national accelerator laboratory

TM-339
0879

MANIPULATIONS TO CHECK AND DEMAGNIFY ERRORS IN BEAM-POSITION MEASUREMENTS WITH THE ELECTROSTATIC BEAM DETECTORS

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January 18, 1972

Introduction

In each service building, a two-channel amplifier and detector combination is used to amplify and detect signals from the electrostatic beam-position detector selected by the relay multiplexer. The output of the amplifier detector is used to calculate the following ratio which should be proportional to beam position:

$$\frac{A_o - B_o}{A_o + B_o}$$

where,

$A_o = A_i\ G_A$ = Amplifier output for Channel A

$B_o = B_i\ G_B$ = Amplifier output for Channel B

A_i = Amplifier input signal for Channel A

B_i = Amplifier input signal for Channel B

G_A = Amplifier gain for Channel A

G_B = Amplifier gain for Channel B.

In particular, if $A_o = B_o$ one hopes that the beam is centered, which is true only if $G_A = G_B$. We know that this constraint is

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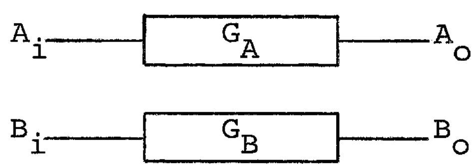
not satisfied in all cases; therefore, it would be desirable to check under operating conditions the extent of the gain inequality and to compensate as required.

The analysis below shows that if the input signals to the amplifier are transposed and the resultant function is first subtracted from and then added to the normal function, the following features are obtained:

1. The beam can be precisely centered without equal gain between channels.
2. With centered beam, the percent gain variation between channels can be quantitatively determined.
3. As long as G_A approximately equals G_B a relatively accurate beam position can be determined.

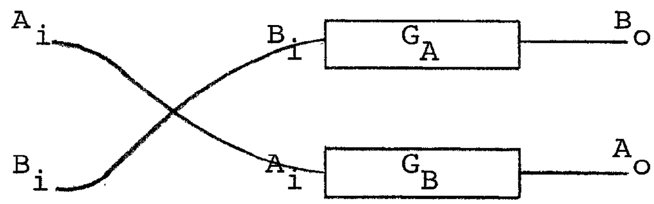
Analysis

Consider the following block diagrams which illustrate the normal and transposed connections with the resultant output functions. Reproducibility of beam intensity and position for the two connections is assumed.



NORMAL

$$\frac{A_o - B_o}{A_o + B_o} = \frac{A_i G_A - B_i G_B}{A_i G_A + B_i G_B} = f_1$$



TRANSPOSED

$$\frac{B_o - A_o}{B_o + A_o} = \frac{B_iG_A - A_iG_B}{B_iG_A + A_iG_B} = f_2$$

After some algebraic manipulations, the difference between the normal and the transposed functions is determined as

$$f_1 - f_2 = \frac{2G_AG_B\left(A_i^2 - B_i^2\right)}{(A_iG_A + B_iG_B)\ (B_iG_A + A_iG_B)}. \qquad (1)$$

Now, the beam will be centered when $f_1 - f_2 = 0$ as that requires $A_i = B_i$ independent of the amplifier gains G_A and G_B assuming, of course, that $G_A \neq 0 \neq G_B$.

Next, the sum of the two functions is calculated as follows:

$$f_1 + f_2 = \frac{2A_iB_i\left(G_A^2 - G_B^2\right)}{\left(A_iG_A + B_iG_B\right)\left(B_iG_A + A_iG_B\right)} \qquad (2)$$

which should ideally equal zero as that requires $G_A = G_B$ independent of input signals A_i and B_i assuming, of course, that $A_i \neq 0 \neq B_i$.

In general, this sum will not equal zero, but the percent gain variation between channels can be quantitatively determined by making Eq. (1) zero (centering the beam). Under this condition, Eq. (2) becomes:

$$f_1 + f_2 = \frac{2(G_A - G_B)}{G_A + G_B} \qquad A_i = B_i \neq 0 \qquad (3)$$

which gives the percent gain variation between channels A and B.

If Eq. (3) is near zero, i.e., $-0.1<f_1+f_2<0.1$, then $0.9<G_A G_B^{-1}<1.1$ and the gain variation is less than 10 percent, a condition which should be easily satisfied in practice. Eq. (1) can then also be used to find, with good precision, the normalized beam position as follows:

$$f_1 - f_2 = \frac{2\left(A_i^2 - B_i^2\right)}{A_i^2 + A_i B_i\left(\frac{G_A}{G_B} + \frac{G_B}{G_A}\right) + B_i^2} \qquad (1)$$

$$f_1 - f_2 \cong 2\frac{\left(A_i - B_i\right)}{A_i + B_i} \qquad 0.9<G_A G_B^{-1}<1.1 \qquad (4)$$

which is twice the normalized beam position based on input signals to the amplifier.

Summary

Clearly, transposing the signals into the amplifier is essential to obtain accurate beam position under all anticipated conditions. Furthermore, the facility to check conveniently under operating condition the gain variation between channels assures better system performance and gives the operators confidence in the system.

Eq. (1) should always be used to determine the beam position. The computer can provide the calculation easily if a transposing system exists. Occasionally, Eq. (2) and (3) should be computed to assess the gain variation.