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VGOS Correlation

VGOS Correlation Workshop

MIT Haystack Observatory

May 9, 2019

Outline

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- Pre-requisites and input
- Configuration and setup
- Running DiFX
- Output

Pre-requisites for nominal operation

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System requirements

- Cluster with DiFX and CALC
- HOPS (fourfit, alist, etc.)
- Storage (Mark6, RAID, etc.)

Input needed

- The raw station data (.vdif)
- The session .vex (schedule)
- A VGOS specific .vex and .v2d template
- EOP data
- The station clock info (ΔGPS, peculiar offsets)
- An initial fourfit control file

Making station data available to DiFX

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Mark6:

- Insert, key-on and mount disk modules.
- Ensure that all disks are present.
- Run vsum to generate the file list (–mark6slot).

RAID/NFS:

- Data that is e-transfered should be gathered before receiving.
- Run vsum to generate the file list.

Assembling a correlator .vex file

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Need a .vex file to describe various aspects of the experiment:

- Assorted meta-data
- Stations involved, properties, and positions
- Frequency, channel and p-cal set-up
- EOP and station clocks
- Schedule and sources

Where to collect this information:

- Some is available from an IVS provided .skd or .vex file.
- Some follows a standard 'template'. This is for settings that do not typically change from session-to-session.
- Some information must be crafted by correlator operator.

This process is necessary as a temporary work around. It is hoped/expected that eventually session .vex files should only need minimal modification by the correlator (clocks).

Correlator .vex: $EXPER section

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- Can obtain a session .skd or .vex file from
  IVS: `https://ivscc.gsfc.nasa.gov/sessions/2019/`
  or CDDIS: `ftp://cddis.nasa.gov/pub/vlbi/ivsdata/aux/2019/`
- Should append the $EXPER section with: exper_num, exper_nominal_start, exper_nominal_stop.

Example snippet:

```
$EXPER;
 def VT9063;
   exper_name = VT9063;
   exper_num = 3685;
   exper_description = "VGOS broadband session";
   PI_name = HAYS;
   target_correlator = HAYS;
   exper_nominal_start=2019y063d00h00m00s;
   exper_nominal_stop=2019y064d23h59m59s;
 enddef;
```

Correlator .vex: $MODE section

- Declares the association of each station with $FREQ, $BBC, $IF, and $TRACK definitions.
- This section is a 'template' as it rarely changes.
- Be aware that not all stations will have identical definition-associations.

Example snippet:

```
$MODE;
  def VGOS;
    ref $FREQ = VGOS_std:Wf:Gs:K2:Yj:Ws:Oe:Ow;
    ref $FREQ = VGOS_std_Is:Is;
    ref $BBC = VGOS_std:Wf:Gs:K2:Is:Yj:Ws:Oe:Ow;
    ref $IF = VGOS_std:Wf:Gs:K2:Is:Yj:Ws:Oe:Ow;
    ref $TRACKS = VDIF_format:Wf:Gs:K2:Is:Yj:Ws:Oe:Ow;
enddef;
```

Correlator .vex: $STATION and $ANTENNA

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- These sections can be obtained directly from IVS/CDDIS system files.
- They change infrequently, and only to be updated when stations are added, or change hardware.

Example snippets:

```
$STATION;
def Gs;
  ref $SITE = GGAO12M;
  ref $ANTENNA = GGAO12M;
  ref $DAS = RDBE_rack;
  ref $DAS = Gs_Gs;
  ref $DAS = Mark6_recorder;
enddef;
...
```

```
  def GGAO12M;
  antenna_diam = 12.00 m;
  axis_type = az : el;
  axis_offset =  0.00000 m;
  antenna_motion = az : 300.0 deg/min : 0 sec;
  antenna_motion = el : 66.0 deg/min :  0 sec;
  pointing_sector = &n : az : 180.0 deg : 720.0 deg : el : 6.5 deg : 88.0 deg;
enddef;
```

Correlator .vex: $SCHED, $SOURCE, $SITE, and $EOP

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- The first three sections should be taken directly from the IVS/CDDIS system files.
- The $SCHED section contains the description of the time/source of each scan and changes every session.
- The $SOURCE section contains a the list of sources observed and could change if sources are added or removed.
- The $SITE section contains stations positions. If/when better estimates are available they should be used.
- Information for the $EOP section should be obtained from IERS rapid service for the appropriate time frame (5 days).

Example snippet:

```
$EOP;
def EOP003;
TAI-UTC = 37 sec;
A1-TAI = 0.03439 sec;
eop_ref_epoch = 2019y104d;
num_eop_points = 5;
eop_interval = 24 hr;
* I E R S Rapid Service from 18 Apr 2019 ser7
ut1-utc =  -0.133051 sec : -0.134035 sec : -0.135226 sec : -0.136583 sec : -0.138049 sec;
x_wobble =  0.05503 asec : 0.05530 asec : 0.05586 asec : 0.05674 asec : 0.05778 asec;
y_wobble =  0.39823 asec : 0.39908 asec : 0.39992 asec : 0.40060 asec : 0.40113 asec;
enddef;
```

Correlator .vex $CLOCKS

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- Correlator operator must construct clocks section based on:
- Station provided 'GPS-fmout' offset
- Station 'peculiar' delays
- The mean maser drift rate

Example snippet:

```
$CLOCK;
def Wf; clock_early = 2019y063d00h00m : 13.199 usec : 2019y064d00h00m0s : 0.304
     e-12; enddef;
def K2; clock_early = 2019y063d00h00m : 8.745 usec : 2019y064d00h00m0s :-0.339e
     -12; enddef;
...
```

- Further discussion on setting clocks will follow this talk.

Correlator .vex $FREQ, $BBC, and $IF

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- Pre-existing declarations in IVS/CDDIS .vex files must be replaced with templates.
- $FREQ needed to describe the channel-frequency, sideband mapping
- Although not necessarily associated with a physical BBC, the $BBC section is needed to map the channel definitions to an $IF.
- $IF section is needed to declare polarization and p-cal tone spacing.
- $TRACKS is needed to specify the station data-format. This can also be set in .v2d file.
- Example snippets for these and other sections are included in manual handout.

vex2difx

Needed to extract data from .vex file for use by DiFX and configures additional details, these include:

- Processing details:
  - .vex file
  - stations involved
  - machines, threads, cores
  - N spectral points
- Data format for each station
  - data location: machine and filelists
  - data format
  - phase-cal interval

vex2difx: data formats

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- Data format must be described by the site operators.
- Depends on the backend used at site, and whether or not the data was ‘gathered’ (i.e. e-transfer).
- Overwrites .vex $TRACKS definition, should be given for each $ANTENNA.

Example snippet for a site using RDBE-Gs and providing data on Mark6 modules:

```
ANTENNA Gs
{
  machine = rc19
  format = VDIFC/0:1:2:3/8224/2
  mark6filelist = vt9063_gs.filelist
  sampling = COMPLEX
  phaseCalInt = 5
}
```

Example snippet for site using DBBC3s and recorded on Flex-Buff, providing 'gathered' data via e-transfer.

```
ANTENNA Oe
{
  machine = rc19
  filelist=vt9063_oe.filelist
  format = VDIF/65568/2
  sampling = REAL
  phaseCalInt = 5
}
```

Running DiFX

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- If correlator nodes to be used are not declared in .v2d file, user must ensure that a cluster definition file is available via $DIFX_MACHINES.
- CALC server must be running and accessible.
- Helper script `startdifx` handles calls to `calcif2`, sets environmental variables, creates job specific .machines files and calls `mpirun`.

Conversion to Mk4-types

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- Use difx2mark4 to convert DiFX output to Mk4 type-1 and type-3 files for HOPS processing.
- Unlike SX, all channels get exported as a single 'X' band using the '-b' option.
- Need to specify mapping of 2-char station-codes to 1-char Mk4-site-ids.

Example:

```
difx2mark4 -v -d -b X 2300 14000 -e <4-digit exp. code> -s <station code file>
```

Current station-code $\Longleftrightarrow$ Mk4-site-id assignment:

```
G Gs
H K2
E Wf
V Ws
I Is
Y Yj
S Oe
T Ow
```

First look with fourfit

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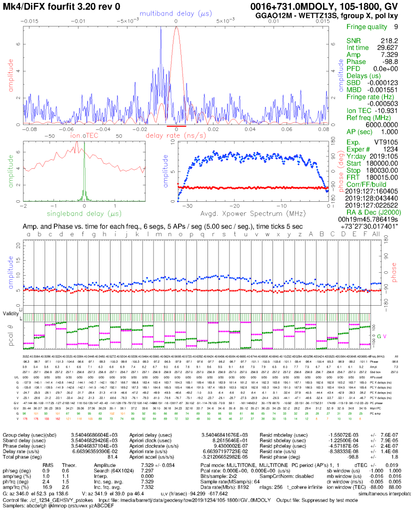
- Once Mk4-type data is available we can start inspecting the data with fourfit.
- Need a control file adapted for VGOS. Example in handout.



First look with fourfit

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- Once Mk4-type data is available we can start inspecting the data with fourfit.
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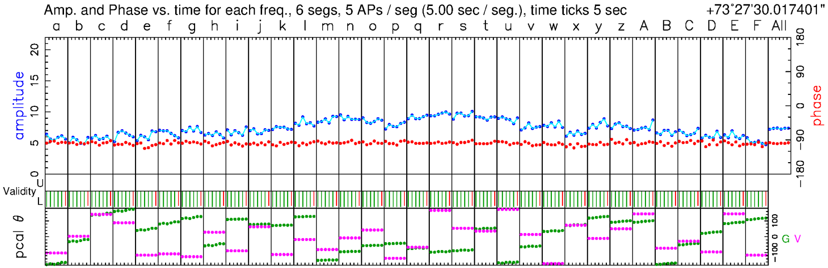
- Obvious difference is large number of channels (32x32MHz) and 5MHz p-cal.



First look with fourfit

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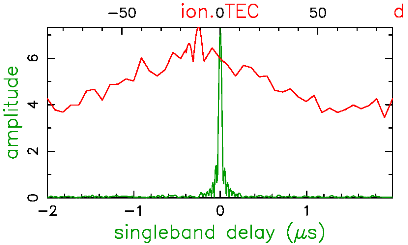
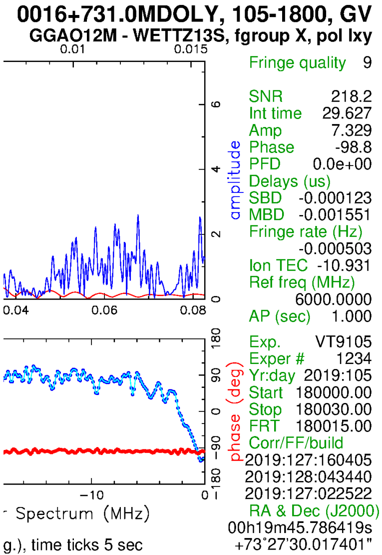
- Once Mk4-type data is available we can start inspecting the data with fourfit.
- Need a control file adapted for VGOS. Example in handout.
- Obvious difference is large number of channels (32x32MHz) and 5MHz p-cal.
- Also simultaneously fit for the differential ionosphere TEC.



First look with fourfit

- Once Mk4-type data is available we can start inspecting the data with fourfit.
- Need a control file adapted for VGOS. Example in handout.
- Obvious difference is large number of channels (32x32MHz) and 5MHz p-cal.
- Also simultaneously fit for the differential ionosphere TEC.
- Other subtle differences buried in details



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Data quality, MBD trends, and setting clocks

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- Once an initial 'prepass' correlation of the data is complete we can get a rough of idea of the data quality.
- To do this, a first-pass initial fringe-fitting of some or all of the data using an a-priori fourfit control file is done.
- Can get a high level view of the data quality with `alist` to examine Q-codes.
- Use `aedit` to construct MBD delay trend plots in order to tune up station clock settings.
- Modify the a-priori control file to accommodate data issues encountered.
- Iterate.