Space Geodesy Practical

Lecture1

prepared by Lecturer
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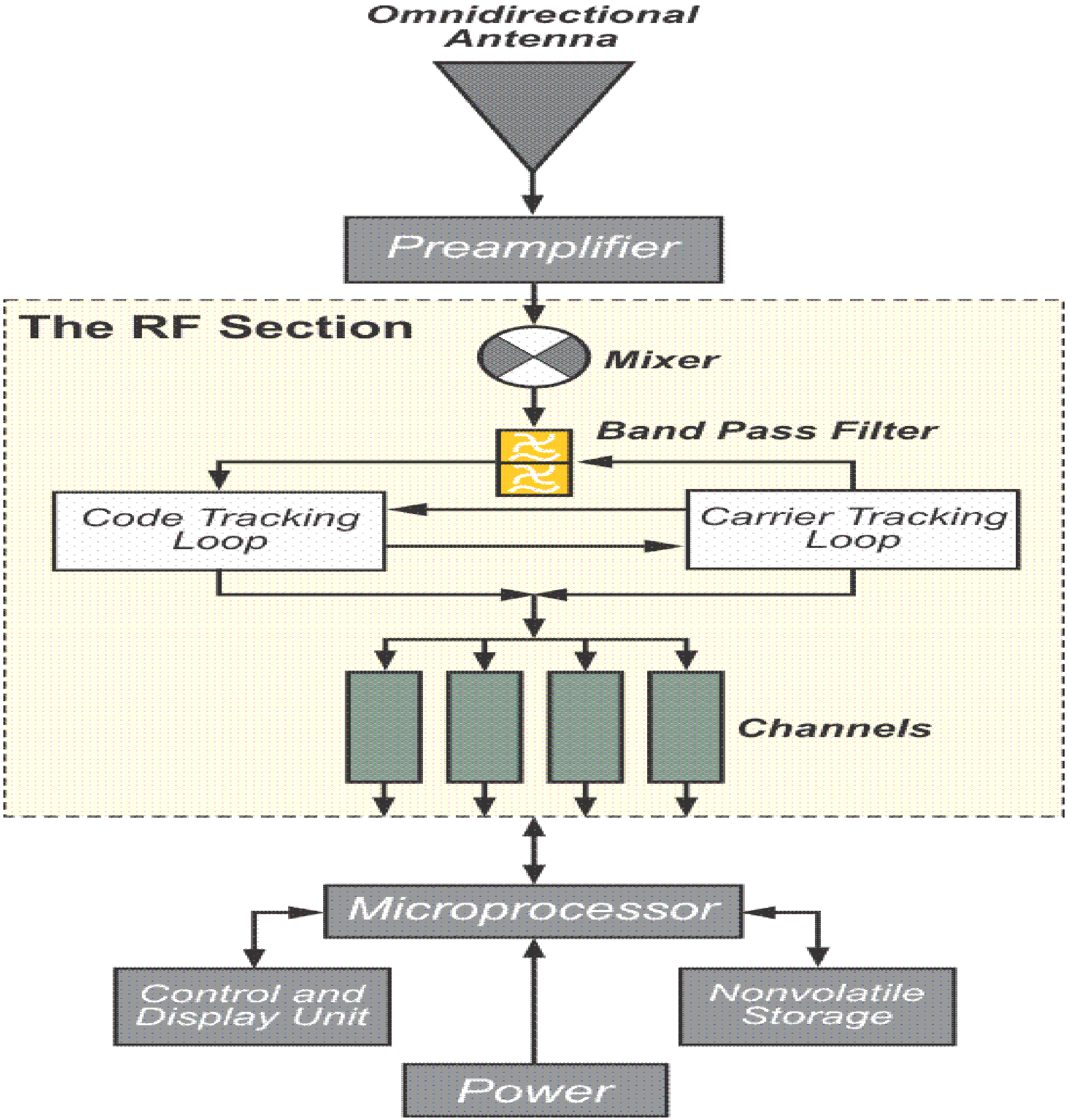
Practical Parts

- Receiver components and configurations
- Observation Methods
- Data Processing

Overview

The characteristics and capabilities of GPS/GNSS receivers influence the techniques available to the user throughout the work, from the initial planning to processing. There are literally hundreds of different GPS receivers on the market. Aside from recreational receivers, all are generally capable of accuracies from sub-meter to sub-centimeter. They are capable of differential GPS, DGPS, real-time GPS, static GPS and other hybrid techniques. They usually are accompanied by post-processing software and network adjustment software. And many are equipped with capacity for extra batteries, external data collectors, external antennas, and tripod mounting hardware. Just as there are many types of GPS receivers, there are many ways to apply them in obtaining GPS positions. Each of these several very different techniques makes unique demands on the receivers used to support it.


Omnidirectional Antenna
Preamplifier
The RF Section
Mixer
Band Pass Filter
Code Tracking Loop
Carrier Tracking Loop
Channels
Microprocessor
Control and Display Unit
Nonvolatile Storage
Power

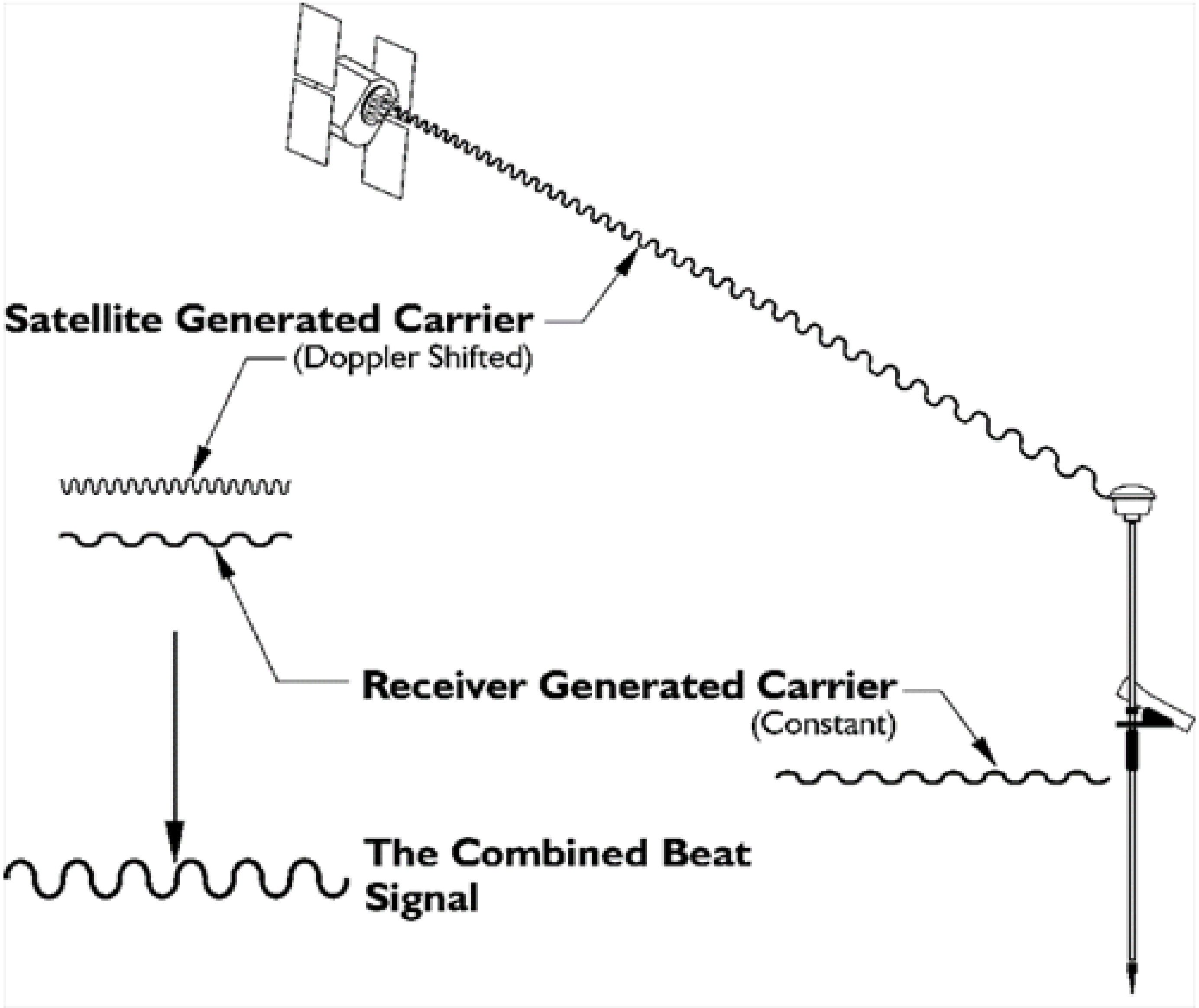
*omnidirectional : receiving signals from or transmitting in all directions.

* The antenna, radio frequency (RF) section, filtering and intermediate frequency elements are in the front of a GPS receiver. The antenna collects the satellite's signals and converts the incoming electromagnetic waves into electric currents sensible to the RF section of the receiver. Several antenna designs are possible in GPS, but the satellite's signal has such a low power density, especially after propagating through the atmosphere, that antenna efficiency is critical. Therefore, GPS antennas must have high sensitivity, also known as high gain. They can be designed to collect only the L1 frequency, L1 and L2, or all signals, including L5. In all cases, they must be Right Hand Circular Polarized, (RHCP), as are the GPS signals broadcast from the satellites..

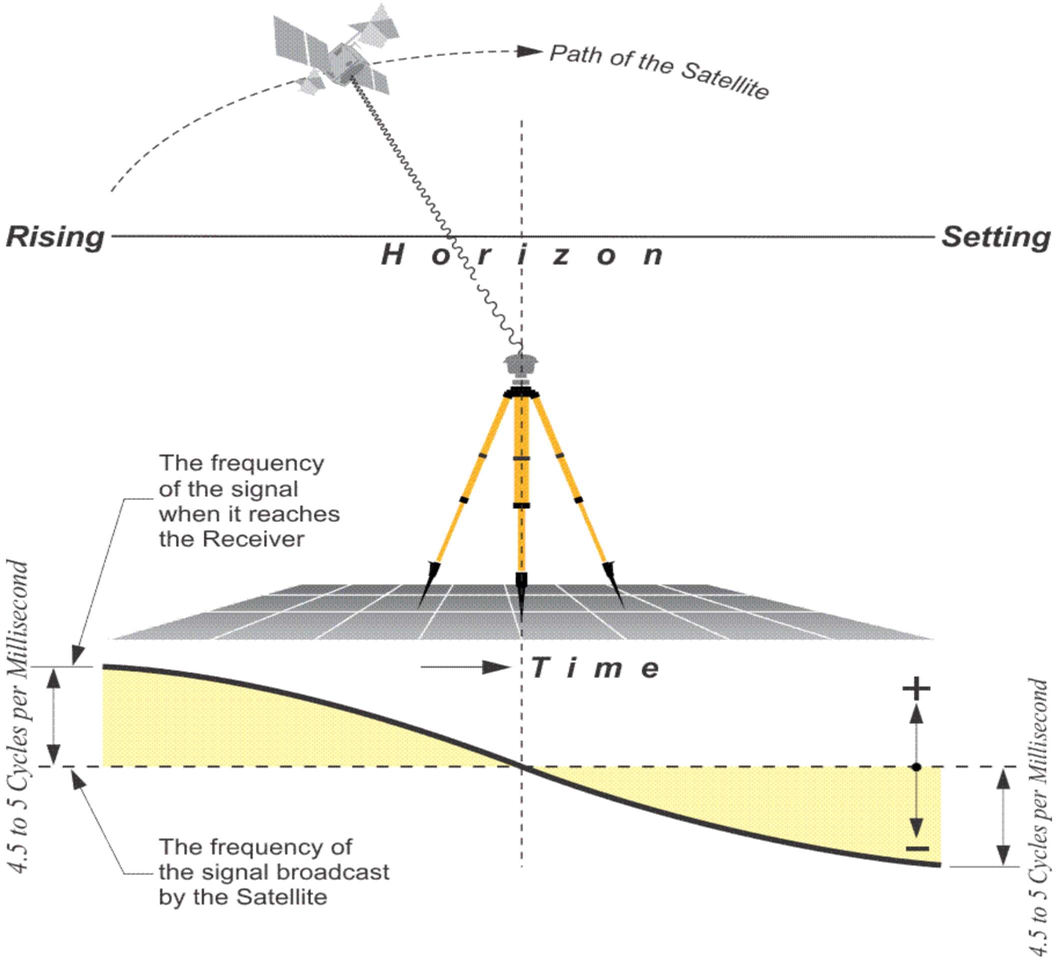
*Circularly Polarized Waves are those where the angle of the electric vector rotates around an imaginary line traveling in the direction of the propagation of the wave. The rotation may be either to the right or left. The GPS signal is a Right-Hand Circularly Polarized (RHCP) wave. You can illustrate it this way. With your right hand, give the thumbs up signal. Now, instead of pointing your thumb up, point it in the direction that the GPS signal is propagating. Your curling fingers show you the direction of the rotation of the field. Most receivers have an antenna built in, but many can accommodate a separate tripod-mounted or range pole-mounted antenna as well. These separate antennas sometimes require connecting coaxial cables. The cables are an important detail. The longer the cable, the more of the GPS signal is lost traveling through it. They are usually in standard lengths to make sure that the impedance of the trip through the cable can be calibrated.

As known that the wavelengths of the GPS carriers are 19 cm (L1), 24 cm (L2) and 25 cm (L5), and antennas that are a quarter or half wavelength tend to be the most practical and efficient, so GPS antenna elements can be as small as 4 or 5 cm. Most of the receiver manufacturers use a microstrip antenna. These are also known as patch antennas. The microstrip may have a patch for each frequency so it can receive one or all of the GPS carriers.

RF section


Satellite Generated Carrier
(Doppler Shifted)
Receiver Generated Carrier
(Constant)
The Combined Beat Signal

The pre-amplifier is necessary, because the signal coming in from the GPS satellite is weak. The preamplifier increases the signal’s power, but it is important that the gain in the signal coming out of the preamplifier is considerably higher than the noise. Noise is always part of the signal. Since signal processing is easier if the signals arriving from the antenna are in a common frequency band, the incoming frequency is combined with a signal at a harmonic frequency. This latter, pure sinusoidal signal is the previously mentioned reference signal generated by the receiver’s oscillator. The two frequencies are multiplied together in a device known as a mixer. Two frequencies emerge: one of them is the sum of the two that went in, and the other is the difference between them. The sum and difference frequencies then go through a bandpass filter, an electronic filter that removes the unwanted high frequencies and selects the lower of the two. It also eliminates some of the noise from the signal. In any case, the signal that results is known as the intermediate frequency (IF), or beat frequency signal. This beat frequency is the difference between the Doppler-shifted carrier frequency that came from the satellite and the frequency generated by the receiver’s own oscillator.

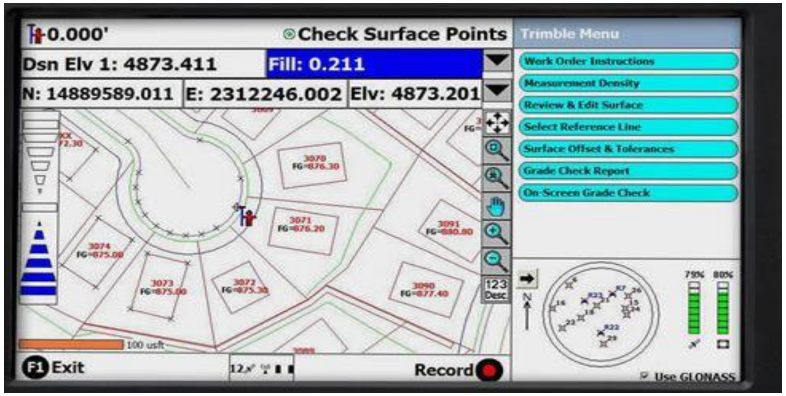


Doppler Effect refers to the change in wave frequency during the relative motion between a wave source and its observer. It was discovered by Christian Johann Doppler who described it as the process of increase or decrease of starlight that depends on the relative movement of the star.

This graphic shows the typical rate of change in the Doppler shift with regards to a stationary, static, GPS receiver. The signal received would have its maximum Doppler shift, +4 1/2 to 5 cycles per millisecond, when the satellite is at its maximum range, just as it is rising or setting. The Doppler shift continuously changes throughout the overhead pass. Immediately after the satellite rises, relative to a particular receiver, its Doppler shift gets smaller and smaller, until the satellite reaches its closest approach, at zenith. At that moment its radial velocity with respect to the receiver is zero, the Doppler shift of the signal is zero as well. But as the satellite recedes, it grows again, negatively, until the Doppler shift once again reaches its maximum extent just as the satellite sets, -4 1/2 to 5 cycles per millisecond.

The microprocessor in a GPS receiver is the computer that manages data collection and is the home of the applications that mitigate multipath, noise, extract the ephemerides and other information from the Navigation message or newer navigation messages such as CNAV. It controls the entire receiver: the digital circuits, the tracking and measurements. The receiver also has storage. However, more and more, the microprocessor is expected to produce the position in real time, or near real-time by processing the ranging data, doing reference frame (datum) conversion, and sending the position to the control and display unit (CDU).

Microprocessor



0.000'

Check Surface Points

Dsn Elv 1: 4873.411

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N: 14889589.011

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Elv: 4873.201

Control and Display Unit (CDU)

*A CDU typically displays status, position data, velocity and time. It may also be used to select different surveying methods, waypoint navigation, and/or set parameters such as epoch interval, mask angle, and antenna height.

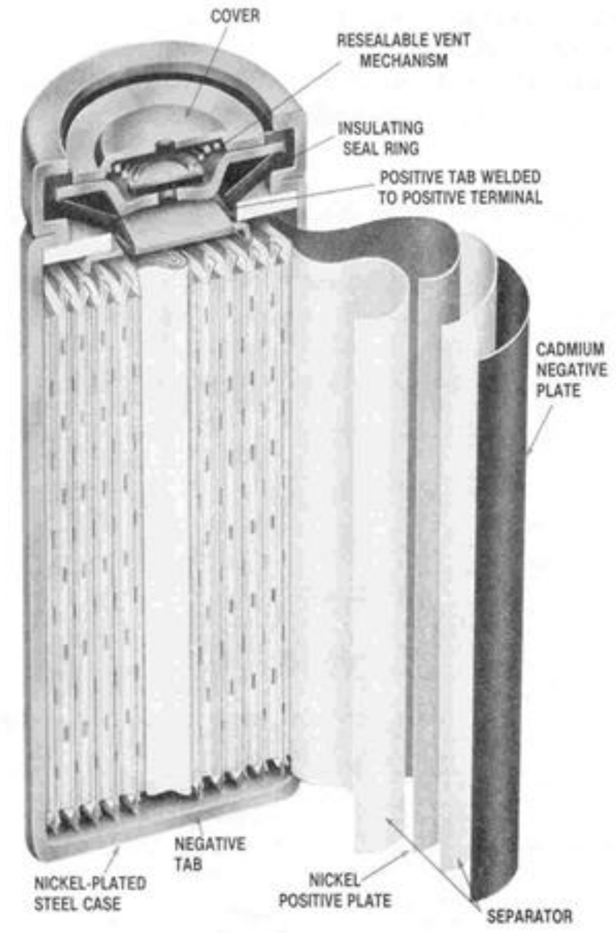
Storage: Most GPS receivers today have internal data logging. The amount of storage required for a particular session depends on several things: the length of the session, the number of satellites above the horizon, the epoch interval, and so forth. For example, presuming the amount of data received from a single GPS satellite is ~100 bytes per epoch, a typical twelve channel dual-frequency receiver observing 6 satellites and using a 1-second epoch interval over the course of a 1-hour session would require ~2MB of storage capacity for that session.

100*(1 sec of epoch) *(6 satellites)* (3600 sec of session)=2160000 bytes

2160000/1024/1024=2.059~2MB

*Kilobyte=1024 bytes, Megabyte= 1024 KB

Power: It is fortunate that GPS receivers operate at low power. From 9 to 36 volts DC is generally required. This allows longer observations with fewer, and lighter, batteries than might be otherwise required. It also increases the longevity of the GPS receivers, themselves. About half of the available GPS carrier phase receivers have an internal power supply, and most will operate 5½ hours or longer on fully charged battery. Most code-tracking receivers, those that do not also use the carrier phase observable, could operate for about 15 hours on the same size battery. Since most receivers in the field operate on battery power, batteries and their characteristics are fundamental to GPS/GNSS . A variety of batteries are used, and there are various configurations. For example, some units are powered by rechargeable batteries. Lithium, Nickel Cadmium, and Nickel Metal-Hydride may be the most common categories, but lead-acid car batteries still have an application as well. The obvious drawbacks to lead-acid batteries are size and weight. Nevertheless, lead-acid batteries are especially hard to beat when high power is required. They are economical and long lasting. Nickel Cadmium batteries (NiCd) cost more than lead-acid batteries, but are small and operate well at low temperatures. Their capacity does decline as the temperature drops. Like lead-acid batteries, NiCd batteries are quite toxic. They self-discharge at the rate of about 10% per month, and even though they do require periodic full discharge, these batteries have an excellent cycle life. Nickel Metal-Hydride (NiMH) batteries self-discharge a bit more rapidly than NiCd batteries and have a less robust cycle life, but are not as toxic. Lithium–ion batteries overcome several of the limitations of the others. They have a relatively low self-discharge rate. They do not require periodic discharging and do not have a memory issues as do NiCd batteries. They are light, have a good cycle life and low toxicity. On the other hand, the others tolerate overcharging, and the lithium-ion battery does not. It is best to not charge lithium-ion batteries at temperatures at or below freezing. These batteries require a protection circuit to limit current and voltage, but are widely used in powering electronic devices, including GPS/GNSS receivers.



Reference:

- GPS for Land Surveyors Book