GAMIT 软件操作手册

目 录

一　GPS 误差分析

GPS 是美国为了满足军事部门和民用对连续实时和三维导航的迫切要求于 1973 年开始研制的，至 1994 年整个系统全面建成。这个系统的全称是“授时与测距导航系统/全球定位系统”（Navigation System Timing and Ranging/Global Positioning System—NAVSTAR/GPS），通常称为“全球定位系统”（GPS）。它能够在全球范围内提供全天候、高精度、连续实时的三维定位和测速，同时它还能够提供时间基准。GPS 是 20 世纪空间技术上的最大成就之一。它的出现使大地测量产生了根本性的变革。目前这一高新技术已广泛地应用于大地测量学、地球动力学、精密工程测量、地壳形变监测、石油勘探、资源调查、城市测量等领域。

影响 GPS 定位的误差按其主要来源可以分为如下几个部分：

1.1　与 GPS 卫星有关的误差

- 星历误差与模型误差
- 卫星钟差与稳定性
- 卫星摄动
- 相位的不稳定性
- 卫星的相位中心

1.2　与信号传播有关的误差

- 电离层折射
- 对流层折射
- 多路径效应

1.3　与接收设备有关的误差

- 接收机钟差
- 天线的相位中心
- 观测误差（天线的整平与对中、量取天线高的误差）

- 接收机噪声

1.4 其他误差来源

- 地球自转的影响（极移、UT1）
- 相对论效应的影响（信号传播与卫星钟）
- 地球潮汐（固体潮、海潮、大气负载潮）

二　GPS 基线处理的几个关键问题

在高精度 GPS 测量中，影响定位精度的主要因素有：卫星的轨道精度、对流层折射的修正精度、多路径效应、相位中心的改正、接收机震荡器的稳定度、数据的后处理技术和起始点坐标的精度。考虑到影响 GPS 定位精度的因素及自动化数据处理的需要，在研制的过程中，主要针对如下几个因素作了一些研究和探讨。

2.1　星历

卫星的轨道误差是影响 GPS 定位的主要因素之一，其对基线的影响可以较精确地用下式表示：:

$$\frac{|\Delta r|}{10|r|} < \frac{|\Delta b|}{|b|} < \frac{|\Delta r|}{4|r|}$$

其中分 $|\Delta r|$ 为卫星轨道的误差，r 为卫星至测站的相对位置矢量，$|\Delta b|$ 为基线矢量的误差，b 为两站之间基线矢量。如令 GPS 点位之间最大距离为 10km 左右（两基准之间距离），

取 r=22000km，轨道的误差为 50 米，根据上其对基线的最大影响为 5mm. 可见，用广播星历解算对较长基线结果有显著影响。因而在有条件的情况下，最好还是采用精密星历（精度在 0.1 米左右）或预报精密星历（精度在 0.5 米左右），从而可以保证星历误差对于基线解算没有影响。

2.2　对流层折射影响

对流层折射是影响高精度 GPS 定位的重要因素之一，虽经模型改正后，有很大的改善，但其残余偏差（经模型改正后的对流层折射残余的影响）也很大影响了垂线方向的精度，对于较大尺度的 GPS 网，其甚至可以对整网有一个尺度上的影响。在长距离 GPS 定位中，对流层折射虽然经双差后得到较好地削弱，但由于 GPS 监测点所在的气候差得较大，即气象条件不一致，从而大气层的影响也不一致，所以对对流层折射我们做了较为深入的研究，对于剩余偏差（是指在 Saastemionen 模型改正的基础上）可以采用随机过程模拟。对待这一问题需做更深入的研究，这将对提高垂线方向上的精度提供有力的保障。

2.3 周跳是否修复是影响基线解算精度的因素之一

周跳是否修复是影响基线解算精度的重要因素之一。特别是在长距离定位中，模糊度的整数特性受大气改正不完善等因素的影响而变得很弱，周跳是否修复的问题尤为突出。修复周跳的方法有多种，如：利用观测值的不同差分、拟合法等

2.4 基准点坐标的确定

在基线解算中，需要一个起算点。起算点的精度将影响基线解算的精度。因此很有必要获得高精度的基准点坐标及监测点的坐标。根据有关文献，起算点对基线解算的最大影响可以用下式表示：

$$\delta s = 0.60 \times 10^{-4} \times D \times \delta X_1$$

式中δs为对基线的影响，D为基线的长度(以千米计)，δX_I为起算坐标的误差。令D=10km，如要对基线的影响小于1cm，则要求起算坐标的误差小于17m。因此，为了获得基准站及其它 GPS 监测站的较为精确的地心坐标，利用 GPS 跟踪站，将它们与基准站及其它 GPS 监测站联测，通过解算获得了高精度的 ITRF 框架坐标。由于 ITRF 坐标是瞬时的，因而这一坐标每隔一段时间要重新获得，能够保证地面站的坐标与星历的一致性。

2.5 基线解算是否在地固系中进行

惯性坐标系是动力学的基础，卫星运动方程就是在惯性坐标系中建立的。因而一般来说，对于高精度 GPS 定位，基线解算在惯性系进行。而提供星历的坐标系却是地固系的，这就需作一个转换：从地固系转到惯性坐标系中。转换需要提供极移、UT1、章动等表，然而这些表是每隔一段时间才发布。可通过 INTERNET（因特网）每隔一段时间实时获取这些表。

2.6 整周未知数的确定

当以相位观测值为观测量进行相对定位时，整周未知数的确定是一个关键问题。其解算的质量如何是相对定位精度的保障。解算整周未知数的方法有多种，如：交换天线法、P码双频技术、滤波法、搜索法和模糊函数法等。整周未知数的结果有两种：整数解和实数解。

高精度定位软件之所以能够优于一般的商业软件（随机软件），因为其所用的数学模型和算法优于一般的商业软件。主要体现在如下两个方面：

考虑的 GPS 定位误差比较全面，模型好
人工干预的方法多，算法好

三　GPS 应用软件介绍

3.1　一般的商用软件

ROUGE　GPS 接收机：TurboSurvey

ASHTECH GPS 接收机：GPPS、PRISM

TRIMLBE GPS 接收机：GPSurvey

LEICA　GPS 接收机：SKI

SOKKIA　GPS 接收机：GSSP

武汉测绘科技大学的 LIP 软件和 PowerADJ 软件

此外，还有 NOVATEL 、SERCEL、JOVAD 等 GPS 接收机的软件。

3.2　高精度 GPS 软件

世界上有四个比较有名的 GPS 软件是：

1. 美国麻省理工学院（MIT）和 SCRIPPS 研究所（SIO）共同开发的 GAMIT 软件。
2. 美国喷气动力实验室（JPL，Jet Propulsion Laboratory）的 GIPSY 软件。
3. 瑞士伯尔尼大学研制的 Bernese 软件。
4. 德国 GFZ 的 EPOS 软件。

另外还有美国德克萨斯大学的 TEXGAP 软件、英国的 GAS 软件、挪威的 GEOSAT 软件。

高精度定位软件其观测值一般可以分为两种：一种是双差观测值，这是我们所常用的，另一种是非差观测值。

双差观测值可以较好地消除或大大地削弱 GPS 卫星钟差和接收机钟差。双差模型被大部分的接收机随机软件所选用（主要用于工程网的短基线处理，也是高精度定位软件常用的一种模型。

四　GAMIT 软件简介

4.1　概述

GAMIT 软件是最初是由美国麻省理工学院研制的，后又与美国 SCRIPPS 海洋研究所共同开发改进的。该软件是世界上最优秀的 GPS 定位和定轨软件之一，采用精密星历和高精度起算点时，其解算长基线的相对精度能达到 10^{-9} 量级，解算短基线的精度能优于 1 毫米。

GAMIT 软件是由许多功能不同的模块组成的，这些模块可以独立的运行。这些模块按其功能来分可以分成两个部分：数据准备和数据处理。此外，该软件还带有功能强大的 SHELL 程序。

数据准备部分包括原始观测数据的格式转换、计算卫星和接收机钟差、星历的格式转换等；

数据处理部分包括观测方程的形成、轨道的积分、周跳的修复和参数的解算等。

各个模块具有一定的独立性，但它们之间又紧密地联系在一起，共同完成数据处理和分析的全过程。

GAMIT for workstation 的总体概况：

- GAMIT 软件包：基线解算；
- KF 软件包　：卡尔漫滤波，GPS 网平差；
- COM 软件包　：外部共用功能软件；
- MAPS 软件包 ：绘图软件；
- GMT 软件包　：绘图。

4.2　主要模块介绍

MAKEXP：数据准备部分的驱动程序。

MAKEJ：生成卫星钟差文件。

MAKEX：将原始观测数据的格式（RINEX）转换成 GAMIT 所需的文件。

BCTOT（NGSTOT）：将星历格式（RINEX、SP3、SP1）转换成 GAMIT 所需的文件。

FIXDRV：数据处理部分的驱动程序。

ARC：轨道积分模块。

MODEL：求偏导数，生成观测方程。

SINCLN、DBLCLN、AUTCLN、CVIEW：周跳修复模块。

CFMRG：为 SOLVE 模块创建一个文件（M），定义和选择有关参数。

SOLVE：利用最小二乘解算模块。

辅助模块：CTOX、XTORX、TFORM 等

五　GAMIT 软件的安装

5.1　设置路径

编辑.cshrc 文件，设置 GAMIT 的有关路径：com、gamit/bin、kf/bin。

然后，运行 source ~/.cshrc。

5.2　执行 intall_software

运行 intall_software（如不能运行，请利用 chmod 将其改为可执行文件）。按照其提示运行。在文件展开后，最好中断运行。

进入 libraries 目录，编辑 Makefile.config 文件，主要包括两项工作。

1、　设置 X11 的路径

如所用的系统为 LINUX，则设置如下：

X11LIBPATH /usr/X11R6/lib

X11INCPATH /usr/X11R6/include/X11

....

2、　设置参数

根据需要，设置最大测站数；最大卫星数；最大对流层偏差参数；最大历元数。

3、重新运行 intall_software 命令

六　GAMIT 软件的运行

6.1　数据整理

按每个时段整理好，每个测站两个文件，一个观测数据 O 文件，一个观测星历 N 文件。

以时段号建立目录，目录的字符最好为六位，如 YYDAYS，YY 为年的后两位，DAY 为年积日，S 为时段号。如 2001 年 1 月 5 号的第二个时段，其目录名为 010052。

6.2　表文件及 E 文件的准备

1)、在 GAMIT 软件中，准备的表文件包括：

LUNTAB、SOLTAB、NUTABL、LEAP.SEC 每年更新一次。

UT1、POLE 表每周更新一次。

其更新的 FTP 地址见附录一。

对于一个 GPS 网，需准备的主要包括如下四个文件

lfile.、Sittbl.、Station.info.、sestbl.

lfile 可以利用 XYZ2NLR 转换。输入的近似坐标可为 RINEX 格式观测值中的 XYZ，也可为精确的 XYZ，格式见 TOOLS 中的 XYZ.DAT 文件。

注意事项为：

- 对于一个 GPS 网，每个测站的近似坐标（要求精度高于 300 米）。
- 注意 Station.info 文件中的第一行为工程名。
- 对于长基线：

  在 sestbl 文件中，type-analysis 可设为 0-ITERATION， Choice of observable 设为 LC 或 LC_RANGE，Choice of Experiment 为 BASELINE。
- 对于短基线：

  在 sestbl 文件中，type-analysis 可设为 2-cleaned， Choice of observable 设为 L1_ONLY，Choice of Experiment 为 SHORT。

2）E 文件

- 将其中的一个星历文件拷贝成 E 文件即可，文件名为：exxxxy.day。xxxx 为工程名，y 为年的第四位，day 为年积日
- 合并其中两个测站的星历文件，将第二个文件的文件头删掉。

3）IGS 精密星历

6.3　运行：

1） links.day 2001 238 ym01，其目的是将 TABLES 目录中的表文件连到数据目录下。

2） makexp

3） sh-sp3fit -f igr****#.sp3

(检查星历文件中的卫星数是否与导航文件中的卫星
数是否一致，并自动更改。不一致时也可以在 session.info 中删改)

4） 继续按 GAMIT 的提示运行。

6.4　结果及其分析

1、结果文件类型：

- H-file：基线的松弛解；
- O-file：约束解；
- Q-file：过程记录文件。

2、精度分析的三项指标

1）postfit_nrms 的计算结果为 0.3 左右时为最佳结果；如大于 1.0，则结果错误。、

2）改正量不能大于 2 倍约束量；

3）B1L1（L1_ONLY）计算的整周模糊度必须是整数。

4）一般来说，基线结算结果的精度是没有代表性的，其精度主要是依据观测的时间长短和基线的长度量。GAMIT 结算结果一般为 2—10mm

附录一、LINUX 操作系统的安装

1、明确硬件及其驱动程序的类型

①网卡：如本机为 fe575c-3com

②声卡：ATI Rage Mobility 128

③显卡：ESS Maestro PCI Audio

2、硬盘空间的重新配置

linux 的启动必须放入总计为 8GB 的区域内，其中：

①Boot:100MB

②Swap:512MB

③Root:3GB

④其它：5.8GB

(在 windows 管理工具中选择计算机管理之磁盘管理功能，实现硬盘的重新分化和定义)

3、LINUX 的安装

手工安装：键入 text↙后回车；

```
..................
......... common system .........↙
        ......... fdisk .........↙
..................
command (infor help):p↙
                     m↙
                     p↙
                     t↙   6↙   83↙
                     t↙   7↙   83↙
                     t↙   8↙   82↙
                     t↙   9↙   83↙
                     p↙
                     w↙
...............
```

Edit(根据本机的实际情况编辑如下)：

1) /win_c ;　2) /win_d ;　3) /boot ;　4) /　;　5)（swap,不变）;
6) /home1　7) /win_e

....

4、配置 lilo.conf 文件，以便兼容 LINIX 及 WINDOWS。
（路径：/etc）

原始设置:

```
  ............
image=/boot/vmlinuz-2.2.16-22
          label=linux
          read-only
          root=/dev/hda7
          ............
```

改为:

```
          ............
image=/boot/vmlinuz-2.2.16-22
          label=linux
          read-only
          root=/dev/hda7

other=/dev/hda1
          label=windows
          table=/dev/hda
              ...............
```

5、配置成如下的 fstab 文件：

路径：/etc

```
LABEL=/          /            ext2     defaults            1 1
LABEL=/boot      /boot        ext2     defaults            1 2
LABEL=/home1     /home1       ext2     defaults            1 2
/dev/cdrom       /mnt/cdrom   iso9660  noauto,owner,ro     0 0
/dev/fd0         /mnt/floppy  auto     noauto,owner        0 0
/dev/hda1        /win_c       auto     defaults            0 0
/dev/hda5        /win_d       auto     defaults            0 0
/dev/hda10       /win_e       auto     defaults            0 0
none             /proc        proc     defaults            0 0
none             /dev/pts     devpts   gid=5,mode=620      0 0
/dev/hda8        swap         swap     defaults            0 0
```

6、软硬件的匹配（一般情况下不进行这一工作）

（有关说明详见/usr/src/linux/readme 文件）

①make mrproper↙

②make menuconfig↙(编辑过后)

③make dep↙

④make modules↙

⑤make modules_install↙

⑥make install↙

7、实现 UNIX 下对 windows 环境下的文件管理（未正常链接时）：

chmod –R 755 win*↙

(超级用户下/root)

8、DOS 下的文件格式转入 UNIX 文件使用：

在 dos2unix-3.0 目录下：

rm mac*↙

make↙

即可编译好 dos2unix 程序

使用：

ls *.01o | awk '{print "dos2unix" $1}' | csh↙

**:任何在 WINDOWS 下编辑的文件，都必须转为 UNIX 下的文件格式。

执行软件:dos2unix↙

附录二、GCC 的安装:

1、GCC 的下载、安装、编译

①软件下载:

地址:北大天网

主要文件有:

- gcc-2.95.3.tar.gz
- gcc-g++-2.95.3.tar.gz
- gcc-g77-2.95.3.tar.gz

②解压缩(解压文件会存在当前的目录内)

gzip –d *gz ↙ ：解压命令;

tar xvf *tar↙ ：TAR 文件展开命令(xvf->cvf 压缩功能)。

③ MXUNIT 的修改:

路径:

../libf2c/libi77/fio.h 文件

……………

define MXUNIT=100

……………

改为: MXUNIT=1000

④建立一个存放执行程序的路径

```
mkdir software↙(自己定义)
cd software↙
mkdir gcc2.953↙
```

⑤在/tools/gcc2.953/下运行

```
configure -- prefix=/jlyue/software/gcc2.953↙
```

其目的是设置系统环境及将 gcc（相当于一个 FORTRAN 语言工具软件）编译后的程序放入指定的目录内：

⑥../tools/gcc2.953/目录下执行 make 命令

⑦../gcc2.953/目录下执行 make install 命令

过程中缺省的存放路径与要求的路径不一致时，请接受中断程序的指令。

附录三 精密星历及相关表文件的获取

精密星历的获取地址：

ftp 132.239.152.86 (或 ftp lox.ucsd.edu 或 igecb.jpl.nasa.gov)

login: anonymous

passwd: e-mail 地址

到/pub/processing/gamit/tables 目录取 UT1 表、POLE 表等 gamit 软件所需的表文件。

到/pub/rinex/目录取全球站的数据

到/pub/products/目录取精密星历。

3、精密星历文件：

igs****#.sp3：快速精密计算结果；

igr****#.sp3: 事后精密星历（所需下载的精密星历数据)；

igu****#.sp3: 预报精密星历；

igs****#.sum: 卫星状态数据（删除卫星可在 sesion.info 文件中进行)。

其中：****为 GPS 周；

#为星期日的序号（如 0，1，2，3，4，5，6）

附录四 RINEX 格式说明

RINEX 是 The Receiver Independent Exchange Format（与接收机无关的数据交换格式）的缩写，它是 GPS 测量领域中的一种广为使用的数据格式，绝大部分的数据处理软件均支持这种格式。

下面是一份有关该格式的文档：

RINEX: The Receiver Independent Exchange Format Version 2
****

(Revision, April 1993)
(Clarification December 1993)
(Doppler Definition: January 1994)
(PR Clarification: October 1994)
(Wlfact Clarification: February 1995)
(Event Time Frame Clarification: May 1996)
(Minor errors in the examples A7/A8: May 1996)
(Naming convention for compressed met files; January 1997)
(Continuation line clarifications: April 1997)
(GLONASS Extensions: April 1997)
(Met sensor description and position records: April 1997)
(Wavelength factor clarifications: April 1997)

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0. INTRODUCTION

0.1 First Revision

This paper is a revised version of the one published by W. Gurtner and G.Mader in the CSTG GPS Bulletin of September/October 1990. The main reasonfor a revision is the new treatment of antispoofing data by the RINEXformat (see chapter 7). Chapter 4 gives a recommendation for data compression procedures, especially useful when large amounts of data are exchanged through computer networks. In Table A3 in the original paper the definiton of the "PGM / RUN BY / DATE" navigation header record was missing, although the example showed it. The redefinition of AODE/AODC to IODE/IODC also asks for an update of the format description. For consistency reasons we also defined a Version 2 format for the Meteorological Data files(inclusion of a END OF HEADER record and an optional MARKER NUMBER record).

```
*  The slight modification (or rather the definition of a bit in the Loss  *
*  of Lock Indicator unused so far) to flag AS data is so small a change   *
*  that we decided to NOT increase the version number!                     *
```

0.2 Later Revisions:

* URA Clarification (10-Dec-93):

The user range accuracy in the Navigation Message File did not contain a definition of the units: There existed two ways of interpretation:

Either the 4 bit value from the original message or the converted value in meters according to GPS ICD-200. In order to simplify the interpretation for the user of the RINEX files I propose the bits to be converted into meters prior to RINEX file creation.

* GLONASS Extensions:

In March 1997 a proposal for extensions to the current RINEX definitions based on experiences collected with GLONASS only and mixed GPS/GLONASS data files was circulated among several instrument manufacturers and software developers.

The results of the call for comments have been worked into this document.

A separate document (glonass.txt) summarizes just the necessary extensions.

* A blank satellite identifier is allowed in pure GPS files only

* Met sensor description and position records were added to facilitate the precise use of met values.

* Description and examples for wavelength factors and their temporary changes

(bit 1 of LLI) clarified.

In order to have all the available information about RINEX in one place we also included parts of earlier papers and a complete set of format definiton tables and examples.

1. THE PHILOSOPHY OF RINEX

The first proposal for the "Receiver Independent Exchange Format" RINEX has been developed by the Astronomical Institute of the University of Berne for the easy exchange of the GPS data to be collected during the large European GPS campaign EUREF 89, which involved more than 60 GPS receivers of 4 different manufacturers. The governing aspect during the development was the following fact:

Most geodetic processing software for GPS data use a well-defined set of observables:

- the carrier-phase measurement at one or both carriers (actually being a measurement on the beat frequency between the received carrier of the satellite signal and a receiver-generated reference frequency).

- the pseudorange (code) measurement, equivalent to 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 satellite) of a distinct satellite signal.

- the observation time being the reading of the receiver clock at the instant of validity of the carrier-phase and/or the code measurements.

Usually the software assumes that the observation time is valid for both the phase AND the code measurements, AND for all satellites observed.
Consequently all these programs do not need most of the information that is usually stored by the receivers: They need phase, code, and time in the above mentioned definitions, and some station-related information like station name, antenna height, etc.

2. GENERAL FORMAT DESCRIPTION

Currently the format consists of four ASCII file types:
1. Observation Data File
2. Navigation Message File
3. Meteorological Data File
4. GLONASS Navigation Message File

Each file type 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 optimized for mimimum space requirements independent from the number of different observation types of a specific receiver by indicating in the header the types of observations to be stored. In computer systems allowing variable record lengths the observation records may then be kept as short as possible. The maximum record length is 80 bytes per record.

Each Observation file and each Meteorological Data file basically contain the data from one site and one session. RINEX Version 2 also allows to include observation data from more than one site subsequently occupied by a roving receiver in rapid static or kinematic applications.

If data from more than one receiver has to be exchanged it would not be economical to include the identical satellite messages collected by the different receivers several times. Therefore the Navigation Message File from one receiver may be exchanged or a composite Navigation Message File created containing non-redundant information from several receivers in order to make the most complete file.

The format of the data records of the RINEX Version 1 Navigation Message file is identical to the former NGS exchange format.

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

3. DEFINITION OF THE OBSERVABLES

GPS observables include three fundamental quantities that need to be defined: Time, Phase, and Range.

TIME:

The time of the measurement is the receiver time of the received signals. It is identical for the phase and range measurements and is identical for all satellites observed at that epoch. It is expressed in GPS time (not Universal Time).

PSEUDO-RANGE:

The pseudo-range (PR) is the distance from the receiver antenna to the satellite antenna including receiver and satellite clock offsets (and other biases, such as atmospheric delays):

```
PR  =  distance + c * (receiver clock offset - satellite clock offset + other biases)
```

so that the pseudo-range reflects the actual behavior of the receiver and satellite clocks. The pseudo-range is stored in units of meters.

See also clarifications for pseudoranges in mixed GPS/GLONASS files in chapter 8.1.

PHASE:

The phase is the carrier-phase measured in whole cycles at both L1 and L2. The half-cycles measured by sqaring-type receivers must be converted to whole cycles and flagged by the wavelength factor in the header section.

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. The phase observations will not contain any systematic drifts from intentional offsets of the reference oscillators.

The observables are not corrected for external effects like atmospheric refraction, satellite clock offsets, etc.

If the receiver or the converter software adjusts the measurements using the real-time-derived receiver clock offsets dT(r), the consistency of the 3 quantities phase / pseudo-range / epoch must be maintained, i.e. the receiver clock correction should be applied to all 3 observables:

```
Time(corr)  = Time(r)  -  dT(r)
PR(corr)    =  PR(r)   -  dT(r)*c
phase(corr) = phase(r) -  dT(r)*freq
```

DOPPLER:

The sign of the doppler shift as additional observable is defined as usual:

Positive for approaching satellites.

4. THE EXCHANGE OF RINEX FILES:

We recommend using the following naming convention for RINEX files:

```
        ssssdddf.yyt      ssss:    4-character station name designator
                           ddd:    day of the year of first record
                             f:    file sequence number within day
                                   0: file contains all the existing
                                      data of the current day
                            yy:    year
                             t:    file type:
```

O: Observation file
N: Navigation file
M: Meteorological data file
G: GLONASS Navigation file

To exchange RINEX files on magnetic tapes we recommend using the following tape format:

- Non-label; ASCII; fixed record length: 80 characters;
  block size: 8000
- First file on tape contains list of files using above-mentioned naming conventions

When data transmission times or storage volumes are critical we recommend compressing the files prior to storage or transmission using the UNIX "compress" und "uncompress" programs. Compatible routines are available on VAX/VMS and PC/DOS systems, as well.

Proposed naming conventions for the compressed files:

System	Obs files	GPS Nav Files	GLONASS Nav Files	Met Files
UNIX	ssssdddf.yyO.Z	ssssdddf.yyN.Z	ssssdddf.yyG.Z	ssssdddf.yyM.Z
VMS	ssssdddf.yyO_Z	ssssdddf.yyN_Z	ssssdddf.yyG_Z	ssssdddf.yyN_Z
DOS	ssssdddf.yyY	ssssdddf.yyX	ssssdddf.yyV	ssssdddf.yyW

5. RINEX VERSION 2 FEATURES

The following section contains features that have been introduced for RINEX Version 2.

5.1 Satellite Numbers:

Version 2 has been prepared to contain GLONASS or other satellite systems' observations. Therefore we have to be able to distinguish the satellites of the different systems: We precede the 2-digit satellite number with a system identifier.

```
snn        s:    satellite system identifier
           G or blank : GPS
           R          : GLONASS
           T          : Transit

           nn :PRN (GPS), almanac number (GLONASS) or two-digit Transit satellite number
```

Note: G is mandatory in mixed GPS/GLONASS files

(blank default modified in April 1997)

5.2 Order of the Header Records:

As the record descriptors in columns 61-80 are mandatory, the programs reading a RINEX Version 2 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 "RINEX VERSION / TYPE" record must be the first record in a file

- The default "WAVELENGTH FACT L1/2" record (if present) should precede all records defining wavelength factors for individual satellites

- 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. However, since they may only be created after having read the whole raw data file we define them to be optional.

5.3 Missing Items, Duration of the Validity of Values

Items that are not known at the file creation time can be set to zero or blank or the respective record may be completely omitted. Consequently items of missing header records will be set to zero or blank by the program reading RINEX files. Each value remains valid until changed by an additional header record.

5.4. Event Flag Records

The "number of satellites" also corresponds to the number of records of the same epoch followed. Therefore it may be used to skip the appropriate number of records if certain event flags are not to be evaluated in detail.

5.5 Receiver Clock Offset

A large number of users asked to optionally include a receiver-derived clock offset into the RINEX format. In order to prevent confusion and redundancy, the receiver clock offset (if present) should report the value that has been used to correct the observables according to the formulae under item 1. It would then be possible to reconstruct the original observations if necessary. As the output format for the receiver-derived clock offset is limited to nanoseconds the offset should be rounded to the nearest nanosecond before it is used to correct the observables in order to guarantee correct reconstruction.

6. ADDITIONAL HINTS AND TIPS

Programs developed to read RINEX Version 1 files have to verify the version number. Version 2 files may look different (version number, END OF HEADER record, receiver and antenna serial number alphanumeric) even if they do not use any of the new features

We propose that routines to read RINEX Version 2 files automatically delete leading blanks in any CHARACTER input field. Routines creating RINEX Version 2 files should also left-justify all variables in the CHARACTER fields.

DOS, and other, files may have variable record lengths, so we recommend to first read each observation record into a 80-character blank string and decode the data afterwards. In variable length records, empty data fields at the end of a record may be missing, especially in the case of the optional receiver clock offset.

7. RINEX UNDER ANTISPOOFING (AS)

Some receivers generate code 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 are flagged using bit number 2 of the Loss of Lock Indicators (i.e. their current values are increased by 4).

8. GLONASS Extensions

8.1 RINEX Observation file

8.1.1 Time System Identifier

RINEX Version 2 needs one major supplement, the explicit definition of the time system:

GLONASS is basically running on UTC (or, more precisely, GLONASS system time linked to UTC(SU)), i.e. the time tags are given in UTC and not GPS time. In order to remove possible misunderstandings and ambiguities, the header records "TIME OF FIRST OBS" and (if present) "TIME OF LAST OBS" in GLONASS and GPS observation files _can_, in mixed GLONASS/GPS observation files _must_contain a time system identifier defining the system that all time tags in the file are referring to: "GPS" to identify GPS time, "GLO" to identify the GLONASS UTC time system. Pure GPS files default to GPS and pure GLONASS files default to GLO.

Format definitions see Table A1.

Hence, the two possible time tags differ by the current number of leap seconds.

In order to have the current number of leap seconds available we recommend to include a LEAP SECOND line into the RINEX header.

If there are known non-integer biases between the "GPS receiver clock" and "GLONASS receiver clock" in the same receiver, they should be applied.

In this case the respective code and phase observations have to be corrected,too (c * bias if expressed in meters).

Unknown such biases will have to be solved for during the post processing

The small differences (modulo 1 second) between GLONASS system time, UTC(SU),UTC(USNO) and GPS system time have to be dealt with during the post-processing and not before the RINEX conversion. It may also be necessary to solve for remaining differences during the post-processing.

8.1.2 Pseudorange Definition

The pseudorange (code) measurement is defined to be equivalent to 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 satellite) of a distinct satellite signal.

If a mixed-mode GPS/GLONASS receiver refers all pseudorange observations to one receiver clock only,

- the raw GLONASS pseudoranges will show the current number of leap seconds between GPS time and GLONASS time if the receiver clock is running in the GPS time frame

- the raw GPS pseudoranges will show the negative number of leap seconds between GPS time and GLONASS time if the receiver clock is running in the GLONASS time frame

In order to avoid misunderstandings and to keep the code observations within the format fields, the pseudoranges must be corrected in this case as follows:

```
PR(GPS) := PR(GPS) + c * leap_seconds   if generated with a receiver clock running in the GLONASS time frame

PR(GLO) := PR(GLO) - c * leap_seconds   if generated with a receiver clock running in the GPS time frame
```

to remove the contributions of the leap seconds from the pseudoranges.

"leap_seconds" is the actual number of leap seconds between GPS and GLONASS(UTC) time, as broadcast in the GPS almanac and distributed in Circular T of BIPM.

8.1.3 More than 12 satellites per epoch

The format of the epoch / satellite line in the observation record part of the RINEX Observation files has only been defined for up to 12 satellites per epoch. We explicitly define now the format of the continuation lines, see table A2.

8.2 RINEX Navigation Files for GLONASS

As the GLONASS navigation message differs in contents from the GPS message too much, a special GLONASS navigation message file format has been defined.

The header section and the first data record (epoch, satellite clock information) is similar to the GPS navigation file. The following records contain the satellite position, velocity and acceleration, the clock and frequency biases as well as auxiliary information as health, satellite frequency (channel), age of the information.

*** In order to use the same sign conventions for the time and frequency bias as in the GPS navigation files, the broadcast GLONASS values are multiplied by -1.

The time tags in the GLONASS navigation files are given in UTC (i.e. _not_Moscow time or GPS time).

Filenaming convention: See above.

9. REFERENCES

Evans, A. (1989): "Summary of the Workshop on GPS Exchange Formats." Proceedings of the Fifth International Geodetic Symposium on Satellite Systems, pp. 917ff, Las Cruces.

Gurtner, W., G. Mader, D. Arthur (1989): "A Common Exchange Format for GPS Data." CSTG GPS Bulletin Vol.2 No.3, May/June 1989, National Geodetic Survey, Rockville.

Gurtner, W., G. Mader (1990): "The RINEX Format: Current Status, Future Developments." Proceedings of the Second International Symposium of Precise Positioning with the Global Positioning system, pp. 977ff, Ottawa.

Gurtner, W., G. Mader (1990): "Receiver Independent Exchange Format Version 2." CSTG GPS Bulletin Vol.3 No.3, Sept/Oct 1990,

National Geodetic Survey, Rockville.

10. RINEX VERSION 2 FORMAT DEFINITIONS AND EXAMPLES

TABLE A1
OBSERVATION DATA FILE - HEADER SECTION DESCRIPTION

HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
RINEX VERSION / TYPE	- Format version (2) - File type ('O' for Observation Data) - Satellite System: blank or 'G': GPS 'R': GLONASS 'T': NNSS Transit 'M': Mixed	I6,14X, 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	- Wavelength factors for L1 and L2 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. 0 or blank: Default wavelength factors for all satellites not contained in such a list. - List of PRNs (satellite numbers) Repeat record if necessary	2I6, I6, 7(3X,A1,I2)
# / TYPES OF OBSERV	- Number of different observation types stored in the file - Observation types If more than 9 observation types: Use continuation line(s)	I6, 9(4X,A2) 6X,9(4X,A2)

```
 |                    | The following observation types are      |            |
 |                    | defined in RINEX Version 2:              |            |
 |                    |                                          |            |
 |                    | L1, L2: Phase measurements on L1 and L2  |            |
 |                    | C1    : Pseudorange using C/A-Code on L1 |            |
 |                    | P1, P2: Pseudorange using P-Code on L1,L2|            |
 |                    | D1, D2: Doppler frequency on L1 and L2   |            |
 |                    | T1, T2: Transit Integrated Doppler on    |            |
 |                    |         150 (T1) and 400 MHz (T2)        |            |
 |                    |                                          |            |
 |                    | 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                 |            |
 |                    |         Transit     : cycles             |            |
 |                    |                                          |            |
 |                    | The sequence of the types in this record |            |
 |                    | has to correspond to the sequence of the |            |
 |                    | observations in the observation records  |            |
 +--------------------+------------------------------------------+------------+
*|INTERVAL            | Observation interval in seconds          |     I6     |*
 +--------------------+------------------------------------------+------------+
 |TIME OF FIRST OBS   | - Time of first observation record       | 5I6,F12.6, |
 |                    |   (4-digit-year, month,day,hour,min,sec) |            |
 |                    | - Time system: GPS (=GPS time system)    |    6X,A3   |
 |                    |                GLO (=UTC time system)    |            |
 |                    |   Compulsory in mixed GPS/GLONASS files  |            |
 |                    |   Defaults: GPS for pure GPS files       |            |
 |                    |             GLO for pure GLONASS files   |            |
 +--------------------+------------------------------------------+------------+
*|TIME OF LAST OBS    | - Time of last  observation record       | 5I6,F12.6, |*
 |                    |   (4-digit-year, month,day,hour,min,sec) |            |
 |                    | - Time system: GPS (=GPS time system)    |    6X,A3   |
 |                    |                GLO (=UTC time system)    |            |
 |                    |   Compulsory in mixed GPS/GLONASS files  |            |
 |                    |   Defaults: GPS for pure GPS files       |            |
 |                    |             GLO for pure GLONASS files   |            |
 +--------------------+------------------------------------------+------------+
*|LEAP SECONDS        | Number of leap seconds since 6-Jan-1980  |     I6     |*
 |                    | Recommended for mixed GPS/GLONASS files  |            |
 +--------------------+------------------------------------------+------------+
*|# OF SATELLITES     | Number of satellites, for which          |     I6     |*
 |                    | observations are stored in the file      |            |
 +--------------------+------------------------------------------+------------+
*|PRN / # OF OBS      | PRN (sat.number), number of observations |3X,A1,I2,9I6|*
 |                    | for each observation type indicated      |            |
 |                    | in the "# / TYPES OF OBSERV" - record.   |            |
 |                    |                                          |            |
 |                    |   If more than 9 observation types:      |            |
 |                    |   Use continuation line(s)               |    6X,9I6  |
 |                    |                                          |            |
 |                    | This record is (these records are)       |            |
 |                    | repeated for each satellite present in   |            |
 |                    | the data file                            |            |
 +--------------------+------------------------------------------+------------+
 |END OF HEADER       | Last record in the header section.       |    60X     |
 +--------------------+------------------------------------------+------------+

                        Records marked with * are optional
```

```
+----------------------------------------------------------------------------+
|                                 TABLE A2                                   |
|              OBSERVATION DATA FILE - DATA RECORD DESCRIPTION               |
+-------------+-------------------------------------------------+------------+
| OBS. RECORD | DESCRIPTION                                     |   FORMAT   |
+-------------+-------------------------------------------------+------------+
| EPOCH/SAT   | - Epoch :                                       | 5I3,F11.7, |
|     or      |     year (2 digits), month,day,hour,min,sec     |            |
| EVENT FLAG  | - Epoch flag 0: OK                              |     I3,    |
|             |              1: power failure between           |            |
|             |                 previous and current epoch      |            |
|             |              1: Event flag                      |            |
|             | - Number of satellites in current epoch         |     I3,    |
|             | - List of PRNs (sat.numbers) in current epoch   | 12(A1,I2), |
|             | - receiver clock offset (seconds, optional)     |    F12.9   |
|             |                                                 |            |
|             |   If more than 12 satellites: Use continuation  |    32X,    |
|             |   line(s)                                       | 12(A1,I2)  |
|             |                                                 |            |
|             |  If EVENT FLAG record (epoch flag  1):          |            |
|             |   - 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)|            |
|             |     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)                  |            |
|             |   - "Number of satellites" contains number of   |            |
|             |     records to follow (0 for event flags 2,5)   |            |
+-------------+-------------------------------------------------+------------+
|OBSERVATIONS | - Observation        | rep. within record for   |  m(F14.3,  |
|             | - LLI                | each obs.type (same seq  |     I1,    |
|             | - Signal strength    | as given in header)      |     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.                                      |            |
|             | 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.|            |
|             |              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	

TABLE A3

NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION

	HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT	
	RINEX VERSION / TYPE	- Format version (2) - File type ('N' for Navigation data)	I6,14X, 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	*
*	ION ALPHA	Ionosphere parameters A0-A3 of almanac (page 18 of subframe 4)	2X,4D12.4	*
*	ION BETA	Ionosphere parameters B0-B3 of almanac	2X,4D12.4	*
*	DELTA-UTC: A0,A1,T,W	Almanac parameters to compute time in UTC (page 18 of subframe 4) A0,A1: terms of polynomial T : reference time for UTC data W : UTC reference week number	3X,2D19.12, 2I9	*
*	LEAP SECONDS	Delta time due to leap seconds	I6	*
	END OF HEADER	Last record in the header section.	60X	

Records marked with * are optional

TABLE A4

NAVIGATION MESSAGE FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
PRN / EPOCH / SV CLK	- Satellite PRN number - Epoch: Toc - Time of Clock year (2 digits) month day hour minute second - SV clock bias (seconds) - SV clock drift (sec/sec) - SV clock drift rate (sec/sec2)	I2, 5I3, F5.1, 3D19.12

```
+--------------------+------------------------------------------+------------+
| BROADCAST ORBIT - 1| - IODE Issue of Data, Ephemeris          | 3X,4D19.12 |
|                    | - Crs                    (meters)        |            |
|                    | - Delta n                (radians/sec)   |            |
|                    | - M0                     (radians)       |            |
+--------------------+------------------------------------------+------------+
| BROADCAST ORBIT - 2| - Cuc                    (radians)       | 3X,4D19.12 |
|                    | - e Eccentricity                         |            |
|                    | - Cus                    (radians)       |            |
|                    | - sqrt(A)                (sqrt(m))       |            |
+--------------------+------------------------------------------+------------+
| BROADCAST ORBIT - 3| - Toe Time of Ephemeris                  | 3X,4D19.12 |
|                    |                          (sec of GPS week)|           |
|                    | - Cic                    (radians)       |            |
|                    | - OMEGA                  (radians)       |            |
|                    | - CIS                    (radians)       |            |
+--------------------+------------------------------------------+------------+
| BROADCAST ORBIT - 4| - i0                     (radians)       | 3X,4D19.12 |
|                    | - Crc                    (meters)        |            |
|                    | - omega                  (radians)       |            |
|                    | - OMEGA DOT              (radians/sec)   |            |
+--------------------+------------------------------------------+------------+
| BROADCAST ORBIT - 5| - IDOT                   (radians/sec)   | 3X,4D19.12 |
|                    | - Codes on L2 channel                    |            |
|                    | - GPS Week # (to go with TOE)            |            |
|                    | - L2 P data flag                         |            |
+--------------------+------------------------------------------+------------+
| BROADCAST ORBIT - 6| - SV accuracy            (meters)        | 3X,4D19.12 |
|                    | - SV health              (MSB only)      |            |
|                    | - TGD                    (seconds)       |            |
|                    | - IODC Issue of Data, Clock              |            |
+--------------------+------------------------------------------+------------+
| BROADCAST ORBIT - 7| - Transmission time of message           | 3X,4D19.12 |
|                    |         (sec of GPS week, derived e.g.   |            |
|                    |    from Z-count in Hand Over Word (HOW)  |            |
|                    | - spare                                  |            |
|                    | - spare                                  |            |
|                    | - spare                                  |            |
+--------------------+------------------------------------------+------------+


+----------------------------------------------------------------------------+
|                                 TABLE A5                                   |
|           METEOROLOCICAL DATA FILE - HEADER SECTION DESCRIPTION            |
+--------------------+------------------------------------------+------------+
|    HEADER LABEL    |               DESCRIPTION                |   FORMAT   |
|  (Columns 61-80)   |                                          |            |
+--------------------+------------------------------------------+------------+
|RINEX VERSION / TYPE| - Format version (2)                     |   I6,14X,  |
|                    | - File type ('M' for Meteorological Data)|   A1,39X   |
+--------------------+------------------------------------------+------------+
|PGM / RUN BY / DATE | - Name of program creating current file  |     A20,   |
|                    | - Name of agency  creating current file  |     A20,   |
|                    | - Date of file creation                  |     A20    |
+--------------------+------------------------------------------+------------+
*|COMMENT            | Comment line(s)                          |     A60    |*
+--------------------+------------------------------------------+------------+
|MARKER NAME         | Station Name                             |     A60    |
|                    | (preferably identical to MARKER NAME in  |            |
|                    |  the associated Observation File)        |            |
+--------------------+------------------------------------------+------------+
*|MARKER NUMBER      | Station Number                           |     A20    |*
|                    | (preferably identical to MARKER NUMBER in|            |
```

	the associated Observation File)	
# / TYPES OF OBSERV	- Number of different observation types stored in the file - Observation types The following meteorological observation types are defined in RINEX Version 2: PR : Pressure (mbar) TD : Dry temperature (deg Celsius) HR : Relative Humidity (percent) ZW : Wet zenith path delay (millimeters) (for WVR data) The sequence of the types in this record must correspond to the sequence of the measurements in the data records If more than 9 observation types are being used, use continuation lines with format (6X,9(4X,A2))	I6, 9(4X,A2)
MET SENSOR MOD/TYPE	Description of the met sensor - Model (manufacturer) - Type - Accuracy (same units as obs values) - Observation type Record is repeated for each observation type found in # / TYPES OF OBSERV record	 A20, A20,6X, F7.1,4X, A2,1X
MET SENSOR POS XYZH	Approximate position of the met sensor - Geocentric coordinates X,Y,Z (ITRF - Ellipsoidal height H or WGS-84) - Observation type Set X,Y,Z to zero if not known. Make sure H refers to ITRF or WGS-84! Record required for barometer, recommended for other sensors.	 3F14.4, 1F14.4, 1X,A2,1X
END OF HEADER	Last record in the header section.	60X

TABLE A6
METEOROLOGICAL DATA FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
EPOCH / MET	- Epoch in GPS time (not local time!) year (2 digits), month,day,hour,min,sec - Met data in the same sequence as given in the header More than 8 met data types: Use continuation lines	6I3, mF7.1 4X,10F7.1,3X

```
|                                    TABLE A7                                    |
|                        OBSERVATION DATA FILE - EXAMPLE                         |
+--------------------------------------------------------------------------------+

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|

     2              OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
BLANK OR G = GPS,  R = GLONASS,  T = TRANSIT,  M = MIXED    COMMENT
XXRINEXO V9.9       AIUB                22-APR-93 12:43     PGM / RUN BY / DATE
EXAMPLE OF A MIXED RINEX FILE                               COMMENT
A 9080                                                      MARKER NAME
9080.1.34                                                   MARKER NUMBER
BILL SMITH          ABC INSTITUTE                           OBSERVER / AGENCY
X1234A123           XX                  ZZZ                 REC # / TYPE / VERS
234                 YY                                      ANT # / TYPE
  4375274.       587466.      4589095.                      APPROX POSITION XYZ
         .9030         .0000         .0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     1     2     6   G14   G15   G16   G17   G18   G19      WAVELENGTH FACT L1/2
     4    P1    L1    L2    P2                              # / TYPES OF OBSERV
    18                                                      INTERVAL
  1990     3    24    13    10   36.000000                  TIME OF FIRST OBS
                                                            END OF HEADER
 90  3 24 13 10 36.0000000  0  3G12G 9G 6                            -.123456789
  23629347.915            .300 8         -.353    23629364.158
  20891534.648           -.120 9         -.358    20891541.292
  20607600.189           -.430 9          .394    20607605.848
 90  3 24 13 10 50.0000000  4  4
     1     2     2   G 9   G12                              WAVELENGTH FACT L1/2
  *** WAVELENGTH FACTOR CHANGED FOR 2 SATELLITES ***        COMMENT
      NOW 8 SATELLITES HAVE WL FACT 1 AND 2!                COMMENT
                                                            COMMENT
 90  3 24 13 10 54.0000000  0  5G12G 9G 6R21R22                      -.123456789
  23619095.450      -53875.632 8    -41981.375    23619112.008
  20886075.667      -28688.027 9    -22354.535    20886082.101
  20611072.689       18247.789 9     14219.770    20611078.410
  21345678.576       12345.567 5
  22123456.789       23456.789 5
 90  3 24 13 11  0.0000000  2
                            4  1
            *** FROM NOW ON KINEMATIC DATA! ***             COMMENT
 90  3 24 13 11 48.0000000  0  4G16G12G 9G 6                         -.123456789
  21110991.756       16119.980 7     12560.510    21110998.441
  23588424.398     -215050.557 6   -167571.734    23588439.570
  20869878.790     -113803.187 8    -88677.926    20869884.938
  20621643.727       73797.462 7     57505.177    20621649.276
                            3  4
A 9080                                                      MARKER NAME
9080.1.34                                                   MARKER NUMBER
         .9030         .0000         .0000                  ANTENNA: DELTA H/E/N
          -- THIS IS THE START OF A NEW SITE  CYCLE SLIPS THAT HAVE BEEN APPLIED TO       COMMENT
                THE OBSERVATIONS                            COMMENT
 90  3 24 13 14 48.0000000  0  4G16G12G 9G 6                         -.123456234
  21128884.159      110143.144 7     85825.18545  21128890.7764
  23487131.045     -318463.297 7   -248152.72824  23487146.149
  20817844.743     -387242.571 6   -301747.22925  20817851.322
  20658519.895      267583.67817    208507.26234  20658525.869
                            4  4
         ***   SATELLITE G 9   THIS EPOCH ON WLFACT 1 (L2)  COMMENT
         *** G 6 LOST LOCK AND THIS EPOCH ON WLFACT 2 (L2)  COMMENT
                (OPPOSITE TO PREVIOUS SETTINGS)             COMMENT

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

```
+------------------------------------------------------------------------------+
|                                   TABLE A8                                   |
|                        NAVIGATION MESSAGE FILE - EXAMPLE                     |
+------------------------------------------------------------------------------+

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
     2              N: GPS NAV DATA                         RINEX VERSION / TYPE
XXRINEXN V2.0       AIUB                12-SEP-90 15:22     PGM / RUN BY / DATE
EXAMPLE OF VERSION 2 FORMAT                                 COMMENT
     .1676D-07   .2235D-07  -.1192D-06  -.1192D-06          ION ALPHA
     .1208D+06   .1310D+06  -.1310D+06  -.1966D+06          ION BETA
     .133179128170D-06  .107469588780D-12   552960       39 DELTA-UTC: A0,A1,T,W
     6                                                      LEAP SECONDS
                                                            END OF HEADER
 6 90  8  2 17 51 44.0 -.839701388031D-03 -.165982783074D-10  .000000000000D+00
     .910000000000D+02  .934062500000D+02  .116040547840D-08  .162092304801D+00
     .484101474285D-05  .626740418375D-02  .652112066746D-05  .515365489006D+04
     .409904000000D+06 -.242143869400D-07  .329237003460D+00 -.596046447754D-07
     .111541663136D+01  .326593750000D+03  .206958726335D+01 -.638312302555D-08
     .307155651409D-09  .000000000000D+00  .551000000000D+03  .000000000000D+00
     .000000000000D+00  .000000000000D+00  .000000000000D+00  .910000000000D+02
     .406800000000D+06
13 90  8  2 19  0  0.0  .490025617182D-03  .204636307899D-11  .000000000000D+00
     .133000000000D+03 -.963125000000D+02  .146970407622D-08  .292961152146D+01
    -.498816370964D-05  .200239347760D-02  .928156077862D-05  .515328476143D+04
     .414000000000D+06 -.279396772385D-07  .243031939942D+01 -.558793544769D-07
     .110192796930D+01  .271187500000D+03 -.232757915425D+01 -.619632953057D-08
    -.785747015231D-11  .000000000000D+00  .551000000000D+03  .000000000000D+00
     .000000000000D+00  .000000000000D+00  .000000000000D+00  .389000000000D+03
     .410400000000D+06

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|


+------------------------------------------------------------------------------+
|                                   TABLE A9                                   |
|                       METEOROLOGICAL DATA FILE - EXAMPLE                     |
+------------------------------------------------------------------------------+

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|

     2              METEOROLOGICAL DATA                     RINEX VERSION / TYPE
XXRINEXM V9.9       AIUB                 3-APR-96 00:10     PGM / RUN BY / DATE
EXAMPLE OF A MET DATA FILE                                  COMMENT
A 9080                                                      MARKER NAME
     3    PR    TD    HR                                    # / TYPES OF OBSERV
PAROSCIENTIFIC      740-16B                       0.2    PR SENSOR MOD/TYPE/ACC
HAENNI                                            0.1    TD SENSOR MOD/TYPE/ACC
ROTRONIC            I-240W                        5.0    HR SENSOR MOD/TYPE/ACC
        0.0           0.0           0.0        1234.5678 PR SENSOR POS XYZ/H
                                                            END OF HEADER
 96  4  1  0  0 15  987.1   10.6   89.5
 96  4  1  0  0 30  987.2   10.9   90.0
 96  4  1  0  0 45  987.1   11.6   89.0

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|


 +----------------------------------------------------------------------------+
 |                                 TABLE A10                                  |
 |        GLONASS NAVIGATION MESSAGE FILE - HEADER SECTION DESCRIPTION        |
```

HEADER LABEL (Columns 61-80)	DESCRIPTION	FORMAT
RINEX VERSION / TYPE	- Format version (2) - File type ('G' = GLONASS nav mess data)	I6,14X, A1,39X
PGM / RUN BY / DATE	- Name of program creating current file - Name of agency creating current file - Date of file creation (dd-mmm-yy hh:mm)	A20, A20, A20
* COMMENT	Comment line(s)	A60 *
* CORR TO SYSTEM TIME	- Time of reference for system time corr (year, month, day) - Correction to system time scale (sec) to correct GLONASS system time to UTC(SU)	* 3I6, 3X,D19.12
* LEAP SECONDS	Number of leap seconds since 6-Jan-1980	I6 *
END OF HEADER	Last record in the header section.	60X

Records marked with * are optional

TABLE A11
GLONASS NAVIGATION MESSAGE FILE - DATA RECORD DESCRIPTION

OBS. RECORD	DESCRIPTION	FORMAT
PRN / EPOCH / SV CLK	- Satellite almanac number - Epoch of ephemerides (UTC) - year (2 digits) - month - day - hour - minute - second - SV clock bias (sec) (-tau) - SV relative frequency bias (-gamma) - message frame time (sec of day UTC)	I2, 5I3, F5.1, D19.12 D19.12 D19.12
BROADCAST ORBIT - 1	- Satellite position X (km) - velocity X dot (km/sec) - X acceleration (km/sec2) - health (0=OK) (Bn)	3X,4D19.12
BROADCAST ORBIT - 2	- Satellite position Y (km) - velocity Y dot (km/sec) - Y acceleration (km/sec2) - frequency number (1-24)	3X,4D19.12
BROADCAST ORBIT - 3	- Satellite position Z (km) - velocity Z dot (km/sec) - Z acceleration (km/sec2) - Age of oper. information (days) (E)	3X,4D19.12

```
|                                TABLE A12                                   |
|                 GLONASS NAVIGATION MESSAGE FILE - EXAMPLE                  |
+----------------------------------------------------------------------------+
```

```
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|

     2              GLONASS NAVMESS DATA                    RINEX VERSION / TYPE
XXRINEXN V1.3 VAX   University of Berne 30-AUG-93 17:57     PGM / RUN BY / DATE
  1993     8     7     -0.141188502312D-04                  CORR TO SYSTEM TIME
                                                            END OF HEADER
 1 93  8  7 15 15  0.0-0.161942094564D-03 0.181898940355D-11 0.542700000000D+05
    0.129469794922D+05-0.130014419556D+01 0.186264514923D-08 0.000000000000D+00
   -0.380712744141D+04 0.266516971588D+01 0.000000000000D+00 0.170000000000D+02
    0.216525634766D+05 0.124328994751D+01-0.186264514923D-08 0.000000000000D+00
17 93  8  7 15 15  0.0 0.717733055353D-04 0.272848410532D-11 0.542700000000D+05
    0.305286718750D+04 0.311648464203D+01 0.000000000000D+00 0.000000000000D+00
   -0.108431787109D+05-0.317855834961D+00 0.000000000000D+00 0.210000000000D+00
    0.229024404297D+05-0.575817108154D+00-0.186264514923D-08 0.000000000000D+00
 7 93  8  7 15 15  0.0-0.902833417058D-04 0.181898940355D-11 0.542700000000D+05
   -0.548300732422D+04-0.442504882813D+00-0.931322574615D-09 0.000000000000D+00
    0.227251596680D+05 0.131087875366D+01-0.931322574615D-09 0.130000000000D+00
    0.998504833984D+04-0.323978710175D+01-0.931322574615D-09 0.000000000000D+00
 2 93  8  7 15 15  0.0-0.975374132395D-04 0.181898940355D-11 0.542700000000D+05
    0.138356103516D+05-0.716581344604D+00 0.279396772385D-08 0.000000000000D+00
   -0.190140761719D+05 0.116566944122D+01 0.000000000000D+00 0.500000000000D+01
    0.991978125000D+04 0.322995281219D+01 0.000000000000D+00 0.000000000000D+00
 8 93  8  7 15 15  0.0-0.292631797493D-03 0.363797880709D-11 0.542700000000D+05
    0.419437841797D+04-0.111876964569D+01 0.000000000000D+00 0.000000000000D+00
    0.141901040039D+05 0.262095737457D+01-0.931322574615D-09 0.200000000000D+01
    0.207799843750D+05-0.155530166626D+01-0.186264514923D-08 0.000000000000D+00
24 93  8  7 15 15  0.0 0.176711939275D-03 0.109139364213D-10 0.544500000000D+05
    0.204199819336D+05 0.176556110382D+01 0.279396772385D-08 0.000000000000D+00
   -0.796999316406D+04-0.311827659607D+00 0.000000000000D+00 0.100000000000D+01
    0.130460561523D+05-0.295512390137D+01-0.931322574615D-09 0.000000000000D+00

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```

```
+----------------------------------------------------------------------------+
|                                TABLE A13                                   |
|                     GLONASS OBSERVATION FILE - EXAMPLE                     |
+----------------------------------------------------------------------------+
```

```
----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|

     2              OBSERVATION DATA    R (GLONASS)         RINEX VERSION / TYPE
XXRINEXO V1.1       AIUB                27-AUG-93 07:23     PGM / RUN BY / DATE
TST1                                                        MARKER NAME
VIEWEG              BRAUNSCHWEIG                            OBSERVER / AGENCY
100                 XX-RECEIVER         1.0                 REC # / TYPE / VERS
101                 XX-ANTENNA                              ANT # / TYPE
  3844808.114   715426.767  5021804.854                     APPROX POSITION XYZ
        1.2340         .0000         .0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     2    C1    L1                                          # / TYPES OF OBSERV
    10                                                      INTERVAL
  1993     8    23    14    24   40.049000      GLO         TIME OF FIRST OBS
                                                            END OF HEADER
 93  8 23 14 24 40.0490000  0  3  2  1 21
  23986839.824       20520.565 5
  23707804.625       19937.231 5
  23834065.096       -9334.581 5
 93  8 23 14 24 50.0490000  0  3  2  1 21
```

```
  23992341.033       49856.525 5
  23713141.002       48479.290 5
  23831189.435      -24821.796 5
 93  8 23 14 25   .0490000  0  3  2  1 21
  23997824.854       79217.202 5
  23718494.110       77092.992 5
  23828329.946      -40219.918 5
 93  8 23 14 25 10.0490000  0  5  2  5 17  1 21
  24003328.910      108602.422 5
  24933965.449      -19202.780 5
  22203326.578       -2987.327 5
  23723851.686      105777.849 5
  23825485.526      -55529.205 5
 93  8 23 14 25 20.0490010  0  5  2  5 17  1 21
  24008828.023      138012.178 5
  24927995.616      -51188.500 5
  22202547.907       -7213.298 5
  23729236.758      134533.636 5
  23822662.277      -70749.590 5
 93  8 23 14 25 30.0490000  0  5  2  5 17  1 21
  24014330.779      167446.477 5
  24922041.288      -83151.666 5
  22201767.457      -11388.909 5
  23734633.024      163360.131 5
  23819848.894      -85881.102 5

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|


+----------------------------------------------------------------------------+
|                                 TABLE A14                                  |
|                MIXED GPS/GLONASS OBSERVATION FILE - EXAMPLE                |
+----------------------------------------------------------------------------+

----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|

     2              OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
YYRINEXO V2.8.1 VM  AIUB                19-FEB-97 13:59     PGM / RUN BY / DATE
TST2                                                        MARKER NAME
001-02-A                                                    MARKER NUMBER
JIM                 Y-COMPANY                               OBSERVER / AGENCY
1                   YY-RECEIVER         2.0.1               REC # / TYPE / VERS
1                   GEODETIC L1                             ANT # / TYPE
  3851178.1849  -80151.4072  5066671.1013                   APPROX POSITION XYZ
        1.2340        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     0                                                WAVELENGTH FACT L1/2
     2    C1    L1                                          # / TYPES OF OBSERV
    10                                                      INTERVAL
    11                                                      LEAP SECONDS
  1997     2     6    11    53    0.000000      GPS         TIME OF FIRST OBS
                                                            END OF HEADER
 97  2  6 11 53  0.0000000  0 14G23G07G02G05G26G09G21R20R19R12R02R11
                                R10R03
  22576523.586  -11256947.60212
  22360162.704  -16225110.75413
  24484865.974   14662682.882 2
  21950524.331  -13784707.24912
  22507304.252    9846064.848 2
  20148742.213  -20988953.712 4
  22800149.591  -16650822.70012
  19811403.273  -25116169.741 3
  23046997.513   -3264701.688 2
  22778170.622 -821857836.745 1
```

```
  22221283.991  -988088156.884 2
  19300913.475   -83282658.19013
  20309075.579  -672668843.84713
  23397403.484  -285457101.34211
 97  2  6 11 53 10.0000000  0 14G23G07G02G05G26G09G21R20R19R12R02R11
                                        R10R03
  22578985.016   -11244012.910 2
  22359738.890   -16227337.841 2
  24490324.818    14691368.710 2
  21944376.706   -13817012.849 2
  22512598.731     9873887.580 2
  20147322.111   -20996416.338 4
  22798942.949   -16657163.594 2
  19812513.509   -25110234.795 3
  23053885.702    -3227854.397 2
  22770607.029  -821898566.774 1
  22222967.297  -988079145.989 2
  19297913.736   -83298710.38413
  20313087.618  -672647337.04113
  23392352.454  -285484291.40311

     ----|---1|0---|---2|0---|---3|0---|---4|0---|---5|0---|---6|0---|---7|0---|---8|
```