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**DESCRIPTION AND OPERATION OF THE D A G A 2 H F
ACQUISITION SYSTEM FOR GRAVITATIONAL WAVE
DETECTORS**

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Abstract

The new acquisition system for the gravitational wave detectors of the *ROG* group, *NAUTILUS* in operation at the *INFN* Laboratori Nazionali di Frascati and *EXPLORER* at *CERN*, is described. The system, operating with a 5 kHz sampling rate, allows on-line data analysis for the search of impulsive excitations of the gravitational wave detectors.

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1 Introduction

The new DAGA2_HF data acquisition system for gravitational wave (GW) antennas has been conceived and realized by S. Frasca and M.A.Papa. The final implementation on the software and hardware system and the necessary corrections have been performed by S.D'Antonio. The final version for user application is described in the following. The new DAGA2_HF is presently in operation on the two detectors of the Rome group: NAUTILUS in Frascati and EXPLORER at CERN. This new system is operating together with the old DAGA2 system, in order to do the final overall checks. The analysis software is written in FORTRAN (about 35,000 lines), and is operating on ALFA VAX under OPEN VMS, while the front-end software is written in PASCAL. The main advantages of the new system are the following ones:

a) higher sampling frequency, 5 kHz with respect to the previous 220 Hz. This makes it possible to explore the full frequency band from 0 up to 2.5 kHz and it allows to obtain a better time resolution;

b) a simpler hardware apparatus. The lock-in amplifiers, relative synthesizers and amplifiers needed with the old system to extract the information at the main frequencies (the two resonance modes, the wide band and the calibration) are eliminated. Their functions are performed via software;

c) capability to perform real time data filtering. With the old system the on-line filtering was done using power spectra obtained at a previous time. Therefore an other off-line filtering was needed, in order to obtain the best signal to noise ratio. With the new system the power spectra are continuously updated and no off-line analysis is needed;

d) the time resolution obtained with the new system is better, for the smaller sampling time and also for a front end readout with a real time system that allows a precise timing of order $200 \mu s$ against $10 ms$ obtained with the old system.

2 Data acquisition

The new read-out hardware system uses the VME standard for an better availability of boards with good performance. Each RUN starts with a pulse from a GPS (Global Position System) rubidium clock at the exact second, the time error on pulse second from GPS is $100 ns$. This is important, in particular for the study of the continuous GW and for cross-correlating the outputs of two different detectors for the measurement of the stochastic background. A single board VME digital equipment VAX processor (KAV30-AD) runs the real-time DEC VAXELN operating system using software developed for the MACRO experiment [6],[7]. This processor adjourns itself every two minutes using the GPS. Checks

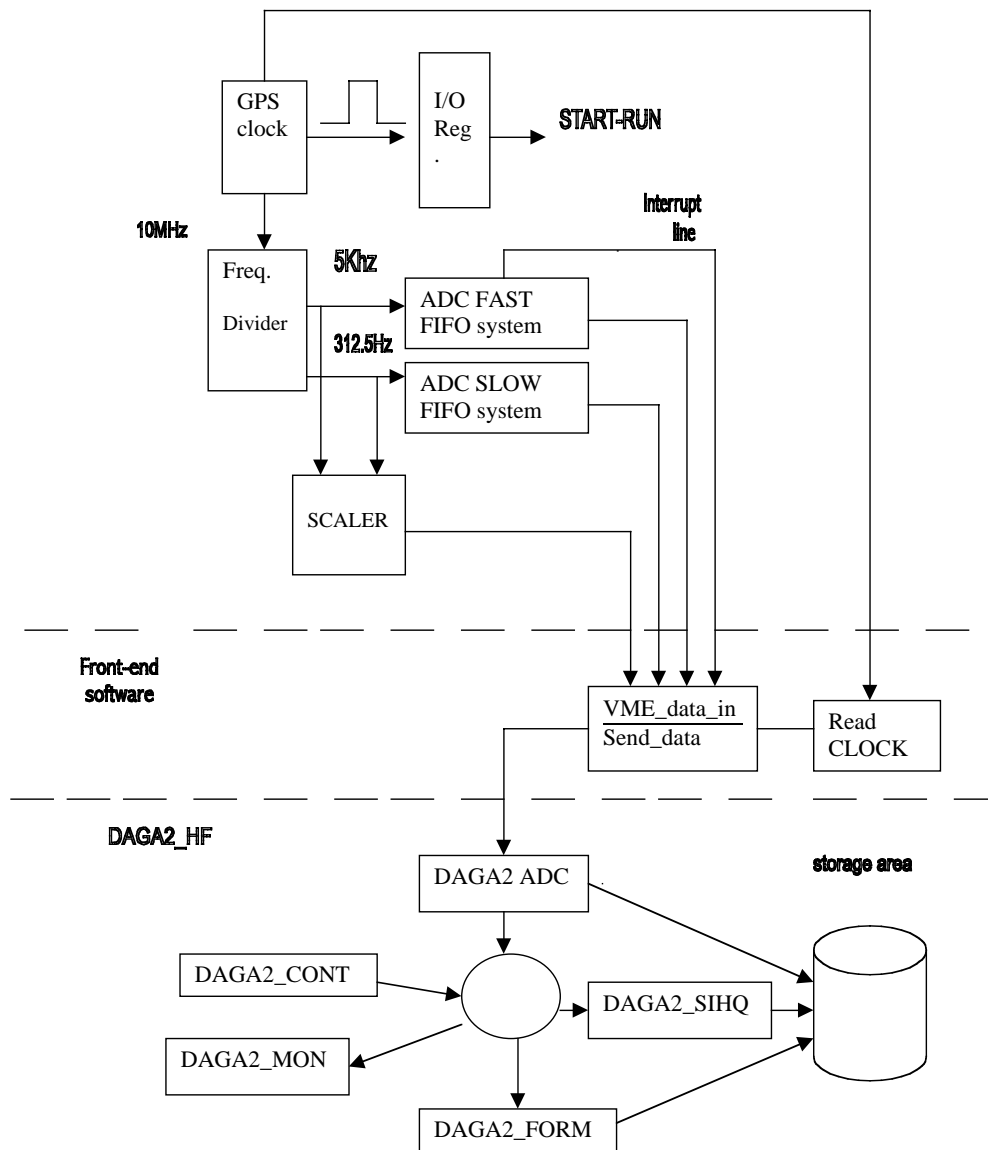


Figure 1: Data acquisition system

on the correct adjourns of KAV30 are performed and information about the GPS (visible satellites and time string) and about the time string of KAV30 are recorded in log files. Furthermore the GPS supplies the 10 MHz frequency that is send to a frequency divider, programmed by front-end software at the start run, to trigger the two Pentland MPX300 ADCs (32 channels at 16 bit). One ADC acquires the 5 kHz data directly from the antenna, the other one acquires at 312.5 Hz the auxiliary channels which give information on the behavior of the overall experimental apparatus (seismometers, pressure gauges, cryogenic liquids indicators, etc). For this last one the acquisition frequency is 9.766 Hz per channel. These trigger frequencies, 5 kHz and 312.5 Hz , are also send to the modulo SCALER to allow the performing of a continuous check via software on the acquired sampled data. A possible loss of data samplings starts an automatic procedure which stops the RUN and starts a new RUN. The ADC converts linearly analog data into a 16 bit value (the input range is selected between $\pm 10\text{ V}$). The converted data are written into a 512×16 FIFO (Firs-in-First-Out) memory system, an interrupt occurs when the FIFO is half full. The buffers data are queued up to 20 and they are sent to the acquisition computer, ALPHA STATION 600, via ETHERNET in a local area network. Then they are processed and archived by DAGA2_HF. Also a possible anomalous status of FIFO system, FIFO empty or FIFO full, is checked and recorded in the log files.

3 Data processing

The DAGA2_HF system consists essentially of six current jobs. The job *DAGA2_ADC* runs at high priority (16), reads data coming from *VME*, writes the raw data and shares them with other jobs.

The job *DAGA2_FORM*, at priority 7, processes, analyzes and stores the data while *DAGA2_SIHQ*, at priority 5, estimates some adaptive parameters, frequency spectra, and implements the matched filter.

The *DAGA2_CONT* manages all acquisition RUN control and the *SUPERVISOR*, at priority 1, checks all the data acquisition parameters. Finally the *DAGA2_MON* allows on-line monitor of data : raw data and already analyzed data.

The 5 kHz data are collected by DAGA2_HF in sets of 262144 samplings and then transformed in the frequency domain by an FFT procedure. This is done with periodicity of 54 seconds; the frequency resolution turns out to be 19 mHz. From the 0 to 2.5 kHz frequency band, several sub-bands are extracted: the high sensitivity band of the antenna, a low frequency band to monitor the seismic noise and other intermediate bands to estimate electronic noises and disturbances. Each sub-band has its own proper sub-sampling time for the corresponding temporal series, depending on its bandwidth. The acquisition

mask contains the information about the band to be extracted and all information for the data analysis. For the band which includes the two resonance modes (896.4539 Hz - 935.5068 Hz) the sub-sampling factor is 64 for a sampling time of 12.8 ms. From this band smaller bands are extracted, for each of the two resonance modes, for the calibration and for the wide-band noise, with an additional sub-sampling factor of 8, for a sampling time of 102.4 ms. To these bands software lock-ins are applied (see fig. 1). The lock-in outputs are recorded in output channels and also processed with the ZOP and Wiener filters. As far as the other ADC data, some of the channels acquired at 9.766 Hz are sub-sampled by a factor of 200 (sampling time $\Delta t = 20.48$ s), the other channels (SQUID working status and the seismometers) remain with a sampling time $\Delta t = 102.4$ ms.

4 Linear filtering for detection of short bursts of gravitational radiation

The DAGA2_HF system includes various types of data filters that we describe in this section: the ZOP and the WIENER filters are implemented in the time domain, the MATCHED filter in the frequency domain.

4.1 The ZOP filter

This is the simplest filter for extracting signals due to delta excitations. Considering one resonant mode (say the minus mode f_0), we send the signal from the low noise amplifier to the lock-in amplifier which extracts the in phase and in quadrature components, $x(t)$ and $y(t)$, of the Fourier transform at the resonance frequency f_0 . The lock-in amplifier has integration time t_o and both components are sampled with a sampling time $\Delta t = 1/t_o$. The ZOP algorithm (zero-order prediction), consists [2] in taking the difference between two successive samplings

$$z(t)^2 = [x(t) - x(t - \Delta t)]^2 + [y(t) - y(t - \Delta t)]^2 \quad (1)$$

The key idea is that a short burst will produce a jump in the data, like a hammer hit, while the fluctuations due to the noise have a long time constant depending on the decay time $\tau_v = \frac{Q}{\pi f_0}$ where Q is the merit factor. Let us now estimate the SNR for this algorithm. The noise is essentially due to the narrow-band Brownian noise in the bar

$$V_{nb}^2 = \frac{\alpha^2 k T_e}{2m\omega_o^2} \quad (2)$$

(increased by the back action from the amplifier) and to the white noise S_o from the amplifier. α is the transducer constant and the factor of two in eq.2 takes care of the fact that

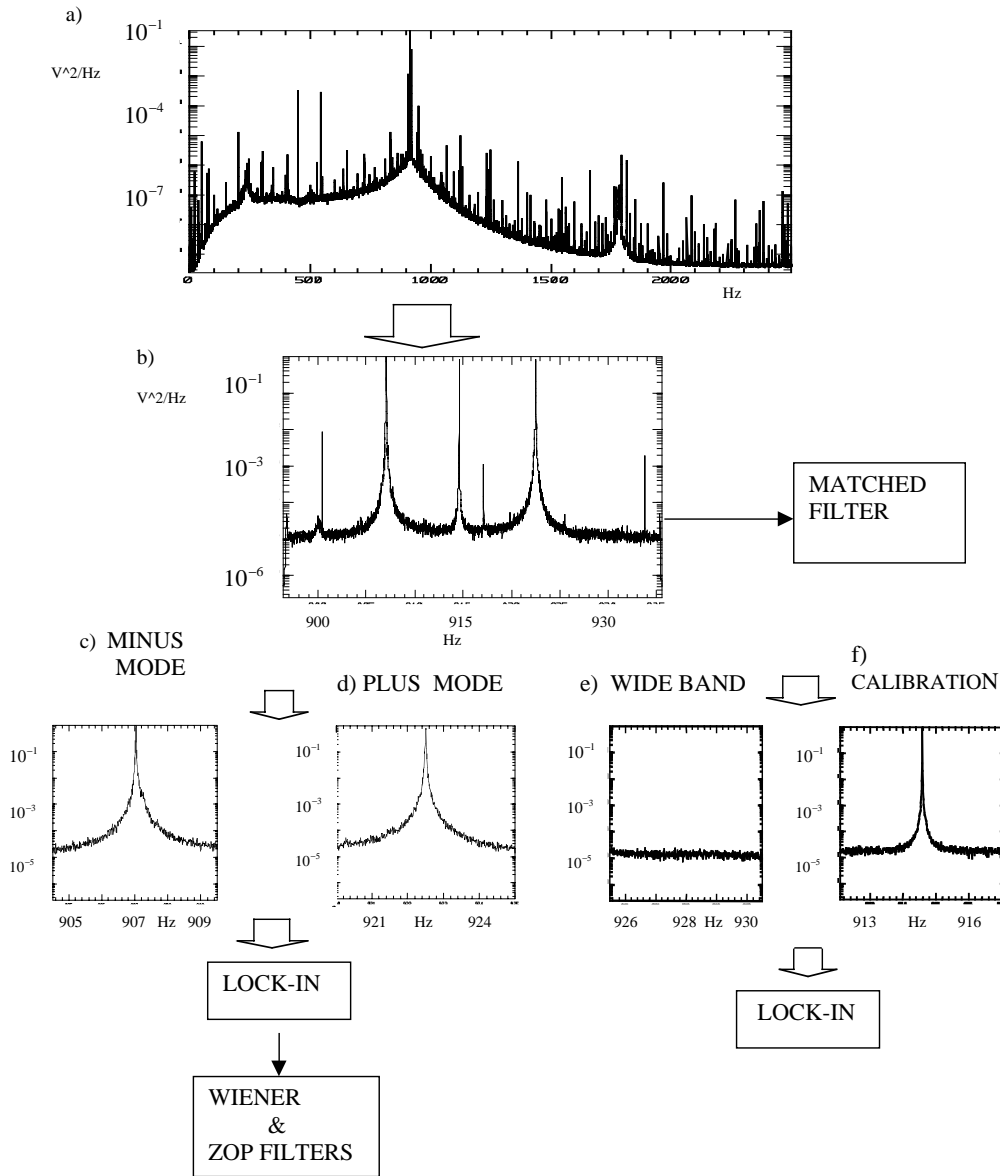


Figure 2: Data processing. Figure a) shows the spectrum from 0 Hz to 2500 Hz. From this spectrum various bands are extracted: the sensible band (fig. b), the two modes (fig. c) and fig. d), the wide band (fig. e) and the calibration (fig. f)).

the energy of the signal is split between the two modes of the transducer bar system. It can be shown [2] that the variance for the variable $z(t)$ is:

$$\sigma^2 = \frac{4V_{nb}^2}{e} \frac{\Delta t}{\tau_v} + 4 \frac{e-1}{e} \frac{S_o}{\Delta t} \quad (3)$$

We notice that the two noises are in competition, one increasing linearly with Δt and the other one with the inverse of Δt . The optimum Δt is given by

$$\Delta t_{opt} = \tau_v \sqrt{(e-1)\Gamma} \quad (4)$$

and

$$\sigma_{min}^2 = 8V_{nb}^2 \frac{\sqrt{(e-1)\Gamma}}{e} \quad (5)$$

where we have made use of the quantity

$$\Gamma = \frac{S_o \tau_v}{V_{nb}^2} \quad (6)$$

This procedure is applied to both resonant modes so that the total noise is given by

$$\sigma_{opt}^2 = \frac{8\alpha^2 k T_e}{m\omega_o^2} \frac{\sqrt{(e-1)\Gamma}}{e} \quad (7)$$

We calculate now the signal for this algorithm. An incoming GW short burst will produce at the low noise amplifier output a jump in the signal from the noise level to a value [2]

$$V_s = \alpha \frac{2L}{\pi^2} \omega_o h(\omega_o) \quad (8)$$

slowly decaying with the time constant τ_v . At the lock-in amplifier output (after the lock-in integration with time constant t_o) we take the difference between two next samples. If we assume that the signal arrives exactly at the time of a sampling the difference with the next sampling is $V_s(1 - 1/e)$. We introduce the signal energy

$$E_s = \frac{1}{2} m \omega_o^2 \left(\frac{V_s}{\alpha} \right)^2 \quad (9)$$

Finally we get

$$SNR = \frac{V_s^2 (1 - 1/e)^2}{\sigma_{opt}^2} = \frac{E_s}{4kT_e \sqrt{\Gamma}} \frac{1}{1.21} \quad (10)$$

It must be remarked that this results is valid for signals arriving exactly at the sampling times. If one considers signals arriving at random times he gets a SNR that, on the average, is smaller by several per cent. Now we introduce the effective noise temperature T_{eff} .

This quantity expresses the overall sensitivity of the apparatus for pulse detection, as it represents the minimum detectable energy of a burst with $SNR = 1$. We obtain:

$$T_{eff} = 1.21kT_e4\sqrt{\Gamma} \quad (11)$$

Since $\Gamma \ll 1$, T_{eff} is much smaller than the noise for the unfiltered data expressed by kT_e .

4.2 The Wiener filter

The ZOP filter can be extended by including not just two samplings but many more. This is done by using the Wiener filter [1] which is based on the idea that the data samplings are processed a few seconds after they have been recorded, in such a way to make use of past as well *future* data. The best estimation of the signal $u(t)$ for the variable $x(t)$ at the lock-in output is

$$\tilde{u}(t) = \int x(t - \tau)W(t)d\tau \quad (12)$$

where $W(t)$ is the filter function which is estimated with the linear mean square method. It can be demonstrated [3] that the Fourier transform $W(f)$ of $W(t)$ which minimizes the average difference $\langle (u(t) - \tilde{u}(t))^2 \rangle$ is

$$W(f) = \frac{S_{ux}(f)}{S_{xx}(f)} \quad (13)$$

where $S_{xx}(f)$ is the power spectrum of $x(t)$, and $S_{ux}(f)$ is the cross spectrum of $u(t)$ and $x(t)$. From this we obtain [3]

$$W(f) = \frac{1}{W_a W_e} \frac{1}{1 + \frac{\Gamma}{W_a^2}} \quad (14)$$

where $W_a(f)$ is the bar transfer function which acts as a low-pass filter with time constant τ_v , and $W_e(f)$ is the integrating part of the lock-in which is again a low-pass filter with time t_o .

The signal reported at the antenna input has Fourier transform V_s (white spectrum because we consider a GW short burst). For simplicity, we consider the signal in phase with the lock-in reference frequency. The application of the Wiener filter gives

$$u(f) = V_s W_a(f) W_e(f) W(f) = \frac{V_s}{1 + \frac{\Gamma}{W_a^2}} \quad (15)$$

We notice that in absence of electronic noise ($\Gamma = 0$) the estimation is perfect, in the sense that its Fourier transform is equal to the Fourier transform of the GW signal. The

maximum SNR occurs at time $t = 0$, when the GW burst arrives. Considering that there is an equal contribution to the noise both from the in-phase and from the in-quadrature responses of the lock-in, and using the signal energy E_s we get

$$SNR = \frac{E_s}{4kT_e\sqrt{\Gamma}} \quad (16)$$

This shows that the improvement over the optimum ZOP filter seems to be just a factor of 1.21. Actually, the advantage is that, for the Wiener filter, one can sample faster than the optimum sampling needed to optimize the ZOP filter. In this way there is no loss in SNR due to the random arrival time of the GW bursts. The T_{eff} obtained by the Wiener filter is

$$T_{eff} = 4T_e\sqrt{\Gamma(\Gamma + 1)} \quad (17)$$

4.3 The matched filter

We give in the following a brief derivation of the matched filter [3]. Let us consider a signal $s(t)$ in presence of noise $n(t)$. The available information is the sum

$$x(t) = s(t) + n(t) \quad (18)$$

$x(t)$ is the measurement at the output of the low noise amplifier and $n(t)$ is a random process with known properties. Let us start by applying to $x(t)$ a linear filter which must be such to maximize the signal to noise ratio SNR at a given time t_o (we emphasize the fact that we search the signal at a given time t_o).

Indicating with $w(t)$ the impulse response of the filter (to be determined) and with $y_s(t) = s(t) * w(t)$ and $y_n(t) = n(t) * w(t)$ respectively the convolutions of the signal and of the noise we have [3]

$$SNR = \frac{|y_s(t_o)|^2}{E[|y_n(t_o)|^2]} \quad (19)$$

It can be show that

$$SNR \leq \frac{1}{2\pi} \int_{-\infty}^{\infty} \frac{|S(\omega)|^2}{N(\omega)} d\omega \quad (20)$$

where the equal sign holds if and only when

$$W(\omega) = constant \frac{S(\omega)^*}{N(\omega)} e^{-j\omega t_o} \quad (21)$$

Let us apply the above result to the case of measurements $x(t)$ done at the end of a chain of two filters with transfer functions W_a (representing the bar) and W_e (representing

the electronics) as already considered for the *Wiener* filter. In this case it is possible to show that the filter transfer function is given by

$$W(\omega) = \frac{S_g^* e^{-j\omega t_0}}{S_{uu}} \frac{1}{W_a W_e} \frac{1}{1 + \frac{\Gamma}{|W_a|^2}} \quad (22)$$

where S_g is the Fourier transform of the GW signal at the bar entrance. Applying this optimum filter to the data we obtain the maximum SNR

$$SNR = \frac{1}{2\pi} \int_{-\infty}^{\infty} \frac{|S(\omega)|^2}{N(\omega)} d\omega \quad (23)$$

where $S(\omega)$ and $N(\omega)$ are, respectively, the Fourier transform of the signal and the power spectrum of the noise at the end of the electronic chain where the measurement $x(t)$ is taken [3,5]. Introducing the signal energy $E_s = \frac{1}{2} m \omega_o^2 \left(\frac{V_s}{\alpha}\right)^2$ we calculate (with the variable $y = \frac{\omega}{\beta_1}$)

$$SNR = \frac{1}{2} \frac{S_g^2 \beta_1}{2\pi S_{uu}} \int_{-\infty}^{\infty} \frac{dy}{1 + \Gamma(1 + y^2)} = \frac{V_s^2}{8V_{nb}^2 \sqrt{\Gamma}} = \frac{E_s}{4kT_e \sqrt{\Gamma}} \quad (24)$$

Consequently the effective noise temperature in terms of the signal energy is [2]

$$T_{eff} = 4T_e \sqrt{\Gamma} \quad (25)$$

as for the *Wiener* filter. There is, however, an important difference between the two procedures. When we consider, as usual, the maximum of the response to a signal burst of energy kT_s , the output of the *Wiener* filter is kT_s (as it behaves as an r.m.s. detector) and the noise is kT_{eff} ; while that of the *matched* filter is $2kT_s$ (as it behaves as a peak detector) and the noise is again kT_{eff} .

4.3.1 The DAGA2-HF spectral noise estimation

We describe briefly the main features of the noise spectral estimations adopted by DAGA2-HF for various types of data filters all matched to delta signals. The differences are due to different evaluation of the noise. We remark that the basic problem with GW detectors designed to measure very small signals is due to the non-stationarity of the noise and to the fact that the noise itself is not Gaussian. This requires a careful study of the noise used for obtaining the maximum signal to noise ratio (for delta signals). For calculating the power spectra DAGA2-HF uses a program which allows a frequency resolution of 9.5 mHz. The data in the 896.4539 Hz – 935.5068 Hz band are collected in sets of 8192 samplings in the time domain, for a total time of 105 s. From these data periodograms are calculated. The periodograms, spanning each one 105 s, are exponentially and autoregressively averaged,

with a varying memory time, for obtaining the adjourned spectrum needed for estimating the matched filter. Three different procedures for combining the various periodograms are used, called CLEAN, ADAPTED and WHOLE. They differ one from each other for the different time constant in the spectrum averaging procedure, and for the selection of the periodograms. All the procedures estimate the spectrum with the recursive equation:

$$S_i = P_i(1 - W) + S_{i-1}W \quad (26)$$

where

$$W = \exp^{-\frac{\Delta t}{\tau_s}} \quad (27)$$

P_i is the actual periodogram, S_{i-1} is the previous estimation of the spectrum and τ_s is the memory time. For the WHOLE and CLEAN algorithms the time constant τ_s is constant and equal to 3600 s, but the CLEAN adjourns the spectrum only if the periodogram is not disturbed. Thus CLEAN uses only clean periodograms, keeping a clean spectrum. This choice is the best one when the disturbances have small time duration and, if not ignored, they would degrade the spectral estimation. For long disturbances it is better to use the ADAPTED, with a time constant which depends on the goodness of the periodogram. The better the periodogram, when compared with the expected spectrum, the longer is the time constant of the memory. It is evident, from this discussion, that it is difficult to select just one algorithm, as the best estimation depends very much on the nature of the noise. Then DAGA2_HF implements all three algorithms and each time it chooses what can be considered to be the best, according to a calibration procedure by means of applied signals. Actually the data filtered by the matched filter have a sampling time of 12.8 ms, but in the future we will implement the rephasing algorithm [5] for obtaining the filtered data at the sampling time of 200 μ s.

5 Monitoring and archiving

The data acquired at 5 kHz, those from the auxiliary channels, the information about the sampling by the SCALER, the GPS and the KAV30 time strings are directly recorded on permanent data-base on files lasting one and a half day (about 1.4 Gbytes). In fig. 4 the format of these files is reported. These data are processed and every day about 50 Mbytes of data are also recorded on permanent data-base. Many files are produced and recorded to allow an easier monitoring for the diagnostic of the entire system and for data analysis. Every one and a half day the files R87 are produced, about 60 Mbytes. In these files data are written in records. The first record contains information about data parameters used for

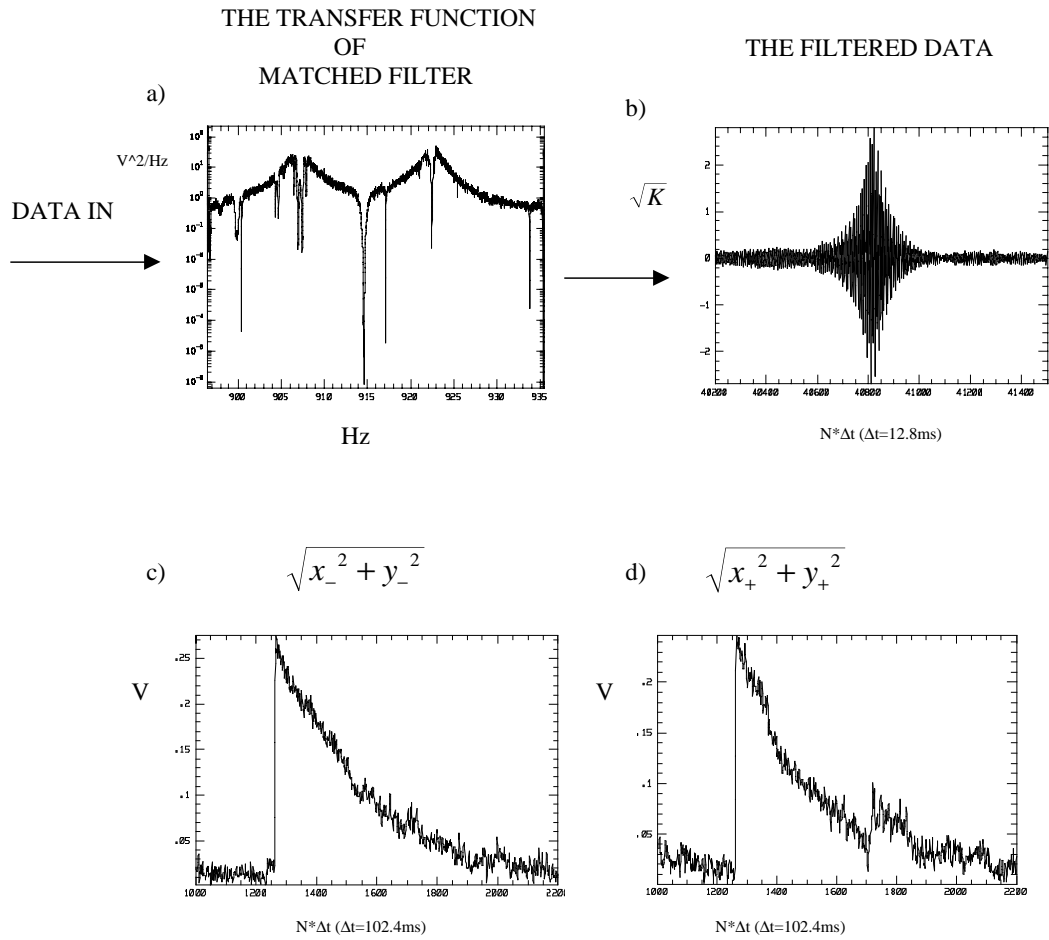


Figure 3: a) shows the matched filter transfer function b) the filtered data for a delta like signal. c) and d) show the amplitude of the minus and plus modes by the lock-ins.

the corresponding RUN, in the second record the acquisition MASK is written. The other records contain the time of the first data of the record and data sampled for a duration of 20.48 s. Each data record is divided in three parts (fields) in relation to the sampling time of the data: field 0 contains the very slow channels (20.48 s), field 1 the slow channels (104.2 ms) and field 3 contains the medium channels at 12.8 ms (the unfiltered data in the high sensitivity band of the antenna and the corresponding filtered data).

New files in ST96 format (about 1 Mbytes) are written daily on permanent data-base and contain one-minute time averages of all output channels, of the integral power spectra in the different sub-bands and of the parameters used in the implementation of the adaptive filters. These files also include the six-minute time averages of some DAGA2 output channels for a final check of the new system. Every hour one histogram of each channel is produced and recorded in the daily file HI96 (less than 500 Kbytes). The spectral information is recorded in the files SP96, 1.2 Mbytes per day. In this file every hour the following spectra are stored: a) the low resolution spectrum (0.1 Hz) of the 0 – 2.5 kHz band; b) the high resolution spectrum (0.01 Hz) of the antenna band, obtained by averaging the periodograms for one hour and finally c) the corresponding matched filter transfer function.

Every day a file EV96 (about 5Mbytes per day) with candidate gravitational events, from filtered data, is written. Events from all the other output channels are also given. Information obtained about the events are recorded: the time of the event, the amplitude, the critical ratio CR, the number of zero crossing, the duration of the event (the time the data is over the threshold, usually set at 6σ). This file also includes the time behaviour of the event for a duration of 5 seconds or less. The monitoring system allows to analyse the events, it allows to select the event from one or many channels in a given period of time, in relation to amplitude, CR, length and other characteristics of the event. It allows to search for coincidences of two series of events on-line, to plot the spectral information and to process the event with the Hilbert filter. For each run a file includes all the information on the system parameters, the mask script, the comments of the operator etc. In Appendix the users guide for DAGA2_HF is reported.

References

- [1] P.Astone, P.Bonifazi, G.V.Pallottino, G.Pizzella, Il Nuovo Cimento 17,713 (1994)
- [2] G.Pizzella "Fisica sperimentale del campo gravitazionale" La Nuova Italia Scientifica, Roma (1993)

Structure of an event record

Byte#	I*2#	I*4#	Meaning	VMS Action
---> Start of the Event Record				
1-4		1	Length of the record (in Integer*2 words)	Overwritten
5-6	3		Data identifier = 1	-
7-8	4		Length of the user header in words = 6	-
9-12		3	Run Number	Overwritten
13-16		4	Event Number	-
17-24			Date / Time	-
25-26	13		Software Trigger Reg	ADC Channel
27-34			Hardware Trigger Reg	word
ADC status				
35-55			- not used	
55-62			Equipment readout pattern	-
63-66			Event error code	-
error type				
70-70+2			Number of I*2 words of the first equipment	-
			Content of the first equipment	
E	⇒ Same sequence for all the declared equipment			

STANDARD RECORD ID'S

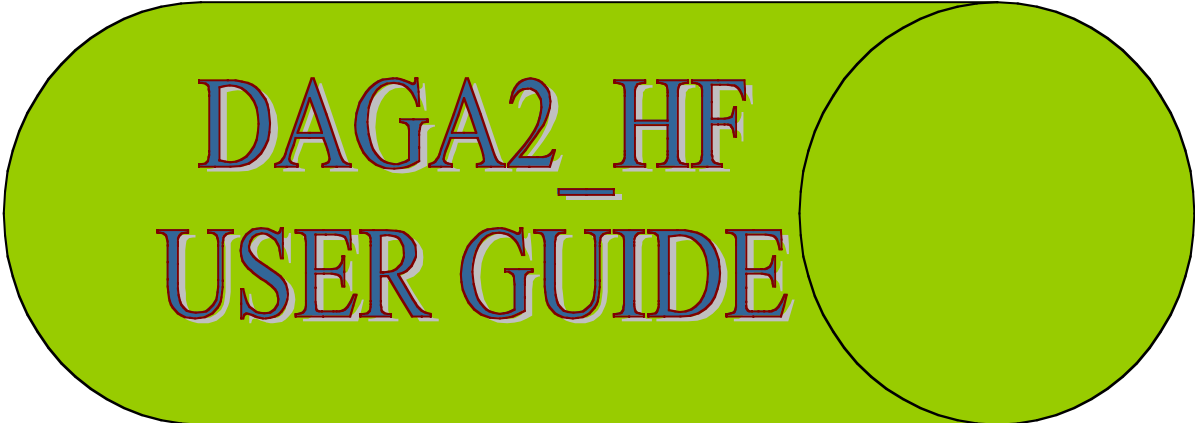
ID	DESCRIPTION
1	event record
10	start of run
20	end of run
30	pause
40	Resume

EQUIPMENT DESCRIPTION

#EQUIPMENT	DESCRIPTION
1	ADC FAST DATA
2	ADC SLOW DATA
3	KAV30 & GPS TIMES
4	TIME OF START RUN
5	SCALER :COUNTING TRIGGER AT 5KHz, 312.5Hz and 10MHz
6	GPS STRING : 2000-11-09 05:58:43 CET
44531400000020001109045851857 1,20,9,11,9,25,9,07,9	

Figure 4: RAW data format

- [3] A.Papoulis "Probability, Random variables and stochastic process" McGraw-Hill Book Co., New York (1965)
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DAGA2_HF
USER GUIDE

This manual describes the main DAGA2_HF procedures

O

The unGOUS BAND29
in the MENU.

They have been introduced in this manual particular explanations.

The examples of possible answers are prece the symbol 🍏

[menu :](#)

STOR stories

HIST histograms

SPEC spectral analysis

FILT filters

EVEN events

LOGS log of the runs (script, parameters, comments,...)

SNAG enters SNAG

PAST Daga2-HF parameters and status

HELP help online

OBSO obsol. menus

COMM insert analysts' comments

RCOM read analysts' and antenna operators' comments

VPUL virtual pulses

R exit

STOR: you can accede at the one minute average of channels acquired by DAGA2_HF, 6 minutes, histories of each sub-band and the time behavior of the SIHF variables.

🍏 STOR

- 1-> Sampled Data Channels (e.g. R^2, Matched Filter,...)
- 2 -> Spectral Bands (e.g. bending, electrical mode, 50 Hz,...)
- 3 -> Sihf Parameters (e.g. modes frequencies, mat.fil. parameters,...)
- 4 -> some VXNAUT acquisition channels
- 5 -> some Explorer acquisition channels
- 7 -> Channels
- 8 -> Help
- 9 -> Snag
- 0 -> End (no more choice)

Which Section ? (0 -> End Selection)

[Choose a section](#)

🍏 Es :1 (1-> Sampled Data Channels: [histories at 1 minute of all daga2-hf channels](#))

1 software channel ? (-1 -> list, 0 -> End Selection) > 🍏-1:

[\(-1 if you want to see the channels list, otherwise give the channel number\)](#)

Channel	T	Avg.	St.dev.	Min	Max	
1	x mode -	S	-0.001	0.320	-0.2014E+01	0.1518E+01
2	y mode -	S	0.008	0.329	-0.1552E+01	0.1754E+01
3	x mode +	S	0.025	0.620	-0.3090E+01	0.2659E+01
4	y mode +	S	0.047	0.667	-0.3404E+01	0.3335E+01
5	calibration	S	0.139	0.004	0.1182E+00	0.1545E+00
7	wide band	S	0.003	0.002	0.2162E-04	0.2313E-01
17	R^2 nu -	S	21.452	36.603	0.2439E-03	0.4611E+03
18	ZOP nu -	S	0.570	3.109	0.6390E-05	0.2242E+03
19	W.K. nu -	S	1.166	5.849	0.2474E-05	0.3027E+03
20	R^2 nu +	S	122.093	222.366	0.2320E-03	0.1877E+04
21	ZOP nu +	S	0.954	6.925	0.6841E-05	0.4630E+03
22	W.K. nu +	S	2.419	13.029	0.5619E-05	0.6421E+03
23	Wide Band phy_0	S	0.000	0.000	0.8282E-07	0.8703E-04
25	W.K. minimum	S	0.811	4.087	0.2474E-05	0.1195E+03
101	- mode band	S	0.000	0.460	-0.2843E+01	0.2852E+01
102	+ mode band	S	0.000	0.913	-0.4909E+01	0.4957E+01
103	center band	S	0.000	0.142	-0.3645E+00	0.3661E+00
104	center band	S	0.000	0.019	-0.2451E+00	0.2433E+00
6	direct	M	0.000	1.033	-0.6383E+01	0.6589E+01
27	T direct	M	68.583	157.590	0.8310E-09	0.2762E+04
31	matched	M	0.000	0.000	0.0000E+00	0.0000E+00
37	mf whole	M	-0.001	0.918	-0.7530E+02	0.1130E+03
38	mf clean	M	0.000	0.349	-0.1020E+02	0.9775E+01
39	mf adapt	M	0.000	0.351	-0.1039E+02	0.8103E+01

301	Seismic l.f.	S	0.026	0.015	-0.2747E-02	0.2155E+00
302	Seismic resonance	S	-0.026	0.002	-0.3937E-01	-0.2045E-01
303	Squid working point	S	-1.989	0.013	-0.2039E+01	-0.1944E+01
304		S	-0.028	0.000	-0.2930E-01	-0.2655E-01
305		S	-0.028	0.000	-0.2930E-01	-0.2655E-01
306	Press. He bath[mbar]	VS	-73.721	0.764	-0.7883E+02	-0.6937E+02
307	He Evapor flux l/min	VS	22.792	0.655	0.2074E+02	0.2504E+02
308	Pres sper. space	VS	0.000	0.000	0.2559E-06	0.1097E-05
309		VS	-0.028	0.000	-0.2930E-01	-0.2777E-01
310	Dewar 1K pot mmHe	VS	561.190	0.186	0.5598E+03	0.5622E+03
311	Level 1K pot (%)	VS	60.911	1.140	0.5905E+02	0.6570E+02
312	Refrig. flux m mol/s	VS	-0.023	0.025	-0.6943E-01	0.2281E+00
313	1 K pot press. mbar	VS	3.435	1.628	-0.1709E+01	0.8240E+01
314	Nitrogen trap	VS	-0.027	0.000	-0.2869E-01	-0.2625E-01
315	Aux temp 2	VS	1.878	0.015	0.1833E+01	0.1909E+01

<CR>

1 software channel ? (-1 -> list, 0 -> End Selection) > 🍏 39

2 software channel ? (-1 -> list, 0 -> End Selection) > 🍏 0 :

[You can see more channels give 0 for end selection](#)

Which Section ? (0 -> End Selection) 🍏 0 :

[Again we show the section list: 0 for end selection](#)

[Otherwise give the section's number](#)

Initial Date ? (year,month,day) def 2000 10 20

🍏 2000 10 20

Final Date ? (year,month,day) def 2000 10 20

🍏,,,,,,,,, (..... for the day in progress but you can give another date .)

How many minutes averaged ? (divisor of 1440 !) def 1(if you want n minutes averages.

Give n, minimum value n =1)

🍏 1

1 -> no virtual events (give enter)

🍏 enter

Nullifying on the basis of one channel:

channel (absolute of story), ampmin, ampmax (for taking) ? (give enter)

Channel 306 : Copy on which GD ? (<CR> -> no) (enter if you don't want to put the data on

GD, otherwise give the GD number)

(Now it shows the graph)

🍏 enter

From the STOR of menu you can see the time progress of the integral of the spectrum

for different sub-bands:

🍏 2

2 -> Spectral Bands (e.g. bending, electrical mode, 50 Hz,...)

Available bands:

1	1	Low frequency	0.0	20.0	36821.543	52.429	1
2	1	Power Supply	50.0	10.0	36821.543	52.429	1
3	1		230.0	20.0	36821.543	52.429	1
4	1		305.0	8.0	36821.543	52.429	1
5	1		458.0	10.0	36821.543	52.429	1
6	1		685.0	10.0	36821.543	52.429	1
7	1	Antenna	916.0	30.0	36821.543	52.429	1

8	1		1010.0	20.0	36821.543	52.429	1
9	1		1115.0	30.0	36821.543	52.429	1
10	1		1235.0	20.0	36821.543	52.429	1
11	1		1385.0	10.0	36821.543	52.429	1
12	1		1685.0	20.0	36821.543	52.429	1
13	1		1810.0	20.0	36821.543	52.429	1
14	1	Total	1250.0	2500.0	36821.543	52.429	1
15	100	Mode -	907.0	2.0	36821.543	104.858	1
16	100	Mode +	922.5	2.0	36821.543	104.858	1
17	100	Calibration	914.6	2.0	36821.543	104.858	1
18	100	Total	916.0	100.0	36821.543	104.858	1

Which band story ? (0 -> end)

[Column 4 shows the value of the central frequency and column 5 the bandwidth used for calculate the spectrum](#)

🍏 1

Which band story ? (0 -> end) [\(0 for ending the band story \)](#)

🍏 0

Sections: [it shows again the sections \(0 for ending the choice of section \)](#)

🍏 0

Initial Date ? (year,month,day) def 2000 10 20

🍏

Final Date ? (year,month,day) def 2000 10 20

🍏

How many minutes averaged ? (divisor of 1440 !) def 1

Special features (default 0 -> no):

1 -> no virtual events (enter)

Nullifying on the basis of one channel:

channel (absolute of story), amp. min, amp. max (for taking) ? (give enter)

🍏 ENTER

Channel 1 : Copy on which GD ? (<CR> -> no) (enter if you don't want to put the data on GD, otherwise give the GD number)

🍏 ENTER

It asks which type of terminal, and shows the graph .

HIST: here you can accede at the past histograms, at the actual RUN histograms of all channels

Histogram analysis

Choose:

HIST selected histograms of the last run

SHIS statistics of histograms

ZIST zero histograms and modify parameters

ARHI AutoRegressive histograms (last run)

PASH Past histograms

SNAG enters SNAG

HELP help online

R exit

HIST SHIST E ZHIST are the same as in the old acquisition

ARHI (you can accede at the histograms of RUN in on-line channels)

🍏 ARHI

old, new or multi ? (0,1,2) old gives the simplest histogram ,

new for a more sophisticated histogram.

Multi shows many histograms simultaneously

as far as 8.

🍏 0

AR histogram groups: (histograms obtained with an autoregressive

exponential average with various time constant

1 -> 1 hour

2 -> 3 hours

3 -> 9 hours

4 -> 27 hours

Which group of AR histograms ?

🍏 3

Histogram (0 -> quit)

Which software channel ? (-1 -> list, 0 -> no) def = 0 (-1 shows ch)

🍏 39

Which GD ? (<CR> -> no) (enter if you don't want to put the data on

GD, otherwise give the GD number)

🍏 ENTER (Now it shows the number of values plotted and it gives their average and sigma)

98338 values plotted

Mean, Stand.Dev. : 2.9921757E-06 9.7141452E-02

Linear or logarithmic ordinates? (0,1)

🍏 0 ([Now graph the histogram](#))

[PASH : for acceding at hourly histograms of past runs:](#)

🍏 PASH

Do you want the list of the hist files ? (1=yes)

[\(Ask if you like see the files list, give 1 \)](#)

🍏 1

[\(Shows the files: these files are written daily and they have in their name the time of creation HN20001014.HI96 \(14-oct-2000\)\)](#)

[Then give the name:](#)

🍏 HN20001014.HI96

Which channel histogram ? (-1 -> list, 0 -> End) >

[Give -1 to see the channels list or give the channel number](#)

🍏 314

Which hour of the day (from 0 to 23)?

🍏 2

Differential or integral ? (1,2)

🍏 2

[It writes on the monitor all the values and then it asks :](#)

Linear or logarithmic ordinates? (0,1)

🍏 0

[Show the plot](#)

SPEC :you can accede at the spectra and at the spectral amplitudes of the actual run or the past runs.

🍏 SPEC

Choose:

1 Real-Time Spectra & hden (default)

2 Archived Spectra & hden

🍏 [1 \(Spectrum and hden of run in progress, you have the following options:\)](#)

Select:

WIDE low resolution wide-band spectra (2500 Hz)

DWID spectral derivatives wide-band spectra

FILT matched filter spectra (Whole, Clear & Adapt)

ANTE antenna band spectra

DANT antenna band spectral derivatives

HDEN h spectral density

ARCH archived spectra and filters

BAND bands stories

DBAN ratio of bands stories

SNAG to SNAG

HELP help online

R return

🍏 WIDE ([You can see the spectra at low resolution of the band](#)

[0-2500Hz obtained by an exponential autoregressive average, using
different time constants](#))

Which spectrum ?

- 1 last periodogram
- 2 AR on 6 minutes
- 3 AR on 1 hour
- 4 AR on 10 hours
- 5 infinite mean
- 6 present hour in progress
- 7 last hour
- 9 to Snag
- 8 Help
- 0 exit (-1 main menu)

🍏 4

On which GD (0 if you don't want to save it on a GD) ? ([enter if you don't want to put the data on](#)

[GD, otherwise give the GD number](#))

🍏 ENTER

Do you want to plot it ? (0->no, 1->yes)

🍏 1

Normal, sqr or log ? (1,2,3)

🍏 3

[Then it shows the plot](#)

DWID spectral derivatives wide-band spectra: ([You can do operations like subtraction or ratio between WIDE spectrum with different time constants](#))

🍏 DWIDE

Available spectra:

- 1 last periodogram
- 2 AR on 6 minutes
- 3 AR on 1 hour
- 4 AR on 10 hours
- 5 infinite mean

Choose an operation as

klm

where k is the first spectrum, l the second and m the operation

m = 1 -> ratio, m = 2 -> subtraction

k = 9 -> to Snag, 8 -> Help, k = 0 -> exit (-1 main menu)

[Now you must give k ,l, m that are respectively the first and the second operand.](#)

[m=1 if you like the ratio , m=2 for subtraction](#)

🍏 241 ([You've the ratio between the spectra obtained by exponential autoregressive average with time constant =6 minutes and those with time constant = 10 hours](#))

On which GD (0 if you don't want to save it on a GD) ?

🍏 ENTER

Do you want to plot it ? (0->no, 1->yes)

🍏 1

Normal, sqr or log ? (1,2,3)

🍏 3

[Then show the plot](#)

[ANTE e DANTE are the analogue of WIDE end DWIDE but are relative to the band of antenna](#)

[FILT: for the noise spectrum used by different filters](#)

[BAND: for the stories of different sub-bands \(the same ones you can see by the option 2 starting from STOR as described before\).](#)

[DBAND: allows to execute the ratio between the BAND spectral bands:](#)

🍏 DBAND

Available bands:

1	1	Low Freq	0.0	20.0	36821.543	52.429	1
2	1	Power Supply	50.0	10.0	36821.543	52.429	1
3	1	Prova	230.0	20.0	36821.543	52.429	1
4	1	Prova	305.0	8.0	36821.543	52.429	1
5	1	Prova	458.0	10.0	36821.543	52.429	1
6	1	Prova	685.0	10.0	36821.543	52.429	1
7	1	Antenna	916.0	30.0	36821.543	52.429	1
8	1	Prova	1010.0	20.0	36821.543	52.429	1
9	1	Prova	1115.0	30.0	36821.543	52.429	1
10	1	Prova	1235.0	20.0	36821.543	52.429	1
11	1	Prova	1385.0	10.0	36821.543	52.429	1
12	1	Prova	1685.0	20.0	36821.543	52.429	1
13	1	Prova	1810.0	20.0	36821.543	52.429	1
14	1	Total	1250.0	2500.0	36821.543	52.429	1

15	100	mode -	907.0	2.0	36821.543	104.858	1
16	100	mode +	922.5	2.0	36821.543	104.858	1
17	100	calib	914.6	2.0	36821.543	104.858	1
18	100	total	916.0	100.0	36821.543	104.858	1

Ratio of which bands story ? (order numbers)

ATTENTION ! TAKE HOMOLOGOUS BANDS !

100,, -> to Snag, 0,, -> exit (-1 main menu)

[Homologous bands means those obtained in the same time interval](#)

🍏 1,2 ([for obtaining the ratio between the band 1 and the band 2](#))

On which GD (0 if you don't want to save it on a GD) ?

🍏 ENTER

Do you want to plot it ? (0->no, 1->yes)

🍏 1

Normal, sqr or log ? (1,2,3)

🍏 1

[then it shows the plot](#)

[HDEN: the spectral density obtained by an exponential autoregressive average with different time constant.](#)

🍏 HDEN

Which h-density ?

- 1 last periodogram
- 2 AR on 6 minutes
- 3 AR on 1 hour
- 4 AR on 10 hours
- 5 infinite mean

9 to Snag

8 Help

0 exit (-1 main menu)

🍏 4

On which GD (0 if you don't want to save it on a GD) ?

🍏 ENTER

Do you want to plot it ? (0->no, 1->yes)

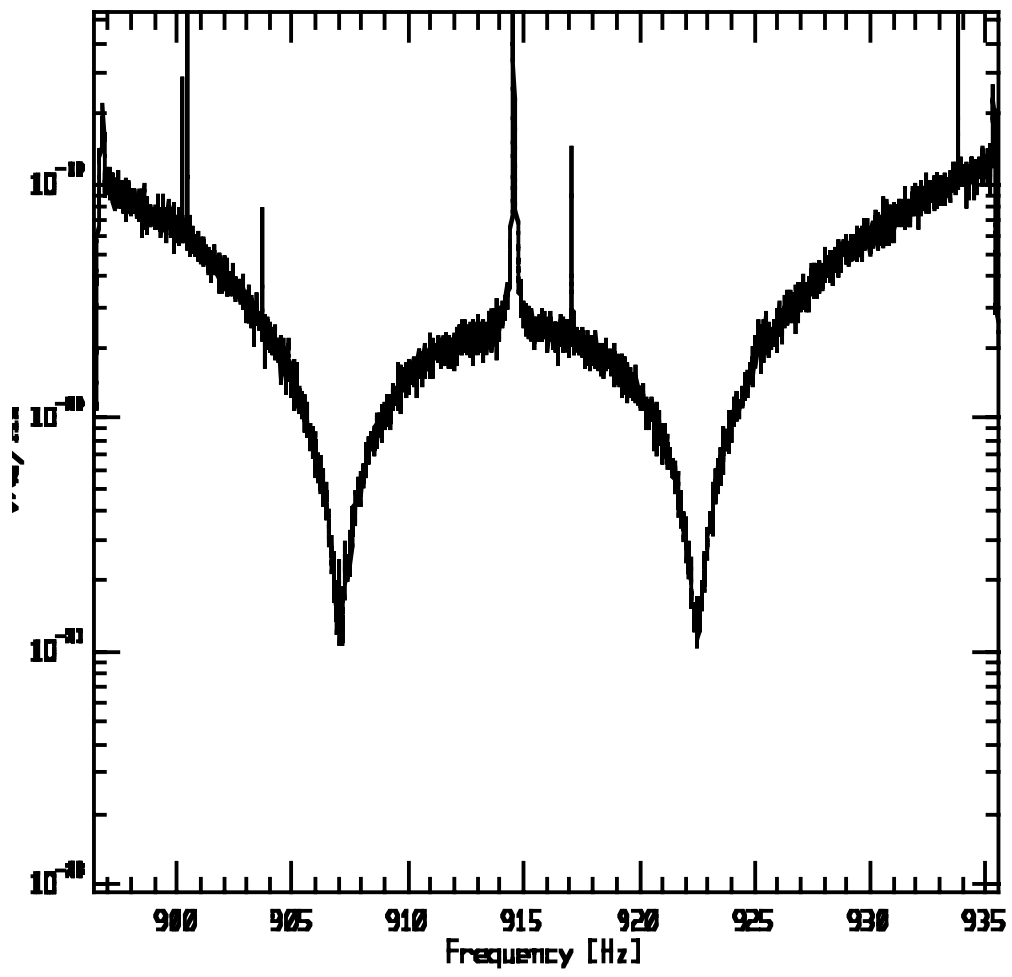
🍏 1

Simplified access ? (1=yes) ([give 1](#))

🍏 1

Normal, sqr or log ? (1,2,3)

🍏 3



[ARCH: to accede to the archived spectra \(the same ones you can see by the option 2](#)

[Archived Spectra & hden from SPEC](#)

🍏 ARCH

Which data ?

- 1 full spectra
- 2 antenna band spectra
- 3 matched filter
- 4 hden
- 6 sub-band analysis
- 9 to Snag
- 8 Help
- 0 exit (-1 main menu)

[You can plot the spectrum of 0-2500Hz band \(1\), of the sensitivity band of the antenna \(2\), of spectral density \(4\) or analyze the sub-bands \(6\).](#)

[If your choice is \(6\):](#)

🍏 6

Which data ?

- 1 full band spectra
- 2 antenna band spectra
- 3 matched filter
- 9 to Snag
- 0 exit

1

[\(Choose which band\)](#)

🍏 1

Single or multiple frequency ? (1,2)

🍏 1 You can see for every hour: the frequency (in the interval) where the spectra is maximum , this maximum value and the integral of the spectra in a selected band

Maximum in which GD ? (0 -> no)

🍏 1 (it writes the maximum value of the spectra on GD 1)

Integral in which GD ? (0 -> no)

🍏 2 (it writes the integral of the spectra on GD 2)

Maximum Frequency in which GD ? (0 -> no)

🍏 3 (it writes the frequency where the spectrum is maximum on GD 3)

3-D graph in which GD ? (0 -> no) NON ANCORA PRONTO

🍏 0

Min, max frequency ? (give the min. and max. frequency of interval)

🍏 900,1000

Initial Date ? (year,month,day) def 2000 10 21

🍏 2000 10 20

Final Date ? (year,month,day) def 2000 10 21

🍏 2000 10 20

Which data ?

1 full band spectra

2 antenna band spectra

3 matched filter

9 to Snag

0 exit

again you can do another choice or plot the data by SNAG (9).

EVEN: for acceding at the events list of all output daga2_HF channels and of 45 channel (matched) of DAGA2. It is possible to see the time evolution of the events (max for 5 seconds) and to process the events.

Events Main Menu

- 1 list of events of events
- 2 event processing
- 9 to Snag
- 8 Help
- 0 exit (-1 main menu)

🍏 1 ([for the events list](#))

- 1 Local acquisition events ([DAGA2 HF events](#))
- 2 VXNAUT (local copy) ([events of channel 45 DAGA2 \(VXNAUT\),only from AXNAUT](#))
- 3 Explorer (local copy)) ([events of channel 45 DAGA2 \(UXEXPL\),only from AXEXPL](#))

🍏 1

Max number of requested channels: 20

[2](#) software channel ? (-1 -> list, 0 -> End Selection) > 🍏 [39](#) ([for to see the history of 39 channel, -1 if you like to see the event lists](#))

software channel ? (-1 -> list, 0 -> End Selection) > 🍏 [0](#) ([end selection](#))

Initial Date ? (year,month,day,hour) def 2000 10 24 0

🍏 ,,1,0

Final Date ? (year,month,day,hour) def 2000 10 24 24

🍏 ,,1,2

On which GD ? (<CR> -> no) 🍏 ENTER

[Now you can select the events in relations to the following quantities](#)

Event Selection Engine

Takes events in selected ranges

- 1 operation flag
- 2 automatic operation flag (2,,, -> no Squid-off)
- 11 length (s)
- 12 amplitude
- 13 CR
- 14 local mean
- 15 local standard deviation
- 16 integral
- 17 abs val integral
- 18 square integral
- 19 number of threshold hops
- 21 first chromatic variable
- 22 second chromatic variable
- 23 third chromatic variable

Type, min, max ? (max<min band exclusion, 0,,, end selection)

[If you like to see all the events give 0,,,,.](#)

[If, for example, you like to see only the events with a CR between](#)

[7 e 10:](#)

🍏 13,7,10

[Again it shows the previous menu \(if you want another selection\)](#)

[give 0,.. for end selection](#)

🍏 0,,,,

0 no display

1 on 80 columns

2 on 132 columns

3 rough

4 calibration events

Which type of output ?

[Choose like to see the events:](#)

🍏 1

Ch	Beginning Time	Del	Max	L	Amp	CR	mu	sigma
----	----------------	-----	-----	---	-----	----	----	-------

39	2000-10-24 0: 1: 8.072	0.000	0.01	0.602E+00	7.0	0.00	0.12
----	------------------------	-------	------	-----------	-----	------	------

39	2000-10-24 0: 1:30.625	0.000	0.09	-0.666E+00	7.9	0.00	0.12
----	------------------------	-------	------	------------	-----	------	------

etc..

[The length of the event is in units of seconds.](#)

113 events found

Events Main Menu

1 list of events

2 see an event

3 event processing

9 to Snag

8 Help

0 exit (-1 main menu)

[For the time behavior of the event → 2](#)

🍏 2

Channel ? (0 -> exit) def 0

🍏 39

Time of the event ? (-1,,,,, -> next calibration, if any)

def 2000 10 24 11 17 29

[\(give the event time\)](#)

🍏 2000 10 20 17 27 54 0 0

[It shows the event characteristics:](#)

Channel 39 event 132 at 2000-10-20 17:27:54.7009

Delay of the top : 1.00 - Length : 3.49 op.flag 0

Amplitude : -10.2551 CR :122.7

Channel mean, dev.stand.: 0.0000 0.1360

Integrals N,A,Q : 13.2989 255.9567 773.7449

Number of threshold hops : 47.

Temporal corrections : 0.0000 0.0000

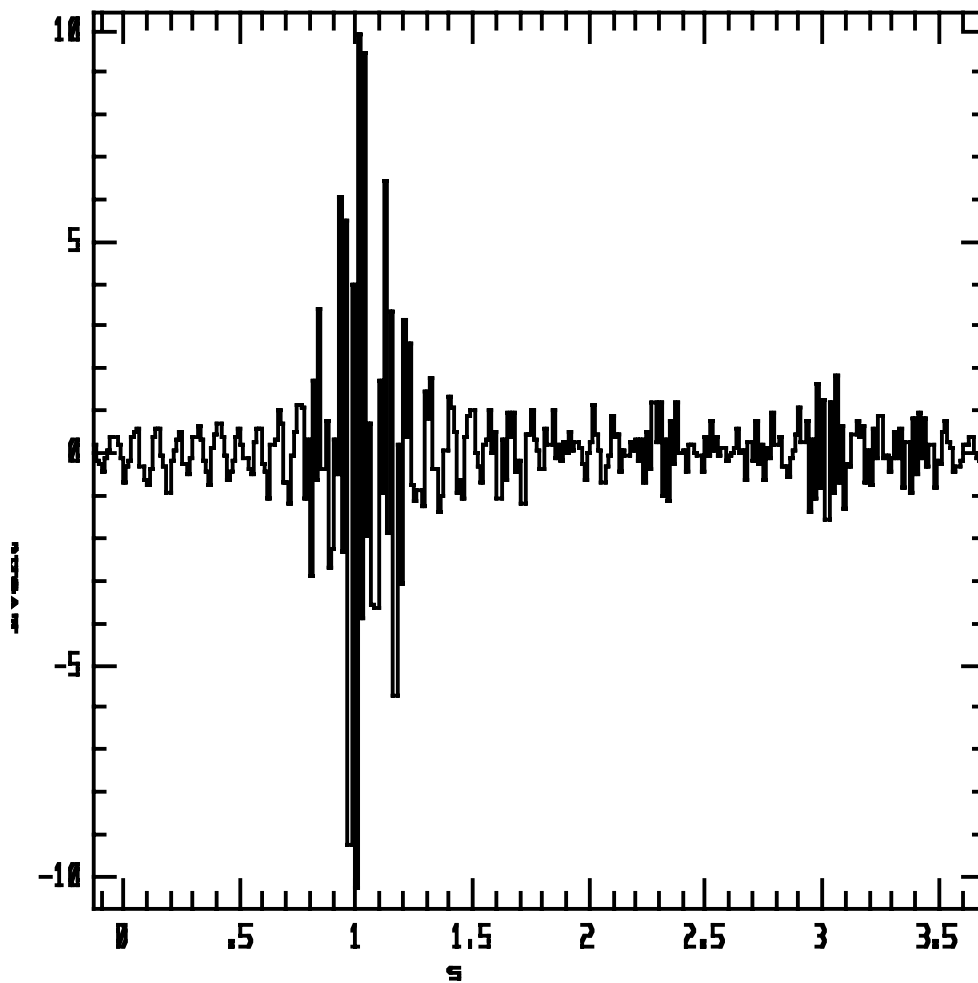
Chromo-variables : 0.0000 0.0000 0.0000

<CR>

🍏 ENTER

On which GD ? (<CR> -> no)

🍏 ENTER



[It shows the time behavior of the event, \(max for 5 seconds\): 0 is the start time of the event](#)

0 -> return

1 -> zoom

2 -> graph printing

3 -> type values

4 -> new graph (different parameters)

5 -> TEST (data obliteration !)

🍏 0

Event analysis:

1 Energy Spectrum

2 Envelope (Hilbert Transform)

3 Phase (Hilbert Transform)

4 Generalized Frequency (Hilbert Transform)

5 Analog Signal

9 Snag

By the option 1 you plot the spectra of the event:

🍏 1

On which GD ? (0 -> no)

🍏 0

