Global Positioning Systems

by Cass Lewart

As by now all technical geeks, including me, are aware, the United States Department of Defense started about 12 years ago a multi billion dollar navigational project. The purpose of the project was to provide a navigational aid - helping to determine time, latitude, longitude and altitude to primarily the US armed forces anywhere in the world. A series of satellites was placed in orbit, the first one in February 1989. The satellites at altitude of approximately 20,000 km make a full orbit every 12 hours. The orbital planes are inclined 55 degrees with respect to the equator. There are six orbital planes with 4 - 5 satellites evenly spaced in each plane. With 28 satellites currently operational, each point on the earth has a continuous line of sight view of at least 5 satellites. Due to the high frequencies used by the satellites (1.2276 and 1.57542 GHz) a direct line of sight view of satellites is required as radio waves at those frequencies travel in straight lines, do not "bend", or are substantially affected by the ionosphere. Each satellite transmits a unique code, allowing the receiver to identify it.

Each satellite carries a precise clock and transmits the time, position and other related information to GPS receivers. Comparison of time signals received from four or more satellites will pinpoint position and altitude on the earth to within a circle of uncertainty. Because of military nature of the original GPS system the civilian GPS users, though welcome, must endure an intentional fudge factor introduced by the system operator. This pseudo random fudge factor is called the Selective Availability (S/A). S/A increases the 95% uncertainty in determining horizontal position to about 100 meters for civilian users, versus 22 meters for military users in possession of cryptographic equipment. I found after using my GPS receiver for a few months, that it deter- mines my position mostly within 0.05 mile. However, on a few occasions I found the error to be up to 0.2 miles.

By the way the orbit period T and the orbiting altitude H of a satellite are related by the following equation. I derived it from the basic equations of motion assuming a spherical earth, no anomalies and no air resistance. Units are cm and sec, R is the radius of the earth, which is 6.37E8 cm.

$$(R + H) = 2.16E(-6) \times T^{(2/3)}$$

I evaluated the formula for 3 types of satellite orbits:

Orbit	**Altitude H (km)**	**Period T (hours)**
Low Orbit (Sputnik)	290	1.5
Medium Orbit (GPS)	20,280	12
Geosync Orbit (Satcom)	35,930	24

As prices of GPS receivers kept dropping in 1997 and several manufacturers introduced more sensitive 12-channel receivers I decided to take the plunge by buying an Eagle Explorer GPS for $150. I checked the mail order house by visiting their Internet home page, but I ordered the unit by calling their toll-free number. Two years later I lost my Eagle Explorer and bought a Magellan 315 with many more features for $10 less at my local K-Mart. To find more

information I first went to Yahoo and searched for "Global Positioning System". I found valuable links in the following URL:

http://www.joe.mehaffey.com

I then searched through the list of Usenet groups and found one dedicated to GPS users. If you send me an e-mail request I will e-mail to you my Usenet search program and the Usenet database. The program is also included on a CD attached to my book about modems ("The Ultimate Modem Handbook" - Prentice Hall, November 1997). The Usenet group which I found is: sci.geo.satellite-nav

This Usenet group carries 10 - 20 new messages each day. I found out about experiences of many GPS users, comparisons of various receivers and sources of hardware and software. You will also find there listings of various GPS Internet resources, links and FAQs explaining the GPS operation.

The slides, on the following pages, show many aspects of GPS.

Cass Lewart is an electrical engineer and a long time computer hobbyist. He is the author of ten books and numerous articles relating to personal computers, database programming and data communications. His most recent book, *The Ultimate Modem Handbook* was published by Prentice Hall. (rlewart@monmouth.com)