PS/AR NOTE 93-20

MEASUREMENT OF TRANSVERSE ACTIVE FEEDBACK AT LEAR

M. Chanel and U. Oeftiger

ABSTRACT

From transverse beam transfer function (BTF) measurements the stability diagrams have been calculated. The diagrams have been used to determine the strength of the transverse feedback system and the contribution of the transverse stochastic cooling system working as a broad band damper.

1. INTRODUCTION

From vertical and horizontal BTF measurements the transverse stability diagram has been calculated at different harmonic numbers and different values for the gain of the feedback system G_{fb} and the gain of the stochastic cooling system G_{st} .

The transverse stability diagram, which we analyse consists of two traces, one is due to the slow wave and the other is due to the fast wave of the beam response [ref. 1, 2]. The damper impedance leads to a displacement of each of the two traces away from the origin. From this shift the damper contribution can be derived (figure 1).

The total damper impedance $Z_\perp$ calculated from the stability diagram has a component $Z_{\perp,fb}$, which is due to the feedback system, and a component $Z_{\perp,st}$, which is due to the stochastic cooling system. Both are inversely proportional to the beam current, but proportional to the gain of the corresponding system and to the efficiency of their pick-up and kicker system.

2. TRANSFER FUNCTION OF THE FEEDBACK SYSTEM

The pick-up of the feedback system is an electrostatic pick-up. It's frequency response is constant in the range considered. The kicker efficiency is given by [ref. 3]

$$S_{fb,kick}(f) \propto \frac{\sin(\pi \frac{f}{f_1})}{f} \quad ,$$

where f_1 is related to the kicker geometry (loop coupler with a length of 1.3m, figure 2). From the kicker parameters and from transfer function measurements through the feedback system electronics f_1 has been calculated to be around 55 MHz, whereas the results from the BTF measurements lead to 30 MHz (see chapter 4).

3. TRANSFER FUNCTION OF THE STOCHASTIC COOLING SYSTEM

The pick-up efficiency of the stochastic cooling system is given by [ref. 4]

$$S_{st,pick}(f) \propto \frac{\left|\sin(\pi \frac{f}{f_2})\right|}{\sqrt{f}} \quad ,$$

where $f_2 \approx 450$ MHz so that $S_{st,pick}(f) \propto f$ in the frequency range of up to 100 MHz. The kicker efficiency is equal to that of the feedback system kicker replacing f_1 by f_2. At lower frequencies it is approximately constant. But in contrast to the feedback system one has to take into account that the transfer function $A(f)$ of the kicker amplifier electronics depends linearly on the frequency, as measurements up to 100 MHz have shown:

$$A(f) \propto 1 + 0.3 \cdot f/[MHz]$$

4. REAL PART OF THE TOTAL DAMPER IMPEDANCE

The total damper impedance consists of a linear superposition of both damping systems. Using the proportional constants C_{fb} and C_{st} the real part of the damper impedance can be written as:

$$\mathrm{Re}\{Z_\perp\} = C_{fb}\, 10^{G_{fb}/20[dB]} \frac{\sin(\pi \frac{f}{f_1})}{f/[MHz]} + C_{st}\, 10^{G_{st}/20[dB]} \sqrt{f/[MHz]}\, (1 + 0.3 \cdot f/[MHz])$$

Three different BTF measurement series in the frequency range between 5 MHz and 85 MHz have been carried out. Each series has been performed using specific values for G_{fb} and G_{st}

Fitting this function to the different measurement points with C_{fb} and C_{st} as the fitting parameter one can calculate the impedance contributions due to the feedback system and the stochastic cooling system separately. In figures 3a,b,c,d the real part of the total damper impedance derived from the BTF measurements is plotted together with the fitting curve $\mathrm{Re}\{Z_\perp(f)\}$ for different values of f_1. The best fit has been reached using $f_1 \approx 30$ MHz. From the results of three measurement series (each having a different setting for the gain of the feedback system and the stochastic cooling system) one obtains as an average value for C_{fb} and C_{st}

$$C_{fb} = (617 \pm 32) \quad , \quad C_{st} = (0.158 \pm 0.020) \quad \text{and} \quad f_1 \approx 30\ \text{MHz}.$$

The damper impedance $\mathrm{Re}\{Z_{\perp,fb}\}$ coming from the feedback system and the impedance contribution $\mathrm{Re}\{Z_{\perp,st}\}$ due to the stochastic cooling system are shown in figure 4.

5. SYSTEM SENSITIVITY IN THE VERTICAL AND HORIZONTAL PLANE

The feedback system is around a factor 4 more sensitive in the vertical plane, than in the horizontal plane. This is due to the different betatron functions at the pick-up and the kicker position and due to the different geometry of the kicker design.
For the same reasons the stochastic cooling system is around a factor 7 more sensitive in the vertical plane. This value is decreased to a factor 4 by stronger amplification of the signals in the horizontal path.
The lower sensitivity in the horizontal BTF measurement loop leads to a larger inaccuracy in the horizontal BTF measurements. This inaccuracy leads to a higher spread in the results of the measurements for the damper impedance. Therefore it was not possible to fit the fitting function given above to the horizontal measurements.

6. CONCLUSION

The vertical impedance contribution from the feedback system and the vertical impedance contribution due to the stochastic cooling system have been separated by analysing beam transfer function measurements. Because of a lower sensitivity in the horizontal systems it was not possible to obtain the horizontal damper contributions with sufficient precision. The passage through zero in the response of the feedback system leads to a negative damping at higher frequencies. A change of the kicker connection has been made to avoid this zero response within the pass band of the system. By this action the transverse beam stability has been improved.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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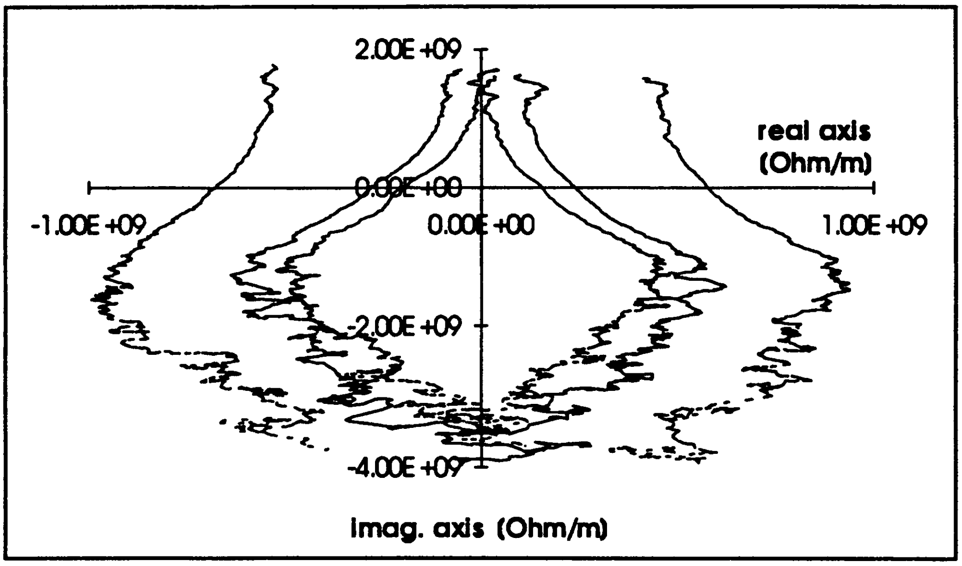

Figure 1: Example of an horizontal stability diagram of a beam with $8 \cdot 10^9$ protons at 310 MeV/c at the 70th harmonic (= 84 MHz) with +50dB gain for the feedback system and different gains for the stochastic cooling system: +50dB, +70dB and +85dB (from inner to outer traces). Increasing the gain improves the stability zone of the beam.

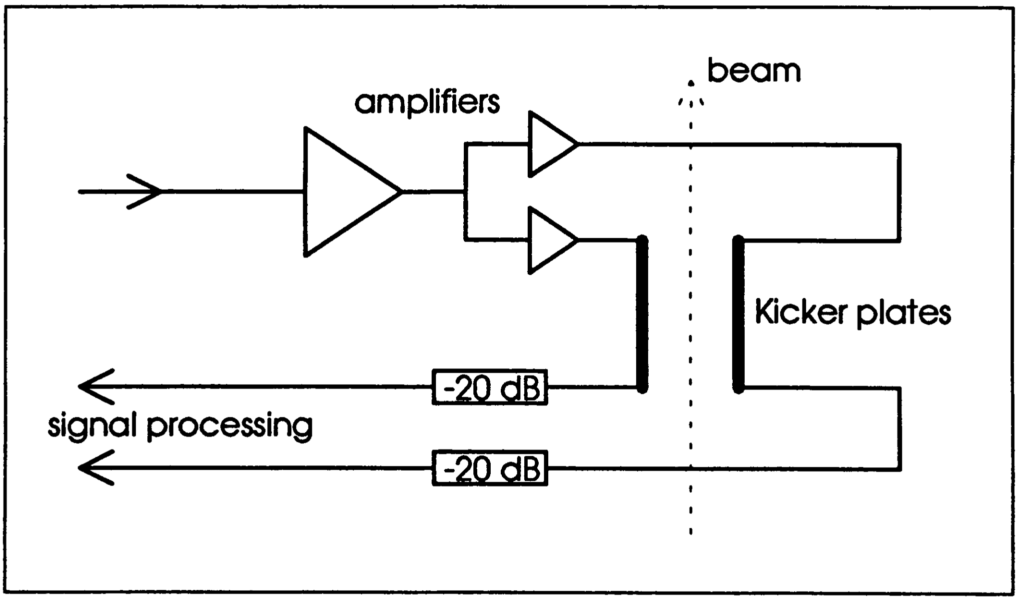

Figure 2: Connection of the kicker of the feedback system. The signal processing loops act as a 50Ω termination of the plates.

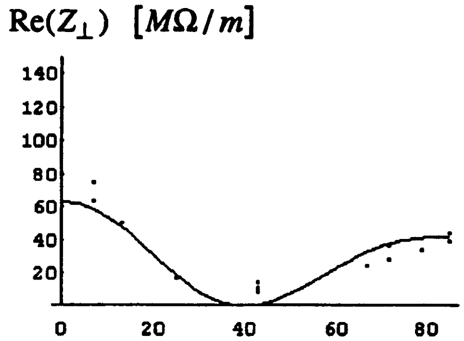

Figure 3a

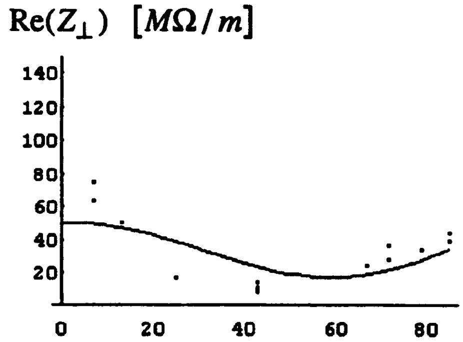

Figure 3b

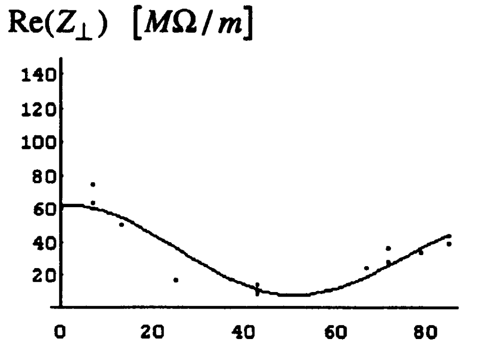

Figure 3c

Figure 3a,b,c: The real part of the transverse damper impedance $\mathrm{Re}\{Z_\perp(f)\}$ for the gains G_{fb} =+50dB and G_{st} =+70dB has been calculated from transverse BTF measurements of a proton beam of 310MeV/c. The line represents a fitting curve using different values for f_1: 30 MHz (a), 40 MHz (b) and 50 MHz (c).

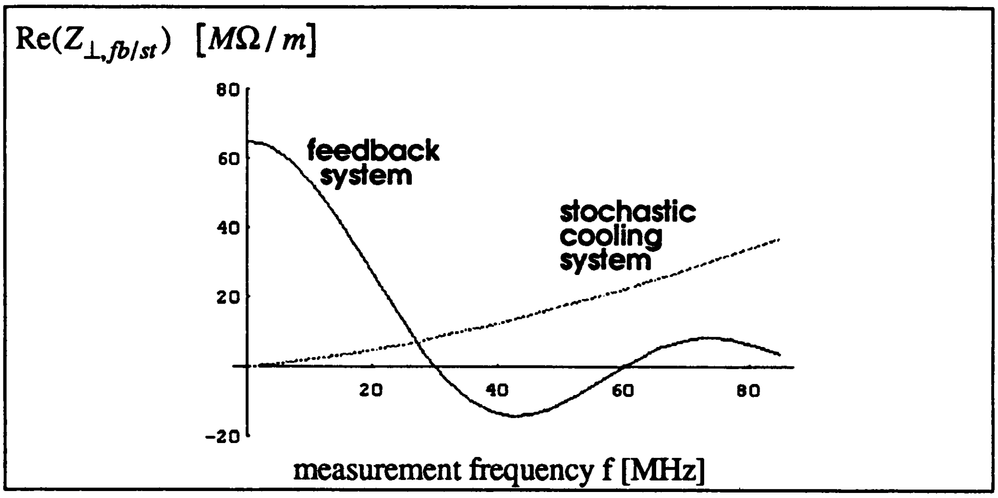

Figure 4: Plot of the estimated real part of the transverse impedance $\mathrm{Re}\{Z_{\perp,fb}\}$ due to the feedback system and of the real part $\mathrm{Re}\{Z_{\perp,st}\}$ due to the stochastic cooling system used as a damper, related to G_{fb}=+50dB , G_{st}=+70dB and f_1=30 MHz.