Multipath

An electromagnetic or sound signal hitting a surface may interact with it one of three ways: the signal may be reflected, absorbed or transmitted. Having once been reflected a signal may be reflected a second, or even third time from another surface. In airborne Lidar multiple reflection results in the recording of faster pulse travel times that ultimately appear as a dip in the elevation model. Since these are usually individual events, they can be removed by spatial filtering. Similarly, in radar imagery multiple reflection causes objects to produce returns of greater signal strength than might be expected from the size of the object; this results in bright spots. Multipath effects may be also experienced when walking along a tower block, when balconies may reflect sharp sounds such as that of a car claxon, making a vehicle seem nearer by than it really is.

Source of Error

The precision of GPS positioning is also affected by reflections from nearby objects such as ground and water surfaces, buildings, vehicles or trees. Multipath results in the same satellite signal being received at least twice by the GPS receiver via different paths, distorting C/A and P-code modulations and carrier-phase measurements. Multipath may even be regarded as the main remaining source of error, since others can be removed by advanced processing methods such as differential and kinematic GPS. Particularly in urban areas that are characterised by multiple reflecting surfaces, multipath may significantly reduce precision. Hence it is of the utmost importance to detect and/or mitigate multipath error. In contrast, multipath effects are minor in a moving vehicle because a mobile GPS receiver results in solutions from indirect signals failing to converge; only direct signals produce stable solutions.

Numerical or Physical

There are three basic approaches to dealing with multipath. The first, adopting the adagio â€˜prevention is better than cureâ€™, is to avoid measuring in environments where multipath might occur. The second is to physically protect the GPS antenna from indirect signals using a reverse umbrella, thus safeguarding the antenna from those â€œbadâ€Â coming from below. The third method is to separate the bad from the good using signal-processing techniques. The first option is obviously impractical and too much impedes operational application of GPS. But caution during field measurements may help. For example, tracking satellites only when they are more than 15 degrees above the horizon already limits multipath effects. It is also possible to filter bad from good signals by numerical techniques utilising redundancy. Reflected signals are always delayed in comparison with direct signals because of their longer paths of travel and this shows as time-dependent variations in measured range to the satellite, which can be detected. In this way a direct signal can be separÂated from indirect. However, when difference in path length between direct and indirect signal is less than a few metres the signal-processing technique proves ineffective. The remedy is then to entirely ignore the signal from the satellite concerned. This is often quite feasible, as GNSS receivers typically receive signals from eight to twelve satellites while only four are needed for determination of the three position coordinates and time bias. And crossing the fingers might help to avoid signals from all satellites being affected by multipath.

Choke-ring

But a more reliable method is to use a reverse umbrella, or "choke-ring". Such a physical device enables rejection of indirect signals hitting the bottom of the antenna, but the device does not stop signals reflected by a building hitting the antenna from above. However, since such indirect signals have a path length of ten metres or even more, they may be mitigated by signal-processing techniques. So numerical and physical protection techniques are complementary: by numerical filtering distant indirect signals hitting the top of the antenna can be mitigated, while choke-rings prevent the antenna picking up signals, usually with a path length of a few metres, reflected from nearby ground.