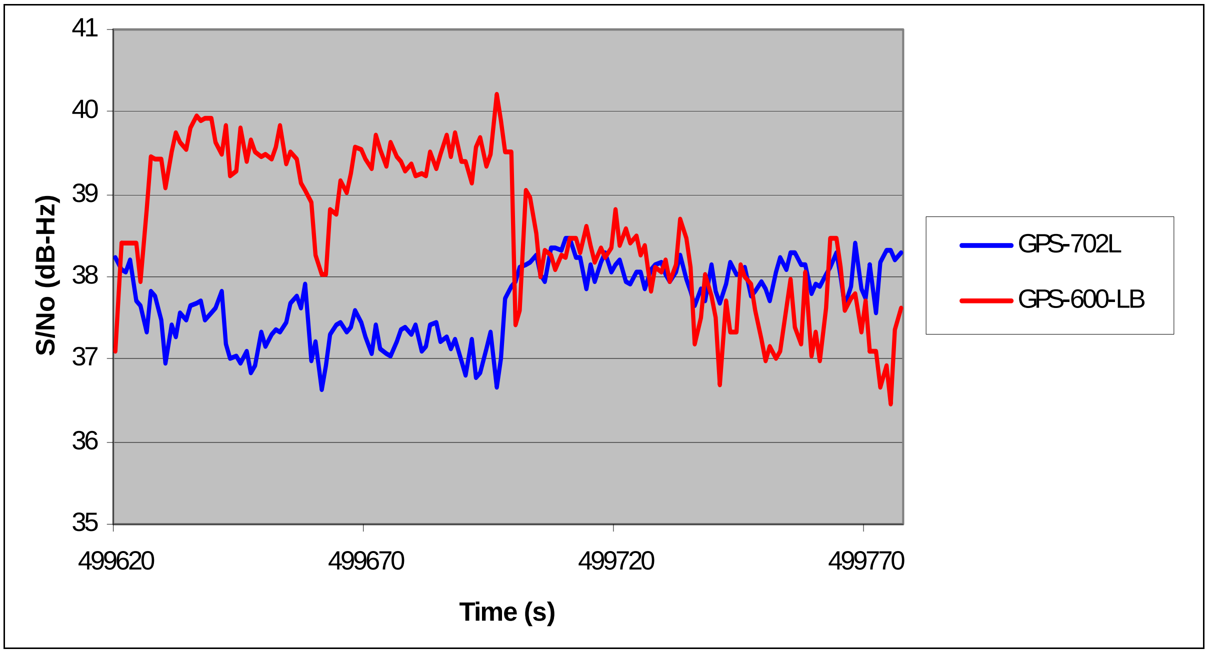


As can be seen from the plots, the GPS-702L shows similar high resistance to multipath as the GPS-702. The GPS-600-LB shows increased variation in the code minus carrier measurement, particularly at satellite elevations below 40 degrees, making it less ideal for high multipath areas.

Stability during Turns

L-band technology is often used in precision agriculture to provide improved accuracy without the need for a separate base station. Typically, agricultural equipment, along with the positioning system, travels up and down the field, with 180-degree turns at each end of the field. To assess antenna performance in this type of application, L-band signal to noise data was collected from side by side GPS-702L and GPS-600-LB antennas during a series of 180-degree turns. The data during a single turn is shown in *Figure 5*.

Figure 5 – L-band Signal to Noise Ratio for a Single 180-Degree Turn



As expected by the design, overall the GPS-702L L-band signal to noise is slightly lower than the GPS-600-LB. However, the GPS-702L shows less variation as the antenna turns 180 degrees, at approximately 499695 seconds. This is supported by the larger variation in azimuth that the GPS-600-LB exhibits, as detailed in the section entitled *Antenna Gain Pattern*.

Resolution Time

Antenna quality can also affect the amount of time required for ambiguity resolution. A GPS-702L, GPS-702, and GPS-600-LB were set up on the edge of the roof at the NovAtel offices and connected to identical receivers. For each antenna, the percentage of narrowlane ambiguities resolved by the receiver at various intervals since RTK reset was measured. The results are shown in *Figure 6*.

Figure 6 - Percentage of Narrowlane Ambiguity Resolutions over Time

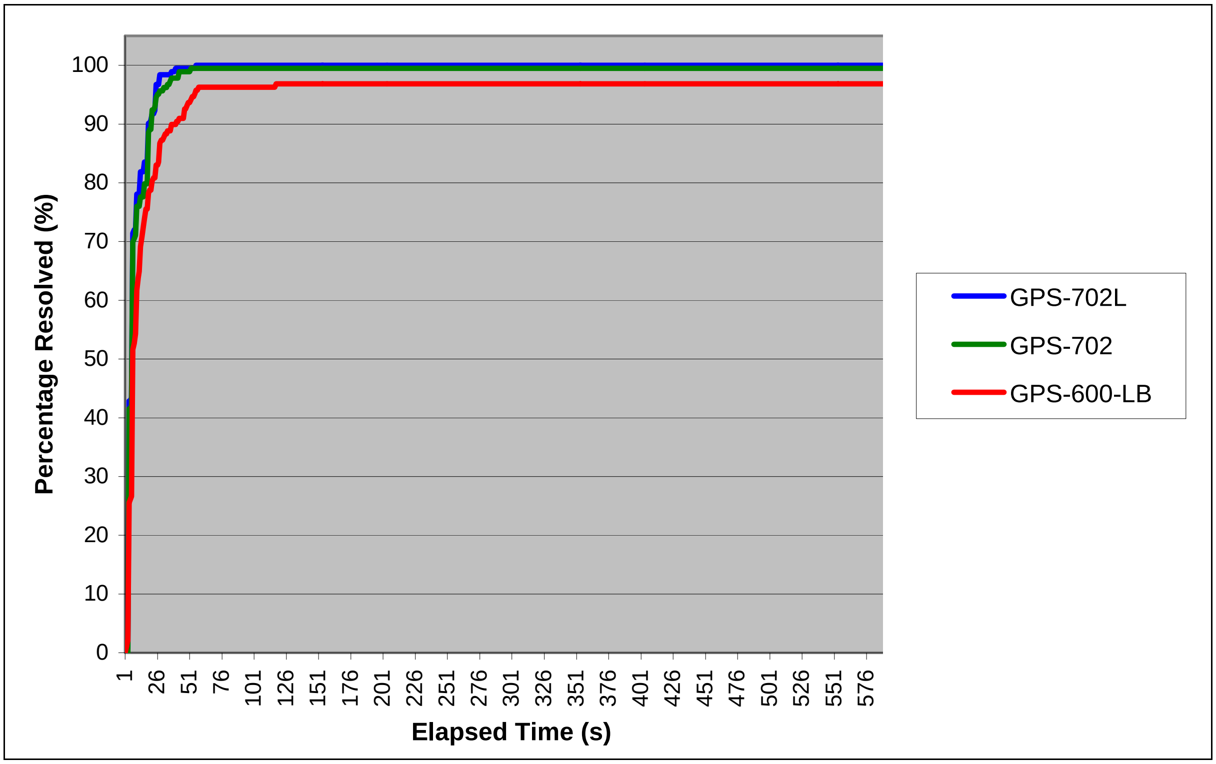
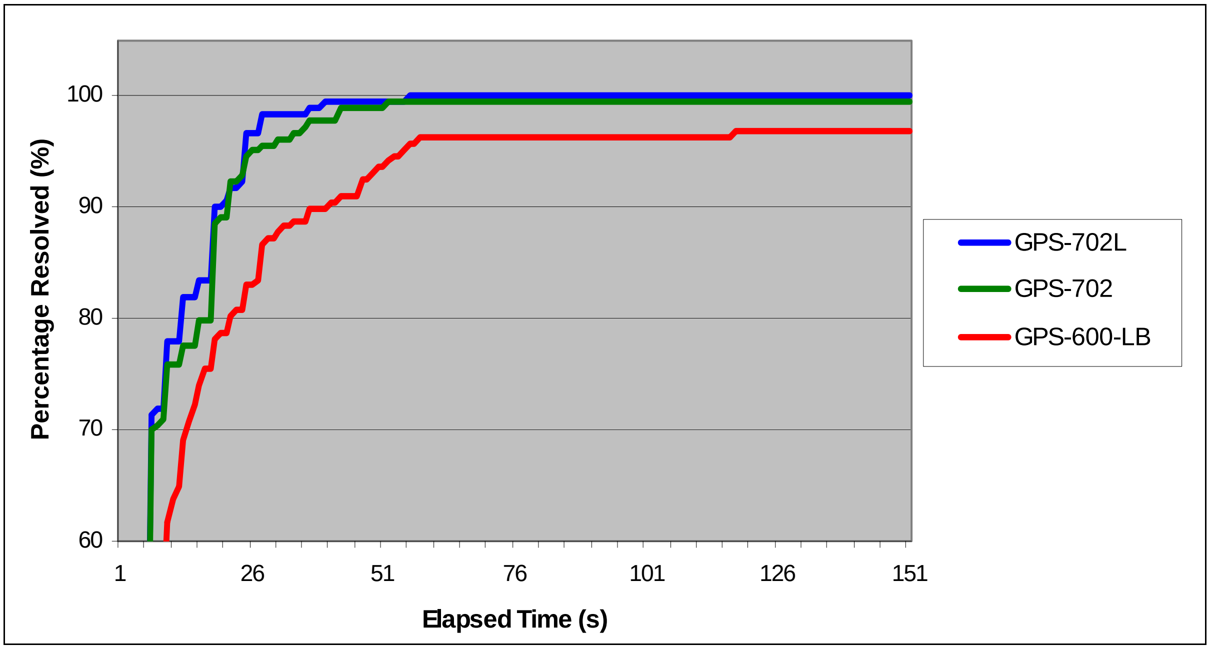


Table 4 shows the same data, but for a selection of time intervals from RTK reset. *Figure 7* that follows provides an enlarged view of a section of the previous plot, highlighting the main area of divergence between the antennas.

Table 4 - Percentage of Narrowlane Ambiguity Resolutions at Various Intervals

Time Since Reset (s)	% Resolved		
	GPS-702L	GPS-702	GPS-600-LB
5	43.407	42.077	26.596
10	78.022	75.956	63.830
30	98.352	96.175	87.766
60	100	99.454	96.277
120	100	99.454	96.809
180	100	99.4536	96.8085
300	100	99.4536	96.8085

Figure 7 - Percentage of Narrowlane Ambiguity Resolutions over Time (Zoomed-In View)



It is clear from the data that similar resolution time can be expected when using the GPS-702L as when using the GPS-702. The plots also show that both antennas outperform the GPS-600-LB. As an example, at 25 seconds from RTK reset, the receiver using the GPS-702L shows approximately 14 percent additional ambiguity resolutions over the identical receiver using the GPS-600-LB.

This difference can be attributed to better antenna performance offered by the GPS-702 and GPS-702L over the GPS-600-LB. A key benefit of the improved resolution time shown by the GPS-702L over the GPS-600-LB is the shorter time needed to reacquire a solution after the position is lost.

In looking at the percentages listed after the 120-second mark for the GPS-702 and GPS-600-LB antennas, it should be noted that the remainder of narrowlane solutions for these receivers were not resolved. This is likely a result of a test tool error as all three antennas tracked well during the test.

Antenna Gain Pattern

To further analyze the characteristics of the GPS-702L, the antenna gain pattern was plotted. The gain pattern is a graphical depiction of the relative field strength received by the antenna in relation to the elevation angle of the satellite transmitting the signal.

The gain patterns for the GPS-702L, GPS-600-LB, and GPS-702 follow. The gain for both right-hand polarized signals, which includes GPS signals, and left-hand polarized signals, such as direct multipath reflections, are included. For ease of use, the plots are normalized to the maximum graph value, 0 dB, and the peak gain value is listed next to each plot.

Figure 8 - GPS-702L Gain Pattern

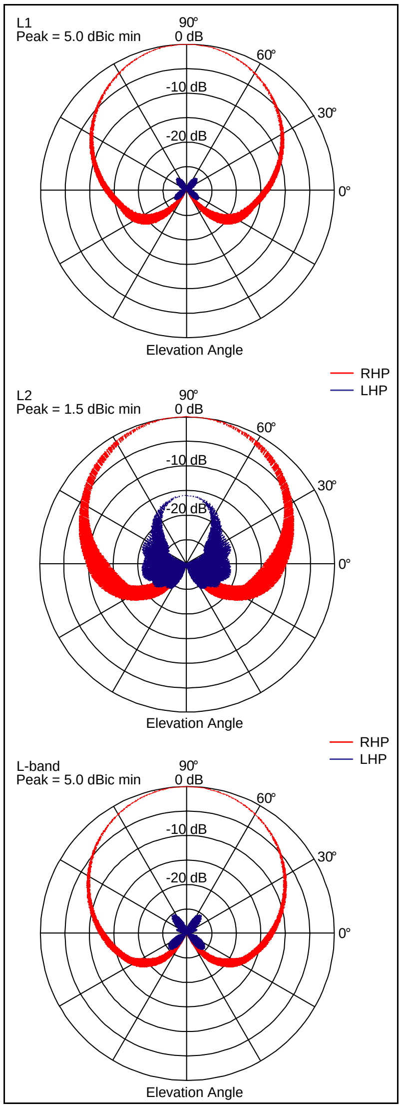


Figure 9 - GPS-600-LB Gain Pattern

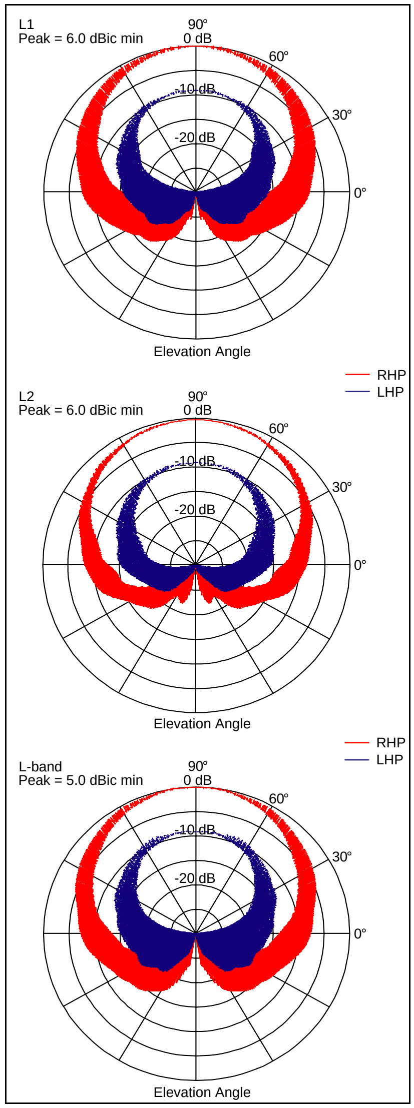
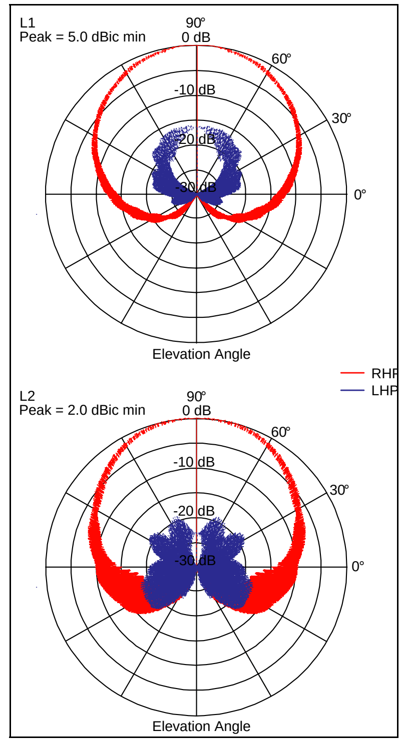


Figure 10 - GPS-702 Gain Pattern



On its own, the GPS-702L gain pattern shows the antenna has excellent multipath immunity. The limited gain for left-hand polarized signals ensures reception of direct reflections is minimized. The amplitude roll-off from peak elevation to 0º is between 12 dB and 13 dB, which compares well with a patch antenna mounted on a choke ring ground plane.

The thickness of the pattern's "line" indicates the amount of variation in gain in the azimuth plane. The GPS-702L shows minimal variation, largely less than 1 dB, especially for the L1 and L-band frequencies. A large variation in azimuth can potentially lead to biases in the range measurements that are difficult to compensate for.

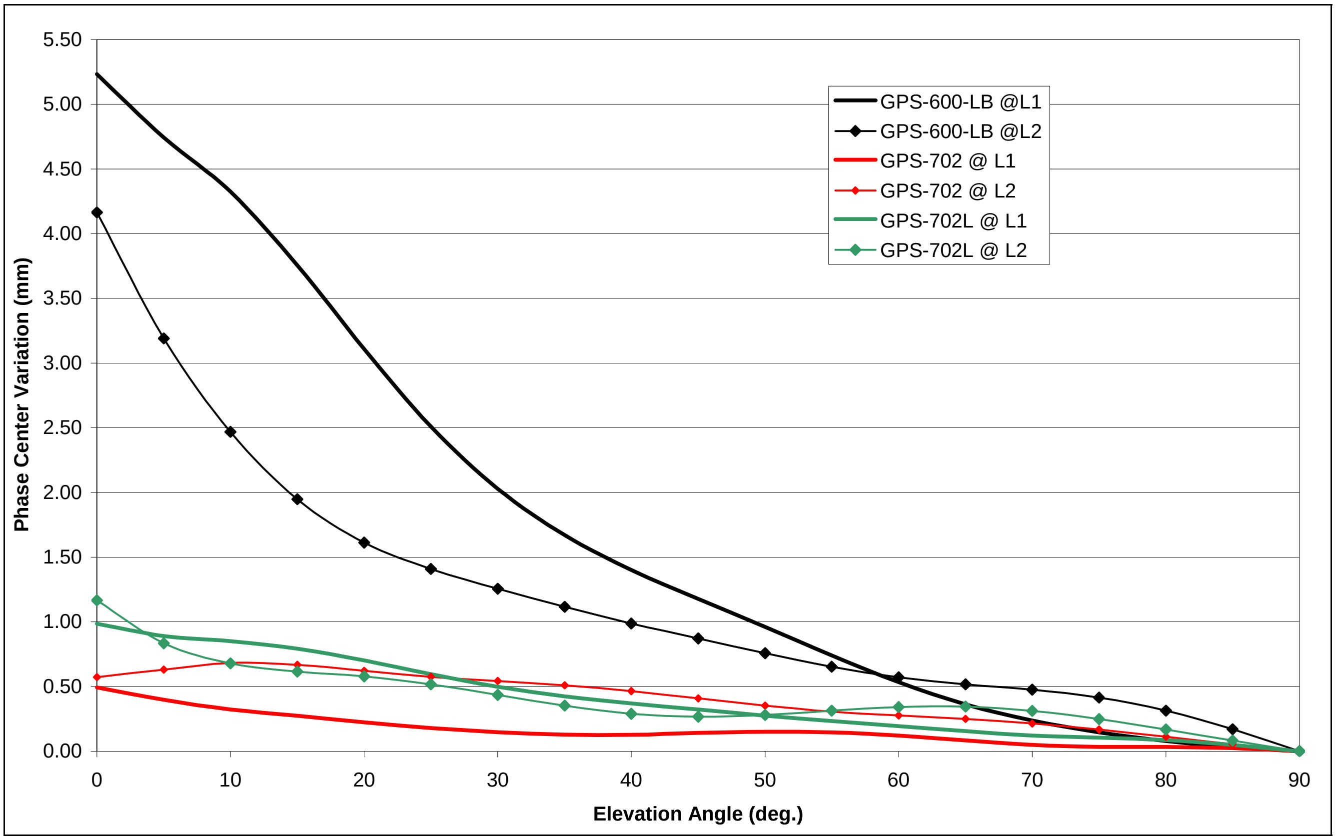
Compared to the GPS-600-LB, the gain pattern shows the GPS-702L to be superior. Left-hand polarized signals are minimized much more by the GPS-702L. Variation over azimuth is also reduced greatly.

When comparing the GPS-702L to the GPS-702, the gain pattern at the L1 and L2 frequencies is comparable, both showing excellent roll-off and minimization of left-hand polarized signals. Multipath detection in the GPS-702L is an improvement on the GPS-702 and much superior to the 600-LB at the L1 and L-Band frequencies.

Phase Centre Measurements

A summary of absolute antenna calibrations performed by Geo++ is shown in *Figure 11*. The elevation dependant absolute phase center variations (PCV) were determined for the GPS-600-LB, GPS-702 and GPS-702L antennas.

Figure 11 Phase Centre Variations



The figure shows that the GPS-702 antenna provides sub-millimeter PCV accuracy while GPS-702L provides millimeter level PCV accuracy. This provides much improved robustness for high accuracy mobile and static RTK applications when compared to the GPS-600-LB antenna.

SUMMARY

As seen from the data presented, NovAtel's GPS-702L antenna provides excellent performance and is an ideal solution for positioning systems requiring superior L-band reception. More specifically, the GPS-702L offers high multipath immunity and stability during turns and aids in quick ambiguity resolution for RTK applications.

The data also shows that the GPS-702L compares very well against the GPS-702, NovAtel's L1/L2 antenna, and consistently outperforms the GPS-600-LB, NovAtel's previous generation L1/L2/L-band antenna.

For more information on the GPS-702L, contact NovAtel at 1-800-NovAtel or 403-295-4900 or visit our website at www.novatel.com.