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Technology Paper

GNSS Equipment Interoperability

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The purpose of this document is to explore and discuss the ramifications of working within non-homogenous GNSS environments. Historically, the GNSS surveying industry has utilized a typical base and rover configuration and in most instances, the base and rover were paired; the base station was very likely the same make and model as the rover. However, the model has changed. GNSS networks of permanently installed reference stations have become common. Surveying firms are looking for ways to keep their older equipment in service while remaining competitive with newer technologies. This mixture of brands and models of equipment creates the obligation to consider various aspects of the equipment configurations that are not issues with paired systems.

The propositions that must be considered include:

1) Real-time correction format
2) Communication
3) Antenna definitions
4) Datums
5) Hardware limitations

REAL-TIME CORRECTION FORMAT

Each manufacturer of GNSS equipment has their own proprietary correction message format. With the exception of CMR which is a Trimble convention, these proprietary formats are not decoded by competitive brands. This is one of the driving forces behind the Radio Technical Commission for Maritime Services, Special Committee 104 (RTCM SC104). This committee has established standards which facilitate the interoperability of various GNSS equipment and network services.

When considering a real-time correction format, the base and rover must share the ability to send or receive a particular data stream. Consider the following Magellan compatibility matrix:

	DBEN	RTCM 2.x	RTCM 3.x	CMR
MobileMapper CE	No	Yes[1,2]	No	No
MobileMapper CX	No	Yes[1,2]	No	No
ProMark 3 RTK	No	Yes[2]	Yes	No
Z-Surveyor	Yes	Yes	No	No
Z-Xtreme	Yes	Yes	No	Yes
Z-Max	Yes	Yes	Yes	Yes
ProMark 500	Yes[2]	Yes	Yes	Yes
DG14	Yes	Yes	Yes[2]	No

[1] DGPS Only [2] Receive only

As the table clearly shows, RTCM 2.x represents the largest interoperability window of existing real-time formats within the Magellan portfolio of GNSS receivers. However, RTCM 2.x is a very inefficient messaging format and this can cause issues on the communication layer. The equipment user should consider their own unique set of circumstances and needs before determining the proper correction format.

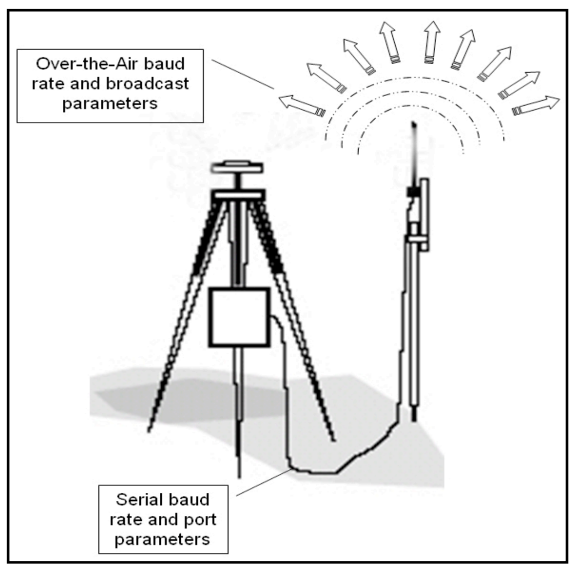
COMMUNICATION

Any person that has used an RTK device has probably had problems with the communication link between the base and the rover. This is the most fragile part of any RTK configuration with many variables that make troubleshooting problematic. There are several common methods for linking the base and rover in the field, which can be summarized as follows:

	Signal range	License Required	Cost to use	Data flow	Remarks
UHF Radios	10 km	Yes	None	Unidirectional	Subject to interference
Cellular Phone*	Unlimited	No	Yes	Bidirectional	Not all legacy receivers can connect to a cell phone and not all cell phones can connect to TCP/IP
Cellular Modem – Integrated*	Unlimited	No	Yes	Bidirectional	Most legacy receivers are not equipped with a modem.
Cellular Modem – External*	Unlimited	No	Yes	Bidirectional	External modem will likely require its own battery and additional cabling.
Spread-Spectrum radio	Line of sight	No	No	Bidirectional	Not subject to interference.

*Depending on the coverage area and bandwidth of the service provider.

When utilizing radios for corrections, the broadcast settings for the base station and rover radios must be in agreement. Forward Error Correction, Scrambling, Over-the-Air baud rates, frequencies and modulation types (i.e. GMSK, 4_Level FSK, TT450S) must match.



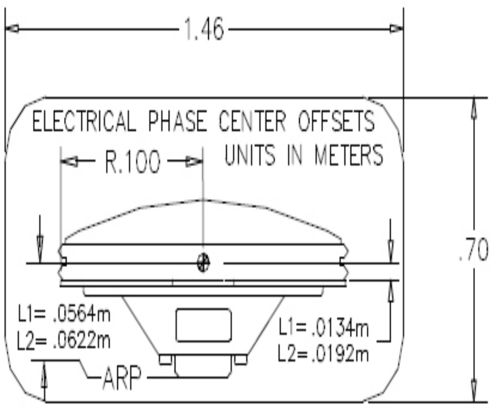
The serial baud rate of the cable connection between the radio and GNSS sensor is a separate issue. The baud rate between the specific radio and specific GNSS sensor must be the same. This may or may not be the same as the over-the-air baud rate that is being broadcast or received. A mis-configuration here is often the root cause of RTK problems. The user must ensure that serial baud rates, parity, stop bits and flow control (RTC/CTS) are identical on both the GNSS sensor and the radio with which it is used.

Cellular plans usually base the monthly charges on the amount of data which is exchanged. Although RTCM 2.x represents the most interoperable message format, it is also the most costly format to utilize with cellular service. Depending upon the amount of time spent receiving corrections and the correction format being used, the following data usage estimates can be made.

	Data usage per hour with 8 satellites (Typical GPS constellation)	Data usage per hour with 12 satellites (Typical GPS + GLONASS constellation)
DBEN	0.779 MB	1.207 MB
RTCM 2.x	1.169 MB	2.011 MB
RTCM 3.x	0.531 MB	0.822 MB
CMR	0.535 MB	0.829 MB

ANTENNA DEFINITIONS

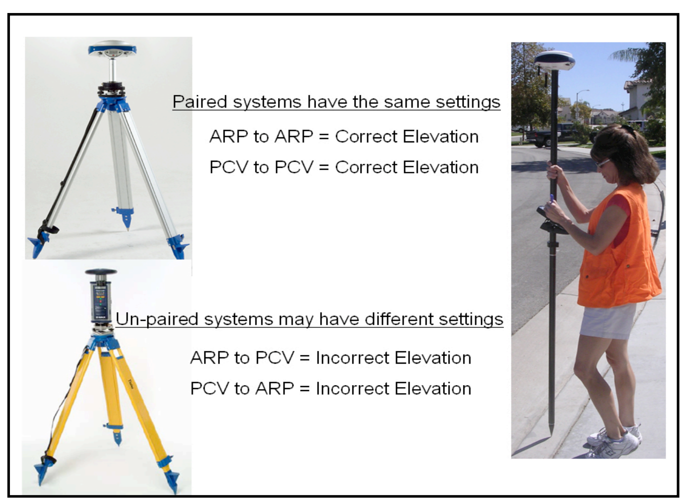
Where is the point that is referenced in the antenna definition? What is the ARP? What position is being broadcast from the base station and how does this information relate to positioning the rover correctly? When using an identical pair of antennas and sensors at the base and rover, these questions tend to cancel themselves out. When working with un-paired or heterogeneous systems, these questions and their answers must be considered.



The precise point that is being referenced with a GNSS antenna is neither a physical nor stable reference point.† The phase center variation (PCV) for any particular antenna will differ based on the angle at which the GNSS signals are being received. The vertical variation can be in the range of 10 centimeters or more. In addition, the phase center is not a physical point that can be accessed with a tape measure. There must be known offsets that relate this phase center to an external Antenna Reference Point (ARP). The National Geodetic Survey (NGS) performs calibration on each submitted antenna to determine the average of these offsets.

Once the reference and rover antenna offset have been properly defined, it is important to look at the correction messages coming from the reference station. In most instances, the reference station will be broadcasting a position based on its ARP. The rover maintains a database with accurate antenna information so that offsets to the reference antenna phase center can be applied. Another approach relies on the base station sending corrections based on the PCV of the antenna (null antenna). In this case, the rover has no need to know the reference station antenna type.

This aspect of antenna management when working in heterogeneous networks cannot be ignored. But the problem can be simplified for the field technician. Nearly all problems related to antenna management are vertical in nature. If three-dimensional positioning is important, check the GNSS measurements against local control. In many cases, an adjustment of the rover's HI (Height of Instrument) can be changed to make the field measurements match the control values.

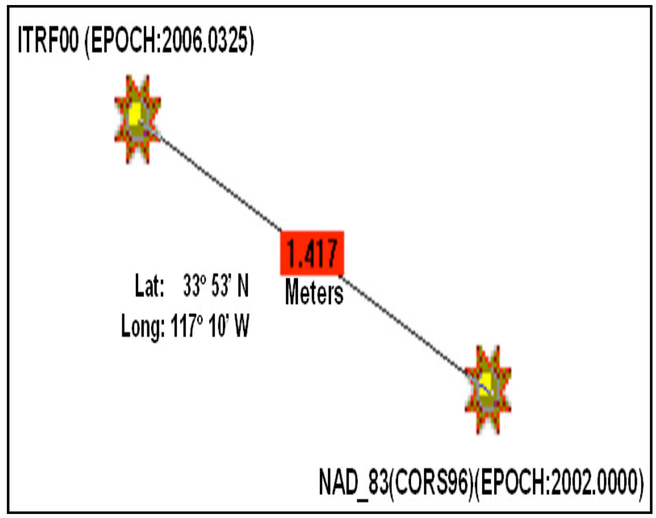


† http://www.ngs.noaa.gov/ANTCAL/images/summary.html

DATUMS

There are many different needs and disciplines that have fueled the growth of regional real-time reference networks. The scientific community seeks to understand the movement of the earth's tectonic plates and the orientation and rotation of the planet. Many GIS disciplines have a need to position features in the one-meter range of accuracy. Other disciplines need highly precise measurements but do not need to be accurate within the structure of a national reference frame. Many times, the land surveying professional must make highly precise measurements while also being very accurate within a well-defined coordinate system.

Increasingly in urban areas throughout the world, GNSS corrections can be obtained from a variety of sources. There are community networks that provide free access and other commercial enterprises that charge a fee. What is the coordinate system of the correction stream based on? If the network is operated by a scientific or academic community, it is likely that the corrections are in the International Terrestrial Reference Frame (ITRF) and is (least-squares) adjusted to some particular date. If the reference station network is operated by an engineering interest such as a roads or water management department, it is likely that the network corrections are based on a datum that best matches the existing maps of these infrastructures.



Once again, the field technician does not need to be a geodesist to solve this issue. Check the measurements against local control before beginning the data collection or stake-out campaign. Only with local checks or calibration can the reference data stream be utilized with confidence. A simple translation may be required to bring the field measurements onto the proper datum. In other instances, it might be appropriate to perform a 7-parameter transformation. Surveying field software facilitates these tasks.

Another method for ensuring the correct datum is being used has just been standardized by the RTCM SC104. Network providers can now provide "localized" correction streams. This technique has not been widely deployed to date but offers an interesting alternative for the field user. In this model, rotation, scaling and translation are computed by the network software and delivered to the rovers in the desired coordinate system. This could be very useful for construction sites or local entities to ensure that all users of the correction stream are on the correct and identical datum.

HARDWARE LIMITATIONS

Technological advances are often the motivation for an engineering firm to purchase GNSS equipment. The industry has evolved from midnight forays for raw data collection that could be post-processed by only the best computers to a world where centimeters are available in real time. At each stage of development, the equipment has become more productive.

When mixing the older technologies with the newer technologies, certain compromises must be made. Some of the compromises can be minimized or completely eliminated by the configuration that is employed. Other compromises cannot be mitigated and must be accepted as part of the equation.

The requirements of a base station are different from those of a rover. The ability to track satellites in noisy environments, weight and battery autonomy are usually not an important consideration for a base station and yet are integral aspects for rating rovers. The newest hardware advances have improved in these areas so it makes sense to convert legacy receivers into base stations and use the newer technology at the rovers. However, the newer receivers also track multiple constellations such as GLONASS and SBAS. If the legacy receiver at the base station cannot broadcast these correctors, then the rover will not be able to take advantage of these additional satellites. A brief overview of the technology capabilities of the Magellan survey-grade family of receivers follows:

	GLONASS	SBAS	BLADE*	Internet Ready	Rover Aesthetics
Z-Surveyor	No	No	No	No	Heavy, bulky
Z-Xtreme	No	No	No	No	Cabled pole or backpack solution
ProMark 3 RTK	No	Yes	Yes	Yes	Lightweight, L1 RTK
Z-Max	No	Yes	Yes	Yes	Heavy, but cable-free solution
ProMark 500	Yes	Yes	Yes	Yes	Lightweight, cable-free smart antenna

*Patented Magellan algorithm – **B**ase**L**ine **A**ccurate **D**etermination **E**ngine

CONCLUSION

Despite the desire of GNSS equipment manufacturers to sell and market complete systems, the reality is a world with a mixture of brands, generations of equipment and correction formats. In these competitive times, a professional land surveying firm must keep costs down while maximizing productivity. The newest GNSS receivers offer the latest technological advances while the legacy receivers continue to operate as intended. In many regions, real-time Continuously Operating Reference Stations (CORS) mitigates the need to set up a local base station, but comes with associated considerations such as antenna offsets and datums.

There will generally be some type of compromise involved when using legacy equipment with the newest systems, but these compromises may be completely acceptable.

Understanding the challenges, potential error sources and risks associated when working with equipment of various makes and models is incumbent upon the professional land surveyor. Seeing a coordinate pair on the data collector and a FIXED solution is not all that is required. The surveyor must continue to be a surveyor. The proof is in the dirt!