USER'S GUIDE FOR TILT SOFTWARE

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Purpose

Tilt program calculates tilt of ionosphere at the specific observation point and time. One of the main features of this program is that it can calculate real time tilt of ionosphere. Calculation is based on data that taken from *Digisonde system*, so called, *drift data*. More precisely, it is based on *sky-data* that is derived from raw *drift data*. Sky-data contains 3-D coordinates of source reflective points together with its radial velocities, i.e. velocity along the ray going from observation point to this source reflective point. Tilt is described as unit-vector that is perpendicular to ionosphere plane. So this unit-vector can be completely presented as two angles in spherical coordinate system, *polar angle* and *azimuthal angle*. We will call *polar angle* by *zenith angle* or, simply, *zenith* and *azimuthal angle* by *azimuth*. We will always to connect spherical coordinates to the left-handed Cartesian coordinates with the center at the point of observation, with axes OZ going upward, OX going to geographical North and OY going to East.

OS Environment

Tilt program is written in *Java language* so it can work on any Operating System that contains *Java Machine*.

Modes

It can work in three modes. They are *graphic interactive*, *console batch* and *real time* mode. Presently, *graphic interactive* and *console batch* modes are intended exclusively for testing various tilt calculation algorithms and developing new ones.
Real time mode is for Digisonde system environment. In this mode Tilt program works silently in non-graphic non-interactive mode analyzing specified *sky-file* together with previously produced *tlt-files* and as result produces new *tlt-file* containing tilt and some additional information that correspond to specified *sky-file*.

Launch

To run program Tilt in *graphic interactive* mode you have (being in directory where Tilt.exe is located) to type:

Tilt.exe

To run Tilt program in *console batch* mode you have (being in directory where Tilt.exe is located) to type:

tilt.exe `-c -f:input_file -e:export_mode -o:output_file`

where

- **`-c`** Set *console batch* mode. This parameter is mandatory, as without it program will be run in *graphic interactive* mode.
- **`-f`** Set name of file to load or name of directory from which all files with extension `.sky` will be loaded.
  Example:
  `-f:``blah_blah.sky`
  Default:
  will be taken from parameter **`CMInput`** of tilt.ini file and if it is not there then it will be set to `tilt.sky`
- **`-e`** Set one of two possible export modes:
  a) *Time Streamed Mode* (**`-e:ts`**)
  b) *Multi-day Mode* (**`-e:md`**)
  Default:
  will be taken from parameter **`CMExport`** of tilt.ini file and if it is not there then it will be set to **`ts`** (*Time Streamed Mode*)
- **`-o`** Set name of output file. If file exists it will be rewritten.
  Example:
  `-o:``blah_blah.txt`
  Default:
  will be taken from parameter **`CMOutput`** of tilt.ini file and if it is not there then it will be set to `tilt.txt`

To run Tilt program in *real time* mode you have (being in directory where Tilt.exe is located) to type:

tilt.exe `script_file`

where `script_file` is the name of script file, which contains some information about files and directories this mode need to work with. See description of script file in appendix A.

To tune parameters that control only some or all of these modes you have to open `tilt.ini` file and set appropriate changes. See description of `tilt.ini` file see in appendix B.

Parameters

You can set appropriate parameters for Tilt program. Most of these parameters you have to put in special file, ini-file, which is, by default, called `tilt.ini` . And only some of it you can or have to put in command line or script file.
Rules for both ini-file and script file are the same:

1. Comment line begins with sign # (pound sigh);
2. Not comment line contains one parameter in the form

```
key = value
```

where you can leave one or more spaces before and after equal sign for readability.

Note that key is a case-sensitive string.

Parameters in the ini-file can be divided into several groups.

Sources Filter parameters

These parameters allow you to discard some of sources and they are used for all modes of work.

Name	Units	Default	Description
SFZenithMax	degrees	10	Sources with zenith greater than this number will be discarded
SFAmpThreshold	dB	0	Sources with amplitude greater than basic threshold plus this number will be discarded
SFUseFreqRestriction	**true** or **false**	false	If `true` than frequency filter will be in force, it means sources with frequency outside of given diapason of frequencies will be discarded
SFFreqMinRestriction	Hz	1000	Minimum value of frequencies diapason
SFFreqMaxRestriction	Hz	3000000	Maximum value of frequencies diapason
SFUseRangeRestriction	**true** or **false**	false	If `true` than range filter will be in force, it means sources with range outside of given range of given diapason of ranges will be discarded
SFRangeMinRestriction	Km	100	Minimum value of ranges

Name	Units	Default	Description
			diapason
SFRangeMaxRestriction	Km	1000	Maximum value of ranges diapason
SFHighDopplerRestrictionPercent	N/A	0	Sources with Doppler number fell into 'high Doppler number sources', according to this number, will be discarded.
SFUseOnlyMaxAmplitudeSourcesOfSubcases	**true** or **false**	false	If true then only sources that have the maximum amplitude inside the subcase they belong to will be accepted
SFPolarizationFilter	N/A	both	Can be set to one of three possible values: both – both polarizations are accepted ordinary – only ordinary polarization is accepted extraordinary – only extra-ordinary polarization is accepted
SFUseCITRestriction	**true** or **false**	false	If true then *CIT* (measurement) restriction filter will be in force, it means that only sources inside given *CIT* number will be accepted
SFCIT	N/A	1	*CIT* number to accept

Method of choosing parameters

These parameters allow you to set which methods you are going to use. You can choose more than one method. Note that these parameters aren't used in *real time* mode of work.

Name	Units	Default	Description
MethodAvgSourceTilt	**true** or **false**	true	Finds average source position on skymap plane and then presents zenith and azimuth of this position as the result.

Name	Units	Default	Description
MethodSecTilt	**true** or **false**	false	Divides skymap circle area into sectors of equaled area and try three more division applying radial and rotary displacement to the first division on 'half of element length'. Then choose the segment that contains the largest number of sources and, applying method **AvgSourceTilt**, find zenith and azimuth of the tilt.
MethodSpotTilt	**true** or **false**	false	Divides sources on skymap plane into spots applying Affinity Based Spot Finding algorithm. Then choose the spot that contains the largest number of sources and, applying method **AvgSourceTilt**, find zenith and azimuth of the tilt.
MethodFitPlaneTiltZOff	**true** or **false**	false	Fits plane into sources in 3-D space using minimization of Z-offsets. Then consider tilt of this plane as ionosphere tilt.
MethodFitPlaneTiltHuang	**true** or **false**	false	Fits plane into sources in 3-D space using Prof. Huang approach, which is supposed to be close to minimization of perpendicular offsets but haven't been proven and, actually, result practically the same as for method **MethodFitPlaneTiltZOff**
MethodFitPlaneTiltRtr	**true** or **false**	false	This is the implementation of Prof. Huang idea about using the results of retracing algorithm for each reflective source based on non-tilted ionosphere profile taken from fresh real-time data (*SAO-file*)

Common calculating option parameters

These parameters allow you to set calculation options that are independent from calculation method use chose. Some of these parameters are used in *real time* mode and some not.

Name	Units	Default	Description
CalculateByFreq	**true** or **false**	false	If true then chosen methods will be applied to each frequency separately. Not used in *real time* mode.
SelectFromFreq	N/A	mean value	This parameter used only if **CalculateByFreq** is **true** and either we perform multi-days average or **OutputByFreq** is false. It means what approach we prefer to get the only one zenith and azimuth from a set of them (one for each frequency). You can choose one of the next three possibilities: mean value by source qty by best fitness or source qty Used in all modes.
MultiDays	N/A	mean	This parameter used only for multi-days average calculation and constitutes the method you want to calculate the value of zenith and azimuth for each time slot using calculated zenith and azimuth for several days for this time slot. You can choose one of the following: mean mean value median median value scatter all showed Used for all modes.
ShiftByPeriodAverageVector	**true** or **false**	true	If true then all values (zenith,azimuth) will be shifted by average vector of (zenith,azimuth) calculated over daytime period (from 9AM to 3PM SLT) Not used in *real time* mode

Output option parameters

These parameters allow you to control output. These parameters aren't used in *real time* mode.

Name	Units	Default	Description
OutputByFreq	**true** or **false**	false	If true then results for each frequency are presented.

			This parameter is no use if **CalculateByFreq** is `true` and we do not perform multi-days average.
OutputFitness	**true** or **false**	`true`	If `true` then *fitness* will be presented (of course, only for methods where it has a sense)
OutputDistance	**true** or **false**	`true`	If `true` then *distance* to observer will be presented (of course, only for methods where it has a sense)

Real time mode parameters

These parameters are intended only for *real time* mode.

Name	Units	Default	Description
DMInput_sky	N/A	""	Name, may be including path, of input *sky-file* or directory containing *sky-files*. If **DMInput_sky** is the directory the all *sky-files* in this directory will be processed in chronological order and results will be saved in the same directory. Note that parameters **DMOutput_tlt**, **DMSecure_dir** and **DMPublic_dir** will be ignored in this case (**DMInput_sky** will be considered as **DMPublic_dir** and **DMSecureDir** simultaneously)
DMOutput_tlt	N/A	""	Name, may be including path, of output *tlt-file*
DMSecure_dir	N/A	""	Name, may be including path, of *secure directory*
DMPublic_dir	N/A	""	Name, may be including path, of *public directory*
DMNoOfPrevDays	day	1.0	Number of previous days (counting from current time) that will be used for daytime shift calculation. You can use fractional number of days.
DMNoOfPrevHours	hour	2.0	Number of previous hours (counting from current time) that will be used for azimuth deviation calculation. You can use fractional number of hours.
DMPoorQuantityIn10DegZen	source quantity	7	Used for calculating of quality *qQ*
DMExcellentQuantityIn10Deg	source	100	Used for calculating of quality *qQ*

Name	Units	Default	Description
Zen	quantity		
DMPoorZenDevByFreq	Degrees	2.0	Used for calculating of quality *qZ*
DMExcellentZenDevByFreq	Degrees	0.4	Used for calculating of quality *qZ*
DMPoorAziDevByTime	Degrees	50.0	Used for calculating of quality *qA*
DMExcellentAziDevByTime	Degrees	10.0	Used for calculating of quality *qA*

Console batch mode parameters

These parameters are intended only for *console batch* mode.

Name	Units	Default	Description
CMnput	N/A	tilt.sky	Input file name
CMOutput	N/A	tilt.txt	Output file name
CMExport	N/A	TimeStreamed	Export type One of the following: TimeStreamed MultiDay

Now look at script-file parameters.

Name	Units	Default	Description
Input_sky	N/A	Taken from ini-file	Name, may be including path, of input *sky-file* or directory containing *sky-files*. If **Input_sky** is the directory the all *sky-files* in this directory will be processed in chronological order and results will be saved in the same directory. Note that parameters **Output_tlt**, **Secure_dir** and **Public_dir** will be ignored in this case (**Input_sky** will be considered as **Public_dir** and **Secure_dir** simultaneously)
Output_tlt	N/A	Taken from ini-file	Name, may be including path, of output *tlt-file*
Secure_dir	N/A	Taken from ini-file	Name, may be including path, of *secure directory*
Public_dir	N/A	Taken from ini-file	Name, may be including path, of *public directory*

Quality calculation in real time mode

We output combined quality, *qC*, for straightforward usage. It is integer number between 0 and 10 inclusively. 0 means the worst quality (tilt is unusable totally), 10 means the best quality. This combined quality is presently calculated as simple average of three other qualities and then multiplying the result by 10 with casting it to integer then:

$$qC = 10 * (qQ + qZ + qA) / 3$$

where, $0 <= qQ <= 1$, $0 <= qZ <= 1$, $0 <= qA <= 1$

Note that it may be happen that for some reason you can't calculate deviation, specifically, you can't calculate *qZ* when only one frequency exists, or you can't calculate *qA* when in previous short tilt history period there no more than one usable (with quality > 0) tilt.
In these cases:

qC = 10 * (*qQ* + *qA*) / 2, when *qZ* has no sense or

qC = 10 * (*qQ* + *qZ*) / 2, when *qA* has no sense or

qC = 10 * *qQ*, when both *qZ* and *qA* have no sense

It will be explained below how *qQ*, *qZ* and *qA* are calculated and how you can control it.

Parameters **PoorQuantityIn10DegZen** and **ExcellentQuantityIn10DegZen** control how quality *qQ* is calculated.
To put it in words, **PoorQuantityIn10DegZen** means minimal admissible number of sources per area equaled to 10-degree zenith circle of skymap for which combined quality *qC* still calculated.
It means that if number of sources per area equaled to 10-degree zenith circle of skymap is less than **PoorQuantityIn10DegZen** then combined quality, *qC*, will be set to 0 without consideration of other qualities (*qZ* and *qA*).
If the number of sources per area equaled to 10-degree zenith circle of skymap is greater or equal to **ExcellentQuantityIn10DegZen** then *qQ* is set to the maximum value, which is 1.
If number of sources per area equaled to 10-degree zenith circle of skymap, say, *qu*, is between **PoorQuantityIn10DegZen** and **ExcellentQuantityIn10DegZen** then

$$qQ = (qu - \textbf{PoorQuantityIn10DegZen}) / (\textbf{ExcellentQuantityIn10DegZen} - \textbf{PoorQuantityIn10DegZen})$$

Parameters **PoorZenDevByFreq** and **ExcellentZenDevByFreq** control how quality *qZ* is calculated. Both parameters are given in degrees.
If zenith deviation by frequency is greater than **PoorZenDevByFreq** then the combined quality, *qC*, will be set to zero without consideration other qualities (*qQ* and *qA*).
If zenith deviation by frequency is less or equal to **ExcellentZenDevByFreq** then *qZ* is set to the maximum value, which is 1.
If zenith deviation by frequency, say, *zDev*, is between **ExcellentZenDevByFreq** and **PoorZenDevByFreq** then

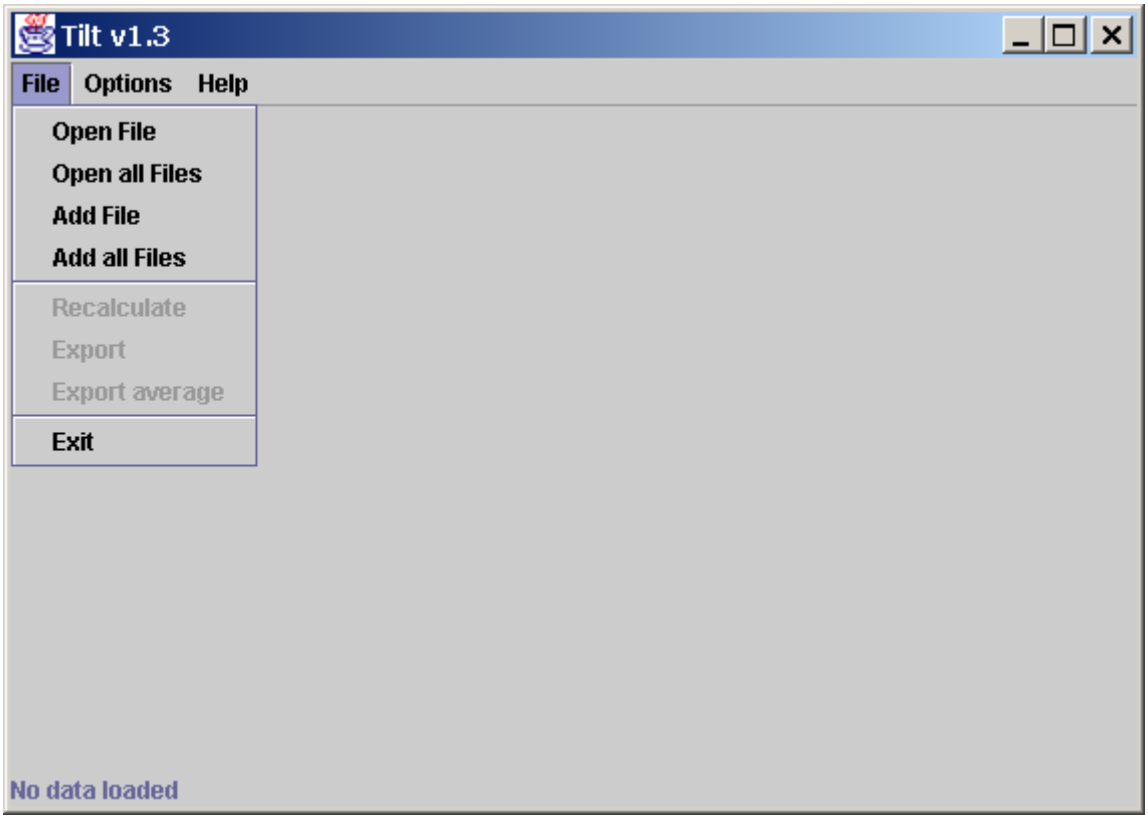
$$qZ = (zDev - \textbf{PoorZenDevByFreq}) / (\textbf{ExcellentZenDevByFreq} - \textbf{PoorZenDevByFreq})$$

Parameters **PoorAziDevByTime** and **ExcellentAziDevByTime** control how quality *qA* is calculated. Both parameters are given in degrees.
If azimuth deviation by time is greater than **PoorAziDevByTime** then the combined quality, *qC*, will be set to zero without consideration other qualities (*qQ* and *qZ*).
If azimuth deviation by time is less or equal to **ExcellentAziDevByTime** then *qA* is set to the maximum value, which is 1.
If azimuth deviation by time, say, *aDev*, is between **ExcellentAziDevByTime** and **PoorAziDevByTime** then

qA = (*aDev* - **PoorAziDevByTime**) / (**ExcellentAziDevByTime** - **PoorAziDevByTime**)

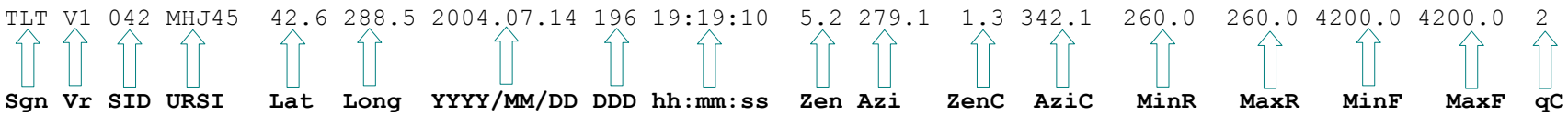
How to retest existing tilt calculation algorithm

It may happen that you will need to test already existing algorithm by changing some source filter parameters or to apply them to some other data. All you need is just tuning parameters to choose this algorithm and supplying source filter parameters with desired values. Then type tilt.exe being in the directory where tilt.exe is located or double-click on program icon. Tilt program started to run in interactive mode where you can open needed *sky-files*, calculate and export. As a result you will receive (after `export` or `export average` menu command) tilt.txt file in the directory where tilt.exe is located. You can import desired data from this file into your favorite presentation package for plotting.



Appendix A
Tilt file format

This is text file consisting of one line like below:



Name	Start pos	Length	Format	Description
Sgn	0	4	'TLT '	Signature, always TLT
Vr	4	2	'V' plus I1	'V' plus version number of data format (1 – 9)
SID	7	3	3 digits	Station ID
URSI	11	5	String	URSI Code
Lat	16	6	F6.1	Station Geographic Latitude, in deg, north +, south -
Long	22	6	F6.1	Station Geographic Longitude, in deg, eastern 0 to 360
YYYY/MM/DD	29	10	YYYY.MM.DD	Year, Month, Day
DDD	40	3	I3	Day of the year
hh:mm:ss	44	8	HH:MM:SS	hour, min, sec (Universal time)
Zen	53	4	F4.1	Raw calculated zenith, in deg, 0 – 90
Azi	58	5	F5.1	Raw calculated azimuth, in deg, geographical, eastern 0 to 360
ZenC	64	4	F4.1	Corrected zenith, in deg, 0 – 90
AziC	69	5	F5.1	Corrected azimuth, in deg, geographical, eastern 0 to 360
MinR	75	6	F6.1	Minimum Range of the detected sources, in km
MaxR	82	6	F6.1	Maximum Range of the detected sources, in km
MinF	89	6	F6.1	Minimum Frequencies of the detected sources, in kHz
MaxF	96	6	F6.1	Maximum Frequencies of the detected sources, in kHz
qC	103	6	I2	Combined quality number, integer number, 0 to 10, 0 is the worst quality (actually means as 'not usable') and 10 is the best quality (actually will never happen)