International Civil Aviation Organization

NINETEENTH MEETING OF THE COMMUNICATIONS/NAVIGATION AND SURVEILLANCE SUG-GROUP (CNS SG/19) OF APANPIRG

Bangkok, Thailand, 21 – 25 July 2014

Agenda Item 5.3: **Review outcome of Fifth Meeting of Ionospheric Studies Task Force (ISTF/5)**

CURRENT STATUS OF ISTF ACTIVITIES AND WORKING PLAN FOR DELIVERY OF ITS FINAL OUTCOMES

(Presented by Chairman, Ionospheric Studies Task Force)

SUMMARY

This paper presents the current status of ionospheric studies task force (ISTF) activities after its 5th meeting (ISTF/5) and the working plan for delivery of its final outcomes in the coming year.

1. INTRODUCTION

1.1 The Ionospheric Studies Task Force (ISTF) has been working on the coordinated ionospheric data collection, analysis and sharing to facilitate ionospheric data collection and sharing in the Asia-Pacific (APAC) region since 2011. The goals of the ISTF activities are to study the need for development of regional ionospheric threat models for GBAS and SBAS, to develop them if the need is identified, and to investigate the effects of space weather on CNS systems in the APAC Region.

1.2 The 5th meeting of the ISTF (ISTF/5) was held in Ishigaki, Japan from 16 to 18 February, 2015, which is reported in a separated working paper presented to this 19th meeting of the CNS subgroup.

1.3 After the ISTF/5, two webconferences were held on 19 June and 2 July 2015, respectively to accelerate the ISTF activities.

2. DISCUSSION

2.1 The 4th webconference of the ISTF (ISTF WC#4) was held on 19 June 2015. The meeting was attended by 6 participants from Australia, Japan, and ICAO. The summary of discussion of the meeting is attached to this working paper as Attachment 1.

2.2 One of the major topics of ISTF WC#4 was the common data format, namely SCINTEX and GTEX. It was reported that the SCINTEX and GTEX formats were approved by the

ITU-R as standard. Following the completion of standardization and recognizing the need of promulgation of the formats among the APAC region, the following draft decision was formulated:

Draft decision – ITU Standard for exchange and sharing of GNSS data

Considering the need for sharing GNSS data to study the ionospheric effects on navigation systems,

That, the SCINTEX and GTEX Formats placed at Attachment 3 and 4, respectively be adopted as ICAO APAC standard for exchange of GNSS data and posted on the ICAO regional office website.

2.3 Dr. Yoshihara, the co-task lead of Task 5, explained how ionospheric anomaly impacts on GBAS and how it should be mitigated. It was noted that a range error of about 8.5m was possible and it could result in several 10s meter errors in vertical and/or horizontal depending on the satellite geometry. Recommended methodology to develop a threat model was presented.

2.4 The 5th webconference of the ISTF (ISTF WC#5) was held on 2 July 2015. The meeting was attended by 9 participants from Australia, India, Japan, Republic of Korea, and ICAO. The summary of discussion of the meeting is attached to this working paper as Attachment 2.

2.5 Dr. Sakai, the co-task lead of Task 5, explained how the SBAS ionospheric threat model is defined and how it is mitigated for the MSAS case as an example. According to the presentation, three action items were closed:

- Identifying operational hazard for SBAS
- Identifying factors influencing SBAS ionospheric threat mitigation strategy
- Developing a structure of a guidance material

2.6 The ISTF WC#5 discussed on the intellectual property and publication of the outcomes of ISTF. It is extensively discussed in a separate working paper.

2.7 The ISTF WC#5 also discussed on the progress of Space Weather issues in a regional perspective (Task 6). Dr. Ishii highlighted the role of the ICAO WG-MISD under the ICAO MET Panel. The objective is to develop requirements on MET information, coordination, and develop ConOps. Space Weather subgroup is placed under the WG-MISD, and Dr. Ishii and Dr. Terkildsen are members of Space Weather subgroup as experts.

2.8 In relation to the Task 6 (Space Weather), collaboration between APANPIRG CNS and MET subgroups was discussed. It would be an effective way because the MET side is a space weather information service provider, while the CNS side is the user of the space weather information. To investigate the effects of space weather on CNS systems in the APAC Region as per ISTF TOR item 8, it was decided to develop high-level requirements for space weather services for CNS in APAC region. The first draft would be delivered by Dr. Saito and Dr. Ishii and then matured by a small group tentatively composed of Ms. Susan E. O'Rourke (MET SG chair), Mr. Lo Weng Kee (CNS SG Chair), Dr. Saito, Dr. Ishii, Mr. Peter Dunda (MET RO) and Mr. Frederic Lecat (CNS RO). Mr. Lecat would coordinate with the global level. Dr. Ishii would also coordinate with the ICAO WG-MISD Space Weather subgroup, being a member of the subgroup.

2.9 The working plan of the ISTF was also discussed by ISTF WC#4 and WC#5. Considering the delay of analysis, which was mainly because it took long time to obtain permission from FAA to use the Long-term Ionospheric Anomaly Monitoring (LTIAM) tool for ISTF. It was decided that the threat models will be delivered to be the CNS-SG/20 meeting in 2016. It was noted by Mr. Lecat that the CNS-SG/20 meeting will be held around May 2016, because 2016 is an ICAO assembly year. Therefore, the target date will be the end of April 2016.

2.10 To make analysis done effectively, it was suggested to share the analysis effort. ROK (Prof. Lee) offered to take part in the analysis, in addition to Australia, India, and Japan. It was also noted that the cross-check of results are important. Dr. Sunda noted the difficulty he met in using the LTIAM tool. Prof. Lee pointed out that there is a manual of the LTIAM tool and was provided by her. It was also agreed to exchange information and experience in using the LTIAM tool. ICAO will offer webconference facility upon request.

2.11 It was recalled that the next face-to-face meeting (ISTF/6) has been scheduled in January 2016 in Bangkok. The next webconference will be held from 12:00 to 14:00 on 26 August 2015 in Bangkok Time. The main topics of the webconference are

- LTIAM experience exchange
- Report and review of AATR analysis results

The revised ISTF work plan reflecting the discussions above has been developed as Table 1.

Table 1. ISTF work plan for delivery in May 2016.

Target Date	Achievements	Remarks
July - August 2015	▪ Continue AATR analysis ▪ Test LTIAM tool for ISTF data ▪ Develop a first draft of SBAS ionospheric threat guidance material ▪ Develop a first draft of regional requirements for space weather	Webconferences as needed
26 August 2015	▪ Finish AATR analysis ▪ Review the AATR results ▪ Share experience in using the LTIAM tool ▪ Review the first draft of the regional requirements for space weather	Webconference
September 2015- January 2016	▪ LTIAM analysis ▪ Cross-validation of LTIAM results with results by ENRI's tool ▪ Develop a draft of SBAS ionospheric threat guidance material ▪ Mature the regional requirements for space weather	Webconferences as needed
January 2016	▪ Review of LTIAM analysis results ▪ Review the SBAS ionospheric threat guidance material ▪ Review the regional requirements for space weather	ISTF/6 (Face-to-face)
February - April 2016	▪ Compile analysis results for GBAS threat model ▪ Draft a technical paper for publication of GBAS threat model	Webconferences as needed
April 2016	▪ Review all the results for report to CNS-SG	Webconference
May 2016	▪ Report to CNS-SG	CNS-20

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper;

b) adopt the SCINTEX and GTEX formats as ICAO APAC Standard for exchange of GNSS data and post on the ICAO regional office website;

c) accept the date of delivery of ISTF outcomes to be the 20th meeting of CNS subgroup in 2016; and

d) discuss any relevant matters as appropriate.

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ATTACHMENT 1

ISTF webconference #4 Summary of Discussion
19 June 2015

- Participants:
  - Dr. Mike Terkildsen, Research Scientist, Space Weather Services, Bureau of Meteorology, Australia
  - Dr. Mamoru Ishii, Director, National Institute of Information and Communications Technology, Japan
  - Dr. Takeyasu Sakai, Principal Researcher, Electronic Navigation Research Institute, Japan
  - Dr. Susumu Saito, Chief Researcher, Electronic Navigation Research Institute, Japan
  - Dr. Takayuki Yoshihara Chief Researcher, Electronics Navigation Research Institute
  - Mr. Frederic Lecat, ICAO APAC Regional Officer, CNS

The agenda was slighty amended and agreed as follows:

1 Review of actions
2 Outcome of ICAO PBN seminar 2015 and PBN ICG/2
3 Progress on ISTF work since ISTF/5
   3.1 Data collection
      - GTEX and SCINTEX format standardization at ITU-R (Dr. Ishii, NICT)
   3.2 Data analysis
   3.3 Data generation
   3.4 Threat models
      - GBAS threat mitigation strategy (Dr. Yoshihara, ENRI)
      - SBAS safety case guidance material (Dr. Sakai, ENRI)
   3.5 Space Weather
4 Publication and intellectual property of the ionospheric threat models
5 Work for next period
      - Report to APANPIRG CNS-SG/19
6 Dates for the next meeting/webconference
7 Any other business

1 Review of actions
Action table updated as per 19 Jun 15 is placed at Attachment A.

2 Outcome of ICAO PBN seminar 2015 and PBN ICG/2
The key note 21 concerning ISTF work was an important outcome of the PBN seminar that took place 08-10 June 2015 in ICAO premises in Bangkok:

Industry is invited to consider implementing ionospheric threat models once available in APAC Regions

3 Progress on ISTF work since ISTF/5
   - Data collection
      - GTEX and SCINTEX format standardization at ITU-R (Dr. Ishii, NICT)
        Dr. Ishii presented a paper on the GTEX and SCINTEX Format.
        He explained that the GTEX and SCINTEX Format originated from the necessity to harmonize the different vendors and future scintillation and total electron content

(TEC) files. The GTEX and SCINTEX format are extensively based on the RINEX v2 and v3.01 format, respectively. The GTEX and SCINTEX formats were proposed to be used in ITU-R WP 3L/3M and were approved to add as standard formats on ITUR P.311. A WP to CNS SG/19 including the following draft decision will enable to post it on ICAO website as regional guidance.

Draft decision – ITU Standard for exchange and sharing of GNSS data

Considering the need for sharing GNSS data to study the ionospheric effects on navigation systems,
That, the SCINTEX and GTEX Formats placed at Attachment X and Y, respectively be adopted as ICAO APAC standard for exchange of GNSS data and posted on the ICAO regional office website.

- Data analysis
  AATR analysis to be completed for end of August 2015

- Data generation
  After AATR analysis, analysis using the LTIAM tool will start.

- Threat models
  - GBAS threat mitigation strategy (Dr. Yoshihara, ENRI)
    Dr. Yoshihara explained how ionospheric anomaly impacts on GBAS and how it should be mitigated. It was noted that the range error of about 8.5m is possible and it could result in several 10s meter errors in vertical and/or horizontal depending on the satellite geometry. Recommended methodology to develop a threat model was presented.

- ISTF Work plan to be refined for 2015-2016
  - It was decided that the threat models will be delivered to be the CNS-SG/20 meeting in 2016. It was noted by Mr. Lecat that the CNS-SG/20 meeting will be held around May 2016, because 2016 is an ICAO assembly year. Therefore, the target date will be the end of April 2016.

Since the time allocated for the webconference ran out, it was decided to have additional webconference from 01:30 to 03:30pm on 2 July 2015 in the Bangkok time.
The agenda for the meeting will be

- SBAS safety case guidance material (Dr. Sakai, ENRI)
- Space Weather
- Publication and intellectual property of the ionospheric threat models
- ISTF Work plan to be refined for 2015-2016
- Work for next period
  - Report to APANPIRG CNS-SG/19
- Dates for the next meeting/webconference
- Any other business

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ATTACHMENT 2

ISTF webconference #5 Summary of Discussion
2 July, 2015

- Participants:
  - Dr. Mike Terkildsen, Research Scientist, Space Weather Services, Bureau of Meteorology, Australia
  - Dr. Surendra Sunda, Sr. Manager (CNS), GAGAN Project Airport Authority of India, India
  - Mr. Pradeep V. Khekale, Sci/Engr 'SG', Indian Space Research Organization, India
  - Dr. Mamoru Ishii, Director, National Institute of Information and Communications Technology, Japan
  - Dr. Takeyasu Sakai, Principal Researcher, Electronic Navigation Research Institute, Japan
  - Dr. Susumu Saito, Chief Researcher, Electronic Navigation Research Institute, Japan
  - Dr. Takayuki Yoshihara Chief Researcher, Electronics Navigation Research Institute
  - Prof. Jiyun Lee, Korean Advanced Institute of Science and Technology, Republic of Korea
  - Mr. Frederic Lecat, ICAO APAC Regional Officer, CNS

The agenda was agreed as follows:

1 SBAS safety case guidance material (Dr. Sakai, ENRI)
2 Space Weather
3 Publication and intellectual property of the ionospheric threat models
4 ISTF Work plan to be refined for 2015-2016
5 Work for next period
6 Report to APANPIRG CNS-SG/19
7 Dates for the next meeting/webconference
8 Any other business

1 SBAS safety case guidance material (Dr. Sakai, ENRI)

Dr. Sakai explained how SBAS ionospheric threat model is defined and how it is mitigated for the MSAS case as an example. Then the responses to the action items identified at the ISTF/5 meeting (AIs 5/3, 5/4, and 5/5) are presented. The summary of discussion on each AI is as follows:

AI 5/3: Identifying operational hazard for SBAS

The spatial variation of ionospheric delay is dominant and the temporal variation is not as significant as the spatial one. The meeting requested to include some typical values for range error for spatial and temporal variation.

AI 5/4: Identifying factors influencing SBAS ionospheric threat mitigation strategy

Observation density, fidelity of ionospheric model, availability of archived data, and system specific implementation of ionospheric correction are identified as the factors of importance.

AI 5/5: Developing a structure of a guidance material

A draft table of contents is presented. After discussion, it was requested to include APAC regional consideration and typical values of influencing factors for SBAS mitigation strategy.

2 Space Weather

- ICAO WG-MISD (MET information and Services Development)

  Dr. Ishii explained on the ICAO WG-MISD under the ICAO MET Panel. The objective is to develop requirements on MET information, coordination, and develop ConOps. Space Weather subgroup is placed under the WG-MISD, and Dr. Ishii and Dr. Terkildsen are members of Space Weather subgroup as expert.

- Collaboration between APANPIRG CNS and MET subgroups
  Dr. Saito explained that there was a discussion on the possible collaboration between the SGs for the study of regional aspects of space weather with Chairs of APANPIRG CNS and MET SGs during the APANPIRG ABSRTF/2 meeting in Bangkok. This is done to investigate the effects of space weather on CNS systems in the APAC Region as per ISTF TOR item 8. It was decided to develop high-level requirements for space weather services for CNS in APAC region. The first draft will be done by Dr. Saito and Dr. Ishii. The maturation of the draft will be done by a small group tentatively composed of Ms. Susan E. O'Rourke (MET SG chair), Mr. Lo Weng Kee (CNS SG Chair), Dr. Saito, Dr. Ishii, Mr. Peter Dunda (MET RO) and Mr. Lecat (CNS RO). Mr. Lecat will coordinate with the global level. Dr. Ishii will also coordinate with the ICAO WG-MISD Space Weather subgroup, being a member of the subgroup.

3 Publication and intellectual property of the ionospheric threat models
A draft working paper on the intellectual property and publication of ISTF outcomes to be presented at the CNS/19 meeting was presented. It was agreed that the ISTF outcomes, namely the GBAS threat model and SBAS guidance material, should be in public domain. They should preferably be published in some technical journals which allow free access of readers. Dr. Saito and Prof. Lee will search suitable journals.

4 ISTF Work plan to be refined for 2015-2016
It was discussed how the analysis will be performed. Since the analysis takes time, it was suggested to share the analysis effort. ROK (Prof. Lee) offered to take part in the analysis, in addition to Australia, India, and Japan. It was also noted that the cross-check of results are important. Dr. Sunda noted the difficulty he met in using the LTIAM tool. Prof. Lee pointed out that there is a manual of the LTIAM tool and was provided by her. It was also agreed to exchange information and experience in using the LTIAM tool. ICAO will offer webconference facility upon request.

5 Work for next period
5.1 Report to APANPIRG CNS-SG/19
Report on ISTF/5 meeting in February will be prepared by Mr. Lecat. It will also refer to the PBN seminar where ISTF activities were presented.
Two working papers will be prepared by Dr. Saito. One of them reports on the discussion and outcomes of the 4th and 5th webconferences. The other is on the publication and intellectual property of the threat model.

6 Dates for the next meeting/webconference
It was recalled that the next face-to-face meeting (ISTF/6) has been scheduled in January 2016 in Bangkok.
The next webconference will be held from 12:00 to 14:00 on 26 August 2015 in Bangkok Time. The main topics are
- LTIAM experience exchange
- Report and review of AATR analysis results

7 Any other business
There was no particular item discussed under this agenda item.

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ATTACHMENT 3

SCINTEX

SCINTINTILLATION AND TEC EXCHANGE FORMAT

VERSION 0.3

For testing scintillation prediction models in Recommendation ITU-R P.531 it would be necessary to maintain a data set of scintillation statistics. To arrive at this, a consistent way of storing the observed data would be desirable - the SCINTEX format has been adopted by scientists around the world and has been proposed to be used in WP 3L at its last meeting. This document is the detailed description of the SCINTEX format.

1. Revision History

01 Apr 2014 **(v0.0)**	**- Creation of the document**
14 Apr 2014 **(v0.1)**	**- Adding ROTI observable.** **- Added comments of Dr. Tsugawa concerning:** **- Naming of files** **- Multi-constellation Examples** **- Missing INTERVAL format on APPENDIX**
22 Apr 2014 **(v0.2)**	**- Suggestions of ISTG included.** **- IRNSS included (Surendra Sunda)**
23 Mar 2015 **(v0.3)**	**- Change on the header description** **- Inclusion of non-frequency dependent observables in the APPENDIX.** **- Inclusion of Slant Tropospheric delay per satellite as non-frequency dependent observable (HTR, WTR, TTR)**

2. References

[1] Werner Gurtner and Lou Estey "RINEX/ The RInex Independent Exchange Format, version 3.01"

3. Introduction

The SCINTEX Format originates from the necessity to harmonize the different vendor and future scintillation and total electron content (TEC) files.

The format is extensively based on the RINEX v3.01 format, see 0[1], trying to keep as much features as possible to allow the *compatibility* and easy adoption of it. The reason behind is that RINEX coped before with the problems of sharing large amounts of data between different multichannel systems and it is the standard for exchange of GNSS data.

4. General format description

The SCINTEX version 0.0 format consists of a single ASCII file containing all necessary information:

1 Observation data File

The file consists of a header section and a data section. The header section contains global information for the entire file and is placed at the beginning of the file. The header section contains header labels in columns 61-80 for each line contained in the header section. These labels are mandatory and must appear exactly as given in these descriptions and examples. The format has been developed to mimic the RINEX v3 in order to maintain as much compatibility as possible. In computer systems allowing variable record lengths the observation records may be kept as short as possible. Trailing blanks can be removed from the records. There is no maximum record length limitation for the observation records.
The actual format descriptions as well as examples are given in the Tables at the end of the paper.

5. The exchange of SCINTEX files

It is recommended the following naming convention:

```
ssssdddf.yyT
|   |   | | |
|   |   | | +--    T:    Scintillation and TEC files
|   |   | |
|   |   | +----   yy:    two-digit year
|   |  +------     f:    file sequence number/character within day.
|   |                    daily file: f = 0 (zero)
|   |                    hourly files:
|   |                    a = 1st hour: 00h-01h; b = 2nd hour: 01h-02h;
|   |                          . . .       x = 24th hour: 23h-24h
|   +---------  ddd:    day of the year of first record
+------------- ssss:    4-charcter station name designator
```

For 15-minutes high-rate data (mostly TEC) the following name convention could be used:

```
ssssdddhmm.yyT
|   |  ||  | |
|   |  ||  | +--  T:    Scintillation and TEC files
|   |  ||  +---- yy:    two-digit year
|   |  |+-----   mm:    starting minute within the hour (00,15,30,45)
|   |  +------    h:    character for the n-th hour in the day.
|   |
|   |                   a = 1st hour: 00h-01h; b = 2nd hour: 01h-02h;
|   |                         . . .       x = 24th hour: 23h-24h
|   +---------  ddd:    day of the year of first record
+------------- ssss:    4-charcter station name designator
```

6. SCINTEX version features

The data for the scintillation parameters will follow the RINEX v3.01 channel allocation, but tailored to the needs of the ionospheric community.

A. Main observables

The main observable will be on the form of the observation code **tna** consists of three parts:

- **t** : observation type: **W** = S4,

Y = Sigma phase index,
S = Signal strength,
V = S4 correction,
T = Lock Time,
M = Code Carrier Divergence (in meters * 10),
N = Sigma Code Carrier Divergence (in meters * 10),
R = Standard deviation of Rate change of TEC (ROTI)
***A** = Ambiguity of the phase observable*

- **n** : band / frequency:
- **a** : attribute:

B. Ionosphere delay observables

Additionally to the **TEC** observable (see Non-frequency dependent data below) the SCINTEX maintains the ionospheric delay as in the RINEX v3. The ionosphere phase delay is expressed in full cycles of the respective satellite system-dependent wavelength as observable.
Additionally the Satellite and Receiver Code Biases can be included (for instance, the Raw Ionospheric delay could be recovered).
It is recommended to use this observable for high accuracy and high frequency ionosphere data.
If the receiver raw ionosphere data is used, then the **TEC** observable (see Non-frequency dependent data below) should be used instead.

- **t** : observation type: **I** = Ionosphere phase delay
  J = Satellite Delay Code Biases
  K = Receiver Delay Code Biases
- **n** : band / frequency: 1, 2,...,8
- **a** : attribute: blank

The Satellite and Receiver Delay Code biases are included for high precision applications. It is allowed high sampling of the Satellite and Receiver Delay Code biases that are provided by a model. Since the Code biases are dependent on 2 frequencies this has to be indicated in the header under the **SYS / DCBS COMB**
The ionosphere delay observable has to be included into the list of observables of the respective satellite system. It is recommended one ionosphere delay observable per satellite.

d_ion(f j) = d_ion(fi) * (f i/fj)^2 (accounting for 1st order effects only)
d_ion(fi): Given ionospheric phase correction for frequency fi

If Delay Code biases are included they should be treated as follows:

d_ion_raw(fi)=d_ion(fi)+dcb_sat(fi)+dcb_rec(fi) ;

with,

dcb_xxx(fj)=dcb_xxx(fi) * (f i/fj)^2

Thus, the relation with the 2 fi and fj observables are derived from (see dual frequency observations **SYS / DCBS COMB**):

dcb_sat(fi)= (TR_sat(fi) – TR_sat(fj))/(1-(fi/fj)^2)
dcb_rec(fi)= (TR_rec(fi) – TR_rec(fj))/(1-(fi/fj)^2)
where TR_xxx(fi) are the group delays on frequency fi

It could also imply that:

d_ion(fi)=d_ion(fi,fj)*1/((fi/fj)^2-1);
where d_ion(fi,fj) := P(fj)-P(fi)

In general, RINEX v3 should be used to exchange GNSS observables. However, SCINTEX allows including the RINEX observables (`P` and `L` as observable type) when high rate Ionospheric data is delivered. It is recommended that if the observables are included they should be checked and filtered, and if possible cycle slips should be removed.
Examples:

– W1C: C/A channel S4 derived index
– W5Q: Pilot channel S4 derived index
– Y1P: P channel Sigma Phase derived index

C. Non-frequency dependent data

Most scintillation receivers could provide the slant TEC (sTEC) as an important output. This TEC is supposed to be less accurate than post-process one, but it can give information about the ionosphere directly from the receiver output.

TEC = Slant Total Electron Content (sTEC) from the receiver (could be either Raw or Calibrated; should be specified in the header) **in TEC Units * 1e3**
(1 TEC Unit = 1TECU = 10^{16} e^{-} m^{-2}*)*

d_ion(fi) = 40.3/fi^2 * TEC *1e16 *1e-3 (in meters of signal in fi)

DEC = difference of sTEC from last epoch (t – INTERVAL) **in TEC Units * 1e3**
ELE = Elevation of the satellite in view **in degrees * 1e6**
AZI = Azimuth of satellite in view **in degrees * 1e6**
HTR = Slant Hydrostatic tropospheric delay **in mm**
WTR = Slant Non-Hydrostatic tropospheric delay **in mm**
TTR = Slant Total tropospheric delay **in mm**

The values are scaled to fully represent the accuracy if necessary.

D. Band and channel description

System	Freq. Band	Frequency	Channel or Code	Channel ID
GPS	L1	1575.42	C/A	1C
			L1C(M)	1S
			L1C(L)	1L
			L1C(M+L)	1X
			P	1P
			Z-Tracking and similar (AS on)	1W
			Y	1Y
			M	1M
			codeless	1N
	L2	1227.60	C/A	2C
			L1(C/A)+(P2-P1) (semi-codeless)	2D
			L2C (M)	2S
			L2C (L)	2L
			L2C (M+L)	2X
			P	2P
			Z-Tracking and similar (AS on)	2W
			Y	2Y
			M	2M
			codeless	2N
	L5	1176.45	I	5I
			Q	5Q
			I+Q	5X
GLONASS	G1	1602+k*9/16 k= -7...+12	C/A (GLONASS M)	1C
			P	1P
	G2	1246+k*7/16	C/A (GLONASS M)	2C

			P	**2P**
	G3	**1202.025**	**I**	**3I**
			Q	**3Q**
			I+Q	**3X**
Galileo	**E1**	**1575.42**	**A PRS**	**1A**
			B I/NAV OS/CS/SoL	**1B**
			C no data	**1C**
			B+C	**1X**
			A+B+C	**1Z**
	E5a	**1176.45**	**I F/NAV OS**	**5I**
			Q no data	**5Q**
			I+Q	**5X**
	E5b	**1207.140**	**I F/NAV OS**	**7I**
			Q no data	**7Q**
			I+Q	**7X**
	E5 (E5a + E5b)	**1191.795**	**I**	**8I**
			Q	**8Q**
			I+Q	**8X**
	E6	**1278.75**	**A PRS**	**6A**
			B C/NAV CS	**6B**
			C no data	**6C**
			B+C	**6X**
			A+B+C	**6Z**
SBAS	**L1**	**1575.42**	**C/A**	**1C**
	L5	**1176.45**	**I**	**5I**
			Q	**5Q**
			I+Q	**5X**

BDS	**B1**	**1561.098**	**I**	**1I**
			Q	**1Q**
			I+Q	**1X**
	B2	**1207.14**	**I**	**7I**
			Q	**7Q**
			I+Q	**7X**
	B3	**1268.52**	**I**	**6I**
			Q	**6Q**
			I+Q	**6X**
QZSS	**L1**	**1575.45**	**C/A**	**1C**
			L1C (D)	**1S**
			L1C (P)	**1L**
			L1C (D+P)	**1X**
			L1-SAIF	**1Z**
	L2	**1227.60**	**L2C (M)**	**2S**
			L2C (L)	**2L**
			L2C (M+L)	**2X**
	L5	**1176.45**	**I**	**5I**
			Q	**5Q**
			I+Q	**5X**
	LEX(6)	**1278.75**	**S**	**6S**
			L	**6L**
			S+L	**6X**
IRNSS	**L5**	**1176.45**	**Unknown**	**5**
	S	**2492.028**	**Unknown**	**9**

Unknown tracking mode: In case of unknown tracking mode or channel the attribute **a** can be left blank. However, a mixture of blank and non-blank attributes within the same observation type of the same frequency band and of the same satellite system has to be avoided.

E. Satellite system-dependent list of observables

The order of the observations stored per epoch and satellite in the observation records is given by a list of observation codes in a header record. As the types of the observations actually generated by a receiver may heavily depend on the satellite system SCINTEX uses the same solution as in RINEX v3 and requests system-dependent observation code list (header record type **SYS / # / OBS TYPES**).

F. Signal strengths

The raw signal strengths optionally stored as **Sna** observations in the data records should be stored in dbHz if possible. The new SIGNAL STRENGTH UNIT header record can be used to indicate the units of these observations. (This is the preferred option)

G. Observation data records

As the types of the observations and their order within a data record depend on the satellite system, the new format should make it easier for programs as well as human beings to read the data records. Each observation record begins with the satellite number snn, the epoch record starts with special character >. It is now also much easier to synchronize the reading program with the next epoch record in case of a corrupted data file or when streaming observation data. There is no record length limitation.

For the following list of observation types for the six satellite systems G,S,E,R,B,J

```
G    7 W1C Y1C S1C T1C TEC AZI ELE                             SYS / # / OBS TYPES
S    7 W1C Y1C S1C T1C TEC AZI ELE                             SYS / # / OBS TYPES
E    7 W1C Y1C S1C T1C TEC AZI ELE                             SYS / # / OBS TYPES
R    7 W1C Y1C S1C T1C TEC AZI ELE                             SYS / # / OBS TYPES
B    7 W1I Y1I S1I T1I TEC AZI ELE                             SYS / # / OBS TYPES
J    7 W1C Y1C S1C T1C TEC AZI ELE                             SYS / # / OBS TYPES
I    7 W5  Y5  S5  T5  TEC AZI ELE                             SYS / # / OBS TYPES
```

The epoch and observation records look as follows *(not real data example)*:

```
> 2011 08 28 21 06  0.0000000  0 09
G09         0.141         0.036        50.000       211.000         3.500   9200000.000  75000000.000
G25         0.121         0.056        43.900       211.000         6.100  55100000.000  45000000.000
S20         0.061         0.066        45.900       321.000         4.000  25200000.000  55000000.000
E19         0.100         0.076        48.000       211.000        11.200   5300000.000  25000000.000
E20         0.541         0.086        43.400       211.000         8.600 245400000.000  35100000.000
R03         0.141         0.022        42.300       213.000        12.700 135700000.000  25900000.000
B01         0.341         0.036        42.700       213.000        12.200 145500000.000  26700000.000
J01         0.141         0.016        41.300       211.000        22.800  45200000.000  10100000.000
I01         0.141         0.016        41.320       211.000        25.800   5200000.000  11100000.000
```

H. Dual frequency observations

In case that the SCINTEX is used to exchange high accuracy TEC information, the **SYS / DCBS COMB** gives valuable and necessary information to know which combination has been used to get the ionosphere phase delay.
The record is allows knowing which observables have been used to compute the ionosphere phase delay. It also records which satellites are using that combination.

Examples:

```
G I 1C2P 1P2P 09 G01 G02 G03 G04 G05 G06 G07 G08 G09
```

The observable I1 for satellites from G01 to G09 has been computed using:

Code: P1C and P2P
Phase: L1P and L2P

```
E I 1C5Q
```

All Galileo satellites uses the same observations for code and phase as follows:

Code: P1C and P5Q
Phase: L1C and L5Q

I. Order of the header records, order of data records

As the record descriptors in columns 61-80 are mandatory, the programs reading a RINEX Version 3 header are able to decode the header records with formats according to the record descriptor, provided the records have been first read into an internal buffer.
We therefore propose to allow free ordering of the header records, with the following exceptions:

- The **SCINT VERSION / TYPE** record must be the first record in a file
- The **SYS / # / OBS TYPES** record(s) should precede any **SYS / DCBS COMB**.
- The **# OF SATELLITES** record (if present) should be immediately followed by the corresponding number of **PRN / # OF OBS** records. (These records may be handy for documentary purposes, and it is up to the user to include them).
- The **END OF HEADER** of course is the last header in the record

Data records: We explicitly exclude multiple epoch data records with identical time tags (exception: Event records). Epochs have to appear ordered in time.

APPENDIX

SCINTEX FORMAT DEFINITIONS AND EXAMPLES

```
+----------------------------------------------------------------------------+
|                               TABLE A1                                     |
|          GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION           |
+--------------------+-----------------------------------------+------------+
|   HEADER LABEL     |     DESCRIPTION                          |  FORMAT    |
```

```
|  (Columns61-80)    |                                          |            |
+--------------------+------------------------------------------+------------+
|SCINT VERSION / TYPE| - Format version : 0.00                  | F9.2,11X,  |
|                    | - File type: SCINTILLATION/TEC DATA      |   A23,1X   |
|                    | - Satellite System: G: GPS               |   A15,1X   |
|                    |                     R: GLONASS           |            |
|                    |                     E: Galileo           |            |
|                    |                     S: SBAS payload      |            |
|                    |                     C: BeiDou            |            |
|                    |                     J: QZSS              |            |
|                    |                     I: IRNSS             |            |
|                    |                     M: Mixed             |            |
+--------------------+------------------------------------------+------------+
|PGM/ RUN BY /DATE   | - Name of program creating current file  |    A20,    |
|                    | - Name of agency creating current file   |    A20,    |
|                    | - Date and time of file creation         |            |
|                    |   Format: yyyymmdd hhmmss zone           |    A20     |
|                    |     zone: 3-4 char. Code for time zone.  |            |
|                    |           UTC recommended                |            |
|                    |        examples:                         |            |
|                    |           CET Central European Time      |            |
|                    |           IST Indian Standard Time       |            |
|                    |           JST Japan Standard Time        |            |
|                    |           PDT Pacific Daylight Time      |            |
|                    |           ‘blank’ if not known           |            |
+--------------------+------------------------------------------+------------+
|COMMENT             | Comment line(s)                          |    A60     |*
+--------------------+------------------------------------------+------------+
|MARKER NAME         | Name of antenna marker                   |    A60     |
+--------------------+------------------------------------------+------------+
|OBSERVER/AGENCY     | Name of the observer / agency            |  A20,A40   |
+--------------------+------------------------------------------+------------+
|REC # / TYPE / VERS | Receiver number, type, and version       |   3A20     |
+--------------------+------------------------------------------+------------+
|ANT # / TYPE / VERS | Antenna number and type                  |   3A20     |
+--------------------+------------------------------------------+------------+
|APPROX POSITION XYZ | Geocentric approximate marker position   |   3F14.4   |
|                    | (Units: Meters, System: ITRS recommended)|            |
+--------------------+------------------------------------------+------------+
|POSITION LON LAT ALT| Ellipsoidal approximate marker position  |  2F14.8,   |
|                    | (Units, degrees and meters, System:      |  F14.4     |
|                    | WGS84 recommended)                       |            |
+--------------------+------------------------------------------+------------+
|SYS/ # / OBS TYPES  | - Satellite system code (G/R/E/S/C/J/M)  |    A1      |
|                    | - Number of different observation types  |   2X,I3    |
|                    | for the specified satellite system       |            |
|                    | - Observation descriptors:               | 13(1X,A3)  |
|                    |  +Non-frequency dependent:               |            |
|                    |o TEC, DEC, AZI, ELE, HTR, WTR, TTR       |            |
|                    |  +Frequency dependent:                   |            |
|                    |o Type                                    |            |
|                    |o Band                                    |            |
|                    |o Attribute                               |            |
|                    | Use continuation line(s) for more than 13|    6X      |
|                    | observation descriptors.                 | 13(1X,A3)  |
|                    | In mixed files: Repeat for each satellite|            |
|                    | system.                                  |            |
|                    |The following observation descriptors     |            |
|                    | are defined in SCINTEX Version 0.xx:     |            |
|                    | Type:                                    |            |
|                    |W = S4                                    |            |
|                    |Y = Sigma phase index                     |            |
|                    |S = Raw signal strength                   |            |
|                    |V = S4 correction                         |            |
|                    |T = Lock Time                             |            |
```

```
|                    |M = Code Carrier Divergence               |            |
|                    |N = Sigma Code Carrier Divergence         |            |
|                    |I = Ionosphere phase delay                |            |
|                    |J = Satellite Code biases                 |            |
|                    |K = Receiver Code biases                  |            |
|                    | Band:                                    |            |
|                    |1= L1        (GPS, QZSS, SBAS)            |            |
|                    |   G1        (GLO)                        |            |
|                    |   E2-L1-E1  (GAL)                        |            |
|                    |   B1        (BDS)                        |            |
|                    |2= L2        (GPS, QZSS)                  |            |
|                    |   G2        (GLO)                        |            |
|                    |5= L5        (GPS, QZSS, SBAS, IRNSS)     |            |
|                    |   E5a       (GAL)                        |            |
|                    |6= E6        (GAL)                        |            |
|                    |   LEX       (QZSS)                       |            |
|                    |   B3        (BDS)                        |            |
|                    |7= E5b       (GAL)                        |            |
|                    |   B2        (BDS)                        |            |
|                    |8= E5a+b     (GAL)                        |            |
|                    |9= S         (IRNSS)                      |            |
|                    | Attribute:                               |            |
|                    |P = P code-based   (GPS,GLO)              |            |
|                    |C = C code-based   (SBAS,GPS,GLO, QZSS)   |            |
|                    |D = semi-codeless  (GPS)                  |            |
|                    |Y = Y code-based   (GPS)                  |            |
|                    |M = M code-based   (GPS)                  |            |
|                    |N = codeless       (GPS)                  |            |
|                    |A = A channel      (GAL)                  |            |
|                    |B = B channel      (GAL)                  |            |
|                    |C = C channel      (GAL)                  |            |
|                    |I = I channel      (GPS,GAL, QZSS, BDS)   |            |
|                    |Q = Q channel      (GPS,GAL, QZSS, BDS)   |            |
|                    |S = M channel      (L2C GPS, QZSS)        |            |
|                    |L = L channel      (L2C GPS, QZSS)        |            |
|                    |S = D channel      (GPS, QZSS)            |            |
|                    |L = P channel      (GPS, QZSS)            |            |
|                    |X = B+C channels   (GAL)                  |            |
|                    |I+Q channels       (GPS,GAL, QZSS, BDS)   |            |
|                    |M+L channels       (GPS, QZSS)            |            |
|                    |D+P channels       (GPS, QZSS)            |            |
|                    |W = Z-tracking     (GPS)                  |            |
|                    |Z = A+B+C channels (GAL)                  |            |
|                    |blank : for types I and X (all) or unknown|            |
|                    |tracking mode                             |            |
|                    |All characters in uppercase only!         |            |
|                    |                                          |            |
|                    |Units:                                    |            |
|                    |S4 and S4 correction:   dimensionless     |            |
|                    |Sigma phase index:      radians           |            |
|                    |Lock Time:              seconds           |            |
|                    |CCD and Sigma CCD:      meters    * 1e1   |            |
|                    |SNR:                    receiver-dependent|            |
|                    |Ionosphere:             full cycles       |            |
|                    |DCB satellite/receiver: full cycles       |            |
|                    |TEC and DEC:            TEC Units * 1e3   |            |
|                    |AZI and ELE:            degrees   * 1e6   |            |
|                    |0 <= AZI*1e-6 < 360                       |            |
|                    |0 <= ELE*1e-6 <= 90                       |            |
|                    |                                          |            |
|                    | The sequence of the observations in the  |            |
|                    | observation records has to correspond to |            |
|                    | the sequence of the types in this record |            |
|                    | of the respective satellite system.      |            |
+--------------------+------------------------------------------+------------+
```

SIGNAL STRENGHT UNIT	Unit of the carrier to noise ratio observables Snn (if present) DBHZ: s/N given in dbHz	A20,40X	*
INTERVAL	Observation interval in seconds	F10.3	

SYS / DCBS COMB	Channels used to perform the ionospheric
	combination.
	- Satellite system (G/R/E/S/C/J)
	- Ionosphere phase delay (I)
	- 1st frequency observation
	  - Code Band (1,2..8)
	  - Code Attribute (P,A..X, blank)
	- 2nd frequency observation
	  - Code Band
	  - Code Attribute
	Additionally the phase observations can
	be specified if different from Code ones
	Otherwise leave 4 additional blanks
	- 1st frequency observation
	  - Phase Band (1,2..8)
	  - Phase Attribute (P,A..X, blank)
	- 2nd frequency observation
	  - Phase Band
	  - Phase Attribute
	- Number of satellites involved 0
	or blank: All
	   - List of satellites
	Use continuation line(s) for more than 11
	satellites
	Repeat record for each Ionosphere phase
	delay
		
		A1,1X
		A1,1X
		I1A1,
		
		I1A1,
		
		1X,
		(4X or
		I1A1,
		
		I1A1,)
		
		1X,I2.2,
		
		11(1X,A3)
		18X,
		11(1X,A3)
			*

# OF SATELLITES	Number of satellites, for which observations are stored in the file	I6	*
PRN / # OF OBS	Satellite numbers, number of observations for each observation type indicated in the SYS/ # / OBS TYPES record If more than 9 observations types: Use continuation line(s) In order to avoid format overflows, 99999 indicates >= 99999 observations. This record is (these records are) repeated for each satellite present in the data file.	3X A1,I2.2 9I6 6X,9I6	*

TIME OF FIRST OBS	- Time of first observation record
	(4-digit- year, month, day, hour, min
	sec)
	Time system:
	  - GPS (=GPS time system)
	  - GLO (=UTC time system)
	  - GAL (=Galileo System Time)
	  - QZS (= QZSS time system)
	  - BDT (=BDS Time system)
	Compulsory in mixed GNSS files Defaults:
	  GPS for pure GPS files
	  GLO for pure GLONASS files
	  GAL for pure Galileo files
	  QZS for pure QZSS files
	  BDT for pure BDS files
		5I6,F13.7,
		
		5X,A3	

TIME OF LAST OBS	- Time of first observation record	5I6,F13.7,	*

	(4-digit- year, month, day, hour, min sec) -Time system: Same value as TIME OF FIRST OBS record	 5X,A3
END OF HEADER	Last record in the header section	60X

Records marked with '*' are optional

TABLE A2
GNSS OBSERVATION DATA FILE - DATA RECORD DESCRIPTION

DESCRIPTION	FORMAT
- Record identifier : > - Epoch - year (4 digits): - month, day, hour, min (two digits) - sec - Epoch flag 0: OK 1: power failure between previous and current epoch >1: Special event - Number of satellites observed in current epoch - (reserved) - Receiver clock offset (seconds, optional)	A1 1X,I4 4(1X,I2.2), F11.7, 2X,I1, I3, 6X, F15.2,
Epoch flag = 0 or 1: OBSERVATION records follow - Satellite number - Observation - repeat within record for each observation This record is repeated for each satellite having been observed in the current epoch. The record length is given by the number of observation types for this satellite. Observations: For definition see text. Missing observations are written as 0.0 or blanks.	 A1,I2.2, m(F14.3)
--> Special events are fully compatible with RINEX v3.0 Listed the most common ones in SCINTEX - Epoch flag 2 - 5: EVENT: Special records may follow - 4: header information follows - "Number of satellites" contains number of special records to follow. 0 if no special records follow. - Maximum number of records: 999 For events without significant epoch the epoch fields in the EPOCH RECORD can be left blank	 [2X,I1] [I3]

Example SCINTEX file for GPS and Galileo:

```
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|0-
     0.00           SCINTILLATION/TEC DATA  M: Mixed        SCINT VERSION / TYPE
scintex_sept_v1     ESA                 20140401 153912 CET PGM / RUN BY / DATE
scintex file containing scintillation information           COMMENT
ESTE                                                        MARKER NAME
Unknown                                                     MARKER NUMBER
Unknown             Unknown                                 OBSERVER / AGENCY
9999999             Septentrio PolaRxS  0.0.0               REC # / TYPE / VERS
Unknown             Unknown                                 ANT # / TYPE
  5760940.0104 -1556238.7358  2276652.7023                  APPROX POSITION XYZ
  344.88314896   21.01074126    11567.5697                  POSITION LON LAT ALT
E  18 W1C V1C Y1C S1C T1C M1C N1C W7Q V7Q Y7Q S7Q T7Q M7Q   SYS / # / OBS TYPES
      N7Q TEC DEC ELE AZI                                   SYS / # / OBS TYPES
G   7 W1C Y1C S1C T1C TEC AZI ELE                           SYS / # / OBS TYPES
S   7 W1C Y1C S1C T1C TEC AZI ELE                           SYS / # / OBS TYPES
E I 1C7Q                                                    SYS / DCBS COMB
    60.000                                                  INTERVAL
  2011     8    28    21    06    0.0000000     GPS         TIME OF FIRST OBS
  2011     8    28    21    59   59.0000000     GPS         TIME OF LAST OBS
    10                                                      # OF SATELLITES
                                                            END OF HEADER
> 2011 08 28 21 06  0.0000000  0 01
E19        0.041         0.036         0.000        48.900        11.000         0.000
0.000         0.037         0.038         0.000        48.500        11.000         0.019
0.019         0.000         0.000         0.000         0.000
> 2011 08 28 21 07  0.0000000  0 06
E19        0.041         0.040         0.000        48.000        71.000      -307.520
409.090         0.037         0.039         0.000        48.300        71.000         0.018
0.129        -8.000    885261.000  13000000.000  57000000.000
E11        0.045         0.036         0.000        48.800        17.000         1.520
0.730         0.033         0.035         0.000        49.200        17.000         0.016
0.040         0.000         0.000  60000000.000 291000000.000
E08        0.040         0.039         0.000        48.200        26.000        -0.020
0.330         0.035         0.038         0.000        48.500        26.000         0.006
0.024         0.000         0.000         0.000         0.000
G09        0.141         0.036        50.000       211.000         3.500   9200000.000
75000000.000
G25        0.121         0.056        43.900       211.000         6.100  55100000.000
45000000.000
S20        0.061         0.066        45.900       321.000         4.000  25200000.000
55000000.000
```

— — — — — — — — — — — —

ATTACHMENT 4

GTEX

The **G**NSS-**T**EC **EX**change Format

Version 0.1

Space Weather and Environment Informatics Laboratory,
Applied Electromagnetic Research Institute,
National Institute of Information and Communications Technology

0. REVISION HISTORY

01 Apr 2015 - Creation of the document

1. INTRODUCTION

The purpose of the GTEX (GNSS-TEC Exchange Format) is to share slant TEC data from each GNSS receiver. By sharing slant TEC data which are not converted to the map data of vertical TEC, various ionospheric studies would be possible without affected by specific analysis procedures such as satellite/receiver bias estimation or different mapping heights.

The structure of GTEX is designed in such a way that the structure is as close to RINEX 2 [1] as possible, because RINEX 2 is a *de facto* standard in exchanging GNSS observation data and potential users of GTEX would be familiar with RINEX 2. GTEX may include more data relevant to TEC analysis in the later revisions. The format is designed to allow future extension.

2. GENERAL FORMAT DESCRIPTION

The GTEX version 1.0 format consists of a single ASCII file containing necessary information for ionospheric studies. The file is composed of two sections, a header section and a TEC data section.

The header section contains global information for the entire file and is placed at the beginning of the file. The header section contains header labels in columns 61-80 for each line. These labels are mandatory and must appear exactly as given in these descriptions and examples. All the items defined in RINEX 2 can be used in GTEX as well. There are some additional header items, such as "POSITION LON LAT ALT", " # / TYPES OF DATA", "RINEX FILE NAME" and so on.

The TEC data section starts from a line with a time stamp and list of satellites with the same format as "EPOCH/SAT" field of RINEX 2. Following the EPOCH/SAT field, TEC data as defined in "# / TYPES OF OBSERV" are recorded. After the record of TEC data for all the satellites, data set of the next epoch follows.

The format has been developed to mimic the RINEX 2 in order to maintain as much compatibility as possible. In computer systems allowing variable record lengths the observation records may be kept as short as possible. Trailing blanks can be removed from the records. There is no maximum record length limitation for the observation records.

The actual format descriptions as well as examples are given in Appendix at the end of the paper.

3. THE EXCHANGE OF GTEX FILES

It is recommended the following naming convention:

```
ssssddd0.yy_TEC
|   |    |
|   |    |
|   |    |
|   |    +----   yy:    two-digit year
|   +---------  ddd:    day of the year of first record
+------------- ssss:    the four-character marker name
```

4. GTEX VERSION 1.0 FEATURES

The data for the TEC parameters will follow the RINEX 2 channel allocation, but tailored to the needs of the ionospheric community.

A. Main data
The main data is raw slant TEC including bias ("R1") or absolute slant TEC ("A1"). Observation data which is used for the derivation of "R1" or "A1" is shown as "1O". If the main data is "A1", the information of bias-estimation program is recommended to be shown in the header section.

B. System identifier
For including TEC data which is derived from other satellite systems than GPS, such as GLONASS, the different satellite systems must be distinguished by using the 2-digit satellite number following a system identifier.

satellite system identifier

G or blank :	GPS
R :	GLONASS
S :	Geostationary signal payload
E :	Galileo

2-digit satellite number

PRN (GPS, Galileo)
slot number (GLONASS)
PRN-100 (GEO)

5. REFERENCES

[2] Werner Gurtner and Lou Estey "RINEX/ The RInex Independent Exchange Format, version 3.11"

APPENDIX:

A1. GTEX Format Definitions

TABLE A1
GTEX FILE - HEADER SECTION DESCRIPTION

HEADER LABEL (Columns61-80)	DESCRIPTION	FORMAT	
GTEX VERSION / TYPE	- Format version : 1.00 - File type: GTEX DATA	F9.2,11X, A1,19X, 20X	
PGM/ RUN BY	- Name of program creating current file - Name of agency creating current file	A20, A20, X20	
EXPONENT OF TECU	Exponent of TECU	I6,A54	*
BIAS ESTIMATION PGM	Program name for bias estimation	A60	**
COMMENT	Comment line(s)	A60	*
MARKER NAME	Name of antenna marker	A60	
REC # / TYPE / VERS	Receiver number, type, and version	3A20	*
ANT # / TYPE / VERS	Antenna number and type	3A20	*
APPROX POSITION XYZ	Geocentric approximate marker position (Units: Meters, System: ITRS recommended)	3F14.4	*
POSITION LON LAT ALT	Ellipsoidal approximate marker position (Units, degrees and meters, System: WGS84 recommended)	2F14.8, F14.4	
# / TYPES OF OBS	- Number of different observation types stored in the original RINEX file - Observation types -Observation code -Frequency code The following observation types are defined in RINEX Version 2.11: Observation code (use upper case only): C: Pseudorange GPS: C/A, L2C Glonass: C/A Galileo: All P: Pseudorange GPS and Glonass: P code L: Carrier phase D: Doppler frequency S: Raw signal strengths or SNR values as given by the receiver for the respective phase observations Frequency code GPS Glonass Galileo SBAS	3X,A2 11(3X, A1, A1)	

	1: L1 G1 E2-L1-E1 L1 2: L2 G2 -- -- 5: L5 -- E5a L5 6: -- -- E6 -- 7: -- -- E5b -- 8: -- -- E5a+b --		
# / TYPES OF DATA	- Number of different data types stored in the file - Data types The following data descriptors are defined in GTEX Version 1.0: R1: raw slant TEC including bias A1: Absolute slant TEC 1F: TEC status flag 1O: Observation data used for TEC ZN: satellite zenith angle AZ: Satellite azimuth angle R1 or A1 is necessary. The sequence of the observations in the observation records has to correspond to the sequence of the types in this record of the respective satellite system.	3X,A2 11(3X,A2)	
INTERVAL	Observation interval in seconds	F10.3	
TIME OF FIRST OBS	- Time of first observation record (4-digit- year, month, day, hour, min sec) Time system: - GPS (=GPS time system) - GLO (=UTC time system) - GAL (=Galileo System Time) - QZS (= QZSS time system) - BDT (=BDS Time system) Compulsory in mixed GNSS files Defaults: GPS for pure GPS files GLO for pure GLONASS files GAL for pure Galileo files QZS for pure QZSS files BDT for pure BDS files	5I6,F13.7, 5X,A3	
TIME OF LAST OBS	- Time of first observation record (4-digit- year, month, day, hour, min sec) -Time system: Same value as TIME OF FIRST OBS record	5I6,F13.7, 5X,A3	*
END OF HEADER	Last record in the header section	60X	

Records marked with * are optional.
A record marked with ** is optional if the main data is "R1".
All the items defined in RINEX 2 can be also used in GTEX.

TABLE A2
GTEX FILE - HEADER SECTION DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
EPOCH/SAT	- Epoch - year - month, day, hour, min - sec - Epoch flag 0: OK 1: power failure between previous and current epoch >1: Event flag - Number of satellites in current epoch - List of PRNs (sat. numbers with system identifier, defined in section IV) in current epoch. If more than 12 satellites: Use continuation lines	 1X,I2.2, 4(1X,I2) F11.7 2X,I1, I3, 12(A1,I2), 32X 12(A1,I2)
TEC data	- Observation Repeated within record for each data type (same sequence as given in header) This record is repeated for each satellite given in EPOCH/SAT- record TEC status flag 0: normal data 1: Lack of observation (TEC=999.) 2: Too large TEC (TEC=999.) 4: Cycle Slip (TEC discontinuity) 5: Cycle slip (LLI) 6: Beginning of arc Units of observables R1: TECU A1: TECU ZN: degrees AZ: degree, clockwise from north	

A2. Example of GTEX file ver 1.0 with a main data of "R1"

```
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
    1.0            GTEX DATA          GNSS                GTEX VERSION / TYPE
RNX2GTEX V1.1.3    NICT, JAPAN                            PGM / RUN BY
    16                                                    EXPONENT OF TECU
     TEC values in 10^16 el/m^2 (1 TEC Unit)              COMMENT
     Types of data   = R1 : Raw slant TEC including bias  COMMENT
                       A1 : Absolute slant TEC            COMMENT
                            R1 or A1 is necessary         COMMENT
                       1F : TEC status flag               COMMENT
                       1O : Observation data used for TEC COMMENT
                       ZN : Satellite zenith angle        COMMENT
                       AZ : Satellite azimuth angle       COMMENT
     TEC status flag  = 0 : Normal data                   COMMENT
                        1 : Lack of observables (TEC=999.) COMMENT
                        2 : Too large TEC (TEC=999.)      COMMENT
                        4 : Cycle slip (TEC discontinuity) COMMENT
                        5 : Cycle slip (LLI)              COMMENT
                        6 : Beginning of arc              COMMENT
                                                          BIAS ESTIMATION PGM
01321310.12o  01321320.12o  01321330.12o                  RINEX FILE NAME
0132                                                      MARKER NAME
00000              TPS NETG3          3.4 EG3 Jul,02,2010 REC # / TYPE / VERS
                   TRM29659.00     GSI                    ANT # / TYPE
 -3690821.3891  2897721.3097  4305504.4426                APPROX POSITION XYZ
      42.7294      141.8640        0.0486                 POSITION LAT LON ALT
     6    L1    C1    L2    P2    S1    S2                # / TYPES OF OBSERV
     5    R1    1F    1O    ZN    AZ                      # / TYPES OF DATA
    30.0000                                               INTERVAL
  2012     5    11     0     0    0.0000000     GPS       TIME OF FIRST OBS
                                                          END OF HEADER
 12  5 11  0  0  0.0000000  0  9G21G 9G18G15G28G 5G27G 8G26
 -61.7242  0  L1L2C1P2  35.83  119.68
 -33.4733  0  L1L2C1P2  68.20   75.21
 -49.7988  0  L1L2C1P2  82.81  161.85
 -55.8391  0  L1L2C1P2  69.68  293.96
 -43.6837  0  L1L2C1P2  62.79   48.64
 -38.7060  0  L1L2C1P2  34.70   49.99
 -44.8228  0  L1L2C1P2  38.39  125.89
 -31.3004  0  L1L2C1P2  72.63  312.53
 -48.7940  0  L1L2C1P2  47.29  138.96
 12  5 11  0  0 30.0000000  0  9G21G 9G18G15G28G 5G27G 8G26
 -61.6869  0  L1L2C1P2  35.72  119.30
 -33.6267  0  L1L2C1P2  68.15   74.99
 -49.8773  0  L1L2C1P2  82.63  161.75
 -55.8704  0  L1L2C1P2  69.69  293.74
 -43.7446  0  L1L2C1P2  62.99   48.64
 -38.6187  0  L1L2C1P2  34.90   50.23
 -44.7950  0  L1L2C1P2  38.24  125.56
 -31.1374  0  L1L2C1P2  72.55  312.35
 -48.7579  0  L1L2C1P2  47.09  138.75
```

A3. Example of GTEX file ver 1.0 with a main data of "A1"

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----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
    1.0            GTEX DATA           GNSS                GTEX VERSION / TYPE
RNX2GTEX V1.1.3    NICT, JAPAN                             PGM / RUN BY
    16                                                     EXPONENT OF TECU
     TEC values in 10^16 el/m^2 (1 TEC Unit)               COMMENT
     Types of data   = R1 : Raw slant TEC including bias   COMMENT
                       A1 : Absolute slant TEC             COMMENT
                            R1 or A1 is necessary          COMMENT
                       1F : TEC status flag                COMMENT
                       1O : Observation data used for TEC  COMMENT
                       ZN : Satellite zenith angle         COMMENT
                       AZ : Satellite azimuth angle        COMMENT
     TEC status flag  = 0 : Normal data                    COMMENT
                        1 : Lack of observables (TEC=999.) COMMENT
                        2 : Too large TEC (TEC=999.)       COMMENT
                        4 : Cycle slip (TEC discontinuity) COMMENT
                        5 : Cycle slip (LLI)               COMMENT
                        6 : Beginning of arc               COMMENT
                                                           BIAS ESTIMATION PGM
01321310.12o  01321320.12o  01321330.12o                   RINEX FILE NAME
0132                                                       MARKER NAME
00000               TPS NETG3           3.4 EG3 Jul,02,2010 REC # / TYPE / VERS
                    TRM29659.00     GSI                    ANT # / TYPE
 -3690821.3891  2897721.3097  4305504.4426                 APPROX POSITION XYZ
      42.7294      141.8640        0.0486                  POSITION LAT LON ALT
     6    L1    C1    L2    P2    S1    S2                 # / TYPES OF OBSERV
     5    A1    1F    1O    ZN    AZ                       # / TYPES OF DATA
    30.0000                                                INTERVAL
  2012     5    11     0     0    0.0000000     GPS        TIME OF FIRST OBS
                                                           END OF HEADER
 12  5 11  0  0  0.0000000  0  9G21G 9G18G15G28G 5G27G 8G26
  28.4668  0  L1L2C1P2  35.83  119.68
  29.6417  0  L1L2C1P2  68.20   75.21
  33.5112  0  L1L2C1P2  82.81  161.85
  21.7009  0  L1L2C1P2  69.68  293.96
  28.2723  0  L1L2C1P2  62.79   48.64
  33.2430  0  L1L2C1P2  34.70   49.99
  27.8022  0  L1L2C1P2  38.39  125.89
  38.0416  0  L1L2C1P2  72.63  312.53
  25.0200  0  L1L2C1P2  47.29  138.96
12  5 11  0  0 30.0000000  0  9G21G 9G18G15G28G 5G27G 8G26
  28.5041  0  L1L2C1P2  35.72  119.30
  39.4883  0  L1L2C1P2  68.15   74.99
  33.4327  0  L1L2C1P2  82.63  161.75
  21.6696  0  L1L2C1P2  69.69  293.74
```

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