

## A HIGH DYNAMIC RANGE BEAM POSITION MEASUREMENT SYSTEM FOR ELSA-2

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### Abstract

New beam lines are presently under construction for ELSA, a 18 MeV electron linac located at Bruyères-Le-Châtel. These lines need a beam position measurement system filling the following requirements : small space occupancy, good sensitivity, wide dynamic range (more than 90 dB), high noise immunity, single-bunch/multi-bunch capability. We designed a compact 4-stripline sensor, and an electronic treatment chain based on log-amplifiers. This paper presents the design, cold and hot test results.

### INTRODUCTION

The ELSA facility [1] was designed in the late 80's as a test bench for high-power FEL physics and technology. It is now mainly used as a versatile 1-18 MeV electron source or as a picosecond hard X-ray source. In response to this shift in the user's needs, dedicated beamlines are under construction in a new experimental area [2].

In 1988, during design stage, two types of diagnostics were chosen for transverse beam monitoring :

- thin OTR screens (300 nm Al on 8  $\mu$ m kapton film)
- button-type or stripline (depending on available space) BPMs

Subsequent ELSA operation showed the limits of these diagnostics :

- OTR screens allow precise measurement of the transverse profile, but are not very sensitive. They were replaced by two-screen systems (like the one described below on fig. 1) with an OTR screen and a scintillator screen (Cr:Al<sub>2</sub>O<sub>3</sub> deposited on a thin film).
- the button BPMs (10 mm in diameter capacitive pickups) are not sensitive enough
- the BPM electronic treatment chain is not reliable enough and was specifically designed for FEL operation. Therefore, it can be used only for 14.44 MHz (and 14.44 MHz/n) rep-rate train of bunches.

### THE ELSA-2 COMBINED STATION

For these reasons, it was decided to design a new diagnostic station (fig. 1 et 2) with the following constraints:

- all-in-one OTR/scintillator/BPM station to save space and allow easy comparison of OTR and BPM data
- simple design
- high sensitivity BPM

- high dynamic range electronics, compatible with every macropulse structure of the beam, which means any sub-pattern extracted from a 144 MHz train.
- a length equal to a standart 6-way tee (164 mm)

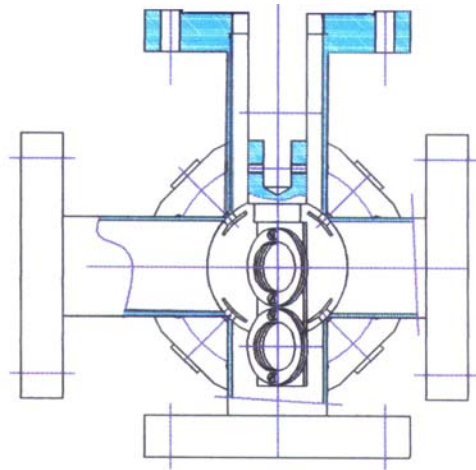


Fig. 1. Schematic drawing of the new diagnostic station combining two screens (OTR and scintillator) and a 4-stripline BPM : transverse view, showing the screens.

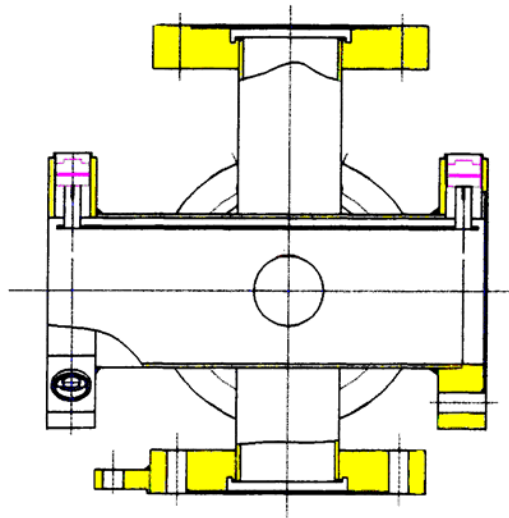


Fig. 2. Longitudinal view, showing the stripline ports.

For the BPM electronics (see details below), we chose a central frequency of 288.89 MHz. The corresponding wavelength (about 1 meter) is much longer than the stripline. In this case, the sensitivity grows with the

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stripline length. For that reason, we chose to house the SMA sockets in the flanges. This symmetrical design also offers the opportunity to get a good impedance matching (see figure 3) by putting an external 50  $\Omega$  load at the downstream port.

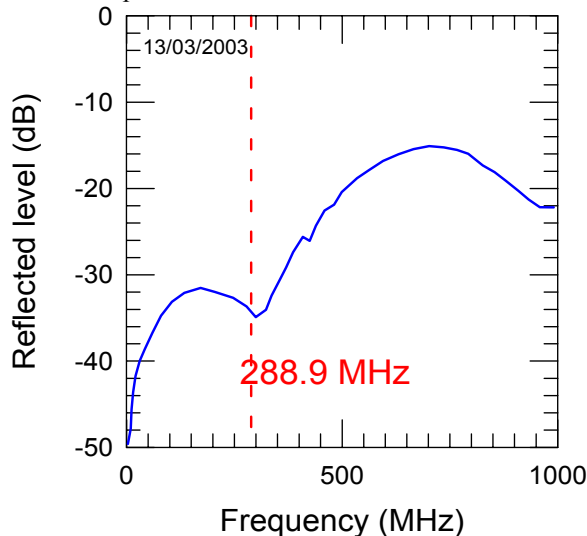


Fig. 3. Measurements show a good impedance matching of the BPM at the working frequency (better than 30 dB return loss).

Compatibility between the screen holder movement and the strips limits the subtended angle of the strips to slightly less than 45°, and imposes their locations at 45° of the horizontal and vertical axis. Numerization and post-processing of the position data will translate these data in the X et Y axis, in accordance with the implementation of the ELSA steerers and quadrupoles.

## BPM ELECTRONICS

Because of the wide variety of beam energy, current and transverse dimension and the wide variety of requirements for the realtime bandwidth, numerous schemes have been proposed for BPM electronics in the last decades [3].

Early stage design was strongly influenced by the arrival on market of inexpensive high performance log amplifiers, offering 100 dB dynamic range and 500 MHz input bandwidth.

Our requirements were :

- a macropulse current between 1 and 100 mA
- a position sensitivity of 100  $\mu\text{m}$  (stripline radius  $R=27$  mm)
- no calibration required after an initial check
- very simple design.

These requirements already imply a dynamic range of more than 80 dB :

- 40 dB for the current range
- 40 dB for the 0.1 mm resolution (to first order :  $\Delta/\Sigma=2$   $\Delta x/R$ )

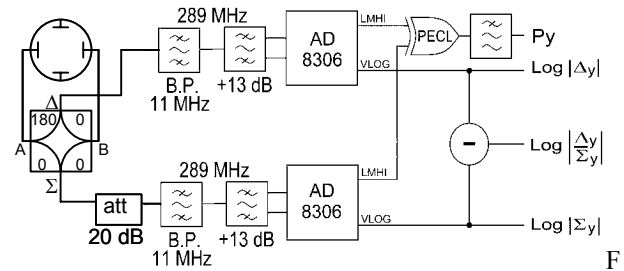


Fig. 4. Scheme of the electronics of one of the two channels of an ELSA-2 BPM.

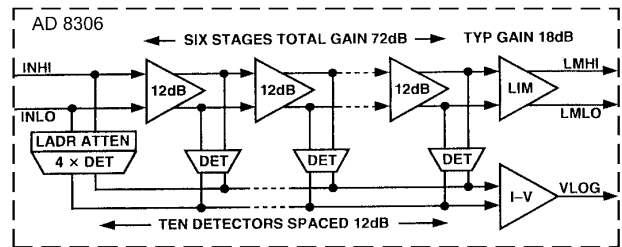


Fig. 5. Functional block diagram of the AD8306 log amplifier (source Analog Devices).

As seen on figure 4, the actual scheme is very simple :

- signals issued from two opposite striplines are carried along two equal-length semi-rigid short cables
- a hybrid  $\Sigma/\Delta$  circuit creates the sum and difference, followed by a 20 dB attenuator on  $\Sigma$  channel
- a narrow-band filter at  $289 \pm 5$  MHz samples a single harmonic of the signal.
- it is followed by a resonant impedance matching filter for adaptation of the 50 $\Omega$  line to the 1 k $\Omega$  input of the log amplifier (giving an extra +13 dB gain)
- an AD8306 limiting-logarithmic amplifier (fig. 5) gives two outputs : the logarithm of the envelope with a slope of 20 mV/dB (video bandwidth of 5 MHz) and a limiter output
- $\log(\Delta)$  and  $\log(\Sigma)$  signals are treated analogically to extract current and position informations
- limiter outputs of the  $\Delta$  and  $\Sigma$  channels are phase-compared to tell on which side of the center the beam actually is.

The 4 channels of a BPM are packed on a 70x100 mm<sup>2</sup> electronic board (cf. figure 6) whose design must be **very** careful from a EMC point of view, not to reduce the dynamic range and log conformance (cross-talk between channels put less constraint than these two points). A box in the accelerator room includes two such circuits (one for each transverse direction). The box is close to the strip line in order to avoid degrading the signal to noise ratio of the  $\Delta/\Sigma$  signals.

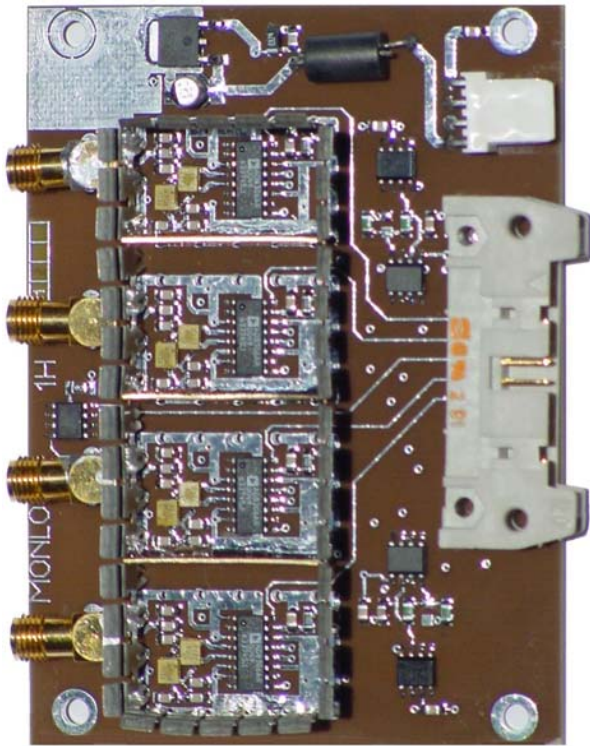


Fig. 6. Top view of the main circuit board

## BPM TESTS

### Electronic board tests on bench

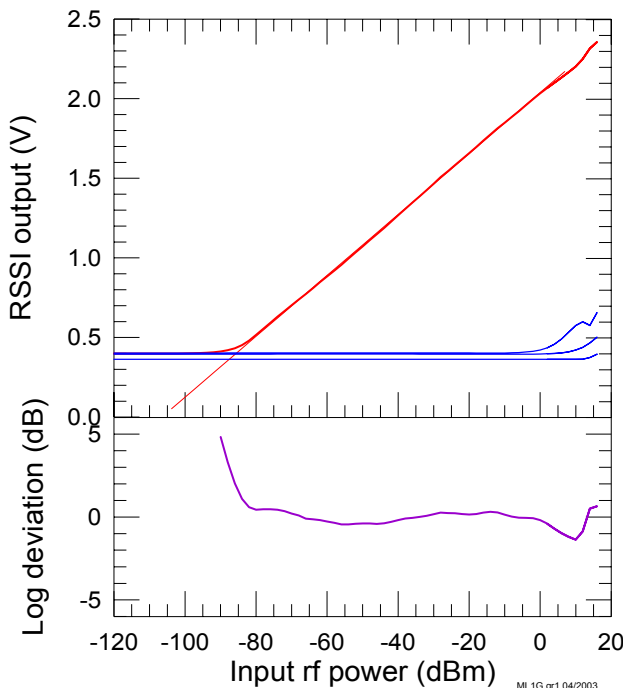


Fig. 7. Log response of the main board.  
The slope is 20 dB/m

Measurement of the log output is very close to the AD8306 datasheet. The useful dynamic is more than 95 dB and the log conformance (lower part of fig. 7) shows a

peak-peak deviation slightly above 1 dB on a 80 dB range. Such a performance requires a very high attention paid on the printed circuit layout.

### BPM tests on ELSA

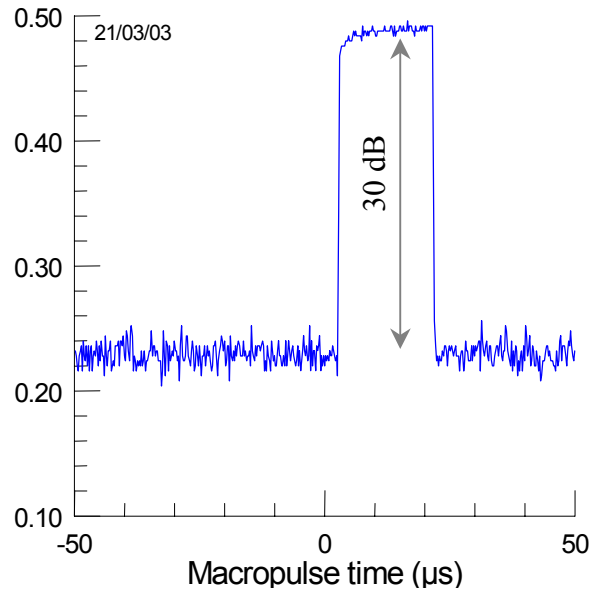


Fig. 8. Response of a  $\Sigma$  channel, on ELSA. The macropulse is 20  $\mu$ s long. Vertical scale is in Volts, 10 mV/dB (half the value of the AD8306 slope, because of the 50  $\Omega$  termination on scope).

First tests on ELSA (cf. figure 8) showed a BPM sensitivity more than 10 dB above the 1990 stripline design and a minimum current around 0.5 mA for the desired position precision of 0.1 mm, with a real-time bandwidth of 3 MHz.

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