Warning and Mitigation Technologies for Travelling Ionospheric Disturbances Effects

TechTIDE

User Manual
The Along Arc TEC Rate (AATR) Indicator and the Medium Scale Travelling Ionospheric Disturbances MSTID-GNSS Index

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1. Introduction

1.1 Some information about the Along Arc TEC Rate (AATR) Indicator

This tool aims to provide an ionospheric activity indicator useful for identifying disturbed periods affecting the performance of Global Navigation Satellite System (GNSS). This index is based in the Along Arc TEC Rate (AATR) and can be easily computed from dual-frequency GNSS measurements. In (Juan, et al., 2018), the AATR indicator has been assessed over more than one Solar Cycle (2002–2017) involving about 140 receivers distributed world-wide. Results show that it is well correlated with the ionospheric activity, sensitive to the regional behavior of the ionosphere and identifies specific effects on GNSS users. Moreover, from a devoted analysis of different Satellite Based Augmentation System (SBAS) performances in different ionospheric conditions, it follows that the AATR indicator is a very suitable mean to reveal whether SBAS service availability anomalies are linked to the ionosphere. On this account, the AATR indicator has been selected as the metric to characterize the ionosphere operational conditions in the frame of the European Space Agency activities on the European Geostationary Navigation Overlay System (EGNOS). The AATR index has been adopted as a standard tool by the International Civil Aviation Organization (ICAO) for joint ionospheric studies in SBAS.

1.2 Some information about the Medium Scale Travelling Indicator Disturbances MSTID-GNSS index

Travelling ionospheric disturbances (TID) are understood as plasma density fluctuations that propagate through the ionosphere at velocities of around 100 m/s over periods of around 1000 seconds. MSTIDs are mostly associated with ionospheric coupling with the lower atmosphere and, having no clear correlation with the geomagnetic activity. MSTIDs occur in the ionosphere (almost) all the time. The basic observable that it is used in this program to detect TIDs is the geometry-free (or ionospheric) combination of the two GPS carrier phases, with measurement noise at the level of few millimeters. This is the basic input to estimate the medium-scale traveling ionospheric disturbances (MSTIDs) characteristics. This procedure allows the study of any ionospheric perturbation and can be used to estimate propagation parameters (from a network of receivers). With this technique it is possible to detect, in any of the receivers, the fluctuations associated with the TIDs. Moreover, correlating these fluctuations on the different receivers in the network, it is possible to estimate the propagation parameters (propagation direction, velocity and amplitude).

For more detailed information on how the AATR and MSTID indexes computations written in the following codes, it is highly recommended users to read the following references:

References

Juan, J. M., Sanz, J., Rovira-Garcia, A., González-Casado, G., Ibañez, D., & Orus-Perez, R. (2018). AATR an ionospheric activity indicator specifically based on GNSS measurements. *Journal of Space Weather and Space Climate*, 11.

Sanz, J., Juan, J., Gonzáles-Casado, G., Prieto-Cerdeira, R., Schluter, S., & Orus, R. (2014). Novel ionospheric activity indicator specifically tailored for GNSS users. *Proceedings of the 27th International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS+ 2014)*(Tampa, Florida, USA), 1173 - 1182.

Hernández-Pajares, M., Juan Zornoza, J., & Sanz, J. (2006). "Medium Scale Traveling Disturbances Affecting GPS Measurements: Spatial and Temporal Analysis". *Journal of Geophysical Research, Space Physics, 111*, A07-S11.

Sanz J, Juan J, González-Casado G, Prieto-Cerdeira R, Schlueter S, Orus R. (2014). Novel ionospheric activity indicator specifically tailored for GNSS users. In: Proceedings of ION GNSS+ 2014. Tampa, Florida (USA), pp. 1173–1182. http://www.ion.org/publications/abstract.cfm?jp=p&articleID=12269

2. AATR+MSTID version 1.0

The *AATR+MSTID version 1.0* tool generates the AATR indicator for identifying ionospheric disturbed periods, as detailed in (Sanz, et al., 2014) and (Juan, et al., 2018), and the MSTID detector to characterize TID, as detailed in (Hernández-Pajares, Juan Zornoza, & Sanz, 2006). The tool takes as input *Receiver INdependent Exchange (RINEX)* observation files version 2 and version 3.

The *AATR+MSTID version 1.0* code is a tool capable of produce outputs in both real time and non-real time. For real time, it is necessary to have access to a continuous stream of RINEX observation files. This can be achieved using a *Network Transport of RTCM data over IP* (NTRIP) client, such as BNC (https://igs.bkg.bund.de/ntrip), to download RINEX observation files from stations broadcasting GNSS data streams in real time. Main NTRIP broadcasters can be consulted for the International GNSS Service (IGS) at www.igs-ip.net or for the EUREF Permanent Network (EPN) at www.euref-ip.net.

Once the tool is correctly executed, it goes throw several stages where different analysis and computations are performed to finally obtain the AATR and MSTID-GNSS corresponding indicators.

3. Contents of the tar file

The *AATR+MSTID version 1.0* code is intended to be executed in a Linux environment. It has been written as *Open Source* and published under license *CCL4.0*, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The following steps should be executed for installing the code:

1. Create a directory where the code will be executed for installing the code (hereafter, “main directory”).
2. Un-tar the downloaded tar in the main directory. Four subdirectories are meant to be created:
    a. `data`
    b. `info_files`
        i. `formats`
    c. `prefits_bin`
    d. `run`

Folder `data` is initially an empty repository to gather the RINEX observation files downloaded from the different data source streams broadcasting in real time. For further information on how to configure a NTRIP client to download this files, please refer to annex 1. Folder `info_files` is created to store necessary information for the computations done by the code and routines files in the folder `prefits_bin`. The folder `info_files` contains a subfolder named `formats` with documentation and information about the formats, files information and this user manual· Finally, in the `run` folder the main executable is allocated to start all the computations, generating all the outputs (log files and data files), including the AATR and MSTID-GNSS indicators.

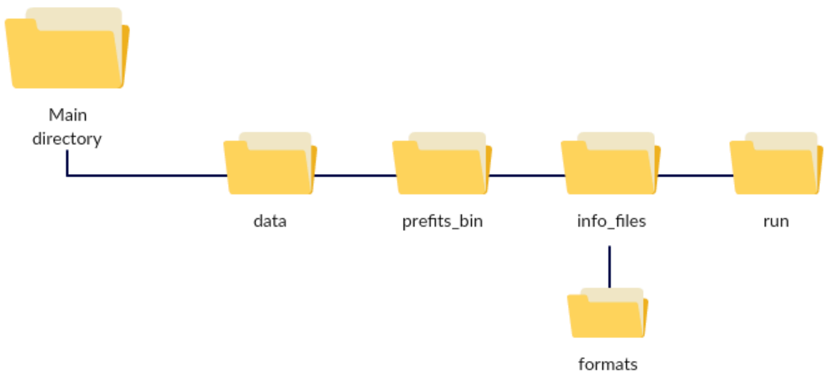

Figure 1 Directory structure

Folders and files in the compressed tar folder are listed in the following table:

File name	Directory	Type	Description
XXXXdoy0.yy0	data	Input file – plain text	RINEX observation file of the *XXXX* station, for the day of the year *doy* and the year *yy*.
GPS_Receiver_Types.gz	info_files	Compressed file	This file contains classifications for GPS receiver types.
igs_pc_sat_new.dat	info_files	Input file – plain text	This files lists the antenna phase center for satellites in use.
Igs_pc_sat_old.dat	info_files	Input file – plain text	This files lists the antenna phase center for satellites in use.
User manual	info_files/formats	PDF document	Document designed as a guide for installation and running the AATR+MSTID code.
AATR_format	info_files/formats	Plain text	Explanatory file of the AATR output format content
MSTID_format	info_files/formats	Plain text	Explanatory file of the medium scale TID output format content
brdc2axis.pl	prefits_bin	source code	Transform the broadcast files (RINEX Observation) into satellite orientation axis.
check_arcs.pl	prefits_bin	source code	Computation of STEC rates (used for AATR index) and double differences of STEC (used for MSTID)
compute_tides.pl	prefits_bin	source code	Computes the lunisolar and ocean loading tides for a receiver.
convert_time.pl	prefits_bin	source code	Converts and formats the time as *year*, *gpsweek*, *gps day*, *month day*, *month*, and *day of the year*.
cycle_rt	prefits_bin	executable	Detects cycle slips
del_eclipse_data.pl	prefits_bin	source code	Deletes data from satellite in eclipse mode.
detect_leamps.pl	prefits_bin	source code	Detects leap milliseconds that are not explicit on the RINEX time record (using pseudorange measurements)
detect_phase_leamps.pl	prefits_bin	source code	Detects leap milliseconds that are not explicit on the RINEX time record (using phase measurements)
hardisp	prefits_bin	executable	Reads in a file of station displacements for ocean loadings, and outputs a time series of

			computed tidal displacements.
model	prefits_bin	executable	Computes the GNSS model of the different delays through the pseudorange method.
mstid_idx.pl	prefits_bin	source code	Computes and detects the Medium Scale TID (MSTID) amplitude
prefits.pl + prefits_rt.pl	prefits_bin	source code	Applies the corrections computed by the program `model`.
read_antenna_pc.pl	prefits_bin	source code	Reads the antenna phase center of the receiver
rnx2txt.pl	prefits_bin	source code	Converts the RINEX observation file format into a plain txt format file
sp32txt.pl	prefits_bin	source code	Converts the Standard Product SP3 files containing precise orbits into a plain txt format file
tide_iers + tide_iers.f	prefits_bin	executable and source code	Computes the lunisolar tide displacement.
time_handle_comparison.pl + time_handle.pl	prefits_bin	source code	This programs downloads rapid and ultra-rapid clock and orbit data to properly compute and run GNSS modeling programs.
run.scr	run	executable	Static executable file for Unix-like (Linux) systems.
sta.coor	run	input – plain text	Contains a wide list of GNSS stations information, such as coordinates, geocentric distance, receiver type.
work.sta	run	input – plain text	Contains the 4 letter stations name to work with (modifiable according to the user needs)

Table 1 File description

It is important to remark source code should not be modified since it has been prepared to work as it is provided to users.

4. Code installation

4.1 Minimum hardware and software requirements

To properly executed the *AATR+MSTID version 1.0* tool it is necessary the following hardware and software minimum requirements:

- 512 MB of system memory (RAM)
- 500 MB of hard disk space free.
- 1 GHz CPU

The hard disk free space highly depends on the contemplated total amount of data to be processed by the *AATR+MSTID version 1.00* code (i.e. RINEX observation files).

4.2 Installation

All binary files are ready to be used in any Linux machine, as they are all pre-compiled. Programs with *.pl* extension do no need to be compiled, as they are perl scripts ready to run. For fortran files (files with the extension *.f*), in case binary files do not work as expected, it is possible to recompile by executing one of the two following commands:

```
f77 -o file.bin file.f -llapack -lblas
```

or

```
gfortran -o file.bin file.f fflushf77.o –llapack –lblas –Wall -Wextra
```

Make sure you have installed either F77 *fortran* compiler or *gfortran* compiler to successfully run the before mentioned commands.

5. Executing the code

The *AATR+MSTID version 1.0* code is executed by running the following command within the ***run*** directory (`main_directory/run/`):

```
./AATR_MSTID.scr
```

It reads from the following files:

1. `work.sta` stations listed in this file for processing
2. `XXXXdoy0.yyO` RINEX observation files downloaded from the NTRIP client and listed in `work.sta`
3. Broadcast navigation files and IGS Ultra-rapid products (IGU) are downloaded automatically to work with `brdc2axis.pl`,`sp32txt.pl`,`add_brdc_clock_2_igu.pl`, `merge_orbit_files.pl`, `detect_eclipse`, `del_eclipse_data.pl` and `model` programs.

It writes to the following files:

1. `rnx2txt.log`
2. `detect_leapms.log`
3. `detect_phase_leapms.log`
4. `cycle.log`
5. `time_handle.log`
6. `axis.dat`
7. `orbit_gnss.dat`
8. `rover.obs`
9. `rover.sta`
10. `antenna.log`
11. `antenna.dat`
12. `tides.sta`
13. `mstid_idx.YY.doy`
14. `aatr_5m.YY.doy`

The output files `mstid_idx.YY.doy` and `aatr_5m.YY.doy` are labelled with the year `(YY)` and day of the year `(doy)` of the processed data. Files with extension `.log` are created to control and monitor the different processing steps.

6 Flow of data processing

This chapter is devoted to explain the data process from the RINEX observation files to the final AATR and MSTID indicator values. These computations can be performed working either in real time or deferred RINEX files, from one (1) up to several hundreds of stations receivers simultaneously.

6.1 From RINEX Observation to plain txt

This transformation extracts the observation time (year, day of the year and seconds), receiver station name, global positioning system (GPS, GALILEO, GLONASS) and the so-called observables: phase measured in whole units of the carrier (L1 and L2), pseudorange code measured (P1 and P2). It is provided information about the arcs, as well as the signal strength for both L1 and L2 observables (expressed as the tenth of a dB). Lastly, GPS week and GPS day are extracted. This programs outputs a log file, called `rnx2txt.log`, indicating the RINEX version of the processed file and the output (standard output).

Year	Doy	Seconds of Day	Station	GNSS constellation + Frequency Identifier	Satellite	L1 (m)	L2 (m)	P1 (m)	P2 (m)	Arc	SNR1 (tenth of dB)	SNR2 (tenth of dB)	GPS week	Day of GPS week
18	304	31050	ACOR	G12	8	20788641.2091	20788642.9319	20788640.6020	20788643.1420	0	512	505	2025	3
18	304	31050	ACOR	G12	10	23943677.9220	23943680.3364	23943679.3620	23943681.2220	0	427	382	2025	3
18	304	31050	ACOR	G12	18	19929990.2494	19929993.0889	19929988.0480	19929988.3480	0	502	495	2025	3
18	304	31050	ACOR	G12	22	21572262.7950	21572263.0205	21572262.3380	21572259.9180	0	487	465	2025	3
18	304	31050	ACOR	G12	28	23039506.6629	23039505.8760	23039506.7080	23039505.8680	0	447	405	2025	3

Table 2 Output format program rnx2txt

6.2 Program detect_leapms.pl and detect_phase_leapms.pl

Both programs take as input data with the format in Table 2 to detects leap milliseconds that are not explicit in the RINEX time record. Pseudorange measurements are used in the program `detect_leapms.pl` while phase measurements are used in the program `detect_phase_leapms.pl`. The format of the output of this two programs are the same as the input in Table 2, with the only change of modifying the leap millisecond correction. Two log files, `detect_leapms.log` and `detect_phase_leapms.log` are generated after the process is done.

6.3 Cycle slip detector: cycle_rt

This program is a cycle slip detector when using phase measurements. It takes input data as it is presented in Table 2, and outputs information as it is shown in Table 3, adding the corresponding information to the column *Arc*. A log file `cycle.log` is generated to control the process.

Year	Doy	Seconds of Day	Station	GNSS constellation + Frequency Identifier	Satellite	L1 (m)	L2 (m)	P1 (m)	P2 (m)	Arc	SNR1 (tenth of dB)	SNR2 (tenth of dB)	GPS week	Day of GPS week
18	304	31260	ACOR	G12	8	20850570.3787	20850572.8972	20850570.4420	20850572.9820	1	512	502	2025	3
18	304	31260	ACOR	G12	10	24075565.1494	24075566.5789	24075565.2200	24075566.8000	1	402	385	2025	3
18	304	31260	ACOR	G12	18	19935989.0798	19935989.3706	19935989.0080	19935989.3080	1	505	495	2025	3
18	304	31260	ACOR	G12	22	21481111.4056	21481109.0494	21481111.3980	21481108.9780	1	487	472	2025	3
18	304	31260	ACOR	G12	28	22974486.7640	22974485.9785	22974486.8680	22974485.9280	1	460	387	2025	3

Table 3 Output format Cycle slips detector program

6.4 Time handle processing

At this point, the program `time_handle` Downloads rapid and ultra-rapid clock and orbit data from the Crustal Dynamics Data Information System CDDIS (ftp://cddis.gsfc.nasa.gov/) in order to properly compute and run GNSS modelling programs. The downloaded files are the so-called GNSS Ultra-Rapid Combined Orbit Solution Product SP3. The program `time_handle` takes data with the format presented on Table 3 and outputs data as it is shown in Table 5. The First 13 columns from the cycle slip detector output are kept the same. Three new columns are added with the following data: the three components, `x`, `y` and z, for the Line of Sight (LoS) vector (unitary dimensionless vector), troposphere mapping and correction, satellite pseudorange (in meters), relativistic correction, satellite phase center, satellite yaw, the satellite along, cross and radial vector, and satellite elevation angle (in degrees). Within the `time_handle.pl` process the programs `brdc2axis.pl`, `sp32txt.pl`, `add_brdc_clock_2_igu.pl`, `merge_orbit_files.pl`, `detect_eclipse`, `del_eclipse_data.pl` and `model` are invoked and executed. The following log files are created: `axis.dat` and `orbit_gnss.dat`.

It is worth to mention that, for both real and non-real applications, the program `time_handle` requires SP3 and RINEX files corresponding not only to the current day to be calculated, but it also requires this two files corresponding to the day before of the current day to be calculated. For instance, if AATR and MSTID indexes are intended to be computed for the day 340 of the year 2018 at Toulouse (TLSE) station, user needs to have access to RINEX of the current day (i.e. TLSE341.18O) and RINEX of the day before (i.e. TLSE341.18O). The program will automatically download the necessary SP3 files corresponding to the current day (i.e. 2030/igu20304_HH.sp3.Z) and the SP3 file corresponding to the day before (i.e. 2030/igu20303_HH.sp3.Z).

6.5 Prefits

Computes the prefits residuals between the measured and the modelled pseudorange. It takes as input data format as indicated in Table 5, and outputs the *prefit residuals* data format shown in Table 6. While executing the `prefits_rt.pl` process, the following programs are invoked and executed: `read_antenna_pc.pl`, `read_antenna_pc_before_w1400.pl`, and `computes_tides.pl`. For control purposes, the following log files are created: `rover.obs`, `rover.sta`, `antenna.log`, `antenna.dat` and `tides.dat`.

6.6 Check arcs

This is one of the main programs, it computes the Slant TEC (STEC) rates for AATR index computations and computes the so-called double differences of STEC (DDSTEC) for the computation of MSTID indicator. It takes input data format as indicates in Table 6. In the first four columns it is written data for seconds of the day, station name, satellite and arcs. The STEC second derivatives with rates at 30, 150 and 300 seconds are computed in the columns five, six and seven. The Ionosphere Pierce Point (IPP) velocity is given at column 8, and its longitude and latitude on columns 10 and 11. Troposphere mapping functions is given on column 9. Columns 12, 13 and 14 provides the three components, `x`, `y` and z, for the Line of Sight (LoS) vector (unitary dimensionless vector). Lastly, the cosine of the sun angle is computed in the column 15. The output format of the program `check_arcs.pl` is given in Table 4.

Seconds	Station	Satellite	Arc	DD STEC 150s	DD STEC 300s	STEC 30s	IPP vel km/s	Mapping	IPP (long)	IPP (lat)	LoS X	LoS y	LoS Z	Sun Angle
31860	ACOR	8	1	-0.0007171	0.0001132	0.0000833	0.9801887	1.3247974	13.8052024	18.04845	0.92333	0.22688	0.30982	0.77545
31860	ACOR	10	1	-0.0003774	0.0023904	0.0006033	0.7534093	7.1537415	107.0427380	40.35366	-0.22335	0.72860	0.64750	0.45711
31860	ACOR	18	1	-0.0000466	-0.0000466	0.0000133	0.9465238	1.0723161	1.7727288	57.94082	0.53054	0.01642	0.84750	0.39346
31860	ACOR	22	1	0.0014120	0.0052860	0.0000033	0.9615753	1.3810168	-22.8754134	12.12238	0.90081	-0.38006	0.21000	0.28652
31860	ACOR	28	1	-0.0002220	0.0015540	0.0001033	0.8133782	2.7027091	-90.5086499	43.72148	-0.00642	-0.72268	0.69115	-0.52572

Table 4 Check arcs data format output

Year	Doy	Seconds	Station	System	Satellite	L1 (m)	L2 (m)	P1(m)	P2(m)	Arc	SN1	SN2	LoS X	LoS y	LoS Z	Trop Map	Pseudorange	Rel Corr	Trop Corr	Sat PC	Yaw x	Along Vector	Cross Vector	Radial Vector	Elevation
18	304	31260	ACOR	G12	8	20850570.3787	20850572.8972	20850570.4420	20850572.9820	1	512	502	0.89781367	0.20360564	0.39048093	1.12064759	20814440.2387	0.5019	2.6665	2.3691	-2.1814	0.10733257	-0.00401023	0.99421509	63.15
18	304	31260	ACOR	G12	10	24075565.1494	24075566.5789	24075565.2200	24075566.8000	1	402	385	-0.16989459	0.70930844	0.68411794	3.64743471	24126352.2647	-2.6680	8.6153	2.2338	3.7817	0.22606047	-0.04673453	0.97299155	15.80
18	304	31260	ACOR	G12	18	19935989.0798	19935989.3706	19935989.0080	19935989.3080	1	505	495	0.52651575	-0.06824271	0.84742203	1.03324223	19958234.7708	1.5503	2.4588	2.4653	4.0541	0.00796775	0.06154685	0.99807239	75.42
18	304	31260	ACOR	G12	22	21481111.4056	21481109.0494	21481111.3980	21481108.9780	1	487	472	0.90779889	-0.39979784	0.12673937	1.27769840	21312799.4427	4.6808	3.0395	2.3253	-2.0424	-0.13966680	-0.05051906	0.98890900	51.48
18	304	31260	ACOR	G12	28	22974486.7640	22974485.9785	22974486.8680	22974485.9280	1	460	387	-0.06495647	-0.69163617	0.71931917	1.91775275	23200041.7455	-4.0345	4.5562	0.9810	-2.1954	-0.13475396	-0.14937751	0.97955486	31.38

Table 5 Time handle output data format

Year	Doy	Seconds	Station	System	Satellite	L1 res	L2 res	P1 res	P2 res	Arc	SN1	SN2	LoS X	LoS y	LoS Z	Trop Map	Along Vector	Cross Vector	Radial Vector	Elevation
18	304	31260	ACOR	G12	8	36129.5064	36132.0436	36129.5037	36132.0437	1	512	502	0.89781367	0.20360564	0.39048093	1.12064759	0.10733257	-0.00401023	0.99421509	63.15
18	304	31260	ACOR	G12	10	-50790.8617	-50789.4647	-50790.6766	-50789.0966	1	402	385	-0.16989459	0.70930844	0.68411794	3.64743471	0.22606047	-0.04673453	0.97299155	15.80
18	304	31260	ACOR	G12	18	-22247.3246	-22247.0686	-22247.2737	-22246.9737	1	505	495	0.52651575	-0.06824271	0.84742203	1.03324223	0.00796775	0.06154685	0.99807239	75.42
18	304	31260	ACOR	G12	22	168306.6490	168304.3104	168306.5796	168304.1596	1	487	472	0.90779889	-0.39979784	0.12673937	1.27769840	-0.13966680	-0.05051906	0.98890900	51.48
18	304	31260	ACOR	G12	28	-225554.5544	-225555.3210	-225554.5169	-225555.4569	1	460	387	-0.06495647	-0.69163617	0.71931917	1.91775275	-0.13475396	-0.14937751	0.97955486	31.38

Table 6 Prefit residuals output data format

6.7 Medium Scale TID index

This programs computes and detects the *Traveling Ionospheric Disturbances* (TIDs) of medium scale (MSTID) amplitude RMS of the DD STEC during the last 10 minutes. It takes as input data format as shown in Table 4, and outputs the following information (see Table 7): Seconds of the day, station name, satellite, arcs, MSTID amplitude, IPP longitude and latitude, the three components, `x`, `y` and z, for the Line of Sight (LoS) vector (unitary dimensionless vector), the mapping tropospheric and a flag indicator in case there is not enough data in a time span of 10 minutes to make the computations. The data file `mstid_idx.yy.doy.dat` is created while executing this program. The fields `yy` and `doy` corresponds to the year and the day of the year of the results.

sec	Station	Satellite	Arcs	MSTID amplitude (LI m)	IPP Long (degrees)	IPP Lat (degrees)	LoS X	LoS y	LoS Z	Mapping	Flag
31260	ACOR	8	1	0.0007922	-134.57	21.74	0.89781367	0.20360564	0.39048093	1.1	0
31260	ACOR	10	1	0.0019113	37.53	53.29	-0.16989459	0.70930844	0.68411794	3.6	0
31260	ACOR	18	1	0.0035796	-116.67	-41.10	0.52651575	-0.06824271	0.84742203	1.0	0
31260	ACOR	22	1	0.0025992	-98.69	54.93	0.90779889	-0.39979784	0.12673937	1.2	0
31260	ACOR	28	1	0.0018164	-3.82	-2.84	-0.06495647	-0.69163617	0.71931917	1.9	0

Table 7 MSTID output data format

6.8 AATR index

Computation of the AATR index is done using the code `aatr.pl`, which takes as input data with the format of the data presented on Table 7 and outputs the AATR index values with a rate of 300 seconds. The data output format is presented in Table 8 and contains: year, day of the year, seconds of the day, station name and the AATR indicator index, in LI cm/s units. The term LI is the result of the basic input of the *AATR+MSTID version 1.0,* that is the geometry-free (or ionospheric) combination of the two GNSS carrier phases (LI=L1-L2) Users may need AATR index in terms of TECU's (Total Electron Content Units) per minute. This is achieved multiplying LI by a constant factor of 5.7. The file `aatr.yy.doy.dat` is created while executing this program and contains the data as shown in Table 8. The fields `yy` and `doy` corresponds to the year and the day of the year of the results.

Year	Day of Year	Seconds of the day	Station	AATR index (cm/s L1)
17	304	31260	ACOR	0.00416
17	304	31260	ACRB	0.01353
17	304	31260	ADIS	0.00447
17	304	31260	AGAB	0.01249
17	304	31260	AJAC	0.00413
17	304	31260	ALBB	0.01006

Table 8 AATR index output data format

Annex 1

NTRIP client software

As it has been mentioned across all the document, RINEX observation files are the basic input of the *AATR+MSTID version 1.0* code. In order to run a real time process, it is necessary to continuously download RINEX files. This process can be achieved using a NTRIP client, which manages to acquire and download data from a network of stations broadcasting RTCM using internet.

There is a consistent list of NTRIP clients with different characteristics and performances dedicated to the different user's needs. To mention some of them:

- Lefebure Design, LLC (http://lefebure.com/software/ntripclient/)
- RTKLIB (http://rtklib.com/)
- GNSS surfer (http://217.9.43.196/Download/GnssSurferV1.10.zip)
- BKG NTRIP Client BNC (http://igs.bkg.bund.de/ntrip/download)

BNC provides a very friendly and ready to use graphical user interface for Windows, Linux and Macintosh operating systems, with capability of working in command line for background processes. This is a great advantage for users requiring real-time data on an automatic basis. The BNC software allows users to choose between RINEX 2 and 3 versions to be downloaded, to select the folder to store and gather data in the host computer, to select the data streams with NTRIP information from different stations belonging to different networks. For detailed information in relation with installation, configuration and operation of BNC please visit http://acc.igs.org/misc/bnchelp.pdf.

When using any of the before mentioned software, it is important to be aware of the following remarks:

- The transmission of information through internet is done using the protocol RTCM, meaning that information from any station is formatted according to this protocol. It is necessary that the NTRIP client software converts RTCM to RINEX.
- Access to different data streams may be not guaranteed: Stations belonging to positioning services networks, such as International GNSS Service IGS (http://www.igs.org/) or EUREF permanent network EPN (http://www.epncb.oma.be), requires a registration and authentication process, necessary to get the access to data streams from different stations.

END OF DOCUMENT