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Data Acquisition System Hardware for GPS Propagation Sentences in Less Developed Countries: A Review

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ABSTRACT

GPS receivers plays a greater role for calculating and determining the precise point positioning and deals with the navigational massages, also one of the main uses of high-end GPS receivers is for scientific research and space science analysis. The handheld GPS receivers were utilized for experimental purposes contrary to the traditional application for recreation and geo-catching activities. The classification of different commercial GPS receivers gave an inside ideas for application and utilization of these receivers in the field of laboratory research. Garmin GPS handheld receivers performed an excellent example in conducting experimental work for GPS propagation data analysis.

Introduction

Global positioning system (GPS) can be categorized as space-base radio navigation system, which is operated and maintained by the Government of the United States under the umbrella of U.S Air Force (USAF). The GPS system provides accurate 3 D position, timing information and velocity twenty four hours, seven days a week anywhere around the earth's surface and above [1][2].The potential market for mobile communications provided by satellite systems has triggered the development of a range of operational systems and conceptual designs, from the more conventional geostationary orbit systems to the medium earth orbit (MEO) systems[3], which L-band operates on the frequencies between 1-2 GHz. The L-band is particularly effective in providing rapid and flexible communication through mobile and portable terminal or transportable earth station. Voice and data communication services can be provided through the link between the satellite and the ground terminal. Mobile Satellite System (MSS) has advantages over Fixed Satellite Systems (FSS) due to its connection in rural areas which is very spotty or generally poor [4]–[9]. The Mobile Satellite (MS) connection exists while on the move and this reflects the reliability of the system to the mobile users [10].

Experimental data for MS signal is important in communication services [11]–[13]. The movable satellite system was designed to promote communication to areas where terrestrial communications is not available. The portable GPS receivers are increasingly popular among the outdoor users, although the handheld GPS receiver prices have dropped, so anybody can afford to buy it. The main focus of this critical review paper is to draw a roadmap for the selection of the economical hardware system setup that will be used to acquire GPS propagation signals in the form of National Maritime Electronic Association (NMEA) code sentences and these sentences that can be used for experimental purposes at low latitude regions [11], [14]–[20]. The low latitude region is the areas or places that are located between ±20^{o} latitude of the earth equatorial line. Figure 1 shows a map of the low latitude region (Http://www.satsig.net/lat_long.htm,).

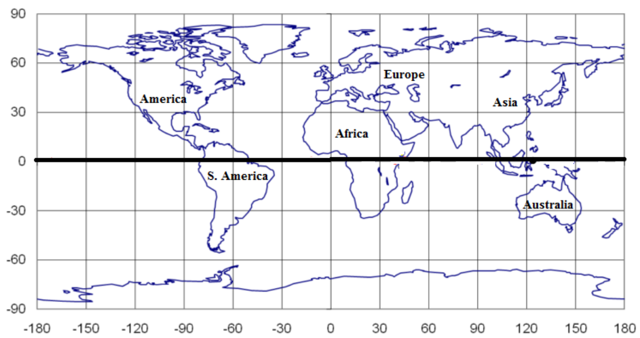

Figure 1. Low latitude areas

L-band frequency

L-band refers to the long wave frequency transmission within 1-2 GHz and it is particularly effective in providing rapid and flexible communication through mobile and portable terminal [22]–[27]. L-band satellites can be located in orbits of GEO, MEO (ICO) or LEO provides the services to MSS, UHF, cellular phones, TV, Microwave and studio television links [5], [9], [28], [29]. Most convenient L-band antennas are small and ideally do not require point toward the satellite in most cases, but patch antenna that comes with a handheld GPS receiver required the receiver display facing the sky [22], [30], [31], meaningfully a very simple cellular whip antenna used on cars and handheld mobile phones. These L-band antennas for use with Inmersat required antenna gain in the direction of the satellite so a coarse pointing is needed. First set of L-band rod or mast antennas are approximately 1meter in length and 2 centimeters in diameter, as in the case of bifilar helix that contained within. Therefore antennas for the handheld phones are more like a fat fountain pen [26], [32]–[34].

Distinct studies conducted shows there is no rain attenuation at L-band [25][35], the ionosphere does not introduce a source of significant link of fading. However L-band represents a regulatory challenge, but not a technical one, because there are more users and uses for this application spectrum than there is spectrum to use [36], [37].

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For example, they improve spectrum efficiency techniques like digital speech compression and bandwidth efficient modulation. This will improve the utilization of this very attractive portion of the spectrum. The challenges for the business failure of LEO system is like Iridium and Globalstar had raised some doubts that L-band spectrum could be increased. However, GPS is best known as a worldwide positioning system and the main purpose is to provide accurate positioning location at all points on the earth's surface at all times [38]–[40]. It is intended mainly for defense purposes, but the civilian community now constitutes the bulk of users. The GPS satellites constellation comprises of 24 satellites such that at least 4 satellites are visible everywhere on earth at any time [39], [41]–[43]. The GPS satellites group mainly located in the orbit of median earth orbit (MEO) or intermediate circular orbit (ICO).

GPS receiver

GPS transmits its signals using microwave with a very short length about 20 cm in compared to AM and FM radio wave. A short length wave is good as it follows a straight path without bending. The disadvantage of short waves is that the penetration to the matter is weak. The LOS is easily blocked by the building, tree canopy or atmosphere gaseous [6], [27], [44]–[46]. The primary classes of GPS receivers are; Recreational/ geocaching type, geographical information system (GIS)[47], survey/mapping, geodetic receiver type and military. This review paper will give more emphasis on recreational / geo-caching receivers, where handheld GPS receiver applications on experimental usage will be discussed.

GPS receivers have been equipped with Standard Positioning Service (SPS). Three-dimensional position and time determination capability provided to a user equipped with a minimum capability [42], [48]–[52], the GPS SPS receiver in accordance with GPS national policy and the performance specifications established in this Signal Specification [53], [54]. However the single frequency receivers have the advantage that they are low cost and the CA-code acquisition for civilian access provides higher signal to noise ratio than the synthesized P-code acquisition [55], [56]. The satellite uses code division multiple access (CDMA) spread technique. Frequencies at L-band are used to cover a great amount of telecommunication services for personal communication systems and satellite communications (SATCOM). The GPS carriers are in the L-Band centered at 1575.42 MHz (L1), 1227.60 MHz (L2), 1381.05 MHz (L3), 1379.913 MHz (L4) and 1176.45 MHz (L5) frequencies [2], [57]–[59].

A GPS receiver is able to calculate its position upon receiving navigation messages, which are packed into two pseudorandom noise (PRN) code sequences [60]–[63]. The Coarse Acquisition (C/A) code is a 1023 bits long sequence being repeated every millisecond. Furthermore, this code is clocked with 1.023 MHz. The second code sequence (Y-code), which is repeated every week, is encrypted and 6 trillion bits long [49], [64]. Its clock rate is 10.23 MHz. By processing navigational messages, receivers obtain information about the position of the individual satellites and the system time [49], [65], [66]. Figure 2 shows the receiver schematic diagram. The receiver comprises of antenna with pre-amplifier stage, which uses sensitive antenna that can detect electromagnetic wave signal transmitted by GPS satellites, then convert the signal to the wave energy [11], [67]. Many different type of antennas were in used for the receivers, such as monopole, Helix, spiral helix, microstrip and choke ring type [26], [31], [34], [68]–[75]. Commercial handheld GPS receiver mostly used microstrip antennas due to its advantage for airborne application and easy design. But geodetic antennas are design to receive two fold frequencies L1and L2 and their antennas were protected against multipath by using extra ground planes or using choke rings. The receiver has radio frequency section with signal identification and processing unit. It also incorporated with microprocessor that control data sampling and data processing, then final stage deal with position, time and velocity [12], [76]–[81].

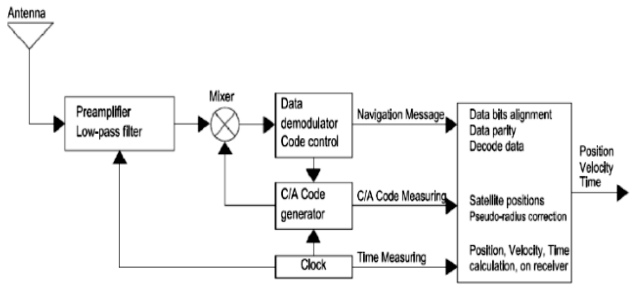

Figure 2. Schematic of GPS receiver

The satellite transmits signals containing the time and orbital data to calculate satellite position and almanac data [66], [82]. Meanwhile, receiver used on the ground, sea and air search the sky for the satellites. The GPS unit needs acquire good signal from at least three satellites to determine a position on the surface of the earth [30], [39], [52], [54], [63]. The table 1 below shows some selected receivers use for data acquisition system to obtain an MS propagation signal.

Table 1. GPS Receiver Classifications

S/N	Model	Frequency	Antenna Type	Experiment conducted	Parameters
I	Zenstar III	Single freq	Built in antenna	Nil	Update rate of 1 second with baud rate of 4800 NMEA 0183 Version 3.01 ASCII output (GPGGA, GPGSA, GPGSV, GPRMC, option GPGLL,GPVTG) Sentences $GPGSV,2,1,07,07,79,048,42,02,51,062,43,26,36,256,42,27,27,138, 42*71
2	HULUX GR-213U	Single freq.	Built in antenna	Design and experiment on intelligent fuzzy monitoring system for corn planters	USB interface with 4800 baud rate, 1sec update rate. NMEA sentences 0183 ver. 2.2 The receiver, USB interface with user selectable baud rate (4800-Default, 9600, 19200, 38400). With NMEA 0183 Version 2.2 ASCII output GGA, GSA, GSV, RMC (option GLL, VTG, ZDA). It has an update rate of 1 second. The GPGSV sentences for the receiver is GNSS Satellites in View (GSV) Table 5-8 contains the values for the following example:$GPGSV,2,1,07,07,79,048,42,02,51,062,43,26,36,256,42,27,27,138, 42*71 $GPGSV,2,2,07,09,23,313,42,04,19,159,41,15,12,041,42*41 Note: the receiver has no external antenna (Corn planters, step-less adjustment, plant spacing, fuzzy control, monitoring system, fault alarm)
3	SkyNavSK M55	Single freq	Embedded patch antenna 25 x 25 x 4.0 mm	NIL	USB interface with 9600 baud rate , NMEA $GPGSV,3,1,12,15,79,333,42,42,50,127,,29,45,263,44,02,36,124,30*7E $GPGSV,3,2,12,26,36,226,34,05,35,046,22,27,33,161,29,21,16,319,*7D $GPGSV,3,3,12,10,15,066,31,18,14,285,45,24,12,319,15,08,09,047,18*7E
4	GPS receiver, GNS 603	Single freq	Internal antenna, provision of external antenna	NIL	Mounting type receiver, every 5 Sec: GSV sentences, baud rate 9600
5	SUP500F Flash-based Low-Power	Single freq		NIL	The receiver is a mounting type with baud rate of 4800 $GPGSV,3,1,12,05,54,069,45,12,44,061,44,21,07,184,46,22,78,289,47*72<CR><LF> $GPGSV,3,2,12,30,65,118,45,09,12,047,37,18,62,157,47,06,08,144,45*7C
6	Garmin GPS25-HVS (but this type receiver is a discontinued product)	Single freq	External	1. Development of a Low-cost Positioning System Using OEM GPS Receivers and Usability in Surveying Applications 2. Design of portable instrument for measuring the agriculture field size based on GPS	Using the OEM Garmin GPS receiver, for survey techniques whereby the receiver was connected to a geodetic single frequency antenna EEPROM storage, RS 232C, LCD, Geometric size calculations, NMEA data
7	GISTM Stations	A dual-frequency GPS receiver	External	The artificial neural network as a model for an ionospheric TEC map to serve the single frequency receiver	ANN, TEC and Global Ionosphere Map (GIM)
8	1. Globalsat Technology Corporation GPS Engine Board ET 312 2. Global Top Tech	Single freq,	Built-in antenna	Localization of Small Mobile Robot by Low-Cost GPS Receiver Jaroslav	PRNS, two dimensional locations and distance, WGS 84, The receivers were used on different robot to detect the location of the robotic system. Leica Geo-systems GPS1200 were used as a reference, while the other 3 receivers are used the testing locations of the robots.

	Inc. FGPMMOP A6B 3. Garmin International Inc. GPS 18-5Hz 4. Leica Geo-systems GPS1200				
9	Standard reference GPS stations Receivers	Dual freq.	External	A New Window-Based Program for Quality Control of GPS Sensing Data	3-D position and receiver clock error, Satellite elevations. Satellite azimuths. Sky plot of observed satellite and DOPs
10	SMIGOL Reflecto-meter architecture	GPS L1 frequency (1.57542 GHz)	Patch antenna	Land Geophysical Parameters Retrieval Using the Interference Pattern GNSS-R Technique	Interference Pattern Technique (IPT),. To produce geophysical parameters (moist soil and vegetation height
11	Garmin map 76s	Single	Patch built-in with provision of external antenna	Integrated approach to predict confidence of GPS measurement	10.2m horizontal accuracy, different measurement accuracy 3.1m, pseudo-range, VDOP and HDOP, WGS 84, coordinate (j , l , h)
12	Garmin GPS III Plus	Single frequency	Built-in antenna with provision of external antenna	Nil	NMEA-0183, Update rate less than 2 seconds,
13	Garmin etrex	Single frequency	Built-in patch antenna	1. Development of low cost data acquisition system for mobile satellite signal performance measurement 2. Characteristics of mobile satellite L-band signal in mid-latitude region: GPS approach	NMEA, SNR, Elevation, azimuth Propagation data
14	Garmin GPSMAP 78	Single frequency	Built-in patch antenna	Nil	NMEA data, update rate less than 2 second
15	Garmin 60 Garmin Forerunner 201 GeoStats GeoLogger Skytrix minitracker MT4100	Single frequency	Built-in patch antenna	Use of Portable Global Positioning System (GPS) Devices in Exposure Analysis for Time-location Measurement	Time-activity, data loggers, data format (GDB, Tex, DMS), GPS coordinates, personal exposure

Acquisition of MS was conducted by Sunehra in 2013 using NovAtel GPS receiver which is a dual frequency type and is equipped with pre-installed software for data logging the propagation sentences. Dual frequency receivers are among the most sophisticates and expensive in the class of commercial available GPS receivers. An experimental study was conducted using low-cost GPS receivers to detect motion mobile robot on the basis of precise positioning by Hanzel 2013. He compared the high-end geodetic receiver (Leica 1200) as a reference to three selected single frequency receiver (ET 312, FGPMMOPA 6B and GPS 18-5Hz) and found out ET 312 gave the best result for location positioning. Hedgecock et al, (2013) demonstrated high-accuracy measurement using positioning algorithm techniques on low-cost Android phones integrates with GPS chips and Bluetooth on them. The relative location information for multiple receivers was achieved.

Handheld GPS receiver was used for precise position by Scwieger 2003, using Garmin handheld receiver to compute the phase and code information to get point positioning by transferring the real time on PC and stored in RINEX file. The baseline was solved after combining the RINEX file created by another GPS site and the phase pseudo-ranges were used in the post processing mode. Commercial single frequency receivers were used for time time-location measurement in exposure analysis by Lee et al (2009). Garmin 60, Garmin forerunner 201, Geostats Geologger and Skytrix mintracker MT 4100 were set up at various locations stationery and moving vehicles and they were used to compute the most accurate readings regarding accuracy applications, whereby Garmin 60 receiver proved more accurate than other 3 receivers. Table 2 shows the distribution of coordinates logged when the receivers were stationery using distance by the percentage of coordinates logged. The other two receivers did not log to any point during the experiments.

Table 2. Coordinates logged when stationery: by distance by percentage of coordinate logged

Distance in meters	Garmin 60		Geo logger	
Location	CHP[1]	KTCP[2]	CHP[1]	KTCP[2]
0 m	0%	41%	0%	6%
0-1m	13%	0%	13%	0%
1-5 m	81%	59%	68%	68%
5-10 m	0.4%	0%	17%	19%
>10m	0%	0%	2%	3%
95th percentile	3.8m	2.1m	7.7m	8.0m

KTCP – Kentuck transport cabinet position

CHP – Campbell house position

Research analysis was carried by Pai et al (2011) using a portable and cost-effective acquisition system to analyze GPS propagation signals. The single frequency receiver used for measurement was Garmin etrax capable of displaying 12 propagation sentences at an update rate of 1 second.

Garmin GPS receivers have their interface settings that follow any data format by which the sentences can be viewed, record or save on to the computer. The settings are given in table 3. Most of Garmin Handheld GPS receivers that transmit output of NMEA sentences at 5Hz frequency when connected to serial port of RS 232 interface give the following baud rate as shown in table 4.

The sentences using NMEA settings containing number characters per each line and will occupy five numeric alphabets; with the sequence as GPRMC, GPGGA, the completed proprietary sentences and character is summarized in table 5. The propagation sentences normally repeat every two seconds, these processes is called update rate. Each sentence transmission takes 2400 baud rate for one complete record, therefore for Garmin receivers that have an update rate of 2 seconds the baud rate will be 4800 at port speed setting.

Table 3. Garmin handheld GPS receiver data format

Receiver setting	Data format
Garmin	Upload / download mapsource
GRMN DGPS	Connection to a beacon receiver
NMEA	Support input/ output of standard NMEA 0183 data
None	This provides no interfacing capabilities
RTCM / TEXT	This allows SGPS input using a standard RTCM formant and simple text (ASCII) output format; time, position and velocity data
TEXT out	Output simple text only (ASCII) that contains time, position and velocity data

Table 4. Garmin GPS receiver baud rate setting

Baud rate	Character / seconds
300	30
600	60
1200	120
2400	240
4800	480
9600	960
19200	1920
38400	3840

Table 5. Garmin receiver proprietary sentences

Sentences	Rate of transfer per second	Character at maximum
GPRMC	once per 2 seconds	74
GPGGA	once per 2 seconds	82
GPGSA	once per 2 seconds	66
GPGSV	once per 2 seconds	70
PGRME	once per 2 seconds	35
GPGLL	once per 2 seconds	44
GPVTG	once per 2 seconds	42
PGRMV	once per 2 seconds	32
PGRMF	once per 2 seconds	82
PGRMB	once per 2 seconds	40
PGRMT	once per 60 seconds	50

Conclusion

The question on this review paper willing to address is whether it is feasible to develop a low-cost data system for mobile satellite propagation parameters that can be used for experimental purposes in a less developed countries such as Africa and some part of South East Asia. Handheld receivers were used for various experiments to study dilution of position (DOP), precise point position (PPP), mapping, farmland measurement. It also uses in the kinematic studies for moving object or vehicle and others applications not mentioned in this paper, but the application for this current research survey is to utilize the transmission data obtained from GPS signal via commercial GPS receiver to analyze ionospheric anomalies. The other high-end GPS receivers like geodetic can have the tracking of all the satellites in-view at the same time and both frequencies can be monitored. Also it has a full length on L2 and low phase noise-low code, having the high sampling rate of L1 and L2 but is extremely costly for simple and low cost data acquisition work.

Therefore, an experimental work is essential to be carried out to investigate the effects and factors such as the tree-shadowed and building-shadowed on the signal strength received from GPS system. These will give communication service providers and commercial user's a guide to improve their services.

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References

[1] P. L. N. Raju, "FUNDAMENTALS OF GPS," in Satellite Remote Sensing and GIS Applications in Agricultural Meteorology' Proceedings of the Training Workshop. 7-11 July, 2003', 2003, pp. 121–150.

[2] L. Lo Presti, B. C. Ferna, and E. Falletti, "Satellite Radiolocalization from GPS to GNSS and Beyond : Novel Technologies and Applications for Civil Mass Market," Proc. IEEE, vol. 99, no. 11, pp. 1882–1904, 2011.

[3] J. Louis J. Ippolito, Communications Atmospheric Effects, Satellite Link Design. Washington: A John Wiley and Sons, Ltd,, 2008.

[4] B. V. Pai, "Characteristics of mobile satellite L-band signal in mid-latitude region : GPS approach," Indian J. Radio Sp. Phys., vol. 40, no. April, pp. 105–112, 2011.

[5] P. K. Chopra, S. Jain, K. M. Paul, and S. Sharma, "' L ' B and Propagation Measurements for DAB Service Planning in INDIA," vol. 2, no. 1, pp. 75–82, 2011.

[6] J. Goldhirsh and W. J. Vogel, Handbook of Propagation Effects for Vehicular and Personal Mobile Satellite Systems Overview of Experimental and Modeling Results, vol. 021, no. December. Texas, 1998.

[7] L. Mousselon, W. L. Stutzman, and W. A. Davis, "Radio Wave Propagation Measurements and Modeling for Land Mobile Satellite Systems Radio Wave Propagation Measurements and Modeling for Land Mobile Satellite Systems," 2002.

[8] L. ed Takashi, Wave summit Course:Satellite Communication System and Design Technology. Olhmsha IOS Press, 2000.

[9] R. Bureau, Handbook of Mobile-satellite service (MSS). Switzerland: International Telecommunication Union, 2002.

[10] L. J. Ippolito, for Satellite Systems Design Section 1 Background, no. February. 1999.

[11] M. A. and M. I. Norsuzila Ya'acob, "GPS Total Electron Content (TEC) Prediction at Ionosphere Layer over the Equatorial Region," 2010.

[12] I. Abba, W. a. W. Z. Abidin, a. K. Othman, K. H. Ping, M. Abdullah, and B. V. Pai, "Best position method for experimental data acquisition systems using low-cost GPS receiver," Proceeding 2011 IEEE Int. Conf. Sp. Sci. Commun., pp. 200–205, Jul. 2011.

[13] B. V. Pai, W. A. W. Z. Abidin, H. Zen, T. Masri, and M. Abdullah, "Open Space Mathematical Model for the Mobile Satellite L-Band Signal in Sarawak using Global Positioning System Technology," in Proceeding of the 2011 IEEE International Conference on Space Science and Communication (IconSpace) 12-13 July 2011., 2011, no. July, pp. 12–13.

[14] G. Li, B. Ning, L. Liu, W. Wan, and J. Y. Liu, "Effect of magnetic activity on plasma bubbles over equatorial and low-latitude regions in East Asia," Ann. Geophys., no. 1980, pp. 303–312, 2009.

[15] S. Chatterjee and P. K. Purohit, "Effect of Ionospheric Perturbation on GPS Observation over Low Latitude Region, Bhopal," 2012.

[16] M. T. A. H. Muella, E. R. de Paula, I. J. Kantor, I. S. Batista, J. H. . Sobral, M. A. Abdu, P. M. Kintner, K. M. Groves, and P. F. Smorigo, "GPS L-band scintillations and ionospheric irregularity zonal drifts inferred at equatorial and low-latitude regions," J. Atmos. Solar-Terrestrial Phys., vol. 70, no. 10, pp. 1261–1272, Jul. 2008.

[17] C. M. Ngwira, G. K. Seemala, and J. Bosco Habarulema, "Simultaneous observations of ionospheric irregularities in the African low-latitude region," J. Atmos. Solar-Terrestrial Phys., vol. 97, pp. 50–57, May 2013.

[18] R. Tiwari, S. Bhattacharya, P. K. Purohit, and a. K. Gwal, "Effect of TEC Variation on GPS Precise Point at Low Latitude," Open Atmos. Sci. J., vol. 3, no. 1, pp. 1–12, Jan. 2009.

[19] N. Ya, M. Abdullah, and M. Ismail, "GPS Total Electron Content (TEC) Prediction at Ionosphere Layer over the Equatorial Region," Trends Telecommun. Technol., pp. 485–508, 2000.

[20] T. A. Musa, S. Lim, and C. Rizos, "Low Latitude Troposphere : A Preliminary Study Using GPS CORS Data in South East Asia," pp. 685–693, 1997.

[21] Http://www.satsig.net/lat_long.htm, "Equatorial region of the World," Access date 11/06/2014. .

[22] I. Abba, W. a. W. Z. Abidin, V. P. Bong, a. K. Othman, and K. H. Ping, "Open space experimental work for L-band mobile satellite (MS) using a simple and low cost data acquisition system," Int. Conf. Comput. Commun. Eng., no. May, pp. 1–5, May 2010.

[23] I. Abba, W. A. W. Z. Abidin, K. H. Ping, and T. Masri, "MEASUREMENTS AND ANALYSIS OF MOBILE SATELLITE SIGNAL PERFORMANCE USING HANDHELD GPS RECEIVER," in World Academy of Science, Engineering and Technology 72 2012, 2012, pp. 627–631.

[24] K. Davies and E. K. Smith, "Ionospheric effects on satellite land mobile systems," IEEE Antennas Propag. Mag., vol. 44, no. 6, pp. 24–31, Dec. 2002.

[25] B. R. Elbert, The Satellite Communication Applications Handbook, Second Edi. London: Artech House, 2004, pp. 7–14.

[26] D. Dissertation, "Development of Simple Antenna System for Land Mobile Satellite Communications," no. February, 2011.

[27] V. P. Bong, W. a. W. Z. Abidin, I. Abba, a. K. Othman, H. Zen, and T. Masri, "A simple and cost effective data acquisition system for mobile satellite experimental work under tree-shadowed and building-shadowed," Int. Conf. Comput. Commun. Eng., no. May, pp. 1–5, May 2010.

[28] S. L. Kota, G. Giambene, and P. Chini, "A Mobile Satellite Systems Frame Work for Network Centric Applications," IEEE, vol. 2, 2008.

[29] B. P. Jackson, "Mobile satellite EMS Communications.," Am. J. Emerg. Med., vol. 13, no. 1, p. 110, Jan. 1995.

[30] S. S. R. Ahamed, "Technological Strategy of Using Global Positioning System : An Analysis," Int. J. Eng. Sci. Technol., vol. 1, no. 1, pp. 8–16, 2009.

[31] K. F. M. T. Wan A. W. Z. Abidin, "Novel Approach to Determine the Effects of MS Environment using the Portable GPS Receiver with Built-in Antenna," Am. J. Appl. Sci., vol. 5, no. 8, pp. 1079–1082, 2008.

[32] M. Škiljo and Z. Blaževi, "Helical Antennas in Satellite Radio Channel," Intech, 1991.

[33] J. J. Carr, Practical Antenna Handbook, Fourth Edi. London: McGraw - Hill, 2001.

[34] [34] C. A. Balanis, Antenna Theory Analysis And Design Third Edition, Third Edit. New Jersey: A John Wiley & Sons, Inc., Publication, 2005.

[35] A. Adhikari and A. Maitra, "Journal of Atmospheric and Solar-Terrestrial Physics Studies on the inter-relation of Ku-band scintillations and rain attenuation over an Earth – space path on the basis of their static and dynamic spectral analysis," vol. 73, pp. 516–527, 2011.

[36] Y. Zeng and Y. Liang, "Spectrum-Sensing Algorithms for Cognitive Radio Based on Statistical Covariances," IEEE Trans. Veh. Technol. VOL. 58, NO. 4, MAY 2009, vol. 58, no. 4, pp. 1804–1815, 2009.

[37] P. Angeletti, M. Lisi, and Z. Noordwijk, "Multiport Power Amplifiers for Flexible Satellite Antennas and Payloads," Microw. J. Freq. mattere, pp. 1–11, 2014.

[38] F. Breu, S. Guggenbichler, and J. Wollmann, "Global Positioning System (GPS) is a navigation and precise-positioning tool," UTHM, 2008.

[39] K. Trajkovski, O. Sterle, and B. Stopar, "Sturdy positioning with high sensitivity GPS sensors under adverse conditions," Sensors, vol. 10, no. 9, pp. 8332–47, Jan. 2010.

[40] Garmin, "GPS III Plus Owner's Manual Reference," 2001.

[41] A. El-rabbany, "Introduction to GPS: The Global Position System," in NavtechGPS Part 1221, Second edi., 2006, p. 230.

[42] [42] E. D. K. and C. J. Hegarty, Understanding GPS Principles and Applications, Second Edi. Boston London: Artech House Inc., 2006.

[43] N. Ya'acob, M. Abdullah, M. Ismail, S. A. Bahari, and M. K. Ismail, "Ionospheric mapping function for total electron content (TEC) using global positioning system (GPS) data in Malaysia," 2008 IEEE Int. RF Microw. Conf., pp. 386–390, Dec. 2008.

[44] T. Charoenkalunyuta, C. Satirapod, H.-K. Lee, and Y.-S. Choi, "Performance of Network-Based RTK GPS in Low-Latitude Region: A Case Study in Thailand," Eng. J., vol. 16, no. 5, pp. 95–104, Oct. 2012.

[45] M. Hernández-Pajares, J. M. Juan, J. Sanz, À. Aragón-Àngel, A. García-Rigo, D. Salazar, and M. Escudero, "The ionosphere: effects, GPS modeling and the benefits for space geodetic techniques," J. Geod., vol. 85, no. 12, pp. 887–907, Sep. 2011.

[46] J. Isabona and S. Azi, "Enhanced Radio Signal Loss Prediction with Correction Factors for Urban Streets in the IMT-2000 Band," Elixir Int. J., vol. 59, pp. 15958–15962, 2013.

[47] A. K. Maurya, S. K. Tripathi, and S. K. Soni, "GIS-Based Geological Mapping in Achanakmar-Amarkantak Biosphere Reserve, Central India," Am. J. Comput. Sci. Inf. Technol., vol. vol.1, no. 1, pp. 051–055, 2014.

[48] A. Angrisano, S. Gaglione, C. Gioia, M. Massaro, and U. Robustelli, "Assessment of NeQuick ionospheric model for Galileo single-frequency users," Acta Geophys., vol. 61, no. 6, pp. 1457–1476, Apr. 2013.

[49] B. Resch and P. Romirer-maierhofer, "Global Positioning in Harsh Environments Master ' s Thesis in Computer Systems Engineering in Harsh Environments Master's Thesis in Computer Systems Engineering," 2005.

[50] G. S. Kumar, G. S. B. Rao, and M. N. V. S. S. Kumar, "GPS Signal Short-Term Propagation Characteristics Modeling in Urban Areas for Precise Navigation Applications," Positioning, vol. 04, no. 02, pp. 192–199, 2013.

[51] M. Kennedy, The Global Positioning System and GIS, Second edi. London: Taylor & Francis Inc, 2002.

[52] K.-Y. Lee, J.-Y. Kim, K. Putti, D. H. Bennett, D. Cassady, and I. Hertz-Picciotto, "Use of Portable Global Positioning System (GPS) Devices in Exposure Analysis for Time-location Measurement," Korean J. Environ. Heal. Sci., vol. 35, no. 6, pp. 461–467, Dec. 2009.

[53] J. J. M. M. C. Moreau, "U. S. PNT / Space Policy and NASA's Role," Vienna Austria, 2012.

[54] J. G. Grimes, "Global Positioning System Standard Positioning Service," Washington DC, 2008.

[55] K. F. and M. T. Wan Azlan W. Z. Abidin, "GPS Receiver and Mobile Satellite Signal Performance for Equatorial Region : Malaysia," in Proceedings of ISAP2007, Niigata, Japan, 2007, pp. 470–473.

[56] R. J. Muellerschoen, B. Iijima, R. Meyer, Y. Bar-sever, and E. Accad, "Real-Time Point-Positioning Performance Evaluation of Single-Frequency Receivers Using NASA's Global Differential GPS System Ronald," in ION GNSS 17th International Technical Meeting of the Satellite Division, 21-24 Sept., 2004, pp. 1872–1880.

[57] S.-S. Jan, T. Walter, and P. Enge, "Reversion from L1--L5 Dual to L5 Single Frequency WAAS in the Presence of RF Interference," IEEE Trans. Aerosp. Electron. Syst., vol. 46, no. 3, pp. 1110–1126, Jul. 2010.

[58] Z. Z. Abidin, R. Umar, Z. a. Ibrahim, Z. Rosli, K. Asanok, and N. Gasiprong, "Investigation on the Frequency Allocation for Radio Astronomy at the L Band," Publ. Astron. Soc. Aust., vol. 00, no. e00, p. e–047, Sep. 2013.

[59] I. Abba, W. A. W. Z. Abidin, A. K. Othman, and K. H. Ping, "Simple and Low Cost Measurement Evaluation Data Acquisition System for Different MS Signals," in Proceedings of EnCon2011 th 4 Engineering Conference Kuching, Sarawak, Malaysia, 2011, pp. 1–5.

[60] M. Ou, H. Zhang, D. Liu, X. Yu, and W. Zhen, "GIM-Ingested NeQuick Model Applied for GPS Single Frequency Ionospheric Correction in China," IEEE Antennas Wirel. Propag. Lett., no. 36, pp. 652–655, 2012.

[61] Shengyue JI, "Positioning Performance Improvements with European Multiple-Frequency Satellite Navigation System - Galileo," Hong Kong Polytechnic University DEPARTMENT, 2007.

[62] A. G. P. S. Receivers, "NMEA-0183 Messages Guide for Ag GPS Receivers," no. February, 2004.

[63] R. Athieno, "Using Co-located Radars and Instruments to Analyse Ionospheric events over South Africa," 2011.

[64] M. L. Ayers, Telecommunications System Reliability Engineering, Theory, and Practice. Hoboken, NJ, USA: John Wiley & Sons, Inc., 2012.

[65] R. Xu, Z. Liu, M. Li, Y. Morton, and W. Chen, "An Analysis of Low-Latitude Ionospheric Scintillation and Its Effects on Precise Point Positioning," vol. 11, no. 1, pp. 22–32, 2012.

[66] W. Hedgecock, J. Sallai, and P. Volgyesi, "High-Accuracy Differential Tracking of Low-Cost GPS Receivers Categories and Subject Descriptors," in MobiSys'13 June 25–28, 2013, Taipei,, 2013.

[67] J. F. Marchán-hernández, S. Member, N. Rodríguez-álvarez, A. Camps, S. Member, X. Bosch-lluis, I. Ramos-pérez, A. Member, and E. Valencia, "Correction of the sea state impact in the L-band brightness temperature by means of delay-Doppler maps of global navigation satellite signals reflected over the sea," … Remote Sens. …, vol. 46, no. 10, 2008.

[68] T. Huang and Y. Qin, "Design of a 1 . 575 GHz Helical LTCC Chip Antenna for GPS Application," pp. 932–935, 2010.

[69] G. O'Neill, "GPS Quadrifilar Antenna Designs for Portable Devices Greg O' Neill GPS Quadrifilar Antenna Designs for Portable Devices Table of Contents," 2005.

[70] S. Koulouridis and J. L. Volakis, "L-Band Circularly Polarized Small Aperture Thin Textured Patch Antenna," IEEE Antennas Wirel. Propag. Lett., vol. 7, pp. 225–228, 2008.

[71] S. Hebib, N. J. G. Fonseca, and H. Aubert, "Compact Printed Quadrifilar Helical Antenna with Iso-Flux-Shaped Pattern and High Cross-Polarization Discrimination," IEEE ANTENNAS Wirel. Propag. Lett. VOL. 10, 2011, vol. 10, pp. 635–638, 2011.
[72] M. Singh Parminder, Manpreet Kaur, "Single Band Helical Antenna in Axial Mode," Int. J. Electron. Commun. Comput. Technol., vol. 2, no. 6, pp. 256–258, 2012.J.
[73] M. A. and S. I. Jawad Yousaf, "Design Of Circularly Polarized Omnidirec-tional Bifilar Helix Antennas With Optimum Wide Axial Ratio Beamwidth," Prog. Electromagn. Res. C, Vol. 39, 119–132, 2013, vol. 39, no. April, pp. 119–132, 2013.
[74] M. Ahamed, K. Bhowmik, and A. Al Suman, "Analysis And Design of Rectangular Microstrip Patch Antenna On Different Resonant Frequencies For Pervasive Wireless Communication," vol. 1, no. 5, pp. 2010–2013, 2012.
[75] R. M. Alkan and T. İ. Ye, "Development of a Low-cost Positioning System Using OEM GPS Receivers and Usability in Surveying Applications Development of a Low-cost Positioning System Using OEM GPS Receivers and Usability in Surveying Applications," in FIG Congress, Facing the Challenges-Building the capacity, 2010, no. April 2010, pp. 11–16.
[76] Garmin, "Technical Specification," 2005.
[77] J. Hanzel and J. Rodina, "Localization of Small Mobile Robot by Low-Cost GPS Receiver," Journal Mech. Eng. Autom. 3, vol. 3, pp. 522–528, 2013.
[78] S. B. Rao, "Design and Implementation of a GPS receiver channel And Multipath Delay Estimation using Master of Technology," Indian Institute of Science Bangalore, INDIA, 2009.
[79] D. Sunehra and A. Pradesh, "Data Acquisition Experiment using NovAtel Dual Frequency GPS Receiver," vol. 2, no. 5, pp. 521–526, 2013.
[80] S. Chakraborty and S. Sen, "Preventing Desensitization of Radio Frequency," Am. J. Comput. Sci. Inf. Technol., vol.2, no. 1, pp. 033–038, 2014.
[81] J. B. Habarulema, "A contribution to TEC modeling over Southern Africa using GPS data," University of Cape Town, South Africa, 2010.