SCINTEX

SCINtintillation and **T**EC **EX**change Format

Version 0.2

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I. 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)

II. REFERENCES

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

III. 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 [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.

IV. 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.

V. 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
```

VI. 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**

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	1B

			OS/CS/SoL	
			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 (Columns61-80)	DESCRIPTION	FORMAT	
SCINT VERSION / TYPE	- Format version : 0.00 - File type: S for Scintillation Data - Satellite System: G: GPS R: GLONASS E: Galileo S: SBAS payload C: BeiDou J: QZSS I: IRNSS M: Mixed	F9.2,11X, A1,19X, A1,19X	
PGM/ RUN BY /DATE	- Name of program creating current file - Name of agency creating current file - Date and time of file creation Format: yyyymmdd hhmmss zone zone: 3-4 char. Code for time zone. UTC recommended LCL if local time with unknown	A20, A20, A20	
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 (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	
SYS/ # / OBS TYPES	- Satellite system code (G/R/E/S/C/J/M) - Number of different observation types for the specified satellite system - Observation descriptors: o Type o Band o Attribute Use continuation line(s) for more than 13 observation descriptors. 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	A1 2X,I3 13(1X,A3) 6X 13(1X,A3)	

	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)	 A1,1X A1,1X	*

	- 1st frequency observation	I1A1,	
	- Code Band (1,2..8)		
	- Code Attribute (P,A..X, blank)		
	- 2nd frequency observation	I1A1,	
	- Code Band		
	- Code Attribute		
	Additionally the phase observations can		
	be specified if different from Code ones	1X,	
	Otherwise leave 4 additional blanks	(4X or	
	- 1st frequency observation	I1A1,	
	- Phase Band (1,2..8)		
	- Phase Attribute (P,A..X, blank)		
	- 2nd frequency observation	I1A1,)	
	- Phase Band		
	- Phase Attribute		
	- Number of satellites involved 0	1X,I2.2,	
	or blank: All		
	- List of satellites	11(1X,A3)	
	Use continuation line(s) for more than 11	18X,	
	satellites	11(1X,A3)	
	Repeat record for each Ionosphere phase		
	delay		
# OF SATELLITES	Number of satellites, for which	I6	*
	observations are stored in the file		
PRN / # OF OBS	Satellite numbers, number of observations	3X	*
	for each observation type indicated	A1,I2.2	
	in the SYS/ # / OBS TYPES record	9I6	
	If more than 9 observations types:	6X,9I6	
	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.		
TIME OF FIRST OBS	- Time of first observation record	5I6,F13.7,	
	(4-digit- year, month, day, hour, min		
	sec)		
	Time system:		
	- GPS (=GPS time system)	5X,A3	
	- 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		
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	5X,A3	
	FIRST OBS record		
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 : >	A1
- Epoch	
- year (4 digits):	1X,I4
- month, day, hour, min (two digits)	4(1X,I2.2),
- sec	F11.7,
- Epoch flag	2X,I1,
0: OK	
1: power failure between previous and current epoch	
>1: Special event	
- Number of satellites observed in current epoch	I3,
- (reserved)	6X,
- Receiver clock offset (seconds, optional)	F15.2,
Epoch flag = 0 or 1: OBSERVATION records follow	
- Satellite number	A1,I2.2,
- Observation - repeat within record for each observation	m(F14.3)
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.	
--> 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	[2X,I1]
- 4: header information follows	
- "Number of satellites" contains number of special records to follow. 0 if no special records follow.	[I3]
- Maximum number of records: 999	
For events without significant epoch the epoch fields in the EPOCH RECORD can be left blank	

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 DATA  M                   SCINT VERSION / TYPE
scintex_sept_v1     ESA                 20140401 153912 LCL 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
```