TS/SU-ACG

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COMPUTATION OF WGS84 GEODETIC COORDINATES AND AZIMUTHS AT THE LHC INTERACTION POINTS

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Abstract

In order to provide the necessary parameters for studying cosmic particles the latitude and longitude of the LHC interaction points in the WGS84 reference system have been computed using the parameters for the transformation from the CERN Geodetic Reference Frame. The geodetic azimuth of the beamline at each interaction point has also been computed.

List of Attached Files

CartesianInv.xls
PtSelectScript.sql
CoordinateFiles.ZIP
ApproximateAzimuthControls.ZIP

Mots-clefs : Points d'Interaction LHC, Coordonnées Géodésiques, Azimut

Keywords : LHC Interaction Points, Geodetic Coordinates, Azimuth

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1. INTRODUCTION

The geodetic position and orientation of the LHC experiments are required if they are to be used for studying cosmic particles. Using the results from GPS campaign to measure the geodetic surface reference network, carried out at CERN in 1998, to determine the transformation parameters between the CERN Geodetic Reference Frame and the WGS84 Reference System the required positional data have been determined in the WGS84 system.

The geodetic coordinates (latitude and longitude) and the geodetic azimuth of the beamline at each interaction point (IP) around the LEP ring have been determined.

2. DATA

The data required for the computation were obtained from the SURVEY database. For the LHC beamline the coordinates of the 8 interaction points were obtained together with the coordinates of a point on the beam line at the end of the long straight section (LSS) passing through the IP.

The following coordinates in the CERN Coordinate System were obtained.

Point Name	**X** / m	**Y** / m	**Z** / m
IP_1	2202.21027	2710.63882	2359.00709
IP_2	-1015.65854	2697.15468	2403.98875
IP_3	-3300.34853	4963.40091	2438.71381
IP_4	-3313.77648	8181.58186	2442.82283
IP_5	-1047.71124	10466.53229	2413.93223
IP_6	2170.15757	10480.01643	2368.96047
IP_7	4454.84756	8213.77020	2334.22699
IP_8	4472.52592	5005.97290	2330.05413

Table 1 LHC IP Cartesian coordinates in the CERN Coordinate System

Point Name	**X** / m	**Y** / m	**Z** / m
MB_A8R1_E	1953.59993	2606.44089	2362.35697
MB_A8R2_E	-1265.59437	2799.47907	2407.60879
MB_A8R3_E	-3404.53211	5212.03360	2440.47521
MB_A8R4_E	-3211.45776	8431.54370	2441.69602
MB_A8R5_E	-799.10091	10570.73022	2410.58486
MB_A8R6_E	2420.09340	10377.69204	2365.33982
MB_A8R7_E	4559.03114	7965.1375	2332.46486
MB_A8R8_E	4365.95678	4745.62741	2331.22681

Table 2 LHC LSS end point Cartesian coordinates in the CERN Coordinate System

3. COMPUTATION

The geodetic coordinates of the IPs were determined by the program CSGEO v3.1 to transform the point coordinates from the CERN Coordinate System into the geodetic coordinate system of the WGS84 reference frame. This generated directly the geodetic coordinates (latitude and longitude).

The IP coordinates were also transformed into the geodetic Cartesian coordinate system of the WGS84 reference frame, thereby providing the additional information required to determine the azimuth of the beamline at each IP.

For each IP in turn, the coordinates of the IP and the corresponding point at the end of the straight section were transformed into a Local Geodetic System of the WGS84 reference frame at the given IP. The transformation applied is defined in [1].

By definition the Local Geodetic System has its axes oriented with respect to North, with it's origin, in this case, at the given IP. The bearing to the transformed point in this system therefore yields the azimuth of the beamline passing through the given IP.

4. RESULTS

For each of the LHC Interaction Points the geodetic coordinates and the ellipsoidal height in the WGS84 Reference System, with the WGS84 reference ellipsoid, have been determined. These coordinates and the azimuth of the beam line at each IP are presented below.

4.1 WGS84 Coordinates of the LHC Interaction Points

The positions of the LHC interaction points are provided in both the geodetic and geodetic Cartesian coordinate systems. The geodetic coordinates (latitude and longitude) are provided in both gons (2π radians ≡ 400 gons) and sexagesimal units.

Point Name	**Latitude** (ϕ)			**Longitude** (λ)			**Ellipsoidal Height** / m
	Deg	Min	Sec	Deg	Min	Sec	
IP_1	46	14	8.5537	6	3	19.0048	409.001
IP_2	46	15	6.4530	6	1	14.1228	454.794
IP_3	46	16	48.6617	6	0	44.7944	491.742
IP_4	46	18	15.3233	6	2	8.3059	498.187
IP_5	46	18	35.6245	6	4	35.8044	470.371
IP_6	46	17	37.6663	6	6	40.7605	424.583
IP_7	46	15	55.4318	6	7	9.9147	387.623
IP_8	46	14	29.0307	6	5	46.7647	381.127

Table 3 LHC IP geodetic coordinates in the WGS84 system (sexagesimal)

Point Name	**Latitude** (ϕ) / gons	**Longitude** (λ) / gons	**Ellipsoidal Height** / m
IP_1	51.37301041	6.72808790	409.001
IP_2	51.39088055	6.68954409	454.794
IP_3	51.42242644	6.68049209	491.742
IP_4	51.44917387	6.70626726	498.187
IP_5	51.45543966	6.75179148	470.371
IP_6	51.43755132	6.79035816	424.583
IP_7	51.40599746	6.79935640	387.623
IP_8	51.37933046	6.77369282	381.127

Table 4 LHC IP geodetic coordinates in the WGS84 system (gons)

Point Name	**X** / m	**Y** / m	**Z** / m
IP_1	4395059.504	466227.012	4583704.115
IP_2	4394088.242	463433.838	4584973.658
IP_3	4391911.569	462572.853	4587182.212
IP_4	4389804.626	464148.059	4589035.974
IP_5	4389001.762	467237.041	4589448.911
IP_6	4389973.031	470030.215	4588179.375
IP_7	4392149.699	470891.199	4585970.814
IP_8	4394251.140	469324.793	4584121.317

Table 5 LHC IP geodetic Cartesian coordinates in the WGS84 system

4.2 Geodetic Azimuths of the LHC Beamline in the WGS84 System

The geodetic azimuths of the LHC beam line at each of the eight interaction points are provided WGS84 system. The azimuths are provided in both gons and sexagesimal units and represent the azimuth of the beam clockwise from the IP.

Point Name	Beamline Azimuth			Beamline Azimuth
	Deg	Min	Sec	Gons
IP_1	281	15	54	312.5167
IP_2	326	14	39	362.4934
IP_3	11	14	21	12.4879
IP_4	56	15	05	62.5015
IP_5	101	16	46	112.5328
IP_6	146	18	31	162.5651
IP_7	191	18	57	212.5731
IP_8	236	17	44	262.5506

Table 6 Geodetic Azimuths in the WGS84 system

4.2.1 WGS84 Coordinates of the LHC LSS Beam Direction Points

For completeness the positions of the point on the beam line at the end of the long straight section are provided in both the geodetic and geodetic Cartesian coordinate systems. The geodetic coordinates (latitude and longitude) are provided in both gons and sexagesimal units. These points were used to determine the geodetic azimuth of the beamline.

Point Name	**Latitude** (ϕ)			**Longitude** (λ)			**Ellipsoidal Height** / m
	Deg	Min	Sec	Deg	Min	Sec	
MB_A8R1_E	46	14	10.2589	6	3	6.6668	412.345
MB_A8R2_E	46	15	13.7245	6	1	7.1171	458.558
MB_A8R3_E	46	16	57.2243	6	0	47.2485	493.716
MB_A8R4_E	46	18	20.1825	6	2	18.8000	497.221
MB_A8R5_E	46	18	33.9168	6	4	48.1582	467.041
MB_A8R6_E	46	17	30.3892	6	6	47.7592	420.830
MB_A8R7_E	46	15	46.8713	6	7	7.4449	385.660
MB_A8R8_E	46	14	23.9751	6	5	35.8419	382.145

Table 7 LHC LSS end point geodetic coordinates in the WGS84 system (sexagesimal)

Point Name	**Latitude** (ϕ) / Gons	**Longitude** (λ) / Gons	**Ellipsoidal Height** / m
MB_A8R1_E	51.37353670	6.72427986	412.345
MB_A8R2_E	51.39312484	6.68738183	458.558
MB_A8R3_E	51.42506922	6.68124953	493.716
MB_A8R4_E	51.45067360	6.70950618	497.221
MB_A8R5_E	51.45491261	6.75560437	467.041
MB_A8R6_E	51.43530530	6.79251828	420.830
MB_A8R7_E	51.40335533	6.79859411	385.660
MB_A8R8_E	51.37777010	6.77032159	382.145

Table 8 LHC LSS end point geodetic coordinates in the WGS84 system (gons)

Point Name	**X** / m	**Y** / m	**Z** / m
MB_A8R1_E	4395051.871	465960.348	4583742.949
MB_A8R2_E	4393945.257	463267.859	4585131.639
MB_A8R3_E	4391717.374	462605.232	4587366.375
MB_A8R4_E	4389672.457	464359.915	4589138.930
MB_A8R5_E	4389009.398	467503.704	4589410.078
MB_A8R6_E	4390116.016	470196.194	4588021.393
MB_A8R7_E	4392343.893	470858.821	4585786.651
MB_A8R8_E	4394388.799	469104.137	4584014.083

Table 9 LHC LSS end point geodetic Cartesian coordinates in the WGS84 system

5. CONCLUSION

Geodetic coordinates in the WGS84 Reference System have been determined for each of the LHC interaction points. In absolute terms the accuracy of these coordinates ~ 1.5 m, largely due to the uncertainty in the determination of the WGS84 system itself.

At each interaction point the geodetic azimuth of the beamline (clockwise direction) has also been determined by using an additional point at the end of the right-hand Long Straight Section of the LHC machine. In absolute terms the accuracy of these azimuths is more difficult to estimate, being dependent on the measurement of the geodetic surface reference network and the alignment of the LHC machine, but should be ~ 10 arc seconds (~ 3 mgons).

REFERENCE:

1 Jones, M., “Spatial Transformations: Transformations Between the Geodetic and Astronomical Reference & Coordinate Systems”, EST-SU Internal Note, EDMS Document No. 107907, CERN, Geneva, Switzerland, November 1999.