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Authors
Stover, G.
Fowler, K.

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March 1987

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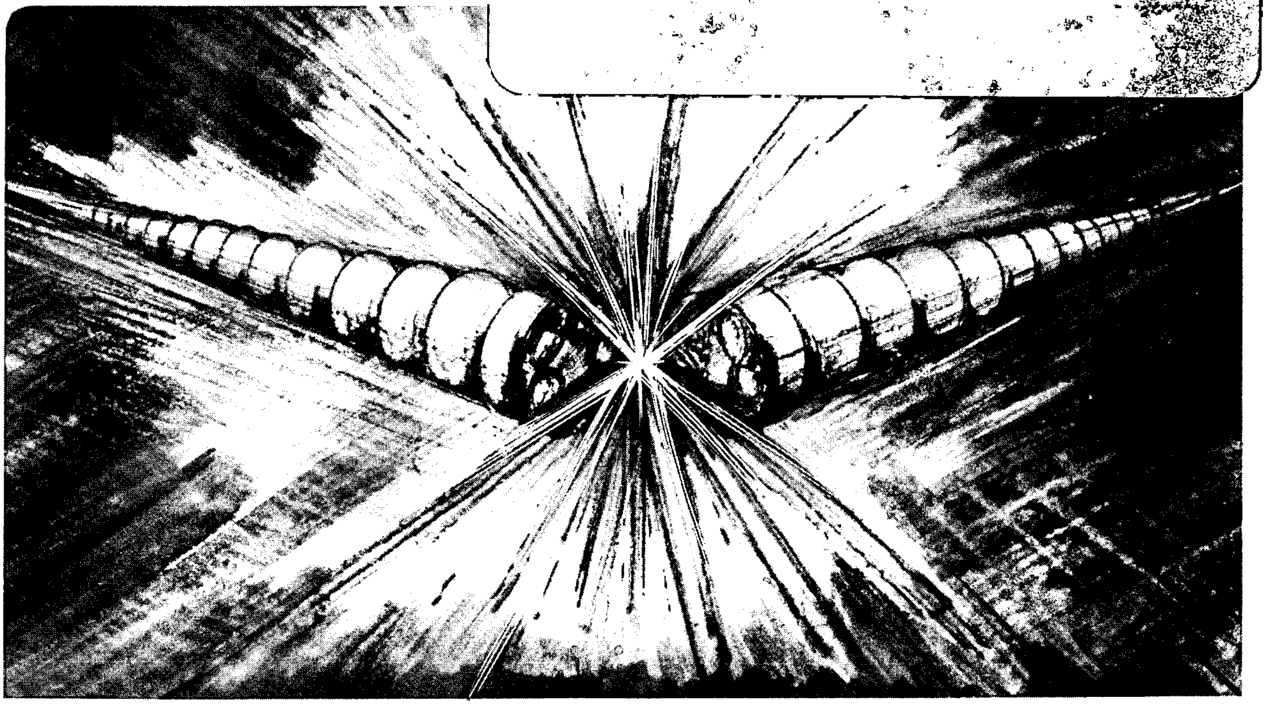

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OPERATING RESULTS FOR THE BEAM PROFILE MONITOR SYSTEM CURRENTLY IN USE AT BEVALAC FACILITY*

G. Stover and K. Fowler
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Abstract

Three stations of a soon to be completed multi-station, multi-wire beam monitoring system(1) have been installed in the Bevalac transfer line. The following article will provide a cursory analysis of the electronic circuitry, discuss new design additions and summarize the operating results obtained over the last year.

Introduction

In 1985 funding was provided, under the Accelerator Improvement project to design and build a new multi-station, wire grid, beam monitoring system for the Bevalac transfer line (1). These instruments were designed to enhance beam position resolution (from 9 segments to 32 wires), and increase detector sensitivities of approximately 500 times (from 500 down to 1.0 nanoamp of electrical wire current) over the existing segmented Faraday cup system. This increased sensitivity had to be maintained in a high electromagnetic interference (EMI) environment with some stations in the injection area being subjected to varying magnetic fields greater than 100 gauss/sec. Additionally, this is a partially destructive ($\leq$ 2.0% intercepted) method of beam monitoring which will allow for future multi-station auto-tuning of the beam transfer line.

Presently three stations have been installed and are being used in the Bevalac tuning operations of the transfer line. Actual operating beam-time data has confirmed the systems reliability, its very adequate noise immunity, and wire current sensitivities at and below the design level of 1.0 nanoampere.

Design philosophy (post construction)

Physical layout

To date, three of the twelve stations have been constructed and installed in critical tuning areas with one at the very top of the transfer line, and two in the injection area mentioned previously. The basic system configuration (See Fig. 1) is very similar to that described in the previous paper which consists of a wire grid assembly, shielded I/V (current to voltage) converter electronics in close proximity, and a processor chassis controlling the I/V converter and transferring data to and from the central computer.

Specifications and noise environment

A determination of the minimum sensitivity of the detector electronics was based on wire diameter, grid geometry, minimum beam intensities, and theoretical estimates of amplifier noise figures. Secondary electron multiplication in tungsten wire for the various ion species and the intensity of the background noise environment were somewhat less well known.

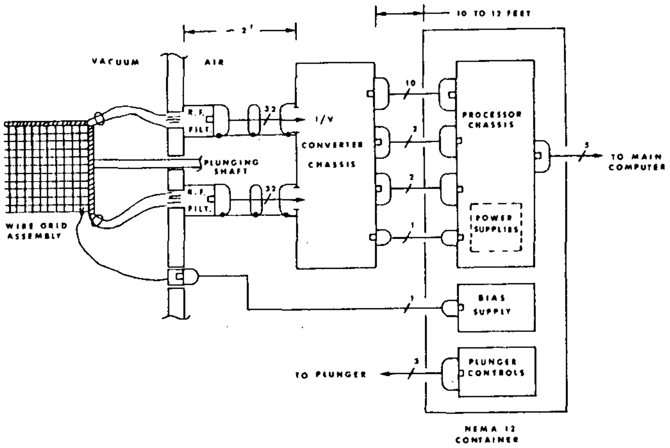

Fig. 1 (Electronic System) XBL 855-2672

The design procedure involved selecting a circuit and amplifier with the sensitivity and noise specifications to detect the lowest expected beam intensities and then carefully shielding the electronic system to reduce the gross effects of external EMI.

Two of the wire grid stations were mounted in the injection line and tangent tank areas of the main Bevatron quadrant magnets. Since this is a weak focusing machine with a very large gap, (approximately 33 cm) the dynamic leakage fields outside the magnet have been measured to exceed 100 gauss/sec, with a number of high frequency components at multiples of 59 Hz. In addition one station was mounted and tested just down stream from the 5 Mev Linac injector Rf system. Given the nature of such a harsh electrical environment a good deal of consideration was given to the grounding and shielding of the detector electronics.

System Description

Shielding considerations

The careful construction of an rf tight enclosure, low noise coaxial cables, and band limiting of the front end amplifiers provided a very effective barrier to EMI noise. Unfortunately metallic enclosures will provide little or no attenuation of the ac magnetic fields described above. The chosen method of optical isolation and single point grounding of the wire grids and the I/V front-end electronics has proved to be very effective against these magnetically induced noise currents.

As an experiment, a deliberately created ground loop in the I/V electronics mounted in the Tangent tank area injected enough noise into the system to completely saturate the amplifiers in the three most sensitive (1 nano to 1 micro amp) ranges. With the ground loop removed the noise floor is well below the measurable limits of the existing Faraday Cup system.

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Wire Grid Assembly

The proposed 16x16 wire grid assembly was retained with only one change. The wire diameter was reduced from .254mm (10.0 mil) to .051mm (2.0 mil). This improved beam transmission from 75 to 98 %. Most of the future wire grids will contain the smaller 2.0 mil wire. At these diameters wire breakage from beam heating and physical shock may be more common.

A very compact calibration signal injection scheme, consisting of a network of capacitively coupled resistor dividers was added to the wire grid frame assembly. This allows an electrical pulse of current to be injected simultaneously into all 32 wires to provide a physical check of not only the condition of the wires but the entire electronic system as well.

I/V electronics and noise analysis

A typical amplifier board, shown in figure 2, consists of 16 identical channels of a gain adjustable I/V amplifier, integrating filter, second stage amplifier, and a sample and hold (S/H) converter. The I/V converter design has proved to be very effective circuit for the amplification of very low currents generated by high impedance sources in noisy environments. Extraneous EMI fields are effectively canceled by the zero impedance input of the converter. Three basic criteria were required for the selection and design of the input amplifier.

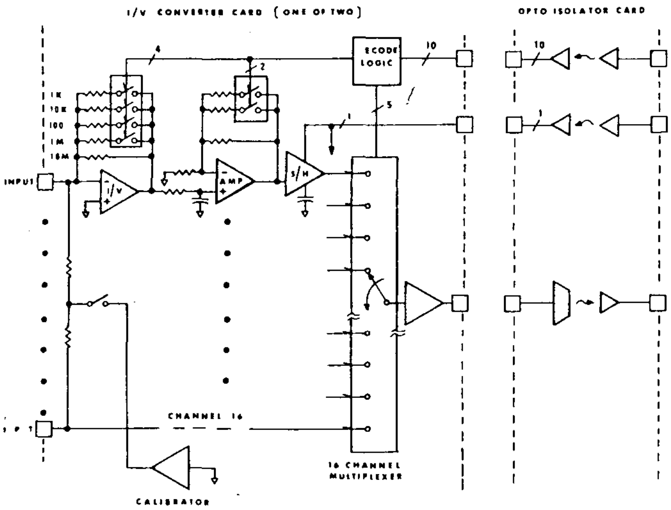

Fig. 2 XBL 855-2673

1) The amplifier was designed to detect electrical wire currents as low as 1.0 nanoampere with a signal to noise ratio (S.N.R.) margin of at least 6.0 db. 2) A reasonably wide amplifier bandwidth of 100 khz was chosen to accommodate spectral components of beam waveforms with rise times of 5.0 µs or greater. 3) Additionally over a standard temperature range (0 to 70 deg.) the maximum offset voltage at the highest amplifier current gain could not exceed .5 volts. This requirement in conjunction with a DC restoring algorithm in the controlling processor software obviated the need for any manual offset voltage adjustments of the numerous amplifiers.

The device selected was the OP-15 (2), a precision JFET input operational amplifier with a maximum Vos of 3.0 mv, a Vos temperature coefficient of 5.0 µv°C, a unity gain bandwidth of 6.0 Mhz, and an input noise voltage density of 20 nv/(hz)$^{1/2}$. As shown in the noise analysis below it quite adequately surpassed the required sensitivity.

The various noise generators which contribute to the total output noise voltage are shown in figure 3. Each wire of the grid is an effective noiseless current source with shunt resistance R_{ca} and capacitance C_{ca} contributed by the low noise coaxial cable connecting the wire to the amplifier. C_a and R_a define the input elements of the op-amp and in conjunction with R_f and C_f the feedback resistor and compensation capacitor make up the complete circuit. The major sources of noise in this circuit are the frequency dependent voltage and current sources of the input stage and the Johnson noise current from the feedback and shunt resistances.

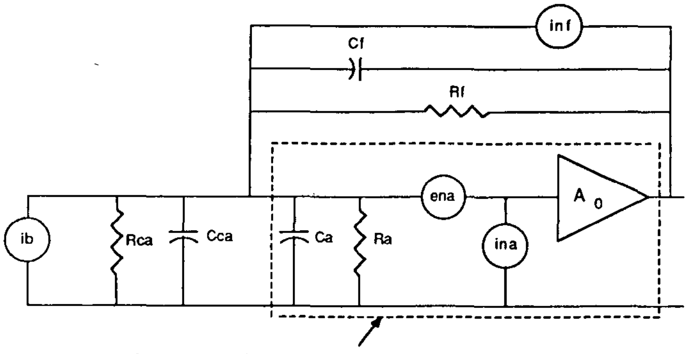

Fig. 3 (Noise circuit model)

Given the complexity of the various frequency dependent parameters a reasonable first approximation of the total noise (3)(4) in the circuit referred to the output is;

$$e_{nt} = Z_f \, [i_{nt}]^{1/2}$$

Both Z_f and i_{nt} are both frequency dependent functions. Assuming a loop gain $A_0B >> 1$, Z_f which is the parallel combination of R_f and C_f is;

$$|Z_f| = \frac{R_f}{(1 + w^2 C_f^2 R_f^2)^{1/2}}$$

The effective noise bandwidth (w) was derived by Bodie plot analysis of the feedback circuit and was chosen to be the point where the open loop gain A_0 is equal to the feedback signal gain B. The noise current components are;

$$i_{nt} = \left(\frac{e_{na}}{Z_s}\right)^2 + (i_{na})^2 + (i_{nsh})^2 + (i_{nf})^2$$

where;

$$|Z_s| = \frac{R_{sh}}{[1 + w^2 (C_{ca} + C_a)^2 (R_{ca} \parallel R_a)^2]^{1/2}}$$

$$i_{nsh} = \frac{4kTB}{R_{sh}}^{1/2}, \quad R_{sh} = R_{ca} \parallel R_a$$

$$i_{nf} = \frac{4kTB}{R_f}^{1/2}$$

This gives;

$$e_{nt} = Z_f \left[\left(\frac{e_{na}}{Z_s}\right)^2 + (i_{na})^2 + (i_{nsh})^2 + (i_{nf})^2\right]^{1/2}$$

Plugging in the specific values;

$w = 2\pi \times 90\text{khz}$
$k = 1.38\text{x}10\text{-}23\ \text{J}/^{o}\text{K}$
$T = 290^{o}\text{K}$
$R_f = 10^{7}\Omega$
$C_f = 2.0\ \text{pf}$
$C_{ca} + C_a = 125\ \text{pf}$
$R_{sh} = 10^{10}\Omega$
$i_{na} = .01\ \text{pa}/(\text{hz})^{1/2}$ and
$e_{na} = 15\ \mu\text{v}/(\text{hz})^{1/2}$

gives $e_{nt} = 280\ \mu v_{rms}$ of noise voltage at the output.

As alluded to above, this equation doesn't take into account the 1/f components of the op-amp noise sources or the frequency dependence of Ao and B which can give rise to closed loop noise gain peaking. Using the aforementioned Bodie analysis and graphically summing the individual noise components a more conservative value is .46 mv_{rms} which is 27 db below the 10 mv output generated by a 1.0 na input current. The input current for a SNR of 1:1 would approximately be 50 pa which is well below the required design value.

Operating results

The picture in figure 4 is a display output from the main control computer at the Bevatron. All three wire grid systems are displayed with station 3 at the top showing a calibration ramp and 17 and 18 displaying typical beam profiles. The vector display on the right which indicates the relative beam centroid is calculated in the main computer.

The digital range of the displays have the resolution to present wire current profiles as low as 0.1 nano amperes. Beam currents monitored at station BL-18 have been correlated with a sensitive downstream cup to check minimum current sensitivities under full operating conditions. Peak beam currents of 10 na or less of Ne +10 and La +32 have been easily observed on the display (1/3 full scale on the most sensitive range) with little or no observable base-line noise. Due to the limitation of the cup electronics peak beam intensities below this value could not be correlated.

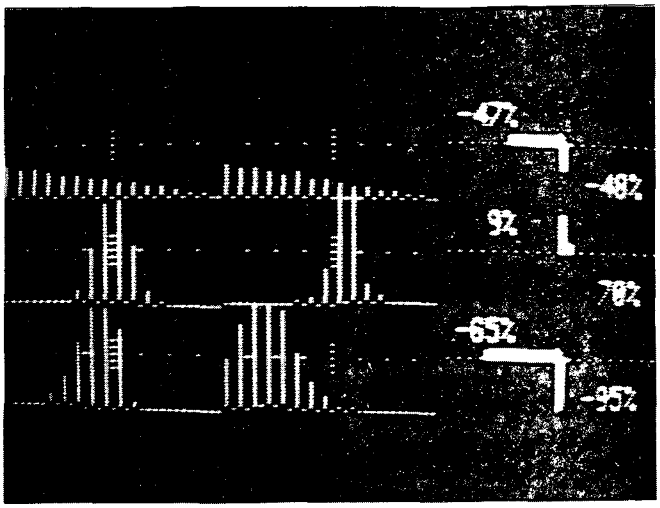

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Fig. 4 (Computer display)

References

1. G. Stover "Beam Profile Monitor System for the Bevalac Transfer Line" 1983 PAC, Vol. NS-32, No.5, Vancouver, 1985, p1988.
2. Device and numeric designation by Precision Monolithics.
3. P. R. Gray & M. G. Meyer, Analysis and Design of Anlog Integrated Circuits, John Wiley & Sons, Inc., 1977.
4. H. W. Ott, Noise Reduction Techniques in Electronic Systems, John Wiley and Sons, Inc., 1976.

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