

# FAST Digital Backends and Science Data

## 1. Introduction of FAST

FAST stands for the Five-hundred-meter Aperture Spherical radio Telescope, with an aperture of 500 meters. During observations, the deforming parabola has an aperture of 300 meters. This effective aperture is used for the calculation of the sensitivity. The maximum zenith angle should be smaller than 40 degrees, and even smaller than 30 degrees for certain observing modes. An error will be reported when the zenith angle exceeds this limit.

### 1.1 Frequency bands and Receivers

Currently, FAST offers only one receiver system which is the 19 beam receiver, covering the frequency range of 1.05 GHz-1.45 GHz.

### 1.2 Observation modes

The currently available observation modes are the following:

- Drift
- DriftWithAngle
- Tracking
- TrackingWithAngle
- BasketWeaving
- OnTheFlyMapping
- MultiBeamOTF
- OnOff
- SnapShot
- MultiBeamCalibration
- DecDriftWithAngle
- SwiftCalibration
- SolarSysTracking
- SolarSysDrift
- SnapShotDec
- PhaseReferencing

## 2. Data type of the digital backend

The current data type of FAST includes: pulsar(psrfits), spectrum(sdfits), SETI(sdfits). There are three kinds of backends with three data types. There are two ways of data recording for the spectral backend: spec(F)--high resolution on the full band, and spec(W+N)--low resolution on the full band + high resolution on a user defined frequency window. The default central frequency of this

window is 1420.0 MHz. For three digital backends can record the data of all the 19 beams or the data of the central beam, M01. Since the SETI and spec backends use the same computing resources, the SETI and spec data cannot be recorded simultaneously.

| Backend   | Parameters Description                                                                                                                  | Notes                                                                                                                                         |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| psr       | sampling time:<br>49.152 us,98.304 us,196.608 us.                                                                                       | channel number:<br>4k (default), 1k,2k,8k.                                                                                                    |
| spec(F)   | bandwidth:<br>500 MHz<br>channel number:<br>1024k<br>resolution: 476.837158203125 Hz.                                                   | The data is indication with 'F'.                                                                                                              |
| spec(W+N) | bandwidth:<br>500 MHz (W), 31.25 MHz (N).<br>channel number:<br>64k<br>resolution:<br>7.62939453125 kHz(W),<br>476.837158203125 Hz (N). | central frequency of the narrow<br>band:<br>1420.0 MHz(default), can be set by<br>the user<br>The data will be indicated with 'W'<br>and 'N'. |
| SETI      | sampling time:10 s<br>channel number: 65536k<br>resolution:7.450580596923828 Hz.                                                        | The precise integrated time of input<br>10 s is 10.200547328 s.<br>The data is indication with 'F'.                                           |

### 3. Parameters for the digital backends

The digital backends introduced above can be used in different combinations with single or multiple backend configuration. When setting up an observation, the backend parameters can be chosen as the following:

a. digital backends: psr / spec /SETI;

b. pulsar backend: 1k/2k/4k/8k;

c. spectral backend: spec(F)/spec(W+N);

d. sampling time:

psr(1k) : 49.152 us,98.304 us,196.608 us;

psr(2k) : 49.152 us,98.304 us,196.608 us;

psr(4k) : 49.152 us,98.304 us,196.608 us;

psr(8k) : 98.304 us,196.608 us;

spec: 0.1 s / 0.5 s / 1 s;

Note: the precise integrated time of input 0.1s,0.5s,1s are 0.100663296s

0.50331648s,1.00663296s,respectively.

e. rfgain: A/D conversion parameter, with range of -11.5 dB~+20 dB, + for amplification, - for damping.

Note: When the L band flux is less than 1 Jy, for pulsar, spectral and drift scan,rfgain should be set to rfgain= 15 dB;

For the flux of 1Jy ~10Jy,rfgain= 9 dB;

For the flux of 11Jy ~15Jy,rfgain= 8 dB;

For the flux of 16Jy~30Jy, rfgain= 4 dB.

f. dgain: pulsar backend 8 bit digital signal adjustment, only for pulsar data.

Note: For psr(1k) backend:3C sources, for a sampling time of 49.152us, use dgain=200;

For 98.304us, use dgain=180;

For 196.608us, use dgain=150.

For pulsar survey, for a sampling time of 49.152us, if the noise diode is high, use dgain=200;if the noise diode is low, use dgain=230; if there are no noise injection, use dgain=250.

For 98.304us, if the noise diode is high, use dgain=150; if the noise diode is low, use dgain=160; if there are no noise injection, use dgain=180.

For 196.608us, if the noise diode is high, use dgain=100; if the noise diode is low, use dgain=110, if there are no noise injection, use dgain=120.

For psr(2k) backend:3C sources, for a sampling time of 49.152 us, use dgain=200;

For 98.304 us, use dgain=190;

For 196.608 us, use dgain=180.

For pulsar survey, for a sampling time of 49.152us, if the noise diode is high, use dgain=350;if the noise diode is low, use dgain=360; if there are no noise injection, use dgain=380.

For 98.304 us, if the noise diode is high, use dgain=230; if the noise diode is low, use dgain=250; if there are no noise injection, use dgain=280.

For 196.608 us, if the noise diode is high, use  $\text{dgain} = 170$ ; if the noise diode is low, use  $\text{dgain} = 190$ , if there are no noise injection, use  $\text{dgain} = 200$ .

For psr(4k) backend:3C sources, for a sampling time of 49.152 us, use  $\text{dgain} = 300$ ;

For 98.304 us, use  $\text{dgain} = 250$ ;

For 196.608 us, use  $\text{dgain} = 200$ .

For pulsar survey, for a sampling time of 49.152us, if the noise diode is high, use  $\text{dgain} = 400$ ; if the noise diode is low, use  $\text{dgain} = 500$ ; if there are no noise injection, use  $\text{dgain} = 600$ .

For 98.304 us, if the noise diode is high, use  $\text{dgain} = 350$ ; if the noise diode is low, use  $\text{dgain} = 400$ ; if there are no noise injection, use  $\text{dgain} = 450$ .

For 196.608 us, if the noise diode is high, use  $\text{dgain} = 300$ ; if the noise diode is low, use  $\text{dgain} = 320$ , if there are no noise injection, use  $\text{dgain} = 350$ .

For psr(8k) backend:3C sources,

For 98.304 us, use  $\text{dgain} = 400$ ;

For 196.608 us, use  $\text{dgain} = 300$ .

For pulsar survey

For 98.304 us, if the noise diode is high, use  $\text{dgain} = 750$ ; if the noise diode is low, use  $\text{dgain} = 780$ ; if there are no noise injection, use  $\text{dgain} = 800$ .

For 196.608 us, if the noise diode is high, use  $\text{dgain} = 600$ ; if the noise diode is low, use  $\text{dgain} = 650$ , if there are no noise injection, use  $\text{dgain} = 700$ .

g. Polarization: for pulsar backends, the default is 2 polarizations. 4 polarizations are possible. For spectral backends, the default is 4 polarizations. For the SETI backend, the default is 4 polarizations.

## 4. Parameters of the noise diode

Noise modes:

ON: keep injecting noise

OFF: turn off the noise diode

MODULATE: turn on and off the noise diode periodically

Noise amplitudes:

high:10 k

low:1 k

Parameter of the period:

delay: the initial phase of the noise injection

ON: the time of noise on

OFF: the time of the noise off

For observation set up, the input parameters delay, ON, OFF are non-dimensional numbers, and the unit is 4 ns. The sequence of noise injection is delay ON OFF ON OFF .

Computing methods:

$$\begin{cases} T_{delay} = delay \times 4ns \\ T_{ON} = ON \times 4ns \\ T_{OFF} = OFF \times 4ns \end{cases}$$

$$Noise_{period} = T_{ON} + T_{OFF}$$

The parameters usually used are as follows:

| Period(s) | delay | On        | Off       |
|-----------|-------|-----------|-----------|
| 0.1       | 0     | 12582912  | 12582912  |
| 0.2       | 0     | 25165824  | 25165824  |
| 1         | 0     | 125829120 | 125829120 |
| 2         | 0     | 251658240 | 251658240 |

Notes: The precise noise diode period of input 0.1s,0.2s,1s,2s are 0.100663296s,0.201326592s,1.00663296s,2.01326592s,respectively.