K5 Software Correlator Manual

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Contents

1 Installation of the package

K5 software correlator was developed to correlate VLBI data with VSSP format observed by a K5/VSSP sampler. But it can now process any kind of data format, such as, Mark-5B, VDIF, ADS, OCTAD besides VSSP format. Software correlator is written in C, so that it can run on most of Linux distributions.

PCPLOT or GNUPLOT is used as a graphics package. Therefore PGPLOT or GNUPLOT should be installed in advance. Some software programs, e.g.,"fx_cor" and "fx_cor_new", suppport the use of FFTW package which improves troughput significantly. If you want to use FFTW, FFTW3 package should be installed in advance. Please see Appendices E and F for how to install these packages.

1.1 Installation from an archive file

Put an archive file "ipvlbi_corYYYYMMDD.tar.gz" on an adequate directory, where YYYYMMDD is archive date (year, month, day) such as 20170119, then decompress as follows.

```
tar xvzf ipvlbi_corYYYYMMDD.tar.gz
```

As the directory named "ipvlbiYYYYMMDD" is created under the current directory, change the working directory to "ipvlbiYYYYMMDD" as follows.

```
cd ipvlbiYYYYMMDD
```

Execute "make" as follows.

```
make T=COR [F=FFTW] [G=GNUPLOT]

  where F=FFTW     ---  use FFTW package for FFT (default is FFT included in the package)
        G=GNUPLOT  ---  use GNUPLOT for graphics instead of PGPLOT (default is PGPLOT)
```

High-speed FFT becomes possible by using the "F=FFTW" option when FFTW package has been already installed.

When re-make, execute

```
make clean
```

then execute

```
make T=COR [F=FFTW] [G=GNUPLOT]
```

1.2 Installation step by step

How to install the package step by step is as follows where $HOME is the directory where an archive file is decompressed.

```
cd $HOME/ipvlbiYYYYMMDD/apri
make
make install
cd $HOME/ipvlbiYYYYMMDD/corr
make F=FFTW        <== in case of using FFTW package
make install
cd $HOME/ipvlbiYYYYMMDD/sdelay
make
make install
cd $HOME/ipvlbiYYYYMMDD/src
make S=NONE install  <== no use of a sampler *1
cd $HOME/ipvlbiYYYYMMDD/mark5
make
make install
cd $HOME/ipvlbiYYYYMMDD/vdif
make
make install
```

*1. Note that how to make at "src" directory differs from other directories (option "install" is used simultaneously with option "S=NONE")

When re-make, issue "make clean" at each subdirectory, then issue "make" at each subdirectory.

1.3 Environment variables

User-defined environment variables are accepted in the most of utility programs. The programs themselves define some environment variables. By typing as follows,

program_name env

the defined variables and current values are displayed.

example: typing

```
fx_cor env
```

The following messages are displayed.

```
Enviroment 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
                   ( /XSERVE )
```

1.4 Directory structure after installation

```
$HOME/ipvlbiYYYYMMDD/
          |
          +readme_e.txt          instruction (this file)
          +readme.txt            instruction in Japanese
          +archive_cor           shell script file to make an archive file
          +pgplot_install.txt    how to install PGPLOT (in Japanese)
          +fftw_install.txt      how to install FFTW (in Japanese)
          +makefile              make file to install K5 utilities
          |
          +apri/      ------ directory for a-priori calculation
          |   +*.c              source file
          |   +*.h              include file
          |   +makefile         makefile for this directory
          |
          +bin/       ------ directory for executable files
          |
          +corr/      ------ directory for software correlator
          |   +*.c              source file
          |   +*.h              include file
          |   +makefile         makefile for this directory
          |
          +corrapri/  ------ directory for a-priori files
          |   +ape_sample.txt         sample a-priori file
          |   +apelist_sample.txt     sample a-priori file list
          |
          +cout/      ------ directory for correlator outputs
          |   +coutNNNN.txt             output from XF-type correlator
          |   +couttNNNN.txt            output from FX-type correlator
          |
          +log/       ------ directory for log output
          |
          +mark5/     ------ directory for Mark5<->K5 format conversion
          |   +*.c              source file
          |   +*.h              include file
          |   +makefile         makefile for this directory
          |   +m5tok5info.txt   sample information file to convert Mrak5 to K5
          |   +k5tom5info.txt   sample information file to convert K5 to Mrak5
          |   +vlbainfo.txt     sample information file to convert VLBA to Mrak5
          |
          +sdelay/    ------ directory for coarse search software
          |   +*.c              source file
          |   +*.h              include file
          |   +makefile         makefile for this directory
          |
          +sked/      ------ directory for schedule files
          |   +sample.skd         sample schedule file (SKED format)
          |   +sample.vex         sample schedule file (VEX format)
          |
          +src/       ------ directory for observation software
          |   +*.c              source file
          |   +*.h              include file
          |   +makefile         makefile for this directory
          |
          +vdif/      ------ directory for VDIF<->K5 format conversion
          |   +*.c              source file
          |   +*.h              include file
          |   +makefile         makefile for this directory
          |
          +man/       ------ diretory for man page
          |
          +doc/       ------ directory for documents
```

1.5 Set up your environment

1. In case that installed directory is, e.g., $HOME/K5/ipvlbiXXXXXXXX make symbolic link as follows.

   ```
   ln -s $HOME/K5/ipvlbiXXXXXXXX $HOME/ipvlbi
   ```

   if link has been already existed, issue command with "f" option as follows.

   ```
   ln -sf $HOME/K5/ipvlbiXXXXXXXX $HOME/ipvlbi
   ```

2. then add following description in your resource file (e.g., .bashrc).

   ```
   export PATH=$PATH:$HOME/ipvlbi/bin     (for .bashrc)
   setenv PATH $PATH:$HOME/ipvlbi/bin     (for .cshrc)
   ```

   Now you can exexute all K5 programs by merely re-linking a symbolic link when new version is installed.

3. Archives with version after 2010-02-08 includes man page files. Therefore you can use K5 software man page by adding following description in your resource file (e.g., .bashrc).

   ```
   export MANPATH=$HOME/ipvlbi/man:$MANPATH     (for .bashrc)
   setenv MANPATH $HOME/ipvlbi/man:$MANPATH     (for .cshrc)
   ```

   e.g., you can issue "man cor" to know how to execute it. "man k5cor" tells about all K5 software correlation programs and utilities with brief instructions.

2 Software programs list

As for software programs listed here except for "sdelay", you can get how to run by just executing a program itself without any option. You can get version information by executing a program with the "`--version`" option.

2.1 A-priori calculation

apri_calc	– a-priori parameter calculation and generate an a-priori file (both standard schedule file and VEX file are supported)	···apri
skdchk	– check schedule file and display disk size required for K5/VSSP observation	···src

Note: Last column shows the directory of source code.

2.2 Correlation processing

fx_cor	– FX-type software correlator for K5/VSSP format data	···corr
fx_cor_all	– "fx_cor" for two or more scan data	···corr
fx_cor_new	– FX-type software correlator supporting a variety of data formats (K5/VSSP, VDIF, Mark5B, ADS)	···corr
fx_cor_all_new	– "fx_cor_new" for two or more scan data	···corr
cor	– XF-type software correlator dedicated to 1 bit sampling data for K5/VSSP format data	···corr
cor_all	– "cor" for two or more scan data	···corr
cor_new	– XF-type software correlator dedicated to 1 bit sampling data supporting a variety of data formats (K5/VSSP, VDIF, Mark5B, ADS)	···corr
cor_all_new	– "cor_new" for two or more scan data	···corr
sdelay	– coarse fringe search. get residual dela and delay rate from correlated data	···sdelay
cor_mon	– display correlation function dynamically (support PGPLOT only)	···corr

Note: Last column shows the directory of source code.

2.3 Data check

oscillo	– display sampled data dynamically for K5/VSSP data (support PGPLOT only)	···src
speana	– display spectrum for K5/VSSP data	···src
speana_n	– display spectrum dynamically for K5/VSSP data (support PGPLOT only)	···src
g_speana	– display spectrum supporting a variety of data formats (K5/VSSP, VDIF, Mark5B, ADS)	···corr
datachk	– check K5/VSSP format data	···src
vdifcheck	– check VDIF format data	···vdif
m5check	– check Mark-5 format data	···mark5

Note: Last column shows the directory of source code.

2.4 Data Format Conversion

k5tom5b	– convert K5 format to Mark5B format	···mark5
k5tom5	– convert K5 format to Mark5 format	···mark5
k5tovdif	– convert K5 format to Mark5B format	···vdif
ads2k5	– convert ADS3000 (DBBC mode) format to K5 format	···mark5
m5btok5	– convert Mark5B format to K5 format	···mark5
m5tok5	– convert Mark5 format to K5 format	···mark5

vdif2k5	– convert VDIF format to K5 format	···vdif
vdif2m5b	– convert VDIF format to Mark5B format	···vdif

Note: Last column shows the directory of source code.

3 A-priori calculation software

3.1 apri_calc

"apri_calc" calculates a priori values and generate an a-priori file necessary for cross correlation processing. Both SKED and VEX format files are supported as a schedule file.

3.1.1 How to execute

Type 1

apri_calc *skdfile* [*options*]

where *skdfile* – schedule file name (either VEX or SKED format)
if "-" is accompanied with skdfile like "-skdfile", it means monitor only the contents of schedule file. option "-monit" as for Ver.2016-10-12 and later, option "-monit" gives the same function.

options (any order: when parameter is omitted, it will be asked it later)

-apedir *apriori_file_out_directory*
– set directory for apriori file out. default is the environment variable K5APRIOUT. If this environment variable is not defined, then "../corrapri" will be applied as a default.

-baseid *baseline_id*	–	set baseline ID (A2 or A4)
-coffset *clock_offset*	–	set clock offset (sec) of Y station to X station. Positive value menas Y clock tic earlier than X clock tic. Default is 0.0
-crate *clock_rate*	–	set clock rate (s/s) difference between X and Y station clock. Default is 0.0
-cepoch *epoch*	–	set epoch of clock offset and clock rate epoch is a format of either YYYY/DDD-HH:MM:SS or YYYY/MM/DD-HH:MM:SS or YYYYDDDHHMMSS or 0 (0 means each PRT: Default is each PRT)
-g *group*	–	set frequency group (1-4) for 4ch mode correspnding to a sampler host PC (default is 1) When data format is set to other than "K5/VSSP", default becomes 0 (all channels will be selected)
-ch *channel*	–	set frequency channel for 1ch mode (default is 1)
-start *start_obs*	–	set start scan# (default is the 1st scan#)
-stop *stop_obs*	–	set stop scan# (default is the last scan#)
-xdir *xdir*	–	set X data file directory (default is "./")
-ydir *ydir*	–	set Y data file directory (default is "./")
-ut1 *ut1_c*	–	UT1-UTC (sec)
-wobbx *wobbx*	–	Wobb X (arcsec)
-wobby *wobby*	–	Wobb Y (arcsec)
-type1 | -type2	–	set K5 observation file naming rule 1: Type I, 2: Type II -type1 : sidDDDNNNN.dat (default) -type2 : sidDDDHHMMSSG.dat (Note: this option is to keep compatibility with the program with the old version. Use "-type" option as follows)
-type *naming_type*	–	set K5 observation file naming rule 1 : Type 1 sidDDDNNNN.dat (default for SKED) -1 : Type -1 sidDDDNNNN.#ch.dat 2 : Type 2 sidDDDHHMMSSG.dat -2 : Type -2 sidDDDHHMMSSG.#ch.dat 3 : Type 3 expid_sidG_scanid_YYYYDDDDHHMMSS.k5 (compliant with the naming rule of e-VLBI) 4 : unused 5 : Type 5 expid_scan#.stcode.k5a(-d) (default for VEX) 6 : Type 6 expid_sid_scanid.k5a(-d)

see Note 1 for details

-typeX *naming_type* – set K5 observation file naming rule for X station

-typeY *naming_type* – set K5 observation file naming rule for Y station

-subnet | -nosubnet – subnet mode control. Default is subnet on (-subnet)

-skey *satellite_key* – set satellite key(s) for "NOZOMI" mode. If there are keys more than one, use " " like -skey "NOZ HYB HEO"

-xcoff *x_clock_offset* – set clock offset (sec) of X station to UTC. Positive value menas X clock tic earlier than UTC clock tic.

-lsb – set sideband LSB compulsory in case of SKED file

-shift *time* – shift start time of 1st scan to given time, where ¡i¿time¡/i¿ is either YYYY/DDD-HH:MM:SS or YYYY/MM/DD-HH:MM:SS or YYYYDDDHHMMSS.

-format VDIF|MK5|M5B|OCTAD|ADS[|VSSP] [*sampling_cond*]

– set data format and sampling information of both station as the same format

-formX VDIF|MK5|M5B|OCTAD|ADS[|VSSP] [*sampling_cond*]

– set data format and sampling information for X station (default is VSSP)

-formY VDIF|MK5|M5B|OCTAD|ADS[|VSSP] [*sampling_cond*]

– set data format and sampling information for Y station (default is VSSP)

where *sampling_cond* is sampling information for MK5, M5B, OCTAD, ADS formats as follows.

xM[Hz]nB[IT]mC[H] (any order)

x – sampling frequency (MHz)

n – # of AD bits

m – # of channels

==== following options are valid for Ver.2016-10-12 and later ====

-source *star_name* – set extracting scans by a star name from a schedule file.

-m[onit] – set monitor mode

Type 2

apri_calc *skdfile* [*apedir* [*baseid coffset roffset frqgr nobs1 nobs2 xdir ydir ut1_c wobbx wobby* [*naming_type* [*subnet* [*xcoff* [*source*]]]]]

where *skdfile* – schedule file name (either VEX or SKED format)
if "-" is accompanied with skdfile like "-skdfile", it means monitor only the contents of schedule file. option "-monit" as for Ver.2016-10-12 and later, option "-monit" gives the same function.

apedir – a-priori file out directory. Default is given by environmental variable K5APRIOUT. If this is not defined program default will be applied.

if following parameters are omitted, they will be asked interactively

baseid – baseline ID (A2 or A4)

coffset – clock offset (sec)

roffset – clock rate offset (s/s)

frqgr – frequency group# corresponding to observation PC (1-4)

nobs1 – start scan#

nobs2 – stop scan# (nobs1=0, nobs2=0 for all scans)

xdir – data file directory for X station

ydir – data file directory for Y station

ut1_c – UT1-UTC (sec)

wobbx – WobbX (arcsec)

wobby – WobbX (arcsec)

naming_type – K5 observation file naming rule

1: Type 1 sidDDDNNNN.dat (default for SKED)

-1: Type -1 sidDDDNNNN.#ch.dat
2: Type 2 sidDDDHHMMSSG.dat
-2: Type -2 sidDDDHHMMSSG.#ch.dat
3: Type 3 expid_sidG_scanid_YYYYDDDHHMMSS.k5 (compliant with e-VLBI)
4: unused
5: Type 5 expid_scan#.stcode.k5a(-d) (default for VEX)
6: Type 6 expid_sid_scanid.k5a(-d)
see Note 1 for details

subnet	–	subnet mode control 0: no-subnet, 1: subnet on(default)
xcoff	–	X clock offset to UTC (sec)

==== following option is valid for Ver.2016-10-12 and later ====

source	–	set extracting scans by a star name from a schedule file

Monitoring environmental variables

check environmental variables used in "apri_calc"
apri_calc env

```
K5SKED    -- default directory for a schedule file
K5APRIDIR -- default directory for an a-priori file
K5NAMING  -- default out file naming rule
```

Note 1: naming rule of observation data file

Type 1 or −1 (I or −I)

XDDDNNNN.[#ch.]dat

where

X	–	station ID (1 letter)
DDD	–	total day of the 1st scan
NNNN	–	scan# (4 digits)
#ch	–	# of channels (1|4) (in case of Type −1)

Type 2 or −2 (II or −II)
sidDDDHHMMSSG.[#ch.]dat

where

sid	–	station ID (1 or 2 letters)
DDDHHMMSS	–	date and time of scan DDD – year (3 digits) HH – hour (2 digits) MM – minute (2 digits) SS – second (2 digits)
G	–	frequency group ID (a|b|c|d) or null
#ch	–	# of channels (1|4) (in case of Type −2)

Type 3 (compliant with the naming rule of e-VLBI)
expid_sidG_scanid_YYYYDDDDHHMMSS.k5

where

expid	–	experiment code
sid	–	station ID (2 lower-case letters)
G	–	terminal (PC) ID (1|2|3|4) or null set by "freqg" parameter

scanid	–	scan ID for VEX file VEX ファイル使用時はスキャンＩＤそのまま ddd-hhmm for SKED file. When multiple scans are included in the same minute, a,b,c,d,... are added for the 2nd scan and later.
YYYYDDDHHMMSS	–	scan start time
.k5	–	file descriptor for K5 format

Type 4 unused

Type 5 default for VEX file (to keep old version of apri_calc)

expid_scan#.stcode.k5a(-d)

where

expid	–	experiment code
scan#	–	scan#
stcode	–	station ID
k5	–	descriptor for K5 format
a–d	–	frequency group (or null)

Note 2: Naming rule of created a-priori file

Type I

apeDDDNNNNXYG.txt

where

'ape'	–	fixed letters
DDD	–	total day of 1st scan
NNNN	–	scan# (4 digits)
XY	–	baseline ID (2 or 4 letters) (ID described in a schedule file: 1 letter for SKED, 2 letters for VEX)
G	–	sampling host PC ID (a,b,c,d) or null corresponding to frequency group ID 1-4 or 0

Type II

apeDDDHHMMSSXYG.txt

where

'ape'	–	fixed letters
DDDHHMMSS	–	date and time of scan DDD – year (3 digits) HH – hour (2 digits) MM – minute (2 digits) SS – second (2 digits)
XY	–	baseline ID (1 or 2 letters)
G	–	sampling host PC ID (a,b,c,d) or null corresponding to frequency group ID 1-4 or 0

Type III

ape_expid_sid1sid2_scanid_YYYYDDDDHHMMSS.txt

where

'ape'	–	fixed letters
expid	–	experiment code
sid1	–	station ID of X station (2 lower-case letters)
sid2	–	station ID of Y station (2 lower-case letters)
scanid	–	scan ID for VEX file

		ddd-hhmm for SKED file. When multiple scans are included in the same minute, a,b,c,d,... are added for the 2nd scan and later.
YYYYDDDHHMMSS	–	scan start time

Note 3: Clock parameters and epoch

Clock offset c_{offset} is given as

$$c_{offset} = c_o + \Delta\tau$$

where c_o is clock offset used at "apri_calc" and $\Delta\tau$ is residual delay obtained by "sdelay". Clock rate c_{rate} is given as

$$c_{rate} = \frac{c_2 - c_1}{t_2 - t_1}$$

where c_1 is clock offset obtained for a scan at time t_1 and c_2 is clock offset obtained for a scan at time t_2, where t_1 and t_2 are PRT (processing reference time) given by a unit of second. If an experiment session extends on the next day, take the day difference into consideration. If clock rate is not 0, clock epock should be set as t_1.

3.1.2 Examples (monitoring schedule)

Ex.1 Checking environmental variables used by "apri_calc"

```
$ apri_calc env
apri_calc (Ver. 2016-10-12)
   Enviroment variables
        K5SKED ---   default directory for schedule file
                    ( (null) ),  program deflt is ( ./ )
        K5APRIDIR ---   default directory for apriori file
                    ( (null) ),  program deflt is ( ../corrapri/ )
        K5NAMING ---   default K5 file naming rule
                      1 | -1 | 2 | -2 | 3 | 5
                    ( (null) ),  program deflt is ( 1 )
        K5SATKEY ---   default satellite keyword of 1ch obs
                    ( (null) ),  program deflt is ( HYB NOZ GEO )
```

Ex.2 Checking a schedule file

```
$ apri_calc -k10189.skd   (or apri_calc k10189.skd -monit)
apri_calc (Ver. 2016-10-12)

====================== RUN CONDITION ========================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
============================================================
SkdMonit: *********** Schedule file monitor **********
SkdMonit: Schedule file = ./k10189.skd
SkdMonit: Expcode       = K10189
SkdMonit: Total Scan #  = 2203
SkdMonit: Total Star #  = 12
SkdMonit:
SkdMonit:  1st   Scan   = 2010/07/07 20:05:00  3C84
SkdMonit:  Last  Scan   = 2010/07/11 00:00:21  3C84
SkdMonit:
SkdMonit: ---------- Station ID Table ----------
SkdMonit:  G --- KOGANEI
SkdMonit:  R --- KASHIM11
SkdMonit: --------------------------------------
SkdMonit: ------- Star Table -------------------
SkdMonit:          NAME1      NAME2  R.A.(deg)   DEC(deg)   EPOCH
SkdMonit:   1   0212+735          $  34.378389  73.825728 2000.000000
SkdMonit:   2   0727-115          $ 112.579635 -11.686833 2000.000000
SkdMonit:   3   1921-293          $ 291.212733 -29.241700 2000.000000
SkdMonit:   4   2134+004    2134+00 324.160776   0.698393 2000.000000
SkdMonit:   5   2145+067          $ 327.022744   6.960723 2000.000000
SkdMonit:   6   1226+023     3C273B 187.277916   2.052388 2000.000000
SkdMonit:   7   1253-055      3C279 194.046527  -5.789312 2000.000000
SkdMonit:   8   1641+399      3C345 250.745042  39.810276 2000.000000
```

```
SkdMonit:   9   2223-052      3C446 336.446914  -4.950386 2000.000000
SkdMonit:  10   2251+158    3C454.3 343.490616  16.148211 2000.000000
SkdMonit:  11   0316+413       3C84  49.950667  41.511695 2000.000000
SkdMonit:  12   0923+392    4C39.25 141.762558  39.039126 2000.000000
SkdMonit: --------------------------------------
SkdMonit: ------- Frequency (MHz) Table --------
SkdMonit: Gr# 1    7700.99 U   7710.99 U   7720.99 U   7850.99 U
SkdMonit: Gr# 2    8090.99 U   8290.99 U   8490.99 U   8550.99 U
SkdMonit: Gr# 3    8570.99 U   8580.99 U   2210.99 U   2220.99 U
SkdMonit: Gr# 4    2240.99 U   2290.99 U   2330.99 U   2340.99 U
SkdMonit: --------------------------------------
SkdMonit: ------- PCAL Freq (kHz) Table ---------
SkdMonit: Gr# 1    4010.0   4010.0   4010.0   4010.0
SkdMonit: Gr# 2    4010.0   4010.0   4010.0   4010.0
SkdMonit: Gr# 3    4010.0   4010.0   4010.0   4010.0
SkdMonit: Gr# 4    4010.0   4010.0   4010.0   4010.0
SkdMonit: --------------------------------------
```

Ex.3 Checking a schedule file (set radio source name)

```
$ apri_calc -k10189.skd -source 3C273B   <== set radio source name "3C273B"
                                              by option '-source'

apri_calc (Ver. 2016-10-12)

====================== RUN CONDITION ========================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
  Pickup Source Name : 3C273B     <== this is the source name to be picked up
=============================================================
SkdMonit: *********** Schedule file monitor **********
SkdMonit: Schedule file = ./k10189.skd
SkdMonit: Expcode       = K10189
SkdMonit: Total Scan #  = 2203
SkdMonit: Total Star #  = 12
SkdMonit:
SkdMonit:  1st   Scan   = 2010/07/07 20:05:00  3C84
SkdMonit:  Last  Scan   = 2010/07/11 00:00:21  3C84
SkdMonit:
SkdMonit: ---------- Station ID Table ----------
SkdMonit:  G --- KOGANEI
SkdMonit:  R --- KASHIM11
SkdMonit: --------------------------------------
SkdMonit: ------- Star Table -------------------
SkdMonit:          NAME1      NAME2  R.A.(deg)   DEC(deg)   EPOCH
SkdMonit:   1   0212+735          $  34.378389  73.825728 2000.000000
SkdMonit:   2   0727-115          $ 112.579635 -11.686833 2000.000000
SkdMonit:   3   1921-293          $ 291.212733 -29.241700 2000.000000
SkdMonit:   4   2134+004    2134+00 324.160776   0.698393 2000.000000
SkdMonit:   5   2145+067          $ 327.022744   6.960723 2000.000000
SkdMonit:   6   1226+023     3C273B 187.277916   2.052388 2000.000000
SkdMonit:   7   1253-055      3C279 194.046527  -5.789312 2000.000000
SkdMonit:   8   1641+399      3C345 250.745042  39.810276 2000.000000
SkdMonit:   9   2223-052      3C446 336.446914  -4.950386 2000.000000
SkdMonit:  10   2251+158    3C454.3 343.490616  16.148211 2000.000000
SkdMonit:  11   0316+413       3C84  49.950667  41.511695 2000.000000
SkdMonit:  12   0923+392    4C39.25 141.762558  39.039126 2000.000000
SkdMonit: --------------------------------------
SkdMonit: ------- Frequency (MHz) Table --------
SkdMonit: Gr# 1    7700.99 U   7710.99 U   7720.99 U   7850.99 U
SkdMonit: Gr# 2    8090.99 U   8290.99 U   8490.99 U   8550.99 U
SkdMonit: Gr# 3    8570.99 U   8580.99 U   2210.99 U   2220.99 U
SkdMonit: Gr# 4    2240.99 U   2290.99 U   2330.99 U   2340.99 U
SkdMonit: --------------------------------------
SkdMonit: ------- PCAL Freq (kHz) Table ---------
SkdMonit: Gr# 1    4010.0   4010.0   4010.0   4010.0
SkdMonit: Gr# 2    4010.0   4010.0   4010.0   4010.0
SkdMonit: Gr# 3    4010.0   4010.0   4010.0   4010.0
SkdMonit: Gr# 4    4010.0   4010.0   4010.0   4010.0
SkdMonit: --------------------------------------
SkdMonit: --------- PICKUP SCAN TABLE ----------    <== scans picked up are displayed
SkdMonit: SCAN#     SOURCE YYYY/DDD HH:MM:SS DURA  STATION_IDS
SkdMonit:    84     3C273B 2010/189 02:56:33   30  G R
SkdMonit:    87     3C273B 2010/189 03:01:02   30  G R
SkdMonit:    90     3C273B 2010/189 03:06:44   30  G R
          ......
SkdMonit:  1791     3C273B 2010/191 10:58:40   30  G R
SkdMonit:  1795     3C273B 2010/191 11:09:26   30  G R
SkdMonit:  1797     3C273B 2010/191 11:14:24   30  G R
SkdMonit:  1799     3C273B 2010/191 11:20:11   30  G R
```

```
SkdMonit: -------------------------------------
```

This is a useful to pick up strong source scans.

Ex.4 Checking a schedule file (set baseline and source name)

```
$ apri_calc -eg094a.vex -baseid KsSh -source 3C454.3
       <== baseline is selected by option 'baseid' (2 letters for SKED file and
           4 letters for VEX). star name is set by option '-source'

apri_calc (Ver. 2016-10-12)

====================== RUN CONDITION ========================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
  Pickup Source Name : 3C454.3      <== radio source name
  Pickup Baseline ID : KsSh         <== baseline ID
=============================================================
search_site: No CLOCK info for ATCA included in the VEX FILE.
search_site: So all 0 for clock information was set.
search_site: No CLOCK info for PARKES included in the VEX FILE.
search_site: So all 0 for clock information was set.
      .... 中略 ....
search_site: No CLOCK info for IRBENE included in the VEX FILE.
search_site: So all 0 for clock information was set.
SkdMonit: *********** Schedule file monitor **********
SkdMonit: Schedule file = ./eg094a.vex
SkdMonit: Expcode       = eg094a
SkdMonit: Total Scan #  = 74
SkdMonit: Total Star #  = 4
SkdMonit:
SkdMonit:  1st   Scan   = 2016/09/20 12:57:00  2223-052
SkdMonit:  Last  Scan   = 2016/09/20 23:47:10  2215+020
SkdMonit:
SkdMonit: ---------- Station ID Table ----------
SkdMonit:  At --- ATCA
SkdMonit:  Pa --- PARKES
SkdMonit:  Mp --- MOPRA
SkdMonit:  Ho --- HOB_DBBC
SkdMonit:  Cd --- CDDBBC
SkdMonit:  Ti --- DSS43LBA
SkdMonit:  Ks --- KASHIM34
SkdMonit:  Ww --- WARK12M
SkdMonit:  T6 --- TIANMA65
SkdMonit:  Ur --- URUMQI
SkdMonit:  Sh --- SHANGHAI
SkdMonit:  Bd --- BADARY
        .......
SkdMonit:  Mc --- MEDICINA
SkdMonit:  O8 --- ONSALA85
SkdMonit:  Tr --- TORUN
SkdMonit:  Hh --- HART
SkdMonit:  Ir --- IRBENE
SkdMonit: (Note that 1 char station ID is not defined in a VEX file)
SkdMonit: -------------------------------------
SkdMonit: ------- Star Table -------------------
SkdMonit:          NAME1      NAME2  R.A.(deg)   DEC(deg)   EPOCH
SkdMonit:   1     FAKERA            180.000000  85.000000 2000.000000
SkdMonit:   2   2215+020            334.450991   2.336309 2000.000000
SkdMonit:   3   2223-052            336.446914  -4.950386 2000.000000
SkdMonit:   4    3C454.3            343.490616  16.148211 2000.000000
SkdMonit: -------------------------------------
SkdMonit: ------- Frequency (MHz) Table --------
SkdMonit: Gr# 1    1668.00 L   1668.00 U   1668.00 L   1668.00 U
SkdMonit: -------------------------------------
SkdMonit: ------- PCAL Freq (kHz) Table ---------
SkdMonit: Gr# 1    2000.0   2000.0   2000.0   2000.0
SkdMonit: -------------------------------------
SkdMonit: --------- PICKUP SCAN TABLE ----------   <== scans satisfying source name and
                                                       baseline are displayed
SkdMonit: SCAN#     SOURCE YYYY/DDD HH:MM:SS DURA  STATION_IDS
SkdMonit:    14    3C454.3 2016/264 14:41:30  480  At Pa Mp Ho Cd Ti Ks Ww T6 Ur Sh Bd
SkdMonit:    29    3C454.3 2016/264 17:01:00  480  At Mp Ho Cd Ti Ks T6 Ur Sh Bd Sv Zc
SkdMonit: -------------------------------------
```

3.1.3 Examples (in case of K5/VSSP)

Ex.1 non-interactive operation

Following example shows non-interactive operation in case that schedule file is "k10189.skd" in the "../cor-rapri" directory, baseline ID="RG", scan#=8, clock offset=8.0μsec, and the directory of a-priori output is "./".

```
$ apri_calc k10189.skd -baseid RG -apedir ./ -start 8 -stop 8 -coffset 8.0e-6
apri_calc (Ver. 2016-10-12)

====================== RUN CONDITION ========================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
  Sub-net mode ON : PRT is set according to each scan length
  Output directory : ./
=============================================================

**************** Schedule File Information ******************
 File name     ---  ./k10189.skd
 File type     ---  SKED
 Exp. code     ---  K10189
 # of stations ---  2
                    G R
 # of stars    ---  12
 # of scans    ---  2203
 1st   Scan : 2010/07/07 20:05:00  3C84
 Last  Scan : 2010/07/11 00:00:21  3C84
*************************************************************

 ------ STATION ID TABLE --------
  G --- KOGANEI
  R --- KASHIM11
 --------------------------------
 Station ID for X station : R
 Station ID for Y station : G
 Selected Baseline is R-G
 Sampling Information is as follows
                  from schedule file          from operator
      KASHIM11  :    32MHz 1bit 16CH         0MHz 0bit  0CH
       KOGANEI  :    32MHz 1bit 16CH         0MHz 0bit  0CH

 Data directory for X station (KASHIM11) : ./
 Data directory for Y station (KOGANEI) : ./
 Frequency group and frequencies
  Gr# 1 :   7700.99MHz U  7710.99MHz U  7720.99MHz U  7850.99MHz U
  Gr# 2 :   8090.99MHz U  8290.99MHz U  8490.99MHz U  8550.99MHz U
  Gr# 3 :   8570.99MHz U  8580.99MHz U  2210.99MHz U  2220.99MHz U
  Gr# 4 :   2240.99MHz U  2290.99MHz U  2330.99MHz U  2340.99MHz U
 Frequency Group# : 1
 Gr# 1 is selected
 PCAL freq (kHz) :  4010.0 4010.0 4010.0 4010.0
 Clock offset and rate : 8e-06 0
 Clock Epoch : 0/000 00:00:00
 X Clock offset against UTC : 0.000000

 ut1,wobbx,wobby : 0.000000 0.000000 0.000000

 # of scans    ---  2203
 Scan range : 8 - 8

   8 2010189001135  4C39.25              0              0              0

 Apriori File  ( ./ape1880008RGa.txt ) created

 Total # of a-priori files created is 1
```

Ex.2 Interactive operation

```
$ apri_calc k10189.skd -apedir apeout <== execute with "-apedir" option to set
                                          a-priori out ditectory to "apeout"
apri_calc (Ver. 2016-10-12)

====================== RUN CONDITION ========================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
  Sub-net mode ON : PRT is set according to each scan length
```

```
  Output directory : apeout        <== if this directory does'nt exits, program will
                                       stop with warning message.
=============================================================

**************** Schedule File Information *****************
 File name     ---  ./k10189.skd
 File type     ---  SKED
 Exp. code     ---  K10189
 # of stations ---  2
                    G R
 # of stars    ---  12
 # of scans    ---  2203
 1st   Scan : 2010/07/07 20:05:00  3C84
 Last  Scan : 2010/07/11 00:00:21  3C84
*************************************************************

 ------ STATION ID TABLE --------
  G --- KOGANEI
  R --- KASHIM11
 ---------------------------------
 Enter Station ID for X station ----> R  <== select station ID for X station
 Enter Station ID for Y station ----> G  <== select station ID for Y station
 Selected Baseline is R-G
 Sampling Information is as follows
                  from schedule file          from operator
      KASHIM11  :    32MHz 1bit 16CH         0MHz 0bit  0CH
       KOGANEI  :    32MHz 1bit 16CH         0MHz 0bit  0CH

 Enter data directory for X station (KASHIM11)
  ---> ./  <== set X station data directory
 Enter data directory for Y station (KOGANEI)
  ---> ./  <== set X station data directory
 Data directory for X station (KASHIM11) : ./
 Data directory for Y station (KOGANEI) : ./
 Frequency group and frequencies
  Gr# 1 :   7700.99MHz U  7710.99MHz U  7720.99MHz U  7850.99MHz U
  Gr# 2 :   8090.99MHz U  8290.99MHz U  8490.99MHz U  8550.99MHz U
  Gr# 3 :   8570.99MHz U  8580.99MHz U  2210.99MHz U  2220.99MHz U
  Gr# 4 :   2240.99MHz U  2290.99MHz U  2330.99MHz U  2340.99MHz U
 Enter Frequency Group# ----> 2  <== select frequency group
 Frequency Group# : 2
 Gr# 2 is selected
 PCAL freq (kHz) :  4010.0 4010.0 4010.0 4010.0
 Enter Clock Offset (sec) ----> 0.0  <== set clock offset
                                          (reflect clock offset after fringe search)
 Enter Clock Rate (s/s)  -----> 0.0  <==  if non zero value is set, epoch will be
                                          asked as follows.

  Enter Clock Epoch (YYYY/DDD-HH:MM:SS|YYYY/MM/DD-HH:MM:SS|YYYYDDDHHMMSS)
   0 for each PRT (old style)
   ----> 2010/07/07-20:05:00       <== enter epoch. If you enter 0, epoch is regarded
                                       as each PRT (processing reference time).
 Clock offset and rate : 0 0       <== here clock rate is reflected
 Clock Epoch : 0/000 00:00:00       <== here epock is reflected
 X Clock offset against UTC : 0.000000  <== this parameter can not be set in case of
                                            interactive operation
 Enter UT1-UTC (sec)   ----> 0.0   <== if precise value is not clear, 0 is OK.
 Enter Wobb X (arcsec) ----> 0.0   <== if precise value is not clear, 0 is OK.
 Enter Wobb Y (arcsec) ----> 0.0   <== if precise value is not clear, 0 is OK.

 ut1,wobbx,wobby : 0.000000 0.000000 0.000000

 # of scans    ---  2203
 Enter Start Scan number ----> 8   <== start scan#
 Enter Stop  Scan number ----> 8   <== stop  scan#
 Scan range : 8 - 8

   8 2010189001135  4C39.25              0              0              0

 Apriori File  ( apeout/ape1880008RGb.txt ) created

 Total # of a-priori files created is 1


$
```

Ex.3 Interactive operation under (limited source name)

```
$ apri_calc k10189.skd -source 3C273B  <== source name is limited to "3C273B" by option '-sour
apri_calc (Ver. 2016-10-12)

===================== RUN CONDITION =======================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
  Sub-net mode ON : PRT is set according to each scan length
  Pickup Source Name : 3C273B                 <== radio source name to be picked up
  Output directory : ../corrapri/
============================================================

**************** Schedule File Information *****************
 File name     ---  ./k10189.skd
 File type     ---  SKED
 Exp. code     ---  K10189
 # of stations ---  2
                    G R
 # of stars    ---  12
 # of scans    ---  2203
 1st   Scan : 2010/07/07 20:05:00  3C84
 Last  Scan : 2010/07/11 00:00:21  3C84
************************************************************

 ------ STATION ID TABLE --------
  G --- KOGANEI
  R --- KASHIM11
 --------------------------------
 Enter Station ID for X station ----> R
 Enter Station ID for Y station ----> G
 Selected Baseline is R-G
 Sampling Information is as follows
                 from schedule file          from operator
      KASHIM11  :    32MHz 1bit 16CH         0MHz 0bit  0CH
       KOGANEI  :    32MHz 1bit 16CH         0MHz 0bit  0CH

 Enter data directory for X station (KASHIM11)
  ---> ./
 Enter data directory for Y station (KOGANEI)
  ---> ./
 Data directory for X station (KASHIM11) : ./
 Data directory for Y station (KOGANEI) : ./
 Frequency group and frequencies
  Gr# 1 :   7700.99MHz U  7710.99MHz U  7720.99MHz U  7850.99MHz U
  Gr# 2 :   8090.99MHz U  8290.99MHz U  8490.99MHz U  8550.99MHz U
  Gr# 3 :   8570.99MHz U  8580.99MHz U  2210.99MHz U  2220.99MHz U
  Gr# 4 :   2240.99MHz U  2290.99MHz U  2330.99MHz U  2340.99MHz U
 Enter Frequency Group# ----> 1
 Frequency Group# : 1
 Gr# 1 is selected
 PCAL freq (kHz) :  4010.0 4010.0 4010.0 4010.0
 Enter Clock Offset (sec) ----> 0
 Enter Clock Rate (s/s)  -----> 0
 Clock offset and rate : 0 0
 Clock Epoch : 0/000 00:00:00
 X Clock offset against UTC : 0.000000
 Enter UT1-UTC (sec)   ----> 0
 Enter Wobb X (arcsec) ----> 0
 Enter Wobb Y (arcsec) ----> 0

 ut1,wobbx,wobby : 0.000000 0.000000 0.000000

 # of scans    ---  2203
 Enter Start Scan number ----> 0      <== 0 means all scans
 Enter Stop  Scan number ----> 0      <== 0 means all scans
 Scan range : 1 - 2203

  84 2010189025648   3C273B             0              0              0
                                       <== scans for 3C273B are extracted

 Apriori File  ( ../corrapri/ape1880084RGa.txt ) created
  87 2010189030117   3C273B             0              0              0

 Apriori File  ( ../corrapri/ape1880087RGa.txt ) created
  90 2010189030659   3C273B             0              0              0

  ..........
```

```
 Apriori File  ( ../corrapri/ape1881797RGa.txt ) created
1799 2010191112026   3C273B              0              0              0

 Apriori File  ( ../corrapri/ape1881799RGa.txt ) created

 Total # of a-priori files created is 168
$
```

Ex.4 Non-interactive operation of Ex.3

```
$ apri_calc k10189.skd ../corrapri RG 0 0 1 0 0 ./ ./ 0 0 0 1 0 0 3C273B
apri_calc (Ver. 2016-10-12)

====================== RUN CONDITION ========================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
  Sub-net mode OFF: PRT is set based on the longest scan
  Pickup Source Name : 3C273B
  Output directory : ../corrapri
=============================================================

**************** Schedule File Information *****************
 File name     ---  ./k10189.skd
 File type     ---  SKED
 Exp. code     ---  K10189
 # of stations ---  2
                    G R
 # of stars    ---  12
 # of scans    ---  2203
 1st   Scan : 2010/07/07 20:05:00  3C84
 Last  Scan : 2010/07/11 00:00:21  3C84
************************************************************

 ------ STATION ID TABLE --------
  G --- KOGANEI
  R --- KASHIM11
 --------------------------------
 Station ID for X station : R
 Station ID for Y station : G
 Selected Baseline is R-G
 Sampling Information is as follows
                  from schedule file          from operator
      KASHIM11  :    32MHz 1bit 16CH         0MHz 0bit  0CH
       KOGANEI  :    32MHz 1bit 16CH         0MHz 0bit  0CH

 Data directory for X station (KASHIM11) : ./
 Data directory for Y station (KOGANEI) : ./
 Frequency group and frequencies
  Gr# 1 :   7700.99MHz U  7710.99MHz U  7720.99MHz U  7850.99MHz U
  Gr# 2 :   8090.99MHz U  8290.99MHz U  8490.99MHz U  8550.99MHz U
  Gr# 3 :   8570.99MHz U  8580.99MHz U  2210.99MHz U  2220.99MHz U
  Gr# 4 :   2240.99MHz U  2290.99MHz U  2330.99MHz U  2340.99MHz U
 Frequency Group# : 1
 Gr# 1 is selected
 PCAL freq (kHz) :  4010.0 4010.0 4010.0 4010.0
 Clock offset and rate : 0 0
 Clock Epoch : 0/000 00:00:00
 X Clock offset against UTC : 0.000000

 ut1,wobbx,wobby : 0.000000 0.000000 0.000000

 # of scans    ---  2203
 Scan range : 1 - 2203

  84 2010189025648   3C273B              0              0              0

 Apriori File  ( ../corrapri/ape1880084RGa.txt ) created
  87 2010189030117   3C273B              0              0              0

  ................

 Apriori File  ( ../corrapri/ape1881797RGa.txt ) created
1799 2010191112026   3C273B              0              0              0

 Apriori File  ( ../corrapri/ape1881799RGa.txt ) created

 Total # of a-priori files created is 168
```

```
$
```

A-priori files are created under the "apeout" directory. If a-priori output directory is not specified, a-priori files are created under "../corrapri" directory.

3.1.4 Example (in case of VDIF Format Data)

```
$ apri_calc ..sked/ks15002.skd -format VDIF  <== Data format "VDIF" is specified
                                                 by "-format VDIF" option
apri_calc (Ver. 2016-10-12)

======================= RUN CONDITION ========================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
  Sub-net mode ON : PRT is set according to each scan length
  X station data format :   VDIF          <== specified data format for X station
  Y station data format :   VDIF          <== specified data format for Y station
  Output directory : ../corrapri/
=============================================================

**************** Schedule File Information ******************
 File name     ---  ../src/ks15002.skd
 File type     ---  SKED
 Exp. code     ---  KS15002
 # of stations ---  5
                    G R Y B O
 # of stars    ---  16
 # of scans    ---  289
 1st   Scan : 2015/01/02 02:00:00  3C345
 Last  Scan : 2015/01/03 02:02:43  0059+581
*************************************************************

 ------ STATION ID TABLE --------
  G --- KOGANEI
  R --- KASHIM11
  Y --- TATEYAMA
  B --- MIURA
  O --- KASHIM34
 --------------------------------
 Enter Station ID for X station ----> R
 Enter Station ID for Y station ----> G
 Selected Baseline is R-G
 Sampling Information is as follows     <==display sampling information
                  from schedule file          from operator
      KASHIM11  :    16MHz 1bit 16CH         0MHz 0bit  0CH
       KOGANEI  :    16MHz 1bit 16CH         0MHz 0bit  0CH

 Enter data directory for X station (KASHIM11)
  ---> ./             <== set data directory for X station
 Enter data directory for Y station (KOGANEI)
  ---> ./             <== set data directory for Y station
 Data directory for X station (KASHIM11) : ./
 Data directory for Y station (KOGANEI) : ./
 Frequency group and frequencies
  Gr# 1 :   7864.99MHz U  7874.99MHz U  7884.99MHz U  8014.99MHz U
  Gr# 2 :   8114.99MHz U  8244.99MHz U  8504.99MHz U  8544.99MHz U
  Gr# 3 :   8564.99MHz U  8574.99MHz U  2214.99MHz U  2224.99MHz U
  Gr# 4 :   2234.99MHz U  2264.99MHz U  2294.99MHz U  2304.99MHz U
 Enter Frequency Group# (0 for all) ----> 0  <== select all frequencies
 All frequency mode is selected!
 Enter Clock Offset (sec) ----> 0
 Enter Clock Rate (s/s)  -----> 0
 Clock offset and rate : 0 0
 Clock Epoch : 0/000 00:00:00
 X Clock offset against UTC : 0.000000
 Enter UT1-UTC (sec)   ----> 0
 Enter Wobb X (arcsec) ----> 0
 Enter Wobb Y (arcsec) ----> 0

 ut1,wobbx,wobby : 0.000000 0.000000 0.000000

 # of scans    ---  289
 Enter Start Scan number ----> 1
 Enter Stop  Scan number ----> 2
 Scan range : 1 - 2

   1 2015002020045    3C345             0              0              0
```

```
 Apriori File  ( ../corrapri/ape0020001RG.txt ) created
   2 2015002020520  3C454.3            0              0              0

 Apriori File  ( ../corrapri/ape0020002RG.txt ) created

 Total # of a-priori files created is 2

$
```

Edit an a-priori file by a text editor if necessary.

3.1.5 Example (in case of Mark-5B format Data)

```
$ apri_calc ..sked/ks15002.skd -format M5B  <-- set data format "Mark-5B"
                                                 by "-format M5B" option
apri_calc (Ver. 2016-10-12)

===================== RUN CONDITION =======================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
  Sub-net mode ON : PRT is set according to each scan length
  X station data format :   Mark-5B       <== specified data format for X station
  Y station data format :   Mark-5B       <== specified data format for Y station
=============================================================

**************** Schedule File Information *****************
 File name     ---  ../src/ks15002.skd
 File type     ---  SKED
 Exp. code     ---  KS15002
 # of stations ---  5
                    G R Y B O
 # of stars    ---  16
 # of scans    ---  289
 1st   Scan : 2015/01/02 02:00:00  3C345
 Last  Scan : 2015/01/03 02:02:43  0059+581
*************************************************************

 ------ STATION ID TABLE --------
  G --- KOGANEI
  R --- KASHIM11
  Y --- TATEYAMA
  B --- MIURA
  O --- KASHIM34
 --------------------------------
 Enter Station ID for X station ----> R
 Enter Station ID for Y station ----> G
 Selected Baseline is R-G
 Sampling Information is as follows     <== display sampling information
                  from schedule file          from operator
     KASHIM11  :    16MHz 1bit 16CH         0MHz 0bit  0CH
      KOGANEI  :    16MHz 1bit 16CH         0MHz 0bit  0CH

 Enter data directory for X station (KASHIM11)
  ---> ./              <== set data directory for X station
 Enter data directory for Y station (KOGANEI)
  ---> ./              <== set data directory for Y station
 Data directory for X station (KASHIM11) : ./
 Data directory for Y station (KOGANEI) : ./
 Frequency group and frequencies
  Gr# 1 :   7864.99MHz U  7874.99MHz U  7884.99MHz U  8014.99MHz U
  Gr# 2 :   8114.99MHz U  8244.99MHz U  8504.99MHz U  8544.99MHz U
  Gr# 3 :   8564.99MHz U  8574.99MHz U  2214.99MHz U  2224.99MHz U
  Gr# 4 :   2234.99MHz U  2264.99MHz U  2294.99MHz U  2304.99MHz U
 Enter Frequency Group# (0 for all) ----> 0   <== select all frequencies
 All frequency mode is selected!
 Enter Clock Offset (sec) ----> 0
 Enter Clock Rate (s/s)  -----> 0
 Clock offset and rate : 0 0
 Clock Epoch : 0/000 00:00:00
 X Clock offset against UTC : 0.000000
 Enter UT1-UTC (sec)   ----> 0
 Enter Wobb X (arcsec) ----> 0
 Enter Wobb Y (arcsec) ----> 0

 ut1,wobbx,wobby : 0.000000 0.000000 0.000000

 # of scans    ---  289
 Enter Start Scan number ----> 1
```

```
 Enter Stop  Scan number ----> 2
 Scan range : 1 - 2

   1 2015002020045    3C345             0             0             0

 Apriori File  ( ../corrapri/ape0020001RG.txt ) created
   2 2015002020520  3C454.3             0             0             0

 Apriori File  ( ../corrapri/ape0020002RG.txt ) created

 Total # of a-priori files created is 2

$
```

Edit an a-priori file by a text editor if necessary.

3.1.6 Example (in case of VSSP format for X station and VDIF format Y station)

```
$ apri_calc ..sked/ks15002.skd -formY VDIF  <== Y station data format is specified
                                                by "-formY" option to VDIF.
                                                X station is default format (VSSP)

apri_calc (Ver. 2016-10-12)

===================== RUN CONDITION ========================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
  Sub-net mode ON : PRT is set according to each scan length

  Y station data format :   VDIF          <== display specified data format
==============================================================

**************** Schedule File Information ******************
 File name     ---  ../src/ks15002.skd
 File type     ---  SKED
 Exp. code     ---  KS15002
 # of stations ---  5
                    G R Y B O
 # of stars    ---  16
 # of scans    ---  289
 1st   Scan : 2015/01/02 02:00:00  3C345
 Last  Scan : 2015/01/03 02:02:43  0059+581
**************************************************************

 ------ STATION ID TABLE --------
  G --- KOGANEI
  R --- KASHIM11
  Y --- TATEYAMA
  B --- MIURA
  O --- KASHIM34
 --------------------------------
 Enter Station ID for X station ----> R
 Enter Station ID for Y station ----> G
 Selected Baseline is R-G
 Sampling Information is as follows     <== display sampling information
                  from schedule file          from operator
      KASHIM11  :    16MHz 1bit 16CH         0MHz 0bit  0CH
       KOGANEI  :    16MHz 1bit 16CH         0MHz 0bit  0CH

 Enter data directory for X station (KASHIM11)
  ---> ./              <== set data directory for X station
 Enter data directory for Y station (KOGANEI)
  ---> ./              <== set data directory for Y station
 Data directory for X station (KASHIM11) : ./
 Data directory for Y station (KOGANEI) : ./
 Frequency group and frequencies
  Gr# 1 :   7864.99MHz U  7874.99MHz U  7884.99MHz U  8014.99MHz U
  Gr# 2 :   8114.99MHz U  8244.99MHz U  8504.99MHz U  8544.99MHz U
  Gr# 3 :   8564.99MHz U  8574.99MHz U  2214.99MHz U  2224.99MHz U
  Gr# 4 :   2234.99MHz U  2264.99MHz U  2294.99MHz U  2304.99MHz U
 Enter Frequency Group# ----> 1   <== select one of groups
 All frequency mode is selected!
 Enter Clock Offset (sec) ----> 0
 Enter Clock Rate (s/s)  -----> 0
 Clock offset and rate : 0 0
 Clock Epoch : 0/000 00:00:00
 X Clock offset against UTC : 0.000000
 Enter UT1-UTC (sec)   ----> 0
```

```
Enter Wobb X (arcsec) ----> 0
Enter Wobb Y (arcsec) ----> 0

ut1,wobbx,wobby : 0.000000 0.000000 0.000000

# of scans    ---  289
Enter Start Scan number ----> 1
Enter Stop  Scan number ----> 2
Scan range : 1 - 2

  1 2015002020045    3C345              0              0              0

Apriori File  ( ../corrapri/ape0020001RG.txt ) created
  2 2015002020520  3C454.3              0              0              0

Apriori File  ( ../corrapri/ape0020002RG.txt ) created

Total # of a-priori files created is 2

$
```

Edit an a-priori file by a text editor if necessary.

3.2 skdchk

"skdchk" reads a schedule file (SKED or VEX format) and display station, source, scan information and compute the size of necessary disk space.

3.2.1 How to execute

skdchk sked_file [-NOEARLY]

where sked_file – schedule file name
-NOEARLY – ignore "tape early start" aparameter

3.2.2 Examples

```
$ skdchk jd0306.skd
skdchk Ver 2.31    2016-10-12
Schedule file is  jd0306.skd

*** SCHEDULE FILE (jd0306.skd) INFORMATION ***
Experiment code    : JD0306
Number of stations : 8
    1  T   TSUKUB32  -3957408.751200   3310229.346600   3737494.836000
    2  A       AIRA  -3530219.322300   4118797.541900   3344015.905900
    3  C   CHICHI10  -4490618.469200   3483908.166600   2884899.205700
    4  J   SINTOTU3  -3642141.844800   2861496.642500   4370361.717900
    5  R   KASHIM11  -3997505.701700   3276878.404550   3724240.703140
    6  Y     GIFU11  -3787123.360830   3564181.693760   3680274.907440
    7  H   TOMAKO11  -3680586.301730   2917515.745560   4300987.652680
    8  K   YAMAGU32  -3502535.908490   3950950.219310   3566374.002980
Number of stars : 114
   (only 20 stars are listed here)
    1   0003-066          $   1.557887  -6.393149 2000.000000
    2   0014+813          $   4.285312  81.585593 2000.000000
    3   0048-097          $  12.672156  -9.484781 2000.000000
    4   0059+581          $  15.690677  58.403094 2000.000000
    5   0104-408          $  16.687950 -40.572211 2000.000000
    6   0106+013          $  17.161546   1.583421 2000.000000
    7   0111+021          $  18.429771   2.371477 2000.000000
    8   0119+115          $  20.423313  11.830670 2000.000000
    9   0119+041          $  20.486924   4.373537 2000.000000
   10   0133+476          $  24.244145  47.858083 2000.000000
   11   0201+113          $  30.944404  11.579280 2000.000000
   12   0202+149          $  31.210058  15.236401 2000.000000
   13   0208-512          $  32.692502 -51.017192 2000.000000
   14   0229+131          $  37.941225  13.381866 2000.000000
   15   0235+164          $  39.662209  16.616465 2000.000000
   16   0316+413       3C84  49.950667  41.511695 2000.000000
   17   0336-019      CTA26  54.878907  -1.776612 2000.000000
   18   0355+508    NRAO150  59.873947  50.963934 2000.000000
   19   0402-362          $  60.973958 -36.083865 2000.000000
   20   0405-385          $  61.745981 -38.441123 2000.000000
Number of scans : 209
```

```
First 5 scans are as follows:
    1       CTA26  3/197 02:00:00  310
    2    1803+784  3/197 02:06:10  784
    3     4C39.25  3/197 02:19:50  100
    4    0727-115  3/197 02:23:10  180
    5    0537-441  3/197 02:26:40  190
Last 5 scans are as follows:
  205    1044+719  3/198 01:22:20  430
  206    0552+398  3/198 01:33:30  160
  207    0202+149  3/198 01:37:00  784
  208    0133+476  3/198 01:50:30  550
  209    0537-441  3/198 02:00:40  180

  Early Start Parameter (sec) : 0

 Maximum Disk requirements
   Total observation time (sec)  = 76038
    Disk requirements
        32Mbps  :    304.152 GBytes
        64Mbps  :    608.304 GBytes
       128Mbps  :   1216.608 GBytes
       256Mbps  :   2433.216 GBytes
```

Disk Requirements by Station (GBytes)

	TSUKUB32	AIRA	CHICHI10	SINTOTU3	KASHIM11	GIFU11	TOMAKO11
sec	46018	65066	65976	37808	76038	76038	76038
#scans	200	186	189	169	209	209	209
32Mbps	184.1	260.3	263.9	151.2	304.2	304.2	304.2
64Mbps	368.1	520.5	527.8	302.5	608.3	608.3	608.3
128Mbps	736.3	1041.1	1055.6	604.9	1216.6	1216.6	1216.6
256Mbps	1472.6	2082.1	2111.2	1209.9	2433.2	2433.2	2433.2

Disk Requirements by Station (GBytes)

	YAMAGU32
sec	29012
#scans	78
32Mbps	116.0
64Mbps	232.1
128Mbps	464.2
256Mbps	928.4

4 Correlation software

4.1 fx_cor, fx_cor_new, cor, cor_new

"fx_cor" and "fx_cor_new" are FX-type software correlator and carry out cross correlation processing using an apriori file. "cor" and "cor_new" are XF-type software correlator dedicated to 1-bit AD data. Correlated data are output to a file with a "cout" format. Auto-correlation or cross correlation with zero apriori value are also available.

"fx_cor" and "cor" are dedicated to K5/VSSP format data, but "fx_cor_new" and "cor_new" can process a variety of data formats, such as Mark5B, VDIF, ADS, OCTAD besides K5/VSSP.

In case of processing geodetic VLBI data with 1-bit sampling with 32 lags, "cor" or "cor_new" are faster than "fx_cor" or "fx_cor_new".

4.1.1 How to execute

Type 1: normal correlation processing

"fx_cor" can be "fx_cor_new", "cor", or "cor_new".

fx_cor *afile* [*options*]

where	*afile*	–	a-priori file name
	options (any order)		
	-integ *integration_time*		
		–	set total integration period (sec) dfault is scan length described in a schedule file in case of negative value, absolute value means integration exceeding scheduled scan length.
	-coffset *clock_offset*		
		–	set clock offset (sec) applied for fringe search purpose. Positive value menas Y clock tic earlier than X clock tic. Default is 0.0
	-crate *clock_rate*	–	set clock rate (s/s) difference between X and Y station clock applied for fringe search purpose. Default is 0.0
	-soffset *start_offset*		
		–	set start time offset (integer second)
	-t1pp *t1pp*	–	PP (parameter period) (sec) for correlation processing. Default is BT1PP in "cor_head.h" (usually 1.0) see Note 1 for available *t1pp* less than 1 sec.
	-pp_nosync	–	turns off the synchronization mode of PP (parameter period) (default is that PP synchronize to second tic)
	-lag *delsize*	–	set the size of delay lag window by a power of 2, e.g., 16, 32, 64, 128, 256, 512, 1024, 2048, ... Default is DELAYSIZE in "cor_head.h" (usually 32)
	-pmode *pmode*	–	set plot device mode 0: XWINDOW (env PGDISP can change PGPLOT display device) and PostScript file (pgplot.ps or gnuplot.ps) out (dfault) 1: PostScript file (pgplot.ps or gnuplot.ps) out only 2: XWINDOW only -1: no graphic output
	-comment "*any comment*"		
		–	set comment appeared in a correlation function plot
	-nopcal	–	suppress PCAL (phase calibration) signal detection
	-ch1 *ch1Y*	–	define Y channel for X CH# 1 (default 1)
	-ch2 *ch2Y*	–	define Y channel for X CH# 2 (default 2)
	-ch3 *ch3Y*	–	define Y channel for X CH# 3 (default 3)
	-ch4 *ch4Y*	–	define Y channel for X CH# 4 (default 4)
	Note: in case of "fx_cor_new" and "cor_new", options upto '-ch16 *ch16Y*' are available		
	-orule *naming_rule*		

– set naming rule of output file name

0 : use program default ("cout.txt" for "fx_cor" and "fx_cor_new", "coutt.txt" for "cor" and "cor_new")

1 : coutNNNN.txt for "fx_cor" and "fx_cor_new"
couttNNNN.txt for "cor" and "cor_new" (default)
where NNNN ： serial number (4 digits)

2 : coutEXP_CODE/coutYYDDDNNNNXYG.txt for "fx_cor" and "fx_cor_new"
couttEXP_CODE/coutYYDDDNNNNXYG.txt for "cor" and "cor_new"

where

EXP_CODE	–	experiment code
YY	–	year (2 digits)
DDD	–	total day (3 digits)
NNNN	–	scan# (4 digits)
XY	–	baseline ID (2 or 4 letters)
G	–	frequency group (a|b|c|d) or null

3 : coutYYDDDNNNNXYG.txt for "fx_cor" and "fx_cor_new"
couttYYDDDNNNNXYG.txt for "cor" and "cor_new"

where

YY	–	year (2 digits)
DDD	–	total day (3 digits)
NNNN	–	scan# (4 digits)
XY	–	baseline ID (2 or 4 letters)
G	–	frequency group (a|b|c|d) or null

-odir *outdir* – set output file directory.
System default is environmental variable K5COUT. If K5COUT is not defined, program default defined by COUTDFLT in "cor_head.h" is used (usually "../cout")

-frstep *frstep* – set fringe phase calculation step in samples

0	–	automatic calculation
1	–	every 1 sample
8	–	every 8 samples (default)
N	–	every N samples (1000/N should be integer) default is FRSTEP_FX_COR (in "cor_head.h")

-frauto – set *frstep*=0 (automatic calculation mode)

-rfoffset *rf_offset* – set RF frequency difference between Y and X (RFy-RFx)(Hz)

-cout *cout_file* – set output file name compulsory. If this parameter is set, naming rule and out directory are ignored.

-fall *pcalf* – set PCAL frequency of all channels compulsory (kHz)

-f1 *pcalf1* – set PCAL frequency of CH# 1 compulsory (kHz)

-f2 *pcalf2* – set PCAL frequency of CH# 2 compulsory (kHz)

-f3 *pcalf3* – set PCAL frequency of CH# 3 compulsory (kHz)

-f4 *pcalf4* – set PCAL frequency of CH# 4 compulsory (kHz)

Note: in case of "fx_cor_new" and "cor_new", options upto '-f16 *pcalf16*' are available

-1ch *x_ch* [*y_ch*] – set 1 channel processing mode

x_ch	–	CH# of X station
y_ch	–	CH# of Y station

=== belows are options for "fx_cor" and "fx_cor_new" ===

-modefr *modefr* – set fringe stopping approximation mode

0	–	no approximation (exact calculation)
9	–	9 level approximation (default)
2	–	2 level approximation
3	–	3 level approximation

-hanning – use Hanning lag window

-hamming – use Hamming lag window

-bpf *flow*:*fhigh*[:*fact*][,*flow*:*fhigh*[:*fact*][,*flow*:*fhigh*[:*fact*][,.....]]]
– set BPF (bandpass filter) parameters by lower and upper cut-off frequencies (upto 20 sets)

flow – lower cut-off frequency in a baseband (MHz)
fhigh – upper cut-off frequency in a baseband (MHz)
fact – amplitude coefficient (0.0−1.0) default is 1.0

-bpf2 fc:*bw*[:$fact$][,fc:[*bw*][:$fact$][,fc:[*bw*]:$fact$][,.....]]]
– set BPF (bandpass filter) parameters by center frequency and bandwidth (upto 20 sets)
fc – center frequency of BPF in a baseband (MHz)
bw – bandwidth (MHz). it can be omitted in case of the same value with the
fact – amplitude coefficient (0.0−1.0) default is 1.0

-fres *fres* – set frequency resolution in case of BPF processing. Default is automatic set up.

Note 1: Valid values as *t1pp* are as follows.

	PP period (sec)						
sampling frequency	0.01	0.02	0.04	0.05	0.1	0.2	0.5
40kHz	×	OK	OK	×	OK	OK	OK
100kHz	×	×	OK	×	×	OK	×
200kHz	×	OK	OK	×	OK	OK	OK
500kHz	×	×	OK	×	×	OK	×
1MHz	×	OK	OK	×	OK	OK	OK
2MHz	OK	OK	OK	OK	OK	OK	OK
4MHz	OK	OK	OK	OK	OK	OK	OK
8MHz	OK	OK	OK	OK	OK	OK	OK
16MHz	OK	OK	OK	OK	OK	OK	OK
32MHz	OK	OK	OK	OK	OK	OK	OK
64MHz	OK	OK	OK	OK	OK	OK	OK

Type 2: old style

fx_cor *afile* [*sekibun soffset coffset roffset t1pp smode pp_mode delsizetzoom pmode comment*]

where *afile* – a-priori file name
sekibun – total integration period (sec)
dfault or 0 is scan length described in a schedule file
in case of negative value, absolute value means integration exceeding scheduled scan length.
soffset – start time offset (integer second)
coffset – clock offset (sec) applied for fringe search purpose. Positive value menas Y clock tic earlier than X clock tic. Default is 0.0
roffset – clock rate (s/s) difference between X and Y station clock applied for fringe search purpose. Default is 0.0
t1pp – PP (parameter period) (sec) for correlation processing. Default is BT1PP in "cor_head.h" (usually 1.0)
see Note 1 above for available *t1pp* less than 1 sec.
smode – delay search range (no more use)
0: Maximum (200000 samples)
1: Middle (10000 samples)
2: Minimum (1000 or 2000 samples)
default is 2 but no more use!
pp_mode – synchronization mode of PP
0: PP synchronize to second tic (default)
1: PP does not synchronize to second tic
delsize – size of delay lag window (a power of 2)
e.g., 16, 32, 64, 128, 256, 512, 1024, 2048, ...

		0 means DELAYSIZE in "cor_head.h" (usually 32)
tzoom	–	time axis zoom ratio in graphics (integer) 0: full scale (default) as same as 1 -VE : Max position is automatically centered. VE is a zoom factor.
pmode	–	plot device selection 0 : XTERM (environmental variable PGDISP can change PGPLOT display device) and PostScript file (pgplot.ps or gnuplot.ps) out (default) 1 : PostScript file (pgplot.ps or gnuplot.ps) out only 2 : XWINDOW only -1 : no graphic output
comment	–	comment appeared in a correlation function plot

Type 3: auto-correlation mode

fx_cor *k5file1* [*k5file2*] [*options*]

where	*k5file1*	–	data file name
	k5file2	–	2nd data file name. If directory is omitted in *k5file2*, directory is considered to be the same as that of *k5file1*. If 2nd data file name is omitted, *k5file1* is used for both X and Y data file. Note: A-priori values are all set to zero. Frequencies are all set to zero.
	options	–	*options* given in Type 1 is available to use

This mode corresponds to use a-priori file as follows.

```
** This is Apriori file for auto correlation
**

$EXPCODE
APE_ZERO

$STATION1
STATION1 k5file1

$STATION2
STATION2 k5file2

$FREQUENCY
0.0 U
0.0 U
0.0 U
0.0 U

$PCAL_FREQ
0.0
0.0
0.0
0.0

$CLOCK
OFST= 0.0
RATE= 0.0

$SOURCE
APE_ZERO

$START
0000000000000

$STOP
0000000000000

$APRIORI
PRT=0000000000000
TAU0= 0.0
TAU1= 0.0
TAU2= 0.0
TAU3= 0.0

$END
```

Monitoring environmental variables

Environmental variables used in software correlator are as follows.
K5COUT – default directory for correlation data out
K5APRIDIR – default directory for apriori file
RGDISP– PGPLOT display device name t

They can be checked by
fx_cor env

4.1.2 Example: "cor"

Use default value except for a-priori file.

```
$ cor ./apeXY10.txt     <== ''apeXY10.txt'' is an a-priori file located in the
                                  current directory

************** run parameters (Ver 2014.8.13 or later)******************
  afile   = ./apeXY10.txt
  Total Integ Period (sec) =  0.000000  (0.0 means integrated as scheduled)
  T1PP (sec)         = 1.000000    PP_sync mode  = 0  (PP sync to 1sec tic)
  Lag Window Size    = 32   Search_mode = 2
  Start Offset (sec) = 0
  Clock Offset (sec) = 0.000000e+00   Clock Rate(s/s) = 0.000000e+00
  PCAL Detection     : ON
  Graphic Out Mode   = 0 (PostScript Out + DISPLAY)  tzoom   = 1
  comment = (null)
  loop_param  = 0 (for regular processing)
  ch assign  =  (1 - 1) (2 - 2) (3 - 3) (4 - 4)
*********************************************************************
ApeMonit: APRIORI file is NEW VERSION
ApeMonit: EXPCODE    JD0306
ApeMonit: OBS_NUMBER 8
ApeMonit: KASHIM11 /home/kondo/data/testspeed/Xk5data.10.dat
ApeMonit:   XYZ -3997505.701700 3276878.404550 3724240.703140
ApeMonit: TOMAKO11 /home/kondo/data/testspeed/Yk5data.10.dat
ApeMonit:   XYZ -3680586.301730 2917515.745560 4300987.652680
ApeMonit: BASEID  RH
ApeMonit: PRT     2003 197 2 41 10
ApeMonit: START   2003 197 2 41 5
ApeMonit: STOP    2003 197 2 41 15
ApeMonit: Frequency Table
ApeMonit:    Ch1 8209990000.000000 U
ApeMonit:    Ch2 8219990000.000000 U
ApeMonit:    Ch3 8249990000.000000 U
ApeMonit:    Ch4 8309990000.000000 U
ApeMonit: PCAL Frequency Table
ApeMonit:    Ch1 10000.000000
ApeMonit:    Ch2 10000.000000
ApeMonit:    Ch3 10000.000000
ApeMonit:    Ch4 10000.000000
ApeMonit: Frequency Group#  1
ApeMonit: Aprioris
ApeMonit:    Tau0     1.540623e-04
ApeMonit:    Tau1dot  1.153642e-07
ApeMonit:    Tau2dot  -1.169617e-12
ApeMonit:    Tau3dot  -6.131427e-16
ApeMonit: Clock offset   2.485000e-06
ApeMonit: Clock rate     0.000000e+00
ApeMonit: X Clock offset 0.000000e+00
ApeMonit:    UT1-UTC (sec) 0.000000
ApeMonit:    X-WOBB (asec) 0.000000
ApeMonit:    Y-WOBB (asec) 0.000000
ApeMonit: Star 3C273B
ApeMonit:    RA  12 29 6.69973194
ApeMonit:    DEC 2 3 8.59818480
ApeMonit:    EPOCH 2000.0
ApeMonit:    GHA 9 46 11.12600000
 Directory ../cout already existed!
corr_engine:  Version 2011-03-22
corr_engine:  maxpp,idsize,irsize,chsize, smode 2048 32 2048 4 2
```

```
corr_engine: X Data File is /home/kondo/data/testspeed/Xk5data.10.dat
corr_engine: Y Data File is /home/kondo/data/testspeed/Yk5data.10.dat
checkheader: Header (K5/VSSP) Sync Detected!!
checkheader:   File : /home/kondo/data/testspeed/Xk5data.10.dat
checkheader:   A/D(bits) 1  CHs 4  SFreq(kHz) 8000  Time 02:41:05  sec 9665
checkheader: Header (K5/VSSP) Sync Detected!!
checkheader:   File : /home/kondo/data/testspeed/Yk5data.10.dat
checkheader:   A/D(bits) 1  CHs 4  SFreq(kHz) 8000  Time 02:41:05  sec 9665
corr_engine:  << runmode  (runmode)             = 1
corr_engine:  << smode    (smode)               = 2
corr_engine:  << # of samples in a unit (usampl) = 4000
corr_engine:  << lag size (idsize)              = 32
corr_engine:  << PP period in sec (t1pp)        = 1.0
corr_engine:  << # of usampl  in a PP (nspp)     = 2000
corr_engine:  << # of usampl  in 1 sec (imax)    = 2000
corr_engine:  << # of bytes   in a usampl (numb) = 2000
corr_engine:  << RF offset (Hz)                 = 0.000000
corr_engine:  << Fringe stopping mode           = 0 (base band)
xros_engine:  << Fringe phase calc mode (modefr) = 3 (3 level approx)
corr_engine:  << Fringe phase calc step (frstep) = 32 sample(s)
corr_engine:  << Pcal detection mode X station   = 1
corr_engine:  << Pcal detection mode Y station   = 1
corr_engine:  << Channel Assignment =  (1 - 1) (2 - 2) (3 - 3) (4 - 4)
corr_engine:  << Temprary file for header  : ./PNRo93hd.tmp
corr_engine:  << Temprary file for PP data : ./agxDGypp.tmp
corr_engine:  chdif_flag =   0
corr_engine:  Atamadashi finished!
corr_engine:   temporary info out file (./PNRo93hd.tmp) Opened!
corr_engine:   temporary corr out file (./agxDGypp.tmp) Opened!
corr_engine: Start X data time : 9665.000000
corr_engine: Start Y data time : 9665.000000
checkheader: Header (K5/VSSP) Sync Detected!!
checkheader:   File : /home/kondo/data/testspeed/Yk5data.10.dat
checkheader:   A/D(bits) 1  CHs 4  SFreq(kHz) 8000  Time 02:41:06  sec 9666
corr_engine: PP# 1 data saved
corr_engine:   Time elapsed for 1PP processing is 1.029115 sec
corr_engine:   X data time (BOPP) : 9665.000000
corr_engine:   processed data (1.0/10.0)
checkheader: Header (K5/VSSP) Sync Detected!!
checkheader:   File : /home/kondo/data/testspeed/Xk5data.10.dat
checkheader:   A/D(bits) 1  CHs 4  SFreq(kHz) 8000  Time 02:41:06  sec 9666
checkheader: Header (K5/VSSP) Sync Detected!!
checkheader:   File : /home/kondo/data/testspeed/Yk5data.10.dat
checkheader:   A/D(bits) 1  CHs 4  SFreq(kHz) 8000  Time 02:41:07  sec 9667
corr_engine: PP# 2 data saved

    ................


corr_engine: PP# 9 data saved
corr_engine:   Time elapsed for 1PP processing is 1.026757 sec
corr_engine:   X data time (BOPP) : 9673.000000
corr_engine:   processed data (9.0/10.0)
checkheader: Header (K5/VSSP) Sync Detected!!
checkheader:   File : /home/kondo/data/testspeed/Xk5data.10.dat
checkheader:   A/D(bits) 1  CHs 4  SFreq(kHz) 8000  Time 02:41:14  sec 9674
checkheader: File EOF! (/home/kondo/data/testspeed/Yk5data.10.dat)
corr_engine: Time-elapsed per PP (sec)  MIN=1.026757  MAX=1.029326
Postscript out file ==> pgplot.ps  <== postscript faile name created

  ==============================================================
     CH#    FREQ(MHz)      MAX AMP       RESIDUAL DELAY (sec)
  --------------------------------------------------------------
      1      8209.99      0.001041            -5.69519e-09
      2      8219.99      0.000707            -5.19374e-08
      3      8249.99      0.000933             4.58736e-09
      4      8309.99      0.000835             2.86532e-08
  ==============================================================

COUT File is ../cout/coutt0006.txt <== correlator output file
Time elapsed (sec) for One obs process is 13.000000
```

```
$
```

Fig.4.1 is displayed after processing.

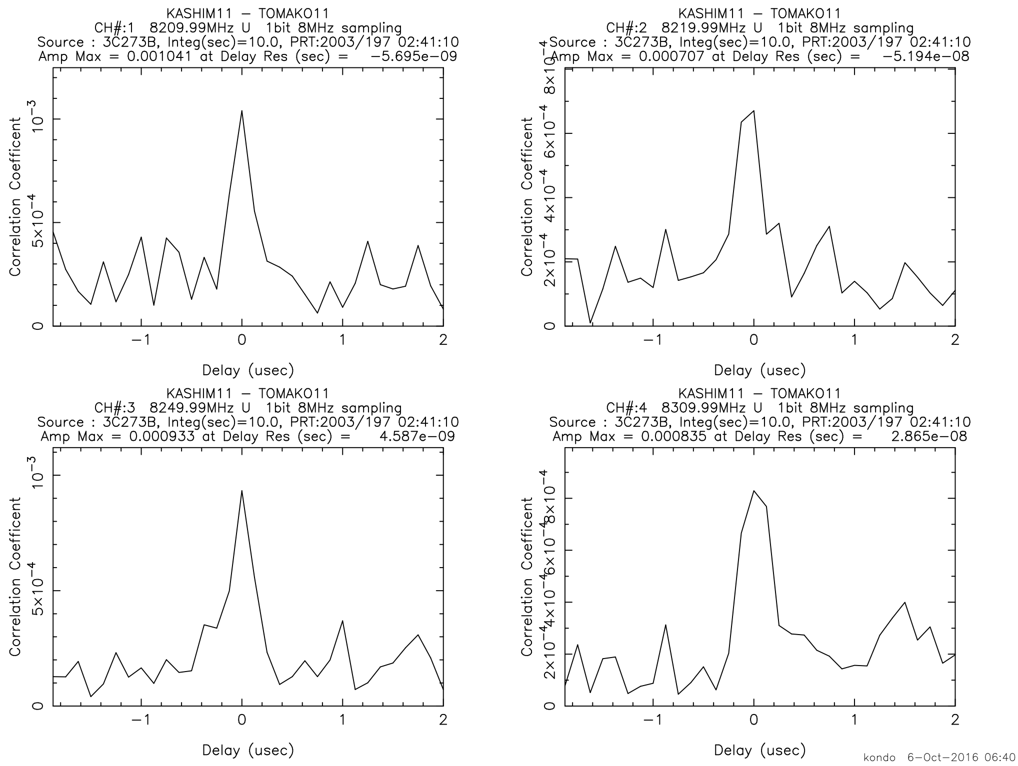

Figure 4.1. Examples of correlation function plot after "fx_cor" and "cor" processing

4.1.3 Example: "fx_cor_new" (Mark5B data)

Default values are used except for a-priori file.

```
$ fx_cor_new ./ape220205919RG.m5b.txt   <== use a-priori file prepared for Mark5B

************* run parameters (Ver 2014.8.13 or later)******************
  afile   = ./ape220205919RG.m5b.txt
  Total Integ Period (sec) =  0.000000  (0.0 means integrated as scheduled)
  T1PP (sec)         = 1.000000    PP_sync mode  = 0  (PP sync to 1sec tic)
  Lag Window Size    = 32   Search_mode = 2
  Start Offset (sec) = 0
  Clock Offset (sec) = 0.000000e+00   Clock Rate(s/s) = 0.000000e+00
  PCAL Detection     : ON
  Graphic Out Mode   = 0 (PostScript Out + DISPLAY)  tzoom   = 1
  comment = (null)
  loop_param  = 0 (for regular processing)
  ch assign  =  (1 - 1) (2 - 2) (3 - 3) (4 - 4)

  BPF parameters
     modebpf  =  0
  Frequency resolution (MHz) (0 measn AUTO)  : 0.000000
*********************************************************************
ApeMonit: APRIORI file is NEW VERSION
ApeMonit: EXPCODE    K10216

   ...............

engine_datafile_open: # of channels to be processed is  16
xros_engine:  << runmode  (runmode)              = 1
xros_engine:  << smode    (smode)                = 2
xros_engine:  << # of samples in a unit (usampl) = 1000
```

```
xros_engine:  << lag size (idsize)              = 32
xros_engine:  << FFT size for processing        = 32
xros_engine:  << Lag Window Type                = Box
xros_engine:  << PP period in sec (t1pp)        = 1.0
xros_engine:  << # of usampl  in a PP (nspp)    = 32000
xros_engine:  << # of usampl  in 1 sec (imax)   = 32000
xros_engine:  << # of bytes   in a usampl (numb) = 2000
xros_engine:  << # of bytes   in a usampl per CH = 125
xros_engine:  << RF offset (Hz)                 = 0.000000
xros_engine:  << Fringe stopping mode           = 0 (base band)
xros_engine:  << Fringe phase calc mode (modefr) = 9 (9 level approx)
xros_engine:  << Fringe phase calc step (frstep) = 8 sample(s)
xros_engine:  << Pcal detection mode X station   = 1
xros_engine:  << Pcal detection mode Y station   = 1
xros_engine:  << # of channels to be processed   = 16
xros_engine:  << X data file format             =  Mark-5B   32MHz 1BIT 16CH   <==
                                                           data format information
xros_engine:  << Y data file format             =  Mark-5B   32MHz 1BIT 16CH
xros_engine:  << Channel Assignment =  (1 - 1) (2 - 2) (3 - 3) (4 - 4)
xros_engine:                           (5 - 5) (6 - 6) (7 - 7) (8 - 8)
xros_engine:                           (9 - 9) (10 - 10) (11 - 11) (12 - 12)
xros_engine:                           (13 - 13) (14 - 14) (15 - 15) (16 - 16)
xros_engine:  << Channel Picked Up  =  (1 - 1) (2 - 2) (3 - 3) (4 - 4)
xros_engine:                           (5 - 5) (6 - 6) (7 - 7) (8 - 8)
xros_engine:                           (9 - 9) (10 - 10) (11 - 11) (12 - 12)
xros_engine:                           (13 - 13) (14 - 14) (15 - 15) (16 - 16)
xros_engine:  << Temprary file for header  : ./qRYFBChd.tmp
xros_engine:  << Temprary file for PP data : ./q2WioCpp.tmp
xros_engine:  << FFT is carried out using FFTW3.0 package
xros_engine:  chdif_flag =   0
xros_engine:  Atamadashi finished!
xros_engine:   temporary info out file (./qRYFBChd.tmp) Opened!
xros_engine:   temporary corr out file (./q2WioCpp.tmp) Opened!
xros_engine: Start X data time : 75559.000000
xros_engine: Start Y data time : 75559.000000
xros_engine: PP# 1 data saved

   ...........

xros_engine: PP# 7 data saved
xros_engine:   Time elapsed for 1PP processing is 45.787053 sec
xros_engine:   X data time (BOPP) : 75565.000000
xros_engine:   processed data (7.0/30.0)
m5b_sync_detect: File EOF! (./R220205919.m5b)
xros_engine: Time-elapsed per PP (sec)  MIN=45.747727  MAX=45.791488
Postscript out file ==> pgplot.ps

  ==============================================================
     CH#    FREQ(MHz)      MAX AMP       RESIDUAL DELAY (sec)
  --------------------------------------------------------------
      1      7700.99      0.000834          -4.24985e-11
      2      7710.99      0.000935           1.00162e-09
      3      7720.99      0.000748           3.14188e-09
      4      7850.99      0.000892           1.04695e-09
      5      8090.99      0.000854           4.31266e-09
      6      8290.99      0.000832           1.02798e-08
      7      8490.99      0.000883           7.45903e-09
      8      8550.99      0.000833           1.06133e-08
      9      8570.99      0.000830           1.49527e-08
     10      8580.99      0.000757           1.01071e-08
     11      2210.99      0.001171           1.84406e-08
     12      2220.99      0.001119           1.64464e-08
     13      2240.99      0.001125            1.6231e-08
     14      2290.99      0.001223           2.18096e-08
     15      2330.99      0.001218           1.84975e-08
     16      2340.99      0.001376           1.57303e-08
  ==============================================================

COUT File is ../cout/cout0005.txt
Time elapsed (sec) for One obs process is 333.220641
$
```

Fig.4.2 is displayed after processing.

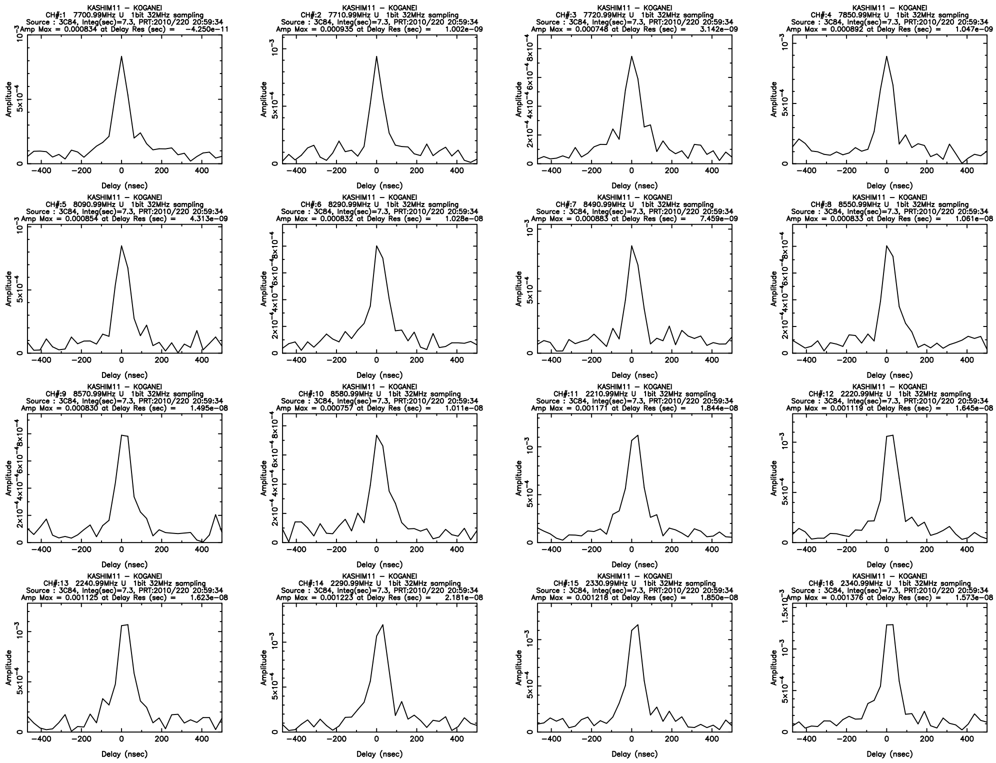

Figure 4.2. Plot of correlation function after "fx_cor_new" processing.

4.2 fx_cor_all, fx_cor_all_new, cor_all, cor_all_new

"fx_cor_all" is "fx_cor" for two or more scan data using a list file that contains a number of a-priori file names. "fx_cor_all_new" is "fx_cor_new" for two or more scan data. So do "cor_all" and "cor_all_new".

An example of how to create a list file is as follows.

An example:

At the directory where a-priori files are located, issue

```
ls -1 ape*.txt > apelist294OU.txt
```

4.2.1 How to execute

"fx_cor_all" can be "fx_cor_all_new" or "cor_all_new" in bellow.

fx_cor_all *pfile* [*options*]

where	*pfile*	–	list file name
	options (any order)		
	-integ *integration_time*		
		–	total integration period (sec) dfault is scan length described in a schedule file in case of negative value, absolute value means integration exceeding scheduled scan length.
	-coffset *clock_offset*	–	set clock offset (sec) Positive value menas Y clock tic earlier than X clock tic. Default is 0.0
	-crate *clock_rate*	–	set clock rate (s/s) difference between X and Y station clock. Default is 0.0.
	-soffset *start_offset*	–	set start time offset (integer second) デフォルトは 0
	-t1pp *t1pp*	–	PP (parameter period) (sec) for correlation processing. Default is BT1PP in "cor_head.h" (usually 1.0)
	-pp_nosync	–	turns off the synchronization mode of PP (parameter period) (default is that PP synchronize to second tic)
	-lag *delsize*	–	set the size of delay lag window by a power of 2, e.g., 16, 32, 64, 128, 256, 512, 1024, 2048, ... Default is DELAYSIZE in "cor_head.h" (usually 32)
	-pmode *pmode*	–	set plot device mode 0: XWINDOW (env PGDISP can change PGPLOT display device) and PostScript file (pgplot.ps or gnuplot.ps) out (dfault) 1: PostScript file (pgplot.ps or gnuplot.ps) out only 2: XWINDOW only -1: no graphic output
	-comment "*any comment*"		
		–	set comment appeared in a correlation function plot
	-nopcal	–	suppress PCAL (phase calibration) signal detection
	-ch1 *ch1Y*	–	define Y channel for X CH# 1 (default 1)
	-ch2 *ch2Y*	–	define Y channel for X CH# 2 (default 2)
	-ch3 *ch3Y*	–	define Y channel for X CH# 3 (default 3)
	-ch4 *ch4Y*	–	define Y channel for X CH# 4 (default 4)
	Note: in case of "fx_cor_new" and "cor_new", options upto '-ch16 *ch16Y*' are available		
	-orule *naming_rule*		
		–	set naming rule of output file name 0 : use program default ("cout.txt" for "fx_cor" and "fx_cor_new", "coutt.txt" for "cor" and "cor_new") 1 : coutNNNN.txt for "fx_cor" and "fx_cor_new" couttNNNN.txt for "cor" and "cor_new" (default)

where NNNN : serial number (4 digits)

2 : coutEXP_CODE/coutYYDDDNNNNXYG.txt for "fx_cor" and "fx_cor_new"
couttEXP_CODE/coutYYDDDNNNNXYG.txt for "cor" and "cor_new"

where	EXP_CODE	–	experiment code
	YY	–	year (2 digits)
	DDD	–	total day (3 digits)
	NNNN	–	scan# (4 digits)
	XY	–	baseline ID (2 or 4 letters)
	G	–	frequency group (a|b|c|d) or null

3 : coutYYDDDNNNNXYG.txt for "fx_cor" and "fx_cor_new"
couttYYDDDNNNNXYG.txt for "cor" and "cor_new"

where	YY	–	year (2 digits)
	DDD	–	total day (3 digits)
	NNNN	–	scan# (4 digits)
	XY	–	baseline ID (2 or 4 letters)
	G	–	frequency group (a|b|c|d) or null

-odir *outdir* – set output file directory.
System default is environmental variable K5COUT. If K5COUT is not defined, program default defined by COUTDFLT in "cor_head.h" is used (usually "../cout")

-frstep *frstep* – set fringe phase calculation step in samples

0	–	automatic calculation
1	–	every 1 sample
8	–	every 8 samples (default)
N	–	every N samples (1000/N should be integer) default is FRSTEP_FX_COR (in "cor_head.h")

-frauto – set *frstep*=0 (automatic calculation mode)

-rfoffset *rf_offset* – set RF frequency difference between Y and X (RFy-RFx)(Hz)

=== belows are options for "fx_cor_all" and "fx_cor_new_all" ===

-modefr *modefr* – set fringe stopping approximation mode

0	–	no approximation (exact calculation)
9	–	9 level approximation (default)
2	–	2 level approximation
3	–	3 level approximation

-hanning – use Hanning lag window

-hamming – use Hamming lag window

4.3 sdelay

"sdelay" carries out coarse search of residual delay and delay rate from correlation data.

4.3.1 How to execute

Type 1: help

sdelay HELP|

Type 2: interactive operation

sdelay [PP] [*options*]

where PP – to make each PP output. See Type 4 for *options*.

Type 3: non-interactive operation

sdelay *coutfile* [PP] [*options*]
where *coutfile* – K5 software correlator output file. See Type 4 for *options*.

Type 4: general operation

sdelay [*options*]

where *options* (any order)

-v	–	verbose
-cout *coufile*	–	set correlator output file (cout file) name
-sdir *coutdir*	–	set search start cout file directory to read
-cdir *coutdir*	–	set cout file directory to process all The differnce between -sdir and cdir is as follows, -sdir : set search start directory -cdir : set cout directory to process all files
-ppout	–	make output file of each PP data by every channel besides normal sdelay out file.
-nosingle	–	force output to multiple files (default: all results are output in a single file)
-odir *outdir*	–	sdelay output directory
-pgplot *device*	–	set PGPLOT device (/NULL for suppression)
-ps	–	set graphics out to PostScript (pgplot.ps or gnuplot.ps)
-2nd [*t2dot*]	–	search up to 2nd order rate and set search range from $-t2dot$ to $+t2dot$ (default for *t2dot* is 1^{-13}s/s^2)
-fringe	–	plot fringe phase and amplitude
-pcal	–	plot PCAL phase and amplitude
-vspeplot	–	plot video cross spectrum and output spectrum data to "vspe-out.txt" file
-no3d	–	suppress plot of coarse search function
-noplot	–	suppress all graphics plots
-integ *tinteg*	–	force integration time to *tinteg* sec. (default is all available period)
-vanvleck	–	make Van Vleck correction using $r = \sin(r_c * \pi/2)$ where r is true correlation coefficient, and r_c is coefficient for 1-bit samplig data. This option will be neglected in case of multi-bit AD data.
-out *ofile*	–	output 2D array data to a text file besides normal sdelay out
-classic	–	classic axis style (no tic marks) for 3D plots
-tzoom *tzoom*	–	delay axis zoom-up factor ($tzoom \geq 1.0$)
-tshift *tshift*	–	delay axis shift value when *tzoom* is set (sec) (set new center value for delay axis).

-bpf $flow$:$fhigh$[:$fact$][,$flow$:$fhigh$[:$fact$][,$flow$:$fhigh$[:$fact$][,.....]]]
– set BPF by lower and higher cut-off frequencies (upto 20 sets)
- *flow* – lower cut-off frequency in a baseband (MHz)
- *fhigh* – higher cut-off frequency in a baseband (MHz)
- *fact* – amplitude factor (0.0–1.0), default is 1.0

-bpf2 fc:bw[:$fact$][,fc:[bw][:$fact$][,fc:[bw]:$fact$][,.....]]]
– set BPF parameters by center frequency and bandwidth (upto 20 sets)
- *fc* – center frequency in a baseband (MHz)
- *bw* – pass bandwidth (MHz). It can be omitted for 2nd and later BPF if it is the same bandwidth with the 1st one.
- *fact* – amplitude factor (0.0–1.0), default is 1.0

-fres *fres*	–	set frequency resolution (MHz) (deflt is automatic)
-line[mode]	–	set line spectrum mode. 1st FFT size is set as same as lag size
-hanning	–	apply Hanning filter on correlation function
-lag[size] *lag*	–	set new lag size to reduce lag size (should be a power of 2). Note: This option cannot be used with '-hanning' and/or '-vanvleck' options
-sub[panels] 1|4|9|16	–	set # of subpanels in a main panel compulsory (default is automatic) (Note: only PGPLOT support this parameter)
-nodel[ay_correction]	–	no delay correction in integrated video spectrum
-obs[out]	–	display observed results and total fringe phase (default is no display)

4.3.2 Example

```
$ sdelay

SDELAY Ver. 2016-08-12
  # of cout files found under ..\cout\ ----------- 107
  # of cout directories found under ..\cout\  ---- 51
     1 ---  Go to File selection
     2 ---  Go to further directory selection
   Enter your selection --> 2          <==== select 2
  Software correlator out directories are as follows
    1 cout
    2 cout02155OR
    3 cout02155ORold
    4 cout02155OU
    5 cout02155OU2
    6 cout02155OUold
    .......
    33 coutCs7200
    34 coutD03C1
    35 coutGIFU
    36 coutGSI
    37 coutJD0306
    38 coutJD0609
    ........
    48 cout_tid06202GY
    49 cout_tid06202GY_8sec
    50 cout_tid06202OG
    51 cout_tid06202OY
  Select directory --> 36         <===== select 36
  Selected directory is  ..\cout\coutGSI\
  Soft correlator out files are as follows
    1 coutt040970001ACa.txt
    2 coutt040970001ACb.txt
    3 coutt040970001ACc.txt
    4 coutt040970001ACd.txt
    5 coutt040970001TAa.txt
    6 coutt040970001TAb.txt
    ............
    28 coutt042420001TVd.txt
    29 coutt042420002TVa.txt
    30 coutt042420002TVb.txt
    31 coutt042420002TVc.txt
    32 coutt042420002TVd.txt
  Select File (0 means all) --> 5     <====== select 5
```

```
  coutt040970001TAa.txt is selected!
sdelay: output file is .\sdelayout.txt
sdelay: correlation data file is ..\cout\coutGSI\coutt040970001TAa.txt
fx_cor_out_hd_read: Data File format 7

 ******************* SDELAY (Ver. 2016-08-12) SUMMARY OUT PUT ************
   COUT     : ..\cout\coutGSI\coutt040970001TAa.txt
   X DATA   : /vncpc1/ad2/JD0404/T097020000a.dat
   Y DATA   : /vncpc1/ad4/JD0404/A097020000a.dat
   BASELINE : TSUKUB32 - AIRA
   SOURCE   :    3C454.3          SAMPLING  : 1 bit   8 MHz
   PRT      : 2004/097 02:00:50    Tinteg(s) : 99.0
   LAG SIZE : 32
   CLOCK    : offset  -1.085e-006(s)   rate  -4.542e-014(s/s)
   EOP      : ut1-utc -0.439965(s)
            : x-wobb  -0.140730(asec)
            : y-wobb  0.333260(asec)
  =========================================================================
   CH#  FREQUENCY       AMP MAX     POSITION          RESIDUAL
          (MHz)                  (  64x 128)  Delay(usec) Rate(ps/s)  SNR
  -------------------------------------------------------------------------
     1    8209.99 U   2.757e-003  (  33,  65)      0.000     0.016    77.6
     2    8219.99 U   2.822e-003  (  33,  65)     -0.012     0.019    79.4
     3    8249.99 U   2.732e-003  (  33,  65)     -0.013    -0.038    76.9
     4    8309.99 U   2.627e-003  (  33,  65)      0.014     0.028    73.9
  -------------------------------------------------------------------------
   Note: No amplitude correction is made.
  =========================================================================

  ====================== PCAL SUMMARY ===========================
   CH#   PCAL FREQ(kHz)     X-Amp  X-Phase    Y-Amp  Y-Phase
  ----------------------------------------------------------------
    1         10.00         0.027   132.8     0.062    45.5
    2         10.00         0.028    89.4     0.061    -4.1
    3         10.00         0.028   -45.4     0.061  -115.5
    4         10.00         0.028   161.1     0.060   155.1
 **************************************************************************

Outfile is .\sdelayout.txt
```

A coarse search function shown in Fig.4.3 will be displayed. Figs.4.4, 4.5, and 4.6 show PGPLOT graphics plots in case of options "-fringe" (phase and amplitude by PP), "-pcal" (PCAL phase and amplitude), and "-vspeplot" (video spectrum), respectively.

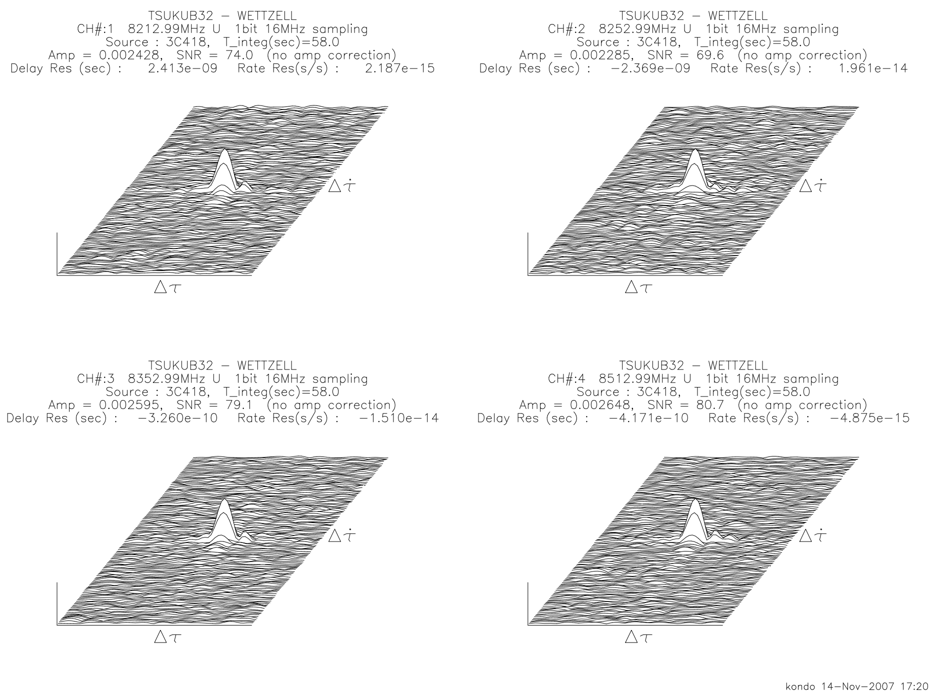

Figure 4.3. An example of graphics plots (coarse search function).

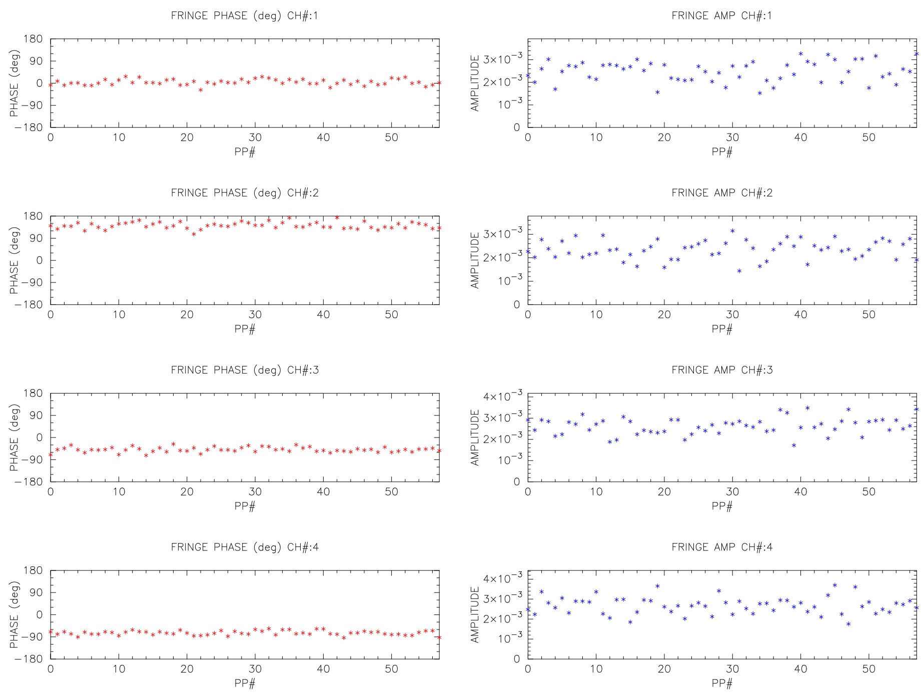

Figure 4.4. An example of sdelay graphics in case of "-fringe" option (fringe phase and amplitude by PP).

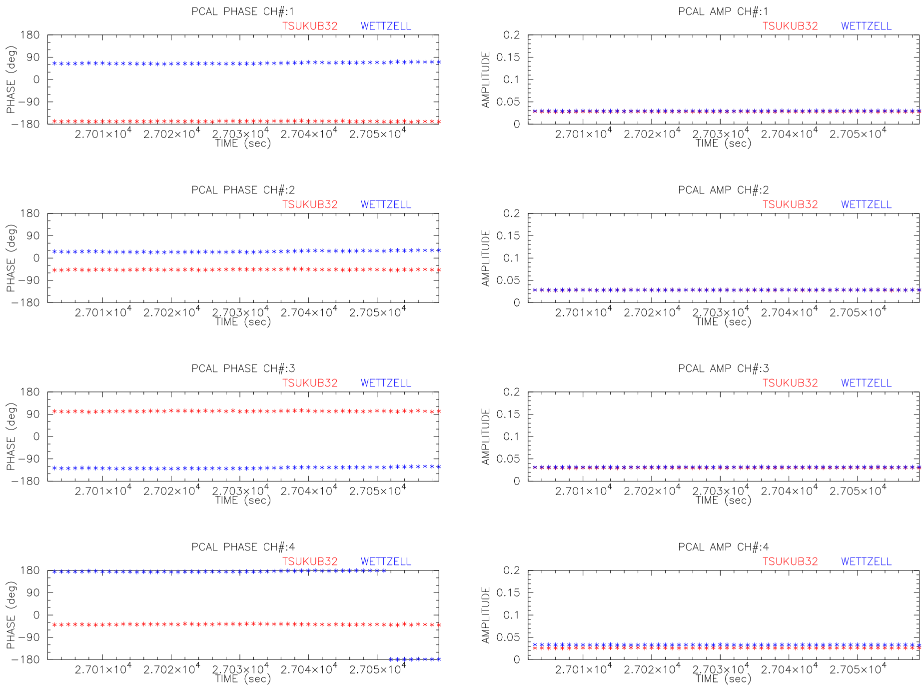

Figure 4.5. An example of sdelay graphics in case of "-pcal" option (PCAL phase and amplitude by PP).

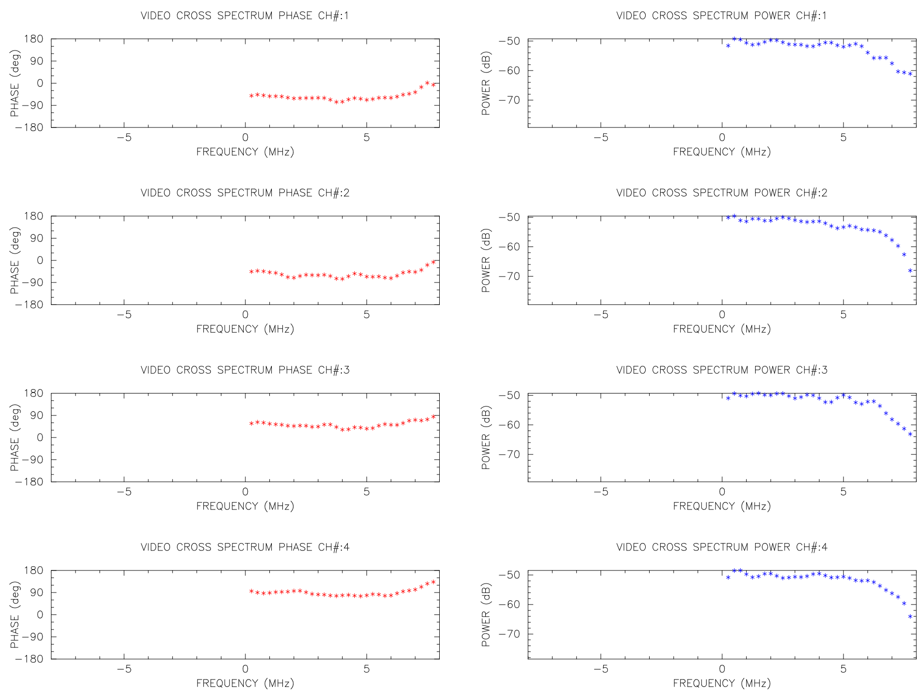

Figure 4.6. An example of sdelay graphics in case of "-vspeplot" option (video spectrum).

An example of text file (vspeout.txt9 output in case of "-vspeplot" option.

```
$FORMAT Ver. 2016-12-19
$OBS
```

```
$BASELINE    HITACHI YAMAGU32
$PRT         2016 300 2 32 30
$PRT (sec in day) 9150.000000
$SOURCE      NRAO512C
$SAMPLING(Hz) 1.6e+07
$VIDEO_BW(Hz) 8e+06
$A/D(bits)    2
$NUMBER of PP 300
$SEKIBUN(s)   300.000000
$APRIORI (TAU(s),TAU1dot(s/s),TAU2dot,TAU3dot)
0.00157071683582578 -1.36274927453641e-07 -5.78903382882255e-12 7.24618531073368e-16
$CLOCK (offset(s),rate(s/s))
3.75e-06 0
$FLAG_DELAY_CORRECTION 1
$RESULTS BY CHANNEL
$CHANNEL# 1
$RESULTS  freq(MHz), amp, residual_delay(s), err, residual_rate(s/s), err, res_t2dot(s/s^2)
6664.000000 0.00120704 3.07581e-08 8.24096e-10 4.30251e-12 3.2977e-15 0
$VIDEO SPECTRUM INTEGRATED COHERENTLY
$ video freq(Hz)    real-part      imag-part        amp      phase(deg)
    -8.000e+06     0.000e+00      0.000e+00      0.000e+00       0.000
    -7.750e+06     0.000e+00      0.000e+00      0.000e+00       0.000
    -7.500e+06     0.000e+00      0.000e+00      0.000e+00       0.000
     ............
    -5.000e+05     0.000e+00      0.000e+00      0.000e+00       0.000
    -2.500e+05     0.000e+00      0.000e+00      0.000e+00       0.000
     0.000e+00     0.000e+00      0.000e+00      0.000e+00       0.000
     2.500e+05    -1.557e-04      5.830e-04      6.034e-04     104.950
     5.000e+05    -1.930e-04      1.234e-03      1.249e-03      98.886
     ............
     7.250e+06     2.905e-04      6.031e-04      6.694e-04      64.285
     7.500e+06     1.522e-04      4.461e-04      4.714e-04      71.156
     7.750e+06     1.468e-05      2.098e-04      2.103e-04      85.997
```

Figs.4.7, 4.8, 4.9, and 4.10 examples of GNUPLOT graphics.

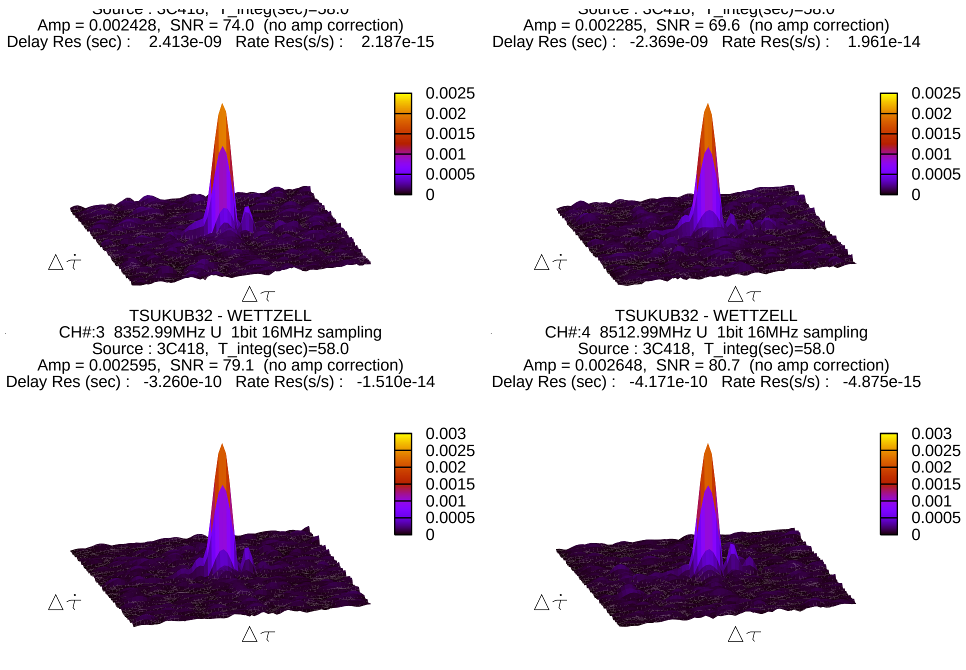

Figure 4.7. plot of coarse search function (GNUPLOT)

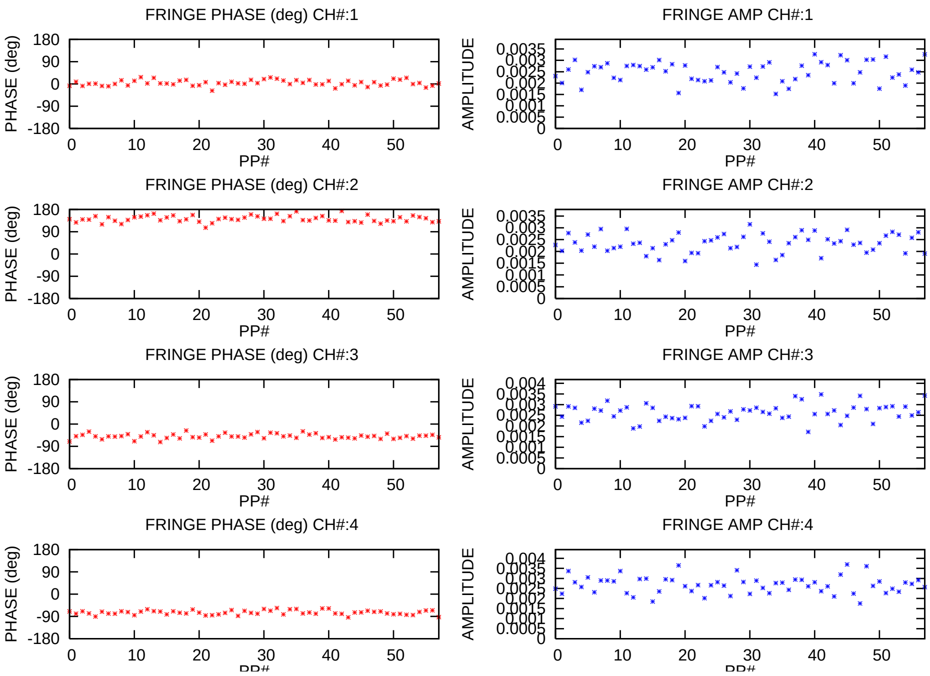

Figure 4.8. An example of sdelay graphics in case of "-fringe" option (fringe phase and amplitude by PP)(GNUPLOT)

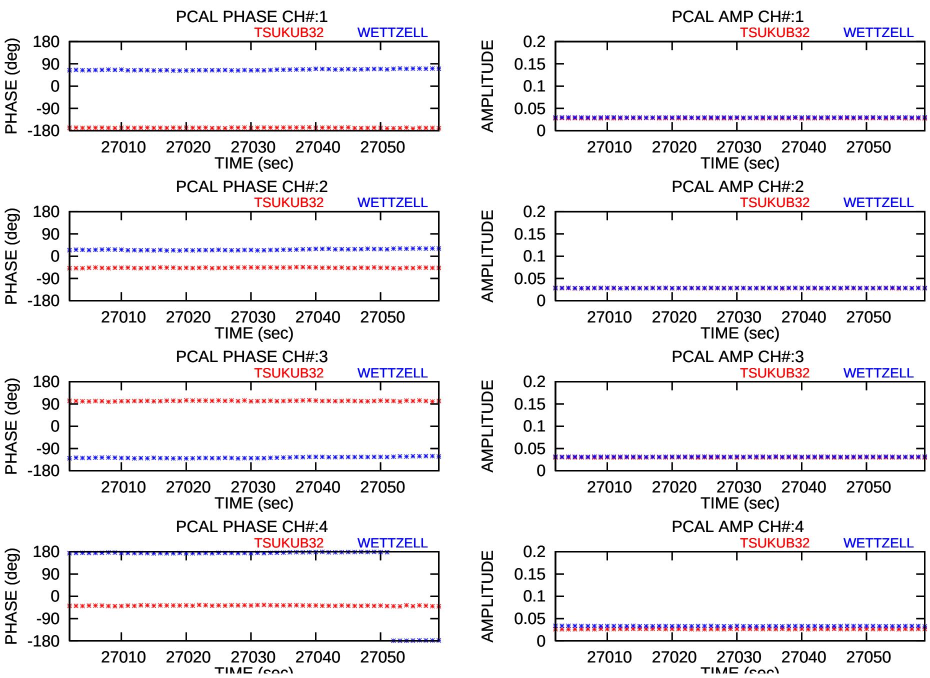

Figure 4.9. An example of sdelay graphics in case of "-pcal" option (PCAL phase and amplitude by PP)(GNUPLOT).

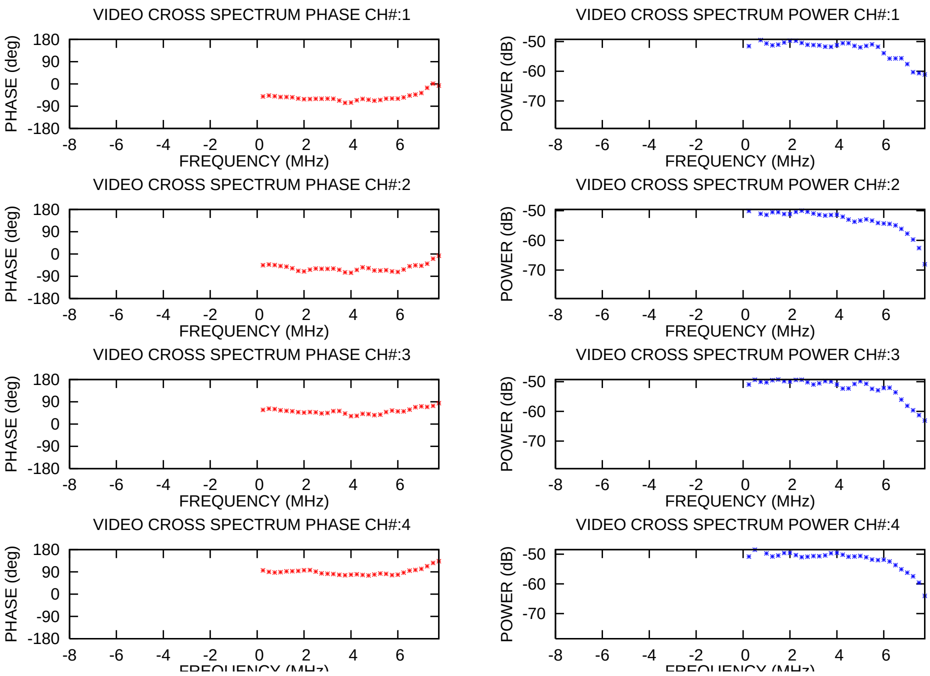

Figure 4.10. An example of sdelay graphics in case of "-vspeplot" option (video spectrum)(GNUPLOT).

4.3.3 Output file format

Default output file

file name — "sdelayout.txt" or the name 'cout' in correlator output file name substituted by 'sdel'.
Example: correlator output file name = coutt0205.txt ==> generated sdelay output file = sdelt0205.txt

Contents of file are as follows.

```
$OBS
$BASELINE    KASHIM11 TOMAKO11
$PRT         2003 197 2 41 10
$SOURCE      3C273B
$SAMPLING(Hz) 8e+06
$VIDEO_BW(Hz) 4e+06
$A/D(bits)   1
$NUMBER of PP 9
$SEKIBUN(s)  9.000000
$APRIORI (TAU(s) TAU1dot(s/s) TAU2dot TAU3dot)
   0.00015406231 1.1536424e-07 -1.1696165e-12 -6.1314267e-16
$CLOCK (offset(s),rate(s/s))
   2.485e-06 0
$RESULTS  Freq(MHz)  AMP  Res_Delay(s)  Err  Res_Rate(s/s)  Err  Res_2dot(s/s^2) Res_Phase(deg)
   8209.99 0.00185916 1.96904e-09 8.73712e-09 4.40734e-13 4.7298e-13 0      65.52
   8219.99 0.00139373 -1.03363e-08 1.16548e-08 3.30101e-12 6.3016e-13 0      96.38
   8249.99 0.00169796 1.62224e-08 9.56661e-09 5.54919e-13 5.15374e-13 0     114.36
   8309.99 0.00188501 -9.87243e-09 8.6173e-09 5.99579e-13 4.6088e-13 0    -114.79
$OBSERVED Freq(MHz)  Observed_Delay(s)  Observed_Rate(s/s)  Total_Phase(deg)
   8209.99  0.000154064279043935  1.15364680734089e-07     134.03
   8219.99  0.000154051973685111  1.15367541008296e-07     342.32
   8249.99  0.00015407853240548  1.15364794919007e-07     240.92
   8309.99  0.00015405243756551  1.15364839579305e-07     322.84
```

Output file by PP

file name — 'cout' in correlator output file name is substituted by 'sdel' + '.CH1'∼'.CH4'.
Example: correlator output = coutt0205.txt ==> generated sdelay output = sdelt0205.txt.CH1, ..., sdelt0205.txt.CH4

Contents of file are as follows.

```
$FORMAT Ver. 2017-02-24
$OBS
$BASELINE    KASHIM11 TOMAKO11
$PRT         2003 197 2 41 10
$PRT (sec in day) 9670.000000
$SOURCE      3C273B
$SAMPLING(Hz) 8e+06
$VIDEO_BW(Hz) 4e+06
$A/D(bits)   1
$NUMBER of PP 9
$SEKIBUN(s)  9.000000
$APRIORI (TAU(s),TAU1dot(s/s),TAU2dot,TAU3dot)
0.00015406231 1.1536424e-07 -1.1696165e-12 -6.1314267e-16
$CLOCK (offset(s),rate(s/s))
2.485e-06 0
$RESULTS  freq(MHz), amp, residual_delay(s), err, residual_rate(s/s), err, res_t
2dot(s/s^2)
8209.990000 0.00185916 1.96904e-09 8.73712e-09 4.40734e-13 4.7298e-13 0
$Obtained Tau0,Tau1,Tau2,Tau3
0.000154064279043935 1.153646807e-07 -1.1696165e-12 -6.1314267e-16
$AVERAGED X-PCAL AMP and PHASE(deg), Y-PCAL AMP and PHASE(deg)
   0.0688    70.362   0.1595   111.713
$Total PP number and PP period in sec  9 1.000000
$REFERENCE FREQUENCY(MHz)  8209.990000
$ EACH PP DATA
$ Date      MOPP_Time         tau(sec)           amp       phs(deg)  xpamp  xpphs(deg)
 ypamp  ypphs(deg)
2003/07/16 02:41:05.50    1.5354512615e-04   0.0013034785    85.446  0.0682    71.240
 0.1594   111.211
2003/07/16 02:41:06.50    1.5366049550e-04   0.0014538306    88.053  0.0692    73.339
 0.1600   111.025
2003/07/16 02:41:07.50    1.5377586369e-04   0.0020580706    50.928  0.0678    71.786
 0.1590   114.300

--- continue upto # of PPs
```

Output of 2D array data
file name — name specified by '-out *ofile*' option

Contents of file are as follows.

```
TSUKUB32 - WETTZELL
CH#:1  2344.99MHz U  1bit 16MHz sampling
Source : 4C39.25,  T integ(sec)=54.0
Amp = 0.004531,  SNR = 133.2  (no amp correction)
Delay Res (sec) :  -2.631e-008   Rate Res(s/s) :   8.603e-013
**** 2D DATA START ****
128 64       <== array size   line (rate direction) X column (delay direction)
6.12758e-005 4.88404e-005 6.13282e-005  ...   <== line#1 64 point data
5.81745e-005 6.01026e-005 5.68238e-005  ...   <== line#2 64 point data
 ....
3.73513e-005 9.13274e-006 4.24058e-005  ...   <== line#128 64 point data
**** 2D DATA END ****

TSUKUB32 - WETTZELL
CH#:2  2352.99MHz U  1bit 16MHz sampling
Source : 4C39.25,  T integ(sec)=54.0
Amp = 0.004311,  SNR = 126.7  (no amp correction)
Delay Res (sec) :  -2.184e-008   Rate Res(s/s) :   1.112e-012
**** 2D DATA START ****
128 64
.....     <== start of CH\#2 data
.....
```

4.4 cor_mon

"cor_mon" displays correlation function dynamically
(Note: only PGPLOT is supported.)

4.4.1 How to execute

cor_mon *file_name* [*options*]

where	*file_name*	–	correlator output file name (either cout format or KSP format)
	-z[oom] *zoom*	–	zooming factor in delay direction
	-a[max] *ampmax*	–	set maximum amplitude (default is 0.001)
	-d[range] *t1 t2*	–	set delay range from *t1* to *t2* (sec) if this option is set, "-z" option is neglected
	-h[alt]	–	stop display by PP (default is continuous display)
	-s[msec] *sleep_msec*	–	suspend time (msec) between plots in case of continuous display (default is 200 msec)
	-ch *ch#1*[,*ch#2*[,*ch#3*[,*ch#4*[,....]]]	–	set display channel (example: -ch 1, 4, 3) (default is all channels)

4.4.2 Example

Fig.4.11 shows an example of 16 channel correlation functions.

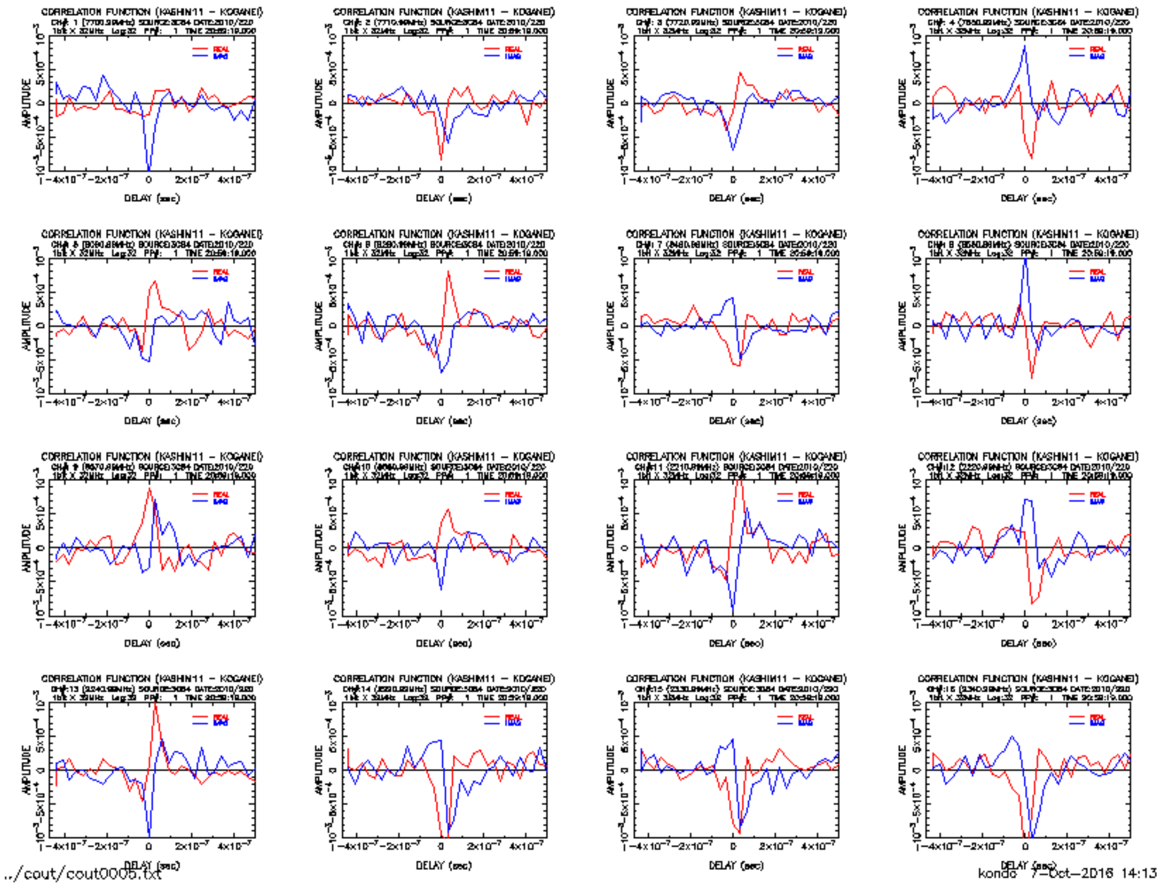

Figure 4.11. An example of correlation function displayed by "cor_mon". Red lines shows a real part and blue lines an imaginary part.

5 Data check utilities

5.1 oscillo

"oscillo" displays time series of sampling data dynamically (dedicated to K5/VSSP format and PGPLOT)

5.1.1 How to execute

oscillo *file_name* [*options*]

where	*file_name*	–	sampling data file name with K5/VSSP format
	-t[span] *tspan*	–	time axis span (sec)
	-h[alt]	–	stop display by a sweep (default is continuous display)
	-s[msec] *sleep_msec*	–	suspend time (msec) between plots in case of continuous display (default is 0)

5.1.2 Example

Fig.5.1 shows an example of display in case of 64MHz×2bit×4ch sampling data.

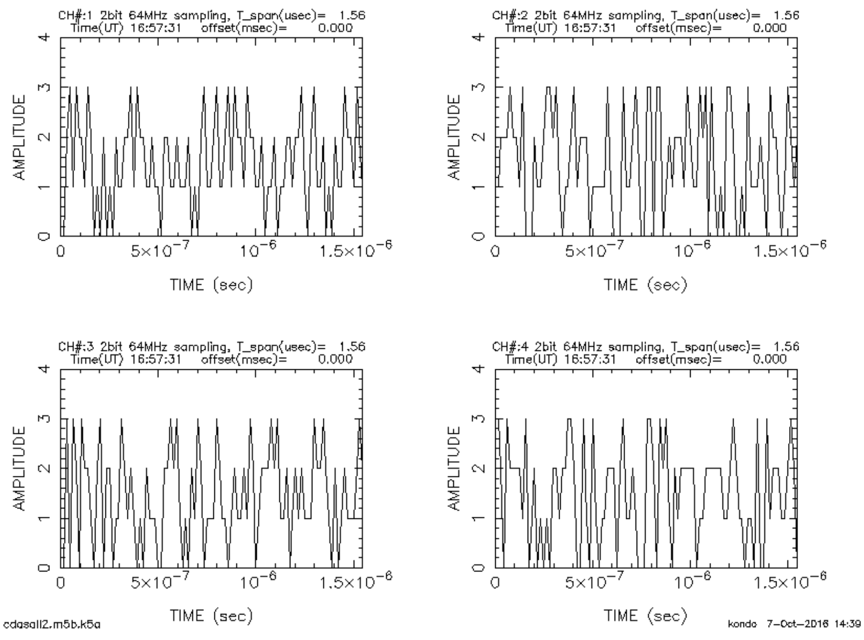

Figure 5.1. Time series plots displayed by "oscillo" for 64MHz×2bit×4ch sampling data.

5.2 speana

"speana" displays spectrum of sampling data (dedicated to K5/VSSP format)

5.2.1 How to execute

speana *data_file* [*options*]

where	*data_file*	–	sampling data file name with K5/VSSP format
	options (any order)		
	-m[ode] *mode*	–	axis mode *mode* : *YX* *X*: X (frequency) axis mode =0: log scale =1: linear sacale (default) *Y*: Y (amplitude) axis mode =0: log scale (default) =1: linear scale (common for all channels) =2: linear scale (independent for channels) $-value$: auto-correlation plot centered at *value* -1: auto-correlation (full range)
	-pmode *pmode*	–	set plot device mode 0: XWINDOW and PostScript file (pgplot.ps or gnuplot.ps) (default) 1: PostScript file (pgplot.ps or gnuplot.ps) out only 2: XWINDOW only
	-se[kibun] *sekibun*	–	total integration period (sec)
	-ti[ntegration] *sekibun*	–	same as '-se' option
	-i[ntegration] *sekibun*	–	same as '-se' option
	-co[mment] *comment*	–	comment display in a plot
	-so[ffset] *soffset*	–	start time offset (default is 0.0)
	-to[ffset] *soffset*	–	same as '-so' option
	-o[ffset] *soffset*	–	same as '-so' option
	-f1[khz] *f1khz*	–	lower frequency of frequency axis (kHz) (default is 0.0)
	-f2[khz] *f2khz*	–	higher frequency of frequency axis (kHz) (default is a video frequency)
	-min[dbm] *mindbm*	–	minimum value of amplitude axis (dBm) (default is automatic)
	-max[dbm] *maxdbm*	–	maximum value of amplitude axis (dBm) (default is automatic)
	-nops	–	suppress Postscript file out (same as "-p 2")

5.2.2 Example

Fig.5.2 shows an example of spectrum displayed by "speana" for 64MHz×2bit×4ch sampling data.

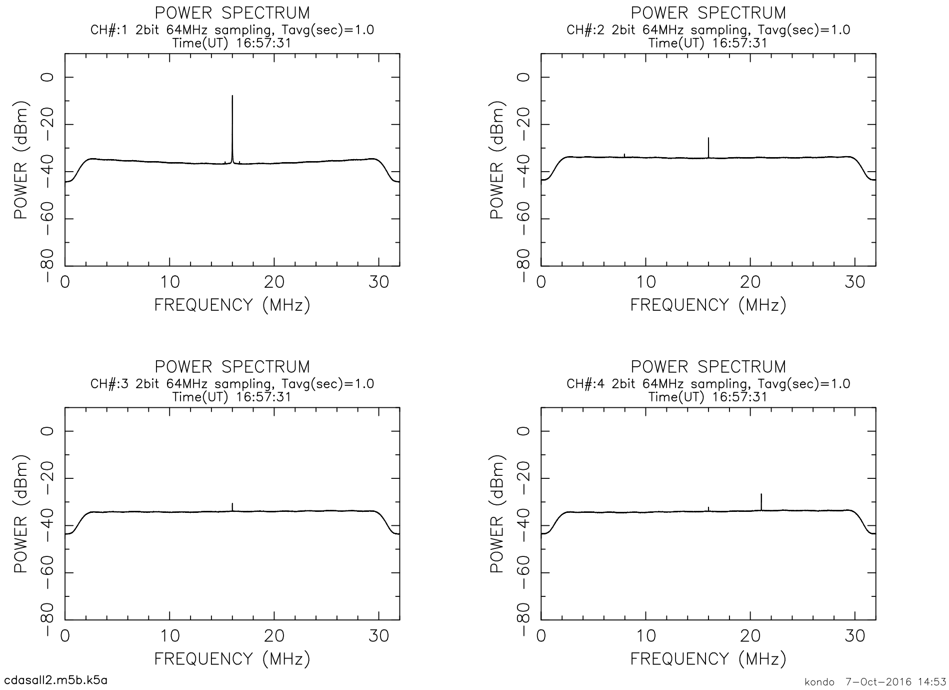

Figure 5.2. An example of spectrum plot displayed by "speana" for 64MHz×2bit×4ch sampling data

5.3 g_speana

"g_speana" displays spectrum of sampling data with a variety of data formats, such as, Mark-5B, VDIF, ADS, OCTAD besides K5/VSSP.

5.3.1 How to execute

g_speana *data_file* [*options*]

ここで	*data_file*	–	sampling data file name with a variety of data formats (Mark-5B, VDIF, ADS, OCTAD, K5/VSSP)
	options (any order)		
	-m[ode] *mode*	–	axis mode *mode* : *YX* *X*: X (frequency) axis mode =0: log scale =1: linear sacale (default) *Y*: Y (amplitude) axis mode =0: log scale (default) =1: linear scale (common for all channels) =2: linear scale (independent for channels) −*value*: auto-correlation plot centered at *value* −1: auto-correlation (full range)
	-pmode *pmode*	–	set plot device mode 0: XWINDOW and PostScript file (pgplot.ps or gnuplot.ps) (default) 1: PostScript file (pgplot.ps or gnuplot.ps) out only 2: XWINDOW only
	-se[kibun] *sekibun*	–	total integration period (sec)
	-ti[ntegration] *sekibun*	–	same as '-se' option
	-i[ntegration] *sekibun*	–	same as '-se' option
	-co[mment] *comment*	–	comment display in a plot

-so[ffset] *soffset*	–	start time offset (default is 0.0)
-to[ffset] *soffset*	–	same as '-so' option
-o[ffset] *soffset*	–	same as '-so' option
-f1[khz] *f1khz*	–	lower frequency of frequency axis (kHz) (default is 0.0)
-f2[khz] *f2khz*	–	higher frequency of frequency axis (kHz) (default is a video frequency)
-min[dbm] *mindbm*	–	minimum value of amplitude axis (dBm) (default is automatic)
-max[dbm] *maxdbm*	–	maximum value of amplitude axis (dBm) (default is automatic)
-nops	–	suppress Postscript file out (same as "-p 2")
-1ch *ch#*	–	set 1 channel plot mode and set channel#
-4ch *ch#1 ch#2 ch#3 ch#4*	–	set 4 channel plot mode and set channel numbers
-ch *ch#1 ch#2*	–	pick up any channels and plot them
-m5b | -vdif | -ads | -oct	–	set sampling data format (deault is K5/VSSP suppoting VSSP32 and VSSP64)
== following is in case of ADS format or M5B format==		
-numch *numch*	–	set # of channels
-adbit *adbit*	–	set AD resolution (bits)
-sf[req] *sfMHz*	–	set sampling frequency (MHz)
-st[ime] *YYYYDDDHHMMSS* | *YYYY/DDD-HH:MM:SS*	–	set start date and time of data in case of ADS format (default value is got from ADS file name)

5.3.2 Example

An example of spectrum of sampling data display with Mark5B format.

```
$ g_speana cdasall2.m5b -m5b    <== use '-m5b' to specify Mark5B format data.
                                    use '-vdif' for VDIF format data.
g_speana Ver. 2016-06-17 compliled with FFTW3.0
 compliled for PGPLOT

Data File is cdasall2.m5b
File cdasall2.m5b opened (638349270 bytes)
Time(UT) MJD 226 16:57:31
  fname   : cdasall2.m5b
  data file start time     : Time(UT) MJD 226 16:57:31
  data pick-up start time  : Time(UT) MJD 226 16:57:31
  sfkHz   : 64000
  adbit   : 2
  numch   : 16
  plot numch  : 16
  plot ch#    : 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
  sekibun : 1.000000
  soffset : 0.000000
CH# 1: Maximum data (dB, dBm) is -16.716162 -7.716162
CH# 2: Maximum data (dB, dBm) is -34.588219 -25.588217
CH# 3: Maximum data (dB, dBm) is -39.548599 -30.548597
CH# 4: Maximum data (dB, dBm) is -35.545822 -26.545824
CH# 5: Maximum data (dB, dBm) is -41.150509 -32.150509
CH# 6: Maximum data (dB, dBm) is -41.239742 -32.239742
CH# 7: Maximum data (dB, dBm) is -42.367371 -33.367371
CH# 8: Maximum data (dB, dBm) is -36.048561 -27.048559
CH# 9: Maximum data (dB, dBm) is -36.417774 -27.417774
CH# 10: Maximum data (dB, dBm) is -41.161625 -32.161625
CH# 11: Maximum data (dB, dBm) is -42.641129 -33.641129
CH# 12: Maximum data (dB, dBm) is -36.593994 -27.593994
CH# 13: Maximum data (dB, dBm) is -40.218788 -31.218788
CH# 14: Maximum data (dB, dBm) is -36.009422 -27.009422
CH# 15: Maximum data (dB, dBm) is -42.393009 -33.393009
CH# 16: Maximum data (dB, dBm) is -37.771706 -28.771704
All CH: Maximum and Minimum data (dBm) are -7.716162 -49.829594
Time elapsed for processing is 50.265196 sec
Created PostScript file ==> pgplot.ps
 Type <RETURN> for next page:     <== at 1st spectra of 4 channels are displayed,
                                      then next 4 channels are displayed after
                                       hit a return key.
$
```

Fig.5.3 shows an example of spectrum displayed by "g_speana" for Mark5B format data (last 4 channels).

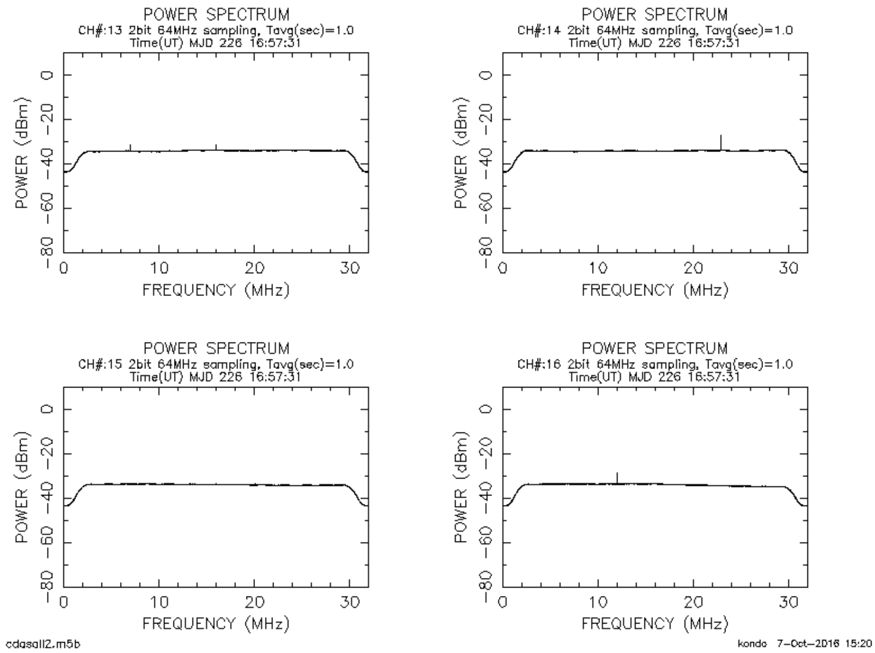

Figure 5.3. An example of spectrum displayed by g_speana for Mark5B format data (last 4 channels).

5.4 datachk

"datachk" checks K5/VSSP or K5/VSSP32 format data and outputs results to log files. Data are checked as follows. Bit-slip or bit-make is checked byy counting the number of bits between adjacent headers of data. If bit-slip or bit-make is ocuured, it is recorded in a log file. "datachk" can also check the percentage of positive sign of analog signals and can monitor the ocuurence distribution of AD data by sampled value.

If AUX MISALIGN (misaligned AUX field) is found by this check, it can be recovered by using "aux_recov" program.

5.4.1 How to execute

datachk file_name [*mode* [*logfile* [*errlog* [*keepmode*]]]][*option*]

where *file_name* – sampling data file name with K5/VSSP format (default is "tds.data")

mode – statistics display mode
- 0 : no display (default)
  display first and last frame information and errored frames only
- 1 : display percentage of '+' sign data in analogue data
- 2 : same as mode=0, but display all frames
- 3 : display occurrence distribution by AD value by 1 second
- 4 : display occurrence distribution of AD value for all data

logfile – log file name for summary output in case of mode=0. file name starting with '-' means append mode open (default is no output)

errlog – log file name to contain errors detected in data file for mode=0. This file will not be created in case of no error (default is no output) file name starting with '-' means append mode open

keepmode	–	set the mode of keeping data file when error occurred in case of mode=0. 0 : nothing to do (default) 1 : rename to original_name+".NNNN.err" 2 : copy to original_name+".NNNN.err", where NNNN is 0001 to 9999. (this number is kept in "counter_file_datachk.tmp" under the current directory
option		
-s2	–	set # of channels to 2 compulsory in case of K5/VSSP64 format data.

5.4.2 Summary file

A summary file is generated when "datachk" is executed with *logfile* option. An exapmle is as follows.

```
# File Name:
D:\IPVLBI\data\test02.dat
# FMT  A/D CH  f(kHz)  LPF(MHz):
  VS32  1   1   32000       16
# Start and Last Time:
  2006/318 23:20:28  84028
  2006/318 23:25:27  84327
# Duration:
300
# Byte offset of 1st header:
0
# STATISTICS total bad discon discon_with_bitslip aux_sep EFLG:
300 1 0 0 147 0
# BIT SLIP:
1 26432
```

5.4.3 Error log file

An error log file is generated when "datachk" is executed with *errlog* option. An exapmle is as follows.

in case of *keepmode*=0

```
# Errored Data File Name:
test02.dat
# FMT  A/D CH  f(kHz)  LPF(MHz):
  VS32  1   1   32000       16
```

in case of *keepmode*=1 (rename mode)

```
# Errored Data File Name:
test02.dat
# FMT  A/D CH  f(kHz)  LPF(MHz):
  VS32  1   1   32000       16
# Renamed to:
test02.dat.0006.err
```

in case of *keepmode*=2 (copy mode)

```
# Errored Data File Name:
test02.dat
# FMT  A/D CH  f(kHz)  LPF(MHz):
  VS32  1   1   32000       16
# Copied to:
test02.dat.0007.err
```

5.5 vdifcheck

"vdifcheck" checks contents of VDIF format data.

5.5.1 How to execute

vdifcheck vdif_file [*options*]

where	*vdif_file*	–	VDIF format data file name to check
	options (any order)		
	-f[ormat] 0|1|2|3|99	–	set display format 0 : automatic according to VDIF format and edv# (default) 1 : legacy format 2 : same as mode=0, but edv# is not considered 3 : set edv# compulsory as that of KASHIMA 99 : for debug
	-d[mode] 0|1|2	–	set display mode 0 : display first and last frame only (default) 1 : display every frame 2 : display frame on the second besides first and last frames
	-n[frame] *nmax*	–	set # of frames to read
	-l[egacy]	–	set header length 16 bytes compulsory
	-s[kip] *n*	–	skip first *n* bytes data
	-k[ashima] [*bytesframe*]	–	set header format to Kashima format compulsory and set frame length *bytesframe*-bytes compulsory

5.5.2 Example

```
$ vdifcheck kas34_2014112035830.3sec.vdif
**********************************************************
*    VDIF data check                                     *
*      Ver 1.11  2014-06-12  by  T.KONDO/NICT            *
*                                                        *
**********************************************************

Data File : kas34_2014112035830.3sec.vdif
 1st header information is as follows

========================= VDIF HEADER INFORMATION =========================
 VDIF header (raw)        : 00928E66 1C000000 000000A4 00000000
    extended header (raw) : 01800800 ACABFEED 6873616B 00616D69

 Invalid flag = 0 :       Legacy flag = 0
 Sec from ref epoch = 9604710 :  Ref epoch = 28   (2014/04/22 03:58:30)
 Frame # = 0 :  VDIF Ver# = 0 : # Chs(log2) = 0
 Frame length in 8 byte unit = 164  (= 1312 bytes)
 Data type = 0 : #bits/sample-1 = 0 : Thread ID = 0
 Station ID (A2) =       ( = 0 in number)
 EDV : 1
 Exteded Data W1 W2 W3 W4 : 800800 ACABFEED 6873616B 00616D69
 --- in case of NICT Extended Format ---
  uflag = 1 :  srate = 2048 :  Sync block = ACABFEED
  DAS/station name (A8) : kashima
===========================================================================

 ===========================================================================
                                                   Sampling
 HH:MM:SS  FRAME#  I  L  VER  CHS     #Bytes  TID SID  (MHz)    SYNC   DAS/Stat
 ---------------------------------------------------------------------------
 03:58:30       0  0  0    0    1       1312    0      2048  ACABFEED  kashima
    ...............

 03:58:32 199999   0  0    0    1       1312    0      2048  ACABFEED  kashima
 ===========================================================================

======================== SUMMARY ============================
```

```
 File Name   : kas34_2014112035830.3sec.vdif
      Size   : 787200000 bytes
 Start Time  : 2014/04/22 03:58:30
               Thread ID : 0      Frame# : 0
 Bytes/Frame : 1312 bytes
 Data type   : Real Data        AD bits : 1    #Channels : 1
 EDV#        : 1
 Extended header information (NICT's EDV)
      Sampling Frequency : 2048 MHz
      Sync block         : ACABFEED
      DAS/Station name   : kashima
 # of frames/sec     : 200000
 # of total frames   : 600000   (#bad frames : 0)
 Data period (sec)   : 3.000000
 Data Rate/thread (Mbps) : 2048.000000
 Sampling Frequency Estimated (MHz) : 2048.000000
================================================================

$
```

5.6 m5check

"m5check" checks the contents of Mark5 format data.

5.6.1 How to execute

m5check *m5file* [*mode*]
or
m5check *m5file* [*options*]

where	*m5file*	–	Mark-5 data file name to check
	mode	–	set format to check 設定
			0 : with parity and 8|16|32|64 bits/word
			1 : without parity and 8|16|32|64 bits/word
			2 : display old style
			when *mode* is neglected, all modes are checked
	options (any order)		
	-a[ll]	–	all data are checked (only for Mark5B format data)
	-old	–	execute with old style
	-f	–	omit checking sync block. if one of options below is set, this option is neglected
	-t[rack] *ntrack*	–	set # of tracks (8|16|32|64). Default is 32
	-vlba	–	set VLBA format (default is Mark-5 format)
	-p[arity]	–	set with parity mode (default is without parity)
	-nrzm	–	set NRZM mode (default is non-NRZM mode)
	-s[kip] *samples*	–	set # of samples to be skipped at first

5.6.2 Examples

An example of checking Mark5B format data.

```
kondo@io:~/chkdata/m5b$ m5check JPddcall.m5b
***********************************************************
*    Mark-5 data structure analysis                       *
*      Ver 1.82  2012-11-26  by  T.KONDO/NICT             *
*                                                         *
***********************************************************

1st STEP: Checking Mark5B format
Data File : JPddcall.m5b
Now analizing the data file is Mark5B or not .....

 OK this is Mark 5B Format data

                          TIME CODE  CRC-
```

```
FRAME#   SYNC   UUUUTFFF MJDsssss.ssss  16  DATA#1   DATA#2     Mbps
 00000 ABADDEED F00F0000 22661050 0000A474 5CB997F7 538A10F3    N.A.
 00001 ABADDEED F00F0001 22661050 0000A474 5B5B6BB7 994A5166    N.A.
 00002 ABADDEED F00F0002 22661050 00012471 8975153B 055BC52A    N.A.
 00003 ABADDEED F00F0003 22661050 00012471 7DAD8195 1744AD2E    N.A.
 00004 ABADDEED F00F0004 22661050 0002247B E0E5EE59 19526019    N.A.
 00005 ABADDEED F00F0005 22661050 0002247B 185A2A95 82166A5D    N.A.
 00006 ABADDEED F00F0006 22661050 0002247B ADC29CD9 4941DA55    N.A.
 00007 ABADDEED F00F0007 22661050 0003A47E 0994A026 2BADDA00    N.A.
 00008 ABADDEED F00F0008 22661050 0003A47E 45A66BF7 E94525D5    N.A.
 00009 ABADDEED F00F0009 22661050 0004246F F40B9359 A7D41C19    N.A.

**************** SUMMARY of DATA FORMAT ANALYSIS****************
 File Name   : JPddcall.m5b
 Data Format : Mark-5B
 File Size   : 534277415 bytes
 Total # of Frames (estimated from file size): 53342.393670
 1st Header Information
   Time (MJD HH:MM:SS.SSSS) : 226 16:57:30.0000
   Frame # (in a second)    :         0
   User Specified (16 bits) : F00F
   TVG data flag            : 0
 Data Rate (Mbps) : 2048.0
 Frames/sec       : 25600
 Data Length (sec): 2.083687
****************************************************************
$
```

6 Data format conversion

6.1 k5tom5b

"k5tom5b" convert K5 format data to Mark5B format data

6.1.1 How to execute

k5tom5b *k5name1* [*k5name2 k5name3 k5name4* [*m5name*]] [*options*]

where	*k5name1*	–	K5 file name for CH#01-04 or CH#01
	k5name2	–	K5 file name for CH#05-08 or CH#02
	k5name3	–	K5 file name for CH#09-12 or CH#03
	k5name4	–	K5 file name for CH#13-16 or CH#04 if K5 file names after the 2nd are not accompanied by directory name, the directory of 1st K5 file is adopted for these files
	m5name	–	Mark5 file name to be created
	options (any order)		
	-o *m5name*	–	Mark5 file name to be created
	-d *m5dir*	–	directory for Mark5 file out (default : mark5 directory)
	-s *soffset*	–	set offset time from data head (sec) (default : 0)
	-p *period*	–	data period to convert (sec) (default : all)
	-e2bit *n*	–	2bit data encode mode n=1 : offset binary 0 1 2 3 n=2 : twisted offset binary 0 2 1 3 n=3 : signed binary 1 0 2 3 (default is 2)
	-nocheck	–	no header error check (adopted for 2nd and later headers)
	-ch1 *nn*	–	set K5 channel corresponding to Mark5 ch #1 *nn* is K5 channel number (1-16)
	-ch2 *nn*	–	set K5 channel corresponding to Mark5 ch #2
	....		
	-ch16 *nn*	–	set K5 channel corresponding to Mark5 ch #16
	-chall *n1*:*n2*: · · · :*n16*		
		–	set K5 channels corresponding to Mark5 all channels *n1* – K5 channel number (1-16) corresponding to Mark5 ch 1 *n2* – K5 channel number (1-16) corresponding to Mark5 ch 2 .... *n16* – K5 channel number (1-16) corresponding to Mark5 ch 16

[Environmental variables]

k5tom5b env

M5DIR	–	default directory for Mark5 data
M5VEX	–	default directory for Mark5 vex file

6.1.2 Example

```
$ k5tom5b ./tds.k5a tds.k5b tds.k5c tds.k5d data.m5bA data.m5b

***********************************************************
*    K5/VSSP to Mark-5B Data Format Converter             *
*      k5tom5b (Ver 1.70  2016-08-15)  by  T.KONDO/NICT   *
```

```
*************************************************************

Second Length :  30.000000
Second Length :  30.000000
Second Length :  30.000000
Second Length :  30.000000

K5 file(s)
 FILE1 CH#  1- 4 : ./tds.k5a
   (A/D(bits) 1  CHs 4  SFreq(kHz) 16000 Time 23:59:54  sec 86394) VSSP32
 FILE2 CH#  5- 8 : ./tds.k5b
   (A/D(bits) 1  CHs 4  SFreq(kHz) 16000 Time 23:59:54  sec 86394) VSSP32
 FILE3 CH#  9-12 : ./tds.k5c
   (A/D(bits) 1  CHs 4  SFreq(kHz) 16000 Time 23:59:54  sec 86394) VSSP32
 FILE4 CH# 13-16 : ./tds.k5d
   (A/D(bits) 1  CHs 4  SFreq(kHz) 16000 Time 23:59:54  sec 86394) VSSP32

Mark5B file (created) : data.m5b
    Observation Date : 3digit MJD =  589
                     :      Year  = 2016
                     :      Month =    7
                     :      Day   =   20
                     :  Total Day =  202
    Conversion length (sec) :  30

                      TIME LABEL MONITOR
 ==========================================================
  K5-FILE1  K5-FILE2  K5-FILE3  K5-FILE4    VLBA-TIME
  HH:MM:SS  HH:MM:SS  HH:MM:SS  HH:MM:SS  JJJSSSSSssss
 ----------------------------------------------------------
  23:59:54  23:59:54  23:59:54  23:59:54  589863940000  OK
  23:59:55  23:59:55  23:59:55  23:59:55  589863950000  OK
  23:59:56  23:59:56  23:59:56  23:59:56  589863960000  OK
  23:59:57  23:59:57  23:59:57  23:59:57  589863970000  OK
  23:59:58  23:59:58  23:59:58  23:59:58  589863980000  OK
  23:59:59  23:59:59  23:59:59  23:59:59  589863990000  OK
  00:00:00  00:00:00  00:00:00  00:00:00  590000000000  OK
  00:00:01  00:00:01  00:00:01  00:00:01  590000010000  OK
  00:00:02  00:00:02  00:00:02  00:00:02  590000020000  OK
  00:00:03  00:00:03  00:00:03  00:00:03  590000030000  OK

   ...........

  00:00:19  00:00:19  00:00:19  00:00:19  590000190000  OK
  00:00:20  00:00:20  00:00:20  00:00:20  590000200000  OK
  00:00:21  00:00:21  00:00:21  00:00:21  590000210000  OK
  00:00:22  00:00:22  00:00:22  00:00:22  590000220000  OK
  00:00:23  00:00:23  00:00:23  00:00:23  590000230000  OK
 ==========================================================

  Mark5 file (data.m5b) has been created.

Time elapsed (sec) for One obs process is 52.000000
$
```

6.2 k5tom5

"k5tom5" convert K5 format data to Mark5 format data

6.2.1 How to execute

k5tom5 *jjj*|*yyyymmdd*|*yyyyddd* *k5name1* [*k5name2 k5name3 k5name4* [*m5name*]] [*options*]

or

k5tom5 -i -*infofile*|make -v *vexfile* [*options*]

.... for information file creation mode

where *jjj*|*yyyymmdd*|*yyyyddd*

– observation date in three ways as follows

jjj : lower 3digits of MJD

or

yyyymmdd : 4 digit year, 2 digit month, 2 digit day of month

or

yyyyddd : 4 digit year, 3 digit day of year

k5name1	–	K5 file name for CH#01-04 or CH#01
k5name2	–	K5 file name for CH#05-08 or CH#02
k5name3	–	K5 file name for CH#09-12 or CH#03
k5name4	–	K5 file name for CH#13-16 or CH#04 if K5 file names after the 2nd are not accompanied by directory name, the directory of 1st K5 file is adopted for these files
m5name	–	Mark5 file name to be created
options (any order)		
-i *infofile*	–	infomation file name that contains track vs channel table bit_psition vs channel table group# vs channel table (default "k5tom5info.txt") "-i *-info_file*" means that create infomation file named *info_file* "-i make" means that create default infomation file
-o *m5name*	–	Mark5 file name to be created
-d *m5dir*	–	directory for Mark5 file out (default : mark5 directory)
-s *soffset*	–	set offset time from data head (sec) (default : 0)
-p *period*	–	data period to convert (sec) (default : all)
-vlba	–	set frame format to VLBA mode (default Mark4 mode)
-long	–	set 64 bit(track) mode (default 32bit mode)
-v *vex_file*	–	VEX file name to be read when "information file creation mode" is set
-sid *stat_id*	–	station ID when "information file creation mode" is set
-scan *scan#*	–	scan# for MODE get when "information file creation mode" is set (default : 1)
-short	–	set Mark5 file scan period to the shotest period of K5 files (default is the longest period. Dummy (all 0) data are filled.
-monit	–	run condition monitor ON
-nocheck	–	no header error check (adopted for 2nd and later headers)

[Environmental variables]

k5tom5 env

M5DIR	–	default directory for Mark5 data
M5VEX	–	default directory for Mark5 vex file

6.2.2 Examples

Example 1: conversion using default information file

set date of observation by year and total day and use default information file "k5tom5info.txt"

```
k5tom5 20031015 02880001.k5a 02880001.k5b 02880001.k5c 02880001.k5d m5test.dat

************************************************************
*    K5/VSSP to Mark-V Data Format Converter               *
*      k5tom5 (Ver 1.21  2005-09-17)  by  T.KONDO/NICT     *
************************************************************

 ---------- RUN CONDITION ----------
   yyyymmdd  : 20031015
   yyyyddd   : 2003288
```

```
    jjj       : 927
    MJD       : 52927
    k5name 1  : 02880001.k5a
    k5name 2  : 02880001.k5b
    k5name 3  : 02880001.k5c
    k5name 4  : 02880001.k5d
    mk5name   : m5test.dat2
    outdir    :
    infofile  : k5tom5info.txt
    channel   : 0
    group     : 0
    soffset   : 0
    period    : 0
    odd       : 0
    parity    : 0
    nrzm      : -1
    vlba      : 0
    nbits     : 32
  -------------------------------------


K5 file(s)
 FILE1 CH#  1- 4 : 02880001.k5a
   (A/D(bits) 1  CHs 4  SFreq(kHz) 4000 Time 17:30:02  sec 63002)
 FILE2 CH#  5- 8 : 02880001.k5b
   (A/D(bits) 1  CHs 4  SFreq(kHz) 4000 Time 17:30:02  sec 63002)
 FILE3 CH#  9-12 : 02880001.k5c
   (A/D(bits) 1  CHs 4  SFreq(kHz) 4000 Time 17:30:02  sec 63002)
 FILE4 CH# 13-16 : 02880001.k5d
   (A/D(bits) 1  CHs 4  SFreq(kHz) 4000 Time 17:30:02  sec 63002)

Mark5 file (created) : m5test.dat2
    Observation Date : 3digit MJD =  927
                     :      Year  = 2003
                     :      Month =   10
                     :      Day   =   15
                     :  Total Day =  288

                   TIME LABEL MONITOR
 ==========================================================
  K5-FILE1  K5-FILE2  K5-FILE3  K5-FILE4   MarkIV-TIME
  HH:MM:SS  HH:MM:SS  HH:MM:SS  HH:MM:SS  YDDDHHMMSSsss
 ----------------------------------------------------------
  17:30:02  17:30:02  17:30:02  17:30:02  3288173002000  OK
  17:30:03  17:30:03  17:30:03  17:30:03  3288173003000  OK
  17:30:04  17:30:04  17:30:04  17:30:04  3288173004000  OK
  17:30:05  17:30:05  17:30:05  17:30:05  3288173005000  OK
  17:30:06  17:30:06  17:30:06  17:30:06  3288173006000  OK
  17:30:07  17:30:07  17:30:07  17:30:07  3288173007000  OK
  17:30:08  17:30:08  17:30:08  17:30:08  3288173008000  OK
  17:30:09  17:30:09  17:30:09  17:30:09  3288173009000  OK
  17:30:10  17:30:10  17:30:10  17:30:10  3288173010000  OK
  17:30:11  17:30:11  17:30:11  17:30:11  3288173011000  OK
 ==========================================================

  Mark5 file (m5test.dat2) has been created.

Time elapsed (sec) for One obs process is 44.000000
```

Example 2: Create an information file

create conversion information file using the VEX file "/home/vlbi/mark5/gg057c.vex". Set station ID "Ks".

```
k5tom5 -i -/home/vlbi/mark5/k5tom5info.txt -v /home/vlbi/mark5/gg057c.vex -sid Ks
K5tom5 running under Information File create mode
info file (/home/vlbi/mark5/k5tom5info.txt) will be created (updated).
VEX file name --- /home/vlbi/mark5/gg057c.vex
SITES (Station ID) defined are

  ID    SITE NAME
 -----------------
  Pt    VLBA_PT
  Kp    VLBA_KP
  La    VLBA_LA
  Br    VLBA_BR
  Fd    VLBA_FD
  Nl    VLBA_NL
  Ov    VLBA_OV
```

```
  Mk    VLBA_MK
  Gb    GBT_VLBA
  Ks    KASHIM34
  At    ATCA
  Sh    SHANGHAI
  Mp    MOPRA
  Cd    CEDUNA
  Ho    HOBART
  Ur    URUMQI
  Pa    PARKES5
 -----------------
Selected Station ID = Ks
search_site: No CLOCK info for KASHIM34 included in the VEX FILE.
search_site: So all 0 for clock information was set.

Detailed site information
   site definition :  KASHIM34
   site name       :  KASHIM34
   site ID         :  Ks
   site position   : -3997649.222000 3276690.753000 3724278.823000
   site clock
      validity epoch : 0 0 0 0 0
      clock epoch    : 0 0 0 0 0
      clock offset   : 0.000000e+000
      clock rate     : 0.000000e+000
  Scan # for mode get is 1
mode is huygS
Mode was taken from Scan #1 as huygS

TRACK and FREQUENCY information for KASHIM34
   BARREL ROLL : off
   FREQDEF = 2034.99MHz8x16MHz   TRACKDEF = MKIV.8Ch2bit1to4
   adbit= 2 sample_rate= 32000000.000000

   bb HS Tr   AD fo   chan  bbcid BBC#     RF(Hz)    S   VBW(Hz)    PASS
    1  1  2 sign  1  &CH01 &BBC01    1  2034990000.0 L  16000000.0
    2  1  4 sign  2  &CH01 &BBC01    1  2034990000.0 L  16000000.0
    3  1  6 sign  3  &CH01 &BBC01    1  2034990000.0 L  16000000.0
    4  1  8 sign  4  &CH01 &BBC01    1  2034990000.0 L  16000000.0
    5  1 10  mag  1  &CH01 &BBC01    1  2034990000.0 L  16000000.0
    6  1 12  mag  2  &CH01 &BBC01    1  2034990000.0 L  16000000.0
    7  1 14  mag  3  &CH01 &BBC01    1  2034990000.0 L  16000000.0
    8  1 16  mag  4  &CH01 &BBC01    1  2034990000.0 L  16000000.0
    9  1 18 sign  1  &CH02 &BBC02    2  2034990000.0 L  16000000.0
   10  1 20 sign  2  &CH02 &BBC02    2  2034990000.0 L  16000000.0
   11  1 22 sign  3  &CH02 &BBC02    2  2034990000.0 L  16000000.0
   12  1 24 sign  4  &CH02 &BBC02    2  2034990000.0 L  16000000.0
   13  1 26  mag  1  &CH02 &BBC02    2  2034990000.0 L  16000000.0
   14  1 28  mag  2  &CH02 &BBC02    2  2034990000.0 L  16000000.0
   15  1 30  mag  3  &CH02 &BBC02    2  2034990000.0 L  16000000.0
   16  1 32  mag  4  &CH02 &BBC02    2  2034990000.0 L  16000000.0
   17  1  3 sign  1  &CH03 &BBC01    1  2034990000.0 U  16000000.0
   18  1  5 sign  2  &CH03 &BBC01    1  2034990000.0 U  16000000.0
   19  1  7 sign  3  &CH03 &BBC01    1  2034990000.0 U  16000000.0
   20  1  9 sign  4  &CH03 &BBC01    1  2034990000.0 U  16000000.0
   21  1 11  mag  1  &CH03 &BBC01    1  2034990000.0 U  16000000.0
   22  1 13  mag  2  &CH03 &BBC01    1  2034990000.0 U  16000000.0
   23  1 15  mag  3  &CH03 &BBC01    1  2034990000.0 U  16000000.0
   24  1 17  mag  4  &CH03 &BBC01    1  2034990000.0 U  16000000.0
   25  1 19 sign  1  &CH04 &BBC02    2  2034990000.0 U  16000000.0
   26  1 21 sign  2  &CH04 &BBC02    2  2034990000.0 U  16000000.0
   27  1 23 sign  3  &CH04 &BBC02    2  2034990000.0 U  16000000.0
   28  1 25 sign  4  &CH04 &BBC02    2  2034990000.0 U  16000000.0
   29  1 27  mag  1  &CH04 &BBC02    2  2034990000.0 U  16000000.0
   30  1 29  mag  2  &CH04 &BBC02    2  2034990000.0 U  16000000.0
   31  1 31  mag  3  &CH04 &BBC02    2  2034990000.0 U  16000000.0
   32  1 33  mag  4  &CH04 &BBC02    2  2034990000.0 U  16000000.0
   33  2  2 sign  1  &CH05 &BBC03    3  2139990000.0 L  16000000.0
   34  2  4 sign  2  &CH05 &BBC03    3  2139990000.0 L  16000000.0
   35  2  6 sign  3  &CH05 &BBC03    3  2139990000.0 L  16000000.0
   36  2  8 sign  4  &CH05 &BBC03    3  2139990000.0 L  16000000.0
   37  2 10  mag  1  &CH05 &BBC03    3  2139990000.0 L  16000000.0
   38  2 12  mag  2  &CH05 &BBC03    3  2139990000.0 L  16000000.0
   39  2 14  mag  3  &CH05 &BBC03    3  2139990000.0 L  16000000.0
   40  2 16  mag  4  &CH05 &BBC03    3  2139990000.0 L  16000000.0
   41  2 18 sign  1  &CH06 &BBC03    3  2139990000.0 U  16000000.0
   42  2 20 sign  2  &CH06 &BBC03    3  2139990000.0 U  16000000.0
   43  2 22 sign  3  &CH06 &BBC03    3  2139990000.0 U  16000000.0
   44  2 24 sign  4  &CH06 &BBC03    3  2139990000.0 U  16000000.0
   45  2 26  mag  1  &CH06 &BBC03    3  2139990000.0 U  16000000.0
   46  2 28  mag  2  &CH06 &BBC03    3  2139990000.0 U  16000000.0
```

```
  47  2 30  mag  3  &CH06 &BBC03    3  2139990000.0 U  16000000.0
  48  2 32  mag  4  &CH06 &BBC03    3  2139990000.0 U  16000000.0
  49  2  3 sign  1  &CH07 &BBC04    4  2286990000.0 L  16000000.0
  50  2  5 sign  2  &CH07 &BBC04    4  2286990000.0 L  16000000.0
  51  2  7 sign  3  &CH07 &BBC04    4  2286990000.0 L  16000000.0
  52  2  9 sign  4  &CH07 &BBC04    4  2286990000.0 L  16000000.0
  53  2 11  mag  1  &CH07 &BBC04    4  2286990000.0 L  16000000.0
  54  2 13  mag  2  &CH07 &BBC04    4  2286990000.0 L  16000000.0
  55  2 15  mag  3  &CH07 &BBC04    4  2286990000.0 L  16000000.0
  56  2 17  mag  4  &CH07 &BBC04    4  2286990000.0 L  16000000.0
  57  2 19 sign  1  &CH08 &BBC04    4  2286990000.0 U  16000000.0
  58  2 21 sign  2  &CH08 &BBC04    4  2286990000.0 U  16000000.0
  59  2 23 sign  3  &CH08 &BBC04    4  2286990000.0 U  16000000.0
  60  2 25 sign  4  &CH08 &BBC04    4  2286990000.0 U  16000000.0
  61  2 27  mag  1  &CH08 &BBC04    4  2286990000.0 U  16000000.0
  62  2 29  mag  2  &CH08 &BBC04    4  2286990000.0 U  16000000.0
  63  2 31  mag  3  &CH08 &BBC04    4  2286990000.0 U  16000000.0
  64  2 33  mag  4  &CH08 &BBC04    4  2286990000.0 U  16000000.0
default Mark-V data format is as follows
  data encode -- NRZL  without parity
  data format -- Mark-IV
  #_of_track  = 64

Information file (/home/vlbi/mark5/k5tom5info.txt) created!!
```

6.3 k5tovdif

"k5tovdif" converts K5 format data to VDIF format data

6.3.1 How to execute

k5tovdif *k5name1* [*k5name2 k5name3 k5name4* [*vdifname*]] [*options*]

where *k5name1* – K5 file name for CH#01-04 or CH#01
k5name2 – K5 file name for CH#05-08 or CH#02
k5name3 – K5 file name for CH#09-12 or CH#03
k5name4 – K5 file name for CH#13-16 or CH#04
if K5 file names after the 2nd are not accompanied by directory name, the directory of 1st K5 file is adopted for these files
vdifname – VDIF file name to be created
options (any order)
-o *vdifname* – VDIF file name to be created (default : extension of 1st K5 name is replaced by '.vdif')
-dir *vdifdir* – directory for VDIF file out (default : K5 directory)
-so *soffset* – set offset time from data head (sec) (default : 0)
-p *period* – data period to convert (sec) (default : all)
-das *das_name* – set station name or compulsoly set station name (in case of VSSP32 station or PC name got from it's AUX data)
-sid *sid* – set station id (A2) (in case of VSSP32 sid got from it's AUX data)
-date *jjj*|*yyyymmdd*|*yyyyddd*
– set date in case of VSSP (not VSSP32) format as follows
jjj : lower 3digits of MJD
or
yyyymmdd : 4 digit year, 2 digit month, 2 digit day of month
or
yyyyddd : 4 digit year, 3 digit day of year
-e2bit *n* – 2bit data encode mode
n=1 : offset binary 0 1 2 3
n=2 : twisted offset binary 0 2 1 3
n=3 : signed binary 1 0 2 3
(default is 2)
-nocheck – no header error check (adopted for 2nd and later headers)
-fr[amelength] *frame_bytes*

	–	set frame length without header (in byte) (default 1280)
-num[frame_sec] *nframe*		
	–	set # of frames per second (default: $2048 \times 10^6/(1280) = 200000$)
-ch1 *nn*	–	set K5 channel corresponding to VDIF ch #1 *nn* is K5 channel number (1-16)
-ch2 *nn*	–	set K5 channel corresponding to VDIF ch #2
....		
-ch16 *nn*	–	set K5 channel corresponding to VDIF ch #16
-chall *n1*:*n2*: $\cdots$:*n16*		
	–	set K5 channels corresponding to VDIF all channels *n1* – K5 channel number (1-16) corresponding to VDIF ch 1 *n2* – K5 channel number (1-16) corresponding to VDIF ch 2 .... *n16* – K5 channel number (1-16) corresponding to VDIF ch 16

[Environmental variables]

k5tovdif env

VDIFDIR – default directory for VDIF data

6.4 ads2k5

"ads2k5" converts ADS3000+(DBBC mode) format to K5 format data

6.4.1 How to execute

ads2k5 *adsname*[*options*]

where	*adsname*	–	ADS3000-DBBC mode data file name
	options (any order)		
	-c *channel*	–	pickup channel (1-16) for 1ch conversion mode (same as '-1ch option'. default 4x4ch mode)
	-u *unit*	–	pickup unit (1-4) for 4 ch conversion mode (-c option is stronger than this option) (default 4x4ch mode)
	-o *k5name*	–	K5 file name to be created (default : see below)
	-d *k5dir*	–	directory for k5 file out
	-fsampl *fmhz*	–	channel sampling frequency (MHz) (deflt=32)
	-adbit *adbit*	–	# of AD conversion bit (deflt=1)
	-1ch *ch*	–	set K5 data to 1ch mode and set pick up ADS3000-DBBC ch (starting at 1)
	-4ch *ch1 ch2 ch3 ch4*		
		–	set K5 data to 4 ch mode and set pick up channels from ADS3000-DBBC (default: convert to 4x4ch K5 files)
	-2bit *mode*	–	select 2bit AD decode table 1: offset binary 0,1,2,3 (no conversion: default) 2: Mark V standard 0,2,1,3 3: signed integer 1,0,2,3
	-t *YYYYDDDHHMMSS*|*YYYY/DDD-HH:MM:SS* or *HHMMSS*|*HH:MM:SS* or *YYYYDDD*|*YYYY/DDD*		
		–	set start date and time of data. If this is omitted, start time is taken from ADS filename.
	-s *soffset*	–	set offset time from data head (sec) (default : 0)

-p *period*	–	data period to convert (sec) (default : all)
-vssp	–	force K5 format to VSSP (default is VSSP32)
-monit	–	monitor run parameters
-adsbit *adsbit*	–	ADS AD bits (2|4|8) (deflt=2). if *adbit*>=4, *adsbit* = *adbit*
-adsnumch *adsnumch*	–	ADS # of channels (1|8) (deflt=8)

[Naming rule for K5 file created]

(ADS : ADS3000 file name or name given by '-o' option)

```
4x4ch mode
  ADS.k5a ---- for group#1 (ch01-04)
  ADS.k5b ---- for group#2 (ch05-08)
  ADS.k5c ---- for group#3 (ch09-12)
  ADS.k5d ---- for group#4 (ch13-16)
4ch mode
  ADS.k5[a|b|c|d]
1ch mode
  ADS.k5-NN ---- where NN is channel number 01-16
```

[Environmental variables]

ads2k5 env

K5_CH_TABLE	–	operator defined CH allocation table
ADSDIR	–	default directory for ADS data
K5DIR	–	default directory for K5 file out

Note:

If ADS3000 file name satisfies following condition, start time and sampling frequency are properly estimated from the file name.

1. File name has a following structure.

   xxx...xxxx_YYYYDDDHHMMSS.raw

   where xxx...xxxx — any characters YYYYDDDHHMMSS – start time (year,day of year, hour, minute, second)

2. "xxx...xxxx" includes a sampling information block like "16MHz" or "8Msps" (don't care about upper-case or lower-case of characters for MHz or Msps).

3. This information block should be precede by a non-number ASCII character or start of the file name, e.g., ...dbbc_16MHz_....... or ...xyz.32MSPS.xxxxxx

6.5 m5btok5

"m5btok5" converts Mark5B format data to K5 format data

6.5.1 How to execute

m5btok5 *m5bname* [*options*]

where	*m5bname*	–	Mark5B data file name
	options (any order)		
	-o *k5name*	–	K5 file name to be created (default : see below)
	-d *k5dir*	–	directory for k5 file out (dfault Mark5 directory)
	-bs *nbitsream*	–	set Mark5B # of bit-stream (1,2,4,8,16,32)
	-fsampl *fmhz*	–	channel sampling frequency (MHz) (deflt=4)
	-adbit *adbit*	–	# of AD conversion bit (deflt=1)
	-1ch *ch*	–	set K5 data to 1ch mode and set pick up Mark5B ch (starting at 1)
	-4ch *ch1 ch2 ch3 ch4*		
		–	set K5 data to 4 ch mode and set pick up channels from Mark5B data
	-2bit *mode*	–	select 2bit AD decode table 1: offset binary 0,1,2,3 (no conversion) 2: Mark V standard 0,2,1,3 (dfault) 3: signed integer 1,0,2,3

[Naming rule for K5 file created]

(MK5 : original mark5 name)

```
4ch mode
  MK5.k5a ---- for group#1 (ch01-04)
  MK5.k5b ---- for group#2 (ch05-08)
  MK5.k5c ---- for group#3 (ch09-12)
  MK5.k5d ---- for group#4 (ch13-16)
1ch mode
  MK5.k5-NN ---- where NN is channel number 01-16
```

[Environmental variables]

m5btok5 env

M5DIR	–	default directory for Mark5 data
K5DIR	–	default directory for K5 file out

6.6 m5tok5

"m5tok5" converts Mark5B format data to K5 format data

6.6.1 How to execute

Mode 1

m5tok5 *m5name* [*options*]

where	*m5name*	–	Mark5 data file name
	options (any order)		
	-c *channel*	–	pickup channel (1-16) for 1ch conversion mode (default all group and 4ch mode)
	-g *group*	–	pickup group (1-4) for 4 ch conversion mode (omitted when '-c' option is set) (default all group)

-i *infofile*	–	infomation file name that contains track vs channel table bit_psition vs channel table group# vs channel table (default "m5tok5info.txt") "-i *-info_file*" means that create infomation file named *infofile* "-i make" means that create default infomation file
-o *k5name*	–	K5 file name to be created (default : see below)
-d *k5dir*	–	directory for k5 file out (dfault Mrak5 directory)
-s *soffset*	–	set offset time from data head (sec) (default : 0)
-p *period*	–	data period to convert (sec) (default : all)
-r	–	reverse track order when fanout=2 or more
-v *vex_file*	–	VEX file name to be read when "information file creation mode" is set
-sid *stat_id*	–	station ID when "information file creation mode" is set
-scan *scan#*	–	scan# for MODE get when "information file creation mode" is set (default : 1)
-subp *subpass*	–	set subpass at information file creation mode (default is "A")
-odd	–	32bit (4byte) shift in reading Mark5 data (this works only for 64 track mode)
-monit	–	run condition monitor ON

Mode 2

m5tok5 *m5name k5file bit1* [*bit2 bit3 .. bitN*] [*options2*]

where	*m5name*	–	Mark5 data file name
	k5file	–	K-5 file name to be created
	bit1	–	1st pick up bit position (0- max track#)
	bit2	–	2nd pick up bit position (0- max track#)
	.....		
	bitN	–	Nth pick up bit position (0- max track#) note: *N* should be (K5 channels)*(AD bits)*(Mark5 Fanout)
	options2 (any order)		
	-track *ntrack*	–	# of Mark5 track (8,16,32,64) (deflt=32)
	-fsampl *fmhz*	–	channel sampling frequency (MHz) (deflt=4)
	-adbit *adbit*	–	# of AD conversion bit (deflt=1)
	-nch *numch*	–	# of channels in K5 format (1 or 4) (deflt=4)
	-parity	–	with parity data
	-noparity	–	non-parity data (default)
	-vlba	–	set VLBA mode (default mark IV mode)
	-s *soffset*	–	set offset time from data head (sec) (default : 0)
	-p *period*	–	data period to convert (sec) (default : all)
	-odd	–	32bit (4byte) shift in reading Mark5 data (this works only for 64 track mode)

[Naming rule for K5 file created]

(MK5 : original mark5 name)

```
4ch mode
  MK5.k5a ---- for group#1 (ch01-04)
```

```
  MK5.k5b ---- for group#2 (ch05-08)
  MK5.k5c ---- for group#3 (ch09-12)
  MK5.k5d ---- for group#4 (ch13-16)
1ch mode
  MK5.k5-NN ---- where NN is channel number 01-16
```

[Environmental variables]

m5tok5 env

M5DIR	–	default directory for Mark5 data
M5VEX	–	default directory for VEX file

6.7 vdif2k5

"vdif2k5" converts VDIF format data to K5 format data

6.7.1 How to execute

vdif2k5 *vdiffile* [*options*]

where	*vdiffile*	–	VDIF data file name
	options (any order)		
	-o *k5name*	–	K5 file name to be created (default : see below)
	-d *k5dir*	–	directory for k5 file out (dfault VDIF directory)
	-fsampl *fmhz*	–	channel sampling frequency (MHz) (deflt=4)
	-adbit *adbit*	–	# of AD conversion bit (deflt=1)
	-1ch *ch*	–	set K5 data to 1ch mode and set pick up VDIF ch (starting at 1)
	-4ch *ch1 ch2 ch3 ch4*		
		–	set K5 data to 4 ch mode and set pick up channels from VDIF data
	-2bit *mode*	–	select 2bit AD decode table
			1: offset binary 0,1,2,3 (no conversion) (dfault)
			2: Mark V standard 0,2,1,3
			3: signed integer 1,0,2,3
	-s *soffset*	–	set offset time from data head (sec) (default : 0)
			in case of negative value: absolute value means skip over bytes

[Naming rule for K5 file created]

(VDIF : original VDIF name)

```
4ch mode
  VDIF.k5a ---- for group#1 (ch01-04)
  VDIF.k5b ---- for group#2 (ch05-08)
  VDIF.k5c ---- for group#3 (ch09-12)
  VDIF.k5d ---- for group#4 (ch13-16)
1ch mode (from multi channel VDIF)
  MK5.k5-NN ---- where NN is channel number 01-16
1ch mode (from 1ch VDIF)
  VDIF.k5
```

6.8 vdif2m5b

"vdif2m5b" converts VDIF format data to Mark5B format data

6.8.1 How to execute

vdif2m5b *vdiffile* [*options*]

where	*vdiffile*	–	VDIF data file name
	options (any order)		
	-o *m5bname*	–	Mark5B file name to be created (default : see below)
	-d *m5dir*	–	directory for Mark5B file out (dfault VDIF directory)
	-fsampl *fmhz*	–	channel sampling frequency (MHz) (deflt=4)
	-2bit *mode*	–	select 2bit AD decode table
			1: offset binary 0,1,2,3 (no conversion)
			2: Mark V standard 0,2,1,3 (default)
			3: signed integer 1,0,2,3
	-s *soffset*	–	set offset time from data head (sec) (default : 0)
	-p *period*	–	data period to convert (sec) (default : all)
	-type1	–	outfile naming Type 1 (replace file extention to "m5b")
	-pid *thread_id*	–	set pickup thread ID compulsory
	-ch1 *nn*	–	set VDIF channel corresponding to Mark5B ch #1
			nn is VDIF channel number (1-16)
	-ch2 *nn*	–	set VDIF channel corresponding to Mark5B ch #2
	....		
	-ch16 *nn*	–	set VDIF channel corresponding to Mark5B ch #16
	-chall *n1*:*n2*: $\cdots$:*n16*		
		–	set VDIF channels corresponding to Mark5B all channels
			n1 – VDIF channel number (1-16) corresponding to Mark5B ch 1
			n2 – VDIF channel number (1-16) corresponding to Mark5B ch 2
			....
			n16 – VDIF channel number (1-16) corresponding to Mark5B ch 16

[Naming rule for Mark5B file created]

(VDIF.vdif : original VDIF name)

```
Type 0  VDIF.vdif.m5b (default)
Type 1  VDIF.m5b
```

7 Actual correlation processing

Correlation processing is devided into two steps as follows.

1. Fringe search: determine clock parameters (offset and rate) by baseline.
2. Processing all scans: process all scan data using clock parameters determined by fringe search.

7.1 Fringe search

Correlation processing for geodetic VLBI data is usually carried out with a small number of lags such as 32 to increase the throughput of processing. To keep a correlation peak at the center of the lag window, clock offset should be determined with an accuracy of better than a few tenths percentage of a sampling period. Fringe search is a correlation processing to find out fringes and to determine a clock offset between two stations.

A-priori delay neccesary for correlation processing is calculated from time of ovservation, station positions, source position, earth orientation parameters, and clock error. It is difficult to obtain an accurate clock error between two stations in advance, so that a clock error measured by GPS at each station is usually used as a temporal value to calculate a-priori delay. If there is no GPS clock measurement, zero is used as a temporal vaule. In case of geodetic VLBI lasting for 24 hours or more, clock rate is slso determined. The concrete method of fringe search and clock parameters determination is out as follows.

1. Determination of the scan for fringe search
   - without clock rate determination: a scan observed a strong source around the middle of the session
   - with clock rate determination: two scans that observed a strong source around the beginning and end of the session

   Source information is found in a schedule file. It is also obtained by executing "apri_calc" with a schedule monitoring mode as follows.

```
apri_calc -/home/vlbi/sked/sample.skd

   or

apri_calc /home/vlbi/sked/sample.skd -monit

   where "/home/vlbi/sked/sample.skd" is a schedule file
```

   then observation information is displayed as follows.

```
apri_calc (Ver. 2016-10-12)

====================== RUN CONDITION ========================
  K5 file naming type is  Type 1 : sidDDDNNNN.dat (SKED deflt)
=============================================================
SkdMonit: *********** Schedule file monitor **********
SkdMonit: Schedule file = ipvlbi/sked/sample.skd
SkdMonit: Expcode       = KS07235
SkdMonit: Total Scan #  = 593
SkdMonit: Total Star #  = 16
SkdMonit:
SkdMonit:  1st   Scan   = 2007/08/23 01:15:00  3C84
SkdMonit:  Last  Scan   = 2007/08/24 00:46:20  3C273B
SkdMonit:
SkdMonit: ---------- Station ID Table ----------
SkdMonit:  G --- KOGANEI
SkdMonit:  R --- KASHIM11
SkdMonit:  Y --- TATEYAMA
SkdMonit: -------------------------------------
SkdMonit: ------- Star Table -------------------
SkdMonit:          NAME1      NAME2  R.A.(deg)   DEC(deg)   EPOCH
SkdMonit:   1   0059+581          $  15.690677  58.403093 2000.000000
SkdMonit:   2   0316+413       3C84  49.950667  41.511695 2000.000000
SkdMonit:   3   0420-014          $  65.815836  -1.342518 2000.000000
SkdMonit:   4   0552+398          $  88.878357  39.813657 2000.000000
SkdMonit:   5   0727-115          $ 112.579635 -11.686833 2000.000000
SkdMonit:   6   0923+392    4C39.25 141.762558  39.039126 2000.000000
SkdMonit:   7   1226+023     3C273B 187.277915   2.052389 2000.000000
```

```
SkdMonit:   8   1253-055      3C279 194.046527  -5.789312 2000.000000
SkdMonit:   9   1308+326          $ 197.619433  32.345495 2000.000000
SkdMonit:  10   1334-127          $ 204.415762 -12.956859 2000.000000
SkdMonit:  11   1641+399      3C345 250.745042  39.810276 2000.000000
SkdMonit:  12   1730-130    NRAO530 263.261274 -13.080430 2000.000000
SkdMonit:  13   1921-293          $ 291.212733 -29.241700 2000.000000
SkdMonit:  14   2134+004    2134+00 324.160776   0.698393 2000.000000
SkdMonit:  15   2145+067          $ 327.022744   6.960723 2000.000000
SkdMonit:  16   2251+158    3C454.3 343.490616  16.148211 2000.000000
SkdMonit: --------------------------------------
SkdMonit: ------- Frequency (MHz) Table --------
SkdMonit: Gr# 1    7714.99 U   7724.99 U   7754.99 U   7814.99 U
SkdMonit: Gr# 2    8034.99 U   8234.99 U   8414.99 U   8524.99 U
SkdMonit: Gr# 3    8564.99 U   8584.99 U   2154.99 U   2164.99 U
SkdMonit: Gr# 4    2234.99 U   2294.99 U   2384.99 U   2414.99 U
SkdMonit: --------------------------------------
SkdMonit: ------- PCAL Freq (kHz) Table ---------
SkdMonit: Gr# 1      10.0      10.0      10.0      10.0
SkdMonit: Gr# 2      10.0      10.0      10.0      10.0
SkdMonit: Gr# 3      10.0      10.0      10.0      10.0
SkdMonit: Gr# 4      10.0      10.0      10.0      10.0
SkdMonit: --------------------------------------
```

Then select a strong source such as "3C273B", and execute "apri_calc" with a schedule monitoring mode with the option "-source" as follows.

```
apri_calc -/home/vlbi/sked/sample.skd -source 3C273B

  or

apri_calc /home/vlbi/sked/sample.skd -monit -source 3C273B
```

A certain baseline can be specified if necessary by using the "-baseid" option as follows.

```
apri_calc /home/vlbi/sked/sample.skd -monit -source 3C273B -baseid RY
```

where "RY" is a combination of Station IDs. Then scan information is displayed as follows.

```
SkdMonit: --------- PICKUP SCAN TABLE ----------
SkdMonit: SCAN#     SOURCE YYYY/DDD HH:MM:SS DURA  STATION_IDS
SkdMonit:    10     3C273B 2007/235 01:36:03   62  G R Y
SkdMonit:    18     3C273B 2007/235 01:50:59   62  G R Y

   ............................

SkdMonit:   571     3C273B 2007/235 23:51:47   62  G R Y
SkdMonit:   579     3C273B 2007/236 00:10:11   62  G R Y
SkdMonit:   586     3C273B 2007/236 00:29:04   62  G R Y
SkdMonit:   593     3C273B 2007/236 00:46:20   62  G R Y
SkdMonit: --------------------------------------
```

Column named "SCAN#" shows the scan number.

2. Calculation of a-priori values

Execute "apri_calc" for a scan selected by the previous step as folows.

```
apri_calc /home/vlbi/sked/sample.skd -start 10 -stop 10 -apedir /home/vlbi/corrapri
```

where "-apedir" option sets the directory of a-priori files created. If you want to execute for all scans selected, execute as follows.

```
apri_calc /home/vlbi/sked/sample.skd -source 3C273B -baseid RY -apedir /home/vlbi/corrapri
```

See "How to run apri_calc" (section 3.1) for details. Since a-priori file is a text file, you can edit it easily if necessary (see Appendix A for the format of a-priori file).

3. Correlation Processing

Execute “fx_cor” (or “fx_cor_new” for not K5/VSSP format data) with a large number of lags such as 1024 or more as follows.

```
fx_cor /home/vlbi/corrapri/apesample.txt -lag 1024
```

where “apesample.txt” is a a-priori file created by “apri_calc” (use actual a-priori file name created by the previous step). After processing, correlation amplitude and residual delay are displayed by channel as follows.

```
===============================================================
   CH#    FREQ(MHz)       MAX AMP        RESIDUAL DELAY (sec)
---------------------------------------------------------------
    1      8209.99      0.000651             -3.26108e-06
    2      8219.99      0.000443             -3.28622e-06
    3      8249.99      0.000589             -3.23678e-06
    4      8309.99      0.000480             -3.25464e-06
===============================================================

COUT File is ../cout/cout0005.txt
```

where ”COUT File” is a correlation results file. Correlation functions are also plotted as shown in Fig.7.1.

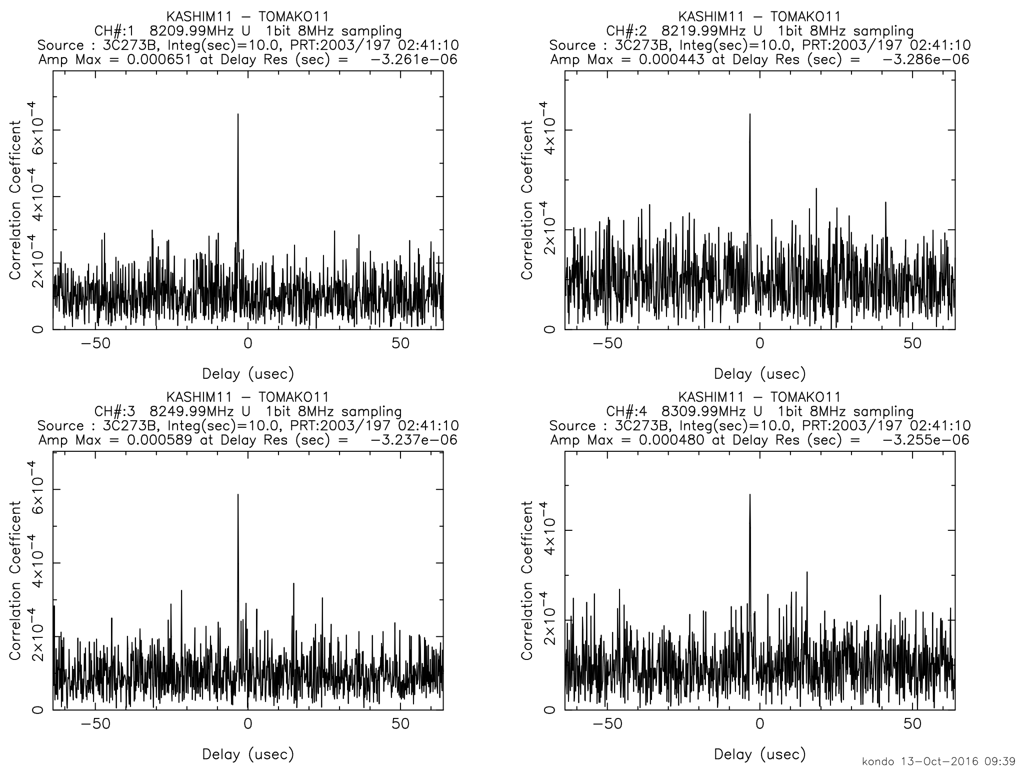

Figure 7.1. Correlation functions displayed after “fx_cor” (or “cor”) processing.

If clear peak appears in the plots of correlation function, we can determine clock offset. If it is not clear, execute the coarse-search program “sdelay” to search a clear peak as follows.

```
sdelay ../cout/cout0005.txt
```

where “../cout/cout0005.txt” is a COUT File (correlator out file) displayed at the end of “fx_cor” processing. After “sdelay” processing, summary of coarse search is displayed as follows and search functions are plotted (Fig.7.2).

```
******************** SDELAY (Ver. 2016-08-12) SUMMARY OUT PUT ************
  COUT     : ../cout/cout0005.txt
  X DATA   : /home/kondo/data/testspeed/Xk5data.10.dat
  Y DATA   : /home/kondo/data/testspeed/Yk5data.10.dat
  BASELINE : KASHIM11 - TOMAKO11
  SOURCE   :    3C273B         SAMPLING  : 1 bit   8 MHz
  PRT      : 2003/197 02:41:10    Tinteg(s) : 9.0
  LAG SIZE : 1024
  CLOCK    : offset    5.735e-06(s)   rate    0.000e+00(s/s)
  EOP      : ut1-utc 0.000000(s)
           : x-wobb  0.000000(asec)
           : y-wobb  0.000000(asec)

 ========================================================================
  CH#  FREQUENCY      AMP MAX     POSITION          RESIDUAL
        (MHz)                   (2048x 128)  Delay(usec) Rate(ps/s)  SNR
 ------------------------------------------------------------------------
    1    8209.99 U   1.192e-03  ( 973,  65)    -3.251     -0.134   10.1
    2    8219.99 U   8.613e-04  ( 973,  68)    -3.270      2.482    7.3
    3    8249.99 U   1.089e-03  ( 973,  65)    -3.239     -0.089    9.2
    4    8309.99 U   1.095e-03  ( 973,  66)    -3.242      0.943    9.3
 ------------------------------------------------------------------------
  Note: No amplitude correction is made.
 ========================================================================

 ====================== PCAL SUMMARY ===========================
  CH#   PCAL FREQ(kHz)      X-Amp  X-Phase    Y-Amp  Y-Phase
 -----------------------------------------------------------------
   1         10.00          0.109    70.6     0.251   111.9
   2         10.00          0.107   -92.2     0.244  -162.7
   3         10.00          0.106   136.2     0.247    84.3
   4         10.00          0.104  -143.5     0.259   -43.2
 ************************************************************************

Outfile is ./sdelayout.txt
```

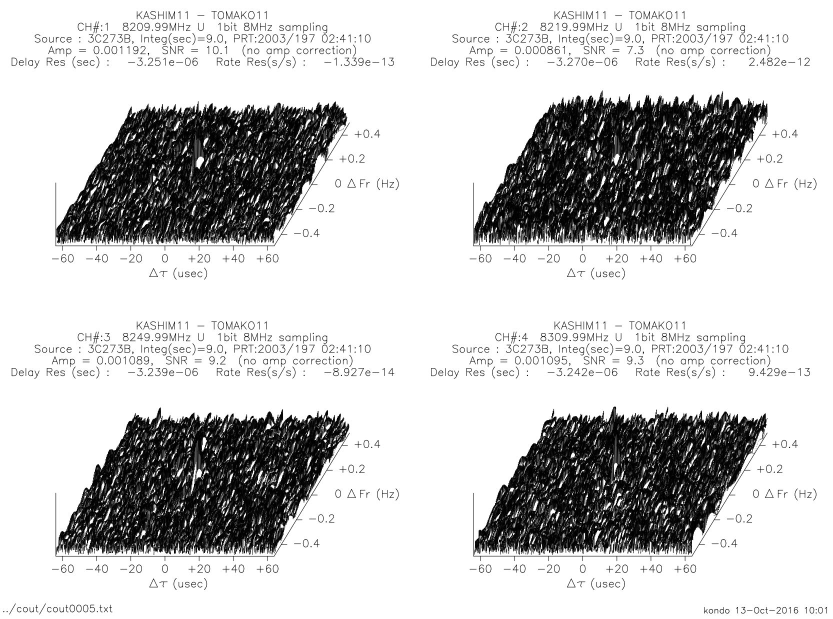

Figure 7.2. Search functions displayed after "sdelay" processing. Peaks are not clear due to a large number of lags. In this case, zoom up using the options "-tzoom" and "-tshift". Fig.7.3 shows search functions with the options "-tzoom 20 -tshift -3.25e-6".

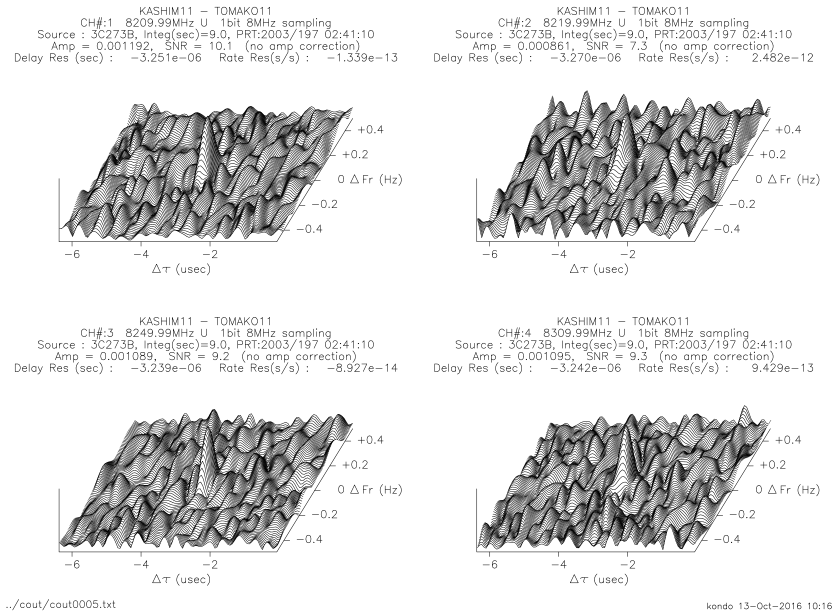

Figure 7.3. Same as Fig.7.2 but with the options "-tzoom 20 -tshift -3.25e-6".

Fringe detection is judged from summary output and plot of search functions as follows.

- peak positions shown at "POSITION" column are the same for all channels
- clear single peak appears in the plot of serach function
- SNR is larger than 7

If above conditions are almost satisfied, we can say "fringe is successfuly detected".

4. Determination of clock offset

   Clock offset c_{offset} is given as

   $$c_{offset} = c_o + \Delta\tau$$

   where c_o is clock offset used at "apri_calc" and $\Delta\tau$ is residual delay obtained by "sdelay".

5. Determination of clock rate

   Clock rate c_{rate} is given as

   $$c_{rate} = \frac{c_2 - c_1}{t_2 - t_1}$$

   where c_1 is clock offset obtained for a scan at the time t_1 and c_2 is clock offset obtained for a scan at the time t_2, and t_1 and t_2 are PRT (processing reference time) given by a unit of second. If a session extends on the next day, take the day difference into consideration.

6. Set up clock parameters at "apri_calc"

   Clock offset, clock rate, and clock epock are set up when executing "apri_calc" as follows.

   - in case of setting up clock offset only:
     set clock offset only, use default or set 0 for rate and epock.
   - in case of setting up both clock offset and rate:
     set c_1 for clock offset, c_{rate} for clock rate, and t_1 (after converting to year, total day, hour, minute, second) for clock epoch

7.2 Processing all scans

1. Calculation of a-priori values

   Calculate a-priori values for all scans with reflecting clock parameters obtained by fringe search. An example of non-interactive execution is as follows.

   ```
   apri_calc  /home/vlbi/sked/jd1606.skd -coffset -3.25e-6 -crate 1.0e-13
             -cepoch 2016/197-02:41:10 -baseid RY -g 2 -xdir /home/vlbi/data/R
             -ydir /home/vlbi/Y -apedir /home/vlbi/corrapri
   ```

   Conditions used in this example are as follows; clock offset is -3.25 μsec, clock rate is 1.0×10^{-13}(s/s), clock epock is 2016/197 02:41:10, baseline is "RY", data directory for X station data is "/home/vlbi/data/R" and for Y station "/home/vlbi/data/Y", directory for a-priori files is "/home/vlbi/corrapri". In case of using clock offset only, omit options "-crate" and "-cepoch".

2. Generation of the list of a-priori files

   Execute linux command as follows.

   ```
   ls -1 /home/vlbi/corappri/ape*RYb.txt > apelistRY.txt
   ```

   where the directory of a-priori files is "/home/vlbi/corrapri" and "apelistRY.txt" is a file generated. "ape*RYb.txt" is a filter to select baseline "RY" and frequency code "b" if there are a-priori files for multiple baselines. If you want to select all a-priori files, execute like,

   ```
   ls -1 /home/vlbi/corappri/ape*.txt > apelistRY.txt
   ```

   where "apelistRY.txt" can be any another name.

3. Correlation processing for all scans

   As for 1-bit sampling data, execute as follows,

   ```
   cor_all ./apelistRY.txt
   ```

   where "apelistRY.txt" is the name of list file located in the current directory. See "How to run software correlator" (section 4.2) for other options. As for multi-bit sampling data, such as 2-bit AD data, use "fx_cor_all" instead. Use "cor_all_new" or "fx_cor_all_new" for format data other than K5/VSSP format.

7.3 Correlation processing for a variety of data formats (VDIF, Mark5B, ADS, OCTAD)

When executing "apri_calc", data format should be specified using options "-format" or "-formX", "-formY". (See "How to execute apri_calc" (section 3.1) for details.) Then use "cor_new", "fx_cor_new", "cor_all_new", "fx_cor_all_new" instead of "cor", "fx_cor", "cor_all", "fx_cor_all".

8 Update history

2016/05/29 add “cor_new” and “fx_cor_new”

2017/03/03 translated to English

2017/03/06 add two sections “6 Data format coversion” and “D VLBI data format”

A A-priori file format

1. A-priori file structure

A-priori file consists of "section" described by letters starting with '$' and parameters followed by the section letter. Table 1 shows the list of sections and their order in an a-priori file. $FORMAT1 and $FORMAT2 are new sections to define data format other than K5/VSSP. Any letters after '*' in a line are treated as comments.

Table 1. List of sections

```
$EXPCODE       <--- experiment title
$OBS_NUMBER    <--- scan (observation) number
$STATION1      <--- station 1 (X) information
$FORMAT1       <--- station 1 data format (new)
$XYZ-STATION1  <--- station 1 position
$STATION2      <--- station 2 (Y) information
$FORMAT2       <--- station 2 data format (new)
$XYZ-STATION2  <--- station 2 position
$BASEID        <--- baseline ID
$FRQ_GRP(1-4)  <--- frequency group
$FREQUENCY     <--- RF frequency
$PCAL_FREQ     <--- PCAL (phase calibration) frequency
$CLOCK         <--- clock parameters
$SOURCE        <--- radio source name
$RA            <--- radio source position (right ascension)
$DEC           <--- radio source position (declination)
$EPOCH         <--- epock of radio position
$GHA           <--- Greenwhich hour angle of radio source
$EOP           <--- earth orientation parameters
$START         <--- scan start time (UTC)
$STOP          <--- scan stop time (UTC)
$APRIORI       <--- a-prioi values (PRT, delay, delay rate, delay 2 dots, delay 3 dots)
$END           <--- end of a-priori file
```

2. Parameters at each section

$EXPCODE	section experimet code
exp_code	experiment code
$OBS_NUMBER	section scan (observation) number
n	scan #
$STATION1	section station 1 (X) information
station1_name data_file	station name and data file name
$FORMAT1	section station 1 data format (can be omitted for VSSP format)
data_format [*sampling_info*]	data format *data_format* and sampling information *sampling_info*
	data format is VDIF|M5B|OCTAD|ADS
	where
	VDIF – VDIF format
	M5B – Mark-5B format
	OCTAD – OCTAD format
	ADS – ADS format
	sampling information is sampling frequency (m), # of channels (n) and AD resolution in bits (k), and described as follows.
	mMHz nCH $k$bit
	sampling information can be omitted for VDIF format
$XYZ-STATION1	section station 1 position
x y z	X(m) Y(m) Z(m)
$STATION2	section station 2 (Y) information
station2_name data_file	Y 局名 データファイル名
$FORMAT2	section station 2 data format (can be omitted for VSSP format)
data_format [*sampling_info*]	data format *data_format* and sampling information *sampling_info*
$XYZ-STATION2	section station 2 position
x y z	X(m) Y(m) Z(m)

$BASEID	section baseline ID
baseline_id	baseline ID (either 2 letters or 4 letters)
$FRQ_GRP(1-4)	section frequency group
n	frequency group # (1-4) or 0 0 means all 16CH processing
$FREQUENCY	section RF frequency
rf_freq side_band [*x-ch* [*y-ch*]]	
	where *rf_freq* – RF frequency (Hz), *side_band* – sideband (U|L) *x-ch* – X data CH#、*y-ch* – Y data CH#
$PCAL_FREQ	section PCAL (phase calibration) frequency
pcal_freq	PCAL frequency (Hz)
$CLOCK	section clock parameters
OFST= *c_offset*	clock offset (s). Positive value menas Y clock tic earlier than X clock tic.
RATE= *c_rate*	clock rate (s/s)
XCOF= *xc_offset*	clock offset (sec) of X station to UTC. Positive value menas X clock tic earlier than UTC clock tic.
$SOURCE	section radio source name
srcnam	radio source name (8 letters)
$RA	section radio source position (right ascension)
hour minute sec	right ascension (hour, minute, second)
$DEC	section radio source position (declination)
deg minute sec	declination (degree, minute, second)
$EPOCH	section epock of radio position
year	epoch (year)
$GHA	section Greenwhich hour angle of radio source
hour minute sec	hour angle (hour, minute, second)
$EOP	section earth orientation parameters
UT1-UTC= *ut1mutc*	UT1-UTC (s)
X_WOBB = *wobbx*	Wobbling X (arcsec)
Y_WOBB = *wobby*	Wobbling Y (arcsec)
$START	section scan start time (UTC)
yyyydddhhmmss	scan start time (UTC) (yyyy – year, ddd – total day, hh – hour, mm – minute, ss – second)
$START	section scan stop time (UTC)
yyyydddhhmmss	scan stop time (UTC) (year, total day, hour, minute, second)
$APRIORI	section a-prioi values
PRT=*yyyydddhhmmss*	PRT (processing reference time) (UTC) (year, total day, hour, minute, second)
TAU0= *tau*	a-priori delay (s)
TAU1= *tau1*	a-priori delay rate (s/s)
TAU2= *tau2*	a-priori delay 2-dots (s/s^2)
TAU3= *tau3*	a-priori delay 3-dots (s/s^3)
$END	end of a-priori file

3. Examples of a-priori file

Ex.1 in case of K5/VSSP format

```
** This is Apriori file made by apri_calc Ver. 2016-09-29
**     for cor, cor_all, fx_cor, and fx_cor_all
**
** SUBNET ON:  PRT is set according to each scan length
**
** Clock parameters at run are as follows,
**   Clock Offset (s) : 0.000000
**   Clock Rate (s/s) : 0.000000
**   Clock Epoch      :     0000/000 00:00:00
**
**
$EXPCODE     <--- section experiment title
KS15002
$OBS_NUMBER  <--- section scan (observation) number
1            <--- scan (observation) number
$STATION1    <--- section X station information
KASHIM11 ./R0020001.dat  <--- X station name and datafile name
$XYZ-STATION1   <--- section station X position
-3997505.701700 3276878.404550 3724240.703140 <--- X station position (X Y Z)(m)
$STATION2    <--- section Y station information
KOGANEI ./G0020001.dat   <--- Y station name and datafile name
$XYZ-STATION2   <--- section station Y position
-3941937.479090 3368150.907990 3702235.288150 <--- X station position (X Y Z)(m)
$BASEID   <--- section baseline ID
RG           <--- baseline ID (2 letters or 4 letters)
$FRQ_GRP(1-4)   <--- section frequency group
1            <--- frequency group # (1-4)
$FREQUENCY   <--- section RF frequency
7864990000.0 U    <--- RF frequency (Hz) and sideband (U|L) for CH #1
7874990000.0 U    <--- RF frequency (Hz) and sideband (U|L) for CH #2
7884990000.0 U    <--- RF frequency (Hz) and sideband (U|L) for CH #3
8014990000.0 U    <--- RF frequency (Hz) and sideband (U|L) for CH #4
$PCAL_FREQ   <--- section PCAL (phase calibration) frequency
10000.0        <--- PCAL frequency (Hz) for CH #1
10000.0        <--- PCAL frequency (Hz) for CH #2
10000.0        <--- PCAL frequency (Hz) for CH #3
10000.0        <--- PCAL frequency (Hz) for CH #4
$CLOCK          <--- section clock parameters
OFST= 0.000000  <--- clock offset (s)
RATE= 0.000000  <--- clock rate (s/s)
XCOF= 0.000000  <--- clock offset (s) of X station to UTC
$SOURCE     <--- sction radio source name
3C345       <--- radio source name
$RA         <--- section radio source position (right ascension)
16 42 58.80996700   <--- right ascension (hour, minute, second)
$DEC         <--- section radio source position (declination)
39 48 36.99406000  declination (degree, minute, second)
$EPOCH       <--- section epock of radio position
2000.0       <--- epoch (year)
$GHA         <--- section Greenwhich hour angle of radio source
16 3 23.584000    <--- hour angle (hour, minute, second)
$EOP          <--- section earth orientation parameters
UT1-UTC= 0.000000
X_WOBB = 0.000000
Y_WOBB = 0.000000
$START        <--- section scan start time (UTC)
2015002020000       <--- YYYYDDDHHMMSS
```

```
$STOP         <--- section scan stop time (UTC)
2015002020130      <--- YYYYDDDHHMMSS

$APRIORI      <--- section a-prioi values
PRT=2015002020045   <--- PRT(processing reference time) YYYYDDDHHMMSS
TAU0=  -8.744597367101878e-05 <--- a-priori delay (s)
TAU1=  -1.740376052034359e-08 <--- a-priori delay rate (s/s)
TAU2=   7.147465473084870e-13 <--- a-priori delay 2-dots (s/s^2)
TAU3=   9.254412615463208e-17 <--- a-priori delay 3-dots (s/s^3)

$END    <--- end of a-priori file
```

Ex.2 in case of VDIF format data

```
** This is Apriori file made by apri_calc Ver. 2016-09-29
**     for cor, cor_all, fx_cor, and fx_cor_all
**
** SUBNET ON:  PRT is set according to each scan length
**
** Clock parameters at run are as follows,
**   Clock Offset (s) : 0.000000
**   Clock Rate (s/s) : 0.000000
**   Clock Epoch      :     0000/000 00:00:00
**
**
$EXPCODE
KS15002

$OBS_NUMBER
1

$STATION1
KASHIM11 ./R0020001.dat

$FORMAT1    <--- section X station data format
VDIF        <--- set VDIF format

$XYZ-STATION1
-3997505.701700 3276878.404550 3724240.703140

$STATION2
KOGANEI ./G0020001.dat

$FORMAT2    <--- section X station data format
VDIF        <--- set VDIF format

$XYZ-STATION2
-3941937.479090 3368150.907990 3702235.288150

$BASEID
RG

$FRQ_GRP(1-4)
0             <--- '0' mean all channels

$FREQUENCY       * RFfreq U|L <pickup ch# for station1>  <pickup ch# for station2>
7864990000.0 U   <--- RF frequency (Hz) and sideband (U|L) for CH #1 (up to CH #16)
7874990000.0 U
7884990000.0 U
8014990000.0 U
8114990000.0 U
8244990000.0 U
8504990000.0 U
8544990000.0 U
8564990000.0 U
8574990000.0 U
2214990000.0 U
2224990000.0 U
2234990000.0 U
2264990000.0 U
2294990000.0 U
2304990000.0 U   <--- RF frequency (Hz) and sideband (U|L) for CH #16

$PCAL_FREQ
10000.0    <--- PCAL frequency (Hz) for CH #1 (up to CH #16)
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
```

```
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0    <--- PCAL frequency (Hz) for CH #1 (up to CH #16)
$CLOCK
OFST= 0.000000
RATE= 0.000000
XCOF= 0.000000
$SOURCE
3C345
$RA
16 42 58.80996700
$DEC
39 48 36.99406000
$EPOCH
2000.0
$GHA
16 3 23.584000
$EOP
UT1-UTC= 0.000000
X_WOBB = 0.000000
Y_WOBB = 0.000000
$START
2015002020000
$STOP
2015002020130
$APRIORI
PRT=2015002020045
TAU0=  -8.744597367101878e-05
TAU1=  -1.740376052034359e-08
TAU2=   7.147465473084870e-13
TAU3=   9.254412615463208e-17
$END
```

Ex.3 in case of Mark-5B format data

```
** This is Apriori file made by apri_calc Ver. 2016-09-29
**     for cor, cor_all, fx_cor, and fx_cor_all
**
** SUBNET ON:  PRT is set according to each scan length
**
** Clock parameters at run are as follows,
**   Clock Offset (s) : 0.000000
**   Clock Rate (s/s) : 0.000000
**   Clock Epoch      :     0000/000 00:00:00
**
**
$EXPCODE
KS15002
$OBS_NUMBER
1
$STATION1
KASHIM11 ./R0020001.dat
$FORMAT1
M5B 16MHz 16CH 1bit  <--- set Mark-5B format and sampling information
$XYZ-STATION1
-3997505.701700 3276878.404550 3724240.703140
$STATION2
KOGANEI ./G0020001.dat
$FORMAT2
M5B 16MHz 16CH 1bit  <--- set Mark-5B format and sampling information
```

```
$XYZ-STATION2
-3941937.479090 3368150.907990 3702235.288150

$BASEID
RG

$FRQ_GRP(1-4)
0

$FREQUENCY
7864990000.0 U
7874990000.0 U
7884990000.0 U
8014990000.0 U
8114990000.0 U
8244990000.0 U
8504990000.0 U
8544990000.0 U
8564990000.0 U
8574990000.0 U
2214990000.0 U
2224990000.0 U
2234990000.0 U
2264990000.0 U
2294990000.0 U
2304990000.0 U

$PCAL_FREQ
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0

$CLOCK
OFST= 0.000000
RATE= 0.000000
XCOF= 0.000000

$SOURCE
3C345

$RA
16 42 58.80996700

$DEC
39 48 36.99406000

$EPOCH
2000.0

$GHA
16 3 23.584000

$EOP
UT1-UTC= 0.000000
X_WOBB = 0.000000
Y_WOBB = 0.000000

$START
2015002020000

$STOP
2015002020130

$APRIORI
PRT=2015002020045
TAU0=  -8.744597367101878e-05
TAU1=  -1.740376052034359e-08
TAU2=   7.147465473084870e-13
TAU3=   9.254412615463208e-17

$END
```

Ex.4 in case of VSSP format and VDIF format data

```
** This is Apriori file made by apri_calc Ver. 2016-09-29
**     for cor, cor_all, fx_cor, and fx_cor_all
**
** SUBNET ON:  PRT is set according to each scan length
**
** Clock parameters at run are as follows,
**   Clock Offset (s) : 0.000000
**   Clock Rate (s/s) : 0.000000
**   Clock Epoch      :     0000/000 00:00:00
**
**
$EXPCODE
KS15002

$OBS_NUMBER
1

$STATION1
KASHIM11 ./R0020001.dat

$XYZ-STATION1
-3997505.701700 3276878.404550 3724240.703140

$STATION2
KOGANEI ./G0020001.dat

$FORMAT2
VDIF         <--- set VDIF format for Y station (X station is defalut data format VSSP)

$XYZ-STATION2
-3941937.479090 3368150.907990 3702235.288150

$BASEID
RG

$FRQ_GRP(1-4)
3

$FREQUENCY
8564990000.0 U  1  9   <--- RF frequency for X station CH# and Y station CH#
8574990000.0 U  2 10
2214990000.0 U  3 11
2224990000.0 U  4 12

$PCAL_FREQ
10000.0
10000.0
10000.0
10000.0

$CLOCK
OFST= 0.000000
RATE= 0.000000
XCOF= 0.000000

$SOURCE
3C345

$RA
16 42 58.80996700

$DEC
39 48 36.99406000

$EPOCH
2000.0

$GHA
16 3 23.584000

$EOP
UT1-UTC= 0.000000
X_WOBB = 0.000000
Y_WOBB = 0.000000

$START
2015002020000

$STOP
2015002020130

$APRIORI
PRT=2015002020045
TAU0=  -8.744597367101878e-05
TAU1=  -1.740376052034359e-08
TAU2=   7.147465473084870e-13
```

```
TAU3=   9.254412615463208e-17
$END
```

4. A-priori file for special processing

By editing parameter at $FREQUENCY, we can change the number of processing channels, and/or channel allocation between X and Y stations. When the number of channels is changed at $FREQUENCY, the number of channels at $PCAL_FREQ should be changed to keep the number of channels same.

Ex.1 change 16CH data to 6CH data and change CH# of Y station

```
$FREQUENCY
7864990000.0 U 1 6
7874990000.0 U 2 5
7884990000.0 U 3 4
8014990000.0 U 4 3
8114990000.0 U 5 2
8244990000.0 U 6 1
$PCAL_FREQ
10000.0
10000.0
10000.0
10000.0
10000.0
10000.0
```

B K5 software correlator output format (Format 7)

line#	items
1	"#FORMAT7" comments — "#FORMAT7" (fixed letters) + comments (comments are program name and fringe rotation parameters)
	A1∼A5 are inserted when filtering processing is carried out by "fx_cor"
A1	`# BPF parameters` (folowing shows set M-times BPF)
A2(1)	`#   flow(MHz)-fhigh(MHz)  factor : 1.250000-1.450000  1.000000` (1st BPF parameters)
	repeat M times
A2(M)	`#   flow(MHz)-fhigh(MHz)  factor : 1.650000-1.850000  1.000000` (last (M times) BPF parameters)
A3	`#   Adopted frequency resolution (MHz)  = 0.040000`
A4	`#   Output lag size                     = 2048`
A5	`#   FFT size for processing             = 2048`
	line# shown below is that for the case without filtering parameters
2	host name — host PC name
3	experiment code
4	scan# (starting from 1)
5	baseline ID
6	date and time of correlation processing (year totalday hour minute second month day)
7	X station name
8	X station position (x,y,z) (m)
9	X data file name
10	Y station name
11	Y station position (x,y,z) (m)
12	Y data file name
13	radio source name
14	radio source right ascension (hour minute second)
15	radio source declination (degree minute second)
16	epoch of radio source position (year)
17	Greenwhich apparent sidereal time at PRT (processing reference time) (hour minute second)
18	scan start time (year totalday hour minute second)
19	scan stop time (year totalday hour minute second)
20	PRT (year totalday hour minute second)
21	a-priori delay τ (sec) at PRT
22	a-priori delay rate $\dot{\tau}$ (s/s) at PRT
23	a-priori delay 2-dots $\ddot{\tau}$ (s/s^2) at PRT
24	a-priori delay 3-dots $d\ddot{\tau}/dt$ (s/s^3) at PRT
25	clock offset (sec) and , clock error of X station (sec) (Positive value menas Y clock tic earlier than X clock tic) (Positive value menas X clock tic earlier than UTC clock tic)
26	clock rate (s/s)
27	UT1-UTC (sec) Wob X (arcsec) Wob Y (arcsec) — earth orientation parameters
28	# of channels [N]
29	CH-1 RF frequency (Hz), PCAL frequency (Hz), sideband (1:USB, 0:LSB)
	...
.	CH-N RF frequency (Hz), PCAL frequency (Hz), sideband (1:USB, 0:LSB)
29+N	sampling frequency (Hz)
30+N	X station AD resolution (1, 2, 4 or 8) Y station AD resolution (can be omitted)
31+N	unit integration period of PP (parameter period) (sec)
32+N	total integration period (sec)
33+N	# of lags [L]
34+N	total # of PP [K]
35+N	"PP# 1" — PP#1 start of correlation result

36+N	lag#, CH#, real part of correlation data, imaginary part of correlation data
repeat N×L times	
36+N(1+L)	"VALIDITY FLAG, FRACTIONAL BIT and FRINGE PHASE (APRIORI)" — fixed letters
37+N(1+L)	vflag dtime ibit fbit frphase1 [frphase2 frphase3 frphase4 .... frphaseN] where vflag – data validity flag (1: OK, 0: error occurred at the previous PP) dtime – time at BOPP (beginning of PP) (seconds from 0h UTC) ibit – integer delay at BOPP (in unit of sampling period) fbit – fractional portion of delay at BOPP (in unit of sampling period) frphase1 – apriori fringe pahse (deg) at BOPP for ch #1 frphase2 – apriori fringe pahse (deg) at BOPP for ch #2 frphase3 – apriori fringe pahse (deg) at BOPP for ch #3 frphase4 – apriori fringe pahse (deg) at BOPP for ch #4 .... frphaseN – apriori fringe pahse (deg) at BOPP for ch #N
38+N(1+L)	"X-PCAL" — fixed letters to show start of PCAL information for X station
39+N(1+L)	m ns PCALR PCALI AMP PHASE where m – channel # ns – # of samples used for PCAL detection PCALR – real part of PCAL detection PCALI – imaginary part of PCAL detection AMP – PCAL amplitude PHASE – PCAL phase (deg)
repeat N (# of channels) times	
39+N(2+L)	"Y-PCAL" — fixed letters to show start of PCAL information for X station
40+N(2+L)	m ns PCALR PCALI AMP PHASE — PCAL data for Y station
repeat N (# of channels) times	
40+N(3+L)	"PP# 2" — PP#2 start of correlation result
repeat K (total # of PPs) times	
...	

C KSP correlator output format including extension

On the bandwidth processing using "KOMB" software package, COUT type correlation data file whichi is the ouput of K5 software correlator are converted to KSP correlation data at first, then processed by KOMB. The number of lags of the original KSP format is fixed to 32, however it is required to increase the number of lags more than 32 these days. Therefore KSP format is extended to support the large number of lags.

Header portion (HD: 512 bytes) of extended format is almost same as that of the original format, but "F" (meaning FULL) is added as the "CRSMODE". The size of correlation counter is changed from 24 bits to 32 bits for "F" mode. Furthermore add "LAG" for lag size and "ADBIT" for AD resolution.

Correlation data (CD) of each integration period PP (parameter period) consists of correlation data of each channel unit (UD) like the original format, but UD can be extended by 256 bytes according to the lag size. Therefore items in UD were changed largely.

HD 512 bytes	CD	CD	···

Figure C.1. Record structure of KSP correlation data format. HD: header, CD:correlation data by PP.

CD(correlation data by PP)				
UD (1unit)	UD (2unit)	UD (3unit)	···	UD (K unit)

Figure C.2. Record structure in CD by PP. UD:unit (channel) data.

Correlation data by UD (channel)				
UD#0 256 bytes	UD#1 256 bytes	UD#2 256 bytes	···	UD#N 256 bytes

Figure C.3. Record structure in UD (unit data). UD#0 includes time information, and 32-lag correlation data are contained in UD#1 and after. In case of 64-lag data, it finish in UD#2. In case of 1024-lag data, UD# continues upto 32.

C.1 Correlation data format: header record (HD)

Table 1. KSP correlation data format: header record (HD: 512bytes)

symbol	# of bytes	byte position	type	note
EXCODE	10	1	A10	experiment code (A10)
NOBS	2	11	I*2	scan #
LFILE	6	13	A6	correlation file name (A6)
LBASE	2	19	A2	baseline ID (A2)
NPP	2	21	I*2	# of PPs
NPPSEC	2	23	I*2	period of PP unit is sec for FMTFLAG "KSP " and "K4" unit is 10 msec for FMTFLAG "KSP1" unit is 1 msec for FMTFLAG "KSP2"
NKOMB	2	25	I*2	# of KOMB processings
KRDATE	8	27	I*2	correlation processing date and time DIM(4) (year, total day, hour, minute)
KBFILE	6	35	A6	KOMB out file name (set by KOMB)
SRCNAM	8	41	A8	radio source name (A8)
SRCRA	4	49	I*2	DIM(2) right ascension of radio source (α) (hour, minute) J2000
	8	53	R*8	right ascension of radio source (α) (second) J2000
SRCDEC	4	61	I*2	DIM(2) declination of radio source (δ) (degree, minute) J2000
	8	65	R*8	declination of radio source (δ) (second) J2000
IPRT	10	73	I*2	DIM(5) PRT (processing reference time) (almost center of scan length) (year, total day, hour, minute, second)
STATX	8	83	A8	X station name (A8)
STATY	8	91	A8	Y station name (A8)
X_XYZ	24	99	R*8	DIM(3) X station position (X, Y, Z)(m)
Y_XYZ	24	123	R*8	DIM(3) Y station position (X, Y, Z)(m)
OSTART	10	147	I*2	DIM(5) scan start time (year, total day, hour, minute, second)
OSTOP	10	157	I*2	DIM(5) scan stop time (year, total day, hour, minute, second)
SRCGHA	4	167	I*2	DIM(2) Greenwich hour angle of source at PRT (hour, minute)
	8	171	R*8	Greenwich hour angle of source at PRT (second)
TSAMPL	4	179	R*4	sampling period (sec)
VBW	4	183	R*4	video bandwidth (Hz)
NCH	2	187	I*2	# of channel at correlation processing
ACLKO	4	189	R*4	clock offset (sec) at PRT positive value menas Y clock tic earlier than X clock tic
ACLKR	4	193	R*4	clock rate difference at PRT (s/s)
DLYINX	4	197	R*4	instrumental delay difference at X band (sec)
DLYINS	4	201	R*4	instrumental delay difference at S band (sec)
AXCLKE	4	205	R*4	clock error of X station (sec) at PRT. positive value menas X clock tic earlier than UTC clock tic
PI	8	209	R*8	π
C	8	217	R*8	light speed (m/s)
FRQTAB	128	225	R*8	DIM(16) RF frequency table(Hz) +VE: USB, -VE: LSB
PCALF	64	353	R*4	DIM(16) PCAL (phase calibration) frequency table (Hz)

APTAU	32	417	R*8	DIM(4) a-priori values of delay etc. τ(sec),$\dot{\tau}$(s/s),$\ddot{\tau}$(s/s^2), $\dddot{\tau}$(s/s^3)
SRCH	2	449	I*2	common channel # for fringe search mode (1∼16)
CMODE	2	451	A2	KSP hardware correlator mode "NO": normal mode,"SE": fringe search mode
UINT	2	453	I*2	# of lags between units in case of fringe search mode (default is 30)
CUNIT	2	455	I*2	unit # that includes 0 lag in case of fringe search mode
CRLDBL	8	457	R*8	8-byte real value set from KSP control work station (unused)
CRLLNG	4	465	I*4	4-byte integer value set from KSP control work station (unused)
CRLSHT	2	469	I*2	2-byte integer value set from KSP control work station (unused)
FRGMOD	2	471	A2	fringe stopping mode "CO": continuous, "EV": initialize each PP
CRSMODE	1	473	A1	flag of integration counter resolution for correlation and PCAL detection "U": take upper 24 bits from 28-bit counter, "L": take lower 24 bits "H": take upper 24 bits from 32-bit counter "F": take full 32 bits from 32-bit counter
VER	8	474	A8	version of correlator ROM for hardware correlator. in case of CRSMODE="F", set "K5-WIDE "
—	1	482	—	unused
JXOFST	4	483	I*4	delay offsets of X station data in case hardware correlator (in unit of sample)
JYOFST	4	487	I*4	delay offsets of Y station data in case hardware correlator (in unit of sample)
LAG	4	491	I*4	# of lags in case of CRSMODE="F" unused or 32 in case of CRSMODE is not equal to"F"
ADBIT	4	495	I*4	AD resolution (bits)
ADBITY	4	499	I*4	AD resolution of Y station when CORTYPE is set
CORTYPE	2	503	A2	correlator type "Xf" for XF or"Fx" for FX
—	4	505	—	unused
FMTFLAG	4	509	A4	format ID. "KSP ","K4 ","KSP1", "KSP2"

C.2 Correlation data file format (in case of CRSMODE="F"): correlation data by unit (UD)

Format is the same as the original one in case that CRSMODE is not "F".

Table 2. KSP correlation data format (UD#0)(1st 256 bytes)

symbol	# of bytes	byte position	type	note
RMKS	2	1	2BYTE	remarks set by correlator byte #1: KSEL (K value at fringe rotation) byte #2: BIT#(LSB=0) 7-3: channel # (1-16) 2: delete flag set by KOMB 1:delete 1-0: unused
COFLG	1	3	BYTE	correlation flag BIT#(LSB=0) 7-6: sign of fringe rotation 10 ··· negative rotation 00 ··· sign reversal occurred during PP 01 ··· positive rotation 5: mode of fringe rotator 1 ··· carried out by hardware 0 ··· carried out by software 4: fringe stopping reference frequency 1 ··· at center of baseband bandwidth 0 ··· at baseband frequency 3: flag for fractiona bit correction 1 ··· carried out by hardware 0 ··· carried out by software 2: PP parameter update flag 1 ··· updated 0 ··· not updated 1-0: unused
TWESTS	1	4	BYTE	integration status BIT#(LSB=0) 7: AVL integration validity flag 1 ··· valid 0 ··· invalid 6-0: unused
**** items below are changed largely ****				
TIMX	7	5	14×4bits	X station time label: YYDDDHHMMSSmmm (by hexadecimal)
TIMY	7	12	14×4bits	X station time label:YYDDDHHMMSSmmm (by hexadecimal)
TMDIFF	4	19	I*4	offset of X and Y time siries (unit of sample) positive for Y station time is ahead
FRADD	4	23	32bits	fringe rotator address (32 bits) at the end of PP when fringe stopping is carried out, a-priori fringe rotator address at PP.
IFBIT	2	27	I*2	fractional part of delay in the unit of sample at PP. $-32768 \sim 32767$ corresponds to $-0.5 \sim +0.5$.
MODE	1	29	BYTE	versatile mode (unused) BIT#(LSB=0) 7-2: unused 1: 2/1 bit mode

				1 ··· 2-bit correlation (K4 hardware correlator only)
				0 ··· 1-bit correlation
				2: weight mode at 2-bit correlation
				1 ··· Weight mode
				0 ··· Binary binary mode
IPP	2	30	I*2	PP#
PCALD	16	32	I*4	DIM(4) counter value for PCAL detection
				real part for X station (4 bytes)
				imaginary part for X station (4 bytes)
				real part for Y station (4 bytes)
				imaginary part for Y station (4 bytes)
COUNTP	8	48	I*4	DIM(2) total # of samples for PCAL detection (real part 4 bytes, imaginary part 4 bytes)
—	—	56	—	unused

Table 3. KSP correlation data format (UD#1)(256 bytes)

symbol	# of bytes	byte position	type	note
CROSP	4	1	I*4	lag #1 real part of correlation data
	4	5	I*4	lag #2 real part of correlation data
				...
	4	125	I*4	lag #32 real part of correlation data
	4	129	I*4	lag #1 imaginary part of correlation data
	4	133	I*4	lag #2 imaginary part of correlation data
				...
	4	253	I*4	lag #32 imaginary part of correlation data

When the number of lags is larger than 32, UD records are added by 256 bytes (32 lags) as follows.

Table 4. KSP correlation data format (UD#2)(256 bytes)

symbol	# of bytes	byte position	type	note
CROSP	4	1	I*4	lag #33 real part of correlation data
	4	5	I*4	lag #34 real part of correlation data
				...
	4	125	I*4	lag #64 real part of correlation data
	4	129	I*4	lag #33 imaginary part of correlation data
	4	133	I*4	lag #34 imaginary part of correlation data
				...
	4	253	I*4	lag #64 imaginary part of correlation data

Table 5. KSP correlation data format (UD#N)(256 bytes)

symbol	# of bytes	byte position	type	note
CROSP	4	1	I*4	lag #$32 \times (N-1)+1$ real part of correlation data
	4	5	I*4	imaginary part
	4	9	I*4	lag # $32 \times (N-1)+2$ real part of correlation data
	4	13	I*4	imaginary part
				. . .
	4	249	I*4	lag # $32 \times N64$ real part of correlation data
	4	253	I*4	imaginary part

C.3 Correlation data file format (in case that CRSMODE is not "F"): correlation data by unit (UD)

Table 6. KSP correlation data format (UD)(256 bytes

symbol	# of bytes	byte position	type	note
RMKS	2	1	2BYTE	remarks set by correlator byte #1: KSEL (K value at fringe rotation) byte #2: BIT#(LSB=0) 7-3: channel # (1-16) 2: delete flag set by KOMB 1:delete 1-0: unused
COFLG	1	3	BYTE	correlation flag BIT#(LSB=0) 7-6: sign of fringe rotation 10 ··· negative rotation 00 ··· sign reversal occurred during PP 01 ··· positive rotation 5: mode of fringe rotator 1 ··· carried out by hardware 0 ··· carried out by software 4: fringe stopping reference frequency 1 ··· at center of baseband bandwidth 0 ··· at baseband frequency 3: flag for fractiona bit correction 1 ··· carried out by hardware 0 ··· carried out by software 2: PP parameter update flag 1 ··· updated 0 ··· not updated 1-0: unused
TWESTS	1	4	BYTE	integration status BIT#(LSB=0) 7: AVL integration validity flag 1 ··· valid 0 ··· invalid 6-0: unused
CROSP	192	5	I*3	DIM(64) correlation data (reset every PP) (real part 3 bytes × 32 lags, imaginary part 3 bytes × 32 lags) according to CRSMODE in HD "L": take lower 24 bits from 28-bit counter, "U": take upper 24 bits "H": take 24 bits from 32-bit counter
COUNTP	8	197	I*4	DIM(2) # of samples for correlation (real part 4 bytes, imaginary part 4 bytes)
PCALD	12	205	I*3	DIM(4) PCAL detection counter (reset every PP) real part (3 bytes) for X station imaginary part (3 bytes) for X station real part (3 bytes) for Y station imaginary part (3 bytes) for Y station according to CRSMODE in HD "L": take lower 24 bits from 28-bit counter, "U": take upper 24 bits "H": take 24 bits from 32-bit counter

TIMX	7	217	14×4bits	X station time label: YYDDDHHMMSSmmm (by hexadecimal)
TIMY	7	224	14×4bits	X station time label: YYDDDHHMMSSmmm (by hexadecimal)
TMDIFF	4	231	I*4	offset of X and Y time siries (unit of sample) positive for Y station time is ahead
FRADD	4	235	32bits	fringe rotator address (32 bits) at the end of PP when fringe stopping is carried out, a-priori fringe rotator address at PP.
IFBIT	2	239	I*2	fractional part of delay in the unit of sample at PP. $-32768 \sim 32767$ corresponds to $-0.5 \sim +0.5$.
MODE	1	241	BYTE	versatile mode (unused) BIT#(LSB=0) 7-2: unused 1: 2/1 bit mode 1 ··· 2-bit correlation (K4 hardware correlator only) 0 ··· 1-bit correlation 2: weight mode at 2-bit correlation 1 ··· Weight mode 0 ··· Binary binary mode
IPP	2	242	I*2	PP#
—	13	244	—	unused

D VLBI data format

D.1 Type of data format

There are two types of VLBI data. One is that consisting of frame data (Type-1), the other is non-frame data (Type-2). The former is further devided into two types Type-1A and 1B. In case of Type-1A, a part of the data portion is substituted by the header, i.e., sampled data are lost at the header portion, while in case of Type-1B, the header is inserted in he data, so that any sampled data are lost (Fig.D.1). When VLBI technique was realized, data wer only the Type-1A format (Mark-III, Mark-IV, K-3). However, Type-1B (VLBA, Mark-5B, VDIF, K5/VSSP, VSSP32/64, ADS/DBBC mode) is nowadays used commonly. Type-2 format (OCTAD, ADS/raw mode) is also used in some samplers.

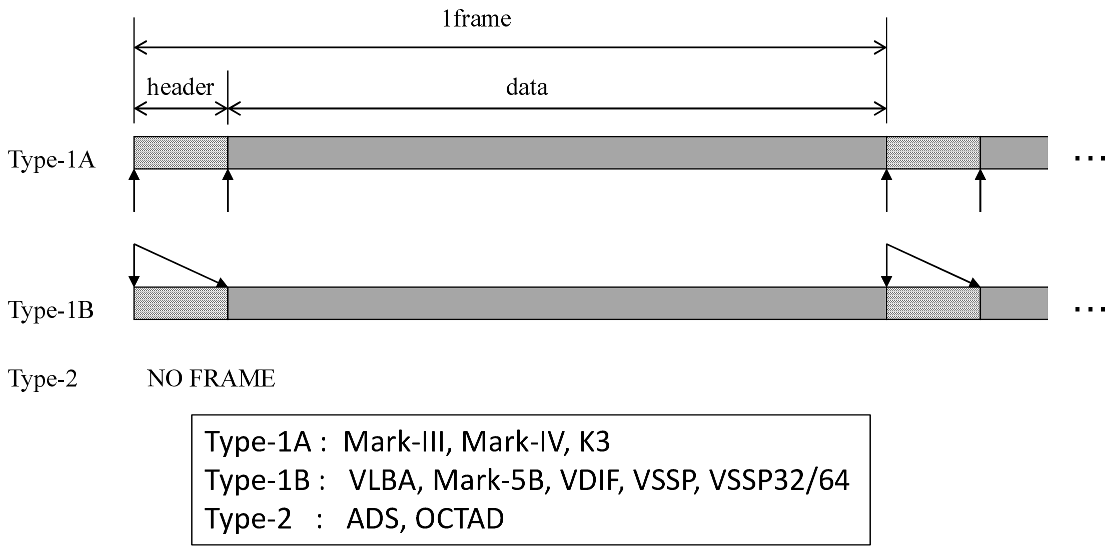

Figure D.1. Type of VLBI data structures

Table D.1 shows the comparison of data formats.

Table D.1. Comparison of data formats

	Frame length (bytes)	Header length (bytes)	Data (bytes)
Mark-III/IV, K3	2500	20	2480
VLBA	2520	20	2500
Mark-5B	10016	16	10000
VDIF	variable	32	variable
VSSP	1 frame/sec	8	variable
VSSP32/64	1 frame/sec	32	variable

Among these formats, VSSP format (including K5/VSSP32, K5/VSSP64) specified NICT, Mark-5B, and VDIF are described in sub-sections below.

D.2 K5/VSSP, VSSP32 and VSSP64 format

D.2.1 Data structure

K5/VSSP, K5/VSSP32, and K5/VSSP64 sampler output is made up of multiple frames, which consist of a header and a data block (Fig.D.2). A header block of VSSP consists of 8-byte data which contain two sync blocks, time information, and sampling parameters. A header block of VSSP32 usually consists of 32-byte data, of which first 8-byte data are as same as that of VSSP excepting the second sync pattern. A rest of header block contains year, date, and user definable auxiliary field. (When VSSP64 sampler operates with a VSSP32 mode, the header block is as same as that of VSSP32. When VSSP64 operates as its native mode, the second sync pattern differs.) A header block doesn't affect a data block, i.e., no data are lost by the insertion of the header blcok.

The size of a data block can be expressed by [sampling frequency (Hz)]×[# of AD bits]×[# of channels], however actual size is limitted by the maximum data rate between a sampler and host PC. In case of VSSP, which adopts PCI-bus interface, 64 Mbits/sec is maximum data transfer speed. As for VSSP32, which adopts USB-2.0 interface, the maximum data speed is 256 Mbits/sec. As for VSSP64, which adopts USB-3.0 interface, the practical maximum data speed is 1024 Mbits/sec.

Header (HD)	Sampled Data (SD)	Header (HD)	· · ·

| < − − − − − − − −   1 sec   − − − − − − − − > | < − − − − − − − −   · · ·

Figure D.2. Data structure of K5/VSSP, K5/VSSP32, or K5/VSSP64 sampler output.

D.2.2 VSSP header format

Fig.D.3 shows VSSP header format. It consists of 8 byte data.

bit	31–24	23–22	21–18	17	16–0
W0	Sync Pattern : '0xFFFFFFFF'				
W1	2nd Sync Pattern '0x8B'	AD	SFREQ	CH	seconds from 0h UTC (17bits)

AD: AD bits Index 0: 1bit, 1: 2bits, 2: 4bits, 3: 8bits
SFREQ: Sampling frequency Index (Note: sampling frequency larger than 32MHz MHz is for format conversion)
0: 40kHz, 1: 100kHz, 2: 200kHz, 3: 500kHz, 4: 1MHz, 5: 2MHz, 6: 4MHz, 7: 8MHz, 8: 16MHz, 9: 32MHz,
10: 64MHz, 11: 128MHz, 12: 256MHz, 13: 512MHz, 14: 1024MHz, 15: 2048MHz
CH: number of channels 0: 1channel, 1: 4channels

Figure D.3. VSSP header format (8 bytes)

where

sync pattern	–	0xFFFFFFFF
2nd sync pattern	–	0x8B (0x8C for VSSP32, 0x8D for VSSP64)
AD	–	number of AD resolution bits 0: 1 bit / 1: 2 bits / 2: 4 bits / 3: 8 bits
SFREQ	–	index for sampling frequency (Note: sampling frequencies faster than and equal to 32 MHz are for supporting data converted from other format data) 0: 40kHz / 1: 100kHz / 2: 200kHz / 3: 500kHz 4: 1MHz / 5: 2MHz /6: 4MHz / 7: 8MHz / 8: 16MHz 9: 32MHz / 10: 64MHz / 11: 128MHz / 12: 256MHz / 13: 512MHz 14: 1024MHz / 15: 2048MHz
CH	–	number of channels used 0: 1ch 1: 4ch
time	–	seconds from 00h00m00s (0∼86399)

D.2.3 VSSP32 and V SSP64 header format (general specifications)

Fig.D.4 shows the specifications of VSSP32 and VSSP64 data header. All current K5 utilities adopt 20 bytes for the size of auxiliary field, so that total size of header is 32 bytes.

<table>
<tr><td>bit</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>W0</td><td colspan="32">Sync Pattern : '0xFFFFFFFF'</td></tr>
<tr><td>W1</td><td colspan="8">2nd Sync Pattern '0x8C'
'0x8D' for VSSP64 mode</td><td colspan="2">AD</td><td colspan="4">SFREQ</td><td>CH</td><td colspan="17">seconds from 0h UTC (17bits)</td></tr>
<tr><td>W2</td><td colspan="4">major version
#</td><td colspan="4">minor version
#</td><td colspan="8">AUX FIELD size (bytes)
(8 bits) (default=20)</td><td>EF
ch</td><td colspan="6">year (2 digits) (6 bits)</td><td colspan="9">total day (9 bits)</td></tr>
<tr><td>W3</td><td colspan="24" rowspan="5">AUX FIELD (user definable)</td><td colspan="8">AUX FIELD Format #</td></tr>
<tr><td>W4</td><td colspan="8" rowspan="4"></td></tr>
<tr><td>W5</td></tr>
<tr><td>W6</td></tr>
<tr><td>W7</td></tr>
</table>

AD: AD bits Index 0: 1bit, 1: 2bits, 2: 4bits, 3: 8bits
SFREQ: Sampling frequency Index (Note: maximum is 64MHz for VSSP32, 128MHz for VSSP64.
sampling frequency larger than 128MHz MHz is for format conversion)
0: 40kHz, 1: 100kHz, 2: 200kHz, 3: 500kHz, 4: 1MHz, 5: 2MHz, 6: 4MHz, 7: 8MHz, 8: 16MHz, 9: 32MHz,
10: 64MHz, 11: 128MHz, 12: 256MHz, 13: 512MHz, 14: 1024MHz, 15: 2048MHz
CH: number of channels 0: 1channel, 1: 4channels
EF: error flag 1: error occurred in the just before frame
ch: 2ch flag for VSSP64 mode 1: 2ch, 0: follow CH flag

Figure D.4. General specifications of VSSP32 and VSSP64 data header.

where

sync pattern	–	0xFFFFFFFF
2nd sync pattern	–	0x8B (0x8C for VSSP32, 0x8D for VSSP64)
AD	–	number of AD resolution bits 0: 1 bit / 1: 2 bits / 2: 4 bits / 3: 8 bits
SFREQ	–	index for sampling frequency (Note: sampling frequencies faster than and equal to 32 MHz are for supporting data converted from other format data) 0: 40kHz / 1: 100kHz / 2: 200kHz / 3: 500kHz 4: 1MHz / 5: 2MHz /6: 4MHz / 7: 8MHz / 8: 16MHz 9: 32MHz / 10: 64MHz / 11: 128MHz / 12: 256MHz / 13: 512MHz 14: 1024MHz / 15: 2048MHz
CH	–	number of channels used 0: 1ch 1: 4ch if '1' is set at EF in case of VSSP64 mode, # of channels is 2
time	–	seconds from 00h00m00s (0∼86399)
major version #	–	major version # of VSSP32 control ROM
minor version #	–	minor version # of VSSP32 control ROM
AUX FIELD size	–	size of auxiliary field (bytes)
EF	–	error flag (set when error occurred in a previous frame) in case of VSSP64, '1' means 2-ch mode
year	–	lower 2 digits of year
total day	–	day of year
AUX FIELD Format #	–	format # of auxiliary field
format #		

User can define the portion of "AUX FIELD" freely except for the first byte of auxiliary field, which is defined as the format number. When user defines a new format, confliction with the format number, that is predefined or reserved, should be avoid.

D.2.4 Predefined and reserved format numbers

Table.D.4 summarizes predefined and reserved format numbers for auxiliary field.

Table D.4. Predefined and reserved format numbers

Format #	Note
0	for test
1	for observation ("autoobs" output data format)
2	for observation ("sampling" output data format)
30∼39	reserved (for ISAS group)
85	for test
170	for test
21	extended format No.1 (to support arbitrary sampling frequency and channels up to 16)
22	extended format No.2 (to support arbitrary sampling frequency, # of AD bits, and channels)

Predefined format numbers are 0, 1, 2, 85, 170, 21, and 22. Numbers 30∼39 are reserved for ISAS group. Format #21 and #22 are defined to support arbitrary sampling frequency and channels up to 16 (arbitrary # of AD bits for #22). This format allows to conbine multiple sampler output. It is also possible to convert data obtained by a sampler other than VSSP-type sampler to VSSP32 format data.

Format #0

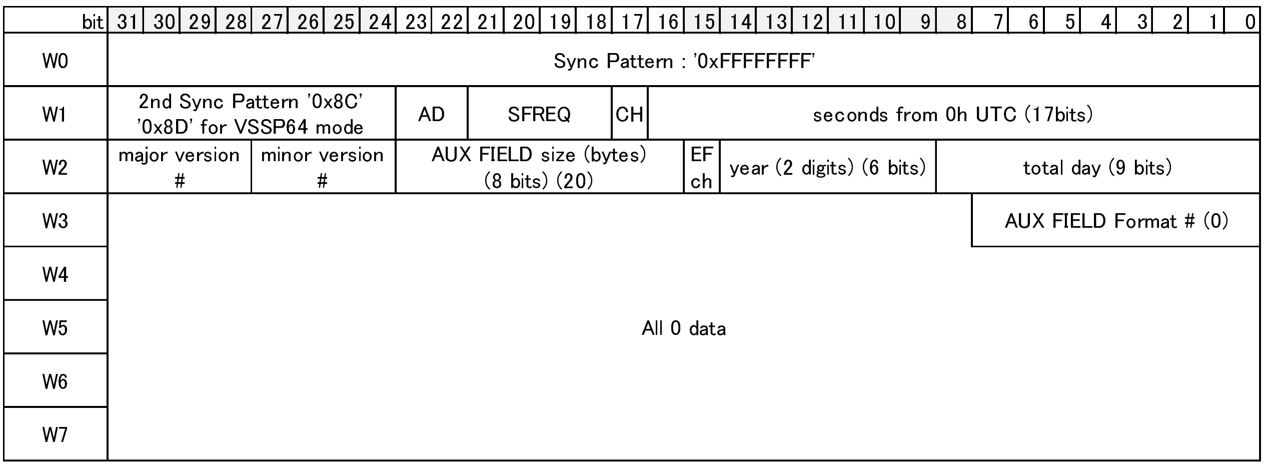

Figure D.5. VSSP32 format #0

Format #1

This is “autoobs” output data format.

<table>
<tr><td>bit</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>W0</td><td colspan="32">Sync Pattern : '0xFFFFFFFF'</td></tr>
<tr><td>W1</td><td colspan="8">2nd Sync Pattern '0x8C'
'0x8D' for VSSP64 mode</td><td colspan="2">AD</td><td colspan="4">SFREQ</td><td>CH</td><td colspan="17">seconds from 0h UTC (17bits)</td></tr>
<tr><td>W2</td><td colspan="4">major version
#</td><td colspan="4">minor version
#</td><td colspan="8">AUX FIELD size (bytes)
(8 bits) (20)</td><td>EF
ch</td><td colspan="6">year (2 digits) (6 bits)</td><td colspan="9">total day (9 bits)</td></tr>
<tr><td>W3</td><td colspan="16">Station ID (max 2 characters)</td><td colspan="8">LPF frequency (MHz)
0 means through</td><td colspan="8">AUX FIELD Format # (1)</td></tr>
<tr><td>W4</td><td colspan="32" rowspan="2">Station name (max 8 charcters)</td></tr>
<tr><td>W5</td></tr>
<tr><td>W6</td><td colspan="32" rowspan="2">PC host name (max 8 charcters)</td></tr>
<tr><td>W7</td></tr>
</table>

Figure D.6. VSSP32 format #1

Format #2

This is “sampling” output data format.

<table>
<tr><td>bit</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>W0</td><td colspan="32">Sync Pattern : '0xFFFFFFFF'</td></tr>
<tr><td>W1</td><td colspan="8">2nd Sync Pattern '0x8C'
'0x8D' for VSSP64 mode</td><td colspan="2">AD</td><td colspan="4">SFREQ</td><td>CH</td><td colspan="17">seconds from 0h UTC (17bits)</td></tr>
<tr><td>W2</td><td colspan="4">major version
#</td><td colspan="4">minor version
#</td><td colspan="8">AUX FIELD size (bytes)
(8 bits) (20)</td><td>EF
ch</td><td colspan="6">year (2 digits) (6 bits)</td><td colspan="9">total day (9 bits)</td></tr>
<tr><td>W3</td><td colspan="16">filler data '0x5555'</td><td colspan="8">LPF frequency (MHz)
0 means through</td><td colspan="8">AUX FIELD Format # (2)</td></tr>
<tr><td>W4</td><td colspan="32">filler data '0x55555555'</td></tr>
<tr><td>W5</td><td colspan="32">filler data '0x55555555'</td></tr>
<tr><td>W6</td><td colspan="32" rowspan="2">PC host name (max 8 charcters)</td></tr>
<tr><td>W7</td></tr>
</table>

Figure D.7. VSSP32 format #2

Format #85

<table>
<tr><td>bit</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>W0</td><td colspan="32">Sync Pattern : '0xFFFFFFFF'</td></tr>
<tr><td>W1</td><td colspan="8">2nd Sync Pattern '0x8C'
'0x8D' for VSSP64 mode</td><td colspan="2">AD</td><td colspan="4">SFREQ</td><td>CH</td><td colspan="17">seconds from 0h UTC (17bits)</td></tr>
<tr><td>W2</td><td colspan="4">major version
#</td><td colspan="4">minor version
#</td><td colspan="8">AUX FIELD size (bytes)
(8 bits) (20)</td><td>EF
ch</td><td colspan="6">year (2 digits) (6 bits)</td><td colspan="9">total day (9 bits)</td></tr>
<tr><td>W3</td><td colspan="16">filler data '0x5555'</td><td colspan="8">LPF frequency (MHz)
0 means through</td><td colspan="8">AUX FIELD Format # (85)
(85=0x55)</td></tr>
<tr><td>W4</td><td colspan="32">filler data '0x55555555'</td></tr>
<tr><td>W5</td><td colspan="32">filler data '0x55555555'</td></tr>
<tr><td>W6</td><td colspan="32">filler data '0x55555555'</td></tr>
<tr><td>W7</td><td colspan="32">filler data '0x55555555'</td></tr>
</table>

Figure D.8. VSSP32 format #85

Format #170

<table>
<tr><td>bit</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>W0</td><td colspan="32">Sync Pattern : '0xFFFFFFFF'</td></tr>
<tr><td>W1</td><td colspan="8">2nd Sync Pattern '0x8C'
'0x8D' for VSSP64 mode</td><td colspan="2">AD</td><td colspan="4">SFREQ</td><td>CH</td><td colspan="17">seconds from 0h UTC (17bits)</td></tr>
<tr><td>W2</td><td colspan="4">major version
#</td><td colspan="4">minor version
#</td><td colspan="8">AUX FIELD size (bytes)
(8 bits) (20)</td><td>EF
ch</td><td colspan="6">year (2 digits) (6 bits)</td><td colspan="9">total day (9 bits)</td></tr>
<tr><td>W3</td><td colspan="16">filler data '0xAAAA'</td><td colspan="8">LPF frequency (MHz)
0 means through</td><td colspan="8">AUX FIELD Format # (170)
(170=0xAA)</td></tr>
<tr><td>W4</td><td colspan="32">filler data '0xAAAAAAAA'</td></tr>
<tr><td>W5</td><td colspan="32">filler data '0xAAAAAAAA'</td></tr>
<tr><td>W6</td><td colspan="32">filler data '0xAAAAAAAA'</td></tr>
<tr><td>W7</td><td colspan="32">filler data '0xAAAAAAAA'</td></tr>
</table>

Figure D.9. VSSP32 format #170

Format #21 (extended format No.1)

This format supports arbitrary sampling frequency and channels up to 16. Smapling frequency and # of channels are newly defined in the AUX field

<table>
<tr><td>bit</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>W0</td><td colspan="32">Sync Pattern : '0xFFFFFFFF'</td></tr>
<tr><td>W1</td><td colspan="8">2nd Sync Pattern '0x8C'
'0x8D' for VSSP64 mode</td><td colspan="2">AD</td><td colspan="4">SFREQ *1</td><td colspan="1">--</td><td colspan="17">seconds from 0h UTC (17bits)</td></tr>
<tr><td>W2</td><td colspan="4">major version
#</td><td colspan="4">minor version
#</td><td colspan="8">AUX FIELD size (bytes)
(8 bits) (20)</td><td colspan="7">year (2 digits) (7 bits)</td><td colspan="9">total day (9 bits)</td></tr>
<tr><td>W3</td><td colspan="13">sampling frequency (MHz: 13 bits) *2</td><td colspan="3"># of CH
(2^n)</td><td colspan="8">LPF frequency (MHz)
0 means through</td><td colspan="8">AUX FIELD Format # (21)</td></tr>
<tr><td>W4</td><td colspan="32" rowspan="4">any data (or 16 characters)</td></tr>
<tr><td>W5</td></tr>
<tr><td>W6</td></tr>
<tr><td>W7</td></tr>
</table>

*1: this is effective only when sampling frequency in AUX field is set to 0.
*2: when 0 is set here, SFREQ becomes valid
*3: the number of channels is expresed by 2^n where 'n' is set to this field

Figure D.10. VSSP32 format #21

where # of channels are defined by n, then # of channels is given by 2^n. n is 0,1,2,3,4, so that maximum # of channels is 16. Sampling frequency (MHz) in the AUX field is specified by 13-bit integer.

Format #22 (extended format No.2)

This format supports arbitrary sampling frequency, arbitrary # of channels, and arbitrary # of AD bits. They are newly defined in the AUX field.

<table>
<tr><td>bit</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>W0</td><td colspan="32">Sync Pattern : '0xFFFFFFFF'</td></tr>
<tr><td>W1</td><td colspan="8">2nd Sync Pattern '0x8C'
'0x8D' for VSSP64 mode</td><td colspan="7">not used</td><td colspan="17">seconds from 0h UTC (17bits)</td></tr>
<tr><td>W2</td><td colspan="4">major version
#</td><td colspan="4">minor version
#</td><td colspan="8">AUX FIELD size (bytes)
(8 bits) (20)</td><td colspan="7">year (2 digits) (7 bits)</td><td colspan="9">total day (9 bits)</td></tr>
<tr><td>W3</td><td colspan="16">sampling frequency (positive: MHz, negative: kHz) *1</td><td colspan="8">LPF frequency (MHz)
0 means through</td><td colspan="8">AUX FIELD Format # (22)</td></tr>
<tr><td>W4</td><td colspan="16" rowspan="4">any data (or 14 characters)</td><td colspan="8">AD bits</td><td colspan="8"># of channels</td></tr>
<tr><td>W5</td><td colspan="16" rowspan="3"></td></tr>
<tr><td>W6</td></tr>
<tr><td>W7</td></tr>
</table>

*1 : 16-bit signed integer

Figure D.11. VSSP32 format #22

D.2.5 VSSP data block

Sampled data output from the VSSP or VSSP32 sampler consists of 4-byte (32-bit) unit. Figs.D.12 and D.13 show the relation among bit position, sample number, and channel number in a 32-bit unit.

<table>
<tr><td colspan="2">bit position</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>1ch x 1bit</td><td>sample #</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>1ch x 2bit</td><td>sample #</td><td colspan="2">15</td><td colspan="2">14</td><td colspan="2">13</td><td colspan="2">12</td><td colspan="2">11</td><td colspan="2">10</td><td colspan="2">9</td><td colspan="2">8</td><td colspan="2">7</td><td colspan="2">6</td><td colspan="2">5</td><td colspan="2">4</td><td colspan="2">3</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">0</td></tr>
<tr><td>1ch x 4bit</td><td>sample #</td><td colspan="4">7</td><td colspan="4">6</td><td colspan="4">5</td><td colspan="4">4</td><td colspan="4">3</td><td colspan="4">2</td><td colspan="4">1</td><td colspan="4">0</td></tr>
<tr><td>1ch x 8bit</td><td>sample #</td><td colspan="8">3</td><td colspan="8">2</td><td colspan="8">1</td><td colspan="8">0</td></tr>
</table>

Figure D.12. Data block format for 1-ch mode.

<table>
<tr><td colspan="2">bit position</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">4ch x 1bit</td><td>ch #</td><td>4</td><td>3</td><td>2</td><td>1</td><td>4</td><td>3</td><td>2</td><td>1</td><td>4</td><td>3</td><td>2</td><td>1</td><td>4</td><td>3</td><td>2</td><td>1</td><td>4</td><td>3</td><td>2</td><td>1</td><td>4</td><td>3</td><td>2</td><td>1</td><td>4</td><td>3</td><td>2</td><td>1</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td>sample #</td><td colspan="4">7</td><td colspan="4">6</td><td colspan="4">5</td><td colspan="4">4</td><td colspan="4">3</td><td colspan="4">2</td><td colspan="4">1</td><td colspan="4">0</td></tr>
<tr><td rowspan="2">4ch x 2bit</td><td>ch #</td><td colspan="2">4</td><td colspan="2">3</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">4</td><td colspan="2">3</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">4</td><td colspan="2">3</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">4</td><td colspan="2">3</td><td colspan="2">2</td><td colspan="2">1</td></tr>
<tr><td>sample #</td><td colspan="8">3</td><td colspan="8">2</td><td colspan="8">1</td><td colspan="8">0</td></tr>
<tr><td rowspan="2">4ch x 4bit</td><td>ch #</td><td colspan="4">4</td><td colspan="4">3</td><td colspan="4">2</td><td colspan="4">1</td><td colspan="4">4</td><td colspan="4">3</td><td colspan="4">2</td><td colspan="4">1</td></tr>
<tr><td>sample #</td><td colspan="16">1</td><td colspan="16">0</td></tr>
<tr><td rowspan="2">4ch x 8bit</td><td>ch #</td><td colspan="8">4</td><td colspan="8">3</td><td colspan="8">2</td><td colspan="8">1</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
</table>

Figure D.13. Data format for 4-ch mode

D.2.6 Data block format for Format #21 and #22 (extended format)

Format #21 (extended format) supports 2, 8, and 16-ch mode besides 1 and 4-ch mode as shown in Figs.D.14, D.15, and D.16. As for 8-ch mode and 8-bit AD, 8 bytes (64 bits) are required for 1 sample data at a time. As for 16-ch mode, 8 bytes (64 bits) are required for 4-bit AD and 16 bytes (128 bits) for 8-bit AD for 1 sample data.

Format #22 (extended format) supports arbitrary sampling frequency, arbitrary # of channels, and arbitrary # of AD bits.

<table>
<tr><td></td><td>bit position</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">2ch x 1bit</td><td>ch #</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td></tr>
<tr><td>sample #</td><td colspan="2">15</td><td colspan="2">14</td><td colspan="2">13</td><td colspan="2">12</td><td colspan="2">11</td><td colspan="2">10</td><td colspan="2">9</td><td colspan="2">8</td><td colspan="2">7</td><td colspan="2">6</td><td colspan="2">5</td><td colspan="2">4</td><td colspan="2">3</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">0</td></tr>
<tr><td rowspan="2">2ch x 2bit</td><td>ch #</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">1</td></tr>
<tr><td>sample #</td><td colspan="4">7</td><td colspan="4">6</td><td colspan="4">5</td><td colspan="4">4</td><td colspan="4">3</td><td colspan="4">2</td><td colspan="4">1</td><td colspan="4">0</td></tr>
<tr><td rowspan="2">2ch x 4bit</td><td>ch #</td><td colspan="4">2</td><td colspan="4">1</td><td colspan="4">2</td><td colspan="4">1</td><td colspan="4">2</td><td colspan="4">1</td><td colspan="4">2</td><td colspan="4">1</td></tr>
<tr><td>sample #</td><td colspan="8">3</td><td colspan="8">2</td><td colspan="8">1</td><td colspan="8">0</td></tr>
<tr><td rowspan="2">2ch x 8bit</td><td>ch #</td><td colspan="8">2</td><td colspan="8">1</td><td colspan="8">2</td><td colspan="8">1</td></tr>
<tr><td>sample #</td><td colspan="16">1</td><td colspan="16">0</td></tr>
</table>

Figure D.14. Extended data format for 2-ch mode.

<table>
<tr><td></td><td>bit position</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">8ch x 1bit</td><td>ch #</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td>sample #</td><td colspan="8">3</td><td colspan="8">2</td><td colspan="8">1</td><td colspan="8">0</td></tr>
<tr><td rowspan="2">8ch x 2bit</td><td>ch #</td><td colspan="2">8</td><td colspan="2">7</td><td colspan="2">6</td><td colspan="2">5</td><td colspan="2">4</td><td colspan="2">3</td><td colspan="2">2</td><td colspan="2">1</td><td colspan="2">8</td><td colspan="2">7</td><td colspan="2">6</td><td colspan="2">5</td><td colspan="2">4</td><td colspan="2">3</td><td colspan="2">2</td><td colspan="2">1</td></tr>
<tr><td>sample #</td><td colspan="16">1</td><td colspan="16">0</td></tr>
<tr><td rowspan="2">8ch x 4bit</td><td>ch #</td><td colspan="4">8</td><td colspan="4">7</td><td colspan="4">6</td><td colspan="4">5</td><td colspan="4">4</td><td colspan="4">3</td><td colspan="4">2</td><td colspan="4">1</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
<tr><td rowspan="5">8ch x 8bit</td><td>ch #</td><td colspan="8">4</td><td colspan="8">3</td><td colspan="8">2</td><td colspan="8">1</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
<tr><td>bit position</td><td>63</td><td>62</td><td>61</td><td>60</td><td>59</td><td>58</td><td>57</td><td>56</td><td>55</td><td>54</td><td>53</td><td>52</td><td>51</td><td>50</td><td>49</td><td>48</td><td>47</td><td>46</td><td>45</td><td>44</td><td>43</td><td>42</td><td>41</td><td>40</td><td>39</td><td>38</td><td>37</td><td>36</td><td>35</td><td>34</td><td>33</td><td>32</td></tr>
<tr><td>ch #</td><td colspan="8">8</td><td colspan="8">7</td><td colspan="8">6</td><td colspan="8">5</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
</table>

Figure D.15. Extended data format for 8-ch mode.

<table>
<tr><td></td><td>bit position</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">16ch x 1bit</td><td>ch #</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td>sample #</td><td colspan="16">1</td><td colspan="16">0</td></tr>
<tr><td rowspan="2">16ch x 2bit</td><td>ch #</td><td colspan="2">16</td><td colspan="2">15</td><td colspan="2">14</td><td colspan="2">13</td><td colspan="2">12</td><td colspan="2">11</td><td colspan="2">10</td><td colspan="2">9</td><td colspan="2">8</td><td colspan="2">7</td><td colspan="2">6</td><td colspan="2">5</td><td colspan="2">4</td><td colspan="2">3</td><td colspan="2">2</td><td colspan="2">1</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
<tr><td rowspan="5">16ch x 4bit</td><td>ch #</td><td colspan="4">8</td><td colspan="4">7</td><td colspan="4">6</td><td colspan="4">5</td><td colspan="4">4</td><td colspan="4">3</td><td colspan="4">2</td><td colspan="4">1</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
<tr><td>bit position</td><td>63</td><td>62</td><td>61</td><td>60</td><td>59</td><td>58</td><td>57</td><td>56</td><td>55</td><td>54</td><td>53</td><td>52</td><td>51</td><td>50</td><td>49</td><td>48</td><td>47</td><td>46</td><td>45</td><td>44</td><td>43</td><td>42</td><td>41</td><td>40</td><td>39</td><td>38</td><td>37</td><td>36</td><td>35</td><td>34</td><td>33</td><td>32</td></tr>
<tr><td>ch #</td><td colspan="4">16</td><td colspan="4">15</td><td colspan="4">14</td><td colspan="4">13</td><td colspan="4">12</td><td colspan="4">11</td><td colspan="4">10</td><td colspan="4">9</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
<tr><td rowspan="12">16ch x 8bit</td><td>bit position</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>ch #</td><td colspan="8">4</td><td colspan="8">3</td><td colspan="8">2</td><td colspan="8">1</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
<tr><td>bit position</td><td>63</td><td>62</td><td>61</td><td>60</td><td>59</td><td>58</td><td>57</td><td>56</td><td>55</td><td>54</td><td>53</td><td>52</td><td>51</td><td>50</td><td>49</td><td>48</td><td>47</td><td>46</td><td>45</td><td>44</td><td>43</td><td>42</td><td>41</td><td>40</td><td>39</td><td>38</td><td>37</td><td>36</td><td>35</td><td>34</td><td>33</td><td>32</td></tr>
<tr><td>ch #</td><td colspan="8">8</td><td colspan="8">7</td><td colspan="8">6</td><td colspan="8">5</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
<tr><td>bit position</td><td>95</td><td>94</td><td>93</td><td>92</td><td>91</td><td>90</td><td>89</td><td>88</td><td>87</td><td>86</td><td>85</td><td>84</td><td>83</td><td>82</td><td>81</td><td>80</td><td>79</td><td>78</td><td>77</td><td>76</td><td>75</td><td>74</td><td>73</td><td>72</td><td>71</td><td>70</td><td>69</td><td>68</td><td>67</td><td>66</td><td>65</td><td>64</td></tr>
<tr><td>ch #</td><td colspan="8">12</td><td colspan="8">11</td><td colspan="8">10</td><td colspan="8">9</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
<tr><td>bit position</td><td>127</td><td>126</td><td>125</td><td>124</td><td>123</td><td>122</td><td>121</td><td>120</td><td>119</td><td>118</td><td>117</td><td>116</td><td>115</td><td>114</td><td>113</td><td>112</td><td>111</td><td>110</td><td>109</td><td>108</td><td>107</td><td>106</td><td>105</td><td>104</td><td>103</td><td>102</td><td>101</td><td>100</td><td>99</td><td>98</td><td>97</td><td>96</td></tr>
<tr><td>ch #</td><td colspan="8">16</td><td colspan="8">15</td><td colspan="8">14</td><td colspan="8">13</td></tr>
<tr><td>sample #</td><td colspan="32">0</td></tr>
</table>

Figure D.16. Extended data format for 16-ch mode.

The size of data block should be an integer multiple of a 4-byte (32-bit) unit. In case when a fractional figure occurs, a rest of data block is filled by '0'. How to define the size of data block is as follows. The size of data sampled in 1 sec can be caclculated as

$$B = F \cdot A \cdot N \quad \text{[bits]}$$

where F, A, and N are sampling frequency (Hz), the number of AD bits, and the number of channels, respectevely. If $B/32$ has a fractional part (not an integer), thse size of data block is defined as follows,

$$S = (int(B/32) + 1) \times 32 \quad \text{[bits]}$$

when int is a function which returns the integer part of a specified number. Then a rest of data block starting from $B + 1$ bits is filled out by '0'. If $B/32$ is an integer, S is set to be B.

D.3 Mark5B data format

D.3.1 Data structure

Mark5B data consist of multiple frames. A frame of data consists of a header (16 bytes) and a data block (10000 bytes).

Header (16 bytes)	Data block (10000 bytes)	Header (16 bytes)	⋯

$|< - - - - - - - -$ frame $- - - - - - - - >|< - - - - - - - -$ ⋯

Figure D.17. Data structure of Mark5B format data.

D.3.2 Mark5B header format

Fig.D.18 shows Mark5B header format (16 bytes).

D.3.3 Mark5B data block

Data block of Mark5B format consists of 10000-byte data, and it is shown as figures below by using the unit of "bit-stream", where bit-stream is the number of bits representing sampled data at a time. There are 6 kinds of bit-stream, such as, 2, 4, 8, 16, and 32. It is expresed as bit-stream= nk where n is the number of channels and k is the number of AD bits.

<table>
<tr><td>bit</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>W0</td><td colspan="32">Sync Pattern : '0xABADDEED'</td></tr>
<tr><td>W1</td><td colspan="16">User-specified</td><td>T</td><td colspan="15">Frame # within second (starting at 0)</td></tr>
<tr><td>W2</td><td colspan="32">VLBA BCD Time code word 1 ('JJJSSSSS')</td></tr>
<tr><td>W3</td><td colspan="16">VLBA BCD Time code word 2 ('.SSSS')</td><td colspan="16">CRC 16bit</td></tr>
</table>

T 1: TVG data

Figure D.18. Mark5B header format

Bit31 — 1 bit-stream data — Bit0

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure D.19. Mark5B data block for 1 bit-stream data. The number in a cell denotes sampling # that lines up in order of a sampling. This format corresponds to 1CH×1-bit AD data.

Bit31 — 2 bit-stream data — Bit0

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure D.20. Mark5B data block for 2 bit-stream data. This format corresponds to 1CH×2-bit AD or 2CH×1-bit AD data.

Bit31 — 4 bit-stream data — Bit0

7	6	5	4	3	2	1	0

Figure D.21. Mark5B data block for 4 bit-stream data. This format corresponds to 4CH×1-bit AD, 2CH×2-bit AD data, and so on.

Bit31 — 8 bit-stream data — Bit0

3	2	1	0

Figure D.22. Mark5B data block for 8 bit-stream data. This format corresponds to 8CH×1-bit AD, 4CH×2-bit AD data, and so on.

Bit31 — 16 bit-stream data — Bit0

1	0

Figure D.23. Mark5B data block for 16 bit-stream data. This format corresponds to 16CH×1-bit AD, 8CH×2-bit AD data, and so on.

Bit31 — 32 bit-stream data — Bit0

0

Figure D.24. Mark5B data block for 32 bit-stream data. This format corresponds to 16CH×2-bit AD and so on.

D.4 VDIF data format

D.4.1 Data structure

VDIF(VLBI Data Interchange Format) data consist of stream of data frames. Each frame contains a header and a data block. The header consists of 32 bytes; fist 16-byte data contain time information, etc., and rest is an extended user blcok (16 bytes). At present time, two formats (EDV #1 and #2) are defined for the extended user block.

Header (32 bytes)	Data block	Header (32 bytes)	⋯
| < − − − − − − − −	frame − − − − − − − − >	| < − − − − − − − −	⋯

Figure D.25. Data structure of VDIF format data.

D.4.2 VDI header format

Common specifications

Fig.D.26 shows VDIF header format (32 bytes).

<table>
<tr><td>bit</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>W0</td><td>I</td><td>L</td><td colspan="30">Seconds from reference epoch</td></tr>
<tr><td>W1</td><td colspan="2">Un-assign</td><td colspan="6">Ref Epoch: Half year counter</td><td colspan="24">Data Frame # within second</td></tr>
<tr><td>W2</td><td colspan="3">Version Number</td><td colspan="5">$\log_2$(#chns)</td><td colspan="24">Data Frame length (units of 8bytes)</td></tr>
<tr><td>W3</td><td>C</td><td colspan="5">bits/sample-1</td><td colspan="10">Thread ID for multi-stream (0-1023)</td><td colspan="16">Station ID</td></tr>
<tr><td>W4</td><td colspan="8">Extended User Data Version Number</td><td colspan="24">Extended User Data</td></tr>
<tr><td>W5</td><td colspan="32">Extended User Data</td></tr>
<tr><td>W6</td><td colspan="32">Extended User Data</td></tr>
<tr><td>W7</td><td colspan="32">Extended User Data</td></tr>
</table>

I= Invalid Flag
L= Legacy mode 0: standard 32-byte VDIF header 1: legacy header-length (16-byte) mode
C: data type 0: real data, 1: complex data

Figure D.26. VDIF header format

EDV#1 specified by NICT

Fig.D.27 shows the extended header format EDV#1 specified by NICT.

EDV#3 for VLBA, VLA, GBT

Fig.D.28 shows the extended header format EDV#3 for VLBA, VLA, GBT.

D.4.3 VDIF data block

Examples of single channel data

bit	31	30	29–24	23–16	15–0
W0	I	L	Seconds from reference epoch		
W1	Un-assign		Ref Epoch: Half year counter	Data Frame # within second	
W2	Version Number		log$_2$(#chns)	Data Frame length (units of 8bytes)	
W3	C	bits/sample-1		Thread ID for multi-stream (0-1023)	Station ID
W4	Extended User Data Version Number			U	Sampling Rate (kHz or MHz)
W5	Sync Pattern : '0xACABFEED'				
W6	DAS/Station Name (8 bytes)				
W7					

U: units of sampling rate 0: kHz, 1: MHz

Figure D.27. VDIF header format (EDV#1 specified by NICT)

real 1bit/sample (Bit31 … Bit0)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure D.29. VDIF data block for 1CH×1-bit AD data. The number in a cell denotes sampling # that lines up in order of a sampling.

real 2bits/sample (Bit31 … Bit0)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure D.30. VDIF data block for 1CH×2-bit AD data.

complex 1bit/sample (Bit31 … Bit0)

15Q	15I	14Q	14I	13Q	13I	12Q	12I	11Q	11I	10Q	10I	9Q	9I	8Q	8I	7Q	7I	6Q	6I	5Q	5I	4Q	4I	3Q	3I	2Q	2I	1Q	1I	0Q	0I

Figure D.31. VDIF data block for complex 1CH×1-bit AD data.

complex 2bits/sample (Bit31 … Bit0)

7Q	7I	6Q	6I	5Q	5I	4Q	4I	3Q	3I	2Q	2I	1Q	1I	0Q	0I

Figure D.32. VDIF data block for complex 1CH×2-bit AD data.

Examples of multiple channel data

real 16ch X 1bit/sample (Bit31 … Bit0)

CH16	CH15	CH14	CH13	CH12	CH11	CH10	CH9	CH8	CH7	CH6	CH5	CH4	CH3	CH2	CH1	CH16	CH15	CH14	CH13	CH12	CH11	CH10	CH9	CH8	CH7	CH6	CH5	CH4	CH3	CH2	CH1
<-- sample 1 -->																<-- sample 0 -->															

Figure D.33. VDIF data block for 16CH×1-bit AD data.

<table>
<tr><td>bit</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>W0</td><td>I</td><td>L</td><td colspan="30">Seconds from reference epoch</td></tr>
<tr><td>W1</td><td colspan="2">Un-assign</td><td colspan="6">Ref Epoch: Half year counter</td><td colspan="24">Data Frame # within second</td></tr>
<tr><td>W2</td><td colspan="3">Version Number</td><td colspan="5">log$_2$(#chns)</td><td colspan="24">Data Frame length (units of 8bytes)</td></tr>
<tr><td>W3</td><td>C</td><td colspan="5">bits/sample-1</td><td colspan="10">Thread ID for multi-stream (0-1023)</td><td colspan="16">Station ID</td></tr>
<tr><td>W4</td><td colspan="8">Extended User Data Version Number</td><td>U</td><td colspan="23">Sampling Rate (kHz or MHz)</td></tr>
<tr><td>W5</td><td colspan="32">Sync Pattern : '0xACABFEED'</td></tr>
<tr><td>W6</td><td colspan="32">LOIF Frequency Tuning Word, unsigned int - # of Hz</td></tr>
<tr><td>W7</td><td colspan="4">Un-assigned</td><td colspan="4">DBE unit</td><td colspan="4">IF</td><td colspan="3">Sub Band</td><td>ESB</td><td colspan="4">Major Rev</td><td colspan="4">Minor Rev</td><td colspan="8">Personality Type</td></tr>
</table>

U: units of sampling rate 0: kHz, 1: MHz
ESB: Electronic Side Band (1: upper, 0: lower)
Personality Type: x00: RFBG, x80: DDC Mark5B, x81: DDC complex, x82: DDC VDIF

Figure D.28. DIF header format (EDV#3 for VLBA, VLA, GBT)

Bit31 real 16ch X 2bits/sample Bit0

CH16	CH15	CH14	CH13	CH12	CH11	CH10	CH9	CH8	CH7	CH6	CH5	CH4	CH3	CH2	CH1

Figure D.34. VDIF data block for 16CH×2-bit AD data.

Bit31 complex 16ch X 2bits/sample Bit0

CH8Q	CH8I	CH7Q	CH7I	CH6Q	CH6I	CH5Q	CH5I	CH4Q	CH4I	CH3Q	CH3I	CH2Q	CH2I	CH1Q	CH1I
CH16Q	CH16I	CH15Q	CH15I	CH14Q	CH14I	CH13Q	CH13I	CH12Q	CH12I	CH11Q	CH11I	CH10Q	CH10I	CH9Q	CH9I

Figure D.35. VDIF data block for complex 16CH×2-bit AD data.

E How to install PGPLOT

E.1 by"apt-get" (for Ubuntu 14.04)

If software package is available, we can install PGPLOT by using "apt-get" command as

```
sudo apt-get install pgplot5
```

E.2 step by step

1. download
   download pgplot5.2.tar.gz from ftp://ftp.astro.caltech.edu/pub/pgplot/pgplot5.2.tar.gz
   copy pgplot5.2.tar.gz to /usr/local/src

2. decompress
   cd /usr/local/src
   gunzip -c pgplot5.2.tar.gz | tar xvof -
   or
   tar xvzf pgplot5.2.tar.gz
   /usr/local/src/pgplot and subdirectories are generated by decompression

3. create the install directory
   mkdir /usr/local/pgplot

4. select driver
   cd /usr/local/pgplot
   cp /usr/local/src/pgplot/drivers.list .
   remove "!" at driver name
   vi drivers.list
   drivers recomended are
   /NULL /PS /VPS /CPS /VCPS /XWINDOW /XSERVE

5. create the makefile
   cd /usr/local/pgplot
   /usr/local/src/pgplot/makemake /usr/local/src/pgplot linux g77_gcc

6. execute "make"
   make
   make cpg
   make clean

   now there are files as follows in the directory
   cpgdemo grexec.f libcpgplot.a pgdemo1 pgxwin_server cpgplot.h grfont.dat libpgplot.a pgplot.doc rgb.txt
   drivers.list grpckg1.inc makefile pgplot.inc
   libpgplot.so

7. copy libralies and include file to stardard directory
   cp libcpgplot.a /usr/lib
   cp libpgplot.a /usr/lib
   cp cpgplot.h /usr/include
   cp libpgplot.so /usr/lib

8. execution of demonstration programs
   set environmental variables as follows
   csh : setenv PGPLOT_DIR /usr/local/pgplot/
   sh : PGPLOT_DIR="/usr/local/pgplot/"; export PGPLOT_DIR
   or
   export PGPLOT_DIR=/usr/local/pgplot/
   As for /XWINDOW or /XSERVE, set as follows
   csh : setenv DISPLAY IP_address(or host_name):0.0

sh : export DISPLAY=IP_address(or host_name):0.0
execute demo programs
pgdemo1 (FORTRAN demo)
or
cpgdemo (C demo)

9. How to compile C program
compile by either Method 1 or Method 2 as follows, where test source code is test.c

Method 1
```
f77 -o test test.c -lcpgplot -lpgplot -L/usr/X11R6/lib -lX11 -lm
```
(Note: use Fortran compiler)

Method 2
```
cc -O2 -c -I. test.c
f77 -o test test.o -lcpgplot -lpgplot -L/usr/X11R6/lib -lX11 -lm
```

F How to install FFTW

1. download
   get the latest version of FFTW from http://www.fftw.org/
   (latest version is ftp://ftp.fftw.org/pub/fftw/fftw-3.3.6-pl1.tar.gz as of March 2, 2017)
   copy fftw-3.3.6-pl1.tar.gz to /usr/local/src

2. decompress
   ```
   cd /usr/local/src
   tar xvzf fftw-3.X.X.tar.gz
   ```
   /usr/local/src/fftw-3.X.X and subdirectories are generated by decompression

3. generate the makefile
   ```
   cd /usr/local/src/fftw-3.X.X
   ./configure
   ```

4. execute "make"
   ```
   make
   ```
   /usr/local/src/fftw-3.X.X/.libs will be created

5. set up library and include file to the standard directory
   ```
   make install
   ```
   by this execution, libfftw3.a and libfftw3.la are copied to /usr/local/lib
   fftw3.h is copied to /usr/local/include

6. How to compile C program

   use "-lfftw3 -lm" at linkage
   and set include file directory and library directory as follows
   -I/usr/local/include
   -L/usr/local/lib

see http://www.fftw.org/ for details