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An Overview of Global Position System (GPS) and Its Technology of Navigation

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I. INTRODUCTION

GPS is one of the most fantastic utilities ever discovered by man. The Global Positioning System GPS is a satellite based Navigation System made up of at least 24 satellites that are eleven thousand nautical miles in space and in six different orbital parts. The satellites are constantly moving to complete orbits around the earth in just under24 hours. GPS works in any weather conditions anywhere in the world, 24 hours a day, with no subscription fees or setup charges. The US Department of Defense (USDOD) originally put the satellite into orbit for military use, but they were made available for civilian use in the 1980s. [www.ja-gps.com.au/what-isgps] by Johny.

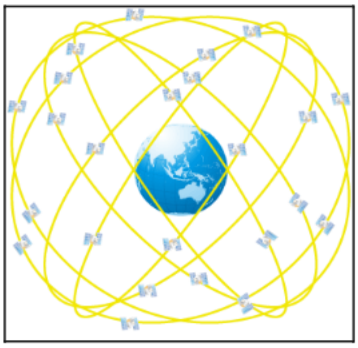

Fig. 1 Orbit of GPS Satellite

Fig. 2 GPS Satellite

The GPS satellites are referred to as NAVISTAR satellite. Each satellite weighs approximately 1 tonne and is about 5 meters across with the solar panels extended. Transmitter power is only 50 watts or less. Each satellite transmits on three frequencies. Civilian GPS uses the L1 frequencies of 1575.42 MHz. Is satellite is expected approximately 10 years. Replacements are constantly being built and launched into orbit. The satellite orbits are roughly 25,000 k.m. from the earth's center or 20,000 kms. Above the earth's surface. The orbital parts of the satellite take them between roughly 60 degree North and 60 degree South latitudes. Satellite signals can be received anywhere in the world at any time. One of the major benefits over previous land based navigation system is that all GPS works in all weather conditions. The GPS signal contains a "pseudo-random code" ephemeris and almanac data. The pseudo random code indentifies which satellite is transmitting an I.D. Code. Ephemeris data is constantly transmitted by each satellite and contains important information's such as status of the satellite, current date and time. Without this part of message the GPS receiver would have no idea what the current time and dates are. This part of the signal is essential to determine a position, of an object.

The almanac data tells that GPS receiver should be at any time throughout the day. Each Satellite transmits almanac data showing the orbital information for that satellite and for every other satellite in the system, each satellite transmits a message - "I'm satellite #x, my position is currently Y, and this message was sent at time Z. The GPS receiver reads the message and saves the ephemeris and almanac data for continual use. The information can also be used to set the clock within the GPS receiver.

To determine our position the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received by the GPS receiver. The time difference tells the GPS receiver how far away that particular satellite is. On adding distance measurement from a few more satellites our position can be triangulated with a minimum of three satellites GPS receiver can determine a 2D-latitude/longitude position. With four or more satellites, a GPS receiver can determine 3D position which includes latitude, longitude and altitude. By continuously updating, a GPS receiver can also accurately provide speed and direction of travel. By capturing the signals from three or more satellites (among a constellation of 31 satellites available), GPS receiver are able to triangulate data and pin point our location. With the addition of computing power and data stored in a memory such as road maps point of interest, topographic information and much more, GPS receivers are available to convert location speed and time information into a useful display format. GPS receivers are generally accurate within 15 meters and newer models that use Wide Area Augmentation System (WAAS) signal are accurate within three meters.

II. STRUCTURE OF GPS

The GPS technology mainly comprises of three parts:

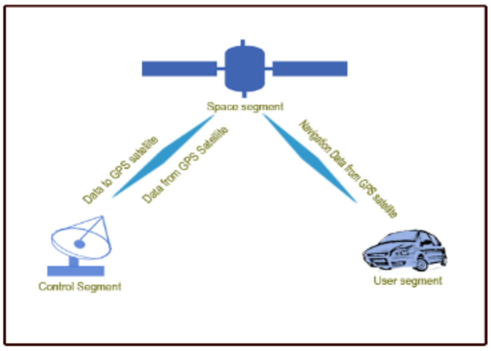

Fig. 3 Structure of GPS

(a) **Space Segment**: The satellites are the heart of GPS which helps to locate the position by broadcasting the signal used by the receiver. The signals are blocked when they travel through buildings, mountains and woods, to calculate the position the signals of four satellites should be locked. You need to keep moving around to get clear reception.

(b) **User Segment:** This segment includes military and civilian users. It comprises of a sensitive receiver which can detect signals (Power of the signal to be less than a quadrillionth power of a light bulb) and a computer to convert to data into useful information. GPS receiver helps to locate your own position but disallows you being tracked by someone else.

(c) **Control Segment:** This helps the entire system to work efficiently. It is essential that the transmission signals have to be updated and the satellites should be kept in there appropriate orbits.

III. METHODOLOGY

The GPS is network of about 30 satellites orbiting the earth at an altitude of 20,000 kms. Whenever you are on the planet at least four GPS satellite are visible at any time. Each one transmits information about its position and the current time at regular intervals. These signals traveling at the speed of light are intercepted by your GPS receiver which calculates how far away each satellite is based on how long it took for the message to arrive. Once it gets information on how far away we are at least three satellites on our GPS receiver can pinpoint our location using the process called “trilateration”.

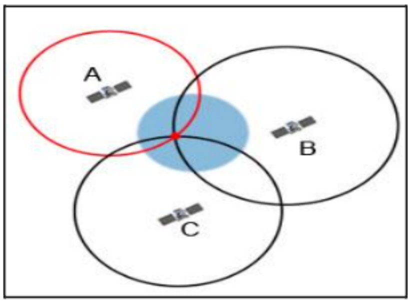

Fig. 4 Identification of Location

(a) **Structure of GPS Signal: The** GPS signal is an electromagnetic wave generated by an oscillating electric force transmitted from GPS satellites. As the distance traveled between the satellites and GPS receiver increases the strength of the signal decreases. All GPS satellites transmit two carrier frequencies. One at 1575.42 MHz (10.23MHz x 154) called L1 and second at 1227.60 MHz (10.23 MHz x 120) is called L2. Two different codes are modulated on GPS signal. The precise code (P-code) is modulated on both L1 and L2 signals P-code is intended for military uses as it is encrypted with additional W-code. This Anti-spoofing (AS) encryption denies civilian users access the P–code.

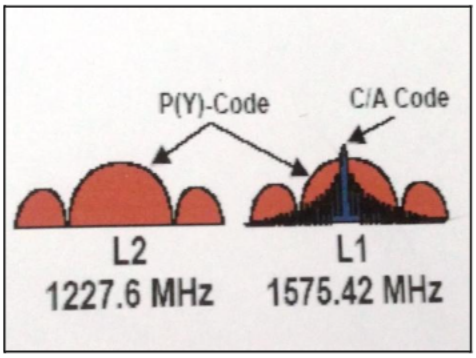

Fig. 5 Signal spectrum for current GPS signal

The second code is the course acquisition code (C/A code) which is transmitted on the L1 frequency as a 1.023 MHz signal using a bi-phase shift keying (BPSK) modulation technique. It is intended primarily for civilian users.

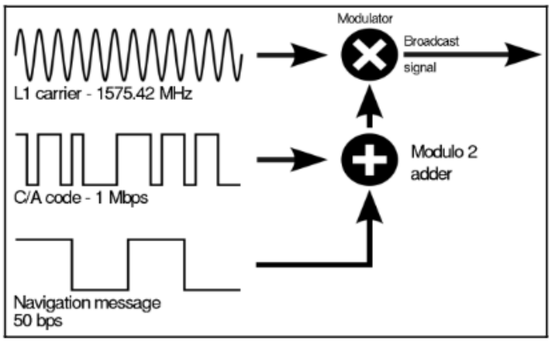

Fig. 6 GPS signal spectrum

(a) **Applications:** Imagine we are standing somewhere on earth with three satellite in the sky above us. If we know how far away we are from satellite A then we know you must be located somewhere on the A circle. If you do the same for satellite B and C we can work out our location by seeing where the three circles intersect. This is just what our GPS receiver dose although it uses overlapping spheres rather than circles. The more satellites there are above the horizon the more accurately our GPS unit can determine where we are.

IV. GPS AND IONOSPHERIC MEASUREMENTS

The GPS constellation of satellite is revolutionizing the science and technology of the Earth's ionosphere nowadays it is widely used to calculate total electron content [TEC] of the ionosphere. It is a unique and unprecedented resource for ionospheric measurements because it provides –

- Instantaneous global coverage
- Continues operation
- High temporal resolution and
- Near real –time data acquisition.

(a) **Satellite Elevation and Ionospheric Effect:** The severity of the ionospheric effect on a GPS signal depends on the amount of time that signal spends traveling through it. A signal originating from a satellite near the observers horizon must pass through a larger amount of the ionospheres to reach the receiver than does a signal from a satellite near the observes zenith. The longer the signal is in the ionosphere, the greater the ionosphere's effect on it. The error introduced by the ionosphere can be very small but it may be large when the satellite is near the observer's horizon, the vernal equinox is near and/or sunspot activity is severe. For example, the TEC is maximized during the peak of 11 years solar cycle. It also varies with magnetic activity, location, time of day, and even the direction of observation. Even given all this variation, it's fair to say that one thin one can depend as is the longer that the GPS signal remains in the atmosphere, the longer its trip through that atmosphere, the greater he effect of attenuation will be and the greater the slowing will be. So one of the things that a GPS receiver ought to do is ignore the signals coming from satellites that are near the observers' horizon. Obviously, as the GPS satellite is low in the sky, the signal is going through a greater atmosphere than it would be when it is directly overhead at zenith. This is one of the reasons why it's a good idea to have a mask angle on the GPS receiver 15-20 degrees, such that we would ignore the signals that are low, coming in across a great deal of atmosphere. So no matter what time of year or the time of day, we won't avoid going through the atmosphere and get signals from satellite that are a little but higher in the sky. The ionosphere in the absence of selective availability can be the greatest source of range and range-rate errors for GPS users. The dual frequency automatic correction for these effects is the best solution, and the single frequency user can correct for approximately 50-60 percent of the rms range. [et.al(ionospheric effect/GEOG862:GPS&GNSS for Geospatial professionals)

(b) **Accuracy of GPS:** Today's GPS receivers are extremely accurate; thanks to their parallel maintain a tracking lock in dense tree cover or in urban setting with tall buildings. Certain atmospheric factors and other error sources can affect the accuracy of GPS receivers. Garmin GPS receivers are typically accurate to within 10 meters. Accuracy is even better on the water. Some GARMIN GPS receiver's accuracy is improved with WAAS (Wide Area Augmentation System). This capability can improve accuracy to better than 3 meters by providing correction to the atmosphere, no additional equipment or fees are required to take advantage of WAAS satellite. Users can also get better accuracy with differential GPS, which corrects GPS distances to within an average of 1 to 3 meters. The U.S. coast guard operates the most common DGPS correction service, consisting of a network of towers that receive GPS signals and transmit a corrected signal by beacon transmitters. In order to get the corrected signal, users must have a differential beacon receiver and beacon antenna in addition to their GPS. (www.engineersgarage.com/articles)

(c) **GPS signals errors sources:** Factor that can affect GPS signals and accuracy includes the following: Ionosphere and troposphere delays: satellite signal slow as they pass through the atmosphere the GPS system uses a built in model to partially correct for this type of error. Signal multipath: The GPS signal may reflect off objects such as tall buildings or large rock surface, they don't penetrate indoor spaces well before it reaches the receiver which will increase the travel time of the signal and cause errors. Receiver clock errors: A receivers built in clock may have slight timing errors because it is less accurate than the atomic clocks on GPS satellite. Orbital errors: The satellite reported location may not be accurate. Number of satellites visible: The more satellites a GPS receiver can "see" the better the accuracy, when a signal is blocked you may get position errors or possibly no position reading at all. GPS units typically will not work under water or underground but high sensitivity receivers are able to track some signals when inside building or under tree cover. Satellite geometry/shading: Satellite signal are more effective when satellites are located at wide angles relative to each other rather than in a line or tight groping. Selective availability: The U.S. Department of Defense once applied Selective Availability (S.A.) to satellites, making signals less accurate in order to keep "enemies" from using highly accurate GPS Signals. The government turned of SA in MAY 2000, which improved the accuracy of civilian GPS receivers. (Garmin/what is GPS)

V. COMPARISON BETWEEN GPS AND OTHER MEASUREMENT TECHNIQUES

There is still considerable interest in comparing GPS-derived ionospheric observables with independent techniques both to validate GPS and to augment the remote sensing capabilities of other methods. Lanyi and Roth (1988) compared GPS measurements to TEC derived from beacon satellite transmissions (Farady-effect) this is followed more recently by comparisons at Boulder, Colorado (Conkright et.al, 1997) both techniques showed good agreement in traking TEC changes. Collocated GPS receivers and ionosondes traking a traveling atmospheric disturbance during a major geomagnetic disturbance over Europe are reported by Ho et al (1996) comparison between GPS and incoherent scatter radar measurement of electron density are discussed by Jakowski et al (1996). Measurement of vertical total electron content available since 1992 from the TOPEX dual-frequency satellite altimeter are discussed in more detail below with reference to assessing the accuracy of global ionosphere TEC maps derived from GPS.

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