

# K5 software correlator users manual

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## 0. Introduction

This document is the users manual describing how to use the K5 Software Correlator package and how to apply it to the fringe detection and clock parameter search in VLBI observations. This package has been developed and maintained by the Radio Astronomy Applications Group in Kashima Space Research Center (KSRC), National Institute of Information and Communications Technology (NICT), Japan. After agreement with the NICT, a user institute is issued a payment-free license and is accepted to use this package only in the academic research.

Joint Institute for VLBI in Europe (JIVE) obtained the license in July 2003 after collaborating with KSRC in developing the software package in order to customize it for usage in international VLBI observations including European VLBI Network (EVN) observations. The first success in fringe detection with this package was made in March 2003 on basis of the EVN-NICT test observation using the Mark-V and K-5 backends (observation code: N03L1, figure 1). The package consists of parts reading a schedule file that is either SKED DRUDGE or SCHED VEX formatted, converting the Mark-V data format into the K-5 format, making data correlation, and displaying fringe-search results. Although the original users manual is written mainly in Japanese, this document interprets the original manual into English for international usage based on actual experiences in using the package at JIVE. The manual should be put in the following web site, [http://www2.nict.go.jp/ka/radioastro/IPVLBI/m5k5\\_e.html](http://www2.nict.go.jp/ka/radioastro/IPVLBI/m5k5_e.html), and will be maintained by either KSRC or JIVE members corresponding for any updating the package.

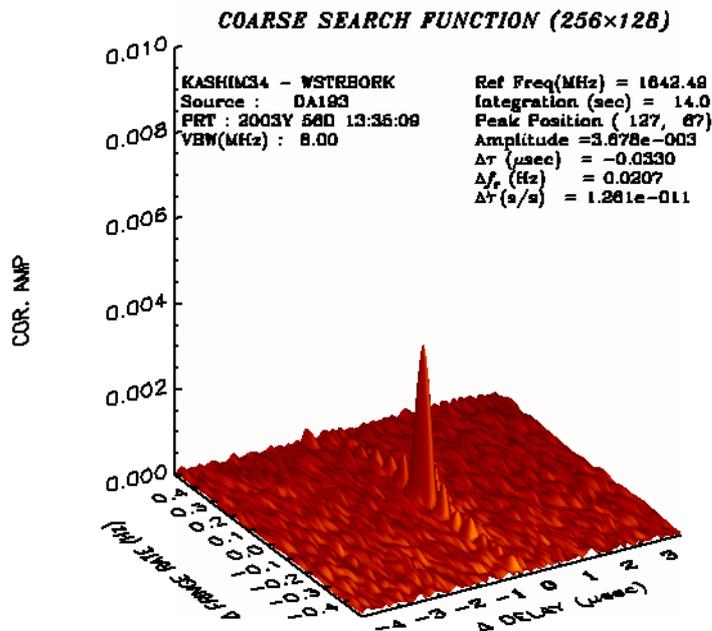


Figure 1: Fringe detected from the baseline between Kashima 34m station and WSRT using the software correlator. The observation was made on March 2003 (N03L1). The

detail of the observation operation and the data correlation is described in the web page, [http://www.evlbi.org/tog/softw\\_corr/Mk5K5\\_fringe.html](http://www.evlbi.org/tog/softw_corr/Mk5K5_fringe.html).

## 1. Installation of the package

### 1.1. Necessary environment

Linux  
PGPLOT (cpgplot.h should be valid)

### 1.2. Unpacking

Make a directory for the package, move to the directory, then extract the package as follows.

```
gunzip -c ipvlbi_corYYYYMMDD.tar.gz [RETURN]
tar xvf ipvlbi_corYYYYMMDD.tar [RETURN]
or
tar xvzf ipvlbi_corYYYYMMDD.tar.gz [RETURN]
```

Here YYYY, MM, DD are the date (year, month, day respectively) when the package was released.

### 1.3. Set environments in "makefile" and "Makefile"

src/makefile, mark5/makefile, ./makefile,  
apri/Makefile, corr/Makefile, network/Makefile, sdelay/Makefile  
for cpgplot.h: add the directory containing the library as a following example,  
CFLAGS = -I./src -I/asp3/pgplot ,  
here the directory /asp3/pgplot contains cpgplot.h .

### 1.4. Start the installer

Type "source install\_cor.sh".

The shell script for JIVE environment at first copies the makefiles in the directory \$CORHOME/jive.makefiles, where \$CORHOME is the directory in which the package is installed. It compiles the necessary modules.

### 1.5. Making an archived package

Type "source archive\_cor" .

### 1.6. Environment variables

User-defined environment variables are accepted in the following modules.

apri/apri\_calc, corr/fx\_cor, corr/fx\_cor\_all, sdelay/sdelay, mark5/m5tok5Rnp

The modules themselves define some environment variables. By typing as follows,

```
<<< module name>>> env
```

the defined variables and current values are displayed.

example: typing

```
fx_cor env
```

the following messages are displayed.

Environment variables

```
K5COUT --- default directory for correlation data out
           ( (null) ), program deflt is ( ../cout/ )
K5APRIDIR --- default directory for apriori file
            ( (null) ), program deflt is ( ../corrapri/ )
PGDISP --- default PGPLOT display device when selected so
           ( (null) ), program deflt is ( /XTERM )
```

## 2. Contents and items essential for the software correlation

```
$CORHOME: home directory of the software correlator package
$CORHOME/ipv1bi/apri/apri_calc: program for calculating a-priori delays.
$CORHOME/ipv1bi/corr/fx_cor: program for fringe search.
$CORHOME/ipv1bi/corr/fx_cor_all: program for full data correlation.
$CORHOME/ipv1bi/sdelay/sdelay: program for delay-rate estimation and display.
```

## 3. Structure of the working space

```
$CORHOME/ipv1bi/
|
|-- archive_cor ..... shell script for creating archived program package
+--- ipv1bi_cor[yyyymmdd].tar.gz .....program package archived by archive_cor
|           ((yyyy, mm, dd indicate the release date (year, month and day))
|
|
+--- readme_cor.txt ..... users manual for the package (in Japanese)
+-- pgplot_install.txt ..... instruction for installing PGPLOT (in Japanese)
+-- install_cor.sh ..... shell script for install the package
+-- nz0294.skd, nz0295.skd ..... example of a schedule file (SCHED output)
|
+-- mark5/..... directory for analyzing VEX files and
|   |           converting from Mark-5 format to K-5 format
|   +--- m5tok5 ..... Mark-5 - K-5 converter
|   |           (for 1-bit sampling in NICT-USA projects)
|   +--- m5tok5R .... Mark-5 - K-5 converter
|   |           (compatible to EVN Mark-5, 2bits/sample data)
|   +--- m5tok5np ..... Mark-5 - K-5 converter
|   |           (for data with no parity bit, or Mark-5A mode)
|   +--- m5tok5Rnp .... Mark-5 - K-5 converter
|   |           (compatible to EVN Mark-5 data with no parity bit, or Mark-5A mode,
|   |           2bits/sample data))
|   +--- m5check .... Checking the Mark-5 format data
|   +--- vex_ana_sample ..... checking the information in a VEX file
|   +--- *.c, *.h ..... utility programs and include files
|   +--- Makefile ..... makefile for the modules
|   +--- cp2bin.sh ..... shell script for copying execution files
|   |           to the "bin" directory ../bin
+-- apri/ --
|   +--- apri_calc
|   +--- *.c, *.h ..... utility programs and include files
|   +--- Makefile ..... makefile for the modules
|   +--- cp2bin.sh ..... shell script for copying execution files
|   |           to the "bin" directory ../bin
+-- corr/ --
|   +--- fx_cor
```

```

|   +-- fx_cor_all
|   +-- corrapri/ ..... directory for "apri_calc" outputs
|   |   + apeDDNXXY.txt ..... a-priori parameter file
|   +-- *.c, *.h ..... utility programs and include files
|   +-- Makefile ..... makefile for the modules
|   +-- cp2bin.sh ..... shell script for copying execution files
|                           to the "bin" directory ../bin
+-- cout/ -- ..... directory for "fx_cor" and fx_cor_all" outputs
|   |
|   +dummy.txt ..... dummy for creating this directory
|   |   (unnecessary unless backup files should be created by archive_cor.)
|   +-- coutNNNN.txt
+- sdelay/ --
|   +-- sdelay
|   +-- *.c, *.h ..... utility programs and include files
|   +-- Makefile ..... makefile for the modules
|   +-- cp2bin.sh ..... shell script for copying execution files
|                           to the "bin" directory ../bin
+-- src/ ..... directory containing utility source programs
|   +-- *.c, *.h ..... utility programs and include files
|   +-- Makefile ..... makefile for the modules, but only for machines with the
|   |   sampler board installed
|   +-- Makefile2 ..... makefile for the modules for machines without
|   |   sampler board installed
|   +-- cp2bin.sh ..... shell script for copying execution files
|   |   to the "bin" directory ../bin
|   +cp2bin2.sh ..... shell script for copying execution files
|   |   to the "bin" directory ../bin, but for machines without
|   |   sampler board installed.
|   +sample.skd ..... sample schedule file

```

## 4. Preparation for data correlation

In this manual, one base band channel (BBC) corresponds to a base band filter, supplying one of IF channels on of left- or right-circular polarization. Each of BBCs is specified in each of lines in the section \$FREQ in VEX and FRUDGE files.

In the correlation process, you need not only Mark-5 and/or K-5 formatted data but also a schedule file that has either VEX or DRUDGE format. It is convenient to put them in the same directory you created. As shown in Sect. 1.7, you can set several environment variables to set several short cuts to, e.g. your data directory.

## 5. Data conversion from Mark-5 to K-5 format

### 5.1. Series of conversion modules

The module m5tok5R is used (m5tok5 is used for NICT-USA experiments having 1-bit sampling).

#### 5.1.1. m5check: Sync-pattern check in a Mark-5 formatted file.

usage:

m5check m5file [mode]

where

m5file: filename of the Mark-5 formatted file.

mode: data format mode

0 (default): 32bit-word (32 tracks), NRZM, with parity.

1: 16bit-word(16 tracks), NRZL, without parity.

Note: You can run in mode=1 at first, then you can recognize the correct mode by finding the

sync-pattern (if you find it, mode=1 is correct).  
 Note: Mark-5 format is NRZM (non return to zero-mark) encoded, while K-5 format is NRZL (non return to zero-level) encoded. Mark-5A and K-5 formats have no parity bit.

example:

```
-----
> m5check G:/ipvlbi/data/evlbi3/288-173
*****
*   Mark-5 data structure analysis                               *
*   Ver 1.10   2003-06-27 by T.KONDO/NICT                       *
*                                                     *
*   NRZM, with parity, 32bit-word mode                         *
*****
```

Mark 5 Data File : G:/ipvlbi/data/evlbi3/288-1730

BIT#	HEADER	AUX	SYNC	TIME	FIELD	CRC	Y/DDD	HH:MM:SS.SSS	FMHz
00	---	---	---	---	---	---	---	---	---
01	---	---	---	---	---	---	---	---	---
02	00310031	04010007	ffffff	22881730	00110b28	2/288	17:30:00.110	4.0	
03	---	---	---	---	---	---	---	---	---
04	00310031	06030007	ffffff	22881730	001106e6	2/288	17:30:00.110	4.0	
05	---	---	---	---	---	---	---	---	---
06	00310031	08050007	ffffff	22881730	0011093f	2/288	17:30:00.110	4.0	
07	---	---	---	---	---	---	---	---	---
08	00310031	10070007	ffffff	22881730	0011061c	2/288	17:30:00.110	4.0	
09	---	---	---	---	---	---	---	---	---
10	00310031	12090007	ffffff	22881730	00110e21	2/288	17:30:00.110	4.0	
11	---	---	---	---	---	---	---	---	---
12	00310031	140b0007	ffffff	22881730	0011032d	2/288	17:30:00.110	4.0	
13	---	---	---	---	---	---	---	---	---
14	00310031	160d0007	ffffff	22881730	00110db2	2/288	17:30:00.110	4.0	
15	---	---	---	---	---	---	---	---	---
16	00310031	18000007	ffffff	22881730	001103b6	2/288	17:30:00.110	4.0	
17	---	---	---	---	---	---	---	---	---
18	00310031	20020007	ffffff	22881730	00110a85	2/288	17:30:00.110	4.0	
19	---	---	---	---	---	---	---	---	---
20	00310031	22040007	ffffff	22881730	0011041a	2/288	17:30:00.110	4.0	
21	---	---	---	---	---	---	---	---	---
22	00310031	24060007	ffffff	22881730	00110916	2/288	17:30:00.110	4.0	
23	---	---	---	---	---	---	---	---	---
24	00310031	26080007	ffffff	22881730	0011012b	2/288	17:30:00.110	4.0	
25	---	---	---	---	---	---	---	---	---
26	00310031	280a0007	ffffff	22881730	00110da3	2/288	17:30:00.110	4.0	
27	---	---	---	---	---	---	---	---	---
28	00310031	300c0007	ffffff	22881730	001101d1	2/288	17:30:00.110	4.0	
29	---	---	---	---	---	---	---	---	---
30	---	---	---	---	---	---	---	---	---
31	---	---	---	---	---	---	---	---	---

1st header time (Y/DDD HH:MM:SS.SSS) : 2/288 17:30:00.110

bit pos	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Validity	0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Track	0	0	4	0	6	0	8	0	10	0	12	0	14	0	16	0

bit pos	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Validity	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0	0

Track 18 0 20 0 22 0 24 0 26 0 28 0 30 0 0 0  
>

### 5.1.2. Data conversion in m5tok5

Note: Read this sub-section to process with m5tok5R, m5tok5np and m5tok5Rnp.

m5tok5 is customized for 1-bit sampling format data to improve the speed for format conversion. This module accepts only the Mark-5 data having 32 tracks, NRZM and parity.

usage (part 1):

m5tok5 mk5\_filename [options]

where

mk5\_filename: filename of the Mark-5 formatted data.

It should be specified before any option described below.

options:

-c [channel]: BBC channel number processed [1-16].

Specified when only one BBC channel is processed.

Without specifying, all of 16 BBC channels are processed.

-g [group]: BBC group number processed [1-4].

Each of the groups consists of 4 BBC channels. This option is

ignored if -c option is specified. If both of -c and -g options are skipped, all of 16 BBC channels are processed.

-i [info\_file]: filename of the conversion information file.

The information file is created based on the information in the schedule file and consists of,

the table of correspondence between tracks and BBC channels,

the table of correspondence between bit positions and BBC channels,

the table of correspondence between groups and BBC channels.

Unless the information file is specified, the default file (m5tok5info.txt) is selected.

Note 1: By adding a minus "-" in front of the filename without blanks, a new information file is created.

Note 2: "-i make" automatically creates the file named "m5tok5info.txt".

To do so, a VEX file should be provided.

-o [k5name]: filename of the output K-5 formatted file.

If skipped, the filename is automatically determined

(see "The rule of given filenames for K-5 formatted file" described below).

-d [k5dir]: directory in which the output K-5 formatted file is created.

If skipped, the directory is set to the same as that in which the used Mark-5 formatted data is contained.

-s [start\_set]: time in seconds for processing from the time at the beginning of the file. The default is set to zero second.

-p [period]: time range of data to be processed in seconds.

The default is to process the whole time range of the scan in the file.

usage (part 2):

m5tok5 mk5\_filename k5\_filename bit1 [bit2 bit3 bit4]

where

mk5\_filename: filename of the Mark-5 formatted data.

k5\_filename: filename of the K-5 formatted data.

bit1, bit2, bit3, bit4:

bit position picked up for processing [0-31] in the Mark-5 formatted data.

If bit2, bit3 and bit4 are skipped, 1-ch mode is assumed.

Note: Each pair of correspondences between the bit positions and

BBC channels can be obtained by the method described in sub-section 5.2.  
EVN users do not need to concern about them.

The rule of given filenames for K-5 formatted file:

For example an original Mark-5 formatted file named "MK5" leads to make the following filenames according to the selected BBC and group number.

in 4-ch mode:

MK5.k5a ---- group #1 in info\_file.  
MK5.k5b ---- group #2 in info\_file.  
MK5.k5c ---- group #3 in info\_file  
MK5.k5d ---- group #4 in info\_file

in 1-ch mode:

MK5.k5-NN ---- NN corresponds to one BBC ch# (1-16).

Example: An EVN data with 8 BBCs, group #1 consists of BBC1, 2, 3, 4,  
while group #2 consists of BBC5, 6, 7, 8.

example 1: making an info\_file file.

```
-----  
> m5tok5 G:/ipvlbi/data/evlbi3/288-1730 -i make  
mk5tok5R running under Information File create mode  
info file (m5tok5info.txt) will be created (updated).  
Enter VEX file name -> G:/ipvlbi/data/evlbi3/2994.ovex  
SITES (Station ID) defined are  
  1 -- Kb  
  2 -- Wf  
Select Station by number ----> 2
```

Detailed site information

```
site definition : WESTFORD  
site name      : WESTFORD  
site ID       : Wf  
site position  : 1492206.600000 -4458130.507000 4296015.532000  
site clock  
  validity epoch : 2002 288 0 0 0  
  clock epoch    : 2002 288 0 37 0  
  clock offset   : 8.500000e-006  
  clock rate     : 0.000000e+000
```

mode is 1230188

TRACK and FREQUENCY information for WESTFORD

```
BARREL ROLL : off  
FREQDEF = CDP-SX-SX01 TRACKDEF = C1-SX01  
adbit= 1 sample_rate= 4000000.000000
```

bb	Tr	AD	fo	chan	RF(Hz)	S	VBW(Hz)
1	18	sign	1	&Ch01	8210990000.000000	U	2000000.000000
2	4	sign	1	&Ch02	8210990000.000000	U	2000000.000000
3	20	sign	1	&Ch03	8210990000.000000	U	2000000.000000
4	6	sign	1	&Ch04	8210990000.000000	U	2000000.000000
5	22	sign	1	&Ch05	8210990000.000000	U	2000000.000000
6	8	sign	1	&Ch06	8210990000.000000	U	2000000.000000
7	24	sign	1	&Ch07	8210990000.000000	U	2000000.000000
8	10	sign	1	&Ch08	8210990000.000000	U	2000000.000000
9	26	sign	1	&Ch09	8210990000.000000	U	2000000.000000
10	12	sign	1	&Ch10	8210990000.000000	U	2000000.000000
11	28	sign	1	&Ch11	8210990000.000000	U	2000000.000000

12 14 sign 1 &Ch12 8210990000.000000 U 2000000.000000  
 13 30 sign 1 &Ch13 8210990000.000000 U 2000000.000000  
 14 16 sign 1 &Ch14 8210990000.000000 U 2000000.000000

Mark 5 Data File : G:/ipvlbi/data/evlbi3/288-1730

BIT#	HEADER	AUX	SYNC	TIME	FIELD	CRC	Y/DDD	HH:MM:SS.SSS	FMHz
00	---	sync	not	detected	---				
01	---	sync	not	detected	---				
02	00310031	04010007	ffffff	22881730	00110b28	2/288	17:30:00.110	4.0	
03	---	sync	not	detected	---				
04	00310031	06030007	ffffff	22881730	001106e6	2/288	17:30:00.110	4.0	
05	---	sync	not	detected	---				
06	00310031	08050007	ffffff	22881730	0011093f	2/288	17:30:00.110	4.0	
07	---	sync	not	detected	---				
08	00310031	10070007	ffffff	22881730	0011061c	2/288	17:30:00.110	4.0	
09	---	sync	not	detected	---				
10	00310031	12090007	ffffff	22881730	00110e21	2/288	17:30:00.110	4.0	
11	---	sync	not	detected	---				
12	00310031	140b0007	ffffff	22881730	0011032d	2/288	17:30:00.110	4.0	
13	---	sync	not	detected	---				
14	00310031	160d0007	ffffff	22881730	00110db2	2/288	17:30:00.110	4.0	
15	---	sync	not	detected	---				
16	00310031	18000007	ffffff	22881730	001103b6	2/288	17:30:00.110	4.0	
17	---	sync	not	detected	---				
18	00310031	20020007	ffffff	22881730	00110a85	2/288	17:30:00.110	4.0	
19	---	sync	not	detected	---				
20	00310031	22040007	ffffff	22881730	0011041a	2/288	17:30:00.110	4.0	
21	---	sync	not	detected	---				
22	00310031	24060007	ffffff	22881730	00110916	2/288	17:30:00.110	4.0	
23	---	sync	not	detected	---				
24	00310031	26080007	ffffff	22881730	0011012b	2/288	17:30:00.110	4.0	
25	---	sync	not	detected	---				
26	00310031	280a0007	ffffff	22881730	00110da3	2/288	17:30:00.110	4.0	
27	---	sync	not	detected	---				
28	00310031	300c0007	ffffff	22881730	001101d1	2/288	17:30:00.110	4.0	
29	---	sync	not	detected	---				
30	---	sync	not	detected	---				
31	---	sync	not	detected	---				

Information file (m5tok5info.txt) created!!

>

the contents in info\_file (m5tok5info.txt):

\*\*\* mk5tok5 information file created by make\_mk5tok5\_info\_file 1.00

\*\*\* station : WESTFORD Wf mode : CDP-SX-SX

\*\*\*

\$CHANNEL; \* channel-track info block

adbit = 1 ; \* A/D resolution

sample = 4000000.000000 ; \* Sampling frequency

fanout = 1 ; \* Fanout

\*\* ch = ch# : sign\_tr# : mag\_tr# : sign\_tr# : mag\_tr# : .....

ch = 01 : 18 ;

ch = 02 : 04 ;

ch = 03 : 20 ;

ch = 04 : 06 ;

ch = 05 : 22 ;

ch = 06 : 08 ;

ch = 07 : 24 ;

ch = 08 : 10 ;

```

ch = 09 : 26 ;
ch = 10 : 12 ;
ch = 11 : 28 ;
ch = 12 : 14 ;
ch = 13 : 30 ;
ch = 14 : 16 ;
$BITPOS;    * bit position versus track information
** bitpos = nit_pos# : track #
bitpos = 00 : -- ;
bitpos = 01 : -- ;
bitpos = 02 : 04 ;
bitpos = 03 : -- ;
bitpos = 04 : 06 ;
bitpos = 05 : -- ;
bitpos = 06 : 08 ;
bitpos = 07 : -- ;
bitpos = 08 : 10 ;
bitpos = 09 : -- ;
bitpos = 10 : 12 ;
bitpos = 11 : -- ;
bitpos = 12 : 14 ;
bitpos = 13 : -- ;
bitpos = 14 : 16 ;
bitpos = 15 : -- ;
bitpos = 16 : 18 ;
bitpos = 17 : -- ;
bitpos = 18 : 20 ;
bitpos = 19 : -- ;
bitpos = 20 : 22 ;
bitpos = 21 : -- ;
bitpos = 22 : 24 ;
bitpos = 23 : -- ;
bitpos = 24 : 26 ;
bitpos = 25 : -- ;
bitpos = 26 : 28 ;
bitpos = 27 : -- ;
bitpos = 28 : 30 ;
bitpos = 29 : -- ;
bitpos = 30 : -- ;
bitpos = 31 : -- ;
$GROUP;    * group # versus channel # table
** group = group# : ch 1st : ch 2nd : ch 3rd : ch 4th;
group = 1 : 1 : 2 : 3 : 4 ;
group = 2 : 5 : 6 : 7 : 8 ;
group = 3 : 9 : 10 : 9 : 10 ;
group = 4 : 11 : 12 : 13 : 14 ;
-----

```

example2: conversion of all groups with 4-ch mode using the info\_file file created in example 1. The converted file is created in the directory in which the Mark-5 formatted file exists.

```
> m5tok5 G:/ipvlbi/data/evlbi3/288-1730
```

example3: same as example 2, but the converted file is created in the directory G:/ipvlbi/data/evlbi3/k5 .

```
> m5tok5 G:/ipvlbi/data/evlbi3/288-1730 -d G:/ipvlbi/data/evlbi3/k5
```

example4: conversion by specifying a bit position in 1-ch mode. A bit position #1 is specified. The converted file is created as G:/ipvlbi/data/evlbi3/k5/k5.dat .

```
> m5tok5 G:/ipvlbi/data/evlbi3/288-1730 G:/ipvlbi/data/evlbi3/k5/k5.dat 1
```

example5: conversion by specifying bit positions in 4-ch mode. The converted file is created as k5.dat in the current directory. Bit positions #1, #2, #3 and #4 are specified.

```
> m5tok5 G:/ipvlbi/data/evlbi3/288-1730 k5.dat 1 2 3 4
```

### 5.1.3. Data conversion in m5tok5np

This module is used for conversion of data in 1-bit sampling and customized for higher-speed processing. A Mark-5 file should have 16 tracks, be NRZL encoded without parity bits.

usage: same as that in m5tok5 (see sub-section 5.1.2).  
info\_file in default: m5tok5npinfo.txt

### 5.1.4. Data conversion in m5tok5R

This module is used for general conversion from Mark-5 to K-5 formats. A Mark-5 file should have 16 or 32 tracks, be NRZL encoded with parity bits.

usage: same as that in m5tok5 (see sub-section 5.1.2).  
info\_file in default: m5tok5Rinfo.txt

### 5.1.5. Data conversion in m5tok5Rnp

This module is used for general conversion from Mark-5 to K-5 formats. A Mark-5 file should have 16 or 32 tracks, be NRZL encoded without parity bits.

Note: Since May 2003 session, the EVN data should be applied by this module.

usage: same as that in m5tok5 (see sub-section 5.1.2).  
info\_file in default: m5tok5npinfo.txt (same as the case in mk5tok5np)

Since 1 August 2003, the following options are also valid only in this module and m5tok5np.

-v [vex\_file]: VEX file used to create the Mark-V data.  
-sid [stat\_id]: Station ID, one or two alphabetical characters.

Example:

```
-----  
jop13{jive}102: m5tok5Rnp d03c1_2.mc -v d03c1.vix -sid Mc -i make  
*****  
*           Mark-5 data conversion           *  
*           Ver 1.40  2003-08-01  by  T.KONDO/NICT           *  
*****  
----- RUN CONDITION -----  
mk5name   : ./d03c1_2.mc  
k5name    :  
outdir    : ./  
infile    : m5tok5npinfo.txt  
channel   : 0  
group     : 0  
soffset  : 0  
period    : 0  
vex_file  : d03c1.vix  
station_id: Mc
```

-----  
mk5tok5R running under Information File create mode  
info file (m5tok5npinfo.txt) will be created (updated).

Enter VEX file name -> d03c1.vix

VEX file name --- ./d03c1.vix

SITES (Station ID) defined are

- 1 -- Ef
- 2 -- Mc
- 3 -- Wb
- 4 -- Nt
- 5 -- Jb
- 6 -- On

Select Station by number ----> Mc

Detailed site information

site definition : MEDICINA  
site name : MEDICINA  
site ID : Mc  
site position : 4461369.868300 919596.955500 4449559.254900  
site clock  
validity epoch : 2003 153 7 30 0  
clock epoch : 2003 153 9 12 30  
clock offset : -8.191700e-05  
clock rate : 3.610000e-13

mode is -1075037092

TRACK and FREQUENCY information for MEDICINA

BARREL ROLL : off

FREQDEF = 4982.49MHz8x8MHz TRACKDEF = MKIV.8Ch2bit1to2

adbit= 2 sample\_rate= 16000000.000000

bb	Tr	AD	fo	chan	RF(Hz)	S	VBW(Hz)
1	2	sign	1	&CH01	4982490000.000000	L	8000000.000000
2	4	sign	2	&CH01	4982490000.000000	L	8000000.000000
3	6	mag	1	&CH01	4982490000.000000	L	8000000.000000
4	8	mag	2	&CH01	4982490000.000000	L	8000000.000000
5	10	sign	1	&CH02	4982490000.000000	L	8000000.000000
6	12	sign	2	&CH02	4982490000.000000	L	8000000.000000
7	14	mag	1	&CH02	4982490000.000000	L	8000000.000000
8	16	mag	2	&CH02	4982490000.000000	L	8000000.000000
9	18	sign	1	&CH03	4982490000.000000	U	8000000.000000
10	20	sign	2	&CH03	4982490000.000000	U	8000000.000000
11	22	mag	1	&CH03	4982490000.000000	U	8000000.000000
12	24	mag	2	&CH03	4982490000.000000	U	8000000.000000
13	26	sign	1	&CH04	4982490000.000000	U	8000000.000000
14	28	sign	2	&CH04	4982490000.000000	U	8000000.000000
15	30	mag	1	&CH04	4982490000.000000	U	8000000.000000
16	32	mag	2	&CH04	4982490000.000000	U	8000000.000000
17	3	sign	1	&CH05	4998490000.000000	L	8000000.000000
18	5	sign	2	&CH05	4998490000.000000	L	8000000.000000
19	7	mag	1	&CH05	4998490000.000000	L	8000000.000000
20	9	mag	2	&CH05	4998490000.000000	L	8000000.000000
21	11	sign	1	&CH06	4998490000.000000	L	8000000.000000
22	13	sign	2	&CH06	4998490000.000000	L	8000000.000000
23	15	mag	1	&CH06	4998490000.000000	L	8000000.000000
24	17	mag	2	&CH06	4998490000.000000	L	8000000.000000
25	19	sign	1	&CH07	4998490000.000000	U	8000000.000000

```

26 21 sign 2 &CH07 4998490000.000000 U 8000000.000000
27 23 mag 1 &CH07 4998490000.000000 U 8000000.000000
28 25 mag 2 &CH07 4998490000.000000 U 8000000.000000
29 27 sign 1 &CH08 4998490000.000000 U 8000000.000000
30 29 sign 2 &CH08 4998490000.000000 U 8000000.000000
31 31 mag 1 &CH08 4998490000.000000 U 8000000.000000
32 33 mag 2 &CH08 4998490000.000000 U 8000000.000000

```

Mark 5 Data File : ./d03c1\_2.mc

Now analyzing the data .....

BIT#	HEADER	AUX	SYNC	TIME	FIELD	CRC	Y/DDD	HH:MM:SS.SSS	FMHz
00	03190319	02110026	ffffff	31531010	09677466	3/153	10:10:09.677	8.0	
01	03190319	03130026	ffffff	31531010	096775fe	3/153	10:10:09.677	8.0	
02	03190319	04510026	ffffff	31531010	096771cb	3/153	10:10:09.677	8.0	
03	03190319	05530026	ffffff	31531010	09677053	3/153	10:10:09.677	8.0	
04	03190319	06310026	ffffff	31531010	09677623	3/153	10:10:09.677	8.0	
05	03190319	07330026	ffffff	31531010	096777bb	3/153	10:10:09.677	8.0	
06	03190319	08710026	ffffff	31531010	0967720a	3/153	10:10:09.677	8.0	
07	03190319	09730026	ffffff	31531010	09677392	3/153	10:10:09.677	8.0	
08	03190319	10100026	ffffff	31531010	09677ddf	3/153	10:10:09.677	8.0	
09	03190319	11120026	ffffff	31531010	09677c47	3/153	10:10:09.677	8.0	
10	03190319	12500026	ffffff	31531010	096778b0	3/153	10:10:09.677	8.0	
11	03190319	13520026	ffffff	31531010	09677928	3/153	10:10:09.677	8.0	
12	03190319	14300026	ffffff	31531010	09677f9a	3/153	10:10:09.677	8.0	
13	03190319	15320026	ffffff	31531010	09677e02	3/153	10:10:09.677	8.0	
14	03190319	16700026	ffffff	31531010	09677af5	3/153	10:10:09.677	8.0	
15	03190319	17720026	ffffff	31531010	09677b6d	3/153	10:10:09.677	8.0	
16	03190319	18010026	ffffff	31531010	09677bcf	3/153	10:10:09.677	8.0	
17	03190319	19030026	ffffff	31531010	09677a57	3/153	10:10:09.677	8.0	
18	03190319	20410026	ffffff	31531010	09677a5d	3/153	10:10:09.677	8.0	
19	03190319	21430026	ffffff	31531010	09677bc5	3/153	10:10:09.677	8.0	
20	03190319	22210026	ffffff	31531010	09677db5	3/153	10:10:09.677	8.0	
21	03190319	23230026	ffffff	31531010	09677c2d	3/153	10:10:09.677	8.0	
22	03190319	24610026	ffffff	31531010	09677818	3/153	10:10:09.677	8.0	
23	03190319	25630026	ffffff	31531010	09677980	3/153	10:10:09.677	8.0	
24	03190319	26000026	ffffff	31531010	09677520	3/153	10:10:09.677	8.0	
25	03190319	27020026	ffffff	31531010	096774b8	3/153	10:10:09.677	8.0	
26	03190319	28400026	ffffff	31531010	09677109	3/153	10:10:09.677	8.0	
27	03190319	29420026	ffffff	31531010	09677091	3/153	10:10:09.677	8.0	
28	03190319	30200026	ffffff	31531010	0967740c	3/153	10:10:09.677	8.0	
29	03190319	31220026	ffffff	31531010	09677594	3/153	10:10:09.677	8.0	
30	03190319	32600026	ffffff	31531010	09677163	3/153	10:10:09.677	8.0	
31	03190319	33620026	ffffff	31531010	096770fb	3/153	10:10:09.677	8.0	

Information file (m5tok5npinfo.txt) created!!

-----

## 5.2. Step-by-step recipe of data conversion

An input Mark-5 formatted files are assigned here as "MK5".

a) Checking the status of your Mark-5 formatted file.

Run m5check and find out whether the data in the file have parity bits.

If sync is found in the processing "m5check MK5", the data have parity bits.

If sync is found in the processing "m5check MK5 1", the data do not have parity bits.

b) Making a table of correspondence between track numbers and BBCs.

> m5tok5 MK5 -i make (the case for data with parity bits)

> m5tok5np MK5 -i make (the case for data without parity bits)

The module asks the VEX filename. After inputting the filename, the module creates the table.

c) Run format converter.

In the case for data with parity bits,

> m5tok5 MK5 -d outdir  
> m5tok5R MK5 -d outdir (for non 1-bit sampling data)

where outdir is the directory in which the output file is created.

In the case for data without parity bits,

> m5tok5np MK5 -d outdir  
> m5tok5Rnp MK5 -d outdir (for non 1-bit sampling data)

d) Repeat (b) and (c) (also (a) if necessary) for individual stations.

This has to be done separately for stations that have different track setups; otherwise run it only once.

### 5.3. Contents of correlation output

The detail of the correlation output is listed in the different document, which is available in the following web page,

[http://www2.nict.go.jp/ka/radioastro/IPVLBI/fx\\_cor\\_output.pdf](http://www2.nict.go.jp/ka/radioastro/IPVLBI/fx_cor_output.pdf) .

## 6. Data correlation

The data correlation procedure is a sequence of preparation of an a-priori parameter file (apri\_calc), fringe (clock parameter) search (fx\_cor), full baseline-based correlation (fx\_cor\_all), and coarse search (residual delay and rate estimation) (sdelay).

### 6.1. Preparation of an a-priori parameter file

work directory: \$HOME/apri/ (previously \$HOME/ipvlbi/apri/)

used module: apri\_calc

The program apri\_calc is valid for a SKED DRUDGE and VEX files.

usage:

apri\_calc skdfile [apedir [baseid coffset roffset frqgr xdir ydir nob1 [nob2] ] ]

where

skdfile: schedule file.

(Note: If adding a minus "-" in front of the filename (without any space after the minus), the module only monitors the contents of the schedule file.)

apedir: directory for the a-priori calculation output . (default= ../corrapri/)

baseid: baseline ID described in two characters.

coffset: clock delay offset [s] (usually set in a VEX file).

roffset: clock rate offset [s/s] (usually set in a VEX file).

frqgr: frequency group (1-4), corresponding to PC. No default.

A frequency group corresponds to a group of base-band channels. In the case of EVN data with BBC, for example, the group 1 consists of BBC#1-4, the group 2 consists of BBC#5-8.

nob1: start scan number for processing.

nob2: end scan number for processing.

(Note: If nob1=nob2=0, all possible scans are selected.)

xdir: data directory for x-station.

ydir: data directory for y-station.

(Note: For parameters baseid, coffset, roffset, frqgr, nob1, nob2, xdir, and ydir, an interactive input is requested when without any input.)

File name of the output: "apeDDDNNNNXYG.txt"

ape: fixed head characters.

DDD: day of the year at 1-st scan.

NNNN: scan number (4-digit number).

XY: baseline ID (2 characters, ID described in the schedule file).

G: Frequency group ID.

## 6.2. Quick correlation and fringe search

```
fx_cor afile [duration soffset coffset roffset t1pp smode pp_mode delsize tzoom pmode
           comment loop]
```

where,

afile: file name of a-priori parameters.(default=0: selecting the internal default file name.)

duration: total duration of integration [s]. (negative: the possible maximum duration, 0: the duration described in the schedule file.)

soffset: start offset, should be integer [s]. (0: zero.)

coffset: clock delay offset [s], positive when the Y-station clock is advanced. (default: 0.0 s.)

roffset: clock rate offset [s/s]. (default: 0.0 s/s.)

t1pp: parameter period [s]. it can be set to be shorter than 1 s only when it equals to 1-second divided by integer (e.g. 1/5=0.2 s). (default: 1.0 s.)

smode: number of data points per process, or a size of the delay search window.

0: Maximum (20,000 points), slow processing.

1: Medium (1,000 points).

2 (default): Minimum (1,000 or 2,000 points), fast processing.

pp\_mode: synchronization mode.

0 (default): The start of PP is set to an integer in unit of second.

1: No synchronization, or the beginning of the data available for processing. delsize: lag window size in the display (16,32,64,128,256,512,1024,2048,...).

(default: set to DELAYSIZE=128, which can be edited in the source program.)

tzoom: absolute factor of time-axis zooming, should be integer. 0 (default): full scale (=1), negative: set to the window center at the fringe peak.

pmode: device mode in plotting. 0 (default): xterm display plus PostScript output.1: Only PostScript output, 2: Only xterm display, -1: No graphic output.

comment: comment described on the top of the plot.

Do not include any space. If skipped, interactive input is requested (space is valid).

loop: infinite loop parameter.

0 (default): no loop (used for fringe search).

1: infinite loop (only for real-time processing, no display).

Since 24 July 2003, it is possible to optionally set above parameters using the option keys listed as follows. Type only "fx\_cor" to see the explanation in detail.

-integ: integration period (sec). Default is scheduled scan period.

If specified explicitly, Quick-look delay windows are displayed.

-coffset: a-priori clock offset (sec) applied for fringe search purpose.

Positive value means Y clock tic earlier than X clock tic. Default is 0.0.

-crate: a-priori clock rate (s/s) difference between X and Y station clock. Default is 0.0

-soffset: start time offset from the scan start (integer sec). Default is 0

-t1pp: unit integration period (parameter period) (sec) for correlation processing.

Default is 1.0

Note: When set < 1.0, 1.0/t1pp should be integer number, e.g., t1pp=0.2, or 0.5 etc.

-smode: search mode selection for processing (for a programmer) internal use.

0: Wide, 1: Mid, 2:Narrow (default 2)

- pp\_nosync: turns off the synchronization mode of PP (parameter period) (default is that PP synchronize to second tic);
- lag: delay lag window size. The value can be set to 16,32,64,128,256,512, and more. Default is DELAYSIZE(in fx\_cor.c). Zero also means the default size.
- pmode: plot mode.
  - 0 : XTERM (env PGDISP can change PGPLOT display device) and PostScript file (pgplot.ps) out (default)
  - 1 : PostScript file (pgplot.ps) out only
  - 2 : XTERM only
  - 1 : No graphic output
- comment: any comment, which will appear in the correlation plot when pmode=0,1,2
- loop: loop parameter for real-time VLBI processing in the future.
  - 0 : no loop (default), 1 : Infinite loop (for real-time use)
- nopcal: turns off the function of the phase calibration signal detection.
  - Note: EVN clock search should set this option to make the processing faster.

The output file named "cout0000.txt" is created in the directory "cout", which includes the fringe-search results.

Note: When duration of correlated data (-integ) is explicitly specified, delay windows appear as shown in figure 2.

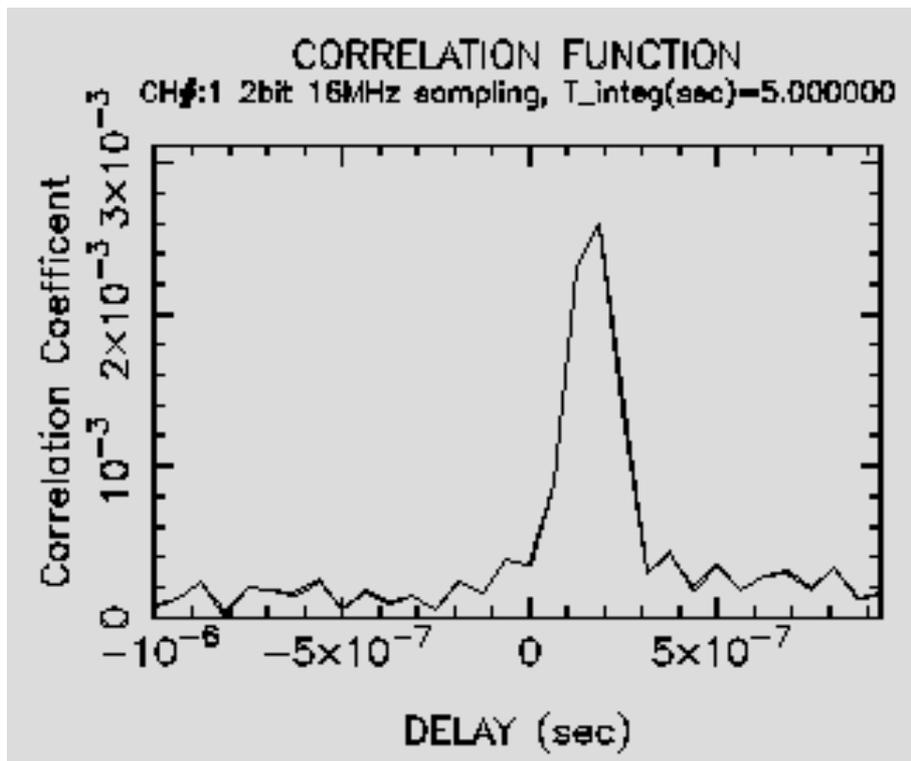


Figure 2: Delay window that appears after executing fx\_col.

Note: In the case of correlation between the different BBC (e.g. for cross-hand circular polarization correlation), use the following options.

- ch1 ch1Y defines Y channel for X ch 1 (default 1), 0 for delete
- ch2 ch2Y defines Y channel for X ch 2 (default 2), 0 for delete
- ch3 ch3Y defines Y channel for X ch 3 (default 3), 0 for delete
- ch4 ch4V defines Y channel for X ch 4 (default 4), 0 for delete

If you want to correlate X:ch1 - Y:ch2, X:ch2-Y:ch1, set parameters as follows.

```
fx_cor afile -ch1 2 -ch2 1
```

### 6.3. Full data correlation

- a) Move to the directory "corrapi".
- b) Prepare a list of a-priori files by typing as follows,  
ls -l apeDDD\*XY\*.txt > apelistDDDXY.txt ,  
where DDD is the day of the year, XY is the baseline code processed. Note that "-1" is minus one.
- c) Move to the directory corr.
- d) Make backup for the directory "cout" in the directory where the K-5 format data exist.
- e) Create the new "cout" directory.
- f) Run fx\_cor\_all as follows,

```
fx_cor_all [file name of the list of a-priori files] .
```

### 6.4. Course search of a residual delay and rate

- a) Move the created directory "cout" to a new directory entitled "coutDDDXX", where DDD is the day of the year and XX is the baseline code.
- b) Run sdelay.

The module sdelay asks

- b.1) a directory (ID) specified above, so input the directory name.
- b.2) data processed, so type "0" that means "all data".
- b.3) file name of the output (cout#####), so choose the file name recommended by the module.

To change the output device, type as follows before executing sdelay.

```
setenv PGDISP /xterm (using XTERM)
setenv PGDISP /ps (creating PostScript file)
setenv PGDISP /xw (using XWINDOW)
```

Note: A displayed correlation coefficient is not corrected for e.g. Van Vleck correction.

### 6.5. Search residual delay and delay rate

The estimated residual delay and rate are displayed in the output of the module "sdelay" (see figure 3). A positive value in the delay means that the Y-station clock is delayed with respect to the X-station. Left-right and front-behind axes in the horizon of the 3-D diagram indicate the delay and delay-rate axes, respectively.

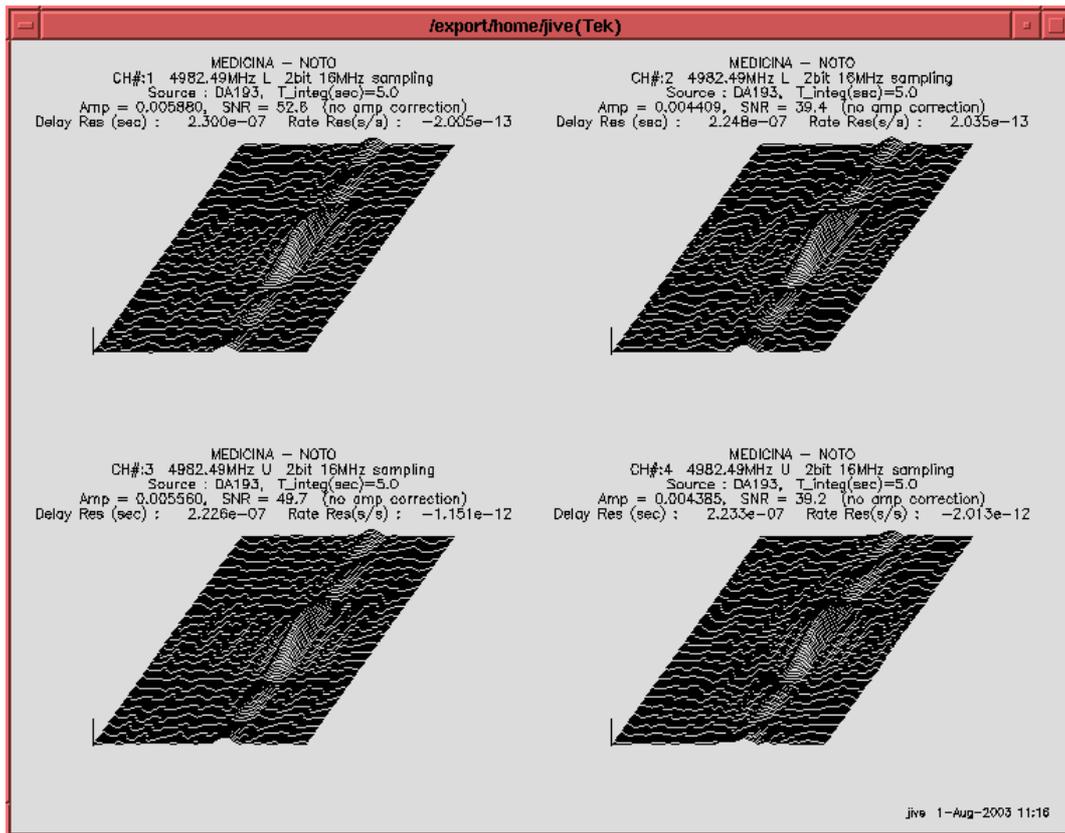


Figure 3: Fringe search windows obtained with the software correlator. These are the output of the module “sdelay”. The data used here was obtained with the Mark-V A backend in the Medicina--Noto baseline in the EVN experiment D03C1 made in May 2003.

Note: If a fringe is located very close to the window edge, a false delay and rate solution might be obtained. In this case, recorrelation is recommended to put the fringe away from the window edge. To do so, increase in a lag number or shift a delay and a rate (by setting a-priori delay and rate residuals) in the a-priori parameter calculation or in data correlation.

## 6.6. Strategy for fringe search

- In fringe search, set  $t1pp=0.2$  for a bright quasar and run `fx_cor` for  $\sim 10$  s.
- Check on the display whether a fringe is detected at the center of the search window.
- Calculate a residual delay (and rate) by running "`sdelay cout.txt`". Check the fringe if  $SNR > 7$ .
- Input the residual delay and rate as clock parameters, then run `apri_calc`.
- Repeat the procedure (a) until the fringe appears at the center of the search window.

Note 1: Without phase-cal tone signals in the data, the processing to find the signals can be skipped to make the whole processing faster. This option improve the CPU speed by about 40%. For this option, type as follows.

```
fx_cor afile -nopcal
or
fx_cor_all afile -nopcal
```

## Appendix

### A.1. Bug information

- 23 June 2003: PGPLOT library link  
CFLAGS = -I./src -I./corr -I/local/lib/pgplot (for JIVE environment)
- 24 June 2003: libtds.a is unnecessary. commented "SAMPLER\_LIBS = -ltds" in Makefile.
- 24 June 2003: tdsio.h is unnecessary. Only the directories apri/, corr/, mark5/, and sdelay/ are used. Commented out tdsio.h. Edited install.sh
- 25 June 2003: time function problem fixed. Used both #include <sys/time.h> and #include <time.h> in fx\_cor.c, fx\_cor\_all.c and sdelay.c.
- 25 June 2003: PGPLOT library link for FORTRAN link SPEANA\_LIBS=-L/local/lib/pgplot -L/usr/X11/lib -lX11 -lX11 -lm -lpgplot -lcpplot
- 4 July 2003: libvex.h line 199: extension of freq. table blocks.
- 7 July 2003: Most of files are updated in ./mark5.
- 9 July 2003: softcorr.setup modified to pass to the software home directory.
- 14 July 2003: New package was installed after fixing the problem in Mark-5 data without parity bit with 32 track. CFLAGS and SPEANA\_LIBS should be edited again in \$CORHOME/corr/Makefile and \$CORHOME/sdelay/makefile. -ltds is not used. Edited install\_jive.sh to avoid accessing \$CORHOME/src.
- 1 August 2003: sdelay was improved in display.

### A.2. Update information

- 3 July 2003: New directory for correlation data ./data
- 7 July 2003: New modules in ./mark5: m5tok5np, m5tok5np
- 21 July 2003: User-defined environment variables are accepted.
- 24 July 2003: New option using "-key parameters" in fx\_cor and fx\_cor\_all. P-cal monitor output is appended.
- 1 August 2003: m5tok5np, m5tok5Rnp were updated to make them accept the new options -v (VEX file) and -sid (station ID).
- 11 September 2003: Updated Chap. 6.2.