Reading RINEX 2.11 Observation Data Files

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1 Motivation and Scope

RINEX[1] version 2.11 is a *de facto* standard for storing all the data needed for all kinds of GNSS[2] positioning and navigation. This standard provides means to seamless store data transmitted from GPS[3], GLONASS[4], GALILEO[5] end GEO[6]/SBAS[7] satellites, as well as meteorological data and the fundamental observations made by GNSS receivers (code, phase, Doppler and time). Its versatility and the good quality of its documentation made RINEX the standard of choice for data input in all kinds a post processing techniques, both in real-world production works as in research and development projects.

The format consists of seven ASCII file types:

1. Observation Data File
2. Navigation Message File
3. Meteorological Data File
4. GLONASS Navigation Message File
5. GEO Navigation Message File
6. Satellite and Receiver Clock Date File
7. SBAS Broadcast Data File

The scope of this report is the Observation Data File. This file allows to store the most important data collected by GNSS receivers, including all the observations needed for GNSS positioning and navigation.

This report is not intended to replace or complement the "RINEX: The Receiver Independent Exchange Format Version 2.11", by Werner Gurtner (Astronomical Institute, University of Berne) and Lou Estey (UNAVCO, Boulder, Co.), available for downloading in several Internet sites (e.g. ftp://igs.org/pub/data/format/rinex211.txt) and the unique true documentation of RINEX version 2.11 Format. This report addresses only subjects that the author considers to be the most significant in view of the experience he had acquired with the development of software for reading RINEX version 2.11 Format files.

The second appendix of this report provides sample code (MatLAB programming language) for reading RINEX 2.11 Observation Data files.

2 Basic definitions

2.1 The observables

The observations are the measurements made by a GNSS receiver using the signals broadcasted by GNSS satellites. The observables include three fundamental quantities: Time, Phase and Pseudo-range. RINEX 2.11 allows for a forth observable: the Signal Strength (or raw SNR (signal-noise ratio). These quantities, which should not be corrected for external effects like

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[1] RINEX stands for "The Receiver Independent Exchange Format".
[2] GNSS stands for "Global Navigation Satellite Systems".
[3] GPS stands for "Global Positioning System", the US satellite navigation system.
[4] GLONASS is the Russian counterpart of GPS.
[5] Galileo will be the European satellite navigation system.
[6] GEO are geostationary satellites.
[7] SBAS stands for Satellite-Based Augmentation Systems. At present time three SBAS are fully functional: WAAS (for North-America), EGNOS (for Europe) and MSAS (for Japan).

atmospheric refraction, satellite clock offsets, etc., are defined in the standard as follows in the next subsections. Their values are stored in the Observation Data File.

2.1.1 Time

The time (t) of the measurement is the receiver time of the received signals. The RINEX 2.11 documentation text states that "…the observation time being the reading of the receiver clock at the instant of validity of the carrier-phase and/or the code measurements".

The time of measurement is identical for the phase and range measurements and is identical for all satellites observed at the same epoch. For single-system data files it is by default expressed in the time system of the respective satellite system. Otherwise the actual time can (for mixed files must) be indicated in the "TIME OF FIRST OBS" header record of the Observation Data File. Obviously in both cases t will be affected by the receiver clock offset relative to the time system adopted.

IMPORTANT: when using GPS time system (GPST) the GPS week number in all RINEX files must be a continuous number. Being so this number will be not affected by the 1024 roll-over, as it will run from 1023 over 1024 to 1025, etc.

2.1.2 Pseudo-range

The pseudo-range (ρ_s) is the distance from the receiver antenna to the satellite antenna including receiver and satellite clock offsets (and other biases, such as atmospheric delays). This quantity equals the speed of light in vacuum (c) times the apparent time travel of the code signal received by the receiver's antenna (Δt_s). The apparent time travel of the code signal is the difference of the time of reception (expressed in the time frame of the receiver) and the time of transmission (expressed in the time frame of the transmitting satellite).

Being d the distance from the transmitting satellite's position at the time of transmission to the receiver's antenna position at time of reception, δt the receiver clock offset and δt_s the satellite clock offset, the pseudo-range is:

$$\rho = c \times \Delta t = d + c \times (\delta t - \delta t_s + \text{other biases})$$

The pseudo-range is stored in units of meters.

2.1.3 Phase

The phase (Φ) is the carrier-phase measured in whole cycles (actually being a measurement on the beat frequency between the received carrier of the satellite signal and a receiver generated reference frequency). The phase changes in the same sense as the range (negative Doppler). The phase observations between epochs must be connected by including the integer number of cycles.

2.1.4 Doppler

The sign of the Doppler shift is an additional observable defined positive for approaching satellites.

2.1.5 Signal Strength (SS)

Raw signal strengths are the signal to noise ratio values as given by the receiver for the respective phase observations. This observation is evaluated for each of the phase observations and stored in the observation data file using the SS data record. This record can be blank, 0, or store signal strength values projected into interval from 1 to 9. The meanings of these values are:

0 or blank:	not known, don't care
1:	minimum possible signal strength
5:	threshold for good S/N ratio
9:	maximum possible signal strength

2.1.6 Loss of Lock Indicator (LLI)

The Loss of Lock Indicator (LLI) can't be considered an observable because it is not measured. It carries valuable information regarding each observation so it is stored in the observation data file immediately following each one of the observation values. The LLI values are three-bit codes (binary 000-111) stored in a record of a RINEX observation files as decimals 0-7. Each bit has a special meaning:

Bit zero set:	Loss-of-lock for this SV[8] and this frequency, meaning that a cycle slip is possible
Bit one set:	Switch wavelength factor to opposite of last WAVELENGTH FACT L1/2 record setting for this SV and this frequency
Bit two set:	Anti-spoofing[9] (A/S) is on for this SV or some other signal degradation/noise enhancement is in effect

The RINEX 2.11 standard states that: "Some receivers generate code (pseudorange) delay differences between the first and second frequency using cross-correlation techniques when AS is on and may recover the phase observations on L2 in full cycles. Using the C/A code delay on L1 and the observed difference it is possible to generate a code delay observation for the second frequency. Other receivers recover P code observations by breaking down the Y code into P and W code. Most of these observations may suffer from an increased noise level. In order to enable the postprocessing programs to take special actions, such AS-infected observations have been flagged in RINEX Version 2 using bit number 2 of the Loss of Lock Indicators (i.e. their current values are increased by 4)."

IMPORTANT: a blank or zero Loss of Lock Indicator means "OK or not known"

2.2 Real-time adjustment of the receiver clock

If the receiver or the converter software adjusts the measurements using the real-time-derived receiver clock offsets $\delta t(r)$, the consistency of the three fundamental quantities must be maintained, i.e. the receiver clock correction should be applied to all 3 observables. Being f the frequency:

$$t = t(r) - \delta t(r)$$
$$\rho_s = \rho(r) - c \times \delta t(r)$$

[8] SV stands for "space vehicle"; the same as satellite.

[9] Anti-spoofing (AS) is a protection against "fake" transmissions by encrypting a GNSS range code. GPS encrypts P-code (precise code) to form the Y-code. This procedure aims to ensure that the GPS signals cannot be disturbed (spoofed) by a GPS-like transmitter. The anti-spoofing procedure converts the P-code to the Y-code which is only usable when a secret conversion algorithm is available to the receiver. The Y-code is the "modulo two sum" of the P-code and the encryption code, also referred to as the W-code. Only selected GPS users have access to the conversion algorithm.

$$\Phi = \Phi(r) - f \times \delta t(r)$$

2.3 Satellite identifiers

Satellites are identified by three-character codes: two-digit satellite numbers preceded by a one-character system identifier. The systems' identifiers are:

G or blank	: GPS ((lank identifiers are only allowed in pure GPS files)
R	: GLONASS
S	: geostationary GPS signal payloads (GEO)
E	: Galileo

The satellite two-digit numbers are the PRN[10] (for GPS and Galileo), the slot number (for GLONASS) and PRN−100 for GEO (e.g. the identifier S20 refers to a GEO satellite having PRN=120).

2.4 Observation codes

Each observation type (pseudo-range, phase, Doppler and signal strength) has a unique RINEX 2.11 identifier named observation code. An observation code is a two-character string: the first one (a capital letter) is an observation identifier and the second one (a digit) is a frequency code. These codes are listed in the following figure (SBAS[11] satellites are GEO satellites):

```
  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
  1:  L1       G1     E2-L1-E1    L1
  2:  L2       G2        --       --
  5:  L5       --        E5a      L5
  6:  --       --        E6       --
  7:  --       --        E5b      --
  8:  --       --       E5a+b     --


Units : Phase       : full cycles
        Pseudorange : meters
        Doppler     : Hz
        SNR etc     : receiver-dependent
```

Figure 1: Components of the observation codes

For example, any phase observation on the 1176.45 MHz carrier will be coded as L5.

Important: observations collected under anti-spoofing must be converted to "L2" or "P2" and flagged with bit 2 of loss of lock indicator (LLI). At present time GPS is the only fully operational system using anti-spoofing.

[10] PRN stands for "pseudo-random noise".

[11] SBAS stands for Satellite-Based Augmentation Systems. At present time three SBAS are fully functional: WAAS (for North-America), EGNOS (for Europe) and MSAS (for Japan).

System	Freq.Band	Frequency	RINEX 2-character Code			
			Ps.Range	Carr.Phase	Doppler	Sign.Strength
GPS	L1	1575.42	C1,P1	L1	D1	S1
	L2	1227.60	C2,P2	L2	D2	S2
	L5	1176.45	C5	L5	D5	S5
Glonass	G1	1602+k*9/16	C1,P1	L1	D1	S1
	G2	1246+k*7/16	C2,P2	L2	D2	S2
Galileo	E2-L1-E1	1575.42	C1	L1	D1	S1
	E5a	1176.45	C5	L5	D5	S5
	E5b	1207.140	C7	L7	D7	S7
	E5a+b	1191.795	C8	L8	D8	S8
	E6	1278.75	C6	L6	D6	S6
SBAS	L1	1575.42	C1	L1	D1	S1
	L5	1176.45	C5	L5	D5	S5

Figure 2: Full set of RINEX 2.11 observations codes

2.5 Number of characters in a line of the file

Each line of an Observation Data File has no more than 80 characters long.

2.6 File naming conventions

RINEX 2.11 proposes the file naming conventions presented in the next figure:

```
We recommend using the following naming convention for RINEX files:

   ssssdddf.yyt

   |   |  | | |
   |   |  | | +--  t:  file type:
   |   |  | |          O: Observation file
   |   |  | |          N: GPS Navigation file
   |   |  | |          M: Meteorological data file
   |   |  | |          G: GLONASS Navigation file
   |   |  | |          L: Future Galileo Navigation file
   |   |  | |          H: Geostationary GPS payload nav mess file
   |   |  | |          B: Geo SBAS broadcast data file
   |   |  | |                      (separate documentation)
   |   |  | |          C: Clock file (separate documentation)
   |   |  | |          S: Summary file (used e.g., by IGS, not a standard!)
   |   |  | |
   |   |  | +---  yy:  two-digit year
   |   |  |
   |   |  +-----   f:  file sequence number/character within day
   |   |               daily file: f = 0
   |   |               hourly files:
   |   |               f = a:  1st hour 00h-01h; f = b: 2nd hour 01h-02h; ...
   |   |               f = x: 24th hour 23h-24h
   |   |
   |   +-------  ddd:  day of the year of first record
   |
   +-----------  ssss:  4-character station name designator


For 15-minutes high-rate tracking data we recommend the following extended
filenames:

   ssssdddhmm.yyo

   |   |  ||  | |
   |   |  ||  | +-  o: observation file
   |   |  ||  |
   |   |  ||  +--- 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: 1h to 2h,...,
   |   |               x=24th hour: 23h-24h. 0= one-day file)
   |   |
   |   +---------- ddd: day of the year
   |
   +------------ ssss: 4-character ID for the LEO receiver/antenna
```

Figure 3: RINEX 2.11 file naming conventions

2.7 Data formats used

All the data must be written in a RINEX 2.11 ASCII text files using the formats (these formats are similar to the FORTRAN formats) defined in the standard. Each data element will occupy a field. The formats define the inner structure of each field.

A format always begins with an uppercase letter defining the type of the data to be stored in the field followed by the definition of the structure of the field.

A sequence of identical fields is coded by inserting the number of repetitions before the format of the field to be repeated. A sequence of distinct fields uses commas to separate fields. If a sequence of distinct fields is to be repeated, then the sequence is enclosed using curved brackets and the number of repetitions is written before the opening bracket. A number before a sequence defines the number of repetitions of that sequence. The following two tables may clarify the concepts:

Table 1: Data Format examples for single variables;
 # is used to identify blanks and the variables are enclosed by single quotes
(adapted from http://gage14.upc.es/gLAB/HTML/LaunchHTML.html)

Variable Type	Format	Examples	Description

Integer	In	`I4: '2010'`
		`I5: '#2010'`
		`I3.3: '010'`
			A 'n' positions integer.
			Note it can be specified the minimum length of the integer by including a number after the floating point symbol. This forces the number to be padded, even with zeros.

Float	Fn.m	`F8.2: '-1402.50'`
		`F8.2: '#1402.50'`
		`F7.3: '#44.000'`
			A 'n' positions double with 'm' decimal positions.
			Note 'n' includes sign space and the floating point symbol.

Exponential	Dn.m	`D12.2: '-1402.50D+02'`
		`D12.4: '#-0.1966D+06'`
		`E12.3: '#44.000E+006'`
		`e12.3: '-44.000E+006'`
			A 'n' positions exponential double with 'm' decimal positions.
			Note 'n' is the total length of the exponential number, this includes sign space, the floating point symbol and the exponent itself.
			In order to account for the various compilers, E, e, D, and d are allowed letters between the fraction and exponent of all floating point numbers in the navigation message files of RINEX 2.11. Zero-padded two-digit exponents are required, however (the last two examples are not possible in RINEX 2.11).

Characters	An	`A7: 'GLONASS'` `A2: '#E'`	A 'n' positions character. Note this includes empty characters.
Empty Fields	nX	`1X: '#'`	A 'n' empty (blank) characters. The fields that are defined as blanks are reserved fields which must remain blank as may be used in future versions.

Table 2: RINEX 2.11 Data Format examples for sequences of variables

Sequence	Examples
I2,1X,A3,1X,F8.2	`'14#G18#-1402.50'`
2D12.2	`'-1402.50D+02#1234.56D+03'`
2(I2,1X,A3,1X,F8.2)	`'14#G18#-1402.5013#R02##1402.50'`

3 GNSS Observation Data File format definitions

The RINEX 2.11 GNSS Observation Data File is an ASCII file composed by a Header Section followed by a Data Section. The Header Section must be placed at the beginning of the file and is metadata, that is to say, “data about data”: it contains global information for the entire file. The Data Section basically contain the observations made by a receiver during one observation session.

3.1 Header Section structure and description

The Header Section is composed of Header Records. Each Header Record is one or more lines of the Header Section. Each line of the Header Section must contain a header label in columns 61-80 of the line; this header label identifies the Header Record the line belongs to. These labels are mandatory and must appear exactly as given in RINEX 2.11 standard. The last record of the Header Section must be labelled “END OF HEADER”.

Free ordering of the header records is allowed, with the following exceptions:

a) The "RINEX VERSION / TYPE" record must be the first record in a file
b) The default "WAVELENGTH FACT L1/2" record must precede all records defining wavelength factors for individual satellites
c) The "# OF SATELLITES" record (if present) should be immediately followed by the corresponding number of "PRN / # OF OBS" records.

The full RINEX 2.11 Header Section description is presented in Table A 1 of Appendix A. MatLAB code for reading the Header Section (function rinexReadsObsFileHeader211) is provided in Appendix B.

```
     2.11           OBSERVATION DATA    M                   RINEX VERSION / TYPE
Spider V4,0,0,3554                      2015 03 07 15:00    PGM / RUN BY / DATE
Antena_3                                                    MARKER NAME
Ant3                                                        MARKER NUMBER
Antonio Pestana     ISEP-LabTopografia                      OBSERVER / AGENCY
                    LEICA GMX902GNSS    4.005               REC # / TYPE / VERS
                    LEIAS10         NONE                    ANT # / TYPE
  4753836.3636  -718468.9092  4177370.7279                  APPROX POSITION XYZ
        0.0000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     7    C1    L1    S1    P2    L2    S2    C2           # / TYPES OF OBSERV
     0.050                                                  INTERVAL
  2015    03    07    14    00    0.0000000     GPS         TIME OF FIRST OBS
  2015    03    07    14    59   59.9500000     GPS         TIME OF LAST OBS
    16                                                      LEAP SECONDS
    17                                                      # OF SATELLITES
   G 5 72000 72000 72000 72000 72000 72000     0           PRN / # OF OBS
   G12 16157 16073 16157 16028 16028 16028     0           PRN / # OF OBS
   G13 72000 72000 72000 72000 72000 72000     0           PRN / # OF OBS
   G15 72000 72000 72000 72000 72000 72000     0           PRN / # OF OBS
   G17 24532 24472 24532 24413 24398 24413     0           PRN / # OF OBS
   G18 35487 35487 35487 34172 33930 34172     0           PRN / # OF OBS
   G21 27801 27801 27801 27801 27801 27801     0           PRN / # OF OBS
   G24 70618 70264 70618 70052 69951 70052     0           PRN / # OF OBS
   G28 72000 72000 72000 72000 72000 72000     0           PRN / # OF OBS
   G30 21001 21001 21001 21001 21001 21001     0           PRN / # OF OBS
   R 3 22578 22578 22578 20656 19980 20656     0           PRN / # OF OBS
   R 4 72000 72000 72000 72000 72000 72000     0           PRN / # OF OBS
   R 5 72000 72000 72000 72000 72000 72000     0           PRN / # OF OBS
   R13 18801 18801 18801 18801 18801 18801     0           PRN / # OF OBS
   R14 72000 72000 72000 72000 72000 72000     0           PRN / # OF OBS
   R15 72000 72000 72000 72000 72000 72000     0           PRN / # OF OBS
   R16 30534 30534 30534 29521 29335 29521     0           PRN / # OF OBS
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
SNR is mapped to RINEX snr flag value [2-9]                 COMMENT
Lx:     = 25dBHz -> 1; 26-27dBHz -> 2; 28-31dBHz -> 3       COMMENT
       32-35dBHz -> 4; 36-38dBHz -> 5; 39-41dBHz -> 6       COMMENT
       42-44dBHz -> 7; 45-48dBHz -> 8; >=49dBHz -> 9        COMMENT
                                                            END OF HEADER
```

Figure 4: Example of a "mixed" GPS+GLONASS RINEX 2.11 Observation Data File Header

3.2 Data Record structure and description

The Data Section of the Observation Data File is composed of Data Records. All the data stored in one Data Record must be collected at one site and at the same epoch. Each Data Record has multiple lines of ASCII text.

The first line(s) of a Data Record stores data regarding all the observations made at a given epoch: it is metadata about the observations stored in the Data Record. This metadata section of the Data Record includes the date/time stamp (the epoch) of the record, a one character "epoch flag", the number of observed satellites at this epoch and the list of respective three-character satellite identifiers. If the number of satellites is greater than 12 this list spans to the next line.

After the Data Record metadata, the Data Record observations section follow. The observations section can be thought as a table having so many lines as satellites in the satellites list, and one column for each of the "n" observation codes stored in the "# / TYPES OF OBSERV" record of the Header Section. Each observation can be a pseudo-range, a phase or a Doppler observation, followed by a loss of lock indicator (LLI) and signal-strength value (SS), by this order. Each cell of the table will store only one observation and the respective LLI and SS using

the format 'F14.3,I1,I1'. No more than 5 of this sequences can be stored in a line of text as each line of the Observation Data File is only 80-character long. So, if "n" is greater than 5, each line of the table will span multiple lines of the text file.

The full RINEX 2.11 Observation Data Record Description is presented in Table A 3 of Appendix A. MatLAB code for reading all the data stored in a Data Record (functions rinexReadsObsBlockHead211 and rinexReadsObsBlock211) is provided in Appendix B.

```
15 03 07 14 00  0.0000000  0 13G05G13G15G21G24G28G30R03R04R05R13R14
                              R15
  21752028.780   114307648.68909        49.650    21752031.320    89070886.61248
        45.050
  20339096.640   106882674.53909        49.900    20339096.500    83285200.21948
        46.250
  21193622.660   111373268.06409        49.000    21193624.520    86784381.08048
        45.750
  24802156.440   130336200.07306        39.250    24802162.340   101560673.46345
        37.800
  23154480.240   121677613.26204        35.700    23154486.000    94813735.70144
        35.200
  22109086.960   116184042.77608        48.750    22109087.460    90533034.98047
        42.050
  24059695.260   126434498.30006        39.800    24059703.680    98520387.60845
        38.750
  22289931.520   119319672.06506        40.850    22289941.280    92804193.34807
        44.050
  19189656.100   102759732.07708        47.800    19189660.760    79924251.82008
        46.050
  20709366.500   110703447.77707        42.100    20709374.380    86102730.12007
        44.600
  23051974.580   123096198.42705        38.500    23051984.020    95741503.69106
        41.850
  19390246.180   103360924.14507        44.750    19390255.460    80391868.93106
        40.950
  20069883.180   107247438.46008        46.100    20069892.380    83414749.05908
        45.900
```

Figure 5: Example of a "mixed" GPS+GLONASS RINEX 2.11 Observation Data Record. This Data Record belongs to the Observation Data File whose File Header is shown in Figure 4. The first two lines of text are the Data Record metadata. Each line of the observations table has two lines of text (seven cells, the last one being always blank in this example).

Appendix A:

Full RINEX 2.11 Observation Data File description

Table A 1: RINEX 2.11 GNSS Observation Data File Header Description

TABLE A1
GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION

	HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
	RINEX VERSION / TYPE	- Format version (2.11) - File type ('O' for Observation Data) - Satellite System: blank or 'G': GPS 'R': GLONASS 'S': Geostationary signal payload 'E': Galileo '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 of file creation	A20, A20, A20
*	COMMENT	Comment line(s)	A60
	MARKER NAME	Name of antenna marker	A60
*	MARKER NUMBER	Number of antenna marker	A20
	OBSERVER / AGENCY	Name of observer / agency	A20,A40
	REC # / TYPE / VERS	Receiver number, type, and version (Version: e.g. Internal Software Version)	3A20
	ANT # / TYPE	Antenna number and type	2A20
	APPROX POSITION XYZ	Approximate marker position (WGS84)	3F14.4
	ANTENNA: DELTA H/E/N	- Antenna height: Height of bottom surface of antenna above marker - Eccentricities of antenna center relative to marker to the east and north (all units in meters)	3F14.4
*	WAVELENGTH FACT L1/2	- Default wavelength factors for L1 and L2 (GPS only) 1: Full cycle ambiguities 2: Half cycle ambiguities (squaring) 0 (in L2): Single frequency instrument - zero or blank The wavelength factor record is optional for GPS and obsolete for other systems. Wavelength factors default to 1. If the record exists it must precede any satellite-specific records (see below).	2I6, I6
*	WAVELENGTH FACT L1/2	- Wavelength factors for L1 and L2 (GPS) 1: Full cycle ambiguities 2: Half cycle ambiguities (squaring) 0 (in L2): Single frequency instrument - Number of satellites to follow in list for which these factors are valid. - List of PRNs (satellite numbers with system identifier) These optional satellite specific lines may follow, if they identify a state different from the default values. Repeat record if necessary.	2I6, I6, 7(3X,A1,I2)
	# / TYPES OF OBSERV	- Number of different observation types stored in the file - Observation types - Observation code - Frequency code If more than 9 observation types: Use continuation line(s) (including the header label in cols. 61-80!) The following observation types are defined in RINEX Version 2.11: Observation code (use uppercase 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 1: L1 / G1 / E2-L1-E1 / L1 2: L2 / G2 / -- / -- 5: L5 / -- / E5a / L5 6: -- / -- / E6 / -- 7: -- / -- / E5b / -- 8: -- / -- / E5a+b / -- Observations collected under Antispoofing are converted to "L2" or "P2" and flagged with bit 2 of loss of lock indicator (see Table A2). Units : Phase : full cycles Pseudorange : meters Doppler : Hz SNR etc : receiver-dependent The sequence of the types in this record has to correspond to the sequence of the observations in the observation records	I6, 9(4X,A1, A1) 6X,9(4X,2A1)

Records marked with * are optional

Table A 2: RINEX 2.11 GNSS Observation Data File Header Description (continuation)

TABLE A1 (Cont.)
GNSS OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION

	HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT	
*	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) Compulsory in mixed GPS/GLONASS files Defaults: GPS for pure GPS files GLO for pure GLONASS files GAL for pure Galileo files	5I6,F13.7, 5X,A3	
*	TIME OF LAST OBS	- Time of last observation record (4-digit-year, month,day,hour,min,sec) - Time system: Same value as in TIME OF FIRST OBS record	5I6,F13.7, 5X,A3	*
*	RCV CLOCK OFFS APPL	Epoch, code, and phase are corrected by applying the realtime-derived receiver clock offset: 1=yes, 0=no; default: 0=no Record required if clock offsets are reported in the EPOCH/SAT records	I6	*
*	LEAP SECONDS	Number of leap seconds since 6-Jan-1980 Recommended for mixed files	I6	*
*	# OF SATELLITES	Number of satellites, for which observations are stored in the file	I6	*
*	PRN / # OF OBS	PRN (sat.number), number of observations for each observation type indicated in the "# / TYPES OF OBSERV" - record. If more than 9 observation types: Use continuation line(s) including the header label in cols. 61-80! This record is (these records are) repeated for each satellite present in the data file	3X,A1,I2,9I6 6X,9I6	*
	END OF HEADER	Last record in the header section.	60X	

Records marked with * are optional

Table A 3: RINEX 2.11 GNSS Observation Data Record Description

TABLE A2
GNSS OBSERVATION DATA FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
EPOCH/SAT or EVENT FLAG	- Epoch : - year (2 digits, padded with 0 if necessary) - month,day,hour,min, - sec	1X,I2.2, 4(1X,I2), F11.7,
	- Epoch flag 0: OK 1: power failure between previous and current epoch >1: Event flag	2X,I1,
	- Number of satellites in current epoch	I3,
	- List of PRNs (sat.numbers with system identifier, see 5.1) in current epoch	12(A1,I2),
	- receiver clock offset (seconds, optional)	F12.9
	If more than 12 satellites: Use continuation line(s)	32X, 12(A1,I2)
	If epoch flag 2-5:	
	- Event flag: 2: start moving antenna 3: new site occupation (end of kinem. data) (at least MARKER NAME record follows) 4: header information follows 5: external event (epoch is significant, same time frame as observation time tags)	[2X,I1,]
	- "Number of satellites" contains number of special records to follow. Maximum number of records: 999	[I3]
	- For events without significant epoch the epoch fields can be left blank	
	If epoch flag = 6: 6: cycle slip records follow to optionally report detected and repaired cycle slips (same format as OBSERVATIONS records; slip instead of observation; LLI and signal strength blank or zero)	
OBSERVATIONS	- Observation | rep. within record for - LLI | each obs.type (same seq - Signal strength | as given in header)	m(F14.3, I1, I1)
	If more than 5 observation types (=80 char): continue observations in next record.	
	This record is (these records are) repeated for each satellite given in EPOCH/SAT - record.	
	Observations: Phase : Units in whole cycles of carrier Code : Units in meters Missing observations are written as 0.0 or blanks.	
	Phase values overflowing the fixed format F14.3 have to be clipped into the valid interval (e.g. add or subtract 10**9), set LLI indicator.	
	Loss of lock indicator (LLI). Range: 0-7 0 or blank: OK or not known Bit 0 set : Lost lock between previous and current observation: cycle slip possible Bit 1 set : Opposite wavelength factor to the one defined for the satellite by a previous WAVELENGTH FACT L1/2 line or opposite to the default. Valid for the current epoch only. Bit 2 set : Observation under Antispoofing (may suffer from increased noise) Bits 0 and 1 for phase only.	
	Signal strength projected into interval 1-9: 1: minimum possible signal strength 5: threshold for good S/N ratio 9: maximum possible signal strength 0 or blank: not known, don't care	

Appendix B:

MatLAB code

Functions:

rinexReadsObsFileHeader211
rinexReadsObsBlockHead211
rinexReadsObsBlock211

```
       function [success, warnings, rinexHeader, gnssType, markerName,
antDelta,...
           numOfObsTypes, typesOfObs, tFirstObs, tLastObs, tInterval, ...
           timeSystem, numHeaderLines, clockOffsetsON, leapSec, eof] = ...
           rinexReadsObsFileHeader211(file)

       %  Extracts  relevant  data  from  the  header  of  a  RINEX  GNSS
observations file.
       %
       % Analyzes the header of a RINEX GNSS observation file and extracts
       % relevant data.
       %
       % Limited tests have been done using RINEX 2.11 observation files.
       %
       %
       % Input:
       %   file: RINEX observation file
       %
       % Outputs:
       %   success: 1 if the reading of the RINEX observations file seems
to be
       %       successful, 0 otherwise
       %   warnings: 1 if the reading of the RINEX observations was done
with
       %       warnings, 0 otherwise
       %   rHeader: cell column-vector containing the following data:
       %         rinexVersion: RINEX version number; string:  '' if not
specified
       %       rinexType: RINEX file type; char
       %        gnssType: GNSS system of the satellites observed; can be
'G', 'R',
       %         'S', 'E' or 'M' that stand for GPS, GLONASS, Geostationary
       %              signal payload, GALILEO or Mixed (satellites from
various of
       %           the previous systems); char
       %       rinexProgr: name of the software used to produce de RINEX
GPS nav
       %           file; '' if not specified
       %       rinexDate: date/time of the RINEX file creation; '' if not
       %           specified
       %   markerName: name of the antenna marker; '' if not specified
       %   antDelta: column vector ot the three components of the distance
from
       %        the marker to the antenna, in the following order - up,
east and
       %       north; reals; null vector by default
       %   numOfObsTypes: number of different observation types stored in
the
       %       RINEX file; THIS IS CRITICAL DATA!
       %   typesOfObs: cell column-vector containing the observation types;
each
```

```
%       observation type is a two-character string, the first one
(a
%       capital letter) is an observation code and the second one
(a digit)
%       is a frequency code. THIS IS CRITICAL DATA!
%
%       According to RINEX 2.11 these codes are:
%
%                           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 (see
comments of
%                              function rinexReadsObsBlock211)
%
%                       Frequency code
%                            GPS    Glonass   Galileo    SBAS
%                         1:  L1       G1     E2-L1-E1    L1
%                         2:  L2       G2        --       --
%                         5:  L5       --        E5a      L5
%                         6:  --       --        E6       --
%                         7:  --       --        E5b      --
%                         8:  --       --       E5a+b     --
%
%                       Observations collected under Antispoofing
%                       are converted to "L2" or "P2" and flagged
%                      with bit 2 of loss of lock indicator (LLI);
%                    read comments of function rinexReadsObsBlock211
%
%    tFirstObs: time stamp of the first observation record in the
RINEX
%       observations file; column vector of reals [YYYY; MM; DD;
hh; mm;
%       ss.sssssss]; THIS IS CRITICAL DATA
%   tLastObs: time stamp of the last observation record in the RINEX
%       observations file; column vector of reals [YYYY; MM; DD;
hh; mm;
%       ss.sssssss]. NaN by default. THIS IS RINEX 2.11 OPTIONAL
DATA
%    tInterval: observations interval; seconds.  NaN by default.
THIS IS
%       RINEX 2.11 OPTIONAL DATA
%   timeSystem: three-character code string of the time system used
for
%         expressing tfirstObs; can be GPS, GLO or GAL; THIS IS
CRITICAL DATA
%   numHeaderLines: total number of lines of the header
```

```
       %   clockOffsetsON: receiver clock offsets flag. 0 if no realtime-
derived
       %       receiver clock offset was applied to epoch, code and phase
data (in
       %       other words, if the file only has raw data), 1 otherwise.
       %       0 by default. THIS IS RINEX 2.11 OPTIONAL DATA
       %    leapSec: number of leap seconds since 6-Jan-1980. UTC=GPST-
leapSec.
       %       NaN by default. THIS IS RINEX 2.11 OPTIONAL DATA
       %   eof: end-of-file flag; 1 if end-of-file was reached, 0 otherwise
       %
       % Based in the work of Kai Borre
       % António Pestana, March 2015
       % Copyright (c) António Pestana

       fid = fopen(file,'rt');


       eof = 0;
       success = 1;
       warnings = 0;
       got_info = 0;
       numHeaderLines = 0;
       antDelta = [0; 0; 0];
       clockOffsetsON = 0;
       numLinTypObs = 0;
       timeSystem = '';
       tFirstObs = [0; 0; 0; 0; 0; 0];
       tLastObs = NaN;
       tInterval = NaN;
       typesOfObs = {};
       leapSec = NaN;
       numOfObsTypes = 0;
       rinexHeader = {};

       while 1 % Gobbling the header
          numHeaderLines = numHeaderLines + 1;
          line = fgetl(fid); % returns -1 if only reads EOF
          if line == -1
              eof = 1;
              if got_info > 5
                  success = 1;
              else
                  fprintf(['Some important data regarding the GNSS '...
                      'observations  may  be  missing...\nProceed  with
caution.'])
                  warnings = 1;
              end
              break
          end;
```

```
        answer = strfind(line,'END OF HEADER'); % [] if the string isn't
found
        if  ~isempty(answer)  % the end of the header was found
            if got_info > 5
                success = 1;
                break
            else
                fprintf(['Some important data regarding the GNSS '...
                    'observations  may  be  missing...\nProceed  with
caution.'])
                warnings = 1;
            end;
            break
        end

        if numHeaderLines == 1
            rinexVersion = strtrim(line(1:9));
            rinexType = line(21);
            if rinexType ~= 'O'
                disp('ERROR: the file is not a RINEX observations data
file!')
                success = 0;
                fclose(fid);
                return
            end
            gnssType = line(41); % reads the GNSS system type
            if ~ismember(gnssType, [' ' 'G' 'R' 'S' 'E' 'M'])
                disp(['ERROR:  "'  gnssType  '"'  '  is  an  unrecognized
satellite '...
                    'system type.'])
                success = 0;
                fclose(fid);
                return
            end
            if strcmp(gnssType,' ')
                gnssType = 'G';
            end
            got_info = got_info + 1;
        end

        answer = strfind(line,'PGM / RUN BY / DATE');
        if ~isempty(answer)
            rinexProgr = strtrim(line(1:20));
            rinexDate = strtrim(line(41:60));
            got_info = got_info + 1;
        end

        answer = strfind(line,'MARKER NAME');
        if ~isempty(answer)
            markerName = strtok(line);
            got_info = got_info + 1;
        end
```

```
          answer = strfind(line,'ANTENNA: DELTA H/E/N');
          if ~isempty(answer)
             for k = 1:3
                [number, line] = strtok(line); % finds the substring
containing
                                                % the deltas of the antenna
                                                % relative to the marker
                antDelta (k,1) = str2num(number);
             end
             got_info = got_info + 1;
          end;

          answer = strfind(line,'# / TYPES OF OBSERV');
          if ~isempty(answer)
             numLinTypObs = numLinTypObs + 1; % one more line of
observations types
             line = strtrim(line(1:60)); % deletes '# / TYPES OF OBSERV'
             if numLinTypObs == 1
                 [nObs, line] = strtok(line);
                 numOfObsTypes = str2num(nObs);
                 for k = 1:min(9,numOfObsTypes)
                     [obsType, line] = strtok(line);
                     if size(obsType,2) ~= 2 || ~ismember(obsType(1),['C'
'P'...
                             'L' 'D' 'S']) || ~ismember(obsType(2),['1'
'2' '3'...
                             '4' '5' '6' '7' '8'])
                         disp(['ERROR     (rinexReadsObsHeader211):     '
obsType...
                             ' is a not a standard RINEX 2.11 observation
type!'])
                         success = 0;
                         fclose(fid);
                         return
                     end
                     typesOfObs = [typesOfObs; obsType];
                     got_info = got_info + 1;
                 end
             else
                 for k = 1:min(9,numOfObsTypes-(numLinTypObs-1)*9)
                     [obsType, line] = strtok(line);
                     if size(obsType,2) ~= 2 || ~ismember(obsType(1),['C'
'P'...
                             'L' 'D' 'S']) || ~ismember(obsType(2),['1'
'2' '3'...
                             '4' '5' '6' '7' '8'])
                         disp(['ERROR     (rinexReadsObsHeader211):     '
obsType...
                             ' is a not a standard RINEX 2.11 observation
type!'])
                         success = 0;
```

```
                        fclose(fid);
                        return
                    end
                    typesOfObs = [typesOfObs; obsType];
                end
            end
        end

        answer = strfind(line,'TIME OF FIRST OBS');
        if ~isempty(answer)
            line = strtrim(line(1:60)); % deletes 'TIME OF FIRST OBS'
            for k = 1:6
                [tok, line] = strtok(line); % finds the substrings
containing
                                            % the components of the time
of the
                                            % first observation (YYYY;
MM; DD;
                                            % hh; mm; ss.sssssss) and
specifies
                                            % the Time System used in
the
                                            % observations file (GPST,
GLOT or
                                            % GALT)
                 switch k
                     case 1
                         yyyy = str2num(tok);
                     case 2
                         mm = str2num(tok);
                     case 3
                         dd = str2num(tok);
                     case 4
                         hh = str2num(tok);
                     case 5
                         mnt = str2num(tok);
                     otherwise
                         ss  = str2num(tok);
                 end
            end

            tFirstObs = [yyyy; mm; dd; hh; mnt; ss];
            got_info = got_info + 1;

            aux = strtok(line);
            switch aux
                case 'GPS'
                    timeSystem = 'GPST';
                case 'GLO'
                    timeSystem = 'GLOT';
                case 'GAL'
                    timeSystem = 'GALT';
```

```
                otherwise
                    switch gnssType
                        case 'G'
                            timeSystem = 'GPST';
                        case 'R'
                            timeSystem = 'GLOT';
                        case 'E'
                            timeSystem = 'GALT'
                        otherwise
                            fprintf(['CRITICAL                    ERROR
(rinexReadsObsHeader211):\n'...
                                'The   Time   System   of   the   RINEX
observations file '...
                                'isn''t correctly specified!\n'])
                            success = 0;
                            fclose(fid);
                            return
                    end
            end
        end

        answer = strfind(line,'TIME OF LAST OBS'); % This is an optional
record
        if ~isempty(answer)
            for k = 1:6
                [tok, line] = strtok(line); % finds the substrings
containing
                                            % the components of the time
of the
                                            % first observation (YYYY;
MM; DD;
                                            % hh; mm; ss.sssssss)
                switch k
                    case 1
                        yyyy = str2num(tok);
                    case 2
                        mm = str2num(tok);
                    case 3
                        dd = str2num(tok);
                    case 4
                        hh = str2num(tok);
                    case 5
                        mnt = str2num(tok);
                    otherwise
                        ss  = str2num(tok);
                end
            end
            tLastObs = [yyyy; mm; dd; hh; mnt; ss];
        end
```

```
            answer = strfind(line,'INTERVAL'); % This is an optional record
            if ~isempty(answer)
                tInterval = str2num(strtok(line));
            end

            answer = strfind(line,'RCV CLOCK OFFS APPL'); % This is an
optional record!
            if ~isempty(answer)
                if (strtok(line)=='0')
                    clockOffsetsON = 0;
                elseif (strtok(line)=='1')
                    clockOffsetsON = 1;
                else
                    success = 0;
                    disp(['ERROR    (rinexReadsObsHeader211): unrecognized
'...
                        'receiver clock offsets flag!'])
                    fclose(fid);
                    return
                end
            end

            answer = strfind(line,'LEAP SECONDS'); % This is an optional
record
            if ~isempty(answer)
                leapSec = str2num(strtok(line));
            end

        end

        if numOfObsTypes == 0||sum(tFirstObs) == 0
            success = 0;
            fprintf(['CRITICAL ERROR (rinexReadsObsHeader211)!\nTake a look
'...
                'at the RINEX observations file %s'], file);
            fclose(fid);
            return
        end


        rinexHeader = {rinexVersion; rinexType; gnssType; rinexProgr;
rinexDate};

        fclose(fid);



        %%%%%%%%% end rinexReadsObsFileHeader211 %%%%%%%%%
```

```
       function  [success,epochflag,clockOffset,date,numSV,SVlist,eof]  =
...
           rinexReadsObsBlockHead211(fid)

       % Reads the metadata of a RINEX 2.11 observations block.
       %
       % ATTENTION: Ignores all data regarding events flagged with numbers
       % greater than 1!!!
       %
       % Positioned in a RINEX 2.11 GNSS observations text file at the
beginning
       % of an observation record of type "EPOCH/SAT OR EVENT FLAG", reads
its
       % contents (the metadata - one or more lines - of a block of
observations)
       %
       % Inputs:
       %   fid: Matlab identifier of an open RINEX 2.11 GNSS observations
text file
       %
       % Outputs:
       %   success: 1 if function performs successfully, 0 otherwise
       %   epochflag: Rinex observations epoch flag, as follows:
       %       0: OK
       %       1: power failure between previous and current epoch
       %      From now on the "event flags":
       %       2: start moving antenna
       %       3: new site occupation
       %       4: header information follows
       %       5: external event (epoch is significant)
       %   clockOffset: value of the receiver clock offset. If not present
in the
       %        metadata of the observations block (it's optional RINEX
2.10
       %       data)it is assumed to be zero. If not zero implies  that
epoch,
       %       code, and phase data have been corrected by applying
       %       realtime-derived receiver clock offset
       %   date: time stamp of the observations block. Six-elements column-
vector
       %       as follows:
       %           year: four-digits year (eg: 1959)
       %           month: integers 1..12
       %           day: integers 1..31
       %           hour: integers 0..24
       %           minute: integers 0..60
       %           second: reals 0..60
       %    numSV: number of satellites for which observations were made
and are
       %       stored in the observations block
       %    SVlist: cell column-vector of the observed satellites three-
characters
```

```
%        strings (system identifier + one or two-digits prn code);
it has as
%       many elements as the number of the satellites observed. The
system
%         identifiers are: 'G', 'R', 'S' and 'E' (note that blank
system
%       identifiers are stored in SVlist as 'G')
%
% António Pestana, November 2012 and March 2015
% Copyright (c) by António Pestana

success = 1;
eof = 0;
gotData = 0;

epochflag = [];
clockOffset = [];
date = [];
numSV = 0;
SVlist = {};

line = fgetl(fid); % returns -1 if only reads EOF
if line == -1
    eof = 1;
    disp(['INFO (rinexReadsObsBlockHead211): End of observations
'...
        'text file reached'])
    return
end;

% The first thing to do: the reading of the epoch flag
epochflag = str2num(line(29));
gotData = gotData + 1;
while epochflag > 1 % case of an event flag
    linejump = str2num(line(30:32));
    disp(['WARNING (rinexReadsObsBlockHead211): observations event
'...
        'flag encountered; ' num2str(linejump) ...
        ' lines were ignored.'])
    for count=1:linejump + 1
        line = fgetl(fid);
    end
    epochflag = str2num(line(29));
end


% Reads the time stamp of the observations block (6 numerical
values)
date = cell2mat(textscan(line,'%f', 6));
year = date(1,1);
if (year > 79)&&(year <= 99)
    year = year + 1900;
```

```
        elseif (year >= 0)&&(year <= 79)
            year = year + 2000;
        else
            success = 0;
            disp(['ERROR (rinexReadsObsBlockHead211): observations block
time '...
                'stamp format unrecognized (not RINEX 2.11)!'])
            return
        end
        date(1,1) = year;

        % Gets the number of used satellites
        numSV = str2num(line(30:32)); % number of used SV

        % Gets the receiver clock offset. It's optional data!
        clockOffset = 0;
        if size(line,2) == 80
            clockOffset = str2num(line(69:80));
        end

        % Creats the list of the satellites used in the observations block
        col = 33;
        for sat=1:numSV
            if ismember(sat,13:13:999)
                line = fgetl(fid);
                col = 33;
            end
            aux = line(col:col+2);
            if aux(1) == ' ' % Case of blanks for GPS identifiers
                aux(1) = 'G';
            end
            SVlist = [SVlist; aux];
            col = col + 3;
        end

        %%%%%%%%%%%%%%%%%%%%%%%%%       end       rinexReadsObsBlockHead211
%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
        function [success, Obs, LLI, SS, eof] =...
            rinexReadsObsBlock211(fid, numSV, numOfObsTypes)

        % Reads all the observations from a RINEX observations block.
        %
        % Positioned at the beginning of the line immediately after the
header of the
        % observations block, reads all the observations in this block of
a RINEX
        % observations file. This function is to be used after using
function
        % rinexReadsObsFileHeader211.
        %
        % Inputs:
        %   fid: Matlab file identifier of a Rinex observations text file
        %   numSV: number of satellites observed at the selected epoch
        %   numOfObsTypes: number of different observation types stored in
the
        %       Rinex observations text file (obtained from the header of
the RINEX
        %     observations file using function rinexReadsObsFileHeader211)
        %
        % Outputs:
        %   Obs: array [numSV x numObs] of observations; reals. Uses 0 for
missing
        %       observations
        %   LLI: array [numSV x numObs] of "loss of lock indicator" numeric
codes
        %         (binary 000 - 111, decimal 0 - 7, see RINEX standard).
According to
        %       http://facility.unavco.org/software/teqc/faqs.html and the
RINEX
        %       standard the following decimal values have the meaning:
        %       0 - binary 000: OK
        %      1 - binary 001: loss-of-lock for this SV and this frequency
(L1 or
        %           L2) (cycle slip possible, original meaning of the LLI
flag)
        %        2 - binary 010: switch wavelength factor to opposite of
last
        %             WAVELENGTH FACT L1/2 record setting for this SV and
this
        %           frequency (L1 or L2)
        %        4 - binary 100: anti-spoofing (A/S) is on for this SV or
some other
        %           signal degradation/noise enhancement is in effect
        %
        %        I think that all the 3-bits possible combinations can be
used. For
        %       example, binary 101 (decimal 5) should flag A/S and loss-
of-lock;
        %      111 (decimal 7) should flag A/S and loss-of-lock and switch
```

```
        %       wavelength factor
        %
        %         IMPORTANT: this function assigns -999 to this indicator
when it is
        %          blank in the file (RINEX 2.11 standard states that blank
        %           means "not known")
        %
        %   SS: array [numSV x numObs] of RINEX signal strength "normalized"
        %         values. Integer values from 1 to 9 plus 0 meaning "not
known". The
        %       RINEX 2.11 standard states:
        %
        %                Signal strength projected into interval 1-9:
        %                 1: minimum possible signal strength
        %                 5: threshold for good S/N ratio
        %                 9: maximum possible signal strength
        %                 0 or blank: not known, don't care
        %
        %         IMPORTANT: this function assigns -999 to this indicator
when it is
        %          blank in the file (RINEX 2.11 standard states that blank
        %           means "don't care")
        %
        %
        % Based in the work of Kai Borre
        % António Pestana, March 2015
        % Copyright (c) António Pestana

        success = 1;
        eof = 0;

        Obs = zeros(numSV, numOfObsTypes);
        LLI = zeros(numSV, numOfObsTypes);
        SS = zeros(numSV, numOfObsTypes);

        for sat = 1:numSV
            lineNum = 0;
            for obsNum = 1:numOfObsTypes
                if ismember(obsNum,[1:5:numOfObsTypes])
                    line = fgetl(fid); % reads one line of text
                    if line == -1
                        eof = 1;
                        disp(['ERROR (rinexReadsObsBlock211): the end of
the '...
                            'observations text file was reached
unexpectedly'])
                        success = 0;
                        return
                    end
                    lineNum = lineNum + 1;
                end
                charPos = ((obsNum -(lineNum - 1)*5)-1)*16 + 1;
```

```
                newObs  =  str2num(line(charPos:charPos+13));  %  reads  one
observation
                if isempty(newObs)
                    newObs = 0;
                end
                newLLI   =   str2num(line(charPos+14));   %   loss   of   lock
indicator
                if isempty(newLLI)
                    newLLI = -999;
                end
                newSS = str2num(line (charPos+15)); % signal strength
                if isempty(newSS)
                    newSS = -999;
                end

                % Stores the data
                Obs(sat,obsNum) = newObs;
                LLI(sat,obsNum) = newLLI;
                SS(sat,obsNum) = newSS;
            end

        end


        %%%%%%%%% end rinexReadsObsBlock211.m %%%%%%%%%
```