VieRDS: Informal Documentation

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Abstract

A informal documentation of VieRDS is presented. This documentation describes download and installation, how to run the software, and several examples with results are presented. The results are presented by fourfit plots obtain from DiFX correlation. All examples can be reproduced by using the corresponding input_val.yaml files which are shown next to the fourfit plots. More information of the algorithms are shown in the corresponding PASP article.

VLBI, raw telescope data, simulations

1 Download and Installation

Download or clone the repository to your directory (e.g. /home/jakob/software/BasebandSim). The folder contains a CODE/ folder, a DIFX/ folder, and an EXAMPLES/ folder. In the CODE/ folder the Matlab library of VieRDS is stored. In the DIFX/ folder auxiliary scripts are stored to run DiFX and fourfit. In the EXAMPLES/ folder examples of VieRDS simulations are stored.

The main function of VieRDS is vierds.m. This function needs to be executed to run VieRDS. The function vierds.m calls the file input_val.yaml file in the same directory level. In the next section 2 an example of how to execute VieRDS is presented. In section 3 several examples are presented to realize simulations with VieRDS.

2 Run

VieRDS is configured by one input text file. It is called input_val.yaml. Several examples of the input_val.yaml file can be found in section 3.

To run VieRDS under Linux execute

```
/usr/local/MATLAB/R2020a/bin/matlab -nodisplay -nosplash -nodesktop
-r "run('/home/jakob/software/BasebandSim/vierds.m'); exit;"
```

Description of command:

```
/usr/local/MATLAB/R2020a/bin/matlab ... Matlab installation directory
-nodisplay -nosplash -nodesktop ...  run it without the GUI
```

```
-r "run('/home/jakob/software/BasebandSim/vierds.m');exit;" ...
... run option and path to vierds.m file in the head of VieRDS folder
```

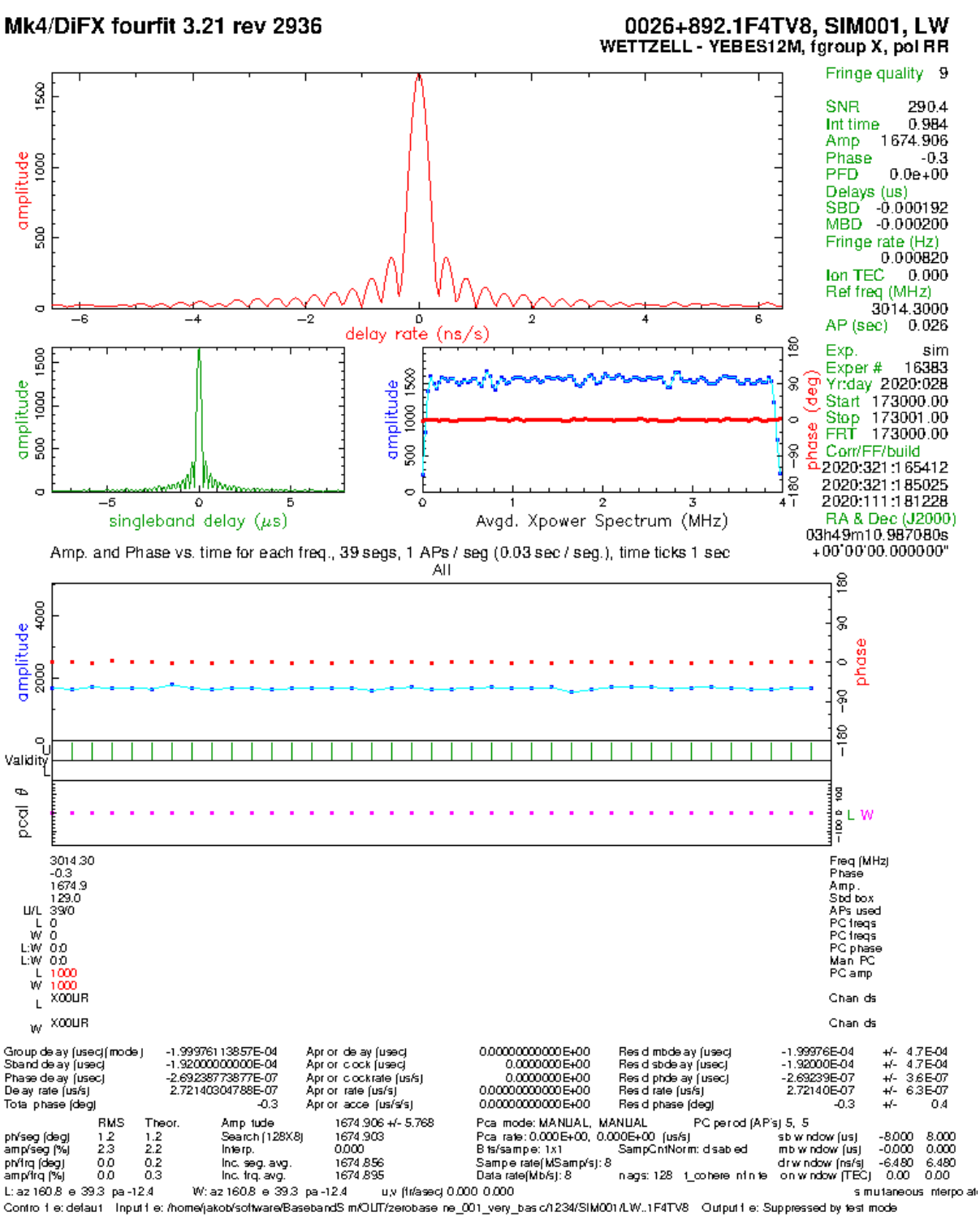
3 Simulation Examples

In this section, several examples for simulations with VieRDS are presented. The input_val.yaml file is shown and the corresponding fourfit fringe-plots are shown. To reproduce the results, copy the presented input_val.yaml file to the head of the VieRDS folder and execute the command shown in section 2.

3.1 Zero Baseline Simulation

3.1.1 Very Basic

```
setup:
  zero_bl: 1
s1:
  date_vec: [2020,1,28,17,30,00]
  station_name: S1
  station_name_8character: WETTZELL
  station_name_trf_coord: Wz
  sampling_frequency: 8
  scan_length: 1
  fluxdensity_targetsource: 10
  fluxdensity_system: 50
  f0: 3016.30
  number_of_bits: 1
  source_name: 0026+892
  bandpass_filter_name: default
s2:
  date_vec: [2020,1,28,17,30,00]
  station_name: S2
  station_name_8character: YEBES12M
  station_name_trf_coord: Ys
  sampling_frequency: 8
  scan_length: 1
  fluxdensity_targetsource: 10
  fluxdensity_system: 50
  f0: 3016.30
  number_of_bits: 1
  source_name: 0026+892
  bandpass_filter_name: default
```


Mk4/DiFX fourfit 3.21 rev 2936
0026+892.1F4TV8, SIM001, LW
WETTZELL - YEBES12M, fgroup X, pol RR
Fringe quality 9
SNR 290.4
Int time 0.984
Amp 1674.906
Phase -0.3
PFD 0.0e+00
Delays (us)
SBD -0.000192
MBD -0.000200
Fringe rate (Hz)
0.000820
Ion TEC 0.000
Ref freq (MHz)
3014.3000
AP (sec) 0.026
Exp. sim
Exper # 16383
Yr:day 2020:028
Start 173000.00
Stop 173001.00
FRT 173000.00
Corr/FF/build
2020:321:165412
2020:321:185025
2020:111:181228
RA & Dec (J2000)
03h49m10.987080s
+00°00'00.000000"
amplitude
delay rate (ns/s)
singleband delay (μs)
Avgd. Xpower Spectrum (MHz)
phase (deg)
Amp. and Phase vs. time for each freq., 39 segs, 1 APs / seg (0.03 sec / seg.), time ticks 1 sec
All
Validity
pcal θ
L W
3014.30
-0.3
1674.9
129.0
U/L 39/0
L 0
W 0
L:W 0:0
L:W 0:0
L 1000
W 1000
L X00UR
W X00UR
Freq (MHz)
Phase
Amp.
Sbd box
APs used
PC freqs
PC freqs
PC phase
Man PC
PC amp
Chan ds
Chan ds
Group delay (usec)(mode) -1.999761138 57E-04
Sband delay (usec) -1.920000000 00E-04
Phase delay (usec) -2.692387738 77E-07
Delay rate (us/s) 2.721403047 88E-07
Total phase (deg) -0.3
Apriori delay (usec) 0.000000000 00E+00
Apriori clock (usec) 0.000000000 00E+00
Apriori clockrate (us/s) 0.000000000 00E+00
Apriori rate (us/s/s) 0.000000000 00E+00
Apriori accel (us/s/s) 0.000000000 00E+00
Resid mbdelay (usec) -1.99976E-04 +/- 4.7E-04
Resid sbdelay (usec) -1.92000E-04 +/- 4.7E-04
Resid phdelay (usec) -2.69239E-07 +/- 3.6E-07
Resid rate (us/s) 2.72140E-07 +/- 6.3E-07
Resid phase (deg) -0.3 +/- 0.4
RMS Theor.
ph/seg (deg) 1.2 1.2
amp/seg (%) 2.3 2.2
ph/frq (deg) 0.0 0.2
amp/frq (%) 0.0 0.3
Amplitude 1674.906 +/- 5.768
Search (128X8) 1674.903
Interp. 0.000
Inc. seg. avg. 1674.856
Inc. frq. avg. 1674.895
Pcal mode: MANUAL, MANUAL PC period (AP's) 5, 5
Pcal rate: 0.000E+00, 0.000E+00 (us/s)
Bits/sample: 1x1 SampCntNorm: disabled
Sample rate(MSamp/s): 8
Data rate(Mb/s): 8 nags: 128 t_cohere nfinte
sb window (us) -8.000 8.000
mb window (us) -0.000 0.000
dr window (ns/s) -6.480 6.480
on window (TEC) 0.00 0.00
L: az 160.8 e 39.3 pa -12.4 W: az 160.8 e 39.3 pa -12.4 u,v (fr/asec) 0.000 0.000
Control e: default Input e: /home/jakob/software/BasebandSim/OUT/zerobase ne_001_very_basic/1234/SIM001/LW..1F4TV8 Output e: Suppressed by test mode

3.1.2 Arbitrary Magnitude Filter: Station Frequency Response

```
setup:
  zero_bl: 1
s1:
  date_vec: [2020,1,28,17,30,00]
  station_name: S1
  station_name_8character: KOKEE12M
  station_name_trf_coord: K2
  X_trf: [4.0755139837000000e+06,9.317353092000000e+05,4.801629401000000e+06]
  sampling_frequency: 64
  scan_length: 1
  fluxdensity_targetsource: 50
  fluxdensity_system: 50
  f0: 3016.30
  number_of_bits: 2
  signal_type_target_source: gaussian-white-noise
  source_name: 0026+892
  bandpass_filter_name: default
  arb_mag_file_1: K2.txt
  arb_mag_filter_signal_type_1: super
  arb_mag_interpolation_res_1: 1e3
  arb_mag_filter_order: 300
s2:
  date_vec: [2020,1,28,17,30,00]
  station_name: S2
  station_name_8character: YEBES12M
  station_name_trf_coord: Ys
  sampling_frequency: 64
  scan_length: 1
  fluxdensity_targetsource: 10
  fluxdensity_system: 50
  f0: 3016.30
  number_of_bits: 2
  source_name: 0026+892
  bandpass_filter_name: default
```

F (GHz)	Mag
3.000400	0.044193
3.000650	0.062204
3.000900	0.103179
3.001150	0.183057
3.001400	0.261378
3.001650	0.393336
3.001900	0.543534
3.002150	0.700005
3.002400	0.876209
3.002650	1.053162
3.002900	1.232959
3.003150	1.412478
3.003400	1.590275
3.003650	1.754650
3.003900	1.915873
3.004150	2.075617
3.004400	2.227008
3.004650	2.362459
3.004900	2.479694
3.005150	2.578114
3.005400	2.654331
3.005650	2.711728
3.005900	2.757487
3.006150	2.802019
3.006400	2.841063
3.006650	2.871627
3.006900	2.898534
3.007150	2.921241
3.007400	2.937567
3.007650	2.951368
3.007900	2.966399
3.008150	2.972899
3.008400	2.977383
3.008650	2.978795
3.008900	2.978899
3.009150	2.980630
3.009400	2.983068
3.009650	2.979730
3.009900	2.980404
3.010150	2.973435
3.010400	2.957100
3.010650	2.942613
3.010900	2.929595
3.011150	2.914425
3.011400	2.901956
3.011650	2.891284
3.011900	2.882199
3.012150	2.875131
3.012400	2.869162
3.012650	2.866354
3.012900	2.864326
3.013150	2.861510
3.013400	2.859163
3.013650	2.854946
3.013900	2.849708
3.014150	2.849802
3.014400	2.844400
3.014650	2.832448
3.014900	2.823164
3.015150	2.806697
3.015400	2.781994
3.015650	2.760481
3.015900	2.744270
3.016150	2.726962
3.016400	2.717698
3.016650	2.710862
3.016900	2.707471
3.017150	2.706091
3.017400	2.703437
3.017650	2.703482
3.017900	2.703735
3.018150	2.704476
3.018400	2.706426
3.018650	2.709184
3.018900	2.712081
3.019150	2.723395
3.019400	2.731020
3.019650	2.733028
3.019900	2.737126
3.020150	2.732720
3.020400	2.717076
3.020650	2.702468
3.020900	2.690739
3.021150	2.674824
3.021400	2.663886
3.021650	2.654963
3.021900	2.648248
3.022150	2.641970
3.022400	2.637719
3.022650	2.633201
3.022900	2.631797
3.023150	2.627386
3.023400	2.624240
3.023650	2.620748
3.023900	2.620170
3.024150	2.625760
3.024400	2.628006
3.024650	2.621404
3.024900	2.618467
3.025150	2.602479
3.025400	2.572535
3.025650	2.541222
3.025900	2.510501
3.026150	2.466307
3.026400	2.420613
3.026650	2.368399
3.026900	2.308377
3.027150	2.239787
3.027400	2.162666
3.027650	2.077228
3.027900	1.982237
3.028150	1.877392
3.028400	1.761273
3.028650	1.634952
3.028900	1.499963
3.029150	1.359951
3.029400	1.196208
3.029650	1.020491
3.029900	0.865441
3.030150	0.709193
3.030400	0.552803
3.030650	0.420985
3.030900	0.310697
3.031150	0.195493
3.031400	0.149515
3.031650	0.097383
3.031900	0.079180
3.032150	0.079675

Figure 1: Frequency-Magnitude table for the simulation of an arbitrary magnitude filter. Copy the values without the header to a text file called K2.txt as specified by the parameter "arb_mag_file_1" to run the simulation.

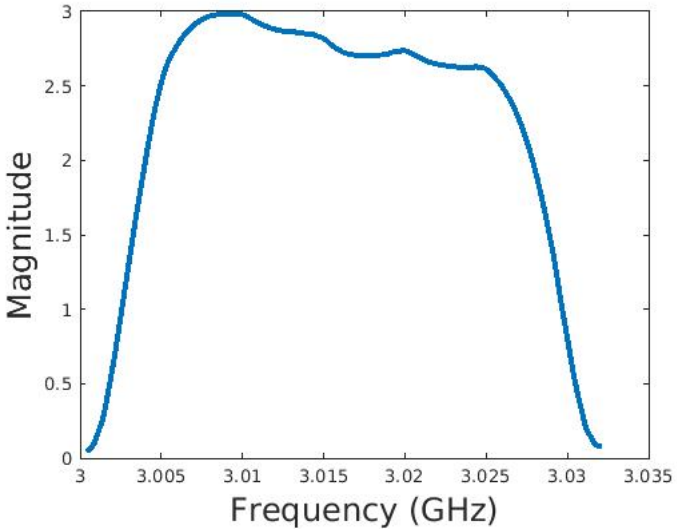
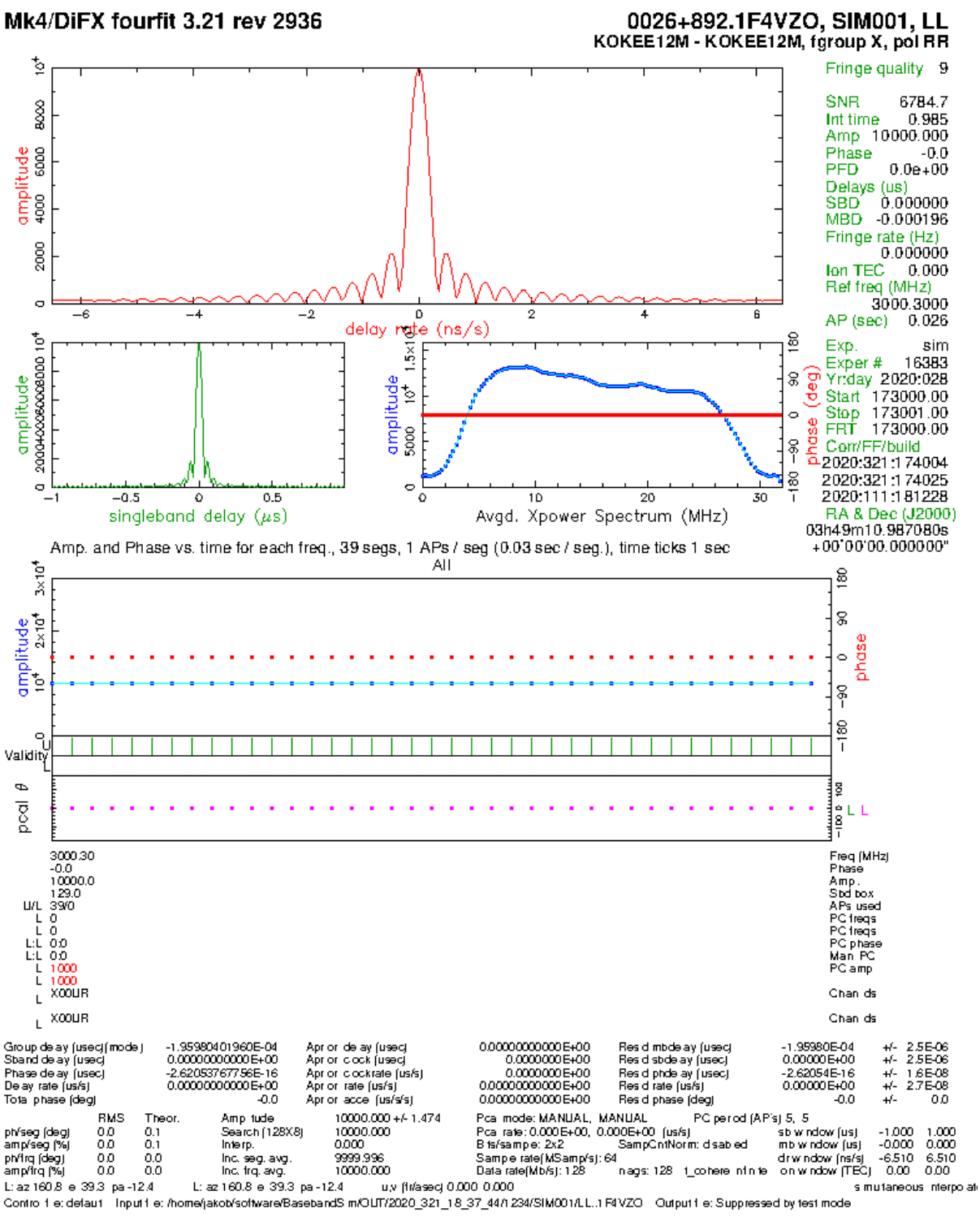
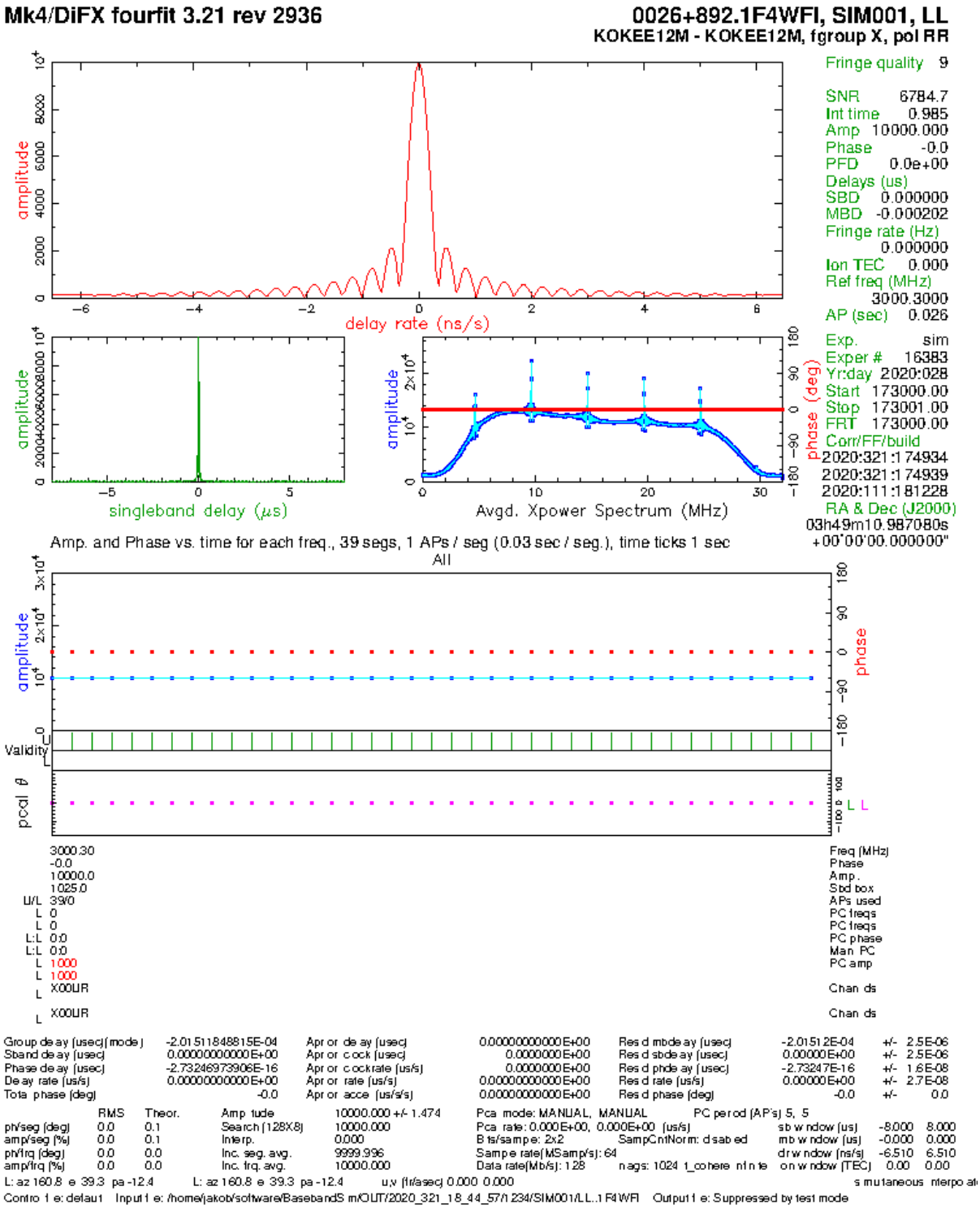


Figure 2: Plot of the values listed in the Figure 1


Mk4/DiFX fourfit 3.21 rev 2936
0026+892.1F4VZO, SIM001, LL
KOKEE12M - KOKEE12M, fgroup X, pol RR
Fringe quality 9
SNR 6784.7
Int time 0.985
Amp 10000.000
Phase -0.0
PFD 0.0e+00
Delays (us)
SBD 0.000000
MBD -0.000196
Fringe rate (Hz)
0.000000
Ion TEC 0.000
Ref freq (MHz)
3000.3000
AP (sec) 0.026
Exp. sim
Exper # 16383
Yr:day 2020:028
Start 173000.00
Stop 173001.00
FRT 173000.00
Corr/FF/build
2020:321:174004
2020:321:174025
2020:111:181228
RA & Dec (J2000)
03h49m10.987080s
+00°00'00.000000"
amplitude
delay rate (ns/s)
singleband delay (μs)
Avgd. Xpower Spectrum (MHz)
phase (deg)
Amp. and Phase vs. time for each freq., 39 segs, 1 APs / seg (0.03 sec / seg.), time ticks 1 sec
All
Validity
pcal θ
Freq (MHz)
Phase
Amp.
Sbd box
APs used
PC freqs
PC freqs
PC phase
Man PC
PC amp
Chan ds
Chan ds
Group delay (usec)(mode) -1.959804019 60E-04
Sband delay (usec) 0.000000000 00E+00
Phase delay (usec) -2.620537677 56E-16
Delay rate (us/s) 0.000000000 00E+00
Total phase (deg) -0.0
Apriori delay (usec) 0.000000000 00E+00
Apriori clock (usec) 0.000000E+00
Apriori clockrate (us/s) 0.000000E+00
Apriori rate (us/s) 0.000000000 00E+00
Apriori accel (us/s/s) 0.000000000 00E+00
Resid mbdelay (usec) -1.959 80E-04 +/- 2.5E-06
Resid sbdelay (usec) 0.000 00E+00 +/- 2.5E-06
Resid phdelay (usec) -2.620 54E-16 +/- 1.6E-08
Resid rate (us/s) 0.000 00E+00 +/- 2.7E-08
Resid phase (deg) -0.0 +/- 0.0
RMS Theor.
ph/seg (deg) 0.0 0.1
amp/seg (%) 0.0 0.1
ph/frq (deg) 0.0 0.0
amp/frq (%) 0.0 0.0
Amplitude 10000.000 +/- 1.474
Search (128X8) 10000.000
Interp. 0.000
Inc. seg. avg. 9999.996
Inc. frq. avg. 10000.000
Pcal mode: MANUAL, MANUAL PC period (AP's) 5, 5
Pcal rate: 0.000E+00, 0.000E+00 (us/s)
Bits/sample: 2x2 SampCntNorm: disabled
Sample rate(MSamp/s): 64
Data rate(Mb/s): 128 nags: 128 t_coherence
sbwindow (us) -1.000 1.000
mbwindow (us) -0.000 0.000
drwindow (ns/s) -6.510 6.510
onwindow (TEC) 0.00 0.00
L: az 160.8 el 39.3 pa -12.4
L: az 160.8 el 39.3 pa -12.4
u,v (fr/asec) 0.000 0.000
simultaneous interpolation
Control file: default
Input file: /home/jakob/software/BasebandSim/OUT/2020_321_18_37_44/1234/SIM001/LL..1F4VZO
Output file: Suppressed by test mode

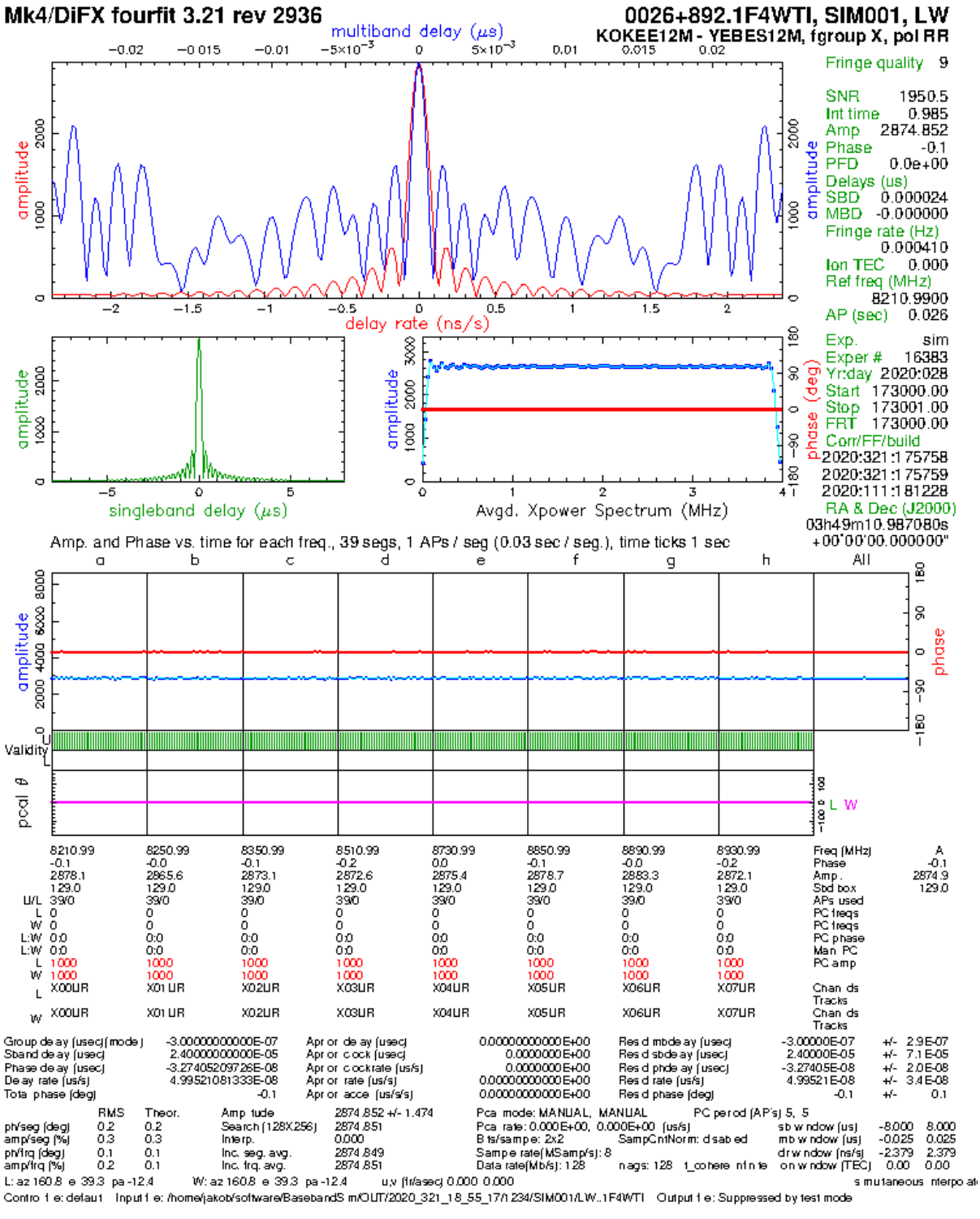
3.1.3 Phase Calibration Signal

```
setup:
  zero_bl: 1
s1:
  date_vec: [2020,1,28,17,30,00]
  station_name: S1
  station_name_8character: KOKEE12M
  station_name_trf_coord: K2
  X_trf: [4.0755139837000000e+06,9.317353092000000e+05,4.801629401000000e+06]
  sampling_frequency: 64
  scan_length: 1
  fluxdensity_targetsource: 50
  fluxdensity_system: 50
  f0: 3016.30
  number_of_bits: 2
  signal_type_target_source: gaussian-white-noise
  source_name: 0026+892
  bandpass_filter_name: default
  arb_mag_file_1: K2.txt
  arb_mag_filter_signal_type_1: super
  arb_mag_interpolation_res_1: 1e3
  arb_mag_filter_order: 300
  phase_cal_tone_power_perc: 0.9
  phase_cal_repetition_rate: 5.0
  phase_cal_phase_offset: 0
  phase_cal_frequency_offset: -310000
  phase_cal_delay: 0.0
s2:
  date_vec: [2020,1,28,17,30,00]
  station_name: S2
  station_name_8character: YEBES12M
  station_name_trf_coord: Ys
  sampling_frequency: 64
  scan_length: 1
  fluxdensity_targetsource: 10
  fluxdensity_system: 50
  f0: 3016.30
  number_of_bits: 2
  source_name: 0026+892
  bandpass_filter_name: default
```


Mk4/DiFX fourfit 3.21 rev 2936
0026+892.1F4WFI, SIM001, LL
KOKEE12M - KOKEE12M, fgroup X, pol RR
Fringe quality 9
SNR 6784.7
Int time 0.985
Amp 10000.000
Phase -0.0
PFD 0.0e+00
Delays (us)
SBD 0.000000
MBD -0.000202
Fringe rate (Hz)
0.000000
Ion TEC 0.000
Ref freq (MHz)
3000.3000
AP (sec) 0.026
Exp. sim
Exper # 16383
Yr:day 2020:028
Start 173000.00
Stop 173001.00
FRT 173000.00
Corr/FF/build
2020:321:174934
2020:321:174939
2020:111:181228
RA & Dec (J2000)
03h49m10.987080s
+00°00'00.000000"
amplitude
delay rate (ns/s)
singleband delay (μs)
Avgd. Xpower Spectrum (MHz)
phase (deg)
Amp. and Phase vs. time for each freq., 39 segs, 1 APs / seg (0.03 sec / seg.), time ticks 1 sec
All
Validity
pcal θ
Freq (MHz)
Phase
Amp.
Sbd box
APs used
PC freqs
PC freqs
PC phase
Man PC
PC amp
Chan ds
Chan ds
Group delay (usec)(mode) -2.015118488815E-04
Sband delay (usec) 0.000000000000E+00
Phase delay (usec) -2.732469739086E-16
Delay rate (us/s) 0.000000000000E+00
Total phase (deg) -0.0
Apriori delay (usec) 0.000000000000E+00
Apriori clock (usec) 0.000000E+00
Apriori clockrate (us/s) 0.000000E+00
Apriori rate (us/s) 0.000000000000E+00
Apriori accel (us/s/s) 0.000000000000E+00
Resid mbdelay (usec) -2.01512E-04 +/- 2.5E-06
Resid sbdelay (usec) 0.00000E+00 +/- 2.5E-06
Resid phdelay (usec) -2.73247E-16 +/- 1.6E-08
Resid rate (us/s) 0.00000E+00 +/- 2.7E-08
Resid phase (deg) -0.0 +/- 0.0
RMS Theor.
ph/seg (deg) 0.0 0.1
amp/seg (%) 0.0 0.1
ph/frq (deg) 0.0 0.0
amp/frq (%) 0.0 0.0
Amplitude 10000.000 +/- 1.474
Search (128X8) 10000.000
Interp. 0.000
Inc. seg. avg. 9999.996
Inc. frq. avg. 10000.000
Pcal mode: MANUAL, MANUAL PC period (AP's) 5, 5
Pcal rate: 0.000E+00, 0.000E+00 (us/s)
Bits/sample: 2x2 SampCntNorm: disabled
Sample rate(MSamp/s): 64
Data rate(Mb/s): 128 nags: 1024 t_coherent
sbwindow (us) -8.000 8.000
mbwindow (us) -0.000 0.000
drwindow (ns/s) -6.510 6.510
onwindow (TEC) 0.00 0.00
L: az 160.8 el 39.3 pa -12.4
L: az 160.8 el 39.3 pa -12.4
u,v (fr/asec) 0.000 0.000
Control file: default Input file: /home/jakob/software/BasebandSim/OUT/2020_321_18_44_57/1234/SIM001/LL..1F4WFI Output file: Suppressed by test mode

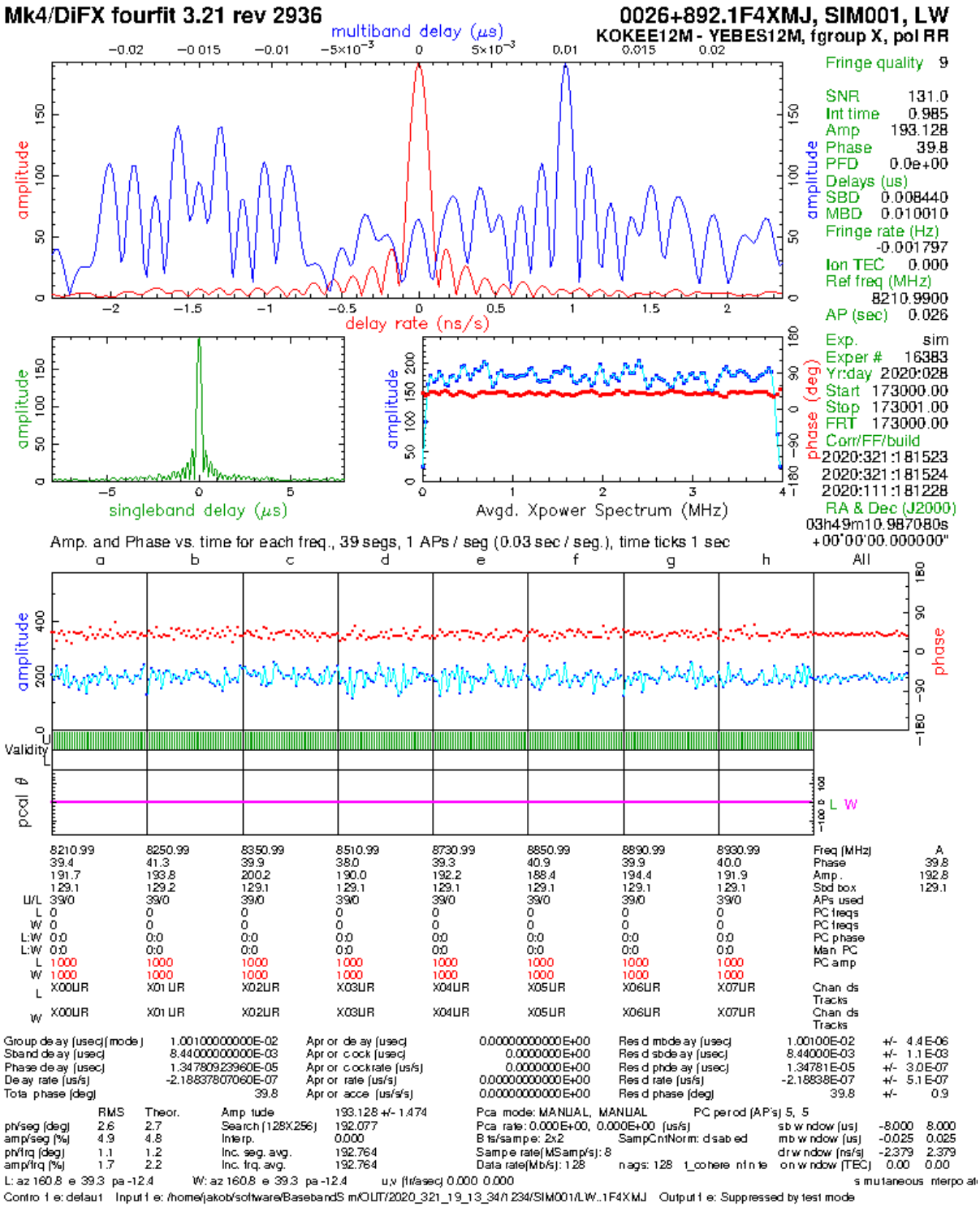
3.1.4 8 Channel X-band

```
setup:
  zero_bl: 1
s1:
  date_vec: [2020,1,28,17,30,00]
  station_name: S1
  station_name_8character: KOKEE12M
  station_name_trf_coord: K2
  X_trf: [4.0755139837000000e+06,9.317353092000000e+05,4.801629401000000e+06]
  sampling_frequency: 8
  scan_length: 1
  fluxdensity_targetsource: 50
  fluxdensity_system: 50
  f0: [8212.99, 8252.99, 8352.99, 8512.99, 8732.99, 8852.99, 8892.99, 8932.99]
  number_of_bits: 2
  signal_type_target_source: gaussian-white-noise
  source_name: 0026+892
  bandpass_filter_name: default
s2:
  date_vec: [2020,1,28,17,30,00]
  station_name: S2
  station_name_8character: YEBES12M
  station_name_trf_coord: Ys
  sampling_frequency: 8
  scan_length: 1
  fluxdensity_targetsource: 10
  fluxdensity_system: 50
  f0: [8212.99, 8252.99, 8352.99, 8512.99, 8732.99, 8852.99, 8892.99, 8932.99]
  number_of_bits: 2
  source_name: 0026+892
  bandpass_filter_name: default
```


Mk4/DiFX fourfit 3.21 rev 2936
0026+892.1F4WTI, SIM001, LW
KOKEE12M - YEBES12M, fgroup X, pol RR
multiband delay (μs)
delay rate (ns/s)
amplitude
Fringe quality 9
SNR 1950.5
Int time 0.985
Amp 2874.852
Phase -0.1
PFD 0.0e+00
Delays (us)
SBD 0.000024
MBD -0.000000
Fringe rate (Hz)
0.000410
Ion TEC 0.000
Ref freq (MHz)
8210.9900
AP (sec) 0.026
Exp. sim
Exper # 16383
Yr:day 2020:028
Start 173000.00
Stop 173001.00
FRT 173000.00
Corr/FF/build
2020:321:175758
2020:321:175759
2020:111:181228
RA & Dec (J2000)
03h49m10.987080s
+00°00'00.000000"
singleband delay (μs)
Avgd. Xpower Spectrum (MHz)
phase (deg)
Amp. and Phase vs. time for each freq., 39 segs, 1 APs / seg (0.03 sec / seg.), time ticks 1 sec
a b c d e f g h All
Validity
pcal θ
L W
8210.99 8250.99 8350.99 8510.99 8730.99 8850.99 8890.99 8930.99 Freq (MHz) A
-0.1 -0.0 -0.1 -0.2 0.0 -0.1 -0.0 -0.2 Phase -0.1
2878.1 2865.6 2873.1 2872.6 2875.4 2878.7 2883.3 2872.1 Amp. 2874.9
129.0 129.0 129.0 129.0 129.0 129.0 129.0 129.0 Sbd box 129.0
U/L 39/0 39/0 39/0 39/0 39/0 39/0 39/0 39/0 APs used
L 0 0 0 0 0 0 0 0 PC freqs
W 0 0 0 0 0 0 0 0 PC freqs
L:W 0:0 0:0 0:0 0:0 0:0 0:0 0:0 0:0 PC phase
L:W 0:0 0:0 0:0 0:0 0:0 0:0 0:0 0:0 Man PC
L 1000 1000 1000 1000 1000 1000 1000 1000 PC amp
W 1000 1000 1000 1000 1000 1000 1000 1000
L X00UR X01UR X02UR X03UR X04UR X05UR X06UR X07UR Chan ds
Tracks
W X00UR X01UR X02UR X03UR X04UR X05UR X06UR X07UR Chan ds
Tracks
Group delay (usec)(mode) -3.000000000000E-07 Apriori delay (usec) 0.000000000000E+00 Resid mbdelay (usec) -3.000000E-07 +/- 2.9E-07
Sband delay (usec) 2.400000000000E-05 Apriori clock (usec) 0.000000000000E+00 Resid sbdelay (usec) 2.400000E-05 +/- 7.1E-05
Phase delay (usec) -3.274052097268E-08 Apriori clockrate (us/s) 0.000000000000E+00 Resid phdelay (usec) -3.274052E-08 +/- 2.0E-08
Delay rate (us/s) 4.995210813338E-08 Apriori rate (us/s) 0.000000000000E+00 Resid rate (us/s) 4.995210E-08 +/- 3.4E-08
Total phase (deg) -0.1 Apriori accel (us/s/s) 0.000000000000E+00 Resid phase (deg) -0.1 +/- 0.1
RMS Theor. Amplitude 2874.852 +/- 1.474 Pcal mode: MANUAL, MANUAL PC period (AP's) 5, 5
ph/seg (deg) 0.2 0.2 Search (128X256) 2874.851 Pcal rate: 0.000E+00, 0.000E+00 (us/s) sbwindow (us) -8.000 8.000
amp/seg (%) 0.3 0.3 Interp. 0.000 Bits/sample: 2x2 SampCntNorm: disabled mbwindow (us) -0.025 0.025
ph/frq (deg) 0.1 0.1 Inc. seg. avg. 2874.849 Sample rate(MSamp/s): 8 drwindow (ns/s) -2.379 2.379
amp/frq (%) 0.2 0.1 Inc. frq. avg. 2874.851 Data rate(Mb/s): 128 nags: 128 t_cohere nfnte onwindow (TEC) 0.00 0.00
L: az 160.8 el 39.3 pa -12.4 W: az 160.8 el 39.3 pa -12.4 u,v (fr/asec) 0.000 0.000 simultaneous interpolate
Control file: default Input file: /home/jakob/software/BasebandSim/OUT/2020_321_18_55_17/1234/SIM001/LW..1F4WTI Output file: Suppressed by test mode

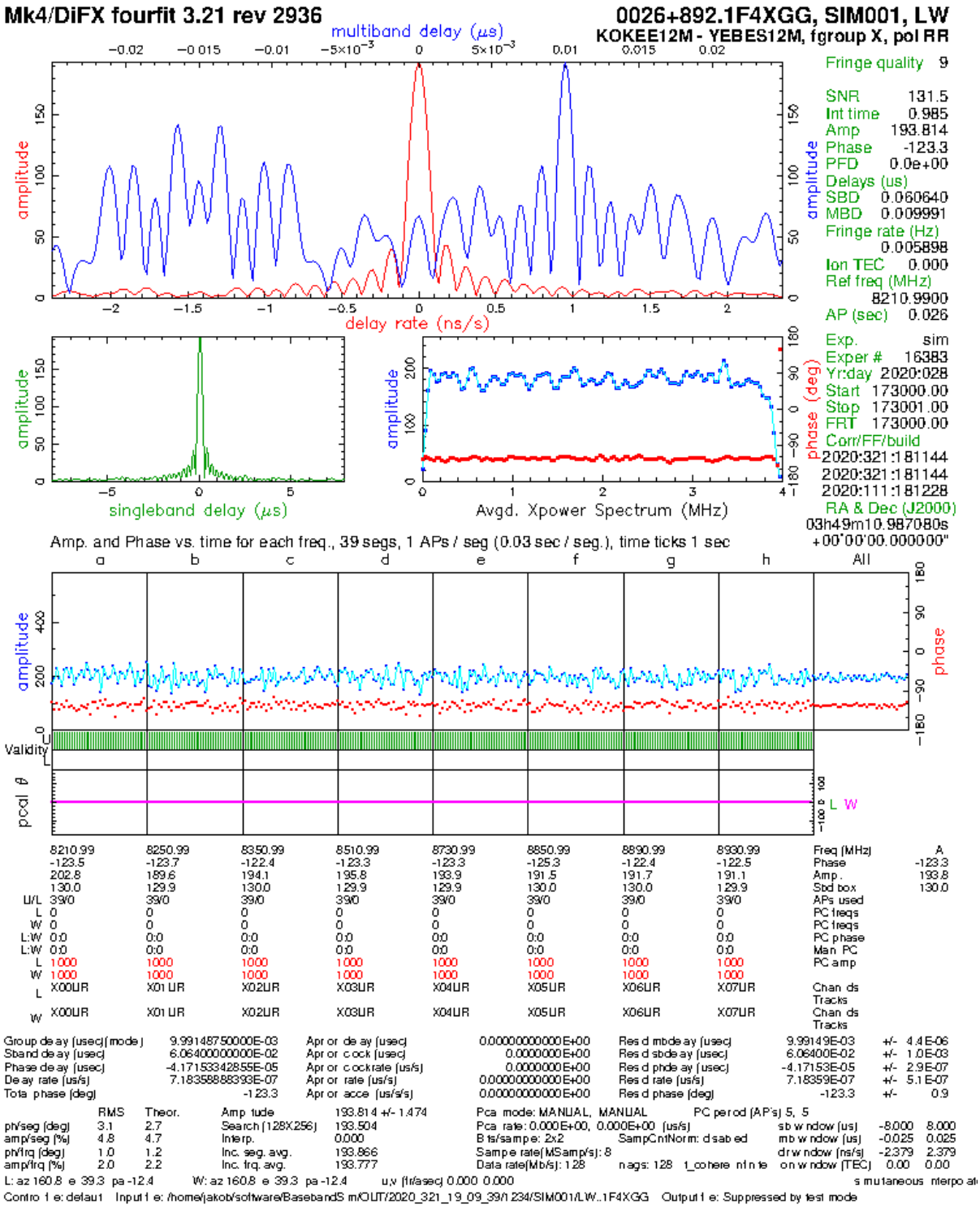
3.1.5 8 Channel X-band plus 10 ns Multiband Delay

```
setup:
  zero_bl: 1
s1:
  date_vec: [2020,1,28,17,30,00]
  station_name: S1
  station_name_8character: KOKEE12M
  station_name_trf_coord: K2
  X_trf: [4.0755139837000000e+06,9.317353092000000e+05,4.801629401000000e+06]
  sampling_frequency: 8
  scan_length: 1
  fluxdensity_targetsource: 1
  fluxdensity_system: 50
  f0: [8212.99, 8252.99, 8352.99, 8512.99, 8732.99, 8852.99, 8892.99, 8932.99]
  number_of_bits: 2
  signal_type_target_source: gaussian-white-noise
  source_name: 0026+892
  bandpass_filter_name: default
  delay_source: 10
s2:
  date_vec: [2020,1,28,17,30,00]
  station_name: S2
  station_name_8character: YEBES12M
  station_name_trf_coord: Ys
  sampling_frequency: 8
  scan_length: 1
  fluxdensity_targetsource: 1
  fluxdensity_system: 50
  f0: [8212.99, 8252.99, 8352.99, 8512.99, 8732.99, 8852.99, 8892.99, 8932.99]
  number_of_bits: 2
  source_name: 0026+892
  bandpass_filter_name: default
```


Mk4/DiFX fourfit 3.21 rev 2936
0026+892.1F4XMJ, SIM001, LW
KOKEE12M - YEBES12M, fgroup X, pol RR
multiband delay (μs)
delay rate (ns/s)
singleband delay (μs)
Avgd. Xpower Spectrum (MHz)
amplitude
phase (deg)
Fringe quality 9
SNR 131.0
Int time 0.985
Amp 193.128
Phase 39.8
PFD 0.0e+00
Delays (us)
SBD 0.008440
MBD 0.010010
Fringe rate (Hz)
-0.001797
Ion TEC 0.000
Ref freq (MHz)
8210.9900
AP (sec) 0.026
Exp. sim
Exper # 16383
Yr:day 2020:028
Start 173000.00
Stop 173001.00
FRT 173000.00
Corr/FF/build
2020:321:181523
2020:321:181524
2020:111:181228
RA & Dec (J2000)
03h49m10.987080s
+00°00'00.000000"
Amp. and Phase vs. time for each freq., 39 segs, 1 APs / seg (0.03 sec / seg.), time ticks 1 sec
a b c d e f g h All
Validity
pcal θ
L W
8210.99 8250.99 8350.99 8510.99 8730.99 8850.99 8890.99 8930.99 Freq (MHz) A
39.4 41.3 39.9 38.0 39.3 40.9 39.9 40.0 Phase 39.8
191.7 193.8 200.2 190.0 192.2 188.4 194.4 191.9 Amp. 192.8
129.1 129.2 129.1 129.1 129.1 129.1 129.1 129.1 Sbd box 129.1
U/L 39/0 39/0 39/0 39/0 39/0 39/0 39/0 39/0 APs used
L 0 0 0 0 0 0 0 0 PC freqs
W 0 0 0 0 0 0 0 0 PC freqs
L:W 0:0 0:0 0:0 0:0 0:0 0:0 0:0 0:0 PC phase
L:W 0:0 0:0 0:0 0:0 0:0 0:0 0:0 0:0 Man PC
L 1000 1000 1000 1000 1000 1000 1000 1000 PC amp
W 1000 1000 1000 1000 1000 1000 1000 1000
L X00UR X01UR X02UR X03UR X04UR X05UR X06UR X07UR Chan ds
Tracks
W X00UR X01UR X02UR X03UR X04UR X05UR X06UR X07UR Chan ds
Tracks
Group delay (usec)(mode) 1.00100000000E-02 Apr or delay (usec) 0.00000000000E+00 Resid mbdelay (usec) 1.00100E-02 +/- 4.4E-06
Sband delay (usec) 8.44000000000E-03 Apr or clock (usec) 0.00000000E+00 Resid sbdelay (usec) 8.44000E-03 +/- 1.1E-03
Phase delay (usec) 1.34780923960E-05 Apr or clockrate (us/s) 0.00000000E+00 Resid phdelay (usec) 1.34781E-05 +/- 3.0E-07
Delay rate (us/s) -2.18837807060E-07 Apr or rate (us/s) 0.00000000000E+00 Resid rate (us/s) -2.18838E-07 +/- 5.1E-07
Total phase (deg) 39.8 Apr or accel (us/s/s) 0.00000000000E+00 Resid phase (deg) 39.8 +/- 0.9
RMS Theor. Amplitude 193.128 +/- 1.474 Pcal mode: MANUAL, MANUAL PC period (AP's) 5, 5
ph/seg (deg) 2.6 2.7 Search (128X256) 192.077 Pcal rate: 0.000E+00, 0.000E+00 (us/s) sbwindow (us) -8.000 8.000
amp/seg (%) 4.9 4.8 Interp. 0.000 Bits/sample: 2x2 SampCntNorm: disabled mbwindow (us) -0.025 0.025
ph/frq (deg) 1.1 1.2 Inc. seg. avg. 192.764 Sample rate(MSamp/s): 8 drwindow (ns/s) -2.379 2.379
amp/frq (%) 1.7 2.2 Inc. frq. avg. 192.764 Data rate(Mb/s): 128 nags: 128 t_cohere nfinte onwindow (TEC) 0.00 0.00
L: az 160.8 el 39.3 pa -12.4 W: az 160.8 el 39.3 pa -12.4 u,v (fr/asec) 0.000 0.000 simultaneous interpolat
Control file: default Input file: /home/jakob/software/BasebandSim/OUT/2020_321_19_13_34/1234/SIM001/LW..1F4XMJ Output file: Suppressed by test mode

3.1.6 8 Channel X-band plus 60 ns Multiband Delay

```
setup:
  zero_bl: 1
s1:
  date_vec: [2020,1,28,17,30,00]
  station_name: S1
  station_name_8character: KOKEE12M
  station_name_trf_coord: K2
  X_trf: [4.0755139837000000e+06,9.317353092000000e+05,4.801629401000000e+06]
  sampling_frequency: 8
  scan_length: 1
  fluxdensity_targetsource: 1
  fluxdensity_system: 50
  f0: [8212.99, 8252.99, 8352.99, 8512.99, 8732.99, 8852.99, 8892.99, 8932.99]
  number_of_bits: 2
  signal_type_target_source: gaussian-white-noise
  source_name: 0026+892
  bandpass_filter_name: default
  delay_source: 60
s2:
  date_vec: [2020,1,28,17,30,00]
  station_name: S2
  station_name_8character: YEBES12M
  station_name_trf_coord: Ys
  sampling_frequency: 8
  scan_length: 1
  fluxdensity_targetsource: 1
  fluxdensity_system: 50
  f0: [8212.99, 8252.99, 8352.99, 8512.99, 8732.99, 8852.99, 8892.99, 8932.99]
  number_of_bits: 2
  source_name: 0026+892
  bandpass_filter_name: default
```



	8210.99	8250.99	8350.99	8510.99	8730.99	8850.99	8890.99	8930.99	Freq (MHz)	A
	-123.5	-123.7	-122.4	-123.3	-123.3	-125.3	-122.4	-122.5	Phase	-123.3
	202.8	189.6	194.1	195.8	193.9	191.5	191.7	191.1	Amp.	193.8
	130.0	129.9	130.0	129.9	129.9	130.0	130.0	129.9	Sbd box	130.0
U/L	39/0	39/0	39/0	39/0	39/0	39/0	39/0	39/0	APs used	
L	0	0	0	0	0	0	0	0	PC freqs	
W	0	0	0	0	0	0	0	0	PC freqs	
L:W	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	PC phase	
L:W	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	Man PC	
L	1000	1000	1000	1000	1000	1000	1000	1000	PC amp	
W	1000	1000	1000	1000	1000	1000	1000	1000		
L	X00UR	X01UR	X02UR	X03UR	X04UR	X05UR	X06UR	X07UR	Chan ds	
									Tracks	
W	X00UR	X01UR	X02UR	X03UR	X04UR	X05UR	X06UR	X07UR	Chan ds	
									Tracks	

Group delay (usec)(mode)	9.99148750000E-03	Apr or delay (usec)	0.00000000000E+00	Res d mbdelay (usec)	9.99149E-03	+/-	4.4E-06
Sband delay (usec)	6.06400000000E-02	Apr or clock (usec)	0.00000000E+00	Res d sbdelay (usec)	6.06400E-02	+/-	1.0E-03
Phase delay (usec)	-4.17153342855E-05	Apr or clockrate (us/s)	0.00000000E+00	Res d phdelay (usec)	-4.17153E-05	+/-	2.9E-07
Delay rate (us/s)	7.18358888393E-07	Apr or rate (us/s)	0.00000000000E+00	Res d rate (us/s)	7.18359E-07	+/-	5.1E-07
Total phase (deg)	-123.3	Apr or acce (us/s/s)	0.00000000000E+00	Res d phase (deg)	-123.3	+/-	0.9

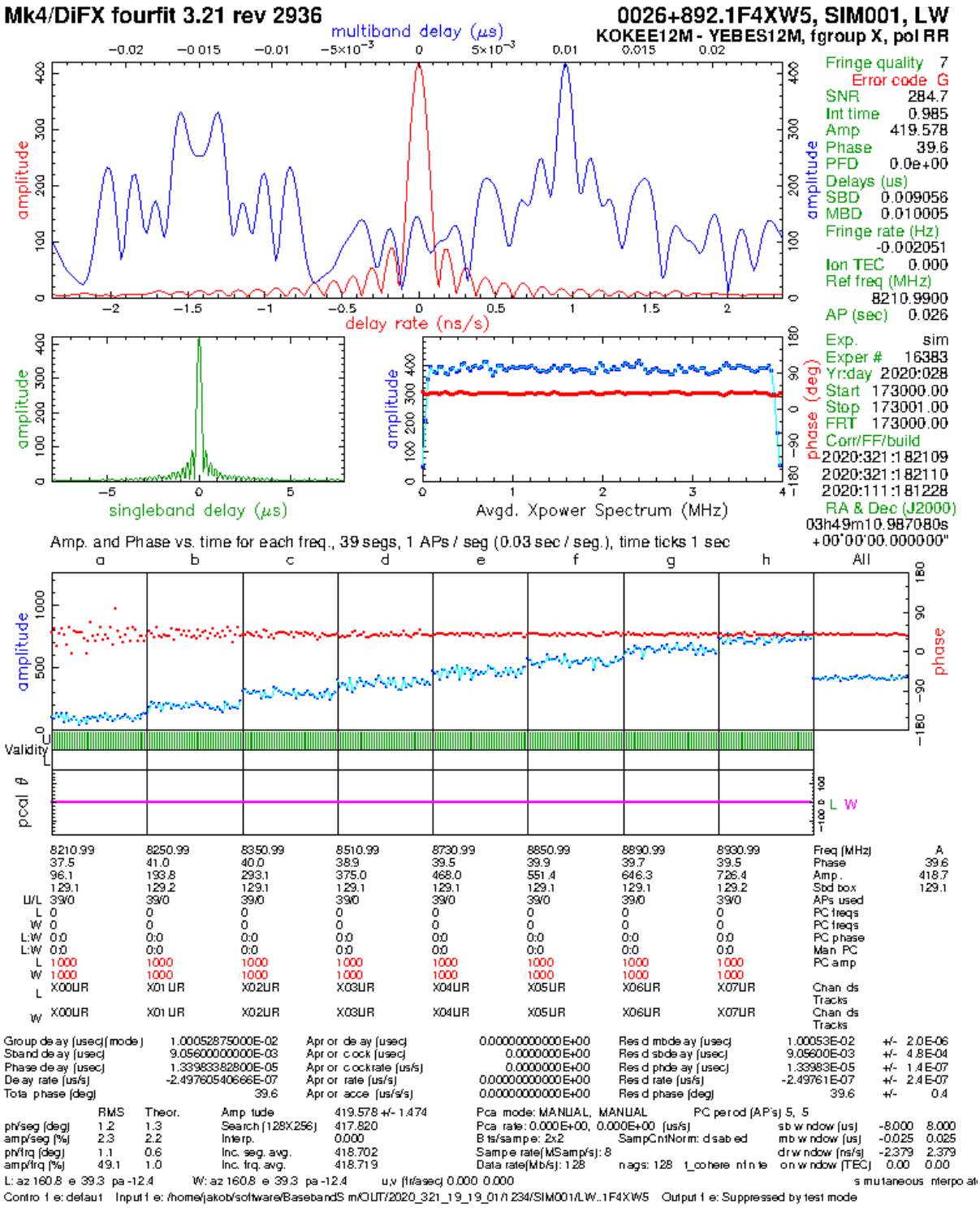
	RMS	Theor.					
			Amplitude	193.814 +/- 1.474	Pcal mode: MANUAL, MANUAL	PC period (AP's) 5, 5	
ph/seg (deg)	3.1	2.7	Search (128X256)	193.504	Pcal rate: 0.000E+00, 0.000E+00 (us/s)	sb window (us)	-8.000 8.000
amp/seg (%)	4.8	4.7	Interp.	0.000	Bits/sample: 2x2 SampCntNorm: disabled	mb window (us)	-0.025 0.025
ph/frq (deg)	1.0	1.2	Inc. seg. avg.	193.866	Sample rate(MSamp/s): 8	dr window (ns/s)	-2.379 2.379
amp/frq (%)	2.0	2.2	Inc. frq. avg.	193.777	Data rate(Mb/s): 128 nags: 128 t_coherence	on window (TEC)	0.00 0.00

L: az 160.8 el 39.3 pa -12.4 W: az 160.8 el 39.3 pa -12.4 u,v (fr/asec) 0.000 0.000 simultaneous interpolation

Control file: default Input file: /home/jakob/software/BasebandSim/OUT/2020_321_19_09_39/1234/SIM001/LW..1F4XGG Output file: Suppressed by test mode

3.1.7 8 Channel X-band with Increasing Source Flux

```
setup:
  zero_bl: 1
s1:
  date_vec: [2020,1,28,17,30,00]
  station_name: S1
  station_name_8character: KOKEE12M
  station_name_trf_coord: K2
  X_trf: [4.0755139837000000e+06,9.317353092000000e+05,4.801629401000000e+06]
  sampling_frequency: 8
  scan_length: 1
  fluxdensity_targetsource: [1,2,3,4,5,6,7,8]
  fluxdensity_system: 100
  f0: [8212.99, 8252.99, 8352.99, 8512.99, 8732.99, 8852.99, 8892.99, 8932.99]
  number_of_bits: 2
  signal_type_target_source: gaussian-white-noise
  source_name: 0026+892
  bandpass_filter_name: default
  delay_source: 10
s2:
  date_vec: [2020,1,28,17,30,00]
  station_name: S2
  station_name_8character: YEBES12M
  station_name_trf_coord: Ys
  sampling_frequency: 8
  scan_length: 1
  fluxdensity_targetsource: [1,2,3,4,5,6,7,8]
  fluxdensity_system: 100
  f0: [8212.99, 8252.99, 8352.99, 8512.99, 8732.99, 8852.99, 8892.99, 8932.99]
  number_of_bits: 2
  source_name: 0026+892
  bandpass_filter_name: default
```



	8210.99	8250.99	8350.99	8510.99	8730.99	8850.99	8890.99	8930.99	Freq (MHz)	A
	37.5	41.0	40.0	38.9	39.5	39.9	39.7	39.5	Phase	39.6
	96.1	193.8	293.1	375.0	468.0	551.4	646.3	726.4	Amp.	418.7
	129.1	129.2	129.1	129.1	129.1	129.1	129.1	129.2	Sbd box	129.1
U/L	39/0	39/0	39/0	39/0	39/0	39/0	39/0	39/0	APs used	
L	0	0	0	0	0	0	0	0	PC freqs	
W	0	0	0	0	0	0	0	0	PC freqs	
L:W	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	PC phase	
L:W	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	Man PC	
L	1000	1000	1000	1000	1000	1000	1000	1000	PC amp	
W	1000	1000	1000	1000	1000	1000	1000	1000		
L	X00LR	X01LR	X02LR	X03LR	X04LR	X05LR	X06LR	X07LR	Chan ds	
									Tracks	
W	X00UR	X01UR	X02UR	X03UR	X04UR	X05UR	X06UR	X07UR	Chan ds	
									Tracks	

Group de ay (usec)(mode)	1.00052875000E-02	Apr or de ay (usec)	0.00000000000E+00	Res d mbde ay (usec)	1.00053E-02	+/-	2.0E-06
Sband de ay (usec)	9.05600000000E-03	Apr or c ock (usec)	0.00000000E+00	Res d sbde ay (usec)	9.05600E-03	+/-	4.8E-04
Phase de ay (usec)	1.33983382800E-05	Apr or c ockrate (us/s)	0.00000000E+00	Res d phde ay (usec)	1.33983E-05	+/-	1.4E-07
De ay rate (us/s)	-2.49760540666E-07	Apr or rate (us/s)	0.00000000000E+00	Res d rate (us/s)	-2.49761E-07	+/-	2.4E-07
Tota phase (deg)	39.6	Apr or acce (us/s/s)	0.00000000000E+00	Res d phase (deg)	39.6	+/-	0.4

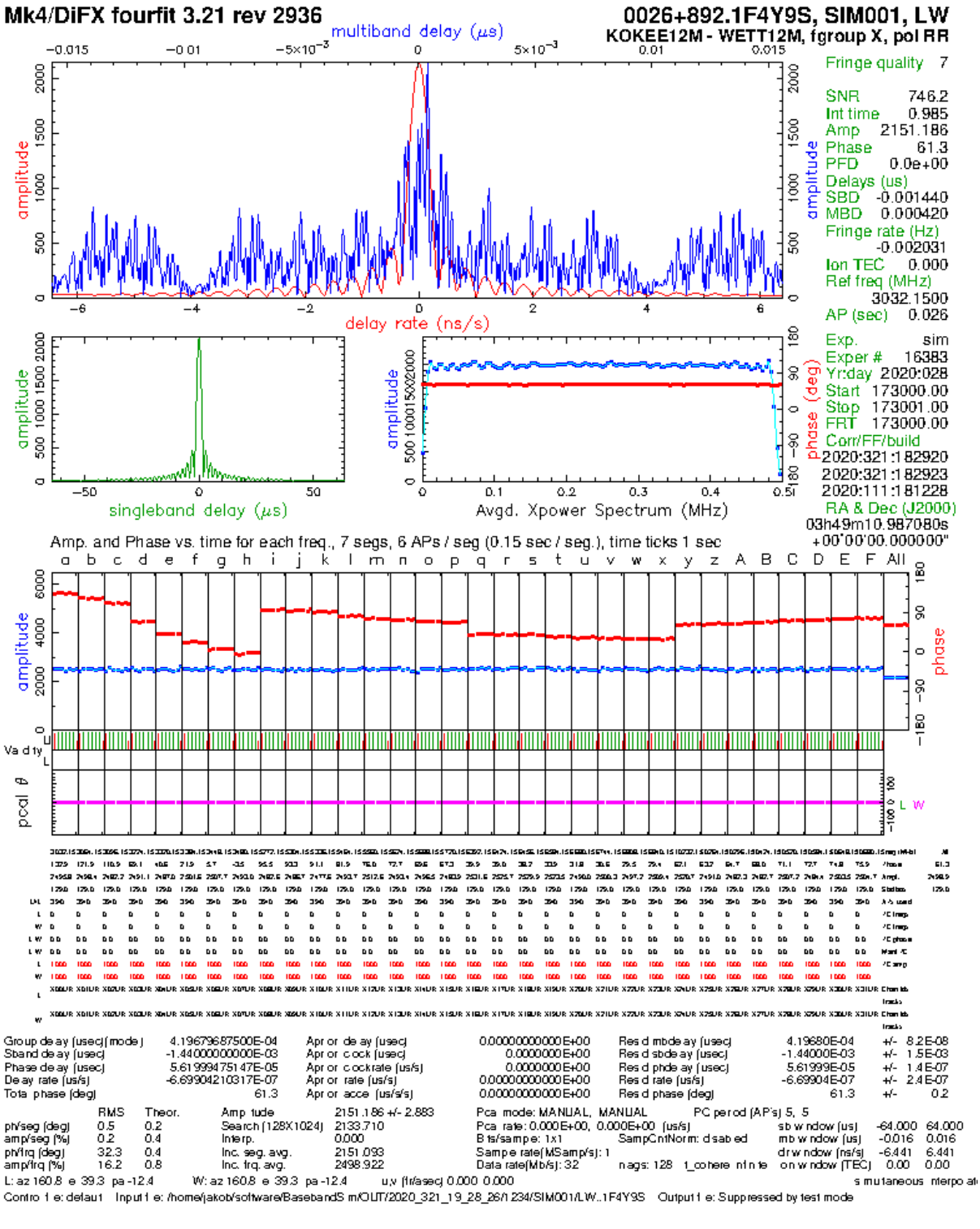
	RMS	Theor.					
			Amp tude	419.578 +/- 1.474	Pca mode: MANUAL, MANUAL	PC period (AP's) 5, 5	
ph/seg (deg)	1.2	1.3	Search (128X256)	417.820	Pca rate: 0.000E+00, 0.000E+00 (us/s)	sb w ndow (us)	-8.000 8.000
amp/seg (%)	2.3	2.2	Interp.	0.000	B ts/sampe: 2x2 SampCntNorm: d sab ed	mb w ndow (us)	-0.025 0.025
ph/frq (deg)	1.1	0.6	Inc. seg. avg.	418.702	Sampe rate(MSamp/s): 8	dr w ndow (ns/s)	-2.379 2.379
amp/frq (%)	49.1	1.0	Inc. frq. avg.	418.719	Data rate(Mb/s): 128 nags: 128 t_cohere n t n te	on w ndow (TEC)	0.00 0.00

L: az 160.8 e 39.3 pa -12.4 W: az 160.8 e 39.3 pa -12.4 u,v (fr/asec) 0.000 0.000 s mu taneous nterpo at

Contro l e: defau l Input l e: /home/jakob/software/BasebandS m/OUT/2020_321_19_19_01/1234/SIM001/LW..1F4XW5 Output l e: Suppressed by test mode

3.1.8 VGOS 32 Channel Setup with Dispersive Group Delay due Ionoshpere 8 TEC (sampling frequency 1 MHz, can be simulated on private machine)

```
setup:
  zero_bl: 1
s1:
  date_vec: [2020,1,28,17,30,00]
  station_name: S1
  station_name_8character: KOKEE12M
  station_name_trf_coord: K2
  X_trf: [4.0755139837000000e+06,9.317353092000000e+05,4.801629401000000e+06]
  sampling_frequency: 1
  scan_length: 1
  fluxdensity_targetsource: 20
  fluxdensity_system: 60
  f0:
[3032.40,3064.40,3096.40,3224.40,3320.40,3384.40,3448.40,3480.40,5272.40,5304.40
,5336.40,5464.40,5560.40,5624.40,5688.40,5720.40, 6392.40, 6424.40, 6456.40,
6584.40, 6680.40, 6744.40, 6808.40, 6840.40,10232.40, 10264.40, 10296.40,
10424.40, 10520.40, 10584.40, 10648.40, 10680.40]
  number_of_bits: 1
  signal_type_target_source: gaussian-white-noise
  source_name: 0026+892
  delay_source: [-0.569826, -0.545521, -0.521966, -0.434654, -0.375689,
-0.339136, -0.304599, -0.288041, 0.213037, 0.217692, 0.222263, 0.239753,
0.252085, 0.259957, 0.267566, 0.271275, 0.336757, 0.339373, 0.341950, 0.351885,
0.358965, 0.363518, 0.367943, 0.370109, 0.497263, 0.497902, 0.498536, 0.501012,
0.502811, 0.503982, 0.505133, 0.505701]
  phaseoff_source: [-44.577691, -44.112163, -43.656258, -41.923135, -40.710988,
-39.941097, -39.199784, -38.839353, -25.638204, -25.483533, -25.330717,
-24.737351, -24.310255, -24.033624, -23.763218, -23.630285, -21.146122,
-21.040791, -20.936505, -20.529497, -20.234477, -20.042462, -19.854058,
-19.761178, -13.210386, -13.169201, -13.128273, -12.967071, -12.848745,
-12.771053, -12.694295, -12.656260]
s2:
  date_vec: [2020,1,28,17,30,00]
  station_name: S2
  station_name_8character: WETT12M
  station_name_trf_coord: WS
  X_trf: [4.0755139837000000e+06,9.317353092000000e+05,4.801629401000000e+06]
  sampling_frequency: 1
  scan_length: 1
  fluxdensity_targetsource: 20
  fluxdensity_system: 60
  f0:
[3032.40,3064.40,3096.40,3224.40,3320.40,3384.40,3448.40,3480.40,5272.40,5304.40
,5336.40,5464.40,5560.40,5624.40,5688.40,5720.40, 6392.40, 6424.40, 6456.40,
6584.40, 6680.40, 6744.40, 6808.40, 6840.40,10232.40, 10264.40, 10296.40,
10424.40, 10520.40, 10584.40, 10648.40, 10680.40]
  number_of_bits: 1
  signal_type_target_source: gaussian-white-noise
  source_name: 0026+892
```



Group delay (usec)(mode)	4.196796875000E-04	Apriori delay (usec)	0.000000000000E+00	Resid mbdelay (usec)	4.19680E-04 +/- 8.2E-08
Sband delay (usec)	-1.440000000000E-03	Apriori clock (usec)	0.000000000E+00	Resid sbdelay (usec)	-1.44000E-03 +/- 1.5E-03
Phase delay (usec)	5.619994751 47E-05	Apriori clockrate (us/s)	0.000000000E+00	Resid phdelay (usec)	5.61999E-05 +/- 1.4E-07
Delay rate (us/s)	-6.699042103 17E-07	Apriori rate (us/s)	0.000000000000E+00	Resid rate (us/s)	-6.69904E-07 +/- 2.4E-07
Total phase (deg)	61.3	Apriori accel (us/s/s)	0.000000000000E+00	Resid phase (deg)	61.3 +/- 0.2

	RMS	Theor.				
ph/seg (deg)	0.5	0.2	Amplitude	2151.186 +/- 2.883	Pcal mode: MANUAL, MANUAL	PC period (AP's) 5, 5
amp/seg (%)	0.2	0.4	Interp.	0.000	Pcal rate: 0.000E+00, 0.000E+00 (us/s)	sb window (us) -64.000 64.000
ph/frq (deg)	32.3	0.4	Inc. seg. avg.	2151.093	Bits/sample: 1x1 SampCntNorm: disabled	mb window (us) -0.016 0.016
amp/frq (%)	16.2	0.8	Inc. frq. avg.	2498.922	Sample rate(MSamp/s): 1	dr window (ns/s) -6.441 6.441
					Data rate(Mb/s): 32 nags: 128 t_cohere nfnte	on window (TEC) 0.00 0.00

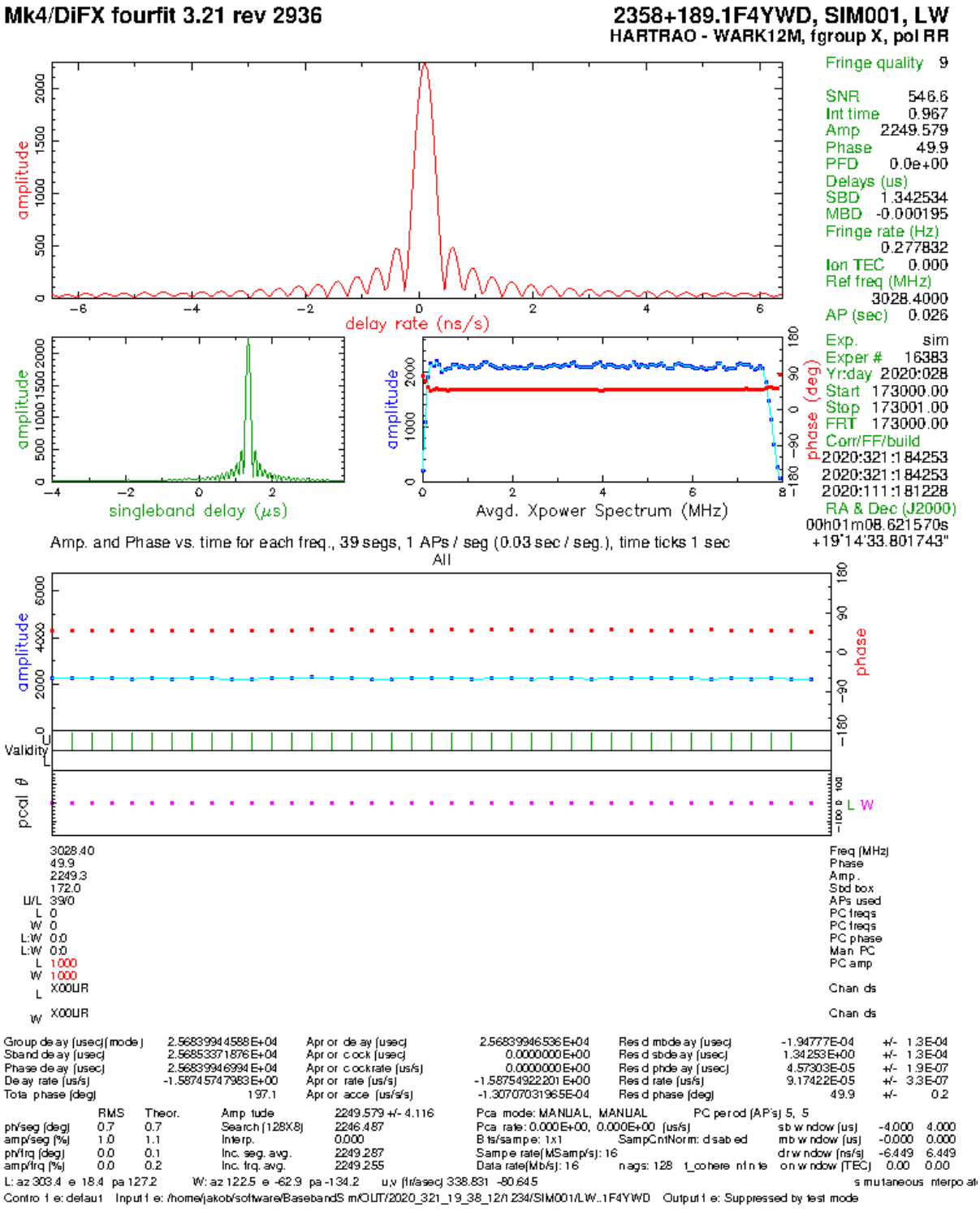
L: az 160.8 el 39.3 pa -12.4 W: az 160.8 el 39.3 pa -12.4 u,v (fr/asec) 0.000 0.000 simultaneous interpolation

Control file: default Input file: /home/jakob/software/BasebandSim/OUT/2020_321_19_28_26/1234/SIM001/LW..1F4Y9S Output file: Suppressed by test mode

3.2 Non-Zero Baseline Simulation

3.2.1 Very High delay rate, single channel

```
setup:
  zero_bl: 0
s1:
  date_vec: [2020,1,28,17,30,00]
  station_name: S1
  station_name_8character: HARTRAO
  station_name_trf_coord: Hh
  sampling_frequency: 16
  scan_length: 1
  fluxdensity_targetsource: 20
  fluxdensity_system: 60
  f0: [3032.40]
  number_of_bits: 1
  signal_type_target_source: gaussian-white-noise
  source_name: 2358+189
s2:
  date_vec: [2020,1,28,17,30,00]
  station_name: S2
  station_name_8character: WARK12M
  station_name_trf_coord: Ww
  sampling_frequency: 16
  scan_length: 1
  fluxdensity_targetsource: 20
  fluxdensity_system: 60
  f0: [3032.40]
  number_of_bits: 1
  signal_type_target_source: gaussian-white-noise
  source_name: 2358+189
```


Mk4/DiFX fourfit 3.21 rev 2936
2358+189.1F4YWD, SIM001, LW
HARTRAO - WARK12M, fgroup X, pol RR
Fringe quality 9
SNR 546.6
Int time 0.967
Amp 2249.579
Phase 49.9
PFD 0.0e+00
Delays (us)
SBD 1.342534
MBD -0.000195
Fringe rate (Hz)
0.277832
Ion TEC 0.000
Ref freq (MHz)
3028.4000
AP (sec) 0.026
Exp. sim
Exper # 16383
Yr:day 2020:028
Start 173000.00
Stop 173001.00
FRT 173000.00
Corr/FF/build
2020:321:184253
2020:321:184253
2020:111:181228
RA & Dec (J2000)
00h01m08.621570s
+19°14'33.801743"
amplitude
delay rate (ns/s)
singleband delay (μs)
Avgd. Xpower Spectrum (MHz)
phase (deg)
Amp. and Phase vs. time for each freq., 39 segs, 1 APs / seg (0.03 sec / seg.), time ticks 1 sec
All
Validity
pcal θ
L W
3028.40 Freq (MHz)
49.9 Phase
2249.3 Amp.
172.0 Sbd box
U/L 39/0 APs used
L 0 PC freqs
W 0 PC freqs
L:W 0:0 PC phase
L:W 0:0 Man PC
L 1000 PC amp
W 1000
L X00UR Chan ds
W X00UR Chan ds
Group delay (usec)(mode) 2.56839944588E-04 Apriori delay (usec) 2.56839946536E-04 Resid mbdelay (usec) -1.94777E-04 +/- 1.3E-04
Sband delay (usec) 2.56853371876E-04 Apriori clock (usec) 0.00000000E+00 Resid sbdelay (usec) 1.34253E-04 +/- 1.3E-04
Phase delay (usec) 2.56839946994E-04 Apriori clockrate (us/s) 0.00000000E+00 Resid phdelay (usec) 4.57303E-05 +/- 1.9E-07
Delay rate (us/s) -1.58745747983E+00 Apriori rate (us/s) -1.58754922201E+00 Resid rate (us/s) 9.17422E-05 +/- 3.3E-07
Total phase (deg) 197.1 Apriori accel (us/s/s) -1.30707031965E-04 Resid phase (deg) 49.9 +/- 0.2
RMS Theor. Amplitude 2249.579 +/- 4.116 Pcal mode: MANUAL, MANUAL PC period (AP's) 5, 5
ph/seg (deg) 0.7 0.7 Search (128X8) 2246.487 Pcal rate: 0.000E+00, 0.000E+00 (us/s) sbwindow (us) -4.000 4.000
amp/seg (%) 1.0 1.1 Interp. 0.000 Bits/sample: 1x1 SampCntNorm: disabled mbwindow (us) -0.000 0.000
ph/frq (deg) 0.0 0.1 Inc. seg. avg. 2249.287 Sample rate(MSamp/s): 16 drwindow (ns/s) -6.449 6.449
amp/frq (%) 0.0 0.2 Inc. frq. avg. 2249.255 Data rate(Mb/s): 16 nags: 128 t_cohere nfnte onwindow (TEC) 0.00 0.00
L: az 303.4 el 18.4 pa 127.2 W: az 122.5 el -62.9 pa -134.2 u,v (fr/asec) 338.831 -80.645 simultaneous interpolat
Control file: default Input file: /home/jakob/software/BasebandSim/OUT/2020_321_19_38_12/1234/SIM001/LW..1F4YWD Output file: Suppressed by test mode