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Abstract

The information attainable in time-of-flight experiments per unit time can be increased in many applications by pseudorandom pulsing, allowing a maximum duty cycle of 0.5. However, it is impossible to make any direct decision on the transfer function (the desired information) from the measured response function. If the necessary cross correlation calculations will be done on-line the monitoring of the experiment and the application of a simple decision theory on its progress is possible. For 10^3 time channels typically 10^6 multiplications have to be made. The design and performance of a correlator system which is intented for thermal neutron spectroscopy using a Telefunken TR 86 computer will be described.

1. Introduction

It is well known in information theory that the time characteristics, the transfer function F(t), of a system under test can be determined by measuring the response Z(t) of the system to an imposed signal function S(t) and cross correlation Z(t) with S(t). A scheme of the procedure is given in Fig. 1.
The cross correlation immediately yields F(t) if S(t) is randomly distributed in time or more precisely if the autocorrelation of S(t) is a delta function in time. In practise "pseudorandom" binary sequences $S_N(t)$ generated with a feedback shiftregister [1] e.g. are used. $S_N(t)$ has a period $T = N\Delta t$ ($N = 2^n-1$, n = integer > 2) where Δt is the smallest distinguishable time interval and the two possible amplitudes +1 and -1. A typical sequence is given in Fig. 2.
If for neutron time-of-flight (TOF) experiments the incident beam is modulated with a S_N-sequence which can be achieved with a modulator having a transmission

$$T(t) = \frac{I_o}{2} \; (1 + S_N(t)) \qquad (1)$$

(I_o = intensity of continuous beam), the correlation technique can be used for the determination of cross sections. The result can be a considerable improvement in duty cycle for many applications. We built a pseudorandom TOF-spectrometer for slow neutron scattering experiments a scheme of which is given in Fig. 3. In this case the time utilisation of the reactor beam could be improved by about a factor 50 so resulting in a similar gain in statistics especially for high background experiments. The directly accumulated nearly statistical TOF-spectrum is too complex to offer any possibility for monitoring the experiment and inspecting the raw data. Before this can be done the cross correlation of the TOF-spectrum with $S_N(t)$ has to be computed.

The correlation computation is therefore an integrated part of the experiment and should be fast and feasible on the experimenter's request to allow especially decisions on further progress of the experiment. The function F(t) for time channel I is essentially determined by the expression

$$F(I) = \sum_{J=1}^{N} S(J) \cdot S(J+I) \qquad (2)$$

For N = 1000 TOF-channels this requires 10^6 multiplications. The on-line data handling system we use for this purpose will be described in the following.

2. Description of the data handling system

The experiment is connected to a new data acquisition system which was built up recently and is now in its testing stage. Besides the correlation experiment several scaler experiments are connected to the divice. The common feature of these experiments is a low mean but very high instantaneous data transfer rate to the computer. The main unit of the system is a Telefunken TR 86-A computer with the following characteristics:

word length:	24 bit
memory cacle time:	0.9 μsec
core memory size:	32 K words

This central processing unit is furnished with an extented peripheral equipment (Fig. 4) consisting of two magnetic units, two magnetic disk units having drum characteristics and several remote display units.

Data channels of high flexibility allow a connection with remote experimental setups supplying different data rates with different formats. The connection is realized by high speed data lines.

The control of the measuring and of the analysis phase is commanded at the remote input station which is furnished with a display unit. All control and analysis results are displayed either automatically or by order of the experimenter.
A block diagram of the organisation system is given in Fig. 5. System parts with the same logical and functional characteristics are grouped into one of six levels.
At the begin of one level, a list of orders for this level is inspected first. If this list is not empty the orders are executed and erased from the list. Then a jump to the point M1 is performed. In this way priority schedule is achieved. In execution possible orders for other levels are inserted in the corresponding lists and a jump to M1 is performed immediatly. The problem execution is divided into the two following parts:

a) time critical data acquisition in problem level A

b) time uncritical data analysis in problem level B

In program level B it is possible to process additional background programs to achieve the maximum efficiency of the system. The available computing time in this level is distributed by timeslicing to all background programs, the time of one slice being not reduced by tasks in higher levels caused by interrupt or I/O-operations. All programs of level B are loaded from the disk area to the working area (core memory) and rolled out after the end of the timeslice. The core memory is divided in 12 K for the organisation system, 12 K for data input buffers and display areas, and 8 K for working areas of level A and B.

3. Interface system

Because of the (2^n-1) period of the pseudostatistical sequence commercially available TOF coding units cannot be synchronised for a full time utilisation of the beam but spare out every second period. To avoid the alternating use of two coding units we developed a more flexible TOF coding system allowing all desirable lengths of periods. To assure the necessary synchronism with the beam modulator the TOF-unit and the chopper driving system are operated by the same quartz oszillator.
The TOF coding unit is connected parallel via a one word buffer to the remote input buffer of the central processing system.

4. Execution of the experiment

The execution of the experiment is initiated by a starting command at the remote station. From there the experimenter also can stop data collecting and order the transfer of the actual data spectrum to his disk library. Then data collecting can be continued and simultaneously a cross correlation analysis of the transferred data can be initiated and after execution displayed at the remote station. Finally the evaluated spectrum is stored in the private library being available for further access.
Because of limitation of the working area it was necessary to divide the 1 K channel TOF-spectra into two parts. Thus about $3 \cdot 10^3$ disk accesses are necessary for swapping the different spectrum parts in the course of one cross correlation evaluation.
The total computation time for one cross correlation including 10^6 fixed point multiplications and double precision additions is presently about five minutes.
It is planned to add further background programs for a quantitative analysis of the statistical accuracy of the cross correlated data and for determining an optimized measuring time.

5. Results

Among all the activities (diffraction, scattering law, dispersion law) done with the pseudorandom chopper, the experimental investigation of the diffraction pattern of $BiFeO_3$ has been chosen to be repeated in order to test the performance of the correlator on-line. $BiFeO_3$ crystallizes in a perovskit like structure with a small rhomboedric deformation. Some of the reflex groups, e.g. (111) ($\bar{1}$11), (220) ($\bar{2}$20), (311) ($\bar{3}$11), should be influenced by the deformation and no longer coincide.
Typical TOF diagrams for a measurement with a diffraction angle $\Theta = 15.7^{\circ}$ are shown in Fig. 6. Fig. 6a shows the measured transmission of the chopper, normalized according to (1), Fig. 6b the measured transfer spectrum, and Fig. 6c the diffraction pattern computed by correlating the former ones.
The derivation of one peak from a gaussian is indicated.
The resolution of the measurement can be increased by enlarging the scattering angle 2Θ. In addition, suppressing possible reflexes by cutting off higher energies by a cooled Be-filter it is possible to identify low indexed reflexes even in spite of rame overlap. The results of such another measurement done on-line are shown by Fig. 7. The (220) ($\bar{2}$20) group is clearly split.

Although the computer system is still in the test status, the incorporated correlator has been proven to be a necessary and very comfortable device for inspecting and deciding on-line the progress of pseudorandom TOF experiments.

[1] PETERSON, W.W., Error Correcting Codes; John Wiley and Sons, New York 1961

Figures

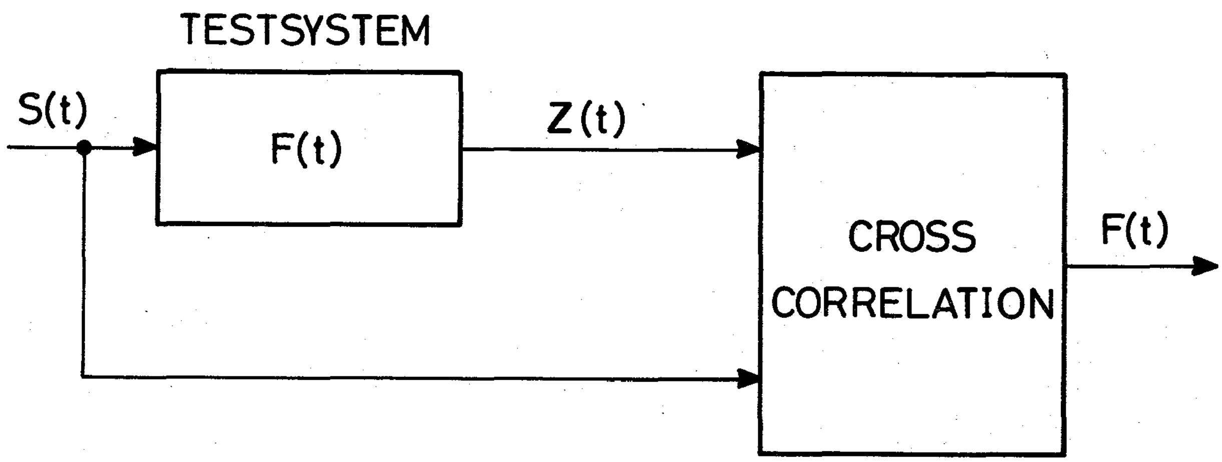


Fig. 1 MEASUREMENT OF THE TRANSFER FUNCTION F(t) BY THE CROSS CORRELATION TECHNIQUE

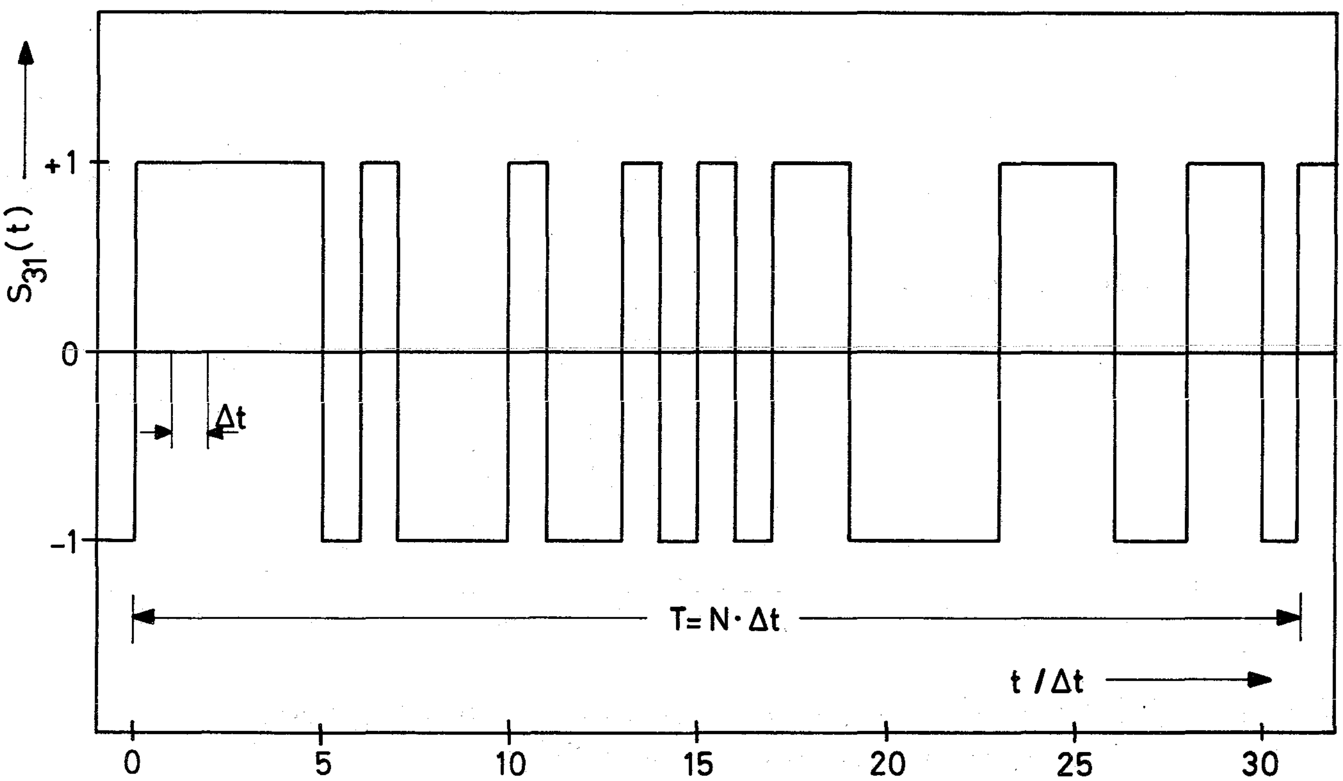


Fig. 2 PSEUDORANDOM SEQUENCE FOR N=5 (31 STEPS)

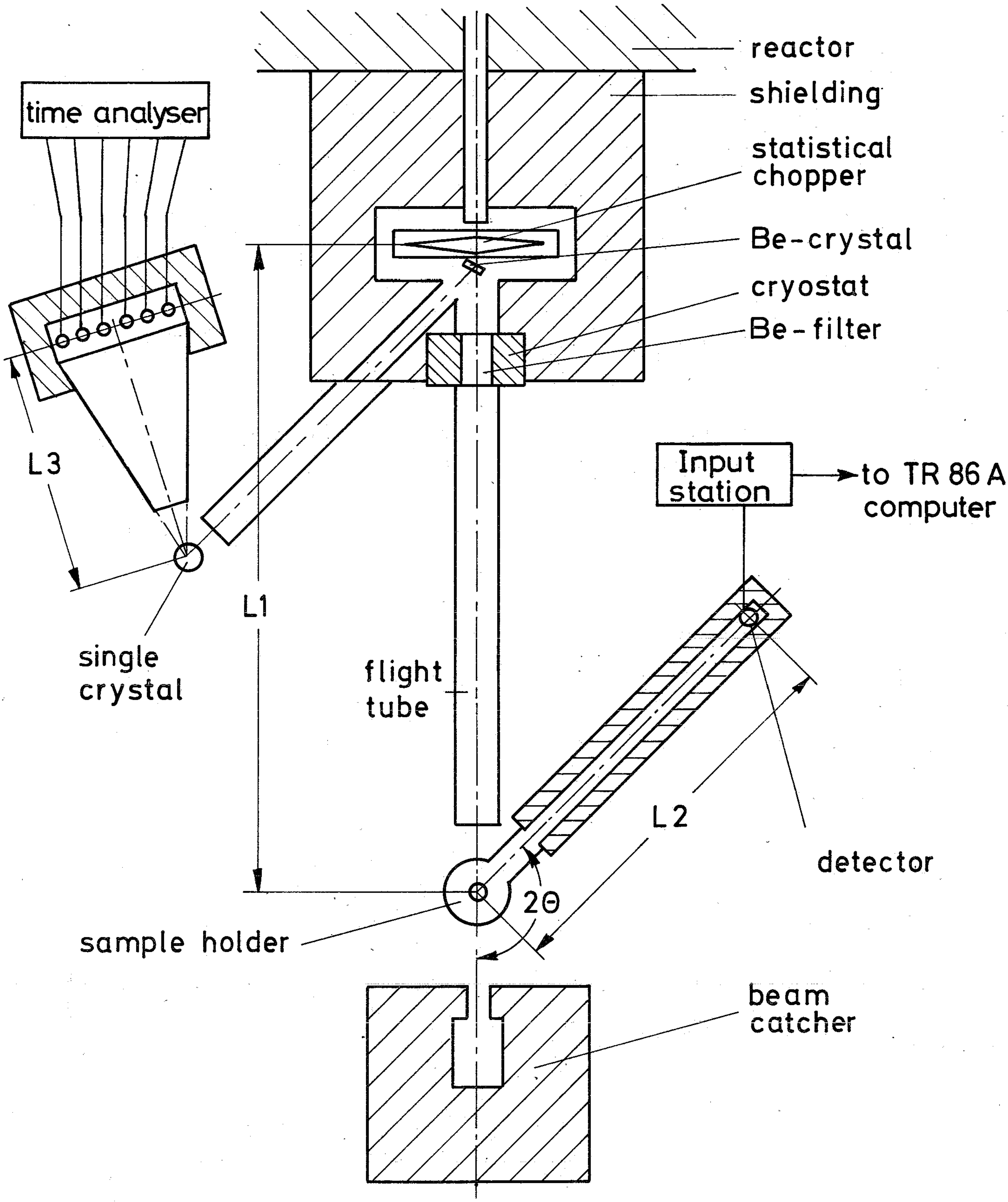


Fig.3 Scheme of the pseudorandom time-of-flight spectrometer at the FR2

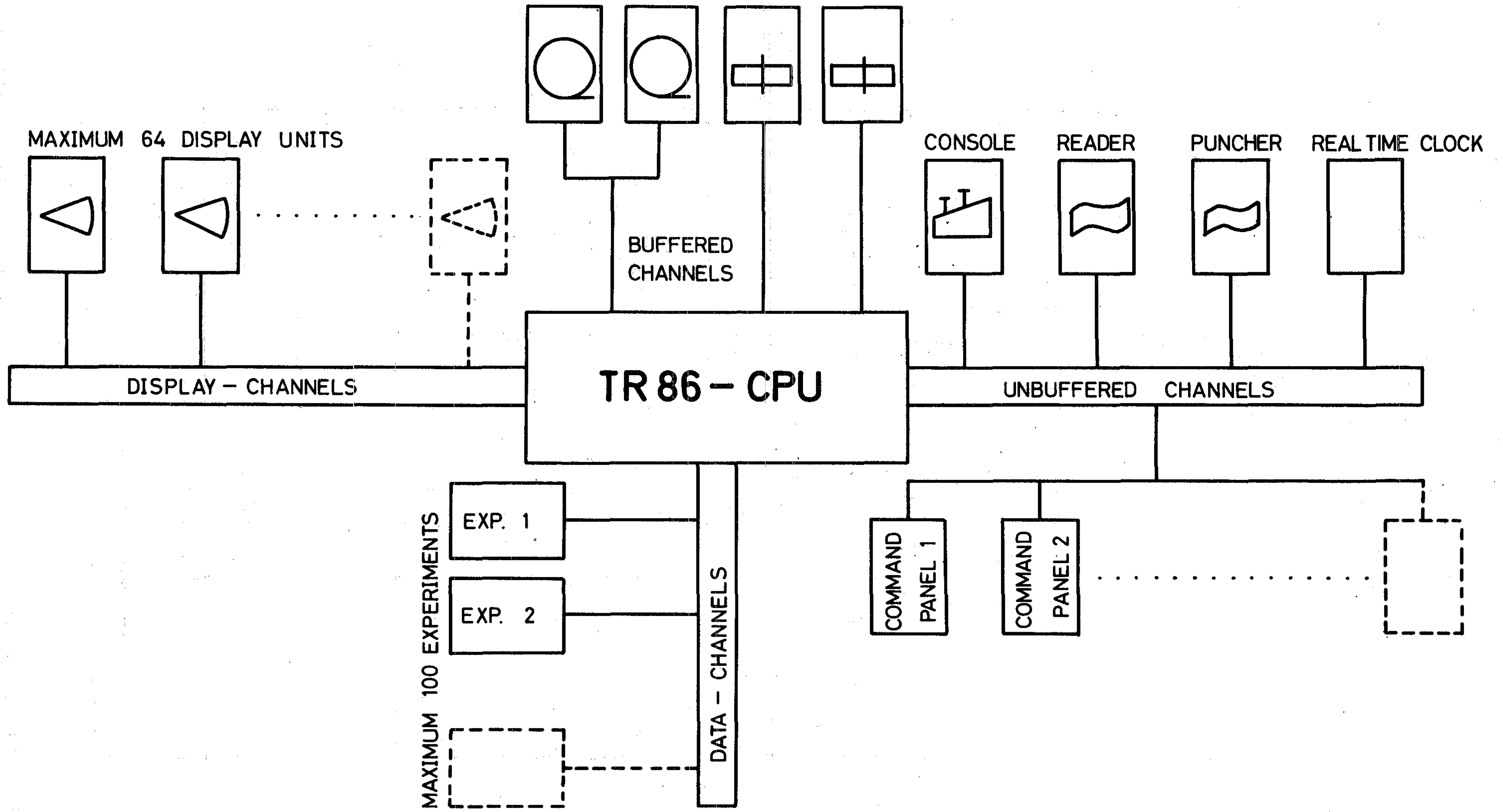


Fig. 4 Configuration of the TR 86-A System

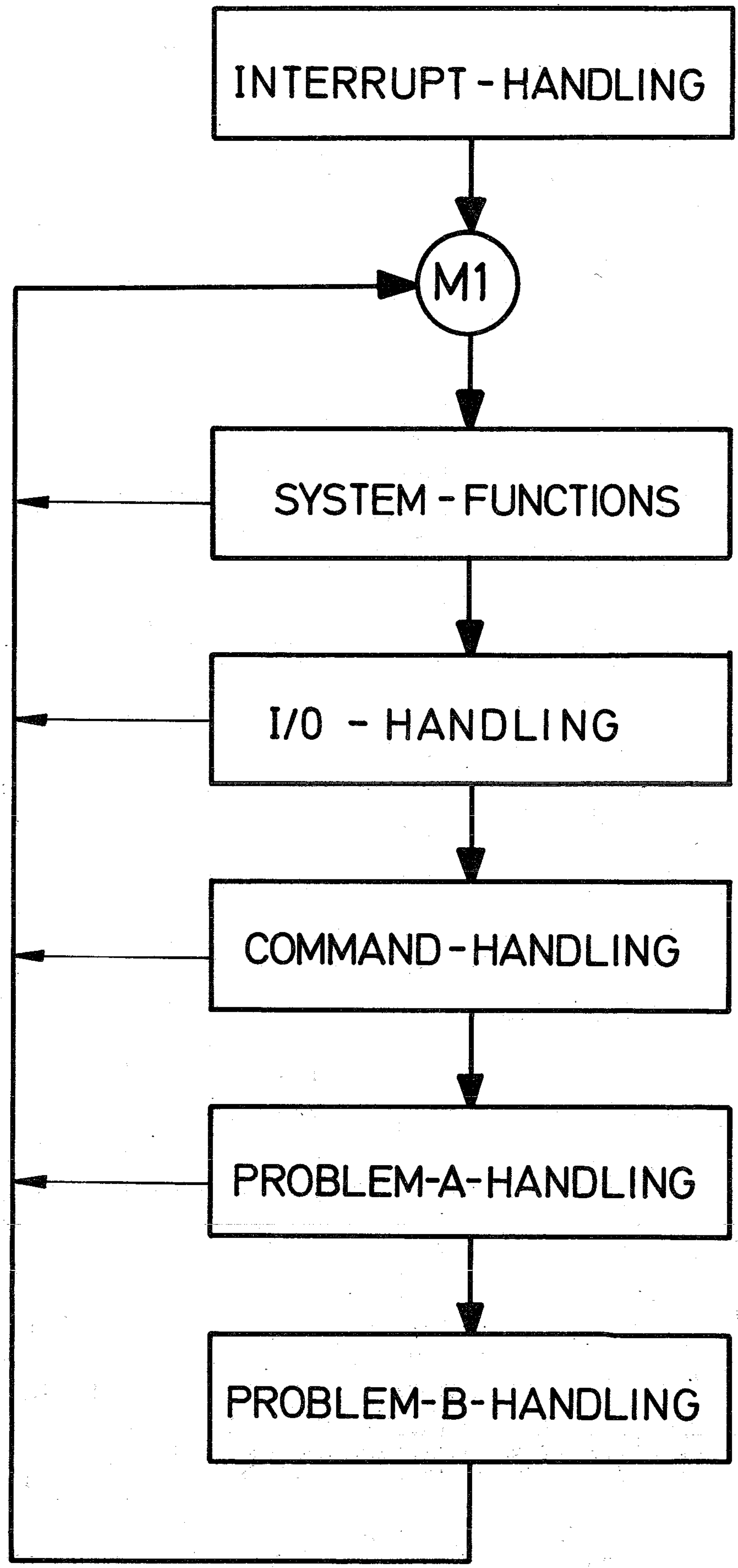
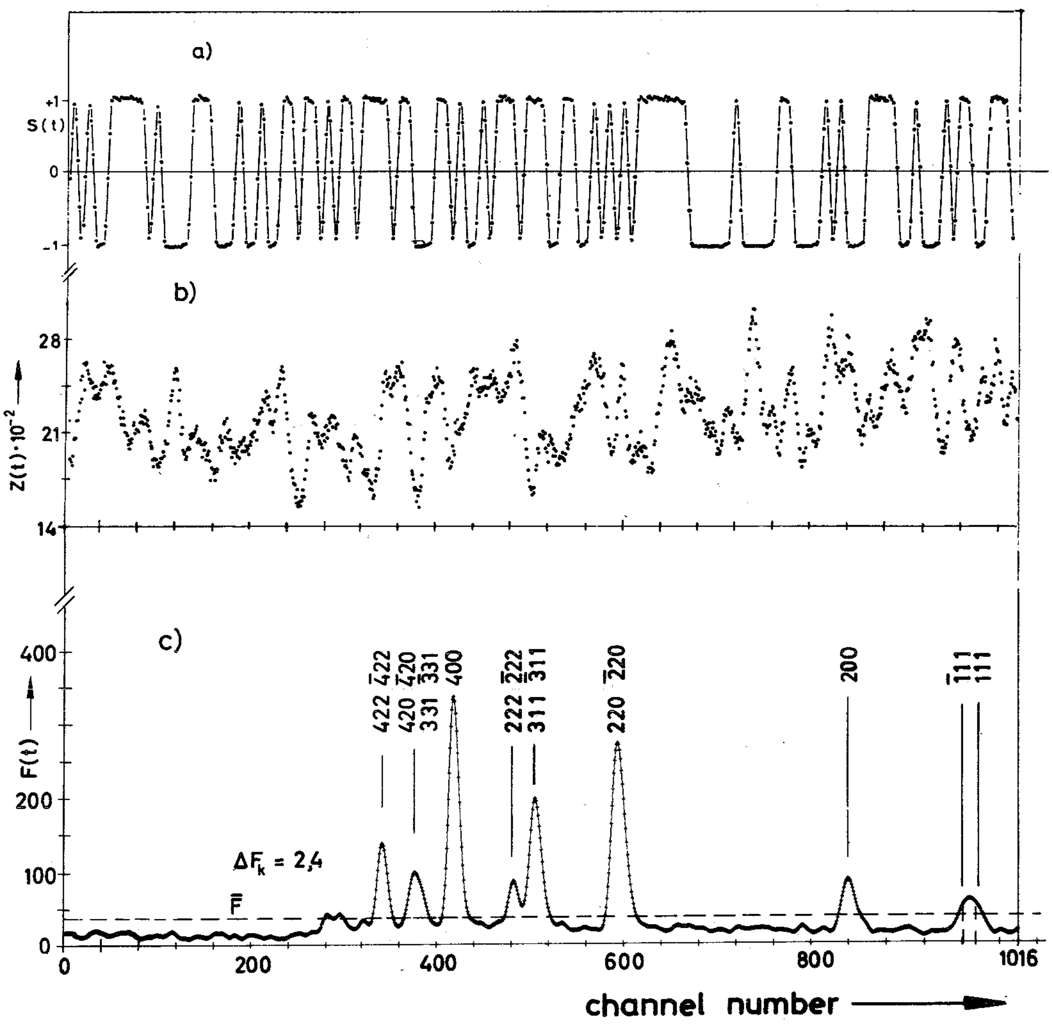


Fig. 5 Organisation System used in the TR 86-A



a) Normalized signal function $S_{127}(t)$
b) Counting rate $Z(t)$ of $BiFeO_3$
c) Diffraction pattern of $BiFeO_3$ at $\Theta = 15.7°$, 6.2m flight path and 6.5h counting time

Fig. 6 Time-of-Flight Spectra of $BiFeO_3$

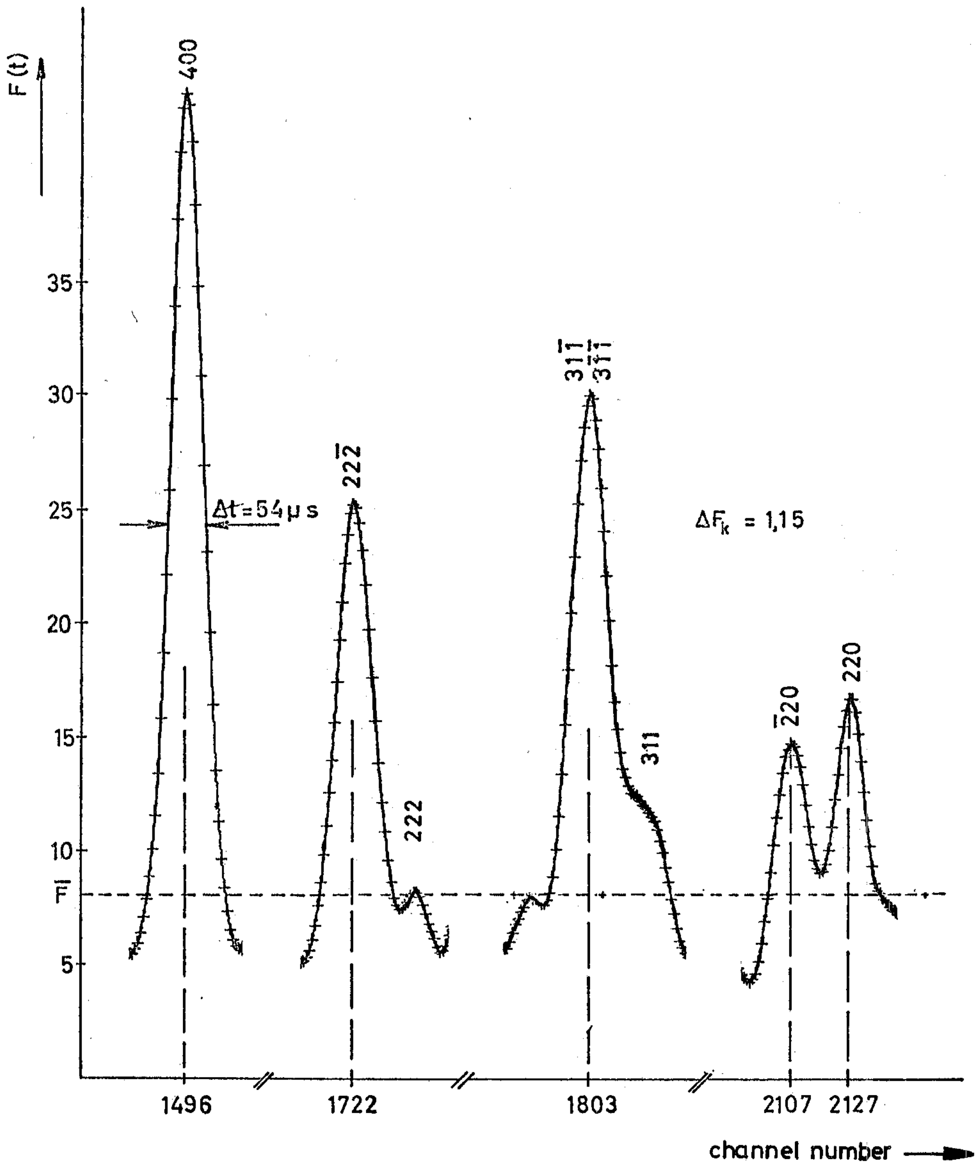


Fig.7 $BiFeO_3$ reflexes at $\theta=75^\circ$, 6.2m flight path and $\lambda \geq 4$ Å (cooled Be-filter in the incident beam)