A MODEL MEASUREMENT OF THE LONGITUDINAL COUPLING IMPEDANCE

PRESENTED BY THE CLEARING ELECTRODES IN THE ISR

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At low frequencies, i.e. far below the lowest resonance, the longitudinal coupling impedance \( Z_{\text{rf}} \) of \( m \) pairs of clearing electrode plates is given by

\[
\frac{Z_{\text{rf}}}{h} = m L \omega_r A^2
\]  

(1)

where \( h \) is the harmonic number, \( L \) the inductance (from end to end) of a pair of plates connected in parallel, \( \omega_r \) the angular revolution frequency and \( A^2 \) a factor taking into account the fact that the plates do not enclose the beam completely (as a drift tube would). Eq. (1) is valid if the external loading impedance is small compared with the electrodes' self-capacitance, a condition that is certainly fulfilled in the ISR.

Neglecting end effects and taking the pair of plates as a homogenous transmission line in vacuum, one has \( cL = \frac{1}{2} Z_0 \), where \( \lambda \) is the length of each electrode pair, \( c \) the velocity of light and \( Z_0 \) the characteristic impedance of the line, with both plates driven in common mode. One finds then for relativistic particles

\[
\frac{Z_{\text{rf}}}{h} = \frac{m}{R} Z_0 A^2 \, .
\]  

(2)

\( R \) being the average machine radius. In the ISR

\[
m = 264 \\
\lambda = 0.25 \, \text{m} \\
R = 150 \, \text{m} .
\]

The factor \( A^2 \) appears to be composed of two factors \( A_1 \) and \( A_2 \). The first factor is the electric flux collected by the plates divided by the total flux emerging from the beam and the second is the fraction
of the plates potential measured at the beam location. In Ref.\textsuperscript{1)} the factor \( A \) has been taken as proportional to the geometrical angle occupied by the plates when seen from the center. This factor is valid for circular geometry. It must be expected to be too small for the actual elliptic geometry.

A measurement of \( Z_0, A_1 \) and \( A_2 \) has been made with an analogue model, consisting of a sheet of weakly conducting (carbon coated) paper on which the cross-section of the electrode assembly and the surrounding wall has been painted with highly conducting paint. Since the electrode assembly is symmetric with respect to the horizontal medium plane, only half the assembly has been modeled, as shown in the attached Figure. The "floating bar" shown in the Figure models a part of the electrode support structure that, in reality, is connected to the outer wall in such a way that magnetic flux can penetrate between the bar and the wall.

The characteristic impedance \( Z_0 \) has been determined by measuring the resistance between the plate and the wall and comparing the result with the resistance produced - on the same carbon paper - by a configuration of known characteristic impedance (the obvious choice being a pair of concentric circles representing a coaxial line). The result obtained (with the floating bar\textsuperscript{*}) is

\[
Z_0 = 20 \ \Omega
\]

with an estimated accuracy of \( \pm 10\% \).

The factor \( A_1 \) was determined by connecting a current source to the point corresponding to the center of the electrode configuration (i.e. the central particle orbit) and measuring the distribution of current

\textsuperscript{*} With the "bar" connected to the wall the measured result was 18 \( \Omega \).

\textsuperscript{1)} A.G. Ruggiero, P. Strolin and V. G. Vaccaro, ISR-RF-TH/69-7.
between the plate and the wall. The fraction of the current collected by the wall equals $1-A_1$ and the measured value for this is 0.072. Hence

$$A_1 = 0.93.$$ 

By applying a voltage $V$ between the plate and the wall and measuring the fractional voltage drop $\Delta V/V$ between the center and the plate one finds $1-A_2$. The value found is 0.069. Hence

$$A_2 = 0.93$$

i.e. $A_1 = A_2$ and

$$A^2 = 0.865.$$ 

Thus one obtains

$$\frac{Z_{lf}}{h} = 7.6 \, \Omega \pm 10\%.$$ 

Half of the electrode pairs are located inside the T-shaped vacuum pump connections in such a way that over roughly half the electrode length the side walls are partially removed. This leads to an increase (although certainly a small one) of both $Z_0$ and $A^2$. In view of this and the limited accuracy of the model measurements we propose to use the value

$$\frac{Z_{lf}}{h} = 8.0 \, \Omega$$

in all future calculations of longitudinal stability.
ANALOG MODEL

floating bar
plate
wall

20
72
130
160

low conductivity

high conductivity