Performance of the Beam Position Monitors of the TRISTAN Accumulation Ring

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Abstract

Eighty-three sets of electrostatic beam position monitors, each set made of four disk electrodes, are welded on the beam duct pieces of the TRISTAN Accumulation Ring (AR). All of their calibration maps are measured on a test bench. After assembly of the beam duct, they are positioned close to most of the quadrupole magnets. Their precise positions relative to the beam line are then measured by a microcomputer-controlled touch sensor. Their performance is satisfactory in the AR operation.

1. Introduction

The design layout of the position monitor system of the AR has been reported in the preceding (4th) Symposium. Since that time we entered into the actual construction period and the system has been completed just before the commissioning at November 1983. The essential parts of the system are vacuum chambers with pickup electrodes, transmission cables and coaxial switches, electronics for beam signal processing, CAMAC modules and softwares for data analysis and hardware control. The outline of these has been described before and will be briefly commented in this paper [1].

Basic requirement for the position monitor is the beam orbit measurement of 0.1 mm precision at the location of every quadrupole magnet. This is not an easy goal at all since various factors contribute to the errors; significant errors come from electrical noises, geometrical setting of the monitor pickups relative to the beam line, electrical calibration of the monitor chamber and characteristics of the electronics such as offset, drift and nonlinearity.

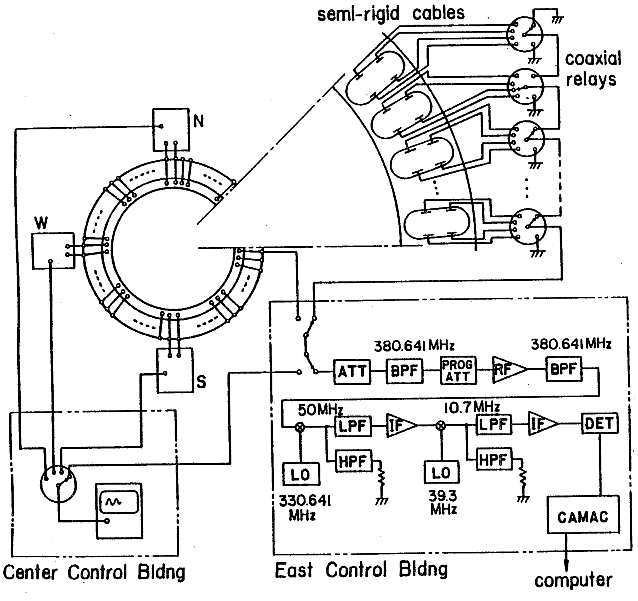


Fig. 1 Layout of position monitor system

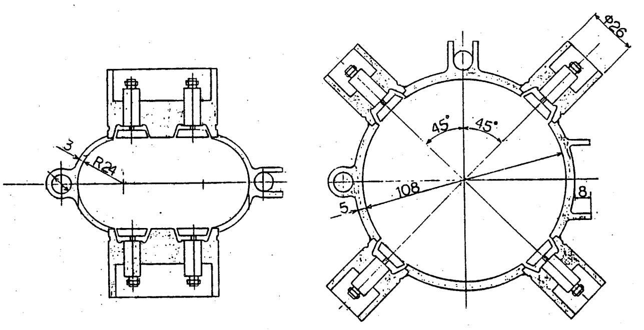
The following is our approach to get high precision of the system; usage of a common electronics circuit for a block of monitors, signal detection by a double superheterodyne circuit, selection of copper tube cables for the beam signals, development of calibration systems with high precision and the preparation of effective maintenance softwares. The layout of the whole system is given in Fig.1.

2. Detection of beam signal

2.1 Structure of the beam monitor chamber

We adopted the electrostatic pickups for the position monitor system. Since the pulse width of AR beam is of the order of 100 ps, the dimension of the pickup electrode should be about 3 cm.

Beam ducts of AR are made of aluminum tube manufactured by extrusion process and the whole ducts are joined by welding without flanges[2]. As the result, the pickup connectors (SMA type) of the position monitors came to be directly welded on to the beam ducts. The cross section of the beam duct is a race track shape in the bending regions and is a circular shape in the colliding regions. Therefore, we have two kinds of pickup structures as shown in Fig. 2(a) and 2(b).



(a) bending section (b) colliding section

Fig. 2 Pickup electrodes

2.2 Signal Processing

A coaxial type 3dB attenuater is set directly on to each SMA connector. A semirigid type coaxial cable leads a signal to a multiplexing coaxial switch attached to the tunnel ceiling above the monitor. The chain of low loss 20D coaxial cables then transmits the signals to one of the four local buildings, situated at north, east, south and west side of the AR ring. Signals are processed there, converted into digital data in CAMAC ADC and transferred to one of the AR control computers settled in the north control building via CAMAC serial highway.

The superheterodyne detection circuit picks up from a train of beam pulse (about 100 ps width) the 479th harmonic (380.641 MHz) of the revolution frequency. This frequency was chosen because we have enough sensitivity even with the high-pass characteristics of the pickup electrode and we can eliminate the influence of the 508.58 MHz RF frequency. The final IF frequency is 10.7MHz. The sensitivity of the pickup is -60 dbm/mA. The linearity range of the circuit is 30 db and overall linearity range is expanded by an input attenuator. The minimum beam current in this range is 0.1 mA. The equivalent offset of the circuit is less than 0.5 uA.

The monitor computer calculates the beam position in three steps. Let signals at four electrodes be A,B,C,D. First, we obtain electrical positions H and V by the following normalization:

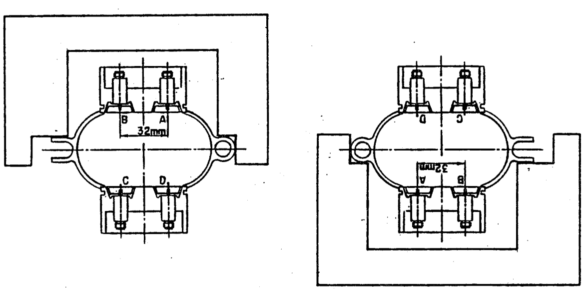
$$H = [(A+D)-(B+C)]/[A+B+C+D],$$

$$V = [(A+B)-(C+D)]/[A+B+C+D].$$

Second, we convert the electrical positions (H,V) into geometrical ones in the beam duct. The conversion relation is experimentally derived for each monitor from a bench test. The third step is to make correction for the setting error of the beam duct with respect to the beam line. These conversion data for each monitor are stored in the data table of the computer.

3. Calibration

As is stated in the section 2, we have to make two kinds of calibration measurements to find out the conversion relations. One is the electrical mapping of the beam duct and the other is the measurement of the geometrical position of the monitor. Since these measurements must be done separately, it is helpful to use the common principle for the recognition of the chamber position in both calibrations. For this purpose, we have developed a location jig method in which a jig block is pushed to the monitor chamber and becomes an indicator of the chamber position. In the setting error measurement, the jig sits on the chamber as shown in Fig. 3(a). In the electrical calibration, on the other hand, the monitor chamber is placed on the jig block, upside down, as in Fig. 3(b). In this way, we have the same contact in both calibrations.



(a) Setting error measurement (b) Mapping measurement

Fig. 3 Position of jigs

3.1 Mapping of a position monitor chamber[3]

The measuring setup is schematically shown in Fig. 4. The antenna, an end-stripped thin coaxial line, radiates 380MHz signal to simulate the beam. The x-y table enables it to survey the 20mm x 12mm area in the beam duct with the step of 1mm.

The microcomputer gives a conversion mapping (H,V) to (X,Y) on the experimental spot. We found that the following third order polynominals are very practical formula;

$$X = a0 + a1*H + a2*V + a3*HH + a4*HV + a5*VV + a6*HHH + a7*HHV + a8*HVV + a9*VVV$$

$$Y = b0 + b1*H + b2*V + b3*HH + b4*HV + b5*VV + b6*HHH + b7*HHV + b8*HVV + b9*VVV$$

We used a large computer to fit the polynominals to the data of 21x13 or 273 points by the least square method. Major contributions come from the terms of a1, a6, a8 for X and b2, b7, b9 for Y.

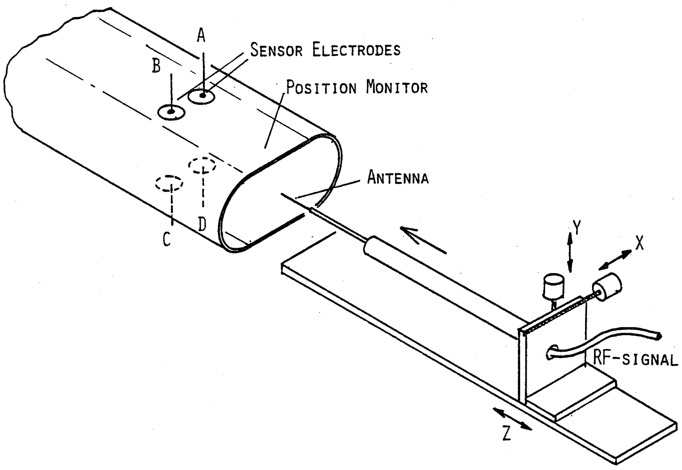


Fig. 4 Setup for mapping measurement

3.2 Measurement of Beam Duct Setting Error

We developed an efficient touch sensor method. The setup consists of a bed, an x-y table and an arm with a touch sensor at its end as shown in Fig. 5. The bed sticks onto two posts of the quadrupole magnet with the help of knock-pins. A microcomputer-controlled sequenser first returns the touch sensor to its home position driving the x-y table. Then the pulse motors move the the touch sensor until it touches the jig, with the ratio of 1um/pulse.

The measured reproducibility of the home position is within 0.5um in both x and y directions. Those of the positions stopped by the touch sensor are 0.7 um in x direction and 0.3 um in y direction.

The sensor touches the jig at four points in this manner. Because we know the exact size of the jig we can derive the three parameters, i.e., x and y coordinates of the vacuum duct and its inclination in the x-y plane, using the non-linear least square method.

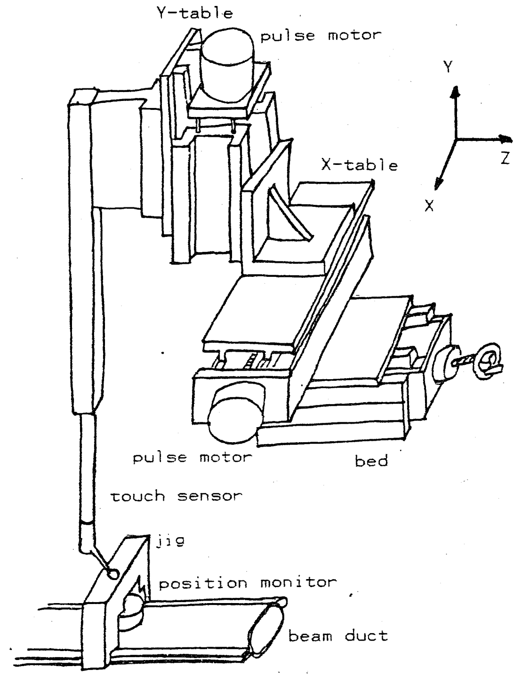


Fig. 5 Touch sensor device

The setting error measurement has been carried out for 64 monitor sets among 83. For the rest, measurement is impossible because of the reason either the setup interfere with the power lines of the magnets, or the cross section of the vacuum duct is irregular that the jig cannot fit. The measured results are summarized in Table 1.

Table 1. Beam duct setting error.

	range	rms	average
angle(mrad)	(-27.67, +22.9)	10.95	-5.52
horizontal(mm)	(-1.55 , +2.06)	0.68	0.78
vertical(mm)	(-0.95 , +1.70)	0.47	0.27

Positive sign is assigned as follows: when the inner side is up (angle), when the chamber center is outside of the ring (horizontal), and when the chamber center is lower than the beam level (vertical).

4. Performance

4.1 Closed orbit measurement

In the AR the beam orbit is measured in the storage mode only. Hence, we can measure the beam positions at 83 monitors serially. Since these monitors are grouped into four blocks and each block has its own electronics, we can save the measuring time by the parallel measurement of four blocks. The designed time consumption is 11 sec and the overall operation by NODAL system takes 11.5 sec. Operators can be patient for such interval.

The measured closed orbit is displayed on the graphic display and the data is stored in the memory file for later analysis. Fig. 6 shows an example of the display. The output voltage of whole pickup electrodes are also available on the graphic display. This subsidiary display is very useful to find out wrong elements in the position monitor system.

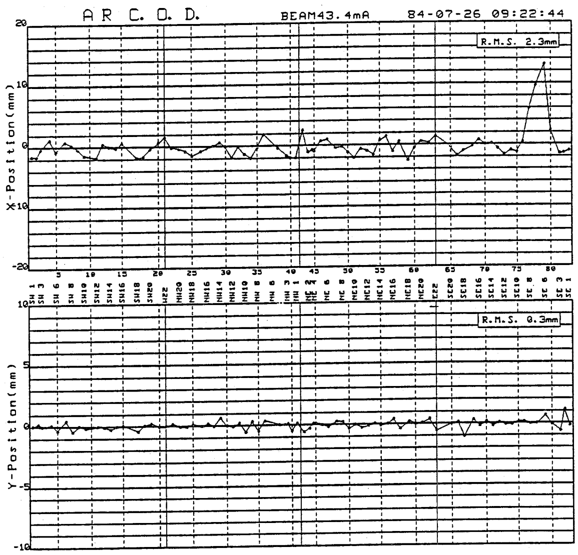


Fig. 6 Display of closed orbit

4.2 Reliability

We repeated closed orbit measurement 110 times during two storage operations (electron current decreases from 40 mA to 0.5 mA) to check the reproducibility of position measurement. It is given in Table 2 in terms of standard deviation at each monitor. Only five monitors showed standard deviation larger than 0.1 mm. We found in each case that the output voltage of one electrode took abnormally small value only once in 110 measurements. It is probably due to false contact in a coaxial relay. The high reproducibility suggests small noise contamination in the system. In this sense, the selection of cables (semi-rigid cables and corrugated cables) is very successful.

Table 2. Reproducibility of position

rms value(mm)	<0.05	<0.1	<0.2	>0.2
number of PM	64	10	2	3

There was some disagreement between the orbit shift excited by the steering magnets and the measured one. Recent analysis solved the problem and suggested the improvement of the mapping calibration [4].

During the first operation period from November 1983 to July 1984, we have some minor troubles in the position monitor system; we had to change a coaxial relay because of damaged contacts and we got two dead monitors because of short circuit of a disk electrode to the beam duct.

Reference

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