Magnetic Navigation

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Introduction

GPS is the most commonly used system for guidance and navigation in the US. Phones can pick up GPS signals to give users information about where they are and where they need to go to get to their specified destination. Civilians also employ GPS systems for surveying, sports, car navigation, geocaching, and robotics. GPS is also a time-telling tool and is used for synchronization of large-scale systems like power grids and financial markets. [9]

GPS was originally created for the military, and is still used for soldiers, manned and unmanned aircrafts, and ships. In night missions, GPS is especially relied upon, and generally is used for navigating through enemy territory.

The issue with GPS for navigation purposes is its vulnerability. GPS was not originally designed to be robust against security threats. GPS was first proposed in 1972, and by 1993 was available for use by aviation systems.[7]

Although GPS is so widely used, it was not originally designed for security, and these security flaws still have not been fixed. There is still a need for a more robust solution, or fixes to GPS. Magnetic navigation is one such proposed resolution for the flaws in GPS systems.

GPS

How GPS Works

GPS or Global Position System is a guidance and navigation system reliant on the use of satellites. Specifically, GPS uses a system of 24 satellites orbiting around the Earth. These satellites fly in medium earth orbit (MEO), about 12,550 miles above the Earth's surface. There are 6 planes in which these satellites orbit, so each plane is occupied by 4 satellites. This is done to ensure that a GPS receiver on Earth can contact any 4 satellites when it needs to locate itself.

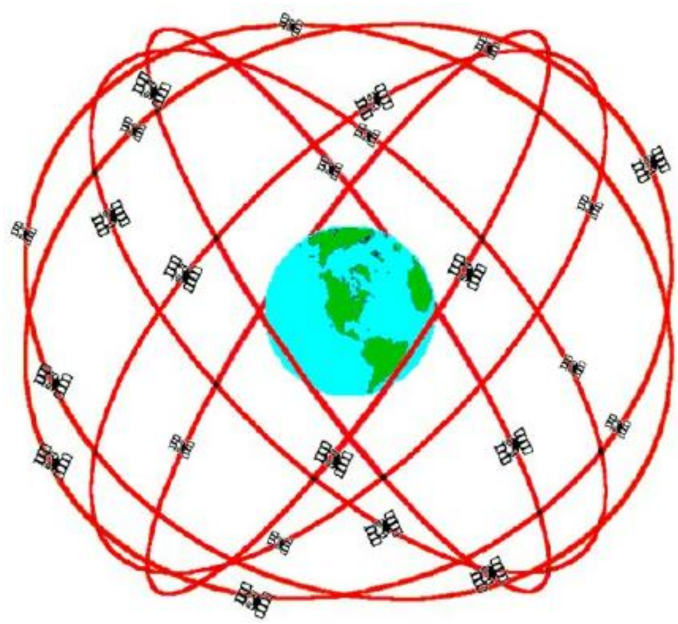

Figure 1. GPS Orbital Planes. [2]

Every GPS satellite has two transmission frequencies. Useful information gets superimposed onto these carrier frequencies, and the time taken for the signals to propagate from the satellite to the receiver is used to calculate the pseudorange. The pseudorange is a measure of distance between the satellite and the receiver at a specific point in time.

Finally, the GPS can determine its position in Cartesian coordinates, with the center of the Earth as the origin. These coordinates are then converted to latitudinal and longitudinal position. [3]

What Makes GPS Vulnerable

Because GPS operates on known frequencies, a GPS signal can be easily spoofed. This is when a radio transmitter sends a signal that resembles a signal coming from a GPS satellite, but instead comes from a malicious source. GPS spoofing is simple and cheap to implement (a cheap spoofing device can cost just $300), making it a particularly dangerous vulnerability. [5, 8]

Jamming is another common and simple attack that GPS signals need to overcome. Because GPS works on two main radio frequencies, and these frequencies are known, people with the requisite expertise can easily make jammers for these signals. Although jamming is illegal, cheap jammers are sold on the black market and large jamming attacks still occur. [4]

Along with being susceptible to attacks, GPS devices are not robust in all scenarios. While travelling through the atmosphere, GPS signals are susceptible to ray bending and propagation delays. Signals usually encounter these issues in the ionosphere or troposphere.

GPS is incapable of use underwater, because radio waves cannot propagate in the water. Mediocre solutions have been used, but these do not provide the full robust functionality of GPS. [3]

Magnetic Navigation

Theory Behind Magnetic Navigation

Magnetic navigation is a proposed alternative for GPS in guidance and navigation intensive scenarios. Magnetic anomalies occur on the Earth when rocks beneath the surface are composed of materials, such as iron, that create magnetic fields. These magnetic fields are measurable from above the Earth's surface. Magnetic navigation is built upon the fact that mappings can be made of these magnetic anomalies, and that there is enough difference in these fields. A magnetometer can measure the magnetic field at any given point and a user can determine where on the map she is by the readings. [1]

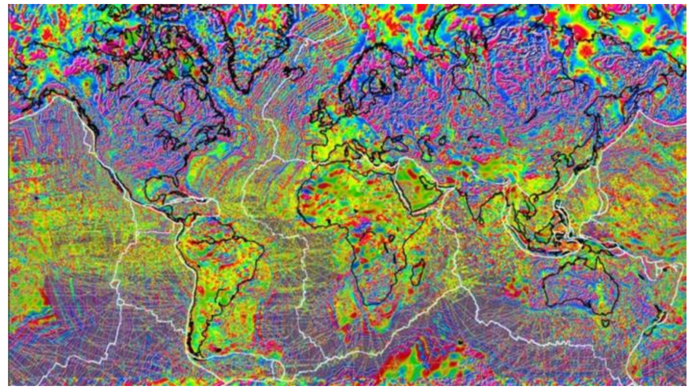

Figure 2. Magnetic anomaly map of the world. [6]

This solution is straightforward, but a few obstacles exist. The main obstacle is that the Earth has a dipole field, the movement of any platform creates a magnetic field, and many other sources of noise exist, so robust algorithms are still needed to be process these signals. Further, detailed magnetic maps of the Earth currently do not exist. Since magnetic navigation is not at the forefront of research, companies equipped to make these maps have no reason to do it. [1]

Despite these challenges, should magnetic navigation come to light, it is much more robust than GPS.

The Robust Nature of Magnetic Navigation

In most scenarios, a GPS receiver can connect to 4 GPS satellites, but this is not always the case. The Earth's magnetic field is always available, regardless of the location. This ensures that a magnetometer can always pick up a signal.

Because magnetic navigation is dependent on ferrous deposits in the Earth, no individual can spoof the signal. Manmade systems, other than power plants, would not be able to generate magnetic fields on the order of the magnetic fields already existing. This means that a single malicious actor could not corrupt the reading from any magnetic anomaly. Further, magnetic fields are not attenuated by the atmosphere or poor weather conditions in the same way that GPS signals can be.

Conclusion

Magnetic navigation cannot replace GPS in all scenarios, specifically those in which GPS is used for timing. Generally, the military uses GPS devices for guidance and navigation, and in these mission critical situations, magnetic navigation provides added safety. Large attacks on GPS devices have occurred, but the numbers have reduced, and extra security measures are still being researched. However, the development of algorithms for processing magnetometer data and more detailed mappings of the Earth's magnetic field would set magnetic navigation to be a robust and secure navigation solution.

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