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Impedance Measurements on Button Electrodes

A. Jacob and G.R. Lambertson

March 1989

For Reference

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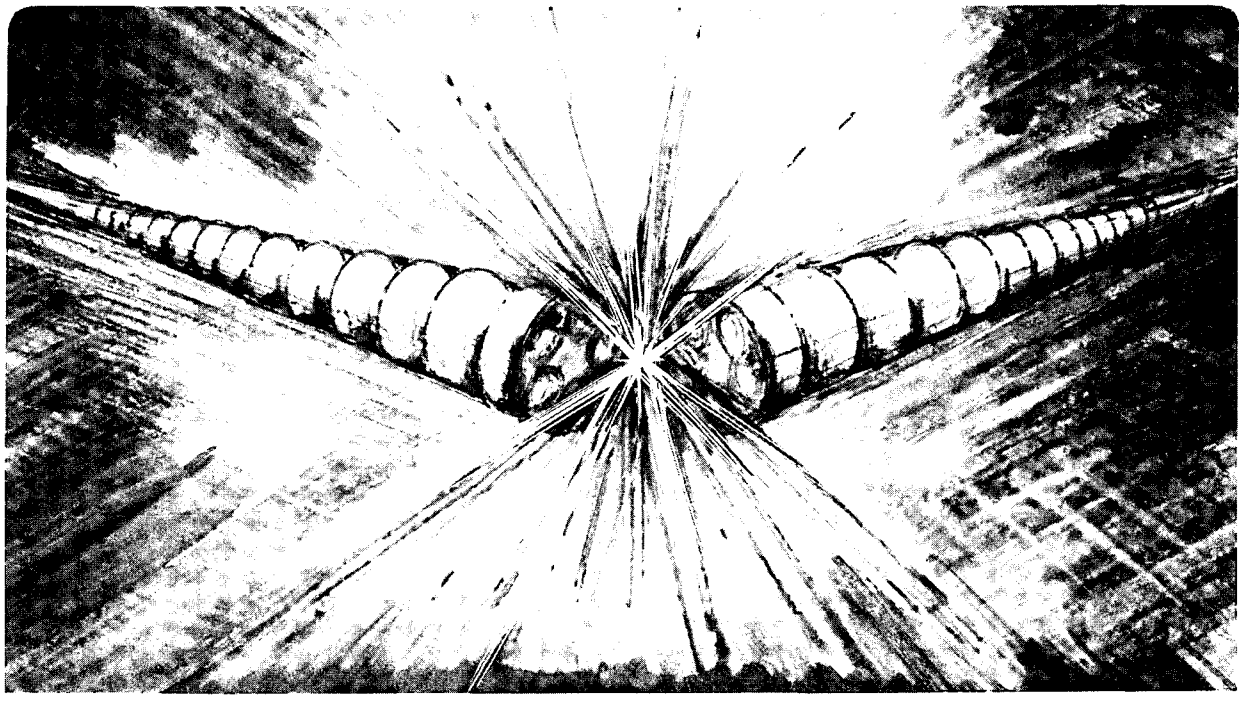

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IMPEDANCE MEASUREMENTS ON BUTTON ELECTRODES*

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March 1989

*This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, High Energy Physics Division, U. S. Dept. of Energy, under Contract No. DE-AC03-76SF00098.

IMPEDANCE MEASUREMENTS ON BUTTON ELECTRODES*

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Abstract

In the Advanced Light Source, there will be about 400 capacitive button electrodes in the beam position monitor (BPM) system, hence the contribution of each button to the machine beam impedance must be very small. We have measured the impedance of a single button as sensed by a coax connected directly to the button surface. This method is very sensitive and did not require a model of the total beam chamber as would the usual wire method. The measurements covered the range 0.1-to-20 GHz. The proportionality factor between the button impedance and the beam impedance depends upon geometry and frequency and was obtained from the measured sensitivity of a developmental BPM at low frequency. Discontinuities in the connection of the coax to the face of the button introduce parasitic effects that must be accounted for in interpreting the data. Below 5 GHz the results compare very well with responses computed from mechanical dimensions of the electrode. Above 15 GHz corrections for the parasitic elements become more uncertain but the accuracy of the method is still adequate. The results show multiple resonances, a prominent example being for one button a beam impedance peak of ~ 1 ohm with a Q of 500 at 16 GHz.

Introduction

It is desired that the position-monitoring electrodes, as designed for the Advanced Light Source (ALS), present an acceptably low impedance to the electron beam in order to avoid exciting coupled-bunch instabilities or heating of the electrodes from induced currents. These concerns require that resonant responses of any one of the 400 assumed identical electrodes have peak beam impedances that are less than 2.5 ohm within the frequency range from 0.5-to-20 GHz.

Description of electrodes

Each pickup is a coaxial structure as sketched in Fig. (1) having a 7.6 mm diameter exposed surface flush with the wall of the beam tube and connected to a 50 ohm cable. Further details of the electrode are found in reference [1]. Measurements with a wire excited at 500 MHz have shown the coupling impedance of a single button to the beam to be $Z_p = 0.05$ ohm as a pickup driving a $R_o = 50$ ohm load. At low frequency the button has capacitance C = 20 pF.

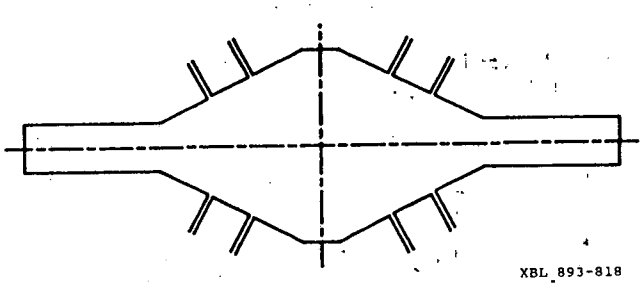

Fig. 1 Schematic cross-section of ALS beam chamber with four button electrodes.

Method

For measuring the beam impedance, we chose to avoid the complexities of the wire method extended to 20 GHz, which is well above the beam-tube cutoff frequency of 5 GHz. Instead, we measured the impedance Z_e presented at the face of a single button and from that calculated the beam impedance.

From the longitudinal beam impedance Z_B, a voltage

$$V_B = I_B Z_B \tag{1}$$

is imposed upon the beam current I_B. Applying reciprocity relations to the circuit in Fig. (2), we have

$$V_B I_B = -(I_e Z_e) I_e \tag{2}$$

where I_e is the current induced in the button by the beam. Combining eqs. (1) and (2) we find

$$Z_B = -Z_e (I_e/I_B)^2 \tag{3}$$

The ratio I_e / I_B is proportional to frequency f and from the values of R_o, C, and Z_p at 500 MHz we obtain

$$I_e/I_B = j(3.3 \times 10^{-3}) \frac{f}{5 \times 10^8} \tag{4}$$

At the highest frequencies this ratio becomes smaller than the above value, being about 30% lower at 20 GHz. We have not applied this correction to the results. If in using this method to find Z_B coupling data at one frequency were not available, one could calculate the ratio I_e / I_B for a reasonably simple geometry.

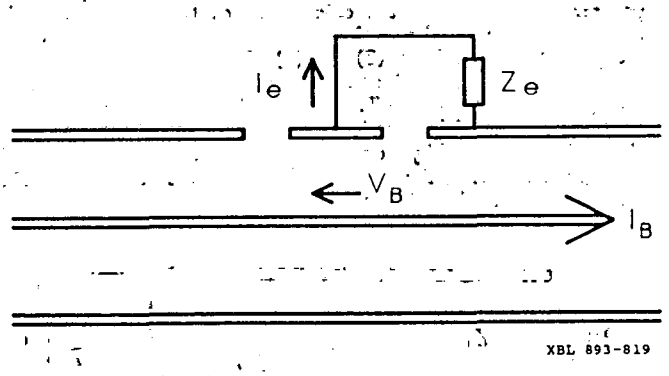

Fig. 2 Model of the button showing relevant currents and voltages.

Measurement Set-Up

One way to assess the button impedance Z_e is to connect the button directly to a coaxial measuring system. Then a transition piece is required in order to adapt the outer diameter of the button to a standard coaxial cable. Fig. (3) is the sketch of a possible arrangement: it simply consists of a coaxial line with abrupt changes in cross section. The diameter of its outer conductor matches the 8.8 mm of the button surround and changes abruptly to the dimension of a standard SMA connector. Its center rod is the prolongation of the SMA center conductor. It contacts the center electrode of the button, leading to another impedance step. The length of the inner and outer conductors of the test fixture have to be carefully matched in order to insure a good contact with the button. A drop of soft solder on the center of the button proved to be helpful. The device is chosen long enough so as to allow higher order modes below cutoff to be sufficiently attenuated from one discontinuity to the other.

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