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COMPARISON OF GPS SATELLITE COORDINATES COMPUTED FROM BROADCAST AND IGS FINAL EPHEMERIDES

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ABSTRACT: There are mainly two different orbital information, namely broadcast ephemerides and IGS final ephemerides (IGS rapid, ultra rapid, predicted and final ephemerides) used in the GPS positioning. The broadcast ephemerides used in practice and real time are obtained through assessments derived from the observations from the USA GPS reference stations. Broadcast ephemerides are formed (depending on GPS week) from satellite information and the accuracies they provide are adequate in many GPS applications. On the other hand, several parameters (for example, information about gravity area, improved satellite orbit information, etc.) need to be known in order to attain high accuracy in engineering and geodetic applications. Final ephemeris information can be downloaded from the related web sites via the internet. In this study, Keplerian motion and Keplerian orbital parameters will be explained briefly and extensive information about ephemerides and numerical applications will be given. Within this scope, for GPS satellites, ECEF coordinates of the satellites were computed using the broadcast ephemerides. The coordinates computed by using broadcast ephemerides were compared with the coordinates obtained from the IGS final orbits.

Keywords: *GPS, Broadcast Ephemerides, IGS Ephemerides, Keplerian Orbital Parameters*

1. INTRODUCTION

Knowledge of ephemerides is an important issue for all GNSS applications because all ground positioning applications begin with the positions of GNSS satellites (Yoon, 2015). The computation and prediction of precise satellite orbits, together with appropriate observations and adjustment techniques is, for example, essential for the determination of;
-geocentric coordinates of observation stations,
−field parameters for the description of the terrestrial gravity field as well as for
the determination of a precise and high resolution geoid,
-trajectories of land-, sea-, air-, and space-vehicles in real-time navigation,
-Earth's orientation parameters in space (Seeber, 1993)
Keplerian elements forming the fundamental information of the satellite orbit motion need to be known in order to make accurate orbit definitions in navigation and other relevant fields where satellite methods are used to determine positions.
Satellite motions are expressed through Kepler's Laws and are defined via six Keplerian orbital elements (Seeber 1993, Hoffmann-Wellenhof et al. 1994, Warren 2002). These are shown in Figure 1 and explained in Table 1.

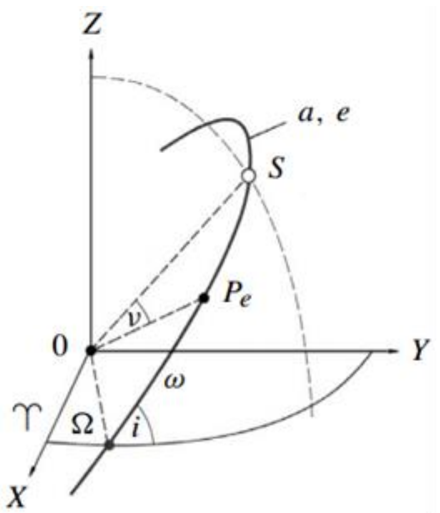

Figure 1 : Keplerian Orbital Elements (Seeber, 1993)

Three of the Keplerian orbital elements (a, e, P) describe the shape of the orbit while the other three elements (i, Ω, ω) enable orientation of the orbit in the ECEF (Earth Centered Earth Fixed) coordinate system.

Ephemerides data involving satellite orbital information are used to determine the position of a point on earth. Ephemerides data express Keplerian Orbital Information and data belonging to the momentary position of the satellite. Basis vector measured via GPS and point position accuracies vary depending on the accuracy of the ephemerides used in calculation.

Table 1 : Keplerian Orbital Elements (Warren, 2002)

Parameter	Explanation
Ω	Right ascension of ascending node (measured as radian on the equatorial plane)
i	Inclination of the Orbital Plane
ω	Argument of Perigee
a	Semi major axis of orbital plane (meter)
e	Numerical eccentricity of ellipse; $e \leq 0.01$
P	Epoch of Perigee Passage

2. GPS EPHEMERIDES

Ephemerides in practical usage are broadcast ephemerides that constitute the control unit of GPS and are obtained through observations. Although broadcast ephemerides provide adequate accuracy in many applications, they may not be adequate for applications requiring high accuracy. Broadcast ephemerides are delivered to users as navigation messages (Seeber, 1993).

The error that occurs when the accuracy of the satellite position information broadcast in GPS Navigation message is low or when it is broadcast deliberately erroneously is called ephemeris error. This error is one of the disturbing effects that are hard to model. Therefore, it is important to take these disturbing effects, which are defined as ephemeris error, into consideration in computation of satellite orbits and this depends on proper measurement and modeling of forces affecting satellites (Tusat and Turgut, 2003). Since ephemeris error is a result of prediction of satellite positions, the size of this error will increase as one moves away from the reference epoch for ephemerides. When the matter is analyzed in terms of the user, the error that will be caused by satellite error in Δr size in fundamental components (Δb) of base in b length can be expressed in the following equation (Kahveci and Yildiz, 2001).

$$\frac{\Delta b\ (m)}{b\ (km)} = \frac{\Delta r}{\rho_R^{sv}(km)} \quad (1)$$

Here, ρ_R^{sv} denotes the satellite-receiver distance.
Thus, if satellite-receiver distance is taken to be approximately 20200 km, errors in lengths that will be obtained for different ephemeris errors and base lengths on the basis of equation (1) are shown in Table 2 (Kahveci and Yildiz, 2001).

Table 2: Error Rates in Baseline from Ephemeris Errors

Ephemeris Error (m)	Baseline (km)	Error (ppm)	Error (mm)
2.5	1	--	--
2.5	10	0.1	1
2.5	100	0.1	12
2.5	1000	0.1	124
0.05	1	--	--
0.05	10	--	--
0.05	100	0.002	0.2
0.05	1000	0.002	2.5

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The effect of ephemeris error is quite low for baselines of a few kilometers. However, the size of this error increases significantly in cases where baselines reach a few kilometers, which causes a problem in the use of GPS system in geodetic applications that require a high level of accuracy (Kahveci and Yildiz, 2001).

Main causes of the error in question involve atmospheric drag and pressure by solar radiation. Sizes of predicted orbit and real orbit may exhibit differences especially during periods of high solar activity. Accuracy of geocentric coordinates obtained through broadcast ephemerides is not better than ± 2-5 cm (Seeber, 1993).

2.1 Broadcast Ephemerides

Users need to know real time satellite positions and satellite system time in order to perform navigation tasks. Orbital information included in the data signal is broadcast via navigation message. Navigation message is determined by the Control Unit and transmitted to users by GPS satellites as “broadcast”. The GPS navigation message file which contains the broadcast ephemeris gives the Keplerian parameters needed to compute the coordinates and clock correction for each satellite (Bidikar et al. 2014).

Broadcast ephemerides are used to compute the following items (Parkinson, 1996);

− satellite position at epoch,
− satellite velocity at epoch,
− three clock parameters per satellite,
− solar radiation pressure coefficients per satellite,
− y-axis acceleration bias,
− two clock parameters per monitor station, and
− one tropospheric scale factor per monitor station.

In the Kalman Filter process, predicted satellite positions are in the form of perturbation parameters and Keplerian elements (Figure 2). All parameters defining the satellite orbit and the state of the satellite clock are summarized in Table 3 below.

The parameters refer to a given reference epoch, t_{0e} for the ephemeris and t_{0c} for the clock, and they are based on a four hours curve fit (ICD, 1993). Hence, the representation of the satellite trajectory is achieved through a sequence of different disturbed Keplerian orbits (Seeber 1993).

The parameter sets in Table 3 are used to compute satellite time and satellite coordinates. The first group of the parameters are used for real satellite time. The second group defines a Kepler ellipse in reference epoch while the third group includes nine perturbation parameters.

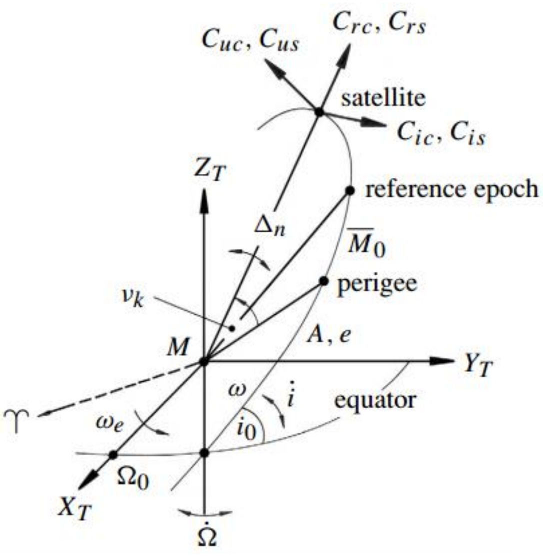

Figure 2 : Keplerian and perturbed parameters in broadcast ephemerides (Seeber, 1993)

Table 3 : Parameters of Broadcast Ephemerides (Seeber, 1993)

Time Parameters	
t_{0e}	Reference time, ephemerides parameters [s]
t_{0c}	Reference time, clock parameters [s]
a_0, a_1, a_2	Polynomial coefficients for clock corrections (bias [s], drift [s/s], drift rate [s/s^2])
IODC	Issue of Data, Clock, arbitrary identification number
Keplerian Parameters	
$\sqrt{a}$, e, i_0, Ω_0, ω, M_0	Keplerian elements of T_{0e}
IODE	Issue of Data, Ephemeris, arbitrary identification number
Perturbation Parameters	
Δn	Mean motion difference from computed value [semicircles/s]
di/dt (or IDOT)	Rate of change for inclination angle, (radian/second)
Ω	Rate of change in ascending node right ascension
Cuc, Cus	Correction coefficients for perigee argument, (radian)
Crc, Crs	Correction coefficients for geocentric distance, (meter)
Cic, Cis	Correction coefficients for inclination angle, (radian)

2.2 IGS Final Ephemerides

Precise ephemerides and clock parameters depend on observations at monitor stations scattered across the world. Dual-frequency receivers that could measure both code phases and carrier phases of all visible satellites were established at some stations. Satellite errors can be purged of time errors of the station clock through use of

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high precision oscillators (rubidium-cesium atomic standard) (Seeber, 1993). Data files are in general compatible with SP3 (standard product 3) data format (Remondi, 1991; Hilla, 2002; IGS 2017).

Today, the most important source for final ephemerides and other GPS products is IGS. Production of IGS (International GNSS Service) orbital information began with an experimental GPS measurement campaign that took place on 21st June 1992. (Kahveci and Yildiz, 2001) Unlike broadcast ephemerides, IGS orbits are formed from phase observations made in an intensive global network. Figure 3 shows IGS points in the world.

Figure 3 : IGS Network (IGS, 2017)

Today, IGS is responsible for collection, archiving and distribution of GPS measurements that could be used, with adequate accuracy, in scientific studies and engineering applications. These GPS measurements are used to obtain the following products (IGS, 2017).

- High accuracy GPS satellite ephemerides
- Earth rotation parameters (ERP)
- Coordinates of IGS monitor stations and their velocities
- Clock information belonging to GPS satellites and IGS monitor stations
- Computation of tropospheric zenith path delay

IGS products enable improvement and development of the ITRF system, determination of the movements of earth's crust, identification of changes on sea surface and provide high accuracy required by ionospheric studies. IGS performs these tasks within the following structure.

- A global observation network consisting of 506 stations
- Three global data centers
  - o CDDIS (Crustal Dynamics Data Information System at Goddard Space Flight Center, USA)
  - o IGN (Institut Geographique National, France)
  - o SIO (Scripps Institution Oceanography)
- Seven centers of analysis; CODE, NRCAN (EMR), ESA, JPL, GFZ, NGS and SIO.

The task of centers of analysis is to produce daily global data uninterruptedly (Kahveci and Yildiz, 2001). IGS produces four different pieces of orbital information according to orbits and clocks: IGS-Ultra-Speed, IGS Speedy, IGS Result orbital information (see Table 4).

Table 4 : IGS GPS satellite and clock accuracy (IGS, 2017)

Type	Accuracy		Latency	Updates	Sample Interval
Broadcast	orbits	~100 cm	real time	--	daily
	Sat. Clocks	~5 ns RMS ~2.5 ns Sdev			
Ultra-Rapid (predicted half)	orbits	~5 cm	real time	at 03, 09, 15, 21 UTC	15 min
	Sat. Clocks	~3 ns RMS ~1.5 ns Sdev			
Ultra-Rapid (observed half)	orbits	~3 cm	3 - 9 hours	at 03, 09, 15, 21 UTC	15 min
	Sat. Clocks	~150 ps RMS ~50 ps Sdev			
Rapid	orbits	~2.5 cm	17 - 41 hours	at 17 UTC daily	15 min
	Sat. & Stn. Clocks	~75 ps RMS ~25 ps Sdev			5 min
Final	orbits	~2.5 cm	12 - 18 days	every Thursday	15 min
	Sat. & Stn. Clocks	~75 ps RMS ~20 ps Sdev			Sat.: 30s Stn.: 5 min

3. MATERIAL AND METHOD

So far, GPS satellite orbits have been explained. In this regard, GPS satellite coordinates were computed in the ECEF coordinate system using the IGS final (igs18632.sp3) and broadcast ephemerides (brdc2650.15n) data belonging to September 22, 2015 at 12.00 hours in order to investigate the effect of ephemerides information on coordinates, and comparisons were made. In the numerical application conducted, the effect of broadcast ephemerides belonging to the points on satellite coordinates was investigated by changing only the orbital information from among the selected parameters in the comparison.

Computation of ECEF Coordinates from Satellite Orbits

RINEX (Recevier INdependent EXchange format) navigation file data are used to compute a GPS satellite orbit or its position at a certain moment in ECEF coordinate system. (Figure 4).

```
1 15  9 22 12  0  0.0
0.961590558290E-06 0.682121026330E-12 0.000000000000E+00   0.470000000000E+02-0.347187500000E+02
0.469659012742E-02 0.954605638981E-05 0.515366348839E+04   0.216000000000E+06 0.800937414169E-07
0.197343750000E+03 0.475413498332E+00-0.799747598412E-08   0.400016662300E-10 0.100000000000E+01
0.000000000000E+00 0.512227416039E-08 0.470000000000E+02   0.214380000000E+06 0.400000000000E+01
```

Figure 4 : RINEX data block for SV 1

Ephemerides parameters used in the computations are given Table 3. It is possible to compute highly accurate satellite coordinates in the ECEF coordinate system using these data in a certain algorithm.

Satellite Position Computation Algorithm

Computation of the position of a satellite in ECEF coordinate system is quite simple. The algorithm to be used to this end is given in Table 5. $\boldsymbol{E_k}$ and $\boldsymbol{V_k}$ variables, which were not in linear correlation, were found using Newton-Raphson iteration technique.

Table 5 : Satellite Position Computation Algorithm

$GM_e = 3.986008\ x\ 10^4\ m^3/\ s^2$	Gravitational Constant
$\dot{\Omega}e = 7.292115167x\ 10^{-5}\ rad/s$	Earth rotation rate
$a = (\sqrt{a})^2$	Semi-major axis
$n_0 = \sqrt{\frac{GM}{a^3}}$	Computed mean motion
$n = n_0 + \Delta n$	Corrected mean motion
$t_k = t - t_{0e}$	Time according to t_{0e}
$M_k = M_0 + n\ .t_k$	Mean anomaly
$E_k = M_k + e\ .\sin E_k$	Eccentric anomaly
$V_K = \tan^{-1}(\frac{\sqrt{1-e^2}.\sin E_k}{\cos E_k - e})$	True anomaly
$V_{K=} \cos^{-1}(\frac{e + \cos f_n}{1 + e\cos f_n})$	True anomaly
$U_k = \omega + V_k$	Argument of latitude
$\delta U_k = C_{uc}.\cos 2U_k + C_{us}.\sin 2U_k$	Argument of latitude correction
$\delta r_k = C_{rc}.\cos 2U_k + C_{rs}\sin 2U_k$	Radius correction
$\delta i_k = C_{ic}.\cos 2U_k + C_{is}\sin 2U_k$	Inclination correction
$\Phi_k = U_k + \delta U_k$	Corrected argument of latitude
$r_k = a(1 - e.\cos E_k) + \delta r_k$	Corrected radius
$i_k = i_o + i.t_k + \delta i_k$	Corrected inclination
$\Omega_k = \Omega_0 + (\dot{\Omega} - \dot{\Omega}_e)t_k - \dot{\Omega}_e t_{oe}$	Corrected longitude of ascending node
$X_k^{'} = r_k.\cos\Phi_k$	Position in the orbital plane
$Y_k^{'} = r_k.\sin\Phi_k$	
$X_k = X_k^{'}.\cos\Omega_k - Y_k^{'}.\sin\Omega_k.\cos i_k$	Earth fixed geocentric satellite coordinates
$Y_k = K_k^{'}.\sin\Omega_k + Y_k^{'}.\cos\Omega_k.\cos i_k$	
$Z_k = Y_k^{'}.\sin i_k$	

4. RESULTS AND DISCUSSION

For a comparison, the data obtained from a broadcast ephemeris file belonging to the selected time and all the coordinates in the ECEF system belonging to all the satellites were computed using the algorithm (see Table 5) and the results are given in Table 6. Since broadcast ephemerides information belonging to satellites 19 and 28 did not exist for the time we studied, it was not included in the computations and comparisons.

Table 6 : Coordinates Computed from Broadcast Ephemeris Data

	BROADCAST EPHEMERIDES		
	Date : 22.09.2015 Time : 12 00 00.0 (UTC)		
SV	X (m)	Y (m)	Z (m)
PG01 / 1	13241509.1112	-22684517.4902	-3185779.0525
PG02 / 2	-19062942.1707	8040568.1264	-16021004.7228
PG03 / 3	10524879.3394	-13434155.3029	-20348279.9791
PG04 / 4	17487635.7595	-18899496.8878	5580890.8762
PG05 / 5	-25726352.4852	2709436.6092	6395764.0177
PG06 / 6	-15102048.5066	-4355823.4206	-21409473.3875
PG07 / 7	1496332.7481	-20904086.3120	16200889.5707
PG08 / 8	9613449.6557	-13567567.5895	20756256.7077
PG09 / 9	-6982217.0162	-24840578.1163	-6271115.2489
PG10 / 10	18020769.3446	3708296.6187	19272097.6589
PG11 / 11	10220819.5620	-23855161.8523	4866821.5666
PG12 / 12	-13429111.3494	11403133.8642	-19910724.6289
PG13 / 13	-14751728.3410	2703241.8466	21782990.8531
PG14 / 14	14467152.0676	20339524.5241	-9046264.9330
PG15 / 15	-9148103.2099	14508567.5799	20105616.2170
PG16 / 16	25972823.0282	-282111.9732	6335651.6228
PG17 / 17	-15209695.7659	-19577725.9601	-9512594.6810
PG18 / 18	9998746.5952	15467674.9555	19733909.5573
PG20 / 20	-13952448.9143	13459192.4687	18035077.8103
PG21 / 21	3030146.4229	19664885.4718	18152398.9758
PG22 / 22	21902903.8949	10072173.1631	11577960.4784
PG23 / 23	4016930.7221	-19851266.3489	-16786537.5994
PG24 / 24	-14556384.6682	22111328.9425	-224097.5724
PG25 / 25	1034402.1893	14955831.4442	-22033883.4358
PG26 / 26	25790651.8787	4884605.0664	-4080593.8351
PG27 / 27	15971808.8445	-394385.3141	21211096.3291
PG29 / 29	3925251.3408	24880784.6118	-8473995.8229
PG30 / 30	-7846485.3755	-14067794.7995	21104373.4715
PG31 / 31	15397134.8865	3526605.8571	-21275951.9003
PG32 / 32	21311233.5969	-6694899.2395	-13990519.1669

Satellite coordinates existing in current IGS final ephemerides file are given in Table 7.

Table 7 : Coordinates Taken from IGS Final Ephemerides File

	IGS FINAL EPHEMERIDES (PG)		
	22.09.2015 - 12 00 00.0 (UTC)		
SV	**X (km)**	**Y (km)**	**Z (km)**
PG01 / 1	13241.510267	-22684.518437	-3185.778312
PG02 / 2	-19062.942489	8040.569306	-16021.003732
PG03 / 3	10524.880813	-13434.156207	-20348.279989
PG04 / 4	17487.636021	-18899.497890	5580.890525
PG05 / 5	-25726.352210	2709.437346	6395.764498
PG06 / 6	-15102.049290	-4355.823474	-21409.474085
PG07 / 7	1496.332264	-20904.086346	16200.889743
PG08 / 8	9613.449439	-13567.568723	20756.257558
PG09 / 9	-6982.216570	-24840.579318	-6271.115865
PG10 / 10	18020.769915	3708.298193	19272.098083
PG11 / 11	10220.820960	-23855.162761	4866.822869
PG12 / 12	-13429.111902	11403.134108	-19910.723909
PG13 / 13	-14751.729370	2703.244991	21782.991689
PG14 / 14	14467.151791	20339.526524	-9046.265445
PG15 / 15	-9148.104842	14508.566576	20105.615974
PG16 / 16	25972.824222	-282.113556	6335.654492
PG17 / 17	-15209.694542	-19577.726766	-9512.594024
PG18 / 18	9998.748167	15467.676057	19733.910223
PG20 / 20	-13952.450041	13459.192872	18035.078960
PG21 / 21	3030.148062	19664.885926	18152.400788
PG22 / 22	21902.903891	10072.173885	11577.959609
PG23 / 23	4016.930809	-19851.266599	-16786.537380
PG24 / 24	-14556.385671	22111.329422	-224.097685
PG25 / 25	1034.402967	14955.832070	-22033.884220
PG26 / 26	25790.653160	4884.605494	-4080.593578
PG27 / 27	15971.809573	-394.384769	21211.097228
PG29 / 29	3925.250834	24880.784699	-8473.995905
PG30 / 30	-7846.486155	-14067.795260	21104.374161
PG31 / 31	15397.134642	3526.606158	-21275.951929
PG32 / 32	21311.233542	-6694.900451	-13990.520418

When the coordinates obtained from two different types of ephemerides information were compared, the differences in Table 8 were reached and they were shown in Figure 5.

Table 8 : Differences in Coordinates Obtained from Broadcast Ephemeris and IGS Final Ephemeris Data

	DIFFERENCES		
SV	**ΔX (m)**	**ΔY (m)**	**ΔZ (m)**
PG01 / 1	1.1558	-0.9468	0.7405
PG02 / 2	-0.3183	1.1796	0.9908
PG03 / 3	1.4736	-0.9041	-0.0099
PG04 / 4	0.2615	-1.0022	-0.3512
PG05 / 5	0.2752	0.7368	0.4803
PG06 / 6	-0.7834	-0.0534	-0.6975
PG07 / 7	-0.4841	-0.0340	0.1723
PG08 / 8	-0.2167	-1.1335	0.8503
PG09 / 9	0.4462	-1.2017	-0.6161
PG10 / 10	0.5704	1.5743	0.4241
PG11 / 11	1.3980	-0.9087	1.3024
PG12 / 12	-0.5526	0.2438	0.7199
PG13 / 13	-1.0290	3.1444	0.8359
PG14 / 14	-0.2766	1.9999	-0.5120
PG15 / 15	-1.6321	-1.0039	-0.2430
PG16 / 16	1.1938	-1.5828	2.8692
PG17 / 17	1.2239	-0.8059	0.6570
PG18 / 18	1.5718	1.1015	0.6657
PG20 / 20	-1.1267	0.4033	1.1497
PG21 / 21	1.6391	0.4542	1.8122
PG22 / 22	-0.0039	0.7219	-0.8694
PG23 / 23	0.0869	-0.2502	0.2194
PG24 / 24	-1.0028	0.4795	-0.1126
PG25 / 25	0.7777	0.6258	-0.7842
PG26 / 26	1.2813	0.4276	0.2571
PG27 / 27	0.7285	0.5451	0.8989
PG29 / 29	-0.5068	0.0872	-0.0821
PG30 / 30	-0.7795	-0.4605	0.6895
PG31 / 31	-0.2445	0.3009	-0.0287
PG32 / 32	-0.0549	-1.2115	-1.2511
Maximum	1.6391	3.1444	2.8692
Minimum	-1.6321	-1.5828	-1.2511
Mean	0.1691	0.0842	0.3392
Standard Deviations	0.9180	1.0769	0.8617

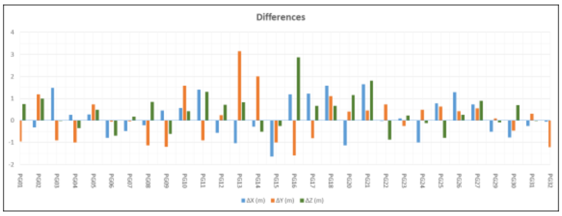

Figure 5 : Differences of ECEF satellite coordinates computed from broadcast ephemerides from IGS final ephemerides

When Table 8 is examined, it is seen that the differences between the coordinate components of broadcast and final ephemerides vary between – 1,6321 m and +1,6391 m on the X-axis, between -1,5828 m and +3,1444 m on the Y-axis and between -1,2511 m and 2,8692 m on the Z-axis. When the means of these differences are taken into consideration, it appears that X coordinate component has an average difference of ~17 cm, Y coordinate component ~8 cm, and Z coordinate component ~34 cm. On the other hand, when the standard deviations of computations are taken into consideration it can be seen from Table 8 that the mean standard deviation values are 0,9180 m, 1,0769 m, 0,8617 m for X, Y and Z components, respectively.

Numerous studies have been conducted from past to present with regard to orbital accuracy and its improvement. FGCC (Federal Geodetic Control Committee) stated in a guidebook entitled Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques published in 1989 that there were small differences between final ephemerides and broadcast ephemerides and that this accuracy was enough to meet the needs of most engineering projects. According to Rui-xi et al. (2014), accuracy of broadcast ephemerides was found to be around ±1 m for each of the X, Y and Z coordinates. Likewise, it was stated in Grzegorz et al. (2015) and in IGS (2017) that satellite coordinates could be obtained with an accuracy of ±1 m through broadcast ephemerides.

5. CONCLUSION

Reliable, consistent positioning accuracy has always driven new product development in the survey and mapping sector of the GNSS market (Cameron 2015). It should not be forgotten that accuracy of the coordinates calculated from broadcast and final ephemerides data is influenced by gravity field information and tropospheric and ionospheric factors. ITRF system, which uses GRS80 reference ellipsoid, is used in productions made from final ephemerides whereas WGS84 system, which again uses GRS80 reference ellipsoid in calculations made from broadcast ephemerides data, but it is pointed out that there is not much difference between WGS84 and ITRF systems in practical applications (Stanaway 2007).

When all the effects are taken into consideration, the desired precision in the study to be conducted needs to be determined properly before deciding on the ephemerides information to be used. Use of IGS final ephemerides data in specific studies such as establishment of first degree Networks and deformation measurements which require extremely high precision may ensure that results have even higher levels of accuracy. For example, it would be appropriate to use IGS final ephemerides data to improve accuracies of ITRF coordinates of local/regional geodetic studies. On the other hand, release period of IGS products ranging from about 1 day to 2 weeks is a major disadvantage for high precision GNSS processing. Therefore, the fact that broadcast ephemerides data can be accessed at any time and that it yields results that are not much different from those obtained from final ephemerides data render broadcast ephemerides a more easily applied alternative in many practical applications.

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