R. Costa, D. Orgiazzi, V. Pettiti, I. Sesia, P. Tavella,

**GPS Common view data processing algorithm**

R.T. 677       Maggio 2004

Rapporto tecnico
Summary

Scope of this IEN Technical Report is to describe in details the algorithms allowing time offset estimation between UTC(IEN) and GPS time as well as time scale comparison with other remote UTC(\(k\)) laboratories.

In particular, after a brief introduction to GPS system, it deals with an overview of the GPS Common View (CV) time comparison technique and the CGGTTS (Common GPS GLONASS Time Transfer Standard) file format. Then, the detailed description of the UTC(IEN)-GPS time processing and UTC(IEN)-UTC(\(k\)) combining algorithms.

Furthermore, it reports an analysis of outliers detection algorithm and a brief user manual of the program implemented for the computation of both UTC(IEN)-GPS time and UTC(IEN)-UTC(\(k\)). Finally, a few applications of the realized software are illustrated.

The programs have been developed in Windows through a Microsoft Visual Basic 5 compiler.

Sommario

Con il seguente rapporto si intende descrivere l’algoritmo del programma utilizzato per stimare l’offset tra i dati della scala di tempo dello IEN [UTC(IEN)] e di altri laboratori internazionali remoti [UTC(\(k\))], con quelli della scala GPS.

In particolare, dopo una breve introduzione al sistema GPS, si descrive la tecnica utilizzata per il confronto GPS Common View (CV) e il formato dei file CGGTTS (Common GPS GLONASS Time Transfer Standard). Successivamente si describe l’elaborazione UTC(IEN)-GPS e il confronto UTC(IEN)-UTC(\(k\)).

Infine, viene effettuata l’analisi delle tecniche utilizzate per eliminare gli outliers e un manuale d’uso descrive brevemente l’utilizzo.

Infine, sono presenti alcuni esempi ed applicazioni.

Questo è realizzato mediante un programma sviluppato con compilatore Microsoft Visual Basic 5 in ambiente Windows.
1. Introduction

Scope of this IEN Technical Report is to describe in details the algorithms (used in the Galileo System Test Bed project) allowing time offset estimation between UTC(IEN) and GPS time (using 3S Navigation timing receiver) as well as time scale comparison with other remote UTC(k) laboratories.

In particular, after a brief introduction to GPS system, it deals with an overview of the GPS Common View (CV) time comparison technique and the CGGTTS (Common GPS GLONASS Time Transfer Standard) file format. Then, the detailed description of the UTC(IEN)-GPS time processing and UTC(IEN)-UTC(k) combining algorithms are reported. Both processing use filtering procedure: ± $n \cdot \sigma$ and MAD [Median of the absolute Deviation].

Furthermore, reports a brief user manual of the program implemented for the computation of both UTC(IEN)-GPS time and UTC(IEN)-UTC(k).

Finally, a few applications of the realized software are illustrated:
- web publication of IEN GPS data on web page: http://www.ien.it/tf/time/datigps.html;
- long term monitoring UTC(IEN) time scale;
- application for Galileo System Test Bed (UTC(IEN)-UTC(k) combining between IEN and PTB, NPL);
- GPS data analysis during sun storm (October – November 2003);
- GPS data analysis satellites parameters (comparison with IGS (International GPS Service) data);
- Masking angle analysis;
2. Introduction to GPS

The GPS global tool for positioning includes a constellation of at least 24 satellites that orbit the earth at a height of 20,200 km in six fixed planes inclined 55° from the equator. The orbital period is 11 h 58 min, which means that a satellite will orbit the earth twice per day. On board there are two cesium clocks and two rubidium clocks.

In the Time and Frequency Laboratory of the IEN there are timing receivers and geodetic receivers. GPS Timing Receiver (TR) is the name usually given to the GPS receivers devoted to time transfer activities. Usually, a TR accepts as inputs the signals of an external clock (1PPS and 10 MHz) used as time and frequency references for the receiver itself.

The kind of measurements performed by a TR are “pseudoranges” from the local antenna and a set of GPS satellites, moreover the receiver collects, from the data contained in the received “navigation message”, the satellite ephemeris, the onboard clock synchronisation data, the time delay corrections for the ionosphere and the troposphere propagation, and other general information about the system itself. With this set of data, the receiver computes for each tracked satellite the time interval between the local reference clock and each satellite clock as well as the time interval between the local reference clock and the GPS time.

The geographic coordinates of the local antenna, have to be known with uncertainties well below 1 meter and inserted in the TR software. The oldest TRs are equipped with a single channel receiver and they can receive a single satellite at a time; the last devices are usually multichannel (8 to 12 channels) and can operate simultaneously on different satellites. The GPS carrier received by a TR is usually L1, and the range measurements, based on the propagation delay of the satellite reference signals, are performed using the C/A GPS code.

For time scale comparisons among different laboratories, the time and frequency community agreed on an international measurement procedure called “Common View” (CV). This scheduled activity, implemented automatically in the TRs, is controlled and updated periodically by BIPM; it indicates for every day the measurement time and the best satellite configuration to be used in a specific geographic area. The different measurement sessions distributed during the whole day, for every typical 13 minutes length track (780 s) according to the CV schedule, supply a mean value of the difference between the local time scale UTC(k) and the GPS one as realised by each received satellite. An example of an output file of CV measurement data, also regulated following an international format called CGGTTS, is reported in table 3 and 4. In the table, after an header reporting general information about the receiver and the laboratory, different data columns report the measurement data where, for instance, the “MJD” column indicates the Modified Julian Date of the measurement, the “hhmmss” identifies the starting measuring time and the “REFGPS” gives the time differences UTC(k) – GPS.

If two laboratories maintaining two time scales, UTC(k1) and UTC(k2) respectively, perform at a generic time $t_i$ a time interval measurement following the CV procedure, we have:

$$\text{UTC(k1)}_i - \text{GPS}_i \quad \text{UTC(k2)}_i - \text{GPS}_i$$

In this case, the reference GPS time scale is identified simply as GPS, for the two laboratories, assuming the CV technique ensures the satellite time scale is the same for the two measurements.

If the CV measurement are exchanged between the laboratories involved in the comparison, it is possible to compute the time difference $\Delta_{12}$ between the two time scales simply computing the difference between the two measurements:

$$\Delta_{12} = \text{UTC(k1)} - \text{UTC(k2)} = [\text{UTC(k1)}_i - \text{GPS}_i] - [\text{UTC(k2)}_i - \text{GPS}_i]$$

To be sure the contribution of the satellite time scale GPS cancels out, the measurements have to be performed on the same satellite and at the same time. An additional improvement in the accuracy of
the time comparisons, can be obtained applying an “a posteriori” computation using precise ephemeris and ionospheric delays supplied by geodetic centres.

The measurement performed using GPS timing receivers, are currently used to synchronise the time scales of the laboratory participating to UTC time scale computed by BIPM. Periodically, BIPM itself, organise “calibration trips” by means of a travelling TR, to calibrate the delays of the laboratory receivers used for the different links.

The best accuracy of this time transfer technique, when the receivers are well calibrated, is around 3-5 ns (1σ).

Geodetic GPS receivers (GR) are commonly used by the centres involved in activities related to geodesy. These devices have usually multichannel capabilities, can receive both the L1 and the L2 carriers and can perform code and carrier phase measurement. The possibility of receiving the same information on carriers with different frequency, allows also a real time evaluation of the ionospheric delay for the different receiver-satellite links.

These receivers doesn’t use a particular tracking schedule, they perform measurement on all the visible satellites with a specified rate, for instance 1s or 30 s, and usually are not “stand alone” devices but belong to national or international networks. They perform only range measurements (observation data) and collect data concerning the GPS system receiving the satellite “navigation message” (navigation data). This data, collected by specialised analysis centres and related to a specific network, allows to obtain a “global solution” for different “observable”, for example the coordinates of the receiving antennas, the ephemeris of the GPS satellites, the time synchronisation among different clocks, investigations on ionospheric or tropospheric delays and so on.

For this kind of receivers, the typical “geodetic applications” as the computation of receiver coordinates, ephemeris of satellites and ionospheric and tropospheric parameters, are the most popular mainly in the geodetic community. They are not widely used for timing applications as time scale synchronisation but in recent years, the measurement of carrier phase has raised some interest for the potential high resolution capabilities in time measurement. Nevertheless, at the moment, some problems related to the solution of the carrier cycle ambiguities are yet open.

For timing applications, GRs must have the possibility to accept from an external clock time and frequency reference signals, as 1PPS and 10MHz, and special “timing options”, for the most common receivers, are available on the market on request.

The data output supplied by GRs, are usually converted in a special international format named RINEX; these files, eventually compressed and transferred via FTP among the receivers and the data analysis centres, contains the pseudoranges (Observation Data) and the navigation messages (Navigation Data). An example of this kind of measurement data, following the RINEX format, is reported in table 1 and table 2.

Using these modified geodetic GPS receivers, piloted by time and frequency references of the local time scales it’s possible, by means of a specific software and starting from the output Rinex files containing the pseudoranges and the navigation data, to obtain data files following the CGGTTS format. This data are then processed using a CV measurement software, as if they are data supplied by a GPS timing receivers, obtaining time synchronisation results with uncertainties at the same level of what obtained by TRs.
Table 1 – Esempio di file RINEX (Navigation Data)

<table>
<thead>
<tr>
<th>GBSS</th>
<th>IEN</th>
<th>10/28/2002 00:40</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAVIGATION DATA</td>
<td>RINEX VERSION / TYPE</td>
<td>PGM / RUN BY / DATE</td>
<td></td>
</tr>
<tr>
<td>GBSS</td>
<td>IEN</td>
<td>10/28/2002 00:40</td>
<td>PGD / RUN BY / DATE</td>
</tr>
<tr>
<td>Option clock adjustments in code and carrier</td>
<td>ION ALPHA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>.3166D-07</td>
<td>.0000D+00</td>
<td>-.1192D-06</td>
<td>.1192D-06</td>
</tr>
<tr>
<td>.1393D+06</td>
<td>-.3277D+05</td>
<td>-.6554D+05</td>
<td>-.3932D+06</td>
</tr>
<tr>
<td>ION BETA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.888178419700D-15</td>
<td>-.931322574615D-09</td>
<td>233472</td>
<td>1190 DELTA-UTC: A0,A1,T,W</td>
</tr>
<tr>
<td>END OF HEADER</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 – Esempio di file RINEX (Observation Data)

<table>
<thead>
<tr>
<th>GBSS</th>
<th>IEN</th>
<th>10/29/2002 00:15</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBSERVATION DATA</td>
<td>RINEX VERSION / TYPE</td>
<td>PGM / RUN BY / DATE</td>
<td></td>
</tr>
<tr>
<td>GBSS</td>
<td>IEN</td>
<td>10/29/2002 00:15</td>
<td>PGD / RUN BY / DATE</td>
</tr>
<tr>
<td>Option clock adjustments in code and carrier</td>
<td>ION ALPHA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IENG</td>
<td>MARKER NAME</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MARKER NUMBER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valerio Pettiti</td>
<td>IEN</td>
<td>OBSERVER / AGENCY</td>
<td></td>
</tr>
<tr>
<td>RT920010203</td>
<td>Ashtech Z-XII3</td>
<td>REC # / TYPE / VERS</td>
<td></td>
</tr>
<tr>
<td>CR5200 10512</td>
<td>Ashtech choke ring</td>
<td>ANT # / TYPE</td>
<td></td>
</tr>
<tr>
<td>APPROX POSITION XYZ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>447637.4104</td>
<td>600431.3929</td>
<td>4488761.1633</td>
<td></td>
</tr>
<tr>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>ANTENNA: DELTA H/E/N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAVELENGTH FACT L1/2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># / TYPES OF OBSERV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERVAL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIME OF FIRST OBS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIME OF LAST OBS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>END OF HEADER</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Algorithm

3.1 Algorithm general description

3.1.1 The GPS “Common View” method

In order to compare the behaviour of UTC(IEN) time scale versus the time scale of other Time and Frequency laboratories, IEN uses regularly the so-called “common view” (CV) method [3]. It is based on GPS C/A code observations obtained from GPS time receivers installed in the involved laboratories. The GPS CV data are also used regularly by BIPM to compare remote clocks and to compute TAI.

These kind of GPS time receiver uses as an input a 1PPS signal, generated by the local realisation of UTC($k$), where “$k$” identifies the laboratory. Internally the receiver, using a software and following a given procedure recommended by the Consultative Committee for Time and Frequency (CCTF) [1], computes the time difference between UTC($k$) and GPS time as realised by each received satellite: each difference is performed processing a set of 780 successive short-term observations, at intervals of 1 second, taken by the receiver itself during a 13 minutes length track (780 s). Since the receiver needs about 2 minutes for locking satellite signal and an additional 1 minute is helpful for data processing, two consecutive tracks are distant at least by 16 minutes.

The starting times of the different 16 minutes daily sessions are chosen according to an international tracking schedule which is arranged by BIPM to assure the best satellite geometry for the laboratories belonging to a specified geographic area. The BIPM schedule lists a series of 48 tracks per day (not equally spaced), which is strictly followed by single-channel GPS time receivers; in case of a multi-channel receiver, such a list is just a subset of the up to 90 tracks per day and per channel which can be nominally performed at every 16 minutes. The tracking schedule is usually updated two times a year by BIPM.

The CTTF procedure to compute the time differences, is based on the broadcast clock parameters and satellite orbits, received from the satellite itself as a navigation message together with the time synchronisation signals. The ionospheric propagation delay is computed according to the satellite broadcast ionosphere model (Klobuchar).

The measured data and other useful information are then collected following a pre-defined format called CGGTTS (Common GPS GLONASS Time Transfer Standard) [2] which is explained in the following section. When the GLONASS receivers became available on the market, an update of this format was proposed in order to include in the standardisation also this kind of data.

3.1.2 The CGGTTS format

Each CGGTTS-formatted data file contains one week of GPS CV measures collected by a Time and Frequency laboratory, starting with the first available track on Tuesdays and ending with the last track on next Mondays. An excerpt of a weekly GPS CV data file, collected by a single-channel GPS receiver installed at IEN for the period starting with MJD 52513 (August 27, 2002), is reported in table 3. With the aim of TAI computation as well as remote clocks comparison, the file concerning the past week data is generally exchanged by the laboratory and BIPM on Tuesdays.

As explained in [1], the file header (the first 16 lines followed by a blank line) reports some general information about the data format, the kind of receiver, the name of the laboratory, the coordinates of the receiving antenna and some other data about the time delays of the receiver and of the reference signals. The lines 18 and 19 identify the names of the data columns (line header) and the relative units (unit header). Starting from the line 20, the measuring data are reported in the same order they are collected: each data line corresponds to one GPS track.
In particular, the first column data (PRN) represents the identification code of the received satellite, the third column (MJD) reports the Modified Julian Date, the fourth (STTIME) the starting measuring time in the format "hhmmss" and the fifth (TRKL) the track length in seconds. The sixth and the seventh columns report the elevation and azimuth angles of the received satellite, expressed in tenth of degrees. The effective measurement data, used to perform the time comparisons, are reported in column 10 (REFGPS): it represents the time difference between the local 1PPS time reference and the received GPS one, expressed in tenth of nanoseconds.

### Table 3 – Example of CGGTTS-formatted file for single-channel GPS receiver.

<table>
<thead>
<tr>
<th>PRN CL</th>
<th>MJD</th>
<th>STTIME</th>
<th>ELV</th>
<th>AZTH</th>
<th>REFSV</th>
<th>SRSV</th>
<th>REFGPS</th>
<th>SRGPS</th>
<th>DSG</th>
<th>IOE</th>
<th>MDTR</th>
<th>SMDT</th>
<th>MDIO</th>
<th>SMDI</th>
<th>CK</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>03400</td>
<td>780 035 2796</td>
<td>-577814</td>
<td>-31</td>
<td>-45</td>
<td>+2</td>
<td>68 058</td>
<td>139</td>
<td>-23</td>
<td>80</td>
<td>-10</td>
<td>B6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 D4</td>
<td>05000</td>
<td>780 420 2823</td>
<td>-577854</td>
<td>-67</td>
<td>-53</td>
<td>-37</td>
<td>49 058</td>
<td>120</td>
<td>16</td>
<td>71</td>
<td>-9</td>
<td>B5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 D5</td>
<td>01200</td>
<td>780 450 1194</td>
<td>+471897</td>
<td>-47</td>
<td>-68</td>
<td>-18</td>
<td>44 159</td>
<td>114</td>
<td>-10</td>
<td>68</td>
<td>-5</td>
<td>DE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 74</td>
<td>01380</td>
<td>780 542 2352</td>
<td>+2538528</td>
<td>+74</td>
<td>-155</td>
<td>+13</td>
<td>46 099</td>
<td>99</td>
<td>5</td>
<td>60</td>
<td>+3</td>
<td>BA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 BC</td>
<td>02100</td>
<td>780 524 1453</td>
<td>+31375</td>
<td>-24</td>
<td>-133</td>
<td>-27</td>
<td>35 226</td>
<td>102</td>
<td>-9</td>
<td>61</td>
<td>-5</td>
<td>B1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 A0</td>
<td>02260</td>
<td>780 338  667</td>
<td>-41756</td>
<td>-45</td>
<td>-85</td>
<td>-0</td>
<td>90 218</td>
<td>144</td>
<td>27</td>
<td>82</td>
<td>+11</td>
<td>AA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 BC</td>
<td>02420</td>
<td>780 189 1920</td>
<td>+31408</td>
<td>-33</td>
<td>-125</td>
<td>-36</td>
<td>66 227</td>
<td>134</td>
<td>21</td>
<td>129</td>
<td>+28</td>
<td>DR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 74</td>
<td>04500</td>
<td>780 569 2809</td>
<td>-191370</td>
<td>+9</td>
<td>-74</td>
<td>+14</td>
<td>44 085</td>
<td>96</td>
<td>-8</td>
<td>89</td>
<td>+1</td>
<td>A4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 4 – Example of CGGTTS-formatted file for multi-channel GPS receiver.

<table>
<thead>
<tr>
<th>PRN CL</th>
<th>MJD</th>
<th>STTIME</th>
<th>ELV</th>
<th>AZTH</th>
<th>REFSV</th>
<th>SRSV</th>
<th>REFGPS</th>
<th>SRGPS</th>
<th>DSG</th>
<th>IOE</th>
<th>MDTR</th>
<th>SMDT</th>
<th>MDIO</th>
<th>SMDI</th>
<th>CK</th>
</tr>
</thead>
<tbody>
<tr>
<td>26 FF</td>
<td>03400</td>
<td>780 135 8128</td>
<td>+714070</td>
<td>-21</td>
<td>-626</td>
<td>+8</td>
<td>101 159</td>
<td>148</td>
<td>-25</td>
<td>85</td>
<td>-10</td>
<td>E7</td>
<td>18</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>25 FF</td>
<td>03400</td>
<td>780 96 2071</td>
<td>+317392</td>
<td>+105</td>
<td>583</td>
<td>+111</td>
<td>150 111</td>
<td>459</td>
<td>+271</td>
<td>136</td>
<td>+18</td>
<td>22</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>124 FF</td>
<td>03400</td>
<td>780 382 817</td>
<td>-745407</td>
<td>+104</td>
<td>-16400</td>
<td>+95</td>
<td>103 15</td>
<td>127</td>
<td>+16</td>
<td>73</td>
<td>+7</td>
<td>05</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 FF</td>
<td>03400</td>
<td>780 698 2684</td>
<td>-492175</td>
<td>-32</td>
<td>-761</td>
<td>+42</td>
<td>51 53</td>
<td>84</td>
<td>-1</td>
<td>52</td>
<td>+0</td>
<td>B5</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 FF</td>
<td>03400</td>
<td>780 526 2960</td>
<td>+2537633</td>
<td>+72</td>
<td>-819</td>
<td>+12</td>
<td>58 99</td>
<td>99</td>
<td>-7</td>
<td>60</td>
<td>-4</td>
<td>B7</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23 FF</td>
<td>03400</td>
<td>780 254 531</td>
<td>+84831</td>
<td>+66</td>
<td>-788</td>
<td>+73</td>
<td>94 198</td>
<td>182</td>
<td>+14</td>
<td>96</td>
<td>+4</td>
<td>C8</td>
<td>23</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>
As a second example and for the same period as before, the table 4 reports a specimen of a weekly GPS/GLONASS CV data file, collected by a multichannel GPS/GLONASS receiver installed at the XXX laboratory. In this case there are more data lines per day than before, besides more data columns, depending on the firmware of the receiver, but the first 18 columns are the same as in the previous case.

The main differences consist in the PRN column, where the numbers below 100 identify the GPS satellite and the numbers over 100 the GLONASS ones, and in the presence of different satellites, GPS or GLONASS, tracked at the same time, due to the multi-channel capabilities of the receiver.

In the last but one column of each data line, to take into account for the different channels used, the channel identification in hexadecimal code is also reported.

3.1.3 GPS CV data processing

Once the GPS or the GPS/GLONASS data files are available from two Time and Frequency laboratories maintaining a time scale, the CV comparison between their time scales consists in selecting from the two files initially the measuring data identified by the same satellite code (PRN), date (MJD) and starting time (STTIME).

The use of measuring data collected for the same satellite at the same time, assures the best uncertainty budget in the comparison, because all the “common” uncertainties are cancelled and the “quasi common” are partially cancelled by the technique itself.

Considering as an example the data reported in table 3 (data collected by the IEN receiver) and table 4 (data of the XXX laboratory receiver), it is possible for instance to find a common observation for the two receivers (MJD = 52513 at 00:34:00 UTC). The two selected common data lines are reported below:

| 3 FF 52513 003400 780 356 2854 | -578468 | -129 | -702 | -96 | 84 | 58 | 135 | -20 | 79 | -9 E8 3 A |
| 3 FF 52513 003400 780 353 2796 | -577814 | -31 | -45 | +2 | 68 | 058 | 139 | -23 | 80 | -10 B6 |

Extracting from these lines the data to be used for the comparison, such as the satellite identification, the date and time of observation, and the difference between the local time scale and the GPS signal, we have the following:

Satellite (PRN): 3  MJD = 52513 00:34:00 UTC  ΔIEN = UTC(IEN) – GPS + k1 = -4.5 ns
Satellite (PRN): 3  MJD = 52513 00:34:00 UTC  ΔXXX = UTC(XXX) – GPS + k2 = -70.2 ns

where the k1 and k2 constants reported above take into account for the cables and for the internal receivers delays (reported in the CGGTTS-formatted file header).

Considering all the pairs of common observations available, and computing the difference of the two observations for the generic date and time i, we obtain:

\[ \Delta_1 = \Delta_{IENi} - \Delta_{XXXi} = [UTC(IEN)_i - GPS + k1] - [UTC(XXX)_i - GPS + k2] \]
\[ = UTC(IEN)_i - UTC(XXX)_i + k12 \]

The contribution of the GPS time scale, thanks to the CV technique, cancels out and the differential delay of the cables and of the receivers (named k12), can be assumed constant and can be experimentally determined.
Converting the measurement date and time in a fractional MJD, by adding to the integer MJD a fractional part obtained as a decimal conversion of the measuring time itself expressed as hours, minutes and seconds (hhmmss):

\[ \text{MJD} + \left( \frac{\text{hh}}{24} + \frac{\text{mm}}{1440} + \frac{\text{ss}}{86400} \right) \]

for every common view comparison, we can obtain a two columns result data set as reported in the following table:

<table>
<thead>
<tr>
<th>$\text{MJD}_i$</th>
<th>$\Delta_i$ (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>52513,0236</td>
<td>65,7</td>
</tr>
<tr>
<td>52513,0347</td>
<td>62,1</td>
</tr>
<tr>
<td>52513,0458</td>
<td>72,3</td>
</tr>
<tr>
<td>52513,0569</td>
<td>58,7</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

The number of CV comparisons per day, in the case of a single-channel GPS receiver which follows a strict CV schedule, is nominally 48. This number is higher in the case of a multi-channel receiver or if the receiver applies the extended CV schedule, sometimes called “all in view”. This last possibility, usually available in the multi-channel receivers, consists in tracking every 16 minutes a different satellite, even if the strict CV schedule doesn’t provide any measurement for that time slot. In this case it is possible to collect nominally 90 tracks per day and per channel. In the case of laboratories equipped with different receivers or different software, the maximum number of CV comparisons per day is determined by the receiver collecting less measurement data. It is worth to notice that the compatibility between multi-channels and single-channel observations is assured by referring track times for both to a common date (the MJD 50722, as stated by BIPM). In the future, when all single-channel receivers are withdrawn from operation, the use of a fixed reference date for "all-in-view" observations by multi-channel receivers will allow to cease publication of the CV tracking schedule.
3.2 Description of UTC(IEN)-GPS processing algorithm

3.2.1 High level description

In the following figure 1, the algorithm for the UTC(IEN)-GPS processing is depicted as a flow chart. Each block of the flow chart is intended to represent an high level, functional item of the algorithm.

Based on a CGGTTS-formatted weekly file as carried out directly by the 3S Navigation GPS receiver, the algorithm will provide the best estimate of the difference UTC(IEN)–GPS time, as one datum per day at 00h UTC. The reported results (hereafter called “processed data”) will be then arranged in a weekly file to be compliant with the CGGTTS standard format, as specified in chapter.

![Flow Chart](image)

**Figure 1:** High level flow chart of the algorithm.

The detailed description of each item of the algorithm is reported in the following section.

3.2.2 Algorithm items description

According to the scheme in the above figure 1, each functional item of the algorithm is hereafter described in detail.

Concerning this aim, let \( \text{REFGPS}_{SVi,tj} \) the time difference (expressed in tenth of ns) between the local reference UTC(IEN) and the GPS time as received from satellite \( SVi \) (i from 1 to \( Nj \)) at epoch
\( t_j \) (\( j \) from 1 to \( M \), where \( M \) is the number of epochs in the CGGTTS-formatted input data file). In general, for each epoch \( t_j \) there will be \( N_j \) measurements related to as many satellites in view, as depicted in figure 2 (a).

In addition, let \([\text{UTC(IEN)} - \text{GPS}]_{d,00} \) UTC the estimate of the time difference \( \text{UTC(IEN)}-\text{GPS} \) time at 00h UTC of day \( d \), expressed in tenth of ns.

![Figure 2: (a) Set of time difference measurements REFGPS\(_{SVi,tj}\) related to as many satellites \( SV_i \) in view at epoch \( t_j \); (b) Plot of raw data measurements for 1 week interval (average: -60.6 ns; std.dev.: 72.2 ns).](image)

### 3.2.3 Raw data outliers filtering

Once the raw measurements data (concerning the receiver hosted by IEN Time and Frequency laboratory) are loaded from a CGGTTS-formatted input file (figure 2 (b)), a filtering procedure is performed with the aim of remove any outliers caused mainly by a not well working satellite. Such a filtering is performed for each epoch \( t_j \) on the set of all the measurements concerning the satellites in view at that epoch (let \( \{\text{REFGPS}_{SVi}\}_{i=1\ldots N_j,t_j} \)).

The filtering procedure can be based either on a dynamic 3\( \sigma \) filter or on a MAD (Median of the Absolute Deviation, [4]) based filter (see 3.6). It is worth to notice that for small datasets (as in the case of the measurements concerning each epoch) the MAD-based filter seems to be a better choice than 3\( \sigma \) filter, in order to detect and remove outliers. In fact, 3\( \sigma \) filter usually fails in practice because the presence of great outliers tends to inflate the variance estimate \( \sigma \), causing too few outliers to be detected.

After the outliers filtering (figure3), for each epoch \( t_j \) there will be \( N'_j \leq N_j \) measurements related to as many surviving measurements (since \( N_j - N'_j \) are the filtered out data).
Figure 3: Plot of time difference measurements after a $3\sigma$ filtering performed on the dat The GPS “Common View” method

3.2.4 Epoch-based average calculation
At this step, the average of all the previously filtered $\text{REFGPS}_{SV_i, t_j}$ values is then computed and only one datum per each epoch $t_j$, let $\text{REFGPS}_{t_j}$, results:

$$\text{REFGPS}_{t_j} = \frac{\sum_{i=0}^{N_j} \text{REFGPS}_{SV_i, t_j}}{N_j}$$

3.2.5 Data outliers filtering
With the aim of removing any anomalous behaviour caused mainly by the local measurement system (that is the receiver), a further filtering procedure is then applied on a daily basis. As cited in section 3.2.1, the filtering procedure can be based either on a dynamic $3\sigma$ filter or on a MAD-based filter (see Appendix 1). Nevertheless, it is worth to notice that for large datasets (as in the case of daily measurements, where up to 90 measurements could be collected), the dynamic $3\sigma$ filter and the MAD-based filter seem to provide the same performance.

3.2.6 Daily linear regression calculation
Finally, the linear regression of all the surviving $\text{REFGPS}_{t_j}$ values is then computed for each 24 hours interval centered at 00h UTC of day $d$. This smoothing procedure has the capabilities to filter out the short-term instabilities caused mainly by the GPS system. Only one datum per each day $d$ is then carried out by the algorithm. This value, let $[\text{UTC(IEN)} - \text{GPS}]_{d, 00\text{ UTC}}$, represents the estimate of the time difference UTC(IEN)–GPS time at 00h UTC of day $d$, expressed in tenth of ns:

$$y_0 = [\text{UTC(IEN)} - \text{GPS}]_{d, 00\text{ UTC}} = \frac{\sum y_i \cdot \sum x_i^2 - \sum x_i y_i \cdot \sum x_i}{n \cdot \sum x_i^2 - (\sum x_i)^2}$$

As later specified in chapter, each daily estimate coming from this processing will be then reported in the “REFGPS” field of a weekly file to be compliant with the CGGTTS standard format.
Figure 4: Plot of the daily estimates of the time difference UTC(IEN)-GPS time, as coming from the processing detailed in this section.
3.3 Description of GPS CV combining algorithm

3.3.1 High level description

In the following figure 5, the algorithm for the UTC(IEN)-UTC(\(k\)) computation is depicted as a flow chart. Each block of the flow chart is intended to represent an high level, functional item of the algorithm.

Based on the CGGTTS-formatted weekly files as carried out by both the 3S Navigation GPS receiver at IEN and a GPS receiver at UTC(\(k\)) remote laboratory, the algorithm will provide the best estimate of the “strictly CV” difference UTC(IEN)–UTC(\(k\)), as one datum per day at 00h UTC. The reported results (hereafter called “combined data”) will be then arranged in a weekly file to be compliant with the CGGTTS standard format, as specified in chapter 3.5.

![Flow Chart](image)

Figure 5: High level flow chart of the algorithm.

The detailed description of each item of the algorithm is reported in the following section.
3.3.2 Algorithm items description

According to the scheme in the above figure 5, each functional item of the algorithm is hereafter described in detail.

Concerning this aim, let \( \text{REFGPS}(\text{loc})_{SVi,tj} \) the time difference (expressed in tenth of ns) between the local reference UTC(IEN) and the GPS time as received from satellite \( SVi \) (i from 1 to \( Nj \)) at epoch \( tj \) (j from 1 to M, where M is the number of epochs in the CGGTTS-formatted input data file). Furthermore, let \( \text{REFGPS}(k)_{SVm,tn} \) the time difference (expressed in tenth of ns) between the reference UTC\((k)\) of the remote laboratory and the GPS time as received from satellite \( SVm \) (m from 1 to \( Nn \)) at epoch \( tn \) (n from 1 to M). In general, for each epoch \( tj \) (resp. \( tn \)) there will be \( Nj \) (resp. \( Nn \)) measurements related to as many satellites in view.

In addition, let \( \text{UTC}(\text{IEN}) - \text{UTC}(k) \)\(_{d,00 UTC} \) the estimate of the time difference UTC(IEN)–UTC\((k)\) at 00h UTC of day \( d \), expressed in tenth of ns.

3.3.3 CV differences calculation

As detailed in section 0, the use of GPS measurements collected for the same satellite at the same time (the so called “strictly CV”), assures the best uncertainty budget in the comparison, because all the “common” uncertainties are cancelled and the “quasi common” are partially cancelled by the technique itself.

Consequently, once the GPS data CGGTTS-formatted files are available from the local (that is, UTC(IEN)) and the remote UTC\((k)\) laboratories, the first step of the “combining algorithm” consists in selecting from the two files the measurements data identified by the same satellite code (PRN), date (MJD) and starting time (STTIME).

Let \( \text{REFGPS}(\text{loc})_{SVi,tj} \) and \( \text{REFGPS}(k)_{SVm,tn} \) a common observation for the two laboratories, being \( SVi = SVn \) (same satellite, say \( SV \)) and \( tj = tn \) (same epoch, say \( t \)). A strict CV difference results as reported in the following:

\[
\Delta \text{REFGPS}_{SV,t} = \text{REFGPS}(\text{loc})_{SV,t} - \text{REFGPS}(k)_{SV,t} = [\text{UTC}(\text{IEN}) - \text{GPS}]_{SV,t} - [\text{UTC}(k) - \text{GPS}]_{SV,t} = [\text{UTC}(\text{IEN}) - \text{UTC}(k)]_{SV,t}
\]

where the contribution of the GPS time scale has been canceled out.

3.3.4 Combined data outliers filtering

With the aim of remove any outliers caused mainly by an anomalous asymmetrical common view of the same satellite by the two laboratories, a filtering procedure is performed for each epoch \( t \) on the set of all the computed differences concerning the satellites in common view at that epoch (let \( \{\Delta \text{REFGPS}_{SVi,t}\}_{i=1\ldots N,t} \)).

As also reported in section 0, the filtering procedure can be based either on a dynamic 3\( \sigma \) filter or on a MAD-based filter (see 3.6). Applying the MAD-based filter seems to be a good choice to detect and eliminate outliers from small datasets (as in the case of the measurements concerning each epoch).

After the outliers filtering, for each epoch \( t \) there will be \( N' \leq N \) values related to as many surviving measurements (since \( N - N' \) are the filtered out data).

3.3.5 Epoch-based average calculation

After the outliers filtering procedure, for each epoch there could be more than one CV differences \( \Delta \text{REFGPS}_{SVi,t} \). In order to have only one datum per each epoch, the average of all the previously filtered \( \Delta \text{REFGPS}_{SVi,t} \) values is then computed as reported below:

\[
\Delta \text{REFGPS}_t = \frac{\sum_{i=1\ldots N'} \Delta \text{REFGPS}_{SVi,t}}{N'}
\]
3.3.6 Combined data outliers filtering
With the aim of removing any anomalous behaviour caused mainly by the asymmetry of the two
different measurement systems (such as the receivers and reference time scales) and/or the different
local weather conditions, a further filtering procedure is then applied on a daily basis.
As reported in section 3.2.1, the filtering procedure can be based either on a dynamic $3\sigma$ filter or on
a MAD-based filter (see 3.6). For large datasets (as in the case of up to 90 nominal daily
measurements), the dynamic $3\sigma$ filter and the MAD-based filter seem to provide the same
performance.

3.3.7 Daily linear regression calculation
Finally, linear regression of all the surviving $\Delta\text{REFGPS}_L$ values is then computed for each 24 hours
interval centered at 00h UTC of day $d$.
Only one datum per each day $d$ is then carried out by the algorithm. This value, let $[\text{UTC(IEN)}-\text{UTC(k)}]_{d,00 \text{ UTC}}$, represents the estimate of the “strictly CV” difference UTC(IEN)–UTC(k) at
00h UTC of day $d$, expressed in tenth of ns:

$$y_a = [\text{UTC(IEN)}-\text{GPS}]_{d,00 \text{UTC}} = \frac{\sum x_i \cdot \sum y_i^2 - \sum x_i y_i \cdot \sum x_i}{n \cdot \sum x_i^2 - \left[\sum x_i\right]^2}$$

As later specified in chapter 3.5, each daily estimate coming from this processing will be then
reported in the “REFGPS” field of a weekly file to be compliant with the CGGTTS standard format.
3.4 Specification of UTC(IEN)-GPS processed data files

3.4.1 File naming convention

Based on the present naming rules for the GPS CV data files delivered by IEN to BIPM, following naming convention will be used for UTC(IEN)-GPS processed data carried out by the E-PTS:

\[
\text{GPP} dddd dddddd.IEN \quad \text{where the GPP suffix points out that the file contains processed data.}
\]

File name example:

\[
\text{GPP52578.IEN} \quad \text{reporting UTC(IEN)-GPS time values, one datum per day at 00h UTC, starting from the MJD 52578.}
\]

3.4.2 File format and content

The UTC(IEN)-GPS processed data will be arranged in a weekly file compliant with the CGGTTS standard format vers. [1].

In each file, the estimated difference UTC(IEN)-GPS time coming out from the algorithm (chapter 0) will be reported in the “REFGPS” parameter of each data line (columns 54-64) with 0.1 ns resolution. In addition, as recommended in the CGGTTS standard, any missing or useless data will be replaced by series of 9.

An example of this data file, concerning the period starting with MJD 52807 (June 17, 2003), is reported in table 5.

3.4.3 File header description

The first 16 lines of each file compliant with the CGGTTS standard format vers. 01 form the header of the file, which contains detailed information on the GPS equipment used by UTC(IEN) laboratory.

Each line, limited to 128 columns and terminated by a carriage-return/line-feed pairs (CR+LF), is associated to a specific parameter as reported in the following table.

<table>
<thead>
<tr>
<th>Line</th>
<th>Parameter</th>
<th>Suggested value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GGTTS GPS DATA FORMAT VERSION =</td>
<td>01</td>
</tr>
<tr>
<td>2</td>
<td>REV DATE =</td>
<td>As in the source CGGTTS file.</td>
</tr>
<tr>
<td>3</td>
<td>RCVR =</td>
<td>As in the source CGGTTS file.</td>
</tr>
<tr>
<td>4</td>
<td>CH =</td>
<td>As in the source CGGTTS file.</td>
</tr>
<tr>
<td>5</td>
<td>IMS =</td>
<td>As in the source CGGTTS file.</td>
</tr>
<tr>
<td>6</td>
<td>LAB =</td>
<td>IEN</td>
</tr>
<tr>
<td>7</td>
<td>X =</td>
<td>As in the source CGGTTS file. ¹</td>
</tr>
<tr>
<td>8</td>
<td>Y =</td>
<td>As in the source CGGTTS file.</td>
</tr>
<tr>
<td>9</td>
<td>Z =</td>
<td>As in the source CGGTTS file.</td>
</tr>
<tr>
<td>10</td>
<td>FRAME =</td>
<td>As in the source CGGTTS file.</td>
</tr>
<tr>
<td>11</td>
<td>COMMENTS =</td>
<td>REFGPS is estimated UTC(IEN)–GPS, as one datum per day at 00h UTC.</td>
</tr>
<tr>
<td>12</td>
<td>INT DLY =</td>
<td>As in the source CGGTTS file.</td>
</tr>
<tr>
<td>13</td>
<td>CAB DLY =</td>
<td>As in the source CGGTTS file.</td>
</tr>
<tr>
<td>14</td>
<td>REF DLY =</td>
<td>As in the source CGGTTS file.</td>
</tr>
<tr>
<td>15</td>
<td>REF =</td>
<td>UTC (IEN)</td>
</tr>
</tbody>
</table>
A blank line (the 17th of the file) must follow the file header.

3.4.4 Line header description
As reported in the Annex III, section 2.1 “No measured ionospheric delays available”, of the CGGTTS standard format vers. [1], the line header is the 18th row of the file. It is limited to 103 columns and terminated by a carriage-return/line-feed pairs (CR+LF).

3.4.5 Unit header description
As reported in the Annex III, section 3.1 “No measured ionospheric delays available”, of the CGGTTS standard format vers. 01 [1], the unit header is the 19th row of the file. It is limited to 103 columns and terminated by a carriage-return/line-feed pairs (CR+LF).

3.4.6 Data line description
As reported in the Annex III of the CGGTTS standard format vers. 01 [1], a series of data lines follows the unit header, starting from the 20th row of the file.
In this case, each data line is related to a daily estimate of UTC(IEN)-GPS time at 00h UTC, coming out from the processing algorithm detailed in chapter 0. The data lines are sorted in chronological order, that is the estimate reported in line \( n \) occurs after the estimate reported in line \((n-1)\).
Each data line is limited to 128 columns and terminated by a carriage-return/line-feed pairs (CR+LF). Following table reports the proposed value for each field of a data line:

<table>
<thead>
<tr>
<th>Columns</th>
<th>Field</th>
<th>Suggested value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-3</td>
<td>PRN</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>As reported in section, only one datum per each epoch results from an epoch-based averaging of the measurements for all the satellites in view: this field is then useless.</td>
</tr>
<tr>
<td>5-6</td>
<td>CL</td>
<td>FF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>As in the source CGGTTS file from IEN 3S Navigation receiver.</td>
</tr>
<tr>
<td>8-12</td>
<td>MJD</td>
<td>Integer Modified Julian Date of the day which the estimate is related.</td>
</tr>
<tr>
<td>14-19</td>
<td>STTIME</td>
<td>0000000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Since the UTC(IEN)-GPS time is estimated for each 24 hours interval centered at 00h UTC.</td>
</tr>
<tr>
<td>21-24</td>
<td>TRKL</td>
<td>9999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Since the UTC(IEN)-GPS time estimate is computed on a daily basis, the original meaning of this field (the track length) is useless.</td>
</tr>
<tr>
<td>26-28</td>
<td>ELV</td>
<td>999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>As for the PRN field.</td>
</tr>
<tr>
<td>30-33</td>
<td>AZTH</td>
<td>9999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>As for the ELV field.</td>
</tr>
<tr>
<td>35-45</td>
<td>REFSV</td>
<td>99999999999999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This field is useless and it is not carried out by the algorithm.</td>
</tr>
<tr>
<td>Column (1)</td>
<td>Column (2)</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>47-52</td>
<td>SRSV</td>
<td>999999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This field is useless and it is not carried out by the algorithm.</td>
</tr>
<tr>
<td>54-64</td>
<td>REFGPS</td>
<td>Estimate of the difference UTC(IEN)-GPS time at 00h UTC of the day reported in the MJD field, as carried out by the algorithm, expressed in tenth of ns.</td>
</tr>
<tr>
<td>66-71</td>
<td>SRGPS</td>
<td>999999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This field is useless and it is not carried out by the algorithm.</td>
</tr>
<tr>
<td>73-76</td>
<td>DSG</td>
<td>9999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This field is useless and it is not carried out by the algorithm.</td>
</tr>
<tr>
<td>78-80</td>
<td>IOE</td>
<td>999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This field is useless and it is not carried out by the algorithm.</td>
</tr>
<tr>
<td>82-85</td>
<td>MDTR</td>
<td>9999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This field is useless and it is not carried out by the algorithm.</td>
</tr>
<tr>
<td>87-90</td>
<td>SMDT</td>
<td>9999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This field is useless and it is not carried out by the algorithm.</td>
</tr>
<tr>
<td>92-95</td>
<td>MDIO</td>
<td>9999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This field is useless and it is not carried out by the algorithm.</td>
</tr>
<tr>
<td>97-100</td>
<td>SMDI</td>
<td>9999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>This field is useless and it is not carried out by the algorithm.</td>
</tr>
<tr>
<td>102-103</td>
<td>CK</td>
<td>As reported in the Annex III, section 4.1 “No measured ionospheric delays available”, of the CGGTTS standard format vers. 01 [1].</td>
</tr>
<tr>
<td>104-128</td>
<td></td>
<td>As reported in the Annex III, section 4.1 “No measured ionospheric delays available”, of the CGGTTS standard format vers. 01[1]. This is an optional comments for the data line.</td>
</tr>
</tbody>
</table>

Any missing column (like the 1st, the 4th and so on) is intended to be a space character (hexadecimal ASCII value 20).
GGTTS GPS DATA FORMAT VERSION = 01
REV DATE = 1995-11-01
RCVR = 3S NAVIGATION GNSS-300T #X #0043 1992 01D
CH = 100
IMS = 99999
LAB = IEN
X = +4476544.43m
Y = +600406.49m
Z = +4488743.59m
FRAME = WGS84
COMMENTS = REFGPS is estimated UTC(IEN)-GPS, as one datum per day at 00h UTC.
INT DLY = 3600.0ns
CAB DLY = -1889.0ns
REF DLY = 0.0ns
REF = UTC(IEN)
CKSUM =

<table>
<thead>
<tr>
<th>PRN</th>
<th>CL</th>
<th>MJD</th>
<th>STTIME</th>
<th>ELEV</th>
<th>AZTH</th>
<th>REFPSV</th>
<th>SRSV</th>
<th>REFGPS</th>
<th>SRGPS</th>
<th>DSG</th>
<th>IOE</th>
<th>MDTR</th>
<th>SMDT</th>
<th>MDIO</th>
<th>SMDI</th>
<th>CK</th>
</tr>
</thead>
<tbody>
<tr>
<td>99</td>
<td>FF</td>
<td>52807</td>
<td>000000</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>99999999999</td>
<td>999999</td>
<td>-592</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
</tr>
<tr>
<td>99</td>
<td>FF</td>
<td>52808</td>
<td>000000</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>99999999999</td>
<td>999999</td>
<td>-598</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
</tr>
<tr>
<td>99</td>
<td>FF</td>
<td>52809</td>
<td>000000</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>99999999999</td>
<td>999999</td>
<td>-549</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
</tr>
<tr>
<td>99</td>
<td>FF</td>
<td>52810</td>
<td>000000</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>99999999999</td>
<td>999999</td>
<td>-507</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
</tr>
<tr>
<td>99</td>
<td>FF</td>
<td>52811</td>
<td>000000</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>99999999999</td>
<td>999999</td>
<td>-501</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
</tr>
<tr>
<td>99</td>
<td>FF</td>
<td>52812</td>
<td>000000</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>99999999999</td>
<td>999999</td>
<td>-536</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
</tr>
</tbody>
</table>

Table 5: Example of CGGTTS-formatted file for UTC(IEN)-GPS processed data.
3.5 Specification of GPS CV combined data files

3.5.1 File naming convention
Based on the naming rules for the GPS CV data files [1], following naming convention will be used for GPS CV combined data (difference values) carried out by the E-PTS:

\[ \text{CV} \text{ddddd} \text{ccc} \]

- ddddd: 5-digits MJD of the delivery weekday
- ccc: 3-characters UTC(k) remote laboratory name:
  - PTB: PTB Braunschweig, Germany
  - NPL: NPL Teddington, UK
  - USN: US Naval Observatory \([TBC]\)

File name example:
\[ \text{CV52578.PTB} \]
reporting UTC(IEN)-UTC(PTB) values, one datum per day at 00h UTC,
starting from the MJD 52578.

3.5.2 File format and content
The GPS CV combined data will be arranged in a weekly file compliant with the CGGTTS standard format vers. [1].
In each file, the estimated difference UTC(IEN)-UTC(k) coming out from the algorithm (chapter 3.3) will be reported in the “REFGPS” parameter of each data line (columns 54-64) with 0.1 ns resolution. In addition, as recommended in the CGGTTS standard, any missing or useless data will be replaced by series of 9.
An example of this data file, concerning the period starting with MJD 52807 (June 17, 2003), is reported in table 6.

3.5.3 File header description
The first 16 lines of each file compliant with the CGGTTS standard format vers. 01 form the header of the file, which contains detailed information on the GPS equipments used by UTC(k) laboratories.
Each line, limited to 128 columns and terminated by a carriage-return/line-feed pairs (CR+LF), is associated to a specific parameter as reported in the following table.

<table>
<thead>
<tr>
<th>Line</th>
<th>Parameter</th>
<th>Suggested value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GGTTS GPS DATA FORMAT VERSION =</td>
<td>01</td>
</tr>
<tr>
<td>2</td>
<td>REV DATE =</td>
<td>Empty, since this parameter is useless.</td>
</tr>
<tr>
<td>3</td>
<td>RCVR =</td>
<td>(RCVR1) (Lab1) ; (RCVR2) (Lab2)</td>
</tr>
<tr>
<td></td>
<td>Example:</td>
<td>3S NAVIGATION GNSS-300T #X #0043</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1992 01D (IEN) ; PTB02 AOA TTR5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SN 156 (PTB)</td>
</tr>
<tr>
<td>4</td>
<td>CH =</td>
<td>(CH1) (Lab1) ; (CH2) (Lab2)</td>
</tr>
<tr>
<td></td>
<td>Example:</td>
<td>100 (IEN) ; 01 (PTB)</td>
</tr>
<tr>
<td>5</td>
<td>IMS =</td>
<td>Empty, since this parameter is useless.</td>
</tr>
<tr>
<td>6</td>
<td>LAB =</td>
<td>(Lab1) - (Lab2)</td>
</tr>
<tr>
<td></td>
<td>Example:</td>
<td>IEN - PTB</td>
</tr>
</tbody>
</table>
A blank line (the 17th of the file) must follow the file header.

### 3.5.4 Line header description
As reported in the Annex III, section 2.1 “No measured ionospheric delays available”, of the CGGTTS standard format vers. 01 [1], the line header is the 18th row of the file. It is limited to 103 columns and terminated by a carriage-return/line-feed pairs (CR+LF).

```
PRN CL  MJD  STTIME TRKL ELV AZTH   REFSV      SRSV     REFGPS    SRGPS  DSG IOE MDTR SMDT MDIO SMDI CKSUM
```

### 3.5.5 Unit header description
As reported in the Annex III, section 3.1 “No measured ionospheric delays available”, of the CGGTTS standard format vers. 01 [1], the unit header is the 19th row of the file. It is limited to 103 columns and terminated by a carriage-return/line-feed pairs (CR+LF).

```
hhmmss  s  .1dg .1dg    .1ns     .1ps/s     .1ns    .1ps/s .1ns  .1ps/s.1ns.1ps/s.1ns.1ps/s
```

### 3.5.6 Data line description
As reported in the Annex III of the CGGTTS standard format vers. [1], a series of data lines follows the unit header, starting from the 20th row of the file. In this case, each data line is related to a daily estimate of UTC(IEN)-UTC(k) at 00h UTC, coming out from the processing algorithm detailed in chapter 3.3. The data lines are sorted in chronological order, that is the estimate reported in line n occurs after the estimate reported in line (n-1). Each data line is limited to 128 columns and terminated by a carriage-return/line-feed pairs (CR+LF). Following table reports the proposed value for each field of a data line:
<table>
<thead>
<tr>
<th>Columns</th>
<th>Field</th>
<th>Suggested value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-3</td>
<td>PRN</td>
<td>99</td>
</tr>
<tr>
<td>5-6</td>
<td>CL</td>
<td>FF</td>
</tr>
<tr>
<td>8-12</td>
<td>MJD</td>
<td></td>
</tr>
<tr>
<td>14-19</td>
<td>STTIME</td>
<td>000000</td>
</tr>
<tr>
<td>21-24</td>
<td>TRKL</td>
<td>9999</td>
</tr>
<tr>
<td>26-28</td>
<td>ELV</td>
<td>999</td>
</tr>
<tr>
<td>30-33</td>
<td>AZTH</td>
<td>9999</td>
</tr>
<tr>
<td>35-45</td>
<td>REFSV</td>
<td>999999999999</td>
</tr>
<tr>
<td>47-52</td>
<td>SRSV</td>
<td>999999</td>
</tr>
<tr>
<td>54-64</td>
<td>REFGPS</td>
<td></td>
</tr>
<tr>
<td>66-71</td>
<td>SRGPS</td>
<td>999999</td>
</tr>
<tr>
<td>73-76</td>
<td>DSG</td>
<td>9999</td>
</tr>
<tr>
<td>78-80</td>
<td>IOE</td>
<td>999</td>
</tr>
<tr>
<td>82-85</td>
<td>MDTR</td>
<td>9999</td>
</tr>
<tr>
<td>87-90</td>
<td>SMDT</td>
<td>9999</td>
</tr>
<tr>
<td>92-95</td>
<td>MDIO</td>
<td>9999</td>
</tr>
<tr>
<td>97-100</td>
<td>SMDI</td>
<td>9999</td>
</tr>
<tr>
<td>102-103</td>
<td>CK</td>
<td></td>
</tr>
<tr>
<td>104-128</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Any missing column (like the 1st, the 4th and so on) is intended to be a space character (hexadecimal ASCII value 20).
GGTTS GPS DATA FORMAT VERSION = 01
REV DATE =
Rcvr = 3S NAVIGATION GNSS-300T #X #0043 1992 01D (IEN) ; PTB02 AOA TTR5 SN 156 (PTB)
CH = 100 (IEN) ; 01 (PTB)
INS = 99999
LAB = IEN - PTB
X =
Y =
Z =
FRAME =
COMMENTS = REFGPS is estimated UTC(IEN)-UTC(PTB), as one datum per day at 00h UTC.
INT DLY = 3600.0ns (IEN) ; 58.0 ns (PTB)
CAB DLY = -1889.0ns (IEN) ; 0238.0 ns (PTB)
REF DLY = 0.0ns (IEN) ; 0000.0 ns (PTB)
REF = UTC(IEN) ; UTC(PTB)
CKSUM =

<table>
<thead>
<tr>
<th>PRN</th>
<th>CL</th>
<th>MJD</th>
<th>STTIME</th>
<th>TRKL</th>
<th>ELV</th>
<th>AZTH</th>
<th>REFSV</th>
<th>SRSV</th>
<th>REFGPS</th>
<th>SRGPS</th>
<th>DSG</th>
<th>IOE</th>
<th>MDTR</th>
<th>SMDT</th>
<th>MDIO</th>
<th>SMDI</th>
<th>CK</th>
</tr>
</thead>
<tbody>
<tr>
<td>99</td>
<td>FF</td>
<td>52807</td>
<td>000000</td>
<td>9999</td>
<td>999</td>
<td>9999</td>
<td>999999999</td>
<td>999999</td>
<td>-202</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>FF</td>
<td>52808</td>
<td>000000</td>
<td>9999</td>
<td>999</td>
<td>9999</td>
<td>999999999</td>
<td>999999</td>
<td>-238</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>FF</td>
<td>52809</td>
<td>000000</td>
<td>9999</td>
<td>999</td>
<td>9999</td>
<td>999999999</td>
<td>999999</td>
<td>-246</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>FF</td>
<td>52810</td>
<td>000000</td>
<td>9999</td>
<td>999</td>
<td>9999</td>
<td>999999999</td>
<td>999999</td>
<td>-207</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>FF</td>
<td>52811</td>
<td>000000</td>
<td>9999</td>
<td>999</td>
<td>9999</td>
<td>999999999</td>
<td>999999</td>
<td>-211</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>FF</td>
<td>52812</td>
<td>000000</td>
<td>9999</td>
<td>999</td>
<td>9999</td>
<td>999999999</td>
<td>999999</td>
<td>-266</td>
<td>999999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Example of CGGTTS-formatted file for GPS CV combined data.
3.6 Dynamic filter
3.6.1 Dynamic 3σ filter

As depicted in figure 6, the filtering procedure based on a dynamic 3σ filter iteratively removes all the data outside a ±3σ range, where σ is the standard deviation of the data available at each iteration

$$\sigma = \sqrt{\frac{\sum (x_n - \bar{x})^2}{n-1}}$$

and where

$$\bar{x} = \frac{\sum x_n}{n}$$

is the average value computed on the n data x_n. The procedure will stop when no further data are removed.

![Figure 6: High level flow chart of 3σ filtering procedure](image-url)
3.6.2 MAD-based filter

The MAD-based filter separates the dataset into the desired normal operation episodes and the uninteresting shutdown episodes. It is obtained by applying the Hampel identifier, which replaces the outlier-sensitive mean and standard deviation estimates with the outlier-resistant median and median absolute deviation from the median (MAD), respectively.

Let $x^C$ the median of a data sequence $\{x_k\}_{k=1..N}$ as obtained by first rank-ordering it from smallest to largest, i.e.

$$x_{(1)} \leq x_{(2)} \leq \ldots \leq x_{(N)}$$

and then taking either the middle value (if $N$ is odd) or the average of the middle two values (if $N$ is even) [PEARSON02].

The MAD scale estimate is then defined as

$$S = 1.4826 \cdot \text{median} |x_k - x^C|$$

where the multiplier 1.4826 assures that we obtain a consistent estimate of $\sigma$ for normally distributed data [5].

Then, a rejection threshold $t$ (with $t$ as an integer positive value) is chosen and if

$$|x_k - x^C| > t \cdot S$$

$x_k$ is declared an outlier and it’s removed from the dataset.

The filtering procedure of the MAD-based filter is shown in figure 7.
START

Measurements data loading \( \{X_k\}_{k=1,...,N} \)

Rank-ordering of the data \( \{X_k\} \)

Determination of the median \( X^C \)

Determination of MAD estimate:
\[
S = 1.4826 \times \text{median} \left( \left| X_k - X^C \right| \right)
\]

\[
\forall X_k \mid X_k - X^C > t \times S \\
\]

Yes

\( x_k \) is an outlier

\( x_k \) is removed from the dataset

STOP

No

\( x_k \) is not an outlier

STOP

Figure 7: High level flow chart of MAD-based filtering procedure
4 Robust outliers detection algorithm

The computation of the time offset between the local UTC(k) and both GPS time and other remote

time scales is one of the major duty of each metrological institute.

At the Time and Frequency Laboratory of IEN, this task is carried out processing the GPS receivers
data through a specific three-stages algorithm, which has the main aim to detect and remove any

outliers.

At first, starting from the CGGTTS-formatted (Common GPS GLONASS Time Transfer Standard,) measurement data collected at IEN (3SN receiver), a MAD (Median of the Absolute Deviation) based filtering procedure is performed with the aim of removing outliers caused mainly by unhealthy satellites. Such a filter is applied on the set of all the measurements concerning the satellites in view at each epoch, in order to detect outliers and to make use of all information available at that epoch. In particular, the MAD-based filter is obtained by applying the Hampel identifier, which replaces the outlier-sensitive classical statistical indexes (mean and standard deviation), with the outlier-resistant median and median absolute deviation from the median, respectively.

As documented in, the median \( x^C \) of a generic data sequence is obtained by first rank-ordering it from smallest to largest, i.e.:

\[
x_{(1)} \leq x_{(2)} \leq \ldots \leq x_{(N-1)} \leq x_{(N)} \quad (1)
\]

and then taking \( x^C \) as either the middle value (if \( N \) is odd) or the average of the middle two values (if \( N \) is even). The MAD scale estimate is then defined as:

\[
S = 1.4826 \cdot \text{median} \left| x_i - x^C \right|, \quad (2)
\]

where the factor 1.4826 in Equation (2) is chosen so that the expected value of \( S \) is equal to the standard deviation \( \sigma \) for normally distributed data.

A rejection threshold \( t \) (with \( t \) as an integer positive value) is then introduced and if

\[
\left| x_i - x^C \right| > t \cdot S \quad (3)
\]

\( x_i \) is declared an outlier and it is removed from the dataset.

Figure 8 shows an example of the general behaviour of both a classical 3\( \sigma \) dynamic filter and a MAD-based filter with a rejection threshold \( t = 3 \) (hereafter named 3\( S \) MAD-based filter) for a small real dataset containing a great outlier.

![Figure 8: Behaviour of different filtering on a small real dataset containing a great outlier (\( \cong 4 \sigma \)).](image)

As it comes out observing the example reported in figure 8, in general the 3\( S \) MAD-based filter seems to be a better choice than the classical 3\( \sigma \) filter, concerning the detection and removal of outliers especially for small data set (as in the case of epoch measurements), as also documented in literature. On the other hand, it is worth to notice that, for large datasets, the 3\( \sigma \) dynamic filter and
the 3σ MAD-based filter seem to provide the same performance, as confirmed by the values in table 8.

<table>
<thead>
<tr>
<th>Data set length</th>
<th>Filter</th>
<th>Mean (ns)</th>
<th>σ (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>89 samples</td>
<td>3σ</td>
<td>5.6</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>3σ MAD</td>
<td>5.6</td>
<td>3.4</td>
</tr>
<tr>
<td>9 samples</td>
<td>3σ</td>
<td>-25.9</td>
<td>47.1</td>
</tr>
<tr>
<td></td>
<td>3σ MAD</td>
<td>-10.4</td>
<td>7.9</td>
</tr>
</tbody>
</table>

Table 8: Effect of 3σ and 3σ MAD filters on both a small dataset (epoch measurements of the example reported in figura 12) and a large dataset (daily measurements for MJD 52988).

Then, after the epoch-based filtering procedure, the average of all survivor validated values is then computed and only one datum per each epoch results. With the aim of removing any residuals anomalies caused mainly by the receiver along with its external reference (the UTC(k) time scale in case of metrological laboratories), a further 3σ filtering procedure is then applied on a daily basis. As mentioned above, since up to 90 daily measurements could be collected by the receiver, both the MAD-based and the 3σ filter are comparable in term of outliers detection performance. The latter has been then chosen only for software implementation purposes.

Finally, the linear regression of all the surviving values is computed for each 24 hours interval centred at 00h UTC of the considered day. This smoothing procedure has the capabilities to filter out the short-term instabilities caused mainly by the GPS system. Only one datum per day is then carried out by the algorithm as the estimate of the mean offset between the local reference UTC(IEN) and either GPS time or other remote UTC(k) laboratories.

The estimated UTC(IEN) versus GPS time offset provided by the described algorithm is plotted in figure 9 for the 2 months period from MJD 52640 (January 1st, 2003) to MJD 52698 (February 28th, 2003). As showed in the plot, the results coming from the processing algorithm are very close to the BIPM Circular T data.

![Figure 9: Behaviour of UTC(IEN) versus GPS time as estimated by the processing algorithm on the 3SN receiver data (January 2003 – February 2003). The BIPM Circular T data (5 days spaced) are also reported.](image)

In case of time scale comparison with remote UTC(k) laboratories, the processing algorithm is quite different, even if it is based on three-stages too. In particular, the 3σ MAD-based epoch filtering is now applied on the set of all the differences concerning the measurements of satellites in common view by the two laboratories.

As a consequence, the low-level differences between raw measurements lead to remove all the “common” source of uncertainties, assuming then the best uncertainty budget in the comparison. Besides, the further filtering on each epoch allows to cope with anomalous asymmetrical common views between the two laboratories.
5 GSTB program
5.1 GSTB graphics interface

On the GSTB form there are four sections: two main sections (shown in Fig. 10, 11) for elaboration data (UTC(k)-GPS Processing and GPS CV combining) and two secondary (shown in Fig. 12, 13) to visualize the graphic results (UTC(k)-GPS Processed Graph and GPS CV Combined Graph).

To change the section it is necessary click on:

- UTC(k)-GPS Processing
- GPS CV Combining
- UTC(k)-GPS Processed Graph
- GPS CV Combined Graph

It’s possible to select lists, options and configuration parameters in both the main sections.

![Figure 10 - UTC(k)-GPS Processing section.](image)

There are five configuration windows:

A. Driver and directory
B. Configurations
C. New Laboratory
D. Options
E. Processing
A. Driver and directory

The are default directories:

- **Source directory** “Cesio\GPS” (network connection default H) it’ possibile to change network connection.
- **Final files in**: the directory where GSTB software writes to the final files
- **OK**: confirm

B. Configurations

Operation command:

- **MJD start** and **MJD stop**
- **Processing** and **CV Processing**

Optional command:

- **Laboratory / Laboratory Combined**: defined the laboratories
- **Type of filter**: there are four type of filters (coeff. multiply S and M default 3):
  - Filter S*sigma epoch
  - Filter M*median epoch
  - Filter S* sigma daily
  - Filter M*median daily
- **Average for**: elaboration of 24 hours.
- **Average at (UTC)**: elaboration at 00:00 or 12:00 UTC.
- **Daily outliers filtering**: filter daily or filter all data.
- **Reset**: reset of MJD start and MJD stop.
- **Exit**: escape from the program.

C. New Laboratory

- In this section It’s possible introduce new temporary laboratories with:
  - **Acronym**: laboratory or receiver acronym
  - **Type**: define timing or geodetic receiver
  - **New Laboratory**: put new acronym in Configurations – Laboratory

D. Options

- **Debug files**: print a set of debug files for outliers data analysis
- GSTB software make debug files for each elaboration:
  - **GPS CV Combining** section:
    - data extract (for the laboratory A and B if)
    - difference between laboratory A and B data
    - epoch filtered data
    - epoch not filtered data
    - epoch average
    - daily not filtered data
    - daily linear regression
  - **UTC(k)-GPS Processing** section:
    - data extract
    - epoch filtered data
    - epoch not filtered data
    - epoch average
    - daily not filtered data
- daily linear regression
- In epoch debug file filtered there is:
  - satellite elevation,
  - satellite azimuth,
  - standard deviation of the set of satellite measurement,
  - ionospheric correction.
- **Calibration**: use the receiver calibration for the elaboration data printed in the CGGTTS final file (*GPS CV Combining* section) (figure 12).

**E. Processing**

**Processing**: elaboration monitoring.

*Wait disposition in progress*: work in progress.

Final file for *GPS CV Combining* section:

```
cvdddd.ccc  dddd:  5-digits MJD of the delivery weekday
ccc:  3-characters UTC(k) remote laboratory name:
      PTB: PTB Braunschweig, Germany
      NPL: NPL Teddington, UK
      USN: US Naval Observatory [TBC]
```

Chapter 6.3 table 12 show an example of final file.

Final file for *UTC(k)-GPS Processing* section:

```
gppdddd.ccc  dddd:  5-digits MJD of the delivery weekday
ccc:  3-characters UTC(k) remote laboratory name:
      IEN: IEN Galileo Ferraris, Italy
      PTB: PTB Braunschweig, Germany
      NPL: NPL Teddington, UK
      USN: US Naval Observatory [TBC]
gpsmdddd.iem  dddd:  5-digits MJD of the delivery weekday
file for IEN web publication.
```
5.2. GSTB instructions use

Installation guide:
- GSTB software program distribution is on the laboratory of Time and Frequency server ("Risorse di rete" → "Cesio" → "Dati" → "Software_IEN" → "GSTB").
- Double click "setup.exe" an installation Wizard will automatically launch.
- The program extract automatically from CGGTTS format files:
  - Modify Julian Data (MJD),
  - Hours (hh), minute (mm), seconds (ss), (STTIME),
  - Satellite number
  - UTC(k)-GPS (REFGPS).

Instructions use:
- Source files on (ADTF) "Risorse di rete" → "Cesio" → "Dati" → "GPS", or "H:\GPS",
- Copy configuration file "Config.txt" in C:,
- Copy calibration file "Tarat.txt" in C:,
- Make network connection "Risorse di rete" → "Cesio" → "Dati" → "GPS" named H,

Figure 11 - GPS common view UTC(k1)-UTC(k2) section
If network connection name isn’t H, put the correct name in **Source driver**,  
Make **C:\Park** directory for the final file,  
If directory name isn’t **Park**, put the correct name in **Final files in;**,  
Click **Ok** and wait for confirmation,  
Select the interest section **UTC(k)-GPS Processing** or **GPS CV Combining**,  
**Mjd start** and **Mjd stop**,  
Select **option**  
**Processing** or **CV Processing**  
GSTB software open **File start e File stop**,  
GSTB software fill **N. xxx** windows,  
**End** for escape from the program,  
**Reset** clean the **Mjd start** and **Mjd stop** windows,  
**UTC(k)-GPS Processed Graph** and **GPS CV Combined Graph** show the final graph (figure 13 and figure. 14).
5.3 Configuration file (Config.txt) and calibration file (Tarat.txt)

5.3.1 Config.txt

GSTB software reads the configuration file and:
- Set network connection default,
- Set the final file path,
- Set default option,
- Put acronym laboratories default (es. IEN, ptb, tp, ash...) and receiver type (timing or geodetic).

New laboratories must be added before “end” and “timing or geodetic” on the list below. Instead with “New Laboratory” button it’s possible to add new temporary laboratories. 

Leggimi.txt explain every line of Config.txt and Tarat.txt files.

Configuration file Config.txt is shown in table 9:

Table 9 – Configuration file Config.txt

<table>
<thead>
<tr>
<th>H</th>
<th>C:\Park\</th>
<th>IEN</th>
<th>IEN ptb</th>
<th>timing</th>
<th>timing</th>
<th>timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>day</td>
<td>IEN</td>
<td>IEN</td>
<td>ptb</td>
<td>tp</td>
<td>ash</td>
<td>jav</td>
</tr>
<tr>
<td>npl</td>
<td>end</td>
<td>timing</td>
<td>timing</td>
<td>timing</td>
<td>geodetic</td>
<td>geodetic</td>
</tr>
<tr>
<td>timing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Description file *Leggimi.txt* is shown in table 10:

### Table 10 – Description of the configuration file in Leggimi.txt

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Driver su cui operare</td>
</tr>
<tr>
<td>2.</td>
<td>Driver e cartella dove salvare i risultati</td>
</tr>
<tr>
<td>3.</td>
<td>Laboratorio di default per sezione &quot;UTC(k)-GPS Processing&quot;</td>
</tr>
<tr>
<td>4.</td>
<td>Laboratorio di default per sezione &quot;GPS CV Combining&quot;, primo laboratorio</td>
</tr>
<tr>
<td>5.</td>
<td>Laboratorio di default per sezione &quot;GPS CV Combining&quot;, secondo laboratorio</td>
</tr>
<tr>
<td>6.</td>
<td>Tipo di ricevitore per sezione &quot;UTC(k)-GPS Processing&quot;</td>
</tr>
<tr>
<td>7.</td>
<td>Tipo di ricevitore per sezione &quot;GPS CV Combining&quot;, primo laboratorio</td>
</tr>
<tr>
<td>8.</td>
<td>Tipo di ricevitore per sezione &quot;GPS CV Combining&quot;, secondo laboratorio</td>
</tr>
<tr>
<td>9.</td>
<td>Attivazione del &quot;Debug file&quot;</td>
</tr>
<tr>
<td>10.</td>
<td>Di default non si somma il valore di calibrazione dei ricevitori GPS in &quot;Calibration&quot;</td>
</tr>
<tr>
<td>11.</td>
<td>Disattivazione del &quot;Filter S * Sigma epoch&quot;</td>
</tr>
<tr>
<td>12.</td>
<td>Attivazione del &quot;Filter M * Median epoch&quot;</td>
</tr>
<tr>
<td>13.</td>
<td>Disattivazione del &quot;Filter S * Sigma daily&quot;</td>
</tr>
<tr>
<td>14.</td>
<td>Attivazione del &quot;Filter M * Median daily&quot;</td>
</tr>
<tr>
<td>15.</td>
<td>Definizione del coeff S per il filtro sigma</td>
</tr>
<tr>
<td>16.</td>
<td>Definizione del coeff M per il filtro median</td>
</tr>
<tr>
<td>17.</td>
<td>Definizione di quanto tempo fare la &quot;daily average&quot;</td>
</tr>
<tr>
<td>18.</td>
<td>Definizione di quanto centrare la &quot;daily average&quot;</td>
</tr>
<tr>
<td>19.</td>
<td>Definizione della durata del &quot;Daily filtering&quot;</td>
</tr>
<tr>
<td>20.</td>
<td>Acronimo per la lista dei laboratori</td>
</tr>
<tr>
<td>21.</td>
<td>Acronimo per la lista dei laboratori</td>
</tr>
<tr>
<td>22.</td>
<td>Acronimo per la lista dei laboratori</td>
</tr>
<tr>
<td>23.</td>
<td>Acronimo per la lista dei laboratori</td>
</tr>
<tr>
<td>24.</td>
<td>Acronimo per la lista dei laboratori</td>
</tr>
<tr>
<td>25.</td>
<td>Acronimo per la lista dei laboratori</td>
</tr>
<tr>
<td>26.</td>
<td>Acronimo per la lista dei laboratori</td>
</tr>
<tr>
<td>27.</td>
<td>Carattere che delimita la fine degli acronimi dei laboratori</td>
</tr>
<tr>
<td>28.</td>
<td>Tipo di ricevitore per la lista dei laboratori</td>
</tr>
<tr>
<td>29.</td>
<td>Tipo di ricevitore per la lista dei laboratori</td>
</tr>
<tr>
<td>30.</td>
<td>Tipo di ricevitore per la lista dei laboratori</td>
</tr>
<tr>
<td>31.</td>
<td>Tipo di ricevitore per la lista dei laboratori</td>
</tr>
<tr>
<td>32.</td>
<td>Tipo di ricevitore per la lista dei laboratori</td>
</tr>
<tr>
<td>33.</td>
<td>Tipo di ricevitore per la lista dei laboratori</td>
</tr>
</tbody>
</table>

For quanto riguarda "Tarat.txt":

Il file contiene i valori di taratura dei singoli ricevitori dei vari laboratori rispetto il BIPM. (nel caso in cui non ci sia la calibrazione il valore è a 0). Il file è organizzato in N righe un dato a riga nello stesso ordine presente nella casella "Laboratory Combined" del programma. I dati hanno il seguente significato:

1. Dato di taratura per IEN
2. Dato di taratura per PTB
3. Dato di taratura per VSL
4. Dato di taratura per ASH
5. Dato di taratura per JAV
6. Dato di taratura per NPL

5.3.2 Tarat.txt

If you select the calibration option the GSTB software elaborates the receiver calibration for IEN, PTB, VSL and NPL laboratiries;

The elaboration is:

\[
[\text{UTC}(k1) - \text{UTC}(\text{OP})] - [\text{UTC}(k2) - \text{UTC}(\text{OP})]
\]

- UTC(OP) receiver used for the calibration,
- UTC(k) laboratory.

The UTC(k)-UTC(.OP) data are present in *Tarat.txt* file

Calibration file *Tarat.txt* is shown in table 11:
Table 11 – Calibration file Tarat.txt

<table>
<thead>
<tr>
<th>UTC(k) - GPS</th>
<th>Es. UTC(ien) - GPS</th>
<th>Mjd: 52999 – 52912</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.5</td>
<td>-4.7</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>-10</td>
<td></td>
</tr>
</tbody>
</table>

Figure 12 - Graph
UTC(k) - GPS
Es. UTC(ien) - GPS
Mjd: 52999 – 52912.

Figure 13 - Graph
GPS CV UTC(k1) - UTC(k2)
Es. UTC(ien) - UTC(ptb)
Mjd: 52899 – 52912.
6. Applications

6.1 Web publication of IEN GPS data

On the web page:
http://www.ien.it/tf/time/gps/gpsdati.shtml

There are the IEN GPS data with the following informations:

- Modify Julian Data (MJD),
- Linear regression [ns] of UTC(IEN)-GPS data elaborated in the UTC(k)-GPS Processing section with the algorithm of paragraph 3.2.6

\[
y_0 = \frac{\sum y_i \cdot \sum x_i^2 - \sum x_i y_i \cdot \sum x_i}{n \cdot \sum x_i^2 - \left(\sum x_i\right)^2}
\]

linear regression [ns]

- Frequency departure

\[
\frac{\Delta_{i+1} - \Delta_i}{86400} \cdot 10^{13}
\]

6.2 Long term monitoring UTC(IEN) time scale

With GSTB data results it is easy make graph for monitoring UTC(IEN) time scale. It’s possible make comparisons graph with international laboratories or GPS scale. figure 14 shown UTC(IEN)-GPS graph during the period 1st July – 20th October 2003. figure 15, instead, shown UTC(IEN)-UTC(PTB) graph during the period 1st January 2002 – 13th October 2003.

![Graph IEN(3SN)-GPS 3S Navigation](image_url)
6.3 Applications for Galileo System Test Bed V1

GSTB make GPS Common View (CV) differences file between IEN [UTC(IEN)-GPS time differences between the local reference UTC(IEN) and the GPS time measurements, performed by the 3S Navigation GPS receiver] and international laboratories measurements performed during the previous week (7 days, from Tuesday to Monday).

Table 12 and table 13 shown this file CGGTTS.

Table 12 – UTC(IEN)-GPS CGGTTS file

<table>
<thead>
<tr>
<th>FORMAT</th>
<th>VERSION</th>
<th>REV</th>
<th>DATE</th>
<th>RCVR</th>
<th>IMS</th>
<th>LAB</th>
<th>COMMENTS</th>
<th>INT DLY</th>
<th>CAB DLY</th>
<th>REF DLY</th>
<th>REF</th>
<th>CKSUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>GGTTS</td>
<td>01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IEN - PTB</td>
<td>REF GPS is estimated UTC(IEN) - UTC(PTB), as one datum per day at 00h UTC.</td>
<td>3600.0 ns</td>
<td>0.0 ns</td>
<td>0.0 ns</td>
<td>UTC(IEN)</td>
<td>PTB</td>
</tr>
</tbody>
</table>

Table 13 – GPS Common View (CV) CGGTTS file

<table>
<thead>
<tr>
<th>FORMAT</th>
<th>DATE</th>
<th>STTIME</th>
<th>TRKL</th>
<th>ELV</th>
<th>AZTH</th>
<th>REFSV</th>
<th>SRSV</th>
<th>REFGPS</th>
<th>SRGPS</th>
<th>DSG</th>
<th>IOE</th>
<th>MDT</th>
<th>SMD</th>
<th>MDIO</th>
<th>SMDI</th>
<th>CK</th>
</tr>
</thead>
<tbody>
<tr>
<td>GGTTS</td>
<td>0000</td>
<td>0000</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>99999</td>
<td>9999</td>
<td>99999</td>
<td>99999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>9999</td>
<td>99999</td>
<td>99999</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 15: Common view UTC(IEN)-UTC(PTB)
6.4 GPS data analysis during sun storm (October-November 2003)

Figure 16: UTC(k)-GPS, common view, DST graphics (period 52919 – 52955).
There was a sun storm between the end of October and November 2003, (peak of storm for day of the year 2003: n. 304).

Figure 16 shown GPS data of international laboratories (IEN, PTB, NPL, USNO):

- **USNO, NPL IEN(3SN), PTB**: graphs shown GPS data spread, during the sun storm
- **IEN(3SN)-PTB**: graph shown the common view between a timing receiver of IEN and PTB, with this technique the sun storm effect is smaller, but GPS data spread is still present.
- **IEN Geodetic (Ashtech)**: graph shown the geodetic receiver’s data, this device realize the ionospheric correction. In this case the sun storm effect is much smaller.
- **DST (Disturbance Storm Time)**: graph shown an activity sun factor the DTS Disturbance Storm Time (source NGDC National Geophysical Data Center, NOAA Satellites and Information). During the observed period there are substantial alterations.

In figure 17 is shown a particular of graph (for the period mjd 52940 – 52951, 28th October – 8th November).

NPL, IEN and PTB european laboratories are on phase while the American USNO is approximately 180° delayed.

![UTC(K)-GPS data for USNO, NPL, IEN, PTB (period 52940 – 52951).](image)

For confirmation in figure 18 is shown a temporal evolution of the performance of five IGS Ionosphere Associate Analysis Centers (IAACs) (CODE, ESA, JPL, NRCan and UPC, they contribute with their ionosphere products to the Ionosphere Working Group (Iono-WG) activities). The large peaks of Total Electron Content (TEC) parameter comparison (JASON dual-frequency altimeters TEC and GPS TEC) coinciding with geomagnetic storm of 31th October 2003 day of the year: n. 304. [10]
Figure 18: TEC comparison for Ionosphere Associate Analysis Centers (IAACs) during 2003
6.5 GPS data analysis: satellites parameters

GSTB software allows to analyze the satellites parameters like elevation and azimuth. Table 14 stress the elevation and azimuth data in a CGGTTS file [0.1°]:

Table 14 – Elevation and azimuth data from CGGTTS file

<table>
<thead>
<tr>
<th>PRN</th>
<th>CL</th>
<th>MJD</th>
<th>STTIME</th>
<th>TRKL</th>
<th>ELV</th>
<th>AETH</th>
<th>REFSV</th>
<th>SRSV</th>
<th>REFGPS</th>
<th>SRGPS</th>
<th>DSG</th>
<th>IOE</th>
<th>MDTR</th>
<th>MDIO</th>
<th>SMDI</th>
<th>CK</th>
</tr>
</thead>
<tbody>
<tr>
<td>26 FF</td>
<td>52513</td>
<td>003400</td>
<td>135</td>
<td>81</td>
<td>208</td>
<td>-998670</td>
<td>+803</td>
<td>-16499</td>
<td>+758</td>
<td>313</td>
<td>154</td>
<td>529</td>
<td>+403</td>
<td>135</td>
<td>+20</td>
<td>53</td>
</tr>
<tr>
<td>18 FF</td>
<td>52513</td>
<td>003400</td>
<td>370</td>
<td>319</td>
<td>1258</td>
<td>+471407</td>
<td>-21</td>
<td>-626</td>
<td>+8</td>
<td>101</td>
<td>159</td>
<td>148</td>
<td>-25</td>
<td>85</td>
<td>-10</td>
<td>49</td>
</tr>
<tr>
<td>25 FF</td>
<td>52513</td>
<td>003400</td>
<td>780</td>
<td>96</td>
<td>2071</td>
<td>-317392</td>
<td>+105</td>
<td>-583</td>
<td>+111</td>
<td>150</td>
<td>111</td>
<td>459</td>
<td>+271</td>
<td>136</td>
<td>+18</td>
<td>22</td>
</tr>
<tr>
<td>124 FF</td>
<td>52513</td>
<td>003400</td>
<td>780</td>
<td>382</td>
<td>817</td>
<td>-745407</td>
<td>+104</td>
<td>-16440</td>
<td>+95</td>
<td>103</td>
<td>15</td>
<td>127</td>
<td>+16</td>
<td>73</td>
<td>+7</td>
<td>05</td>
</tr>
<tr>
<td>22 FF</td>
<td>52513</td>
<td>003400</td>
<td>780</td>
<td>689</td>
<td>2684</td>
<td>-4921175</td>
<td>+32</td>
<td>-781</td>
<td>+42</td>
<td>51</td>
<td>53</td>
<td>84</td>
<td>-1</td>
<td>52</td>
<td>+0</td>
<td>85</td>
</tr>
<tr>
<td>2 FF</td>
<td>52513</td>
<td>003400</td>
<td>780</td>
<td>526</td>
<td>2960</td>
<td>+2537633</td>
<td>+72</td>
<td>-819</td>
<td>+12</td>
<td>58</td>
<td>99</td>
<td>99</td>
<td>-7</td>
<td>60</td>
<td>-4</td>
<td>87</td>
</tr>
<tr>
<td>23 FF</td>
<td>52513</td>
<td>003400</td>
<td>780</td>
<td>254</td>
<td>531</td>
<td>-84831</td>
<td>+66</td>
<td>-788</td>
<td>+73</td>
<td>94</td>
<td>198</td>
<td>182</td>
<td>+14</td>
<td>96</td>
<td>+4</td>
<td>CB</td>
</tr>
</tbody>
</table>

As it comes out observing the example reported in figure 19 the satellites at low elevation result to be the most filtered ones.

![Figure 19: histogram of outliers elevation data satellites](image)

Figure 21 A, and B shown the correspondence of polar plots for tracking satellites.
Where elevation [$^\circ$] and azimuth [$^\circ$] are converted in $\rho$ [rad] and $\theta$ [rad] (figure 21):

$$\rho = \cos \left( \frac{2 \cdot \pi \cdot \text{elevation}}{360} \right)$$

$$\theta = \frac{2 \cdot \pi \cdot \text{azimuth}}{360}$$

In figure 21-A and 21-B, are depicted the polar plot by IGS (specificking riferiment web page: [http://www.epncb.oma.be/_trackingnetwork/qualityplots/IEng.html](http://www.epncb.oma.be/_trackingnetwork/qualityplots/IEng.html)) and the polar plot realized by real 3S Navigation data.

[U.S. Global Positioning System (GPS) constellation of satellites plays a major role in regional and global studies of Earth. In the face of continued growth and diversification of GPS applications, the worldwide scientific community has made an effort to promote international standards for GPS data acquisition and analysis, and to deploy and operate a common, comprehensive global tracking system.

As part of this effort, the **International GPS Service (IGS)**, along with a multinational membership of organizations and agencies, provides GPS orbits, tracking data, and other high-quality GPS data and data products on line in near real time to meet the objectives of a wide range of scientific and engineering applications and studies.

The Global Data Centers archive and provide on-line access to tracking data and data products. The online data are employed by the Analysis Centers to create a range of products, which are then transmitted to the Global Data Centers for public use. This web site is part of the IGS Central Bureau Information System (CBIS), providing both IGS member organizations and the public with a gateway to all the IGS global data and data product holdings, as well as other valuable information.

The EUREF Permanent GPS Network is the European densification of the Global Network of the **International GPS Service for Geodynamics (IGS)**.

Figure 22 A and B show the outliers satellites traking for both 3SN receiver and Ashtech geodetic receiver.
Figure 21: polar plot satellites tracking comparison

A - polar plot satellites tracking from IGS
B – polar plot satellites tracking from real 3SN data

Figure 22: polar plot of outliers satellites tracking for 3SN receiver and Ashtech geodetic receiver.

A – polar plot for outliers satellites tracking from real 3SN data
B – polar plot for outliers satellites tracking from real Ashtech data
6.6 Masking angle analysis

In figure 23 is shown the percentage of outliers data (violet) and not outliers data (yellow) in comparison to the all extract data from 3SN receiver (MAD epoch filter, 11th January – 10th February 2004, MJD 53015 – 53045). Analysing the data obtained by the use of the previously described algorithm, it is possible to notice that most of the data eliminated by the filtering procedure are related to low elevation satellites. However, to apply a masking angle as filtering solution, it seemed not to be an optimal solution, because many data at low elevation still carry a correct information.

![Figure 23: outliers data and not outliers data of a real data set](image.png)
Conclusions

In the Time and Frequency Laboratory of the IEN is weekly operating GSTB software. It use the previously described algorithm for the UTC(IEN)-UTC(\(k\)) combining comparison. This for the experimental phase of the Galileo System Test Bed project supported by the European Space Agency (ESA), implemented at IEN in collaboration with Alenia Spazio Roma, with the aim to disseminate the Experimental Galileo System Time for the whole experimentation period planned for 2004.

8. Index

1. Introduction.
2. Introduction to GPS
3. Algorithm.
   3.1. Algorithm general description
      3.1.1. The GPS “Common View” method.
      3.1.2. The CGGTTS format
      3.1.3. GPS CV data processing
3.2. Description of UTC(IEN)-GPS processing algorithm
   3.2.1. High level description
   3.2.2. Algorithm items description
   3.2.3. Raw data outliers filtering
   3.2.4. Epoch-based average calculation
   3.2.5. Data outliers filtering
   3.2.6. Daily linear regression calculation
3.3. Description of CV combining algorithm
   3.3.1. High level description
   3.3.2. Algorithm items description
   3.3.3. CV differences calculation
   3.3.4. Combined data outliers filtering
   3.3.5. Epoch-based average calculation
   3.3.6. Combined data outliers filtering
   3.3.7. Daily linear regression calculation
3.4. Specification of UTC(IEN)-GPS processed data file
   3.4.1. File naming convention
   3.4.2. File format and content
   3.4.3. File header description
   3.4.4. Line header description
   3.4.5. Unit header description
   3.4.6. Data line description
3.5. Specification of GPS CV combined data files
   3.5.1. File naming convention
   3.5.2. File format and content
   3.5.3. File header description
   3.5.4. Line header description
   3.5.5. Unit header description
   3.5.6. Data line description
3.6. Dynamic filter
   3.6.1. Dynamic 3\(\sigma\) filter
   3.6.2. MAD-based filter
4. Robust outliers detection algorithm.
5. GSTB program
   5.1. GSTB graphics interface
   5.2. GSTB structue use
   5.3. Configuration file “Config.txt“ and calibration file “Tarat.txt"
      5.3.1. Config.txt
      5.3.2. Tarat.txt
6. Applications
   6.1. Web publication of IEN GPS data
   6.2. Long term monitoring UTC(IEN) time scale
   6.3. Applications for Galileo System Test Bed V1.
   6.4. GPS data analysis during sun storm (October-November 2003)
   6.5. GPS data analysis: satellites parameters
   6.6. Masking angle analysis
7. Conclusions
8. Index
9. References

9. References